Adoption of Connected Automated Vehicles for Traffic Safety

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# DENSO Background

## Automotive Areas

### Environment
- Hybrid and electric vehicle components,
- Products for fuel cell vehicles,
- Gasoline engine management system,
- Diesel engine management system,
- Starter, alternator, radiator, etc.

### Safety
- Sensing technologies for driving assist systems,
- Actuator & computer for antilock brake system (ABS) / electronic stability control (ESC),
- Adaptive front-lighting system (AFS),
- Airbag sensors & electronic control units,
- Periphery monitoring system, instrument cluster,
- Rain sensor for automatic windshield wiper, etc.

### Comfort & Convenience
- Car air-conditioning system,
- Air conditioner for buses, air purifier,
- Car navigation system,
- Electronic toll collection system (ETC),
- Remote security system,
- Remote touch controller, smart key,
- Advanced vehicle operation system (AVOS), etc.

## Key Figures

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Established</td>
<td>December 16, 1949</td>
</tr>
<tr>
<td>Capital</td>
<td>US$1.6 billion</td>
</tr>
<tr>
<td>Revenue as of March 31, 2016</td>
<td>US$40.2 billion</td>
</tr>
<tr>
<td>Operating Profit</td>
<td>US$ 2.8 billion</td>
</tr>
<tr>
<td>Employees</td>
<td>151,775</td>
</tr>
<tr>
<td>Consolidated Subsidiaries</td>
<td>188</td>
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</table>

## Affiliates under the Equity Method

(Japan 13, North America 4, Europe 4, Asia 13, Others 2)

*There is one non-consolidated subsidiary.

Notes:
- Exchange rate: 112.68 yen = US$1,
- The approximate rate prevailing on March 31, 2016.

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38,000 Active Patents Worldwide
Future Mobility Society

Ubiquitous Society

Anyone, Anytime, Anywhere: enjoy various services through network without any stress

Widespread Use of IT Services

Permanent Connection

Cloud

Smart Phone

POI

Map

Route

Smart Grid

Generation

Transmission

Management

O & M Center

Charging Spot

Expected Travel Distance

PLC or Radio

Monitoring smart meter

VC: Vehicle to Vehicle communication

V2I: Vehicle to Infrastructure comm

DSRC: Dedicated Short-Range Comm

Cellphone Network

V2I

Wi-Fi

V2V

Crash Avoidance

DSRC

Distance Control

Pedestrian Detection

Control Center

Park & Ride

Car Sharing

Transit Fee

Multi-modal Mobility

New mobility society in cooperation with social infrastructure
Holistic ADAS – Automation Concept

Driver sensor
Notify and operation device

Surrounding sensor
Driving environment recognition
Vehicle motion control

HMI

society・infrastructure
Information and communication
Communication device

vehicle

actuator Control unit

Based on the basic study of human, perform holistic research & development combined with human, vehicle, society・infrastructure

Basic research, investigation and analysis
study on human’s character and driving assistance traffic accident analysis
social acceptability regulatory・NCAP
Connected Automation Concept

Product Lineup – For Driving Safety
- Sonar
- Millimeter-wave Radar Sensor
- Front Camera
- SVSS
- CMS

Autonomous sensors
- 100m
- 1,000m
- 10,000m

V2X

HMI Products
- Cockpit System
- Instrument Cluster / HUD

Information & communication products
- ADAS Locator
- V2X ECU
- ETC
- TCU

AEB: Autonomous Emergency Braking
CMS: Camera Monitor System
DSM: Driver Status Monitor
DSRC: Dedicated Short Range Communications
HUD: Head-Up Display
SVSS: Surround Video Sensing System
TCU: Telematics Communication Unit
V2X: Vehicle to X
Global ADAS Regulatory Trend

- **Law (Mandatory)**
- **NCAP**
- **Top Safety Pick (IIHS)**

<table>
<thead>
<tr>
<th>Year</th>
<th>ADAS Feature</th>
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<tbody>
<tr>
<td>~2013</td>
<td>FCW, AEBS, CIB (Car)</td>
</tr>
<tr>
<td>2014</td>
<td>AEBS-PD, AEBS (Ped)</td>
</tr>
<tr>
<td>2015</td>
<td>AEBS (Car) / LDW, Rear camera</td>
</tr>
<tr>
<td>2016</td>
<td>AEBS (Ped), Kids &amp; Transportation</td>
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<tr>
<td>2017</td>
<td>AEBS for truck, LDW</td>
</tr>
<tr>
<td>2018+</td>
<td>LKA, AEBS-PD</td>
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</table>

AEBS: Advanced Emergency Brake System
CIB: Crash Imminent Braking
FCW: Forward Collision Warning
LKA: Lane Keep Assist
LDW: Lane Departure Warning
ISA: Intelligent Speed Adaptation

Cartalk.com
http://www.cvel.clemson.edu/
http://virtual.vtt.fi/
Sensors – How Many and What Kind?

Automatic Lane Change
- side/back LIDAR
- backward Radar

Automated Cruise on Highway
- Radar & LIDAR

Cross Traffic Avoidance at Parking Area
- cross traffic LIDAR
- Sonar

Automated Drive in Town Street
- Radar & LIDAR (ranging) Wide angle Radar (cross traffic)
- Camera (scene recognition)
- Sonar (supplementary)
Options to Choose

In Production
- vision sensor (camera)
- LIDAR
- mm wave RADAR
- sonar
- telematics control unit (cellular radio)
- V2x radio
- FCW, LKA software

Next Generation
- Next Gen front LIDAR
- pedestrian detection
- mini stereo camera
- Next gen LIDAR surround
- LIDAR + camera
- 3D flash LIDAR
- GPS Locator
Sensors are Imperfect

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<tr>
<th>On Board Sensor Capability</th>
<th>LIDAR</th>
<th>Camera</th>
<th>RADAR</th>
<th>V2X &amp; Cellular*</th>
<th>Map &amp; Location</th>
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<tr>
<td>Traffic objects</td>
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<td>Path / Road structure</td>
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<td>Dynamic Static</td>
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<td>Robustness</td>
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<td>Rain / Snow</td>
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</tbody>
</table>

*depends on coverage
Combination of HW/SW ≈ CPS

Sensor System

- **Sensor Components**
  - Global map
  - GPS locator
  - V2X radio
  - Cellular radio
  - LIDAR
  - Radar
  - Sonar
  - Camera

- **Signal Process & Detection**
- **Monitoring & Recognition**

- **Sensor Fusion Processing**
- **Surroundings Recognition (Local Map)**

Vehicle

- **Motion**
- **HMI**
  - Speed
  - Throttle
  - Yaw
  - Brake
  - Gyro
  - Steer

- **ADAS & AD Applications**
  - ADAS App. #1
  - ADAS App. #2
  - AD App. #1
  - AD App. #2

- **Open I/F**

Driver

- **Open I/F**
- **Driver Monitoring**
- **Intervention from Vehicle Safety**
  - Longitudinal acc. arbitration
  - Lateral acc./yaw rate arbitration
  - Distribution (accel. / decel.)
  - Distribution (steer / yaw)

ADAS & AD Applications

- **Arbitration & Distribution**
  - Longitudinal acc. arbitration
  - Lateral acc./yaw rate arbitration
  - Distribution (accel. / decel.)
  - Distribution (steer / yaw)

Actuation

- Power train
- Brake
- Steer
- Chassis
- HMI

Driver

- Open I/F
- Driver monitor
- Bio sensor
Let’s not forget connectivity
Connected Drive in Unfavorable Conditions
Connected Automation

V2V DSRC Communication

Leading Vehicle (Manual Drive)

Following Vehicle (Automated Drive)
Connected Automation
Cooperative Systems Have Taught Us

- Not one company can do it all
- No longer is a vehicle its own entity, separate from infrastructure and other road users
- We can’t necessarily predict how connected and automated drivers interact with “regular” vehicles of all types

Requires collaboration between industry, academia, and governments to be effective.
With connectivity comes...responsibility!

Infiltration **end point** is an ECU running a critical vehicle control function

1. remote
2. in-vehicle network
3. ECU direct

**But what should we do?**
- Better understand today’s threat, impact, resolution
- Forecast and adapt to future **UNKNOWN** threats
A continuum of ADAS is evolving from no assistance at all to the driver to full control by cyber systems.

A suite of devices with multi spectral sensing (e.g., RADAR, LIDAR, camera, ultrasonic) is likely to be necessary but not sufficient for all scenarios.

One approach is to evolve the idea of cooperative sensors (e.g. V2X, cellular WAN, GPS/GNSS) via connectivity to enhance robustness.

Stakeholders must collaborate and cooperate across industry, academia and government for safe and comfortable connected automation.

Understand the importance of security across the supply chain to help ensure trust in the CPS which assumes control of the vehicle.
ANy QUESTIONS?

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roger_berg@denso-diam.com
(760) 597 - 7404
# Automated Drive Definitions

<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>
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<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>
</tbody>
</table>

**Automated driving system (“system”) monitors the driving environment**

<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>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>
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<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>
## ADAS - Automation Roadmap

### 2015

**Driver assistance**
- **Driver Assistance** (SAE: LV2)
  - Full-speed-range ACC
- **Advanced driver assistant**
  - Single-lane driving
  - Multiple-lane change

### 2020

**Advanced driver assistance** (SAE: LV3)
- Split & Merge
- Emergency stop (Driver/system fail)
- Split & Merge

### 202X

**Fully automated driving** (SAE: LV4/5)

### Function & Object Recognition
- **Recognition Domain**
  - Cut in vehicle
  - Safe headway
  - Moving vehicle
  - Stopped vehicle

### Active safety

- **AEB Pedestrian**
  - ’16 NCAP
  - (night)
  - Pedestrian (day)
  - Pedestrian (night)
  - Cyclist

- **AEB Crossing**
  - ’18 NCAP
  - Cyclist

- **AEB Intersection Vehicle**
  - Crossing vehicle
  - Oncoming vehicle

- **Cooperative Safety Assistance** (e.g., V2X communication)
  - Merging vehicles
  - Road edge
  - Obscured vehicle

### Recognition Objects & Domain expansion, Look-ahead of local information

- **Camera**
- **Radar**(Front)
- **Radar**(Front side & Rear Side)
- Sensing technology
  - + Surround information linkage (V2X, ADAS map)
AD in Unfavorable Conditions