GM at Exascale
Leveraging National Lab Engagement

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Director Vehicle Systems Research
GM R&D Center

ASCAC Review – September 30, 2022

Outline

Why National Labs?

How Do We Collaborate?

What Have We Done?

USCAR

Future

Benefits of National Lab Collaboration

- Excellent Researchers / Expertise
- Unique Equipment and Exascale Capability
- Combined Access to Data
- Leverage

The ability to combine data, experimental techniques with advanced computational capability is key to these collaborations

Collaboration Models

- **“Direct Projects” (GM stand-alone projects) with the National Labs**
  - Cooperative Research & Development Agreements (CRADAs)
  - Strategic Project Partnership (SPP) Agreements
  - Contracts – GM subcontractor to National Lab

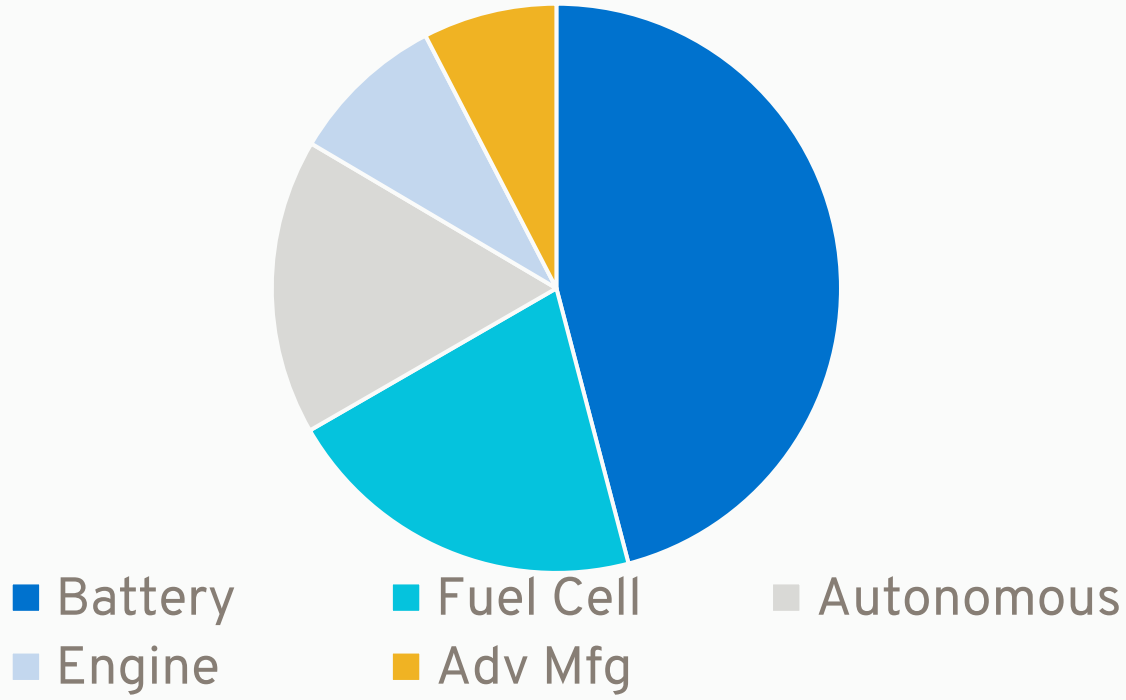
- **National Labs as “project partners” on GM’s DOE Projects**
  - Subaward – GM sets up a subaward agreement (CRADA or SPP) but funds come from DOE either directly by DOE or indirectly through GM’s DOE Funds
  - National Lab Consortium Agreements (i.e. Fuel Cell Performance and Durability “FCPAD” National Lab Consortium) which are usually mandated by DOE in specific DOE funding opportunities.

Collaboration Models Cont.

- **General Facilities Usage at the National Labs**
  - Allows access to National Lab facilities (i.e. beam time, high performance computers, etc)

- **General Discussions**
  - Non-disclosure Agreements (NDAs) for confidential discussions outside any other agreement – rare
  - General (non-proprietary) discussions

Direct Funding by Technology Area

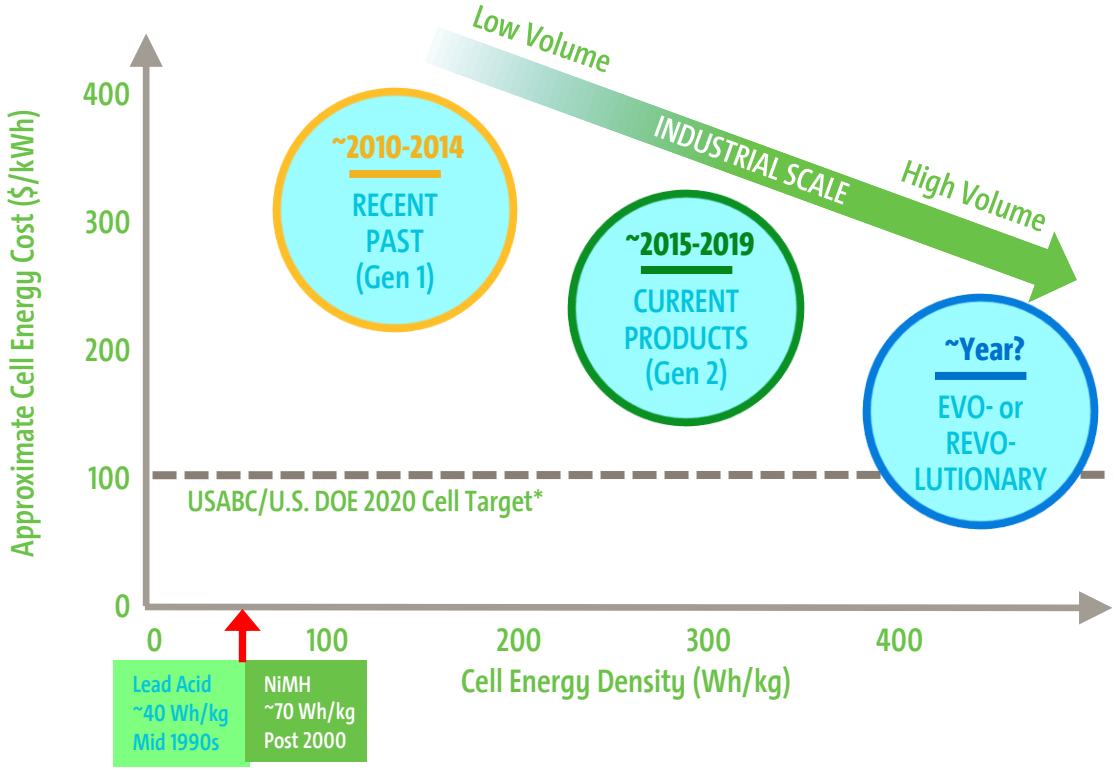


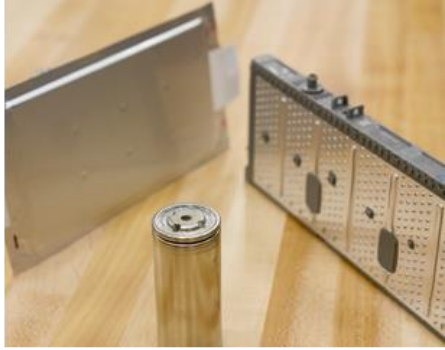
RESEARCH & DEVELOPMENT

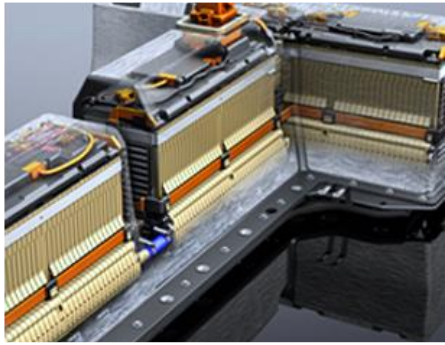

zero crashes
zero emissions
zero congestion
general motors

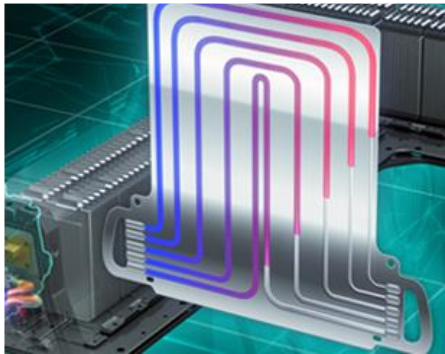
Electrification

Enabling High-volume EVs







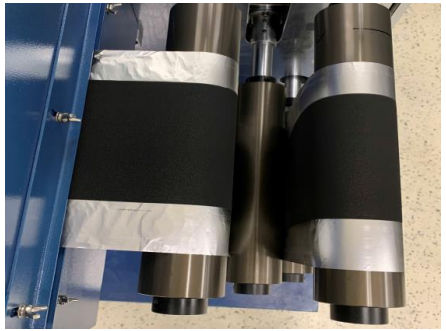


*Cell Target Estimate Based on 2020 DOE EV Pack Target: 125 $/kWh, 250 Wh/kg

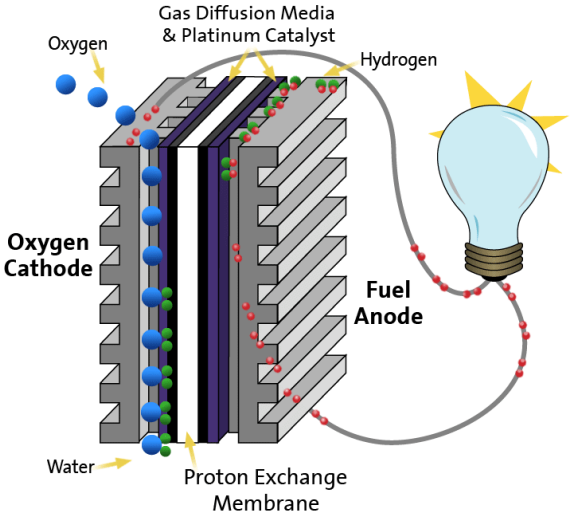
Battery 500

- Goal – Accelerate the development of high-energy, rechargeable Li metal batteries for future vehicle electrification.

- Participants – 4 National labs led by PNNL
- Multiple Universities – Binghamton, Penn State, Stanford, Texas A&M, UCSD, Maryland, Pitt, Texas, Washington
- Key Results
  - Developed proof-of-concept of new dual-phase electrolyte and validate electrochemical performance of polymer anolyte in symmetrical cell format
  - Developed oxide/C coated separator with enhanced sulfur utilization while mitigating polysulfide shuttle. The coating process can be easily scaled-up for pouch cell fabrication.
  - Scaled up coating of S electrode and distributed to other teams for baseline verification
  - Coordinated Li-S team meetings and aligned testing protocols



Fuel Cell Electric Vehicle (FCEV)



NREL
NATIONAL RENEWABLE ENERGY LABORATORY

ENERGY SYSTEMS INTEGRATION

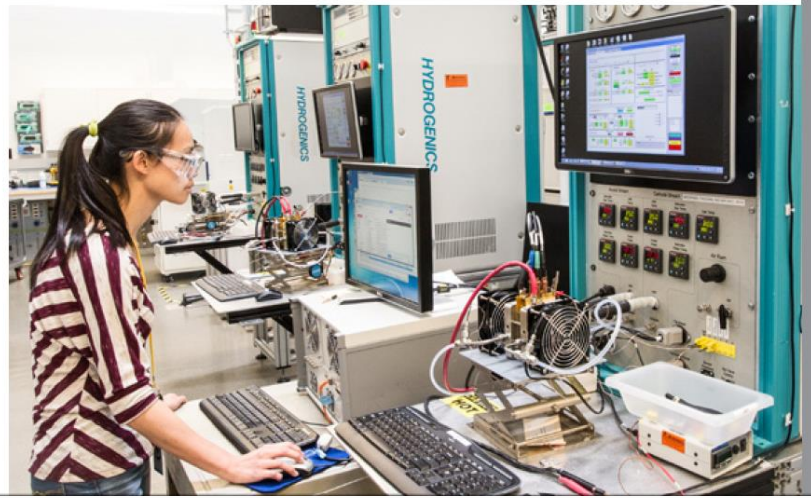
ESI optimizes the design and performance of electrical, thermal, fuel, and water pathways at all scales.

PARTNERSH

NREL + GENERAL MOTORS

NREL and General Motors Corporation (GM) are collaborating on multiple projects to improve the cost, performance, and durability of polymer electrolyte membrane (PEM) fuel cells, which convert hydrogen and oxygen into electricity to power vehicles without emitting pollutants.

Hydrogen and oxygen gases are fed into PEM fuel cells via separate gas-diffusion layers and react on platinum-based catalysts, embedded in electrodes, to produce hydrogen



gm RESEARCH & DEVELOPMENT

H2FillS: Hydrogen Filling Simulation

The Hydrogen Filling Simulation (H2FillS) software is a thermodynamic model designed to track and report on the transient change in hydrogen temperature, pressure, and mass flow when filling a fuel cell electric vehicle (FCEV).

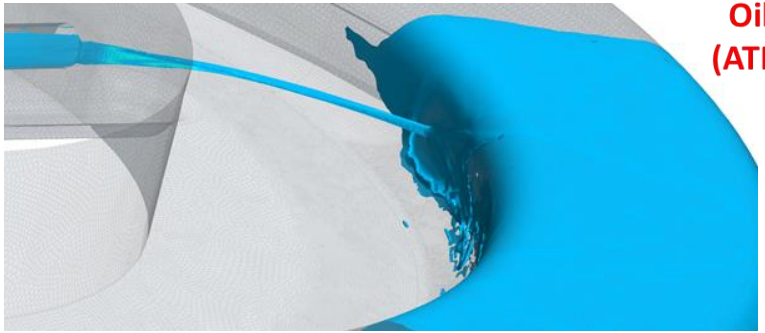
H2FillS simulates gas flow from the hydrogen station to the FCEV storage system. Using empirical fueling data sets, the model has been validated over a range of fueling conditions to match common light-duty FCEV fill profiles. Overall, it provides significant benefits to the light-duty fueling market and fill knowledge gaps of the interaction between a hydrogen station and an FCEV.

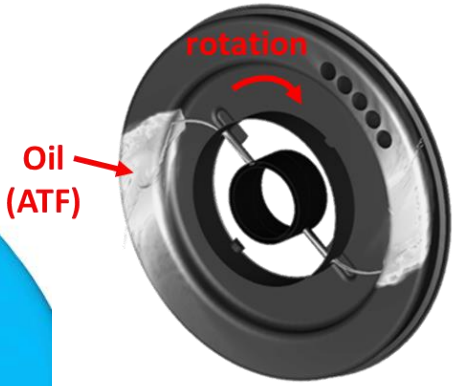
Text version

RESEARCH & DEVELOPMENT

Electric Motor Thermal Management Analysis

- Goal – Leverage computational capability at ANL to understand proper thermal management of an electric motor for vehicle applications.
- Drive improved efficiency for extended operating range
- National Laboratory Discretionary Allocation of 5 million core-hours on Theta at Argonne National Laboratory





Autonomy

ORNL licenses revolutionary AI system to General Motors for automotive use

menndl
Multinode Evolutionary Neural Networks for Deep Learning

MENNDL (Multi-node Evolutionary Neural Networks for Deep Learning) is an AI software optimization tool for convolutional neural networks (CNN), a branch of algorithms used by computers to recognize patterns in datasets of images, text, sounds etc. MENNDL was licensed to GM R&D and used for automatically tuning CNN hyper-parameters to expedite the training process and selecting the best performing CNN architectures / models used in the autonomous driving research in GM.

gm RESEARCH & DEVELOPMENT

Joint Publications

Real-World Driving Features for Identifying Intelligent Driver Model Parameters

Preprint

Bharatkumar Hegde,[1] Michael O'Keefe,[2] Steven Muldoon,[1]
Jeffery Gonder,[2] and Chen-Fang Chang[1]

1 General Motors LLC
2 National Renewable Energy Laboratory

Presented at the SAE WCX World Congress Experience Digital Summit
April 13-15, 2021

This paper explores identification of the parameters for the PDM to best represent human drivers using naturalistic driving data from the TSDC. Short driving features, categorized by driving maneuvers, are used in this study to facilitate exploration of driver model parameter dependence on maneuvers and external road conditions.

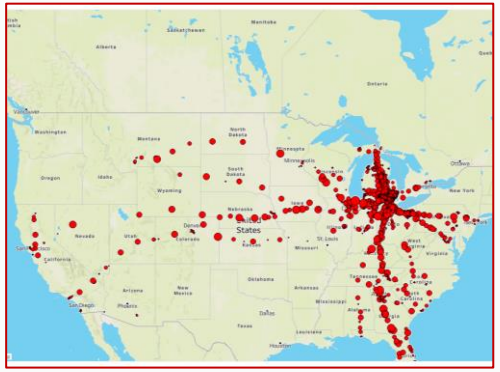
Connected Vehicle

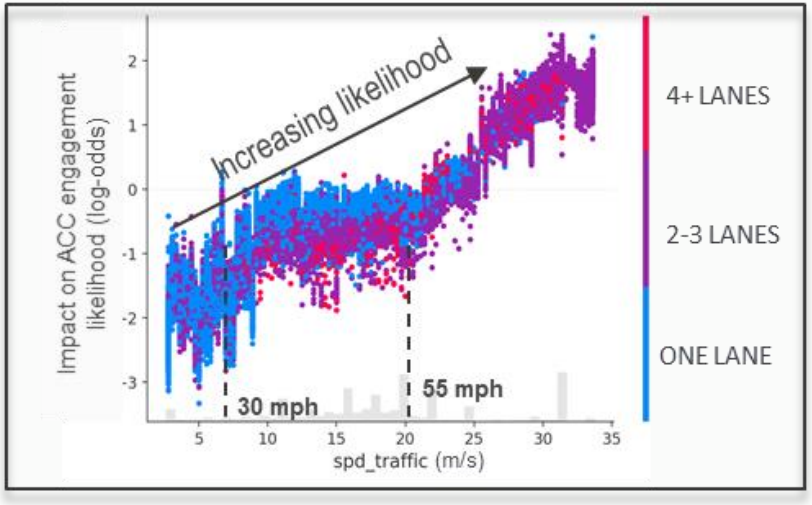
Adaptive Cruise Control (ACC)

U.S. DEPARTMENT OF ENERGY
SMARTMOBILITY
Systems and Modeling for Accelerated Research in Transportation

Idaho National Laboratory
Renewable Energy Laboratory
Argonne National Laboratory
Oak Ridge National Laboratory
Lawrence Berkeley National Laboratory
University of Illinois at Chicago

- **Real-world Driving Data from Vehicles w/ Automation Provided Weekly by GM**
- **Automated Big Data Pipeline**
  - Understand usage of ACC
  - Impact on Energy Usage



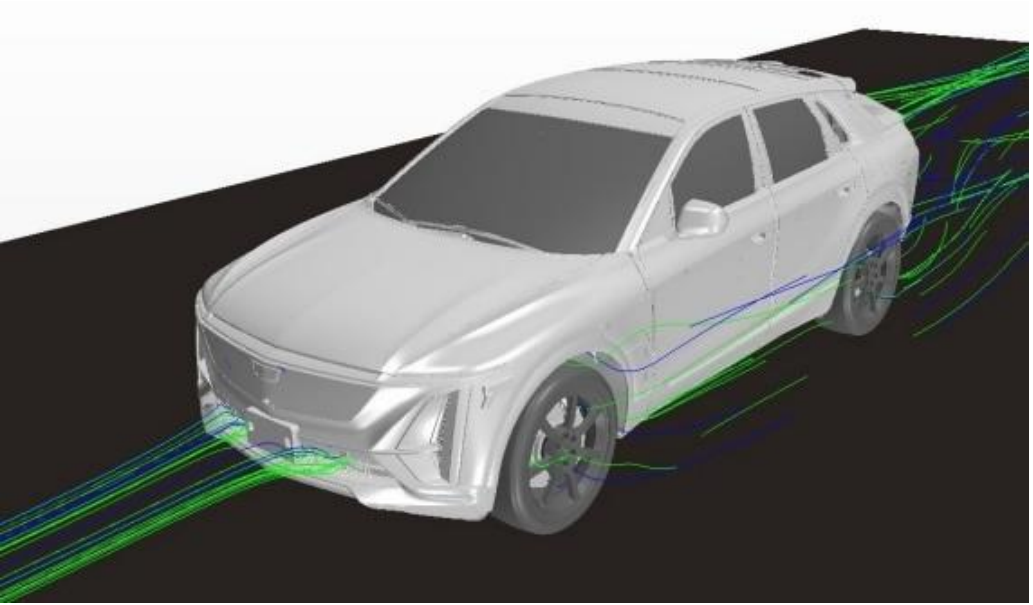


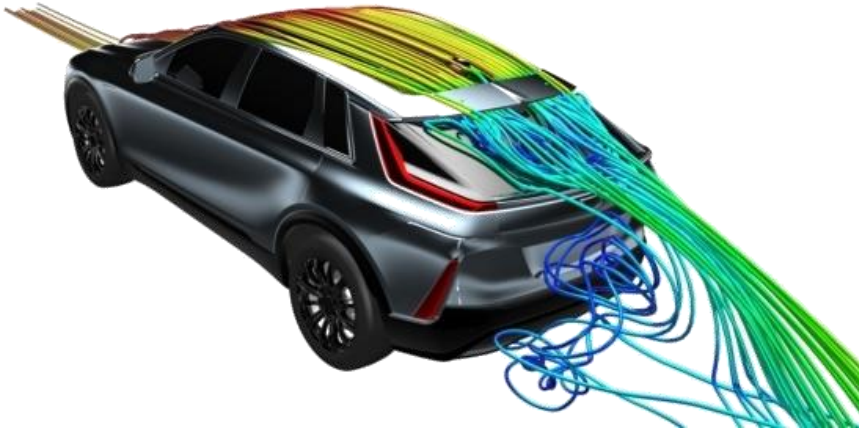
Used large quantities of data to predict with high accuracy (84%) when drivers would engage cruise control, based on solely environmental factors (e.g. location and road type).

RESEARCH & DEVELOPMENT

Virtualization

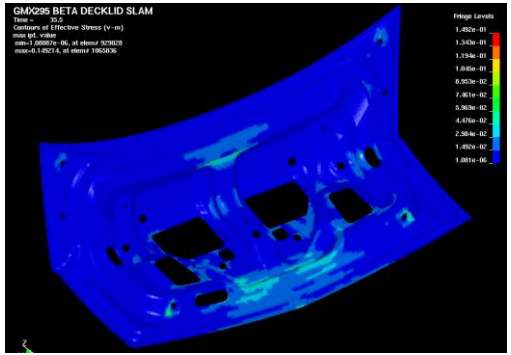
We are targeting 100% virtual validation by 2025.

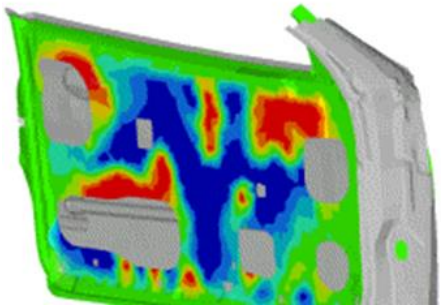




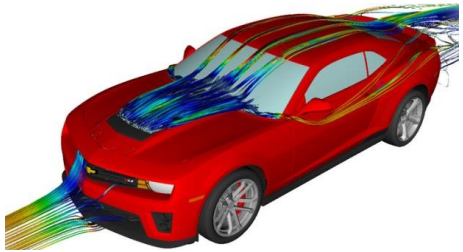
Material Models

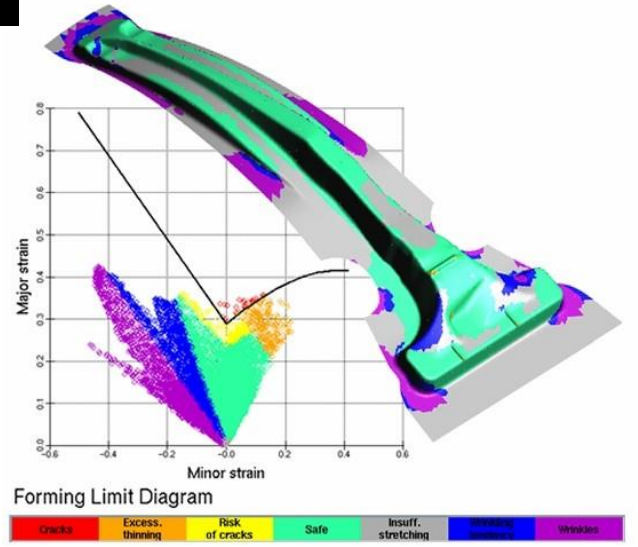
- Morphing / Shape Optimization
- Formability
- Static Performance
- Dynamic Performance
- Crash
- ICME

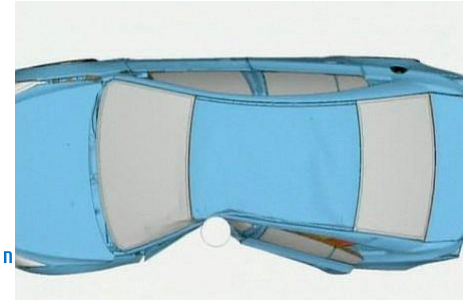




http://insider.altairhyperworks.com/articles/closure-simulation

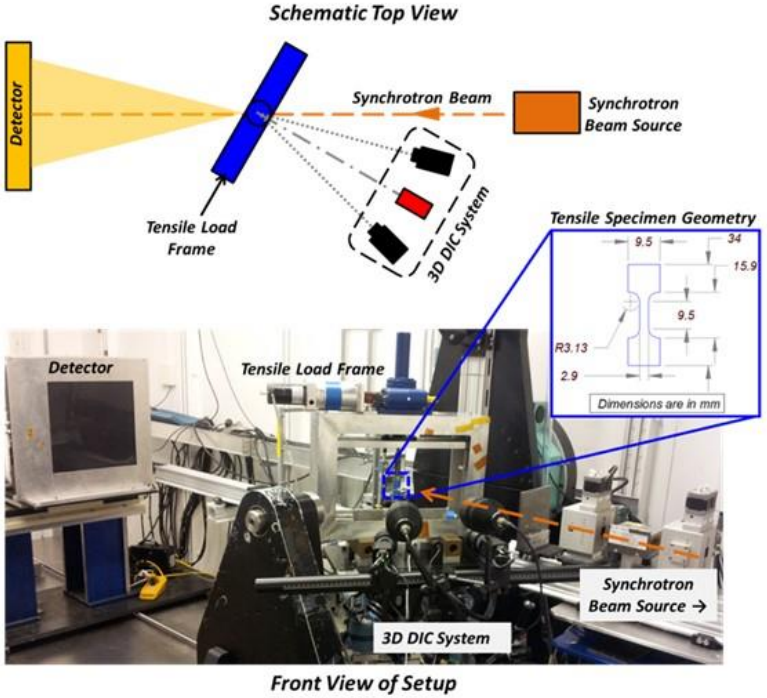


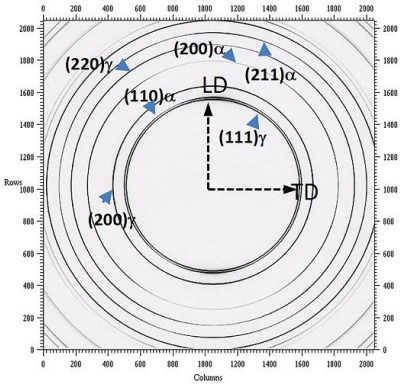




Gen 3 Steel Characterization

- Developed New Test at Advanced Photon Source, Argonne National Lab.
- Couples Strain Measurement from Digital Image Correlation with Synchrotron X-ray Diffraction
- Measurement of Martensitic Transformation during a Quasi-static tension test of Gen 3 steels.



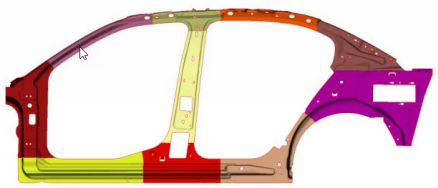


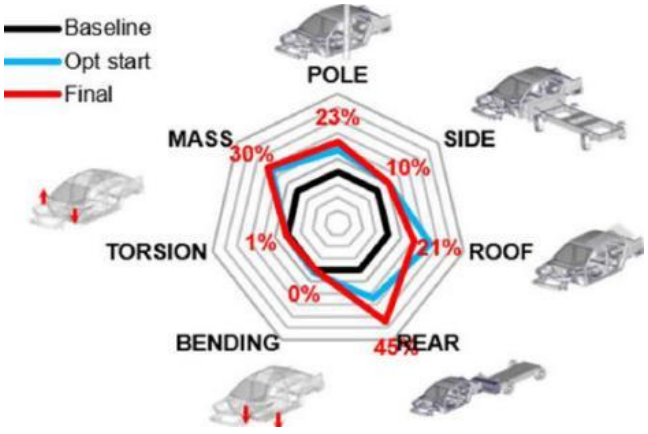
Advanced Photon Source

Argonne NATIONAL LABORATORY

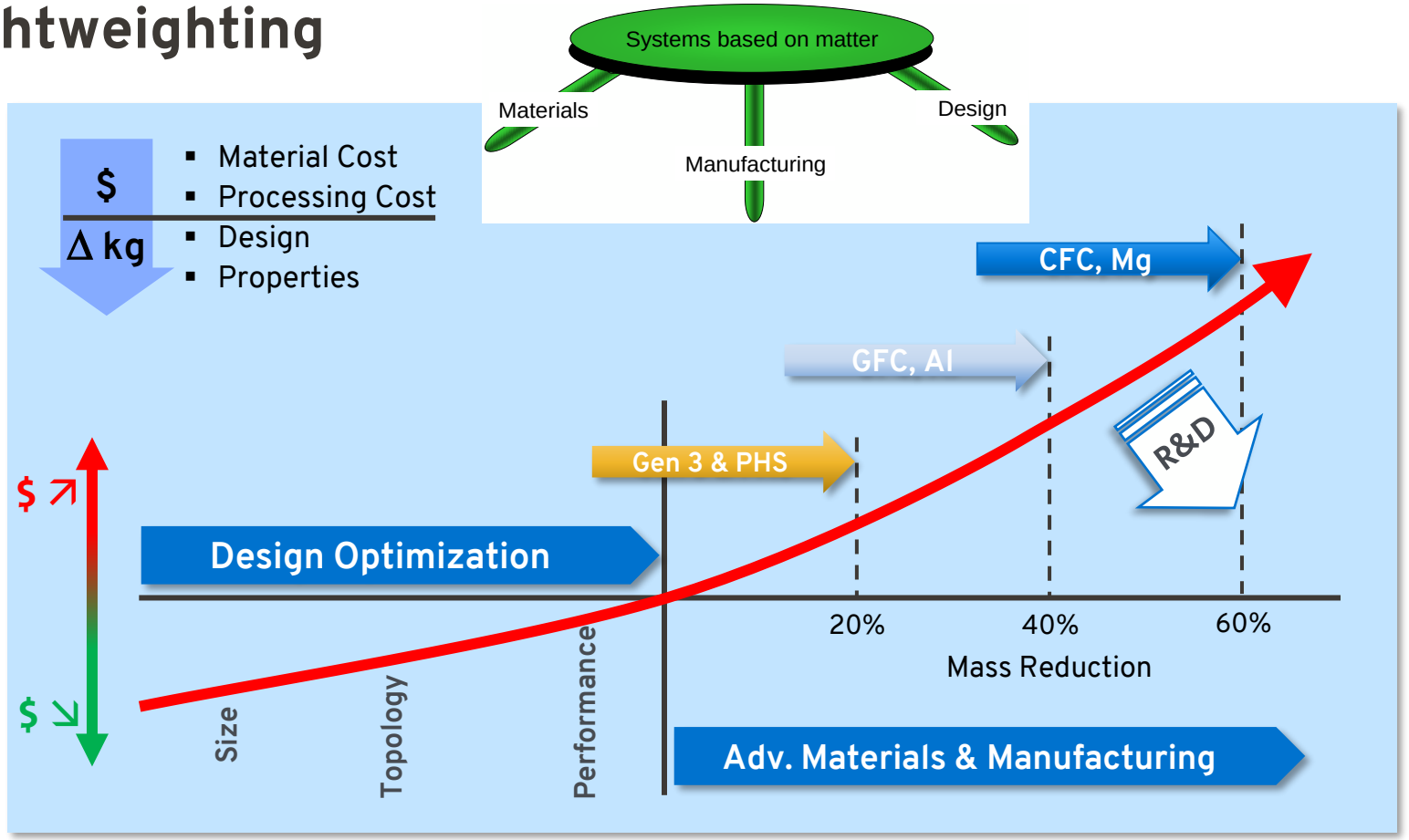
Gen 3 Steel Application

- Goal: Reduce mass by ~30% relative to the baseline sedan by optimizing gauge, geometry, and grade.
- Finite Element Optimization on Massively Parallel NREL Peregrine Cluster



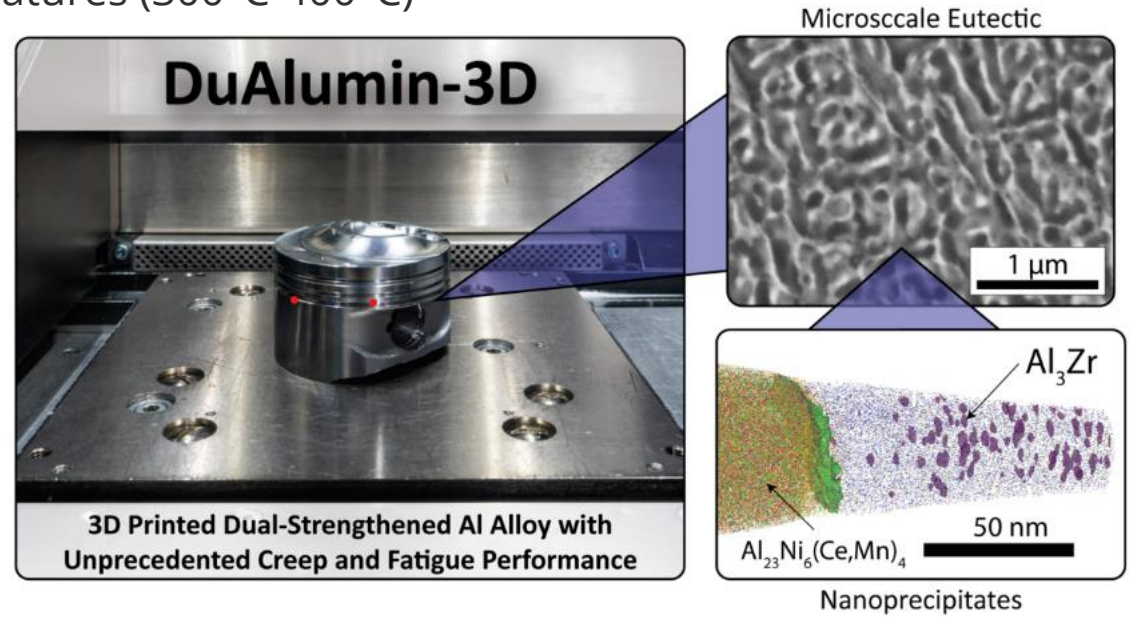


Lightweighting



DuAlumin 3D

A new aluminum alloy designed to take advantage of the rapid solidification characteristics of additive manufacturing to produce a dual-strengthened microstructure, resulting in a superior combination of tensile, creep, fatigue, and corrosion properties, particularly at extreme temperatures (300°C-400°C)



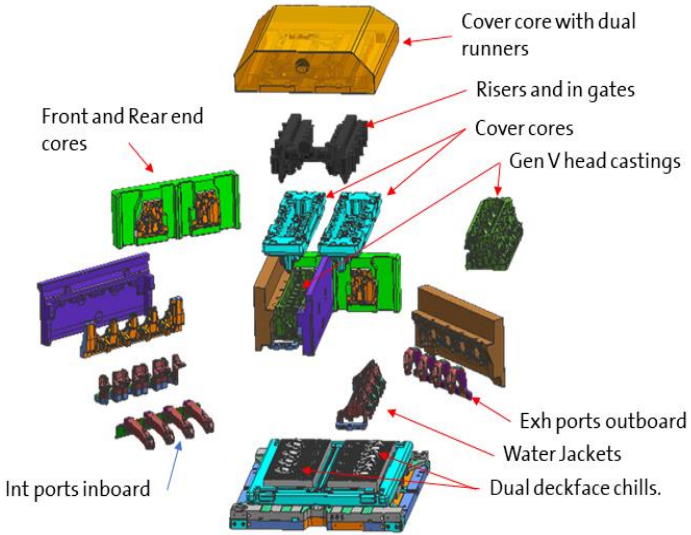
LightMAT

The Lightweight Materials Consortium, or LightMAT, is part of the Energy Materials Network (EMN), a network of 11 national laboratories with technical capabilities highly relevant to the development and commercial use of lightweight materials and manufacturing processes.

LightMAT leadership provides straightforward access to laboratory resources and expertise via a single point of contact, matching industry research teams with expertise and equipment found only at national laboratories.

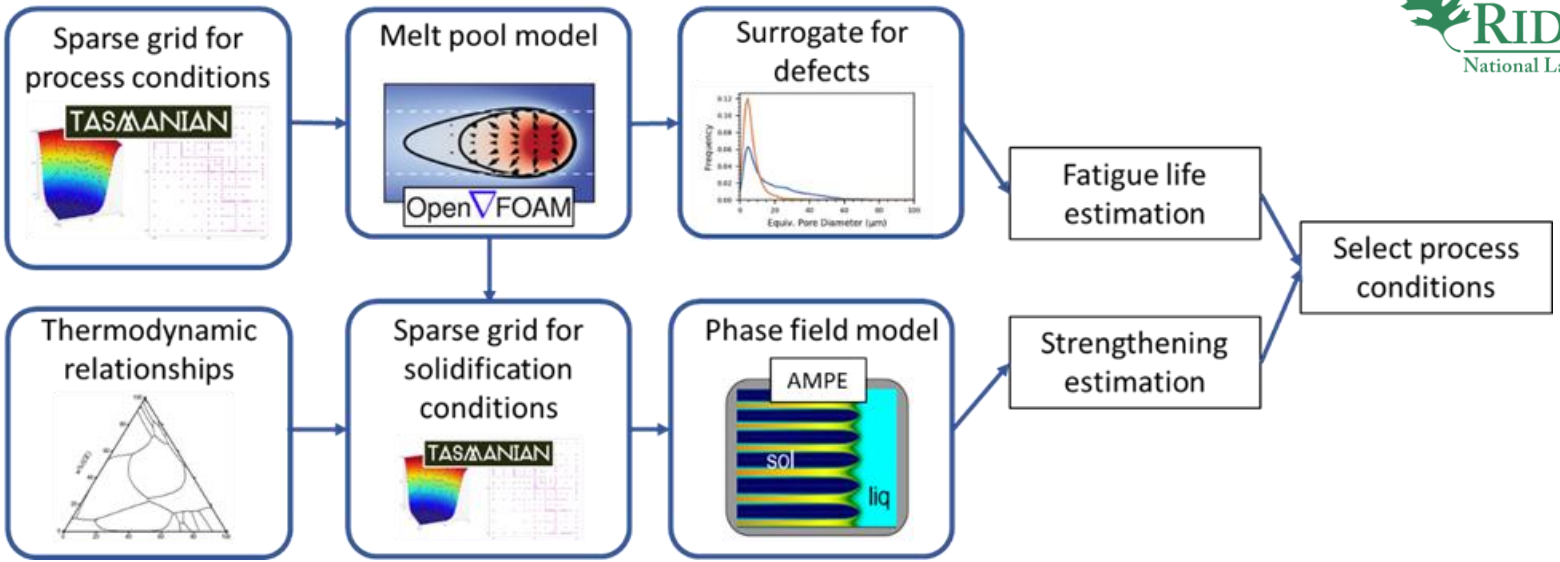
Lightmat – High Precision Aluminum Castings

Goal: To develop a novel casting process – Pressure-Assistant Precision Sand Casting (PAPSC) for producing high quality cast aluminum components with minimum manufacturing and energy cost.



ICME – Integrated Computational Materials Engineering

Goal: To utilize state-of-the-art ICME (Integrated Computational Materials Engineering) tools (e.g. ECP ExaAM) to develop a high-performance component through material design, microstructure control, and process optimization.



USCAR

- USCAR (United States Council for Automotive Research LLC) is a collaborative automotive technology company located in Southfield, Michigan, USA. Its Member companies are Ford Motor Company, General Motors and FCA(LLC US)Stellantis.

- Founded in 1992, USCAR facilitates the legal collaboration of its Members to create teams and conduct projects that address pre-competitive challenges and opportunities in major automotive technology areas.

- These areas are advanced propulsion, electrical & electronics, energy storage, hydrogen fuel cells, manufacturing, materials and safety.

USCAR Areas of Interest

USCAR
UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

Argonne NATIONAL LABORATORY	OAK RIDGE National Laboratory	NREL	Pacific Northwest NATIONAL LABORATORY	Sandia National Laboratories	Los Alamos NATIONAL LABORATORY	Lawrence Livermore National Laboratory	BERKELEY LAB	NVFEL Vehicle Technology Showcase
Batteries Adv. compute ICE modeling	Additive Manuf. Materials Charact. Infra-structure Vehicles Highway	EERE lab Charging Cyber. Fuels	Charging Materials Hydrogen safety Codes and standards Adv. compute Bio-mass	Modeling Battery abuse Nano-materials ICE Bio-fuels	Fuel cells Hydrogen storage Emission sensors (ICE)	Hydrogen storage Adv. compute Heavy vehicle efficiency	Hydrogen storage Batteries Fuel cells	Emission reduction

gm RESEARCH & DEVELOPMENT

USCAR Example Projects

USCAR
UNITED STATES COUNCIL FOR AUTOMOTIVE RESEARCH

Argonne NATIONAL LABORATORY	OAK RIDGE National Laboratory	NREL	Pacific Northwest NATIONAL LABORATORY	Sandia National Laboratories	Los Alamos NATIONAL LABORATORY	Lawrence Livermore National Laboratory	BERKELEY LAB	NVFEL Vehicle Technology Showcase
DC meter bench-marking USABC Inductive coupled plasma	Light-weight metal stamping (CRADA)	Multi-physics modeling of Li-ion batteries	Cyber impact on high power charging	Drop tower testing of batteries/ components	Gas diffusion layer for materials and treatments	Additive Manuf. Comp. Modeling Battery	High energy cathodes Emerging cathode materials and metal oxides	AIGER (CRADA)

USCAR SYMBIOTIC RELATIONSHIP WITH THE NATIONAL LABS


brightdrop


PUREWATERCRAFT


LOCKHEED MARTIN

Summary

- National Lab collaboration is essential to drive technology development for future transportation.
- Numerous models exist to facilitate that collaboration.
- The combination of critical data/experiments with computational capability is key to these collaborations.

Acknowledgements

- Ed Gundlach
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- Jeremy Wise
- Warwick Stirling (USCAR)

Images courtesy NREL