

50 year Perspective of Automotive Engineering Body Materials and an Analysis of the Future

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General Motors Manufacturing Engineering

Great Designs in Steel 2008



Steel Becomes the “Material of Choice” for Auto Bodies



Benz Patent Motorwagen 1886 (Replica)

- 1914 Dodge & Budd produce 5,000 all-steel bodies
- All-steel body was lighter, stronger, easier to make
- Most significant advantage was in painting

- Original bodies made of wood & steel
- Quick to tool, easy to change
- Large number of skilled workers



Dodge Brothers Touring Car 1917



“Every time the price of steel goes up,
Detroit’s auto makers moan in anguish
and intensify their search for
replacements”



Magnesium shell of the Essex Aero,
held easily aloft by a
company worker, weighs only
132 lbs.

THE **real threat** TO **STEEL CARS**

gas
“Every time the price of ~~steel~~ goes up,
Detroit’s auto makers moan in anguish
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replacements”

Materials Causing the Biggest Stir in Body Technology

Plastics

- “been getting the big play ... as successor to steel”

Aluminum Alloys

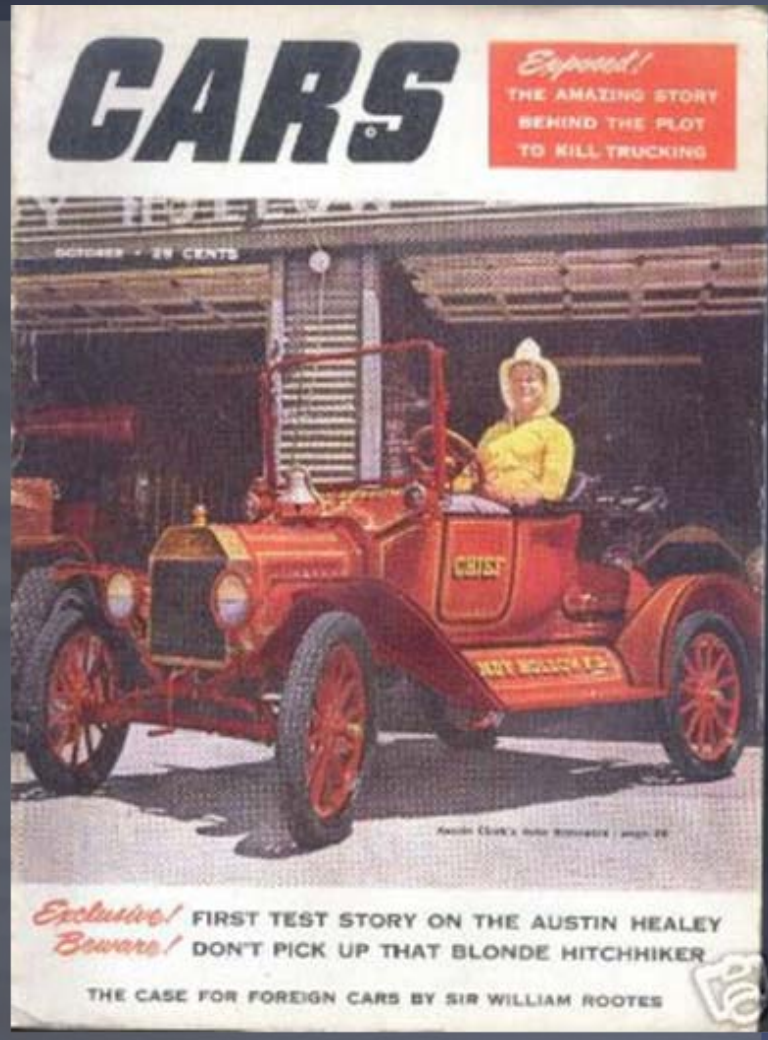
- “about as strong as steel, less than half the weight”
- “used ...since birth of auto”
- “most plentiful metal on earth”

Magnesium Alloys

- “even lighter than aluminum, stronger for its weight than steel”
- “most easily machined and cast”
- “enough in the ocean... to provide 100,000,000 tons a year”

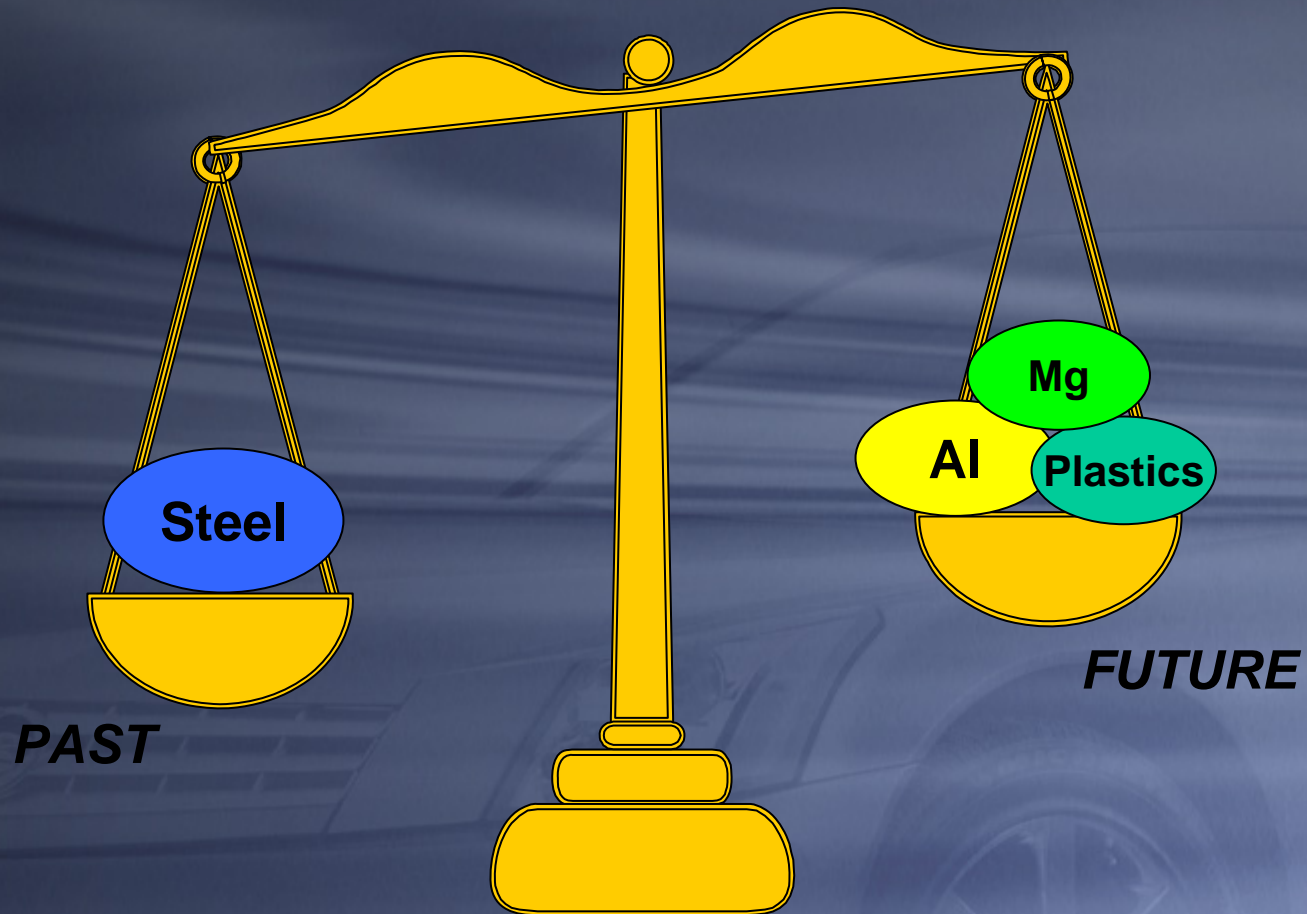


Published October 1953

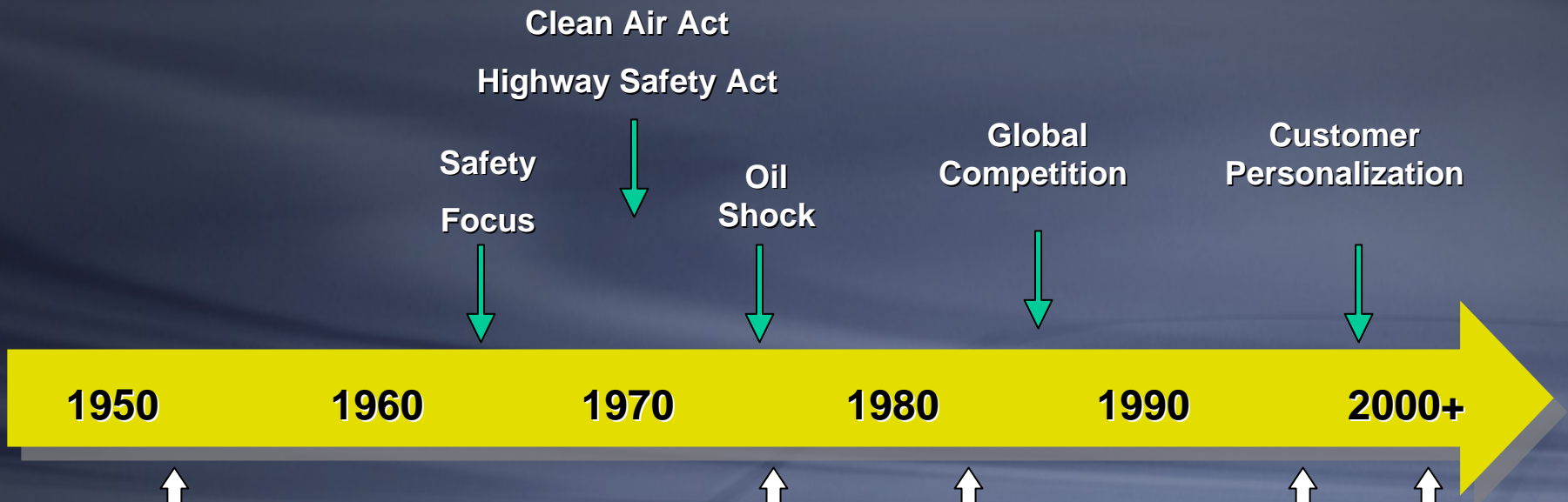


“The day of the passenger car *made primarily of iron and steel* is on the wane! Some sources predict that *by 1960* a Cadillac will weigh less than a 1953 Chevrolet and a Chevy will probably weigh about as much as a motorcycle.”

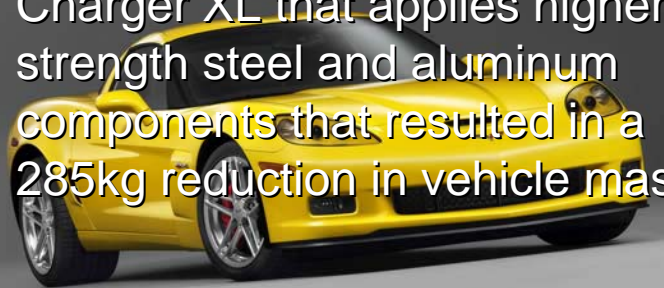
Prediction 50+ Years Ago...



Key Product Drivers & Resulting Vehicles



Late 1970's – Dodge releases Charger XL that applies higher strength steel and aluminum components that resulted in a 285kg reduction in vehicle mass.



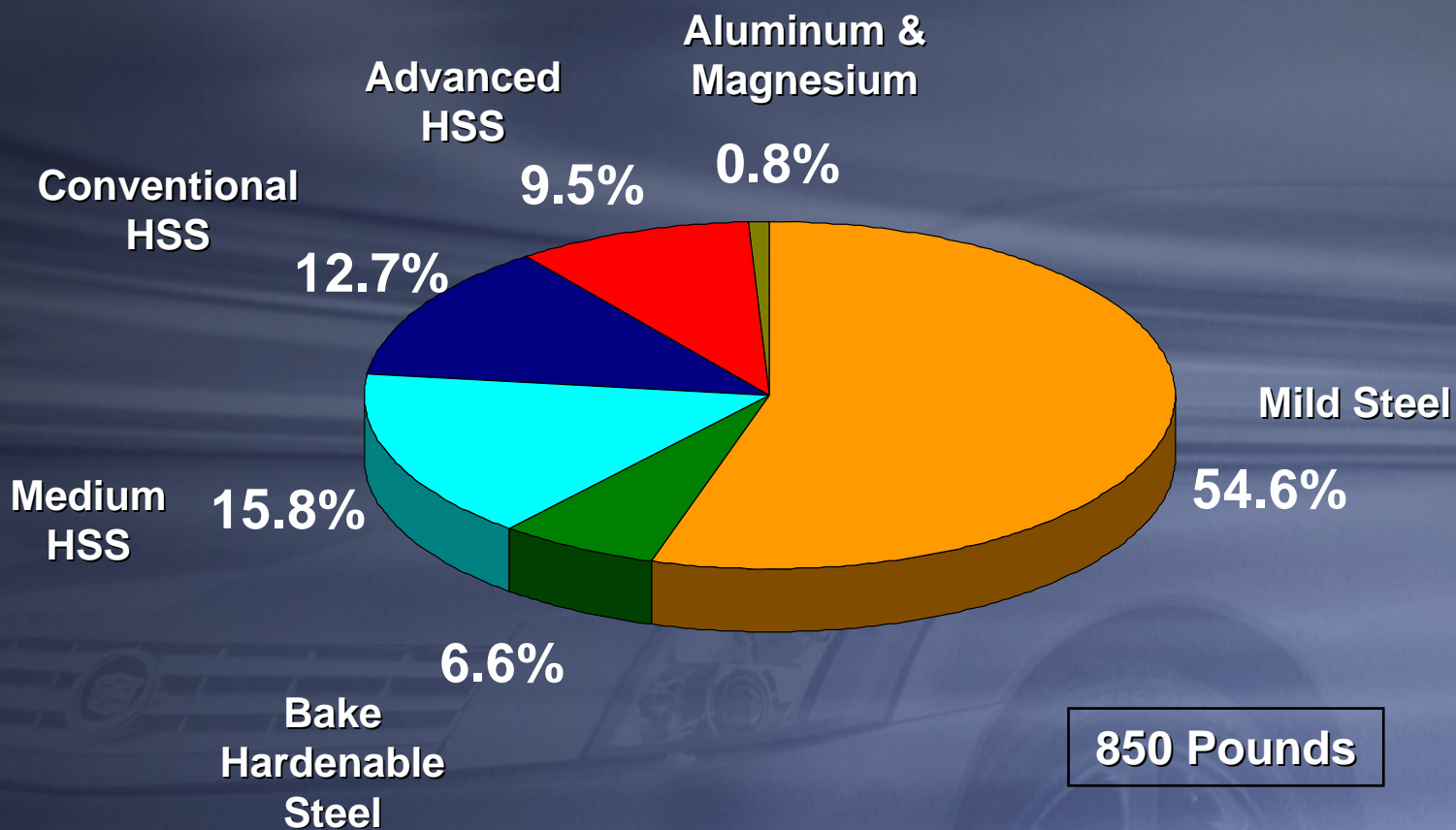
FastCoolCars.com

Steel Mass Reduction



Current Body and Closure Metallic Material Content by Type for North America

*Source: Ducker Worldwide
2007*



The Question is ...

Why do these materials continue to fall short of the prediction?

Comparison of Materials by Performance

	Density	Modulus	Tensile Strength	Elongation	Corrosion Resistance
Mild Steel	----- BASELINE -----				
Aluminum	+	-	0	0	0 / +
Magnesium	+	- -	0	-	0 / -
Polymers & Composites	+	0 / -	- / 0 / +	-	+

KEY: 0 = equal + = better - = worse

Comparison of Materials by Manufacturability

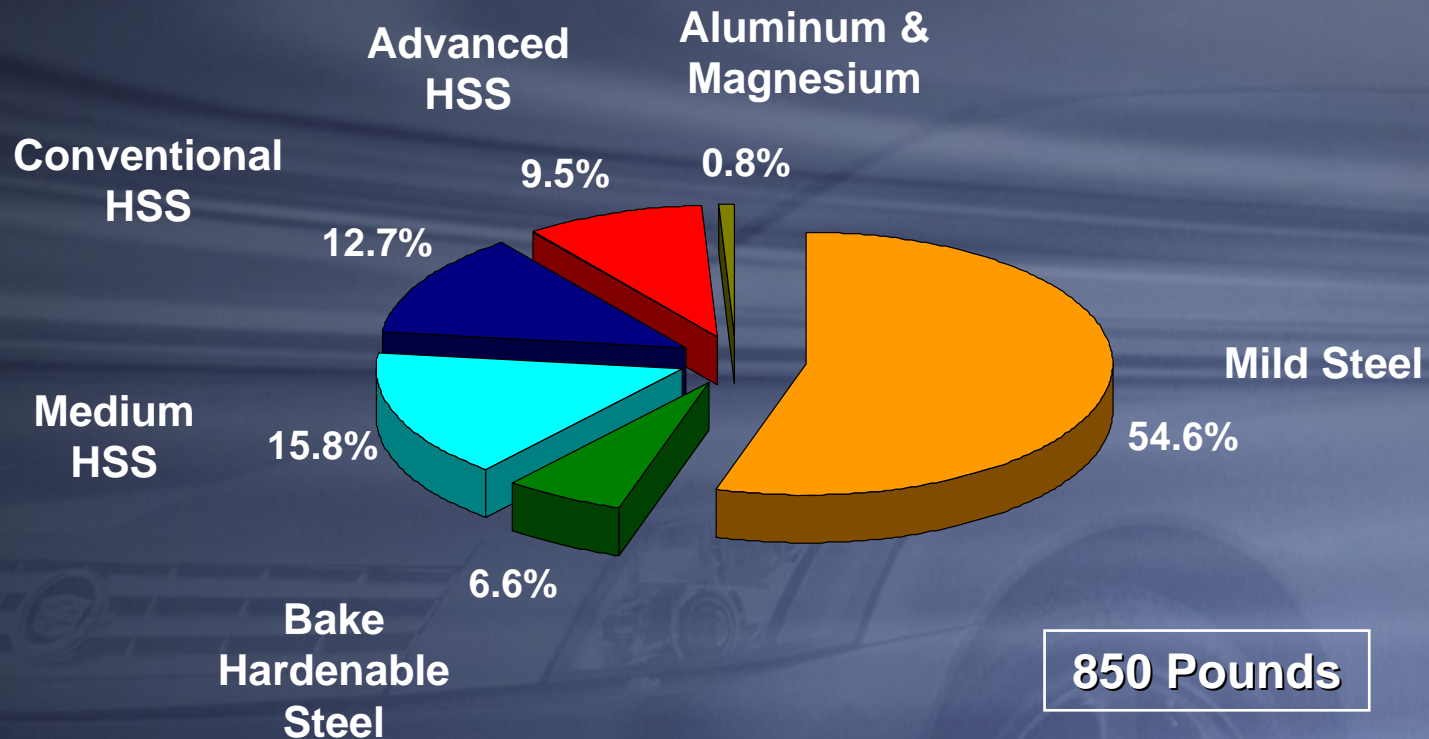
<u>Steel</u>	<u>Aluminum</u>	<u>Magnesium</u>	<u>Polymer/Composites</u>
<u>Advantages:</u> <ul style="list-style-type: none">• Formability• Weldability• Infrastructure• Painted Surface	<u>Advantages:</u> <ul style="list-style-type: none">• Formability• Castability• Painted Surface	<u>Advantages:</u> <ul style="list-style-type: none">• Castability	<u>Advantages:</u> <ul style="list-style-type: none">• Low cost tooling• Shorter lead time
<u>Disadvantages:</u> <ul style="list-style-type: none">• Castability	<u>Disadvantages:</u> <ul style="list-style-type: none">• Lower formability than steel• Weldability	<u>Disadvantages:</u> <ul style="list-style-type: none">• Formability• Elevated temperature stamping & hemming• Weldability	<u>Disadvantages:</u> <ul style="list-style-type: none">• Cycle Time• Infrastructure• Difficult to repair• Painted Surface

Comparison of Materials by Other Important Characteristics

	Cost (Est. \$/lb.)	Availability (Annual Metric Ton Production)	Environment (Primary Production Emissions reported by industry)
Mild Steel (Baseline)	\$0.50	110 Million	<ul style="list-style-type: none"> • easy to recycle • Emissions = 2.3 – 2.7 kg CO₂/kg
Aluminum (Al)	\$1.00	2.5 Million	<ul style="list-style-type: none"> • easy to recycle • Emissions = 13.9 – 15.5 kg CO₂/kg
Magnesium (Mg)	\$1.50	0.5 Million	<ul style="list-style-type: none"> • easy to recycle • Emissions = 18.0 – 24.8 kg CO₂/kg
PMC	\$1.20 - 6.50	Unknown	<ul style="list-style-type: none"> • difficult to recycle • Emissions = 2.5 – 23.0 kg CO₂/kg

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Magnesium	+	- -	0	-	0 / -
Polymers & Composites	+	0 / -	- / 0 / +	-	+
HSS/AHSS	0	0	++	0 / -	0

Comparison of Materials by Manufacturability

Steel & HSS/AHSS

Advantages:

- Formability
- Weldability
- Infrastructure
- Painted Surface

Disadvantages:

- Castability

Aluminum

Advantages:

- Formability
- Castability
- Painted Surface

Disadvantages:

- Lower formability than steel
- Weldability

Magnesium

Advantages:

- Castability

Disadvantages:

- Formability
- Elevated temperature stamping & hemming
- Weldability

Polymer/ Composites

Advantages:

- Low cost tooling
- Shorter lead time

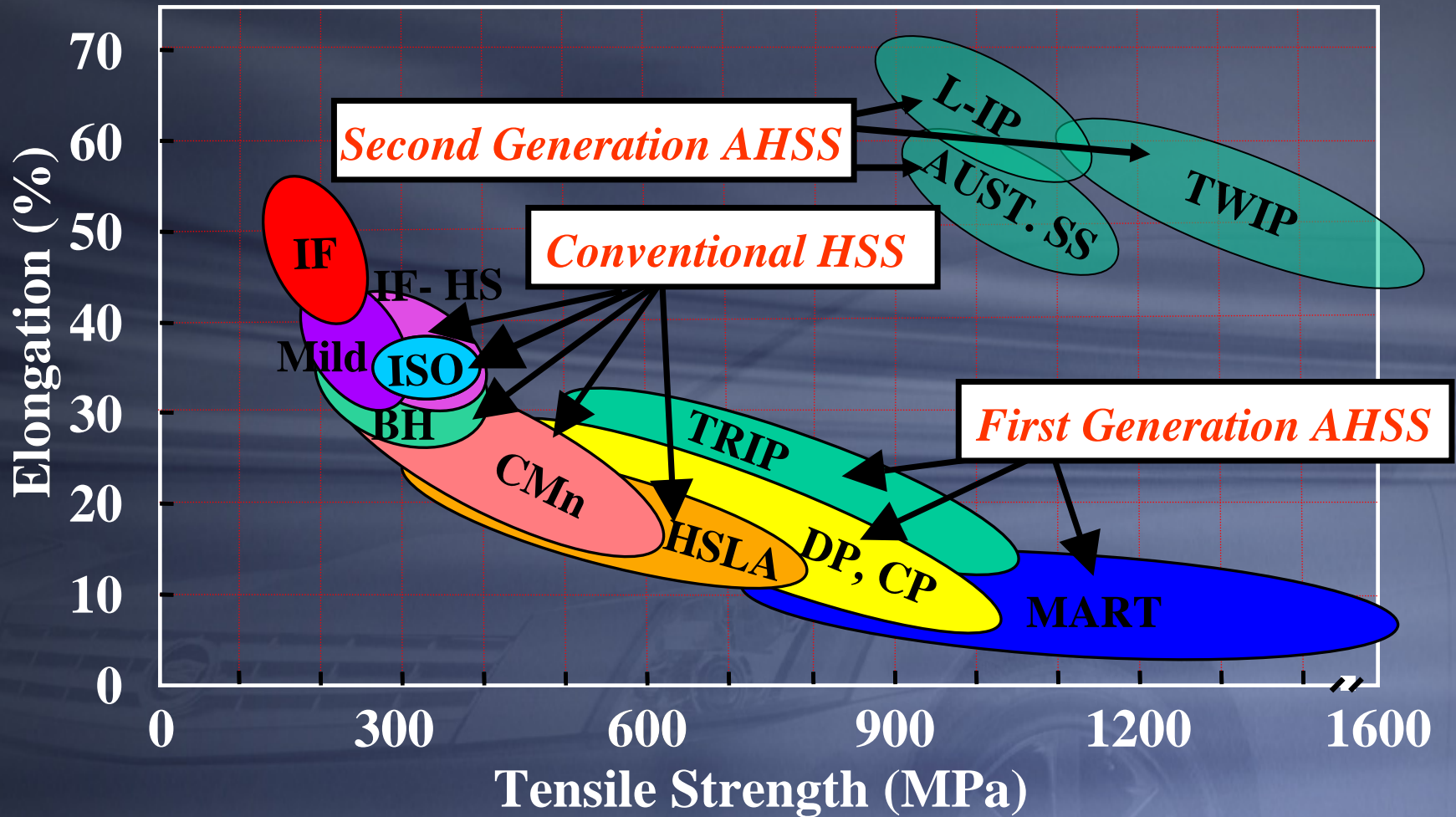
Disadvantages:

- Cycle Time
- Infrastructure
- Difficult to repair
- Painted Surface

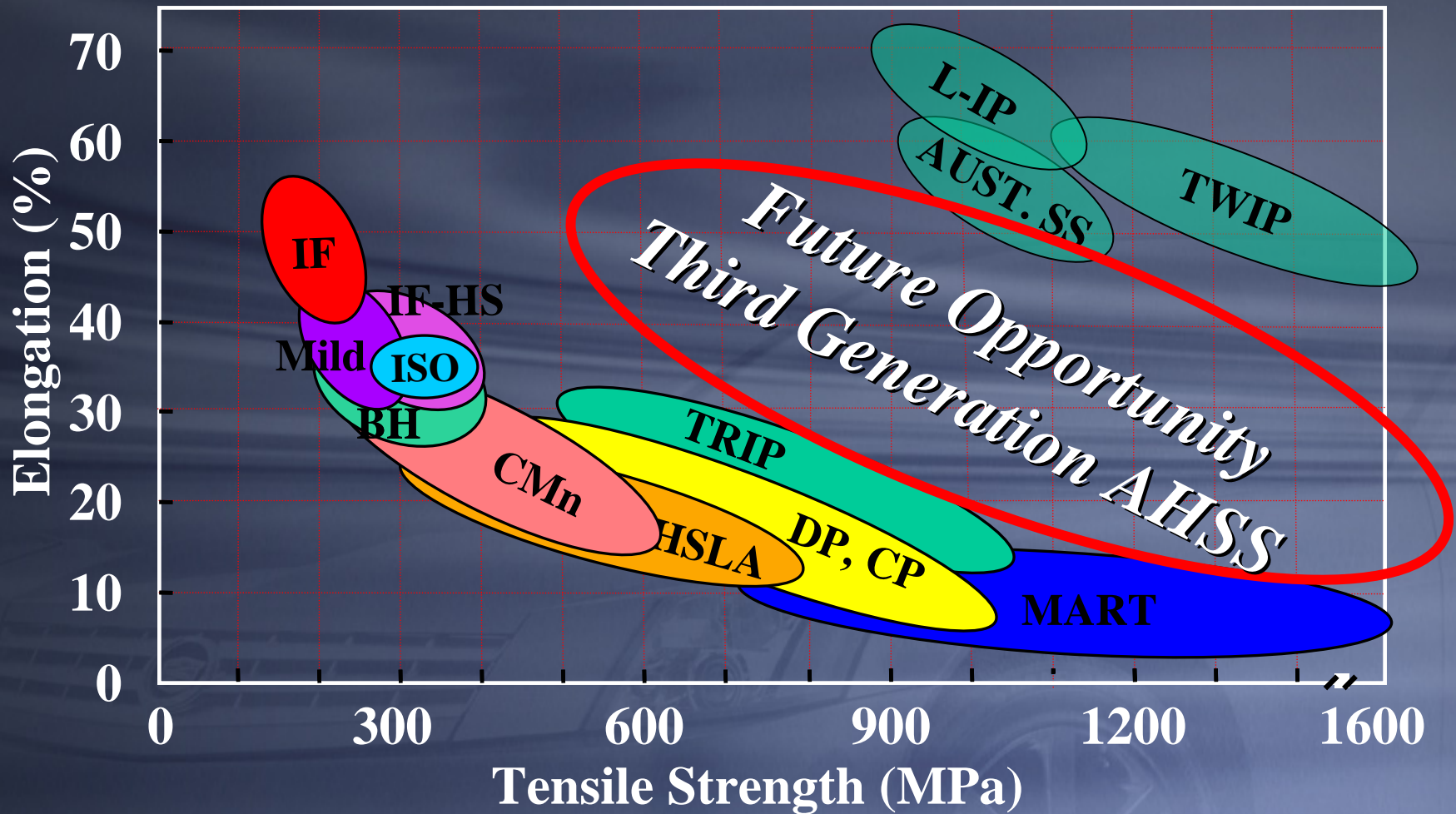
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PMC	\$1.20 - 6.50	Unknown	<ul style="list-style-type: none"> • difficult to recycle • Emissions = 2.5 – 23.0 kg CO₂/kg
HSS/AHSS	\$0.55	Included in Mild Steel	<ul style="list-style-type: none"> • easy to recycle • Emissions = 2.3 – 2.7 kg CO₂/kg

Steel Strategy



Steel Strategy - GAP



What's the same?

- Other than prediction of lightweight material usage and the elimination of steel (by some)
- Relative amongst materials:
 - Cost
 - Performance
 - Manufacturability
 - Availability
- Fuel Cost
- Strategy for material implementation

Engineering Strategy

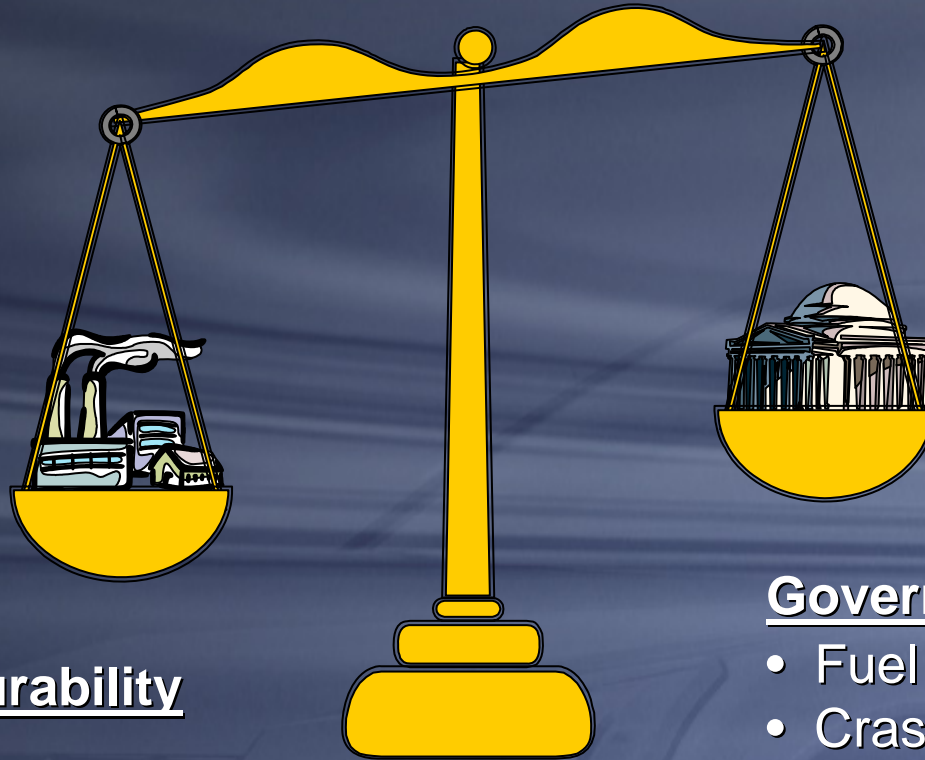


Materials

Design

Manufacturing

Business Strategy



Manufacturability & Cost:

- material
- design
- manufacturing

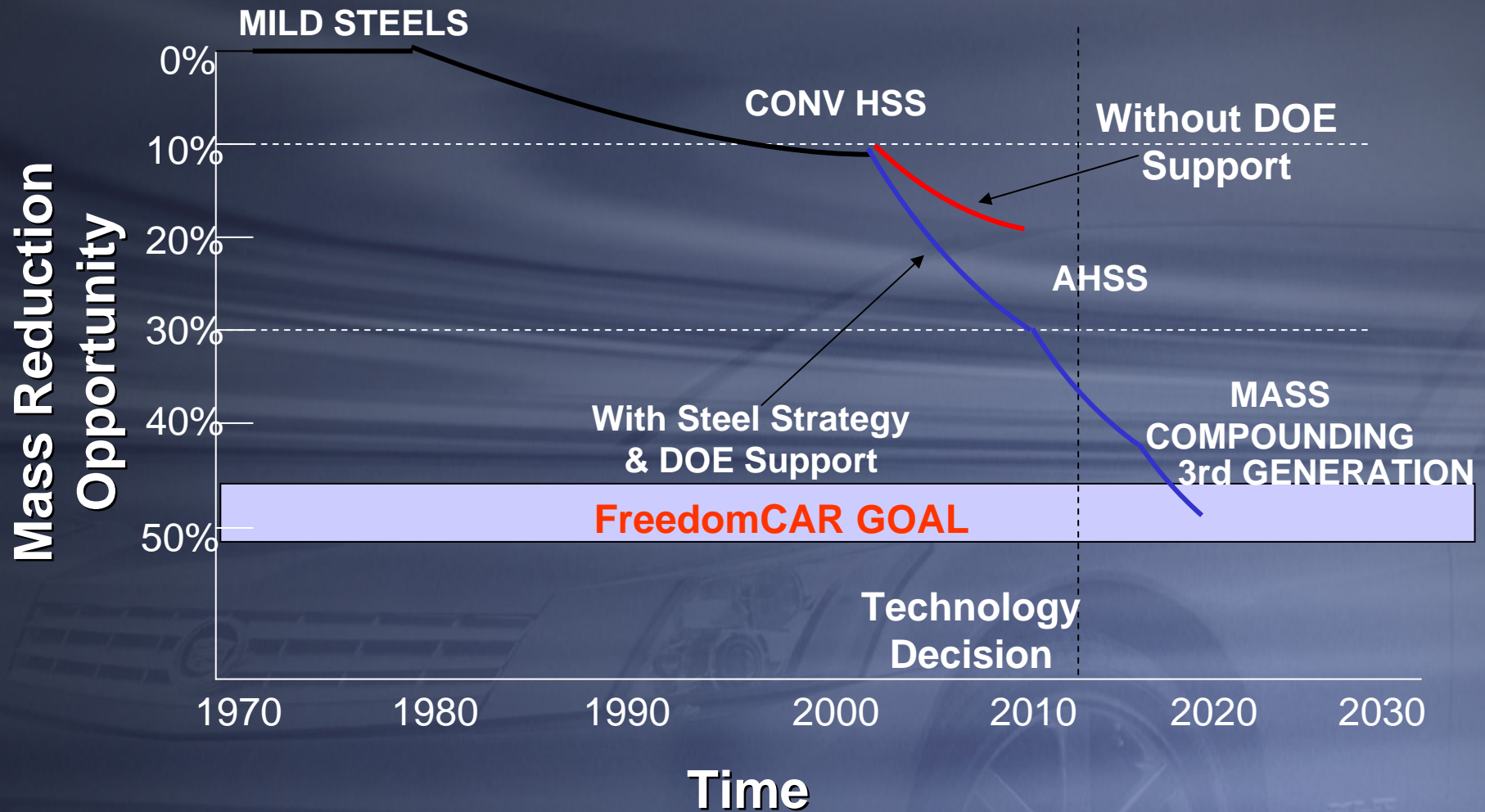
Government Regulations

- Fuel Economy
- Crash Performance
- Emissions

& Customer Requirements

- Cost
- Quality/Styling
- Features

Steel Mass Reduction Opportunities



Global Market

North America

- Well developed market
- Consumer demand

Latin America,

- Diverse market
- New market
- Lead in alternative vehicles particularly in Brazil
- Primary challenge is high cost
- Opportunity

Europe

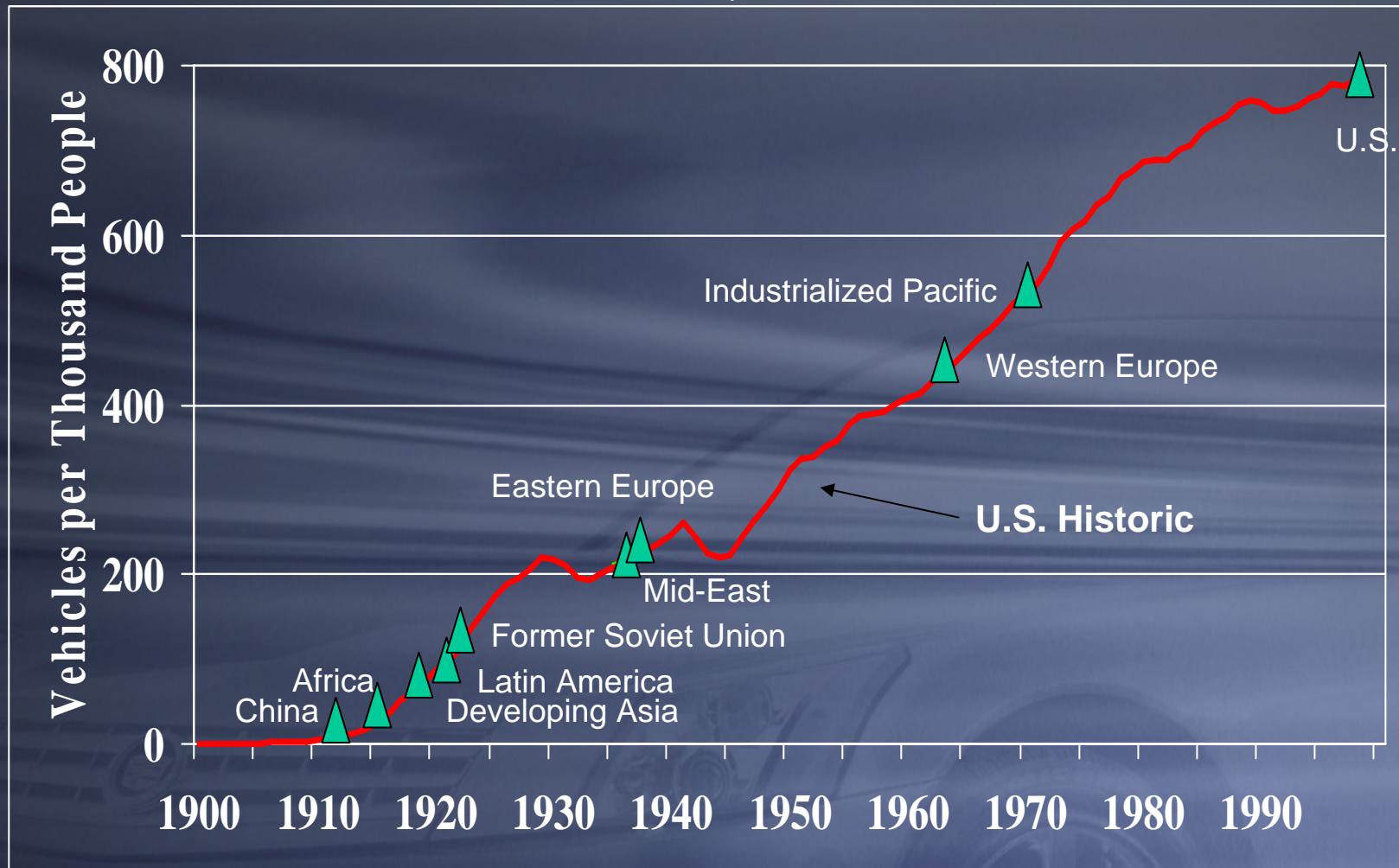
- Well developed market

Asia Pacific

- Fast growing diverse market
- Infrastructure still developing
- Primary challenges are new fuel economy/emission regulations

Global Transportation Growth

Source: Joe Carpenter, DOE



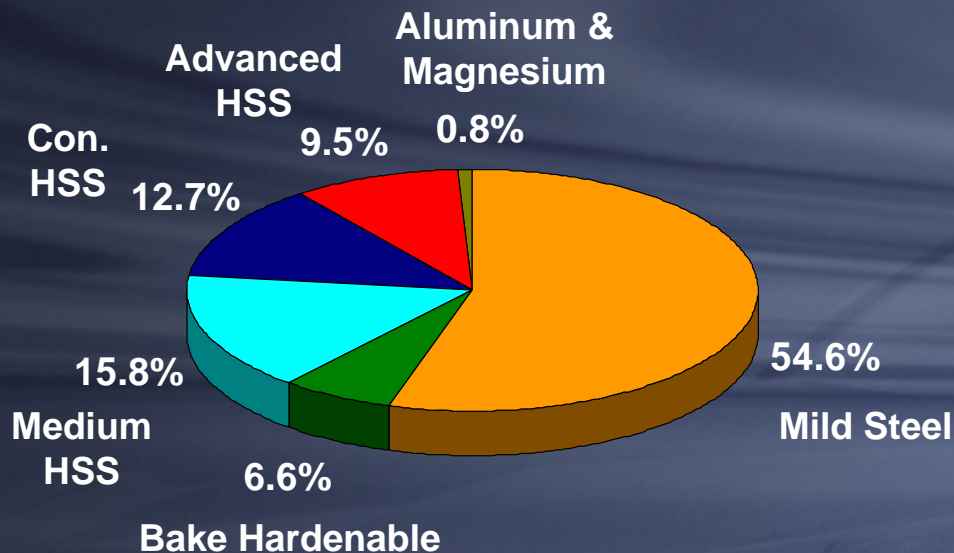
China, with 13 vehicles per 1000 people, is where the U.S. was in 1913
China's population is currently 4 times the population of the U.S.

**What materials will be used
to meet these demands?**

NORTH AMERICAN LIGHT VEHICLE METALLIC MATERIAL TRENDS

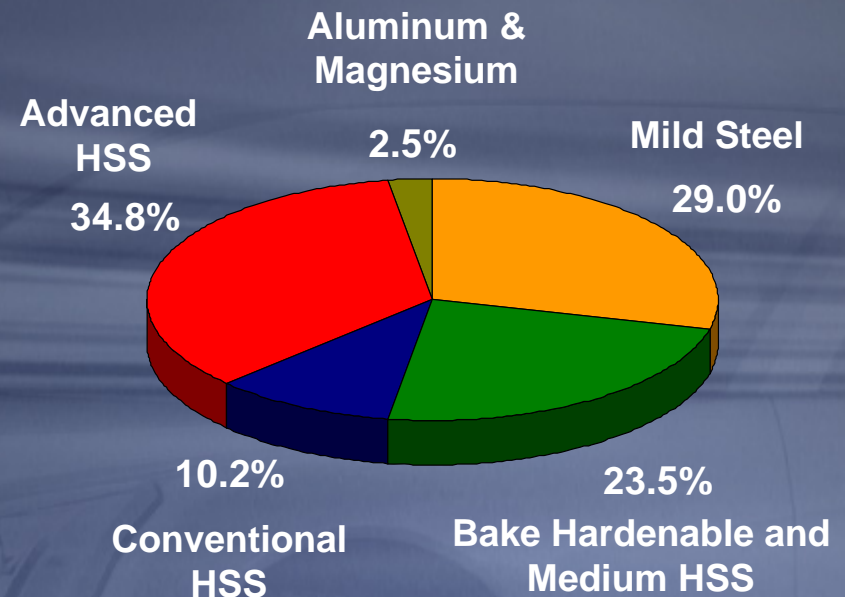
Body and Closure Metallic Material Content by Type

2007



850 Pounds

2015



800 Pounds with an Equal
Footprint to 2007

Source: Ducker Worldwide

NORTH AMERICAN LIGHT VEHICLE METALLIC MATERIAL TRENDS

North American Light Vehicle Material Content Per in Pounds

	1975	2005	2007	2015	Change From 1975 to 2015
Mild Steel	2,180	1,751	1,748	1,314	Down 866 lbs.
High Strength Steel	140	324	334	315	Up 175 lbs.
Advanced HSS	--	111	149	403	Up 403 lbs.
Other Steels	65	76	76	77	Up 12 lbs.
Iron	585	290	284	244	Down 341 lbs.
Aluminum	84	307	327	374	Up 290 lbs.
Magnesium	--	9	9	22	Up 22 lbs.
Other Metals	120	150	149	145	Up 25 lbs.
Plastic/Composites	180	335	340	364	Up 184 lbs.
Other Materials	546	629	634	650	Up 104 lbs.
Total Pounds	3,900	3,982	4,050	3,908*	Up 8 lbs.

* Same vehicle mix and average footprint as 2007

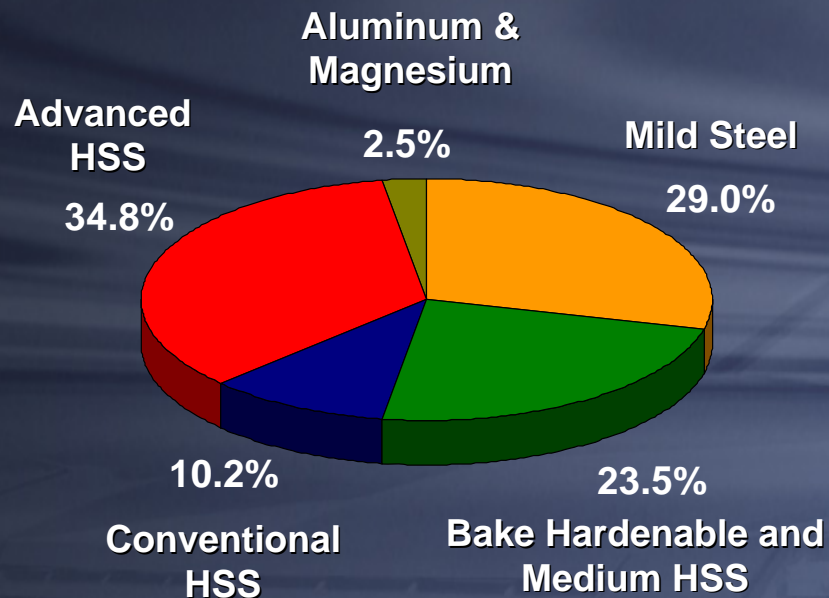


Source: Ducker Worldwide

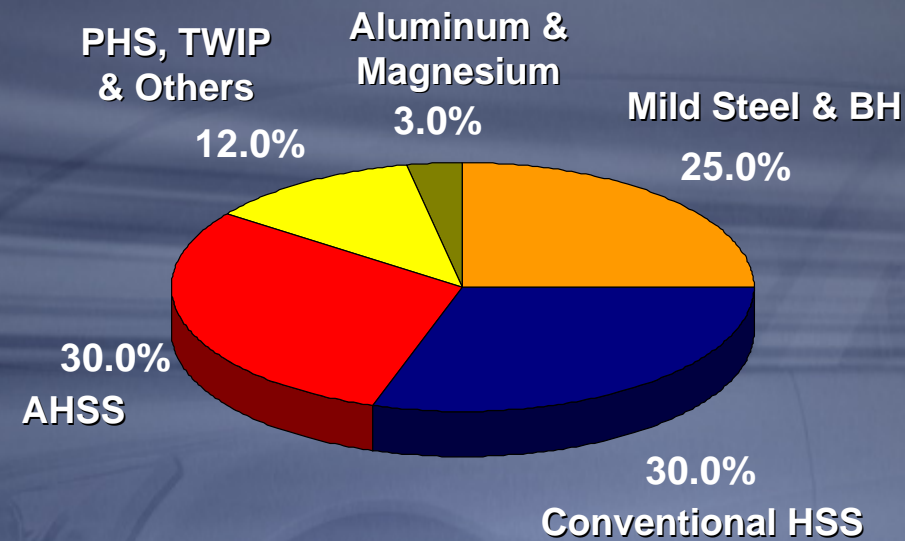
NORTH AMERICAN LIGHT VEHICLE METALLIC MATERIAL TRENDS

Body and Closure Metallic Material Content by Type

North America



Europe



2015

Why is this reasonable?

- No real changes in basic trends over past 50 years
- “Cash is King” – customer paying less than before & demanding more
- Infrastructure not ready
- Availability – Infrastructure of metal production
- Global Differences in Needs

What could 'disrupt' this prediction

- Fuel Cost & Availability
- Material Cost & Availability
- Economic Stability
- Government Regulations
- Technological Discoveries/Advances

Conclusions

- Always be a need/desire to push to lightweight materials for the auto industry
- Doesn't mean no steel
- Current prediction is mainly some form of steel
 - Best value to customer (performance/cost)
- However, disruptive event(s) is as likely, or even more likely, than ever before