The future of driver assistance and semi-automated driving systems has never looked brighter. Pressure to improve road safety is coming from all sides – the US government, in the form of the National Highway Traffic Safety Administration (NHTSA); the European Commission; the World Health Organization; and numerous consumer bodies, most notably New Car Assessment Programs (NCAPs).

Regulation and new NCAP ratings are tangible market drivers while vehicle manufacturers – and even non-automotive companies like Google – are ensuring there is plenty of media hype on the topic. (See Issue 36 for more on the market drivers for safety).

According to a 2012 J D Power survey of 17,400 vehicle owners, 37 percent of all responders initially said they would be interested in purchasing a fully automated car. However, that figure dropped to 20 percent once they learned the technology would cost an additional $3,000. Even at that price point 25 percent of male vehicle buyers were willing to pay for a fully automated vehicle along with 14 percent of women.

Now, the main questions being asked are: what are the technologies behind the ‘semi-automated’ buzzword; and what will the roadmap look like that takes us, eventually, to a vehicle that will drive us to work while we deal with the overnight emails?

Today’s Driver Assist Systems (DAS) are mostly independent functions using input from sensors to support the driver or respond to an emergency situation. There is a difference between emergency or safety functions such as automatic emergency braking (AEB), and comfort functions like lane centering assist (LCA) or lane keeping assist (LKA). And there is another distinction between systems that respond for a limited time period of time, such as LKA which ‘nudges’ a vehicle back when an unintended lane departure is detected, and those that provide...
continuous support, like LCA helps ensure vehicles remain in the center of the lane.

Semi-automated driving describes situations when support is applied for an extended time period. For example, adaptive cruise control (ACC) and LCA could work at the same time to control longitudinal and lateral driving in a highway driving situation to enable a Highway Driving Assist (HDA) function (see panel). What makes semi-automated driving functions attractive is that they support the daily driving experience. In other words, the consumer has made an investment that is not there simply as an emergency back-up but provides tangible value every day.

The semi-automated functions in production today will become mainstream in the next five to ten years with technology advances accommodating greater levels of intervention and driver support at higher speeds. Fully automated driving will require a complete vehicle-to-vehicle and vehicle-to-infrastructure network. These technologies continue to evolve and global experts agree that the time is right to begin introducing them to world roadways. This is planned to begin in the next three years, and should accelerate as applications mature and driver acceptance is achieved.

The principal components of semi-automated driving technologies – sensors, controllers and actuators – could be described as the eyes, brain and muscle of systems.

TRW’s focus today
Alongside global vehicle manufacturers, TRW is currently using these components to develop semi-automated driving technologies that will be in production in the next three to five years. These will cover the three phases of driving supported by active systems – ‘normal driving’ involving comfort features such as ACC Stop & Go, traffic jam assist (TJA) and HDA (see panel on page 5); the ‘emergency’ phase that uses the same sensor configuration at a higher level of intervention to provide AEB and emergency steering assist (ESA); and the ‘pre-crash’ scenario that covers the timeframe where an accident is unavoidable and occupant safety systems (OSS), like active buckle lifter (ABL) and active control retractor (ACR), are prepared for the oncoming crash.

The industry is moving in the direction whereby data fusion between a forward-looking camera and radar will be virtually a standard requirement in support of advanced longitudinal control functions. Today, the industry norm is for this processing to take place in the radar unit because all the decision-making and arbitration in forward-looking longitudinal control functions are classically in that sensor. The camera can have its own connection to the steering, through a

Key semi-automated driving developments
Two developments, requiring high levels of data fusion, look set to make important contributions to coming generations of vehicles fitted with semi-automated driving systems.

Traffic Jam Assist (TJA)
In the near future, the combination of longitudinal vehicle control (such as ACC Stop & Go) and lateral vehicle control (such as lane centering assist) will help drivers in heavy traffic situations at low speeds down to a complete vehicle standstill – Traffic Jam Assist. This function will enable a car to follow the vehicle in front while keeping in its lane, up to a specific vehicle speed. The driver may overrule the function at any time.

This will be a first step towards semi-automated driving, although still limited to specific low-speed scenarios. The benefits are a high comfort level in monotonous situations and the potential to reduce accidents caused by inattentive drivers. The Human Machine Interface (HMI) will be designed to keep the driver in the loop as the ‘master controller.’ TRW’s TJA uses the same sensor configuration (the video camera and a radar with sensor data fusion) as automatic emergency braking (AEB) and emergency steering assist (ESA).

Highway Driving Assist (HDA)
Highway Driving Assist will involve the integration of radar, cameras, and GPS map data. The forward looking radar is shared with the ACC Stop & Go feature that keeps a vehicle at a set speed while slowing if the car ahead slows, or if another car cuts across the lanes in front of it. Braking can be strong but, typically, not emergency braking. The forward-looking camera that makes up today’s lane centering assist (LCA) keeps the car within a few centimeters of the center of the lane. The driver can easily override steering inputs at any time. Additional side-looking radars complete the 360-surround-view and enable HDA to monitor traffic in neighboring lanes as a prerequisite for a Lane Change Control (LCC). This allows the vehicle to change lanes in a semi-automated mode if requested by the driver. Integration of these features – ACC Stop & Go, Lane Centering and Lane Change Control – will enable highly automated driving in specific scenarios.
separate CAN connection, providing lateral control functions that are purely camera based.)

However, semi-automated driving requires the integration of additional sensors – perhaps navigation data and outputs from ultrasonic sensors – in which data fusion becomes much more complex. At this level, TRW engineers recommend a change in architecture to a Safety Domain ECU (SDE). SDE is a separate ECU that can allow the extension of DAS and semi-automated driving functionality and handle the increased bandwidth of data. For example, if it is required to fuse some ultrasonic outputs on top of a forward-looking radar and a camera in an ACC Stop & Go system, or if a car manufacturer wants to move towards 360 degree sensing, a centralized data fusion unit is the most effective option.

The challenge for highly automated driving – besides the legal aspects – is to bring the driver, who may be driving hands off and possibly be distracted by non-driving-related tasks (such as reading or typing) back into the loop within a specific timeframe, if necessary.

**Redundancy issues**

During this delay, which might be in the range of 5 to 10 seconds, all systems need to remain working in a way that safety is assured for all road users. So, on top of enabling system features, highly automated driving raises considerations of

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### Safety systems and the three driving phases

<table>
<thead>
<tr>
<th>Normal Driving Phase (DAS like TJA, ACC, HDA)</th>
<th>Emergency Phase (AEB, Emergency Steering Assist)</th>
<th>Pre-Crash Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Driver assist features like</td>
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<td>• Crash unavoidable</td>
</tr>
<tr>
<td>– ACC Stop&amp;Go</td>
<td>• Brake Prefill for immediate braking support</td>
<td>• Preparation of OSS systems, eg</td>
</tr>
<tr>
<td>– Traffic Jam Assist</td>
<td>• Maximum brake support when reaching the last</td>
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</tr>
<tr>
<td>– Highway Driving Assist</td>
<td>point to brake (full deceleration applied)</td>
<td>Lifter</td>
</tr>
<tr>
<td></td>
<td>• Last point to steer: Emergency Steering Assist (ESA) supports the driver in an emergency situation where the driver initiates an evasive steering maneuver</td>
<td>– Active Control</td>
</tr>
<tr>
<td></td>
<td>• Additional steering torque is applied to assist the driver during evasive maneuvers and assist the driver in stabilizing the vehicle</td>
<td>Retractor</td>
</tr>
</tbody>
</table>

The 'emergency' driving phase uses safety features working with the same sensor configuration as the comfort features in the 'normal' driving phase. The 'pre-crash' phase is the timeframe in which an accident is unavoidable and occupant safety systems (OSS) are prepared for a crash.

The diagram illustrates the phases of driving with key features highlighted, including Forward collision warning (FCW), Brake prefill, Haptic warning, CMB, AEB, Last point to brake (LPB), Last point to steer (LPS), and the transition phases from normal driving to emergency and pre-crash scenarios.

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**Normal Driving Phase**

- Driver assist features like ACC Stop&Go, Traffic Jam Assist, Highway Driving Assist

**Emergency Phase**

- Collision Warning (optical, haptic, acoustic)
- Brake Prefill for immediate braking support
- Maximum brake support when reaching the last point to brake (full deceleration applied)
- Last point to steer: Emergency Steering Assist (ESA) supports the driver in an emergency situation where the driver initiates an evasive steering maneuver
- Additional steering torque is applied to assist the driver during evasive maneuvers and assist the driver in stabilizing the vehicle

**Pre-Crash Phase**

- Crash unavoidable
- Preparation of OSS systems, eg
  - Active Buckle Lifter
  - Active Control Retractor

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The diagram uses icons and symbols to visually represent the different driving scenarios and safety features, aiding in understanding the progression and role of each phase in the context of automated driving systems.
system redundancies, fall-back strategies, safe stop scenarios and last, but not least, the legal responsibilities of drivers and car manufacturers.

The process for testing future DAS and semi-automated functions at TRW begins with software simulations. These are then integrated into a complete build using existing hardware. In this hardware-in-the-loop set-up, the system is injected with data – either artificially generated or recorded from a real-life scenario – to enable it to replicate a vehicle’s behavior. This is then taken forward onto a vehicle.

Real world testing takes place on the road. For example, TRW uses ten ‘reference roads’ near its R&D center in Koblenz, Germany. These roads all have different characteristics in terms of traffic density, bends, curvature, number of lanes, rural and urban environments and so on. TRW has defined tests which are repeated two or three times during a program to arrive at a statistical statement on the development’s progress. By repeating the tests, engineers are able to calculate the number of false alarms, as well as how many critical observations have been reported correctly.

The final, vital, element is to test the systems in a broad mix of countries and at extremes of temperature. This is to cover, for example: left-hand and right-hand driving conditions; the winding roads of the Italian Alps; the arid environment of a desert; and the cool of an arctic region. Cameras, in particular, need to be tested in a wide range of light and weather conditions.

**The future is now**

TRW is working with a number of vehicle manufacturers in several regions globally to determine the most effective way of introducing semi-automated driving functions. However, it is certain that they will come and will be on mainstream vehicles. The challenge is to manage consumers’ expectations and introduce technologies in a consistent way to encourage their wide acceptance. The most significant benefit of moving from emergency assistance to semi-automated driving is that customers will experience the benefits every time they get into their cars.