AUTONOMOUS VEHICLES: PAST, PRESENT, FUTURE

CEM U. SARAYDAR
Director, Electrical and Controls Systems Research Lab
GM Global Research & Development
“Highways & Horizons” showed an imagined world of 1960, complete with automated highways
AUTONOMOUS HIGHWAY OF THE FUTURE – 1950s
EARLY GM AUTOMATED VEHICLES
Demonstration August 1997 along I-15 near San Diego
Focus on platooning for safety and increased traffic density

Demonstrated Technologies
- Vision-based road following
- Lane departure warning
- Magnetic nail following
- Radar reflective strip following
- Radar-based headway maintenance
- Lidar-based headway maintenance
- Partial automation and evolutionary systems
- Close vehicle following (platooning)
- Cooperative maneuvering
- Obstacle detection and avoidance
- Mixed automated and manual driving
- Mixed automated cars and buses
- Semi-automated maintenance operations
DARPA URBAN CHALLENGE 2007

- 60 miles, <6 hrs, <30 mph
- Urban traffic; mixed (human + robot operated) traffic
- 89 → 35 → 11 → 6 → 1
- GM/Carnegie Mellon “BOSS” finished 1st in 4 hours 10 minutes!
SECOND-GENERATION ELECTRIC NETWORKED VEHICLE

- Low-speed city car equipped with active safety and automated driving technology
- Ideal for short distance or “last-mile” personal transportation in inner cities, business campuses, retirement communities, etc.
- Outfitted with cameras, GPS, Lidar, maps, V2X communications, smartphone, and RFID technologies
- Capabilities
  - State-of-the-art autonomous chauffeur
  - Autonomous valet parking and retrieval
  - Urban automated platooning/traffic jam assist
  - Intersection collision assist
  - Pedestrian crash avoidance
- Demonstrated at ITS World Congress, Detroit MI, September 2014
CADILLAC TO INTRODUCE SUPER CRUISE ON ALL-NEW CT6

ACTIVE SAFETY

AUTOMATED STEERING & LANE FOLLOWING

HOW IT WORKS

LANE FOLLOWING: Using a combination of GPS and optical cameras, Super Cruise watches the road ahead and adjusts steering to keep the car in the middle of its lane.

COLLISION AVOIDANCE: A long-distance radar system detects vehicles more than 300 ft. ahead. The vehicle will automatically accelerate or apply the brakes to maintain a preset following distance.
A spy photographer has come across a fleet of all-electric Chevy Bolt EVs testing today that appear to be equipped with arrays of self-driving sensors. The Bolt EVs are already testing the electric cars that could ferry Lyft passengers sometime in the next year.

And they're looking for test drivers.

Cruise Automation, the startup acquired earlier this year by General Motors, has been making plans for its autonomous vehicle operations. GM's Cruise Automation is Testing Self-Driving Chevy Bolts in Arizona
WHY DO WE CARE ABOUT AUTONOMOUS?

Stay Safe and Secure

Avoid Danger

Reach Destination on Time

Door-to-door Transportation

Be Productive

Communicate with Others

Child Safety
<table>
<thead>
<tr>
<th>SAE 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>
</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>
</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>
</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>
</tr>
<tr>
<td></td>
<td>Automated driving system (&quot;system&quot;) monitors the driving environment</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>
</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>
</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>
</tr>
</tbody>
</table>
THE AUTOMATED DRIVING PUZZLE

- Legal/Regulatory/Insurance
- Human Factors
- Localization
- Vehicle Motion Control
- Testing (Verification & Validation)
- Economic
- Perception
- Planning & Decision Making
- Social/Political
AUTOMATED DRIVING SYSTEM – CONTEXT DIAGRAM

- Law Enforcement/First Responders
- Passengers
- Wireless Services
- Base Vehicle
- Other Road Users
- Roadway and Static Objects
- Driver/Operator
- Service
TYPICAL AUTONOMOUS VEHICLE SYSTEM

SENSING & PERCEPTION

- Sensors & Signal Sources
- Environment Perception
  - Scene Understanding
  - Data Fusion
  - Data Association
- Mapping & Localization

PLANNING & CONTROL

- Planning & State Management
- Vehicle Control
# AUTOMATED DRIVING TECHNOLOGY ELEMENTS

<table>
<thead>
<tr>
<th>HARDWARE</th>
<th>LOGIC, SOFTWARE AND DATA</th>
<th>SYSTEMS INTEGRATION</th>
<th>MANUFACTURING</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensors</strong> (Camera, Radar, Lidar)</td>
<td>Image Processing, Sensory Fusion, Perception, Planning, Behavior</td>
<td>Validation and Testing</td>
<td>Assembly and Programming</td>
</tr>
<tr>
<td><strong>Processors</strong> (CPU, GPU, FPGA)</td>
<td></td>
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<tr>
<td><strong>Actuators</strong> (Brakes, Steering, Gear Select)</td>
<td>High-definition Maps, Real Time Road Conditions</td>
<td></td>
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<tr>
<td><strong>Transceivers</strong> (Connectivity)</td>
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</tbody>
</table>
DIMENSIONS OF STATE-OF-THE-ART: AUTOMATED DRIVING OPERATIONAL DOMAINS

Geographic Location and Road Geometry

- Freeways
- City center local roads
- Arterial roads
- Residential local roads
- Industrial local roads
- Parking lots/parking garages/residential driveways and garages
- Tunnels, covered/multi-level bridges
- Construction zones
Environmental Conditions

- Road surface conditions
  - Clear
  - Wet/puddles
  - Snow covered
  - Icy
  - Pot holes

- Illumination
  - Daylight
  - Dawn/Dusk
  - Night

- Atmospheric conditions
  - Clear
  - Rain
  - Snow
  - Fog
  - Blowing dust/leaves/debris
Traffic Conditions

- **Density**
  - Light (flowing at or above speed limit)
  - Moderate (continuous flow, below speed limit)
  - Congested (surging, stop and go)

- **Speeds**
  - Very low speeds (e.g., up to 5 mph)
  - Stop and Go (e.g., up to 20 mph)
  - Local road speeds (e.g., up to 35 mph)
  - Arterial road speeds (e.g., up to 50 mph)
  - Freeways (e.g., 80 mph)
DIMENSIONS OF STATE-OF-THE-ART: AUTOMATED DRIVING OPERATIONAL DOMAINS

Parking

- Driver/operator role and position
  - In vehicle, beside vehicle, or remote
  - Supervised or unsupervised (valet)

- Parking environments
  - Street side
  - Parking lot
  - Parking garage
  - Residential garage or carport

- Parking spot
  - Parallel
  - Angle
  - Back in
AUTONOMOUS DRIVING CHALLENGES AND OPPORTUNITIES

- Production-viable sensing/perception
- Fault-tolerant/fail-safe automated vehicle control (with driver-in-the-loop)
- Situational analysis in complex environment
- Emergency situations and rare events
- Dealing with diverse behaviors of others (non-autonomous vehicles)
- Detection of driver distraction (inattentiveness)
- Positioning
  - Digital maps with lane-level accuracy, road signs, etc.
  - GPS lane level accuracy and availability (urban canyons,…)
  - Localization with limited accuracy or no GPS
- Virtualization
  - Physics-based active sensor models
  - Verifiable driver (non-robot) model
- V2X: Security/privacy, interoperability, congestion
ENABLING TECHNOLOGIES IN CURRENT PRODUCTION VEHICLES

Sensors

- RADAR
  - Long Range – 120m x 14°
  - Medium Range – 70m x 90°
  - Short Range – 30 m x 150°
- Video
  - Mono and Stereo
  - Visible and IR
  - Front and rear
- LIDAR
- GPS/map databases for navigation systems

Actuators Controlled by Computers

- Electric Power Steering
- Brake Systems (Antilock Brakes/ Traction Control/Stability Control)
- Engine and Transmission

Communication Networks

- CAN, Flexray (for safety critical systems)
- Ethernet (for infotainment)
ENABLING TECHNOLOGY NEEDS

Sensors

- Object Sensing
  - Smaller/easier to fit on the vehicle
  - Less expensive
  - Higher resolution (range, horizontal and vertical angle)
  - Larger field of view (longer, wider)
  - Higher update rates and lower latency

- Road Sensing
  - Sign/traffic signal information
  - Lane geometry
  - Surface friction

- Driver State Sensing
  - Attention
  - Intent

Fail Operational Functionality

- Sensing
- Actuation
- Processing
- Communications
- Power

Networking and Infrastructure Information

- Maps/GPS
  - Lane level information
  - Faster update rates

- Vehicle to Vehicle and Vehicle to Infrastructure Communication
I believe the auto industry will change more in the next five to 10 years than it has in the last 50

Mary Barra
CEO and Chairman of General Motors
THANK YOU!

Cem Saraydar
cem.saraydar@gm.com