Lightweighting and Aerodynamics

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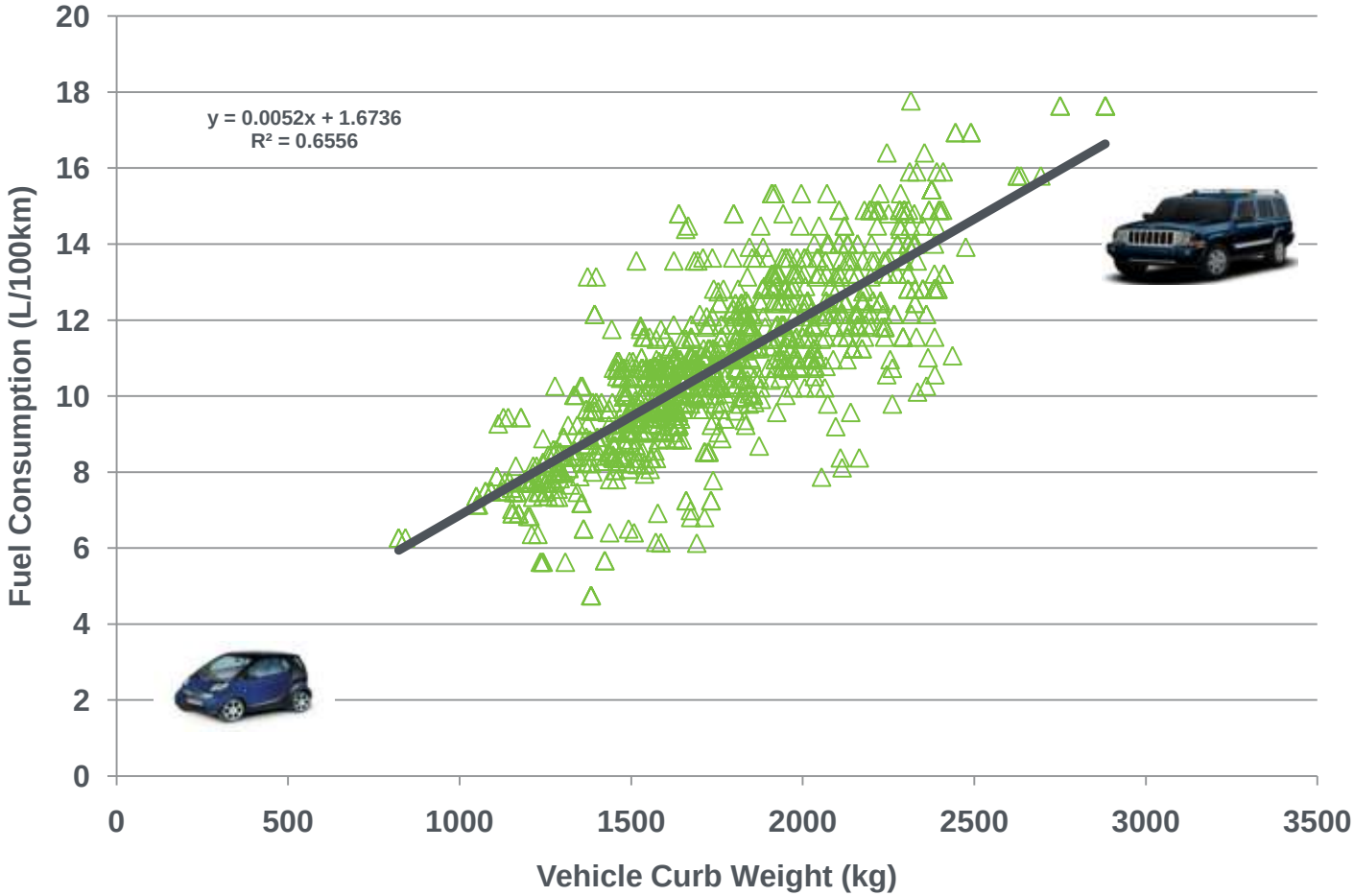
Vehicle Weight Influences Fuel Consumption



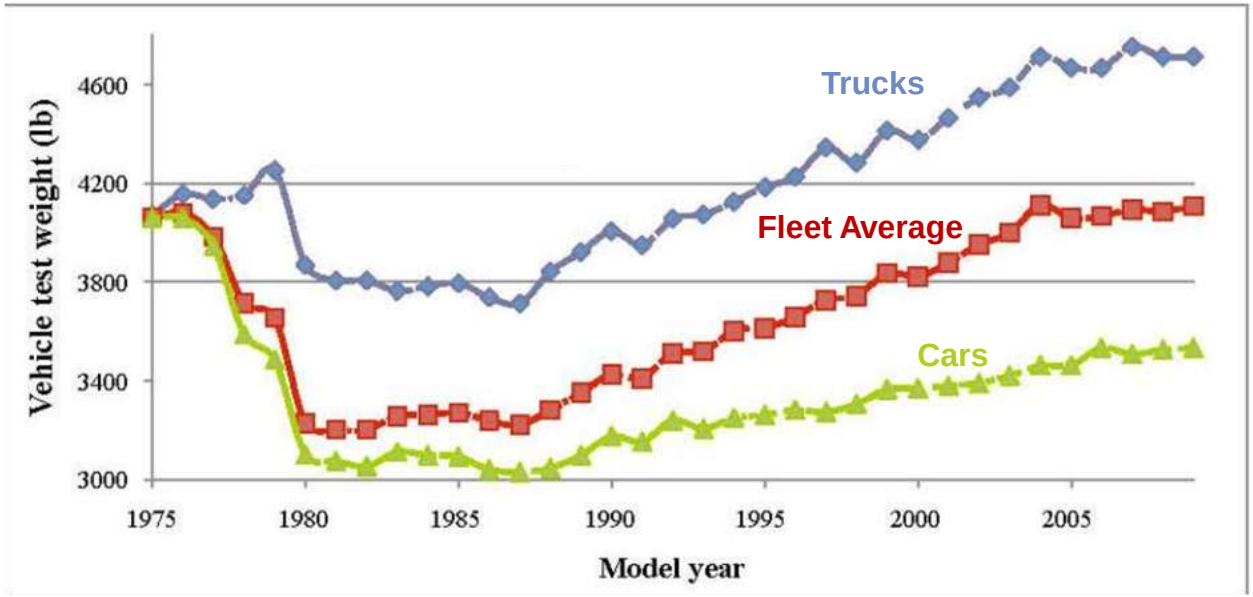
Source: 2011 Model Car U.S. Specifications and Prices, Ward's Automotive Group, a division of Penton Media Inc.

- 10% Weight Reduction ➔ 6-8% FE Improvement
- 1 kg Weight Reduction ➔ 20 kg CO_2 Reduction

Increasing Vehicle Weight

Despite the benefits of weight reduction, vehicle weight has been increasing.

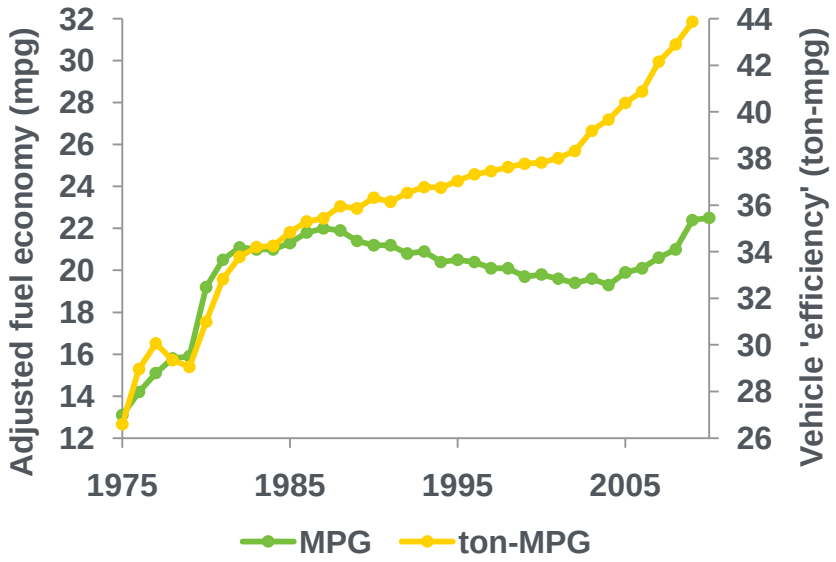
Light Duty Vehicle Weight Trends for Model Years 1975 to 2009

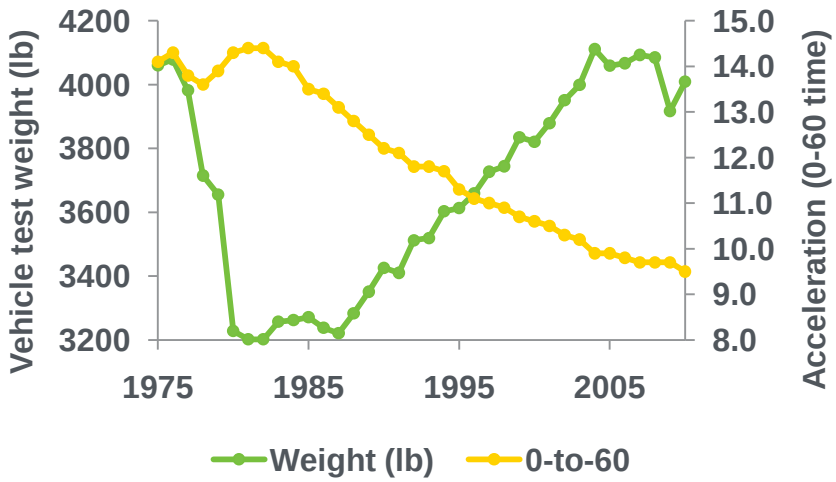


Source: U.S. EPA, 2009a

- US passenger vehicles increasing in weight since the last major CAFE standard revision of 1978–1985.
- Part of the increase is the result of a consumer preference for trucks, larger cars, and increased features.
- Part is the result of increased safety standards.

Improved Efficiency but Increased Weight and Performance



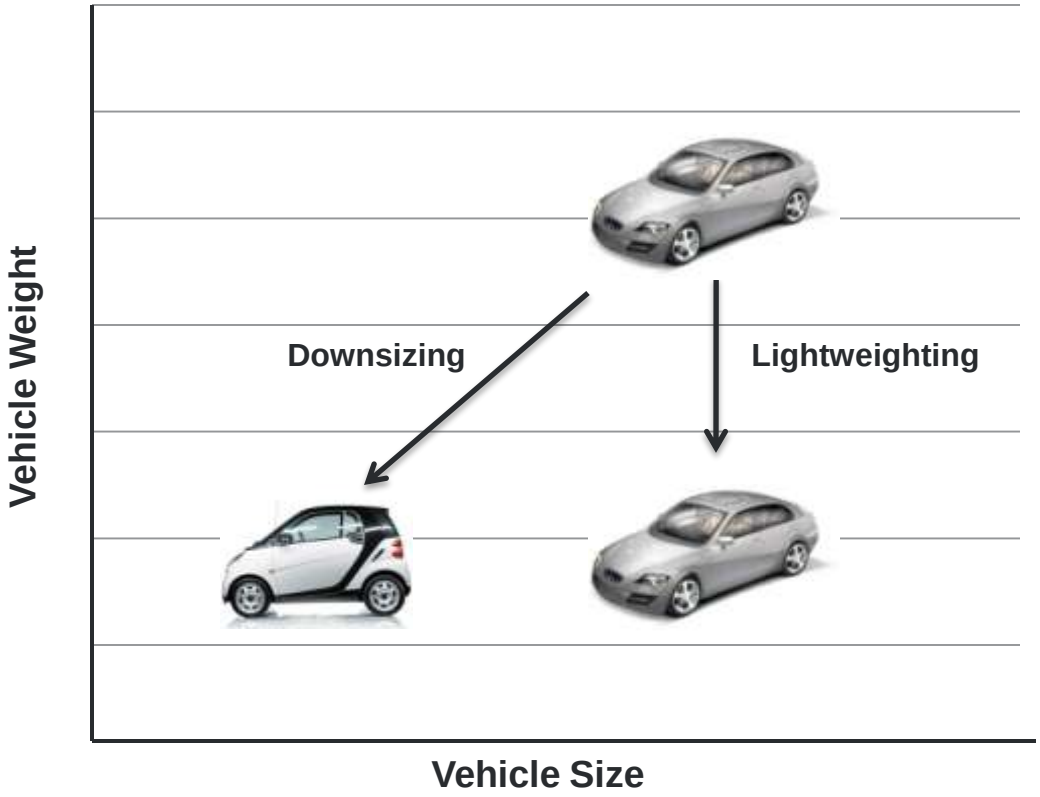


- The U.S. fleet has gotten increasingly heavy since 1987.
  - Larger
  - Faster
  - More content
- Lightweighting is occurring, it's just not overwhelming the other factors.

Reversing the Trend

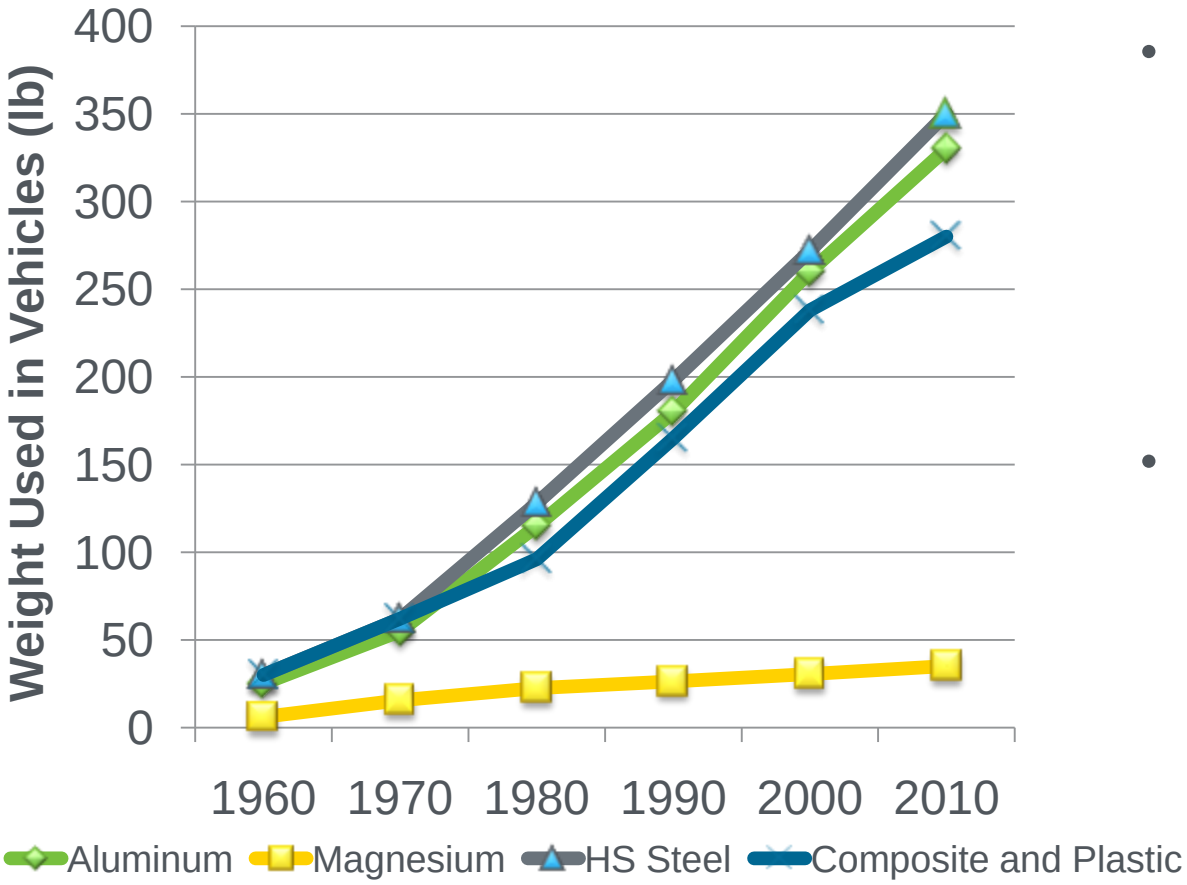
- Is it possible to reverse this trend of ever increasing vehicle weight?

- DOE Lightweighting focus is on ways to reduce vehicle mass rather than vehicle size.



Lightweight Materials

Lightweight materials are being increasingly used in vehicles.



- Advanced lightweight materials, primarily high strength steel, aluminum, and composites are increasingly used.
- Without increased use of lightweight materials, today's 4000 lb car would be over 200 lbs heavier.

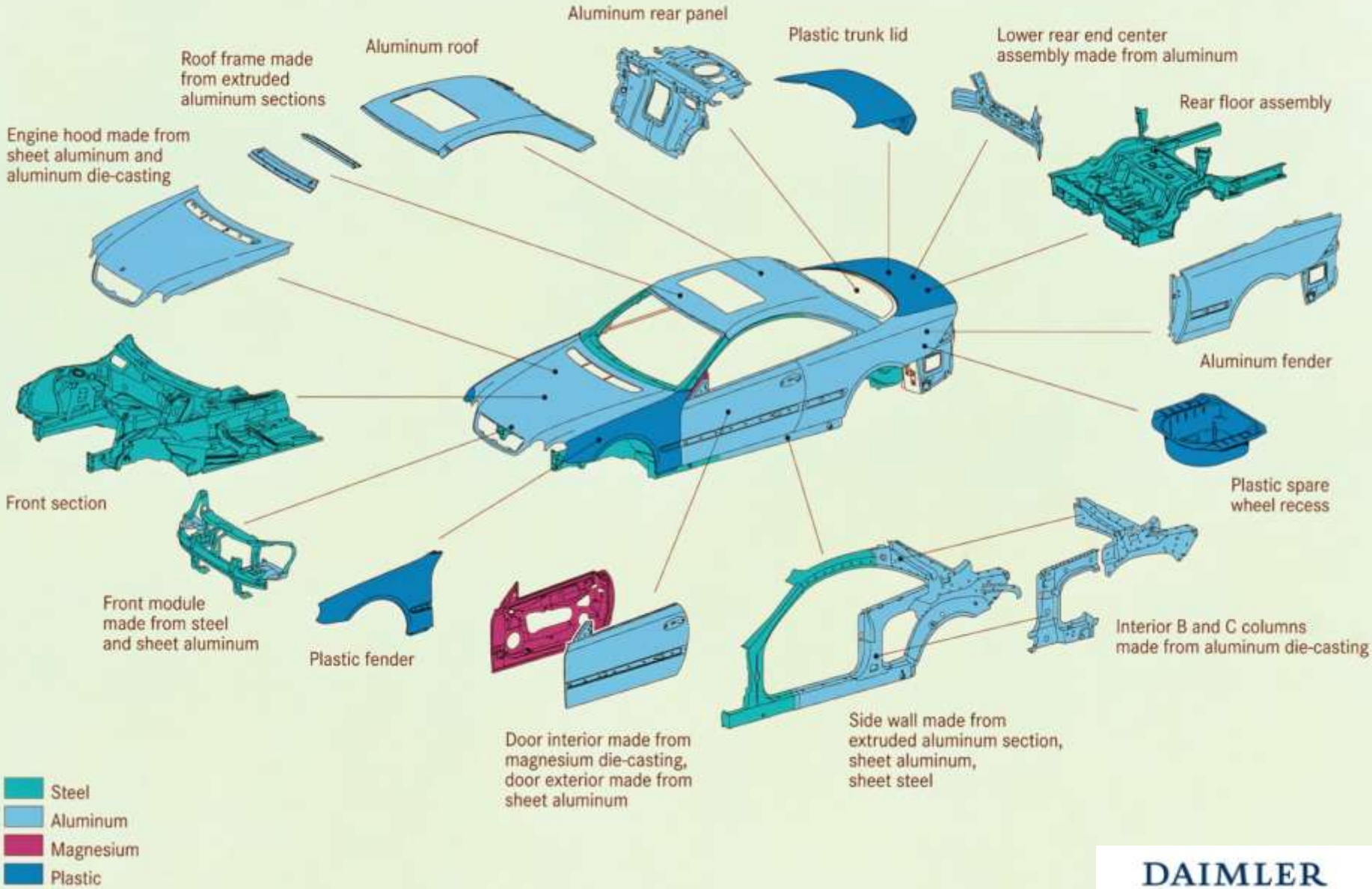
Multi-Material Vehicles

Multi-material Vehicles incorporating large lightweight structures are being developed and produced.

Mercedes-Benz CL (C215)

Chevrolet Corvette

Mercedes-Benz CL
Hybrid construction: A combination of aluminum, magnesium, plastic and steel



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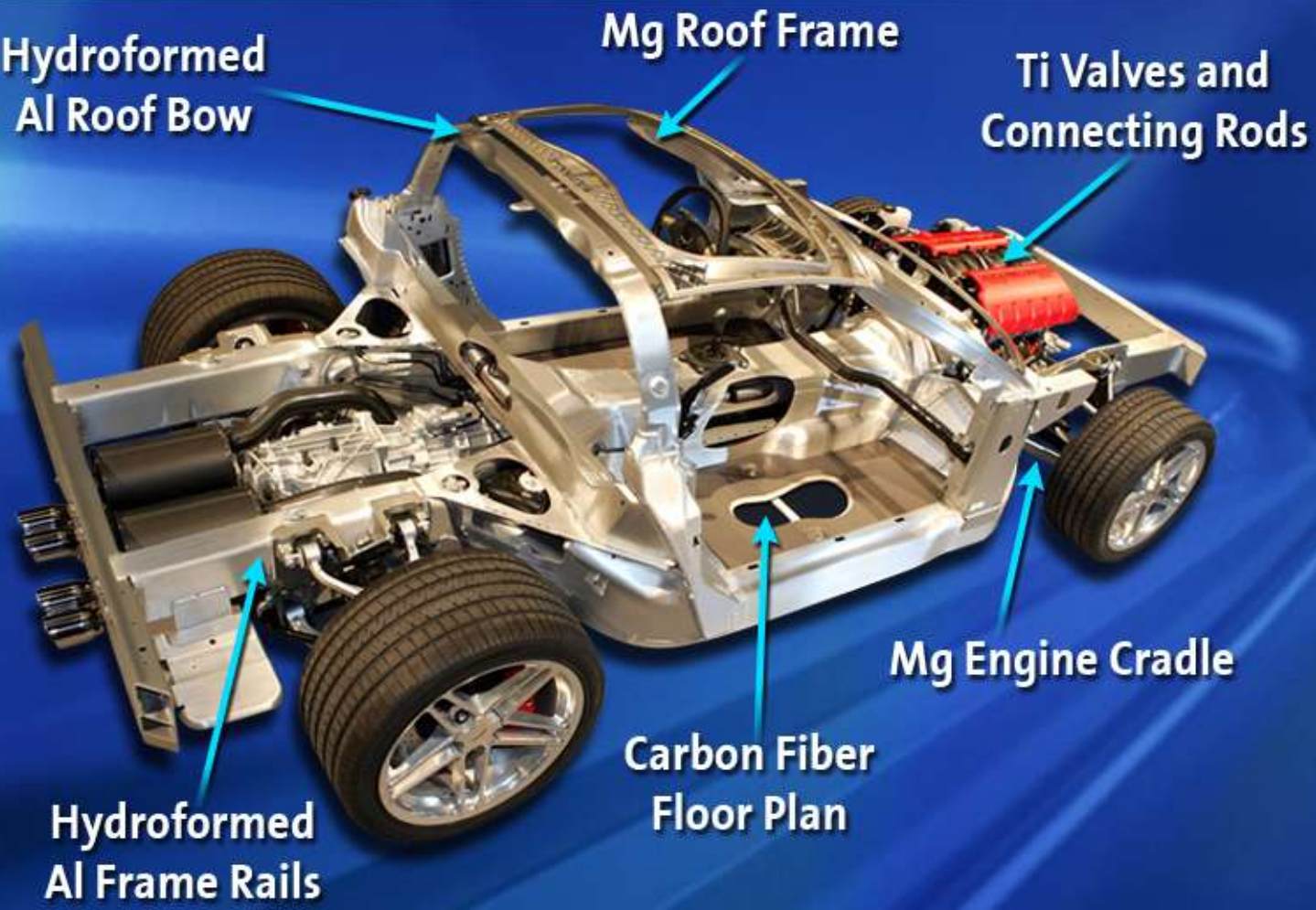
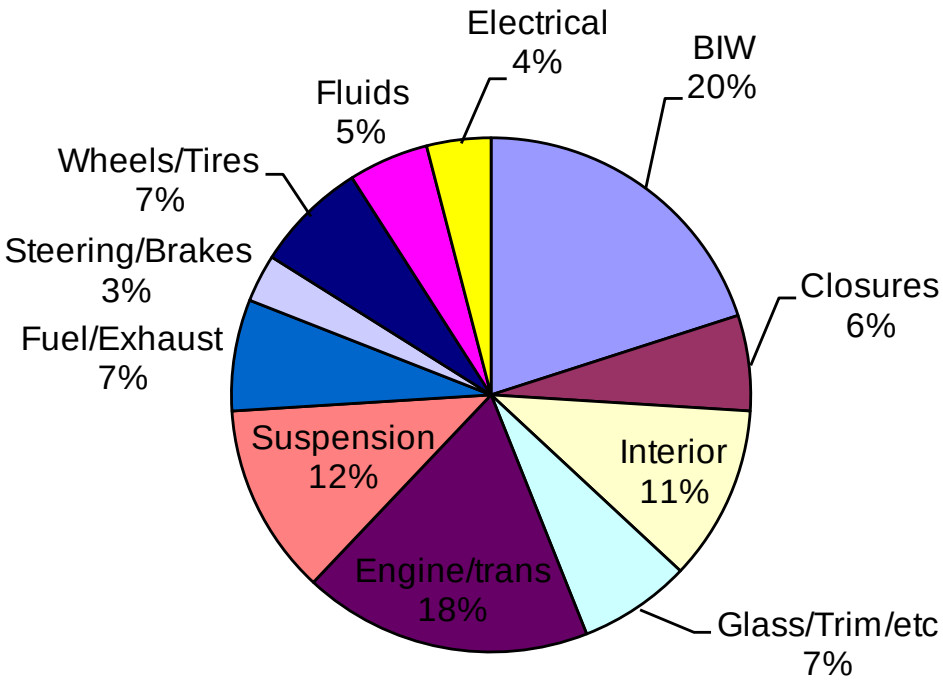
2006 Chevrolet Corvette Z06



What Weight Savings Are Possible?



Source: Ultra Light Steel Auto Suspension (ULSAS) Consortium

Publication	Max .Weight Reduction, %
NRC 2010	20
Lotus 2010	38
EPA/NHTSA2010b	30
Lovins 2004	50
Lutsey 2010	35

Body Structure : 1/3; Powertrain : 1/3; Others : 1/3

Crash Safety

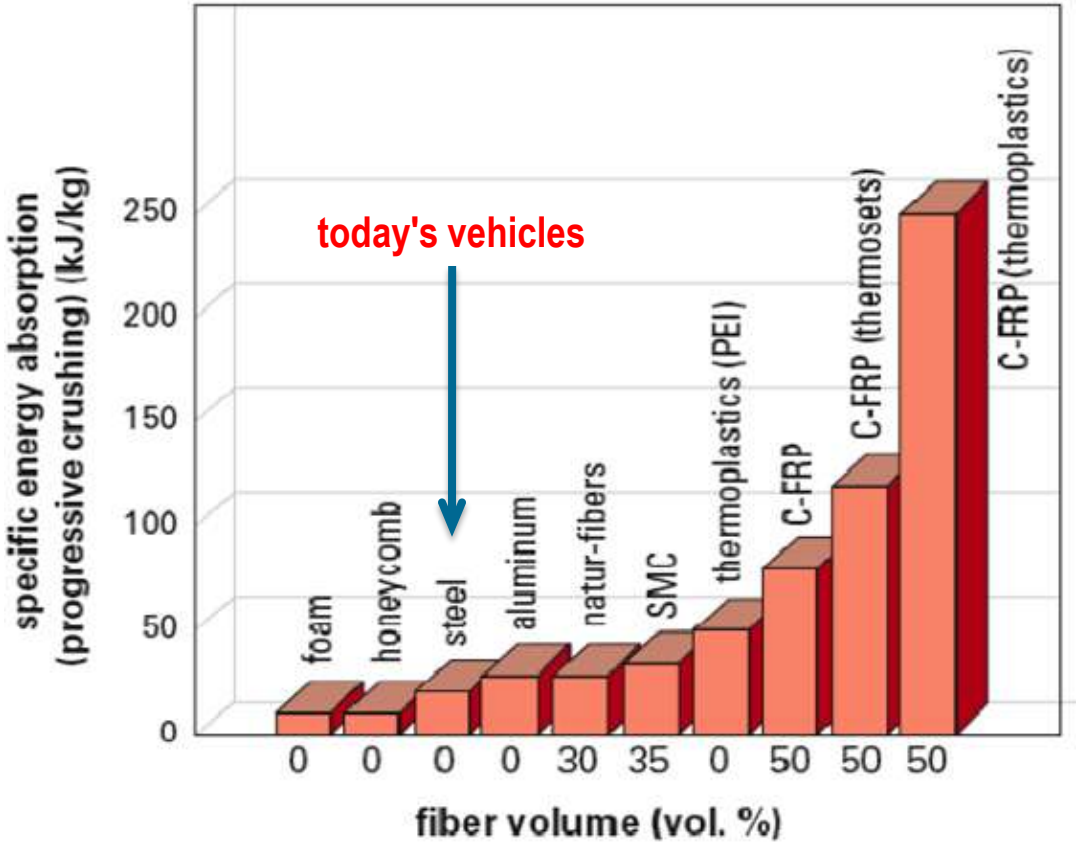
In collisions with heavier vehicles, the perception is that the lighter vehicle loses.

- US DOT (NHTSA) has conducted several detailed statistical analyses of mass reduction on occupant fatality risk, based on recent historical vehicle technology and design.
  - Initially suggested that mass reduction would result in a net increase in fatalities.
  - More recent analyses suggest that mass reduction while maintaining size (footprint) would have a much smaller effect on safety.
  - Car-based crossover utility vehicles with 10% lower mass, higher fuel economy, and the same footprint as truck-based SUVs have about 30% lower risk.
  - Statistical analysis of historical data cannot predict the effect on risk of using new lightweight materials to reduce vehicle mass while maintaining size.
- NHTSA, EPA, and CARB are using computer crash simulation to study what effect extensive use of new materials will have on safety.

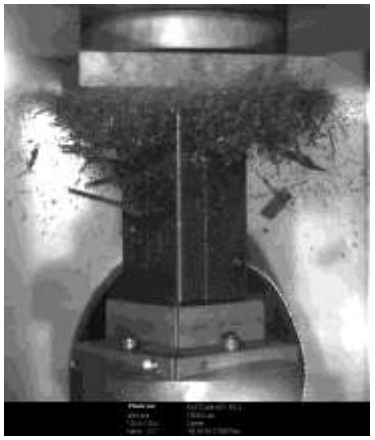
Crash Protection of Candidate Lightweighting Materials

Composites offer substantial energy absorption, with the opportunity to dissipate substantial energy compared to steel.

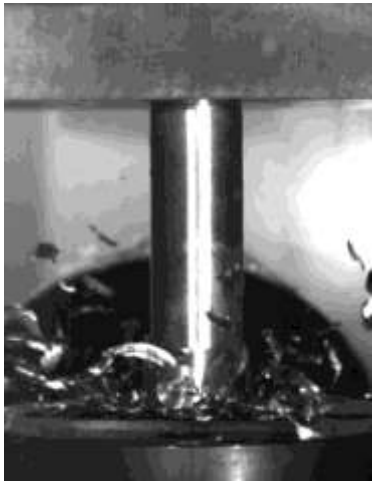
Specific Energy Absorption *(Energy per Kg of Material)*



Source: Herman, Mohrdeck and Bjekovich, 2002



Carbon Fiber Composite Crush Test
(Excellent Energy Absorption)



Magnesium Alloy Crush Test
(Poor Energy Absorption)

Opportunities and Barriers

- There are material options for substantial reduction in vehicle mass, beyond that available from AHSS, aluminum, and plastics.

- There are substantial barriers to new material adoption, that can be overcome.

Lightweighting Materials Scope

Materials that offer moderate < 50% Mass reduction and could be implemented** in high volume within the next 5-10 years are:

Aluminum
Plastics
High Strength Steels
Glass Fiber Composites
(including SMC)

Materials that offer the largest > 50% Mass reduction have the largest barriers to be overcome and can be implemented** in high volume in 10* or more years are:

Magnesium
Titanium
Carbon Fiber Composites
Metal Matrix Composites

* Some low volume implementation can occur now.
** Material introduction can be expected to occur in low volume prior to high volume introduction

Barriers to Lightweighting

- Historically low prices of fuel
- Higher costs of lightweighting materials
- Lack of familiarity (data and design tools)
- Sunk capital in metal-forming technologies
- High temperature paint curing infrastructure
- Lack of large automotive composites and magnesium industries
- Perceptions of safety
- Damage assessment and repair technology

Materials and Critical Challenges

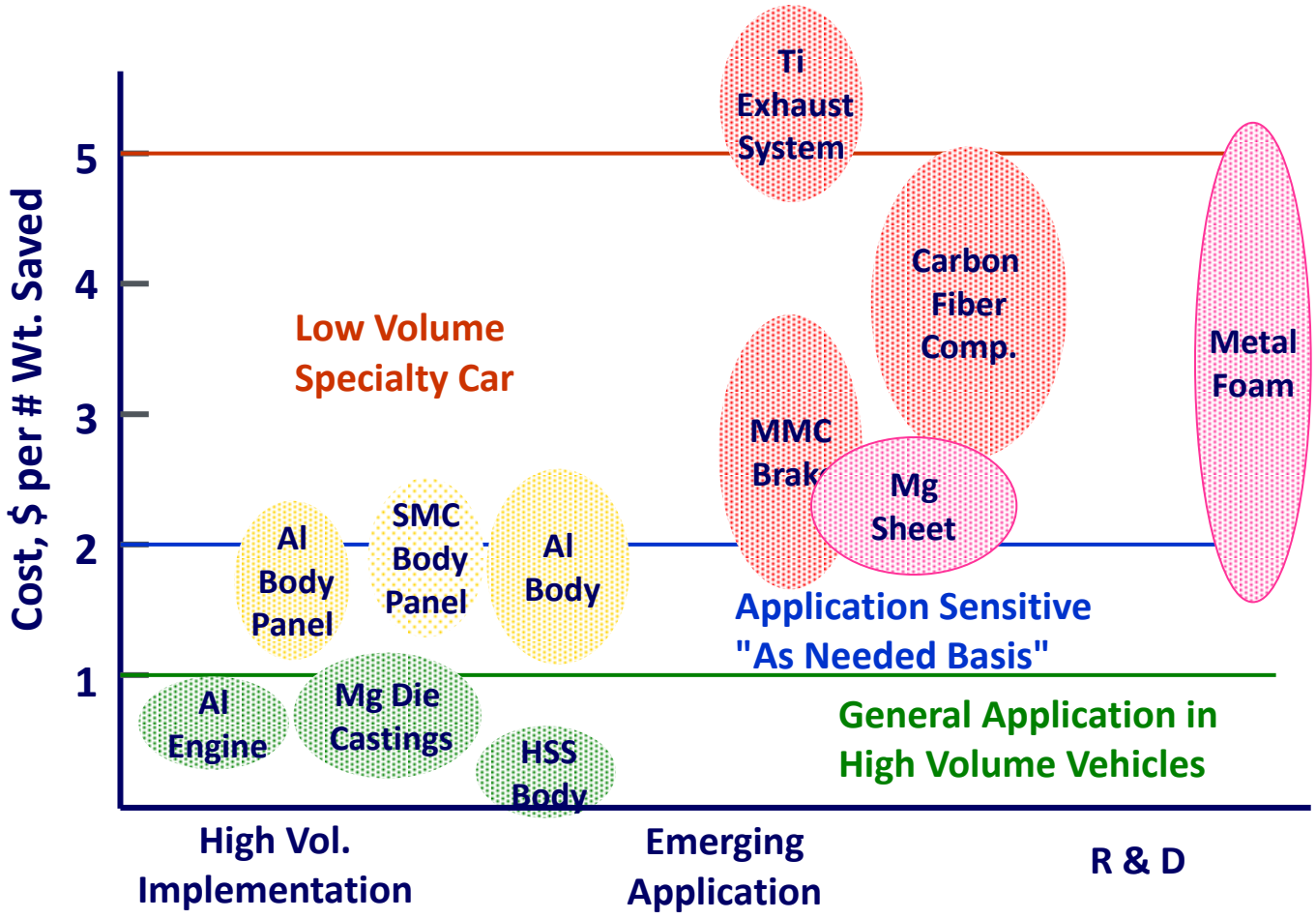
Increasing Severity of Challenge

Increasing Impact on Lightweighting

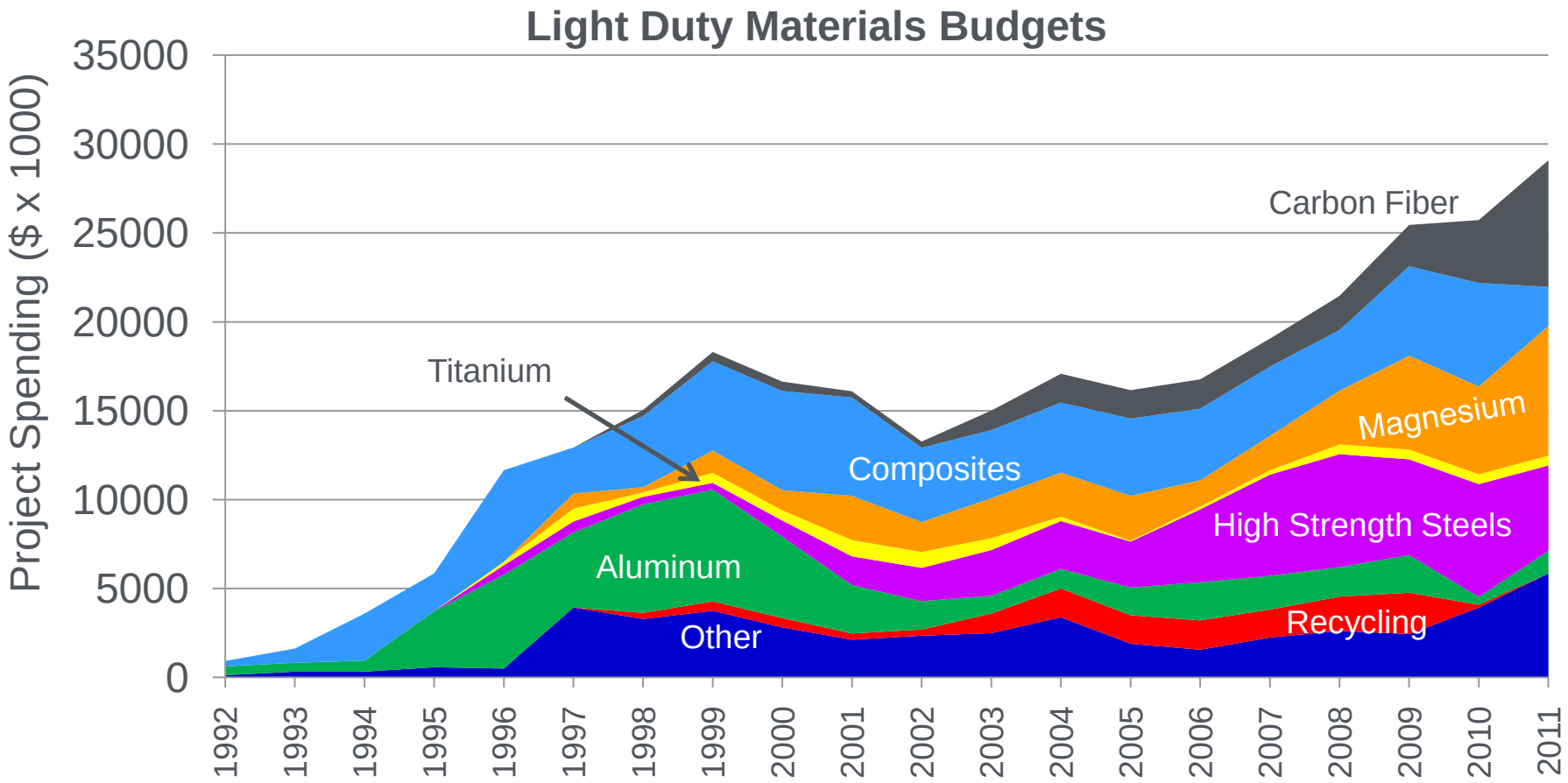
Material	Critical Challenges				
Carbon-fiber Composites	Low-cost fibers	High-volume Mfg.	Recycling	Joining	Predictive Modeling
Aluminum	Feedstock Cost	Manufacturing	Improved Alloys	Recycling	
Magnesium	Feedstock Cost	Improved Alloys	Corrosion Protection	Manufacturing	Recycling
Advanced High-strength Steels	Manufactur-ability	Wt. Reduction Concepts	Alloy Development		
Titanium	Low-cost Extraction	Low-cost Production	Forming & Machining	Low-cost PM	Alloy Development
Metal-matrix Composites	Feedstock Cost	Compositing Methods	Powder Handling	Compaction	Machining & Forming
Glazings	Low-cost Lightweight Matls.	Noise, struc. models simulations	Noise reduction techniques	UV and IR blockers	
Emerging Materials and Manufacturing	Material Cost	Manufacturing	Design Concepts	Performance Models	

Lightweight Automotive Materials- Market Penetration vs. Cost

- Light duty vehicles cost about $8 / lb.
- These cost boundaries are based on market observations



Major Program Emphasis

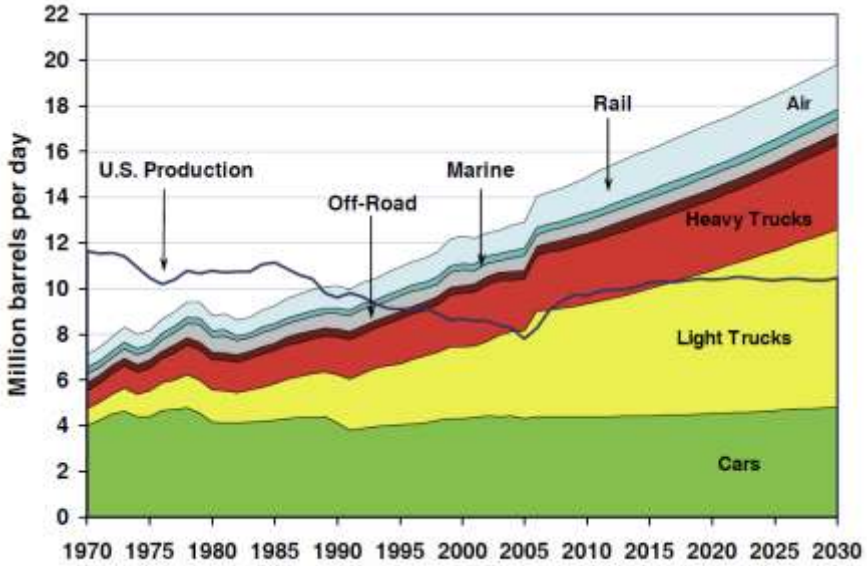


Major Program and Partner Transitions

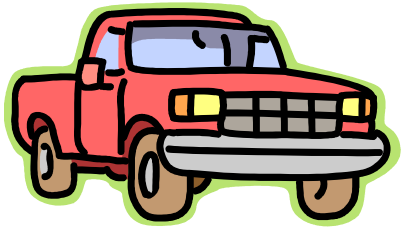
Light Duty Program	ACC	USCAR	USCAR + Tier I		All OEMs + Tier I + Suppliers + HV OEMs
Heavy Duty Program		HSWR – HD OEMs	HSWR – HD OEMs + Tier I	No Prog.	

Vehicle Aerodynamics Influence Fuel Economy

Heavy vehicles can significantly benefit from aerodynamic improvements - high gains in fuel efficiency

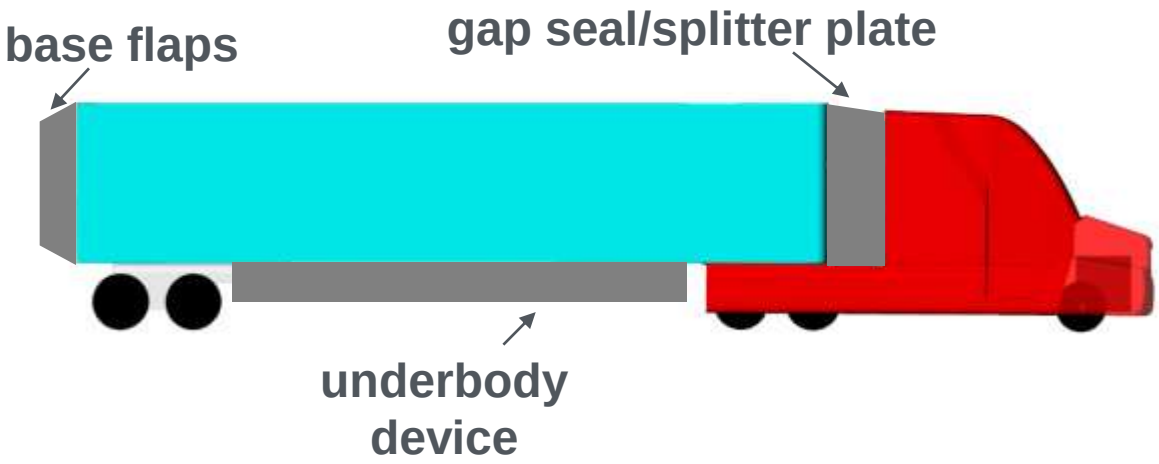


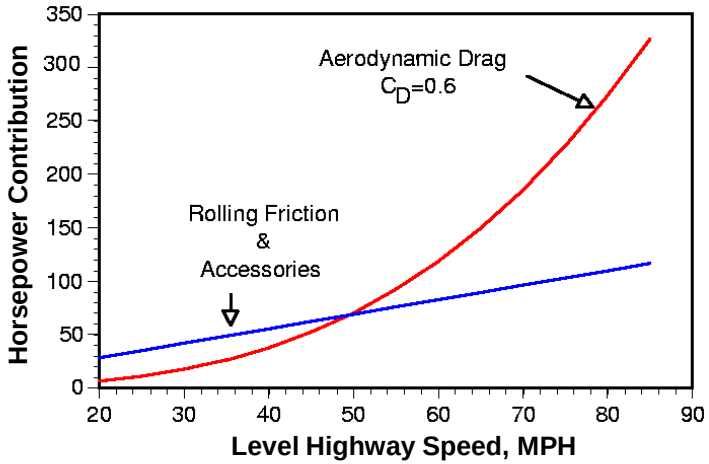
Source: U.S. Department of Energy, Transportation Energy Data Book, Edition 26, 2007



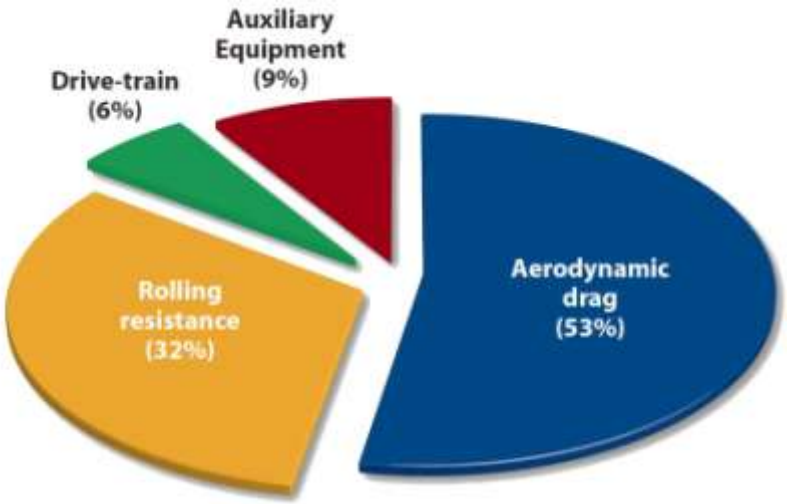
Light duty vehicles can marginally benefit from additional aerodynamic improvements – low gains in fuel efficiency

Aerodynamic Drag Reduction Contribution to Fuel Economy Improvement





- Base flaps: 4-7% FEI (Fuel Economy Improvement)
- Underbody devices: 5-7% FEI
- Gap devices: 1-2% FEI
- Wide-base single tires: 4-5% FEI



Energy breakdown for heavy vehicles

Aerodynamics

- Light duty vehicle aerodynamics are well developed
  - Continuing industrial focus on aerodynamics
  - Little pre-competitive work believed needed
  - No data on how much LDV opportunity remains
- Heavy duty vehicle aerodynamics
  - Class 8 truck operations could benefit substantially
  - Design tools and techniques developed
  - Barriers include business models

Aerodynamic Drag Reduction Funding History

Questions?

Thank You!

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Web site:
http://www.eere.energy.gov/vehiclesandfuels