Michigan Connected and Automated Vehicle Working Group

March 14, 2019

Meeting Packet

1. Agenda
2. Meeting Notes
3. Attendance List
4. Handouts
5. Presentations
Michigan Connected and Automated Vehicle Working Group

March 14, 2019

Washtenaw Community College
Morris Lawrence Building, Room 101
4800 E. Huron River Dr.
Ann Arbor, MI 48105

Meeting Agenda

12:30 PM  Registration and Networking

1:00 PM  Introduction and Update
Richard Wallace, Vice President, Transportation Systems Analysis, CAR

Washtenaw Community College Welcome Remarks
Kimberly Hurns, Vice President for Instruction, Washtenaw Community College

Scalable Cloud-based Simulation: The Key Enabling Technology Making AV’s Possible
Jeff Blackburn, Head of Business Development, Metamoto

Importance of High-fidelity Vehicle Dynamics for AV/ADAS Development
Robert McGinnis, Senior Account Manager, Mechanical Simulation Corporation

Linking the World to Sensor Models for Realistic Simulation
Tony Gioutsos, Director Portfolio Developer for Autonomous Americas, Siemens

2:20 PM  Networking Break

2:40 PM  Hot Topics Discussion
Scott Shogan, VP, Connected/Automated Vehicle Market Leader, WSP
Frank Perry, Principal Consultant, CAV Program Manager, WSP

Update on MDOT CAV Activities
Joseph Gorman, Connected Vehicle Engineer, Michigan Department of Transportation

Car Hackers: The Auto Industry’s Latest Safety Feature
Jennifer Tisdale, Director Connected Mobility & Critical Infrastructure Security, GRIMM

Automotive Cybersecurity
Cyndi Millns, Professional Faculty – Cybersecurity, Washtenaw Community College

4:00 PM  Meeting Adjourned

Organized by Center for Automotive Research (CAR)  www.cargroup.org
Meeting Notes

The Winter 2019 meeting of the Michigan Connected and Automated Vehicle Working Group was held on March 14, 2019 and hosted by Washtenaw Community College; the meeting was held at the Morris Lawrence Building, 4800 E. Huron River Dr. Ann Arbor, MI 48105.

Richard Wallace, Vice President, Transportation Systems Analysis, CAR welcomed the Michigan CAV Working Group attendees, reviewed the meeting agenda and mentioned noteworthy CAV (and related) news. Richard also invited Barb Land, COO of Square One Education Network to provide a brief introduction to the 2019 Innovative Vehicle Design Challenge which will be held on May 11, 2019, at the Kettering University GM Mobility Research Center, Flint, MI. An invitation to the Innovative Vehicle Design Challenge can be found in the last section of this meeting packet.

Dr. Kimberly Hurns, Vice President of Instruction at Washtenaw Community College (WCC), also welcomed all attendees to WCC. Dr. Hurns highlighted WCC’s initiatives related to CAV, ITS, advanced manufacturing, cybersecurity, and mobility education. The goal is to make students ready for the upcoming industry transformation and labor force development. WCC faculty members are pioneers in developing new curriculum and offering new courses in these areas. Sixteen such courses are being offered at WCC now that have helped many students to successfully transfer to four-year colleges.

Jeff Blackburn, Head of Business Development, Metamoto, introduced the start-up simulation company Metamoto. Jeff highlighted that it is statistically impossible to accrue enough real-world testing miles for automated driving systems to validate them as a human-equivalent level of safety. Creating the right testing scenarios that reflect the behavioral competencies (such as freeway high-speed merging) and incorporating them into scalable simulations is the key enabling technology for making AV’s possible. Metamoto offers a cloud-based simulation service allowing ADS developers to run hundreds of simulated scenarios overnight.

Robert McGinnis, Senior Account Manager, Mechanical Simulation Corporation, presented the “Importance of High-fidelity Vehicle Dynamics for AV/ADAS Development”. Mechanical Simulation Corp offers a simulation platform that emphasizes the physics of complex dynamic mechanical systems. The tool allows for easy manipulation of virtual vehicles to simulate dynamic performance with high-fidelity. An example use-case is predicting the dynamic performance of a vehicle with a variety of load-types, such as pulling a trailer or carrying a roof-rack. Such work is critical for all vehicles regardless of the level of automation. Distinct tools are available for general vehicle type, including CarSim, BikeSim, and TruckSim.
Tony Gioutsos, Director Portfolio Developer for Autonomous Americas, Siemens, presented "Linking the World to Sensor Models for Realistic Simulation". Tony started with discussing the necessity of linking detailed world models with sensor models and available modeling framework. Then he introduced the Siemens Prescan Simulation tool. Prescan is an open-architecture simulation tool able to support multiple uses and levels of fidelity. A current focus of the Prescan development team is to develop accurate user-configurable simulations for a variety of sensors. Tony presented approaches for simulating raw camera, radar, and lidar sensor inputs, as well as V2X wireless communication.

After the networking break, Scott Shogan, VP, Connected/Automated Vehicle Market Leader, and Frank Perry, Principal Consultant, CAV Program Manager, WSP, continued the meeting with the Hot Topics Discussions. Scott Shogan briefly recalled high-level discussions from the 2019 Consumer Electronics Show (CES) in Las Vegas, implying that the futuristic hype of previous years has been tempered by the difficult work of real-world deployment. Then, Frank provided a view from his ongoing work with the OmniAir Consortium—a group set-up to certify DSRC V2X devices. Work is ongoing to deploy a U.S. national V2X-based ITS system but has been complicated and delayed by various factors.

Joseph Gorman, Connected Vehicle Engineer, Michigan Department of Transportation, provided an update on MDOT CAV activities, including infrastructure deployment plan (especially in SE Michigan region), CV design and maintenance guidelines, connected signals policy, and current CAV and ITS projects. Michigan continues to deploy a statewide DSRC-based connected vehicle system. An RSU has recently been installed in Houghton. MDOT is soon planning to contract a vendor to set-up a statewide Security Credentials Management System (SCMS) for the various deployments around the state.

Jennifer Tisdale, Director Connected Mobility & Critical Infrastructure Security, GRIMM, presented “Car Hackers: The Auto Industry’s Latest Safety Feature.” Jennifer highlighted automotive- and defense industry focused on cybersecurity issues and challenges. For example, the risks are associated with EVs and charging stations, shared mobility, connectivity, and increased SW applications. Training and skill development are also essential to the industry.

Cyndi Millns, Professional Faculty – Cybersecurity, Washtenaw Community College, spoke about automotive Cybersecurity. WCC is offering an associate degree in Applied Science Cybersecurity (APSCY). The program features flexible learning environments, industry best practices and certifications, and soft skills development. The cybersecurity degree also works closely with other WCC programs, such as advanced transportation center, mobile hacking workbench integration, and development of certificate in automotive cybersecurity. Industry partnerships are also key to the success of the program.

The meeting adjourned at 4:15.

MDOT maintains a webpage dedicated to its work related to CAV technologies (http://www.michigan.gov/mdot/0,1607,7-151-9621_11041_38217--,00.html). The page includes documents, presentations, and other materials that may be of interest to CAV stakeholders. Meeting packets containing materials (agenda, meeting notes, attendance, and presentation slides) from past Michigan Connected and Automated Vehicle Working Group meetings are also available on this page.
# Michigan Connected and Automated Vehicle Working Group

**March 14, 2019**

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## Attendance List

<table>
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<tr>
<th>First</th>
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<th>Organization</th>
<th>Position</th>
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<tbody>
<tr>
<td>Alex</td>
<td>Sergay</td>
<td>Washtenaw Community College</td>
<td>Senior Instructional Designer</td>
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<td>Anthony</td>
<td>Magnan</td>
<td>Verizon Wireless</td>
<td>5G Solutions Engineer</td>
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<tr>
<td>Barb</td>
<td>Land</td>
<td>Square One Education Network</td>
<td>COO</td>
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<tr>
<td>Barbara</td>
<td>Hauswirth</td>
<td>Washtenaw Community College</td>
<td>Experiential Learning Coordinator</td>
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<tr>
<td>Bert</td>
<td>Baker</td>
<td>Great Wall Motors R&amp;D</td>
<td>Program Manager - Autonomous Vehicle Systems</td>
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<tr>
<td>Bill</td>
<td>Shreck</td>
<td>MDOT</td>
<td>Interdepartmental Liaison</td>
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<tr>
<td>Bob</td>
<td>Feldamier</td>
<td>Macomb Community College</td>
<td>Dean - Engineering &amp; Advanced Tech</td>
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<tr>
<td>Brandon</td>
<td>Barry</td>
<td>Block Harbor Cybersecurity</td>
<td>CEO</td>
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<td>Brandon</td>
<td>Tucker</td>
<td>Washtenaw Community College</td>
<td>Dean of Advanced Technologies and Public Service Careers</td>
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<td>Chase</td>
<td>Chen</td>
<td>AECOM</td>
<td>Traffic Engineer</td>
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<td>Cheryl</td>
<td>Harvey</td>
<td>Washtenaw Community College</td>
<td>Assistant Director of CS</td>
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<td>Christyn</td>
<td>Lucas</td>
<td>Detroit Regional Chamber</td>
<td>Manager, Business Research</td>
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<td>Corey</td>
<td>Reiter</td>
<td>Morpace, Inc.</td>
<td>Business Development Manager</td>
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<td>Cyndi</td>
<td>Millns</td>
<td>WCC</td>
<td>Professional Faculty</td>
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<tr>
<td>David</td>
<td>Walmroth</td>
<td>Ann Arbor Autonomous Vehicle Group</td>
<td>Co-Organizer</td>
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<tr>
<td>Elizabeth</td>
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<tr>
<td>Eric Paul</td>
<td>Dennis</td>
<td>CAR</td>
<td>Senior Transportation Systems Analyst</td>
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<td>Erin</td>
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<td>P3Mobility</td>
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<td>Frank</td>
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<td>Raymond</td>
<td>Hess</td>
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<td>Transportation Manager</td>
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<td>Richard</td>
<td>Murphy</td>
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<td>Program Coordinator, Civic Innovation Labs</td>
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<td>Scott</td>
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<td>VP, Connected/Automated Vehicle Market Leader</td>
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<td>Sia</td>
<td>Lyimo</td>
<td>WESTERN MICHIGAN UNIVERSITY</td>
<td>STUDENT</td>
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<td>Stephen</td>
<td>Selander</td>
<td>Selander Law Office, PLLC</td>
<td>Attorney</td>
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<td>Susan</td>
<td>Proctor</td>
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<td>Strategic Initiatives Director</td>
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<td>Zahra</td>
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<td>CAR</td>
<td>Transportation Systems Analyst</td>
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Michigan Connected and Automated Vehicle Working Group

Handouts
2019 Innovative Vehicle Design Challenge Competition

Date: Saturday, May 11, 2019
Time: Challenge Competitions 10am to 4pm
Gates open at 8am
Location: Kettering University GM Mobility Research Center
Kettering University 1700 University Ave. Flint MI 48504

Join us for an amazing day of student led engineering and innovation at the Square One Education Network’s 12th Innovative Vehicle Design (IVD) Challenge Competition!

Volunteer here: https://www.surveymonkey.com/r/IVDVolunteer19

Developing talent for tomorrow’s mobility industry workforce is crucial to economic success. Square One links excellent teaching and learning practices to real world engineering challenges to grow skilled, creative and energetic talent. The Square One Innovative Vehicle Design programs showcase the creative engineering strengths of today’s students at a regional competition focused on innovative solutions leading to superior vehicle performance.

Teams compete in one of the following challenges: student-built, go-kart sized electric vehicles, autonomous vehicles built on Power Wheels Jeep platforms, and a 1/10th scale radio-controlled re-engineering challenge. Each has a unique connected (V2X) component to the mission challenge.

These three vehicular engineering projects are exciting, complex and relevant learning opportunities to inspire youth toward science, technology, engineering, or math (STEM) oriented career pathways. Join us to meet the 50 competing teams from around the state and see their engineering solutions in action!

Admission is free.

Square One is a Michigan-based 501c3 STEM educational organization serving K-12 students and teachers. Our mission is to empower teachers with a complete set of resources for students to engage, using hands-on learning tools and modern learning fundamentals, with the intent of developing skills needed for the next generation technical workforce. Our vision is to prepare students with the essential skillset for higher learning institutions and the rapidly evolving needs of STEM related jobs.
The Square One Education Network Innovative Vehicle Design Challenge Competition is Made Possible With the Support of...

P3 Group
Washtenaw Community College
Nissan
MIAT College of Technology
Michigan Dept. of Talent and Economic Development (TED)
Michigan Economic Development Corporation – Planet M
MIS Cares ~ AM General ~ NDIA
Eisbrenner Public Relations ~ WSP
Good Sense Media ~ RC Fun House

Special thanks to our hosts at Kettering University
**Intelligent Ground Vehicle Competition**

The 27th Annual IGVC 7-10 June 2019 at Oakland University Rochester Michigan

**IGVC Student Challenges**

1. Autonomous Navigation
2. Design, Documentation & Presentation
3. Computer Architectures
4. Self Drive

**Competition Objectives**

- Full spectrum systems engineering experience for engineering and computer science student teams
- World Class Career building University/College education project experience for Mechanical, Electrical & Computer Engineers and Computer Science Majors
- Direct application to Autonomous & Intelligent manned & unmanned vehicles for the Automotive and Defense Markets
- Provide Industry & Government Managers, Sponsors and Engineers, a multi-day interaction with students, teams and faculty

**Student Team Benefits**

- First full project experience for your resume
- Intelligent & Autonomous proficiency
- Great recruiting by sponsors
- Published technical papers
- Multiple awards; Cash & certificates
- Networking with other US and International students & faculty
- Tailored to support 4-8 credits per year, one or two semesters
- Under-Graduate or Graduate eligible

**Student Teams & Robots**

For Rules and more IGVC Info go to: [WWW.IGVC.org](http://WWW.IGVC.org)
Bluefield State AN
Bob Jones University SD
Boise State University AN
British Columbia Institute of Technology AN
Case Western Reserve University AN
Delhi Technological University AN
Delhi Technological University AN
Embry-Riddle SD
Florida Tech AN
Florida Tech SD
Gannon University AN
Georgia Tech AN
Hosei University AN
Indian Institute of Technology Kanpur AN
Indian Institute of Technology Kharagpur AN
Lawrence Technological University AN
Lawrence Technological University SD
Manipal Institute of Technology Manipal AN
Michigan Technological University AN
Millersville University AN
New York University SD
North Dakota State University AN

Oakland University AN
Ohio University AN
Old Dominion University AN
Rochester Institute of Technology AN
Roger Williams University AN
SRM Institute of Science and Technology AN
The Citadel AN
Trinity College AN
United States Military Academy AN
United States Military Academy SD
Univ. of Detroit Mercy - AN
Univ. of Detroit Mercy - SD
University at Buffalo AN
University of Central Florida AN
University of Cincinnati AN
University of Michigan AN
University of Michigan Dearborn AN
University of Toronto AN
Wayne State University Engineering AN
Western Illinois University AN
Worcester Polytechnic Institute AN
Michigan Connected and Automated Vehicle Working Group

Presentations
Michigan Connected and Automated Vehicle Working Group

Richard Wallace, V.P., Transportation Systems Analysis, CAR
March 14, 2019
Washtenaw Community College
Ann Arbor, MI
Meeting Agenda

1:00 PM

**Introductions and Update**
Richard Wallace, V.P., Transportation Systems Analysis Center for Automotive Research

_Washtenaw Community College Welcome Remarks_
Kimberly Hurn, VP of Instruction, Washtenaw Community College

**Scalable Cloud-based Simulation: The Key Enabling Technology Making AV's Possible**
Jeff Blackburn, Head of Business Development, Metamoto

**Importance of High-fidelity Vehicle Dynamics for AV/ADAS Development**
Robert McGinnis, Senior Account Manager Mechanical Simulation Corporation

**Linking the World to Sensor Models for Realistic Simulation**
Tony Gioutsos, Director Portfolio Developer for Autonomous Americas, Siemens

2:20 PM

**Networking Break**

2:40 AM

**Hot Topics Discussion**
Scott Shogan, V.P., Connected/Automated Vehicle Market Leader, WSP

**Update on MDOT CAV Activities**
Joseph Gorman, ITS Program Manager, Michigan Department of Transportation

**Car Hackers: The Auto Industry’s Latest Safety Feature**
Jennifer Tisdale, Director, Connected Mobility & Critical Infrastructure Security, GRIMM

**Automotive Cybersecurity**
Cyndi Millns, Professional Faculty – Cybersecurity, Washtenaw Community College

4:00 PM

**Meeting Adjourned**
Working Group Mission

Cooperatively pursue projects and other activities that are best accomplished through partnerships between multiple agencies, companies, universities, and other organizations and that ultimately advance Michigan’s leadership position in connected and automated vehicle research, deployment, and operations.

Goals

• Benefit our state and our industry (automotive and more)
• Enhance safety and mobility in Michigan and beyond
Upcoming CAV Events

• **ADAS Sensors**  
  March 20-21, 2019 | The Henry Hotel, Dearborn, MI

• **Michigan Defense Expo (MDEX)**  
  April 3-4, 2019 | Macomb Community College (MCC) Expo Center, Warren, MI

• **SAE Government and Industry**  
  April 3-5, 2019 | Walter E. Washington Convention Center, Washington, D.C.

• **2019 Washington D.C. Auto Show**  
  April 5-14, 2019 | Walter E. Washington Convention Center, Washington, D.C.

• **SAE WCX**  
  April 9-11, 2019 | Cobo Center, Detroit, MI

• **2019 Innovative Vehicle Design Challenge**  
  May 11, 2019 | Kettering University GM Mobility Research Center, Flint, MI

• **Next Gen Mobility Summit**  
  May 23-24, 2019 | Somewhere in Silicon Valley, CA

• **TU-Automotive Detroit 2019**  
  June 4-6, 2019 | Suburban Showcase, Novi, MI
Noteworthy CAV (and Related) News

• The Partnership for Autonomous Vehicle Education (PAVE) was announced in January. Its goal is to educate the public and policymakers about AVs.

• GM is closing factories in the region
  • But Waymo and FCA are adding them

• Meanwhile, Ford and Volkswagen have announced a partnership to make pickup trucks and commercial vans, but they also are exploring collaborations on EVs, AVs, and mobility services.

• Similarly, Daimler and BMW have extended their mobility partnership, which includes five joint ventures:
  • REACH NOW for multimodal services
  • CHARGE NOW for charging
  • FREE NOW for taxi ride-hailing
  • PARK NOW for parking
  • SHARE NOW for car-sharing

• Both Uber and Lyft have announced plans for IPOs sometime this year
Thank you to our hosts!

Washtenaw Community College
Scalable Cloud-based Simulation: The Key Enabling Technology Making AV's Possible
About Me

Jeff Blackburn
Head of Business Development
Metamoto, Inc.

6+ years experience with Legacy Simulation tools (Siemens Tass PreScan)

10+ years experience in AV development (IVBSS - embedded code development with National Instruments)

Developed and Teach the SAE classes
  “Introduction to the Highly Automated Vehicle”
  “Autonomous Vehicle Regulations and Liability”
  “Autonomous Vehicle Simulation Hands-on Workshop”
# The Empirical Problem - Scale

~5 to 9 billion miles required*

95% CI with 5% to 20% degree of precision

100 AV’s with 100% uptime → 12.5 to 400 years to completion

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<thead>
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<th>How many miles (years) would autonomous vehicles have to be driven…</th>
<th>Benchmark Failure Rate</th>
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<tr>
<td>(1) without failure to demonstrate with 95% confidence that their failure rate is at most…</td>
<td>(A) 1.09 fatalities per 100 million miles?</td>
</tr>
<tr>
<td>275 million miles (12.5 years)</td>
<td>3.9 million miles (2 months)</td>
</tr>
<tr>
<td>(2) to demonstrate with 95% confidence their failure rate to within 20% of the true rate of…</td>
<td>8.8 billion miles (400 years)</td>
</tr>
</tbody>
</table>

* "Driving to Safety: How Many Miles of Driving Would it Take to Demonstrate Autonomous Vehicle Reliability?", Nidhi Kalra, Susan M. Paddock, RAND Corporation, 2016
The Tactical Problem - Testing Coverage

The relevant real-world cases (accidents) shouldn’t be reproduced in the real world

Shadow Driving/Partial AV is neither adequate or safe
Using Simulation Efficiently

Computational Cost

- Workstation: Physics based sensor models
  - ~5% of all simulations

- Cloud GPU: Full Stack with high fidelity sensor models
  - ~45% of all simulations

- Cloud CPU or GPU: Testing of algorithms and sub-systems
  - Simplified to high fidelity sensor models depending on SUT
  - ~50% of all simulations

metamoto Coverage
Waymo and Simulation

Waymo is performing millions of simulations per night.

“In raw miles, Waymo is by far the leader,” said Grayson Brulte, a Beverly Hills-based driverless industry consultant. “They’re like Jesse Owens or Carl Lewis – running a 100-meter dash around everybody.”

Scalable Simulation Drives AV Performance

Source: California DMV
Scalable Simulation Drives AV Performance

![Graph showing the relationship between disengagements per simulation hour and simulation hours. The graph indicates a decreasing trend in disengagements as simulation hours increase.]
Behavioral Competencies - An Overview

Edge cases should be classified and categorized into behavioral competencies

Don’t test useless miles

NHTSA  28 behavioral competencies
Waymo  19 behavioral competencies
Total  47 behavioral competencies
## Behavioral Competencies - Example

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Perform High-Speed Merge (e.g., Freeway)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameterization</td>
<td>8 variables with 5 possible values per variable</td>
</tr>
<tr>
<td></td>
<td>$5^8 = \sim 400,000$ test cases (without intelligent parameterization)</td>
</tr>
<tr>
<td>Assume</td>
<td>10 scenarios are required per behavioral competency</td>
</tr>
<tr>
<td></td>
<td>Each behavioral competency has a possible 4,000,000 test cases</td>
</tr>
</tbody>
</table>

$\sim 200,000,000$ test cases are required to prove out all 47 behavioral competencies
The Legacy Scale Problem - Serial Test Execution

~200,000,000 test cases are required to prove out all 47 behavioral competencies

Legacy Simulation – Serial Test Execution
5 minutes per simulation → ~25,000 simulations per year
200,000,000 / 25,000 → ~8,000 years (or Workstations)
~$45k per workstation → $1.80 per simulation

Cloud Based Simulation – Parallel Test Execution
10,000 parallel instances → ~250 million simulations per year
200,000,000 / 250,000,000 → ~10 months
$3 per hour → $0.42 per simulation

Assumes running 8/5/260 (Typical use case)
The Legacy Scale Problem - Serial Test Execution

~200,000,000 test cases are required to prove out all 47 behavioral competencies

Legacy Simulation – Serial Test Execution
5 minutes per simulation → ~105,120 simulations per year
200,000,000 / 105,120 → ~1,903 years (or Workstations)
~$45k per workstation → $.43 per simulation

Cloud Based Simulation – Parallel Test Execution
10,000 parallel instances → ~1 billion simulations per year
200,000,000 / 1,000,000,000 → ~2 months
$3 per hour → $ 0.00003 per simulation

Assumes running 24/7/365 (Max Thru-Put Use Case)
Product Offering

**Designer**
*Scenario Creation*
- Script AV Exercises
- Expose Parameters

**Director**
*Cloud Simulation*
- Scalable, On Demand
- Usage Based Pricing

**Analyzer**
*Simulation Replay*
- Analyze Results
- AV Debugging
Integration

Modern DevOps Processes

Tools
- Bamboo
- Jenkins
- Jira
- Jama
- GitHub
- Bitbucket
Parameter Exploration

Environmental Factors
- Weather
- Time of Day
- Road Conditions
- Lane Markings
- Pedestrians
- Traffic

Hardware Factors
- Vehicle Properties
- Sensor Placement
- Controller Settings
- Sensor Settings
- Environment Noise
- Latency
- Failure Rate(s)
Sensor Simulation

Camera / IR Camera
- Spectral Density
- Lens Distortion
- Dirty Lens
- Foggy / Wet Lens
- Vignetting & Bloom

Lidar
- Beam Widening
- Multiple Returns
- Material Reflectivity
- Atmospheric Attenuation

Radar
- Custom Scan patterns
- MIMO
- Multipathing
- Clutter
- Material Properties
- Micro-Doppler
- Custom Waveforms

GPS / IMU
- Positional Noise
- Gyro Noise / Bias
- Accelerometer Noise / Bias
- Abbe Error

V2X
- BSM 1 & 2
- Multipathing
- Dropped packets
- Signal Fade With Distance
Sensor Simulation

Visible Light Configurable Camera Settings

- Image output type
- Encoding of the image data published to the data bus
- Frame width in pixels
- Frame height in pixels
- Frame rate
- Vertical field of view
- Pixel size in micrometers
- Focal length in millimeters
- Lens radial distortion coefficient $k_1$
- Lens radial distortion coefficient $k_2$
- Lens radial distortion coefficient $k_3$
- Lens tangential distortion coefficient $t_1$
- Lens tangential distortion coefficient $t_2$
- Principal point x offset
- Principal point y offset
- Enables or disables HDR

- Dirt texture to use
- Level of dirt on the lens
- Blooming
- Vignetting
- Fogged lens
- Wet lens
- Stuck pixels
- Low light noise
- Labeled image output by their ground-truth object type
- Origin corner of the image data
- Cropping
- Object list output
- Remove outlier pixels
- Object types to report
- Minimum width (in pixels) for detection
- Minimum height (in pixels) for detection
Low distortion regular lens

- frameWidth: 1280
- frameHeight: 720
- pixelSize: 4.08
- focalLength: 3.8
- distortionK1: -0.06
- distortionK2: 0.0005
- distortionK3: 0
- principalCxOffset: 0
- principalCyOffset: 0

Full frame distorted wide-angle lens

- frameWidth: 1280
- frameHeight: 720
- pixelSize: 7.32
- focalLength: 3.01
- distortionK1: -0.12
- distortionK2: 0.01
- distortionK3: 0
- principalCxOffset: 0
- principalCyOffset: 0
- fullFrame: true

Uncropped 120° fisheye lens

- frameWidth: 1280
- frameHeight: 1280
- pixelSize: 4.36
- focalLength: 1.61
- distortionK1: -0.06
- distortionK2: -0.1
- distortionK3: -0.43
- principalCxOffset: 0
- principalCyOffset: 0
- fullFrame: false
System Architecture

Overview

Director

Public Interfaces

- Parameter Space Explorer
- Scheduler
- Resource Manager

Engine

- Services
  - Physics, Imaging, EM Propagation
- Event System
- Traffic
- Pedestrians
- Ground Truth

- Sensor Library
  - Metamoto Sensors
    - Lidar, Camera, Radar, GPS, IMU, ...
  - Customer Sensors

- Ego Vehicle
  - Software Stack
    - Perception, Planning, Actuation, ...
  - Vehicle Model

- Observer
  - Pass / Fail Criteria
  - Custom Logic

- Version Control

Director

- Suites
- Vehicles
- Scenarios
- Geometries
- Scenes
- Materials
- Results

Third Party Integration

- Designer
  - UI
  - API
- Analyzer
  - Container Registry
- Third Party Integration
System Under Test (SUT) Integration

- Containerized External Code
  - Sensors
  - Controllers – driving data, processing, etc.
  - Vehicle Dynamics
- gRPC and Protobuf API
- Publish – Subscribe Data Bus
- SUT Connector for Local Testing

**SUT**

- Controller Server
- Data Bus Client
- 5. Step Model

**Engine**

- Controller Client
- Data Bus Server
- 2. Simulate
- 3. Update ( )
- 1. Initialize ( )
- 4. Read Sensor & State Data
- 6. Write Vehicle Controls
- 7. Close ( )
BAIDU APOLLO INTEGRATION

Feeding raw sensor data from Metamoto simulation into Apollo and visualizing its perception stack output
The Solution

Scalable, cloud based simulation, integrated into a continuous build and test software development workflow, is the key enabling technology making AV's possible
Questions?

jeff.blackburn@metamoto.com
650-313-3649
Ax  0.282
Ay  -0.757
Roll -0.722
Pitch -1.164
Yaw  168.3
Mechanical Simulation Snapshot

- University of Michigan / UMTRI origins
- Founded 1996
- 50 Employees
- 7 Global Agents
- Customers in 60+ countries
100+ OEMs and Tier 1 Suppliers
250+ Universities
4700+ Active Licensed Seats
40+ Worldwide Car and Truck OEMs

- GM
- Toyota
- Ford
- Chrysler
- Geely
- Mitsubishi Motors
- Fiat
- Mazda
- Nissan
- Subaru
- Honda
- Hyundai
- Isuzu
- Daewoo
- Land Rover
Technology Partners
Car/Truck/BikeSim

- Braking
- Steering
- Powertrain
- Suspension kinematics
- Suspension compliance
- Tire models
- Driver models
- Autonomous driving
- Weight distribution
- Fuel economy
- 3D roads
- Road roughness
- Traffic vehicles
- Pedestrians
- ADAS Range sensors
- Camera sensors
- VS/Python scripting
Vehicle Simulation and Testing Platform

**Tire Models**

**Steering Models**

**Driver Models**

**Active Suspension Models**

**Testing Complex Driving Sequences**

**ESC/ABS/Traction Controllers**

**ICE and Hybrid Powertrain Controllers**

**Autonomous and ADAS Systems:**
- Lane Keeping / departure
- Cooperative Active Cruise Control
- Forward Collision
- Level 4/5 Handoff
- Sensor Models

**VS Commands scripting**
- Python
- Matlab/Simulink, LabView, ASCET
- API - C/C++
- HPC and Cloud Computing

**VS Connect**
- FMI and FMU
- Hardware in the Loop
- V2V, V2I, GPS Communication
- Driving Simulators
MATLAB/Simulink Interface (when necessary)

- S-Function loads the CarSim Solver
- Use Simulink from CarSim
- Use CarSim from Simulink

- Multiple S-Functions support running multiple vehicles in the same simulation (CACC for example)
Multiple Car Interactions
Autonomous Vehicles from Recent Futurists

- Never crash
- Never exceed .3g acceleration
- Straight to Level 5
- Mass deployment in 2021 models

- Passenger sickness
- Pedestrian bullying
OEMs have Invested Millions in Simulation

- Software tools
- HIL benches
- Test equipment
- Data storage
- Engineering
- Validation and Certification

Value
- Trusted technologies
- Reduce time to market
- Improves domain knowledge
- Continual validation

- Wide range of maneuvers
- Road surfaces
- Weather conditions
- Vehicle payloads
- Controller settings
All AV Companies Understand Simulation is Essential

- 8,000,000,000,000,000 miles are required
- Tests must be run every night/day
- Pass/Fail must be analyzed automatically
- How is pass/fail determined?
  - Variance from path – lane keeping
  - Avoidance of collision – how much distance is ideal
  - Reduction of energy in collision
  - Network benefit – if we all stop…we won’t get anywhere

- Trusted Simulation is the only answer.
Bicycle Model / Game Engine Model

First model taught at university

Bicycle model – very limited

Game Physics – more sophisticated, not intended for engineering

Minimal Degrees of Freedom

Cannot handle wide range of vehicles: motorcycle, tractor-trailer, etc.

Nobody has time to second guess unproven/unvalidated physics
High-Fidelity Models Provide

- ABS/ESC/TC controls
- Active dampers, torque vectoring, new steering strategies
- Hybrid technologies – regen braking
- Loaded vehicles behave differently – passengers, roof racks
- Road conditions (crowns, drop off, gravel, pot holes, roughness, ice patches, etc.)
- Understeer/oversteer
- Ackerman steering
- Comprehensive tire models
- Sensor motion (roll, pitch, yaw)
- Ride motion is important
Connectivity Required for Complete Solution

- Developing driver controls
- Handoff Strategies
- Regression tests
- Hardware-in-the-loop
- Machine learning/optimization
- Mapping
- Scenarios
- Sensor simulation
  - Best of class
  - Prescan

- Matlab/Simulink, C/C++, Python
- Windows, Linux, HIL, Embedded
- AWS, Azure, HPC
- Tools for DOE/optimization
- Tools for Cloud/HPC
Thank you

- Robert McGinnis
- Mechanical Simulation
- rmcginnis@carsim.com
Linking the World to Sensor Models for Realistic Simulation

Tony Gioutsos – Portfolio Developer TASS - Siemens
World & Sensor Modeling
The necessity of linking detailed World models with detailed Sensor models

- Simcenter Prescan is constructed from the ground up to perform realistic ADAS/AV V&V
- ADAS/AV Integration environment commercially available since 2006
- Far ahead of the competition
Available Data in the Sensor Processing Chain

Random and Variability

Detailed Physics

Sensor # 1 → Processing Step #1
Sensor # 2 → Processing Step #1
Sensor # N → Processing Step #1

Physics Based

Processing Step #M
Processing Step #L
Processing Step #K

Fusion

Control

Perfect “target”
Simcenter Prescan
The most realistic and comprehensive solution for Digital Twin of the World

Fidelity of World Model must match Sensor Model

- Detailed Physics – Physics Based Camera, Physics Based Radar, Detailed V2X models, Ray Tracing Lidar/Camera
- Random & Variability of Word & Sensors
- Physics Based
- Perfect “target” – No sensor info

Realism

Detailed Physics

Random & Variability

Physics Based

Perfect “target”

World Modeling
Competition

Simcenter Prescan

Computation

Real-time
Camera Sensor Models
Physics Based Camera (PBC) Pipeline Overview
Camera Spectral Density

- The spectrum of light that reaches the lens is calculated.
- The user can specify the number of bands to be used.
  - For example, 10 bands for visible light (320-720 nm).
- Materials
- Puddles with reflections
- Retro reflections for physics-based materials
- Assignment of materials to regions/objects
- Environment
- Configuration of sky SPD and intensity
- Ability to control ambient lighting
Camera Inputs

Lens modelling
• according to Zmax standard
• Focal length
• Aperture
• Vignetting
• Modulation Transfer Function
• Barrel and Pincushion distortion

Color Filter Array
• RCCC or BGGR filters
• edit the transmittance

Image sensor
• Imager layout
• Imager electrons

Circuit board
• Digital precision
• Off-chip gain

Noise model
• Read noise
• Dark noise
• Photon dependent noise, array uniformity

Detailed information is available in the manual.
Example Usage for Adapting Camera Exposure
PBC Imagery Injected into NVIDIA Drive PX2
(DIL simulator at Ford September 5th)

Free space detection on Nvidia Drive PX2
Effect of Lane Line Corrosion

Lane Corrosion 0%

Lane Corrosion 50%

Lane Corrosion 80%
Effect of Lane Line Corrosion

Lane Corrosion 0%
Lane Corrosion 50%
Lane Corrosion 80%
Simulate Light in the Scene

- Multi-bounce
- Spectral Effects
- Weather
- Physics Based
- Dirt/Dust
- Refraction/Reflection
- Temporal Effects

\[ L_o(x, w) = L_a(x, w) + \int_{\Omega} f_r(x, w', w) L_i(x, w')( - w' \cdot n)d w' \]
Radar Sensor Models
Object Level Radar/Lidar

**AIR sensor**
- Idealized radar model
- Bounding box detection
- Occluded targets are visible
- No distortions
- Output on target level

**Radar/TIS sensor**
- Single-path reflection radar model
- Detection of actual target geometry
- Occluded objects will not be detected
- Distortions like noise, drift and misalignment
- Output on detection level
- Different scan patterns
- Targets have radar cross section (RCS) definition
- Calculation of dB loss (attenuation)
- Use of antenna gain maps

**Radar and Lidar sensor settings**
- Position & orientation
- Frequency
- Scan pattern (fixed or user controlled)
- Resolution cell size (range & angle)
- Max. detected objects
- Antenna parameters / gain map
- Noise, drift and misalignment

**Output signals for each target**
- Distance to target (Range)
- Velocity (x,y,z) relative to target (Rangedot)
- Detection angles in azimuth (θ) and elevation (φ)
- Local incidence angles in azimuth and elevation
- Energy loss (dB loss)
- Target ID and Target Type
Example of Real-time Physics Based Sensor Data - Radar Energy Loss

- Energy Loss affected by Angle of Object
- Note Attenuation difference
- Energy Loss affected by Angle & Weather (Small Attenuation)
Detailed Physics Based Radar Module (PBRM)

- Transmitter
- Receiver
- Raw radar data
- I and Q
- Frequency data
- Detections
- CAN data
- Object recognition
- Processsing

- Waveform
- ADC
- FFT

- PreScan PBRM
- Sensor Competitors
- PreScan - Sample algorithms available

Outside world

World Competitors

Competitors
Simulation Overview

- **Ray tracing module (RT)**: Set of rays along all possible propagation paths from transmitter to receiver.
- **Signal recombination module (SR)**
- **Hardware model & signal processing (SP)**: Different types of data possible.

World model

Scene description

Raw radar data
Multipath Simulation and Perfect Ground Truth
Capabilities

Multipath simulation up to any number of bounces.
Configurable tradeoff between fidelity and performance.
Multistatic antenna configurations (MIMO).
Fully customizable waveforms (FMCW, Fast Chirp Modulation, etc).
Physical material properties, including polarization effects.
Clutter simulation.
Micro-doppler effects.
Interference between different radar sets.
Non-perfect component behaviour.
City Example

Camera image from point of view of radar.

Simulated radar data, processed to Range-Doppler
Highway Example

Example without thermal and receiver noise
Sweep bandwidth 600 Mhz
Verification of RCS - Corner reflector 15dBm2
Verification of RCS - Vehicle

PBRM Simulation (YARIS)

Denso Measurements (Prius)
Lidar Sensor Models
Point Cloud Sensor

Made for real-time applications
Able to generate 240,000 points and run in real-time for a highway scenario that contains up to 7 target vehicles

Outputs:
Point cloud measurements in x,y,z coordinates
Range and angle
Intensity values used for object differentiation
PCS Ground Truth

**De-clustered Point Cloud Data**

**Clustered Point Cloud Data**

Point Cloud Sensor Settings

**Resolution**
- Horizontal #Samples: 320
- Vertical #Samples: 160

**Field of View**
- FoV Azimuth [deg]: 60
- FoV Elevation [deg]: 30
Detailed physics LiDAR sensor model – in development

**Input**
- Sensor Parameters:
  - Beam shape
  - Beam divergence
  - Wavelength
  - Scan pattern (direction and time)
  - Directional sensitivity
  - Pixel sensitivity

**World Definition**
- Simulate Light in the Scene:
  - Multi-bounce
  - Time Effects
  - Weather
  - Dirt/Dust
  - Spectral Effects
  - Refraction / Reflection

**Simulation**
- Tx Optics
- Rx Optics

**Output**
- Raw Data
- Signal Processing

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Detailed Physics Based Lidar Simulation
Detailed Physics Based Lidar Simulation

Simulated Full-Waveform Lidar Data

Energy Received

Time [ns]

0 50 100 150 200 250 300

10^-8

Partial Intersections

Secondary Intersections
Weather Effects

LIDAR sensors are affected by weather (e.g. rain, snow, fog) and dust. Therefore it is important to simulate how light from a LIDAR beam scatters in an environment. This can impact both the waveform and the final point cloud generated by the LIDAR.
V2X Sensor Models
## Application layer: Building your control algorithms

## Facilities layer: Select your message set using standard message sets in PreScan GUI

<table>
<thead>
<tr>
<th>Layer</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Application layer</strong></td>
<td>Building your control algorithms</td>
</tr>
<tr>
<td><strong>Facilities layer</strong></td>
<td>Select your message set using standard message sets in PreScan GUI</td>
</tr>
<tr>
<td><strong>Network layer</strong></td>
<td>How is the message distributed?</td>
</tr>
<tr>
<td>Distance based / ideal sensor</td>
<td>No license needed</td>
</tr>
<tr>
<td>Fraunhofer statistical sensor</td>
<td>Separate license required</td>
</tr>
<tr>
<td>Physics based sensor</td>
<td>Separate license required</td>
</tr>
<tr>
<td><strong>Access layer</strong></td>
<td>Message scheduling &amp; queuing</td>
</tr>
<tr>
<td>Distance based / ideal sensor</td>
<td>N/A</td>
</tr>
<tr>
<td>Fraunhofer statistical sensor</td>
<td>N/A</td>
</tr>
<tr>
<td>Physics based sensor</td>
<td>Framework ready Hopping, geo-addressing to be added by TASS or partner in future versions</td>
</tr>
<tr>
<td><strong>Radio channel layer</strong></td>
<td>Message scheduling &amp; queuing</td>
</tr>
<tr>
<td>Distance based / ideal sensor</td>
<td>N/A</td>
</tr>
<tr>
<td>Fraunhofer statistical sensor</td>
<td>Effects are lumped in one statistical model for specific scenarios</td>
</tr>
<tr>
<td>Physics based sensor</td>
<td>802.11p (ITS-G5,DSRC)</td>
</tr>
<tr>
<td><strong>Network layer</strong></td>
<td>How is the message distributed?</td>
</tr>
<tr>
<td>Distance based / ideal sensor</td>
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</tbody>
</table>

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Page 35

Siemens PLM Software
Conclusions

• It is important to link the world with your sensor models
• Your sensor models should be a tradeoff between computation and realism
• Detailed Physics Based Sensor models were depicted for camera, Radar, Lidar and V2X

THANK YOU!!!!
MICHIGAN DEPARTMENT OF TRANSPORTATION

Statewide
CAV Program
Update
MISSION

MDOT will work to ensure Michigan remains the national leader in the evolution of CAV technologies, to deliver enhanced transportation safety and reliability, providing economic benefit and improved quality of life.
Goal 1: Serve as a national model to catalyze CAV deployment

Goal 2: Establish Foundational systems to support wide-scale CAV deployment

Goal 3: Make Michigan the go-to state for CAV research and development

Goal 4: Accelerate CAV benefits to users

Goal 5: Exploit mutual benefit opportunities between CAV tech and other department business processes/objectives

Goal 6: Use Michigan experience to lead dialogue on national standards and best practices
Infrastructure Deployment Plan

- Expansion underway to create one of the largest CV infrastructure deployments in the world
CV Design & Maintenance Guidelines

Statewide Guidelines Document

- Develop roles and responsibilities for the designer, MDOT, integrator, and general contractor
- Develop criteria for general deployment
- Standards development for different scenarios
  - Freeway vs Intersection
  - Installation on different structure types
  - Communication architectures to be applied
- Plan delivery requirements for different procurement methods
Updating Standards - Connected Signals Policy

- Coordinated effort with Signals Division to update traffic signal controller specification standards
- All new or upgraded traffic signals on the MDOT system will be CV-enabled going forward
- Developing process to configure and test RSUs at Signals Shop
Current CV Efforts

- Working to procure and implement SCMS
- Developing device/backoffice interoperability conformation process.
- Test and deploy ITIS phrase support for TIM.
- Houghton CV Deployment
Upcoming CV Efforts

- Statewide ITS Architecture update to include CV
- US-23 FlexRoute RSU deployment
- Houghton CV deployment integration
Michigan is Open for Business for CV Partnership Opportunities

- Infrastructure
- Applications
- Data
- Talent
- Research
- Vehicles
- Communications
HACKERS:
THE AUTO INDUSTRY’S LATEST SAFETY FEATURE

March 14, 2019
Connected & Automated Vehicle Working Group
Center for Automotive Research (CAR)
● Executive Director, MI Homeland Security Consortium

● Cyber-Mobility Program Manager, Michigan Economic Development Corporation

● Cybersecurity Manager, R&D, Mazda North America

● Director, Strategic Partnerships & Transportation Security Programs, GRIMM Cyber Research

● Cybersecurity Director, NDIA MI
  ○ Cybersecurity: Defense Sector Summit
  ○ Cyber Military Vehicle Industry Collaboration
What this presentation is NOT...
What This Talk IS About...

- Overview of Automotive Industry Trends
- Focus on Cybersecurity Implications
- What Is Working?
- Where Do We Need Improvement?
- Building a Framework
- Embracing Hackers in the Industry
- The Business of Hacking
- Talent of Tomorrow, Today
Automotive Industry Trends & Cybersecurity Considerations
EVs and Charging Stations

The Promise
- Energy Security
- Environmental Benefits
- Cost Savings
- Noise Reduction
- Tax Incentives

The Risk
- Shorter Range
- Long Charging Times
- Bi-Lateral Data Exchange
- Data Ownership
Shared, Smart Mobility

The Promise

- Cost-Efficient
- Solve Urban Density Issues
- Environmental Benefits
- On-Demand Transportation
- Social Experience

The Risk

- The Car is the Center of the IoT discussion
  - Data
  - Data
  - Data
Increasing R&D for Connected, Automated & Autonomous Systems

The Promise
- Fewer Fatalities
- Increased Safety
- Economic Empowerment; Commercially
- Traffic Management; Ant Farm Theory

The Risk
- Biometric Data; Heart, Glucose, Vital Signs
- Increasing Software Applications; POEs
- Shift of Fatality Responsibility; Driver to Programmer
- Secure Vehicle in an Insecure Environment
- Lack of Regulation and Legal Guidance
Positive Cyber Automotive Trends

R&D Security by Design

Auto ISAC

Meet Ups Industry Professionals

Bug Bounties

Increased Hacker Embrace

2017 Car Hacking Village, DEFCON, Las Vegas, Mazda CX-5
Cyber AutoMobility Goals

- Building a Framework to Validate Security Products
- Legacy System Security Practices
- Standardization of Compliance
- Investment into Security Similar to Safety
- Improved Cyberscurity Organizational Strategy; including IR Plans
- Knowledgeable Cyber Automotive Workforce
Creating a business model where a business model did not exist

Changing the narrative around “Hackers”

Bringing Calm to Chaos

Use Moral Compass
### The GRIMM Business Model

**A SDVOSB* Cybersecurity Firm with a Holistic Approach**

<table>
<thead>
<tr>
<th>CONSULTATION</th>
<th>RESEARCH</th>
<th>TRAINING</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Technical Consultation  ○ System Review</td>
<td>● Advanced Penetration Testing</td>
<td>● Defensive Automotive Security Engineering</td>
</tr>
<tr>
<td>● Non-Technical Consultation  ○ C-Level  ○ IR Planning  ○ Standards &amp; Practices</td>
<td>● Reverse Engineering  ● Application of Adversarial Methodologies  ● Embedded Talent</td>
<td>● Telematics Security  ● Executive Leadership</td>
</tr>
<tr>
<td>● Government Testimony, Consulting &amp; Research</td>
<td></td>
<td>● Applications Security</td>
</tr>
<tr>
<td>● Hacker Motivation &amp; Mindset</td>
<td></td>
<td>● Aerospace/UAV</td>
</tr>
<tr>
<td>● Classified Cyber Ranges</td>
<td></td>
<td>● Custom Built</td>
</tr>
</tbody>
</table>

*GRIMM offers SME’s with Secret and Top Secret Clearance*
<table>
<thead>
<tr>
<th>Skills</th>
<th>Beyond Skills</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can they recommend practical and effective counter-measures to their findings?</td>
<td>Expensive; Market Competition</td>
</tr>
<tr>
<td>Education requirements preferred: CS vs Mechanical / Electrical / Systems Engineering</td>
<td>Confidential Information is at stake</td>
</tr>
<tr>
<td>Qualify / Quantify their experience</td>
<td>Do they understand your business needs ____ technical needs?</td>
</tr>
<tr>
<td></td>
<td>Hobbyist vs Professional; Scope-creep</td>
</tr>
</tbody>
</table>
The Common Bond: Cyber Talent Shortage
Let's stay in touch!

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Automotive Cybersecurity

Cyndi Millns, Professional Faculty
Evolution of Cybersecurity

- Computers
- People
- Things
Associate in Applied Science
Cybersecurity (APSCY)

• Linux
• Introduction to Programming
• Networking (Cisco – CCENT/ICND1)
• System Administration (Client OS and Servers)
• Scripting (PowerShell and Python)
• Introduction to Network Security – Security+
• Essentials of Network Penetration Testing (Ethical Hacking)
• Introduction to Cryptography or Cybersecurity Operations
• Network Perimeter Protection – CCNA Security
Program Features

- Transferability
- Flexible learning environments
- Industry best practices and certifications
- Soft skills development
- Critical thinking through reverse engineering and analysis
Why Automotive Cybersecurity?

Image courtesy of the U.S. Department of Transportation
Lines of Code

1 Million

14 Million

100 Million
http://www.informationisbeautiful.net
What could go wrong?

- Safety
- Theft
- Terrorism
- Revenge
- Mischief
- Extortion-Ransomware
- Insurance fraud
- Espionage
- Stalking
- Feature de(activation)
- Identity theft
- Counterfeiting
Entry Points for Hackers

• External
  • Bluetooth
  • Internet
  • Wi-Fi
  • Key fob
  • LIDAR
    Digital broadcasts
  • Tire Pressure Monitors
  • Tail light
  • DSRC

• Internal
  • Diagnostic Port
  • CD/DVD
  • USB/SD card
  • Aux input
  • CAN Bus
  • Other networks
  • Mobile phone
Automotive Cybersecurity at WCC

- Cybersecurity Associates Degree
- Advanced Transportation Center
- Mobile Hacking Workbench integration
- Development of Certificate in Automotive Cybersecurity
Cybersecurity

Automotive

Manufacturing

Health Sciences

HVAC/Construction

Business/Finance

Retail/Hospitality
Mobile Hacking Workbench - ACE
Analyze
Isolate
Replay
Proposed Certificate in Automotive Cybersecurity

Pre-requisite: Linux

- CST185 Essentials of Local and Mobile Networks
- CSS200 Introduction to Network Security
- CPS171 Intro to Programming with C++ or CPS141 Introduction to Programming using Python
- CSS205 Essentials of Penetration Testing (Ethical hacking)
- CSSxxx Pentesting Automotive Platforms
- Automotive Technology Course (to be determined)
Faculty Preparation

• Professional faculty in Automotive Technologies, Information Technology & Cybersecurity and Mechatronics
• Grimm's Defensive Automotive Engineering Training
• Non Credit Course Offerings in Intelligent Transportation
  • Intelligent Transportation Systems Basics
  • Automated Vehicle Localization Techniques
• Industry Partnerships
Next Steps

• Automotive Cybersecurity Certificate launch
• Program integrations
• K-12 pipeline
• Industry events and partnerships