Michigan Connected and Automated Vehicle Working Group Meeting Packet

October 9, 2014

1. Agenda
2. Meeting Notes
3. Attendance List
4. Handouts
5. Presentations
MICHIGAN CONNECTED AND AUTOMATED VEHICLE WORKING GROUP

Thursday, October 9, 2014

DC3S Conference Center
7205 Sterling Ponds Court
Sterling Heights, MI 48312

MEETING AGENDA

NOON Lunch provided by DC3S

- Opportunities to experience the RAVE CAVE\(^1\) also will made available in this period via on-site sign-up sheets

1:00 PM Introductions and Update, Richard Wallace, CAR

1:15 PM Welcome to and Overview of DC3S, Ron Lamparter, Founder, DC3S

1:35 PM Debrief of the ITS World Congress, ALL

2:00 PM Overview of New Michigan Connected Vehicle Corridor (as announced by Mary Barra at the ITS WC), Matt Smith, MDOT

2:20 PM Results of Survey of AUVSI/TRB Automated Vehicle Summit Attendees, Dr. Steve Underwood, University of Michigan-Dearborn

2:45 PM Networking Break (and RAVE CAVE session)

3:05 PM Overview of U.S. Army and SAE project “Reference Architectures for Automated Vehicles,” Dan Bartz, Booz Allen

3:30 PM DC3S Tour and RAVE CAVE Opportunities

4:00 PM Adjourn

---

\(^1\) RAVE = Reconfigurable Automated Virtual Environments; CAVE = Computer Automated Virtual Environments.
MICHIGAN CONNECTED AND AUTOMATED VEHICLE WORKING GROUP

The autumn 2014 meeting of the Michigan Connected and Automated Vehicle Working Group was held at the Defense Corridor Center for Collaboration and Synergy (DC3S) in Sterling Heights, Michigan, on October 9, 2014.

MEETING NOTES

Richard Wallace of the Center for Automotive Research (CAR) gave a brief welcome and began introductions around the room. He then introduced Ron Lamparter, the founder and chairman of DC3S, who provided an overview of the center and the defense corridor in Sterling Heights and Warren area. He mentioned TACOM, TARDEC, NAC, GM Tech Center, BAE Defense Systems, General Dynamics Land Systems, Navistar Defense, and Oshkosh Defense. Ron also discussed the DC3S’s Reconfigurable Automated Virtual Environments/Computer Automated Virtual Environments (RAVE CAVE), which is a virtual reality environment for modeling and simulation. He invited participants to experience a demonstration of the RAVE CAVE during the meeting.

Richard returned to the podium to discuss the meeting agenda, working group mission, and noteworthy CAV news. He highlighted the NHTSA Advanced Notice of Proposed Rulemaking for vehicle-to-vehicle (V2V) safety and Mary Barra’s announcements at the opening ceremony of the ITS World Congress in September. Richard then led a discussion on the ITS World Congress and encouraged attendees to share their experiences. Working group members participated quite heavily in the World Congress from technical sessions to exhibits to tech demos.

Several high-profile individuals visited Belle Isle to view the demonstrations, including Mary Barra of General Motors, Michael Finney of Michigan Economic Development Corporation (MEDC), and Michigan’s Governor, Rick Snyder. Several attendees spoke about their company’s demonstrations. Information on company demonstrations can be found in the ITS World Congress agenda; see pages 122-126 for Belle Isle demonstrations, pages 126-127 for the Atwater Parking Lot demonstrations, pages 136-137 for technical tours, and pages 140-177 for the demonstration hall booths). During the ITS World Congress, ITS Michigan and MDOT received several awards, with Collin Castle of MDOT receiving the Best Paper Award. Photos from the ITS World Congress are available here and here.

Next, Matt Smith of MDOT spoke about the 120 mile smart and connected corridor that the agency is developing along with partners at General Motors, Ford, and University of Michigan. The corridor will be developed primarily along I-96/I-696 and I-94, but will also include part of US-23 and the Ann Arbor Connected Vehicle Testing Environment. MDOT has identified 400-470 locations where roadside units could be located along the corridor.

After a short break, Dr. Steve Underwood of the University of Michigan-Dearborn presented results from his survey research on the introduction of automated vehicle technologies. Dr. Underwood’s research involved an iterated survey of a small panel of experts, as well as a larger survey of more than 200 attendees at a symposium on the future of automated vehicles (many of whom were also experts). He summarized SAE’s levels of automation (Levels 0-5) and discussed the survey responses which suggested that over the next several years, highly automated vehicles—from shuttles, to freeway driving, to freight platooning—will be introduced. Respondents thought that in 10-15 years, automated vehicles capable of handling urban highways and surface roads and fully-automated “robot taxis” would be introduced.
Following Dr. Underwood’s presentation, Richard mentioned several upcoming events and invited attendees to share information additional events. In addition to those listed on Richard’s slide, upcoming events include:

- SAE 2014 Active Safety Systems Symposium on October 23-24 (http://www.sae.org/events/cass/)
- Los Angeles Auto Show on November 18-20 (http://laautoshow.com/)

Another source of relevant upcoming events is the events page of the Driverless Transportation website. Driverless Transportation wrote an article about the October 9th meeting which can be accessed here.

The meeting concluded with a presentation from Dan Bartz of Booz Allen. Dan discussed work sponsored by the U.S. Army and the Society of Automotive Engineers on reference architectures for automated vehicles. He talked about the evolution of safety standards, and how system developers are working to improve network security for automated vehicles. He also discussed the differences between automated vehicle systems being designed for large (100+ ton) military vehicles and those that will be needed for light-duty civilian vehicles. The projects initial requirements focus on a system that will stop a military vehicle in the middle of the road if there is a failure (which is not a simple task to accomplish), but future iterations will focus on a more complex system that will be able to react to a wide variety of situations.
# MICHIGAN CONNECTED AND AUTOMATED VEHICLE WORKING GROUP

## ATTENDANCE LIST

<table>
<thead>
<tr>
<th>First</th>
<th>Last</th>
<th>Organization</th>
<th>Email</th>
</tr>
</thead>
<tbody>
<tr>
<td>John</td>
<td>Abraham</td>
<td>Macomb County</td>
<td><a href="mailto:jabraham@rcmcweb.org">jabraham@rcmcweb.org</a></td>
</tr>
<tr>
<td>Daniel</td>
<td>Bartz</td>
<td>Booz Allen Hamilton</td>
<td><a href="mailto:daniel.j.bartz.ctr@mail.mil">daniel.j.bartz.ctr@mail.mil</a></td>
</tr>
<tr>
<td>Debby</td>
<td>Bezzina</td>
<td>UMTRI</td>
<td><a href="mailto:dbezzina@umich.edu">dbezzina@umich.edu</a></td>
</tr>
<tr>
<td>Jeff</td>
<td>Blackburn</td>
<td>TASS</td>
<td><a href="mailto:jeff.blackburn@tassinternational.com">jeff.blackburn@tassinternational.com</a></td>
</tr>
<tr>
<td>Luke</td>
<td>Bonner</td>
<td>Ann Arbor SPARK</td>
<td><a href="mailto:lucae@annarborusa.org">lucae@annarborusa.org</a></td>
</tr>
<tr>
<td>Phil</td>
<td>Callihan</td>
<td>NCMS</td>
<td><a href="mailto:phile@ncms.org">phile@ncms.org</a></td>
</tr>
<tr>
<td>Joshua</td>
<td>Cregger</td>
<td>CAR</td>
<td><a href="mailto:jcregger@cargroup.org">jcregger@cargroup.org</a></td>
</tr>
<tr>
<td>Kirtika</td>
<td>Dommeti</td>
<td>Delphi</td>
<td><a href="mailto:kiritika.dommeti@delphi.com">kiritika.dommeti@delphi.com</a></td>
</tr>
<tr>
<td>Jennifer</td>
<td>Dukarski</td>
<td>Butzel Long</td>
<td><a href="mailto:dukarski@butzel.com">dukarski@butzel.com</a></td>
</tr>
<tr>
<td>John</td>
<td>Estrada</td>
<td>Driverless Transportation</td>
<td><a href="mailto:john@driverlesstransportation.com">john@driverlesstransportation.com</a></td>
</tr>
<tr>
<td>Douglas</td>
<td>Fertuck</td>
<td>Macomb County</td>
<td><a href="mailto:fertuckd@macomb.edu">fertuckd@macomb.edu</a></td>
</tr>
<tr>
<td>Angela</td>
<td>Fortino</td>
<td>DRC</td>
<td><a href="mailto:afortino@detroitchamber.com">afortino@detroitchamber.com</a></td>
</tr>
<tr>
<td>Anthony</td>
<td>Gasicorowski</td>
<td>Parsons Brinckerhoff</td>
<td><a href="mailto:gasicorowski@pbworld.com">gasicorowski@pbworld.com</a></td>
</tr>
<tr>
<td>John</td>
<td>Geisler</td>
<td>MAMA</td>
<td><a href="mailto:john@michman.org">john@michman.org</a></td>
</tr>
<tr>
<td>Tony</td>
<td>Gioutsos</td>
<td>TASS</td>
<td><a href="mailto:tony.gioutsos@tassinternational.com">tony.gioutsos@tassinternational.com</a></td>
</tr>
<tr>
<td>Joe</td>
<td>Gorman</td>
<td>MDOT</td>
<td><a href="mailto:gormanj4@michigan.gov">gormanj4@michigan.gov</a></td>
</tr>
<tr>
<td>Neil</td>
<td>Gudsen</td>
<td>WCC</td>
<td><a href="mailto:ngudsen@wccnet.edu">ngudsen@wccnet.edu</a></td>
</tr>
<tr>
<td>Morrie</td>
<td>Hoovel</td>
<td>FHWA - MI Division</td>
<td><a href="mailto:morris.hoovel@dot.gov">morris.hoovel@dot.gov</a></td>
</tr>
<tr>
<td>Qiang</td>
<td>Hong</td>
<td>CAR</td>
<td><a href="mailto:qhong@cargroup.org">qhong@cargroup.org</a></td>
</tr>
<tr>
<td>Kiumars</td>
<td>Jalali</td>
<td>Ricardo</td>
<td><a href="mailto:kiumars.jalali@ricardo.com">kiumars.jalali@ricardo.com</a></td>
</tr>
<tr>
<td>Ahmad</td>
<td>Jawad</td>
<td>RCOC</td>
<td><a href="mailto:ajawad@rcoc.org">ajawad@rcoc.org</a></td>
</tr>
<tr>
<td>Jack</td>
<td>Johns</td>
<td>Macomb County</td>
<td><a href="mailto:jack.johns@macombgov.org">jack.johns@macombgov.org</a></td>
</tr>
<tr>
<td>Tim</td>
<td>Johnson</td>
<td>NextEnergy</td>
<td><a href="mailto:timj@nextenergy.org">timj@nextenergy.org</a></td>
</tr>
<tr>
<td>Sean</td>
<td>Kelley</td>
<td>Mannik Smith Group</td>
<td><a href="mailto:skelley@manniksmithgroup.com">skelley@manniksmithgroup.com</a></td>
</tr>
<tr>
<td>Kevin</td>
<td>Kelly</td>
<td>Automotive Events</td>
<td><a href="mailto:kkelley@automotive-events.com">kkelley@automotive-events.com</a></td>
</tr>
<tr>
<td>Matt</td>
<td>Klawon</td>
<td>URS Corporation</td>
<td><a href="mailto:matt.klawon@urs.com">matt.klawon@urs.com</a></td>
</tr>
<tr>
<td>Greg</td>
<td>Kruger</td>
<td>Leidos</td>
<td><a href="mailto:gregory.d.kruger@leidos.com">gregory.d.kruger@leidos.com</a></td>
</tr>
<tr>
<td>Steve</td>
<td>Kuciemba</td>
<td>Parsons Brinckerhoff</td>
<td><a href="mailto:kuciemba@pbworld.com">kuciemba@pbworld.com</a></td>
</tr>
<tr>
<td>Ron</td>
<td>Lamparter</td>
<td>DC3S</td>
<td><a href="mailto:ron.lamparter@defensec3s.com">ron.lamparter@defensec3s.com</a></td>
</tr>
<tr>
<td>Jerry</td>
<td>Lane</td>
<td>GLS&amp;T</td>
<td><a href="mailto:glane@comcast.net">glane@comcast.net</a></td>
</tr>
<tr>
<td>Fei</td>
<td>Li</td>
<td>Delphi</td>
<td><a href="mailto:tie.li@delphi.com">tie.li@delphi.com</a></td>
</tr>
<tr>
<td>Perry</td>
<td>MacNeill</td>
<td>Ford Motor Company</td>
<td><a href="mailto:pmacneill@ford.com">pmacneill@ford.com</a></td>
</tr>
<tr>
<td>Ali</td>
<td>Maleki</td>
<td>Ricardo</td>
<td><a href="mailto:ali.maleki@ricardo.com">ali.maleki@ricardo.com</a></td>
</tr>
<tr>
<td>Heinz</td>
<td>Mattern</td>
<td>Valeo</td>
<td><a href="mailto:heinz.mattern@valeo.com">heinz.mattern@valeo.com</a></td>
</tr>
<tr>
<td>Brad</td>
<td>McNett</td>
<td>U.S. Army NAC</td>
<td><a href="mailto:brad.a.mcnett.civ@mail.mil">brad.a.mcnett.civ@mail.mil</a></td>
</tr>
<tr>
<td>Savita</td>
<td>Monroe</td>
<td>MTAM</td>
<td><a href="mailto:savita.monoce08@gmail.com">savita.monoce08@gmail.com</a></td>
</tr>
<tr>
<td>Eric</td>
<td>Morris</td>
<td>HNTB</td>
<td><a href="mailto:emorris@hntb.com">emorris@hntb.com</a></td>
</tr>
<tr>
<td>Yusuke</td>
<td>Narita</td>
<td>Mitsubishi Motors</td>
<td><a href="mailto:yusuke2.narita@na.mitsubishi-motors.com">yusuke2.narita@na.mitsubishi-motors.com</a></td>
</tr>
<tr>
<td>Frank</td>
<td>Perry</td>
<td>Leidos</td>
<td><a href="mailto:frank.perry@leidos.com">frank.perry@leidos.com</a></td>
</tr>
<tr>
<td>Mohammad</td>
<td>Poorsartep</td>
<td>TTI</td>
<td><a href="mailto:m-poorsartep@ttimail.tamu.edu">m-poorsartep@ttimail.tamu.edu</a></td>
</tr>
<tr>
<td>Vicky</td>
<td>Rad</td>
<td>Macomb County</td>
<td><a href="mailto:vicky.rad@macombgov.org">vicky.rad@macombgov.org</a></td>
</tr>
<tr>
<td>Stan</td>
<td>Richard</td>
<td>Integral Blue</td>
<td><a href="mailto:srichard@integral-blue.com">srichard@integral-blue.com</a></td>
</tr>
<tr>
<td>Anil</td>
<td>Sanne</td>
<td>Avittor</td>
<td><a href="mailto:asanne@avittor.com">asanne@avittor.com</a></td>
</tr>
<tr>
<td>Ann</td>
<td>Schlenker</td>
<td>Argonne</td>
<td><a href="mailto:aschlenker@anl.gov">aschlenker@anl.gov</a></td>
</tr>
<tr>
<td>Treec</td>
<td>Sekela</td>
<td>MDOT</td>
<td><a href="mailto:sekelat@michigan.gov">sekelat@michigan.gov</a></td>
</tr>
<tr>
<td>First</td>
<td>Last</td>
<td>Organization</td>
<td>Email</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
<td>---------------------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Scott</td>
<td>Shogan</td>
<td>Parsons Brinckerhoff</td>
<td><a href="mailto:shogan@pbworld.com">shogan@pbworld.com</a></td>
</tr>
<tr>
<td>Bill</td>
<td>Shreck</td>
<td>MDOT</td>
<td><a href="mailto:shreckw@michigan.gov">shreckw@michigan.gov</a></td>
</tr>
<tr>
<td>Andrew</td>
<td>Sivulka</td>
<td>ADS Technology Solutions</td>
<td><a href="mailto:andrew.sivulka@gmail.com">andrew.sivulka@gmail.com</a></td>
</tr>
<tr>
<td>Matt</td>
<td>Smith</td>
<td>MDOT</td>
<td><a href="mailto:smithm81@michigan.gov">smithm81@michigan.gov</a></td>
</tr>
<tr>
<td>Amine</td>
<td>Taleb</td>
<td>Valeo</td>
<td><a href="mailto:amine.taleb@valeo.com">amine.taleb@valeo.com</a></td>
</tr>
<tr>
<td>Bill</td>
<td>Tansil</td>
<td>MDOT</td>
<td><a href="mailto:tansilw@michigan.gov">tansilw@michigan.gov</a></td>
</tr>
<tr>
<td>Jennifer</td>
<td>Tisdale</td>
<td>MEDC</td>
<td><a href="mailto:tisdalej1@michigan.org">tisdalej1@michigan.org</a></td>
</tr>
<tr>
<td>McConnell</td>
<td>Trapp</td>
<td>Honeywell</td>
<td></td>
</tr>
<tr>
<td>Steve</td>
<td>Underwood</td>
<td>U of M - Dearborn</td>
<td><a href="mailto:underw@umich.edu">underw@umich.edu</a></td>
</tr>
<tr>
<td>Richard</td>
<td>Wallace</td>
<td>CAR</td>
<td><a href="mailto:rwallace@cargroup.org">rwallace@cargroup.org</a></td>
</tr>
<tr>
<td>Scott</td>
<td>Watkins</td>
<td>Mobile Data Holdings</td>
<td><a href="mailto:watkins@mobiledata1.com">watkins@mobiledata1.com</a></td>
</tr>
<tr>
<td>Ken</td>
<td>Yang</td>
<td>Iteris Inc.</td>
<td><a href="mailto:kqv@iteris.com">kqv@iteris.com</a></td>
</tr>
<tr>
<td>Hongwei</td>
<td>Zhang</td>
<td>WSU</td>
<td><a href="mailto:hongwei@wayne.edu">hongwei@wayne.edu</a></td>
</tr>
</tbody>
</table>
Conference Rooms…
Two fully equipped conference rooms accommodating 12-18 people.

Media Center…
Media Center seats 48 people with tiered theater-style seating. High quality projection equipment includes three screens and digital surround sound.

Dining Availability…
Rental includes optional continental breakfast, lunch, snack, and beverage.

Multi-Purpose Room…
This room seats 48 people with large flat screen monitors in each corner of the room. Adjacent to the Media Center, this room can be rented separately or as an overflow area.
Display/Reception Area...
- 6000 sq. ft.
- Product Exhibit
- Reception
- Entertaining

Facility Features....
- Five Meeting Rooms
- State-of-Art Audio-Visual
- Teleconferencing Capabilities
- Wireless Access in Meeting Rooms
- Large Display Capabilities
- Conference Break Station
- Coat Room
- Abundance Free Parking
- Easy Load-In Grade Door/Exhibit Entry
- Competitive Pricing
- Support from our Friendly Staff
- Option of Catering Services

Rave Cave...
Michigan’s only non-profit modeling-simulation-visualization center.

DC3S Conference Center
7205 Sterling Ponds Court
Sterling Heights, MI 48312
www.DC3S.com

Contact our staff to discuss your events needs...

Mary Lamparter
marylamparter@gmail.com
586-567-1150

Robin Putrycus
robin.putrycus@DefenseC3s.com
586-274-4695

Ann Williams
ann.williams@DefenseC3s.com
586-274-4695
MICHIGAN CONNECTED AND AUTOMATED VEHICLE WORKING GROUP
PRESENTATIONS
Agenda for This Afternoon

- Noon LUNCH and RAVE CAVE—thanks to DC3S
- 1:00 PM Introductions and Update, Richard Wallace, CAR
- 1:15 PM Welcome to and Overview of DC3S, Ron Lamparter, Founder, DC3S
- 1:35 PM Debrief of the ITS World Congress, ALL
- 2:00 PM Overview of New Michigan Connected Vehicle Corridor (as announced by Mary Barra at the ITS WC), Matt Smith, MDOT
- 2:20 PM Results of Survey of AUVSI/TRB Automated Vehicle Summit Attendees, Dr. Steve Underwood, University of Michigan-Dearborn
- 2:45 PM Networking Break (and RAVE CAVE session)
- 3:05 PM Overview of U.S. Army and SAE project “Reference Architectures for Automated Vehicles,” Dan Bartz, Booz Allen
- 3:30 PM DC3S Tour and RAVE CAVE Opportunities
- 4:00 PM Adjourn
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.
  - Benefit our state and our industry (automotive and more)
  - Enhance safety and mobility in Michigan and beyond
Noteworthy News

- NHTSA released Advance Notice of Proposed Rulemaking for V2V safety and a long report that supports it
  - Seeking comments through October 20, 2014
  - http://www.regulations.gov/#!docketDetail;D=NHTSA-2014-0022

- At the ITS World Congress in Detroit, GM President Mary Barra announced that select 2017 Cadillac models will include “Super-Cruise” and V2V technology

- Barra also announced a public-private partnership with MDOT, Ford, and the University of Michigan to build 120 miles of connected roadway in Michigan

- Hot off the press: Scott Belcher leaving ITSA for TIA
  - Tom Kern to be interim President and CEO of ITSA effective Nov. 1
Upcoming Connected and Automated Vehicle Events

- SAE Convergence, October 21-22, Detroit, MI
- Telematics West Coast, October 30-31, San Diego, CA
- Connected Fleets, November 20-21, Atlanta, GA
- Florida Automated Vehicles Summit, December 15-16, Orlando, FL
- Annual Meeting of the Transportation Research Board, January 11-15, 2015, Washington, D.C.
- North American International Auto Show, January 12-25, 2015, Detroit, MI
  - Planning for CAV technology showcase during preview days
- Automotive News World Congress, January 13-14, 2015, Detroit, MI
- Automotive World Megatrends, March 17, 2015, Dearborn, MI
Michigan Connected and Automated Vehicle Working Group

Debrief of ITS World Congress
Overview of ITSWC

- Is an international meeting and exhibition that rotates among three major geographic regions, the Americas, Europe and Asia Pacific annually
- Attracted 9,106 delegates from more than 65 countries, including legislators, ministers of transportation, transportation officials, international standards experts, engineers, manufacturers, and other ITS stakeholders
  - Most attendees of any ITSWC ever held in North America
  - Five times more media present than at any other ITSWC
- Included interactive technology showcases (Belle Isle and other locations), more than 250 technical sessions, a 350,000 square-foot exhibit hall, and numerous networking events
CAV Technology at the ITS WC

- Connected and automated vehicles are at the center of future intelligent transportation systems. They were visible and widely discussed at sessions, exhibitions, and the Technology Showcase.

- Connectivity and automation will:
  - Fundamentally change the vehicles, personal driving experience, and transportation services
  - Require upgrades to intelligent infrastructure
  - Accelerate the convergence of auto and tech companies

- ITS and CAV sectors are driving forces for national and regional growth
  - To be developed by encouraging excellence, innovation, and the creation of new businesses
  - Requires close international and cross-sector collaborations
100 % Driverless
Mary Barra’s Announcements

• A new vehicle-to-vehicle "Super Cruise" long-distance driver-assist system into its 2017 Lansing-built Cadillac CTS model

• Being equipped with V2V technology that will utilize the 5.9-gigahertz Wi-Fi spectrum to connect with other vehicles and has the ability to control acceleration, braking and steering on the freeway

• The creation of more than 120 miles of V2I-enabled freeway corridor through a network of sensors and cameras, warning drivers of potential hazards (partner with MDOT, UM, and Ford)
Bill Ford Focused on Redefining Future Mobility

- Integrated transportation systems (all components to talk to each other, including non-Ford autos)
- Collaborations
- Car-sharing business
- Need for national discussions about energy and environmental issues
- Willing to work with data and software companies while keeping Ford’s own vision
Congratulations in Order
Next year in Bordeaux!


22nd ITS World Congress Bordeaux
FRANCE
5 – 9 October 2015

“TOWARDS INTELLIGENT MOBILITY – Better use of space”
The Following Slides Were Presented by Matt Smith of MDOT
*There are three towers not pictured (two in University region and one in Bay).
Survey: Opinions about Future of Automated Vehicles

• Objectives
  – Outreach for the Graham Sustainability Institute expert survey on automated and connected vehicles
  – Explore the range of opinions among Symposium attendees about the future of automated vehicles
  – Help develop a collective scenarios for the emerging market for automated vehicle

• Features
  – 217 responses, Friday, July 11
  – Complete anonymity
  – Four sections: (1) general, (2) forecasts, (3) Graham, and (4) demographics
  – Reference to SAE J3016 Definitions and Levels

• Contributors
  – Steve Shladover, Bob Denaro, Jane Lappin
Level of Education: 80% Masters and Ph.D.
Education:
78% Engineering: Electrical, Computer Science, Civil

<table>
<thead>
<tr>
<th>Field</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical or mechanical...</td>
<td>39.77%</td>
</tr>
<tr>
<td>Computer science</td>
<td>14.77%</td>
</tr>
<tr>
<td>Civil engineering...</td>
<td>23.86%</td>
</tr>
<tr>
<td>Public policy, urban planning</td>
<td>15.34%</td>
</tr>
<tr>
<td>Human factors or automotive</td>
<td>8.52%</td>
</tr>
<tr>
<td>Architecture or construct...</td>
<td>1.70%</td>
</tr>
<tr>
<td>Law</td>
<td>5.11%</td>
</tr>
<tr>
<td>Social sciences</td>
<td>15.91%</td>
</tr>
</tbody>
</table>
Technical Expertise: 40% AVS, 35% Active Safety, 33% CV
### Expertise:
- **23% Traveler Behavior**
- **20% Human Factors**

<table>
<thead>
<tr>
<th>Category</th>
<th>%</th>
<th>%</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Markets for automotive</td>
<td>30</td>
<td>53</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>Automotive law and liability</td>
<td>44</td>
<td>48</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Human Factors</td>
<td>22</td>
<td>58</td>
<td>13</td>
<td>7</td>
</tr>
<tr>
<td>Traveler behavior</td>
<td>31</td>
<td>45</td>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td>Land use and planning</td>
<td>53</td>
<td>34</td>
<td>12</td>
<td>1</td>
</tr>
<tr>
<td>Finance</td>
<td>49</td>
<td>41</td>
<td>7</td>
<td>3</td>
</tr>
</tbody>
</table>
Types of Organizations: Univ/Research, Automotive, Consulting, Government

- National government: 9.14%
- State or local government: 7.61%
- Research institute or...: 31.47%
- Automotive industry,...: 23.86%
- Consulting firm: 12.69%
- Association: 1.02%
- Insurance: 3.55%
- Finance: 1.02%
- Other (please specify): 9.64%
Where We Live: North America, Europe, Asia

USA
80%

US - United States

Minor Outlying Islands
Where We Live: CA, MI, VA, MD, IL, TX, PA

CA 30%
MI 14%

Employer Headquarters: USA, Japan, Germany, etc.

- USA: 71%
- Japan: 11%
- Germany: 5%
- Other countries: 5%
Q1: What is your ranking of the difficulty of overcoming barriers in fielding SAE Level 5 fully automated vehicles in all environments, with the first column being the most difficult barrier and seventh column the least?

<table>
<thead>
<tr>
<th>Barriers</th>
<th>1. Most Difficult Barrier</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7. Least Difficult Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legal liability</td>
<td>5.16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Regulations</td>
<td>4.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
</tr>
<tr>
<td>Cost</td>
<td>4.36</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Technology</td>
<td>4.26</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Roadway/infrastructure</td>
<td>3.73</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Social acceptance</td>
<td>3.24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Consumer acceptance</td>
<td>2.92</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>
Q2: What level of safety do you believe an automated driving system (at any level of automation) should be required to demonstrate before it is authorized for public use?
Q3: If automated vehicles result in a significant reduction in road accidents and fatalities, will society accept that automated vehicles occasionally cause some of the remaining accidents and fatalities?
Q4: Do you expect automated driving systems (SAE Level 3 or above) to be first sold to the general public as aftermarket retrofits to existing vehicles, or as original equipment on new vehicles, or both?
Conditional Automation Not Practical?

Q5: Is SAE Level 3 conditional automation, in which the driver is expected to intervene quickly if needed, not practical or safe because drivers are likely to become complacent with automated operation and not behave as required?

![Bar chart showing the survey results. The majority (54.24%) believe conditional automation is not practical due to driver complacency, while 45.76% disagree.]
Q6: Do you believe that vehicle-to-vehicle communication will be necessary for fully automated SAE Level 5 operation, to extend the sensing horizon to other vehicles or to improve the availability of information about the other vehicles?
## Automated Vehicle Forecast Summary

<table>
<thead>
<tr>
<th>Q#</th>
<th>Automated Vehicle Systems</th>
<th>SAE Level</th>
<th>Fail Safe</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; Quartile</th>
<th>Median</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt; Quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>19</td>
<td>Automated Freeway Driving</td>
<td>3</td>
<td></td>
<td>2017</td>
<td>2018</td>
<td>2019</td>
</tr>
<tr>
<td></td>
<td>TRB/AUVSI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2018</td>
<td>2019</td>
<td></td>
<td></td>
<td>2020</td>
</tr>
<tr>
<td>20</td>
<td>Automated Freeway Driving</td>
<td>4</td>
<td>✔</td>
<td>2018</td>
<td>2019</td>
<td>2022</td>
</tr>
<tr>
<td></td>
<td>TRB/AUVSI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2018</td>
<td>2020</td>
<td></td>
<td></td>
<td>2024</td>
</tr>
<tr>
<td>21</td>
<td>Automated Freight Platooning</td>
<td>4</td>
<td>✔</td>
<td>2019</td>
<td>2020</td>
<td>2022</td>
</tr>
<tr>
<td></td>
<td>TRB/AUVSI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2019</td>
<td>2020</td>
<td></td>
<td></td>
<td>2024</td>
</tr>
<tr>
<td>22</td>
<td>Automated Shuttle</td>
<td>4</td>
<td>✔</td>
<td>2015</td>
<td>2016</td>
<td>2017</td>
</tr>
<tr>
<td></td>
<td>TRB/AUVSI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2016</td>
<td>2018</td>
<td></td>
<td></td>
<td>2020</td>
</tr>
<tr>
<td>23</td>
<td>High Automation</td>
<td>4</td>
<td>✔</td>
<td>2024</td>
<td>2025</td>
<td>2028</td>
</tr>
<tr>
<td></td>
<td>TRB/AUVSI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2024</td>
<td>2025</td>
<td></td>
<td></td>
<td>2030</td>
</tr>
<tr>
<td>24</td>
<td>Full Automation (e.g., taxi)</td>
<td>5</td>
<td>✔</td>
<td>2025</td>
<td>2030</td>
<td>2035</td>
</tr>
<tr>
<td></td>
<td>TRB/AUVSI</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2027</td>
<td>2030</td>
<td></td>
<td></td>
<td>2035</td>
</tr>
</tbody>
</table>
Q17: When do you first expect an automated driverless shuttle vehicle to be operating at low speed in pedestrian zones or malls in the U.S.?
Automated Shuttle, SAE Level 4 (Q22)

- Low-speed, short distance, fully automated,
- On “campus” or roadway with limited vehicle and pedestrian traffic.
- Operator or passenger intervention may be required in unusual circumstances (e.g., animal will not move off the path).
- The vehicle is designed to fail safely if a problem occurs.

**1st Quartile**
- 2015
- 2016

**Median**
- 2016

**3rd Quartile**
- 2017
- 2020
Q10: Automated valet parking with nobody in the vehicle, in general public parking facilities?
Q8: Automated freeway driving under most conditions, but requiring driver ability to take over in emergencies within 5 to 10 seconds?
Automated Freeway Driving, SAE Level 3 (Q19)

- Vehicle travels on the highway from entrance to exit without driver assistance
- Driver can engage or disengage this capability like cruise control
- The driver may be required to respond to a request to intervene in case of problem.
- Was not addressed in previous forecast

<table>
<thead>
<tr>
<th>1st Quartile</th>
<th>Median</th>
<th>3rd Quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>2018</td>
<td>2019</td>
</tr>
<tr>
<td>2018</td>
<td></td>
<td>2020</td>
</tr>
</tbody>
</table>

Institute for Advanced Vehicle Systems
University of Michigan – Dearborn
Q9: Automated freeway driving under most conditions, with the ability to ensure safety even if the driver is incapacitated?
Automated Freeway Driving (Fail Safe), SAE Level 4 (Q20)

- Vehicle travels on the highway from entrance to exit without driver assistance
- Driver can engage or disengage this capability like cruise control
- The driver may be required to respond to a request to intervene in case of problem.
Q12: Automated truck platoons driving in close formation on dedicated truck lanes, with drivers in all trucks?
Automated Freight Platooning, SAE Level 4 (Q21)

- Cooperative adaptive cruise control and automated steering
- Short headways to reduce wind resistance Drivers in all trucks.
- Driver may be required to respond to request to intervene in case of problem.
- This may or may not involve a dedicated lane.
- The vehicle is designed to fail safely if a driver does not respond

<table>
<thead>
<tr>
<th>1st Quartile</th>
<th>Median</th>
<th>3rd Quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019</td>
<td>2020</td>
<td>2022</td>
</tr>
<tr>
<td>2019</td>
<td>2020</td>
<td>2024</td>
</tr>
</tbody>
</table>
Q13: Automated truck platoons driving in close formation on dedicated truck lanes, with no drivers in the following trucks?
Q11: Automated driving on general urban streets, with the ability to ensure safety even if the driver is incapacitated?
High Automation, SAE Level 4 (Q23)

- Vehicle is in control from beginning to end of trip both on highway and surface streets, urban and rural, where human driver responds to request to intervene.
- The vehicle is designed to fail safely if the driver does not respond.

<table>
<thead>
<tr>
<th>1st Quartile</th>
<th>Median</th>
<th>3rd Quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>2024</td>
<td>2025</td>
<td>2028</td>
</tr>
<tr>
<td>2024</td>
<td>2025</td>
<td>2030</td>
</tr>
</tbody>
</table>
Q15: Fully automated taxi system capable of operating under all conditions where human drivers can drive (SAE Level 5) including all roadway types, weather and traffic conditions?
Full Automation, SAE Level 5 (Q24)

• Vehicle is in control from beginning to end of trip, both on highway and surface streets, urban and rural, without human intervention.

• The vehicle is designed to fail safely if problem occurs. (e.g., automated taxi);

<table>
<thead>
<tr>
<th>1st Quartile</th>
<th>Median</th>
<th>3rd Quartile</th>
</tr>
</thead>
<tbody>
<tr>
<td>2025</td>
<td>2030</td>
<td>2035</td>
</tr>
<tr>
<td>2027</td>
<td>2030</td>
<td>2035</td>
</tr>
</tbody>
</table>
Q16: When do you expect to be able to trust a fully automated taxi to take your elementary-school-age child or grandchild to their school (with no licensed driver onboard)?
# Automated Vehicle Systems Forecast

<table>
<thead>
<tr>
<th>Category</th>
<th>Before 2020</th>
<th>2020</th>
<th>2024</th>
<th>2025</th>
<th>2029</th>
<th>2030</th>
<th>2039</th>
<th>2040 &amp; After</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shuttle Pedestrian Zones</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valet Parking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freeway Driving, take-over</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freeway Driving, fail-safe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck Platooning, drivers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck Platooning, lead driver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban Driving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Child to School</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Low Speed**
- **Freeway Limited Access**
Automated Vehicle System, Graham
Market Introduction (SAE Levels), Median, IQR

5 FULL AUTOMATION
(Driver not required, e.g., robotic taxi)

4 HIGH AUTOMATION
(fail-safe)

3 CONDITIONAL AUTOMATION
(driver fallback)

S. Underwood
Institute for Advanced Vehicle Systems
University of Michigan – Dearborn
Automated Vehicle System, TRB/AUVSI
Market Introduction (SAE Levels), Median, IQR

5 FULL AUTOMATION
(Driver not required, e.g., robotic taxi)

4 HIGH AUTOMATION
(fail-safe)

3 CONDITIONAL AUTOMATION
(driver fallback)

S. Underwood
Institute for Advanced Vehicle Systems
University of Michigan – Dearborn
## Automated Vehicle Systems Forecast

<table>
<thead>
<tr>
<th>System</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2025</th>
<th>2030</th>
<th>2040 &amp; After</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Speed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freeway Driving, take-over</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freeway Driving, fail-safe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valet Parking</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban Driving</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck Platooning, drivers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Truck Platooning, lead driver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shuttle Pedestrian Zones</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before</td>
<td>2020</td>
<td>2024</td>
<td>2025</td>
<td>2029</td>
<td>2030</td>
<td>2039</td>
<td></td>
</tr>
<tr>
<td>After</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **2018**: Low Speed
- **2019**: Freeway Limited Access
- **2020**: Full Driver Replacement
- **2025**: Urban Driving
- **2030**: “Taxi”
• Steve Underwood
• 810.333.5328
• underw@umich.edu
Automated Vehicle Systems (AVS) Reference Architecture and Interface (RAI)

On-Road Automated Vehicle (ORAV) Task Group

Daniel Bartz - Booz Allen Hamilton

IAVS 1301
October 23, 2014
Reference Architecture and Interface Task Group

- **Specify Reference Architecture**: Revise reference architecture (e.g., behaviors, maneuvers, hardware and software requirements, physical and logical, key performance parameters, etc.)

- **Define Interface**: Revise and document autonomy kit (A-kit) to by-wire active safety controller kit (B-kit) (i.e., communication buses and message set, message characteristics)

- **Simulate and Test (HIL/Vehicle)**: Provide HIL (U of M Dearborn) group with input on tests/simulation to be run. Evaluate results of test and simulations and capture lessons learned for feedback into architecture and interface work products
Specify Reference Architecture

• Requirements analysis (functional and non-functional)
  – Scenario-based use-case development (maneuvers, road geometry)
  – Software and hardware requirements (e.g., modularity, testability, etc.)
  – Key performance parameters

• Influencing factors (Broad and inclusive for reference architecture)
  – Organizational (e.g., cost/budget), assumed hardware

• Risk identification (compare requirements and influencing factors)
  – Minimize the impact of influencing factors

• Architecture design (layered physical and logical, software)
  – Heuristics and modularity, literature

• Implementation

• Evaluation (evaluate against requirements list)
<table>
<thead>
<tr>
<th>Capability</th>
<th>Description</th>
<th>Man-Vehicle Tasks</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>System Off</td>
<td>Current fleet, no intelligence or additional external sensors</td>
<td></td>
<td>All manned vehicles</td>
</tr>
<tr>
<td>Driver Warning</td>
<td>Additional sensors being added to monitor activity immediately around Vehicle. Info task is shared.</td>
<td></td>
<td>Blind-side detectors, collision warning, roll-over warning, V2I and V2V</td>
</tr>
<tr>
<td>Driver Safety</td>
<td>By-wire hardware being added w/ additional sensing. Info task shared and Control task occasionally taken by Vehicle for safety reasons.</td>
<td></td>
<td>At this point, by-wire kit (brake, throttle, gear and steer) is integrated into the vehicle</td>
</tr>
<tr>
<td>Optionally Operated (Auto-Pilot)</td>
<td>Human still in vehicle but can ‘willingly’ give up control so that he/she can perform other tasks (autonomy kit first needed)</td>
<td></td>
<td>Under certain conditions, ‘distracted driving’ is the preferred mode of operation</td>
</tr>
<tr>
<td>Optionally Manned</td>
<td>All of the previous capabilities plus the additional feature of the vehicle being operated w/o a driver present and a OCU (e.g. convoying, perimeter security). AMAS-JCTD</td>
<td></td>
<td>Includes emergency modes; Chauffer and Ambulance where I, C and R are Vehicle tasks</td>
</tr>
</tbody>
</table>

UNCLASSIFIED
<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Narrative definition</th>
<th>Execution of steering and acceleration/deceleration</th>
<th>Monitoring of driving environment</th>
<th>Fallback performance of dynamic driving task</th>
<th>System capability (driving modes)</th>
<th>BAPA level</th>
<th>NHTSA level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
<td>the full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Human driver</td>
<td>n/a</td>
<td>Driver only</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>the driving mode-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>Human driver and system</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
<td>Assisted</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation</td>
<td>the driving mode-specific execution by one or more driver assistance systems of both steering and acceleration/deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task</td>
<td>System</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
<td>Partially automated</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Automated driving system (&quot;system&quot;) monitors the driving environment</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>Human driver</td>
<td>Some driving modes</td>
<td>Highly automated</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>High Automation</td>
<td>the driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
<td>Fully automated</td>
<td>3/4</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation</td>
<td>the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All driving modes</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Evolution of Safety Standards

Generic Standards
- MIL STD 882
- IEC 61508

Aero Standards
- SAE ARP 4754
- SAE ARP 4761
- RTCA DO-178
- RTCA DO-254

Automotive Standards
- ISO 26262
- MISRA

Industry Standards
- DIN 19250
- ISA-S84.01
- IEC 62061
- IEC 61511
- IEC 61513
- IEC/EN...
# MIL STD-882E

## RISK Acceptance Levels per DoDI 5000.02, B Dec 08

Risk Assessment Levels & Definitions per Tables A-I thru A-IV of MIL-STD 882E, 11 May 12

### HAZARD SEVERITY

<table>
<thead>
<tr>
<th>HAZARD SEVERITY</th>
<th>Catastrophic</th>
<th>Critical</th>
<th>Marginal</th>
<th>Negligible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specific Individual Item</td>
<td>Fleet or Inventory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Frequent</strong></td>
<td>Likely to occur often in the life of an item, with a probability of occurrence greater than $10^{-1}$ in that life.</td>
<td>Could result in one of the following: permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, reversible significant environmental impact, or monetary loss equal to or exceeding $1M but less than $10M.</td>
<td>Could result in one or more of the following: permanent total disability, irreversibly significant environmental impact, or monetary loss equal to or exceeding $10M.</td>
<td>Could result in one or more of the following: injury or occupational illness resulting in one or more lost work day(s), reversible moderate environmental impact, or monetary loss equal to or exceeding $100k but less than $1M.</td>
</tr>
<tr>
<td><strong>Probable</strong></td>
<td>Will occur several times in the life of an item, with a probability of occurrence less than $10^{-1}$ but greater than $10^{-2}$ in that life.</td>
<td>1-A HIGH AAE</td>
<td>2-A HIGH AAE</td>
<td>3-A SERIOUS PEO</td>
</tr>
<tr>
<td><strong>Occasional</strong></td>
<td>Likely to occur some time in the life of an item, with a probability of occurrence less than $10^{-2}$ but greater than $10^{-3}$ in that life.</td>
<td>1-B HIGH AAE</td>
<td>2-B HIGH AAE</td>
<td>3-B SERIOUS PEO</td>
</tr>
<tr>
<td><strong>Remote</strong></td>
<td>Unlikely but possible to occur in the life of an item, with a probability of occurrence less than $10^{-3}$ but greater than $10^{-5}$ in that life.</td>
<td>1-C HIGH AAE</td>
<td>2-C SERIOUS PEO</td>
<td>3-C MEDIUM PM</td>
</tr>
<tr>
<td><strong>Improbable</strong></td>
<td>So unlikely it can be assumed occurrence may not be experienced, with a probability of occurrence less than $10^{-6}$ in that life.</td>
<td>1-D SERIOUS PEO</td>
<td>2-D MEDIUM PM</td>
<td>3-D MEDIUM PM</td>
</tr>
<tr>
<td><strong>Eliminated</strong></td>
<td>Incapable of occurrence. This level is used when potential hazards are identified and later eliminated.</td>
<td>1-E MEDIUM PM</td>
<td>2-E MEDIUM PM</td>
<td>3-E MEDIUM PM</td>
</tr>
</tbody>
</table>

### HAZARD PROBABILITY

<table>
<thead>
<tr>
<th>HAZARD PROBABILITY</th>
<th>Frequent</th>
<th>Probable</th>
<th>Occasional</th>
<th>Remote</th>
<th>Improbable</th>
<th>Eliminated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Continuously experienced</td>
<td>Will occur frequently</td>
<td>Will occur several times</td>
<td>Unlikely, but can reasonably be expected to occur</td>
<td>Unlikely to occur, but possible</td>
<td>Incapable of occurrence. This level is used when potential hazards are identified and later eliminated</td>
</tr>
<tr>
<td><strong>Eliminated</strong></td>
<td>1-A</td>
<td>1-B</td>
<td>1-C</td>
<td>1-D</td>
<td>1-E</td>
<td>1-F</td>
</tr>
</tbody>
</table>

### Definitions

- **Catastrophic**: Could result in one or more of the following: death, permanent total disability, irreversible significant environmental impact, or monetary loss equal to or exceeding $10M.
- **Critical**: Could result in one of the following: permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, reversible significant environmental impact, or monetary loss equal to or exceeding $1M but less than $10M.
- **Marginal**: Could result in one or more of the following: injury or occupational illness resulting in one or more lost work day(s), reversible moderate environmental impact, or monetary loss equal to or exceeding $100k but less than $1M.
- **Negligible**: Could result in one or more of the following: injury or occupational illness not resulting in a lost work day, minimal environmental impact, or monetary loss less than $100k.
Not all robots are alike

Weight 50 lbs
Top Speed: 5.8 mph
Max Kinetic Energy: 76 J
Skid Steering (Holonomic)
Turning Radius 0 ft

≠

Max Combined Weight 231,400 lbs
Top Speed: 50 mph
Max Kinetic Energy: 26,170,000 J
Ackerman Steering (Non-holonomic)
Turning Radius 100 ft
Initial Requirements

- Vehicles can weight over 100 tons and travel at speeds over 65 mph
- Autonomous system life is expected to be greater than 10,000 hours of operation
- In Tactical vehicles drive-by-wire robotic systems failure in a component may lead to catastrophic effects. Therefore it is required to:
  - Be fail-operational until a safe state (e.g. safely pull over to side of road).
  - Tolerate of single point failure and achieve catastrophic failure rate of less than $10^{-9}$ per hour
Assumptions

- There is no fail-safe state for an **unmanned** automated vehicle system traveling at high speeds
  - Vehicles taking 10’s of seconds to stop need to maintain steering control and obstacle avoidance abilities
  - Many circumstances exist where harsh braking can have catastrophic results, especially when trailers are involved

- When a sub-system has a fault that could result in a catastrophic system failure
  - The fault must be detected and system must retain control of the vehicle until it can be brought to a controlled stop
  - These systems need to be fail-operational and tolerant of at least 1 single point failure.

- Both kits contribute to functional safety
  - The Autonomy Kit is responsible for path planning and obstacle avoidance
  - The By-Wire Kit is responsible for actuation
  - Both kits must continue to communicate during a sub system failure, even if there is a single point failure is the Autonomy/ By-Wire kit interface
US Army Interoperability Profile for Applique System

Appliqué & Safety Critical Systems Specialty
WIPT

Platform Diagnostics & Power Mgmt
- Maintenance data port
- Vehicle network & time mgmt
- On-platform data routing
- Platform health & maintenance info
- Reset/reboot
- Software reporting
- Platform stability
- Review from VICTORY:
  - A1 – Time Synchronization Service;
  - A2 – Position Service;
  - A3 – Orientation Service;
  - A4 – Direction of Travel Service;
  - P1 – Automotive System;
  - Q1 – Power Distribution System;
  - S1 – CBM System;
- Review & update:
  - Power plant management
  - On-vehicle E-stop
  - Power profiles
  - NATO receptacle

Databus WG
- Safety critical databus & infrastructure
- Vehicle network & time management
- On-platform data routing
- Review & update:
  - On-vehicle E-stop
  - Network physical & electrical interfaces

A-Kit/B-Kit Messaging WG
- Actions on waypoint
- Drive path trajectory
- Full list of required messages
- Advanced mobility control

Co-Leads:
Dan Bartz & Cristian Balas

10/23/2014
Systems Engineering Process

- Definition of System Requirements
- Specification of System Architecture
- Specification of Software and Hardware Components
- Design and Implementation (Hardware & Software)
- Test Cases
- Component Verification Procedures
- Traceability
- System Validation Plan
- System Verification Plan
- Overall System Validation
- Integration and Parameterization of the System
- Integrating and Testing of Components
- Test Cases
- Test Cases

• Management Plan
• CONOPS

• Commissioned System
• Operations and Maintenance
Define the Interface: Messages and Databus

AMAS
Autonomy Kit

OCI – Victory: GigE
Connector: TBD

OEM Bus – J1939 (CAN)
Connector: TBD

A/B Control Bus: FlexRay
Connector: TBD

B-Kit Sensor Bus: GigE
Connector: TBD

Power: 24, 12, GND
Connector: TBD

AMAS
By-Wire/
Active-Safety Kit

COMM

Vehicle

UNCLASSIFIED
Logical Architecture of Autonomy Kit

- **User Interface**
- **Sensor and Status Data** from B-Sensor and Autonomy Kit Sensors
- **OEM J1939**
- **Autonomy Kit Comm Interfaces**
- **Autonomy Kit Sensors**
- **Mission Planning**
- **Behaviors**
- **Short-Term Path Planning**
- **Road-World Model**
- **Sensor Fusion**
- **Autonomy Kit Data Logger**
- **Autonomy Kit Embedded Computing Platform**

Health Monitor
Logical Architecture of By-Wire Kit

- By-Wire Kit Health Monitor
- By-Wire User Interface
- B-Perception
- B-Sensors
- Vehicle By-Wire Controls
- By-Wire Kit Data Logger
- By-Wire Kit Embedded Computing Platform
- User Interface
- Autonomy Kit Control Commands
- By-Wire Kit Sensor and Status Data
- OEM J1939

UNCLASSIFIED
Define Interface:

• Leverage/reference existing standards when appropriate
  – J1939, JAUS, AUTOSAR, ADASIS, VICTORY, etc

• Develop messages/data-dictionary
  – Designed to work on multiple different databus implementations
  – Flexibility to support a wide variety of implementations
Hardware-in-the-Loop

• Simulate and Test HIL
  – Determine top level autonomous vehicle operational states
  – Map IOP messages to operational states and different network configurations
  – Run test scenarios and collect performance measurements for different network configurations e.g. FlexRay, CAN, BroadReach (Automotive Ethernet)

• Simulate and Test Vehicle
  – Determine detailed autonomous vehicle state diagram
  – Mature map IOP message set based on detailed vehicle states
  – Integrate HIL into vehicle dynamics model
  – Run test scenarios and collect performance and safety measurements for different network configurations
Interface Verification: HIL and Simulation of Messages

TRUCK SIM

Obstacle Detection

Obstacle Notification

Steering Angle

A Kit
CANoe 8.1

VN8970

FlexRay

B Kit
CANoe 8.1

VN8970

TRUCK SIM HIL
Interested?

• Contact Daniel Bartz – bartz_daniel@bah.com
  or
  Steve Underwood – underw@umich.edu