

## CURRENT WORLDWIDE SIDE IMPACT ACTIVITIES – DIVERGENCE VERSUS HARMONISATION AND THE POSSIBLE EFFECT ON FUTURE CAR DESIGN

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### ABSTRACT

Car manufacturers design vehicles and side impact restraint systems to protect passengers from the risk of serious injury in the event of a side impact. In each of the major markets of the world, the side-impact testing requirements as set by the regulatory and the consumer interests are generally different. This paper will document and compare the international side impact regulatory and consumer test requirements of now and the future.

Using a sample of results from vehicles tested in accordance with the discussed future regulations and consumer tests, it is shown that vehicles currently “best rated” for side-impact protection in consumer tests need to be redesigned in order to meet the prospective regulatory requirements. This paper will discuss the vehicle structural, interior and restraint design changes, which could be required.

The global side-impact tests and requirements are diverging, and not converging towards a harmonized Side-impact Testing Protocol as presented by the IHRA at the 2003 ESV Conference. It is our goal that side-impact requirements and procedures should become less diversified and more harmonized as we continue to improve side-impact protection for all customers worldwide.

### INTRODUCTION

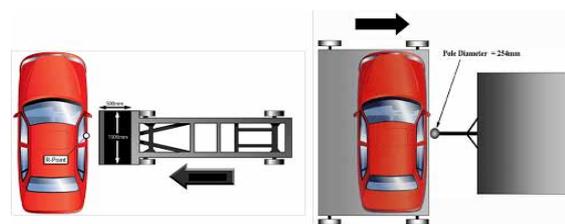
Global accident statistics show that side impacts account for approximately 30 % of all impacts and 35 % of the total fatalities (Source – German In Depth Accident Study - GIDAS, National Automotive Sampling System - NASS & BMW accident databases).

It is essential for us as vehicle manufacturers to provide adequate protection in order to minimize the potential negative effects of such impacts on our customers.

Most side impacts can be classified into two impact types. Either a “Car to Car” or a “Car to narrow object” (tree, lamp post etc).

Side impact protection forms a very important part of any total vehicle protection system. To design, develop and test the optimum level of protection into a vehicle these two impact types are generally used.

A “Car to Car” impact is simulated with a stationary target vehicle being hit sideways by a moving bullet vehicle or barrier. In the event of “Car to narrow object” impact, a moving target vehicle comes into contact with a stationary pole, simulating a post or tree. A schematic showing a barrier and pole type crash test can be seen in Figure 1.



**Figure 1. Barrier and pole crash test schematic.**

The following describes the mechanism of a “Car to Car” impact:

- Contact occurs between the two vehicles.
- The outer skin of the target vehicle is accelerated to the velocity of the outer surface of the intruding surface of the bullet vehicle. The lateral velocity of the occupant is zero. The airbag sensing system detects a crash and ignites the countermeasures.
- The body structure of both vehicles is increasingly loaded and deformed. Airbags deploy.
- The kinetic energy of the bullet vehicle is dissipated by elastic and plastic deformation of each partner.
- The countermeasures dampen the effect of the intruding structure.

- The vehicle and occupant reach the same velocity. The peak dynamic deformation and injury results are reached. Further energy is absorbed through the kinetic energy change of the target vehicle.

The art of side impact protection is about ensuring that the intruding velocities are kept to a minimum through a suitable vehicle structure and deploying an appropriate restraint system to dampen the effect of the intruding structure, thus reducing the effect of the impact on the occupants.

Vehicle manufacturers have made great leaps in terms of side impact protection over the last 10 years. Protection has been steadily increasing as technology has allowed. Most vehicles are now equipped with thorax airbags, head airbags, interior padding and an optimized vehicle structure. A total vehicle protection system is shown in Figure 2.



**Figure 2. Side impact countermeasures & small female dummy.**

In order to assess the likelihood of injury during a given crash scenario, several different anthropomorphic test devices, so called crash test dummies, are used. They simulate a human occupant, and are designed to reflect injuries in important regions of the human body, such as head, thorax, abdomen and pelvis. See Figure 2.

### **SIDE IMPACT - CURRENT, FUTURE & HISTORICAL SITUATION**

The worldwide activities to improve passive safety in side impact, started in the 1980's with research work at the National Highway Traffic Safety Administration (NHTSA). A static side intrusion test was developed. This became the Federal Motor Vehicle Safety Standard No. 214 (FMVSS 214).

In 1990 FMVSS 214 was extended to include the dynamic crabbled barrier test. This was the first side impact regulation that included a side impact

dummy (SID) and was enacted in 1993, with a phase in of three years.

In 1997 NHTSA included a lateral impact consumer test known as SINCAP. This was an additional test to the frontal NCAP. Instead of the FMVSS214 speed of 53 km/h, the rating test is completed with a velocity of 61 km/h. The rating is based on acceleration measured in the thorax region of the dummy. More than 40 cars were tested in the first year, none obtained the best score of 5 stars. In the following year two cars achieved a 5 star rating for the driver. Following a further 2 years the first passenger car improved to point of earning a double 5 star rating (for the first two seating rows). Today most cars have a 4 to 5 star rating and only one car in 2004 earned only a two star rating.

Parallel in Europe the European Enhanced Vehicle Safety Committee Working Group 13, (EEVC WG13) started their research activities to create a European wide regulation – ECE-R95. This included a new European barrier and a new generation of dummy, EuroSID1 (ES1). The implementation date for new type approvals was October 1998.

During 1997 prior to this regulation taking effect, Euro NCAP decided to implement the research work of the EEVC WG13 into their program. The more stringent targets at Euro NCAP, especially rib intrusion and abdominal forces, were set at a higher level than current European legislation. Most models earned less than 10 out of 16 points. Today more than ½ of all cars tested achieve the maximum 16 points for the side impact barrier test.

In 1995 NHTSA issued an amendment to FMVSS 201 to include upper interior head impact protection using a 'Free Motion Head Form' (FMH). During 1998 a further final rule was issued, this allowed a reduced impact speed for FMH testing in the area where a head protection was packaged. The head protection system's effectiveness needed to be proved through a dynamic pole crash test. This enabled car manufacturers to implement side impact curtains whilst still meeting the upper interior head protection requirements. For this test the Side Impact Dummy was redeveloped in the neck and head area and called SIDHIII. This dummy was also integrated in the SINCAP procedure.

Euro NCAP implemented the lateral pole test procedure in the year 2000 similar to the US standard, but using the ES1 dummy. The test is voluntary and awards two extra points towards the side impact score. With the implementation of the pole impact, Euro NCAP changed the highest

possible score from four to five stars. Today many manufacturers are able to achieve the Euro NCAP goals for pole impact (even with the new 2002 head acceleration limits and the modifier for improper airbag deployment). Many manufacturers now build head protection airbags into their vehicles as standard. This provides the best possible protection for customers whilst also achieving a 5 star rating.

During 2003 an EEVC proposal for an updated barrier was implemented into the existing ECE-R95 requirement. This was closely followed in 2004 with a change to the dummy from ES1 to Euro SID 2 (ES2). ES2 was shown to have a slightly higher biofidelity rating compared to ES1. See Figure 3.

Again Euro NCAP decided to implement these changes from WG13 into the rating in 2003. This was four years before the changes became mandatory for new vehicle type approvals.

In June 2003 the Insurance Institute for Highway Safety focused on the predominately North American issue of heavy SUVs involved in side impact. A new barrier was designed to duplicate the front-end stiffness and overall size of a typical North American SUV (Sport Utility Vehicle). The 5%ile female dummy SIDII (SID II) was used as the occupant for both seat rows.

Looking forward to the next 3 years the following regulations will influence the design of cars:

Firstly: “The Procedure for evaluating occupant injury risk from deploying side airbags”, as developed by the Technical Working Group (This includes manufacturers, government, special interest groups and OEM suppliers). The requirement has a phase in starting from 2000 with 100% of all 2007 model year cars needing to meet this procedure. The target is to reduce the chance of injuries to small occupants and children from deploying side airbags.

Secondly: The memorandum of understanding for “Front to Side Compatibility” (F2S) signed by most of the vehicle manufacturers within the Alliance. This has a dual stage phase in. During the first phase manufacturers can choose to assess the likelihood of head injury, with either a FMVSS201 pole impact or an IIHS barrier side impact. In phase 2 only the IIHS barrier test can be used.

Current research work for regulations in the next three to seven years includes the upgrade of the US regulation FMVSS214. A notice of proposed rulemaking was published by NHTSA in spring 2004 and proposes four full-scale side impact tests instead of the current, one. The main differences to the existing regulation is the replacement of the

dummy: ES2 modified with a rib extension kit (ES2re), this replaces the SID and a new dummy SID IIs modified with a floating rib guide (SIDIIsFRG). Both will be used in the barrier test (unchanged crabbed barrier) and in a newly developed 75° pole impact.

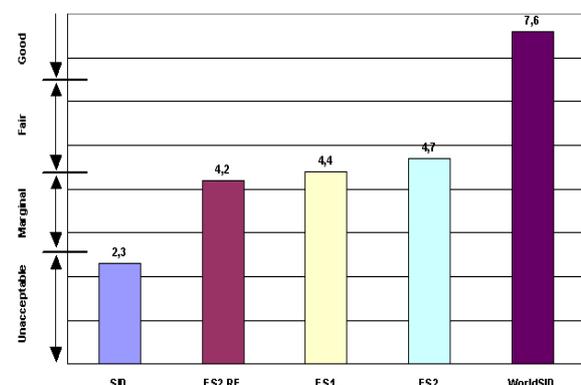
Phase 3 of the F2S voluntary agreement is currently being discussed. It is possible that further injury limits will be agreed using the IIHS side impact test configuration.

In Europe the EEVC WG13 is working closely together with the Japanese authorities to develop an Advanced European – Mobile Deformable Barrier (AE-MDB). The target for the barrier is to better represent the current fleet of European vehicles.

The WG13 is also close to finalizing a “European Interior Head-Form Test Procedure” for lateral collisions. This is an expected addition to the ECE-R95 regulation. This procedure differs immensely to the US FMVSS201 standard.

Since 1997 the “ISO World Side Impact Dummy Task Group” has been developing a new dummy (WorldSID). The design and development of this dummy, a 50% male side impact dummy was completed in March 2004.

The funding for this programme was achieved through a worldwide consortium from the vehicle industry, research institutes and government agencies. The WorldSID heralds a significant improvement in the ability of crash dummies to duplicate human motions and responses in side impact tests. The use of this dummy should lead to improved vehicle designs and occupant protection. Based on the ISO/TR9790 rating scale, the WorldSID biofidelity rating is 7.6 (“Good” on a 10 point rating scale). In comparison to other side impact dummies currently in use, WorldSID has a far superior biofidelity rating. See Figure 3.



**Figure 3. Dummy biofidelity ratings to ISO/TR9790**

Five working groups were established after the 15<sup>th</sup> ESV 1996 conference, as “The International Harmonisation Research Association” (IHRA). Their aim was to provide the automotive community with harmonised research to develop test procedures, which could then become the basis for global regulations and consumer tests. At the 18<sup>th</sup> ESV conference in 2003, the IHRA Side Impact Working Group (SIWG) presented an outline for a possible Global Technical Regulation (GTR) for Side impact protection.

The proposals main points are simplified below:

- MDB barrier test to simulate “Car to Car” impacts (up to 2 tests to cover worldwide fleet differences).
- Oblique pole test to simulate “vehicle to narrow object impacts”.
- Upper interior head impact test.
- OOP side airbag tests.

Summarising the current and future side impact requirements means over the next 7 years there may be 5 additional test configurations and two additional dummy types. Manufacturers developing world vehicles whilst also providing good side impact protection will have to certify using a total of 7 different barrier configurations:

IIHS, FMVSS 214, Multi 2000 Advanced, AE MDB, Oblique Pole 5%ile, Oblique Pole 50%ile and 90° Pole.

And a total of 6 different dummies:

ES2, ES2re, SIDIIs, SIDIIsFRG, WorldSID, SIDHIII

The total side impact requirements including both legal and consumer tests can be seen in Figure 4.

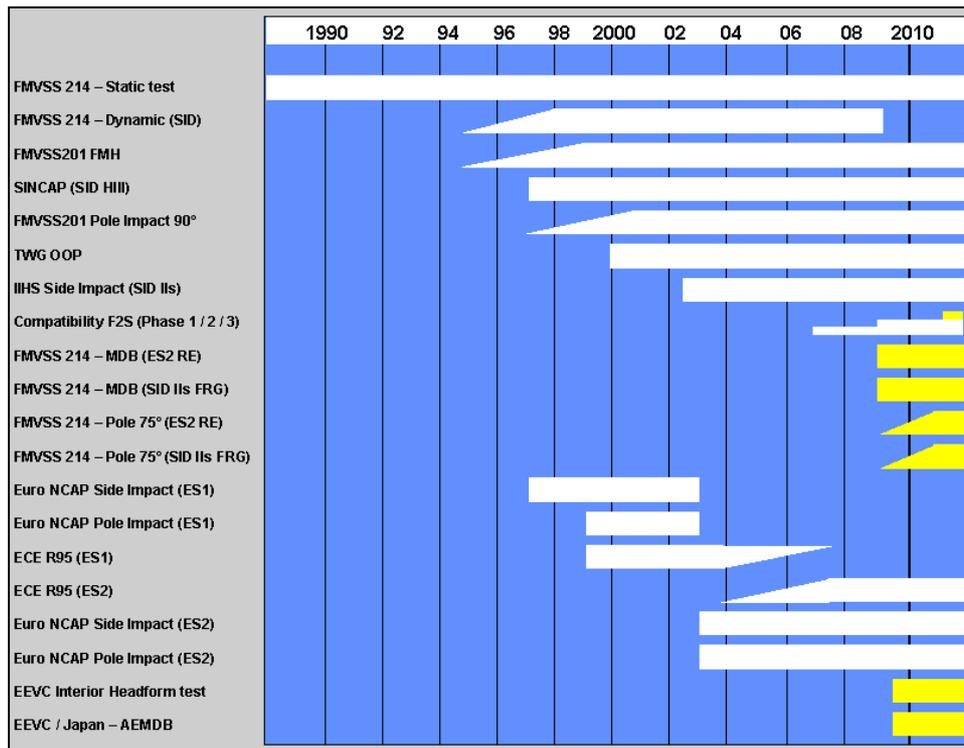


Figure 4. Side impact requirements (proposed new requirements shown in yellow)

# NEW LEGISLATIVE PROPOSALS – VEHICLE BASED ANALYSIS

## Advanced European Mobile Deformable Barrier

The currently proposed design of the AE-MDB (Version 2) has been investigated with full-scale crash tests and simulation. Special emphasis has been given to the stiffness distribution of the particular blocks (D, E, F). See Figure 5. The different barrier versions have then been compared to the front-end structures of typical current vehicles.

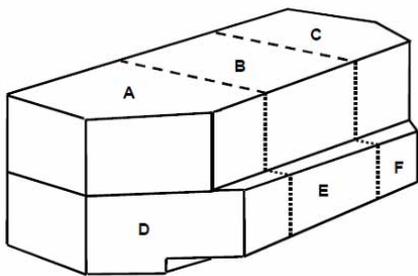


Figure 5. AE-MDB schematic

The stiffness (100% - ~40% - 100%) of the lower row of blocks (D – F) has been criticized for not reflecting the stiffness distribution of modern car front ends (The percentage stiffness values relate to the stiffness of block D). The outer blocks of the barrier have a high stiffness relative to the middle block. This stiffness distribution was supposed to better represent the front longitudinals of vehicles.

However, modern cars are being designed to have an even stiffness distribution of the front end. This is achieved through bumper crossbeams of high stiffness for compatibility and offset impact reasons. Vehicles designed in such a way are able to load struck vehicles with a more homogenous loading pattern.

The discussion of this discrepancy resulted in various proposals for changing the stiffness setup of the lower row of blocks. Figure 6 summarises the simulation carried out by the German Alliance in order to support the barrier development.

Bullet Vehicle	Barrier Specification	Remarks	Target Vehicle			
			VW Golf V	Audi A6	Mercedes E-class	BMW 3-Series
ECE R95	Multi 2000 Advanced		X	X	X	X
AE-MDB v2	(100% - ~40% - 100%)	Reference	X	X	X	X
AE-MDB v3.1	(100% - ~40% - 100% + Bumper)	Japanese Proposal	X	X	X	X
AE-MDB v3.5	(40% - 60% - 40%)	German Alliance	X	X	X	X
AE-MDB v3.6	(70% - 60% - 70% + Bumper)	Task Force - WG13	X	X	X	X
AE-MDB v3.9	(55% - 60% - 55% + Bumper)	BAST Proposal	X	-	X	X
VW Golf V	-	-	X	X	-	-
Audi A6	-	-	-	X	-	-
Mercedes E-class	-	-	-	-	X	-
BMW 3 Series	-	-	-	-	-	X

Figure 6. Matrix of simulations completed with different AE-MDB Specifications and modern vehicles.

For this example the simulation from the VW Golf 5 has been analysed, specifically the following:

- Deformation distribution (homogeneity).
- Intrusion depth.
- Intrusion velocities.

Figure 7 shows the deformation profiles of the AE-MDB version compared to Multi 2000 advanced barrier, AE-MDB (40% - 60% - 40%) and VW Golf 5 “Car to Car”. The AE-MDB (40% - 60% - 40%) best represents the deformation distribution of the “Car to Car” test.

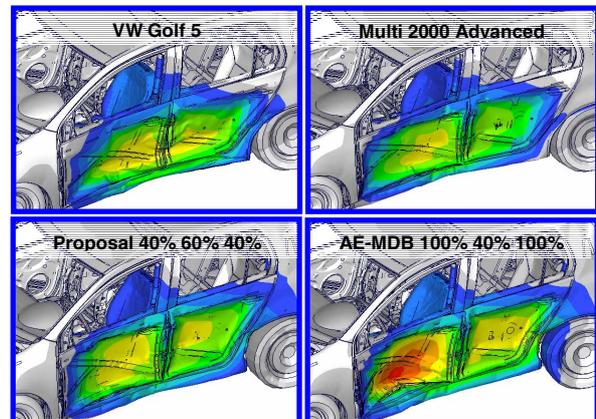
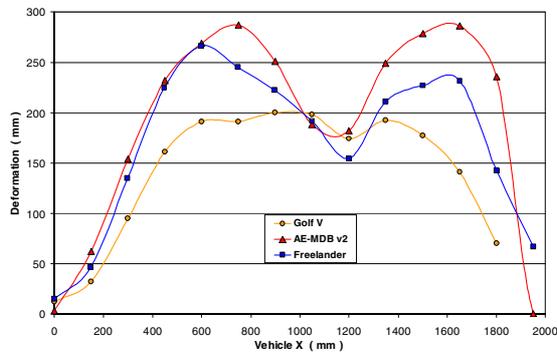


Figure 7. Comparison of deformation profiles (90° Side impact with MDB at 50 km/h & target vehicle at 0 km/h; VW Golf 48 km/h to VW Golf 24 km/h)

In addition to the crash simulations various vehicle tests have been performed. Figure 8 shows the static deformation profiles, recorded at the pelvis height of the dummy. Bullet vehicles included were:

- AE-MDB v2.
- “Car to Car” VW Golf 5.
- “Car to Car” Land Rover Freelander.



**Figure 8. Deformation profiles**

The Land Rover Freelander represents a European SUV and is agreed in WG13 to be the upper limit for consideration in the development of the AE-MDB.

The crash tests results concur with the simulation that the deformation characteristics made by the AE-MDB are not as homogenous as the “Car to Car” test, particularly the VW Golf 5.

It is noted that the total deformation depth with the AE-MDB v2 is even higher than with the suggested “worst case” Land Rover Freelander.

The same trend is seen in Figure 9. This shows the results with Audi A6.



**Figure 9. Deformation characteristics AE-MDB V2 to Audi A6 & “Car to Car” Audi A6**

The intrusion velocities show the same tendency as the static deformations recorded.

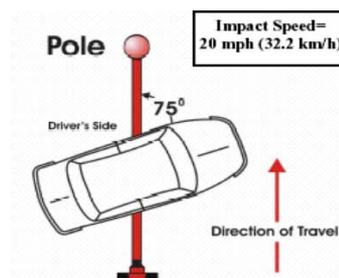
Considering the results of the investigations, the stiffness distribution of the blocks of the AE-MDB

needs to be reconsidered in order to be more reflective of real world crashes. If the current barrier is used as a basis for a new legal requirement, this will undoubtedly lead to unnecessary reinforcements being added to future vehicles. Using the results as presented this can in no way be justified from a “Real World” viewpoint.

### FMVSS214 NPRM

The proposed upgrade of US-standard for side impact protection prescribes side impact crash tests with four different configurations, two oblique pole tests (75-degree, 32km/h) and two tests with the “crabbed” mobile deformable barrier (MDB). Each test, pole and MDB, is to be performed with both, ES2RE (50% male) and SID2sFRG (5% female) dummy.

When performing an oblique pole test, the vehicle impacts with an angle of 75°. Most vehicles are currently developed using a 90° pole as specified by Euro NCAP and FMVSS 201. The centre line of the pole is aligned with the Centre of Gravity of the dummy head. See Figure 10.



**Figure 10. Oblique pole test schematic**

The level of understanding is somewhat limited regarding the FMVSS 214 NPRM. This is due to lack of dummy availability and the incomplete pre development programs. However through the first investigations a number of issues become apparent.

Is it possible to develop a restraint system, (thorax airbag, head airbag and interior padding) which can fulfil all the requirements? This may be the case for the FMVSS 214 NPRM but when other test configurations are taken into account, such as IIHS or SINCAP this seems unlikely.

It could be that we are on the verge of requiring more adaptive restraint systems for side impact with the associated airbag and sensing technology.

With Cabriolet / Convertible vehicles, the current state of the art system is a head thorax airbag. This offers combined head and thoracic protection. In order to meet the oblique pole requirements such airbags will need to be designed to cover a

significantly larger area. A larger airbag and therefore aggressive deployment will then be required. This will be a clear conflict to the requirements of TWG (Technical Working Group) voluntary agreement “Procedure for evaluating occupant injury risk from deploying side airbags”.

## CONCLUSIONS

Due to the “disharmonisation” between governments and consumer test organisations, there is a real potential for an ever-increasing number of tests and dummies. Each individual test is always justifiable, but together from a global perspective this is not the case.

Are accidents and people the world over so different to warrant a potential of seven different test configurations and six different dummies?

In order for a vehicle manufacturer to meet the different requirements increasingly complex safety systems and vehicle structures will be required.

It cannot be proven whether such systems will provide any real world benefit other than satisfying “disharmonisation” and increasing vehicle weight, with the corresponding negative effect on vehicle emissions & fuel consumption.

The goal for all parties involved must be that safe vehicles are produced in the most efficient way, to ensure that all consumers are able to enjoy the best possible protection. Harmonisation of global side impact requirements would make a large contribution towards this.

Lastly, the IHRA has been pushing worldwide harmonisation with an enormous investment and engagement of its members. The output from this group in our opinion is not being taken seriously enough. This can be seen with the new legislative proposals currently being published.

## RECOMMENDATIONS

Worldwide harmonisation is not receiving adequate consideration. The vehicle manufacturers AUDI, BMW, DaimlerChrysler, Porsche and Volkswagen strictly support all ongoing harmonisation activities and particularly the work of the IHRA. The following needs to be considered:

- “Global Technical Regulation Side Impact Protection” with a timing plan for introduction.
- World NCAP based on a future GTR

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National Highway Traffic Safety Administration Federal Motor Vehicle Safety Standards; *Side Impact Protection*, Part 571. (FMVSS 214 Revision 2004)

National Highway Traffic Safety Administration Federal Motor Vehicle Safety Standards; *Side Impact Protection*, Parts 571 and 598 (FMVSS 214 upgrade NPRM 2004)

ECE Regulation No. 95 - *Uniform provisions concerning the approval of vehicles with regard to the protection of the occupants in the event of a lateral collision* (Revision 2004)

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Dakin, - *Insurance Institute for Highway Safety Side Impact Crashworthiness Evaluation Program: Impact Configuration and Rationale*, Paper No. 172, 18<sup>th</sup> ESV Conference, Nagoya, 2003.

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Van Ratingen, M.R. et al, *Development of a European Side Impact Interior Headform Test Procedure*, Paper No.138, 18<sup>th</sup> ESV Conference, Nagoya, 2003.

GIDAS: German In Depth Accident Study [www.gidas.org](http://www.gidas.org)

NASS: National Automotive Sampling System [www-nrd.nhtsa.dot.gov](http://www-nrd.nhtsa.dot.gov)

EEVC – European Enhanced Vehicle Safety Committee [www.eevc.org](http://www.eevc.org)

Euro NCAP – European New Car Assessment  
Program [www.euroncap.com](http://www.euroncap.com)

IIHS – Insurance Institute for Highway Safety  
[www.hwysafety.org](http://www.hwysafety.org)