System Architecture for Advanced Safety Vehicle Technology

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Adoption Factors

1. **Regulations**
   - European Union Safety Program
   - eSafety Initiative

2. **New Car Assessment Programs**
   - US NCAP
   - Euro NCAP
   - J NCAP
   - K NCAP

3. **Consumer Preferences**
   - Increasing priority of safety features
   - Influence on purchase decision
   - Insurance cost reduction potential for vehicles with advanced safety features

4. **Technology Advancements**
   - Technology progress in hardware, software and enabling technologies
   - Improved cost effectiveness
Market Barriers

1. Cost
   - Required R&D investments make vehicle safety features expensive when launched
   - Advanced sensors & electronics still very expensive
   - Use of more expensive materials in vehicle body developments add to costs

2. Fear of Litigation
   - Increasingly sophisticated safety systems carry an inherent risk of system failure, which might result in death, injury or property damage
   - Litigation are a risk for OEMs and suppliers, especially in the US, reducing attractiveness of ASV

3. Consumer Awareness
   - Consumer awareness for safety systems is comparatively low in many developing markets
   - The more essential many safety systems are simply assumed → No differentiating potential for OEMs

4. Weight Penalty
   - Increasing number of vehicle dynamics, driver assistance and active and passive safety systems add weight to the vehicle
   - Increased weight makes it more difficult to achieve required CO2 emission standards

Key Barriers for Advanced Safety Vehicle Technology
Why the System Architecture?

- Powerful System Architecture

- Performance enhancement
- Standardization
- Competitiveness
- Flexibility
- Innovative architecture
Basic Concept

Control Strategy

<table>
<thead>
<tr>
<th>Performance</th>
<th>Integrated Control</th>
<th>Cooperative Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>no performance restrictions</td>
<td>by control structure</td>
<td>performance limited by arbitration interfaces</td>
</tr>
<tr>
<td>Complexity</td>
<td>low complexity by top down concept</td>
<td>high effort for arbitration &amp; state coordination algorithms</td>
</tr>
<tr>
<td>Scalability</td>
<td>scaling of controller leads to variants of central controller</td>
<td>designed for scalability due to independent function chains</td>
</tr>
<tr>
<td>Variants</td>
<td>subsystem variants influencing complete structure</td>
<td>subsystem variants influencing only one branch in the structure</td>
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</table>
### Basic Concept

#### S/W Distribution

<table>
<thead>
<tr>
<th></th>
<th>Centralized</th>
<th>Distributed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Complexity</strong></td>
<td><img src="+" alt="Green" /></td>
<td><img src="-" alt="Red" /></td>
</tr>
<tr>
<td></td>
<td>minimum communication effort between unit and subsystems</td>
<td>big communication effort due to ASV functions distribution</td>
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<tr>
<td><strong>Flexibility</strong></td>
<td><img src="+" alt="Green" /></td>
<td><img src="-" alt="Red" /></td>
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<td></td>
<td>subsystems can easily exchanged</td>
<td>change of subsystems have impact on ASV systems</td>
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<tr>
<td><strong>Resources</strong></td>
<td><img src="+" alt="Green" /></td>
<td><img src="-" alt="Red" /></td>
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<tr>
<td></td>
<td>IVSS functions do not require resources in other subsystems</td>
<td>sharing subsystems’ resources relevant to function content</td>
</tr>
<tr>
<td><strong>Scalability</strong></td>
<td><img src="+" alt="Green" /></td>
<td><img src="-" alt="Red" /></td>
</tr>
<tr>
<td></td>
<td>scalability &amp; variants concentrated on one spot</td>
<td>each subsystem concerned by scalability &amp; variants</td>
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<tr>
<td><strong>Availability</strong></td>
<td><img src="-" alt="Red" /></td>
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<td></td>
<td>central unit is essential for availability of all ASV functions</td>
<td>failure of one unit allows certain ASV functions to continue</td>
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</table>
Centralized Electronics | Smart Actuators | Intelligent Subsystems

Packaging | Packaging optimum | Minimum electronics effort in subsystems | Packaging not optimized

E/E Cost | Depending on variants & market volumes | Minimum electronics cost in subsystems | Reuse of mass production stand-alone subsystems

Safety & Availability | Central unit failure shuts down all functions | Central unit failure shuts down all functions | Basic functions available with failure of one subsystem

Technology Variants | Subsystem technology variants lead to H/W variants of central unit | Subsystem technology variants lead to S/W variants in central unit | Subsystem technology variants encapsulated in subsystems
Basic Concept

S/W Decomposition

Functions = Features

Functional Modules

$S =$ Sensor  $\text{Algo} =$ Algorithm for $\mu$C  $A =$Actuator  $D =$ Output Driving Stage  * according ISO WD 26262
Basic Concept

S/W Decomposition for ACC System

\[
\begin{align*}
\text{d} & \quad \text{v} & \quad \text{a} & \quad \text{F} & \quad \text{M}_B & \quad \text{M}_{PT} \\
\text{Distance} & \quad \text{Speed} & \quad \text{Acceleration} & \quad \text{Tire Force} & \quad \text{Brake Torque} & \quad \text{Drive Torque} \\
\text{Radar} & \quad \text{Signal} & \quad \text{Information} & \quad \text{Situation} & \quad \text{Interpretation} & \quad \text{& Target} & \quad \text{Selection} \\
& \quad \text{Distance} & \quad \text{Control} & \quad \text{Speed} & \quad \text{Control} & \quad \text{Accel.} & \quad \text{Control} & \quad \text{a-Arbiter} & \quad \text{ABS} & \quad \text{TCS} & \quad \text{TRQ} & \quad \text{ARB} & \quad \text{Combustion} & \quad \text{Engine} & \quad \text{Functions} \\
& & & & & & & & \quad \text{Brake} & \quad \text{Hydraulic} & \quad \text{Functions} & \quad \text{Combustion} & \quad \text{Engine} & \quad \text{Functions} \\
& & & & & & & & & & & & & \quad \text{generic functional modules – used by several functions}
\end{align*}
\]
System Architecture Procedure

System Architecture Elements

- Functional Architecture
  - What is the relationship and order between vehicle functions?

- Software Architecture
  - How shall vehicle functions be implemented in software?

- Hardware Distribution
  - Where shall vehicle functions be implemented in hardware?
  - relevant to E/E architecture area

- Networking Architecture
  - How shall hardware system elements communicate?
System Architecture Procedure

- **Work Package**

  - **Functional Architecture**
    - preparation of system requirements’ specifications
    - operation scenarios analysis
    - general features of functional modules

  - **Software Architecture**
    - definition of functional modules’ specifications
    - functional modules design including external modules’ interfaces
    - conversion functional modules into generic application S/W components

  - **Hardware Distribution**
    - restrictions criteria
    - mapping of functional modules on S/W platform including AUTOSAR
    - optimal H/W distribution analysis relevant to vehicle platforms

  - **Networking Architecture**
    - definition of general requirements (ex. communication speed, access priority) for functional modules
    - specific network design
Definition & Design of Functional Modules (ex. ACC Systems)

- **Radar Signal Information**: Radar signal information is used for distance control.
- **Situation Interpretation & Target Selection**: Situation interpretation and target selection for speed control.
- **Distance Control**: Controls distance based on radar signal.
- **Speed Control**: Controls speed based on target selection.
- **Accel. Control**: Controls acceleration based on speed control.
- **a-Arbiter**: arbitrates between acceleration control and tire force.
- **ABS**: Anti-lock braking system.
- **TCS**: Traction Control System.
- **M_B**: Brake torque control.
- **M_PT**: Drive torque control.
- **Combustion Engine Functions**: Combustion engine functions are controlled by drive torque.

**Generic functional modules – used by several functions**
Software Architecture

Conversion into generic application S/W components

Surround Sensors (Radar, Video, Ultrasonic etc.)

Longitudinal dynamics management

Lateral dynamics management

Generic Application S/W Compliant

Wheel Force Control

Coordinator

ABS TCS

Actuators

Arbitration

M_{PT}, i
P.T.

M_{B}, i
Brake

\delta, M
Steering
Conversion into generic application S/W components: ex. AUTOSAR

※ VSS = Vehicle Stabilizing System; DAS = Driver Assist System; AWD = All Wheel Drive
Hardware Distribution

Restrictions to be considered

\[ S = \text{Sensor} \quad \text{Algo} = \text{Algorithm for \( \mu C \)} \quad A = \text{Actuator} \quad D = \text{Output Driving Stage} \quad * \text{according ISO WD 26262} \]
Mapping of Functional Modules

Mapping Example 1

S1 → Algo → D1 → A1
S2 → D2 → A2

ECU1 → Bus → ECU2

Mapping Example 2

S1 → Algo → D1 → A1
S2 → D2 → A2

ECU1 → Bus → ECU2

S = Sensor   Algo = Algorithm for μC   A = Actuator   D = Output Driving Stage   * according ISO WD 26262
## AUTOSAR Enabling Technology

- **Generic Application Software Component-Configuration**

- **Specific Network-Design**

![Diagram showing AUTOSAR components and configurations](image-url)
Hardware Distribution

**Small-Medium Platforms (ex. ACC System)**

- **Radar**
  - Signal Information
- **Situation Interpretation & Target Selection**
- **Distance Control**
- **Speed Control**
- **Accel. Control**
- **a-Arbiter**
- **ABS + TCS**
- **M_B**
  - Brake Hydraulic Functions
- **M_PT**
  - Combustion Engine Functions

**Hardware Distribution**
- **LRR**
- **ESC**
- **EMS**

**CAN**
Active Safety Systems for ASV

Active Safety

Normal Driving (Information)
- FRMS
- SMS
- Night Vision

Warning
- PAS
- LDWS
- SOWS
- DSM
- Active N.V.

Assistance (Active Control)
- APAS
- LKAS
- LCDAS
- ACC
- AFLS

CW
- Warning
  - Audible Warning
  - Visual Warning
  - Haptic Warning
    - Seatbelt Warning

Seatbelt Pretension

Collision
- Automatic Emergency Braking

Collision Avoidance By Automatic Braking

Collision Avoidance By Driver’s Steering or Braking

Driver Assistance By Active Control of Actuators

Danger Object Warning By Surrounding Sensors

Blind Spot Monitoring By Vehicle Cameras


Development Roadmap for ASV

**Single Sensor & Single System**
- ACC (Stop & Go), CDM (Headrest)
- LCDAS, LDWS, LKAS, SOWS
- APAS, FRMS, PAS, SMS / AFLS, DSM, Night Vision

**Multi Sensors & Multi Systems**
- Virtual Bumper = 360° Surround Sensing System
- Vehicle-to-Vehicle Communication
- Intersection/Roadway Infrastructure
- Satellite-linked Communication

**2005**
- ACC (Stop & Go), CDM (Headrest)
- LCDAS, LDWS, LKAS, SOWS
- APAS, FRMS, PAS, SMS / AFLS, DSM, Night Vision

**2010**
- ACC (Stop & Go) & CDM (Headrest)
- LCDAS & LDWS & LKAS & SOWS
- APAS & FRMS & PAS

**2015**
- Multi Sensors & Multi Systems
  - ACC (Stop & Go) & CDM (Headrest)
  - LCDAS & LDWS & LKAS & SOWS
  - APAS & FRMS & PAS

Surround Sensors for ASV

<table>
<thead>
<tr>
<th>Sensor Features</th>
<th>Ultrasonic</th>
<th>Vision</th>
<th>Radar</th>
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<tr>
<td></td>
<td>24/77GHz</td>
<td></td>
<td>Laser</td>
</tr>
<tr>
<td>Bed Weather</td>
<td>×</td>
<td>×</td>
<td>○</td>
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<tr>
<td>Performance</td>
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<tr>
<td>Stationary</td>
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<tr>
<td>Target</td>
<td></td>
<td></td>
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<td>○</td>
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<tr>
<td>Multi Target</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Detection Range</td>
<td>×</td>
<td>△</td>
<td>△/○</td>
</tr>
<tr>
<td>Cost Benefit</td>
<td>○</td>
<td>△</td>
<td>△/×</td>
</tr>
</tbody>
</table>

Applicable Systems

- APAS
- PAS

Ultrasonic (Camera Processor)

- ACC/CW/CDM
- APAS
- DSM
- FRMS
- LDWS/LKAS
- Night Vision
- SMS
- SOWS/LCDAS

Vision (Camera Processor)

- ACC/CW/CDM
- APAS
- CW/CDM

Radar

- 24Ghz
- 77Ghz
- Laser

## Standardization Status for ASV

### ISO/TC 204 Organization
- **ISO/TC 204 Chairman**
- **Secretariat: TIA (USA)** (Telecommunications Industry Association)

### Liaison within ISO/IEC
- TC 8
- TC 22
- TC 104
- TC 154
- TC 211
- ISO/IEC/JTC 1
- ISO/IEC/JTC 1/SC 31
- TC 122-TC 104 JWG
- IEC/TC 9

### Liaison with organizations outside
- ITU-R SG5 (WP5x)
- ITU-R SG6 (WP6x)
- CEN/TC 278
- APEC
- IEEE
- OGC
- UN/CEFACT/TBG 3
- IrDA
- ETSI/ERM/TG 37
- WCO

### Working Groups

<table>
<thead>
<tr>
<th>Working Group</th>
<th>Description</th>
<th>Lead Country</th>
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</thead>
<tbody>
<tr>
<td>WG 1</td>
<td>Architecture</td>
<td>United Kingdom</td>
</tr>
<tr>
<td>WG 3</td>
<td>ITS Database Technology</td>
<td>Japan</td>
</tr>
<tr>
<td>WG 4</td>
<td>Automatic Vehicle Identification/Automatic Equipment Identification</td>
<td>Norway</td>
</tr>
<tr>
<td>WG 5</td>
<td>Electronic Fee Collection</td>
<td>Sweden</td>
</tr>
<tr>
<td>WG 6</td>
<td>General Fleet Management and Commercial Freight Operations</td>
<td>Canada</td>
</tr>
<tr>
<td>WG 7</td>
<td>Public Transport and Emergency</td>
<td>United States</td>
</tr>
<tr>
<td>WG 8</td>
<td>Integrated Transport Information, Management and Control</td>
<td>Australia</td>
</tr>
<tr>
<td>WG 9</td>
<td>Traveller Information Systems</td>
<td>Germany</td>
</tr>
<tr>
<td>WG 10</td>
<td>Route Guidance and Navigation Systems</td>
<td>Vacant</td>
</tr>
<tr>
<td>WG 11</td>
<td>Vehicle/Roadway Warning and Control Systems</td>
<td>Japan</td>
</tr>
<tr>
<td>WG 12</td>
<td>Dedicated Short-Range Communications</td>
<td>Germany</td>
</tr>
<tr>
<td>WG 13</td>
<td>Wide Area Communication</td>
<td>United States</td>
</tr>
<tr>
<td>WG 14</td>
<td>Nomadic Device</td>
<td>Undetermined</td>
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</tbody>
</table>

### Participating members (23 countries): Take part in conferences and play an active role in operations with a voting requirement.
## Standization Status for ASV

<table>
<thead>
<tr>
<th>Work Item</th>
<th>Status</th>
<th>Work Item</th>
<th>Status</th>
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<tbody>
<tr>
<td>ISO 15622 ACC</td>
<td>Published</td>
<td>DIS 22178 LSF</td>
<td>IS: Autumn, 2008</td>
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<tr>
<td>ISO 15623 FVCWS</td>
<td>Published</td>
<td>DIS 22179 FSRA</td>
<td>IS: Autumn, 2008</td>
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<tr>
<td>ISO 17366 MALSO</td>
<td>Published</td>
<td>PWI 26684 ISIVWS</td>
<td>NP: Autumn 2007</td>
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<td>ISO 17361 LDWS</td>
<td>Published</td>
<td>PWI 11067 CSWS</td>
<td>NP: Spring 2009</td>
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<tr>
<td>IS 17387 LCDAS</td>
<td>IS: April 22, 2008</td>
<td>PWI 11270 LKAS</td>
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<td>PWI 22839 FVCM</td>
<td>NP: Spring, 2008</td>
<td>PWI 15662 Revised ACC</td>
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<td>CD 22840 ERBA</td>
<td>DIS: Spring 2008</td>
<td>PWI Revised MALSO</td>
<td>CD: Spring 2008</td>
</tr>
</tbody>
</table>

**ACC:** Adaptive Cruise Control Systems  
**FVCWS:** Forward Vehicle Collision Warning System  
**MALSO:** Maneuvering Aid for Low Speed Operation  
**LDWS:** Lane Departure Warning Systems  
**LCDAS:** Lane Change Decision Aids Systems  
**FVCM:** Forward Vehicle Collision Mitigation Systems  
**ERBA:** Extended Range Backing Aid Systems  
**LSF:** Low Speed Following Systems  
**FSRA:** Full Speed Range ACC  
**ISIVWS:** Intersection Signal Information and Violation Warning Systems
System Architecture for ASV (ex. 13 systems)

- ASV with macro system architecture based on information, warning and active control features
- ASV with cooperative & integrated control logics and network interfaces among safety (chassis, active safety, passive safety), body, multimedia and powertrain domains

<table>
<thead>
<tr>
<th>Major items</th>
<th>(Macro) System architecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAS, LDWS, SOWS, DSM, (Active) Night Vision</td>
<td>Safety, Multi media, Body, Powertrain</td>
</tr>
<tr>
<td>FRMS, SMS, Night Vision</td>
<td>Warning, Active Control, Information</td>
</tr>
<tr>
<td>APAS, LKAS, LCDAS, ACC, CDM, AFLS</td>
<td>Safety, Multi media, Body, Powertrain</td>
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</tbody>
</table>
# System Architecture for ASV (ex. 13 systems)

<table>
<thead>
<tr>
<th>Functions</th>
<th>Informing</th>
<th>Warning</th>
<th>Active Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>FRMS</td>
<td>Front and rear blind spot monitoring</td>
<td>LDWS</td>
<td>lane departure warning</td>
</tr>
<tr>
<td>SMS</td>
<td>side blind spot monitoring</td>
<td>SOWS</td>
<td>driver’s less intensity warning</td>
</tr>
<tr>
<td>Night Vision</td>
<td>night drive monitoring</td>
<td>DSM</td>
<td>lane departure warning</td>
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## Systems

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<tbody>
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## Sensors

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## ECU

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<tr>
<th>Separated ECU</th>
<th>Integrated ECU</th>
<th>Chassis ECU</th>
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## Actuators

<table>
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System Architecture for ASV (ex. 13 systems)