AUTONOMOUS VEHICLES: PAST, PRESENT, FUTURE

GM RESEARCH & DEVELOPMENT

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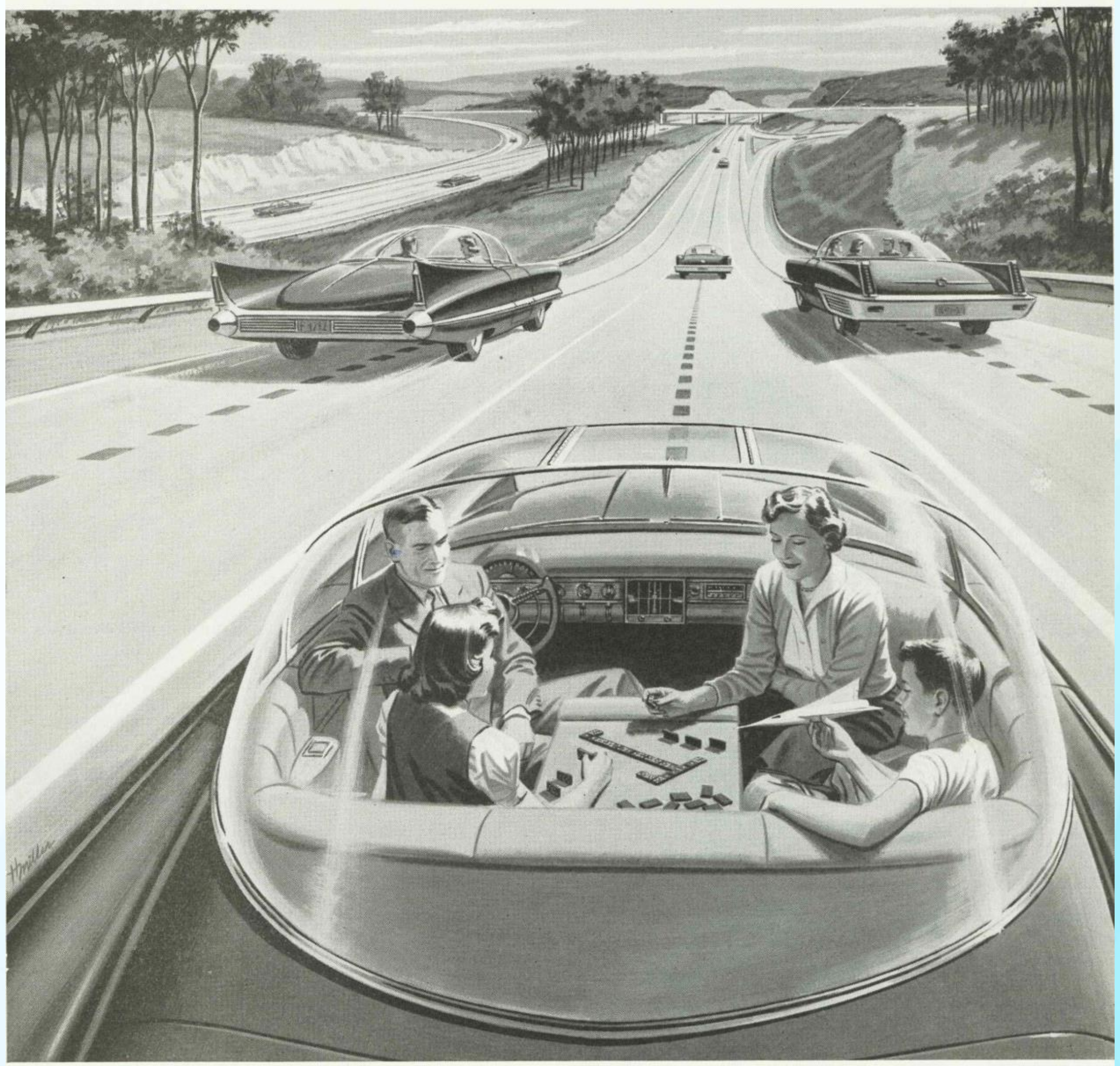
GENERAL MOTORS FUTURAMA – 1939

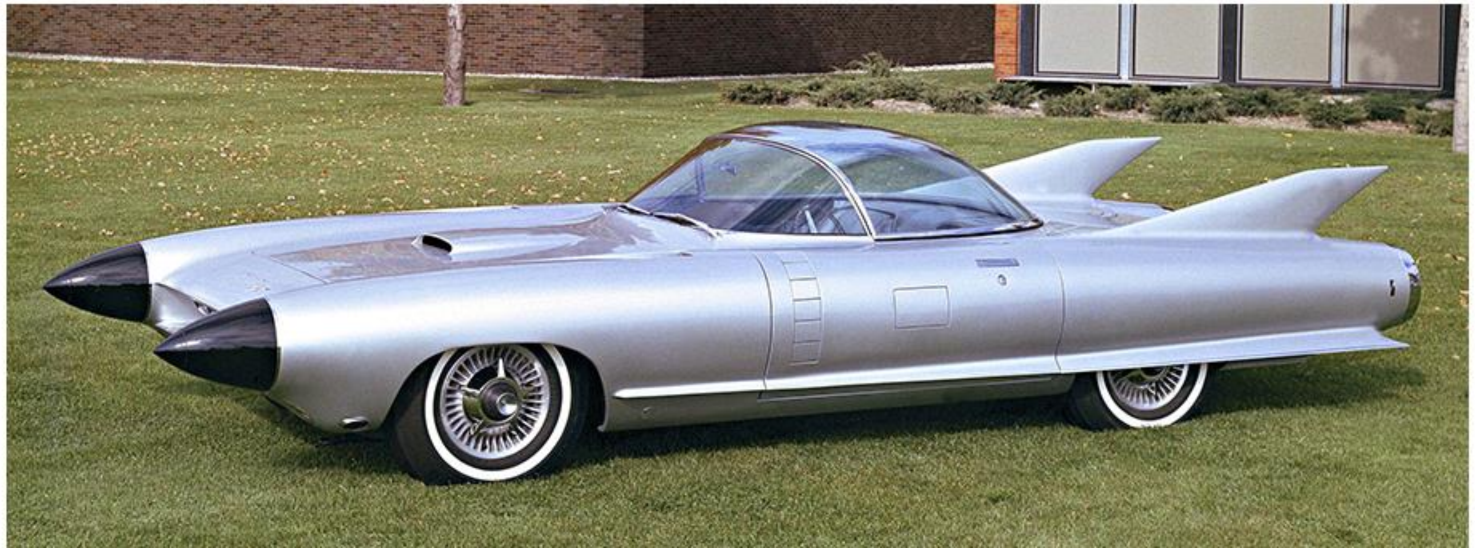
“Highways & Horizons” showed an imagined world of 1960, complete with automated highways

AUTONOMOUS HIGHWAY OF THE FUTURE – 1950s



ELECTRICITY MAY BE THE DRIVER. One day your car may speed along an electric super-highway, its speed and steering automatically controlled by electronic devices embedded in the road. Travel will be more enjoyable. Highways will be made safe—by electricity! No traffic jams . . . no collisions . . . no driver fatigue.

EARLY GM AUTOMATED VEHICLES



NATIONAL AUTOMATED HIGHWAY SAFETY CONSORTIUM

- Demonstration August 1997 along I-15 near San Diego
- Focus on platooning for safety and increased traffic density

Demonstrated Technologies

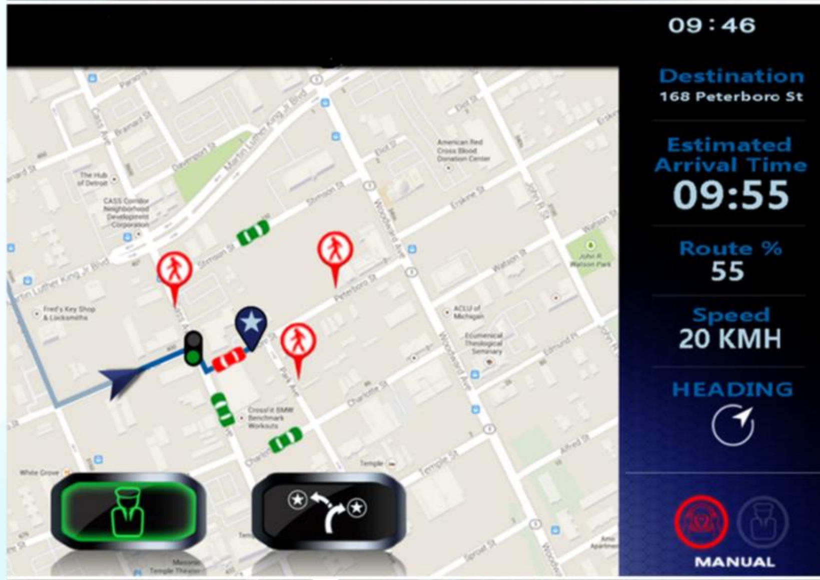
- Vision-based road following
- Lane departure warning
- Magnetic nail following
- Radar reflective strip following
- Radar-based headway maintenance
- Lidar-based headway maintenance
- Partial automation and evolutionary systems
- Close vehicle following (platooning)
- Cooperative maneuvering
- Obstacle 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!

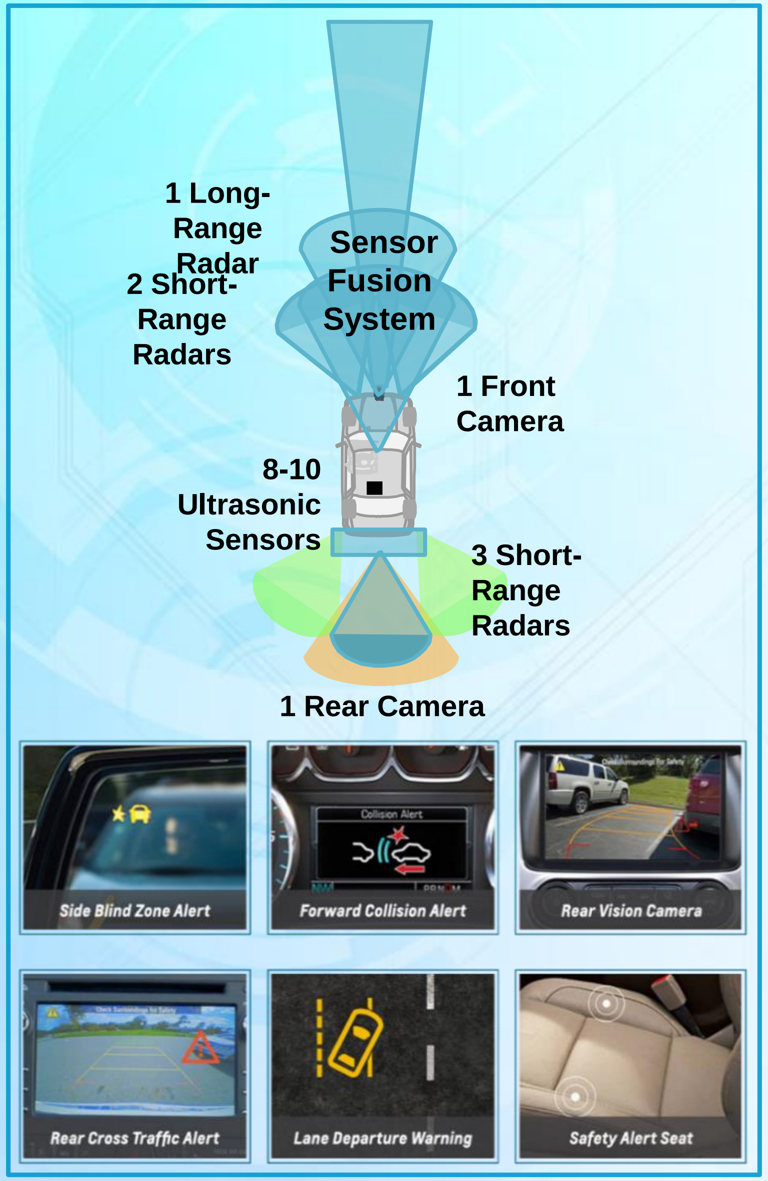
SECOND-GENERATION ELECTRIC NETWORKED VEHICLE

- 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

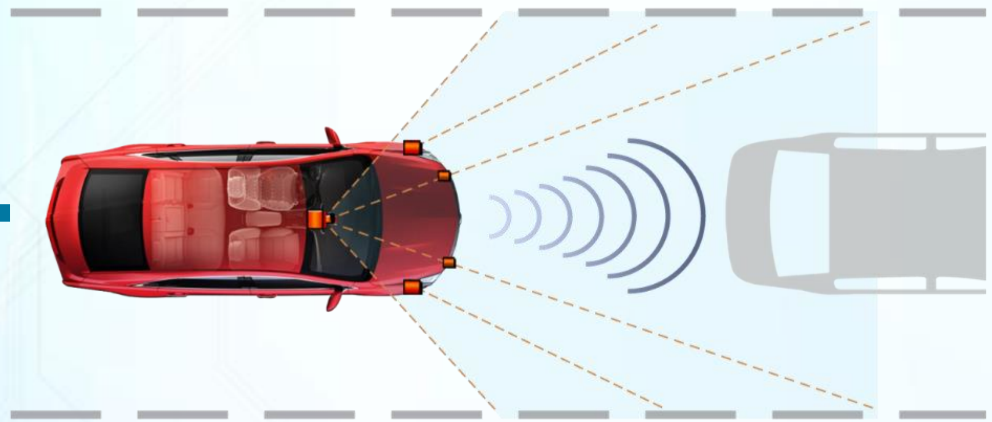


CADILLAC TO INTRODUCE SUPER CRUISE ON ALL-NEW CT6

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.

CADILLAC SUPER CRUISE

THE VERGE

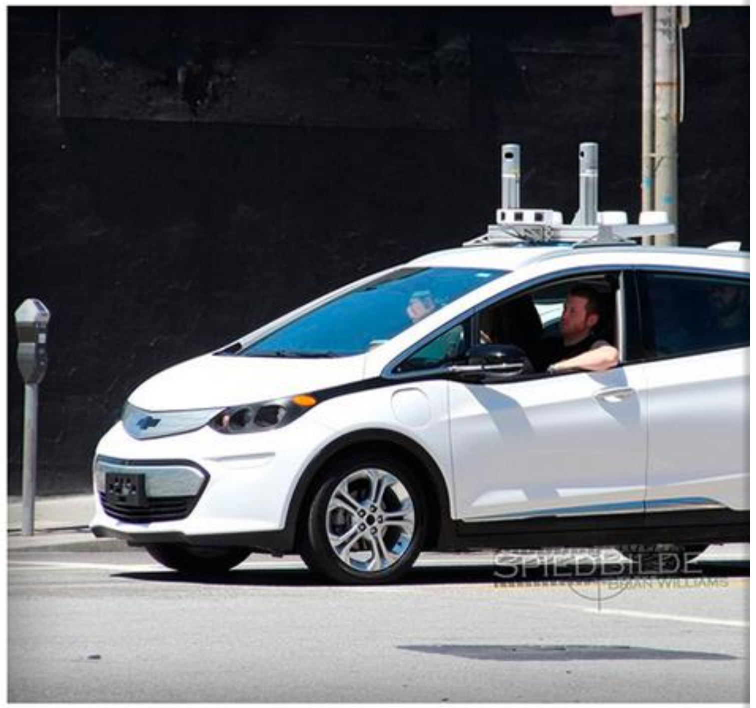
LONGFORM REVIEWS VIDEO TECH CIRCUIT BREAKER SCIENCE

TRANSPORTATION CARS GM

Self-driving Chevy Bo streets of San Francis

by Chris Ziegler · May 18, 2016, 12:24p

SHARE TWEET LINKEDIN PIN



SpiedBilde

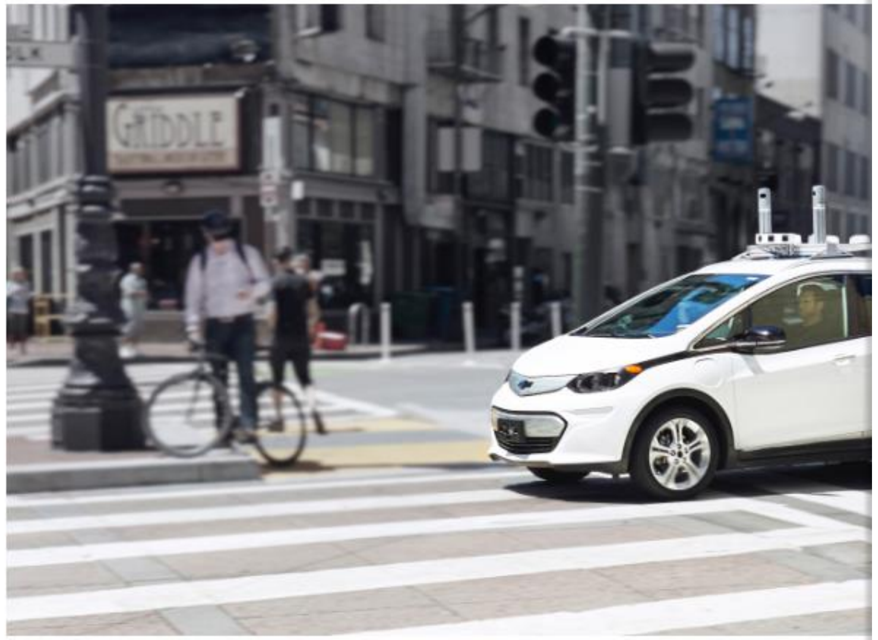
A spy photographer has come across a fleet of all-electric Chevy B today that appear to be equipped with arrays of self-driving sensor already testing the electric cars that could be ferrying Lyft passeng sometime in the next year.

FORTUNE

TECH CRUISE AUTOMATION

GM's Cruise Automation Is Testing Self-Driving Chevy Bolts in Arizona

by Kirsten Korosec @kirstenkorosec AUGUST 9, 2016, 2:01 AM EDT



And they're looking for test drivers.

A Chevy B driving te streets of

Helena Price

Cruise Automation, the startup acquired earlier this

Automotive News

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EDITOR'S PICKS >

SEARCH

GM's Cruise Automation tests autonomous Bolt EVs

May 20, 2016 @ 3:45 pm

Jack Walsworth

18 Shares

Photo credit: BRIAN WILLIAMS / SPIEDBILDE

PHOTO GALLERY: Autonomous Chevrolet Bolt spy photos

PHOTO GALLERY >>

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

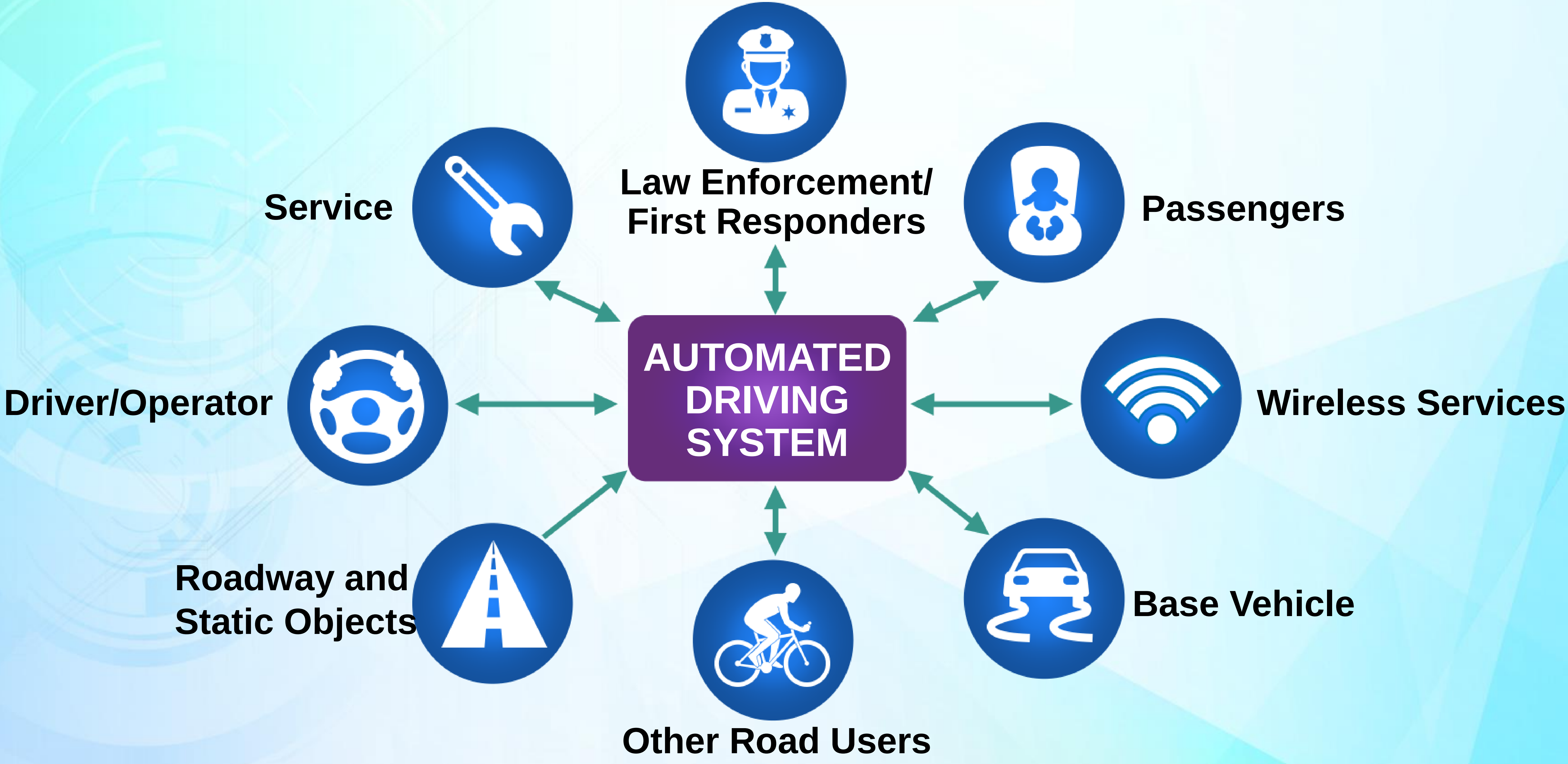
SOCIETY OF AUTOMOTIVE ENGINEERS – LEVELS OF AUTOMATED DRIVING

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	**No Automation**	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	**Driver Assistance**	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*	Human driver and system	Human driver	Human driver	Some driving modes
2	**Partial Automation**	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*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	**Conditional Automation**	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*	System	**System**	Human driver	Some driving modes
4	**High Automation**	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*	System	System	**System**	Some driving modes
5	**Full Automation**	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*	System	System	System	**All driving modes**

THE AUTOMATED DRIVING PUZZLE

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

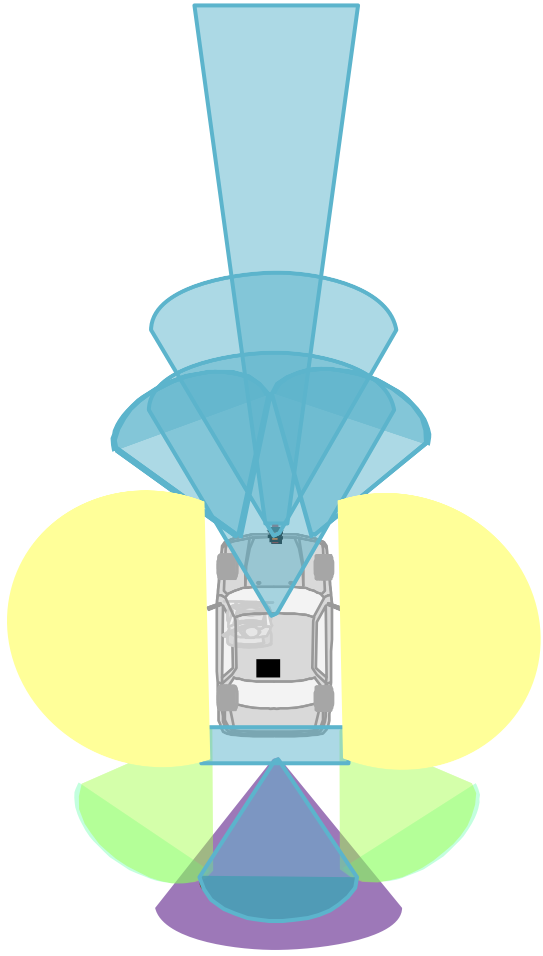
AUTOMATED DRIVING SYSTEM – CONTEXT DIAGRAM



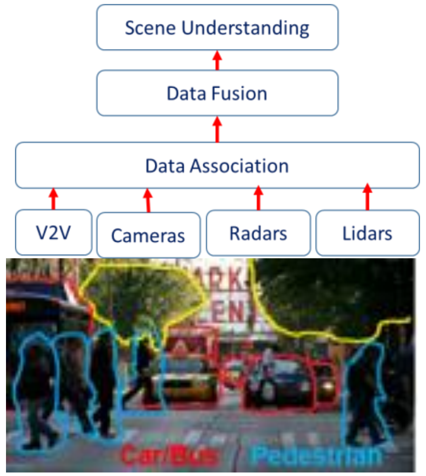
TYPICAL AUTONOMOUS VEHICLE SYSTEM

SENSING & PERCEPTION

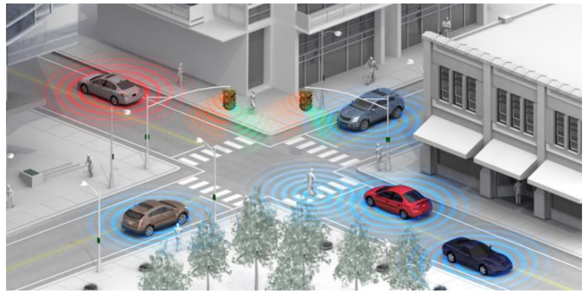
Sensors & Signal Sources



Environment Perception

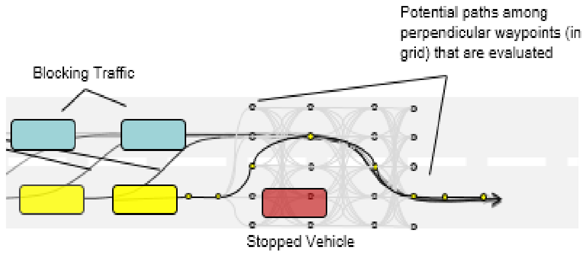


Mapping & Localization

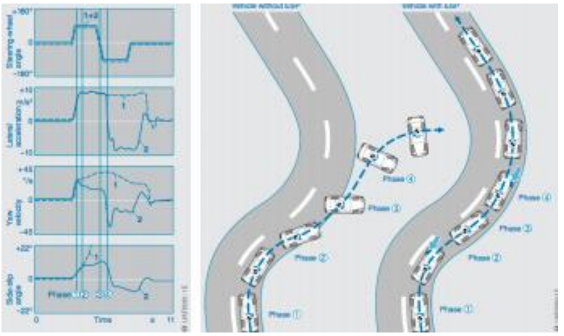


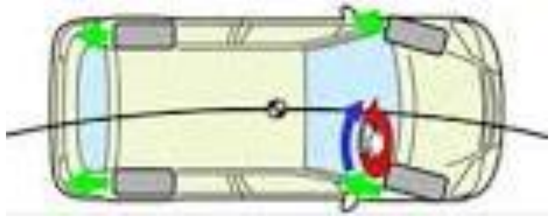
PLANNING & CONTROL

Planning & State Management



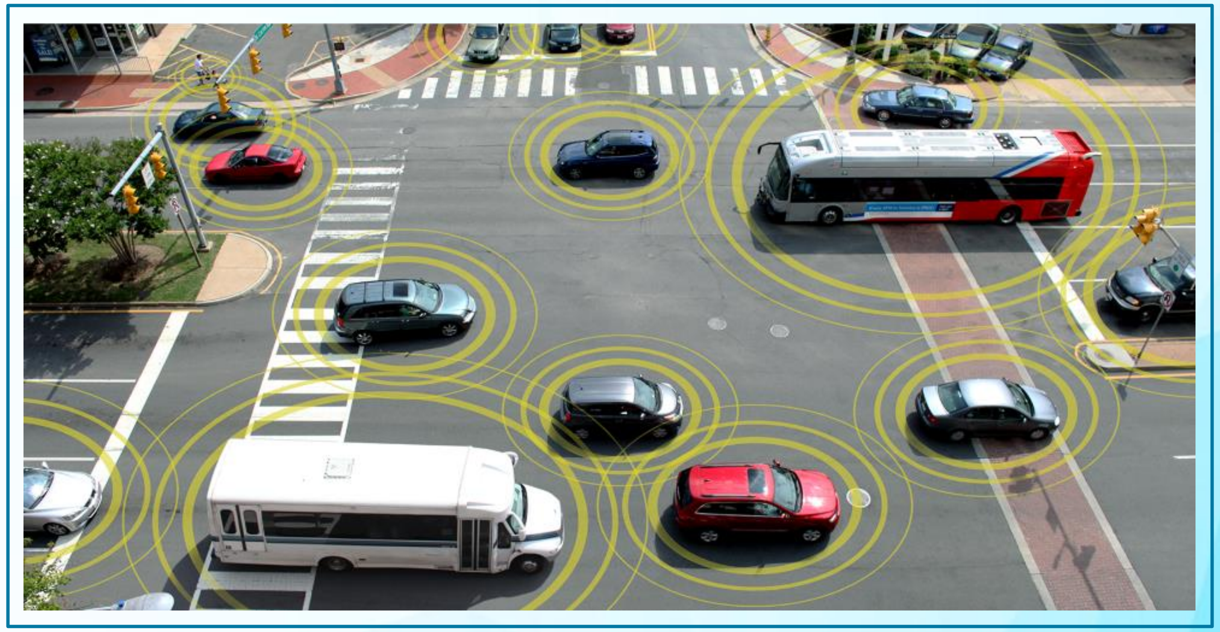
Vehicle Control

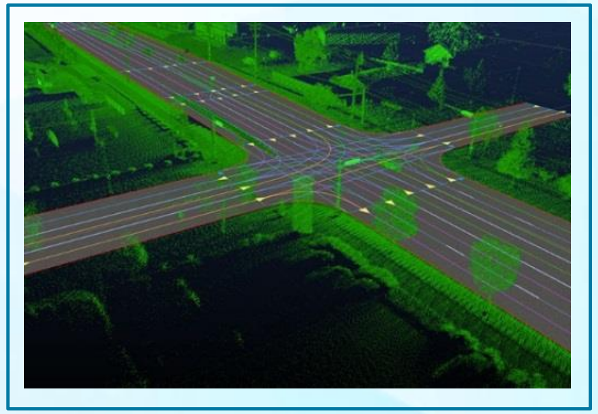




AUTOMATED DRIVING TECHNOLOGY ELEMENTS

HARDWARE	Sensors (Camera, Radar, Lidar)
	Processors (CPU, GPU, FPGA)
	Actuators (Brakes, Steering, Gear Select)
	Transceivers (Connectivity)
LOGIC, SOFTWARE AND DATA	Image Processing, Sensory Fusion, Perception, Planning, Behavior
	High-definition Maps Real Time Road Conditions
SYSTEMS INTEGRATION	Validation and Testing
MANUFACTURING	Assembly and Programming





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

DIMENSIONS OF STATE-OF-THE-ART: AUTOMATED DRIVING OPERATIONAL DOMAINS

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

DIMENSIONS OF STATE-OF-THE-ART: AUTOMATED DRIVING OPERATIONAL DOMAINS

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 14º
  - Medium Range – 70m x 90º
  - Short Range – 30 m x 150º
- 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

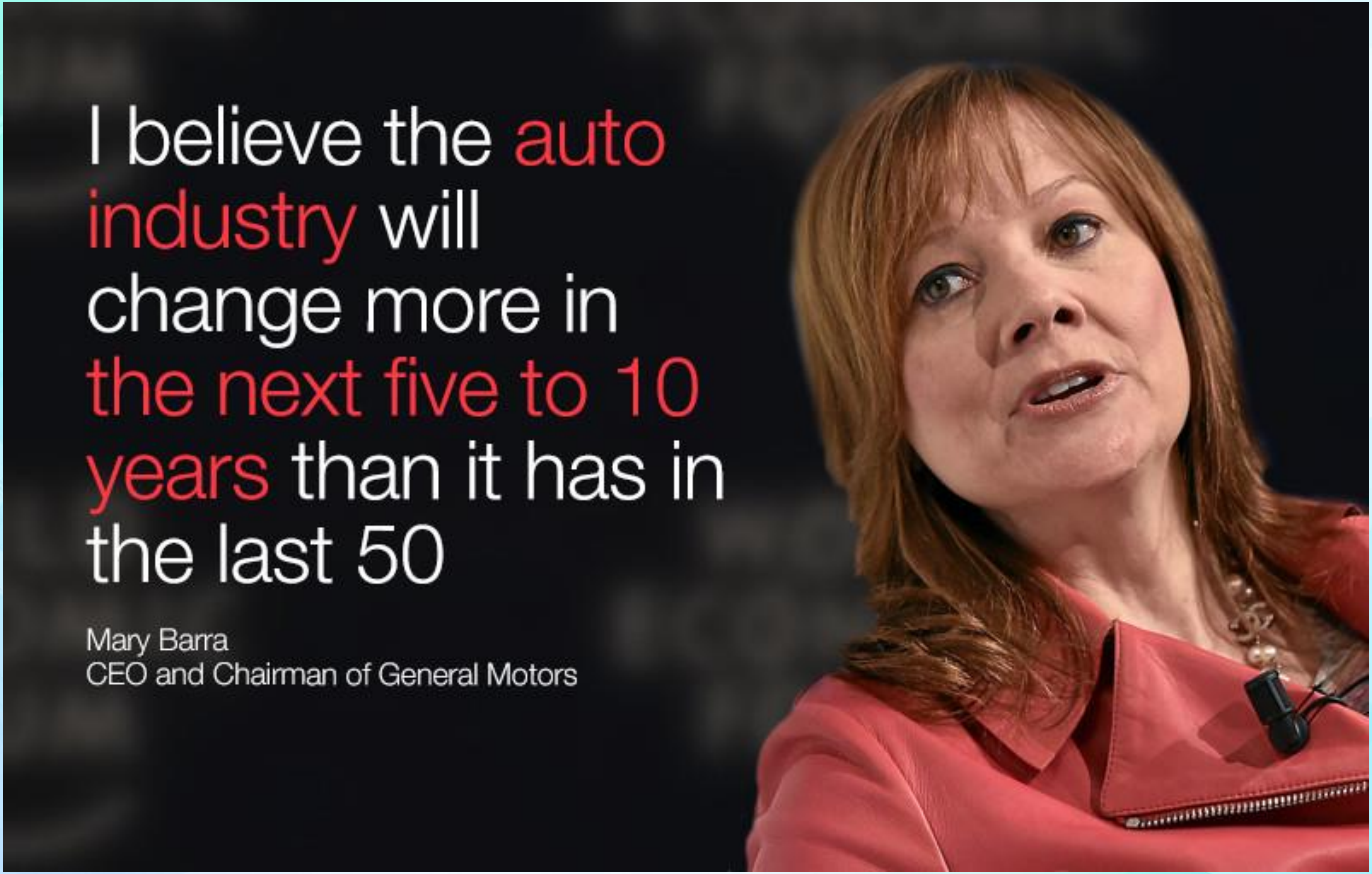
- Object Sensing
  - Smaller/easier to fit on the vehicle
  - Less expensive
  - Higher resolution (range, horizontal and vertical angle)
  - Larger field of view (longer, wider)
  - Higher update rates and lower latency
- Road Sensing
  - Sign/traffic signal information
  - Lane geometry
  - Surface 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!

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