Digital Data Flows Masterclass #7: Connected and Autonomous Vehicles

June 25, 2020
Future of Privacy Forum

Our Mission

Bridging the policymaker-industry-academic gap in privacy policy

Developing privacy protections, ethical norms, & responsible business practices.

Our Workstreams

- Mobility & Data
  - Youth Privacy
  - AI & Machine Learning
- Location & Ad Tech
  - Internet of Things
  - Biometrics
- De-identification
  - Smart Communities

Our Supporters

- 150+ Companies
- 25+ Leading Academics
- 15+ Advocates and Civil Society
- 5 Foundations
Digital Data Flows Masterclass Series:

1. Artificial Intelligence & Machine Learning
2. Location Data: GPS, Wi-Fi, Spatial Analytics
3. De-Identification, Differential Privacy, and Homomorphic Encryption
4. Online Advertising Technologies
5. Mobile Apps
6. Facial Recognition

Archived videos and slides available at www.fpf.org/classes.
Guest Experts for Class 7: Connected and Autonomous Vehicles (CAVs)

Chelsey Colbert
Policy Counsel, Mobility & Location Data, Future of Privacy Forum

Bryant Walker Smith
Associate Professor of Law and Engineering at the University of South Carolina and Co-Director of the Project on Law and Mobility at the University of Michigan
Primer on Automated Driving and Connected Driving

Bryant Walker Smith

Associate Professor
University of South Carolina School of Law
and (by courtesy) School of Engineering

Affiliate Scholar
Center for Internet and Society at Stanford Law School

Codirector
Program on Law and Mobility at University of Michigan Law School
“Driverless remote-controlled cars”? • Driver assistance • Automated driving • Remote driving • Connected driving
Increasing automation and connectivity

- Driver assistance
- Automated driving
- Remote driving
- Connected driving
This is not your father's Oldsmobile.

Don't go looking for this Oldsmobile in any family album. Road & Track would be a lot more likely.

Because this Oldsmobile is the totally new Cutlass Supreme. So new, its past is just beginning.

Its most noticeable change you've probably already noticed. The way your neighbors will when they see its new aerodynamic shape.

But this sleek new styling standard is much, much more than merely a pretty face.

The inclusion of four-wheel independent suspension, front-wheel drive, four-wheel disc brakes, and a 2.8-liter multiport fuel-injected V6 is rare outside the world's most technologically advanced automobiles.

For more information on this remarkable vehicle, send for a free catalog. Write: Oldsmobile Cutlass Supreme Catalog, P.O. Box 14238, Lansing, Michigan 48901.

OLDSMOBILE QUALITY CUTLASS SUPREME
<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Adaptive Cruise Control" /></td>
<td>Adaptive Cruise Control</td>
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<tr>
<td><img src="image" alt="Adaptive Headlights" /></td>
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<tr>
<td><img src="image" alt="Anti-Lock Braking System" /></td>
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<td><img src="image" alt="Automatic Emergency Braking" /></td>
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<td><img src="image" alt="Automatic Parallel Parking" /></td>
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<td><img src="image" alt="Back-up Camera" /></td>
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<td><img src="image" alt="Back-up Warning" /></td>
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<td><img src="image" alt="Bicycle Detection" /></td>
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<tr>
<td><img src="image" alt="Blind Spot Warning" /></td>
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<tr>
<td><img src="image" alt="Brake Assist" /></td>
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<td><img src="image" alt="Curve Speed Warning" /></td>
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<td><img src="image" alt="Drowsiness Alert" /></td>
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<td><img src="image" alt="Electronic Stability Control" /></td>
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<td><img src="image" alt="Forward Collision Warning" /></td>
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<td><img src="image" alt="High Speed Alert" /></td>
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<tr>
<td><img src="image" alt="Hill Descent Assist" /></td>
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<td><img src="image" alt="Hill Start Assist" /></td>
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<td><img src="image" alt="Lane Departure Warning" /></td>
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<td><img src="image" alt="Lane Keeping Assist" /></td>
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<td><img src="image" alt="Left Turn Crash Avoidance" /></td>
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<td><img src="image" alt="Obstacle Detection" /></td>
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<td><img src="image" alt="Parking Sensors" /></td>
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<td><img src="image" alt="Pedestrian Detection" /></td>
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<tr>
<td><img src="image" alt="Push Button Start" /></td>
<td>Push Button Start</td>
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<tr>
<td><img src="image" alt="Rear Cross Traffic Alert" /></td>
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<tr>
<td><img src="image" alt="Sidewall Camera" /></td>
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<tr>
<td><img src="image" alt="Temperature Warning" /></td>
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<tr>
<td><img src="image" alt="Tire Pressure Monitoring System" /></td>
<td>Tire Pressure Monitoring System</td>
</tr>
<tr>
<td><img src="image" alt="Traction Control" /></td>
<td>Traction Control</td>
</tr>
</tbody>
</table>

mycardoeswhat.org
What do we call all these?

- Advanced driver assistance systems (ADAS)
- Active safety systems
- Automated emergency intervention systems (AEIS)
- Driver support features
Driving
(“performing the dynamic driving task”)∗

• **Driving** involves paying attention to the vehicle, the road, and the environment so you can steer, brake, accelerate, and communicate as needed.

• If you’re expected to pay attention, **you’re still driving** — even when a feature is assisting you with steering, braking, accelerating, and/or communicating.

• Driving may have an even broader legal meaning.

∗SAE J3016
newlypossible.org/wiki/index.php?title=Automated_Driving_Definitions
futurist.law.umich.edu/how-reporters-can-evaluate-automated-driving-announcements
SAE J3016
(and soon-to-be ISO PAS 22736)

• Widely adopted industry document

• Key definitions for driving automation

• Levels of driving automation (L0 - L5)
  – Driver assistance / driver support (L0 - L2)
  – Automated driving (L3 - L5)
Assisted driving features

**L0:** You’re driving

**L1:** You’re driving, but you’re assisted with **either** steering or speed

**L2:** You’re driving, but you’re assisted with **both** steering and speed
**L2:** You’re driving, but you’re assisted with both steering and speed

- Adaptive cruise control *plus* lane-keeping assist
- Automatic parking (speed and steering)
- GM’s “Super Cruise”
- Tesla’s “““Autopilot and Full Self-Driving Capability””
Tesla’s “Smart Summon”

youtu.be/enkRALcdPbo?t=364
Why is this still level 2?

If you’re expected to pay attention, you’re still driving — even when a feature is assisting you with steering, braking, accelerating, and/or communicating.
Driver assistance features work unless and until they don’t
Complemented by interior sensors

- Occupancy/weight/seatbelt use: Many kinds (in all cars)
- Inattention: Camera (GM Super Cruise)
- Hands-on-wheel: Presence and torque (many cars)
- Drowsiness: Steering angle and torque (many cars)
- Intoxication: Alcohol detectors (aftermarket)
- Break-ins: Camera (Tesla?)
- Gestures: Camera (Bosch)
- Crash assessment: Microphone (OnStar)
- And more!
Increasing automation and connectivity

- Driver assistance
- Automated driving
- Remote driving
- Connected driving
Increasing automation and connectivity

• Driver assistance

• Automated driving

• Remote driving

• Connected driving
Automated driving (SAE L3 - L5)

- Autonomous
- Driverless
- Self-driving
- A shibboleth in the technical world
- A (mostly) neutral and inclusive term
<table>
<thead>
<tr>
<th>Level</th>
<th>Name</th>
<th>Narrative definition</th>
<th>DDT</th>
<th>OEDR</th>
<th>DDT fallback</th>
<th>ODD</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Driving Automation</td>
<td>The performance by the driver of the entire DDT, even when enhanced by active safety systems.</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>The sustained and ODD-specific execution by a driving automation system of either the lateral or the longitudinal vehicle motion control subtask of the DDT (but not both simultaneously) with the expectation that the driver performs the remainder of the DDT.</td>
<td>Driver and System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
</tr>
<tr>
<td>2</td>
<td>Partial Driving Automation</td>
<td>The sustained and ODD-specific execution by a driving automation system of both the lateral and longitudinal vehicle motion control subtasks of the DDT with the expectation that the driver completes the OEDR subtask and supervises the driving automation system.</td>
<td>System</td>
<td>Driver</td>
<td>Driver</td>
<td>Limited</td>
</tr>
<tr>
<td>3</td>
<td>Conditional Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems, and will respond appropriately.</td>
<td>System</td>
<td>System</td>
<td>Fallback-ready user (becomes the driver during fallback)</td>
<td>Limited</td>
</tr>
<tr>
<td>4</td>
<td>High Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Limited</td>
</tr>
<tr>
<td>5</td>
<td>Full Driving Automation</td>
<td>The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Unlimited</td>
</tr>
</tbody>
</table>
**ADS ("System")** performs the entire **DDT** (while engaged)

<table>
<thead>
<tr>
<th>Level</th>
<th>Condition</th>
<th>Description</th>
<th>System</th>
<th>Fallback-ready user (becomes the driver during fallback)</th>
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<tr>
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<td>Conditional Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT with the expectation that the DDT fallback-ready user is receptive to ADS-issued requests to intervene, as well as to DDT performance-relevant system failures in other vehicle systems, and will respond appropriately.</td>
<td>System</td>
<td>Limited</td>
</tr>
<tr>
<td>4</td>
<td>High Driving Automation</td>
<td>The sustained and ODD-specific performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
</tr>
<tr>
<td>5</td>
<td>Full Driving Automation</td>
<td>The sustained and unconditional (i.e., not ODD-specific) performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.</td>
<td>System</td>
<td>System</td>
</tr>
</tbody>
</table>
Complete DDT performance + fallback
Level 4
Highway traffic pilot
Level 3
ACC+lane centering, parking/traffic jam assist
Level 2
ACC, parking
Level 1
Minimum of markings required
Level 0
Warning/intervention

Some ODD parameters:
- Speed
- Geography
- Roadway
- Environment

Level 2 example:
- Roadway = expressway
- Speed ≤ 35mph
- Daytime only

Level 4 example:
- Roadway = campus roads
- Speed ≤ 25mph
- Daytime only

Unlimited ODD

ADS ("System") performs tasks

Conditional Driving Automation
Level 3
The system of the ADS of DDT fails to requests relevant

High Driving Automation
Level 4
The system of expect Sustained motion control

Full Driving Automation
Level 5
The sustained (domain specific) performance by an ADS of the entire DDT and DDT fallback without any expectation that a user will respond to a request to intervene.

Level 0
Level 1
Level 2
Level 3
Level 4
Level 5

Domain specific
Unlimited domain

Driver fallback
System fallback
Partial OEDR
Complete OEDR

Lat OR Long Lateral AND Longitudinal motion control

Momentary Sustained motion control

Circa 2016
Future
Driver n/a

Law of the newly Possible
newlypossible.org
Figure 8 - Simplified logic flow diagram for assigning driving automation level to a feature

- **Driver DDT Performance**
  - Receptive fallback ready user
  - Driver performs fallback and, if necessary, achieves minimal risk condition

---

**Complete DDT performance + fallback**

**Level 4**

- Airport people movers (enclosed tracks)
- High speed, limited roads
- City pilot

**Does the feature:**

- Perform the complete DDT and DDT fallback **without** ODD limitation?
  - Yes → Full Driving Automation Level 5
  - No → Sustained lateral motion control

- Perform the complete DDT and DDT fallback **within** a limited ODD?
  - Yes → High Driving Automation Level 4
  - No → Sustained lateral motion control

- Perform the complete DDT, but not DDT fallback, **within** a limited ODD?
  - Yes → Conditional Driving Automation Level 3
  - No → Warn

- Perform both longitudinal and lateral vehicle motion control (on a sustained basis), but not complete OEDR?
  - Yes → Partial Driving Automation Level 2
  - No → ADS DDT Performance

- Perform either longitudinal or lateral vehicle motion control (on a sustained basis), but not complete OEDR?
  - Yes → Driver Assistance Level 1
  - No → Perform none of the DDT or DDT fallback?
    - Yes → No Driving Automation Level 0

---

**Unlimited domain**

**Unlimited ODD**

**Level 5**

- Campus roads
Figure 8 - Simplified logic flow diagram for assigning driving automation level to a feature

Driver DDT Performance

- Receptive fallback ready user
  - Driver performs fallback and, if necessary, achieves minimal risk condition

ADS DDT Performance

- Perform either longitudinal or lateral vehicle motion control (on a sustained basis), but not complete OEDR?
  - Yes → Driver Assistance Level 1
  - No → Perform none of the DDT or DDT fallback?
    - Yes → No Driving Automation Level 0
    - No → Perform the complete DDT and DDT fallback within a limited ODD?
      - Yes → High Driving Automation Level 4
      - No → Perform the complete DDT and DDT fallback without ODD limitation?
        - Yes → Full Driving Automation Level 5
        - No → Complete DD Level 5

City pilot

High speed, limited roads

Airport people movers (enclosed tracks)
# SAE J3016™ Levels of Driving Automation

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Level 0</strong></td>
<td>You are driving whenever these driver support features are engaged – even if your feet are off the pedals and you are not steering.</td>
<td>These features are limited to providing warnings and momentary assistance. Example Features: automatic emergency braking, blind spot warning, lane departure warning.</td>
</tr>
<tr>
<td><strong>Level 1</strong></td>
<td>You must constantly supervise these support features; you must steer, brake or accelerate as needed to maintain safety.</td>
<td>These features provide steering OR brake/acceleration support to the driver. Example Features: lane centering OR adaptive cruise control.</td>
</tr>
<tr>
<td><strong>Level 2</strong></td>
<td>You are not driving when these automated driving features are engaged – even if you are seated in “the driver’s seat.”</td>
<td>These features provide steering AND brake/acceleration support to the driver. Example Features: lane centering AND adaptive cruise control at the same time.</td>
</tr>
<tr>
<td><strong>Level 3</strong></td>
<td>You are not driving when these automated driving features are engaged – even if you are seated in “the driver’s seat.”</td>
<td>These automated driving features will not require you to take over driving. Example Features: traffic jam chauffeur.</td>
</tr>
<tr>
<td><strong>Level 4</strong></td>
<td>You are not driving when these automated driving features are engaged – even if you are seated in “the driver’s seat.”</td>
<td>These automated driving features will not require you to take over driving. Example Features: local driverless taxi.</td>
</tr>
<tr>
<td><strong>Level 5</strong></td>
<td>You are not driving when these automated driving features are engaged – even if you are seated in “the driver’s seat.”</td>
<td>These automated driving features will not require you to take over driving. Example Features: same as level 4, but feature can drive everywhere in all conditions.</td>
</tr>
</tbody>
</table>

*SAE International*
• “Drive means to drive, operate, move, or be in actual physical control of a vehicle…”

• “Operate … means to drive…”

• “Operating … is generally given a broader meaning [than driving]”
Assisted driving features

**L0**: You’re driving

**L1**: You’re driving, but you’re assisted with either steering or speed

**L2**: You’re driving, but you’re assisted with both steering and speed
Automated driving features

L3: You’re not driving, but you will need to drive if prompted in order to maintain safety

L4: You’re not driving, but either
a) you will need to drive if prompted in order to reach your destination (in a vehicle you can drive) or
b) you will not be able to reach every destination (in a vehicle you can’t drive)

L5: You’re not driving, and you can reach any destination
ADS

• Automated Driving System

• “vehicle equipped with an (engaged) automated driving system”

• Automated Vehicle (AV)
**L3**: You’re not driving, but you will need to drive if prompted in order to maintain safety

By B137, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=48998674

Audi press release (August 2017); europe.autonews.com/automakers/audi-quits-bid-give-a8-level-3-autonomy
L3: You’re not driving, but you will need to drive if prompted in order to maintain safety

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[Image of a road with a caution sign and snowflakes, indicating winter conditions]
L4: You’re not driving, but either:
a) you will need to drive if prompted in order to reach your destination (in a vehicle you can drive)....
L4: You’re not driving, but either:

a) you will need to drive if prompted in order to reach your destination (in a vehicle you can drive)....

Pulling over on shoulder = minimal risk condition (...)

L4: ... or you will not be able to reach every destination (in a vehicle you can’t drive)
Operational design domain (ODD)

When and where a feature is specifically designed to function

Google Maps; Straßenverkehrsordnung, commons.wikimedia.org/w/index.php?curid=49947; miro.medium.com/max/1400/0*9MQpiBhfRaPZhra

law of the newly Possible newlypossible.org
L5: You’re not driving, and you can reach any destination (an “unlimited” ODD...)

Vehicle types

- Vehicles you can drive:

- Vehicles you can’t drive:
Trip types

• You must drive for the entire trip (L0 - L2)

• You will need to drive if prompted in order to maintain safety (L3)

• You will need to drive if prompted in order to reach your destination (L4)

• You will not need to drive for any reason, but you may drive if you want (L4 - L5)

• You will not need to drive for any reason, and you may not drive (L4 - L5)
What’s driving today?

• You cannot buy an AV

• You might be able to ride in an aspirational AV

• You might be able to use a delivery robot

• But they will almost certainly be supervised
Lt. Jeanine Menze by PO2 Jennifer Johnson,
alaska.coastguard.dodlive.mil/2014/03/breaking-barriers-and-becoming-the-change-for-women-in-coast-guard-aviation/
Starship - Food Delivery

Starship Technologies Essen & Trinken

☆☆☆☆☆ 8,7 272,00

E Jedes Alter

 Diese App ist mit allen deinen Geräten kompatibel.

Zur Wunschliste hinzufügen

Installieren

Waymo (Early Access)

Waymo LLC Karten & Navigation

☆☆☆☆☆ 8,7 424,00

E Jedes Alter

 Diese App befindet sich noch in der Entwicklungsphase. Sie ist möglicherweise instabil.

Diese App ist mit allen deinen Geräten kompatibel.

Installiert

starship.xyz; waymo.com
Looking ahead

Some combination of:

• Slow speeds
• Simple environments
• Supervised operations
Increasing automation and connectivity

• Driver assistance

• **Automated driving**

• Remote driving

• Connected driving
Increasing automation and connectivity

- Driver assistance
- Automated driving
- Remote driving
- Connected driving
Tesla’s “Smart Summon”
Platooning
Really remote driving

The End of Starsky Robotics

In 2015, I got obsessed with the idea of driverless trucks and started Starsky Robotics. In 2016, we became the first street-legal vehicle to be paid to do real work without a person behind the wheel. In 2018, we became the first street-legal truck to do a fully unmanned run, albeit on a closed road. In 2019, our truck became the first fully-unmanned truck to drive on a live highway.

And in 2020, we’re shutting down.
Pop quiz!

On reaching a crash site, an automated vehicle stops in its lane until someone at a faraway monitoring center sketches a travel path. Using its sensors, the vehicle then follows this path.
Pop quiz!

On reaching a crash site, an automated vehicle stops in its lane until someone at a faraway monitoring center sketches a travel path. Using its sensors, the vehicle then follows this path.

1) Is this L3 or L4 automated driving?
2) Is there a remote driver?
Pop quiz!

1) Is this L3 or L4 automated driving?

Is standing in this lane a minimal risk condition?
Pop quiz!

2) Is there a remote driver? Is the remote agent (a) “performing the dynamic driving task” or (b) merely providing additional information for the automated driving system?
Increasing automation and connectivity

• Driver assistance

• Automated driving

• Remote driving

• Connected driving
Increasing automation and connectivity

- Driver assistance
- Automated driving
- Remote driving
- Connected driving
Automation versus connectivity

L5 ADS

V2X

Increasing automation

Increasing connectivity
**Communications**

**V2V:** Vehicle-to-Vehicle

**V2P:** Vehicle-to-Pedestrian

**V2I:** Vehicle-to-Infrastructure

**V2C:** Vehicle-to-Cloud

**V2D:** Vehicle-to-Device

**V2X:** Vehicle-to-Everything

But really: This image is everywhere. Everywhere. Back in the day, no briefing on V2V was complete without it. I think people started expecting that cars of the future would shoot golden halos. So does anybody actually know where this image originally came from? Or does it have a kind of transcendent always-has-and-always-will-be permanence, much like those mysterious golden halos?
A narrow version of vehicle connectivity

- Direct communication to/from vehicles
- Really fast (“low latency”) and super reliable
- Supports safety-critical applications
Basic safety message (BSM) in US*

Ten times a second: “Hey there vehicle neighbors! My temporary pseudonym is BigSister389. I’m a 15-ft-long vehicle at 34°/81°/300ft moving NW at 30mph but slowing at 15fps with my steering wheel at 15° and my brakes engaged….”

Every few seconds: “And by the way, it’s 32° outside, I think it’s raining, my lights and wipers are on, I weigh 3000lbs, and here’s some other fun trivia that you might find safety-relevant… oh, but first, watch out for the black ice!”

*The EU’s cooperative awareness message is vaguely similar….
Devil in the details

• Competing technologies
  – DSRC/ITS G5/802.11p (Wi-Fi)
  – C-V2X LTE & 5G (Cellular)

• Spectrum (re)allocation and spectrum sharing

• Sloooow adoption

• Regional differences and incompatibilities

youtube.com, but please don’t go there now; the cat videos will still be there when this is done
Few and (literally) far between

<table>
<thead>
<tr>
<th>DSRC/ITS G5</th>
<th>C-V2X</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some Cadillacs since 2017</td>
<td>All Fords from 2022?</td>
</tr>
<tr>
<td>Some VW Golfs from 2020</td>
<td></td>
</tr>
<tr>
<td><strong>All US Toyotas from 2021?</strong></td>
<td></td>
</tr>
<tr>
<td>Some cars in Japan since 2016</td>
<td></td>
</tr>
<tr>
<td><strong>To be mandated in US (2018)</strong></td>
<td>Preferred in China</td>
</tr>
<tr>
<td><strong>Preferred in EU (2019)</strong></td>
<td></td>
</tr>
<tr>
<td><strong>EU to be “technology neutral” (2019)</strong></td>
<td></td>
</tr>
</tbody>
</table>
Automation versus connectivity

Increasing automation

L5 ADS

Increasing connectivity

V2X

freesvg.org/unicorn-vector-clipart-pdv
A broad version of vehicle connectivity

• Telematics
• Infotainment
• OBD II dongles
• In-vehicle Wi-Fi
• In-vehicle Bluetooth
• Mobile vehicle apps
• Over-the-air updates
• OnStar (and its competitors)
A broad version of vehicle connectivity

- Telematics
- Infotainment
- OBD II dongles
- In-vehicle Wi-Fi
- In-vehicle Bluetooth
- Mobile vehicle apps
- Over-the-air updates
- OnStar (and its competitors)

All this is here now (and has been for years)
Automation versus connectivity

Increasing automation

L5 ADS

Increasing connectivity

V2X
Key questions for a data discussion

• (How) are mobile phones and other connected devices different than motor vehicles?

• (How) are V2V-capable motor vehicles different than conventional motor vehicles?

• (How) are automated vehicles different than conventional motor vehicles?
Increasing automation and connectivity

• Driver assistance

• Automated driving

• Remote driving

• Connected driving
Increasing automation and connectivity

- Driver assistance
- Automated driving
- Remote driving
- Connected driving
END PART ONE

BEGIN PART TWO

tenor.com/view/adam-workaholics-way-to-work-cat-driving-gif-16820165. As promised
Automated Driving Technologies and Data
Increasing automation and connectivity

- Driver assistance
- Automated driving
- Remote driving
- Connected driving
How the technologies work

• Driver assistance

• Automated driving

• Remote driving

• Connected driving
Automated driving is a wide range of:

- Underlying technologies
- Applications of those technologies
- Business cases for those applications
- Participants in those business cases
Driving
("performing the dynamic driving task")*

• Driving involves paying attention to the vehicle, the road, and the environment so you can steer, brake, accelerate, and communicate as needed.

• If you’re expected to pay attention, **you’re still driving** — even when a feature is assisting you with steering, braking, accelerating, and/or communicating.

• Driving may have an even broader legal meaning.

*SAE J3016
newlypossible.org/wiki/index.php?title=Automated_Driving_Definitions
futurist.law.umich.edu/how-reporters-can-evaluate-automated-driving-announcements
Driving

- What’s around me?
- What should I do?
- I’m doing it!
- ...

Driving

• What’s around me? Perception

• What should I do? [Path] Planning

• I’m doing it! Actuation

• ...

Driving

• What’s around me? **Perception**

• What should I do? **[Path] Planning**

• I’m doing it! **Actuation**

• ...

Data and privacy
Some of Waymo’s external sensors

Plus microphones, ultrasonic sensors, inertial sensors, and GPS receivers (but not DSRC receivers)

As well as numerous internal sensors
Why so many?

• Inches away to hundreds of feet away

• Day and night, sunrise and sunset....

• Snow, rain, fog, glare....

• Distance, size, color, detail....

• Accuracy, reliability, and confidence
Sensors and mapping: What do I expect?

• **Beforehand:** Build a highly detailed 3D map

• **During:** Compare the map to the real world
  – Where am I?
  – What’s different?
    • What has changed?
    • What is there to see?

• **Afterward:** Update the map

*(unless you’re Tesla)*
Detect, classify, and track people walking, people running, people biking, people walking bikes, people walking in crowds, people trying to cross, buses, cars, motorcycles, scooters, trucks, trucks pulling cars, cars pulling trucks, trailers, cats, dogs, birds, turtles, snakes, alligators, deer, elk, police cars, ambulances, firetrucks, garbage trucks, construction equipment, construction detours, first responders, crossing guards, temporary traffic signals, new traffic signs, potholes, mattresses, plastic bags, shredded tires, trees, tree limbs, shadows, hanging wires, low-flying planes, marathons, towtrucks, towtrucks towing other towtrucks, cars backing up, cars going the wrong way, cars upside down, millions of other things we’ve seen before and millions of things that we haven’t...

...and then predict what they’ll do next
Example: Uber’s fatal crash

[Link to NTSB report on Uber's fatal crash]
Example: Uber’s fatal crash

• Volvo’s emergency braking system disabled in favor of Uber’s human and machine system

• 6 sec before impact: Software is unsure about classification and path (unknown object / vehicle / bicycle) and so does nothing

• 1.3 sec before impact: Software anticipates collision and so does nothing

• < 1 sec before impact: Human driver finally intervenes
Example: Uber’s fatal crash

• Believing the safety driver will be careful, Uber’s engineers create a vehicle that behaves recklessly

• Believing the vehicle will be careful, Uber’s safety driver behaves recklessly

• A woman dies

ntsb.gov/investigations/AccidentReports/Pages/HWY18MH010-prelim.aspx
This failure is unacceptable
You’re helping

Select all squares with **crosswalks**
If there are none, click skip

Select all squares with **traffic lights**

Learn.g2.com/captcha; wingarc.com.au/2019/09/is-google-using-us-to-train-self-driving-cars
Machine learning

• Supervised

• Unsupervised

CC BY-SA 3.0, wikipedia.org/w/index.php?curid=2508139; www.youtube.com/watch?v=BxODSKCNook
Like a thesaurus

- aloofness
- concealment
- confidentiality
- isolation
- penetralia
- privateness
- quiet
- retirement
- retreat
- seclusion
- separateness
- separation
- sequestration
- solitude
- clandestineness
- one’s space

www.thesaurus.com/browse/privacy
Increasing automation and connectivity

- **Driver assistance**
  - Some systems use machine learning techniques

- **Automated driving**
  - All systems will use machine learning techniques

- **Remote driving**

- **Connected driving**
Stylized Data Pathways

Onboard (Vehicle)

- Generated/Received
- Processed
- Discarded
- Used
- Stored
- Transmitted

Offboard (Cloud)

- Processed
- Stored
- Used
- Shared
- Transmitted

A giant meaningless number

Terabytes/hour?*
Terabytes/hours?*

* Equivalent to a large home hard drive with millions of photos or hundreds of thousands of songs
Automated driving data

- To operate the system (*implicit*)
- To develop the system (*implicit/intended*)
- To document performance (*intended*)
- During operation of the system (*incidental*)
Inside the vehicle

The vehicle

Outside the vehicle
Unimaginable possibilities?
Real-time Streetview?
Automated enforcement by private networks?
Can Big Automakers Be Trusted With Big Data?

Autonomy will turn cars into rolling supercomputers. That’s a problem.

BY ERIC ADAMS  APRIL 13, 2018

“It's not just that automated vehicles will be supercomputers,” said Bryant Walker Smith, a law professor at the University of South Carolina who studies the impact of autonomous technology on society. “They'll be mobile supercomputers powered by big batteries, fed by all kinds of capable sensors both inside and outside the vehicle, and connected back to huge companies with even greater collective computing resources.”
law of the newly possible newlypossible.org
Connected Car Data Flows

- **CAN-BUS**: Internal communication bridge between Electronic Control Units
- **AUTONOMOUS VEHICLE IMAGING AND SCANNING**: LIDAR, radar, ultrasonic sensors, or exterior cameras
- **DSRC RADIO**: Vehicle to vehicle and vehicle to infrastructure communication
- **TELEMATICS CONTROL UNIT (TCU)**: Interconnects CAN Bus and external systems
- **TIRE PRESSURE SENSORS**: Short range radio, goes to radio receiver
- **EVENT DATA RECORDER**: Black box with accident data
- **CRASH DATA RETRIEVAL UNIT**: Extracts EDR data
- **THIRD PARTY MONITORING DEVICE**: OBD-II or external device communicates with fleet operator
- **License Plate**
Regulatory Landscape
Data Protection by Design & by Default

- Legal requirements in the GDPR
  - embedded safeguards and mechanisms throughout the lifecycle of the application, service or product
  - requires the Controller to implement appropriate technical and organizational measures
  - a risk-based approach that is contextual and dynamic

- European Data Protection Board
  - Draft guidelines Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications
Privacy by Design

1. Proactive not reactive; Preventative not remedial
2. Privacy as the default setting
3. Privacy embedded into design
4. Full functionality - Positive-sum, not zero-sum
5. End to end security - full lifecycle protection
6. Visibility and transparency - keep it open
7. Respect for user privacy - keep it user-centric
Example of PbD Practices with optical sensors and computer vision
Thank-you!
Questions?