SMART AND CONNECTED MOBILITY IN SMART CITIES: BEYOND 2020

GREG JANKORD
GRADUATE RESEARCH ASSISTANT

THE OHIO STATE UNIVERSITY
CENTER FOR AUTOMOTIVE RESEARCH

June 21st, 2018
More than 5000 researchers

18 colleges and schools

66,000+ students across all campuses

The breadth, scope and excellence of its research programs make Ohio State a leading force of innovation and change – locally, nationally and globally.

Nearly $1B in research expenditures
COLLEGE OF ENGINEERING
Quick Facts

- 12 departments
  - Biomedical Engineering
  - Center for Aviation Studies
  - Civil, Environmental and Geodetic Engineering
  - Computer Science and Engineering
  - Electrical and Computer Engineering
  - Engineering Education
  - Food, Agricultural and Biological Engineering
  - Integrated Systems Engineering
  - Knowlton School of Architecture
  - Materials Science and Engineering
  - Mechanical and Aerospace Engineering
  - William G. Lowrie Department of Chemical and Biomolecular Engineering

- 28 research centers
- 8,652 undergraduate students
- 2,047 graduate students
- 100+ student organizations
1. To provide world-class education for the next generation of automotive industry leaders, through on-campus learning and continuous professional development

2. To be a catalyst for innovation in automotive technology, through collaborative, interdisciplinary research

3. To support economic development, regionally and nationally
PERSONNEL 2016-2017

283 total associates in 2016-2017

- 45 Research and Administration Support Staff
- 40 Visiting Scholars
- 56 Undergraduate Student Assistants
- 42 CAR-Affiliated Faculty
- 100 Graduate Students
  - Mechanical and Aerospace Engineering: 59
  - Electrical and Computer Engineering: 32
  - Materials Science and Engineering: 2
  - Nuclear Engineering: 1
  - Computer Science and Engineering: 1
  - Food, Agricultural and Biological Engineering: 2
  - Biomedical Engineering: 2
  - Civil, Environmental and Geodetic Engineering: 1
FISCAL YEAR 2017

TOTAL EXPENDITURES
In fiscal year 2017, CAR has secured:

- $3.3 million in industry-sponsored activity
- $3.5 million in federal government-sponsored activity
- $200 thousand in state-sponsored activity

RESEARCH AND ENGINEERING SERVICES ACTIVITY
In fiscal year 2017 CAR has delivered:

- $7.4 million of Research
  - 40% Connected and Autonomous Vehicles
  - 60% Fuel Economy
- $0.6 million of Engineering Services
- $0.9 million of Motorsports Activity
- $0.3 million of Continuing and Distance Education
# Membership Consortium: 2018

## Platinum

- FCA (FIAT CHRYSLER AUTOMOBILES)
- Ford
- Honda
- Hyundai
- Renault
- TRC

## Gold

- Bosch
- Cummins
- Delphi Technologies
- GM
- Schaeffler Group
- Mercury
- TE Connectivity
- Teradata
- Toyota
- Wind

## Pending

- Aptiv
- Dana
- HCL
- Magna
- Valeo
- Kenworth
- National Instruments
CAR is located on a 50,000 square foot complex on the West Campus of The Ohio State University

Advanced propulsion systems research facilities

- Plug-in hybrid electric vehicle (PHEV) and hybrid electric vehicle (HEV) test beds
- Hydrogen refueling station
- Battery aging laboratory
- Battery thermal and electrochemical characterization laboratory
- Energy storage systems laboratory

Autonomous vehicle fleet

- Traffic data-collection research vehicle
- Communication and coordination research vehicle
- Vehicle-to-vehicle (V2V) and vehicle autonomy laboratories
- Driving simulator laboratory
- DENZO V2V and Embedded System Laboratory
- OSU-CITR indoor testbed
FACILITIES

Engine combustion and flow research facilities

Dynamometer test cells
- Engine dynamometers (4)
- Light-duty chassis dynamometer
- Four wheel drive heavy duty chassis dynamometer

Noise and Acoustics laboratories
- Hemi-anechoic chambers, including one with 2 chassis dynamometer
Largest independent vehicle test facility and proving grounds in the U.S.
BUCKEYE CURRENT
Buckeye Current

• Fully electric motorcycle built to compete against professional race teams on both national and international stages
  • Started at the Isle of Man, moved to Pikes Peak International Hill Climb more recently

• Engineering Goals:
  • Advance technology far enough to surpass gas equivalent competitor performance
  • Give young engineers real-world automotive engineering experience

• Current competing at Pikes Peak
OSU FORMULA SAE
• Scaled-Down Formula-1 Style race-car that competes with hundreds of teams across America and internationally.

• Engineering Goals:
  • Improve engine performance through custom header and exhaust.
  • Hybrid carbon fiber and space frame chassis integration that will hold many benefits in manufacturing and testing time.

• We finished 13\textsuperscript{th} in Michigan out of 118 teams and 3\textsuperscript{rd} in Canada
BUCKEYE BULLET
• Students desire to set a record for the fastest electric vehicle

• Engineering Goals:
  • Push the limits of electric technology beyond current applications to achieve new possibilities

• 4 Buckeye Bullets have set world records
  • Currently: 341 MPH (549km/h)
EcoCAR 3

• 4-year Advanced Vehicle Technology Competition (AVTC) challenging 16 college teams to rebuild a 2016 Chevrolet Camaro

• Engineering Goals:
  • Increase fuel economy
  • Reduce emissions and energy consumption
  • Maintain performance and consumer acceptability
FOUR YEAR COMPETITION

Year One: 0 Buyoff
- Design the car
  - Choose engine, transmission, other key components

Year Two: 50% Buyoff
- Build the car
  - Received car in December 2015
  - Had three months to completely rebuild as a hybrid vehicle

Year Three: 65% Buyoff
- Refine the car
  - Work out all bugs and problems in car
  - Begin to tweak vehicle and its systems to achieve maximum performance and efficiency
  - Test emissions and energy usage

Year Four: 99% Buyoff
- Refine and Optimize the car (cont.)
  - Ensure car drives and feels as good as one just bought from a showroom
  - Tweak vehicle and its systems to achieve maximum performance and efficiency
Vehicle Architecture

Unique Feature

- 40 mile EV range
- 40 MPGge
- EHC providing 85% cold start emissions reduction
- AMT featuring magnetic position sensing
- ADAS system displaying safety warnings and improving fuel economy

Parallel – Series Plug-in Hybrid Electric Vehicle

- 32 kW Denso ISG Belted Alternator Starter
- 2.0L E85 Engine (119kW)
- 5-Speed Tremec Automated Manual Transmission
- 18.9 kWh A123 Lithium Ion Battery Pack
- 112 kW Peak Power Parker Hannifin Electric Machine
## Controls Architecture

### Team Developed Controllers

#### Hybrid Supervisory Controller

- Torque Split
- Shift Logic
- Low-Level Shift Control
- ADAS & Driver Controls
- Connectivity App Controls
- CAN Bridging
- Hybrid Operating Mode
  - Active Rev Matching
  - Fault Detection
  - Fault Mitigation Strategy
  - Drivability Management
  - Start up and Shutdown Management
- Data Recording
- Charging Management
  - Engine Thermal Management
  - Electronic Thermal Management
  - ESS Thermal Management
  - Electrically Heated Catalyst Controls

#### General Control Module

- Electrical Actuation
- Signal Processing

#### Engine Controller

- Air Fuel Ratio (AFR) Calibration
Algorithm Modeling and Simulation
Model Improvement to Support xIL V/V

• Large engine DOE:
  • Goal:
    • Torque map
    • Fuel map
    • Efficiency map
    • Lambda validation
  • Execution:
    • Swept 1500-3000 RPM, 0-100% Load
    • Recorded fuel in, power out, lambda, etc.
  • Enabled torque estimation needed for DP torque split
  • Provided detailed experimental engine maps
  • Average fuel correction: 3.8%
  • Average torque correction: 6.6%
Hardware Packaging

**Upper Group**
- Battery Modules
- Base Plate and Cooling Fins
- Manual Service Disconnect
- High Voltage Connector
- Battery Module Housing

**Lower Group**
- Battery Modules
- Base Plate and Cooling Fins
- Current Sense Module
- Electronic Distribution Module
- CSM and EDM Support
- HV Fuse
- LV Fuse holder
- Mounting Structure
ESS Simulated Testing

- Adequate cooling validated through CFD on Star-CCM
- Safe vehicle operation at 45°C ambient for US06
  - Modeled by SMS team and validated from previous EcoCAR 2 design
Structural Supports – Lower Group

- Aluminum cradle bolted to rigid body (frame rails)
- Modules represented as a point mass rigidly connected to the bolt locations
- Peak stress value is an artifact of the rigid bolted connection

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Max Stress (Mpa)</th>
<th>Factor of Safety</th>
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<tbody>
<tr>
<td>20g Forward</td>
<td>144</td>
<td>1.67</td>
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<tr>
<td>20g Rear</td>
<td>141</td>
<td>1.71</td>
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<tr>
<td>20g Right</td>
<td>145</td>
<td>1.66</td>
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<tr>
<td>20g Left</td>
<td>147</td>
<td>1.63</td>
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<tr>
<td>8g Up</td>
<td>33</td>
<td>7.30</td>
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<tr>
<td>8g Down</td>
<td>42</td>
<td>5.73</td>
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LV and HV Wire Routing

**Vehicle Front**

- **High Voltage Routing**
  - 4, 5, 6, and 7 are the upper pack
- **Low Voltage Routing**
  - 3, 2, 1 are the lower pack

**Vehicle Rear**

- 1, 2, and 3 are the lower pack
- 4, 5, 6, and 7 are the upper pack

- HVIL
- Other Low Voltage
ESS Final Integration
Commitment to Outreach

• Welcomed over 1500 guests during the past fiscal year
• Hosted numerous outreach events
• Partnership with the PAST Foundation, focused on K-12 outreach
PERSONAL MOBILITY BEYOND 2020

GIORGIO RIZZONI
THE FORD MOTOR COMPANY CHAIR IN ELECTROMECHANICAL SYSTEMS
PROFESSOR, MECHANICAL AND AEROSPACE AND ELECTRICAL AND COMPUTER ENGINEERING
DIRECTOR CENTER FOR AUTOMOTIVE RESEARCH
• Mobility is essential to a productive society

• Energy is a necessary part of mobility

• Congestion and urbanization are changing the way we think about mobility

• How will this translate into new business and technology development models?
Mobility: The movement of people and goods from place to place, job to job, or one social level to another (across bridges – physical or assumed).
URBANIZATION AND CONGESTION
How many cars do you think are in circulation today, worldwide?
Today, there are 1 billion cars on the road. Can we sustain a 2 billion car world?
A NEW CHALLENGE: CONGESTION!

1917 football parking, The Ohio State University Archives
By 2030, 60% of the world’s population will live in urban areas, up from 50% today (70% by 2050). Within 20 years, 80% of wealth will be concentrated in cities. As the urban population increases, traffic congestion in large metro areas will become an even bigger issue.
REDUCING VEHICLE MILES TRAVELED?
Over the next decades, all of the world’s population growth will be in urban areas, with Asia and Africa accounting for 90% of the growth

• By 2030, urban areas are projected to account for 60% of the population and greater than 80% of the wealth

Implications for transportation systems

• **Personal** vs. mass transportation
• Car sharing
• Low-/zero-emission capability
• Growth of urban vehicles to cope with parking problems
• Increasing use of information systems
• And, of course, telecommuting and virtual presence
SMART CITIES, SMART COMMUNITIES

SMART COLUMBUS

WE ARE THE SMART CITY
TOMORROW'S MOBILITY?

New mobility solutions and business models, traffic and transportation systems, urban logistics

Net carbon free fuels

Increased vehicle intelligence and autonomy

Improved efficiency, electrification

Weight reduction
PERSONAL MOBILITY TOMORROW…
EVERYTHING OLD IS NEW AGAIN
THANK YOU QUESTIONS?
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