



**Siemens Restraint Systems**



**Crash Sensors - Overview & Trends**

4. LS-DYNA Forum 2005  
20. - 21. Oktober 2005, Bamberg

Gerd Scholpp



**Crash Sensors - Overview and Trends Overview**



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- t Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- ADAS

- n **Accident Statistics**
- n **Crash Sensing – Frontal Impact**
- n **Occupant Detection**
- n **Crash Sensing - Lateral Impact**
- n **Rollover Sensing**
- n **Pedestrian Detection**
- n **Accident Avoidance - ADAS**



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- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- ADAS

## Crash Sensors - Overview and Trends Overview

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- Overview
- Accident Statistics
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## Crash Sensors - Overview and Trends Overview - Integrated Passive and Active Safety Systems

	Active Safety			Passive Safety	
	Reduction of accident probability		Get ready for the accident	Mitigation of accident impact for passengers	
Scope					
System	<b>ADAS</b> Blind Spot Detection Lane Departure Warning Night View Adaptive Cruise Control Driver Monitoring	Vehicle Dynamics ABS Anti Slip Control (e.g. ESP)	Pre-Crash system Reversible Pretensioner (e.g. EMA) Seat positions occupant Window closed	Restraint System Belt System Pretensioner Load Limiter Front Airbags Side Airbags Active Head Rest Occupant Sensing	Post-Crash system GSM Telematics Rescue
Situation	Normal Driving	Critical Condition	Pre-Crash	In-Crash	Post-Crash
	Accident avoidance			Accident happens	

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Crash Sensors - Overview and Trends  
Accident Statistics

- Overview
- † Accident Statistics**
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- ADAS

## Accident Statistics




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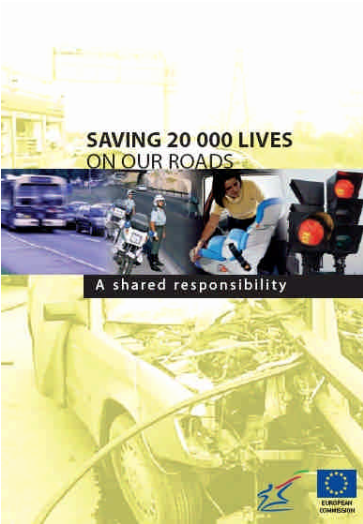
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Crash Sensors - Overview and Trends  
Accident Statistics – European Union

- Overview
- † Accident Statistics**
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- ADAS



**SAVING 20 000 LIVES  
ON OUR ROADS**

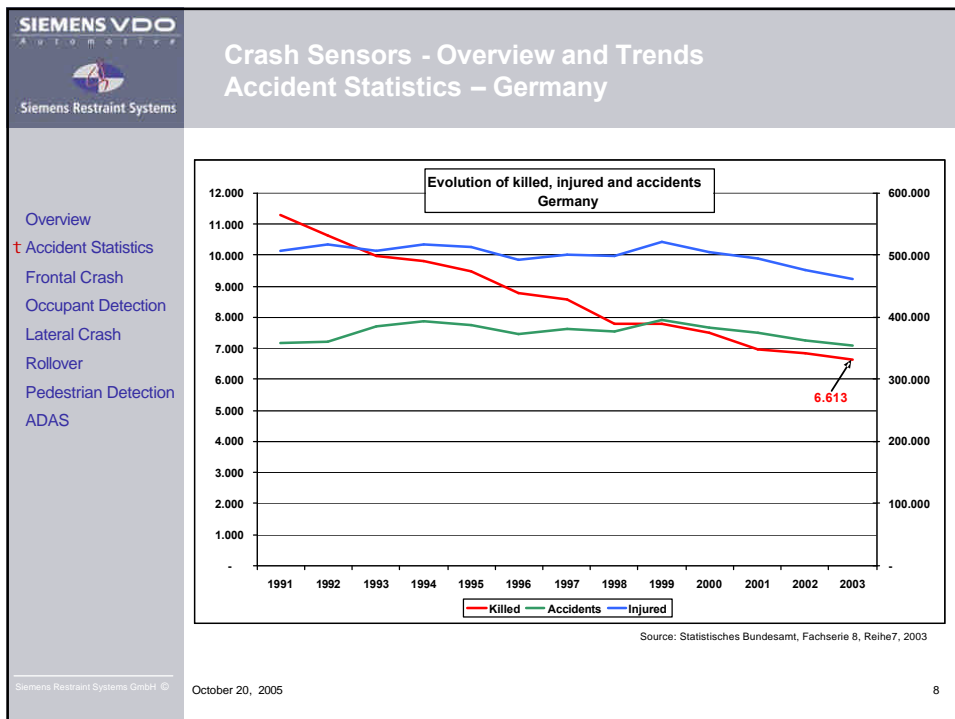
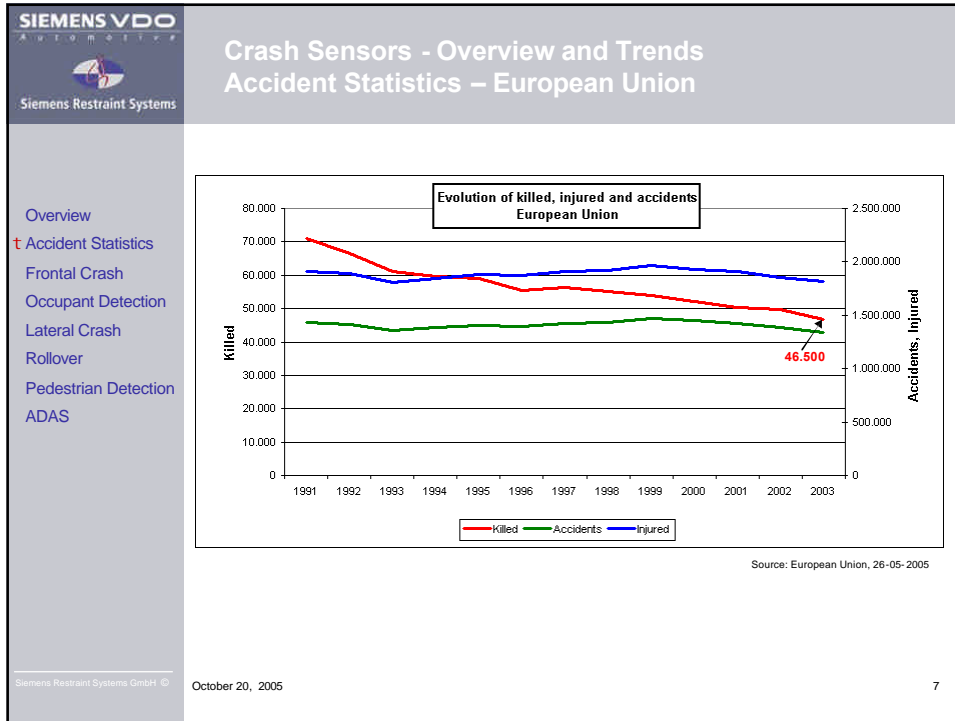
**EUROPEAN ROAD SAFETY ACTION PROGRAMME**  
Halving the number of road accident victims  
in the European Union by 2010:  
A shared responsibility

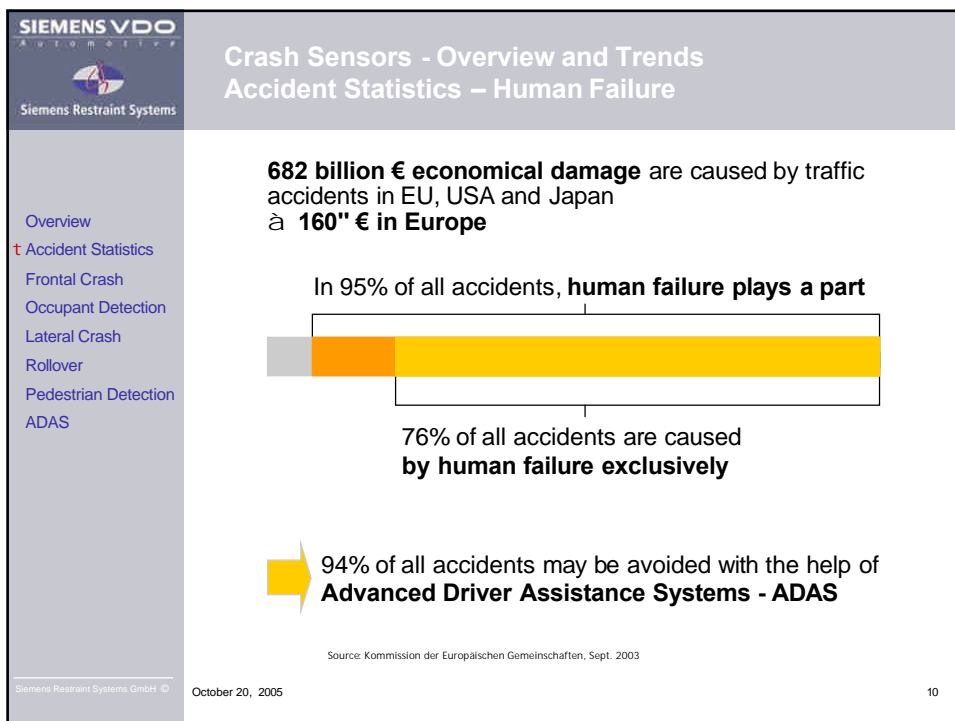
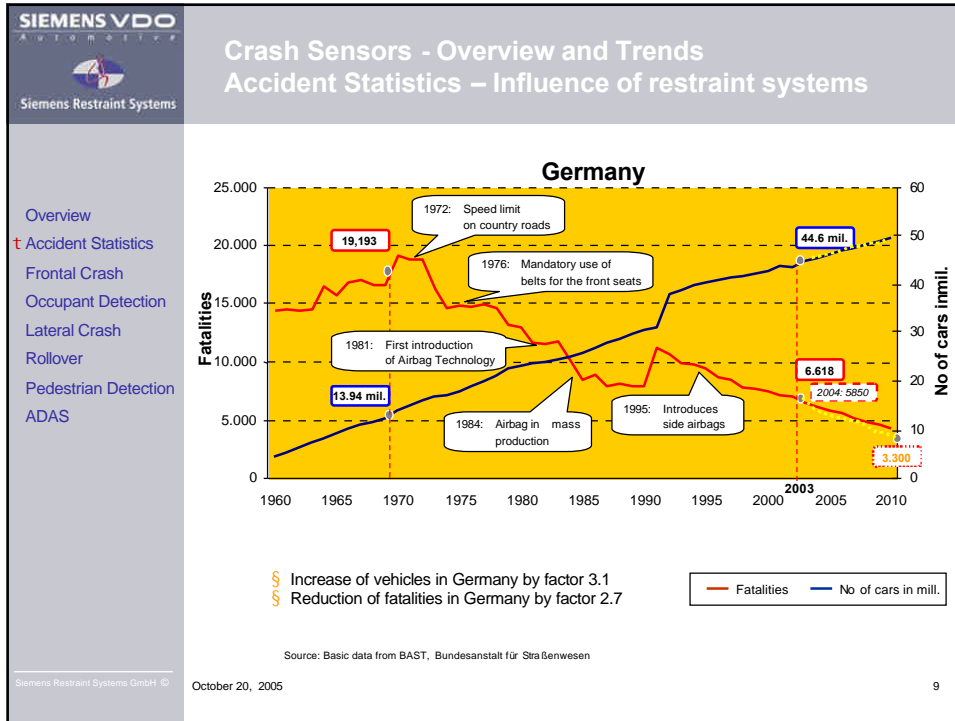
COMMUNICATION FROM THE COMMISSION  
COM (2003) 311 final

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Crash Sensors - Overview and Trends  
Crash Sensing – Frontal Impact

- Overview
- Accident Statistics
- † Frontal Crash**
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- Lateral Crash
- Rollover
- Pedestrian Detection
- ADAS


## Crash Sensing – Frontal Impact

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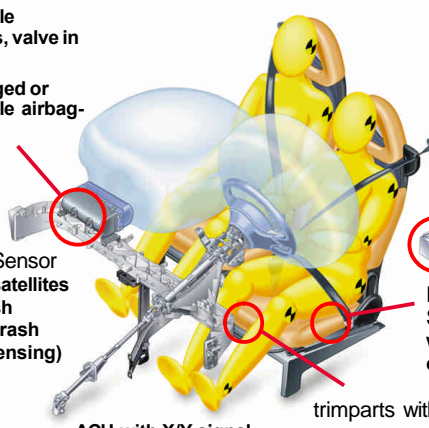
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Crash Sensors - Overview and Trends  
Frontal Crash - Frontal Impact Features

- Overview
- Accident Statistics
- † Frontal Crash**
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- ADAS



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**Passenger-Airbag**  
controlable  
ventholes, valve in  
module  
multi-staged or  
controlable airbag-  
inflater

**Seat Belt System**  
Pretensioner  
variable belt  
pretensioner force  
Force Limiter  
multi-staged or  
controlable belt-  
force-limiter  
Buckle Switch

**Satellite-Sensor**  
frontal g-satellites  
(early crash  
sensing, crash  
severity sensing)

**Passenger Seat OC**  
System  
weight / occupant /  
child-seat detection

**CISS**  
crash  
discrimination


**ACU with X/Y signal**

trimparts with knee protection  
variable active kneebolster force  
active knee airbag

A - I - 112

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## Crash Sensors - Overview and Trends

### Frontal Crash - Early Crash Sensor

- Overview
- Accident Statistics
- † Frontal Crash**
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- ADAS

**Features of the acceleration satellite G-Sat**

- Micro-mechanical acceleration sensor
- Acceleration range: + 40g; ± 100g; ± 250g
- Sensitive axes: x, y or z
- Connector integrated housing
- Dimensions: 57 x 24 x 25,5 mm
- Excellent production quality (close to 0 ppm)
- Smart front airbag deployment (dual stage)
- Huge field experience worldwide (More then 50 Mio. pieces since 1996)



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## Crash Sensors - Overview and Trends

### Frontal Crash - Definition of the G-Sat location by Sim

- Overview
- Accident Statistics
- † Frontal Crash**
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- ADAS



0 ms



16 ms




26 ms







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- Overview
- Accident Statistics
- † Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- ADAS

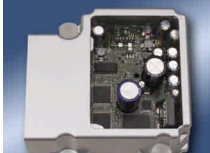
## Crash Sensors - Overview and Trends

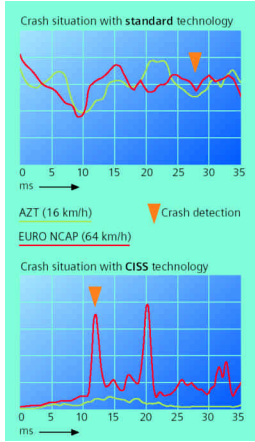
### Frontal Crash - Crash Impact Sound Sensing (CISS)

**Features**

- q Extention of classic crash sensing technology by additional physical effect "Makes the sensor hear and feel "
- q Utilizing speed of structural sound waves to analyze crash after a few milliseconds
- q Increased flexibility for sensor packaging
- q More robust and faster crash discrimination
- q Faster activation of belt pretensioners
- q Optimized airbag deployments
- q Cost savings using less sensors
- q Integrable into ACU








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## Crash Sensors - Overview and Trends

### Occupant Detection

# Occupant Detection


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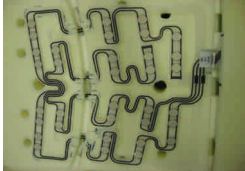
## Crash Sensors - Overview and Trends

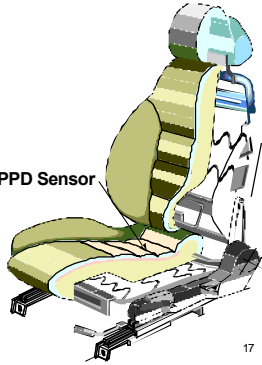
### Passenger Presence Detection & Seat Belt Reminder

- Overview
- Accident Statistics
- Frontal Crash
- † Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- ADAS

**Features**

- q Passenger Presence Detection (PPD) and Seat Belt Reminder (SBR) have separate thresholds
- q Classification of:
  - Empty Seats
  - Human Beings
- q Adaptation of restraint system
- q Integration of PPD ECU in Airbag ECU possible
- q High system robustness
- q No calibration at seat manufacturer
- q Independent to crash events
- q Independent to external seat loads
- q No influence to H-point






PPD Sensor

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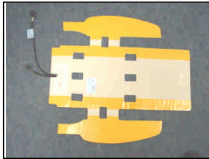
## Crash Sensors - Overview and Trends

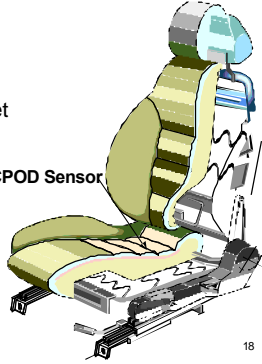
### Child Seat Presence and Occupant Detection System

- Overview
- Accident Statistics
- Frontal Crash
- † Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- ADAS

**Features**

- q Child Seat presence and Occupant Detection System (CPOD) is a system with redundancy for detecting child seats
- q No gray zones for applications for child seats / humans
- q Adaptation of restraint system
- q Integration in seat heater layer possible
- q ECU located below seat
- q Combinations with SBR possible
- q Proven technology for European market since '98
- q Reduction of misuse vs. key switch
- q No calibration at seat manufacturer
- q Benefit in child restraint sector EURO NCAP expected





CPOD Sensor

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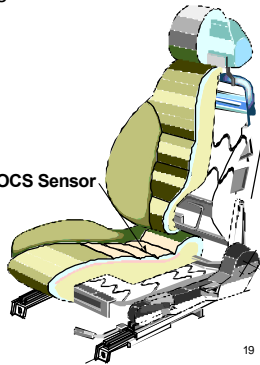
- Overview
- Accident Statistics
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### Crash Sensors - Overview and Trends Occupant Classification System (OCS)

**Features**

- q Up to 96 single sensor cells on the mat
- q Transformation in 3D force patterns
- q Classification of patterns in:
  - Non-Human objects
  - Specified child seats
  - Different classes of Human Beings
- q Adaptation of restraint system
- q High system robustness
- q No calibration at seat manufacturer
- q Independent to crash events
- q Independent to external seat loads
- q No influence to H-point

OCS Sensor

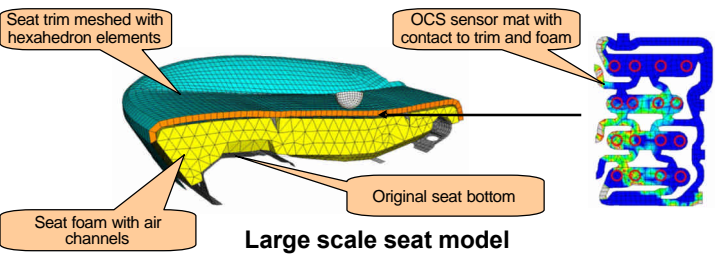
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- Overview
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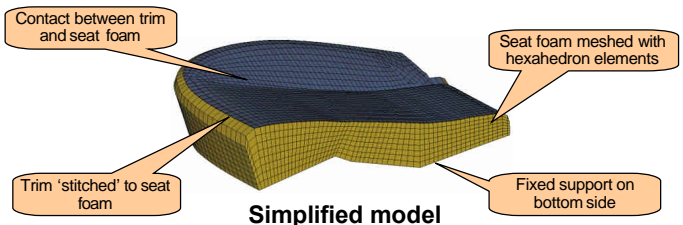
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### Crash Sensors - Overview and Trends Simulation of OCS Sensor Mat - Seat Models



**Large scale seat model**

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**Simplified model**

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### Crash Sensors - Overview and Trends

#### Simulation of OCS Sensor Mat - Dummy Models

- Overview
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**50 %tile man**

**6 year old child**

**5 %tile woman**

**Century smart fit**

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### Crash Sensors - Overview and Trends

#### Simulation of OCS Sensor Mat - Pressure Profiles

- Overview
- Accident Statistics
- Frontal Crash
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- ADAS

**50 %tile man**


**5 %tile woman**

**6 year old child**

**Dummies**

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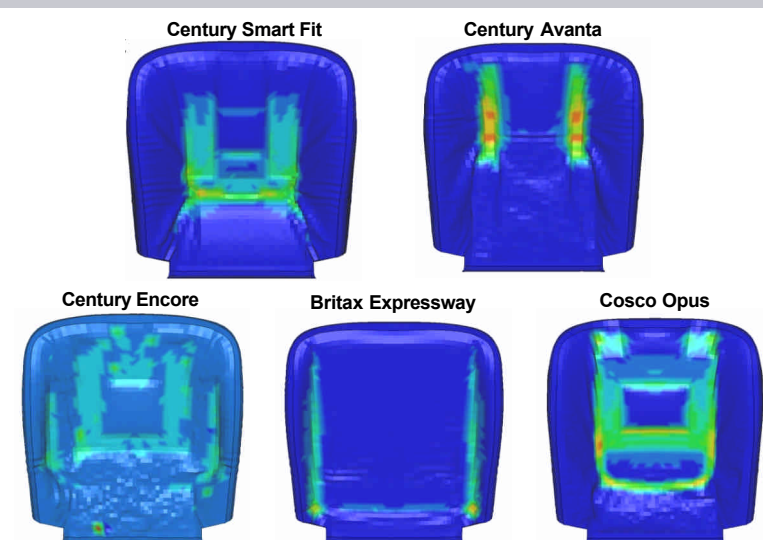


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### Crash Sensors - Overview and Trends

#### Simulation of OCS Sensor Mat - Pressure Profiles


- Overview
- Accident Statistics
- Frontal Crash
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- ADAS



**Child seats**

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### Crash Sensors - Overview and Trends

#### Advanced Weight Sensing (AWS II)

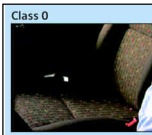
- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- ADAS

**Features**

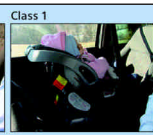
- q Seat frame integrated system
- q 4 sensors in load path of seat
- q Contactless inductive sensing
- q H-Point neutral seat frame integration
- q Standardization across car lines and seat designs
- q Adaptation of airbag firing and intensity according to the occupant's weight
  - Class 0: Seat not occupied
  - Class 1: Child (1/3/6yr)
  - Class 2: 5% Female
  - Class 3: 50% Male
  - Class 4: 95% Male


Class 0




Class 1



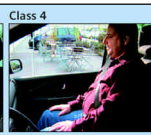
Class 2



Class 3




Class 4



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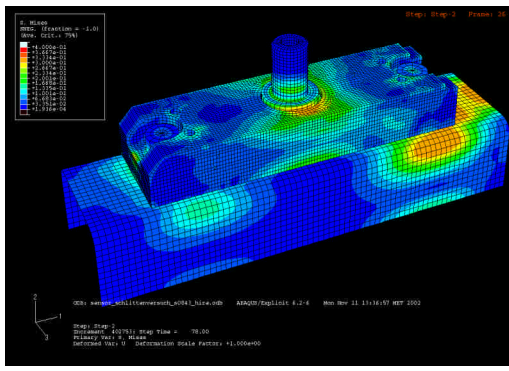
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### Crash Sensors - Overview and Trends Simulation of AWS I - Structure Analysis

- Overview
- Accident Statistics
- Frontal Crash
- † Occupant Detection
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- Pedestrian Detection
- ADAS



**Calculation of the component stability for maximum crash load**


**AWS Sensor mounted on Seat rail**

**AWS = Advanced Weight Sensing**

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### Crash Sensors - Overview and Trends Crash Sensing Lateral Impact

- Overview
- Accident Statistics
- Frontal Crash
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- † Lateral Crash
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- ADAS

## Crash Sensing – Lateral Impact

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## Crash Sensors - Overview and Trends

### Lateral Crash - Side Impact Sensor G-Sat


- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash**
- Rollover
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- ADAS

**Features of the acceleration satellite G-Sat**

- q Micro-mechanical acceleration sensor
- q Acceleration range: + 40g; ± 100g; ± 250g
- q Sensitive axes: x, y or z
- q Connector integrated housing
- q Dimensions: 57 x 24 x 25,5 mm
- q Excellent production quality (close to 0 ppm)
- q Smart front airbag deployment (dual stage)
- q Huge field experience worldwide (More then 50 Mio. pieces since 1996)



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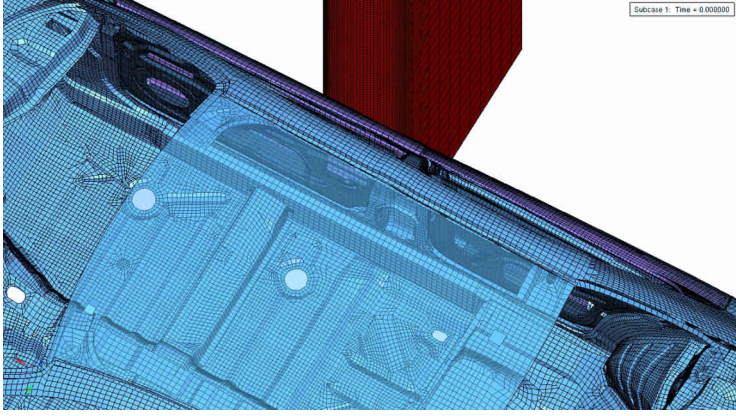


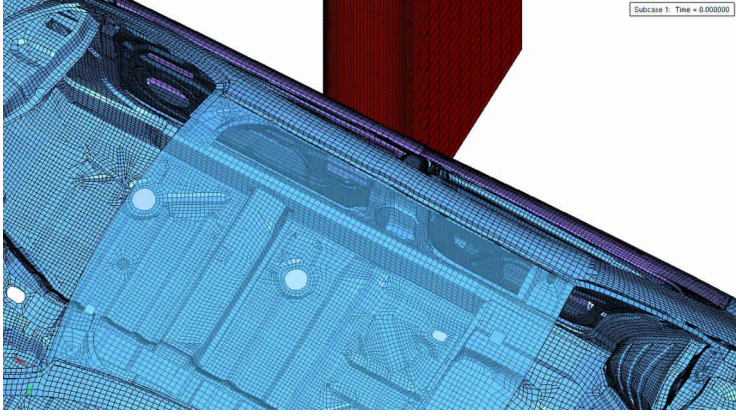
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## Crash Sensors - Overview and Trends

### Side Impact Simulation for Definition of Sensor Positions

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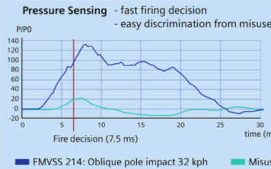
## Crash Sensors - Overview and Trends Lateral Crash - Side Impact Sensor P-Sat

**Features**

- Pressure measurement in door cavity
- Deformation of door leads to pressure increase in door cavity
- Door deformation and intrusion directly linked to injury risk
- No deployment without severe door damage
- Reliable crash severity information
- Short deployment times
- Excellent misuse immunity

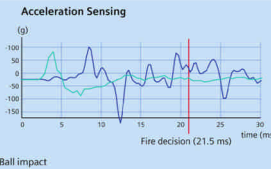



**Pressure Sensing** - fast firing decision  
- easy discrimination from misuse



Fire decision (7.5 ms)

**Acceleration Sensing**



Fire decision (21.5 ms)

■ FMVSS 214: Oblique pole impact 32 kph    ■ Misuse: Ball impact

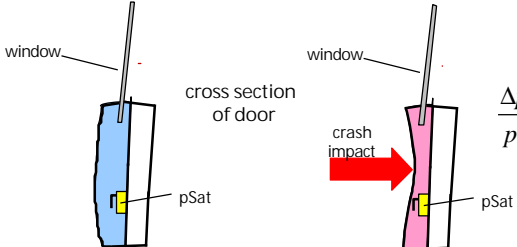
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## Crash Sensors - Overview and Trends Lateral Crash - Physical principle of P-Sat

- § Crash events cause deformation in door cavity
- § Air is compressed and causes increasing pressure in door cavity



$$\frac{\Delta p}{p_0} = \kappa \frac{-\Delta V}{V_0} \quad (\text{air: } \kappa=1.4)$$

Pressure sensing is a direct measurement of the door deformation and intrusion which are directly linked to the danger for the passengers

(Acceleration sensing measures vibration and velocity change which are only indirectly and not unambiguously linked to injury risks)

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### Crash Sensors - Overview and Trends Side Impact Simulation - Simple Door Model for P-Sat

- Overview
- Accident Statistics
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- Rollover**
- Pedestrian Detection
- ADAS

Wet area  
Door outer part  
Cross beam  
Door inner part  
Screen  
Speaker  
Screen Rails

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### Crash Sensors - Overview and Trends Rollover Sensing

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**Rollover Sensing**

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## Crash Sensors - Overview and Trends Rollover Protection

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- ADAS

## Crash Sensors - Overview and Trends Rollover Sensor

**Features**

- Micro-mechanical acceleration sensors for front and side crash sensing
- Integrated rollover sensors in ECU
- 20 firing loops
- 8 satellites interfaces (G-Sat/P-Sat)
- High speed CAN BUS
- Interface for occupant sensing (OCS/AWS)
- State of the art crash sensing
- Protection of occupants from ejection in rollover event (by curtain/side airbag, belt pretensioner, roof protection)

Z acceleration

Angular velocity

Y acceleration

z-acceleration  
w-acceleration

Angular velocity  
Inclination

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### Crash Sensors - Overview and Trends Rollover Algorithm Concept

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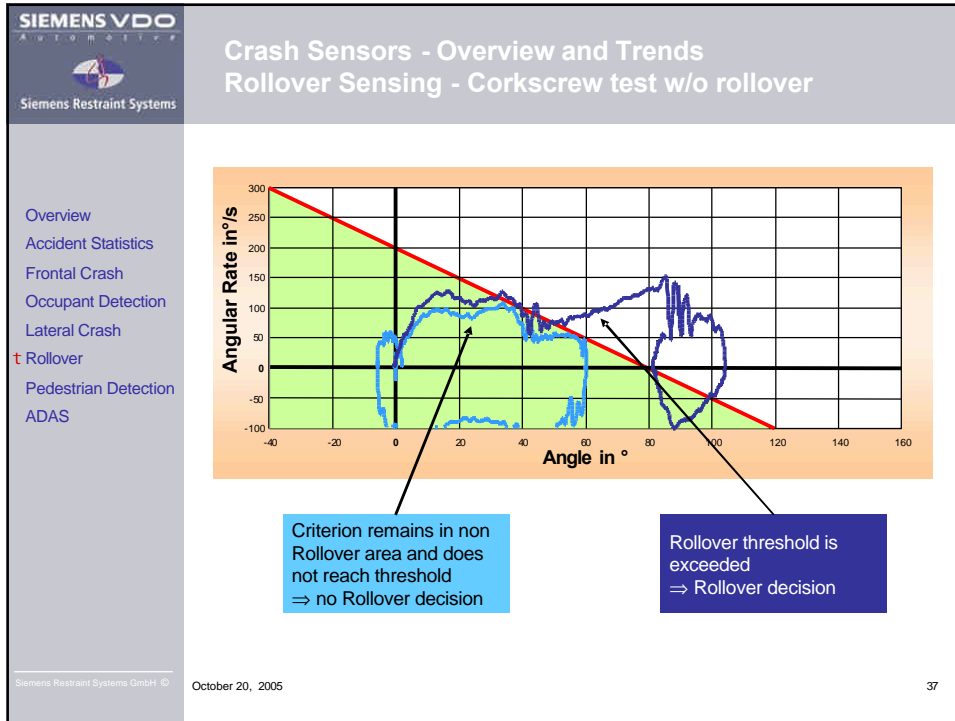
### Crash Sensors - Overview and Trends Rollover Sensing - Threshold for rollover decision

The threshold is derived from a comparison of the potential energy necessary to get a vehicle roll and the current kinetic energy at certain inclinations.


If the car is statically lifted, the vehicle characteristics lead to an angle where it will rollover (here 70°). This is the static roll point.

The dynamic roll point is the angular rate needed to roll a certain vehicle without no initial inclination (0° inclination).

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## Crash Sensors - Overview and Trends

### Rollover Sensing - Soil Trip Test



**50 km/h**


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 Rollover  
 Pedestrian Detection  
 ADAS

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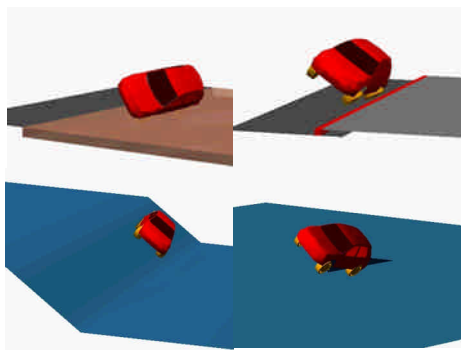
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## Crash Sensors - Overview and Trends


### Rollover Sensing - Simulation



**Vehicle Dynamics  
Simulation  
(ADAMS)**

↓

roll rate<sub>x</sub>, a<sub>y</sub>, a<sub>z</sub>



**Occupant  
Simulation  
(MADYMO)**

↓


RTTF

Overview  
 Accident Statistics  
 Frontal Crash  
 Occupant Detection  
 Lateral Crash  
 Rollover  
 Pedestrian Detection  
 ADAS

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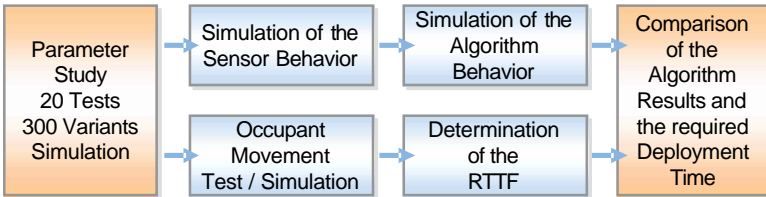


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## Crash Sensors - Overview and Trends

### Rollover Sensing - Robustness Analysis


- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover**
- Pedestrian Detection
- ADAS



```

graph LR
    A[Parameter Study  
20 Tests  
300 Variants  
Simulation] --> B[Simulation of the  
Sensor Behavior]
    A --> C[Occupant  
Movement  
Test / Simulation]
    B --> D[Simulation of the  
Algorithm  
Behavior]
    C --> E[Determination  
of the  
RTTF]
    D --> F[Comparison  
of the  
Algorithm  
Results and  
the required  
Deployment  
Time]
    E --> F
            
```

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## Crash Sensors - Overview and Trends

### Pedestrian Detection

- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection**
- ADAS



Pedestrian Detection

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- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- † Pedestrian Detection
- ADAS

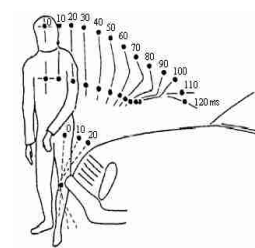
### Crash Sensors - Overview and Trends Pedestrian Detection – Accident Sequence

**Adult:**

Impact of leg to bumper	Contact of thigh to front hood edge	Impact upper part of the body to hood	Impact of head to hood
<b>0 ms</b>	<b>20 ms</b>	<b>80 ms</b>	<b>140 ms</b>

**Child:**

Impact of leg to bumper	Impact of head to hood
<b>0 ms</b>	<b>60 ms</b>



max. reaction time of **50 ms**

➔ System requirement

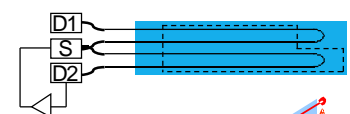
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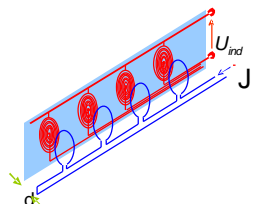
- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- † Pedestrian Detection
- ADAS

### Crash Sensors - Overview and Trends Pedestrian Detection – Sensor Overview


**Fibre optical sensor (FOS)**  
 Detection of intrusion and contact area  
 Calculation of intrusion velocity and impacting mass



**Inductive contact sensor (ICS)**  
 Detection of intrusion and contact area  
 Calculation of intrusion velocity and impacting mass

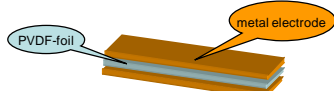



**Force sensing resistor (FSR)**  
 Detection of contact area



**PVDF sensor**  
 Detection of contact

**g-sensor**  
 Detection of contact





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- Overview
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- Lateral Crash
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- † Pedestrian Detection
- ADAS

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### Crash Sensors - Overview and Trends Pedestrian Detection - IPPS General System Concept

Source: Witte/Velbert, ETO Magnetic, FESTO

(IPPS : Intelligent Pedestrian Protection System)

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- † Pedestrian Detection
- ADAS

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### Crash Sensors - Overview and Trends Pedestrian Detection - Fiber Optical Sensor (FOS)

**Features**

- q Bumper with bending sensitive FOS
- q Detection of duration and intensity of intrusion on any location of the bumper
- q If a pedestrian contacts the bumper, bumper and FOS change shape
- q Before the pedestrian's head hits the hood, the hood is raised and cushions the impact of the head

**Advantages**

- q High system robustness
- q High detection / discrimination performance
- q Misuse insensitive
- q Easy to integrate







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### Crash Sensors - Overview and Trends Pedestrian Detection - Fiber Optical Sensor (FOS)

FOSE (90mm x 58mm x 31mm)

\* Length variable 10-800,  
1440-1600

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### Crash Sensors - Overview and Trends Pedestrian Detection – FOS Sensing Principle

#### Physical effect

**Segment voltage output proportional to segment bending angle**

#### Mathematical sensor model (top view)

Bending in °	Modulation in V
-45	1.6
-35	1.8
-25	2.0
-15	2.2
-5	2.4
0	2.5 (Zero Offset)
5	2.6
15	2.8
25	3.0
35	3.2
45	3.4

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- Overview
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- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
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### Crash Sensors - Overview and Trends Pedestrian Detection – Sensor Integration

The FOS sensor should be mounted on the most forward position of the vehicle to provide an early impact signal. Minimum intrusion ca. 20mm

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- † Pedestrian Detection
- ADAS

### Crash Sensors - Overview and Trends Pedestrian Detection - FOS Simulation Model

#### Force - Displacement Curve

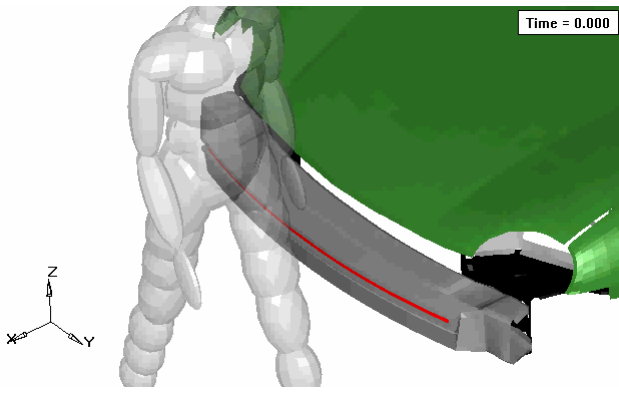
Displacement (mm)	Force (kN) - Detailed Model	Force (kN) - Simplified Model
0.0	0.0000	0.0000
0.2	0.0010	0.0010
0.4	0.0020	0.0020
0.6	0.0030	0.0030
0.8	0.0040	0.0040
1.0	0.0050	0.0050
1.2	0.0060	0.0060
1.4	0.0070	0.0070
1.6	0.0080	0.0080
1.8	0.0090	0.0090

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### Crash Sensors - Overview and Trends Pedestrian Simulation - 50% Dummy 40 km/h FOS

- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- † Pedestrian Detection
- ADAS



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### Crash Sensors - Overview and Trends Accident Avoidance - ADAS


- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- † ADAS

## Accident Avoidance - ADAS

**A**dvanced  
**D**river  
**A**ssistance  
**S**ystems

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## Crash Sensors - Overview and Trends

### Definition of ADAS

- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- † ADAS

**Definition:**  
ADAS uses environmental sensing in order to assist the driver in his driving task to increase safety and comfort


**Siemens VDO's Vision:**  
ADAS is the "smart Copilot" who:

- § makes driving more safe
- § expands the drivers own senses and perceptions
- § relieves the driver
- § provides overview and orientation
- § enhances the driving pleasure

But never takes the responsibility from the driver!

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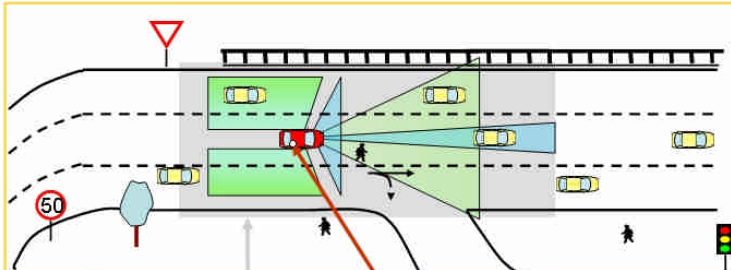


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## Crash Sensors - Overview and Trends

### ADAS - Local Environment Sensing

- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- † ADAS



Global Data	Local Data	Internal Data	Driver
<ul style="list-style-type: none"> <li>• Lane segments</li> <li>• Traffic signs</li> <li>• ...</li> </ul>	<ul style="list-style-type: none"> <li>• Lane recognition</li> <li>• Object detection</li> <li>• ...</li> </ul>	<ul style="list-style-type: none"> <li>• Steering angle</li> <li>• Wheel speed</li> <li>• ....</li> </ul>	<ul style="list-style-type: none"> <li>• Destination</li> <li>• Action</li> <li>• Dynamic etc...</li> </ul>

➔ Local environmental sensing is the missing link between vehicle, digital map and real world !

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### Crash Sensors - Overview and Trends ADAS - Environmental Sensing Overview

- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- † ADAS

**1) Near Distance Range**

- Radar (24 GHz)
- Video
- 3D-Kamera

**2) Medium Distance Range**

- Video

**3) Far Distance Range**

- Radar (77/79 GHz)
- Lidar

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### Crash Sensors - Overview and Trends ADAS - Key Sensors (1)

- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- † ADAS

<p><b>Radar</b></p> <ul style="list-style-type: none"> <li>▫ 77 GHz for far range</li> <li>▫ 24 GHz for near range</li> </ul> <p><b>Advantages</b></p> <ul style="list-style-type: none"> <li>▫ Provides accurate range and velocity</li> <li>▫ Resistant to dirt, invisible mounting</li> </ul> <p><b>Applications</b></p> <ul style="list-style-type: none"> <li>▫ Adaptive cruise control</li> <li>▫ Near distance sensing</li> </ul>	<p><b>Video</b></p> <ul style="list-style-type: none"> <li>▫ Monocular vision</li> <li>▫ Stereo vision</li> </ul> <p><b>Advantages</b></p> <ul style="list-style-type: none"> <li>▫ High angular resolution</li> <li>▫ Emission free</li> </ul> <p><b>Applications</b></p> <ul style="list-style-type: none"> <li>▫ Lane departure warning</li> <li>▫ Object detection or classification</li> </ul>	<p><b>Lidar</b></p> <ul style="list-style-type: none"> <li>▫ Laser Range Detection</li> <li>▫ SIT 3D Camera</li> </ul> <p><b>Advantages</b></p> <ul style="list-style-type: none"> <li>▫ Small beams</li> <li>▫ Angular resolution</li> <li>▫ Low cost</li> </ul> <p><b>Applications</b></p> <ul style="list-style-type: none"> <li>▫ Adaptive Cruise Control</li> <li>▫ Object detection</li> </ul>
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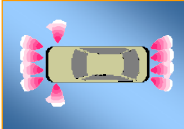
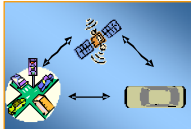


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## Crash Sensors - Overview and Trends


### ADAS - Key Sensors (2)

- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- † ADAS

 <p><b>GPS &amp; Map</b></p> <ul style="list-style-type: none"> <li>▫ Localization by GPS and map</li> </ul> <p><b>Advantages</b></p> <ul style="list-style-type: none"> <li>▫ Global data base</li> <li>▫ Infrastructure data</li> </ul> <p><b>Applications</b></p> <ul style="list-style-type: none"> <li>▫ Navigation</li> <li>▫ Global data input for ADAS</li> </ul>	 <p><b>Ultrasonic</b></p> <ul style="list-style-type: none"> <li>▫ Short range low cost Distance sensor</li> </ul> <p><b>Advantages</b></p> <ul style="list-style-type: none"> <li>▫ Provides accurate range</li> <li>▫ Low cost</li> </ul> <p><b>Applications</b></p> <ul style="list-style-type: none"> <li>▫ Park assistance</li> <li>▫ Near distance sensing</li> </ul>	 <p><b>Communication</b></p> <ul style="list-style-type: none"> <li>▫ Car to car</li> <li>▫ Car to infrastructure</li> </ul> <p><b>Advantages</b></p> <ul style="list-style-type: none"> <li>▫ Mid range</li> <li>▫ Information bandwidth</li> </ul> <p><b>Applications</b></p> <ul style="list-style-type: none"> <li>▫ Research</li> </ul>
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## Crash Sensors - Overview and Trends


### ADAS - Blind Spot Detection (BSD)

- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- † ADAS



**Description**

- Detection of other road users in the blind spot area
- Classification of detected objects
- Optical warning signal in the side mirror when an object is detected in the blind spot area



<p><b>Key Components</b></p> <ul style="list-style-type: none"> <li>▫ 24 GHz radar/video for the surveillance of the adjacent traffic zones</li> <li>▫ Algorithm for sidewise object detection</li> </ul>	<p><b>Benefits</b></p> <ul style="list-style-type: none"> <li>▫ Reduced driving stress and workload</li> <li>▫ Increased safety for lane change and turn off maneuvers</li> </ul>
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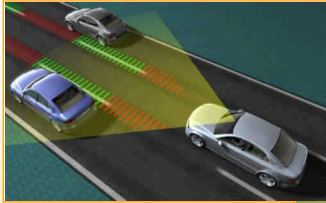


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## Crash Sensors - Overview and Trends

### Lane Departure Warning - LDW

- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- † ADAS



#### Description

- Lane recognition based on road track marking
- Consideration of curve and bend radii
- Optional link into the navigation system
- Monitoring of vehicle dynamic and driver actions



#### Key Components

- CMOS HDR camera sensor for lane detection, incl. robust lane boundary detection algorithm
- Steering wheel angle
- Warning HMI (dash board lights, sounds, seat vibrations)

#### Benefits

- Warning against unintentional lane departures caused by sleepiness or distraction
- Reduced work load

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## Crash Sensors - Overview and Trends

### Adaptive Cruise Control - ACC

- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- † ADAS



#### Description

- Automatic control of speed and distance with respect to the preceding vehicle
- Adaption to the traffic flow by motor management and brake system



#### Key Components

- Radar / Lidar sensor for the distance measurement
- Speed information from the vehicle
- Algorithm for vehicle detection and tracking


#### Benefits

- Increased comfort by release of the driver from monotonous driving activities
- Increased safety by automatic distance adjustment due to the required safety margin

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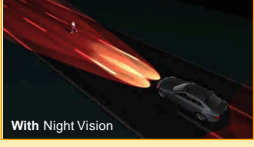
## Crash Sensors - Overview and Trends ADAS - Night Vision

- Overview
- Accident Statistics
- Frontal Crash
- Occupant Detection
- Lateral Crash
- Rollover
- Pedestrian Detection
- † ADAS



### Description

- Illumination of the lanes with invisible near infrared high beam light without glare of the oncoming traffic
- Visualization of a contrast optimized camera image of the road scene on a (head-up) display




### Key Components

- Near infrared (NI) high beam head lights
- NI sensitive video camera
- Algorithm for image optimization
- Standard or head-up display for the visualization

### Benefits





- Increased safety by improved vision at night

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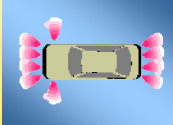


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## Crash Sensors - Overview and Trends

# Thank you very much for your attention

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