GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

CUICAR
CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

DOE GATE Center of Excellence in Sustainable Vehicle Systems

Director and PI: Dr. Imtiaz Haque
Co-director and Co-PI: Dr. Beshah Ayalew
Presenter Co-PI: Dr. Pierluigi Pisu

CLEMSON UNIVERSITY

06/09/2015

Project ID # TI024

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Overview

Timeline

- Project start date: 10/1/2011
- Project end date: 09/30/2016
- Percent complete: 70.6%

Barriers

- Graduate engineering workforce
- Technology barriers addressed:
  - System Cost
  - Reliability and life
  - Performance

Budget

- Total project funding: $1,250,000
  - DOE share: $1,000,000
  - CU share: $250,000
- Funding received in FY14: $325,000
- Funding received for FY15: $ 113,543
  Total received: $ 924,416 (as of April 10th,2015)

Partners

- Many automotive OEMs and suppliers
- Project Lead: Clemson University

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

Project Objectives - Relevance

- DOE's VT Program Vision for GATE
  - Help overcome technology barriers in the design and development of high-energy efficiency and low environmental impact vehicle propulsion systems through an integrated research and education graduate program

- Clemson GATE Center's Specific Goal: Establish a GATE Center of Excellence in Sustainable Vehicle Systems that trains graduate Fellows at the MS and Ph.D. level by:
  - Creating a dedicated GATE Curriculum
  - Establishing a new Advanced Powertrain Integration Laboratory by leveraging state-of-the art equipment at CU-ICAR and acquiring new equipment
  - Engaging in graduate research endeavors that address specific technical challenges in the area of sustainable vehicle systems

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

FY14-15 Objectives-Relevance

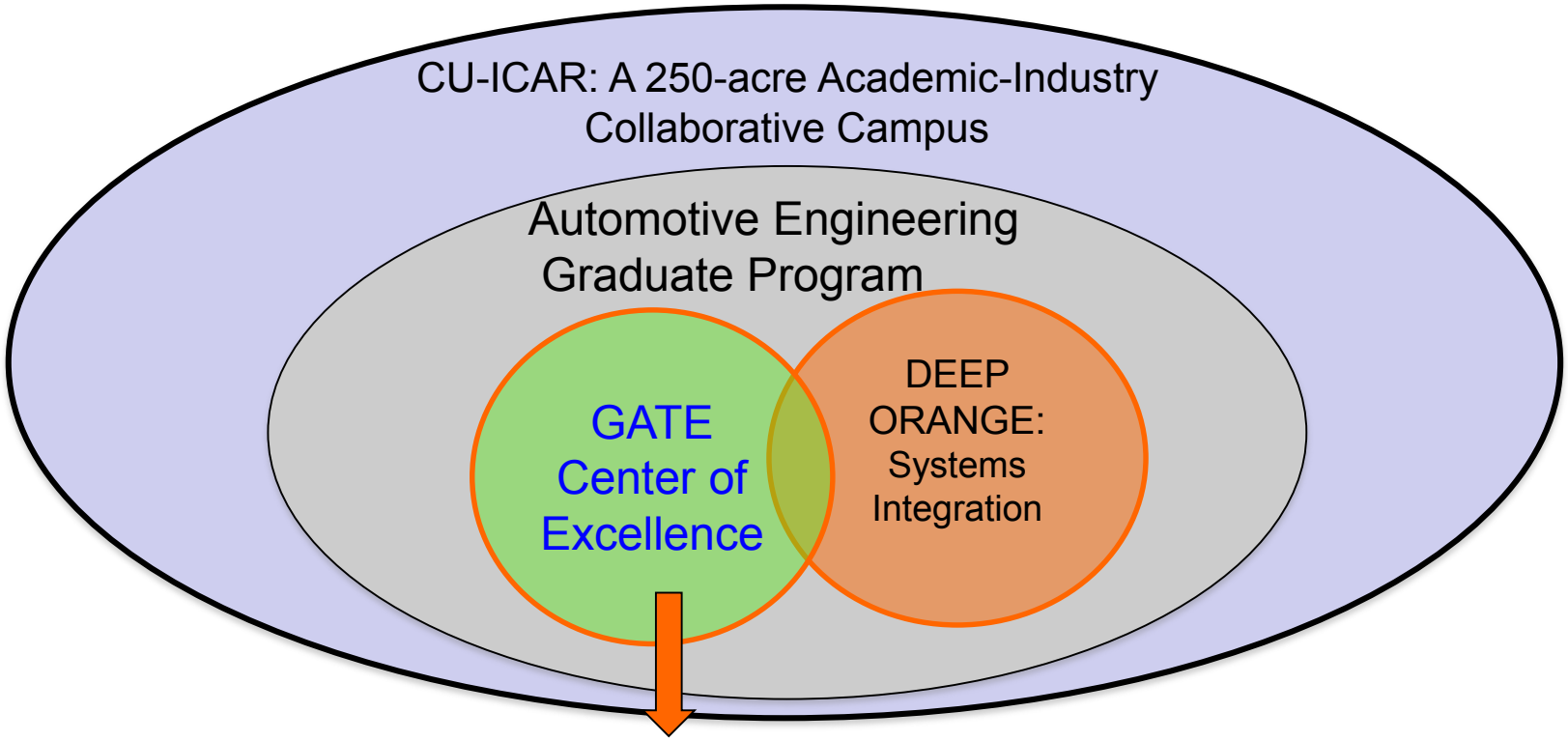
- Continue to recruit MS and Ph. D. students to populate the GATE program
- Advertise the opportunity provided by the GATE Center
- Maintain GATE Hybrid Vehicle Powertrain Integration Laboratory
- Leverage industry, departmental and CU-ICAR facilities and partnerships
- Teach and revise course offerings AuE 881, AuE 817 and AuE 827
- Third offering of AuE 893-4: Hybrid Powertrain Control course
- Graduate second cohort of MS GATE students
- Graduate first cohort of PhD students
- Issue a US DOE GATE Certificate of Excellence in Sustainable Vehicle Systems for completing the program.

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

Milestones FY14 and FY15

- Milestone 2.2 - Advertised and Recruited fourth cohorts of MS, PhD GATE fellows
- Milestone 5.1 - AuE 893-4: Hybrid Powertrain Control: Third offering Fall 2014 (next offering Fall 2015 – on Schedule)
- Milestones 5.2, 5.3 – Class Teaching Third Offering (next offerings – on Schedule)
  - AuE 817: Advanced Vehicle Propulsion Systems
  - AuE 827: Powertrain Control Systems
  - AuE 881: Automotive Systems Overview
- Milestone 3.5 - Vehicle Powertrain Integration Lab Development Completed
- Milestone 4.3 - Expected Review of GATE Center with DOE VTP Rep. (2015)
- Milestone 7.1 – Second MS cohort graduated, August 2014
- Milestone 7.2 – First PhD cohort expected to graduate in Summer 2015
- Milestone 8.2 – Submitted Semi-annual reports on April 2014, Oct 2014

Approach 1:
Deployment of the Clemson DOE GATE Center



GATE MS and Ph.D. Curriculum

- ✓ Core GATE Automotive Engineering courses
- ✓ GATE-designated electives
- ✓ Sustainability minor for Ph.D. GATE Fellows
- ✓ 6-month internship for MS GATE Fellows
- ✓ Graduate Seminars

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Approach 2:

Application and Selection of GATE Fellows

- Candidates must satisfy admission requirements to the Automotive Engineering graduate program at Clemson University, including the following:
  - BS degree in an engineering or applied science discipline
  - GPA above 3.5 in the last degree attained
  - Preferably two years of post BS work experience
  - Exceptional GRE scores
  - Research plan essays for Ph.D. candidates
  - At least three recommendation letters
  - If deemed necessary, interview with selection committee
- Fellowships
  - Merit-based paid fellowships ranging from $10k-$18k/year with possible remission of tuition to the top candidates, subject to availability of funding.
  - Select candidates may also be supported independently through research grants, awards, scholarships and other means.
- Milestone 2.2 – Recruit fourth cohorts of MS, PhD GATE fellows (Completed)

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

Approach 3:

GATE MS Program

- Goals of Program:
  - To train the highly skilled automotive engineering workforce with the technical depth and breadth needed to address applied system integration challenges with sustainable vehicle systems including:
    - Design, control and integration of advanced powertrain concepts
    - Component and system diagnostics and reliability
    - Light-weight design and manufacturing
    - Business perspectives and market viability of ideas/products
- Current Requirements:
  - 13 Credits from 4 Core GATE courses plus a seminar (in Green)
  - 18 Credits from 6 support courses (current AuE/DO Core (in Blue))
  - 6 Credits of AuE 890 internship at industry location or at CU-ICAR
  - 6 Credits from GATE-designated electives (in Red)
  - Students not participating in Deep Orange may replace AuE 883 with another GATE-designated electives (in Red)

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Approach 4:

MS GATE Course Plan (Revised on 10/28/14)

	Fall	Spring	Summer	Fall	Spring	Summer
AuE/DO + GATE Required Courses	AuE 881: Automotive Systems Overview	AuE 817: Alternative Energy Sources	AuE 890:Auto Internship Projects	AuE 893-4: Hybrid Vehicle Powertrain Control		
	AuE 833: Auto Manuf. Process	GATE-Designated Elective		GATE-Designated Elective		
	AuE 835: Auto Electronics	AuE 893-2: Autovation		AuE 883: Applied Systems Integration		
	AuE 880:Vehicle Project Management	AuE 892: Seminar (1cr.)		2nd Business Course (3 Cr.)	AuE 890: Auto Internship Projects	
		AuE 882: Systems Integration methods			Total 43 Credits	
GATE Designated Electives		AuE 829: Tire Behavior		AuE 893-3: Advanced Engine Combustion		
		AuE 850: Stability and Safety Systems		AuE 826: On-board Diagnostics	AuE 866: Advanced Automotive Materials	
		AuE 877: Lightweight Design		AuE 828: Vehicle Drivelines	AuE 893-1: Electromagnetic Compatibility (Hubing)	
		AuE 816: Engine Combustion and Emissions		AuE 827: Automotive Control Systems		
		AuE 893-5: Power Electronics		AuE 893-6: Advanced IC Engine Concepts		
				AuE 893-7: Automot. Composites		

AuE: Automotive Engineering

Keys: GATE Core Courses | AuE/DO Required Courses | GATE Electives

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Approach 5:

GATE Ph.D. Program

- Goal of Program:
  - To train technical experts at the Ph.D. level who act as thought and innovation leaders with an understanding of the broader challenges and opportunities for the automotive sector from the perspectives of energy resource economics, life-cycle impact and public policy
  - For technical expertise (Revised on 12/05/13):
  - 13 Credits from 4 Core GATE courses plus a seminar (in Green)
  - Sustainability Minor (two courses minimum)
  - More courses as needed for specific research (minimum of 60 credits post BS)
  - Complete doctoral research dissertation in the GATE program specific area

- Sustainability Minor: Select 2 courses from those identified by the CU President's Commission on Sustainability. Examples:
  - AP EC 657 Natural Resource Use, Technology and Policy
  - EN SP 671 Man and his Environment
  - EN SP 400 Studies in Environmental Science
  - ME 620 Energy Sources and their Utilization

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

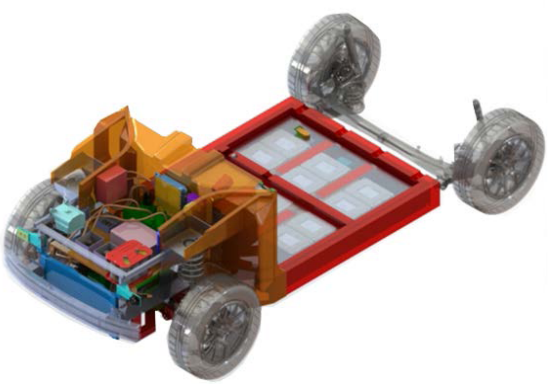
GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Approach 6:

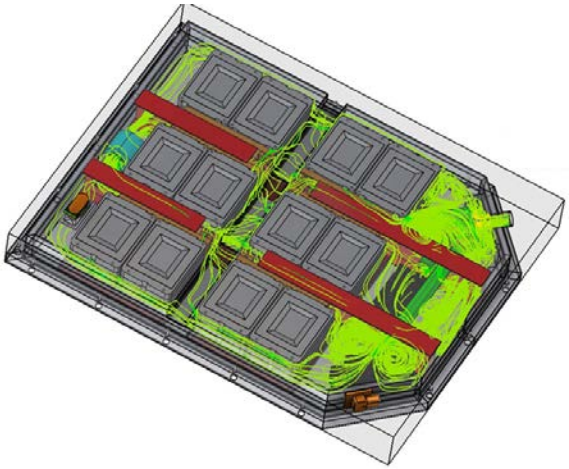
Deep Orange - Emulating OEM Vehicle Development Process

Processes in 2-Yr Graduate Education

Deep Orange is a framework that immerses graduate AuE students into the world of a future OEM and/or supplier. Working collaboratively, students, multi-disciplinary faculty, and participating industry partners focus on designing and producing a new vehicle prototype each year. Deep Orange 6 (Toyota sponsored) will realize an all electric utility/activity vehicle for American youth with an anticipated market introduction date in 2020. The fully functional vehicle will be completed in Q4/2015.



Electric drive light-duty architecture



Energy storage system CFD analyses

HIL eDrive calibration in GATE lab

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Accomplishment 1:

Expanded Technical Electives (FY14- FY15)

- Total number of required credits is unchanged, but now students have the choice of two GATE elective courses.
- Added two new courses to the technical electives (first time offered in 2014)
  - AuE 893-5: Power Electronics
  - AuE 893-7: Automotive Composites
- Course AuE 893-6: Advanced IC Engine Concepts was first offered in Fall 2013 and second offering in Fall 2014.

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

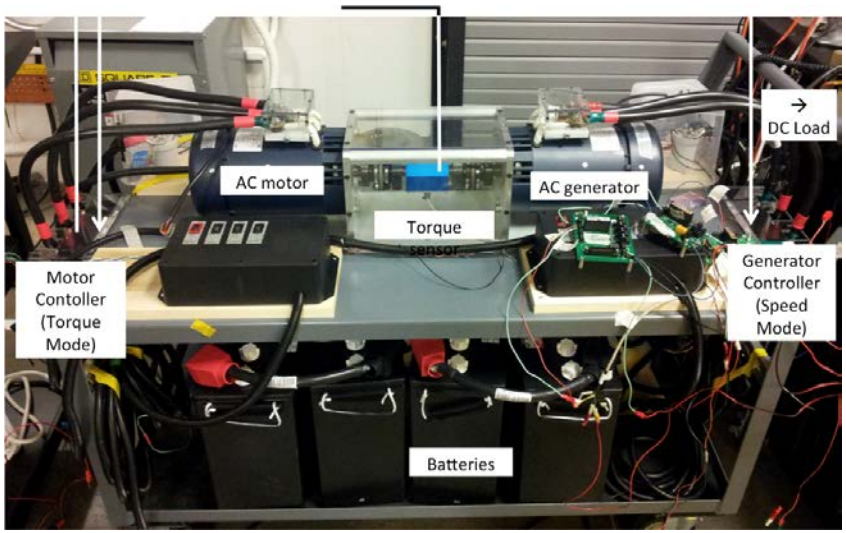
Accomplishment 2:

Offering of Course AuE 893-4: Hybrid Powertrain Laboratory

- Lab modules Include
  - Characterization of EV/HEV batteries
    - OCV curves
    - Pulse characterization and EIS
  - AC Motor/Generator: Control and Efficiency Mapping
  - EV Drive Cycle Emulation
  - Series/Parallel Drive
  - Fuel Cell Demo System
  - HEV Energy Management
- Third Offering in Fall 2014
- Next offering Fall 2015

NEW Modules developed:

- Active and Passive Battery Management/Control
- DC/DC buck converter implementation and testing
- Hybrid Golf Cart



EV Hardware-in-the-Loop Emulation Platform

- Motor, inverter and battery in hardware
- Vehicle and driver simulated in software

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Accomplishment 3:

Completion of GATE Powertrain Integration Laboratory

HEV ECMS Energy Management Strategy

GATE Laboratory enables research and educational activities:

- AuE 893-4 course
- Characterization of electric and hybrid vehicle driveline components
- HIL testing of powertrain systems
- Advanced engine control research
- Fault diagnostics and prognostic algorithms for advanced hybrids

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

Accomplishment 4:

Course AuE 892 Seminar

- Seminar series on topics of interest to automotive engineers in the area of leadership, and sustainable and networked mobility.

Sample of seminar speakers FY 2014-2015:

- **March 25, 2015 - Towards model-based functional-safety-driven fault tolerance in automotive control systems implementation,** Giorgio Rizzoni**,** The Ohio State University.
- **March 10, 2015 – Modeling the Mechanical Behavior of Lightweight Metals and Polymer Composites**, Farhang Pourboghrat, Professor, Michigan state University.
- **February 13, 2015 –** Mr. Michael Roeth, Executive Director, NACFE, Operations Leader, Carbon War Room
- **October 28, 2014 – Overview of the DoE EERE Sustainable Transportation vision and Programs in the Vehicle Technologies Office**, Dr. Gurpreet Singh, Program Manager, Advanced Combustion Engines Program, DOE EERE VTO.
- **October 16, 2014 - Toward a Multiscale Modeling Framework of Lithium-IonBattery Dynamics**, Dr. Ilenia Battiato, Assistant Professor, San Diego State University.
- **September 15, 2014 - Recent Developments and Key Challenges in Automated and Connected Vehicles**, Dr. Huei Peng, Professor, University of Michigan.

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Accomplishments 5:

New Course Developed: AuE 893-5: Power Electronics

- This course considers the design and control of power converters in electric drive vehicles. The course includes an overview of system architectures and covers system-level dynamic modeling and control using MATLAB/Simulink at levels appropriate to determine requirements and validate the performance of switched-mode power converters in the vehicle system. Analysis, modeling and design of switched-mode power converters in electric-drive vehicle systems are then covered, including battery DC-DC converters, battery management electronics, motor drive inverters and battery chargers.

- First offering in Spring 2014
- Students count: 14

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Accomplishments 6:

New Course Developed: AuE 893-7: Automotive Composites

- The course aims to provide fundamental principles of the mechanics and manufacturing of composite materials and structures. The course deals with thermoplastic and thermoset, composites, their design, analysis, manufacturing, defects and repair, machining, and assembly, all in the context of automotive applications.

- First offering in Fall 2014
- Students count: 18

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Accomplishments 7:

Status of Recruiting and Enrollment (Year 4)

- Total number of GATE Enrollees since inception: 74
- Total number of application received in past 3 years: 95
- GATE students graduated to date: 26
- GATE certificate issued: 13. Currently suspended pending approval of logo use.
- Number of current GATE track students is 37:
  - 17 second year students and 20 first year students, exceeding for the second time the target of 25 that was established by the second year of the program
  - 28 MS students (including 2 female students)
  - 14 students pursuing Ph.D. degrees
    - 3 female Ph.D. students: Sara Mohon, Jacqueline Rios, Zholeika Abdollahi
- 3 PhD GATE students expected to graduate in Summer 2015 (Sara Mohon, Jacqueline Rios, Satadru Dey)
- All Ph.D. GATE students are supported through research assistantships:
  - 3 directly by the DOE GATE Grant
  - 11 by other sponsored research in the focus area of the GATE Center
- 3 MS GATE students received MAZDA-GATE Fellowships ($10,000 each)
- Most MS students in the program are self-supported!

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Accomplishment 8:

Impact of the GATE Curriculum on the existing AuE program

	Fall 2012	Spring 2013	Summer I	Summer II	Fall 2013	Spring 2014	Summer I	Summer II	Fall 2014	Spring 2015
students / course										
AuE 893- Autovation	11	17			59	79			67	58
AuE 881- Automotive Systems Overview	80				96					
AuE 827- Automotive Control Systems	22				39				48	
AuE 816- Engine Combustion and Emissions		53			37	29				47
AuE 817- Alternative Energy Courses		37				40				41
AuE 892- GATE Seminar		17				31				23
AuE 893- Hybrid Powertrain Control Lab	13				17				16	
AuE 890- External Industry Internship	9	35	44	37	8	11		50	50	
AuE 890- Internal Deep Orange Internship	14	13	23	23		16		55	55	16

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Accomplishment 9:

Sample of Research Publications by GATE Fellows and Faculty

- **S. Dey** and B. **Ayalew** (2014), "Nonlinear Observers for State of Charge Estimation of Li-ion Batteries", Proceedings of the American Control Conference, June 4-6, Portland, OR.
- **S. Dey**, **B. Ayalew** and **P. Pisu** (2014), "Combined Estimation of State-of-Charge and State-of-Health of Li-ion Battery Cells Using Sliding Mode Observers on Electrochemical Model", 13th International Workshop on Variable Structure Systems, June 29-July 2, Nantes, France.
- **S. Mohon**, **S. Dey**, **B. Ayalew** and **P. Pisu** (2014), "A Hardware-In-the-Loop Platform for a Series Hybrid Powertrain Featuring Two Equivalent Consumption Minimization Strategies," *16th International Conference on Advanced Vehicle Technologies*, ASME IDETC 2014-35310, August 17-20, Buffalo, NY.
- Abdelhamid, M., Singh, R., Qattawi, A, Omar, M.**, Haque, I**, "Evaluation of On-Board Photovoltaic Modules Options for Electric Vehicles," IEEE Journal of Photovoltaics, vol.PP, no.99, pp.1-9 doi: 10.1109/JPHOTOV.2014.2347799112.
- X. Zhang and **P. Pisu**, "Prognostic-Oriented Fuel Cell Catalyst Aging Modeling and Its Application to Health Monitoring and Prognostics of a PEM Fuel Cell, " *PHM Journal,* 5(1) 003*,* 2014.
- X. Zhang and **P. Pisu**, "An Unscented Kalman Filter Based On-Line Diagnostic Approach for PEM Fuel Cell Flooding," *PHM Journal,* 5(1) 004*,* 2014.
- Xu, S., Anderson, D., Singh, A., Hoffman, M., **Prucka, R.**, Filipi, Z., "Development of a Phenomenological Dual-Fuel Natural Gas Diesel Engine Simulation and Its Use for Analysis of Transient Operation", SAE Int. J. Engines, Oct. 2014 7:1665-1673; doi:10.4271/2014-01-2546
- J. H. Hayes and **T. Hubing**, "Monitoring Transistor Degradation in Power Inverters Through Pole Shifts," Proc. of the 2014 IEEE International Symposium on Electromagnetic Compatibility, Raleigh, NC, USA, August 2014, pp. 465-469.
- L. Niu and **T. Hubing**, "Application of the Imbalance Difference Method to the EMC Design of Automotive ECUs," Proc. of the 2014 Int. Symposium on Electromagnetic Compatibility, Tokyo, Japan, 15P-H1, May 12-16, 2014, pp. 453-456.

*Participating GATE faculty and students identified by bold face.

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Accomplishment 10:

Leveraging DOE GATE Funds FY14-15

- 3 Mazda GATE Fellowships $10,000 each ~ $30,000
- 1 FEV GATE Fellowship $10,000
- 2 Toyota Fellowships for Deep Orange 6, $5,000 each ~$10,000
- 1 Safety Kleen Fellowship for Deep Orange 6, $15,000
- Fellowship support is also provided by Altair ($4K), Bridgestone ($25K), Staubli ($10K), Bosch ($20K), and SafetyKleen ($15K).
- AuE Department additional cost share
  - One GATE Fellow support: $16,000+ plus tuition remission ($11,086) ~ $27,086
- Deep Orange 7: MINI Re-Invented, from May 2014 to December 2016, funded $1.8M.
- New faculty/staff hires in the topical areas of the GATE Center:
  - Dr. Simona Onori, Assistant Professor in power electronics (New Hire, 2013)
  - Dr. Srikanth Pilla , Assistant professor in biodegradable materials (New Hire, 2013)

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

Accomplishment 11:

Projects in last 12 Months from Leveraging DOE GATE Laboratory and Funds

- "Optimization of Organic Rankine Cycle Waste Heat Recovery System for Maximum Fuel Economy," Sponsored by BorgWarner, $709,984.
- "Gasoline Particulate Filter Regeneration, Control-Oriented Oxygen Storage Capacity Model Identification and Optimization-Based Control Design for Particulate Emissions Reduction," Sponsored by Fiat-Chrysler Automobiles, $827,174.
- "Synthetic Drive Cycle Generation to Support Studies on the Hybrid Electric Vehicle Battery Aging", *Johnson Controls Power Solutions*, 2014-2015, $98K
- "Sensor-based In-Cylinder Mixture Composition Prediction", *Fiat Chrysler Automobiles*, 2014-2016, $337K
- "Model Based Parameter Estimation of the Vehicle Rolling Resistance and Aerodynamic Drag", Allison Transmissions, $97K

total: $2,069M

Response to Previous Year Reviewers' Comments

- The project did not receive any review last year.

FY 2013 Reviewers' Comments and Response

- Widespread agreement expressed that project supports overall DOE objectives, approach is good, well integrated with others, and appropriate technical barriers being addressed
  - "Clemson University (Clemson) GATE Center project was well-designed and had a good strategy for addressing technology barriers in the development of sustainable vehicles through an integrated education and research program for graduate students. Clemson had successfully integrated a number of related activities (e.g., Deep Orange) to provide an impressive array of opportunities for graduate students."
  - "Clemson seemed to have a fairly specific coursework plan for candidates. The identified approach was to follow vehicle development processes seen in the industry, developed through Clemson's relationship with industry partners."
  - RESPONSE: We will continue to expand our collaborative interaction with industry and academic partners as the program matures. We will work expanding the coursework and improve opportunities for candidates.

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Coordination and Collaborations with Other Institutions

- The following companies participate in Industrial Advisory Board for the Center and the Department of Automotive Engineering: BMW, Mazda, FEV, Michelin, Proterra, ZF Lemforder, Okuma, Koyo Bearings, Timken, and SEMA.
- A meeting of this board and other stake holders is scheduled for Spring 2015
- We are currently looking to expand the list of industry collaborators participating in our Industrial Advisory Board.
- Collaboration with the Ohio State University:
  - Hosted Prof. Giorgio Rizzoni as seminar speaker, Spring 2015.
  - Dr. Pisu is part of the International Program Committee and Dr. Onori is part of the National Organizing Committee for the ECOSM'15 - IFAC workshop on Engine and Powertrain Control, Simulation and Modeling to be held at the Ohio State University, Aug 2015.
  - Dr. Pisu hosted for sabbatical leave at the Center for Automotive Research, the Ohio State University, Fall 2014.

CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Proposed Future Activities (Year 4)

- Secure more fellowship and internship opportunities for the GATE Fellows
- Continue offering of newly developed courses and course content improvement
- Foster additional collaboration with remote lectures, research forums and workshops
- Host workshops, conferences and events in the area of sustainable Vehicle Systems
- Initiate construction of Campbell Center Advanced Powertrain Lab

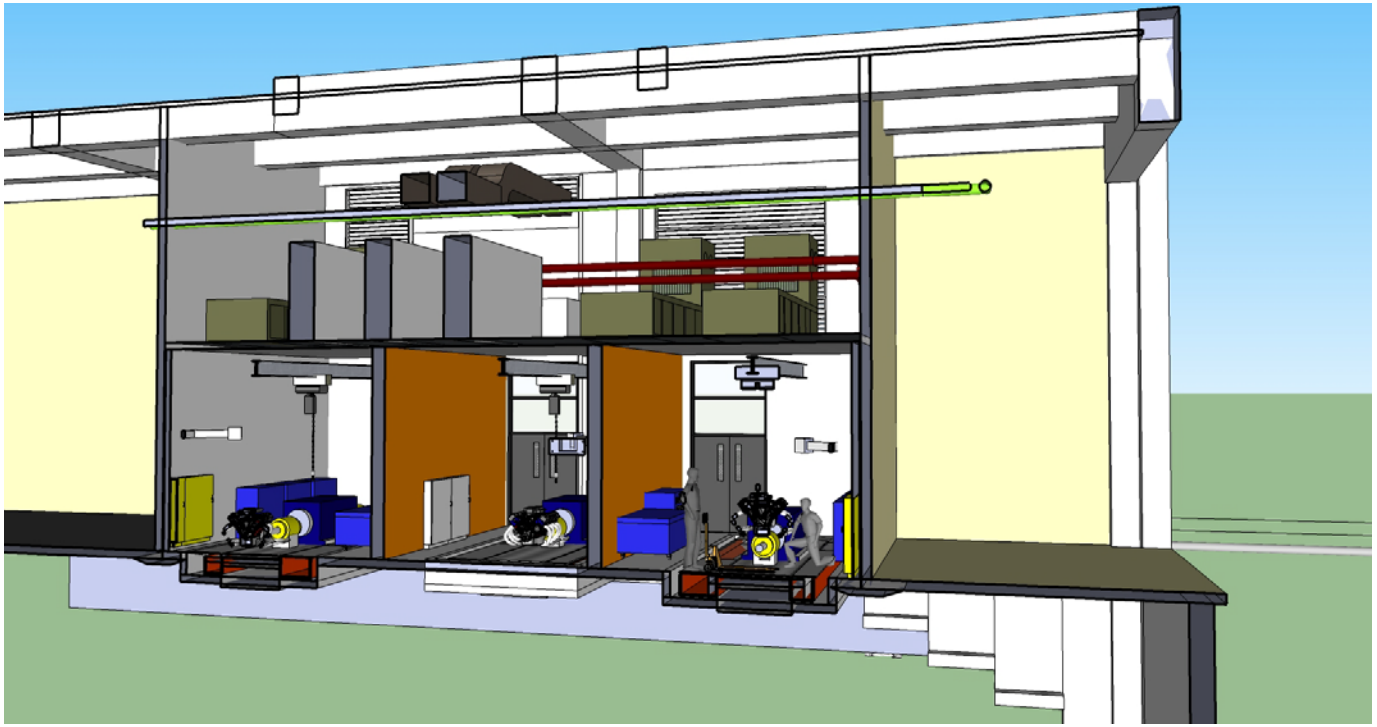
CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Future Activities:

Campbell Center Advanced Powertrain Lab (APL)

- Work on three engine test cells to begin in May 2015
- Completion is expected by December 2015



CLEMSON UNIVERSITY INTERNATIONAL CENTER FOR AUTOMOTIVE RESEARCH

GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Summary

- Significant Progress made in establishing Clemson's DOE GATE Center of Excellence in Sustainable Vehicle Systems.
- Revised GATE MS Program requirements to create more flexibility by reducing the number of core GATE courses and increase the GATE electives.
- 37 MS and Ph.D. students in the program this FY.
- New Power Electronics and Automotive Composites course developed.
- GATE Faculty and Fellows engaged in specific research and publishing work in topical areas of the GATE Center.
- GATE Center curriculum integrated with Deep Orange Project.
- Good progress on leveraging funds for GATE Fellow support and for providing internships.
- Continued Collaboration with Industry partners and other Institutions.