Lightweight Materials for Vehicles
Needs, Goals, and Future Technologies

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**Title:** Lightweight Materials For Vehicles Needs, Goals, And Future Technologies  

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**DISTRIBUTION/AVAILABILITY STATEMENT**  
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Vehicle Technologies Program
Lightweight Materials Breakdown

**By Recipient**
- National Labs: 52%
- USAMP: 25%
- Solicitations: 23%

**By Technology**
- Automotive Metals: 26%
- Joining: 6%
- Solicitations & Demonstrations: 25%
- Cross-cutting: 2%
- Recycling: 5%
- SBIR/STTR/Program: 10%
- Polymer Composites: 10%
- Low-cost Carbon Fiber: 12%
- NDE: 4%
- Solicitations & Demonstrations: 25%

Total FY 2010 Funding: $30,652,000
Why Lightweight?
Lightweight Goals

Key administration goal relevant to Vehicle Technologies

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

**Materials**
- Average vehicle weight reduced by 50%

**HE Systems**
- Electric drive production cost reduced to $12/Kw

**Fuels**
- Research into 3rd Gen biofuels expanded

**ACE R&D**
- Gasoline engine fuel economy improved by 25%

2030
- 57 mpg fleet, 7% LDV VMT electrified

2050
- 111 mpg fleet, 24% total LDV VMT electrified
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

Why Lightweight?

**Customer Value Balancing Act**

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

- Improve vehicle performance
  - Improve 0-60 acceleration without increasing engine size
  - 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**

**Vehicle Technologies Program**
Topics Of Interest

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
- MM Mechanical Fastening
- Lightweight Systems
- Solid State Joining
- Low-cost Corrosion Prevention
- Non-destructive Evaluation

Modeling and CMS
- Process/Property/Structure Modeling
- Dynamic Structural Simulation
- Materials Informatics
- Detailed Process Modeling
## Mg Alloy Development

### 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
Carbon Fiber Composites Development

**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

[Image of carbon fiber processing]
Advanced High Strength Steel Development

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 \(\gamma-\alpha\)’ SFE chemistries do not exist

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

Active Research

**Fundamental Study of \(\gamma-\alpha\) 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

![Graph showing Elongation (%) vs. Yield Strength (MPa)](image-url)
Multi-material Joining Development

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

Vehicle Technologies Program
eere.energy.gov
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

- **Mississippi State** – Hierarchical Modeling
- **USAMP/MFERD** – Mg Product Simulation
- **ORNL/PNNL** – Various modeling activities
- **Mississippi State** - Cyberinfrastructure
- **PNNL** - Cyberinfrastructure
- **MFERD Task Team** Engineering Problems – Casting, Extrusion, etc.
Upcoming Activities

**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
Additional Information

- **Annual Reports**
  [http://www1.eere.energy.gov/vehiclesandfuels/resources/fcvt_reports.html](http://www1.eere.energy.gov/vehiclesandfuels/resources/fcvt_reports.html)

- **Notice of Intent**

- **Annual Merit Review Presentations**

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Questions?