Office of Vehicles Technologies Materials Program

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Overview of Propulsion Materials

Project ID PM000

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Propulsion Materials
Vehicle Technologies Program

Materials Research Role

Propulsion Materials Activities

Materials for Combustion Systems / High Efficiency Engines
Turbocharger, Valve Train, Fuel Injection, Structural Components Head/Block, Sensors, Materials/Fuel Compatibility

Materials for Exhaust and Energy Recovery
DPFs, Catalysts, Thermoelectric Materials, Materials for High Temperature Structures

Materials for Electric and Hybrid Drive Systems
High Temperature Power Electronics Materials, Solder Joints, Materials/Coolant Compatibility, and Materials for Electric Drive Motors

Materials By Design
Materials Synthesis, Characterization, Multi-Scale Computer models, Testing Standards, and Coatings

VTP Team Collaborations

Advanced Combustion Engine

LD 45%e @ $30/kW
HD 55%e
Biofuels

Hybrid Electric Systems

55kW @ $12/kW
300Whr @ $20/Whr

Fuels Technologies

Petroleum Displacement

Propulsion Materials Research Relevant to VT Goals

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- Improve efficiency of advanced vehicles through innovative material solutions
- Critical enabler supporting Advanced Combustion, Thermoelectric, and Hybrid-Drive Systems
  - Material compatibility for Alternative Fuels
  - Materials for high efficiency CI/SI Engines
  - Thermoelectric materials
  - Materials for reliable high performance hybrid and EV drive systems
- Vehicle weight reductions and freight efficiency improvements through increased engine power density (hp/liter and hp/kg)

Successful Projects Rely on Smooth Transitions

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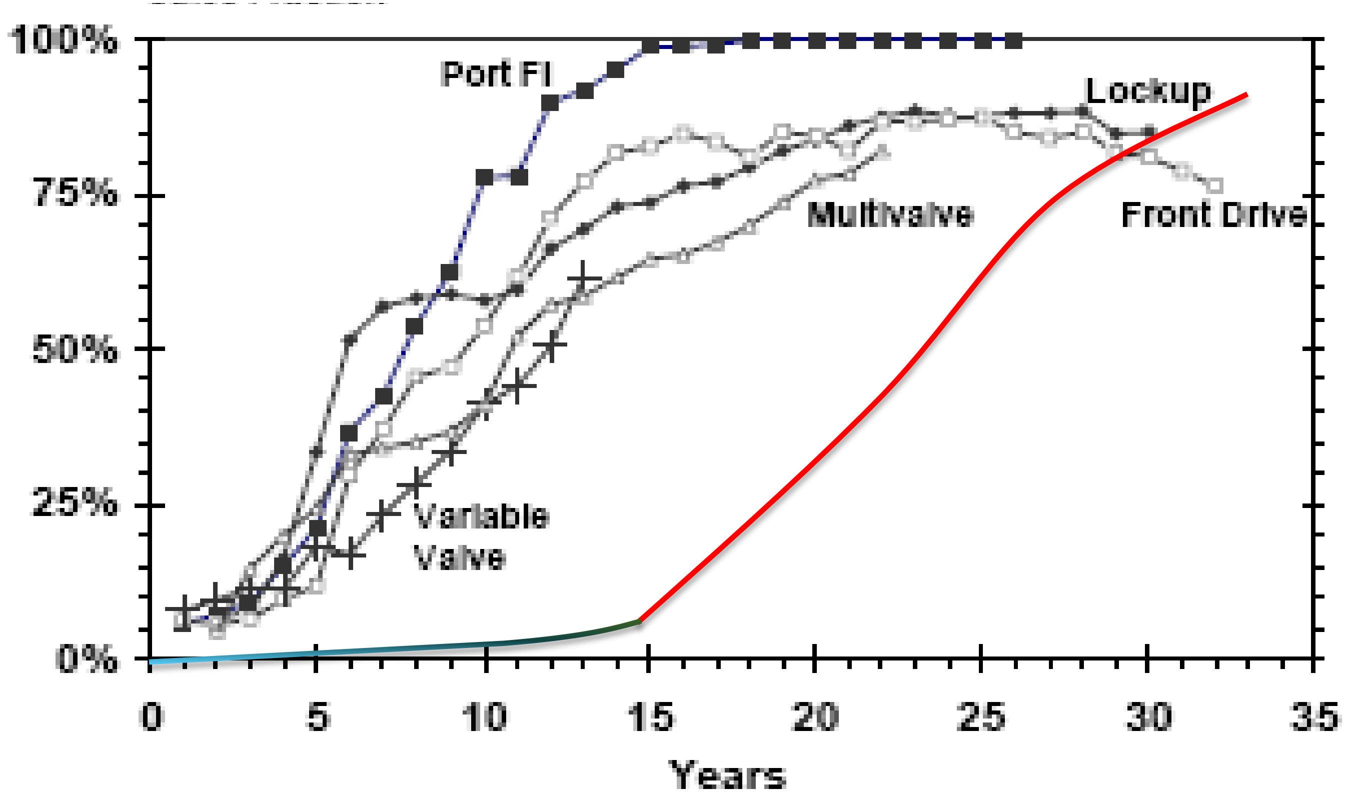
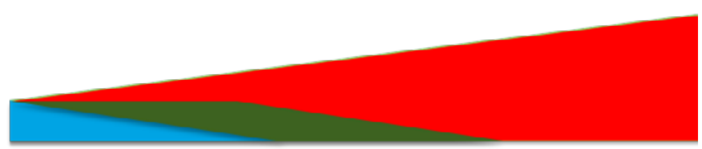
Vehicle Technology Penetration

Years After Initial Significant Use

Technology Implementation Timeline



Technology Research Effort



Basic Science **Applied Science** **Industry**

March 2011 Materials Workshop

- Objectives: identify technology gaps to be overcome such that advanced materials systems are available for heavy & light duty vehicles
  - Lightweighting and Engine Efficiency Sub-Topic Areas:
    - Identify maximum potential reduction by vehicle class and time
    - Identify material requirements necessary to reach potential
    - Identify technical hurdles and gaps on the critical path
    - Identify time based cost targets

- 135 participants representing light duty vehicles (LDV) and heavy duty vehicles (HDV)
  - OEMs **(36)**
  - Material & Tier 1 suppliers **(43)**
  - U.S. Government experts **(8)**
  - Canadian government **(4)**
  - Trade Organizations **(5)**

Workshop Participating Organizations

TARDEC
DAIMLER
Dow
A/SP Auto Steel Partnership
STATE
ArcelorMittal
HONDA
Canada
Natural Resources Canada
USS
Honeywell
Ford
DEARBORN
GM
TOYOTA
PACCAR
PLASAN CARBON COMPOSITES
Globe Composite Solutions, Ltd.
CHRYSLER
PlastiComp
NUCOR
eta
MAGNA COSMA INTERNATIONAL
NADCA NORTH AMERICAN DIE CASTING ASSOCIATION
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ADITYA BIRLA NOVELIS
tsi
MICHELMAN YOUR COMPETITIVE EDGE.
ArvinMeritor
BOEING
MOXST Metal Oxygen Separation Technologies Inc
Materials Innovation TECHNOLOGIES
AOC World Leader in Resin Technology
OAK RIDGE National Laboratory
ThyssenKrupp
faurecia
Cummins
BASF The Chemical Company
KAISER ALUMINUM
American Iron and Steel Institute
DETROIT DIESEL
Argonne NATIONAL LABORATORY
nabmag technologies LLC
TORAY
ZOLTEK
Pacific Northwest NATIONAL LABORATORY
VOLVO
TohoTenax
EATON Powering Business Worldwide
American Chemistry Council
tpi
ARL
ALLIED COMPOSITE TECHNOLOGIES LLC
NAVISTAR
Magnesium Elektron SERVICE & INNOVATION IN MAGNESIUM

Workshop Considerations

- Vehicle subsystems include:

- Structural systems:
  - Body structure
  - Chassis structures
  - Suspension and drivetrain systems
  - Engine and transmissions
  - Turbo-machinery
  - Exhaust and cooling systems

- Semi-structural and non-structural systems:
  - Appearance panels
  - Enclosures
  - Bumpers

- Materials considered:
  - Advanced high strength steels
  - Cast iron
  - Aluminum
  - Magnesium
  - Carbon fiber composites
  - Glass fiber composites
  - Unreinforced plastics
  - Advanced materials such as:
    - Titanium
    - MMCs
    - Ni-based alloys

Published Workshop Reports

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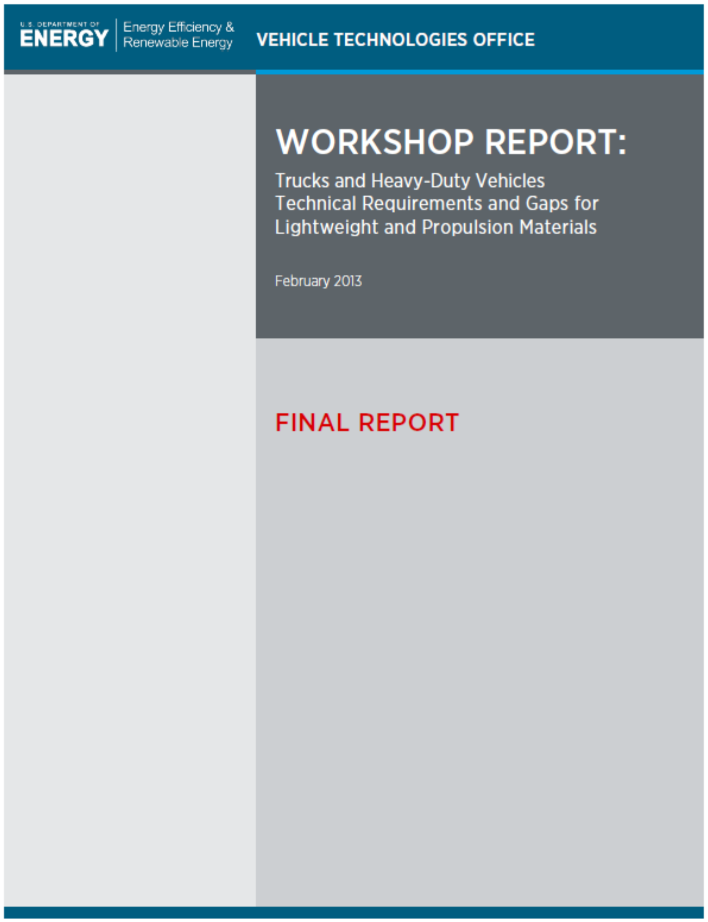
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VEHICLE TECHNOLOGIES OFFICE

WORKSHOP REPORT:

Trucks and Heavy-Duty Vehicles Technical Requirements and Gaps for Lightweight and Propulsion Materials

February 2013

FINAL REPORT


U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

VEHICLES TECHNOLOGIES OFFICE

WORKSHOP REPORT:

Light-Duty Vehicles Technical Requirements and Gaps for Lightweight and Propulsion Materials

February 2013

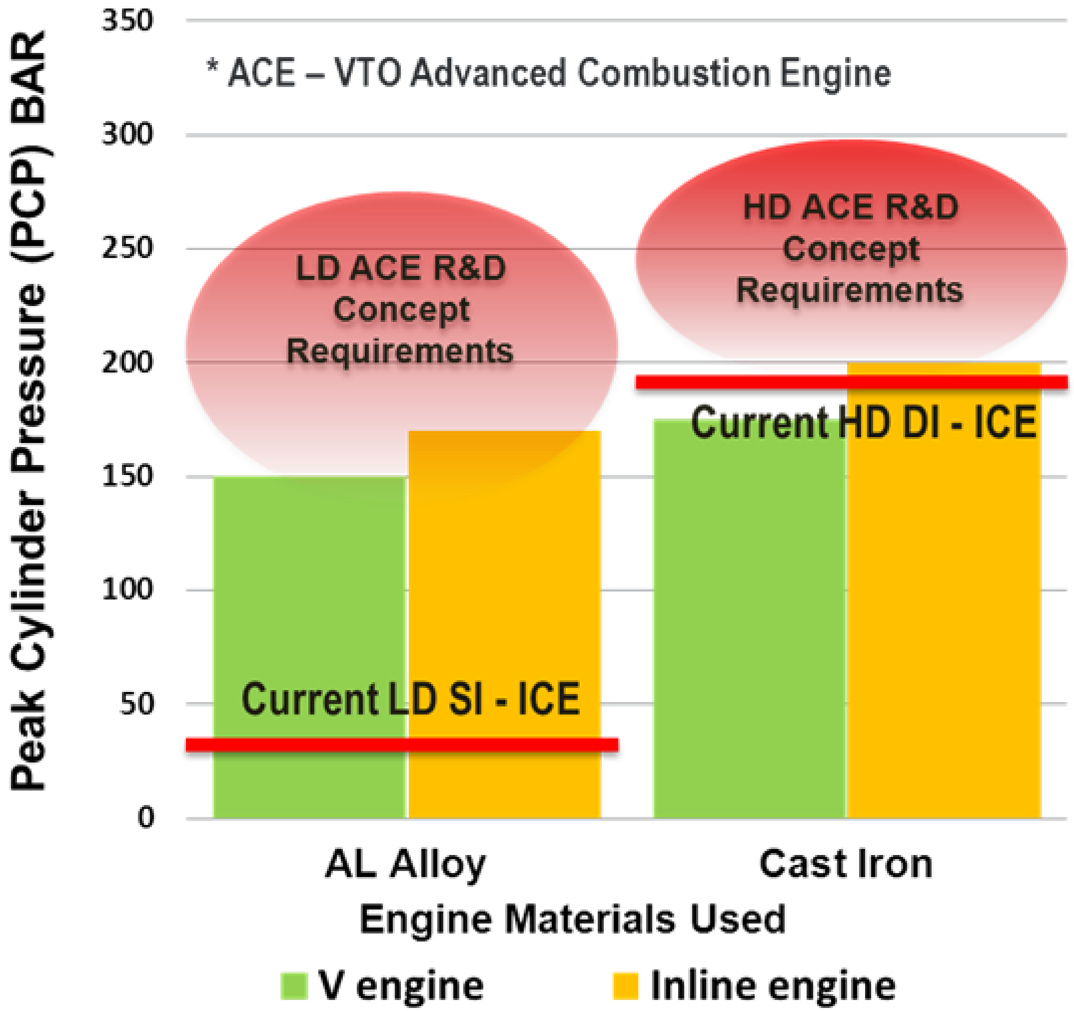
FINAL REPORT

Workshop Propulsion Materials R&D Gaps and Targets

	2010	2025	2050
Powertrain Weight Reduction (ICE/HEV)	Baseline - LDV Baseline – HDV	25% lighter - LDV 15% lighter - HDV	40% lighter- LDV 20% lighter- HDV
Power density **Fossil Fuel LDV ICE** **Fossil Fuel HDV ICE**	LDV Baseline Midsize Car -2.7L 196 HP (73.4 HP/L) 15L 475HP (32 HP/L) - HDV baseline	10% augmented –LDV 1.6L 196 HP (125 HP/L) 1.2L 139 HP (125 HP/L) 30% augmented –HDV 11L 475HP (45HP/L)	30% augmented – LDV 1.3L 196 HP (150 HP/L) 0.7L 98 HP (150 HP/L) 40% augmented-HDV 9L 475HP (53 HP/L)
Efficiency **Waste heat recovery – LDV** **Thermal - LDV** **Thermal - HDV**	5% recovery – LDV Turbo Machinery LDV Thermal Baseline 30% efficiency 42% efficiency – HDV	20% recovery – LDV Turbo / Thermoelectric(TEs) LDV - 25% improvement (37% e) 50% efficiency- HDV	50% recovery – LDV Turbo/TEs/ Rankine Cycle LDV - 50% Improvement (45% e) 60% efficiency- HDV
Exhaust Temperatures (Exhaust Valve to Turbo Inlet)	870 C - LDV 700 C- HDV	950 C - LDV 800 C - HDV	1000 C - LDV 900 C - HDV
Cylinder Peak Pressures	Baseline – LDV ~ 50 bar 190 bar - HDV	75 bar - LDV gasoline 250 bar - HDV	>103 bar - LDV gasoline 300 bar - HDV

Background Graphic Courtesy of Daimler Trucks North America

VTO ACE Materials Gaps



Next Generation Engines face new materials issues

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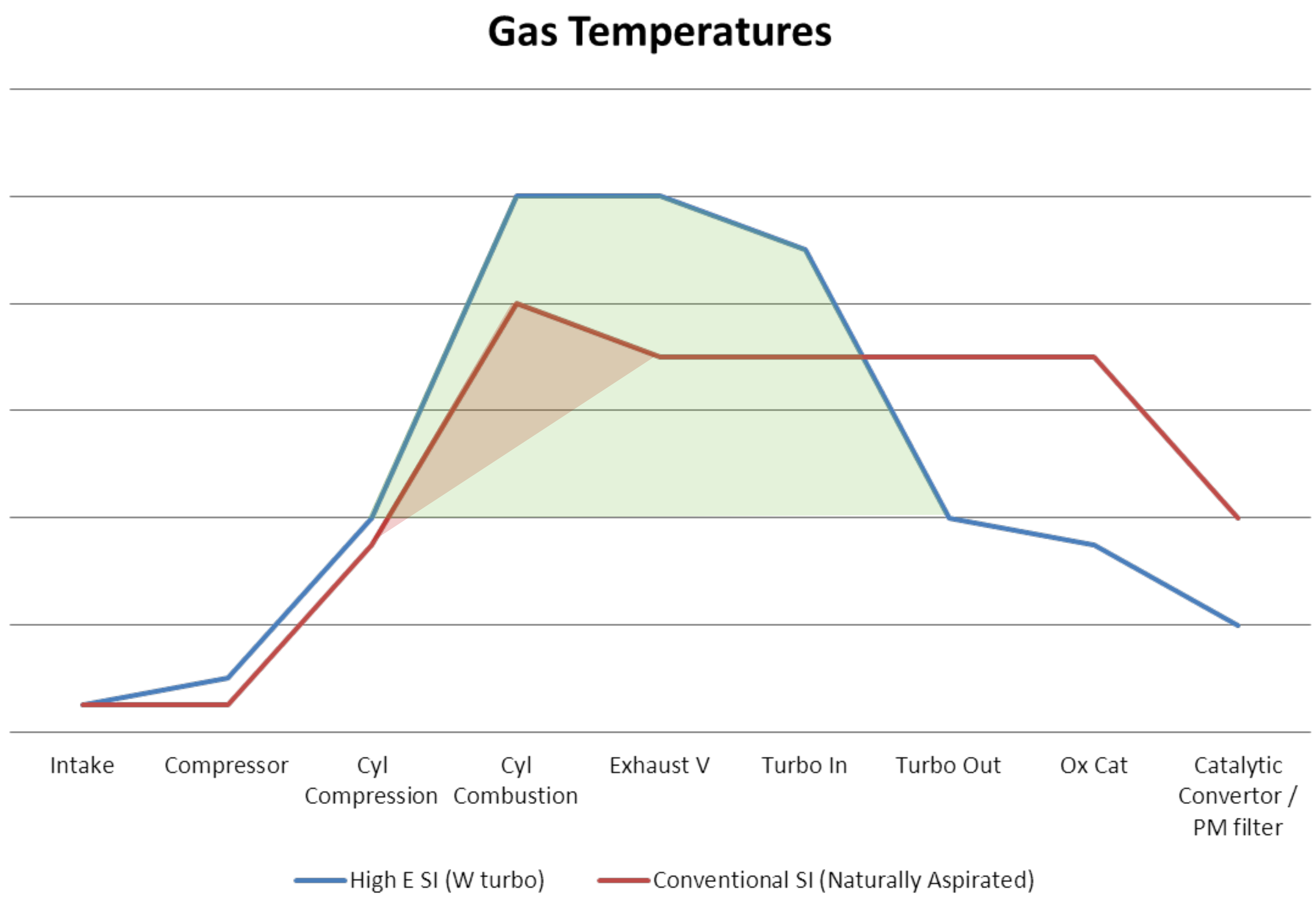

Response to Workshop and VTO ACE Materials Needs

- In 2012 three new Propulsion Materials solicitation topics were released:
- Advanced Light-Weight Cast Alloy Development for LD Applications and High-Strength Cast Alloys for HD Application (two topics). Each topic includes:
  - ICME application and gap analysis
  - Alloy development
  - OEM technology transfer path
  - Alloy validation
  - Component validation
- SBIR Topic: low-temperature catalysts materials targets:
  - 90% effectiveness at 150C

Project Objectives

- Develop new, high-strength ferrous alloys to allow for higher cylinder pressures in heavy-duty diesel engines
- Develop a low-cost high-strength material that can enable heavy-duty diesel engines to increase their specific power density (horsepower/weight) and increase their thermal efficiency
- Application of ICME models to predict alloy properties and reduce the number of iterations necessary in the alloy development process

Partnerships and Commercialization

- Caterpillar Inc.
- QuesTek
- Argonne National Laboratory (ANL)
- University of Alabama – Birmingham (AMB)

Key Tasks

- Define the requirements and concept for the new alloy design and how its performance will be evaluated
- Establish design of the high potential alloy concepts and refine the structure and process objectives
- Perform alloy design optimization and complete characterization by application of various testing and evaluation
- Apply ICME modeling to demonstrate the final prototype alloy
- Develop an accurate cost model plan for the new alloy

Budget and Project PI

- DOE Budget – $3.5 million over 4 years
  Industry Cost-Share - $1.6 million over 4 years
  Total Funding - $5.1 million
- Project Principal Investigator: Richard K. Huff

Ford DE-EE0006020
ICME Guided Development of Advanced Cast Aluminum Alloys for Automotive Engine Applications

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Project Objectives

- Development of new, lightweight alloy materials to allow for higher cylinder pressures in high efficiency, light-duty passenger vehicle engines
- Provide a 25% improvement in component strength relative to components made with A319 or A356 and measured using standard material characterization techniques
- Develop a comprehensive cost model that demonstrates the ability of the components (cylinder head or engine block) made using the new alloy

Partnerships and Commercialization

- Ford Motor Company
- Alcoa
- University of Michigan
- MAGMA Foundry Technologies, Inc.

Key Tasks

- Complete ICME guided alloy development by assessing the feasibility of the new alloys and establishing microstructural characterization and property qualification
- Apply model gaps analysis based on the validation of the VAC tools and associated ICME models
- Demonstrate and validate the new alloys on engine components
- Complete a cost model for the new alloys and establishment of a technology transfer and commercialization plan.

Budget and Project PI

- DOE Budget – $3.2 million over 3 years
  Industry Cost-Share - $1.4 million over 3 years
  Total Funding - $4.6 million
- Project Principal Investigator: Dr. Mei Li

General Motors DE-EE0006082
Computational Design and Development of a New Lightweight Cast Alloy for Advanced Cylinder Head in High Efficiency Light Duty Engines

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Project Objectives

- Development of new, lightweight alloy materials to allow for higher cylinder pressures in high efficiency, light-duty passenger vehicle engines
- Provide a 25% improvement in component strength relative to components made with A319 or A356 and measured using standard material characterization techniques
- Develop a comprehensive cost model that demonstrates the ability of the cylinder head made using the new alloy

Partnerships and Commercialization

- General Motors
- QuesTek Innnovations LLC
- Northwestern University
- MIT
- Camaneo Associates
- GKS Engineering Services
- J Fred Major Consulting
- AFS

Key Tasks

- Use ICME tools to design and optimize high-performance lightweight cast alloy(s)
- Utilize advanced experimental and analytical approaches to characterize multi-scale microstructure and defects of the computationally designed alloys
- Perform standard materials thermal-physical and mechanical property testing
- Develop cost models to accurately predict the manufacturing cost with the project's newly developed alloy.

Budget and Project PI

- DOE Budget – $3.5 million over 4 years
- Industry Cost-Share - $1.65 million over 4 years
- Total Funding - $5.15 million
- Principal Investigator: Mike Walker

High Performance Cast Aluminum Alloys for Next Generation Passenger Vehicle Engines

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Project Objectives

- Develop high performance cast aluminum alloys with improved castability, high temperature strength and fatigue performance compared to industry standard A319 and A356 baseline alloys. Engine cylinder heads cast with the new alloys will have a minimum of 25% strength improvement compared to those cast from the baseline alloys, and will cost approximately 10% more than heads manufactured by A319 or A356. The new alloy will be designed to enable an increase in maximum component operating temperature by ~ 50^{o}C.

- Evaluate the adequacy of existing ICME models and codes for the prediction of properties and development of cast aluminum alloys. A gap analysis report for existing ICME codes for cast aluminum alloy development will be generated.

Partnerships and Commercialization

CHRYSLER

nemak

Nemak casts aluminum cylinder heads for Chrysler engines

OAK RIDGE National Laboratory

Key Tasks

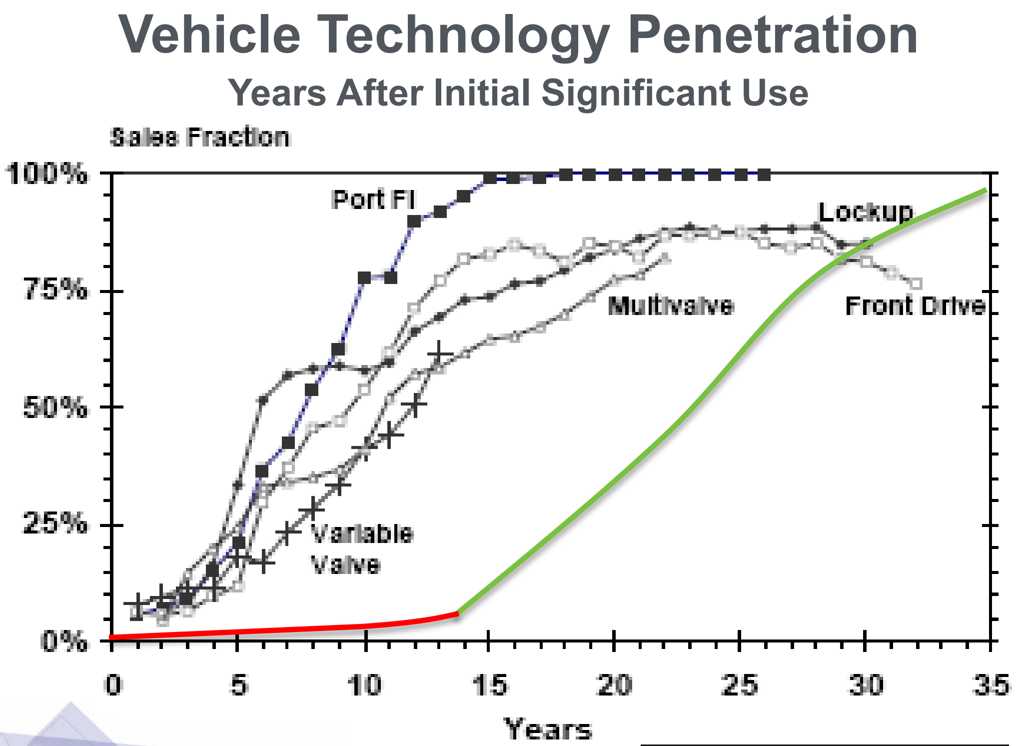
Task Title
Task 1: Define requirements, acceptance criteria and performance targets for cast parts
Task 2: Alloy development, trial casting and screening of alloys
Task 3: Refine alloy compositions by application of existing ICME models to predict performance
Task 4: Alloy selection and demonstration of improved properties
Task 5: Component level demonstration
Task 6: Cost modeling

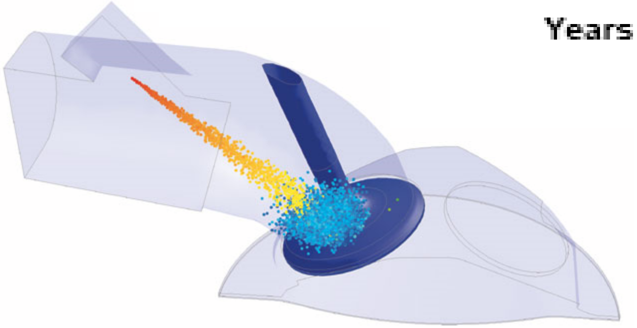
Budget and Project PI

- DOE Budget – $3.5 million over 4 years
  Industry Cost-Share - $2.0 million over 4 years
  Total Funding - $5.5 million

- Project Principal Investigator
  Amit Shyam
  Oak Ridge National Laboratory

Planning is Critical





Food for Thought

- Design process is about 4 years
- For inclusion, new materials must be qualified before designs begin
- New materials typically take 10+ years to develop

Materials Research Must be Focused on the Horizon

Project/Agreement Management

Prospective New Agreements in Each Technology Area are Evaluated On:

- Relevance to Vehicle Technologies Program Objectives
- Supported Team's priorities
- Potential for co-funding from other VTP Teams
- Industry support for activity
- Perceived risk/benefit to Program
- Mechanism for Technology Transfer

- Existing activities are evaluated annually
  - Identify activities that should be transitioned to other VTP Teams or Industry
  - Identify activities requiring changes in effort
- Approximately 15% of activities are retired each year
- Goal to migrate over 70% of portfolio to competitively awarded solicitations by 2015

Funding Direction

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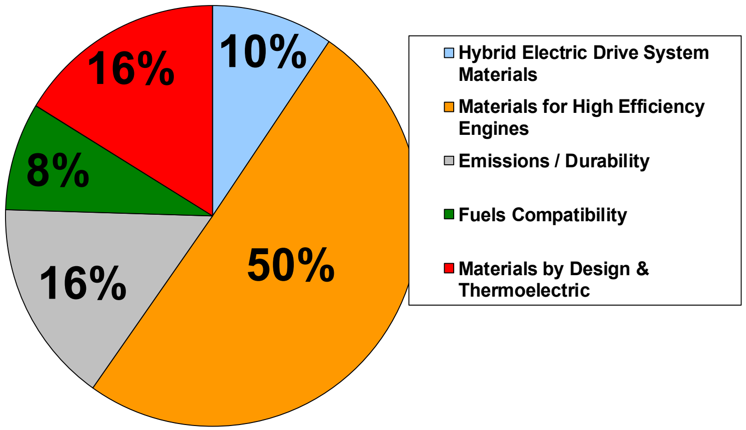
Funding	FY 2012* Enacted	FY 2013** Full Year CR	FY 2014*** Request
Direct Funding	$8.2	$5.8	$4.0
Solicitations	$4.8	$6.5	$6.0
Total	$13.0	$12.3	$10.0
Solicitations %	36%	53%	60%

* FY 2012 SBIR/STTR removed.
** FY 2013 full year CR inclusive of SBIR/STTR.
*** FY 2014 budget request inclusive of SBIR/STTR.



Expert Reviewers are essential

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- Expert Reviewers can provide a non-biased evaluation of project at the Merit Review
  - Identify activities that should be transitioned to other VTP Teams or Industry
  - Ask questions that can lead to better activities
  - Identify activities requiring changes in effort (increase or decrease)
- Non-biased expert Reviewers are key to reaching goal to migrate over 70% of portfolio to competitively awarded solicitations by 2015*
  - Every proposal must be reviewed by at least 3 expert reviewers
  - Range of potential topic areas adds to complexity of finding reviewers

* Goal was shifted out 1 year due to lower request level in 2014

Thank You

www.vehicles.energy.gov

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