

U.S. DEPARTMENT OF  
**ENERGY**

Office of  
ENERGY EFFICIENCY &  
RENEWABLE ENERGY

# The Challenges of Lightweighting Vehicles

## (and how the government is here to help)

October 23, 2018

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# First, why lightweight?

## Compliance with Regulations



## Delight Consumers



# Lightweight Vehicles are a Reality



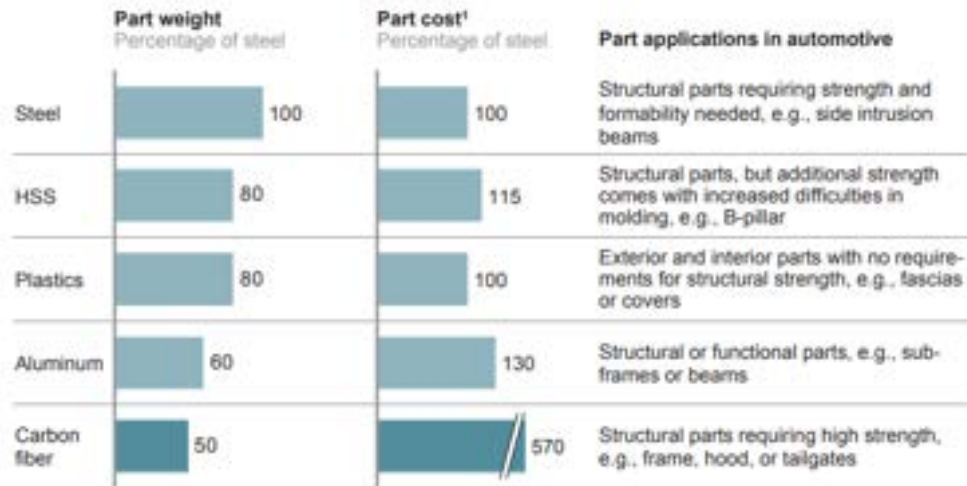
When cost is not a constraint, extreme lightweighting can be achieved.

# Challenge: Cost of Materials

Lightweight materials – such as raw magnesium, the rare earth elements that are used in magnesium alloys, carbon fibers, and even aluminum – are more expensive than traditional steel components on a raw material basis.

Today lightweight materials are costly but offer significant weight advantages

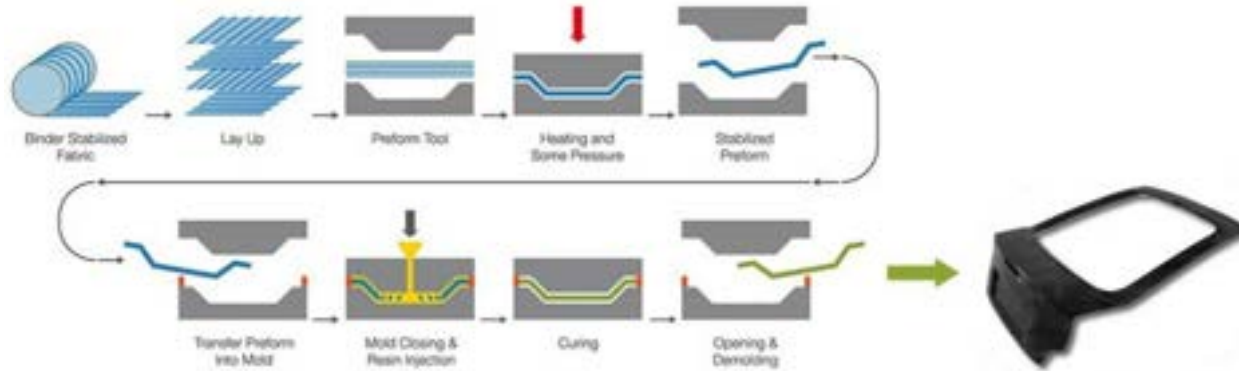
EXAMPLE AUTOMOTIVE FENDER



<sup>1</sup> On a 60,000 pieces-per-year assumption  
SOURCE: McKinsey

# Challenge: Cost of Processing

- Carbon Fiber Composite components have a long cycle time



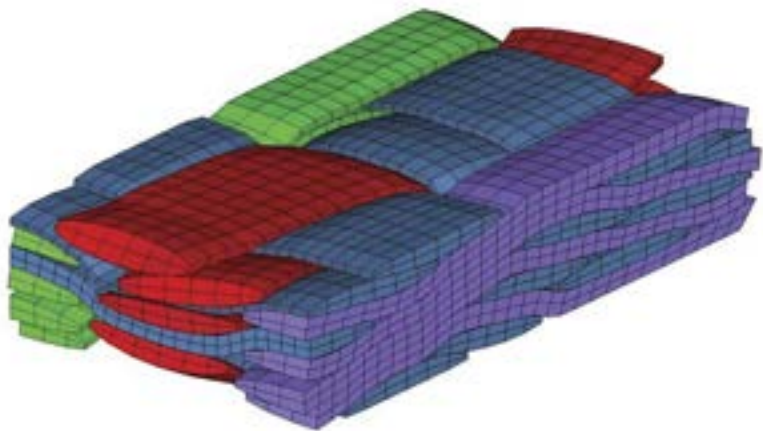
- Magnesium sheet alloys, high strength aluminum, and AHSS have low room temperature ductility



# Challenge: Designing Multi-Material Vehicles



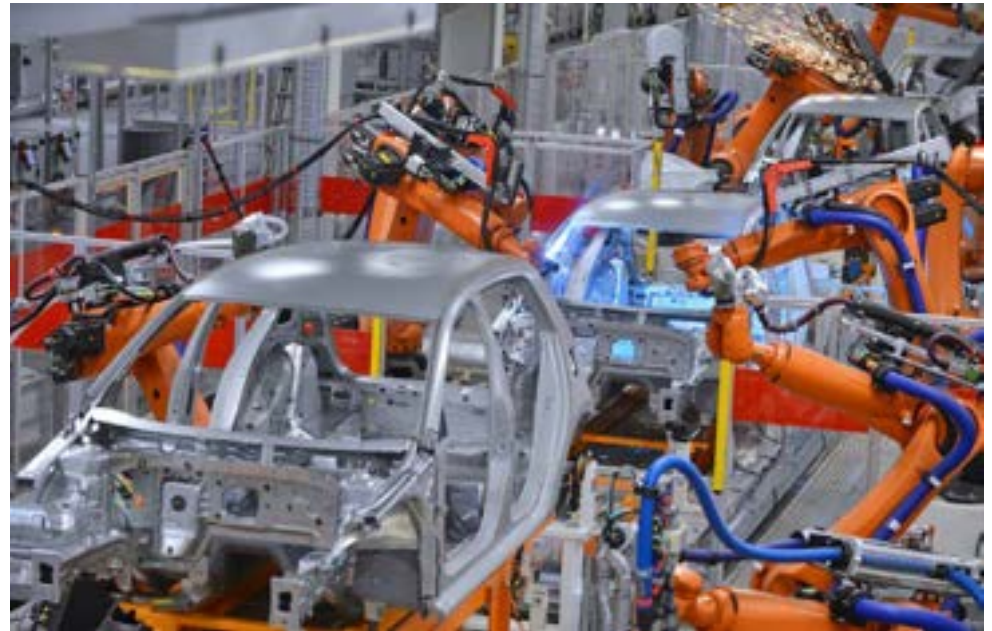
Experience designing components made from single phase steel and predicting and testing their performance is not always applicable to new lightweight materials.



# Challenge: Manufacturing Multi-Material Vehicles



Legacy systems for capturing scrap for recycle, priming and painting, and welding components into assemblies don't apply to multi-material structures.



# Challenge: Joining Lightweight Materials

- Coefficient of Thermal Expansion mismatch
- Formation of brittle intermetallics
- Liquid Metal Embrittlement
- Galvanic Corrosion
- Heat affected zones destroy properties
- Stress concentration
- Extra processing steps for pilot holes and surface cleaning
- Lack of NDE techniques and in-line process controls



# So should we give up on lightweighting?

“I’m with the government, and I’m here to help”



# Materials Technology Program

**Lightweight Materials** enable an improvement in fuel economy through vehicle **mass reduction**.

Research areas include:

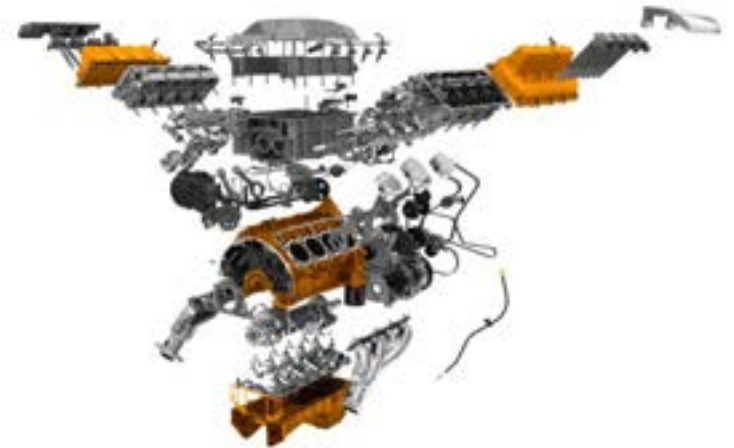
- Sheet Metals (Al, AHSS, Mg)
- Carbon Fiber Composites
- Multi-Material Joining



**Propulsion Materials** enable an improvement in fuel economy through **increased engine efficiency**.

Research areas include:

- Cast Metals (Al, Cast Iron, Stainless Steel)
- High Temperature Alloys (500 – 1100 C)



**Program Goals: 25% glider weight reduction at less than \$5 / lb-saved and 25% improvement in high temperature component strength by 2025.**

# Low Cost Carbon Fiber

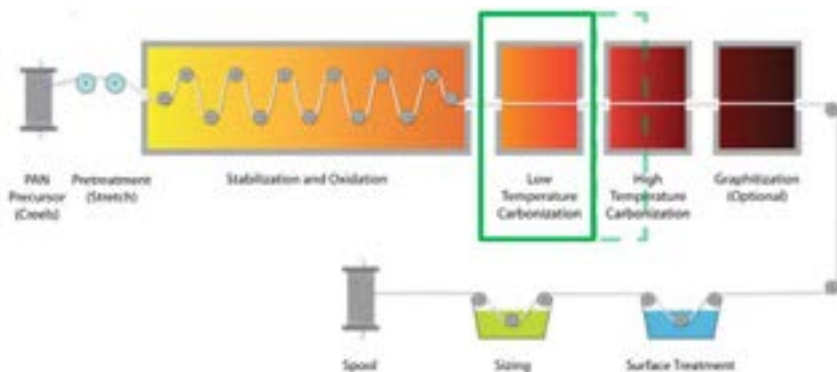
## Close Proximity Electromagnetic Carbonization (CPEC)

Oak Ridge National Laboratory, Oak Ridge, TN

Other Participants: RMX Technologies, 4M Industrial Oxidation. C.A. Litzler Company

### Objective

Develop a faster and more efficient carbonization process to reduce energy consumption in the carbon fiber conversion process and therefore total carbon fiber cost.



October 2015 – September 2018

Total DOE budget: \$4.5M

### Innovations

- Uses electromagnetic coupling to directly heat the fiber, rather than surrounding gas.
- Without the need for insulation, furnace wall temperature remains lower than 125C after 30 min of operation as compared to 400 – 600C

### Impacts

- Reduce unit energy consumption (kWh/kg) by 50% and operational costs by 25%.
- Produce the same or better quality carbon fiber and demonstrate scale up.
- Projected full scale cost savings of CPEC based upon current capabilities is 48-51% of conventional carbonization.

# Low Cost Mg Sheet

## Low-Cost Mg Sheet Component Development and Demonstration

### USAMP, Southfield, MI

Other Participants: AET Integration, Inc., Camanoe Associates, Fuchs, Henkel Technologies, Quaker Chemical Corporation, PPG Industries, Vehma International of America, Xtalic Corporation, Oak Ridge National Lab., Pacific Northwest Nat. Lab, The Ohio State University, University of Florida, University of Illinois, University of Michigan, University of Pennsylvania

### Objective

Demonstrate the feasibility of producing Mg sheet components, with the potential of achieving a mass reduction of 55% compared to conventional stamped steel sheet, with a fully accounted integrated component cost increase of no more than \$2.50/lb. saved.



*(Door from MFERD Project)*

October 2016 – March 2020

Total project budget: \$6.75M

DOE Cost Share: \$6.56M

### Innovations

- Utilizing ICME to design non-rare earth experimental alloys with increased ductility targeting room temperature formability.
- Evaluating and improving pre-treatments, lubricants, coatings, and joining processes to enable greater use of using existing Mg-alloy sheet in automotive manufacturing.

### Impacts

- Addresses the major cost barriers to Mg implementation
- Simultaneously and holistically addresses major Mg challenges in cost, corrosion, modeling, and manufacturing.

# Designing with AHSS

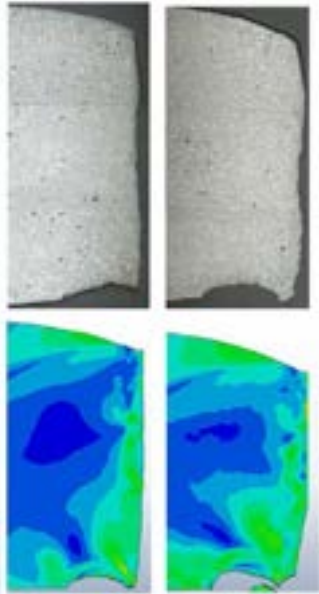
## Enhanced Sheared Edge Stretchability of Advanced / Ultra High Steels

Pacific Northwest National Lab, Richland, WA

Other Participants: US Steel, Oakland University

### Objective

Enhance the sheared edge stretchability of AHSS/UHSS by developing quantitative and predictive models of the microstructure effects on sheared edge fracture



October 2014 – September 2017

Total project budget: \$2.25M

DOE Cost Share: \$1.35M

### Innovations

- Developing microstructurally-informed models of deformation and fracture for advanced high strength steels
  - Phase strength disparity can be a primary factor influencing the shearing induced edge damage (i.e., plastic strain, voids) for AHSS
- Applying models to develop manufacturing process configurations that reduce trimming damage and increase formability in subsequent processes

### Impacts

- Increasing formability allows advanced steels to reduce weight in a broader range of components.
- Coupled computational/experimental approach delivers a validated process simulation tool to the community

# Manufacturing Multi-Material Assemblies

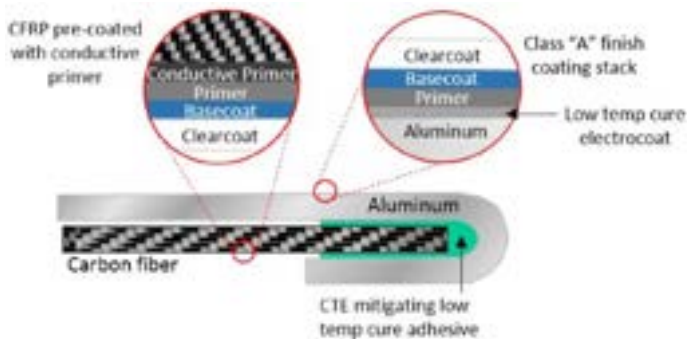
## Corrosion Control in CFRP Composite-Aluminum Closure Panel Hem Joints

PPG, Allison Park, PA

Other Participants: Ford Motor Company, Ohio State University

### Objective

Develop new coatings and adhesives that cure between 150 and 180° C, new joint geometries, and establish and validate corrosion characterization techniques that enable demonstration and implementation of Al door outer / CFRP door inner hem flange joints.



October 2016 – September 2019

Total project budget: \$3M

DOE Cost Share: \$2.2M

### Innovations

- Investigation of the effect of geometry, adhesive cure, and differential thermal expansion of CFRP and aluminum on the stress and robustness of the dissimilar material joint.
- Determination of the appropriate balance of primer conductivity to allow for e-coating of CFRP while preventing galvanic corrosion

### Impact

- Low-cure electrocoat and adhesive technology that enable CFRP processing through an existing paint line and enable more widespread CFRP use beyond closure panels.

# Material Technology Roadmap

Increasing Need for R&D

Increasing Impact on Reducing Vehicle Mass

Material	Critical Challenges				
Multi-Material Systems Enablers	High Volume Joining (Fusion, Mechanical, Adhesives)	Engineered Surfaces (Corrosion, Wear, Friction)	Predictive Modeling	NDE & Life Monitoring	Recycling
Carbon-Fiber Composites	Low-cost High-Volume Manufacturing	Low-Cost Fibers	Predictive Modeling	Joining, NDE, Life Monitoring & Repair	Recycling (OFFAL / Vehicle)
Aluminum	Low-cost Al Manufacturing Processes	Improved Alloys (Body/Powertrain) for Performance & Manufacturing	Joining Mixed Al Products	Recycling Vehicle	
Ultra High-Strength Steels	Improved Alloys for Room Temp Forming	Weldability for Dissimilar Steel Alloys	Predictive Modeling (Formability, Crash)		
Magnesium	Low Cost Feedstock, Low Carbon Footprint Production	Galvanic Corrosion Protection	Improved Alloys for Energy Absorption	Manufacturing (Sheet and Extrusions)	Recycling
Glazings	Low Cost Feedstock for Polymer Glazings	Low Temp Processed Chemically Toughened Glass	Durable, Scratch Resistant, UV Resistant Coatings		
Metal / Ceramic Composites	Feedstock Cost	Compositing Methods	Powder Handling	Compaction	Machining & Forming

# Thank You

Questions for me?

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# EERE'S VEHICLE TECHNOLOGIES OFFICE (VTO)

## Vehicle Technologies Office


Electrification




Materials Technology



Advanced Combustion Systems & Fuels



Energy Efficient Mobility Systems



Technology Integration



Analysis, Comms, & Operations

*VTO develops advanced transportation technologies that:*

- ✓ Improve energy **efficiency**
- ✓ Increase domestic energy **security**
- ✓ Reduce operating **cost** for consumers & business
- ✓ Improve global **competitiveness** of US economy

# Joining of Dissimilar Lightweight Materials

**Goal:** Enable the use of the right lightweight material for the application by identifying, validating, and demonstrating joining techniques appropriate for a wide library of material combinations. At cycle time, at cost, meeting corrosion requirements, strength requirements, and aesthetic requirements.

	Al	CFRP	Mg
AHSS	VFAW, FBJ, RSR, RSW, SPR, FAST	Adhesive	FSW, USW
Al	FAST	FBJ, RSR, Low Temp Adhesives	Arplas, Clinch, BSR, FSW, RSW
CFRP			FSI, F-SPR

- Mechanical Fastening
- Solid State Joining
- Intermediate materials
- Fusion Welding

Currently 15 active projects supported by \$15M in DOE funding

# Powertrain Core Materials Program

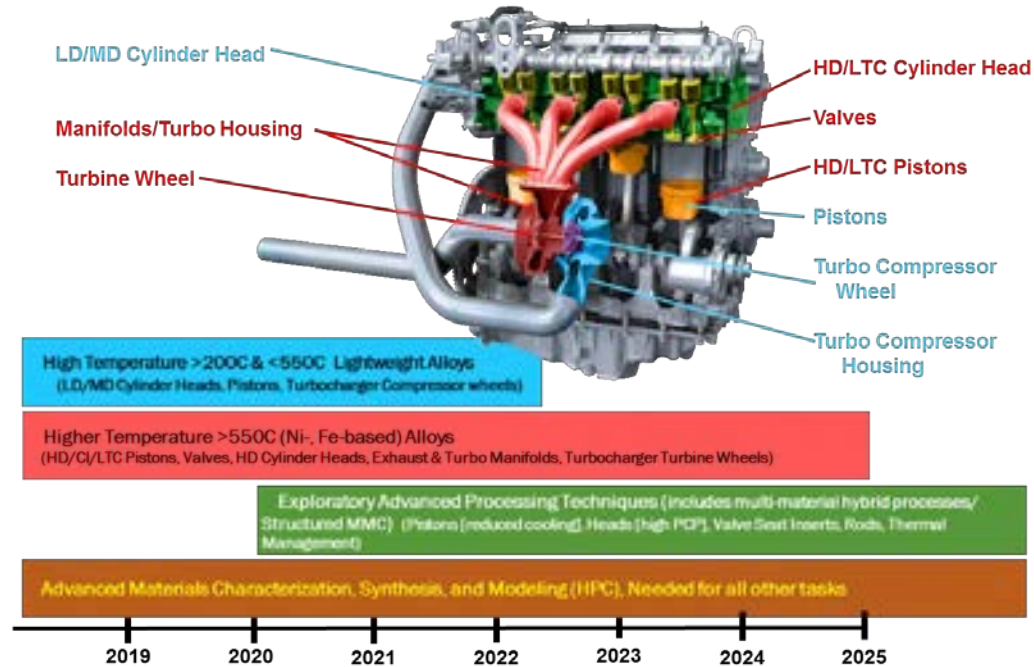
**Goal:** Enable powertrain weight reductions and efficiency improvements over a wide range of vehicle classes

Utilizes ICME approach to address materials needs for critical engine components

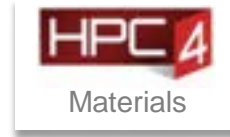
## Impacts:

Enable 15% powertrain weight reduction through a combination of lightweight material utilization and increased engine power density (HP/Kg)

Enable expanded design space for next generation high efficiency engines

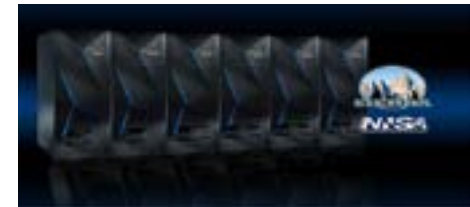


# HPC4EnergyInnovation



- Leverages the vast HPC capabilities at the national labs to partner with industry and address critical challenges
- DOE labs possess 4 of the top 10 HPC systems worldwide and broad expertise in their application and dedicated teams of expert practitioners
- Some larger companies use HPC, but struggle to stay current – few small to medium companies use HPC

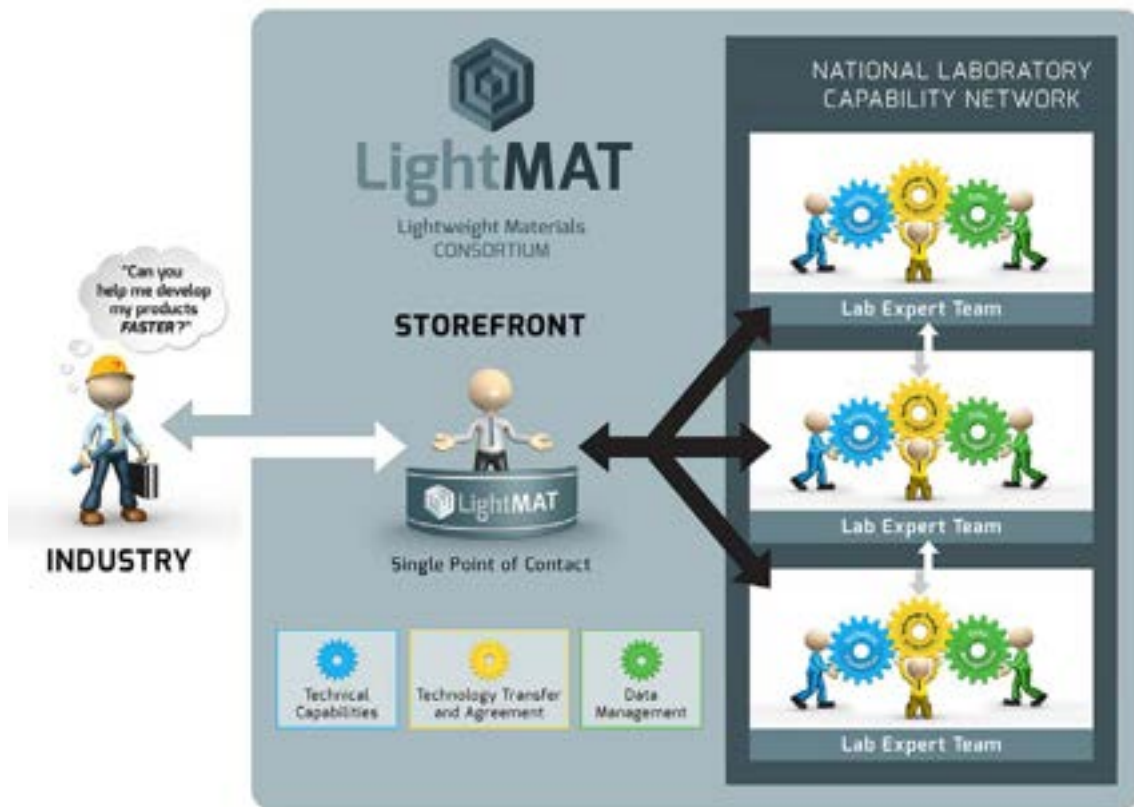
This program introduces the power of HPC to US companies at low risk.



# Energy Materials Network: LightMAT

*Facilitating connections between industry and the National Labs by:*

- Building a network of **unique National Lab resources**
- Providing a **single point of contact** and concierge
- Managing materials **data and tools**
- **Streamlining** the agreements process



<http://LightMAT.org>

# World Class Materials Network

- Capability catalog listing lightweight metals, composites, and joining in place at: <https://lightmat.org>

- Network is continuously expanded to support a broader selection of LW materials capabilities



The screenshot displays the LightMAT website interface. At the top, there are navigation tabs for 'ABOUT', 'CAPABILITIES', 'NEWS', and 'CONTACT'. The main header features the LightMAT logo and the text 'Lightweight Materials Consortium'. Below the header, the page title is 'LightMAT Capabilities'. A brief introduction states: 'The LightMAT resource network contains capabilities from the U.S. Department of Energy National Laboratory system. This search function enables you to view and filter these capabilities within LightMAT.' Below this, a paragraph explains that many capabilities are user facilities managed by the U.S. Department of Energy's Office of Science, and users are encouraged to visit the respective energy.gov sites for more information.

Capability	National Lab	Description
Trislogram Testing and Modeling	Oak Ridge National Laboratory	Oak Ridge National Laboratory is a national leader in trislogram research and development (R&D).
Transport and Thermophysical Properties	Oak Ridge National Laboratory	Oak Ridge National Laboratory provides world-class facilities and a staff of technical experts for determining transport and thermophysical properties, such as thermal conductivity, diffusivity...
Prediction of Corrosion Resistance and Component Life With and Without Protective Coatings	Pacific Northwest National Laboratory	Pacific Northwest National Laboratory offers an integrated experimental/modeling capability that predicts oxide-scale (without coating) or subscale (with coating) growth, characteristics, and spallation.
Atom Probe Tomography (Cameras LEAP 3000)	Sandia National Laboratories	The Camera LEAP 3000 atom probe is a voltage pulsed instrument that allows three-dimensional atomic characterization of metals.
Enhanced Understanding and Expertise of Structural Defects in Metals	Sandia National Laboratories	Sandia National Laboratories' staff have the experience and expertise in investigating the mechanisms governing strain localization and dislocation transmission at interfaces of metals. This includes...
Finite Element Tools and Simulations Connecting Processes to Performance	Sandia National Laboratories	Fundamental consideration of finite deformation mechanics within the context of nonlinear finite element methodologies integrated with constitutive model domain expertise provides a path to material...
Multiscale Process Modeling of Bulk Nanostructures	Los Alamos National Laboratory	Computational models at Los Alamos National Laboratory can help guide the design of processing pathways for making stable bulk nanostructure microstructures with tailored properties. The current model...
Predicting the Formability of Lightweight Alloys	Pacific Northwest National Laboratory	Researchers at Pacific Northwest National Laboratory have demonstrated expertise in predicting formability of lightweight alloys, including magnesium sheet. A heated rolling line height (0.25m)...
Dynamic Transmission Electron Microscope	Lawrence Livermore National Laboratory	The Dynamic Transmission Electron Microscope, or DTEM, is a unique in situ electron microscope at Lawrence Livermore National Laboratory that is designed to observe fast materials processes at the...

On the right side of the page, there are several filter sections: 'Event Filters', 'Currently Matching 88 Results', 'Search Capabilities' (with a search button), 'National Laboratory' (with checkboxes for various labs), 'Characterization' (with checkboxes for different testing methods), and 'Computational Tools' (with checkboxes for simulation types).

# Materials R&D Program - Funding Sources

- **Primary Funding Sources:**
  - Funding Opportunity Announcements (FOAs)
    - Solicitation for specific technology topic areas
  - Annual Operating Plans (AOPs)
    - Standard performance agreement between EERE and the National Laboratories
  - LightMAT Directed Funding Assistance Program
    - Industry users approach LightMAT (or vice versa) and develop project plan with concierge at no cost
  - High Performance Computing (HPC) for Manufacturing
    - Leverage the vast HPC capabilities at the national laboratories to partner with industry and address critical challenges
  - High Performance Computing (HPC) for Materials
    - Designed to enable a step change in the cost, development time, and performance of materials
- **Secondary Funding Sources:**
  - Small Business Innovation Research (SBIR)
  - Small Business Voucher (SBV)
  - Technology Commercialization Fund (TCF)