Dan Addison
Liox Inc.

CEO of Liox, a private R&D laboratory founded in 2009. Liox is focused on electrochemical energy storage and related systems. Our technology portfolio includes next generation batteries, carbon neutral liquid fuel systems and new lithium extraction processes.

- Propose concepts
- Recruitment and team building

Technology Overview

Relevant Liox R&D

- High energy density lithium batteries that operate at elevated temperature, which therefore require support systems for deployment in EVs
- Modeling and design of dual battery and ICE-battery range extender architectures to support use of intermediate temperature energy conversion and storage systems in EVs

Terry Alger
Powertrain Engineering, Southwest Research Institute

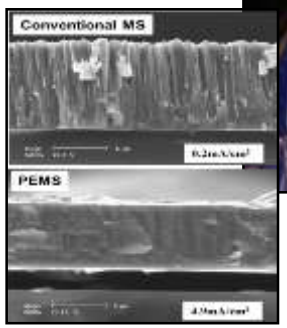
Dr. Alger has a BSME from The United States Military Academy, a MSME and PhD from The University of Texas and an MBA from UT-SA. He is the Director of Spark Ignited Engine R&D at SWRI, focusing on advanced IC engines, vehicle efficiency and advanced electrification concepts

My goals for this meeting:

- Understand the technologies that would apply to this workscope
- Help contribute to the potential requirements of the FOA

Technology Overview

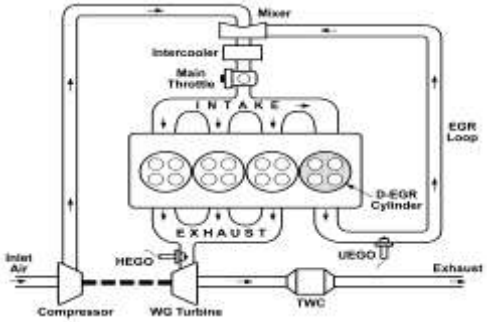
SwRI works in advanced engine and vehicle technologies. We have several potential solutions to improving the efficiency of hybrid vehicles using advanced IC engines and electric machines. In addition, we have several complementary technologies that can be applied to several components on the engine



HEDGE

HIGH-EFFICIENCY DILUTE GASOLINE ENGINE

A Consortium of SwRI



Arne Andersson, Powertrain Advanced Engineering, Volvo Group

VOLVO

Volvo Group

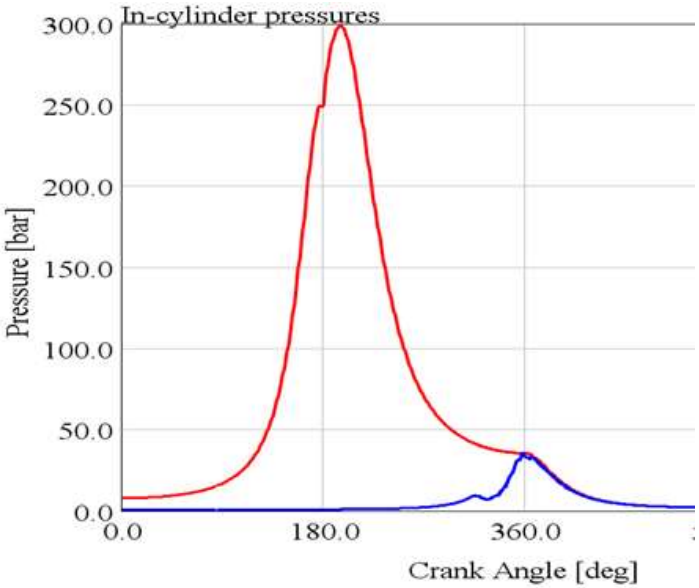
HD vehicle and powertrain platforms
Engine thermal management research
CFD based combustion research
Advanced concepts and future powertrains

Identify opportunities and trends regarding development of future powertrains

Technology Overview

DCEE
(Dual Compression/Expansion Engine)
This IC engine can achieve 55 % BTE using the following key technologies:

- Over-expansion in two stages
- Insulation of hot parts
- Fast valves



Two-stage expansion

Engine Research Center (ERC)

Michael Andrie – UW-Madison

- IC Engine Research
- Director of ICE Training
- 25 years ICE Industry
- 10 years ICE Academia
- 3 patents, 20+ papers
- UMinn BSAE, MSME

- Largest US academic IC Engine Center
- >70 year existence (Est. 1946)
- Funding: Consortium/Industry, DOE, DOD
  - **WSEC – Wisconsin Small Engine (6+)**
  - **DERC – Direct-injection Engine Research (30+)**
  - **WEMPEC – Wisconsin Electric Machines and Power Electronics (80+)**

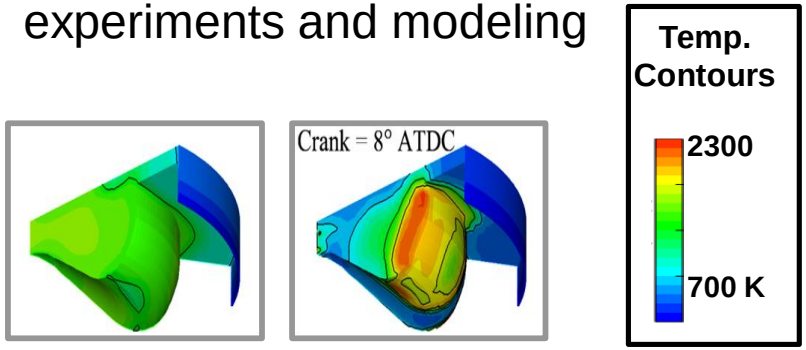
ERC Interests

- IC Engine and Related Technology Funding
- Opportunities to Improve Engine/Hybrid Technology and Simulations
- Educating Students and Professionals on Internal Combustion Engines and Hybrids

Technology Overview

ERC Technical Expertise

- High efficiency, Low emission combustion, Thermal barriers
- High-fidelity engine codes, detailed chemistry for emission prediction, spray & turbulence modeling
- In-cylinder gaseous species measurement and high resolution spray analysis
- Control strategies for advanced comb
- Fuel , air, and combustion optimization
- Particulate and Aftertreatment experiments and modeling



Dimitris Assanis

University of Delaware

Dr. Assanis is a Postdoctoral Research Associate on connected and automated vehicles at the Univ. of Delaware.

He completed his doctoral thesis at the University of Michigan in 2016, titled “Computational and Experimental Development of Novel Combustion Strategies for Advanced Internal Combustion Engines.”

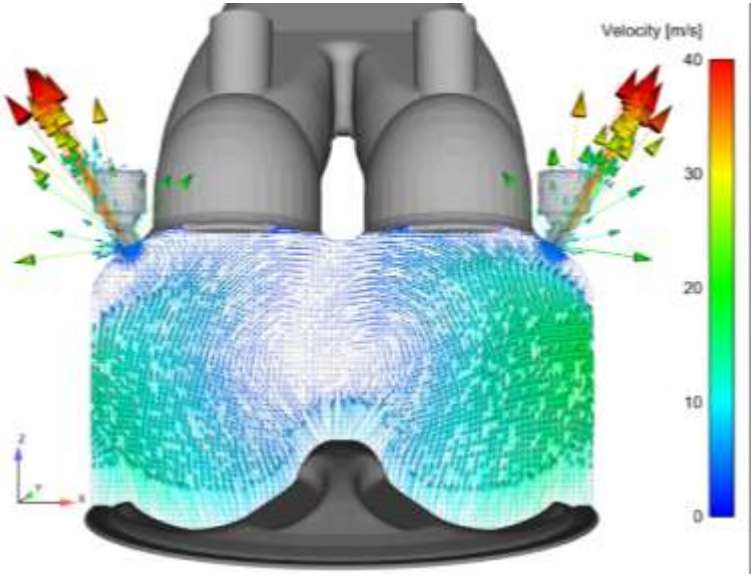
Dr. Assanis has carried out fundamental combustion experiments exploring the interaction between flames and auto-ignition events of dilute isooctane air mixtures. He has further worked on the development of a lean burn, gasoline, dual pre-chamber engine using computational tools and optical diagnostics in a single-cylinder optical engine facility.

Understanding the future propulsion needs of HEV/PHEV based CAVs.

Technology Overview

Dual Pre-Chamber Engine Technology

- Two, diametrically opposed, passively-fueled, self-purging pre-chambers.
- Multiple connecting orifices to enhance turbulent jet ignition based combustion.
- Ultra lean-burn, low NOx combustion design.



Czero

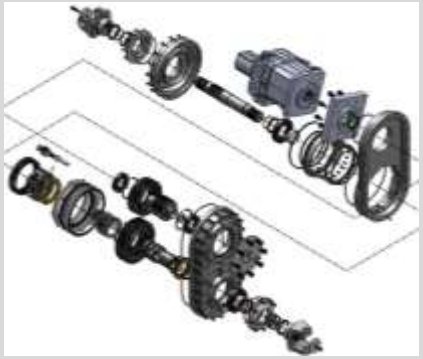
Czero - President & CEO
Ph.D. ME University of Wisconsin – Madison
MSEE University of Wisconsin – Madison
MSME University of Michigan – Ann Arbor
Saturn/General Motors
Sturman Industries

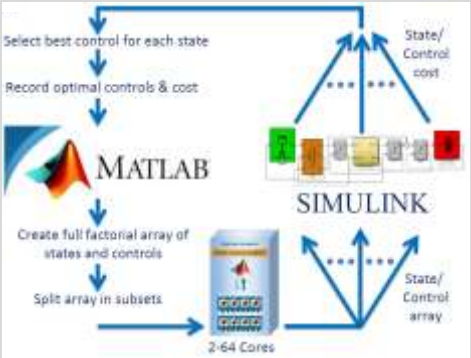
Czero is an engineering service company specializing in early stage R&D. Extensive hybrid experience. Czero has supported 5 ARPAe awards to date.

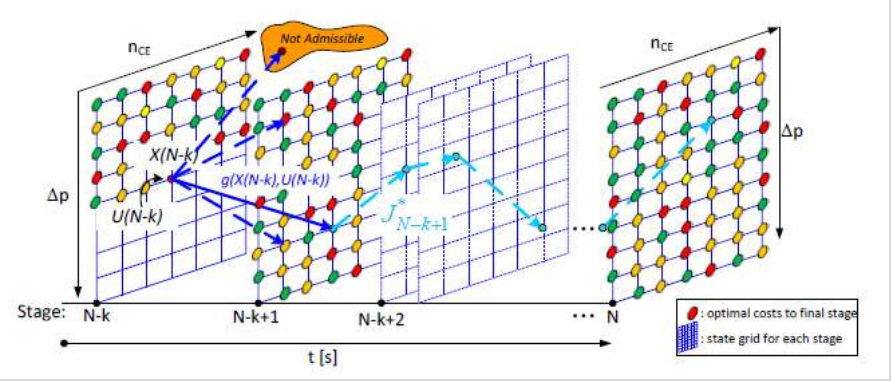
**** We are interested in partnering with other companies or organizations on proposals***

Technology Overview

Clean sheet to fully functional prototypes
- Modeling and simulation
- Optimal control: Dynamic programming, Neural nets
- Architecture selection
- Mechanical design
- Build / test
- Controls





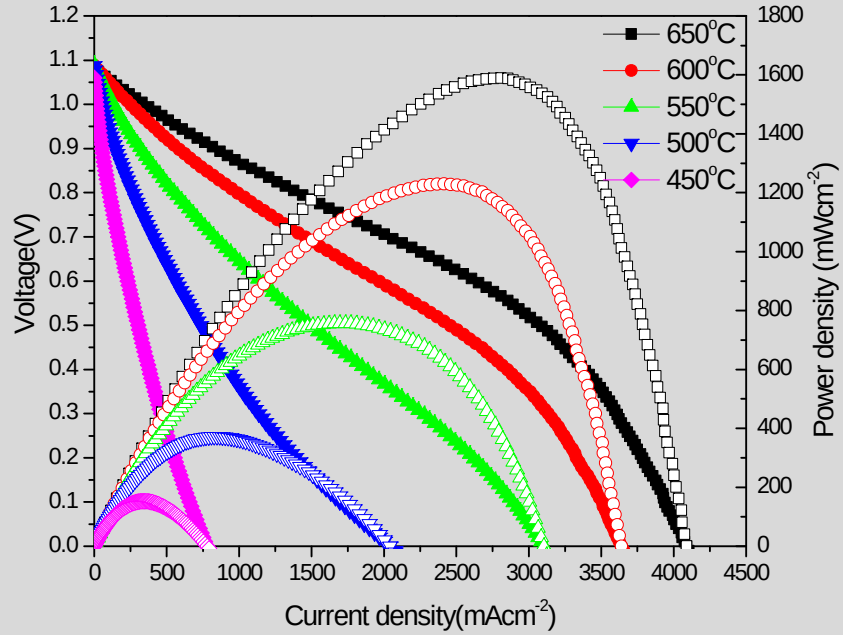


Scott A Barnett
Northwestern University

Barnett is a professor in the Department of Materials Science and Engineering at Northwestern University. Research in solid oxide fuel cells include three-dimensional tomography, degradation phenomena, SOFC operation with hydrocarbon fuels, reversible solid oxide cells for energy storage, and development of new fuel cell anode and cathode materials.

- Interested in solid oxide fuel cells as range extenders in battery electric vehicles
- Interested in development of transportation using renewable hydrocarbon fuels

Technology Overview



- Developing low-temperature (< 650 C) solid oxide fuel cells
- Novel fuel electrode structures that allow on-anode internal reforming of liquid hydrocarbons, *e.g. iso*-octane
- These approaches have potential to provide stable operation, reduced balance of plant, and high conversion efficiency

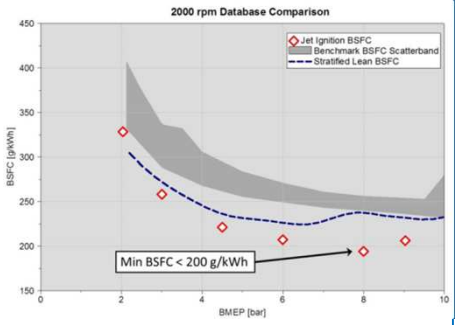
Hugh Blaxill, MAHLE Powertrain LLC

General Manager of MAHLE Powertrain LLC and Head of Engineering Services. Based at the newly acquired Plymouth, MI Test Facility, managing a team of 60+ in providing engineering services to the global industry. Previously Head of R&D for MAHLE Powertrain UK. Projects include MAHLE Downsizing, MAHLE Range Extender and MAHLE Jet Ignition

Looking for collaboration in high efficiency hybrid technologies to further develop future vehicles and capability in areas such as:

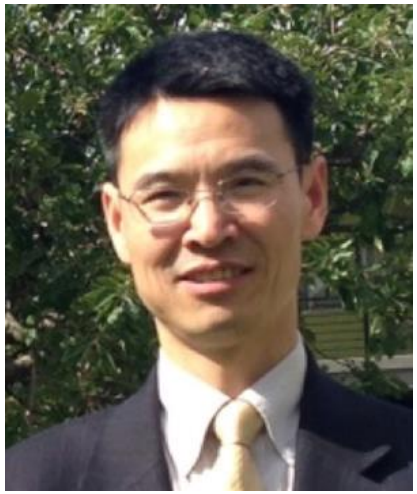
- MAHLE's Range Extender Engine, Vehicle and Control Systems
- MAHLE's and other high efficiency IC engine technologies

Technology Overview



MAHLE Powertrain is very interested in the development of advanced powertrain hybrid systems. This is evidenced by its investment in multiple hybrid technology demonstrators, from mild to parallel to series configurations, advanced control systems, future high efficiency combustion engines and system level based development projects

Fanglin (Frank) Chen, University of South Carolina



UNIVERSITY OF SOUTH CAROLINA

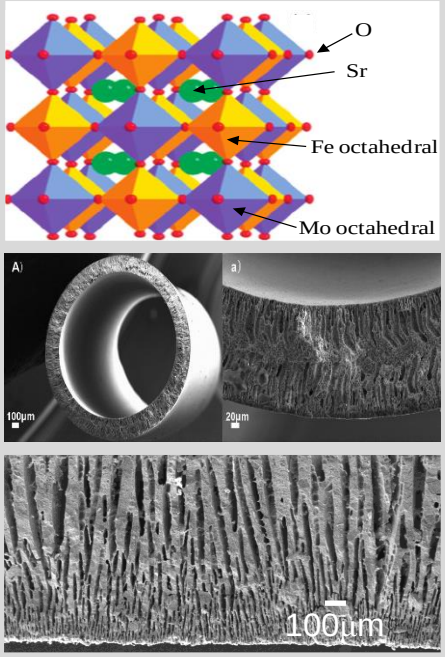
Professor

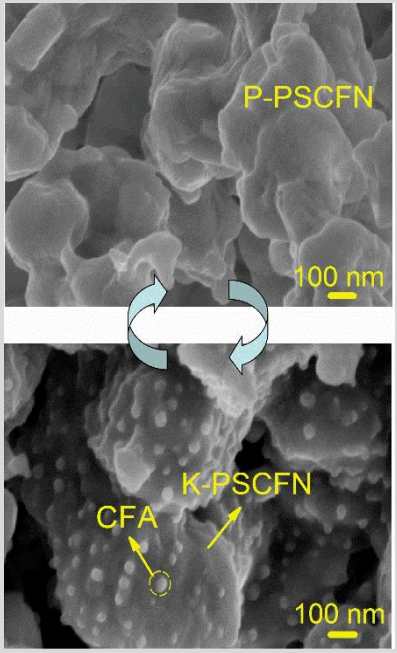
Department of Mechanical Engineering
College of Engineering and Computing
University of South Carolina
300 Main Street, Columbia, SC 29208

Contribute in fuel cell technology

Provide materials expertise

Technology Overview





- **Designed composition**
  - -- Coking resistant & sulfur tolerant
  - -- Internal reforming
- **Open channel microstructure**
  - -- Facile mass and heat transport
  - -- Fast start-up

Calum R.I. Chisholm, CEO
SAFCell, Inc.

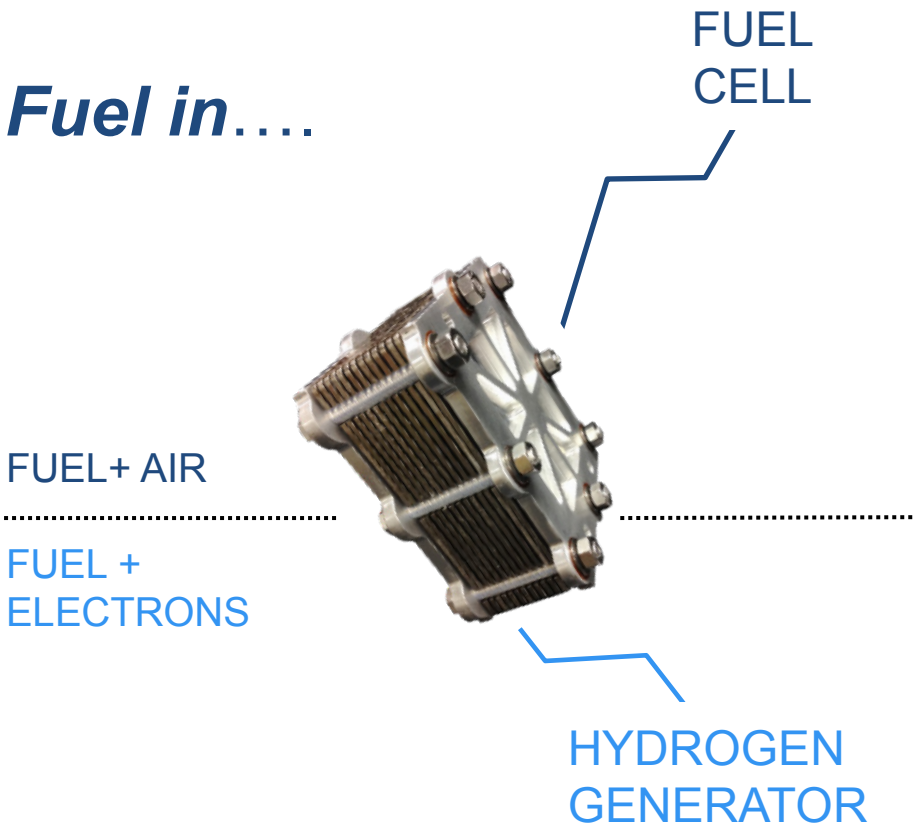
Calum founded ***SAFCell*** in November, 2009 to develop and commercialize solid acid fuel cells (SAFCs), hydrogen generators, and membrane reactors. ***SAFCell*** is partnering with targeted system integrators to enter first portable and remote, and then stationary markets.

<u>Primary Takeaways</u>

- Intermediate temperature operation (250°C) results in fuel flexibility, on-board reforming, and high durability
- Looking for help in developing full systems

SAFCell: mid-temperature, solid state conversion

Fuel in….



…high value out

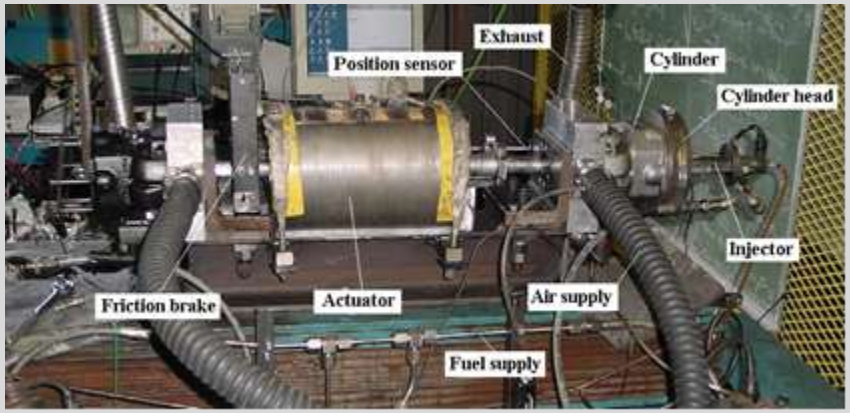
Nigel N. Clark, Ph.D.
West Virginia University, Mechanical & Aerospace Engineering

Nigel Clark, Professor and George B. Berry Chair at WVU, has led numerous programs in alternative fuels, engines and emissions. He is is currently engaged in linear engine design (ARPA-e GENSETS program) and quantifying methane losses. He is an SAE Fellow.

- Optimized architectures matched with adaptive control strategies to maximize cycle-averaged energy efficiency
- Internal combustion engine designs directed at specific hybrid vehicle configurations

Technology Overview

Linear engines offer high efficiency potential because they have no crankshaft and can be coupled directly to a linear alternator. Also, their piston motion and variable compression ratio properties support alternate combustion modes. WVU has engaged in linear engine-alternator modeling and design for twenty years, producing working compression and spark ignition units. A comprehensive model has been used for both design and parametric analysis. WVU has pioneered the use of springs to raise system frequency and power density and is currently engaged in a 1kW natural gas design for the ARPA-e GENSETS program. Twin cylinder systems are ideally suited to hybrid series and range extender architectures.



Tim Coatesworth
FCA US LLC

FCA
FIAT CHRYSLER AUTOMOBILES

Working in Powertrain at OEMs for 35 years.
Last 7 years in Electrified Powertrain.

What is your interest in this meeting?
Looking for promising Topographies that include an ICE.

Technology Overview

N/A.

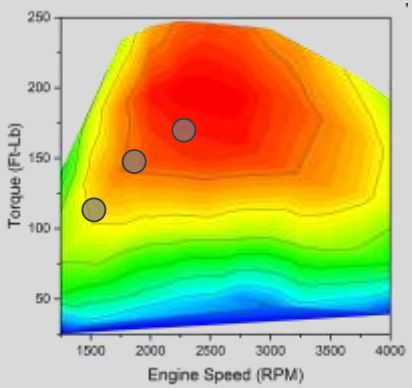
Scott Curran, Oak Ridge National Laboratory

Scott Curran is a R&D staff member at ORNL's National Transportation Research Center. He the is principal investigator for light-duty advanced combustion R&D and is involved in vehicle system R&D including being the lead for a 3D-printed range extender vehicle.

- Hoping to better understand current opportunities and challenges for integrating next generation engines with electrified powertrains

Technology Overview

Current interests include:
Exploring synergies of advanced engines with range extender and blended power hybrid vehicle architectures using HIL facilities at ORNL



Nilesh Dale
Nissan North America Inc.

NISSAN GROUP
OF NORTH AMERICA

NISSAN

Brief Bio

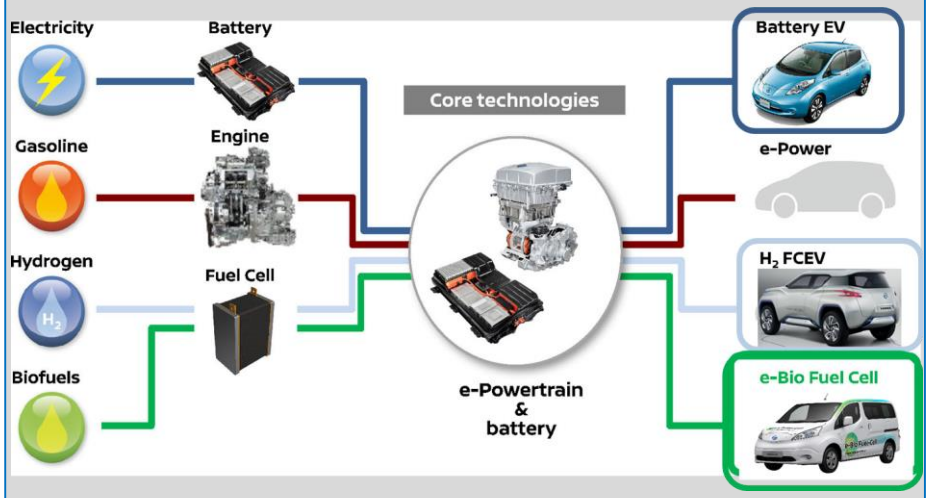
- Main Interests – Fuel cells, electrochemical energy conversion devices and storage
- Manages Nissan's fuel cell research in US
- Co-PI on 6 DOE funded research projects

Primary takeaway

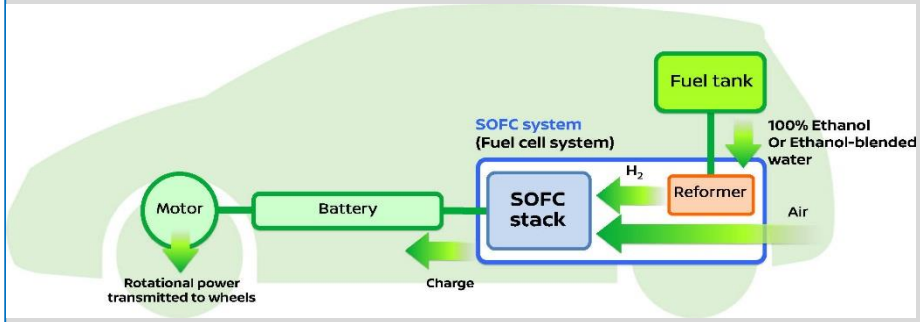
- Understand other stakeholder's interest
- To get support from Arpa-e and research community's support for Nissan's unique approach for SOFC

Technology Overview

Diverse application of EV technologies



e-Bio SOFC EV system



- Carbon neutral cycle
- Range equivalent to gasoline engine
- No need to charge from grid

Eaton Vehicle Group

EATON
Powering Business Worldwide

Director, Vehicle Group Advanced R&D
Director, Controls Dept., Eaton Corp. R&D
Modeling/Simulation/Controls at United Technologies Research Center
FEA Simulations, Comsol AB, Sweden
PhD, Applied Mathematics, Royal Inst Technology & Stockholm Univ., Sweden, 1995

- Powertrain system level trade-offs in hybrids, motor vs transmission vs ICE efficiency and technology/costs, especially for commercial vehicle applications
- Fuel cell and micro-turbine latency vs battery storage trade-off in context of drive cycle transient demand

Technology Overview

- Multi-speed transmissions for EV

- Commercial vehicle hybrid systems

- Complex valve actuation and engine air breathing for fuel efficiency and exhaust thermal management for NOx mitigation

- Fuel cell transient response controls

Michael Duoba
Argonne National Laboratory

Argonne NATIONAL LABORATORY

Mr. Duoba is the senior research engineer at the Advanced Powertrain Research Facility testing and evaluating xEVs for 23 years. He chaired and co-chaired SAE committees that developed the test procedures for plug-in hybrid and electric vehicle range and efficiency.

- What are the system efficiency issues for future engine and e-motor technology?
- What new technologies are suitable for HEVs that increase system efficiency to 55%?

Technology Overview

Technology Assessment

Assess state-of-the-art transportation technology for the Department of Energy and Argonne research interests

Advanced Testing Procedure Development

Adoption not possible unless test method provides fair and accurate results

Research Oriented Test Facilities

4WD chassis dynamometer
- Thermal Chamber: 0F to 95F
- Solar emulation

2WD chassis dynamometer
- Up to medium duty

Vehicle Technology Assessment

Vehicle level
- Energy consumption (fuel + electricity)
- Emissions
- Performance
- Vehicle operation and strategy

'In-situ' component & system testing
- Component performance, efficiency, and operation over drive cycles
- Component mapping

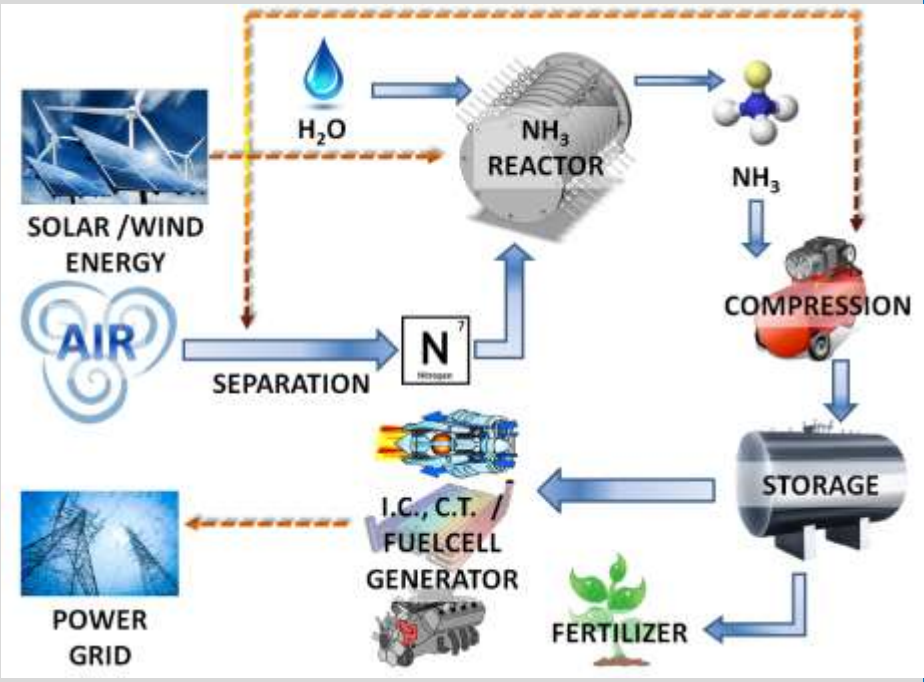
Fernando Garzon, Prof. ChE, UNM/Sandia National Lab

THE UNIVERSITY of NEW MEXICO

Sandia National Laboratories

Joint appointment as a UNM Professor of Chemical and Biological Engineering and a Faculty Research Scientist at Sandia National Laboratory
30+ years experience in Electrochemical Sciences and Technology: Fuel cells, Electrolysis, Batteries, Sensors
Fellow and Past President of the Electrochemical Society, Member: ECS, ISE, MRS, ACerS, AAAS

- My main goal is to develop solid electrolytes and catalyst systems for electrochemical ammonia production and fuel cells
- Design technical approaches to chemical energy storage through ammonia synthesis
- Demonstrate electrochemical synthesis of ammonia on pilot scale
- Develop catalysts for efficient ammonia electro-oxidation



- Electrochemical synthesis of fuels from electricity and abundant feed stocks
- Improve performance and durability of fuel cells
- Develop research program to further technology

John German
International Council on Clean Transportation

icct
THE INTERNATIONAL COUNCIL ON CLEAN TRANSPORTATION

- Worked about a decade each at Chrysler, EPA, Honda, and ICCT, primarily on powertrain
- First recipient of SAE award for Excellence in Automotive Policy Analysis.
- Part of team that found the VW defeat device

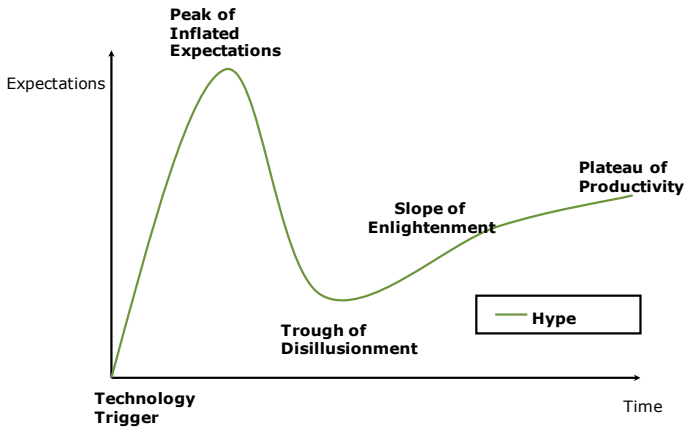
Invited to speak on vision of the makeup of the future light-duty vehicle fleet in the US

Overview

Consumers and the hype cycle have been routinely ignored:

- Transition from early adopters to mainstream customers
- Resale value
- Recharge time
- ICE improvements
- 48 volt hybrid development
- Can H2 delivery costs be reasonable?

Hype cycle phases



Source: Gartner (July 2009)

Dave Ginter - Caterpillar

CATERPILLAR®

Bio

- Experience in combustion, emissions, fuels, catalysts.
- Focus on low NOx technologies, alternative fuels.

Key Insights/Takeaways

- Mobile electrification and hybridization
- Fuel cell performance and commercialization

Technology Overview

Relevant Technology/Capabilities

- Diesel, natural gas and dual fuel engines.
- System Integration.
- Durability and reliability.
- Wide range of applications base.
  - kW to MW power nodes
- Electric drive.
- Energy storage.

Shimshon Gottesfeld, Adj Prof.,
Univ. of Delaware, Dept of Chemical & Biomolecular Engineering

1984-2000 LANL, R&D Fuel Cell Team Leader
National Lab Rep. on PNGV Tech Committee
1999 LANL Fellow, ECS Fellow
2006 Grove Medal, Fuel Cell Science and Technology
2007 Cellera, Inc. & next POcelltech Ltd :
Alkaline Membrane FC Tech Dev.;
2015 Adj. Prof Udel ; 2017,PI, Direct NH_3 FCs

•Automotive Industry Reps feedback to the idea of liquid fuel replacing compressed hydrogen in delivery and on-board storage for FCEVs and FC/Battery EVs

•Automotive Industry Reps feedback to ammonia as fuel of choice for FCEVs

Technology Overview

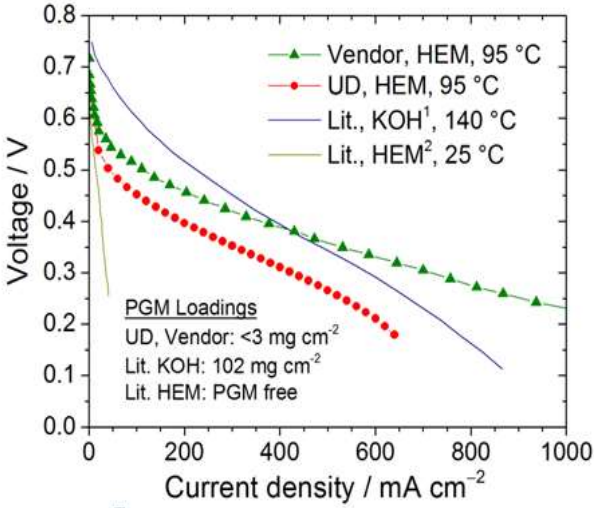
Our REFUEL Project Target:

Create a high power density direct ammonia fuel cell (DAFC) suitable for transportation by using a hydroxide exchange membrane electrolyte and operating the cell near 100 °C.

A practical ammonia fuel cell enables use of the lowest cost carbon-free or carbon-neutral liquid fuel for clean, long-range transportation.

Record power densities for DAFCs with HEM electrolyte using in the anode ~3 mg/cm^2 PGM

Novel, stable OH^- ion conducting ionomers prepared at RPI and UD -- a critical development



Adam Gould
PACCAR Technical Center (PTC)

PACCAR TECHNICAL CENTER

Bio

- Manager, PTC Michigan Office (Farmington Hills, MI)
- Prior Role Powertrain Validation Manager
- Previously Worked at U.S. Army Cold Regions Test Center & Transportation Research Center
- B.S. Automotive Engineering Technology
- M.E. Systems Engineering (in Progress)

Desired Takeaways

- Battery Technology Roadmap (Cost Trending, Energy Density, Battery Types)
- Fuel Cell Technology Roadmap (Infrastructure, Costs, New Technologies)

Relevant Technology

- Cost Effective Anti-Idling Overnight
- Powertrain Integration with New Technologies

Dr. Kiran Govindswamy, FEV North America, Inc.

Kiran Govindswamy currently holds the position of Business Unit Director at FEV's North American Technical Center with responsibilities for Powertrain Development, and Vehicle Engineering.

- Primarily interested in understanding the latest trends on efficiency enhancement for hybrid vehicles

Technology Overview

JAMES GRIEVE MicroEra Power / AHEAD Energy

microEra Power
DISTRIBUTED GENERATION SOLUTIONS

AHEAD ENERGY

Start-up, focused on ultra-efficient DG using automotive engine, fuel cell and hybrid technology (licensed from Delphi).

Not-for-Profit, focused on renewable hybrid power systems fuels (ammonia, DME, etc.)

Chief Scientist at Delphi (retired 2016)

Seeking partners for research and commercialization of ultra-efficient vehicle powertrains.

Exploiting dual-use opportunities in stationary/distributed generation applications.

Technology Overview

PREMISES:

(1) SOFC is very efficient at producing by-product HEAT and HYDROGEN, especially with easy to reform fuels (methane, ammonia etc.).

(2) HEAT can be used in a Rankine or Brayton cycle to boost power and efficiency.

(3) HYDROGEN can be used in an ICE or second FUEL CELL to boost power and efficiency.

(4) LIQUID FUELS (LNG, LPG, DME, AMMONIA) are more practical to transport/dispense/store than HYDROGEN and are easier to make ultra-efficient and zero emissions than drop-in fuels.

(5) Light, aerodynamic EVs can have acceptable top speed and autonomy with relatively low power.

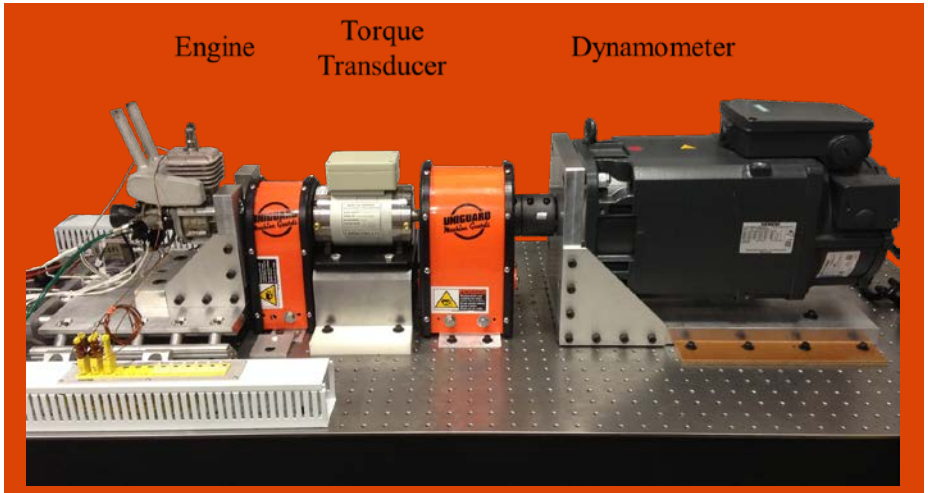
Chris Hagen, Oregon State University

Oregon State University

Chris focuses on energy systems, advanced internal combustion engines, unconventional fuels, applied thermodynamics and fluid mechanics.

Goal: Help “Identify advanced, high efficiency combustion engine and hybrid architectures and technologies”

Technology Overview

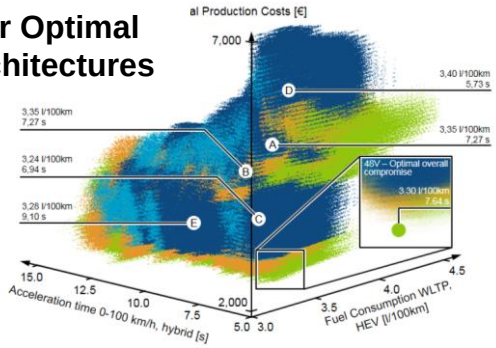


We have developed a ~1kW hybrid electric power for unmanned aerial vehicles (UAV’s) with flight time over 1 hour. We have a development test bed.

Chris Hennessy – Vice President Powertrain Engineering
IAV Automotive Engineering Inc., Northville, MI

automotive engineering iav

Analysis Tools & Methods for Optimal System Architectures

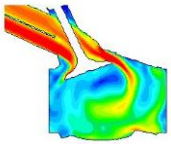


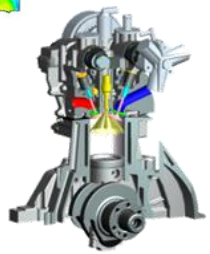
Over 20 years of experience in powertrain engineering with program lead roles ranging from Advanced Hybrid Powertrain Development for A-segment PHEV's up to Class 8 Heavy-Duty Hybrids, as well as Advanced Concepts Engine design & development. These programs span a multitude of use cases including automotive, commercial truck, and the military vehicles.

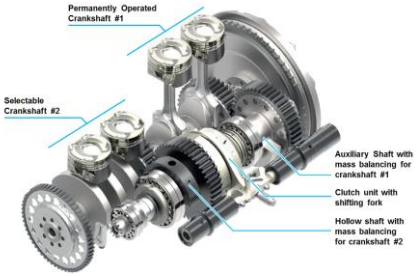
- Focus on the Complementary Integration of Advanced Combustion Engine Technology w/ High Levels of Electrification. *(It's not an all or nothing game)*
- The reduction in Li-Ion Battery costs will enable more optimally balanced PHEV technology solutions

Advanced Mechanical Systems Design & Development

Advanced Thermodynamic & Energy Management Systems







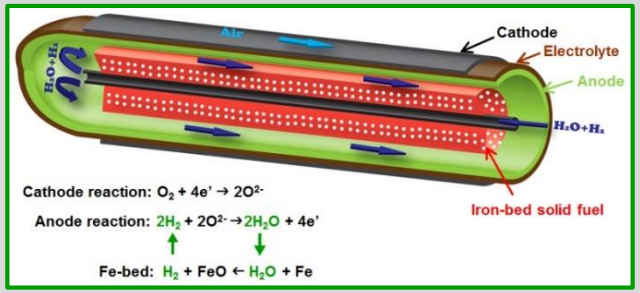
Prof. Kevin Huang, University of South Carolina

Prof. Kevin Huang is currently a professor at University of South Carolina. His current research interests include materials and designs for SOFCs, storage batteries, gas separation membranes and multiscale computational modeling.

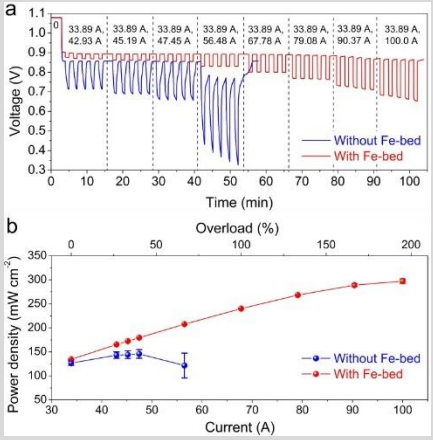
- Why: Learning more about new ideas and networking with people
- Takeaway: Learning more about the focus of the program and finding the right partners to respond potential FOA

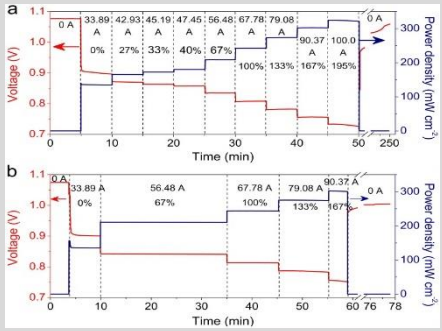
Technology Overview

- High-performance SOFCs with secondary solid fuels
- Performance and cost analysis of SOFC-battery hybrid systems



Performance





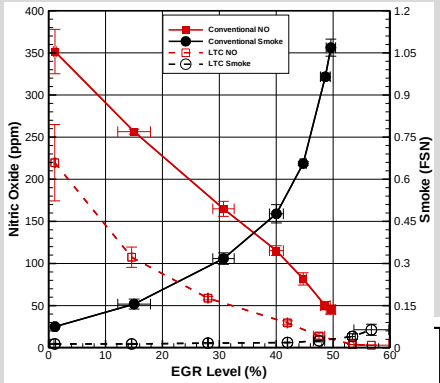
Timothy J. Jacobs, Ph.D
Texas A&M University

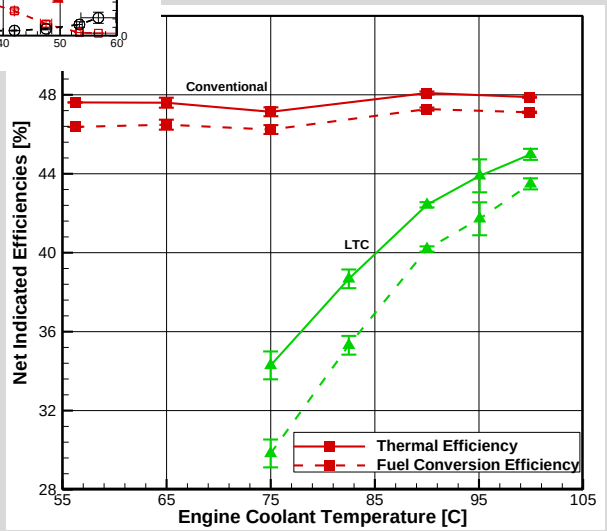
Dr. Jacobs is Professor and Steve Brauer ’02 Faculty Fellow of Mechanical Engineering at Texas A&M University. His teaching and research interests lie generally in the area of thermodynamics, and specifically in the area of internal combustion engines.

- Identify opportunities to integrate high-efficiency, low-emissions internal combustion engines into enabling hybrid technology.
- Promote the rigor of life-cycle analysis when down-selecting technologies for the automotive industry.

Technology Overview

- Low temperature combustion for simultaneous reductions in nitrogen oxides and particulate matter with increases in efficiency.
- Optimized fuel properties for improved emissions and efficiency





Motohisa Kamijo
NISSAN MOTOR CORPORATION

NISSAN MOTOR CORPORATION

Brief Bio

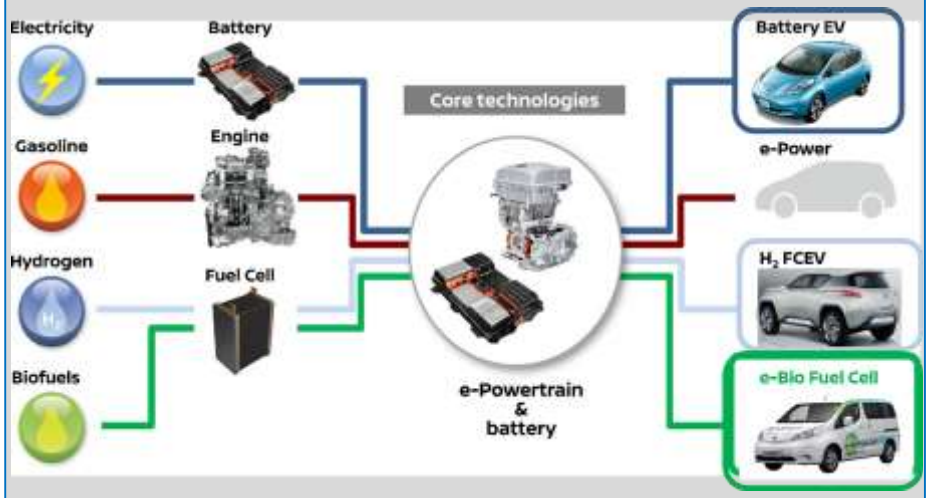
- Field : Fuel cell system, SOFC, Fuel Reformer
- Current job : Development of “e-Bio Fuel-Cell”
- Position : Deputy GM, EV system Laboratory
- Manager of SOFC Society of Japan

Primary takeaway

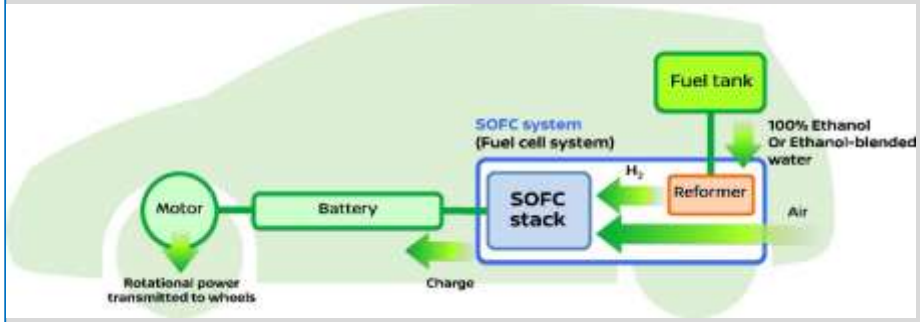
- Understand other OEM’s and Supplier’s interest
- To get support from Arpa-e and research community for Nissan’s approach for SOFC

Technology Overview

Diverse application of EV technologies



e-Bio Fuel-Cell



- Carbon neutral cycle
- Range equivalent to gasoline engine
- No need to charge from grid

Ryan Kemmet, Linamar

Director Global Innovation at Linamar Corporation. Pairing technologies with manufacturing, primarily focused in the energy and automotive sectors. Previously developed oil field catalytic cracking technology and heavy duty CNG technologies.

Determine how Linamar can help advance the latest in internal combustion and fuel cell propulsion.

Technology Overview

Global Tier One manufacturer of powertrain components and assemblies. Currently largest independent producer of camshafts, gears, and cylinder heads. Expertise in launching new products and manufacturing technologies.
Testing capabilities for all types of propulsion.
Experience in novel energy generation – stirling engines, battery, alternative fuels.

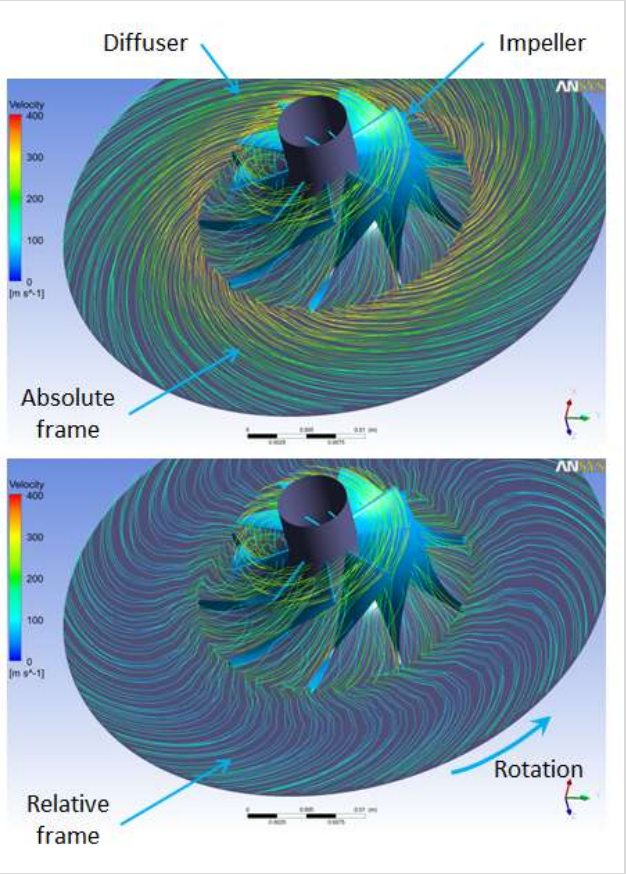
Dr. Rory Keogh, Metis Design Corporation

metis design

- PI for DARPA, NASA and ARPAe funded innovative turbo-alternator efforts (1-40kW)
- MS and PhD from the MIT Gas Turbine Lab
- 5 years mechanical systems engineer at Boeing

- Better understand the state-of-the-art for range extenders for hybrid vehicles
- Determine the opportunity for low-cost, high performance turbo-alternators

Turbo-Alternator Overview



- High-performance compressor (ARPAe)
- Low-cost, lightweight power take-off (NASA)

John Kopasz Argonne National Laboratory

Argonne NATIONAL LABORATORY

Dr. Kopasz assists the US DOE Fuel Cell Technologies Office and has been working in the fuel cell and hydrogen field since 1999. John led Argonne's research efforts on fuel composition effects for hydrogen production from petroleum-based fuels and on high temp PEM membranes

Takeaway I hope to get are targets and goals for fuel cells, fuel reformer, (if needed) and system, for efficiency, weight, volume and cost.

Technology Overview

John Kresse, Cummins Inc. *Research and Technology*

bio

- Principal Investigator for DOE-funded range extender EV class 6 truck (ETREE)
- 20+ years developing powertrain controls for commercial vehicle applications (engines, transmissions, hybrid systems)
- 32+ patents on powertrain controls granted

interest

- Range extender architectures & fuels which may soon be commercially viable
- How does the commercial vehicle industry see use of range extenders in the future? Emergency, charge sustaining, blended?

Technology Overview

- **Diesel range extenders**
  - ETREE using ISB4.5
  - emissions compliant aftertreatment
  - reliable, efficient, high volume

- Investigating **spark-ignited range extenders**
  - gasoline, E85, propane, CNG

Cummins ETHOS 2.8L E85

- Investigating **reducing cost** while still satisfying requirements of high speed, high power density, reliability, efficiency targeted to the range extender operational envelope
- Investigatory projects on **scalable fuel cells**
- **State-of-Charge trajectory** optimization
- **Emissions certification** process improvements

Dr. Benjamin Lawler, *Assistant Professor*

Advanced Energy Research and Technology Center, Stony Brook University

Stony Brook University

Biography

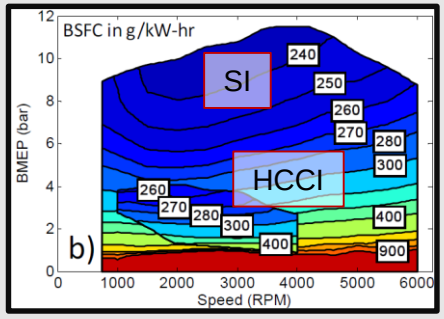
- Assistant Professor at Stony Brook University (SBU) since January of 2015
- Expertise in advanced combustion concepts
- Experience simulating various HEV configurations with advanced combustion engines

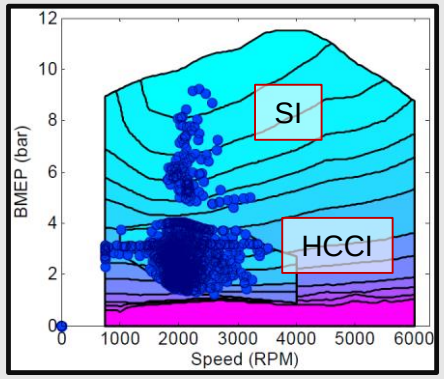
High Efficiency Hybrid Vehicles

- HEVs with advanced powertrains can significantly increase vehicle fuel economy
- Research is needed to better understand the system-level interactions of various configurations and to tailor the control strategy

Engine Combustion Research Group

- Several fully instrumented, single cylinder research engines capable of LTC modes
- CFD (both RANS and LES) of conventional and advanced combustion concepts
- Experience with system-level modeling of engines and vehicles as well as drive-cycle simulations for fuel economy quantification





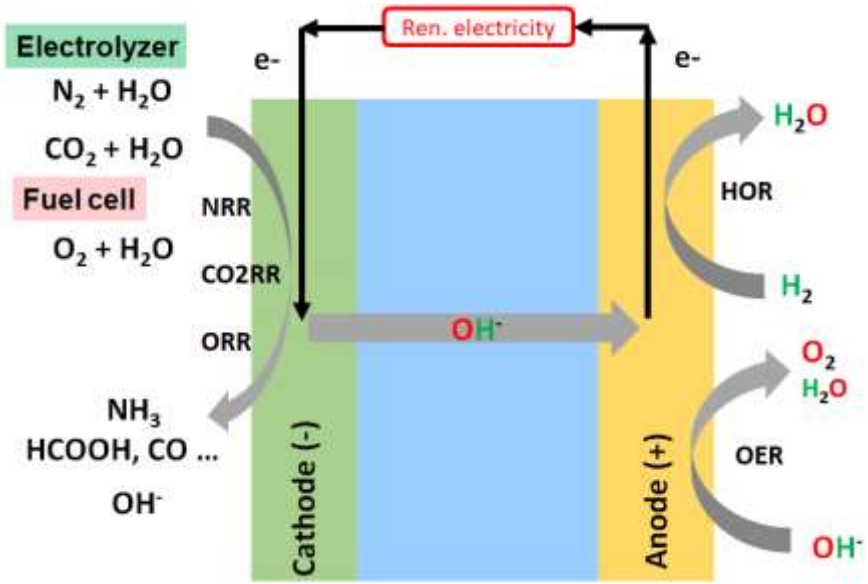
References: Lawler, SAE 2011-01-0888; Lawler, ICEF2011-60160 and Lawler, JEGTP, 2011

Dr. Wenzhen Li, Iowa State University & DOE Ames Lab

- Associate professor at ISU and Associate Scientist at DOE
- Active researcher in hydrogen & direct alcohol fuel cells and ammonia electrolyzers
- Strong track-record experiences in R&D of electrocatalysts, membrane electrode assembly (MEA), fuel cells & electrolyzers
- PI for two active ARPA-E sub-awards

- Network with participants to establish hybrid vehicle R&D collaborations
- Know more about new ARPA-E funding opportunity and topics

Technology Overview



- Low loading precious metal and non-precious metal electrocatalysts
- Hydrogen oxidation and oxygen reduction reaction in Polymer and solid-state alkaline fuel cells
- Electro-synthesis of ammonia
- Intermediate temperature (150~300°C) fuel cell and electrolzyer technologies

Meilin Liu
Georgia Institute of Technology, Atlanta, GA

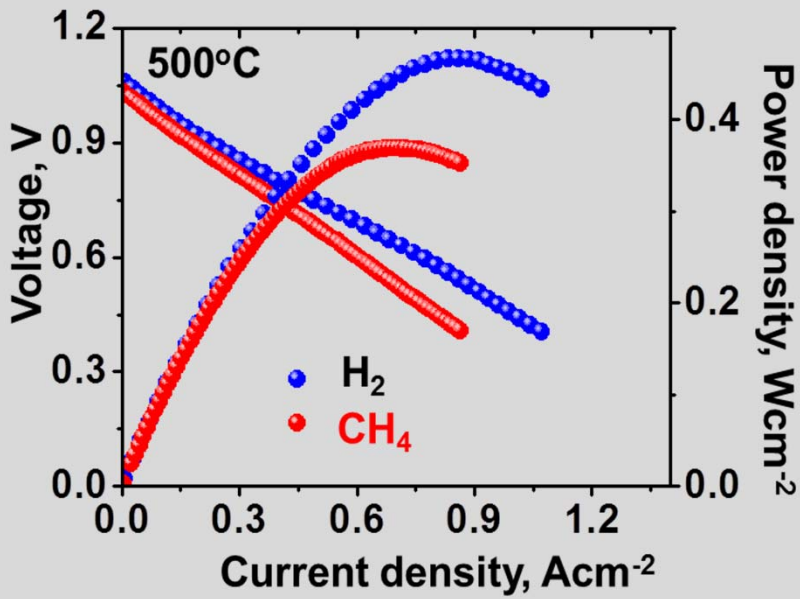
School of Materials Sci. & Engineering
Atlanta, GA, 30332-0245
E-mail: meilin.liu@gatech.edu
Tel: 404-894-6114
http://fcbt.mse.gatech.edu/liu.htm

B. Mifflin Hood Chair, Regents' Prof., and Associate Chair of the School of MSE, Ga Tech. Design, fabrication, *in situ/operando* characterization, & modeling of nanostructured electrolytes and electrodes, aiming at achieving rational design of new materials with unique functionalities and high-performance fuel cells.

- To define the scientific/technical challenges facing the development of a new generation of ITFCs for vehicle applications
- To form a strong team to address the critical challenges and advance ITFC technology

Technology Overview

Developed a robust intermediate-temperature fuel cell (ITFC) that enabled **direct utilization** of **nearly dry methane** (with ~3% H_2O) at 500°C, achieving a peak power density of ~380 mW cm^{-2} for a stable operation of >400 h. The cell consists of a highly efficient nano-fiber based cathode and a multi-functional anode, designed for internal reforming of methane promoted by an highly-efficient catalyst coated on the anode.



Xingbo Liu, West Virginia University

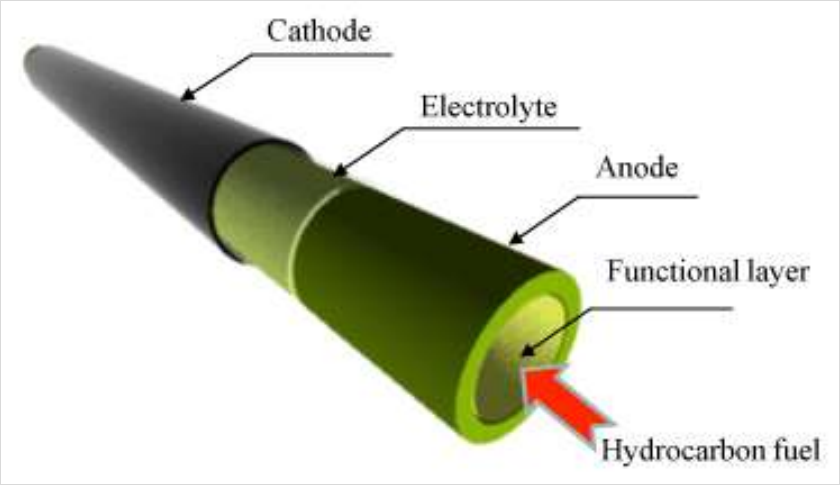
- PhD (1999) in MSE – Ni-base Superalloys
- Current Research Focus: High Temperature Electrochemical Materials & Processes (SOFC, HT electrochemical corrosions, etc.
- Associate Chair of Research in MAE Dept.: ICE, Hybrid systems.

- Vehicle system design to efficiently operate hybrid vehicle powertrains in real-world drive cycles;
- Required levels of hybridization for a range of transportation applications

Technology Overview

Metal-Supported Intermediate Temperature Solid Oxide Fuels

- Improved Toughness
- Improved Stability
- Reduced start-up Time
- Extra Functionalities

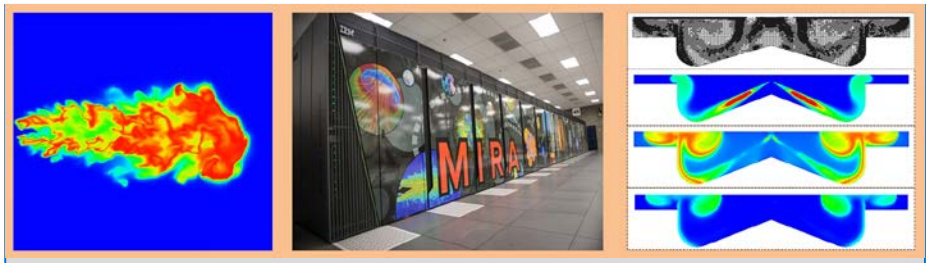


Douglas E. Longman
Argonne National Laboratory

Manager of Engine Combustion Research. This research spans internal combustion engine CFD, experimental study of fundamental combustion properties, automotive low-temperature combustion, heavy-duty IC engine biofuels, and large engine stationary and locomotive combustion and emissions research. Currently has a leadership role in DOE's Co-Optima Initiative.

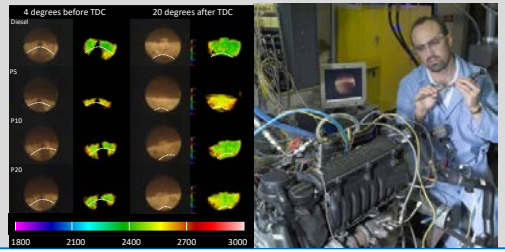
- The future role of internal combustion engines in hybrid vehicles and their contributions to efficiency, range, overall GHG, and vehicle cost.
- The future of IC engine fuels.

Technology Overview



Argonne's Center for Transportation Research (CTR) provides innovative solutions to challenges involving fuel efficiency, emissions, durability, safety, design and operating efficiency, petroleum dependence, interoperability, compatibility and codes/standards compliance and harmonization.

- Advanced Vehicle Technologies
- Engines and Fuels
- Friction, Wear, and Lubrication Technologies
- Thermal-Mechanical Technologies
- Transportation and Vehicle Energy Modeling
- Vehicle-Grid Interoperability



Ed Lovelace, CTO & VP Engineering, XL Hybrids

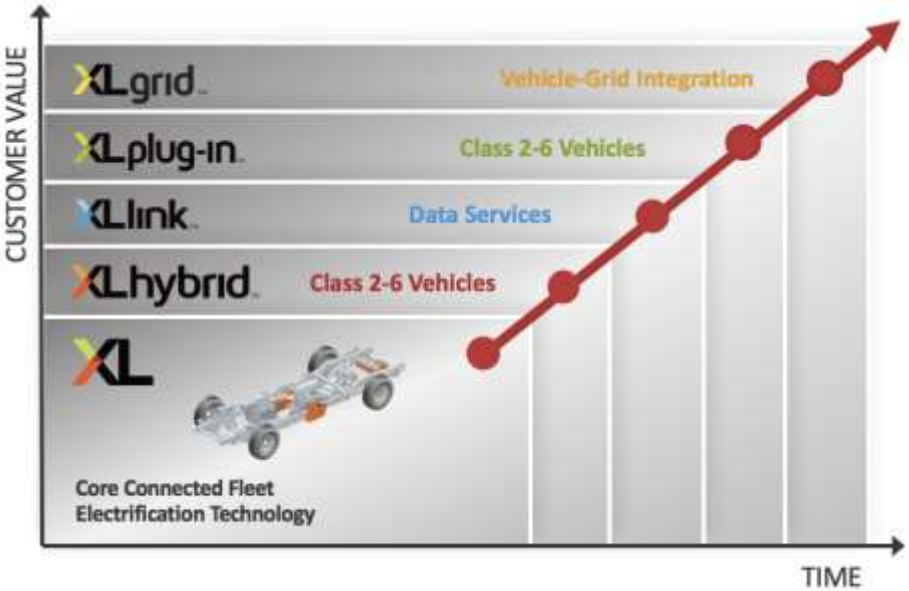
XLhybrids™

- Focus in electric power conversion technology for advanced transportation and renewable energy
- Previously at Free Flow Power (hydrokinetics), SatCon (mechatronics), and GE (aircraft engines)
- U.S. DOT Doctoral Fellow with MIT/Industry Automotive Consortium
- EE Ph.D., ME & EE M.S., and ME B.S. from MIT

- What is the DOE vision and how can our company participate with it
- Inform and understand stakeholder views on the product development factors that are specific to commercial vehicles

Technology Overview

- fleet electrification and connectivity solutions with over 51 million customer miles with the largest fleets in N.A.
- "platform product" strategy with a hybrid electric (HEV and PHEV) upfit for major OEM vans, trucks, and buses
- 20% to 33% fuel and GHG and up to 90% NOx through regenerative braking & propulsion assist
- little or no government incentives in some fleets
- XL is executing an electrification roadmap to leverage decreasing storage costs & increasing infrastructure



Peter Lynn, Otherlab

Otherlab

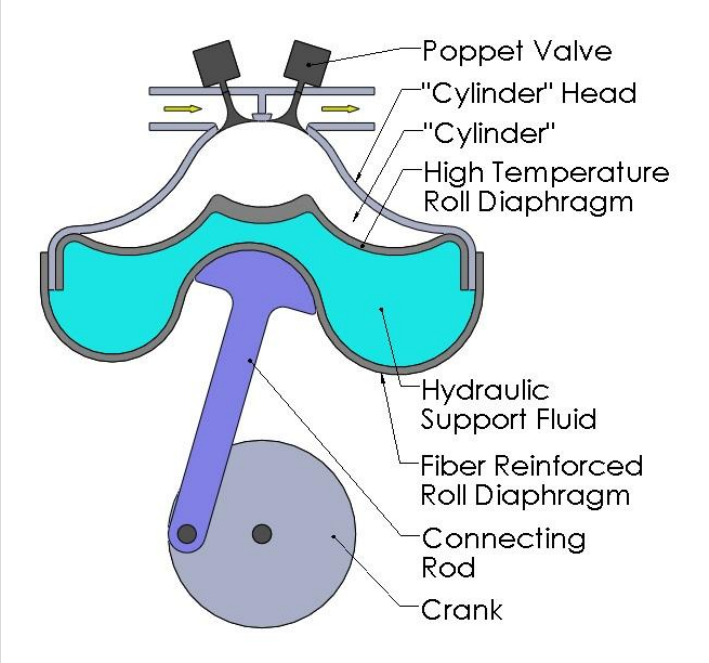
Thermodynamics, fluid dynamics, structures, and mechanical systems design. Airborne wind energy, inflatable robotics, solar tracking, electric aircraft, heat exchangers, compressors.

- Compliant adiabatic engine applicability to a possible FOA?
- $/kW capabilities of advanced fuel cell and/or engine systems - commercial viability?

Technology Overview

Inflatable Engines?

- No sliding seals
- No active cooling
- High power to weight ratio
- High expansion ratios
- Interesting materials challenges



Arkady Malakhov
Solid Cell Inc / NOVOROCS Technologies Llc

CEO, Solid Cell Inc
Managing Director NOVOROCS Technologies

Since 1998, Mr. Malakhov has been an investor and serial entrepreneur in the field of fuel cells. He started Solid Cell in 2006 to commercialize SOFC technologies.

- Explore R&D opportunities in hybrid vehicles
- Improved understanding of market drivers & customer needs for hybrid vehicle technology
- Identify potential partners for future collaboration & grant opportunities

Technology Overview

Solid Cell

- Early stage R&D in 3D printing of SOFCs
- Segmented micro-tubular SOFC stack design
- Patented cermet interconnect material
- Integrated TEGs for waste heat recovery

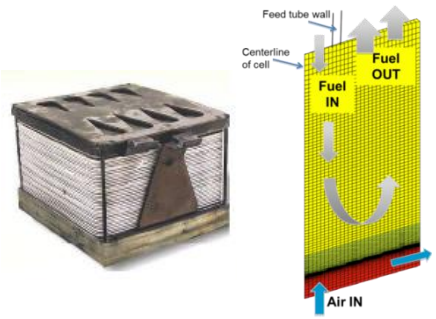
NOVOROCS Technologies

- Onboard catalytic fuel reforming of liquid fuels with metal foam supported structured catalysts
- Catalytic recuperators / tail gas combustors

Anode tail gas recuperator prototype for FC Bus

Olga Marina, Energy Processes and Materials
Pacific Northwest National Laboratory

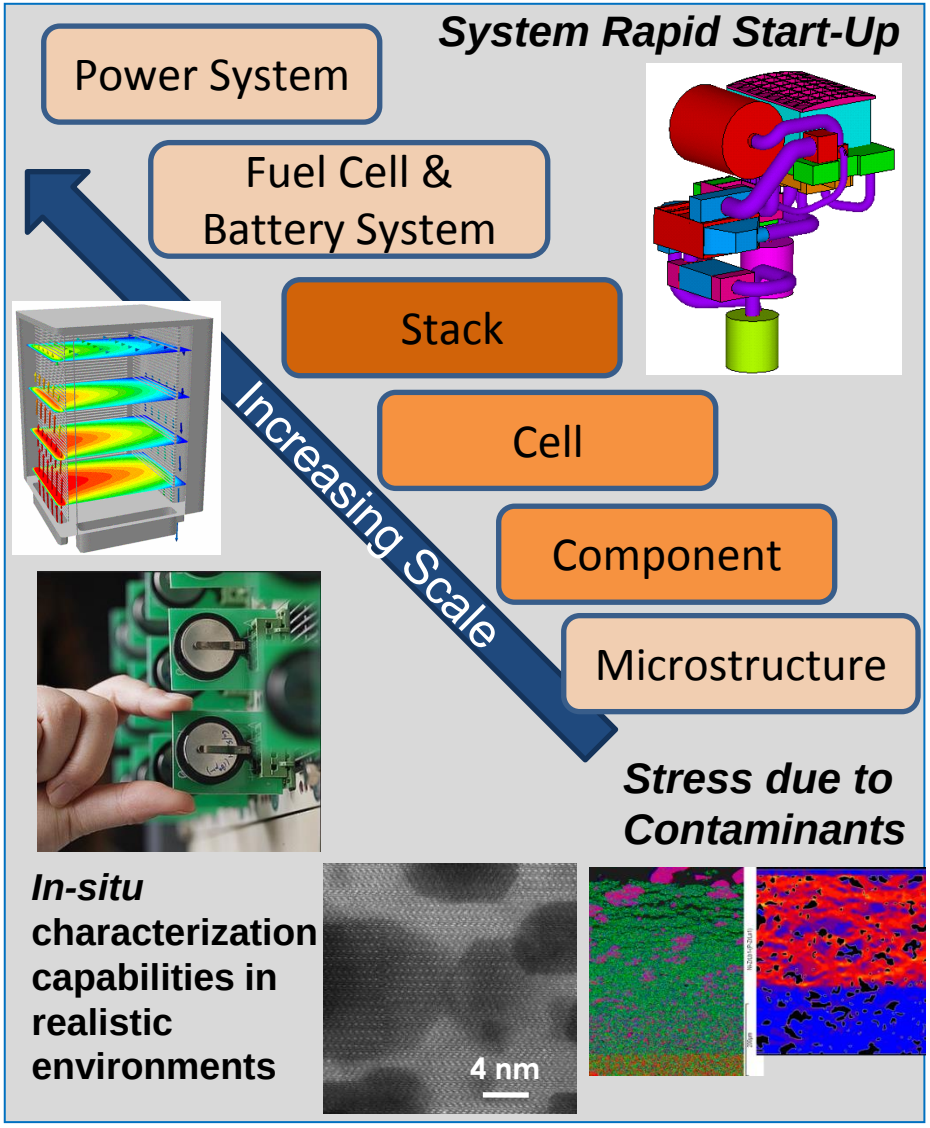
Pacific Northwest
NATIONAL LABORATORY



- Development of innovative materials for fuel cells, electrolyzers, sensors, and batteries.
- Fuel purification and fuel processing.
- Catalysis & Electrocatalysis. Electrochemical fuel and chemicals syntheses.
- Joint PNNL in 1999. PhD in Chemistry.

- We offer PNNL's expertise and unique capabilities in modeling, developing, fabricating, testing, and characterizing multiple cells and stacks.
- Will partner to establish successful programs.

Technology Overview



Brian McKay, Continental Automotive

Continental
The Future in Motion

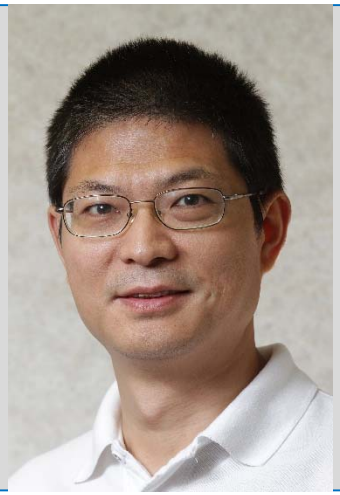
- Director of Powertrain Technology & Innovation for North America
- Spans electrification, combustion and emissions. Focus on future mobility.
- Previously worked at Marathon Petroleum & U.S. Army TARDEC

- Interests: brainstorming breakthrough technologies with the brightest & best.
- Takeaway: identify technology interest areas/concentrations

Technology Overview

- Continental has a broad range of components and systems to support electrification, combustion and emissions.
- Bring forth technology concepts and advanced prototypes to discussion.

Chris Mi, Ph.D, Fellow IEEE
Professor and Chair, San Diego State University



SAN DIEGO STATE UNIVERSITY

Leadership Starts Here

Chris Mi is a fellow of IEEE, Professor and Chair of the Department of Electrical and Computer Engineering at San Diego State University. He was previously a professor at the University of Michigan, Dearborn from 2001 to 2015. He received the B.S. and M.S. from Northwestern Polytechnical University China and the Ph.D. from the University of Toronto.

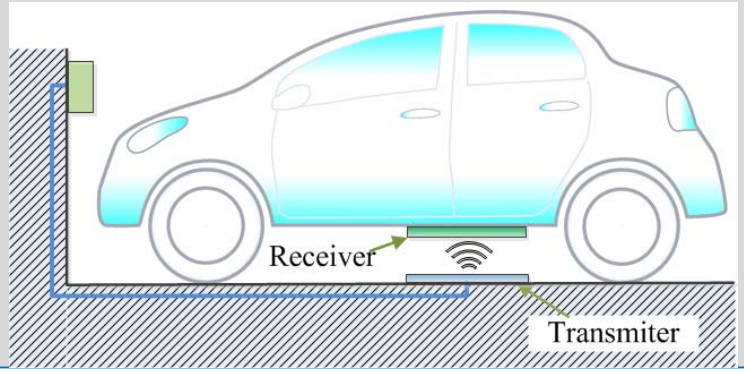
- Learn the latest technology in HEV energy efficiency
- Learn the future funding opportunities and collaboration opportunities with the government and the industry

Technology Overview

Wireless power transfer (WPT) technology offers significant improvement in convenience and electric safety for electric vehicle (EV) charging. Our research aims at novel designs that considerably reduce size and cost while increasing the coupling coefficient and improving the misalignment capability.

We have developed a double-sided LCC topology to further enhance the system efficiency in the tens of kilowatts, over 200mm distance, efficiency of 97% (DC-DC), and a misalignment tolerance of up to 300mm.

We have shown that it is also possible to achieve excellent efficiencies with a capacitive system, reaching kW range and 93% efficiency for CPT.



Nguyen Minh

University of California, San Diego (UCSD),Center for Energy Research

UC San Diego

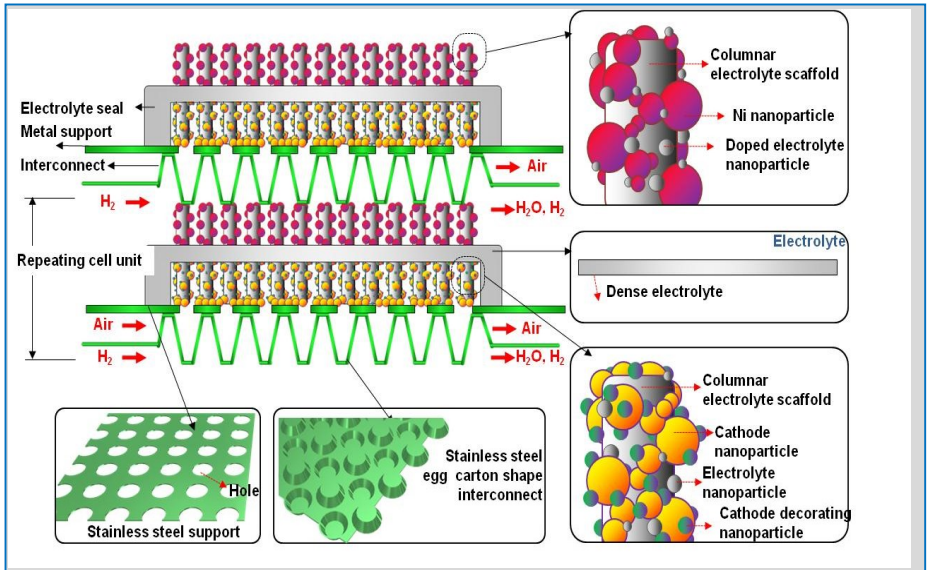
CER Center for Energy Research

•An internationally well known expert on solid oxide fuel cells and related technologies
• Extensive experience on a full spectrum of industrial and product R&D areas
• Former Chief Scientist and Manager, Fuel Cells at GE and Honeywell/AlliedSignal

Obtain a better understanding of

- Critical issues in incorporating fuel cells in hybrid vehicle power systems
- Requirements for the key drivers (cost, efficiency and reliability) to enable commercialization

Technology Overview



Stack design

• Metal supported cell configuration with an engineered structure and reliable gas seals for efficient operation at reduced temperatures
• Egg carton shaped prime-surface interconnect

Stack features

• Reduced weight and volume
• Increased reliability
• Potential cost competitive cost

Los Alamos National Laboratory

Rangachary Mukundan (Mukund) is a technical staff member at the Materials Synthesis and Integrated Devices (MPA-11) group. He received his Ph.D. in Materials Science and Engineering from the University of Pennsylvania (Philadelphia) in February 1997. His current research interests include fuel cells, electrochemical gas sensors, and energy storage devices.

What role can Polymer Electrolyte Fuel Cells (PEFCs) play in hybrid card other than FCEVs

What role can Ammonia play as a hydrogen carrier or an alternative high energy density fuel

Technology Overview

PEFC durability (Range extenders for Battery vehicles)

Electrochemical NH3 production (Electricity to useful chemicals)

Keith Oglesby
Manager, Electrified Powertrain Systems

Research & Advanced Engineering

Background:

Over 20 years of experience in advanced automotive powertrain technologies. Mr. Oglesby has implemented several hybrid, battery electric, and fuel cell powertrains in both prototype and production vehicles. He has held various Ford positions in product development, advanced engineering, and research, and also served as the Research Director of the Automotive Fuel Cell Cooperation joint venture.

Meeting Interests:

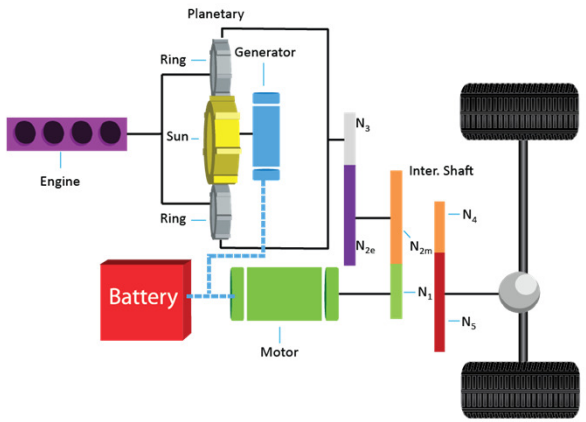
Technology solutions to address key challenges:

- High Efficiency & Criteria Emissions
- P/T technology sharing across applications
- Solutions for Commercial vehicles

Technology Overview

Powertrain systems combining energy conversion and electric propulsion technologies:

- Hybrid Electric Vehicles
- Plug-in Hybrid Electric Vehicles
- Battery Electric Vehicles
- Fuel Cell Vehicles



Gen I

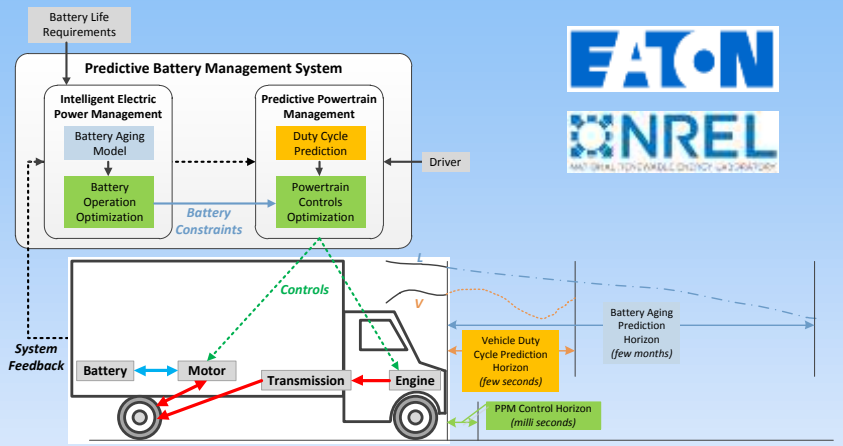
Gen III

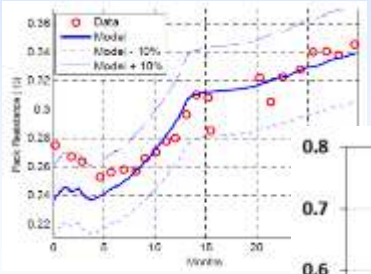
Chinmaya Patil

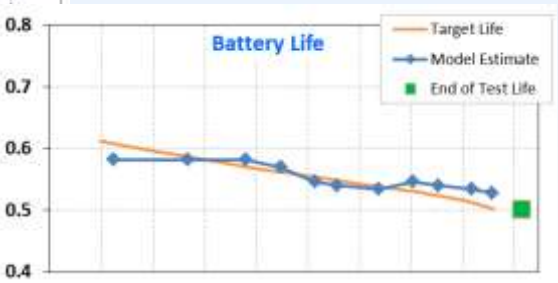
- Senior Engineering Specialist with Eaton Corporate Research and Technology
- Leading the development of advanced energy storage management
- Ph.D. in Mechanical Engineering from The University of Texas at Austin (2008)
- Over fifteen publications in peer-reviewed conferences and journals in dynamic systems, model predictive controls, and system optimization applied to hybrid power systems.

- Opportunities and Challenges of next gen high efficiency hybrid electric vehicles
- Energy storage management needs for ICE and Fuel-cell HEVs

- Predictive Battery Management System for Commercial HEVs – funded by ARPA-e AMPED Program (2013 – 16)







Mike L. Perry, United Technologies Research Center (UTRC)

United Technologies Research Center

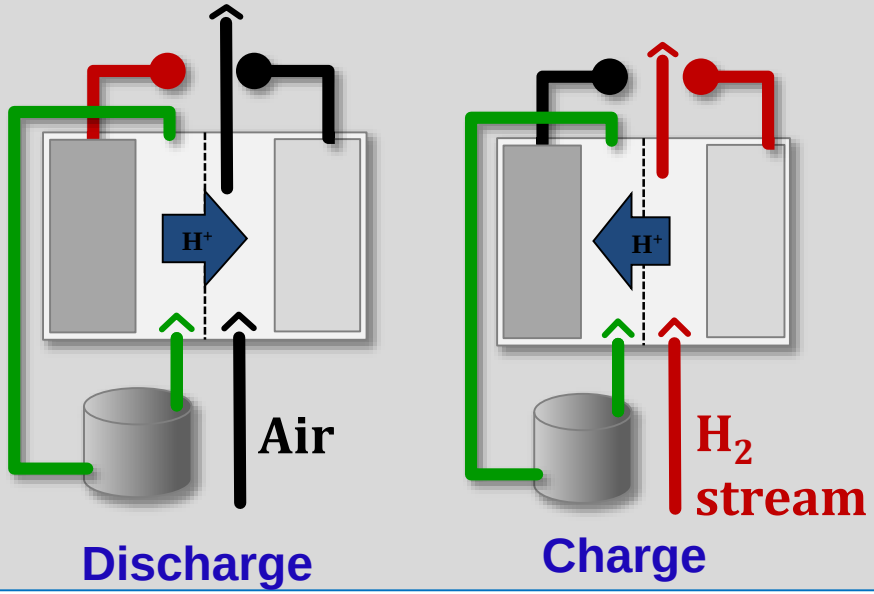
- **Associate Director, UTRC,** 2008 to present
  - Electrochemical Systems
    - Redox Flow Batteries (RFBs) & PEFCs
- **R&D Engineer, UTC Power,** 1999 to 2008
  - PEFC technology: cells, stacks, & systems
  - UTC's PEFC transit Bus has > 25,000 hours
- **> 60 patents/applications** (PEFCs or RFBs)
- **M.S., Chem. Engineering, U.C. Berkeley**
  - Professors John Newman & Elton Cairns
- **Naval Aviator, U.S. Navy,** 1986 to 1995

Learn more about:
- Advanced hybrid-vehicle powertrain architectures
- Perspective of automotive OEM on new liquid fuels

Technology Overview

Rechargeable Liquid Fuel Cells

- ***Energy stored in a liquid that can be electrochemically dehydrogenated and re-hydrogenated reversibly***
- ***System potentially enables the best attributes of both BEVs and FCEVs:***
  - ***No gas-phase storage***
  - ***No H_2 purification or compression***
  - ***Onboard recharging OR fast refueling***
  - ***Liquid stored in conformable tanks***



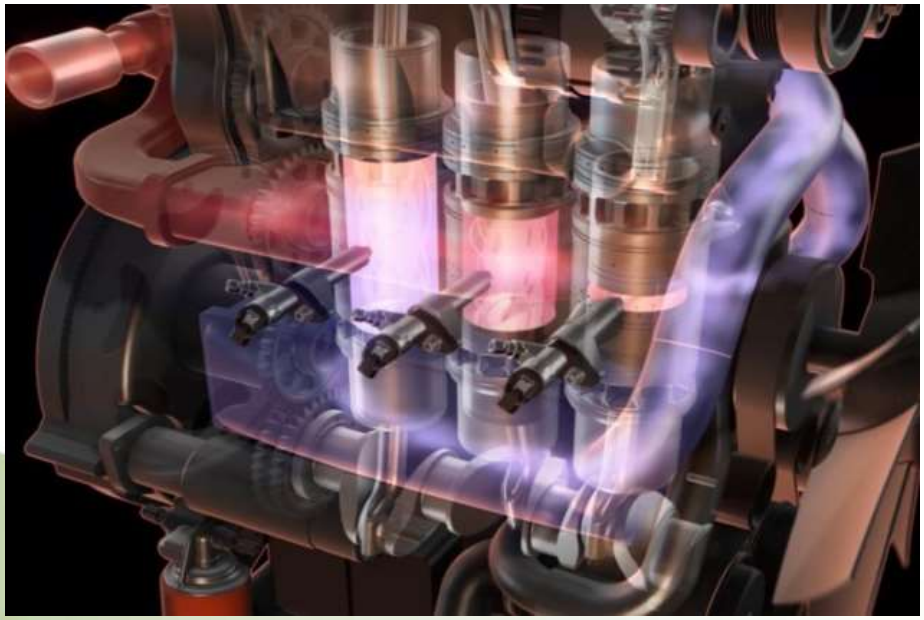
achatesPOWER™ Fundamentally Better Engines®

Mr. Fabien G. Redon,

Joined Achates Power in 2009 as Vice President of Performance and Emissions, now Vice President of Technology Development, formerly at General Motors and Detroit Diesel.

Looking to contribute internal combustion engine expertise to the team and to find synergies with other technologies to create the most efficient hybrid powertrain system.

Opposed Piston Engine



- 50%+ efficiency
- Superior emissions controls
- Over 8000 hours, vehicle development on-going
- Runs on conventional fuels
- Perfectly balanced
- Fast starting
- Cost competitive to current high volume production engines
- Utilizes conventional engine materials and manufacturing processes

Denise M. Rizzo
US Army RDECOM TARDEC - Analytics

- Senior Research Mechanical Engineer
- Specialize in modeling, simulation and control of propulsion systems of ground vehicles
- Ph.D. from Michigan Technological University
- Controls research and development engineer in the Powertrain Group at Chrysler LLC (2000-8).
- Published 14 journal articles, 23 conference proceedings papers, 4 technical government reports, and holds 2 patents.

- Greater understanding of commercial direction
- To bring the scalability challenge to the forefront

Technology Overview

Potential military hybrid vehicle programs:

- SCARAB
- Squad Mission Equipment Transport (SMET)
- Electric / Hybrid Combat Vehicle

Giorgio Rizzoni, The Ohio State University, MAE and ECE Departments, Center for Automotive Research

THE OHIO STATE UNIVERSITY

CENTER FOR AUTOMOTIVE RESEARCH

BS, MS, PhD, UMich, 1980, 1982, 1986. Modeling, control and diagnosis of advanced propulsion systems, vehicle energy efficiency, alternative fuels, policy and economic analysis of alternative fuels and vehicle fuel economy. Fellow of SAE (2005) and IEEE (2004)

- Seeking partners to develop high efficiency hybrid propulsion concepts
- 25 years of experience in the development of electric and hybrid vehicle prototypes and concept vehicles

Technology Overview

Participated in the development of 10 hybrid electric and two fuel cell prototype vehicles, and four high performance electric vehicles that have set numerous records,.

System integration expertise includes system modeling, design optimization, energy efficiency analysis and energy management and control of hybrid propulsion systems, with strong physical understanding of combustion engines, fuel cells, electric drives, electrochemical energy storage systems and mechanical transmission.

Darrell Robinette
Michigan Technological University

Michigan Technological University

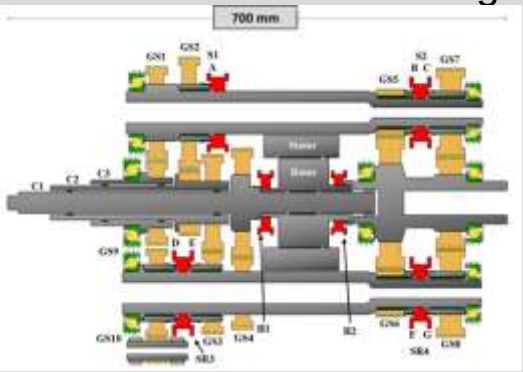
APS LABS

- General Motors Powertrain – 9 years
  - Drivetrain design, controls, integration and NVH
- Michigan Technological University – 1 year
  - Assistant Prof – Mechanical Engineering

- Insight into next generation architecture for electrified propulsion systems
- Prime mover (ICE and/or FC) technologies are being developed and synergies with new drivetrains

Technology Overview

- Transmissions highly adaptable to new engines and electrification configurations



- Connectivity and automation of propulsion system controls to reduce fuel consumption

Chris Robinson – Lux Research

luxresearch

As an analyst, I cover emerging energy storage technologies and how they are impacting the automotive industry.

In this discussion, I'm looking to: understand the role hybrid vehicles will play in automakers meeting emissions regulations and what battery technologies can enable this.

Technology

As an analyst at Lux I'm not a developer of new technology, but rather help companies identify opportunities in the energy storage industry. We build economic models, conduct primary interviews with technology developers, and generally keep a pulse on the future of the automotive industry.

Precision Combustion, Inc.

North Haven, CT

PCI
Precision Combustion, Inc.

- Vice President R&D
- M.S., D.E. Mechanical Engineering
- *Expertise in* catalysis, reactors, combustion, fuel cell systems, fuel reforming, H_2 generation, IC engines, turbines, generators, catalytic after-treatment, air-purification.
- Holds over 30 patents.

Interests:

- Identifying technical viability of *mobile* high efficiency IC engine/Fuel Cell configurations
- Utility of multi-fuel reformers & H_2 generators as an enabling technology

Technology Overview

- PCI has been working primarily on advanced catalyst based solutions for reforming and sulfur cleanup of liquid fuels (Jet-A, diesel and gasoline) for fuel cell applications.
- PCI has developed complete fuel cell & IC engine based hybrid power generation solutions, including balance of plant components and power electronics suitable for mobile applications, largely for the DoD.
- PCI does not develop Fuel Cells or IC engines.
- Our objective is to advance and implement the developed technologies for cost-effective, practical solutions in future commercial vehicles.

Ben Saltsman, Director Advanced Product Development
Magna International, Corporate R&D

Technology Overview

MAGNA
DRIVING EXCELLENCE.
INSPIRING INNOVATION.

- 20+ yrs in NPD at OEM, Tier 1
- Lead innovation projects from concept to implementation, collaborating with internal and external stakeholders
- MS Materials Science, Stevens Inst of Tech
- MS System Design and Management, MIT

- Help evaluate potential technologies
- Seek out areas of interest, partners for Magna
- Information gathering and awareness building

Jason Schwanke – Sr. Engineer, Team Leader
Robert Bosch LLC – Gasoline System & Advanced Engineering

BOSCH
Invented for life

- Graduated in 2009 from the University of Wisconsin, BSME
- System & Advanced Engineering since 2011
- Participated in projects relating to HCCI/SACI combustion, mHEV and PHEV powertrain controls

- To understand the landscape regarding opportunities to research purpose built ICEs for hybrid applications
- Understand the technology roadmap for FCV vs ICE based hybrid vehicles and where we want to grow in future research

Technology Overview

- Embedded control systems and control software for traditional ICE powertrains as well as hybrid, battery and fuel cell vehicles
- Sensing solutions and core components for all the above powertrains as well as enabling technology for autonomous vehicle operation

Dr. Alexey Serov,
Pajarito Powder, LLC

PAJARITO POWDER
FUEL CELL CATALYSTS

Dr. Alexey Serov is Chief Scientist at Pajarito Powder, LLC. He manages all Pajarito R&D activity, including projects funded by: industry, ARPA-E, DOE-EERE and SBIR.

Goals for workshop:

- Understand the general/specific technological requirements for High Efficiency Hybrid Vehicles
- Find the best fit of fuel cell technologies for HEHV application

Technology Overview

Pajarito Powder works on design, synthesis, scale up and manufacturing of fuel cell and electrolyzer materials.
The range of our materials fits to: Proton Exchange Membrane, Anion Exchange Membrane, and HT PEM fuel cells operated with gaseous (H_2) and liquid (alcohols, DME etc) fuels.
Pajarito manufactures and commercially supplies:

- Engineered Catalysts Supports (ECS) for highest utilization of PGM nano-structures with improved stability and durability of final electrocatalysts
- Completely PGM-free ORR catalysts for low power density applications
- Custom designed anodic electrocatalysts for different fuels oxidation (both AEMFC and PEMFC)
- Materials for electrolyzers (HER/OER) still in R&D stage

Chris Shamie

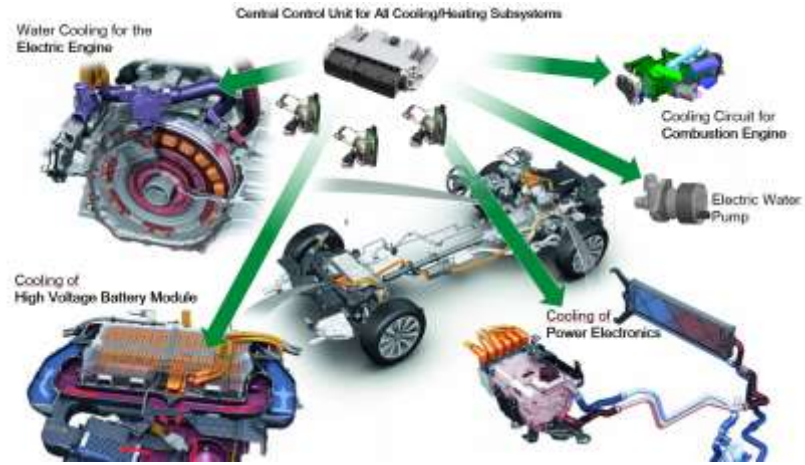
Manager of Application Engineering at Schaeffler

SCHAEFFLER

Chris's group oversees the integration of Schaeffler transmission technology such as P2 electric drives, eAxles, torque converters, double clutches, CVT chains, and other transmission systems and subsystems. Chris has been with Schaeffler for 16 years and has a background in product development.

Meeting Objective: To determine if Schaeffler technology can be used to further the development of high-efficiency electrified vehicles.

Technology Overview



Thermal Management Module for Complete Powertrain

Variable Cam Phasing

Switchable Valvetrain

Uni-Air

Torque-dense eAxle Gearboxes

Phillip Sharer
Argonne National Laboratory

- AMBER Developer 2015-Current
- Autonomie Developer 2007-Current
- PSAT Control/Studies 1999 - 2007
- Master's Degree Engineering 2002
  - Purdue University Northwest

Understand how we can help predict the benefits that the next stage of advanced vehicle technologies will have on certification cycles and real world cycles, while considering any future effects that CAVs will have on these benefits

Technology Overview

AMBER – Model Based System Engineering Framework – integration, workflow creation

Autonomie – Large scale vehicle simulations

- Parallel Pre, Post, Split, Multi-mode, PHEV, fuel cell, BEV across all classes
- Control for each of these configurations
- 100,000s of individually **sized** vehicles across both light and heavy duty classes millions of vehicle simulations
- Control development PMP, MPC

www.autonomie.net

RoadRunner - Closed-loop CAV simulation framework to model Eco-Driving

- Mixed powertrains hybrid, fuel cell, Electric, PHEV
- Platooning & CACC situations, V2I, V2V

SVTrip -
Synthetic Vehicle Trip Profile Prediction

- HERE maps generates naturalistic speed profiles

POLARIS

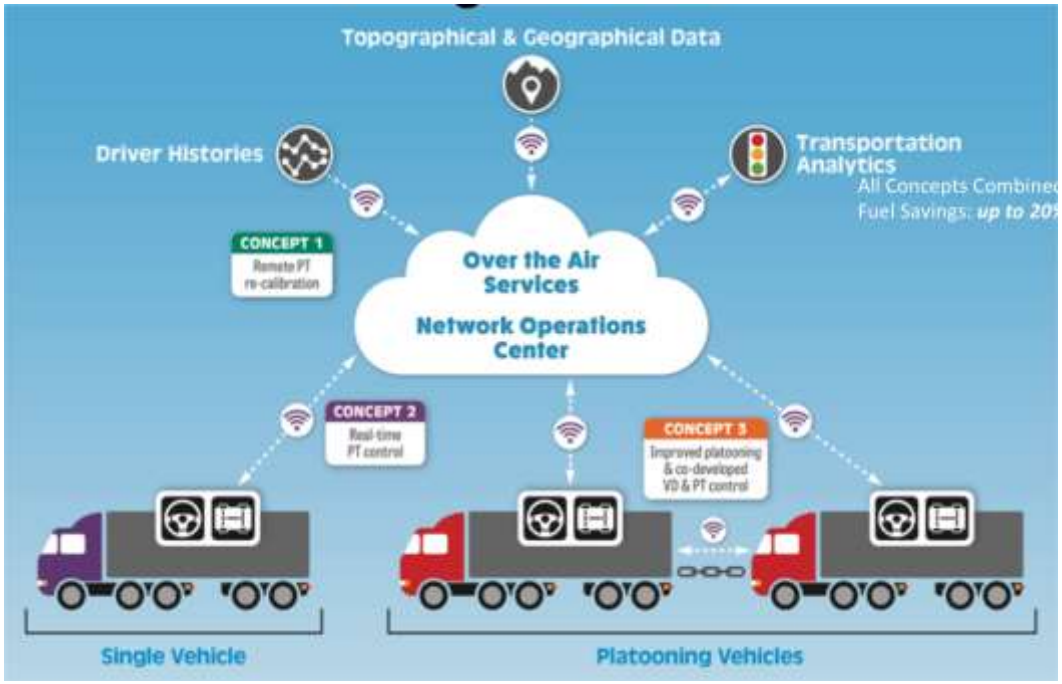
- Agent based decision modeling, predicts activity

Greg Shaver, PhD
Professor of Mechanical Engineering, Purdue University

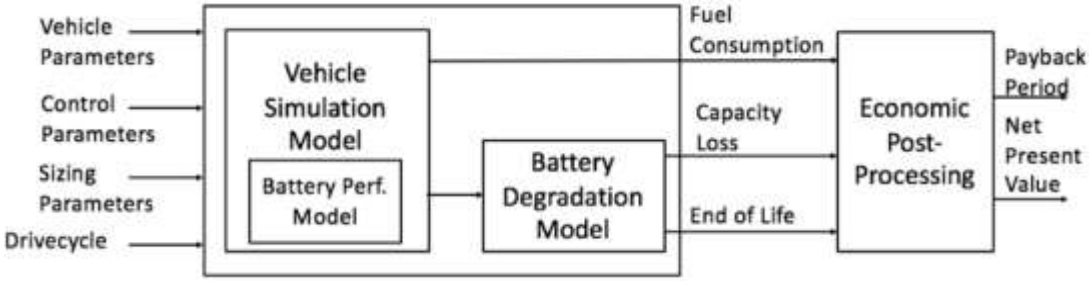
Univ. Faculty Scholar & Early Career Research Awardee. >100 peer-reviewed papers. PI for DOE Heavy Hybrid Center & ARPA-E project focused on 20% fuel consumption reduction of class 8 trucks. 2005 Stanford PhD. 2000 Purdue BSME.

- Understand & influence future of highly efficient, clean vehicle powertrains.
- Share relevant research ongoing at Purdue & create new partnerships/collaborations.

Technology Overview



Integrated control/design of powertrains & vehicles (including connectivity & automation)



Integrated control/design of hybrid powertrains

Tom Shieh
TOYOTA MOTOR NORTH AMERICA Research & Development

TOYOTA MOTOR NORTH AMERICA
Research & Development

Position:
Executive Engineer, Powertrain

- 2002-present: Toyota Motor North America
- 1995-2001: Ford Motor Company
- 1992-1995: NASA Johnson Space Center

- What is the major influencing factors for the selection of future powertrain? (regulation, material cost, etc.)

Technology Overview

Optional: Describe your technology relevant to this workshop in a few bullets and add a summary graphic if possible.

Nikolay Shkolnik, LiquidPiston, Inc. (LPI)

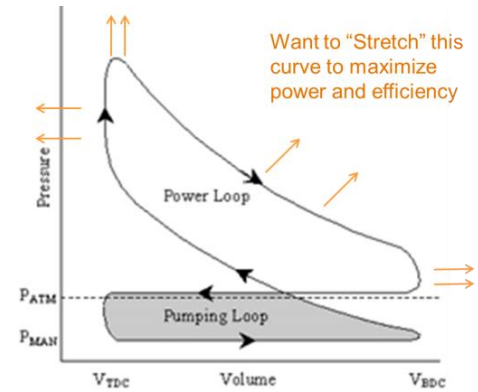
Chief Technology Officer, cofounder, LiquidPiston

Ph.D. in Physics from University of Connecticut. 13 publications, 27 patents, 11 patent applications pending. TRIZ practitioner and recipient of the Motorola award for creativity.

Desired meeting goals:

- For ARPA-e: to consider novel thermodynamic cycles and engine architectures
- For LPI: interested in teaming opportunities

Technology Overview



High-efficiency
- 57% BTE potential

Compact and lightweight
- 1.5 hp / lb.

Scalable

Low cost at volume

Quieter

Low-vibration

Kalyan Srinivasan
The University of Alabama

Dr. Srinivasan's primary research interests are in developing high-efficient combustion concepts for future light- and heavy-duty transportation applications. He has published more than 50 peer-reviewed articles on combustion, waste energy recovery and other related technologies in the last 12 years.

- Exploring powertrain architectures that have potential to yield high efficiencies with low CO_2 foot-print.
- Interested to learn about system-level barriers that prevent optimal operation of current ICE-hybrids

Technology Overview

Optional: Describe your technology relevant to this workshop in a few bullets and add a summary graphic if possible.

Anna Stefanopoulou
University of Michigan -- Ann Arbor

Powertrain Control

University of Michigan

- Diploma in Propulsion Power, Naval Arch
- PhD in Engine Controls, Electrical Engr.
- Technical Specialist, Ford, US
- 2007 ASME Felow, 2009 IEEE Felow
- 20 patents, 250 pubs, 10k citations
- Professor of Mechanical Engineering
- William Clay Ford Professor of Manufacturing
- Automotive Research Center Director

Highly efficient engines and fuel reformers do not like transients nor fuel variability, hence:

- How much model-predictive control will be essential for this solicitation?
- What are the assumption on sulfur level and fuel variability in this solicitation?

Technology Overview

- **Control of Advanced Engine Systems**

Novel Actuation (camless, boosting, …)
Highly Diluted Combustion (at the misfire limit)
Fuel variability (adaptation, recognition, learning)

- **Balance of Plant for Fuel Cell**

PEM (humidity, thermal, poisoning)
SOFC (thermal gradient constraints)
Dead-ended Anodes
Free Breathing Cathodes

- **Control of Reformers**

Hydrogen on demand (start-stop, sensors)
CPOX
Steam Reforming
Membrane Separators

- **Battery Management Systems**

Modeling (Equivalent Circ, Electrochemical)
Estimation of SOC, SOH, SOP
(2016 IEEE Control sys techn award)

Neal P. Sullivan

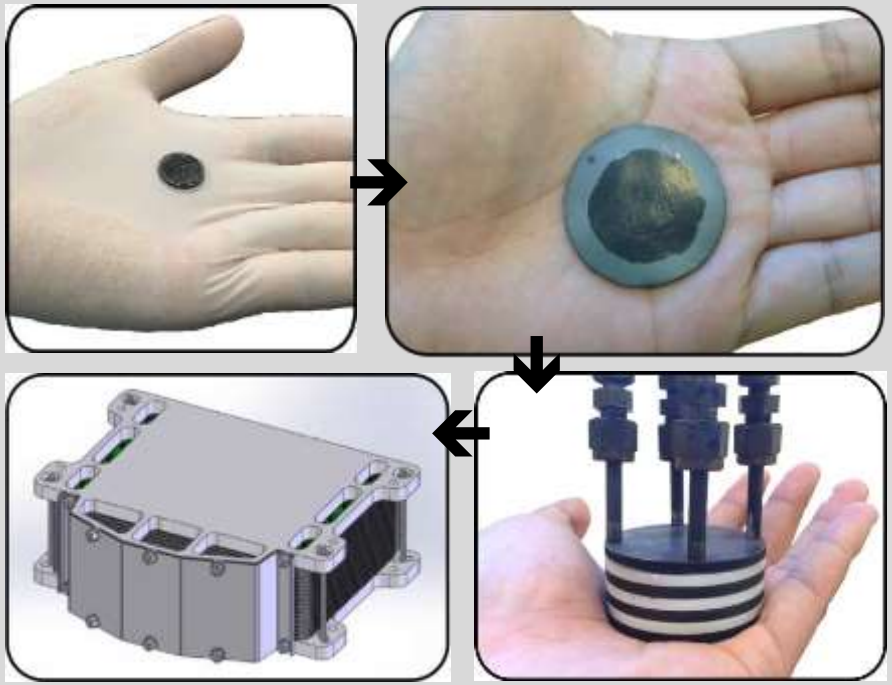
Associate Professor of Mechanical Engineering, Colorado School of Mines

- Director of the Colorado Fuel Cell Center
- Experimentation in solid-oxide fuel cells
- Next-generation ceramic ion conductors
- Proton-conducting ceramics
- Cell fabrication and characterization
- Stack development
- kW-scale system demonstrations

Meeting objectives

- Explore opportunities to apply proton-conducting ceramics in system hybridization
- Network with developers to understand technological needs

Scale-up of Proton-Conducting Ceramic Fuel Cells at Mines



Benefits of protonic ceramics

- Small charge carrier for higher conductivity
- Lower temperature operation (400 – 600 ºC)
  - More robust for longer life
  - Less-expensive hardware
- Fuel flexibility
  - Gaseous and liquid hydrocarbons
  - Ammonia fuel

Bapi Surampudi, Southwest Research Institute

Dr. Bapi Surampudi has been active in control system development for automotive hybrid powertrains for the last 26 years. He has been managing the Energy Storage System Evaluation and Safety (EssEs) Consortium which benchmarks commercial battery cells for characterization, life and safety. Dr. Surampudi also conducts xEV operational benchmarking with in-situ instrumentation

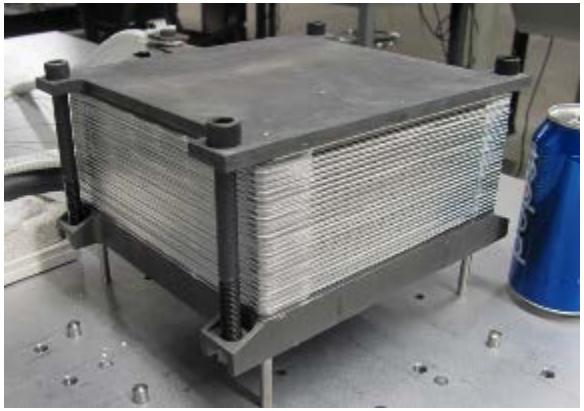
- Participate in brainstorming of state of the art hybrid powertrain topologies
- Become aware of peer thinking and direction of current research

Technology Overview

SwRI has access to customized HIL test stands for validating advanced control strategies in hybrid powertrains with free piston engines, integrated engine-motor systems and battery-fuel cell hybrids

Scott L. Swartz, Ph.D. (Nexceris, LLC)

NEXCERIS
where energy meets environment



Dr. Swartz a co-founder of Nexceris and serves as Chief Technology Officer. He has a B.S. in Ceramic Engineering from Alfred University and a Ph.D. in Solid State Science from The Pennsylvania State University. He has 30+ years of experience and a rich history of innovation in electronic ceramics, solid oxide fuel cells, catalysts and sensors.

Nexceris Interest in this Workshop

- Nexceris is interested in applications where our SOFC stack technology has enabling attributes.
- We offer to customize our SOFC stacks to meet the requirements of hybrid propulsion systems

Relevant Nexceris Technologies

- Ultra-high power density SOFC stack designs and anode technology that enables sulfur tolerant SOFC operation.
- Hydrogen safety sensors for hybrid systems that include PEM fuel cells
- Off-gas monitoring for enhancing safety of lithium ion batteries

Greg Tao, Chemtronergy

CTG Chemtronergy
from laboratory concepts to marketable products

3619 West 1987 South
Salt Lake City, UT 84104
Tel: (801) 981-9997
gtao@chemtronergy.com

- Vice President of Chemtronergy
- >19 years' hands-on experience in
  - Solid-oxide fuel cell for power generation – highly performing materials, cell/stack design & optimization
  - Solid-oxide electrolyzer for hydrogen production oxygen/fuel cogeneration – cell/stack long-term stability enhancement, sealability, cogeneration flexibility
  - Na-metal halide battery for grid scale energy storage

Fuel-flexible SOFCs for hybrid vehicles

- Application – operating conditions, power/energy limitation, start-up, cycling
- Implementation – power/energy limitation, CHP/CCP, system architecture
- Other associated challenges & needs – i.e. sensors

Technology Overview

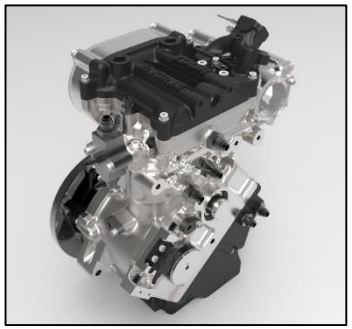
State-of-the-art SOFC Technologies

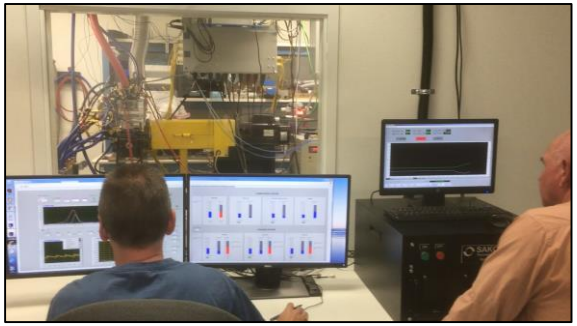
- **Cell structure**
  - Self-supported configuration (electrolyte-supported, anode-supported, cathode-supported)
  - Externally-supported configuration (i.e. metal-supported)
- **Cell architecture**
  - Picture frame design, internally-manifolded design, and cassette design
- **Cell manufacturing techniques**
- **Stack design**

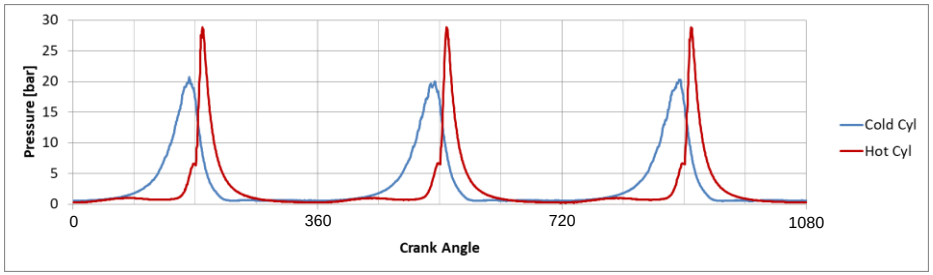
Chemtronergy SOFC Technology

- Engineering highly-performing cell materials for performance enhancement
- Implementing advanced solutions for cell/stack lifetime extension
- Advanced stack design for easy manufacturing
- Unique manufacturing processes enabling light-weight, high-energy density, fast-ramping SOFC

Dr. Oded Tour, Tour Engine, Inc.







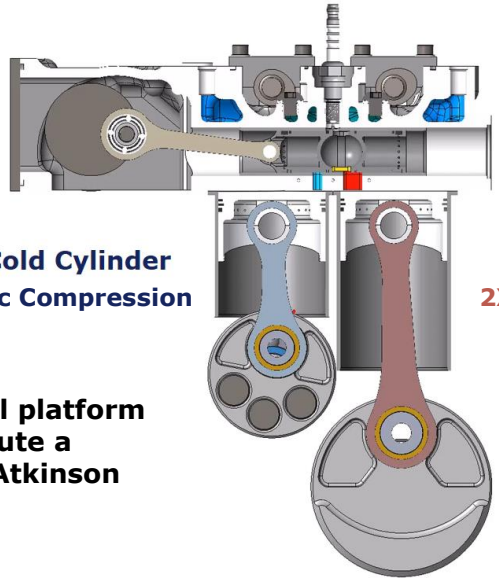
- 1 kW NG engine for ARPA-E GENSETS
- 10 people are developing the engine and collaborating with partners such as WERC
- Proposing a 35 - 50 kW gasoline engine

Oded Tour's Bio:
- CEO and Co-Founder of Tour Engine, Inc.
- Developing split-cycle engines since 2006

Interest in this ARPA-E workshop:
- Form a strong collaborative group
- Establish joint ventures

Technology Overview

Thermally Optimized, Spit-Cycle Design



Spool-shuttle + crossover valve + combustion chamber

Cold Cylinder
X cc Compression

Hot Cylinder
2X cc Expansion

An ideal platform to execute a Miller/Atkinson cycle

Reducing Cooling Loss

- At the Cold-Cylinder: Intake and compression occur in a separate cylinder that is relatively cold, therefore less active cooling is needed
- At the Hot-Cylinder: The extra expansion lowers the average temperature of the working fluid and reduces the need for active cooling

Reducing Exhaust Loss

- At the Hot-Cylinder: Extra expansion lowers the exhaust enthalpy and increases the usable kinetic energy output of the engine

Reducing Dead Volume

- The Tour engine is designed to have a high volumetric efficiency

Michael Traver, Aramco Services Company

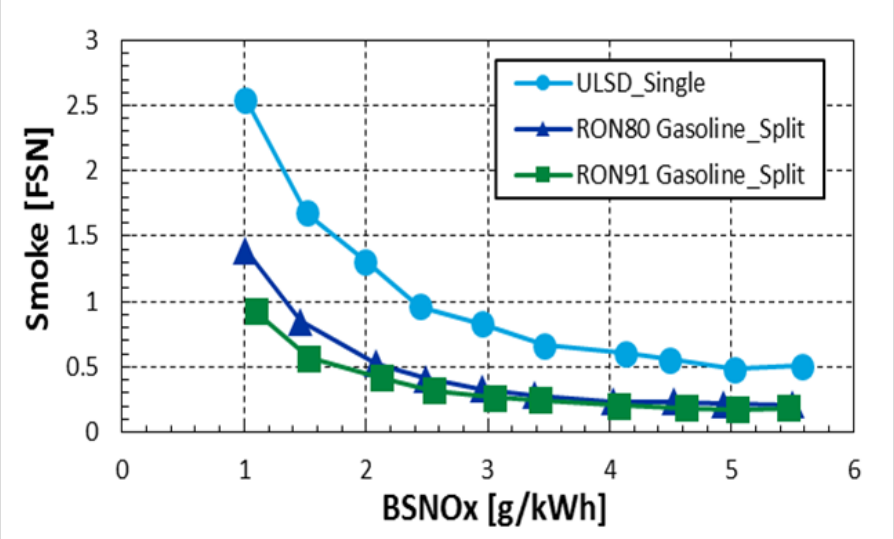
- Earned Ph.D. from West Virginia University
- From Project Engineer to Business Unit Director - Diesel Engines at IAV
- Currently at Aramco Leading Commercial Transport Fuels Research
- Chair SAE TEVEM/Member EMA-EMTC

What is the role of the ICE in future commercial transportation scenarios?

What is the optimum level of electrification in a well-to-wheel analysis?

Technology Overview

- Investigating the optimization of fuels and engines together
- Exploring the behavior of low reactivity fuels in both mixing controlled (diesel) and pre-mixed (GCI) combustion modes
- Experimental and simulated results suggest there are opportunities for emissions and efficiency improvements with compression ignition of gasoline range fuels



Mike Tucker
LBNL

Research Scientist, Energy Conversion group

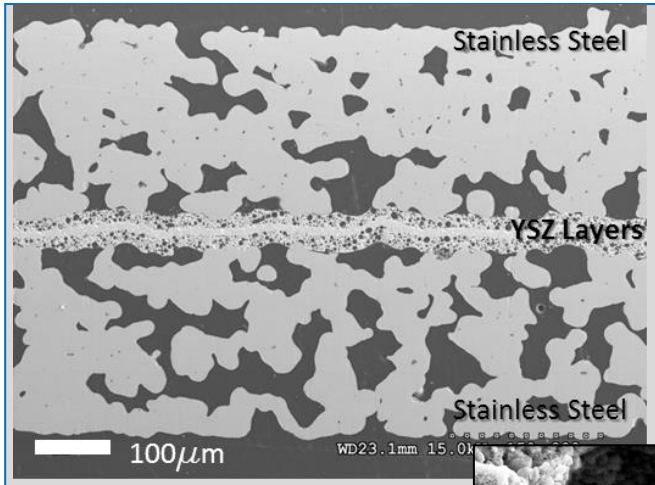
Co-Founder, CTO of Point Source Power (2008-2013)

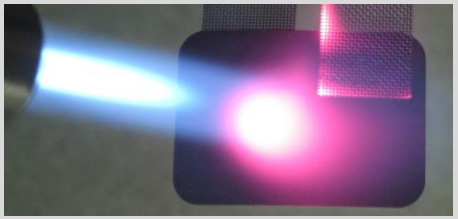
13 years developing Metal-Supported SOFCs

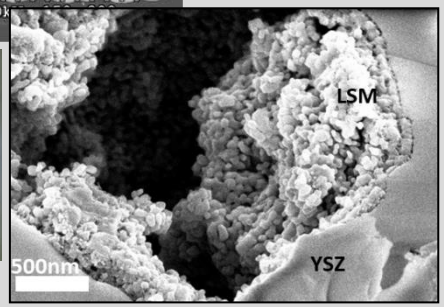
Also Lithium Batteries, Redox Flow Batteries

- Partner on scale-up, stack development

Technology Overview



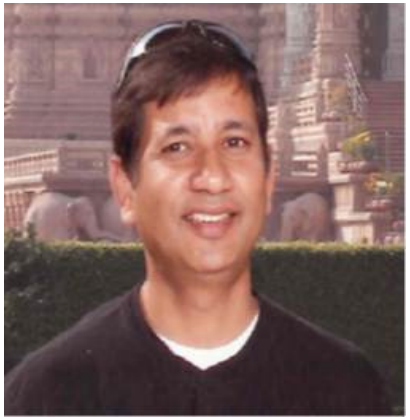




Metal-supported SOFC
- Symmetric backbone architecture
- Infiltrated catalysts

- High power density >1W/cm^2 at 700°C
- Startup in seconds or minutes
- Tolerates thermal gradients 100's °C/cm
- Tolerates anode oxidation

Devesh Upadhyay Ford Motor Company



Technical Expert at Research and Advanced Engineering.
Focus areas: Modeling, Control and OBD of powertrain and aftertreatment systems.
Connected and Autonomous vehicles extensiosn to Powertrain Control and OBD.
Data mining and ML in powertrain Control and OBD.

Electrification benefits
The energy equation: Electrical and/or Conventional fuels.

Brian Van Batavia
Chief Engineer – Electrification, AVL North America

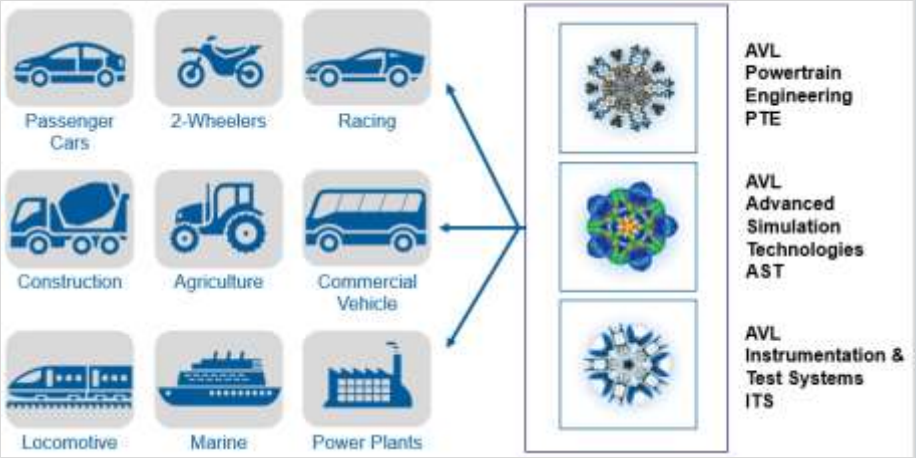
BS Elec & Comp Eng, University of MN
ME Interdisciplinary Eng, Purdue University
MTS Systems (1998-2006)
Eaton Corporation (2006-2013)
Polaris Industries (2013-2015, 2016-2017)
Logic PD (2015-2016)
AVL North America (2017+)

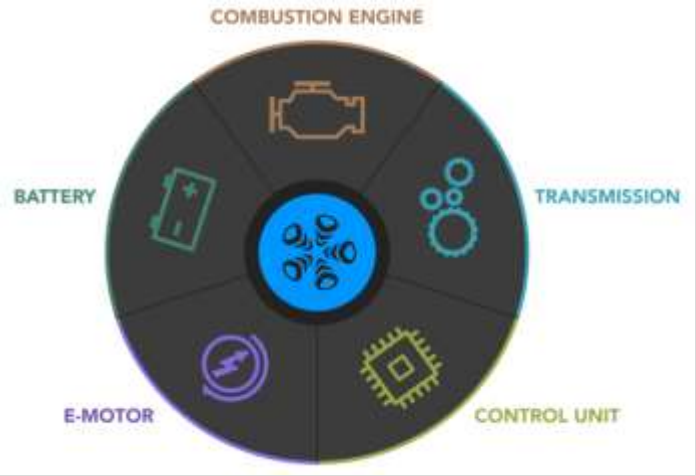
Desired Meeting Outcome:

Identification of attractive engine architectures with potential for achieving high efficiency transformation of liquid fuel energy to electric power and barriers presently limiting commercial viability.

Technology Overview

AVL is the world's largest independent organization focused on the simulation, test, and development of advanced powertrain systems.





Adam Vaughan – Dauntless.io, Inc.

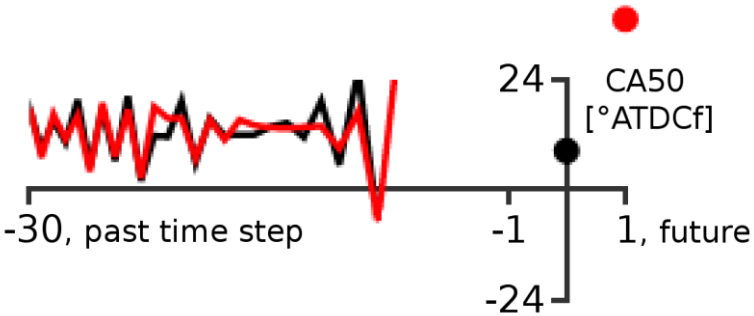
dauntless.io

- I build ultra-fast (0.00001 - 0.001 second), adaptive machine learning control systems using a $5 processor.
- I was originally focused on up to 30% more fuel efficient HCCI, but I'm now broadening the scope to also target new applications.

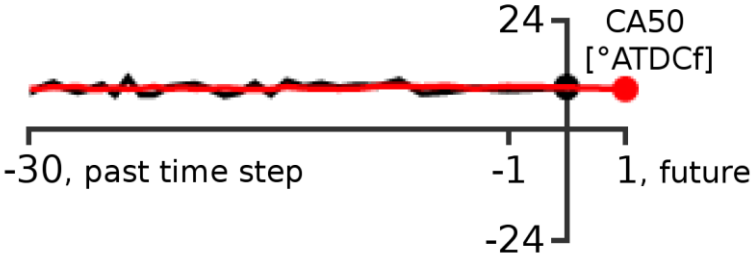
- I'm looking for modeling and control collaboration opportunities in:
  - Combustion / fuel cells
  - Electric motors / batteries
  - Autonomous vehicle powertrains

Technology Overview

We predict "off the chart" misfiring, chaotic combustion in real-time



We stabilize combustion with in-cycle / cycle-to-cycle control



Demo video: **http://dauntless.io/control**

model predicted
experimentally measured

Matthew Viele, Ph.D.
Vieletech, Inc.

Vieletech
Research Engines and Controllers

Matt has an undergrad in EE, masters in CS, and a Ph.D. in ME.
He built ECU for SwRI and Woodward before founding Drivven.
From Drivven->NI PCG->Vieletech Matt has designed and built research engine controllers

Meeting Interests:

- Find funding for free-piston engines
- Look for opportunities to provide control systems for other research projects

Technology Overview

Vieletech makes research engine controllers with a mix of custom and COTS hardware. We specialize in advanced combustion engines that have novel control and I/O requirements.
Vieletech is working with Libertine to provide complete control and actuation solutions for free piston engine research and development.

mviele@vieletech.com

Dr. Matti Vint, Valeo North America Inc.

Matti is the Engineering R&D Director for Powertrain Systems at Valeo. His responsibilities include systems development and R&D activities, covering combustion engine and electrified powertrains. He has over 30yrs automotive experience having commenced in the 1980's on hybrid vehicles R&D at the University of Queensland in Australia.

- Gain a broader understanding of technology capability and development needs to meet future regulations
- Participate in developing technology that can meet consumer/regulatory requirements and extend the life of the ICE

Technology Overview

Valeo is a global Tier 1 Supplier that designs & manufactures a wide range of innovative products that support the key priorities of **CO_2 emissions reduction and intuitive driving.**

Currently 50% of Valeo's order intake involves innovations, this being products having less than 3yrs in production.

Examples of Valeo technologies potentially relevant to high efficiency hybrids include;

- Electrical machines: BSG, CMG, GMG, DMG, REX
- Power electronics: inverters, chargers, DCDC
- Electric supercharger, air pumps, EGR valves
- Exhaust heat recovery systems (EHRS), latent heat accumulator
- Battery pack & e-machine thermal cooling products
- Heat pump, variable displacement AC compressor
- Connectivity, mobility, cloud computing
- Autonomous vehicle technologies, sensors

Eric Wachsman, Maryland Energy Innovation Institute

MARYLAND ENERGY INNOVATION INSTITUTE

Director of the Maryland Energy Innovation Institute at the University of Maryland. Fellow of The Electrochemical Society and American Ceramic Society, recipient of the Carl Wagner, Sir William Grove, and Fuel Cell Seminar Awards. Research focused on development of solid oxide fuel cells and solid-state batteries.

Integration of solid state batteries and fuel cells for greater range and power

Technology Overview

Founder of:

Ion Storage Systems (solid state batteries) and
Redox Power Systems (solid oxide fuel cells)

Robert Wagner
Oak Ridge National Laboratory

Dr. Robert Wagner is the Director of the National Transportation Research Center (NTRC) at Oak Ridge National Laboratory. His responsibilities include strategic vision and leadership of the NTRC, coordination of researchers and resources, and management of the NTRC as a DOE-designated National User Facility.

- Better understanding of the state-of-the-art and new ideas in hybridization
- Exposure to new innovative ideas for high efficiency propulsion systems and controls

Technology Overview

My research has primarily focused on high efficiency combustion concepts and predictive controls. This includes the development of a new understanding of the stochastic and deterministic nature of cyclic dispersion for improved predictive control of engine combustion, and addressing the challenges and opportunities associated with transitioning advanced combustion strategies to production-viable multi-cylinder engines.

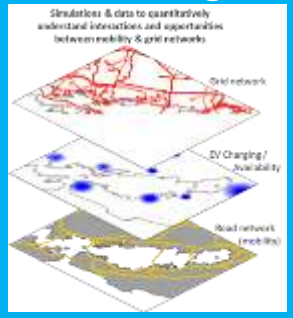
Kevin Walkowicz
National Renewable Energy Laboratory

- Managing NREL's Advanced Vehicle and Fueling Infrastructure Group: Supports U.S. DOE Vehicle Technology Office
- Focus is on acquiring advanced technology vehicle and infrastructure data to develop analysis, simulation & visualization tools & assess impacts and opportunities for improved EV efficiency
- Prior to NREL: Product engineer at GM leading advanced evaporative emission control system projects
- B.S.M.E (LTU) & M.S.E.S (RPI)

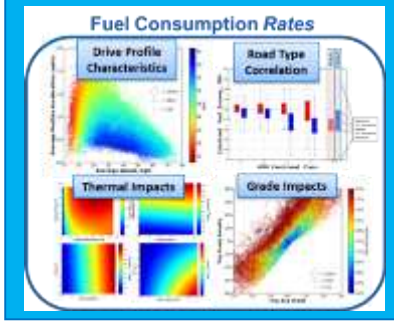
- Looking to identify areas to improve efficiency while improving commercial viability of electric drive vehicles

Technology Overview

- Grid Integrated, Connected and Automated Plug-In Vehicle Capabilities: Working to increase value equation of PEV/HEV by exploring novel hardware, control and communication approaches between vehicles, mobility systems, buildings and a 'Smart Grid



- Real World Driving Research to Understand Optimal Technology Relative to Duty Cycle: Developing large datasets, tools and techniques to look at real-world opportunities for advanced PEV/HEV technology



Thomas Wallner, Manager FEAR

Center for Transportation Research, Argonne National Laboratory

PhD from Graz University of Technology/Austria
Manager, Fuels, Engine and Aftertreatment Research (FEAR) at Argonne Natl. Lab
SAE (Society of Automotive Engineers) Fellow
Adjunct faculty at Michigan Tech. University
More than 80 peer-reviewed technical papers

Understand Scope and Direction of ARPA-e Call

Identify Partnership Opportunities

Technology Overview

Unique engine and combustion modeling capabilities using Argonne's world-class high-performance computing facilities

Extensive state-of-the-art engine and powertrain testing facilities

Track record of successfully completing high-efficiency powertrain concept demonstrations

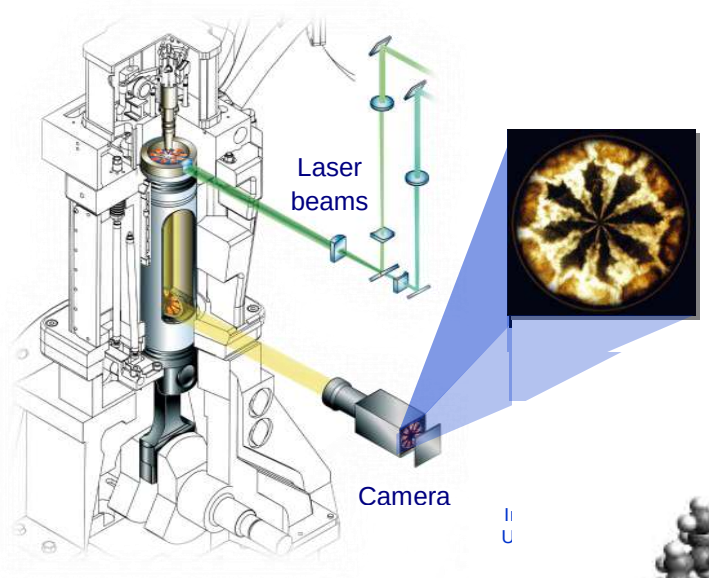
Dr. Mike Weismiller
Vehicle Technologies Office, DOE-Energy Efficiency and Renewable Energy

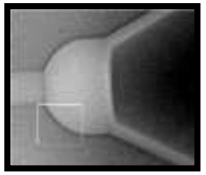
U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

I am a technology manager in the Advanced Engine and Fuel Technology Program within VTO, managing a portfolio of R&D projects focused on advanced diagnostics for combustion, predictive modeling, low-temperature combustion, new/alternative fuels, and advanced lubricants.

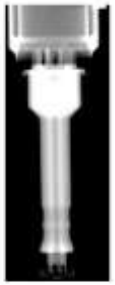
- Ensure work in VTO engine and fuels work is well aligned with future trends, ARAPA-E goals, and overall DOE strategy on transportation

Technology Overview



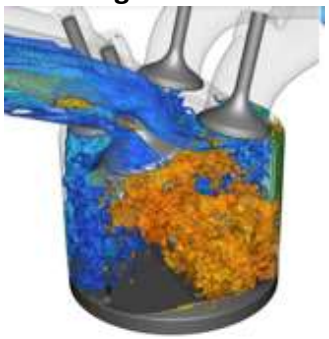


Nozzle Sac X-Ray Image



Neutron Imaging-GDI Injector

Engine Simulation



Kurt Wellenkotter

General Motors

Senior Manager Business Strategy, GM Fuel Cell Business

- The Future Belongs to Electric Vehicles
- Fuel Cell Electric is Complementary to Battery Electric
- GM is Committed to Fuel Cells as Disruptive Technology
  - Creating New Markets
  - Solving Problems

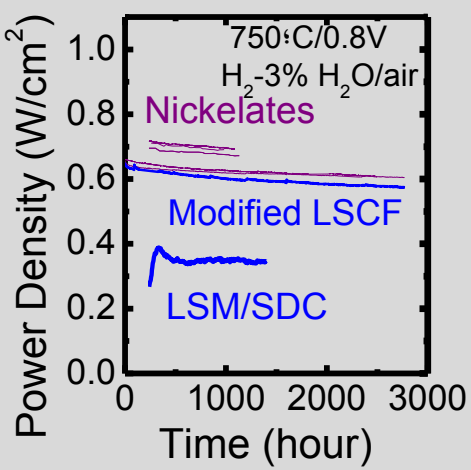
Xiao-Dong Zhou, University of Louisiana at Lafayette

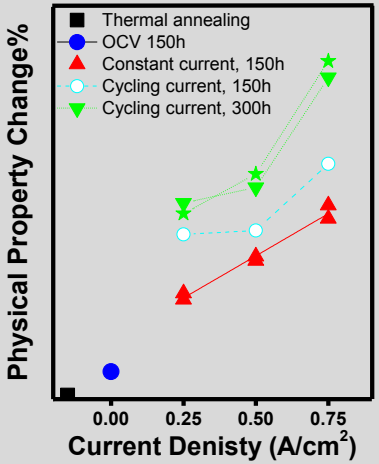
1. Ph.D. in Ceramic Engineering from University of Missouri-Rolla
2. Worked at PNNL on SOFCs (2005-2010)
3. Professor at U. of South Carolina (2010-17)
4. Currently, Director of Institute of Materials (IM) and the Stuller Endowed Chair

1. Establish a connection between UL and other institutions to better use fossil fuels in the Gulf of Mexico off Louisiana.
2. Learn more about the PHEV technology and look for the collaboration on batteries and high temperature fuel cells for PHEV.

Technology Overview

1. Ceramic process/sintering and the development of SOFC materials.
2. Science governing durability and stability of the interfaces and electrochemical performance.
3. Accelerated test protocols for the predictive analysis of all SOFC constituents.
4. Research was funded by NSF and DOE SOFC Core Technology Programs for 15 years.





Tianli Zhu, UTRC

United Technologies Research Center

Current position: Research Engineer at UTRC.
Background: Material R&D, reaction engineering, and process development. >15 year experience on fuel cells, including fuel processing development, catalyst research and development, and coating development.

- Understand program objectives and requirements/challenges for hybrid electric vehicles
- How UTRC's expertise and capabilities can help to address some of the challenges.

Technology Overview

- Fuel cell system integration and modeling
- Metal-supported solid oxide fuel cell development (ARPA-E Rebels and DOE HT Electrolysis project)

Pajarito Powder, LLC

PAJARITO POWDER
FUEL CELL CATALYSTS

Dr. Barr Zulevi is President & Chief Technology Officer at Pajarito Powder, LLC. He oversees all R&D efforts, as well as represents the company externally to our partners. He is the PI on ARPA-E project DE-AR0000688

Goals for workshop:

1. Understand the performance envelope requirements and trade-offs for High Efficiency Hybrid Vehicles
2. Understand the requirements of fuel cell technology for HEHV

Technology Overview

Pajarito Powder is a fuel cell and electrolyzer catalyst developer and manufacturer.

We develop, manufacture, and sell a range of products to support Proton Exchange Membrane, Anion Exchange Membrane, and Polybenzimidazole-based fuel cells and electrolyzers. For both H_2/Air and direct liquid fuels.

Our Precious Metal catalysts are based on our Engineered Catalyst Supports (ECSs) what improve the performance of catalysts while reducing the amount of precious metal used.

Our Precious Metal Free (PMF) Catalysts provide near-term, low-cost solutions for lower power density applications, such as back-up power, CHP and waste water treatment. PMF materials offer the long term solution for replacing precious metals in fuel cell catalysts.