Overview of FreedomCAR and Its Composites Crash-Energy Management Work

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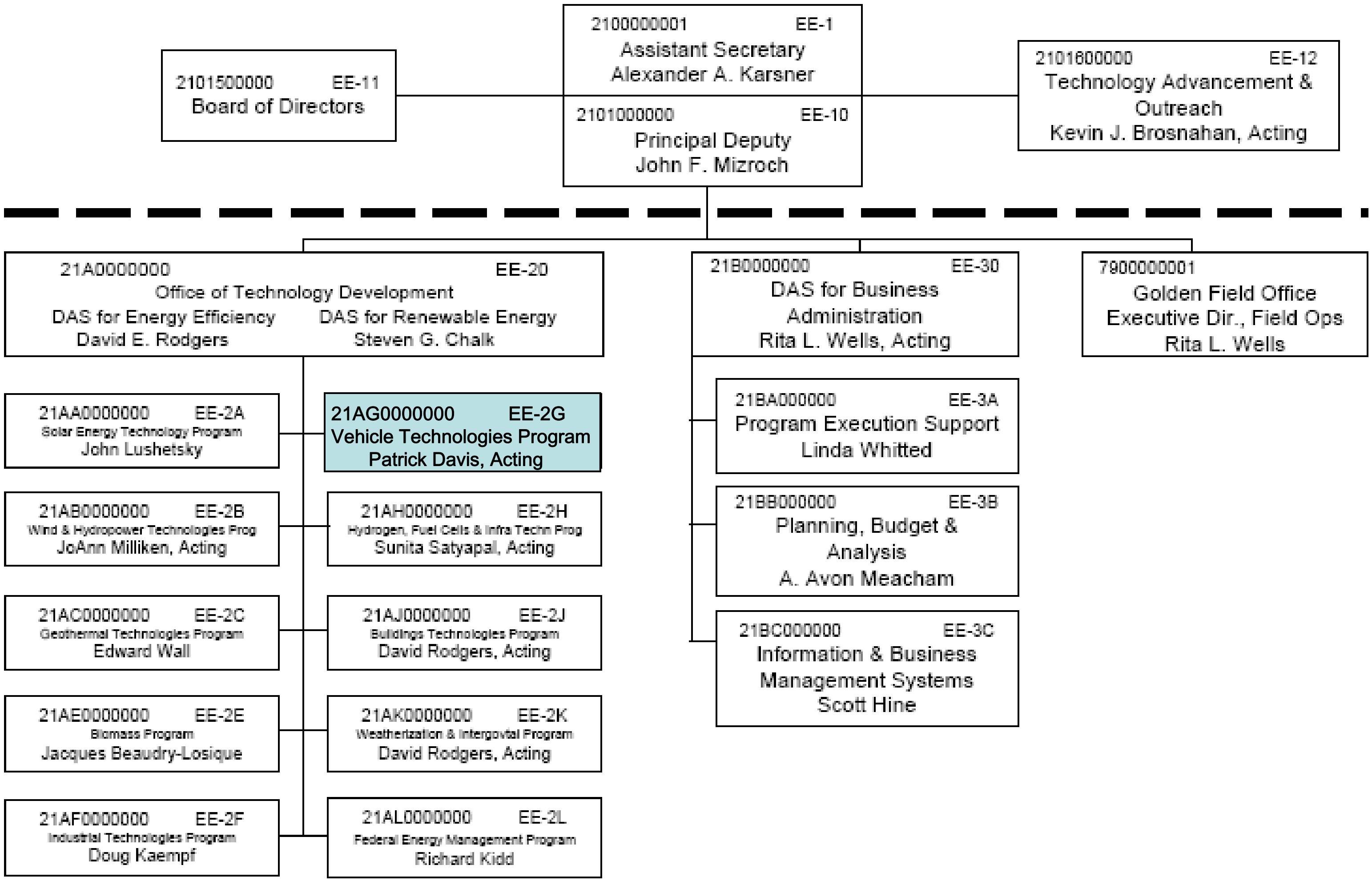
The Safety Characterization of Future Plastics and Composite-Intensive Vehicles (PCIVs) Workshop

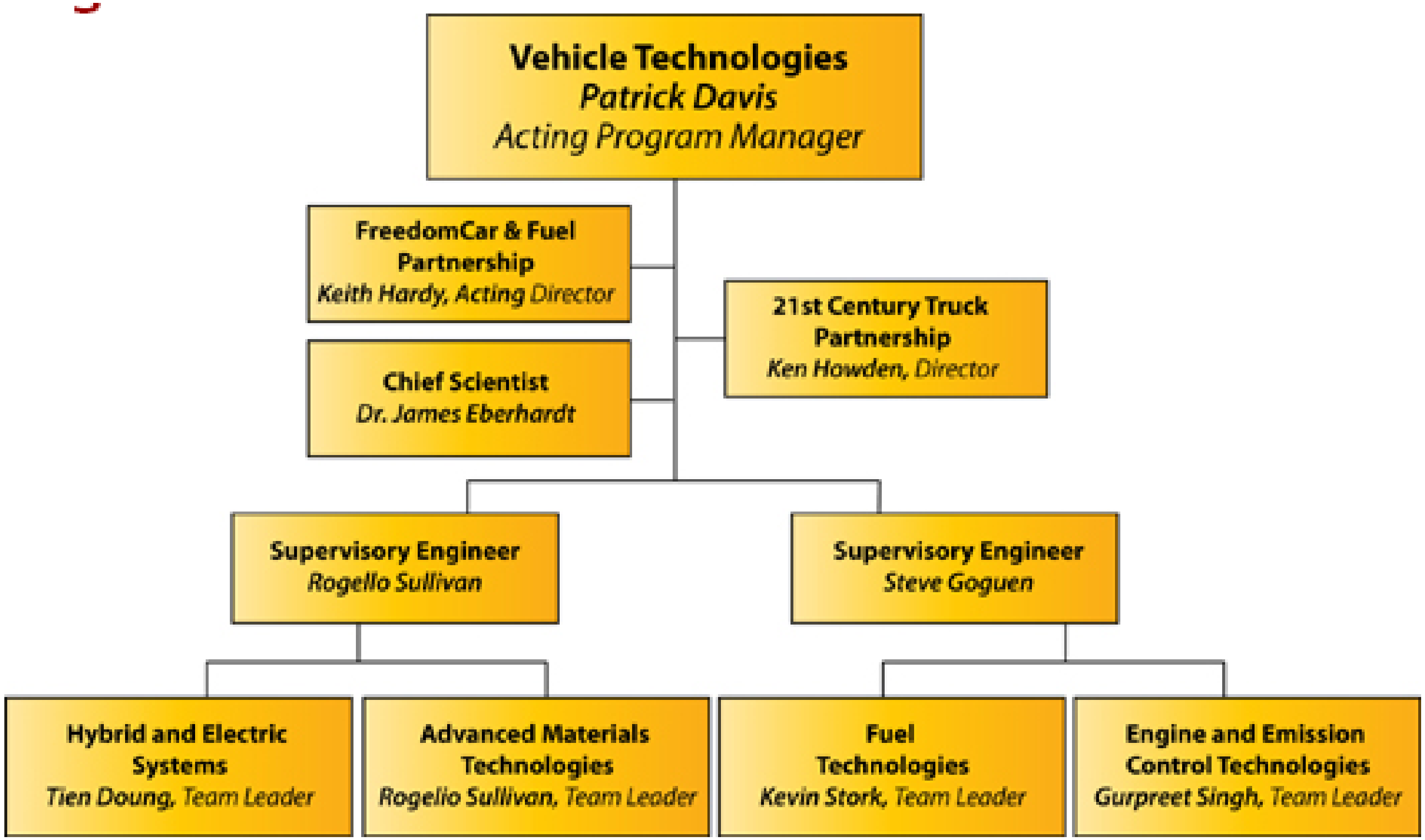
DOT/RITA Volpe Center
Cambridge, MA
August 4, 2008

Energy Efficiency and Renewable Energy 07/07/08



Vehicle Technologies Program

Organization and Contacts



Materials Portfolio Funding

DOE Lightweighting Materials - Operation

Shared Materials R&D Philosophy

Direct-funded Research

Materials Tech Team

- National Labs
- Universities
- Contractors
- Vehicle Recycling Partnership
- American Chemistry Council – Plastics Div.

USAMP/DOE Cooperative Agreement

USAMP – Steering Committee

- Automotive Metals Division (AMD)
- Automotive Composites Consortium (ACC)
- Non-Destructive Evaluation (NDE)
- Auto/Steel Partnership (A/SP)
- Multi-Material Vehicle (MMV)

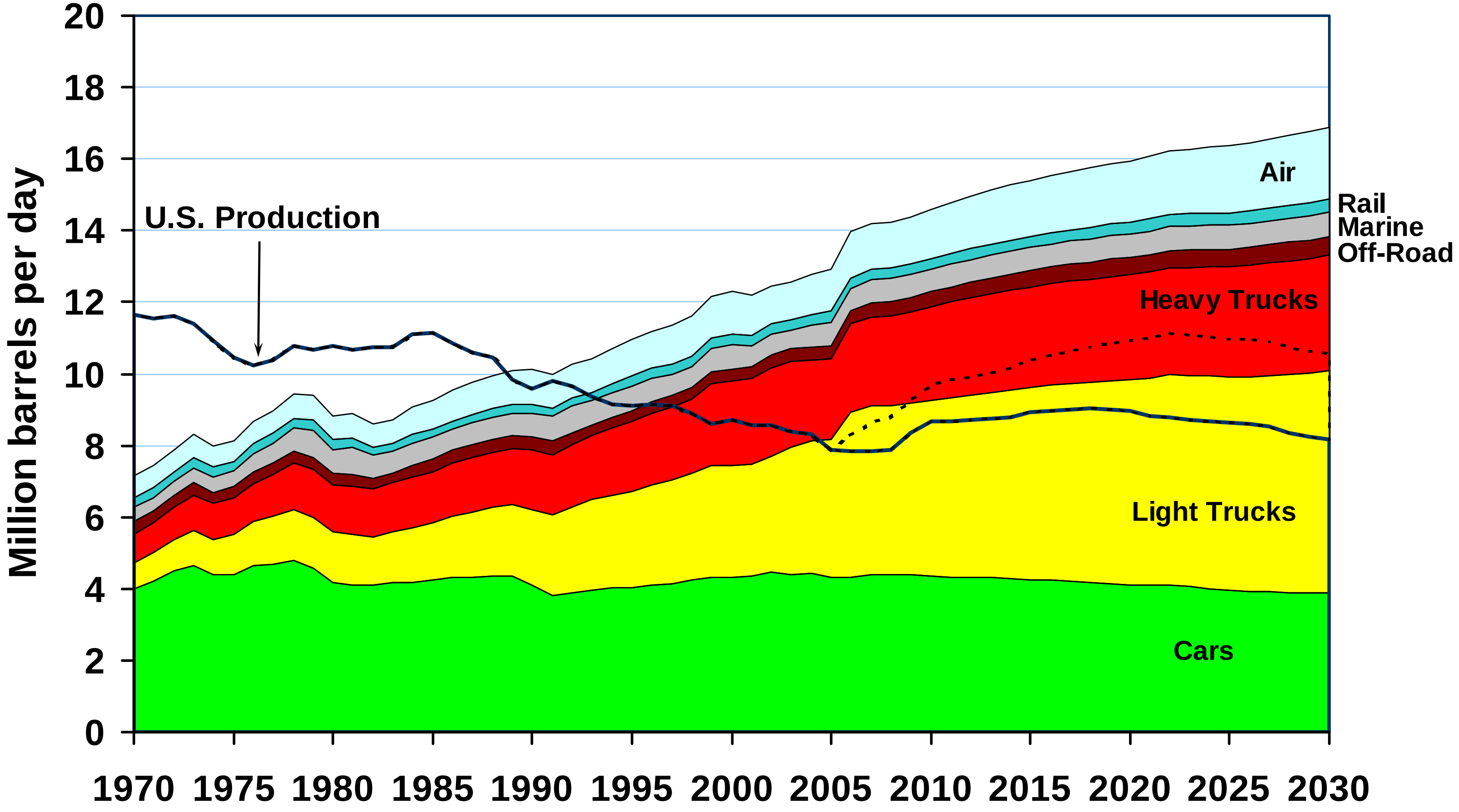
[teams of OEM's, Suppliers, Universities]

LM Program
DOE Investment (Approx $22.3 M.)

Direct Funded Projects – Approx $16.5 M	USAMP Cooperative Agreement Approx. $5.8M.	OEM and Supplier "in kind" Approx. $5.8 M

Equal Match

U.S. Petroleum Production and Consumption, 1970-2030

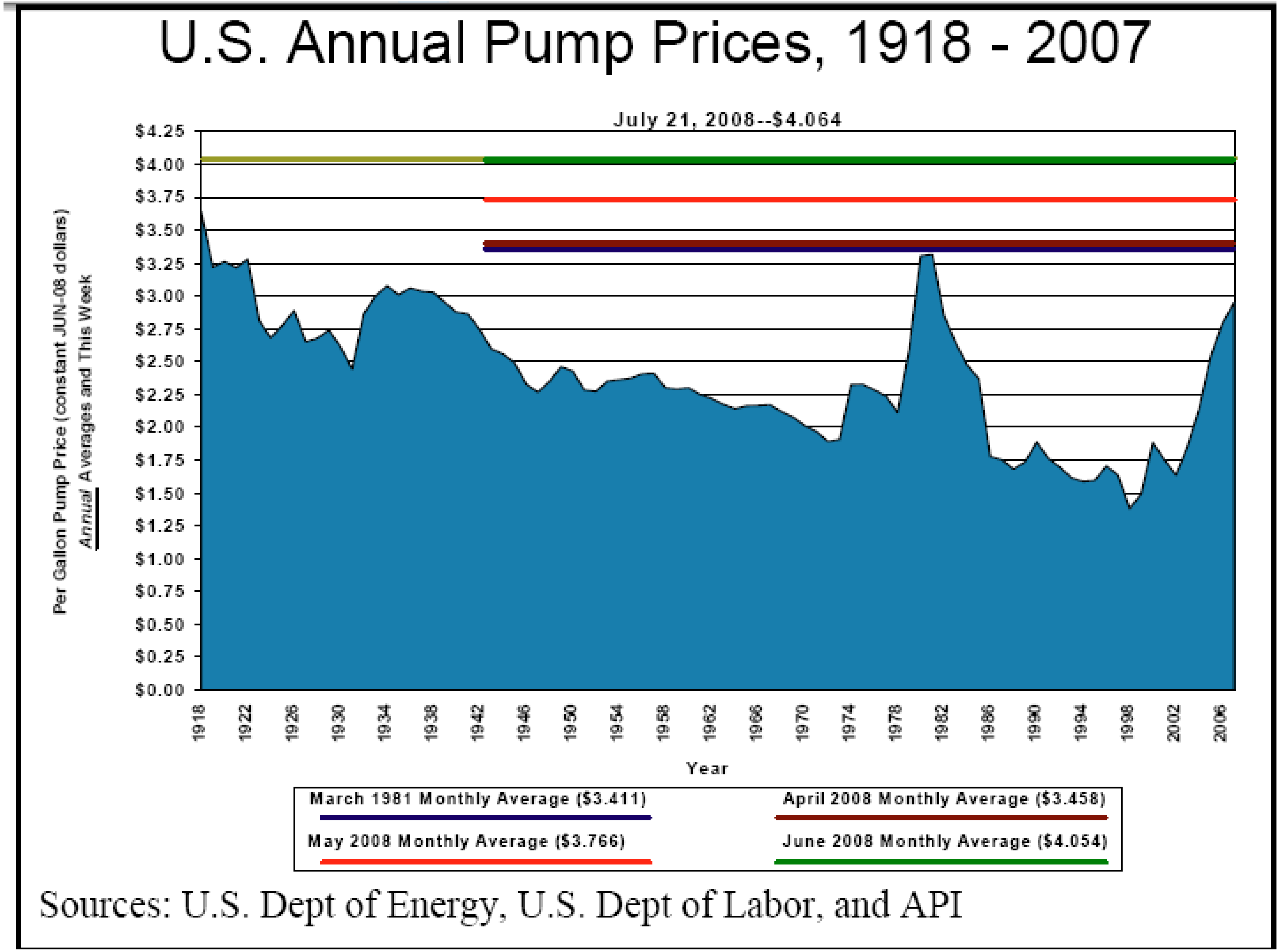


Sources: *Transportation Energy Data Book: Edition 26* and projections from the *Annual Energy Outlook 2008*.

Notes:

• The U.S. Production has two lines after 2005. The solid line is conventional sources of petroleum. The dashed line adds in other inputs -- ethanol and liquids from coal. Historical petroleum production includes crude oil, natural gas plant liquids, refinery gains, and other inputs, which include liquids from gas, liquids from coal, and alcohols, ethers, petroleum product stock withdrawals, domestic sources of blending components, other hydrocarbons, and natural gas converted to liquid fuel.

•The sharp increase in values between 2005 and 2006 are the result of the data change from historical to projected values.



Source: Retrieved from the American Petroleum Institute web site on July 29, 2008
http://www.api.org/aboutoilgas/gasoline/upload/PumpPriceUpdate.pdf

FreedomCAR Lightweighting Materials

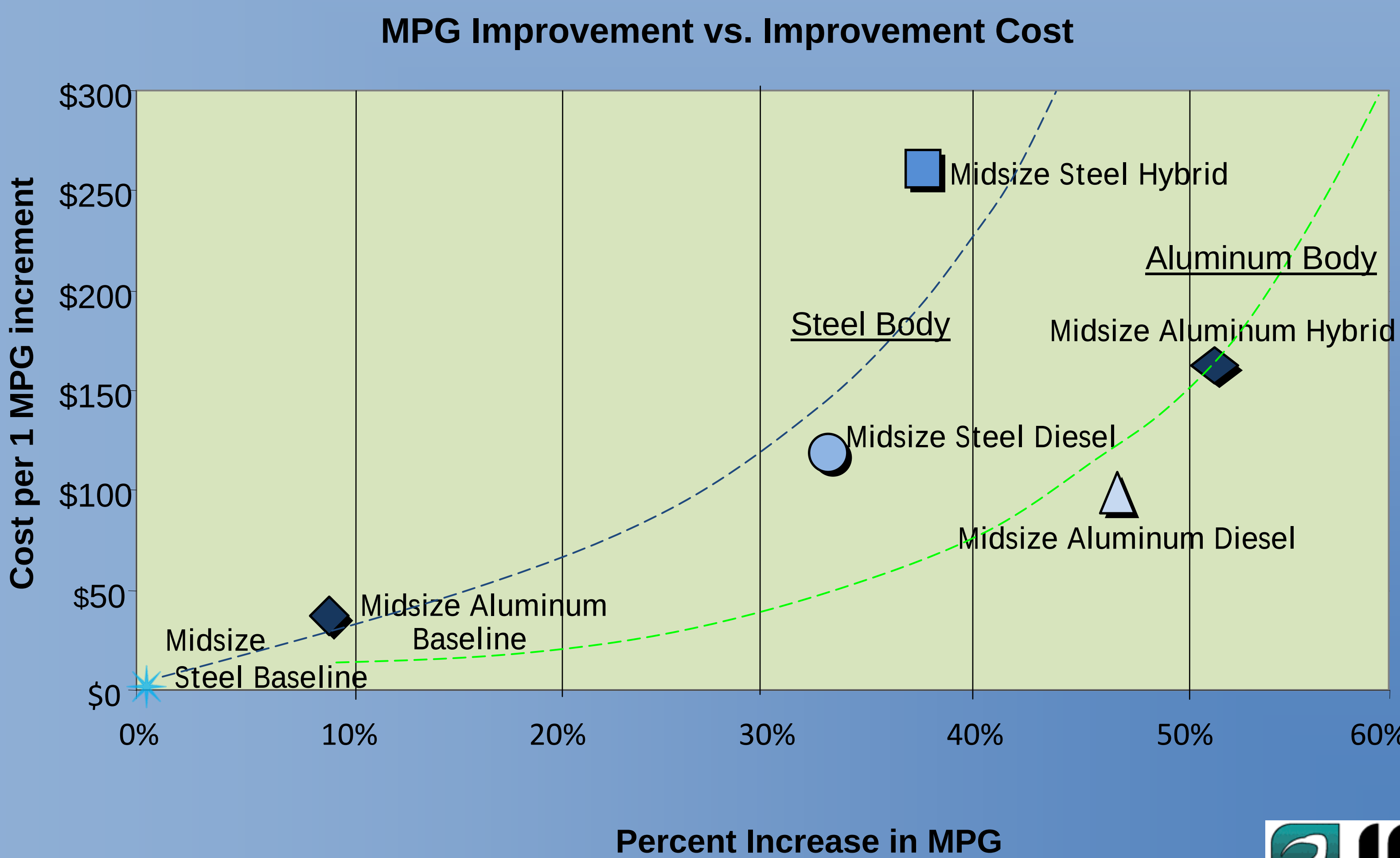
- Goals (wrt 2004 baseline)

  - 50% reduction of structural mass
  - Affordability
  - Same (about 85% by weight) or increased recyclability

- Roles

  - 6 to 8% (with mass compounding) increase in fuel economy for every 10% drop in weight, everything else the same
  - Offset the increased weight and cost per unit of power of alternative powertrains (hybrids, fuel cells) with respect to conventional powertrains (*Alice in Wonderland* syndrome)

Optimizing Power-trains with Aluminum Structures



Weight Savings and Costs for Automotive Lightweighting Materials

Lightweight Material			
High Strength Steel	Mild Steel	10 (25?)	1 (<?)
Aluminum (AI)	Steel, Cast Iron	40 - 60	1.3 - 2
Magnesium	Steel or Cast Iron	60 - 75	1.5 - 2.5
Magnesium	Aluminum	25 - 35	1 - 1.5
Glass FRP Composites	Steel	25 - 35	1 - 1.5
Carbon FRP Composites	Steel	50 - 60	2 - 10+
Al Matrix Composites	Steel or Cast Iron	50 - 65	1.5 - 3+
Titanium	Alloy Steel	40 - 55	1.5 - 10+
Stainless Steel	Carbon Steel	20 - 45	1.2 - 1.7

•***Includes both materials and manufacturing.***

Ref: *William F. Powers, Advanced Materials and Processes, May 2000, pages 38 – 41.*

FreedomCAR Automotive Lightweighting Materials Focus Areas

- Largest Focus Areas
  - Aluminum and magnesium casting
  - Aluminum sheet formation and fabrication
  - Low(er)-cost carbon fiber production
  - Polymeric-matrix composites processing

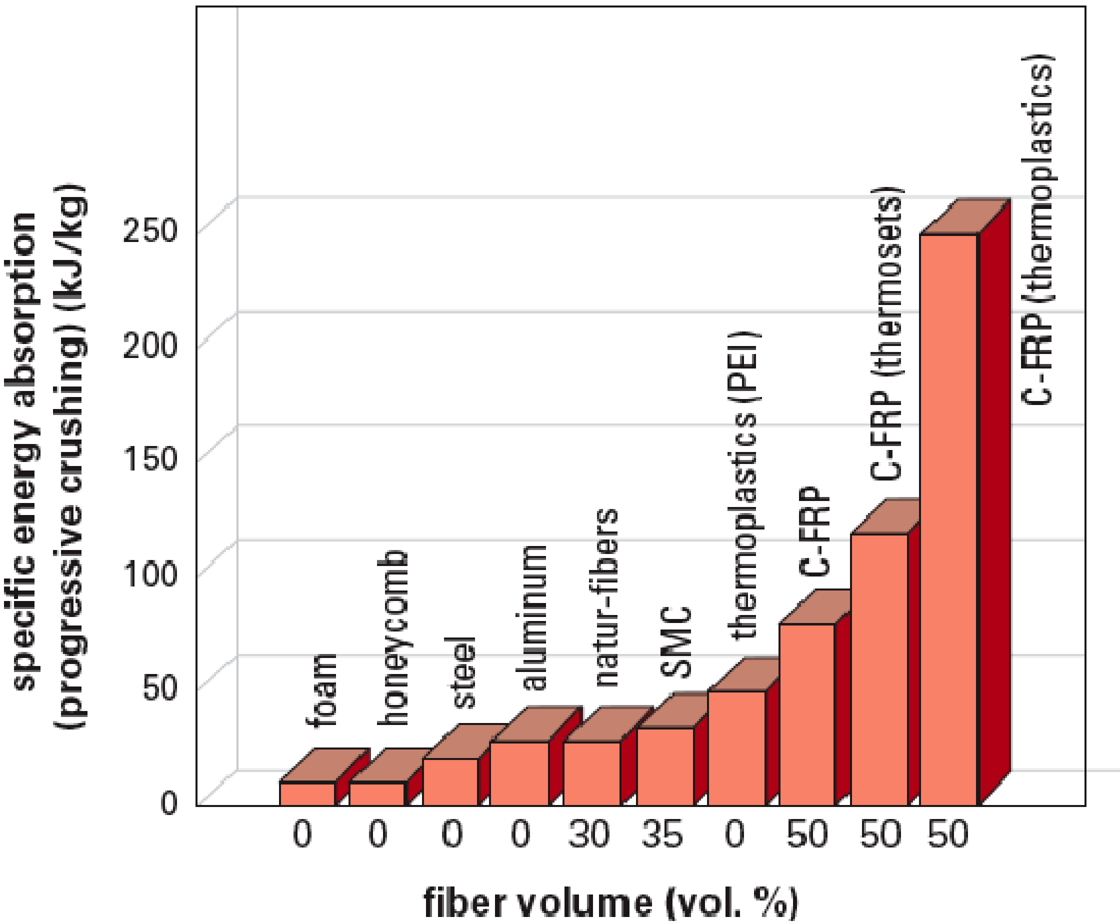
- Smaller Focus Areas
  - Aluminum and magnesium metal production
  - Metal-matrix composites
  - Titanium metal production and fabrication
  - Fabrication of sheet steel components
  - General manufacturing (e.g., joining, NDE, IT)
  - Glazing (glass)
  - Crashworthiness
  - Recycling

Advantages of Composites in the Automotive Industry

- Weight: Reduction of 20%-40+% (versus steel)
- Styling flexibility: Deep draw panels not possible stamped in metal
- Tool Investment: 40%-60% save in part tooling vs steel
- Part Consolidation: Reduced assembly costs and time
- Customer Satisfaction: Resistance to corrosion, scratches, dents, and improvement in damping and NVH
- Safety: Highest specific energy absorption of all major structural materials

Figure 15: Advanced composites' remarkable crash energy absorption

Carbon-fiber reinforced polymer (C-FRP) crush cones and similar structures can absorb ~120 kJ/kg if made with a thermoset resin like epoxy, or ~250 with a thermoplastic, vs. ~20 for steel.[309] Crush properties can also be optimized by mixing carbon with other fibers.

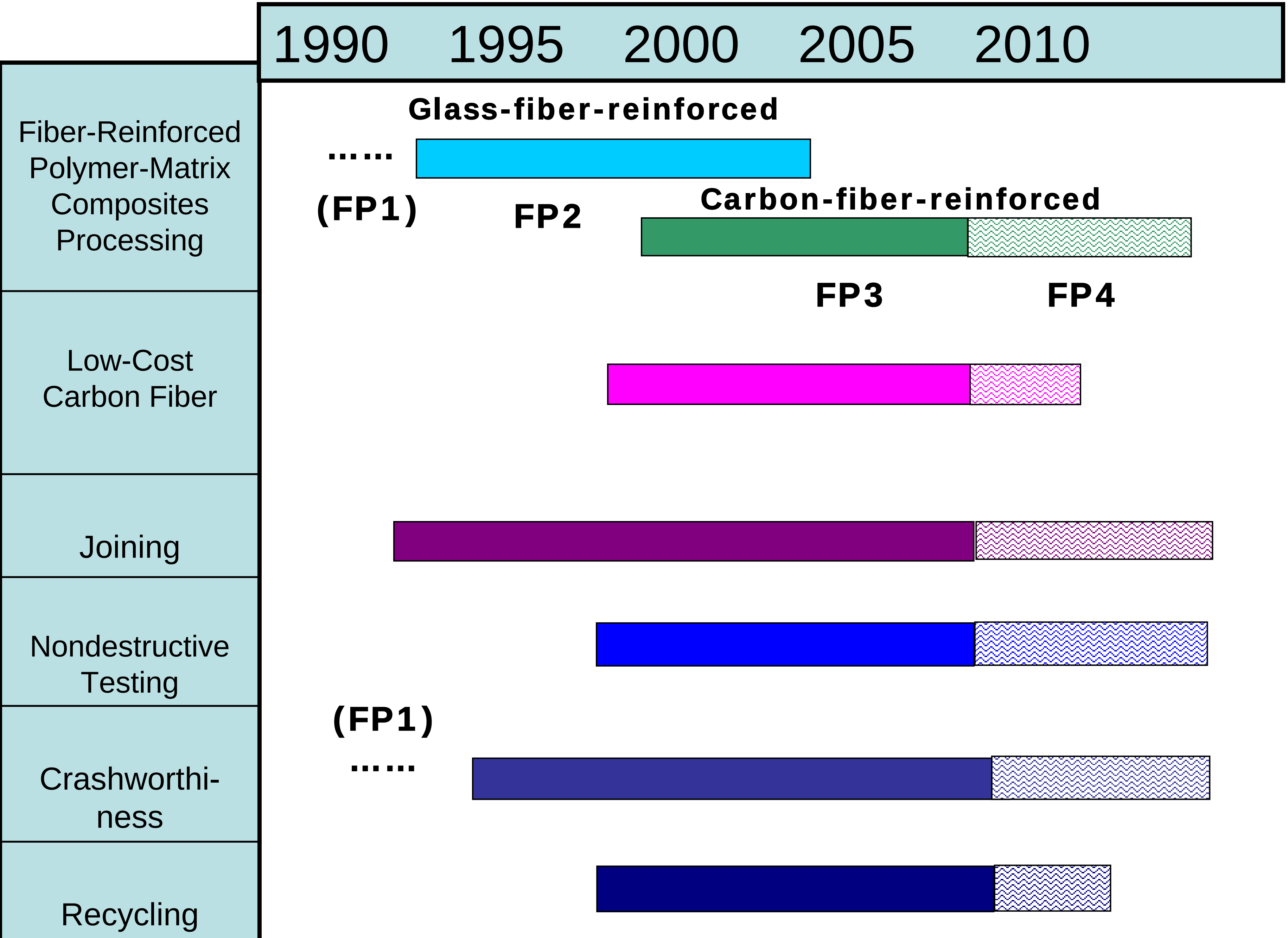


Source: Herrman, Mohrdeck, & Bjekovic 2002, p. 17.

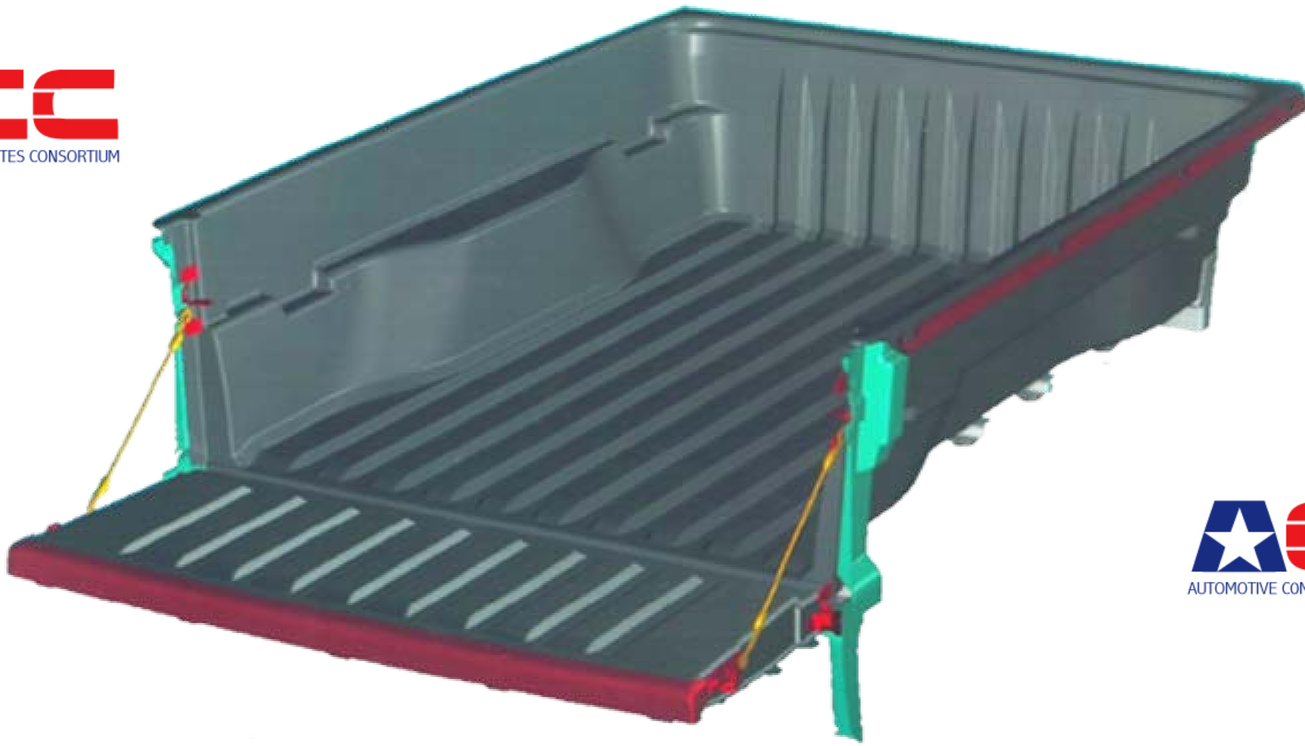
Barriers to Lightweighting

- Historically low prices of fuel.
- Higher costs of lightweighting materials.
- Lack of familiarity with them.
- Sunk capital in metal-forming technologies.
- Lack of large automotive composites and magnesium industries
- Preferences for large vehicles.
- Perceptions of safety.
- Recycling (plastics).
- Alternative fuels such as non-conventional petroleum, biofuels and electricity.
- Alternative propulsion systems such as hybrids and fuel cells.

LM Historical Timeline – Composites

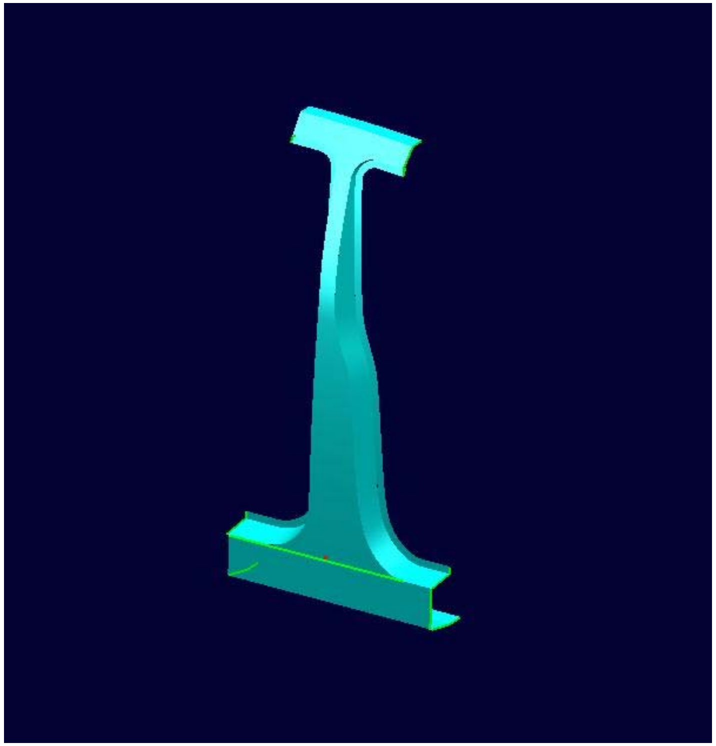


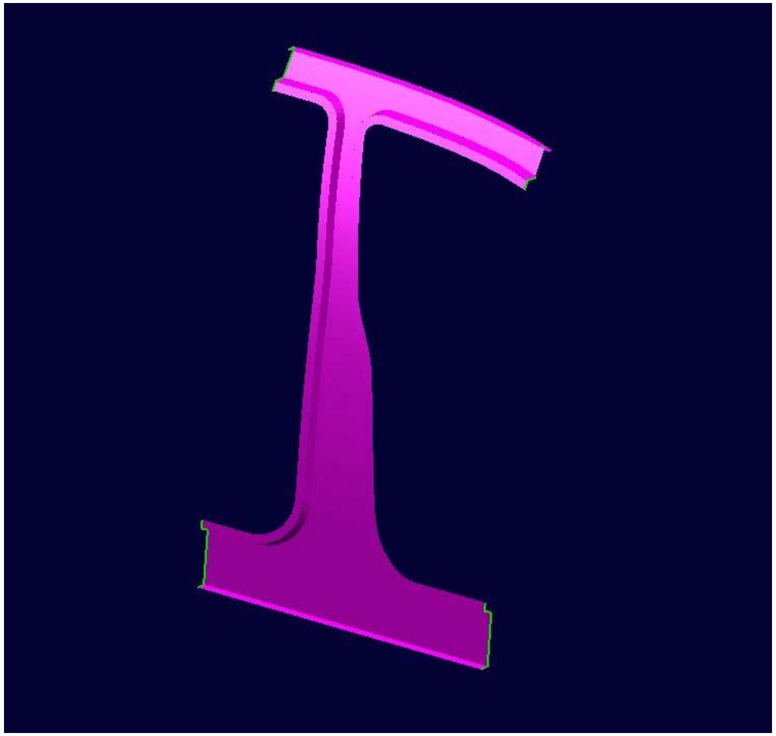
Automotive Composites Consortium



Focal Project 2: Composite Pickup Truck Box

Test Piece Design: Multi-Purpose B-Pillar Tool





COMPOSITE MATERIALS RESEARCH (2008)
What we are Doing --- Carbon Fiber Composites

FreedomCAR ***Materials***

✓ Previously Briefed
✓ Briefed Now
✓ Briefed Later

Processing
TPP4
✓ High Vol Process of Composites
(- CF SMC, Press, Inj Tools, etc)
✓ Next Generation P4
✓ P4 Preforming

Low Cost Carbon Fiber
✓ Lignin Based Precursors
✓ Lignin Purification
✓ Advanced Oxidation
✓ Advanced Stabilizaton
✓ LCCF Integration Line
✓ FSD of Textile Precursors
Higher Performance Fibers

Materials
✓ Natural Fiber Composites
✓ Recycling PMCs
✓ Predictive Modeling of PMCs

Focal Projects IV
✓ - Underbody
- Comp Seat

Joining
Bond-line Read Through
Bonding of TP
Composite Underbody

Other
✓ Cost Modeling – Program
Focal Project 3

✓ **Energy Management**
Crash Adsorp of Bonded Structures
Crash Energy Management **(7)**
Testing Machine for Auto Crash

FreedomCar &
21Century Truck
Goals

Coordinated with Hydrogen Program
Current

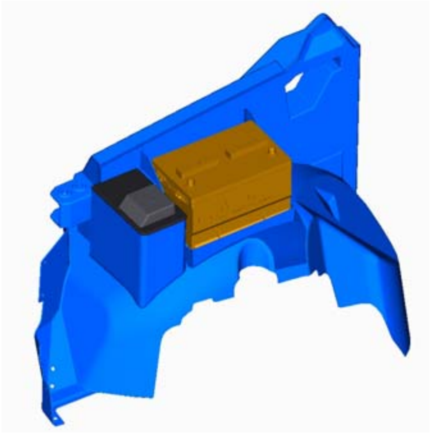
ACC Key Deliverables

Composite Underbody

Low Cost Carbon Fiber

Carbon Fiber SMC Hood

2008 **2010** **2012** **2014**



Polymer Encapsulated Mega-Module

Composite Seat

EMWG Composite Front Structure

Trends in Automotive Composites

Materials Technologies

• Glass-fiber-reinforced polymer-matrix composites (PMCs) will compete for "as-needed applications" with Al and Mg for high-volume models (> 50-100K per annum).

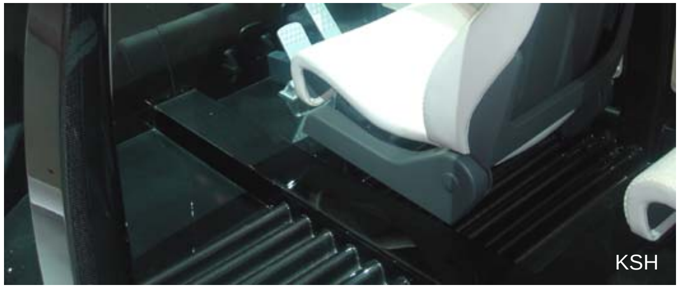
- Natural fibers may challenge glass fibers.

• Carbon-fiber-reinforced PMCs will find limited use in high-end, low-volume models (<50K per annum).

• Advent of lower (than aerospace) cost and performance carbon fiber could open a new era for composites in high-volume applications.

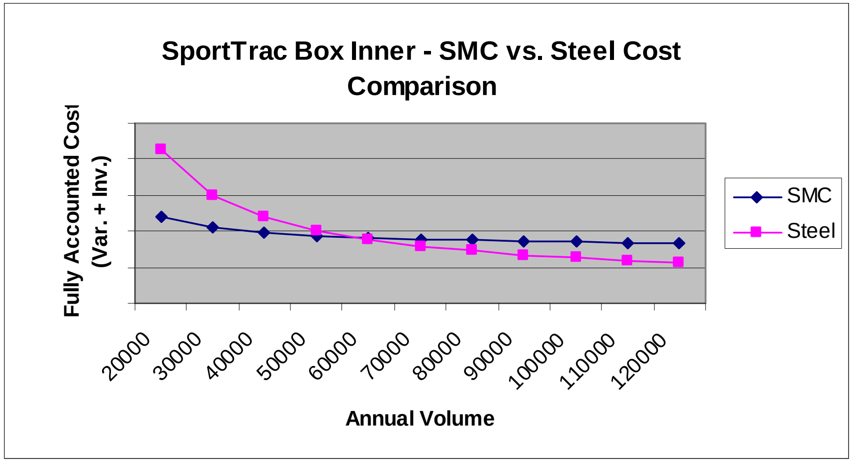
Holistic Vehicle Efficiency Approach

- Combined synergistic technologies
  - Body and chassis of lightweight materials
  - Small flex-fuel engine in a hybrid system
  - Advanced batteries and/or capacitors
- Toyota 1/X Concept (Prius mock-up)
  - 33% weight
  - 50% fuel consumption
  - ‘Plausible’ application of carbon fiber reinforced plastic (CFRP)
    - *Benefit from Lexus LF-A sports car development and Toray’s increased production for the aircraft industry*
  - 500 cc engine (could be) adapted from available (hybrid) motorcycle technology
  - Plug-in hybrid with Li-ion battery



Case Study -Composite Pickup Boxes

Ford SportTrac (70K), Toyota Tacoma (170K), Honda Ridgeline (100K)



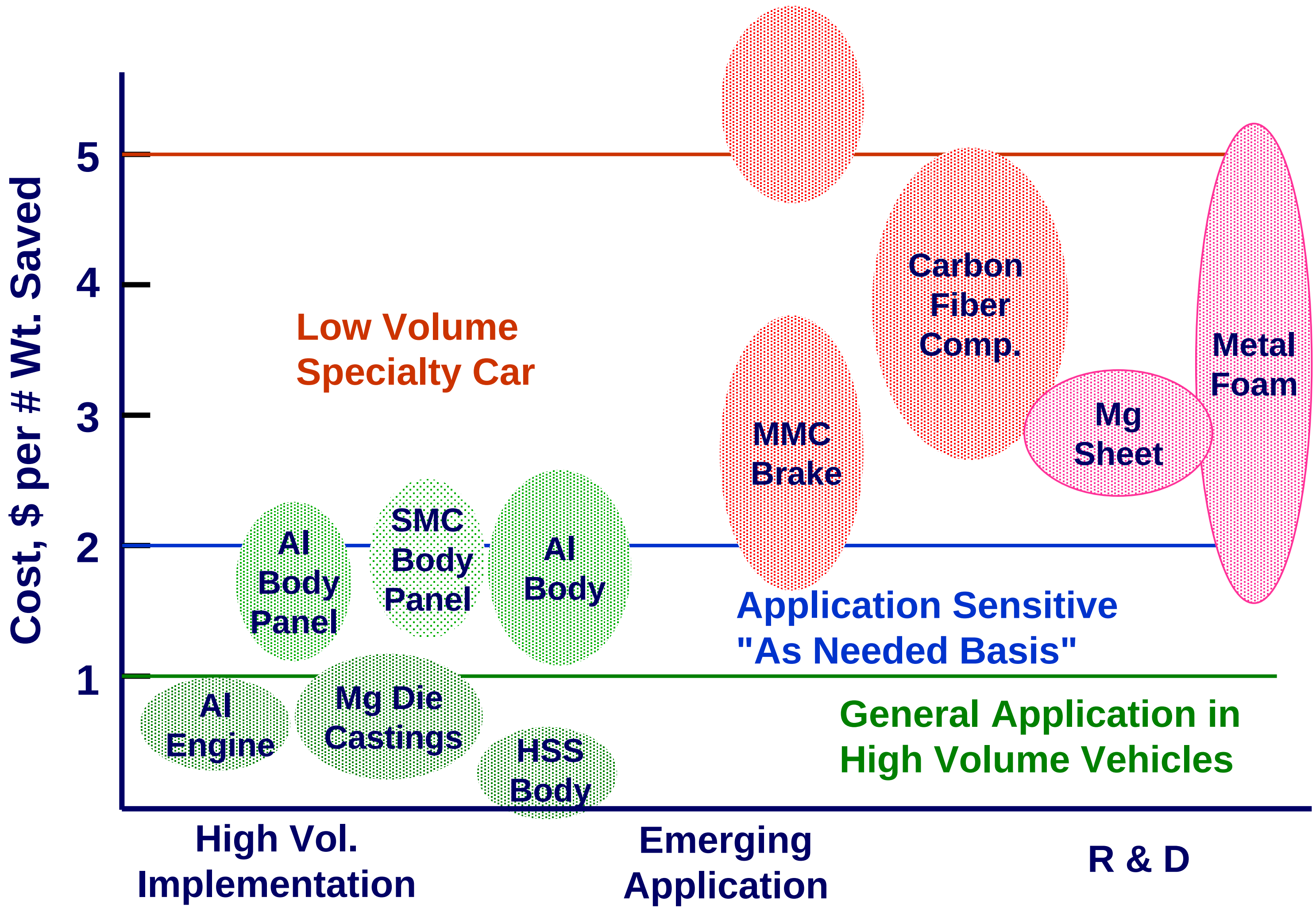
Customer Advantages

- Improved scratch and dent resistance
- Features and functionality (e.g. power points, storage, etc.)
- Improved entry/egress
- Tie down/rack systems (improved methods to secure cargo)

OEM Advantages

- Total program cost savings (x-over 70K)
- 4X capital investment reduction
- Design and styling flexibility
- Part integration, reducing assembly and tooling costs
- 25% weight savings over steel
- Ease of prototyping

Lightweight Automotive Materials - Market Penetration vs. Cost



Future

(… barring some major, long-term shift in politics or economics)

- Steel will predominate for high volume (numbers) models.
- Mg castings, Al, plastics and glass- and natural-fiber composites will compete for “as-needed” applications.
- Mg sheet and carbon-fiber composites will find use in lower-volume niche vehicles mainly for performance reasons.
- The ultimate factors on adoption will likely be economic and political.

(most predictions of the future turn out to be wrong.)

Challenge

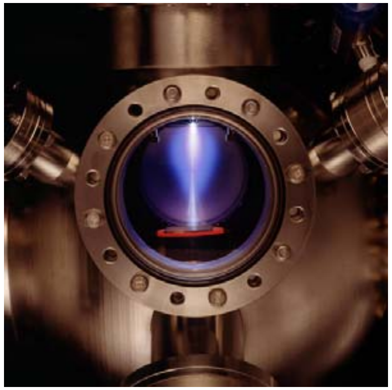
- “Steel is for cars, aluminum is for airplanes, and plastics are for toys”
  - Francois Castaing, Chief Engineer, Chrysler Corporation, 1995

Office of Energy Efficiency and Renewable Energy

Materials Technologies

http://www.eere.energy.gov



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