



Lightweight Materials for Vehicles

Needs, Goals, and Future Technologies

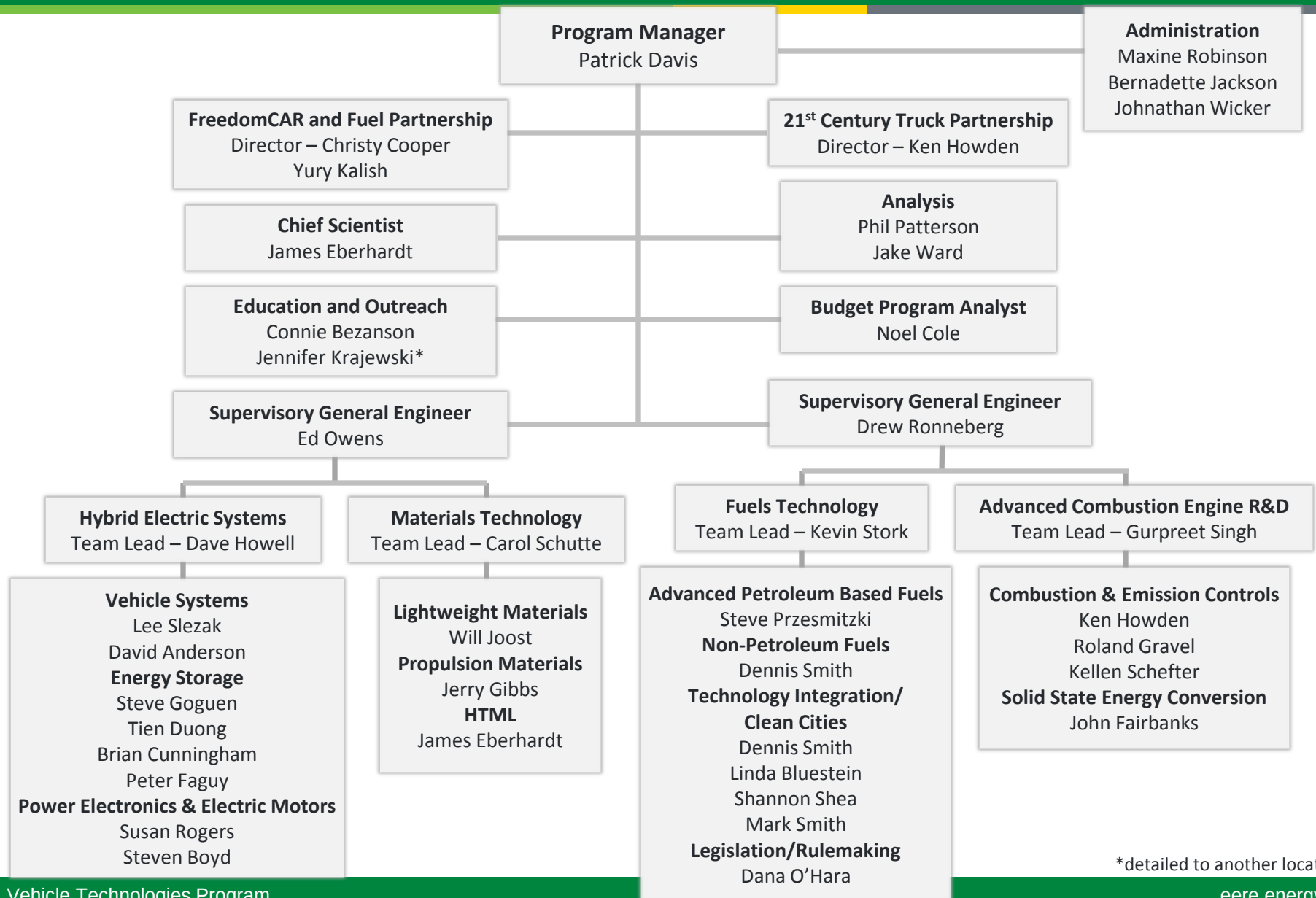
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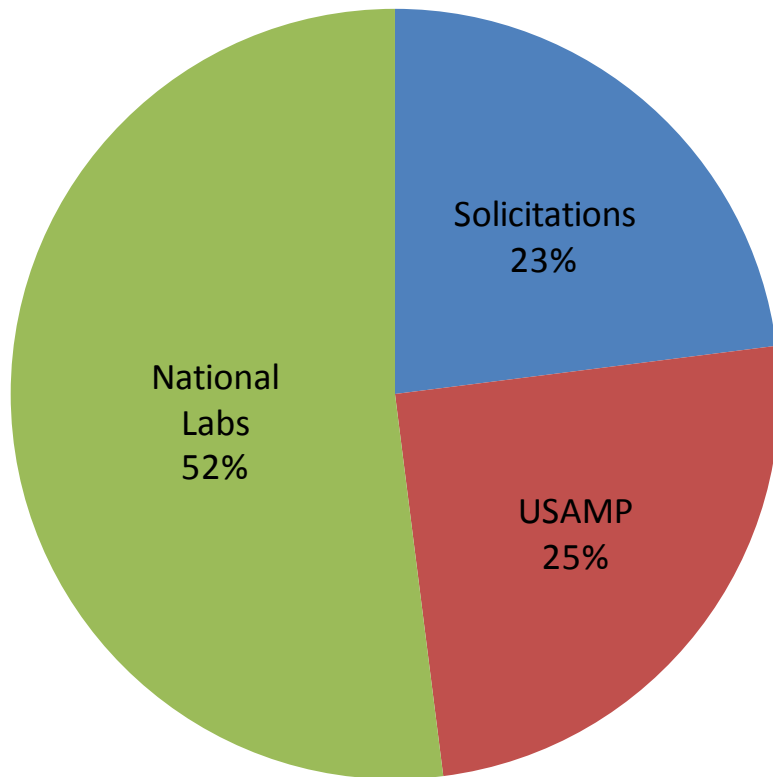
Vehicle Technologies Program

Vehicle Technologies Program

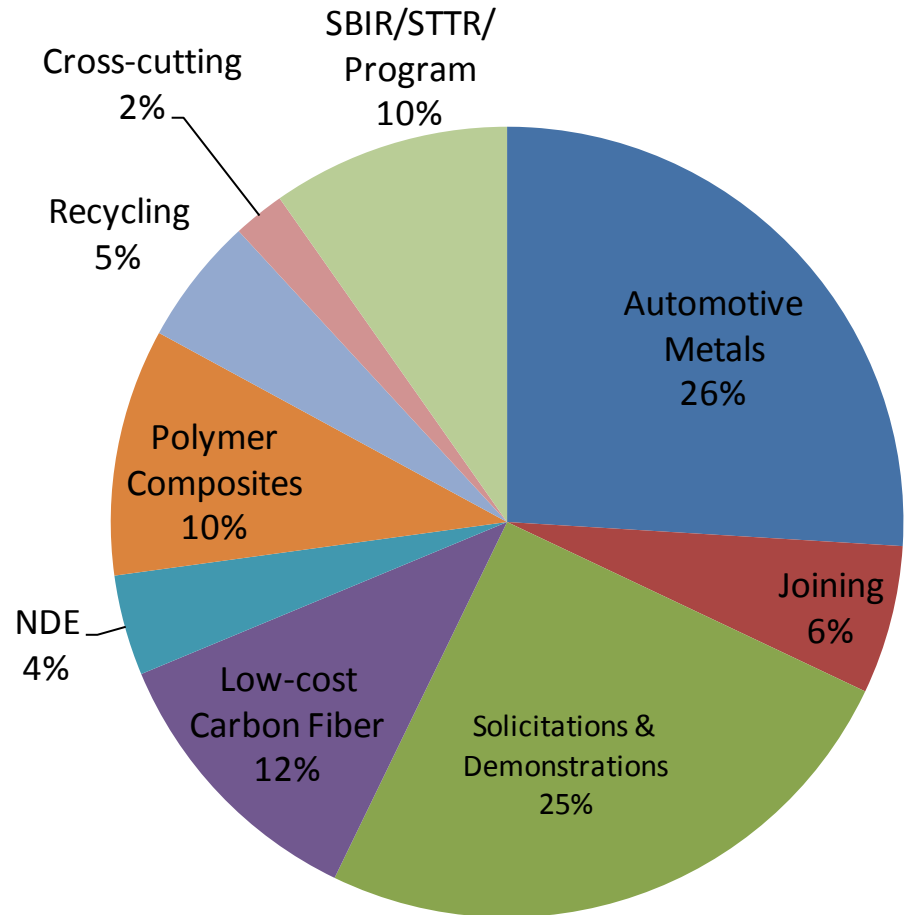


Lightweight Materials Breakdown

By Recipient



By Technology

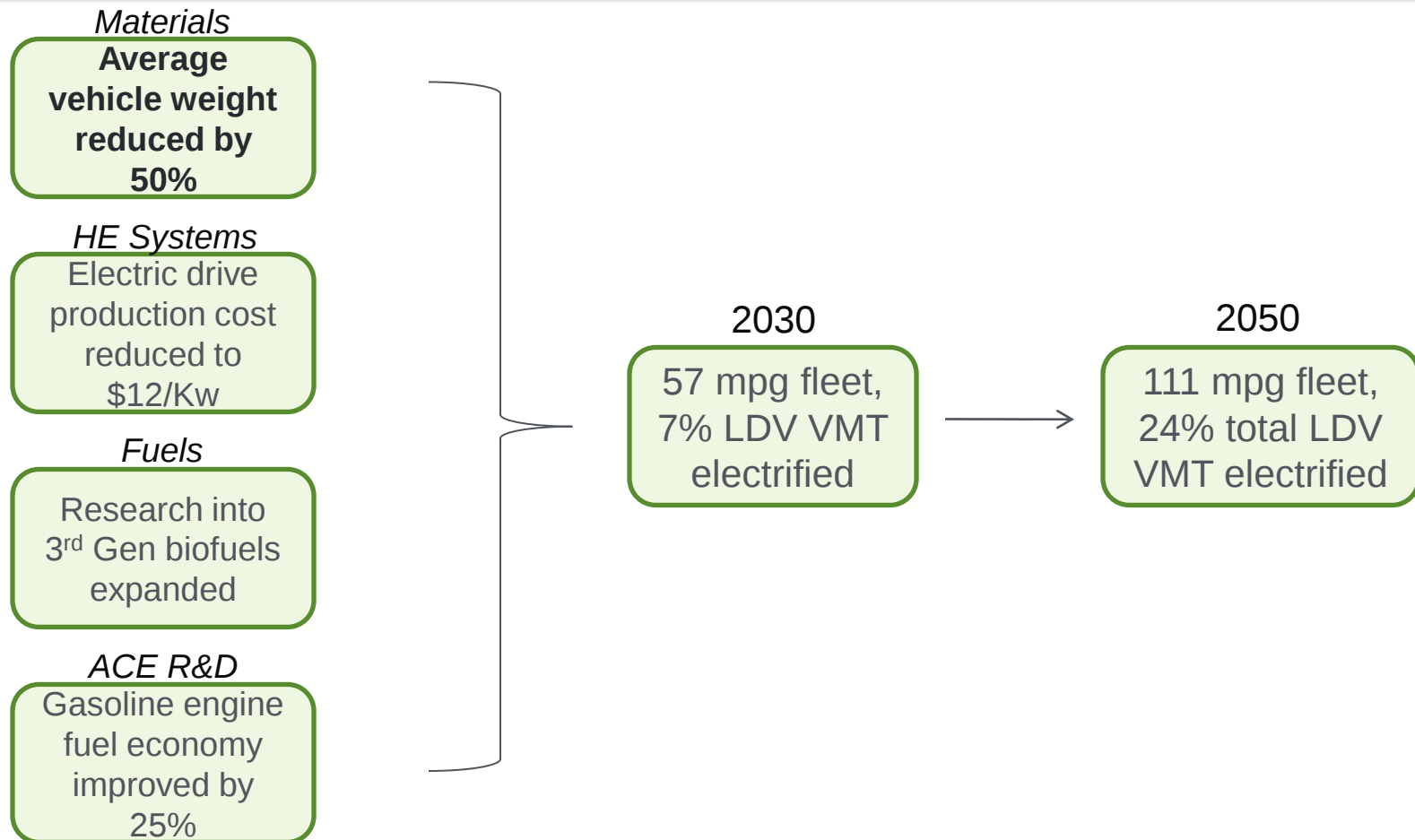


Total FY 2010 Funding: \$30,652,000

Why Lightweight?

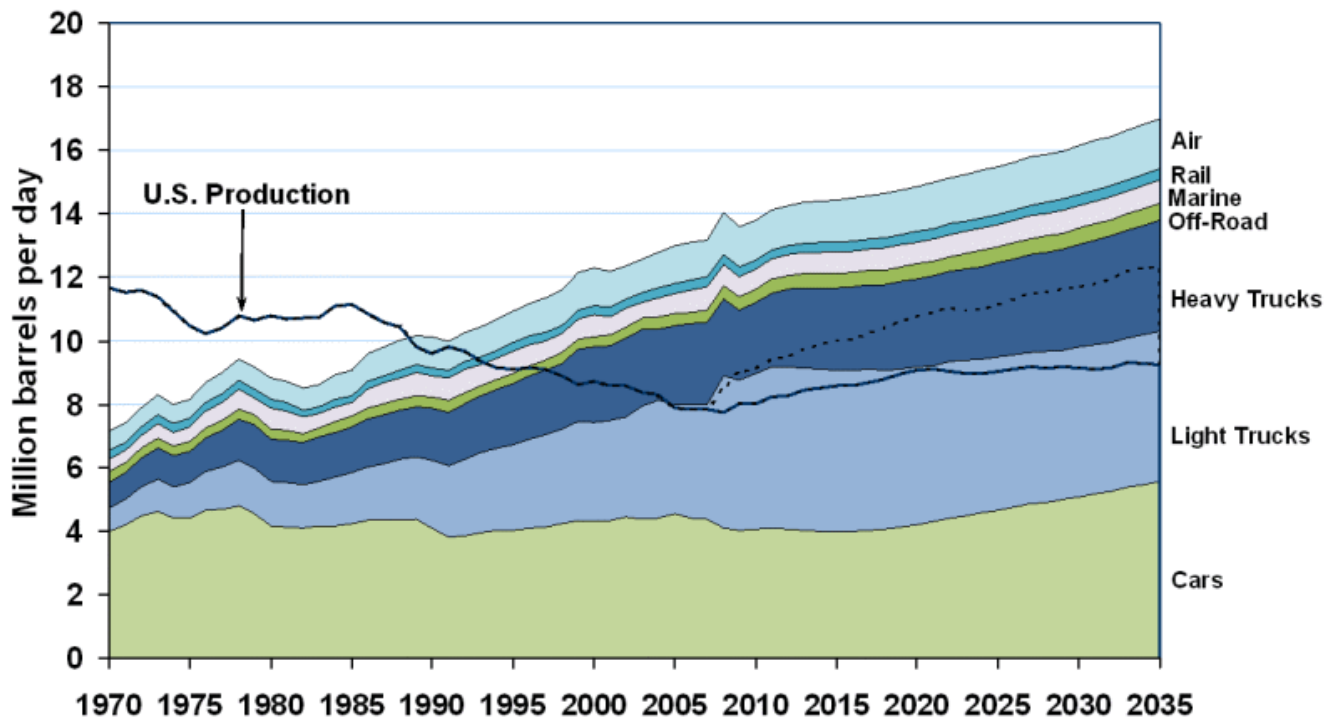
Key administration goal relevant to Vehicle Technologies

- Reduce greenhouse gas emissions by 40% by 2030 and 80% by 2050 (compared to a 2002 baseline)



Why Lightweight?

- Improve efficiency and reduce emissions for conventional gasoline and diesel engines
 - *A 10% reduction in weight yields a 6-8% improvement in fuel economy*
- Reduce dependence on imported oil

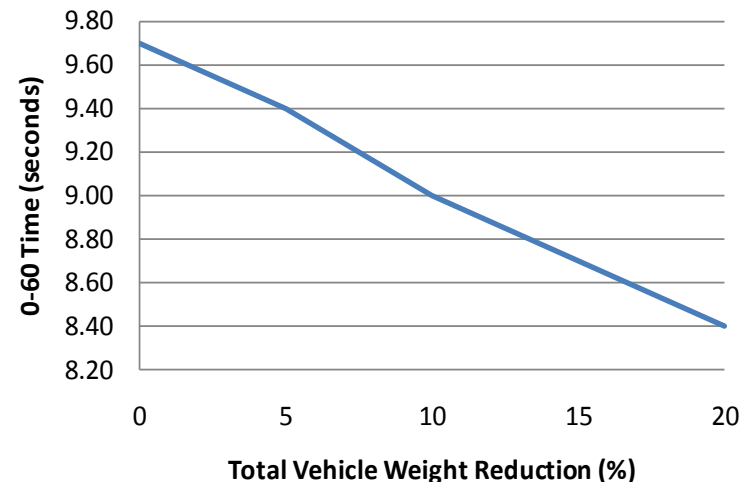


Customer Value Balancing Act

- Improve commercial viability of electric, plug-in hybrid, and fuel cell vehicles
 - Improve range for existing battery set
- Or*
- Maintain range with smaller battery set (reduced cost)

- Improve vehicle performance
 - Improve 0-60 acceleration without increasing engine size
- Or*
- Maintain 0-60 acceleration while decreasing engine size

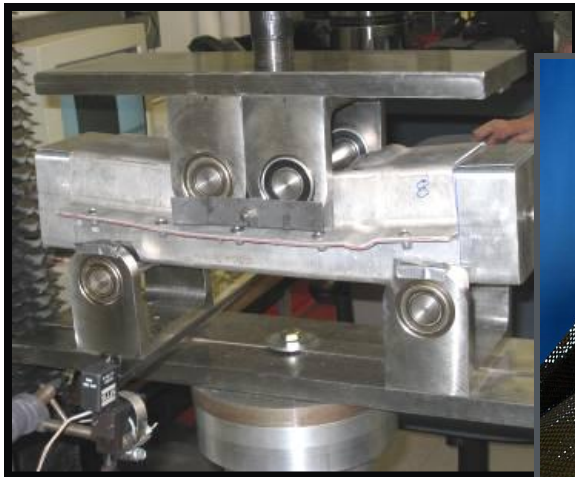
Effect of Weight Reduction on 0-60 Time



http://aluminumintransportation.org/downloads/AluminumNow/Ricardo%20Study_with%20cover.pdf

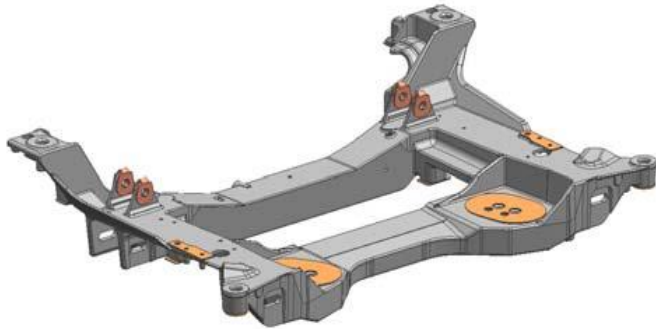
Why Not Lightweight?

- Gaps in light weight material technology (performance, manufacturability, cost)
- Sunk capital in metal forming equipment
- Limited production capacity of some light weight materials
- Perceptions of safety
- Preference for larger vehicles
- Limited recyclability

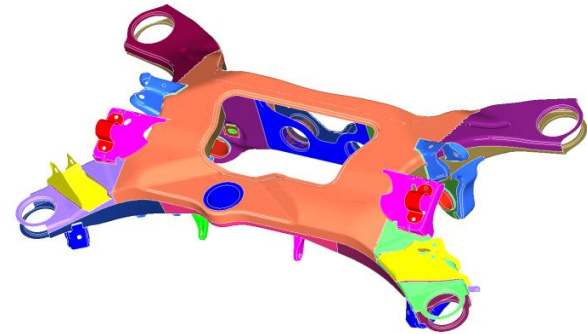


What is required for a 50% weight reduction?

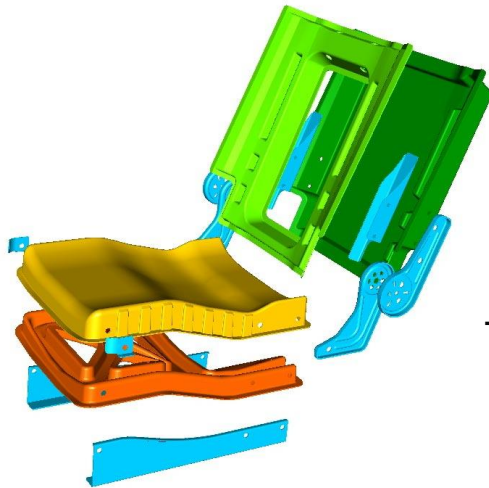
Example Component Lightweighting



- Mg engine cradle for Corvette Z06
- **60%** lighter than steel, **35%** lighter than Al
- Single piece Mg casting vs. 28 piece steel assembly



- AHSS rear cradle for RWD vehicles
- **28%** lighter than conventional design, no loss of stiffness
- Cost neutral

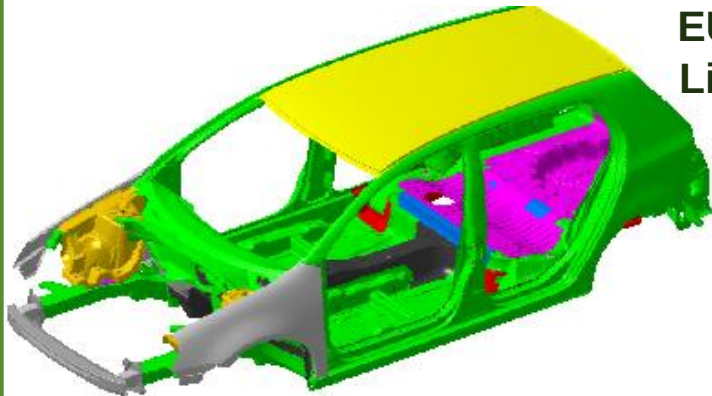


- Carbon Fiber Composite seat structure
- **58%** lighter than standard design



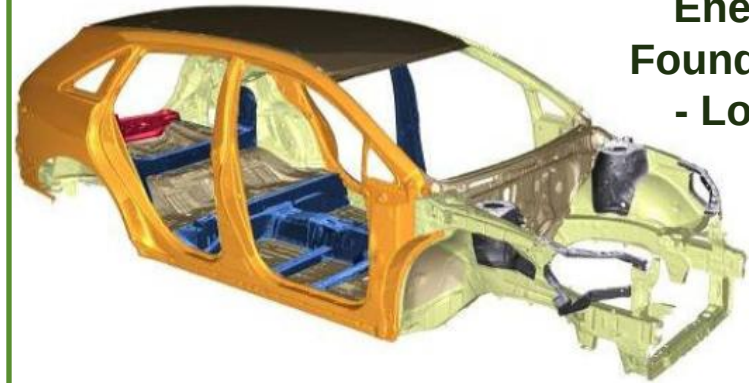
- Mg engine block, bedplate, oil pan, and engine cover
- **28%** lighter than Al version

Example System Lightweighting



**EU Super
Light Car**

- Multi-material vehicle, Al intensive
- **30%** weight reduction for BIW



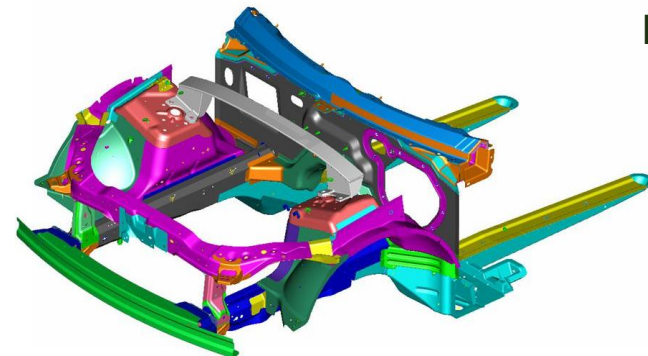
**Energy
Foundation
- Lotus**

- AHSS intensive vehicle
- **16%** weight reduction for BIW



PNGV

- Multi-material vehicles
- **~25%** overall vehicle weight reduction



**Mg Front
End**

- Mg intensive front end structure
- **45%** weight reduction compared to steel
- 56% reduction in part count

50% Weight Reduction?

- Will not occur through optimization and trimming in existing designs
 - Tubular sections with holes, scalloped flanges, etc.
- Will not occur through material substitution in existing designs
 - Component or system level
- Unlikely to occur using existing vehicle composition
 - Aluminum, magnesium and composites all will play a larger role



- Will require material specific designs
 - The right design using the right material for the right application
- Will require advancements in multi-material technology
 - Joining, corrosion, modeling, manufacturing, cost reduction



How will we get there?

Research and Development Approach

Strategy and Road Map Development

- Identify technology gaps
- Establish performance targets
- Determine technology alternatives and milestones



Fundamental Research

- Fundamental Materials Science
- High Risk Research



Pre-competitive Research

- Applied Materials Science
- Cost and Manufacturing Research



Solicitations and Demonstrations

- Validate technology worthiness
- Identify new gaps and opportunities



Technology Transfer to Industry



Direct Commercialization
by Industry

Light Duty
Vehicle -
Materials Road
Map

Heavy Duty
Vehicle -
Materials Road
Map

Properties and
Manufacturing

Mg Alloys

CF Polymer
Composites

Al Alloys

AHSS

Ti Alloys

MMCs,
Nano-
materials,
etc.

Multi-material
Enabling

Advanced
Fusion
Joining

Solid State
Joining

MM
Mechanical
Fastening

Low-cost
Corrosion
Prevention

Lightweight
Systems

Non-
destructive
Evaluation

Modeling and
CMS

Process/
Property/
Structure
Modeling

Materials
Informatics

Dynamic
Structural
Simulation

Detailed
Process
Modeling

Key Technology Gaps

Gap: Rare Earth elements are required to achieve superior alloy properties for certain applications

- High temperature creep resistance
- High strength and ductility sheet (e.g. WE43)
- High energy absorption structures



Gap: Inferior ductility impedes use of cast Mg in most structural applications

- Ductility in actual castings is lower than in coupons
- Our understanding of the process > structure > property relationship is limited



Gap: Deformation at high strain rates is not well explored

Gap: Mg alloy set is very limited. Large sets of binary and ternary alloys are not explored at all.

Gap: Design methods for managing high anisotropy are not well established



Active Research

Non-RE High Performance Mg Alloys *Pacific Northwest National Laboratory*

- Expanding on work done with BRL in the 1990's for Mg in interior "ballistics applications"
- Developing Mg extrusions with energy absorption comparable to 6061 Al
- Exploring low-cost process modeling method

Modeling of Complex, Ductile Mg HPDC *New Start*

- Focusing on improved structure > property model development, including intrinsic and extrinsic defects
- Moving from empirical/curve fitting models to physics based models for ductility in HPDC
- Includes significant model validation

?



Key Technology Gaps

Gap: Use of high-grade PAN precursors limits cost to >\$20/lb

- How can alternative precursors to PAN be converted to carbon fiber in a cost effective way?
- What processing innovations can also contribute to lower cost mfg of carbon fiber?



Gap: Properties of injection molded long fiber composites can not be accurately predicted

- How do conditions of molding influence Fiber length and distribution in a molded part?
- How accurately can one predict strength stiffness fatigue creep etc?



Gap: There is a continued need for validation (CF and Models) in increasingly complex applications



Active Research

Low Cost Carbon Fiber *Oak Ridge National Laboratory*

- Study different low cost precursors
- Study innovative conversion processes to speed up and improve conversion of fiber
- Longer term transition innovation to ARRA demonstration line to validate cost models to lower the cost for industry to make decisions to commercialize

Predictive Engineering of Long Fiber Injection Moldable Composites *Oak Ridge National Laboratory, Pacific Northwest National Laboratory , American Chemistry Council Plastics Division Autodesk Moldflow*

- Validate existing models with progressively more complex shapes

?



Key Technology Gaps

Gap: Retained Austenite formation and stability in AHSS can not be controlled at levels required for 3rd Gen properties

- Austenite is likely a significant component of 3rd Gen AHSS
- Current method use high cost elements (Co, Ni, Mn) or processing



Gap: Microstructural damage during welding limits potential usefulness

- Many AHSS formulations rely on complex multi-phase structures
- Joint efficiency can be very low due to formation of cast-like microstructures



Gap: Formability and springback modeling are nearly absent for AHSS

Gap: New high γ - α' SFE chemistries do not exist

Gap: High performance steels (without standard automotive cost limits) are not being widely researched



Active Research

Fundamental Study of γ - α Transition

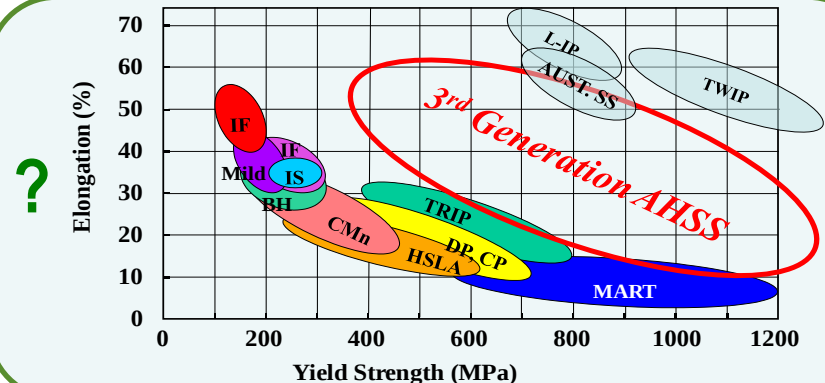
Oak Ridge National Laboratory

- Using an in-line Gleeble at the Argonne APS to perform in-situ XRD during heating, cooling, and deformation
- Developing an improved understanding of the kinetics and mechanisms for transition

Friction Stir Welding of AHSS

Oak Ridge National Laboratory

- Focusing on improved structure > property model development, including intrinsic and extrinsic defects
- Moving from empirical/curve fitting models to physics based models for ductility in HPDC
- Includes significant model validation



Key Technology Gaps

Gap: Solid-state joining techniques for MM joints are not well characterized

- USW and FSW both show promise
- Insufficient characterization and model development for auto deployment



Gap: Mg/Al joints can not be riveted, limiting multi-material designs for certain applications

- Mg room temperature ductility may be insufficient
- Elevated temperature processes are not developed



Gap: Galvanic corrosion protection schemes add considerable cost

Gap: Structural adhesives are not prepared for use as primary/sole joining technique

Gap: Existing paint systems are not compatible with many light materials



Active Research

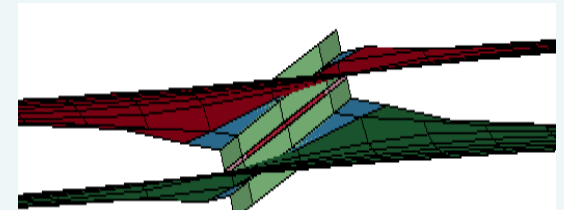
USW and FSW of Mg to Steel
PNNL/ORNL

- Optimizing FSW parameters such as rotating speed, lateral speed, bit material and bit design
- Demonstrating high efficiency USW joints
- Developing initial physical models for predictive engineering and crash simulation

Efficient Mechanical Fastening of Mg/Al Joints
New Start

- Simulate SPR process for Mg/Al and determine process requirements for room temperature riveting
- Understand temperature profile required for elevated temp riveting
- Develop processing method to meet requirements

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Can we use computational materials science and engineering to solve light weight materials engineering problems more efficiently?

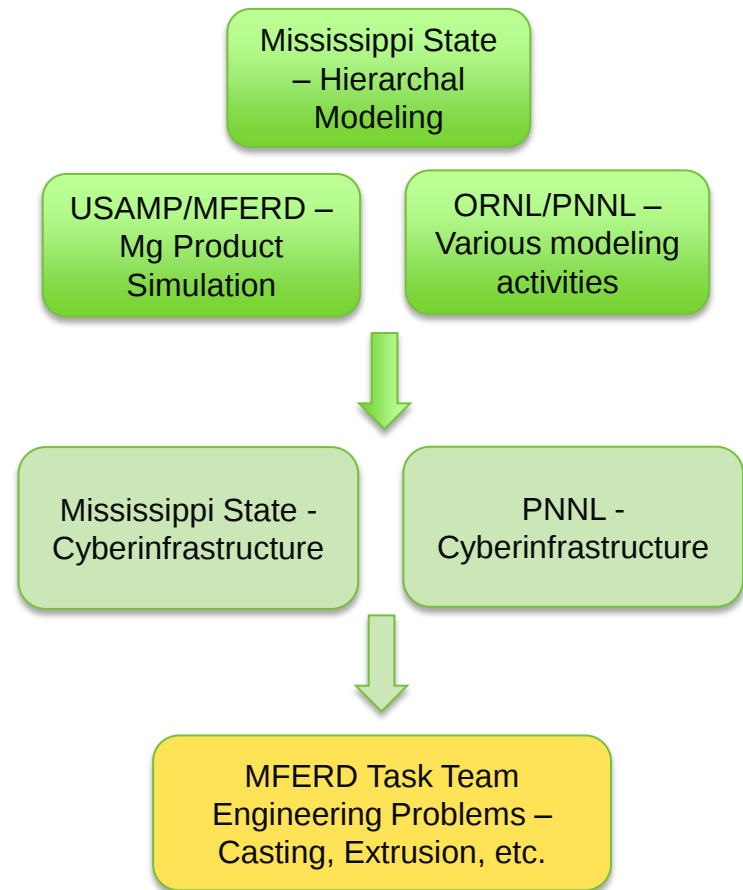
Key Organizational Gaps

Gap: Ongoing activity in “ICME” is occurring throughout the government, industry, and academia but is difficult to coordinate

Gap: Mutually interesting foundational engineering problems have not been identified

Gap: Balance between competitive investment and open development is difficult to establish

Active Research



ARRA Funded Low-cost Carbon Fiber Line

- A \$34.7M ARRA funded user facility currently being installed at ORNL to develop new carbon fiber manufacturing techniques.
- Supports development and commercialization of carbon fiber that can be manufactured at \$5/lb



Vehicle Technologies Solicitation NOI

- The Vehicle Technologies Program has issued a Notice of Intent for an upcoming Broad Agency Announcement
- Three topics in Lightweight Materials
 - Low Cost Development of Magnesium from a Domestic Source
 - Development of Low Cost Carbon Fiber
 - Demonstration Project for a Multi-material Light Weight Vehicle as part of the Clean Energy Dialogue with Canada

- Annual Reports
http://www1.eere.energy.gov/vehiclesandfuels/resources/fcvt_reports.html
- Notice of Intent
<http://www.netl.doe.gov/business/solicitations/NOTICE%20OF%20INTENT.pdf>
- Annual Merit Review Presentations
<http://www1.eere.energy.gov/vehiclesandfuels/resources/proceedings/index.html>

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Questions?