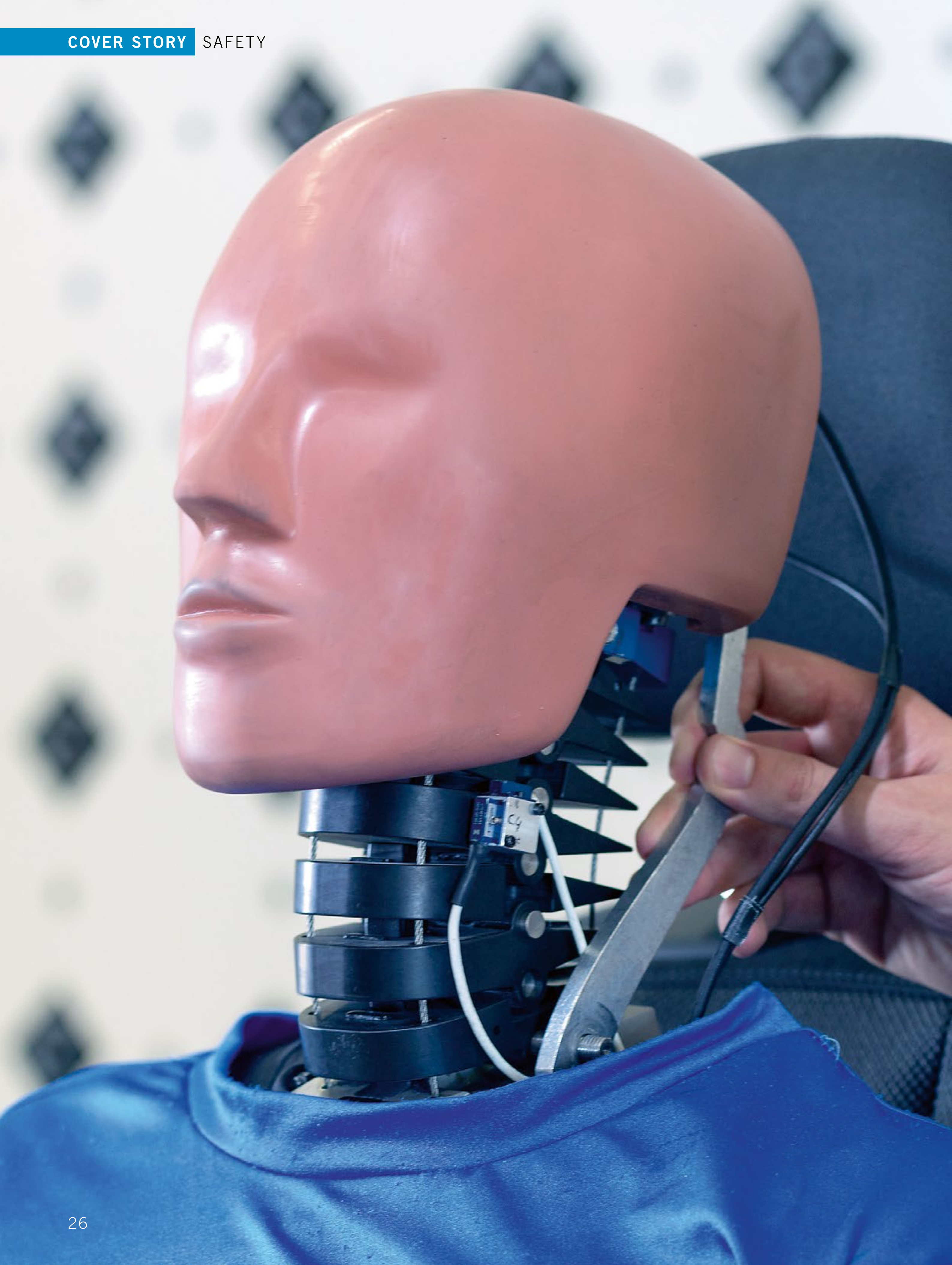



# Automated Driving Influences on Restraint Systems

The roadmap to fully automated driving has now been prepared. It is time for Bertrandt, to carry out an initial assessment of what this might mean for restraint system development. Even the simple possibility of enabling the driver to sit facing the rear of the passenger car will result in changes to the requirements placed on individual components of the system due to the greater degrees of freedom involved. Whether it is seatbelts, airbags or sensors, new application scenarios will mean that some components will have to be completely redesigned in the future.

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## CLASSICAL RESTRAINT SYSTEMS AND THEIR PROTECTIVE EFFECT

An effective restraint system mainly consists of the following components, **FIGURE 1**: seatbelt system with belt pre-tensioner and belt load limiter, driver's and passenger's airbags (in some cases supported by knee airbags), head and side airbags, a suitably modified steering wheel with steering column, vehicle's seat, an instrument panel and a body structure of the vehicle with a defined survival space.

All components are optimally adapted to each other in order to protect the vehicle's occupants. At the same time, various requirements, some of which differ throughout the world, need to be considered. In this context, legislators and consumer protection organisations worldwide focus on around 60 to 70 different load cases in the complete vehicle alone, with the aim of ensuring comprehensive occupant protection. All of these load cases are based on occupants in the range between the 5-% dummy and the 95-% dummy seated in a normal position in the vehicle, which is specified in the

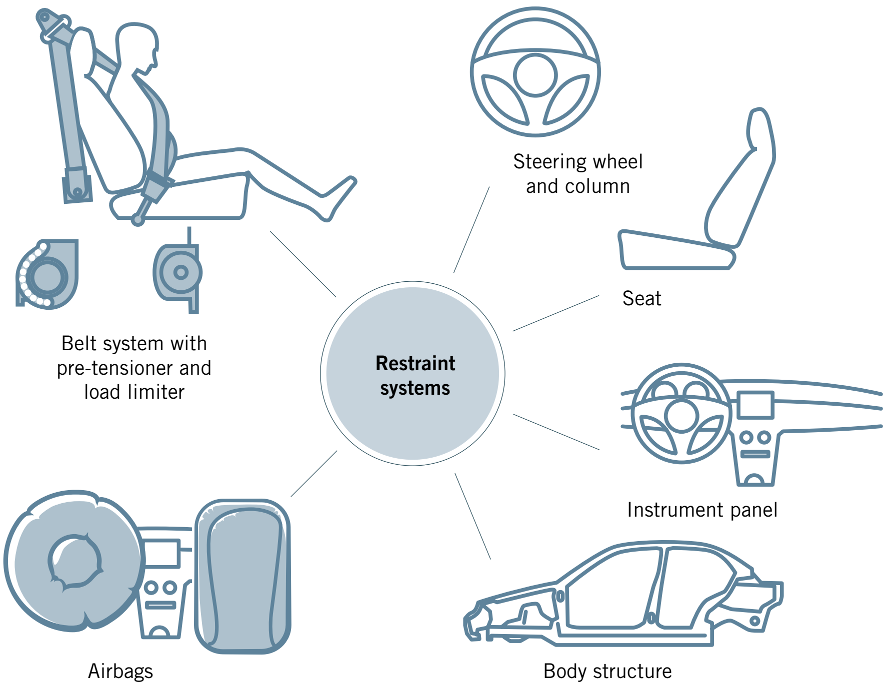


**FIGURE 1** Components of a classical restraint system (© Bertrandt)

x-direction. The success of these complex systems is impressively demonstrated today (as of 2016) by traffic accident statistics, **FIGURE 2**. [1]

One could say that vehicle occupants today are comprehensively protected by the passenger car from accidents in a high-energy range due to the interaction of the components mentioned before. However, this assumes that the occupants are seated in the optimum position in the vehicle.

## EFFECTS OF HIGHLY AUTOMATED DRIVING ON THE RESTRAINT SYSTEM

A glance at the figures of road traffic fatalities shows, **FIGURE 2**, that there is still a long way to go before one can achieve accident-free mobility. One positive aspect is that the risk of being killed in a vehicle has already significantly fallen. Actual occupant protection is at an excellent level and is now related to only one third of the fatalities in the statistics. Experts believe that automated driving will present a major opportunity for further reducing the numbers of accidents. Even the introduction of an emergency braking system alone (level 1 according to SAE J3016 [2], **FIGURE 3**) already shows a benefit of more than 30 % in terms of accidents being avoided or reduced to a non-critical level in everyday driving situations [3]. And these systems are not yet even in widespread use in the vehicles on our roads.

What effects will automated driving have on the components of current restraint systems? Can some of them be eliminated or is a further evolutionary step required in order to at least maintain current safety levels?

First of all, one can assume that the user of a passenger car will want to experience at least the same level of

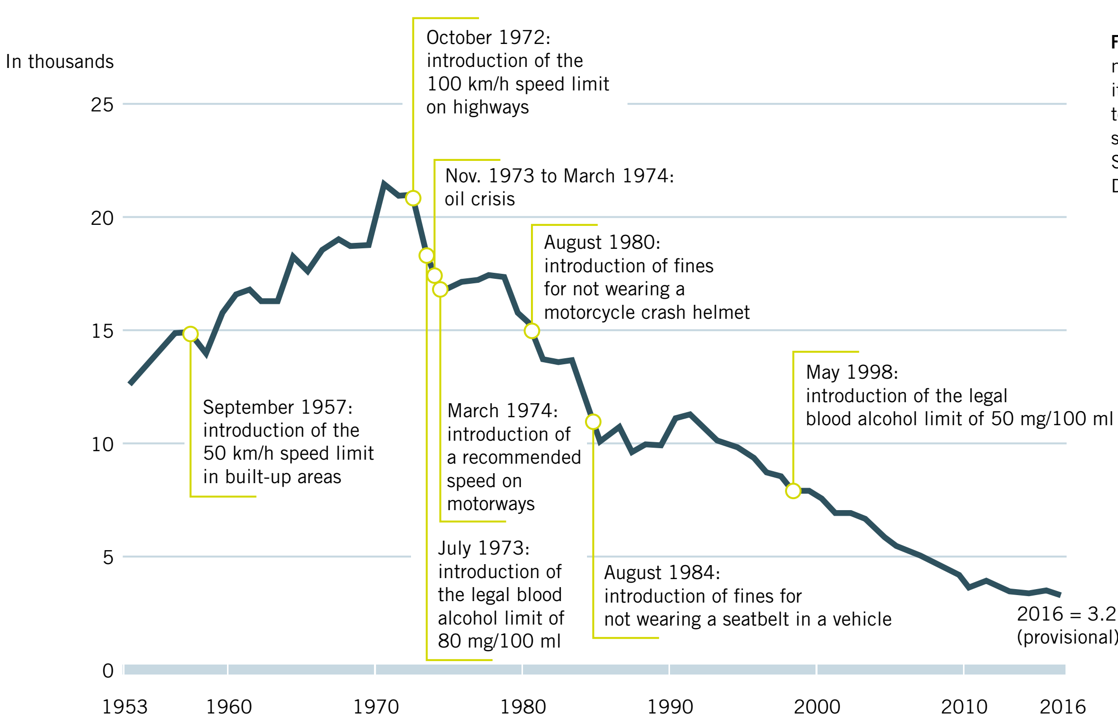


**FIGURE 2** Development of the number of road traffic fatalities in Germany from 1953 to 2016 – a falling curve since 1970 (source: Federal Statistical Office Germany Destatis [1], © Bertrandt)

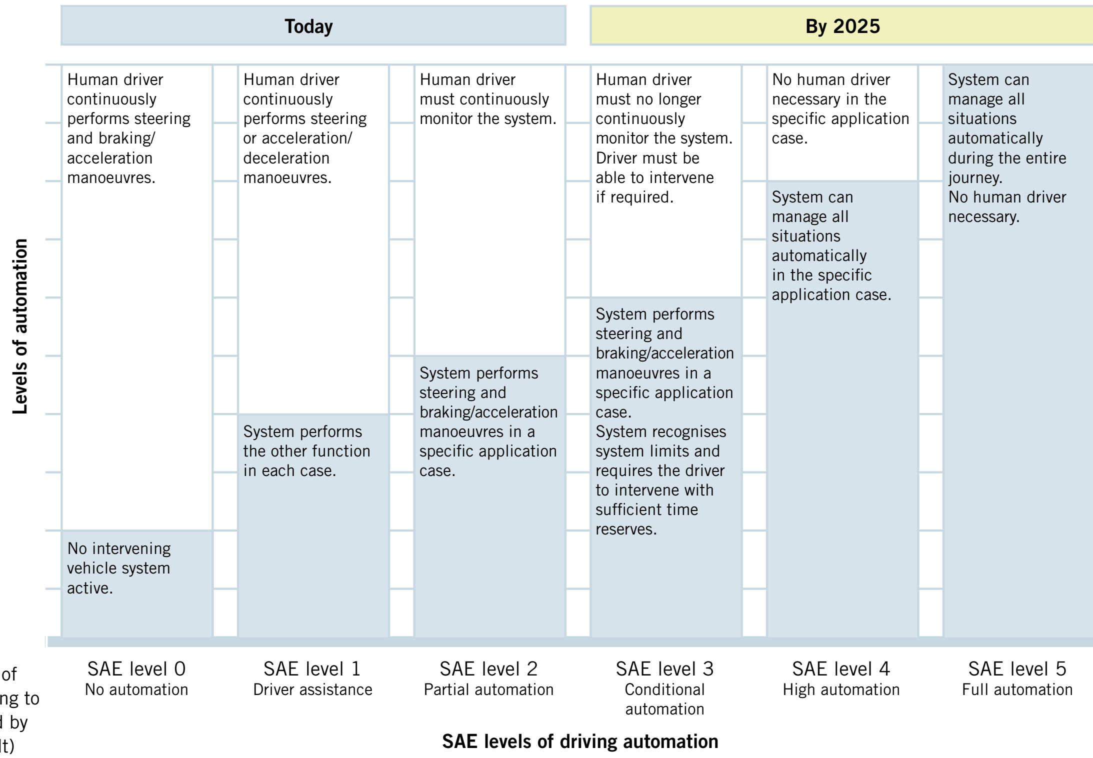


**FIGURE 3** SAE levels 0 to 5 of driving automation according to SAE J3016 [3] – today and by the year 2025 (© Bertrandt)

protection as today. In other words, one will continue to need all of the components and none of them can be eliminated. At least as long as there is a mix of fully automated and conventional vehicles sharing the roads.

Car manufacturers and supplier industry are expecting fully automated vehicles to be introduced from 2025, **FIGURE 3** [4]. There are too many technical risks that are not yet fully manageable, even though the decisive technologies such as radar, cameras and lasers are already available today. It is continuously shown that the systems are limited – whether it is due to the influence of the weather, the lack of road markings or the unavailability of current real-time data in the vehicle to enable it to react to the situations it encounters. If one assumes a life cycle of 10 to 15 years, this means that we are unlikely to have almost completely automated traffic in highly developed countries until 2035 or 2040.

If attention is paid to the question of occupant protection and one compares the situation with the concepts already available today, the first point which has to be noticed is the potentially different location of the occupants in the vehicle, **FIGURE 4**. The automotive industry is assuming that vehicle occupants will have maximum degrees of position freedom and that the seats will therefore have every possible rotation around the z-axis. This requires that the driver can be entirely released from the task of driving the vehicle. This will result in numerous challenges relating to the potentially available residual risk.

## SEATBELT ANCHOR POINTS MOVE INTO THE SEAT STRUCTURE

When the new concepts are compared to a conventional restraint system, the first question immediately arises: How can the seatbelt and airbags in these new versions follow the positions of the occupants? If it is started by considering the seatbelt, which already performs the main restraining task in today's restraint systems, there can be seen a relocation of the anchor points. At present, these are usually mounted directly to the body-in-white at predefined points on the body shell, often in the area of the B-pillar and the vehicle floor.

Coupled with the demand for a greater degree of freedom, the anchor points for the seatbelt will more and more be relocated into the structure of the seat itself. This will mean that, with safety requirements similar to those of today, the strength of the seat structure must be increased to ensure that it can safely absorb the forces being applied. Here too, the coupling of the occupants to the seat will continue to have the highest priority. One issue will definitely be the question of whether the three-point seatbelt system in use today will still be sufficient or whether it will be necessary to convert to a four-point system – in particular for the front seats, which may now also be used in a rear-facing direction.

## SEATS BECOME MORE RELEVANT FOR OCCUPANT PROTECTION

The task of occupant protection will now be shifted entirely to the seat. Therefore, the seat will need to completely accommodate both the coupling of the occupants and the necessary dissipation of energy.

Today's generation of airbag systems will become less important, as it will no longer be possible to apply them optimally based on interaction between the seatbelt and the airbag. The occupants' degrees of freedom will be too great, which means that the deployment of a sufficiently large airbag system will represent a not inconsiderable risk.

Additional systems based on today's airbag technology – such as small airbag modules to limit crash-related occupant kinematics or to provide additional energy dissipation at the occupant – may become necessary, but they must be installed in additional spaces such as the roof liner or, due to the variable requirements, also in the seat or the seatbelt itself.

In turn, this will require a very extensive sensor concept for the interior and the vehicle's surroundings in order to detect the real crash situation. Detection of the occupants and the actual severity of the crash will be necessary at all times when the vehicle is in use. Detecting the crash severity should not be a particularly great technical challenge, as fully automated vehicles will already be fitted with a large number of environmental sensors for the driving process itself. By contrast, an occupant detection system must be able to safely classify the entire interior and to evaluate the position of the individual occupants relative to their restraint systems before a deployment decision can be taken. From today's point of view, this will mean the use of ultrasound sensors or camera systems that guarantee complete monitoring of the interior space.

## VALIDATION METHODS MUST BE FURTHER DEVELOPED

From a conventional perspective, variance in validation would also end in a large number of load cases. With regard to validation, experts are already questioning whether the methods are still up-to-date in a legislative and consumer protection environment in order to address a further increase in load cases, in particular for occupant protection. This question must be critically considered. Currently, a large number of load cases are tested on the basis of a nominal position of the occupants in a real vehicle environment in order to evaluate the protective effect. Without doubt, the industry owes the successes of recent years to these tests.

However, if the increase in variance is considered that results from the potentially flexible position of the occupants alone, it quickly becomes clear that these interactions cannot be completely represented. Neither the testing technology nor the dummy world is prepared for a large number of possible out-of-position combinations.

It is currently possible to robustly represent static occupant positions. But even in the dummy world, it is difficult with current models to clearly demonstrate the beneficial value of safety functionalities. The injury risk functions that are currently used for evaluations result in low injury severities for the occupants on the basis of mechanically measured data from the dummy world. However, a more precise resolution of the measured data is no longer possible with these methods. In this case, the use of virtual methods may help. Even the human models available today show much greater sensitivity in evaluating interactions with high parameter variance. These methods must successively replace real tests in order to evaluate the variance of system

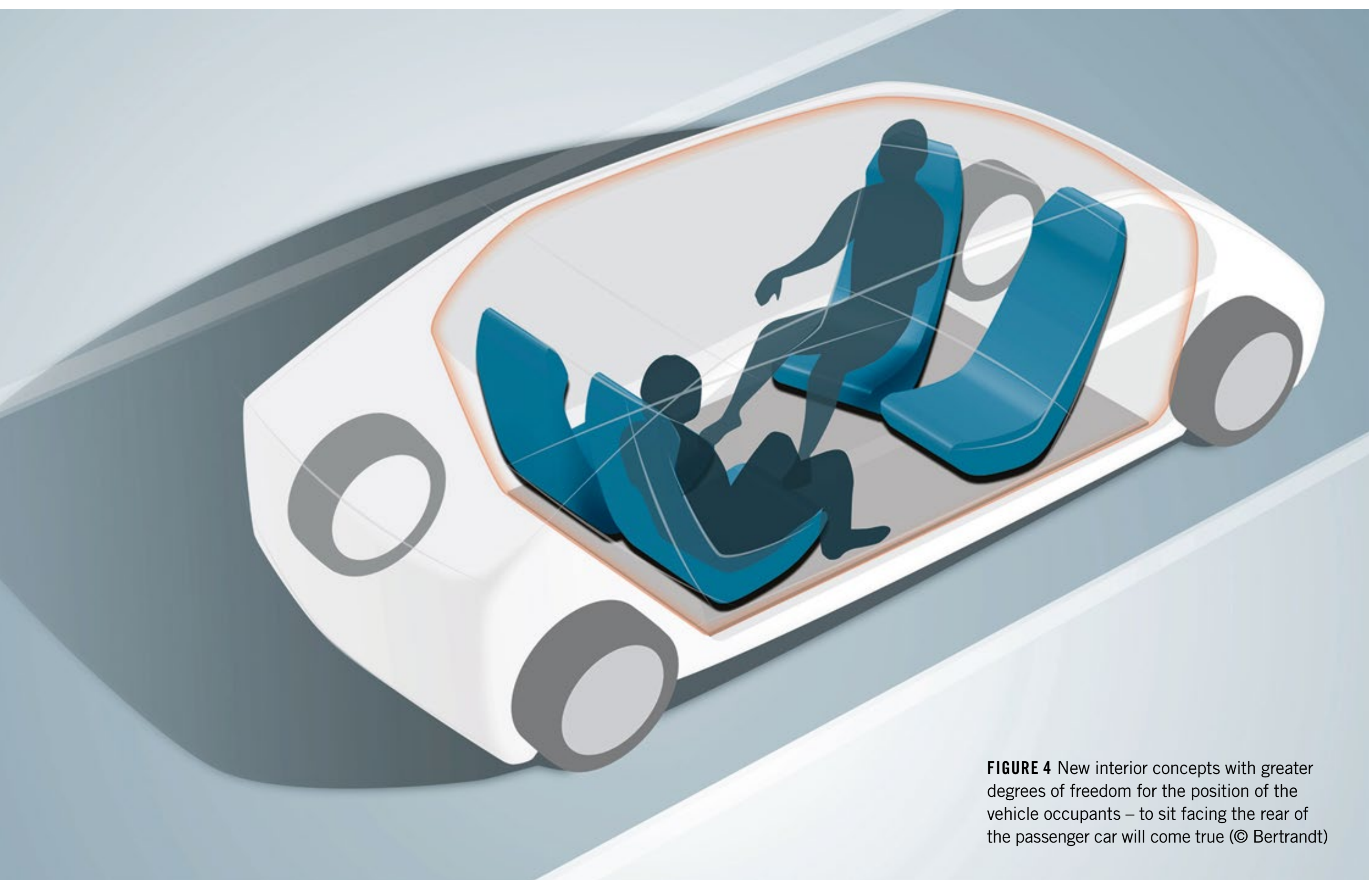

**FIGURE 4** New interior concepts with greater degrees of freedom for the position of the vehicle occupants – to sit facing the rear of the passenger car will come true (© Bertrandt)

conditions in a conventional occupant protection system.

## NEW APPROACHES INCLUDE ACCIDENT FREQUENCY AND SEVERITY

The question is whether this is a productive approach and whether one can achieve today's safety level by this means. Another approach proceeds from a completely different perspective. On the one hand, the approach must evaluate accident frequency, while on the other hand it must consider accident severity.

Even today, it can be observed that there are significant interactions between the conventional systems of the restraint system and the real accident event. If the actual design load cases are compared in the higher speed range of >50 km/h and in the nominal position with the active safety systems currently available due to ACC and emergency braking systems – which result in a lower crash velocity but also a different position of the occupants when the airbag is activated – one can see significant shifts in the injury risk. In certain marginal conditions, the airbag systems are too hard for the accident situation. If there is a greater degree of freedom, this risk will increase even further.

Parallel to this, initial studies on the effectiveness of emergency braking systems show that, for example, the risk of serious injury to occupants in vehicles equipped with an emergency braking system is reduced by more than 30 % compared to vehicles that do not have such a functionality. Other studies also show that the relative crash velocity, simply on the basis of systems available today, is already reduced by at least 20 km/h, therefore often taking it below the actual airbag deployment threshold.

Based on the assumption that both accident frequency and accident severity can be significantly reduced, it can be assumed that occupant protection can be achieved with a similar safety level to that of today simply on the basis of an optimised seatbelt system that is integrated into the seat. In addition, this approach can be supported by a corresponding adaptation of the seat geometry. Even today, experts are already tentatively talking about a future survival space. If this restraint is effectively controlled by the seatbelt/seat system, one can nevertheless consider additional restraint of the head/neck area.

This once again leads to a discussion of airbag systems that are integrated into the seat or the roof and surround the head area. In these solutions, the focus is on the displacement of the head and neck area relative to the upper body. A corresponding side support of the head to counteract excessive rotation may also be necessary. In most cases, this is a question of reducing the severity of the accident for the occupants, but no longer of ensuring their survival. For that, the reduced severity of the crash alone is sufficient. And this can be robustly achieved in the event of automated driving.

## CONCLUSION: NOT COMPLETELY NEW, BUT DIFFERENTLY APPLIED

In conclusion, one can say that restraint systems will in future not necessarily be new but will be designed for different application scenarios and under different assumptions. The systems available today will be retained as such, but they will be applied differently and their dimensions will be reduced. The transition period from individual means of transport to fully automated road traffic will result in a conventional realignment. Today's protection objectives must still continue in parallel for some years. All in all, the benefits of accident-avoiding systems by far outweigh the risks of current technologies in so-called out-of-position deployment in the effective range of the occupants. The roadmap has now been prepared and Vision Zero is one step closer.

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