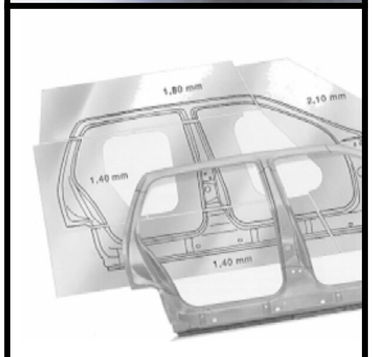
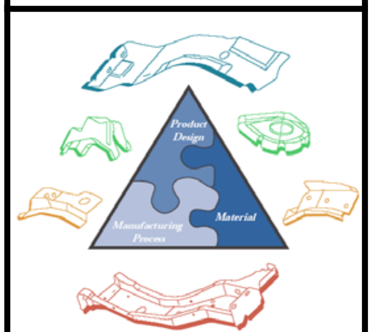


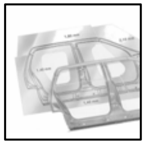


Overview: STEEL Lightweighting Projects

Joseph Polewarczyk
General Motors Corporation

Auto/Steel Partnership

www.a-sp.org

PURPOSE

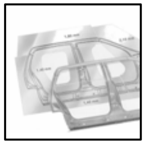
- Future Generation Passenger Compartment (FGPC)
  - Mass optimization of passenger compartment of mid-sized sedan structure designed to meet safety performance requirements

  Mass Efficient Architecture for Roof Strength (MEARS)
  - Mass optimization of roof structure of worst case vehicle (pick-up body w/o B-pillar) designed to meet new roof strength requirements

  Mass Compounding
  - Regression analysis to quantify potential vehicle mass reduction made available by reduced mass components

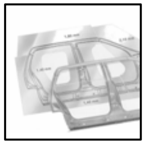
- Lightweight Front End Structure (LWFES)
  - Optimization of front end structure of mid-sized sedan structure designed to meet current safety performance requirements

- Rear Chassis Structure
  - Mass optimization of rear chassis cradle

TECHNICAL BARRIERS

- Results indicate that higher strength, thinner gauge materials could be applied to body-in-white structures to further reduce mass
- These materials have the following challenges
  - Higher strength steels are currently unavailable in the thinner gauges called for
  - Formability of some of these materials is more challenging than lower grade materials, or material costs increases are significant
  - Class A (show surface) capability of these materials is poor
  - These materials present joining challenges compared to current materials
- A/S P Light-Weighting projects feed these requirements to "enabler teams" to obtain solutions to these challenges. E.g.:
  - The Joining Team is addressing welding and/or bonding the proposed combinations of materials from FGPC Phase I
  - The hydroform tube team is working to implement a hydroformed version of the LWFES front rails

PROJECT TIMELINE

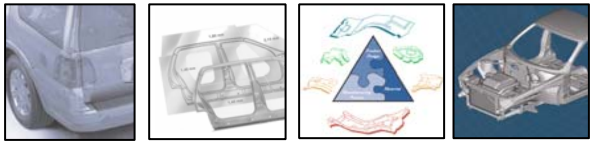
- FGPC
  - Phase I Complete
  - Phase II Validation completion date: March 2009

  MEARS
  - Phase I Complete
  - Phase II completion date: September 2008

  Mass Compounding
  - Project complete

- LWFES
  - Project Complete

- Rear Chassis Structure
  - Completion date: December 2008



Design Process

Concept Design

↓

Select Design (s)

↓

CAE Study

↓

Optimization/DOE

↓

Prototype/Build/Test

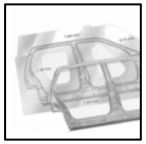
↓

Compare Results / Report Out

Project approach applies to:

- FGPC
- LWFES
- MEARS

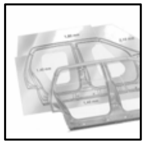
Variations on this process are typically driven by software choice of CAE / Design firm and the number of design iterations evaluated. Overall process is same

PROJECT APPROACH

MASS COMPOUNDING

- Acquire competitive benchmarking teardown data from Chrysler, Ford & General Motors.
- Adjust data categories to obtain equivalent content between subsystems (Auto companies do not categorize sub-systems exactly the same).
- Use regression techniques to identify mass reduction potential of vehicle sub-systems as related to one another.
- Create simple tool to predict mass reduction potential from mass reductions of one or more subsystems.

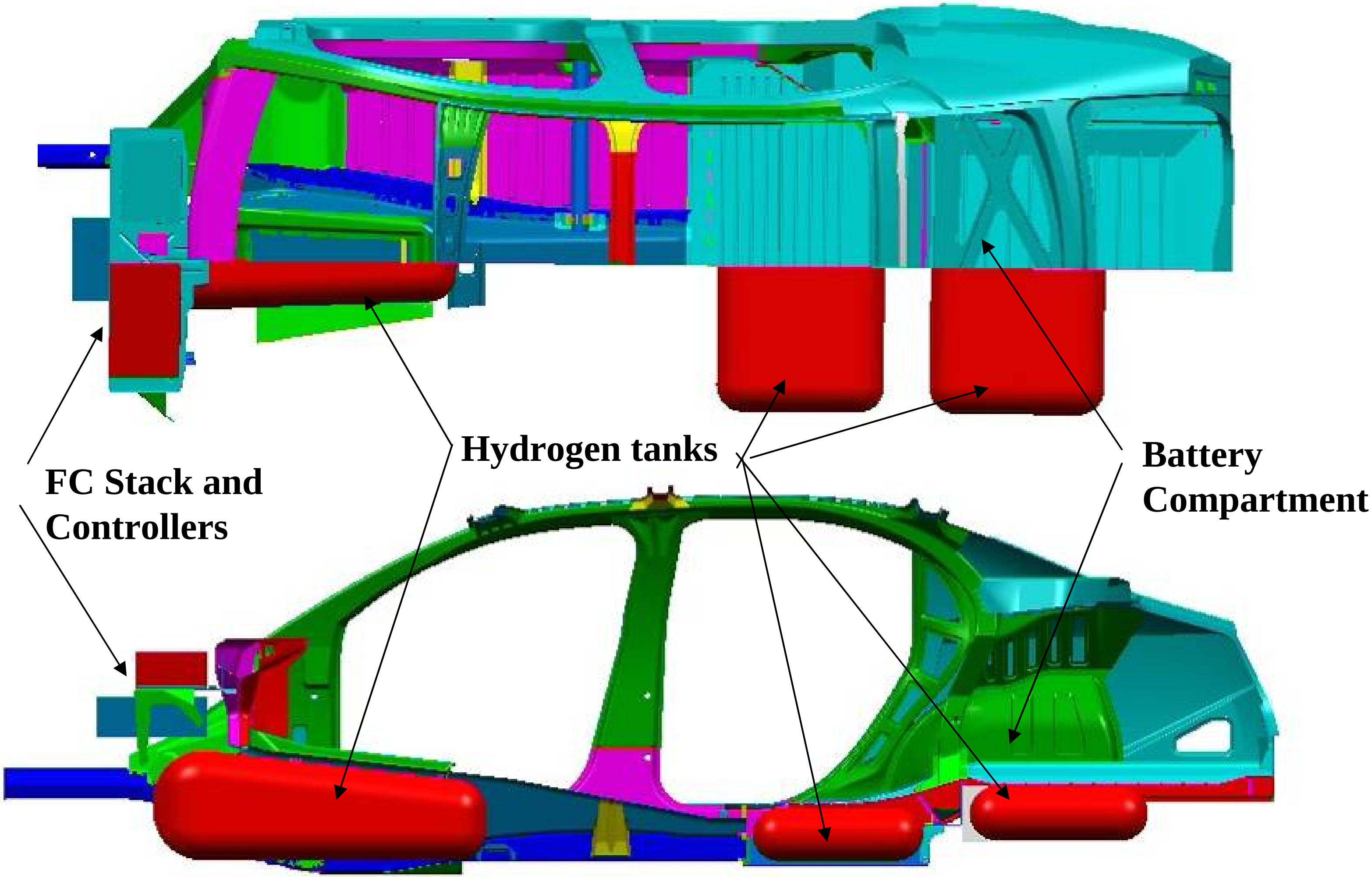



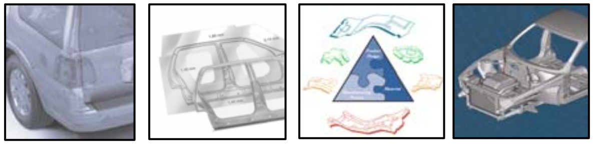
PROJECT STATUS

- FGPC Phase I (Complete)
  - Benchmarking and Baseline Calibration tasks complete, reports issued and posted on A/SP member website.
  - Load path optimization analysis to establish best geometry to resist crash load cases and maintain global stiffness complete.
  - Impact studies for vehicle mass and barrier height complete.

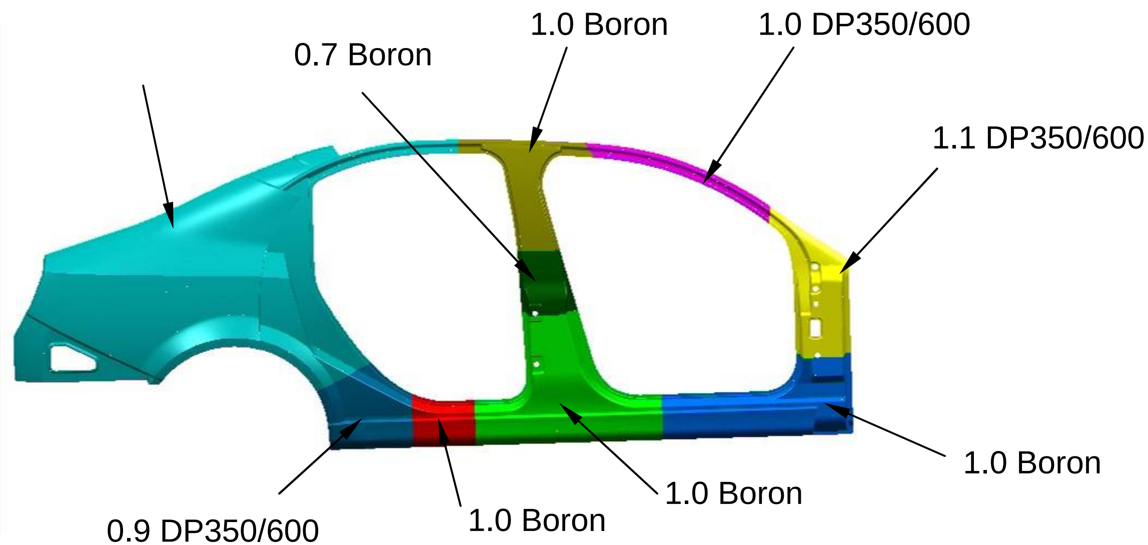
- FGPC Phase II (Validation):
  - Initial Optimization complete, topology results from phase I confirmed (CAE Study).
  - Refining design solutions for new load paths to prepare for final optimization (Optimization / DOE study).

Fuel Cell Packaging





FGPC - PHASE I - PROJECT RESULTS

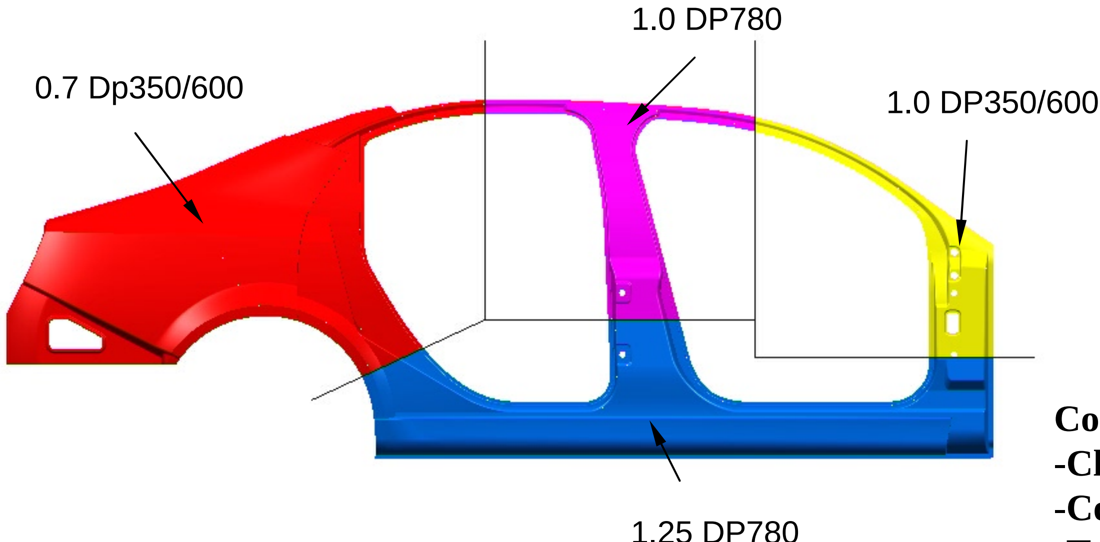


Optimized Results Analysis

FGPC optimized Weight: 12.97 kg

Proposed Optimized

Taylor welded Construction



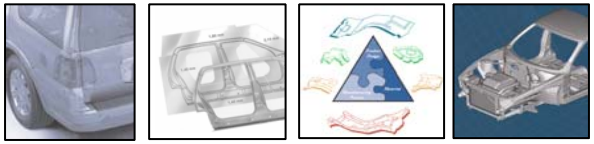
ULSAB AVC weight:	**20.89 kg**
FGPC Optimized Weight:	**12.97 kg**
FGPC design weight:	**17.37 kg**

Considered for Construction decision:

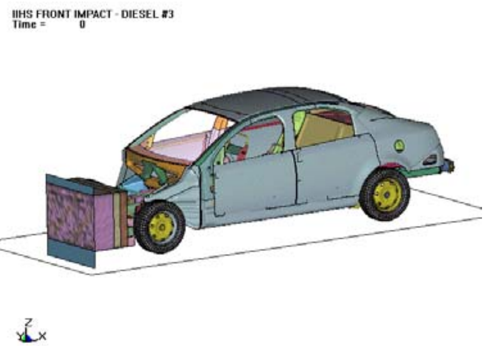
-Class A capability

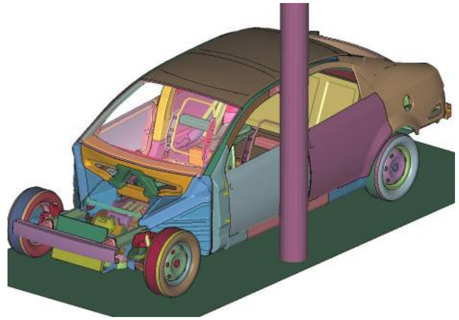
-Cost of Taylor welded blank

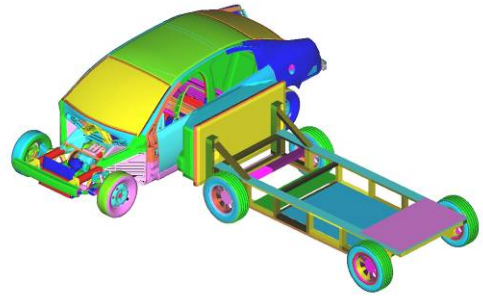
-Treatment

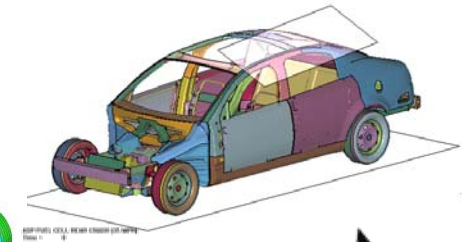


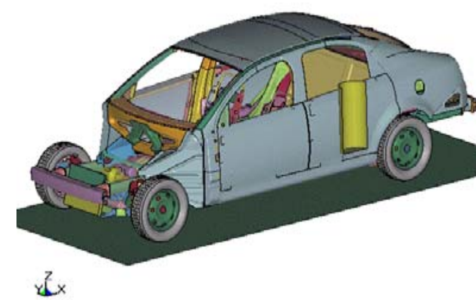
FGPC - PHASE I - PROJECT RESULTS

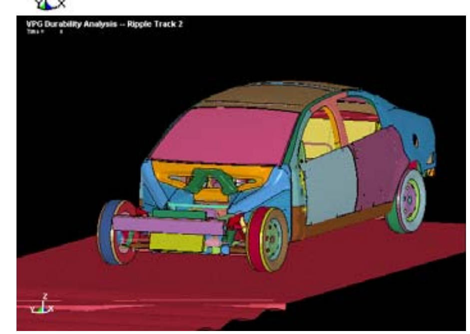






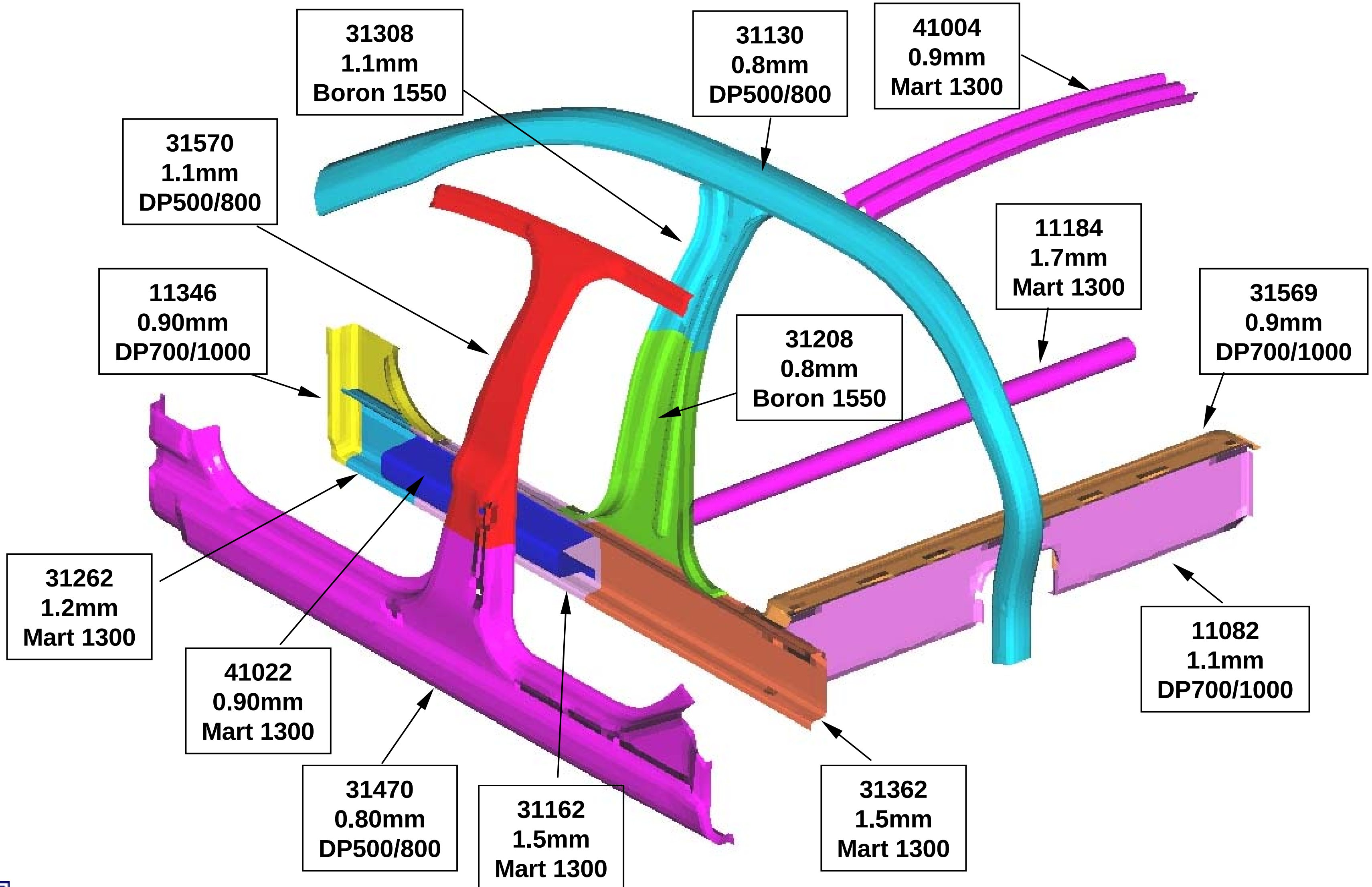


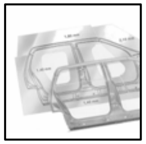




- Task 7.0 – Final Design Check
  - Side Pole Impact — Met FGPC Targets
  - Roof Crush — Met FGPC Targets
  - IIHS Front Crash — Met FGPC Targets
  - IIHS Side Impact — Met FGPC Targets
  - Side Door Intrusion — Met FGPC Targets
  - Rear Crash — Met FGPC Targets
  - Bending/Torsion — Met FGPC Targets
  - Model Analysis — Met FGPC Targets
  - Durability — Met FGPC Targets

FGPC - PHASE I - PROJECT RESULTS



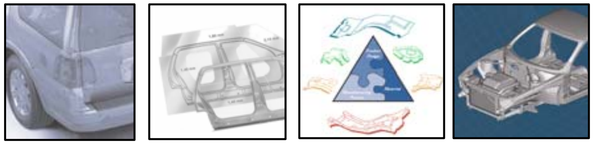



FGPC - PHASE I - PROJECT RESULTS

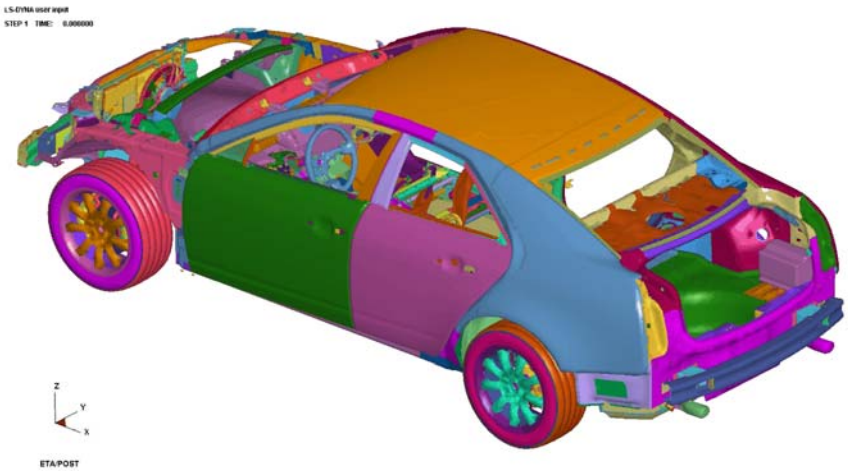
Total Mass Savings: 108.2 kg

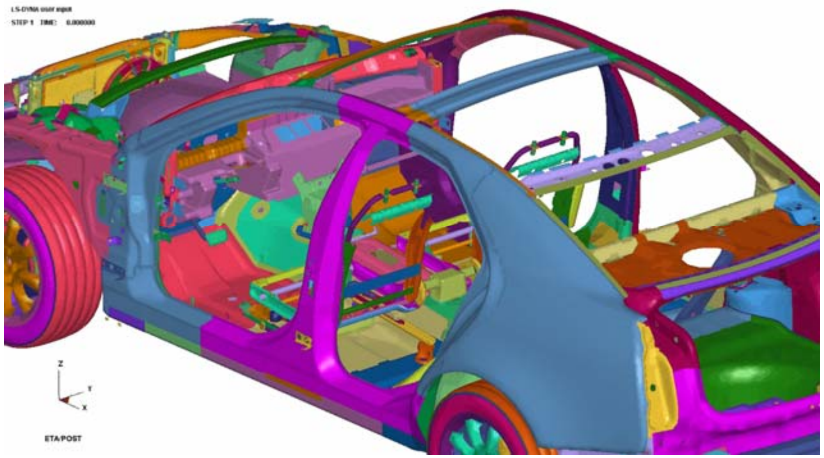
	Industry Standard	FGPC - Final	Mass Savings	% Savings
BIW + IP Beam	310.0	217.6	92.4	30%

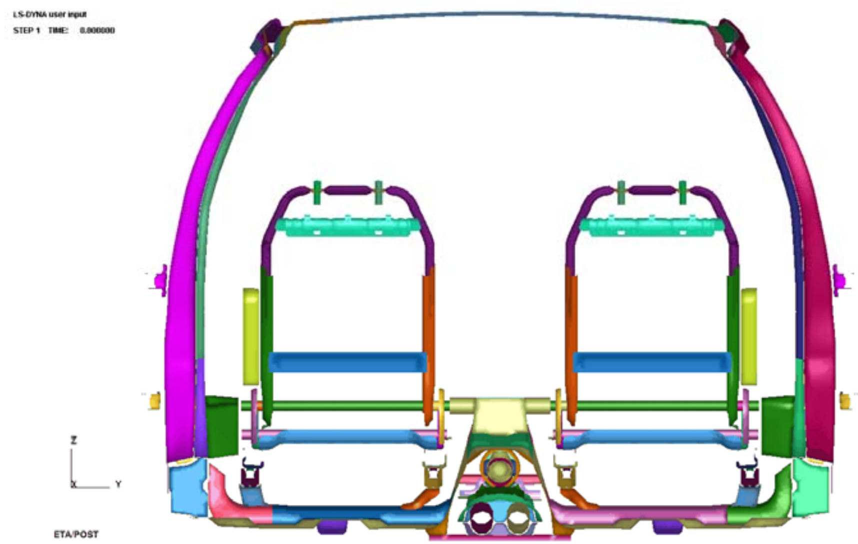
	Baseline-FGPC	FGPC-Final	Mass Savings	% Savings
Mod. Parts, Door Beams	143.2	127.4	15.8	12%

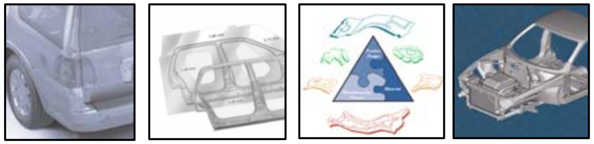


INITIAL OPTIMIZATION IIHS SIDE IMPACT

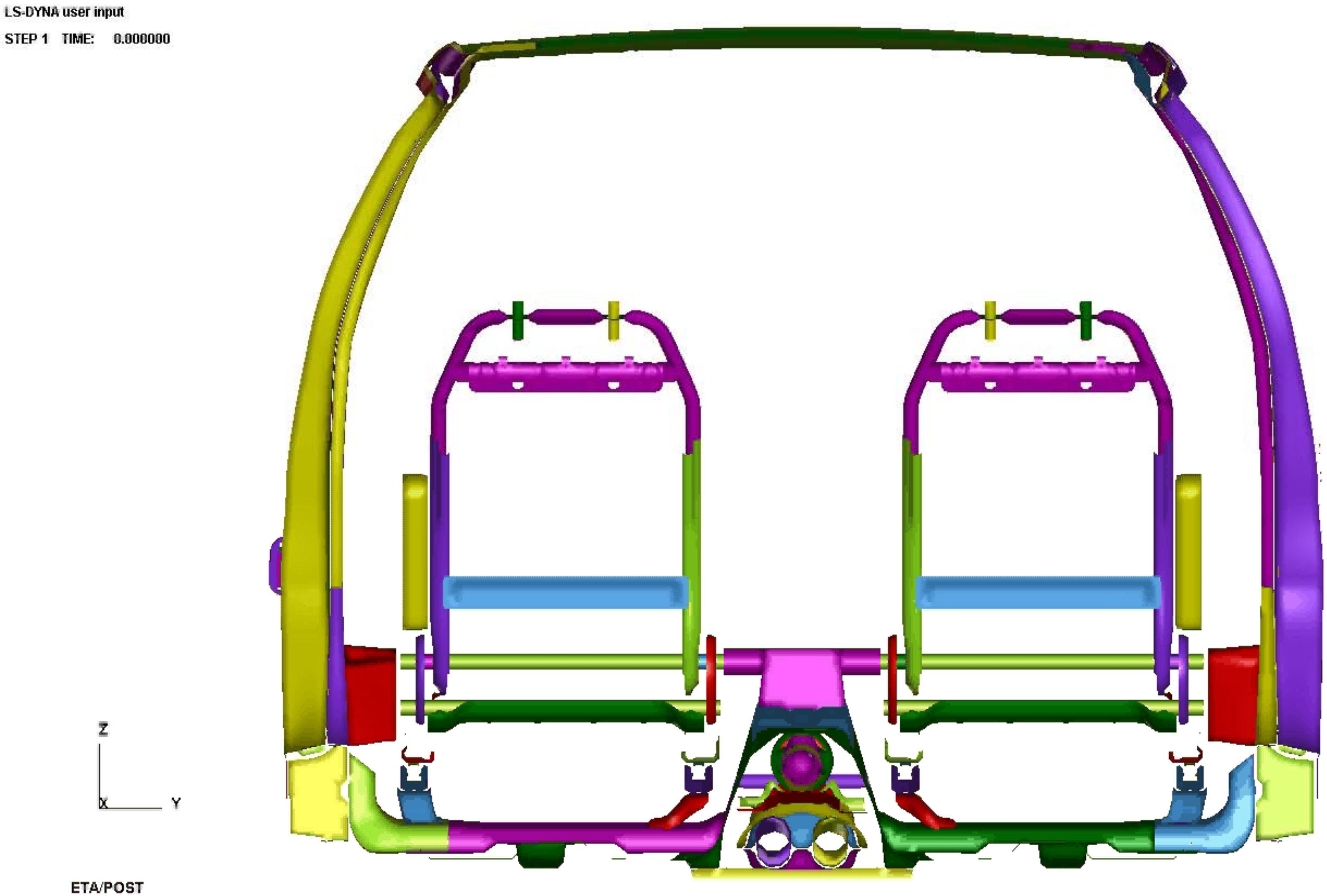


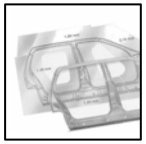






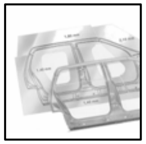
FGPC - PHASE II IIHS SIDE IMPACT



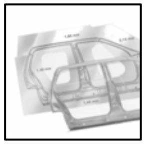
FGPC - TECHNOLOGY TRANSFER

- Reports and presentations placed on www.a-sp.org.
- Roadshow of results to be presented to member companies.
- Results presented at 2007 Great Designs in Steel seminar.
- Phase II will follow a similar tech transfer process when complete.

MEARS – PROJECT GOALS

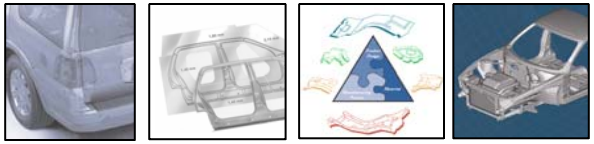
- Develop designs for the B-Pillarless body architecture that is capable of achieving the loads specified in the NPRM for FMVSS 216.
  - Structure must support a load of 2.5 times the maximum unloaded vehicle weight.
  - Maximum load requirement must be achieved before there is contact between a 50th Percentile Hybrid III Dummy and any component of the vehicle.
- Minimize the weight impact to the vehicle with the use of AHSS materials and structural design concepts.
- Best solution selected based on weight efficiency, cost effectiveness, and ease of manufacturing.

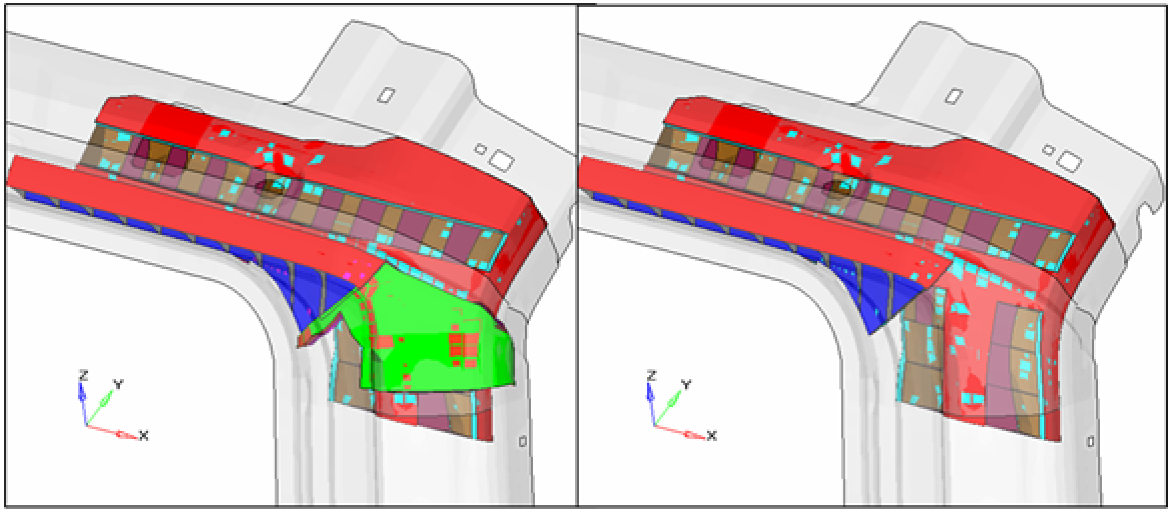



MEARS – FINAL DESIGN

- Weighted Rating developed for solutions from each concept
- Based on weight impact, variable cost, manufacturing impact, and repairability
- Nylon Inserts and Steel Inserts came out equal – Nylon Inserts selected due to lower weight increase over baseline model

S.No	Concept	Load Factor	Mass [kgs]	Cost	Rating				Weighted Rating
					Mass	Cost	Manufacturability	Repair	
Weight Factor --------------------------->					**4**	**3**	**2**	**1**	
1	Stamping Intensive	3.06	17.6	$108	1	1	4	3	18
2	Hydroform intensive	3.00	10.5	$79	4	3	3	3	34
3 A1	Steel Inserts-Tube in C-Pillar	3.00	14.9	$79	2	3	3	4	27
3 A2	Steel Inserts-Stamped C-Pillar Rnf	3.06	13.8	$67	3	5	4	4	39
3. B	Nylon Inserts (Drop-in)	3.06	7.5	$80	5	3	4	2	39
3. C	BetaFoam (Injected)	2.95-3.82*	8.4	$78	5	3	2	2	35





C3_I211_Baseline

C3_I221

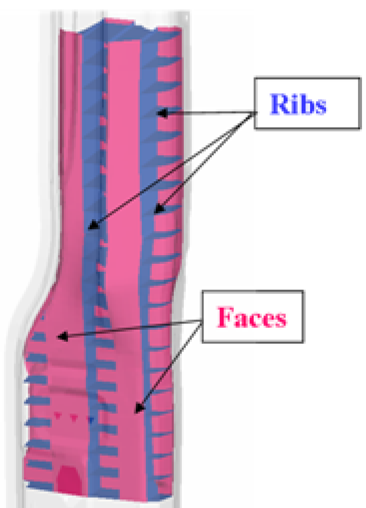
Nylon Insert at
C-Pillar Top trimmed

Insert Optimization

Size Reduction

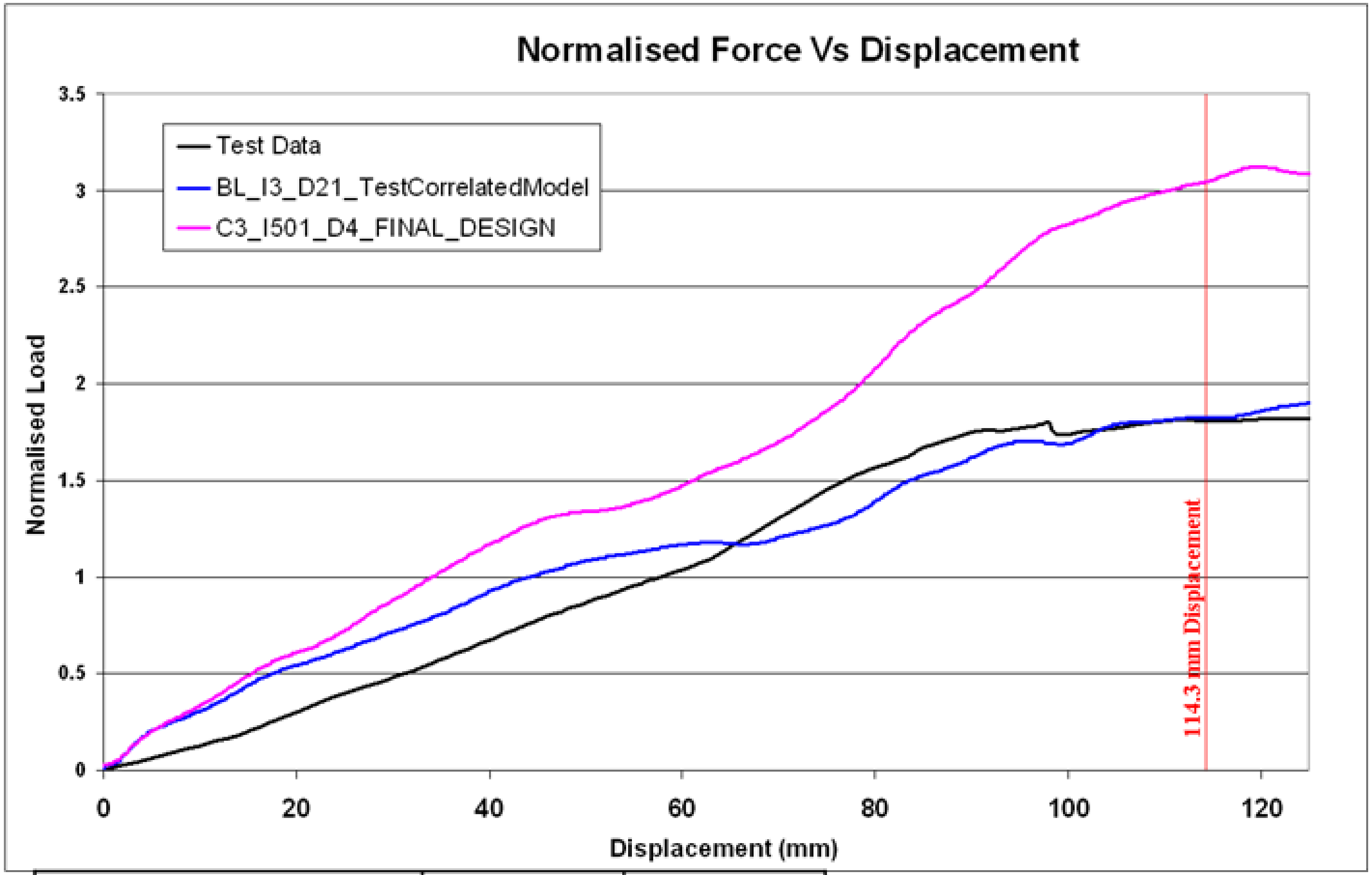
Insert Optimization

Design Modification

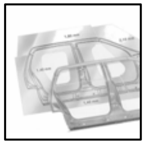


Design	Load Factor	Mass increase (kg)
C3_I211 [Baseline , All Faces = 2.5 mm, 33% Glass Filled Nylon In All Locations]	3.06	7.54
C3_I225 [All Faces = 2 mm, 33% Glass Filled Nylon In C Pillar , In Other Locations 13% Glass Filled]	3.00	6.62
C3_I226 [All Faces = 2 mm, Removed Alternate Ribs At All Locations]	2.96	6.08
C3_I228 [All Faces = 2 mm, 33% Glass Filled Nylon In All Locations]	3.06	7.02
C3_I236 [All Faces = 2.5 mm, 13% Glass Filled Nylon In All Locations]	2.96	6.76

Optimized Design – Force Deflection Curve

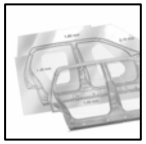


Design	Load Factor	Increase in Mass (kg)
BL_I_D21_TestCorrelatedModel	1.87	
C1_I501_D4_FINAL DESIGN	3.05	1.22

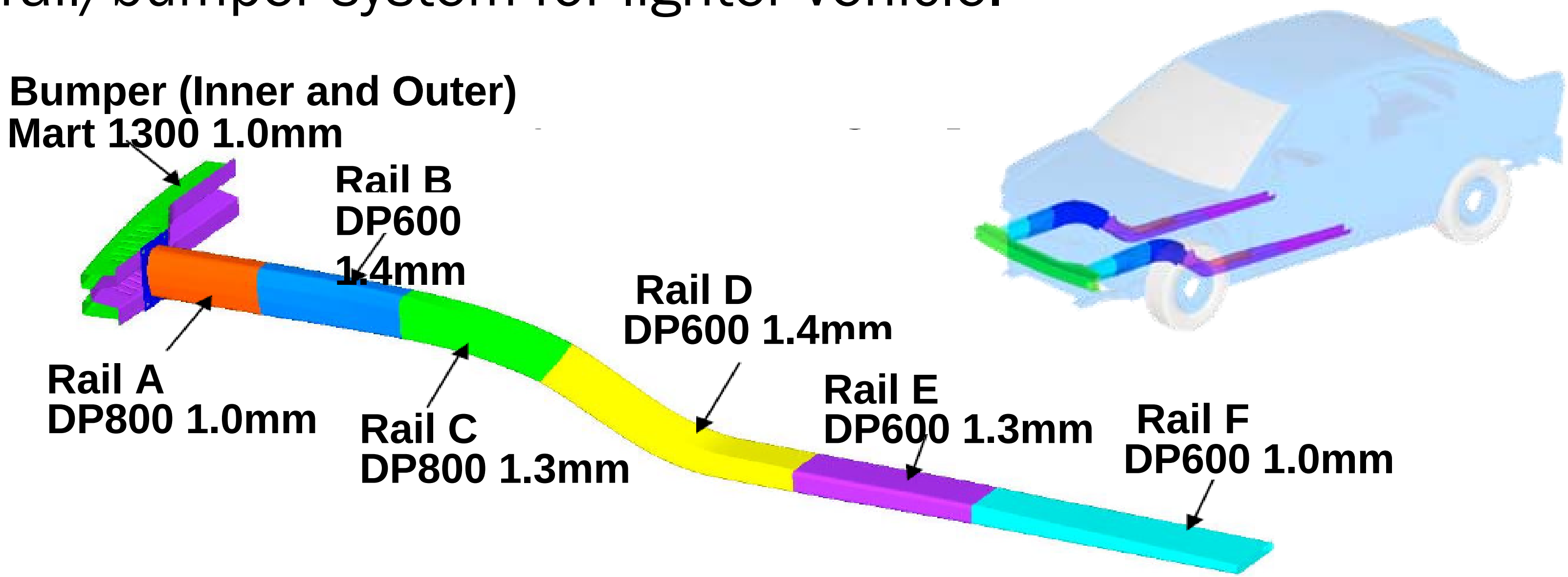
MEARS – FUTURE WORK

- Validation of the performance of the composite reinforcements used in the hybrid solutions through the use of component level bench testing.
- Finalized hybrid design concept.
- Cost analysis of the hybrid concept.
- Verification of impact of design modification of hybrid design on other safety test modes (side impact, frontal impact).
- Submission of Phase 2 Final report.

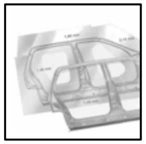



LWFES – PROJECT RESULTS

- Demonstrated a 31.8% mass savings for full vehicle mass
- Study then reduced vehicle mass by 20% and retuned rail/bumper system for lighter vehicle.



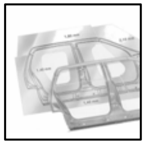
- 20% curb weight reduction resulted in bumper/rail system decreasing from 26.8 kg to 23.6 kg (12% reduction) or 39.8% less than baseline at cost parity.

REAR CHASSIS – PROJECT APPROACH

Phase I
- Select baseline chassis structure
- Prepare an AHSS design
- Build prototypes
- Use prototypes to address technology gaps
- Conduct NVH, fatigue and corrosion resistance tests on prototypes

Phase II
- Prepare clean sheet design
- Prototypes not required because technology gaps adequately addressed using Phase 1 prototypes
- Fabricate parts/specimens if necessary to resolve formability/technical issues
- Perform fatigue simulation of Phase 2 design
- Evaluate mass compounding

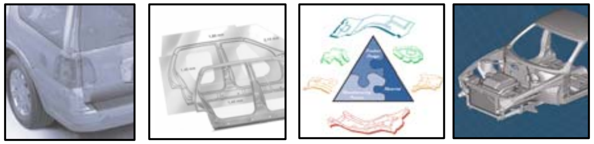



REAR CHASSIS – PROJECT GOALS

Phase 1 :
- Conduct 10% mass reduction through “material substitution”

Phase 2 :
- Minimum 25% mass reduction through “design/process optimization” with no more than a 9% cost premium.

Phase 3 :
- Technology Transfer

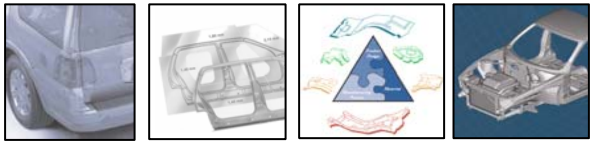


REAR CHASSIS – PHASE 1 RESULTS

- Achieved a 26.2% mass reduction (loss of stiffness not a consideration in this phase)
- Chassis parts were formed with available DP590 and TRIP780 steels
- Developed Design Rules for GMAW welded AHSS
- Evaluated the Verity and BS 5400 methods for running fatigue simulations of chassis structures
- Corrosion resistance of thin AHSS chassis parts being addressed

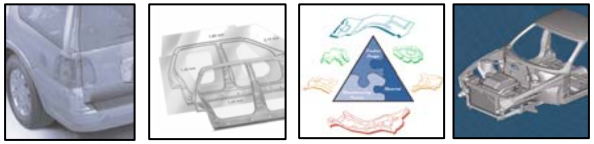
REAR CHASSIS – PHASE 2 RESULTS

- Preliminary design prepared
- Initial mass reduction of 12% with no reduction in stiffness
- Shape and size optimization and new technologies being applied to increase mass reduction

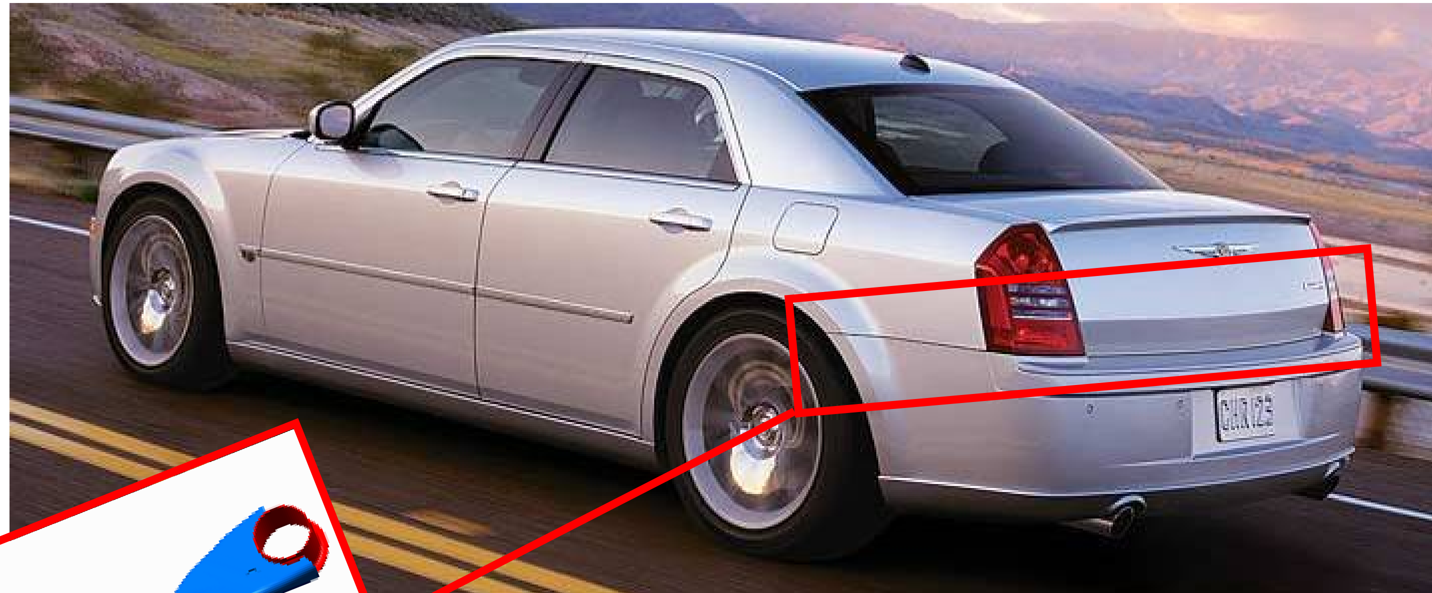


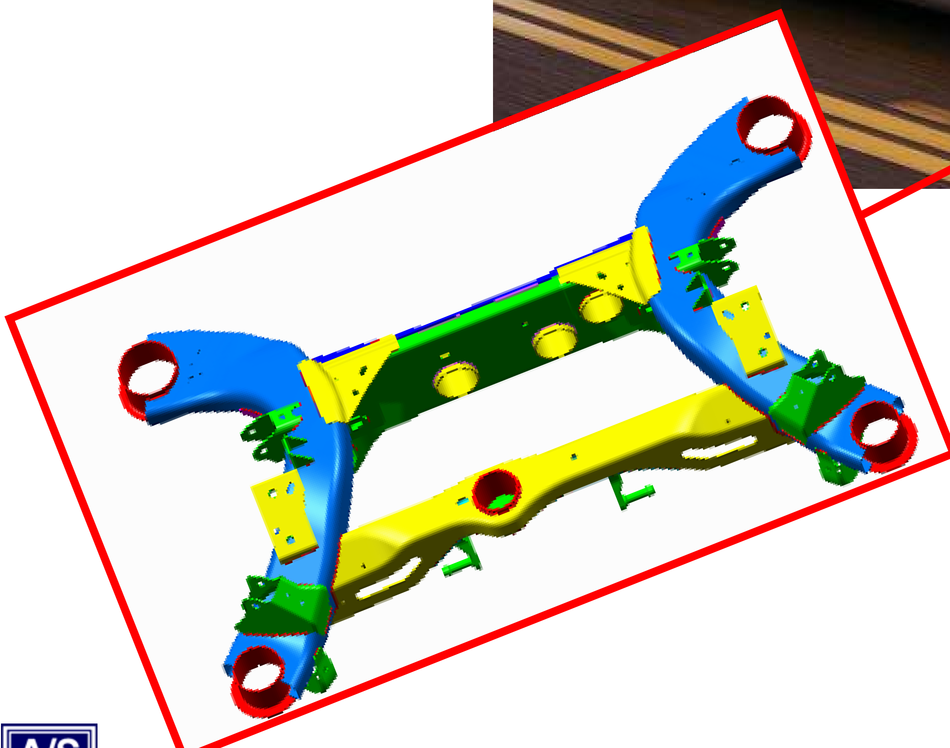
REAR CHASSIS – NEXT STEPS

Activity	Completion Date
Phase 1 Final Report	July, 2008
Phase 2 Final Design	April, 2008
Cost Analysis	April 2008
Mass Compounding	May, 2008
Parts/Specimens	July, 2008
Phase 2 Final Report	December, 2008
Phase 3 Communications	June, 2009



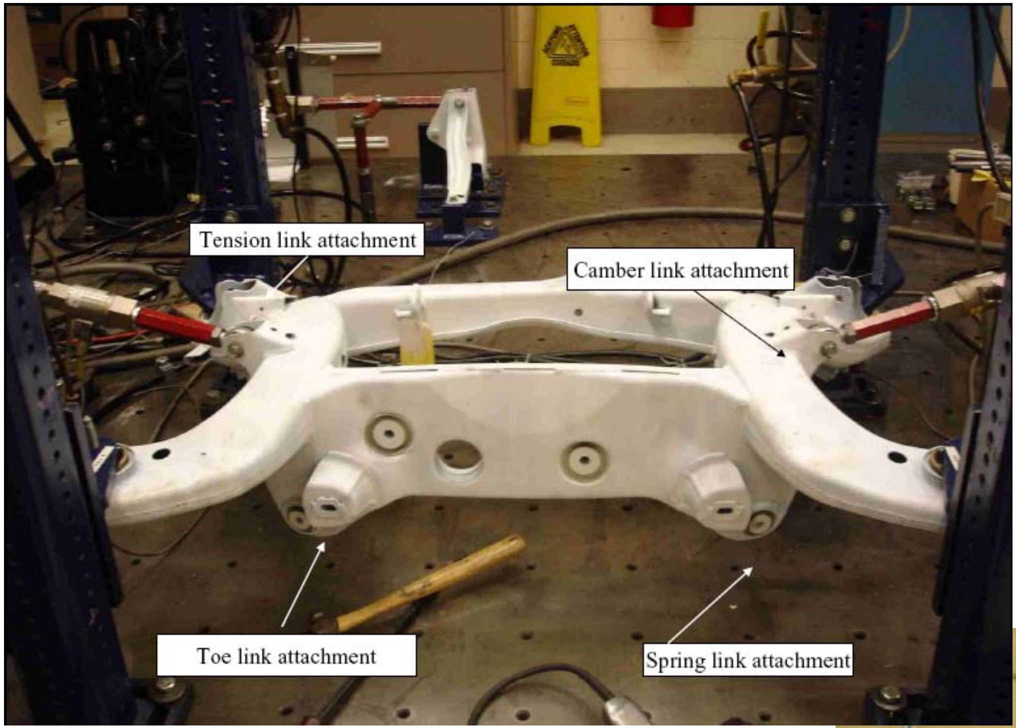
BASELINE CHASSIS STRUCTURE



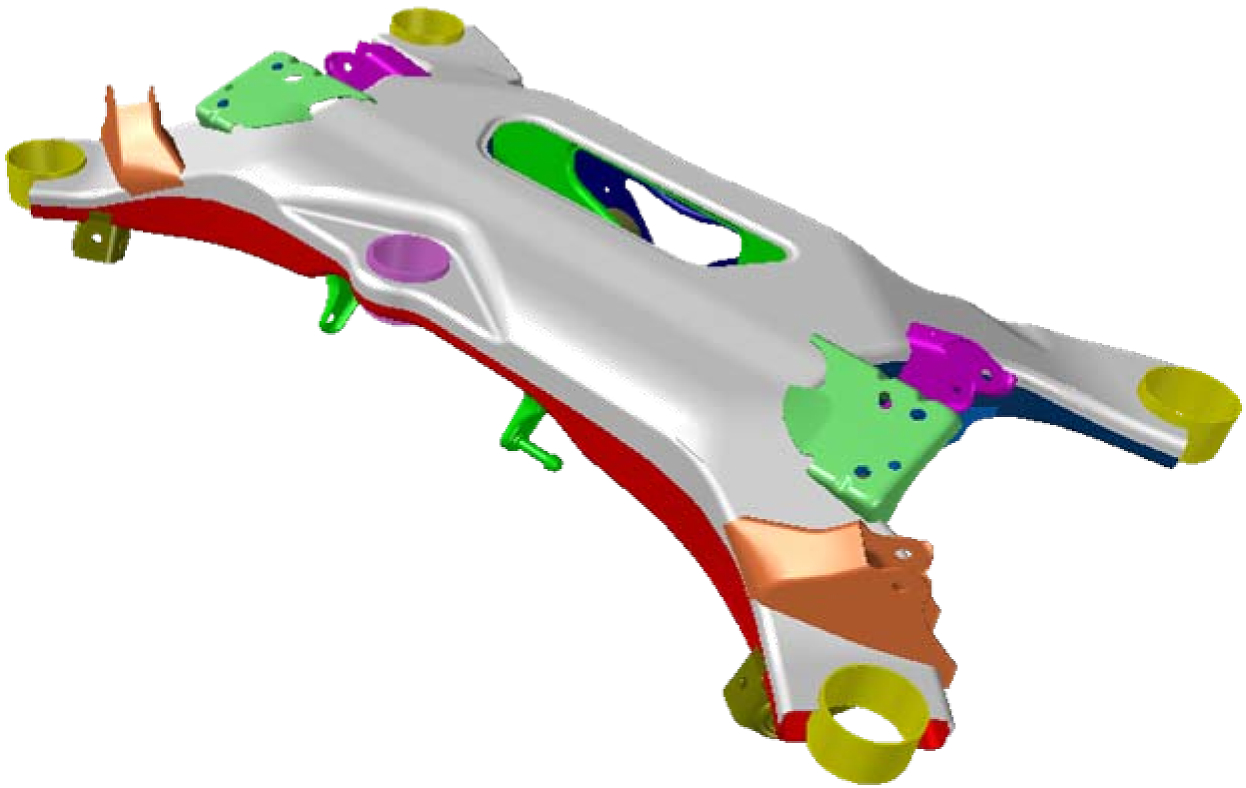


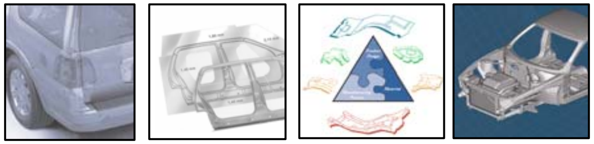
- DaimlerChrysler LX
- Rear Chassis Structure

PHASE I - FATIGUE AND MODAL TESTS



- Hybrid design
- Best opportunity to achieve goals

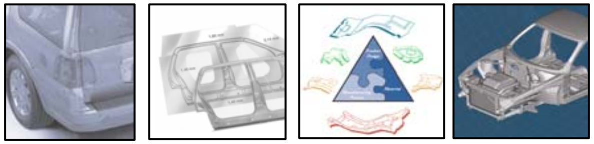




MASS COMPOUNDING - OVERVIEW

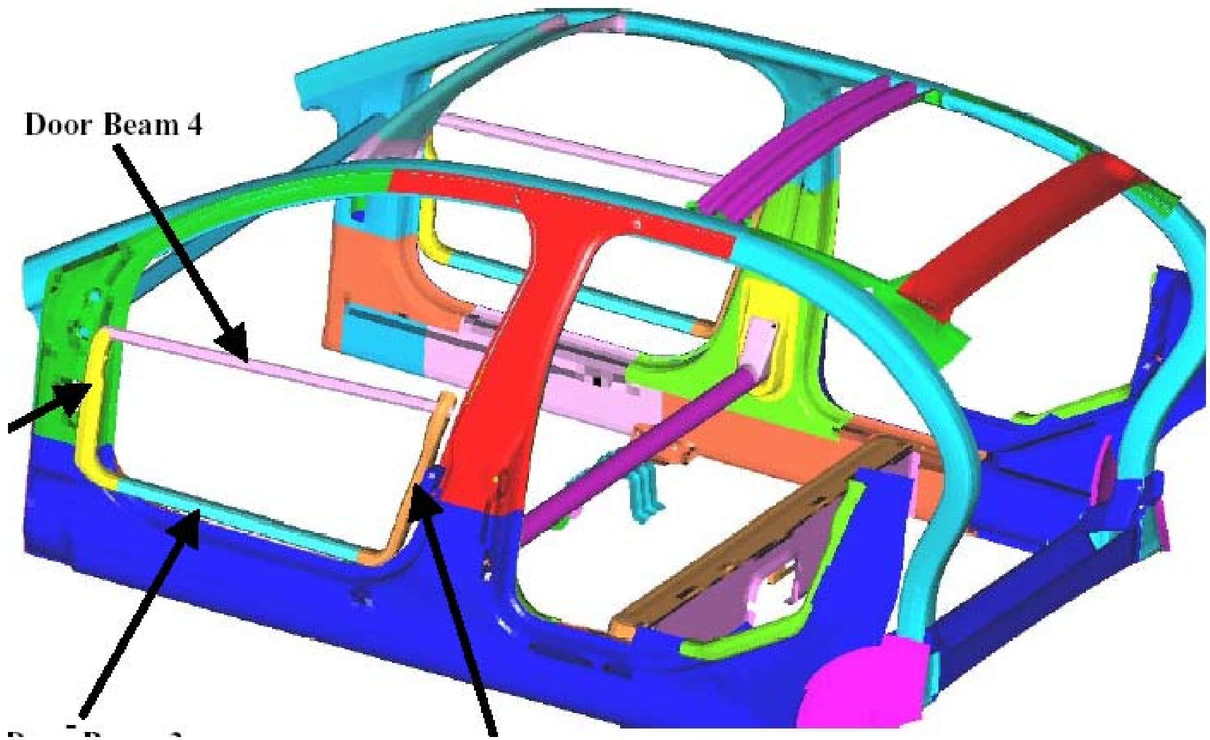
- Lightweighting projects have demonstrated mass savings of over 30% without consideration for mass compounding.

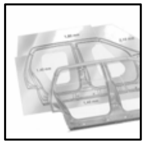
- Mass Compounding.
  - unplanned mass increases in a component during a vehicle design has a ripple effect through out the vehicle, other components need to be resized Increasing mass event more. Mass begets mass describes this phenomenon.
  - A more encouraging view of this behavior is the reduction of a component’s mass resulting in greater mass savings for the entire vehicle.



MASS COMPOUNDING - RESULTS

- Preliminary Optimization Study Results:
  - 30% mass reduction at no cost for full size vehicle.
  - 40% mass reduction for full vehicle 25% reduced mass vehicle.
  - At no additional cost.

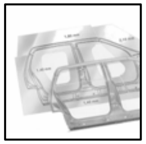


MASS COMPOUNDING - MODEL

Body structure and suspension reduced by 30% → Results in **41%** reduction in Body Structure and **39%** in Suspension

	Influence Coefficients for Small Cars	Initial Mass Estimate	Initial New Mass	1	2	3	4	5	6	7
				Iterations for number for compounding						
Body Non-structural	0	**386.7**	386.7	386.7	386.7	386.7	386.7	386.7	386.7	386.7
Body Structural	0.166	**303.9**	212.7	193.2	185.1	181.6	180.2	179.6	179.3	179.2
Ft Susp	0.029	**44.6**	31.3	27.9	26.4	25.8	25.6	25.5	25.4	25.4
Rr Susp	0.012	**42.1**	29.5	28.1	27.5	27.3	27.1	27.1	27.1	27.1
Brakes	0.016	**51.1**	51.1	49.2	48.4	48.1	48.0	47.9	47.9	47.9
Engine	0.1	**205.5**	205.5	193.8	188.9	186.8	186.0	185.6	185.4	185.4
Trans&Dr Shafts	0.032	**97.3**	97.3	93.5	91.9	91.3	91.0	90.9	90.8	90.8
Fuel System&exhaust	0	**87.3**	87.3	87.3	87.3	87.3	87.3	87.3	87.3	87.3
Steering	0.031	**20.2**	20.2	16.5	15.0	14.4	14.1	14.0	13.9	13.9
Wheels &Tires	0.022	**103.1**	103.1	100.5	99.5	99.0	98.8	98.7	98.7	98.7
Electrical	0.006	**42.3**	42.3	41.6	41.3	41.2	41.1	41.1	41.1	41.1
Cooling	0	**22.2**	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2
bumpers&brackets	0.006	**38.0**	38.0	37.3	37.0	36.8	36.8	36.8	36.8	36.8
passengers @70kg each	0	**350.0**	350.0	350	350	350	350	350	350	350
cargo	0	**120.0**	120.0	120	120	120	120	120	120	120
CURB (kg)		**1444.1**	1326.9	1277.7	1257.0	1248.3	1244.7	1243.1	1242.5	1242.2
GVM (kg)	0.42	**1914.1**	1796.9	1747.7	1727.0	1718.3	1714.7	1713.1	1712.5	1712.2

LIGHTWEIGHTING SUMMARY

- Mass reduction projects achieved between 10% and 30% mass reduction using a combination of optimization techniques and the application of Advance High-Strength Steel.
- Roof strength project achieved a 63% improvement in load capacity with a minimal mass increase using a combination of optimization techniques and the application of Advance High-Strength Steel with plastic inserts.
- Further mass reduction can be achieved by applying mass compounding estimates to drive initial design criteria.