Auto/Steel Partnership

National Institute of Standards and Technology

Steel Market Development Institute

a business unit of AISI
www.smdisteel.org

OAK RIDGE National Laboratory

Pacific Northwest National Laboratory

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A Steel Industry Perspective on Advanced High-Strength Steels

Ronald Krupitzer
Vice President, Automotive Market

February 9, 2012
AHSS Technology Workshop - Southfield MI

The New Steel

Outline

Automotive Steels Keeping Pace with Demand

- Oil Crisis → High Strength, HSLA Steels
- PNGV → ULSAB → A/SP projects → AHSS

New Challenges for Steel

- Double Fuel Economy → Mass reduction
- New AHSS Grades → Promises and Roadblocks

Early HSS - HSLA

- **<u>Oil Crisis of 1973</u>**
- Embargo by Arab Exporting Countries
- High gasoline prices
- Shortages with long lines at the pump
- No lights on National Christmas Tree

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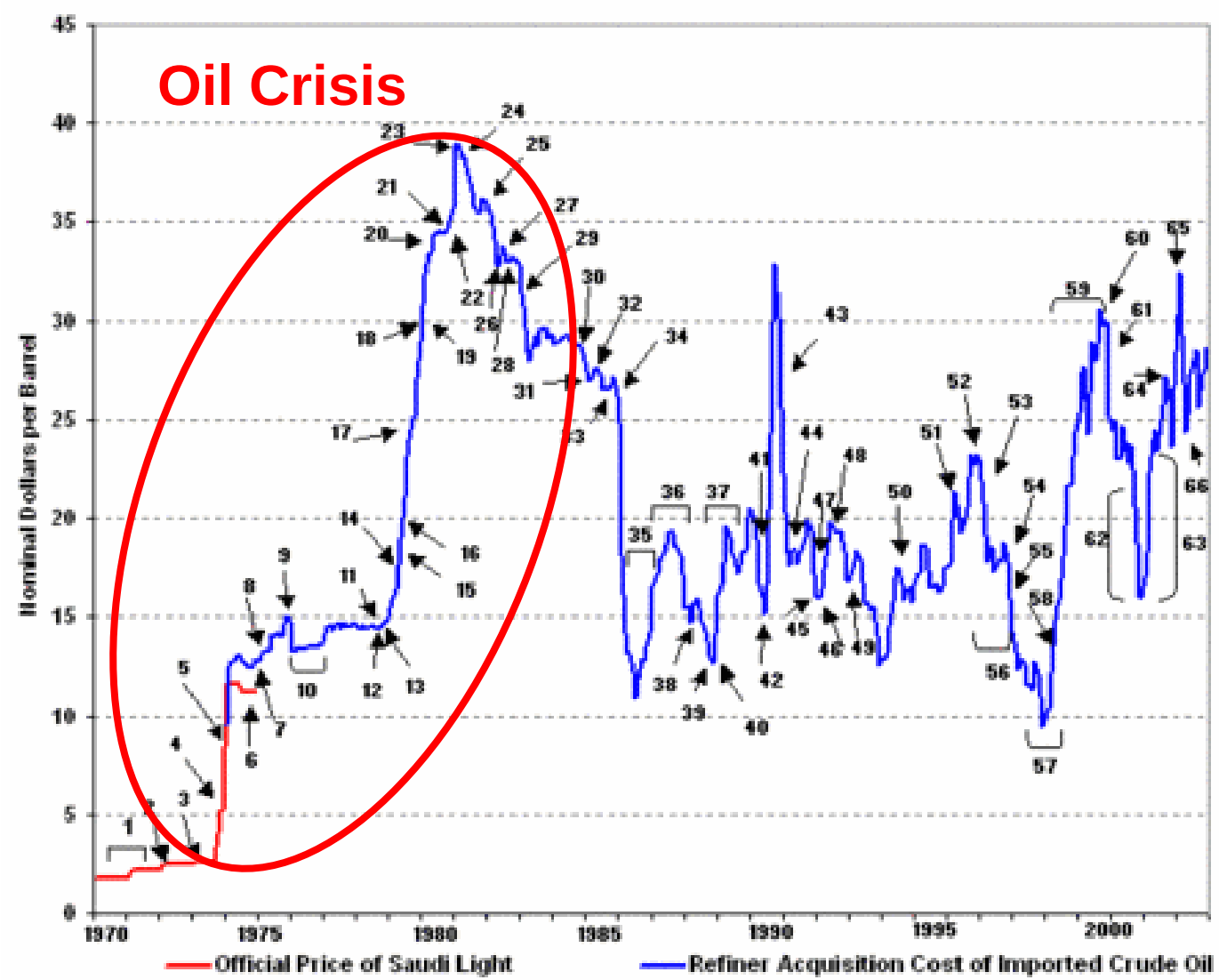
Early HSS - HSLA



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Early HSS - HSLA

- **<u>Steel High Strength Low Alloy Technology</u>**
- **(Alaska Arctic Line Pipe Project, 1970s)**
- Strength
- Toughness
- Weldability
- Consistency
- Low Cost

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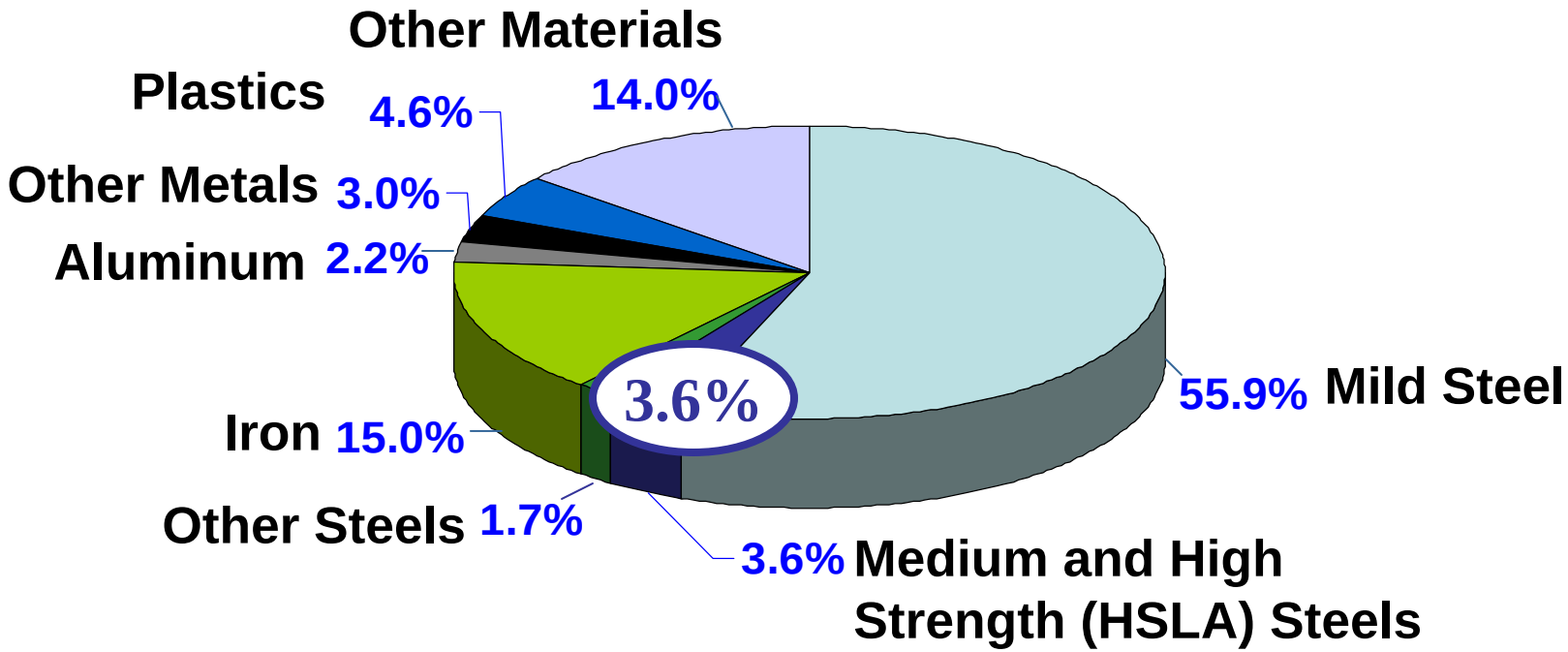
Early HSS - Materials Content

Calendar Year 1975



3,900 Pounds of Material Content

Richard Schultz, Ducker Research, MST 2006

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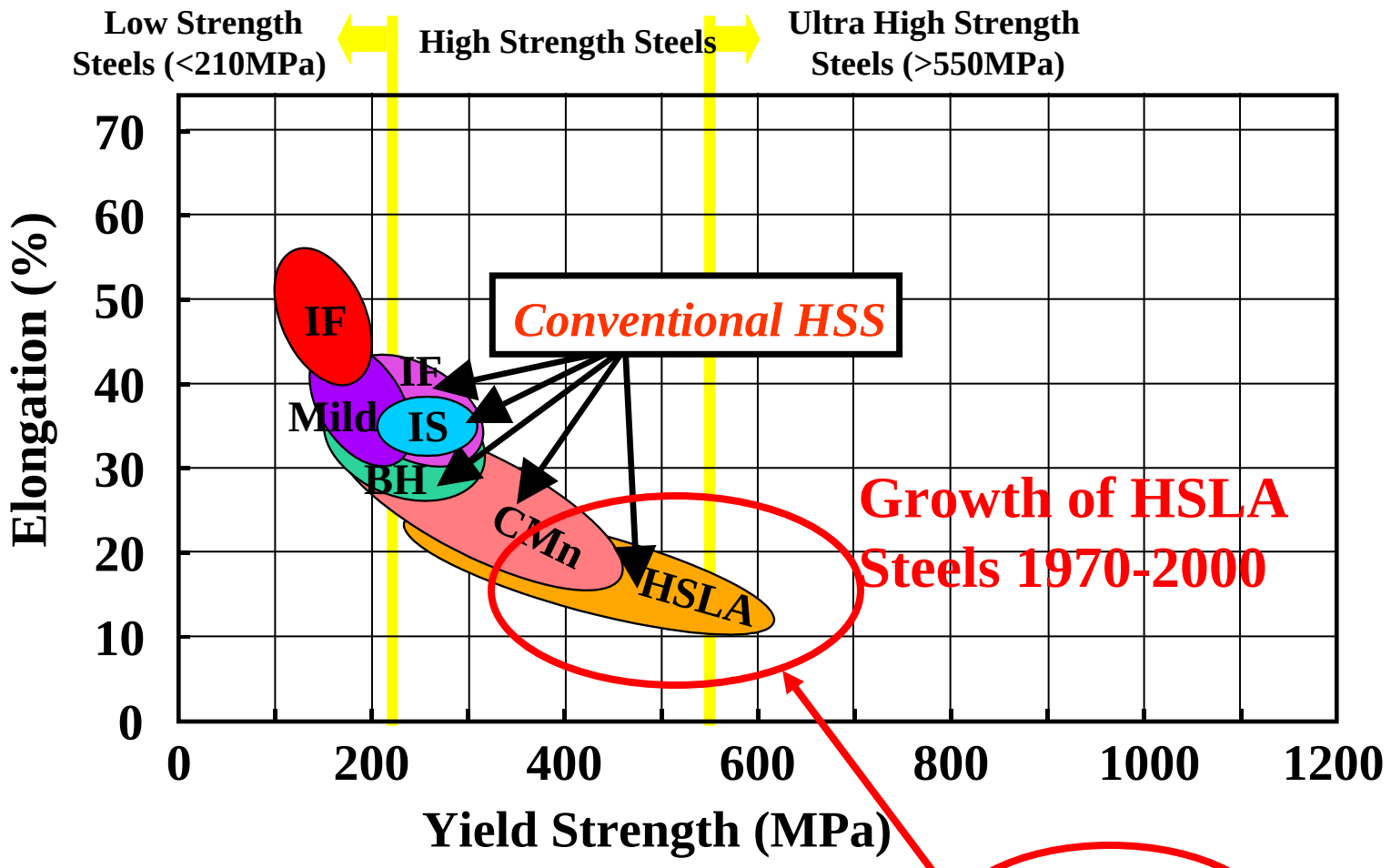
Early HSS - HSLA



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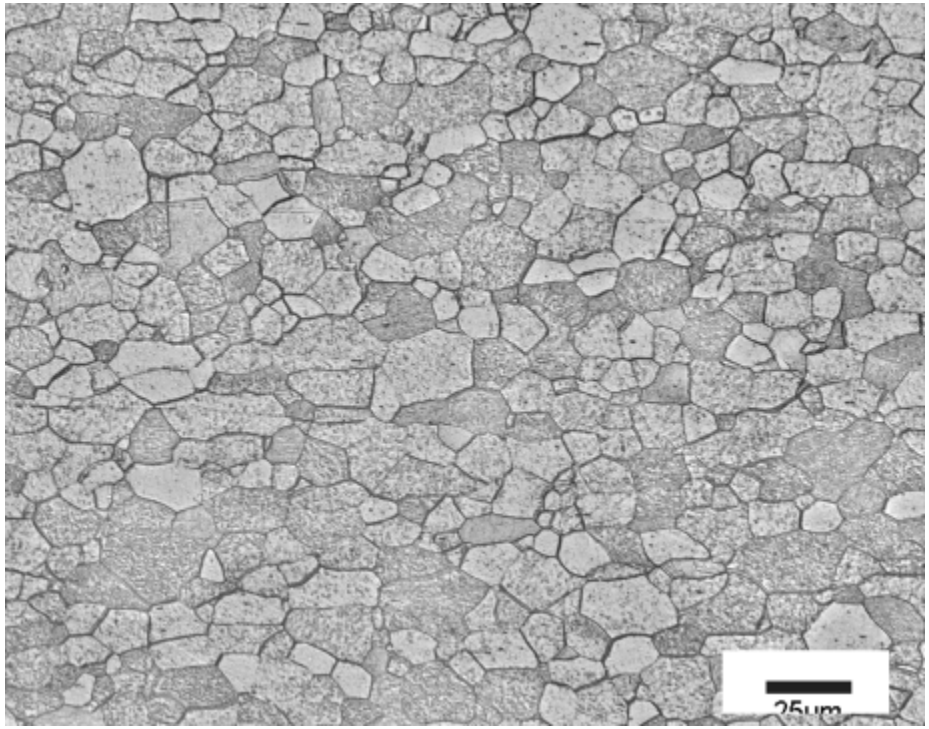
Early HSS - HSLA Metallurgy

Low Sulfur and Inclusion Shape Control



Fine Ferrite Grain Size

Precipitation Hardening

Microally Additions of Columbium, Vanadium, Titanium

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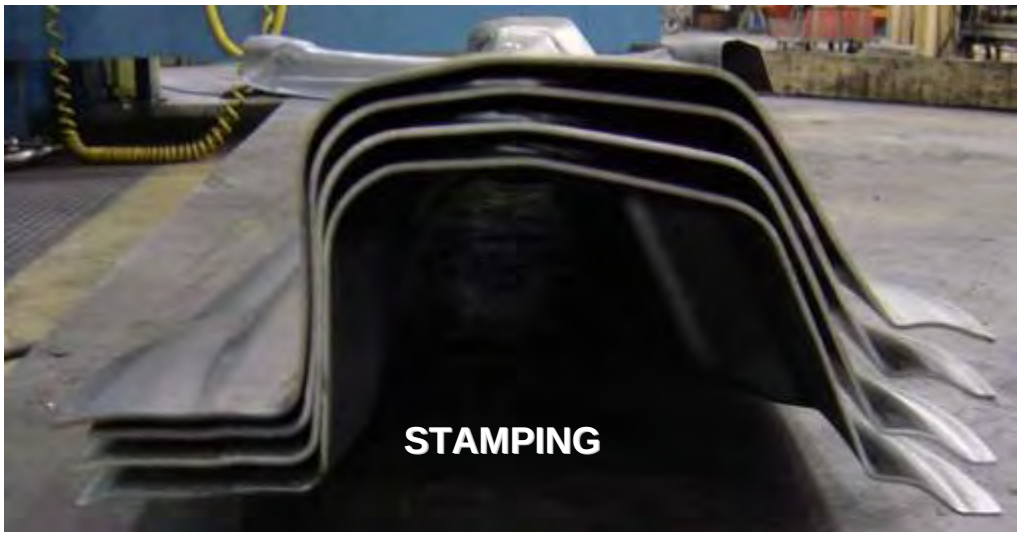
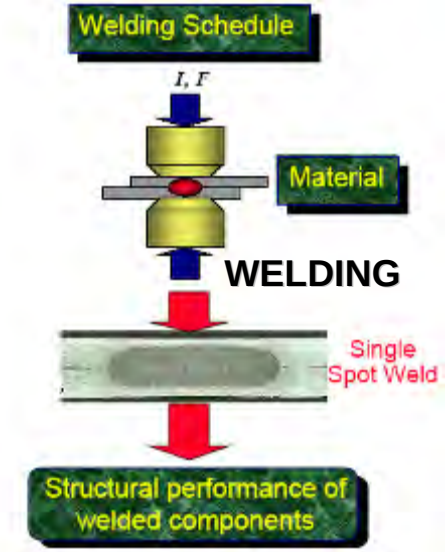
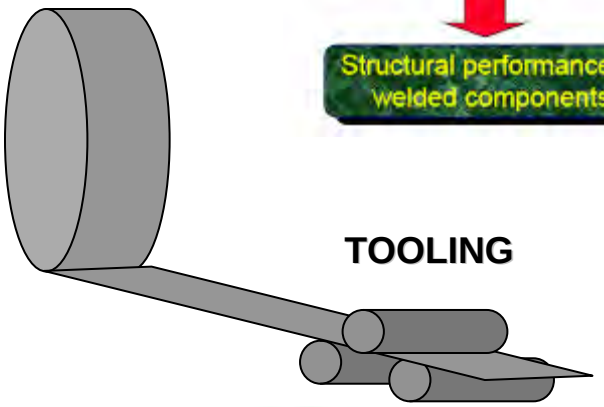
Early Issues - High Strength Steels

- Materials Uniformity (A/SP Project 1987-1995)
- Tooling Costs, Tribology, etc. (A/SP 1987 -2012)
- Stamping (A/SP 1989 - 2012)
- Welding (A/SP 1989 – 2012)
- HSS Design Manual (A/SP 1994-1996)







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ULSAB – Then AHSS Development

- Partnership New Generation of Vehicles (PNGV)
  - 1993 Goal Fuel Economy of 80 MPG
  - USCAR and Federal Government
  - Lightweight Materials, but no Steel

- ULSAB Projects – Global Steel Initiative
  - Why ULSAB (1994-2002)
  - What it accomplished

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2002 ULSAB-AVC Mass Reduction

A Series of Global Vehicle Engineering Studies

ULSAB-AVC (2002)

UltraLight Steel Auto Body -Advanced Vehicle Concept

- 25% (*) mass reduction
- Improved crash performance
- At no additional cost

ULSAS (2001)

UltraLight Steel Auto Suspensions

- 25% - 34% (*) mass reduction
- At no additional cost

ULSAC (2001)

UltraLight Steel Auto Closures

- 25% - 30% (*) mass reduction
- At no additional cost

* Mass Reductions versus PNGV Mild Steel Benchmark Vehicle

Source: WorldAutoSteel

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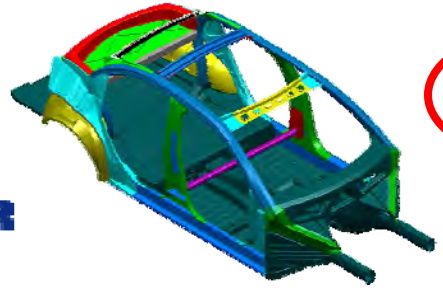
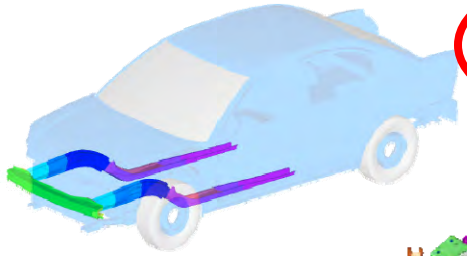
2002-2009 A/SP Projects

Domestic (Auto/Steel Partnership) DOE-Funded Engineering Projects 22% to 32% Weight Reduction, 2002-2009



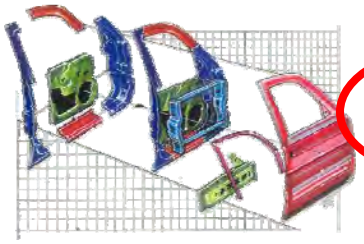
Future Generation Passenger Compartment
- 30% (*) mass reduction
- Improved crash performance
- At no additional cost



Lightweight Front-End Structures
- 32% (*) mass reduction
- At no additional cost

Lightweight Rear Chassis
- 24% (*) mass reduction
- At no additional cost

FreedomCAR Goals
50% mass reduction
same cost



Lightweight Closures
- 22% (*) mass reduction
- At no additional cost

* Mass Reductions versus actual OEM donor vehicles

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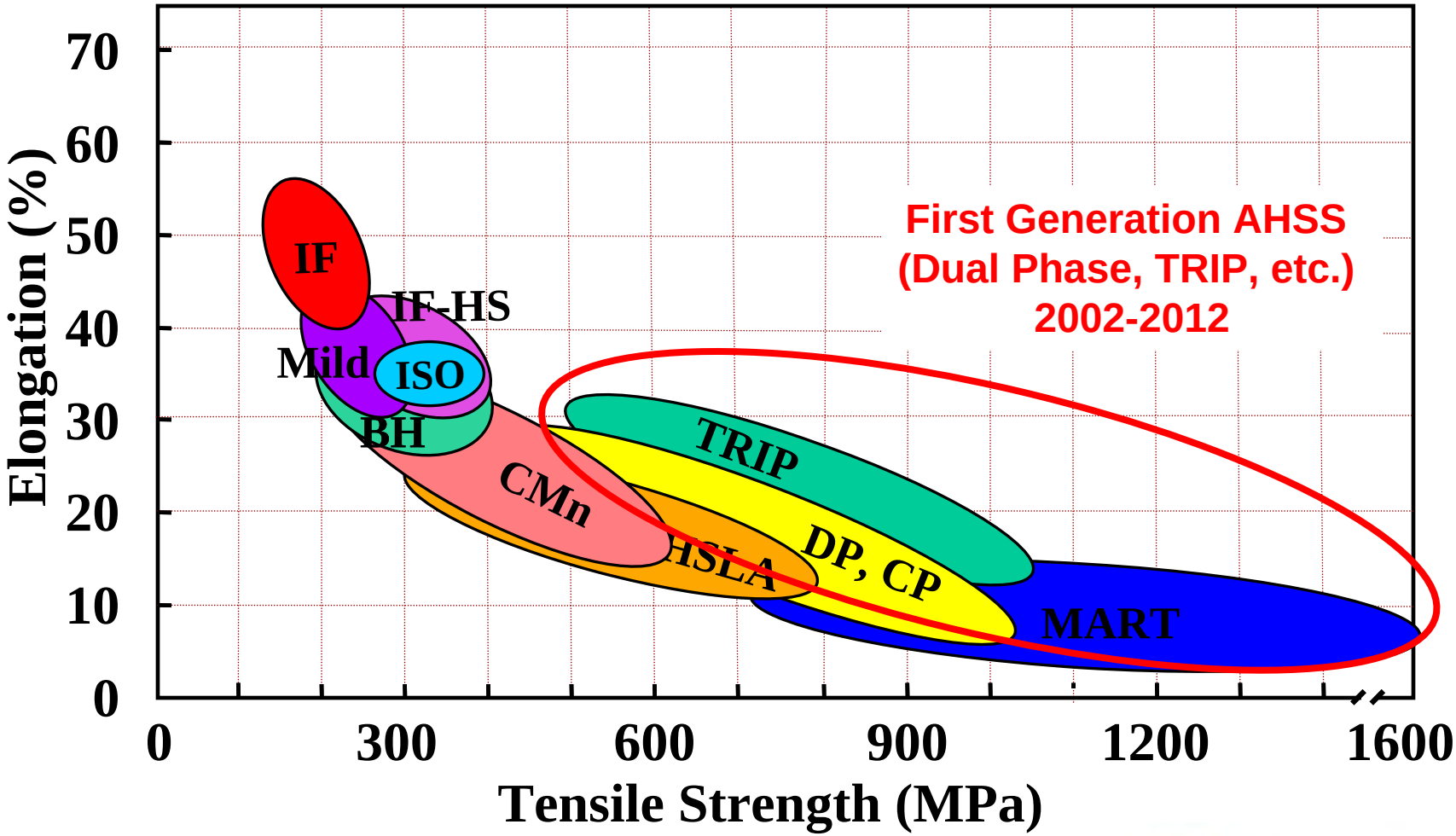
Cost of Steel-based Mass Reduction

No.	Project	Mass Reduction	Cost
1	ULSAS	25-34%	$0
2	ULSAC	25-30%	$0
3	ULSAB-AVC	25%	$0
4	Future Generation Passenger Compartment	30%	$0
5	Lightweight Front End Structures	32%	$0
6	Lightweight Rear Chassis	24%	$0
7	Lightweight Closures	22%	$0
8	Lower Control Arm	Equivalent mass to aluminum	-33%

ULSAB-AVC => First Generation AHSS



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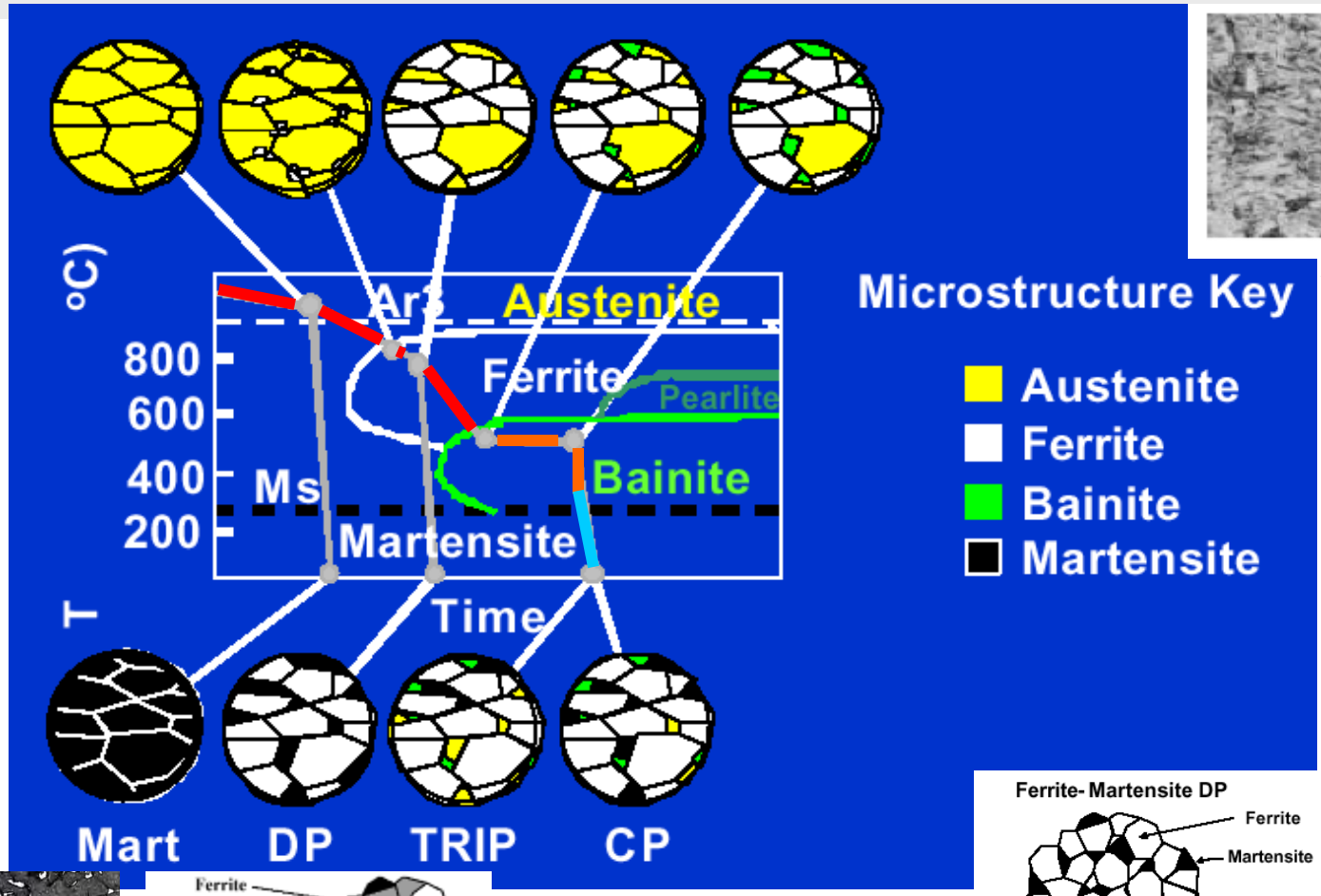
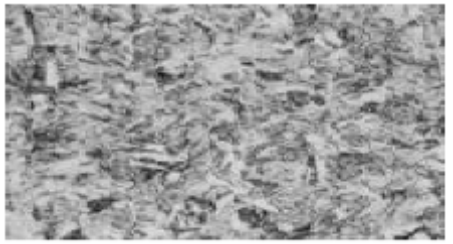
Physical Metallurgy of AHSS

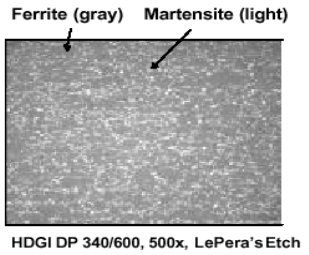




Actual Microstructure

Martensite

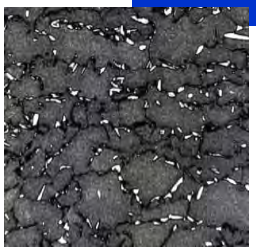
Dual Phase



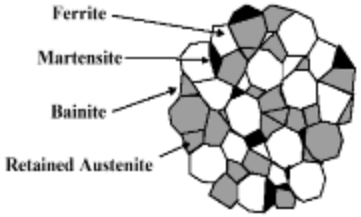
Actual Microstructure

Schematic Illustration

TRIP



Actual Microstructure



Schematic Illustration

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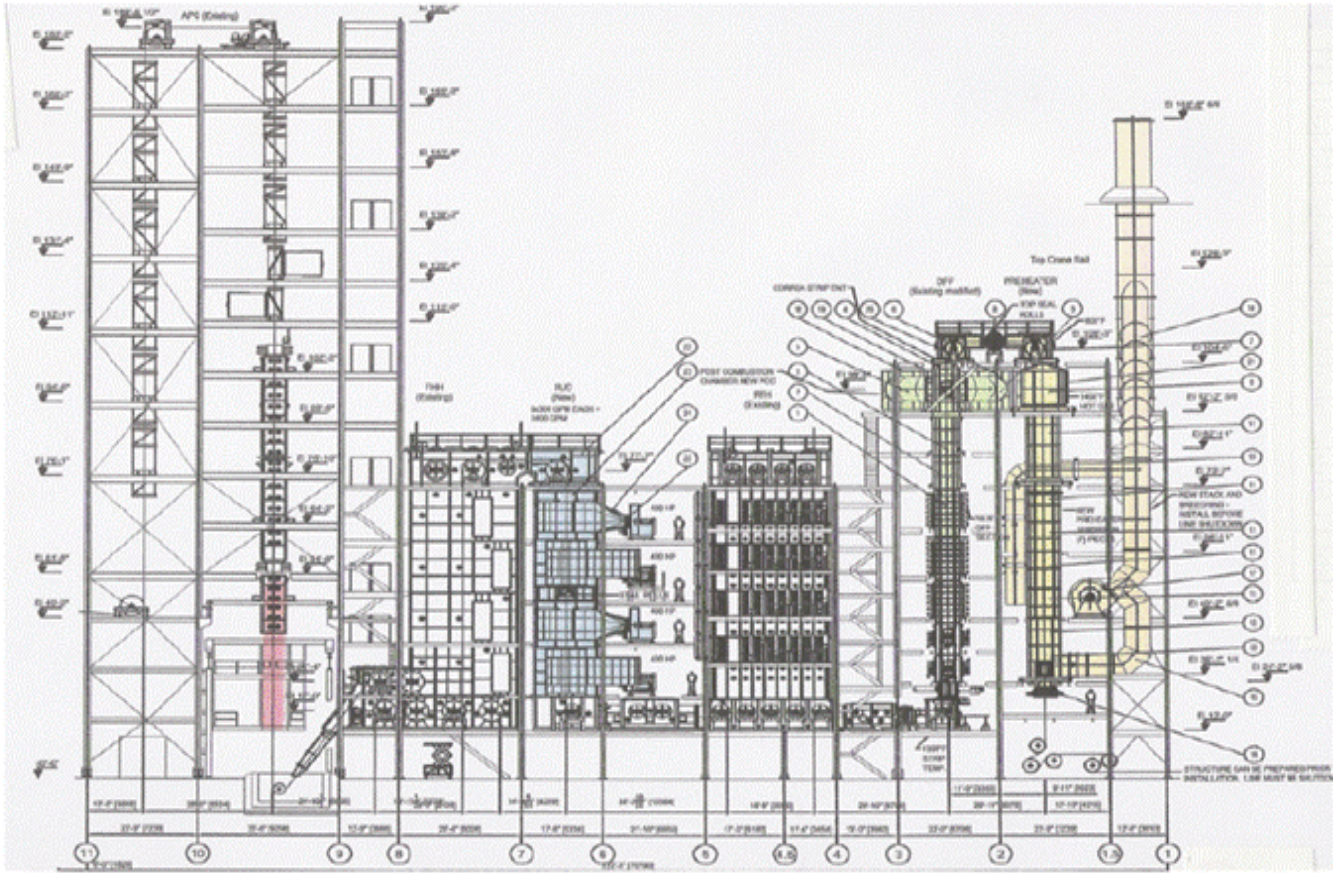
AHSS Processing: Hot Dip Line



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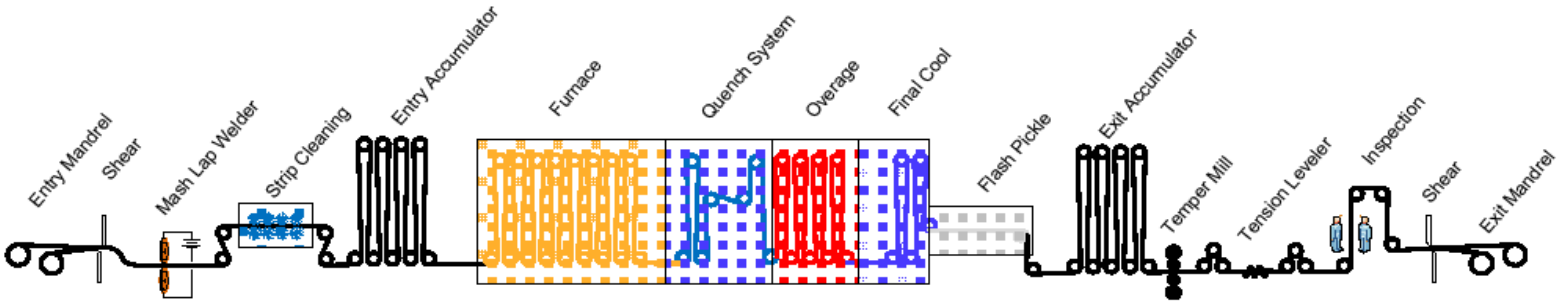
AHSS Processing: CA Line

Continuous Annealing Line



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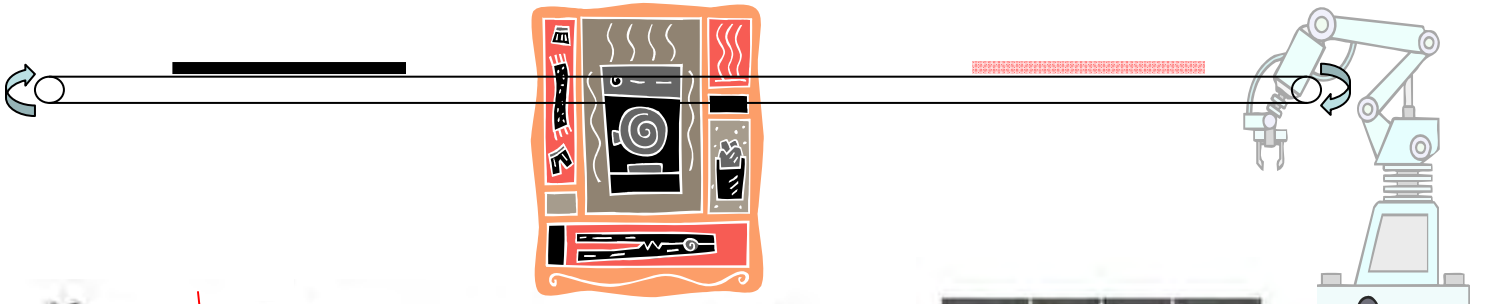
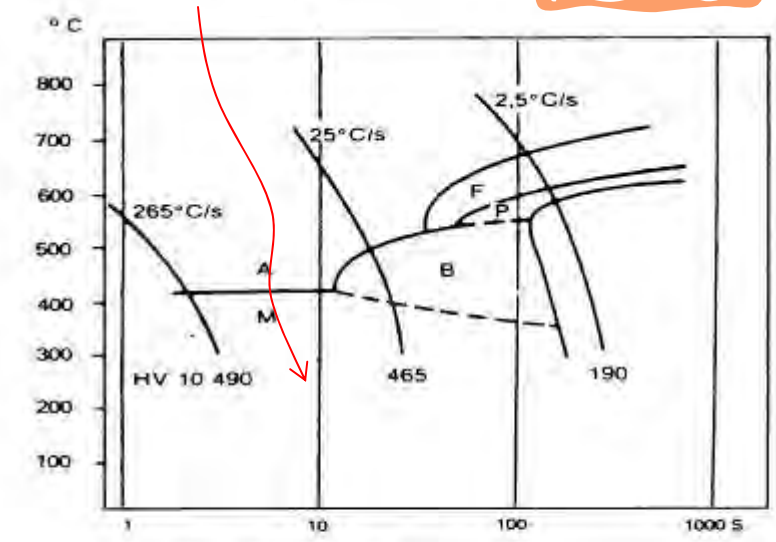
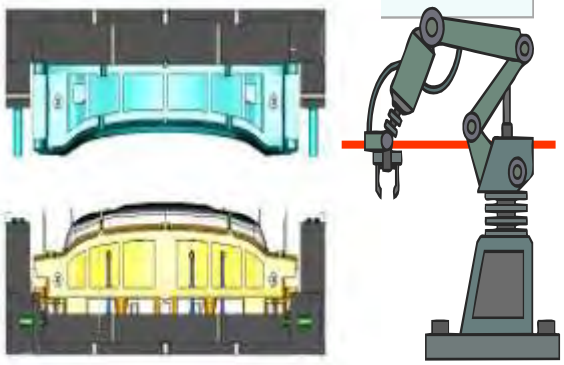
The Hot Stamping Process





A = Austenite
F = Ferrite
P = Pearlite
B = Bainite
M = Martensite



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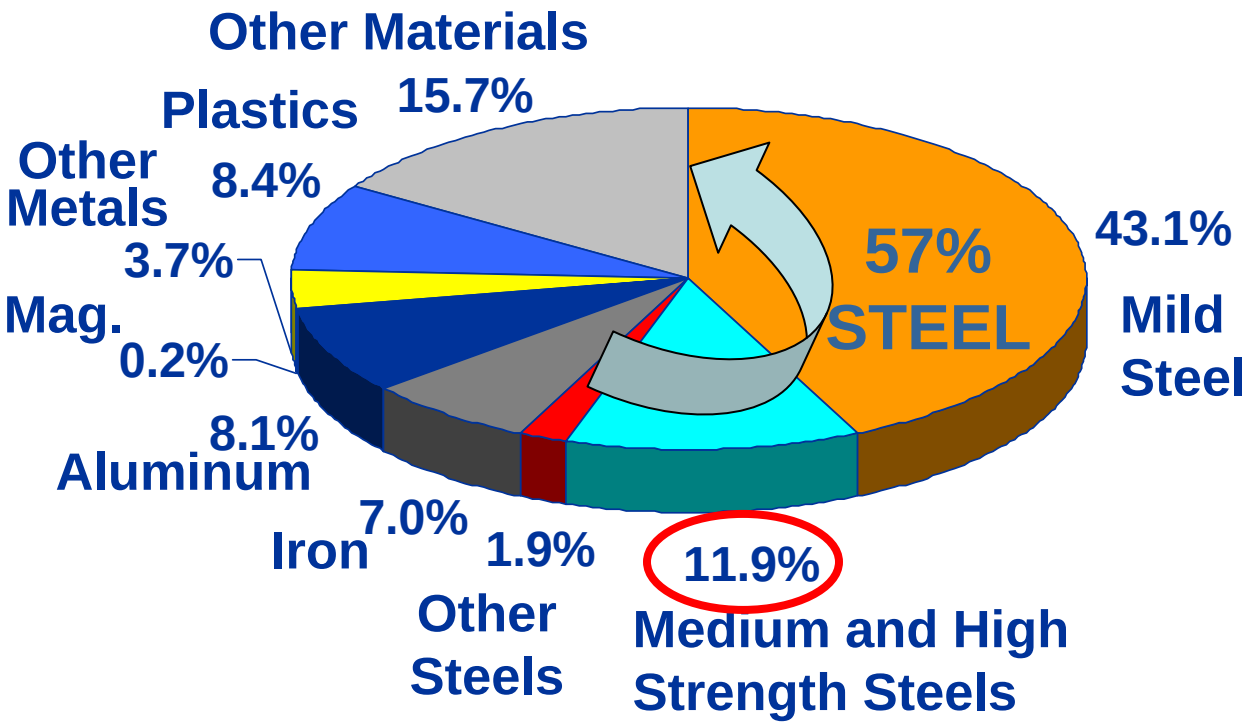
Light Vehicle Materials Content

Average North American 2007 Vehicle

4050 lbs.

2007



Source: Ducker Worldwide

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Materials Trends

North American Net Material Content Per Light Vehicle in Pounds

Material	1975	1995	2009
Mild Steel	2,268	1,702	1,542
Bake Hard and HS Steels	146	258	357
Advanced & Ultra HS Steels	-	35	191*
Cast Iron	609	333	258
Other Ferrous (PMP& SS)***	65	70	75
Cast Aluminum	70	170	259
Other Aluminum	14	42	65
Cu, Zn, Mg & other Metals			
Plastics and Composites			
Glass, Rubber, Textiles etc	581	550	540
Total Pounds/Curb Weight	4,058	3,503	3,755

59% STEEL | 59% STEEL | 58% STEEL

*Totals for 2009, 2015 and 2020 contains 40 lbs., 66 lbs. and 90 lbs. of AHSS long products
**Excludes the impact of batteries for high volume electric and hybrid vehicles
*** Powdered Metal Parts and Stainless Steel

DUCKER WORLDWIDE

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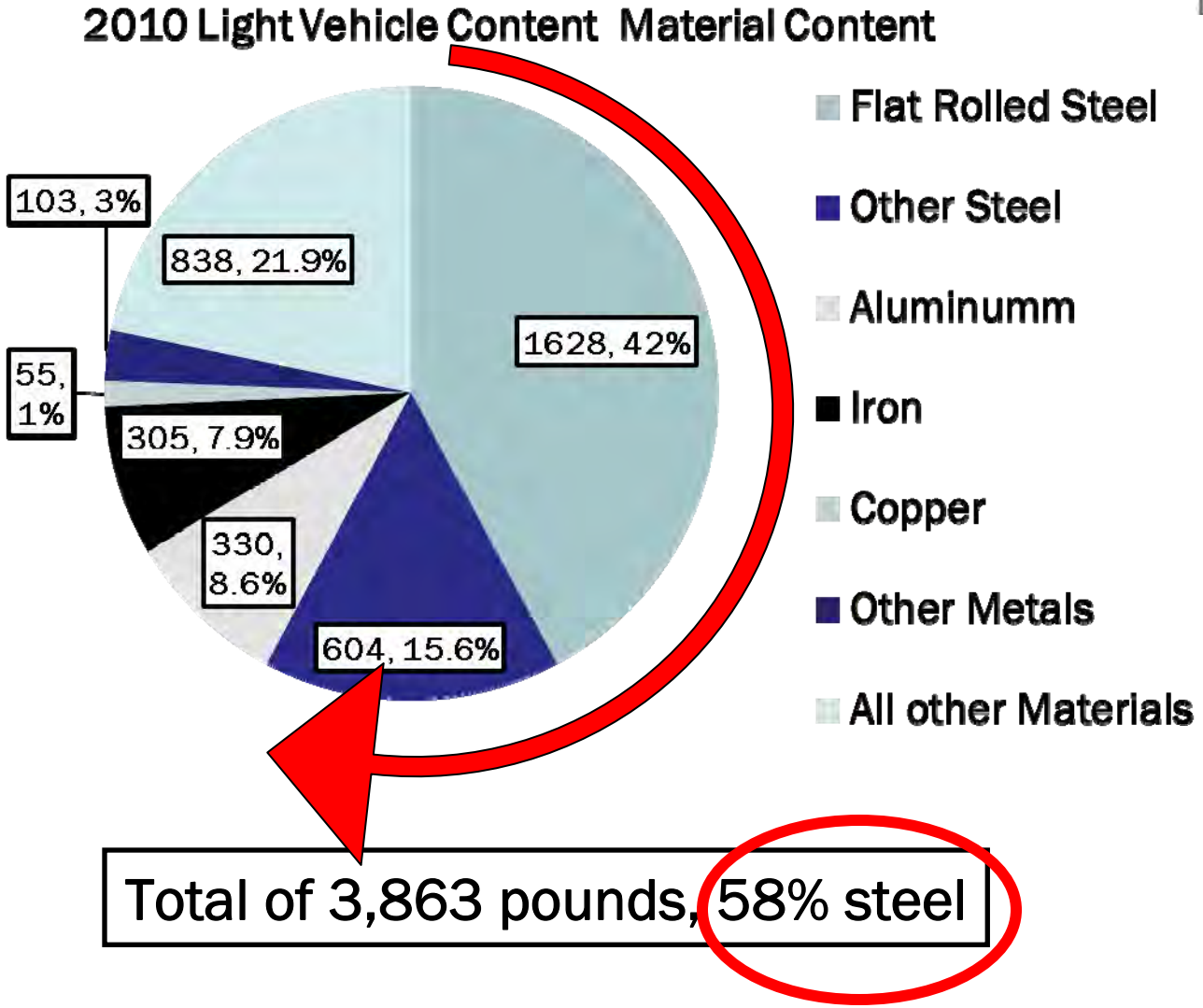
Goal 1: Total Steel Content >57%

DUCKER WORLDWIDE



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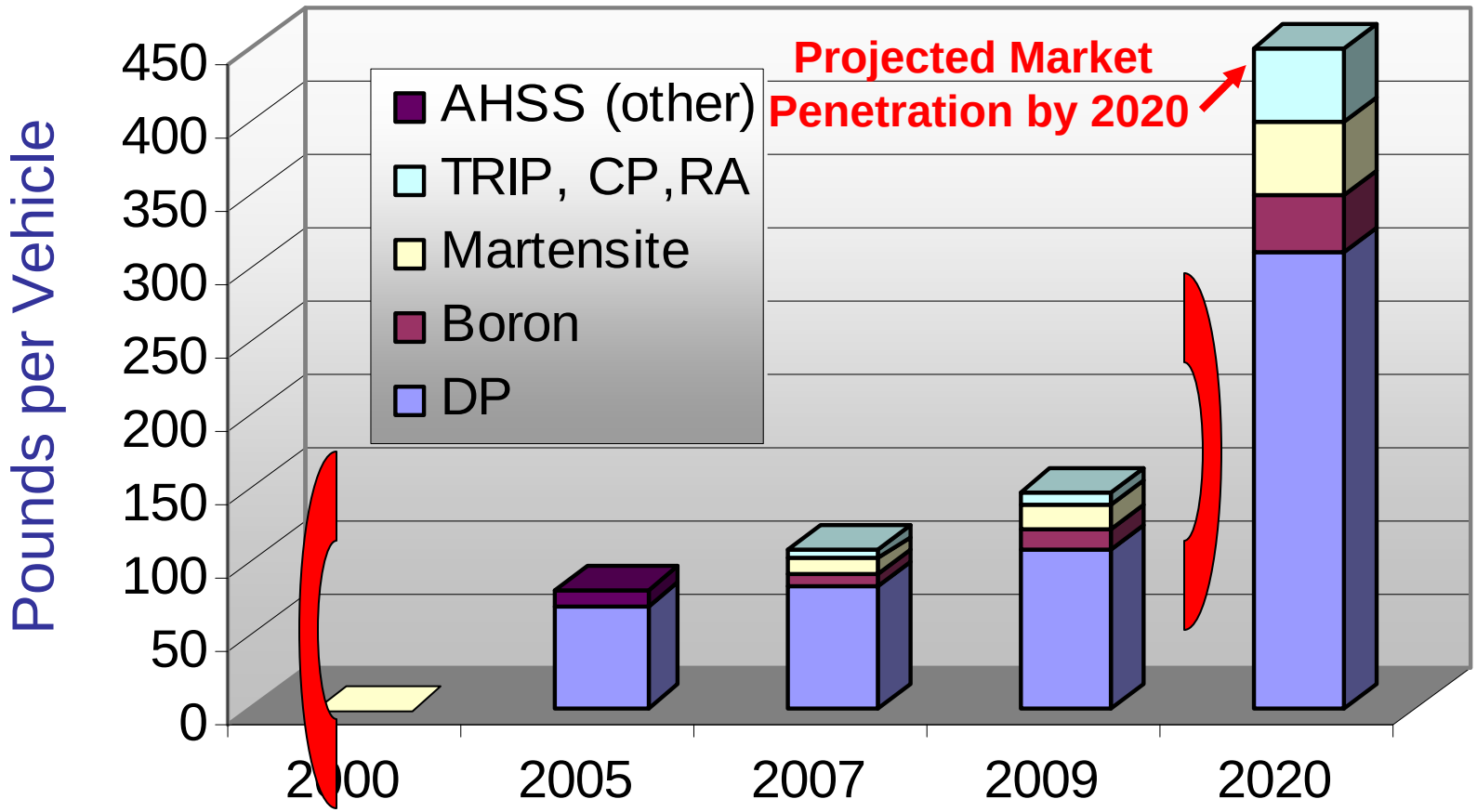
AHSS Growth in NA Vehicles

AHSS - Fastest Growing Automotive Material



Source: Ducker Worldwide 2009

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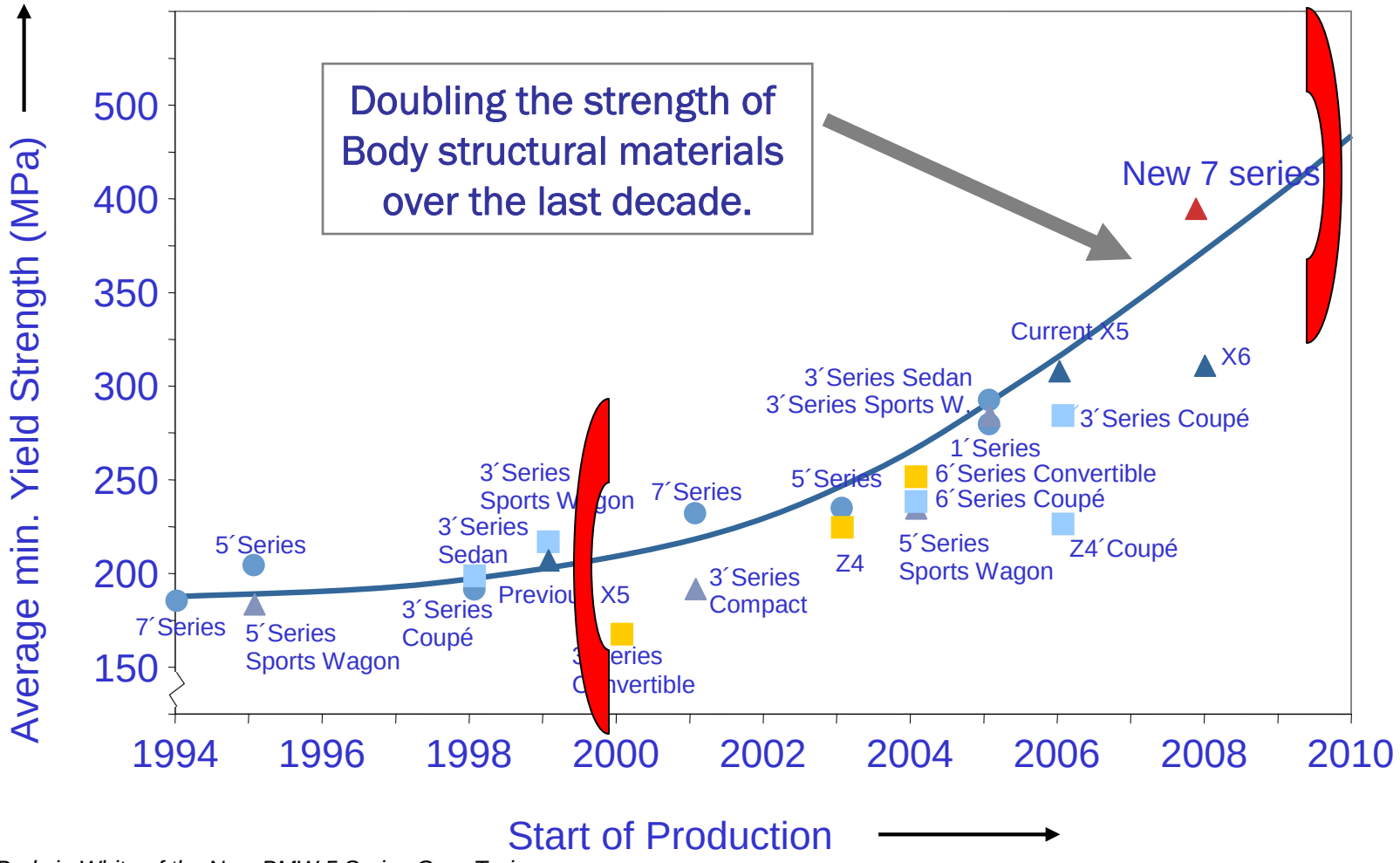
Implementation of AHSS

BMW Implementation of AHSS



The Body in White of the New BMW 5 Series Gran Turismo,
Duane Copeland and Markus Pfesdorf, BMW, GDIS 2010, Livonia MI

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Mass and Performance Trends

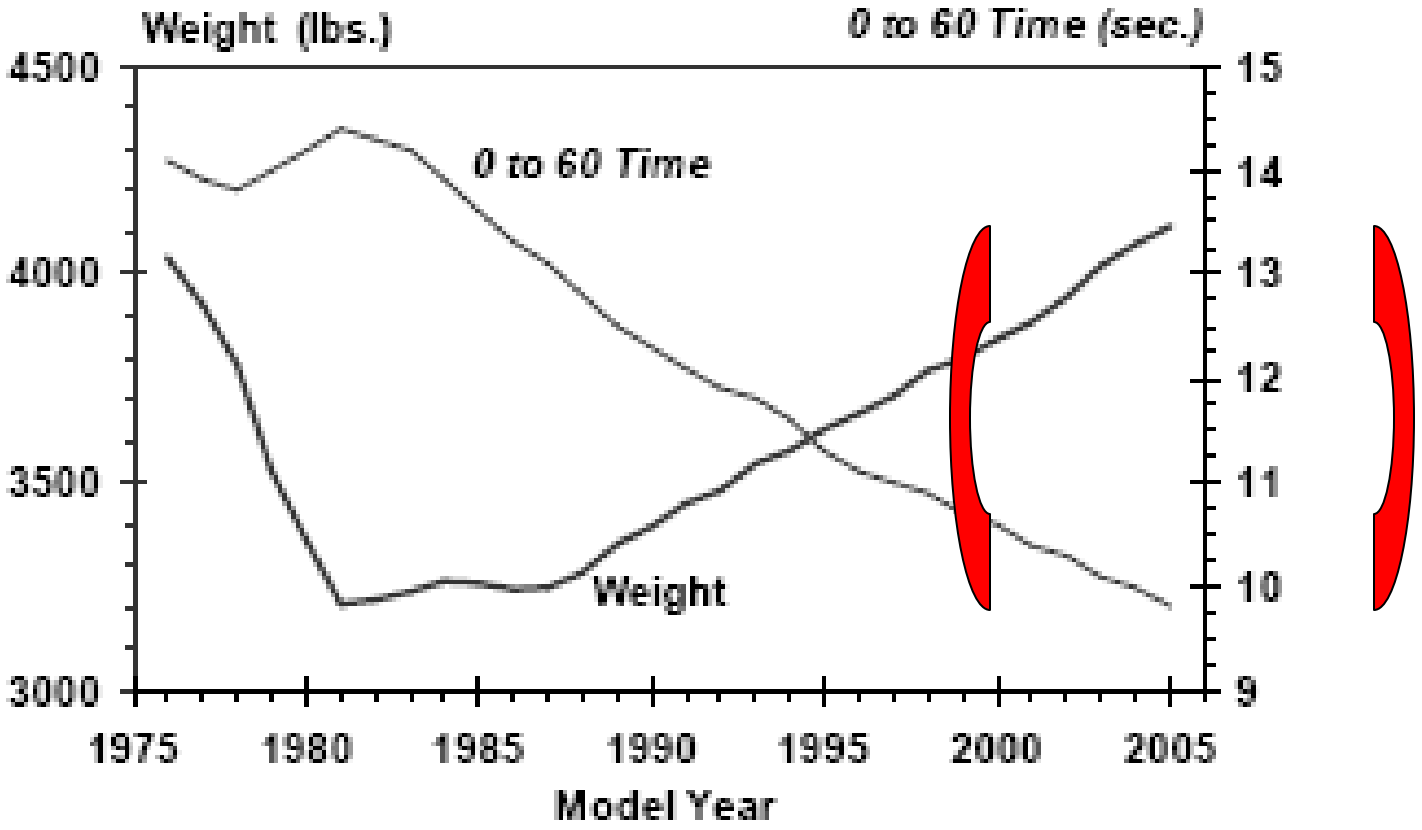

Figure 19. Vehicle Weight and Performance since 1975 (Heavenrich 2006).

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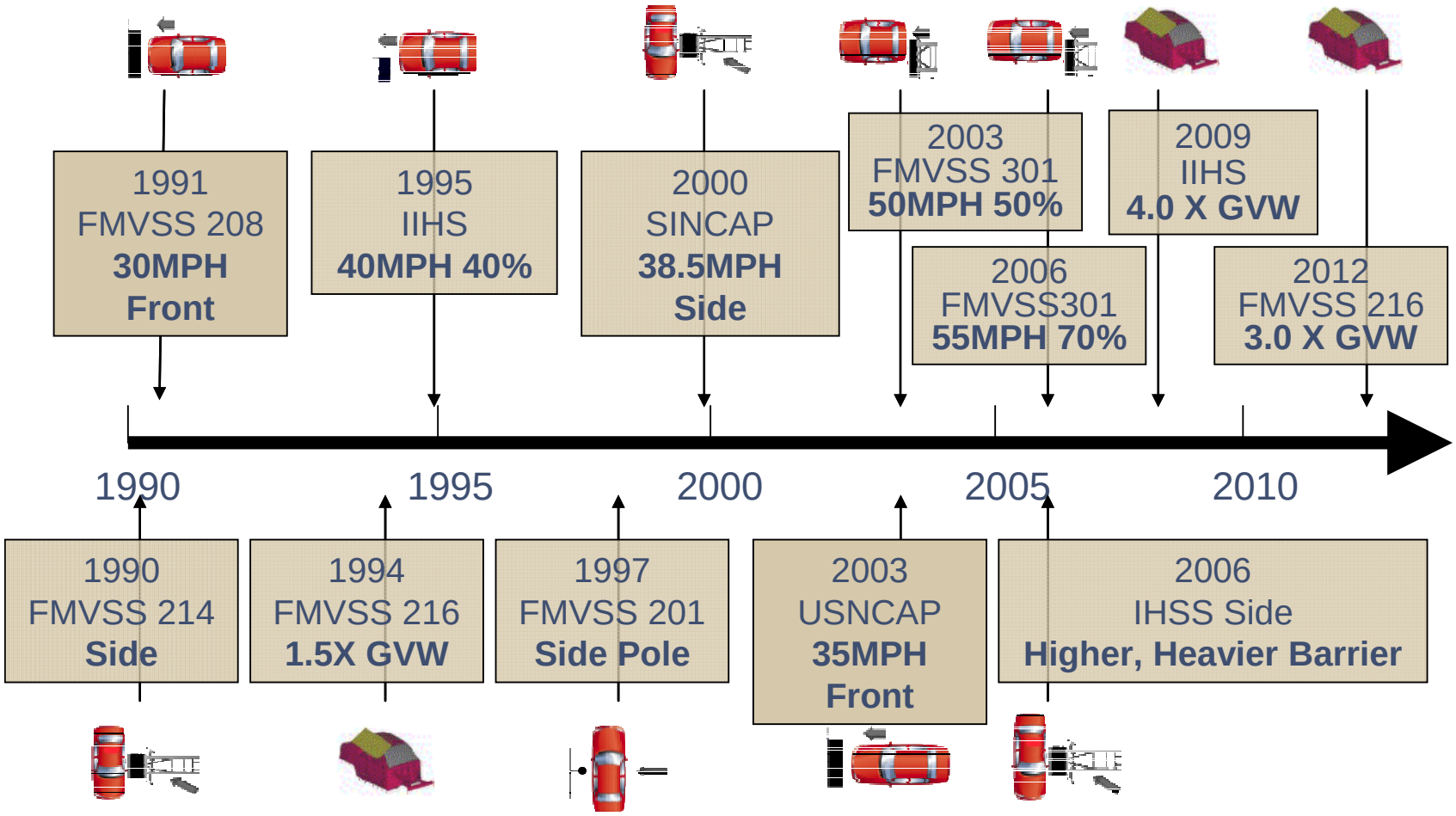
Increasing Crash Requirements



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IIHS Side Impact Test

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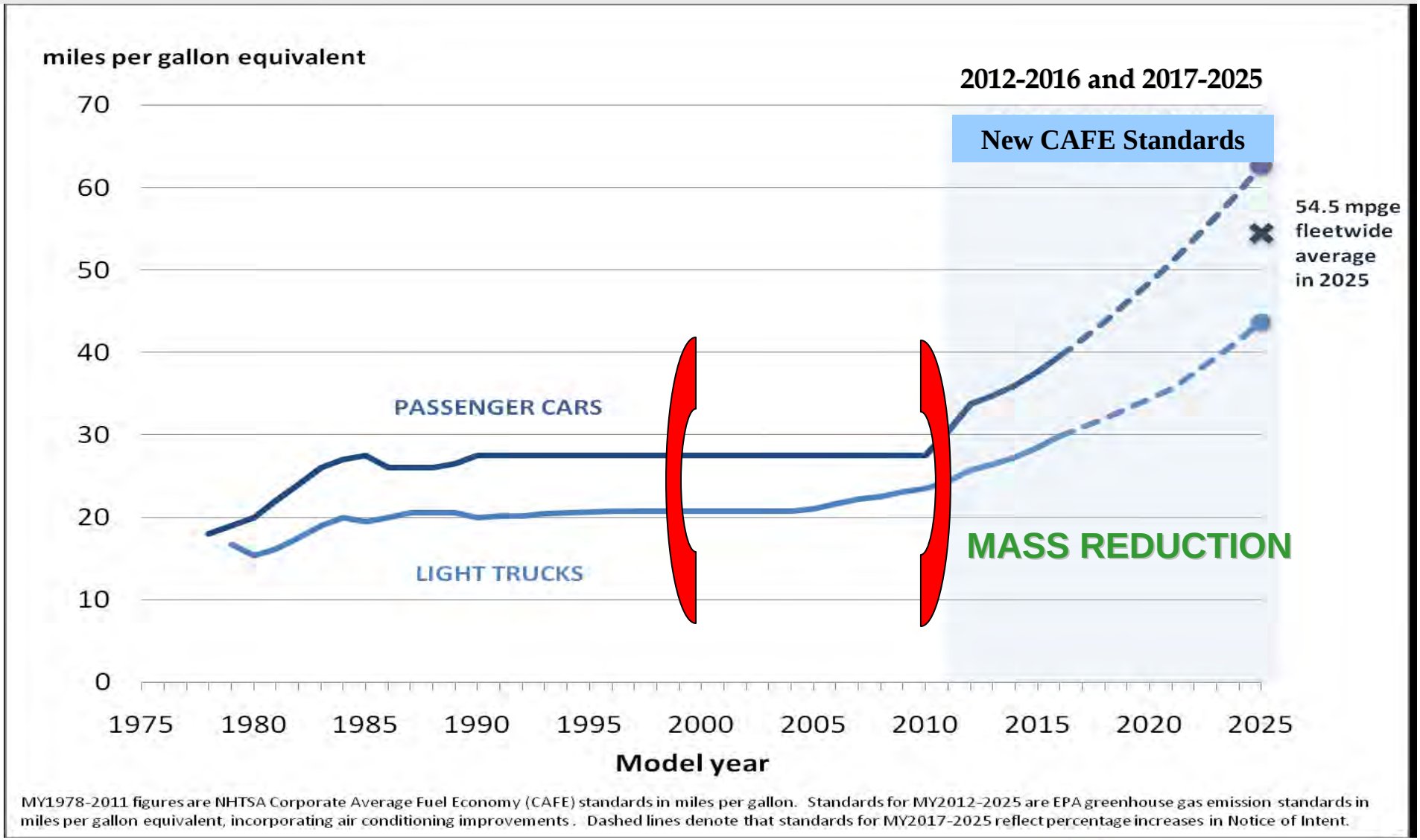
Fuel Economy Regulations



MY1978-2011 figures are NHTSA Corporate Average Fuel Economy (CAFE) standards in miles per gallon. Standards for MY2012-2025 are EPA greenhouse gas emission standards in miles per gallon equivalent, incorporating air conditioning improvements. Dashed lines denote that standards for MY2017-2025 reflect percentage increases in Notice of Intent.

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Mass Reduction and Fuel Consumption

Chapter 5: Simulation – Results Summary

fka

- At 10 % weight saving and <u>without</u> powertrain re-sizing the percentage fuel consumption reductions are as follows:

	NEDC ICEV-G	NEDC ICEV-D	NEDC HV-G	NEDC HV-D	NEDC FCV	HYZEM ICEV-G	HYZEM ICEV-D	HYZEM HV-G	HYZEM HV-D	HYZEM FCV
Compact Class	-2.6 %	-3.5 %					-3.4 %	-3.2 %	-3.4 %	-4.9 %
Mid-Size Class	-1.9 %	-2.7 %					-3.4 %	-4.2 %	-3.8 %	-5.1 %
SUV	-2.4 %	-2.6 %	-2.9 %	-4.5 %	-4.7 %	-3.0 %	-3.2 %	-3.4 %	-3.3 %	-4.6 %

2 to 5 %

- At 10 % weight saving and <u>with</u> powertrain re-sizing the percentage fuel consumption reductions are as follows:

	NEDC ICEV-G	NEDC ICEV-D	NEDC HV-G	NEDC HV-D	NEDC FCV	HYZEM ICEV-G	HYZEM ICEV-D	HYZEM HV-G	HYZEM HV-D	HYZEM FCV
Compact Class	-6.8 %	-7.1 %					-5.5 %	-4.9 %	-4.8 %	-3.0 %
Mid-Size Class	-8.2 %	-7.9 %					-6.6 %	-5.4 %	-5.9 %	-5.0 %
SUV	-7.4 %	-7.1 %	-5.1 %	-6.0 %	-5.9 %	-5.7 %	-5.6 %	-5.5 %	-5.2 %	-4.6 %

5 to 8 %

Determination of Weight Elasticity of Fuel Economy for Conventional ICE Vehicles, Hybrid Vehicles and Fuel Cell Vehicles, fka Report 55510, June 2007

Source: Market Data

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Growing Threat from Competing Materials

Expect Ford's next-generation F-Series full-size pickup to feature aluminum body panels.

WardsAuto, Jan. 3, 2012

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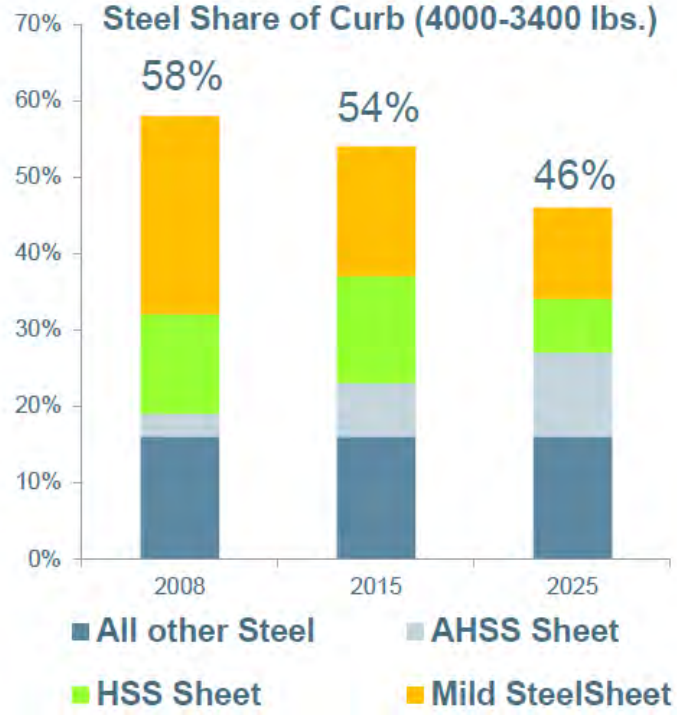
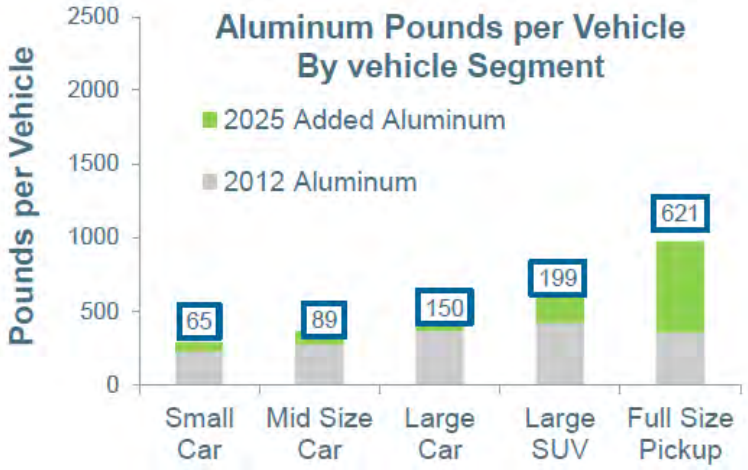
Growing Threat from Competing Materials

"It's good news for the aluminum industry. It's not a death knell for steel," said Ducker's Richard Schultz, "**Vehicles will still be predominantly steel 20 years from now**, but steel will have to share the body and closure market with aluminum going forward."

Pittsburgh Post Gazette, October 9, 2011





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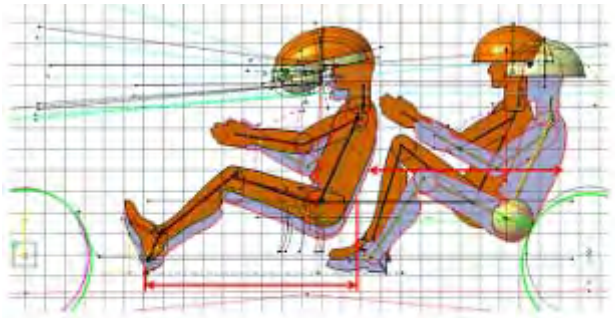
FutureSteelVehicle

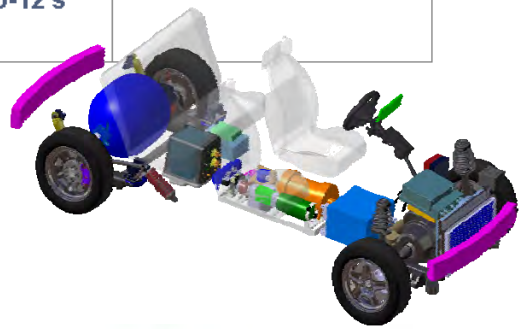


Vehicle	Front Leg Room (mm)	Rear Leg Room (mm)	Luggage (Liters)
FSV 1	1065	825	250
FSV 2	1065	925	370

Representing 70% market share worldwide:

- Small cars
  (up to 4,000mm, A/B class)
- Mid-Class cars
  (up to 4,900mm, C/D class)

FSV 1 4-door hatchback 3700 mm	**PHEV20** Electric Range: 32km Total: 500km Max Speed: 150km/h 0-100 km/h 11-13 s	**BEV** Total Range: 250km Max Speed: 150km/h 0-100 km/h 11-13 s
FSV 2 4-door sedan 4350 mm	**PHEV40** Electric Range: 64km Total: 500km Max Speed: 161km/h 0-100 km/h 10-12 s	**FCEV** Total Range: 500km Max Speed: 161km/h 0-100 km/h 10-12 s



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More AHSS Grades = More Mass Reduction

FutureSteelVehicle's Steel Portfolio

Mild 140/270	DP 350/600	TRIP 600/980
BH 210/340	TRIP 350/600	TWIP 500/980
BH 260/370	SF 570/640	DP 700/1000
BH 280/400	HSLA 550/650	CP 800/1000
IF 260/410	TRIP 400/700	MS 950/1200
IF 300/420	SF 600/780	CP 1000/1200
DP300/500	CP 500/800	DP 1150/1270
FB 330/450	DP 500/800	MS 1150/1400
HSLA 350/450	TRIP 450/800	CP 1050/1470
HSLA 420/500	CP 600/900	HF 1050/1500
FB 450/600	CP 750/900	MS 1250/1500
HSLA 490/600		

Expanded range of steel grades

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denotes steel included in ULSAB-AVC

denotes steel grades added for FSV

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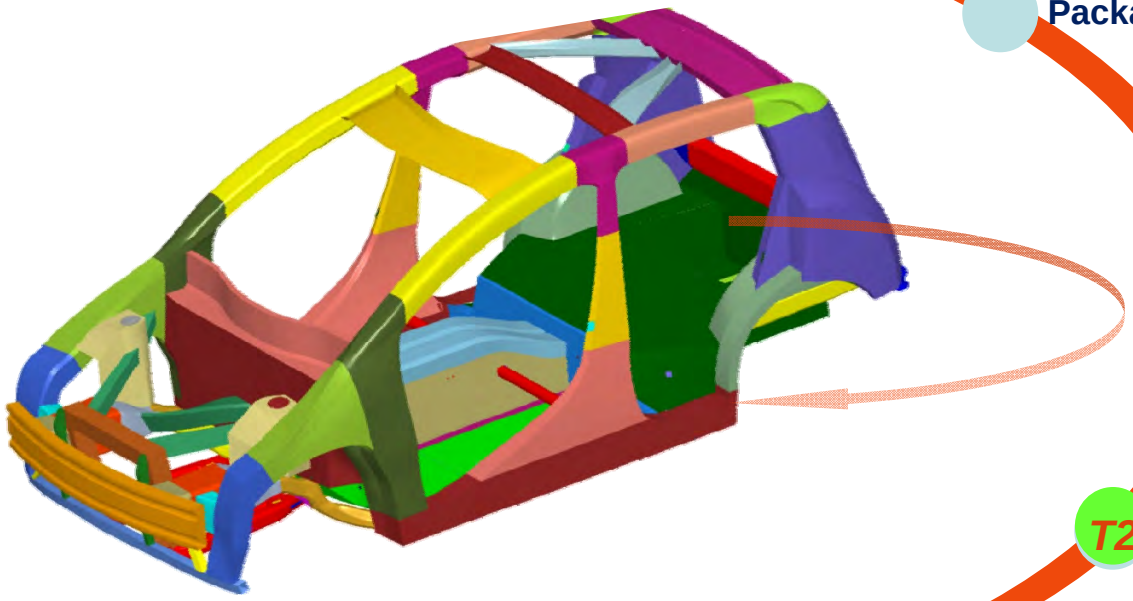
Mass Reduction Through Load Path and 3G Optimization with AHSS



Phase1
Technology Assessment

Packaging

Styling &
aerodynamic

T1

T2 Linear-Static
Topology
Optimization

T3 Non-Linear Dynamic
Topology Optimization
(LF3G)

T4 Sub-System
3G Optimization

T5 Detail Design

Design
Confirmation

T6 Gauge
Optimization

Final Design
Confirmation

Phase 2
Report

WorldAutoSteel

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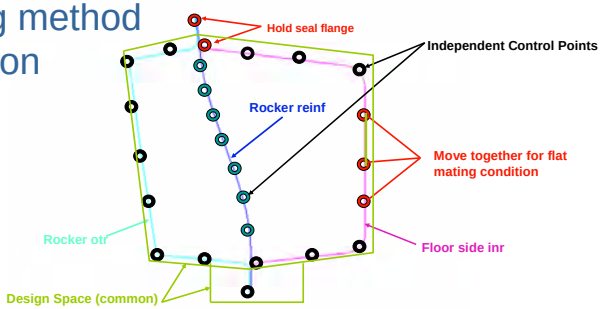
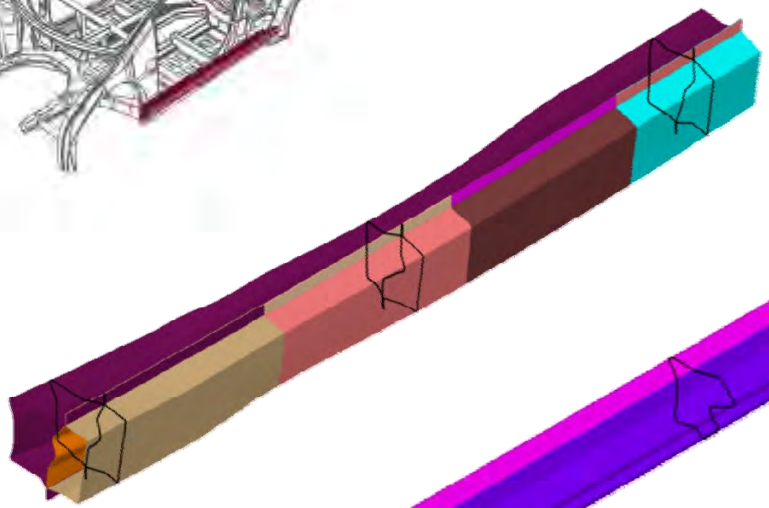
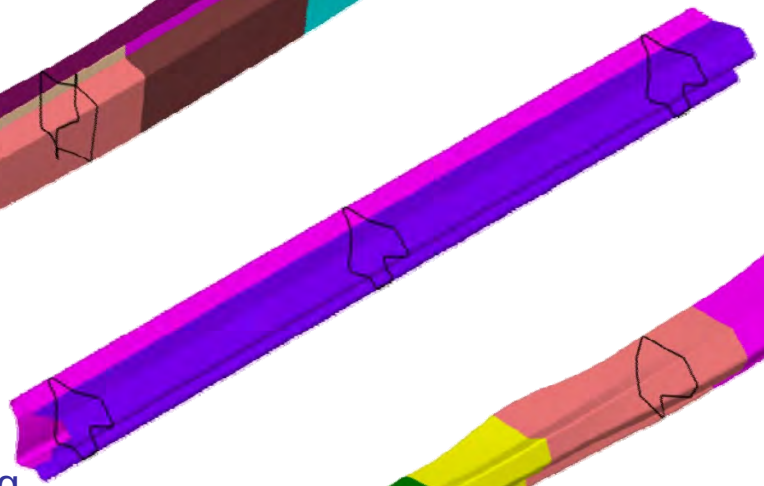
Mass Reduction Through Sub-System Optimization

Section control points – constraining method determines the manufacturing solution

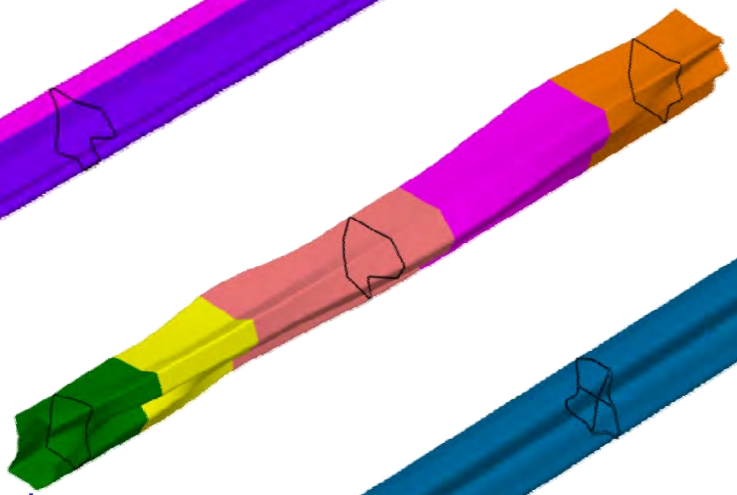




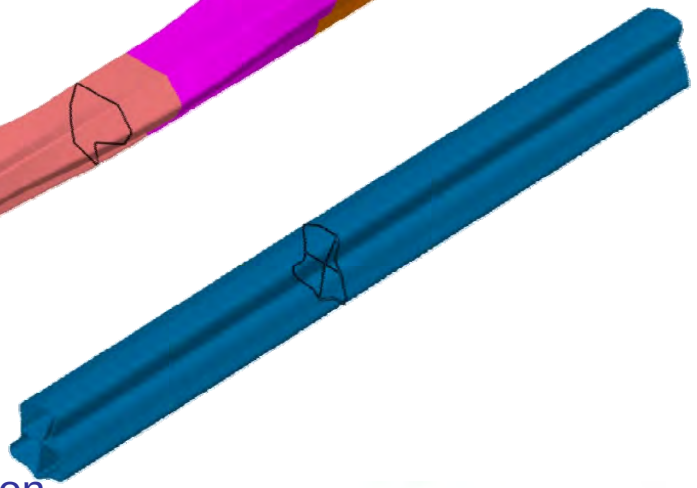
Stamping AHSS



Roll-forming AHSS



Hydroforming AHSS



Extrusion Aluminum

WorldAutoSteel

www.smdisteel.org

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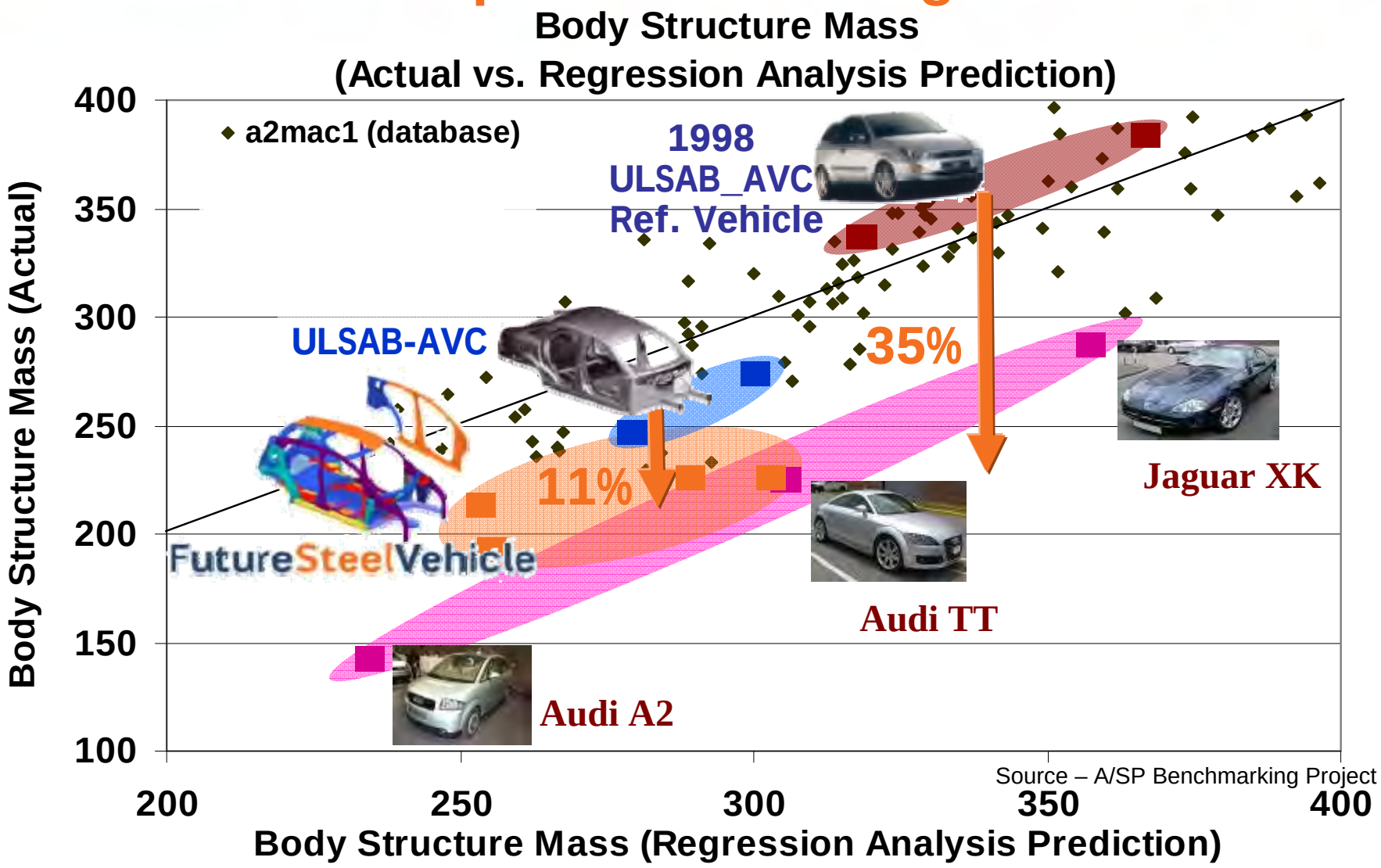
FSV Compared to UltraLight – Mass



Source – A/SP Benchmarking Project

Steel Mass Similar to Aluminum

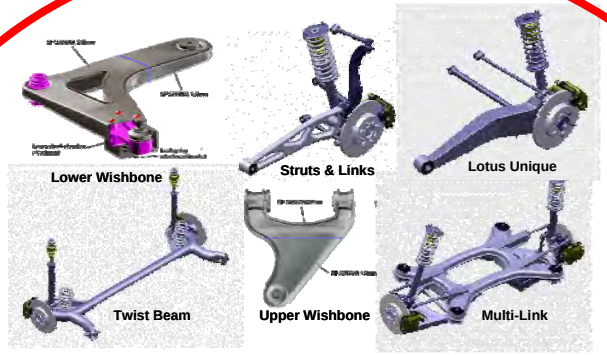
AAC Project Addressing Threats

CLOSURES

Doors, 2011 – 2012

WHEELS

Wheels, 2011 – 2012



SUSPENSIONS

Lower Control Arm, 2010 – 2011
Twist Beam - 2012

FUEL TANKS

Fuel Tanks, 2010 – 2011

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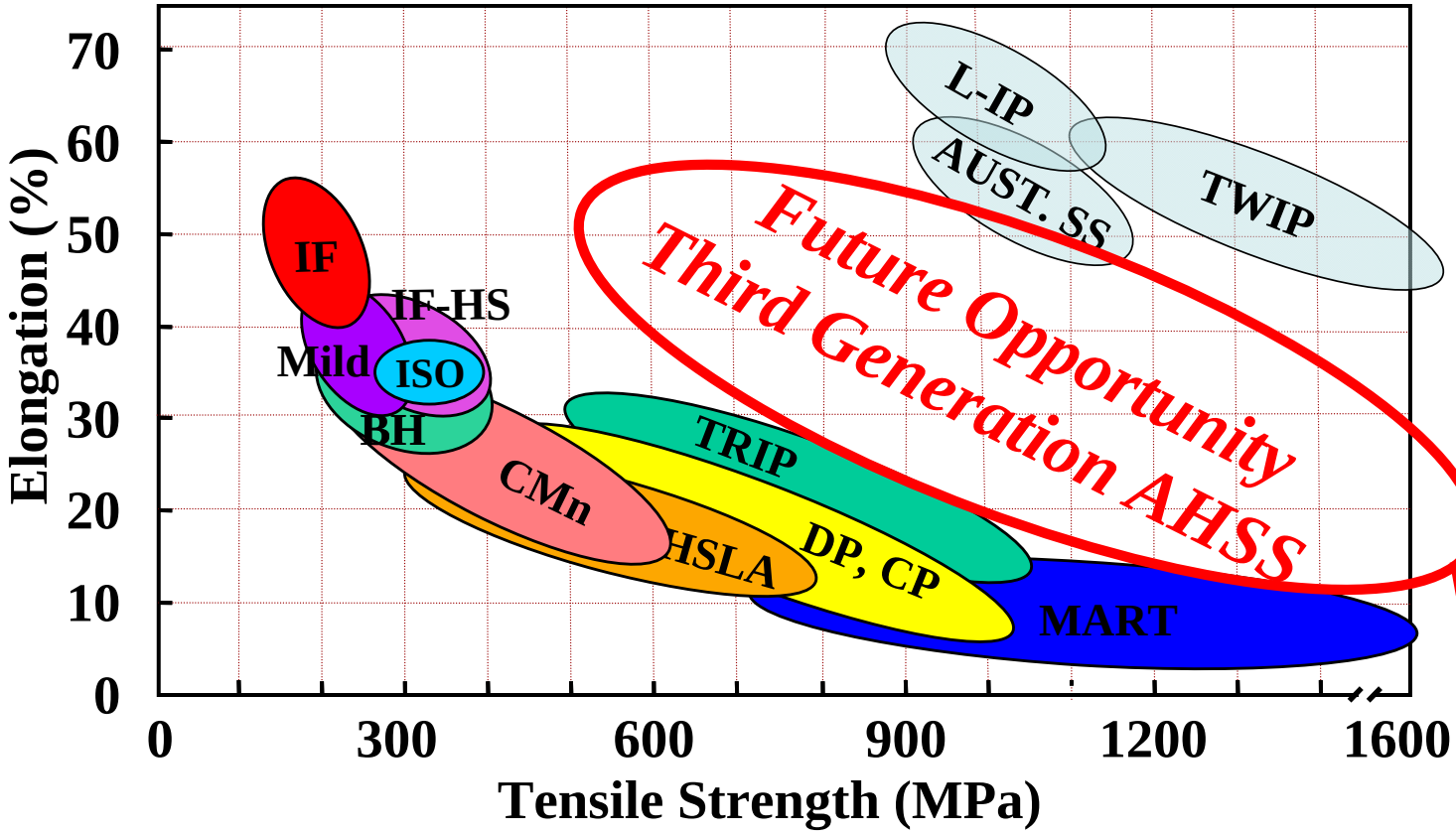
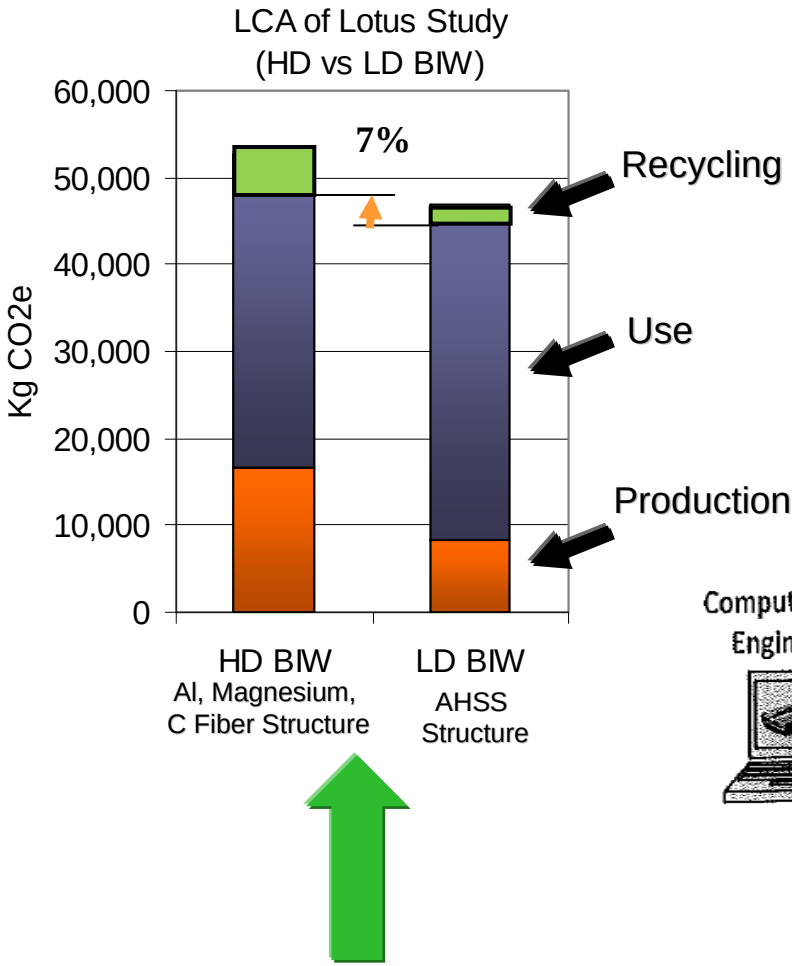
3rd Generation of AHSS

New 3rd Generation AHSS Grades offer more mass reduction with AHSS, because more parts can be made at high strength



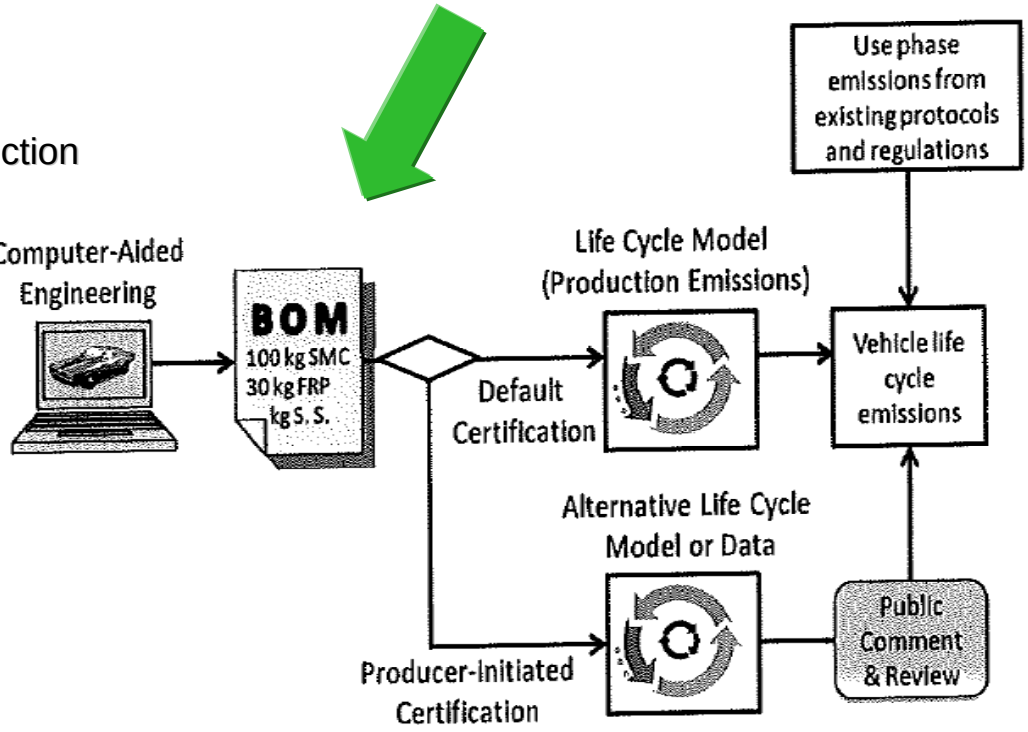
For 2017-2025, new formable AHSS grades will enable more steel mass reduction

LCA Research at UC Davis



Materials Matter

Bill of Materials Approach for OEMs



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Steel Conclusions

- Steel products have kept pace with OEM demands for decades.
- New aggressive fuel economy standard are putting a premium on mass reduction, right or wrong.
- Optimized (3G - gage, geometry, grade) steel structures approach the mass of aluminum structures in many cases.
- 10% mass reduction results in 2 - 3.5% reduction in fuel consumption for ICE vehicles and 5.5 - 8.2% if powertrains are resized.
- 3rd Generation AHSS grades are being researched and will add more mass reduction capability for steel parts which today cannot be easily formed.
- WorldAutoSteel's *FutureSteelVehicle* project is an engineering study showing the growing potential of steel to fulfill future vehicle demands.
- LCA gives a decided advantage to steel in terms of enabling lower total emissions in future high-fuel-economy vehicles.