Requirements and Design of a New Vehicle Test Center for Physical Testing of Integrated Safety Systems

Prof. Dr.-Ing. Rodolfo Schöneburg

Prof. Dipl.-Ing Norbert Schaub

Dipl.-Ing. Helmut Ruoff

Dipl.-Ing. Matthias Struck

DAIMLER AG
Mercedes-Benz Cars Development
Germany

Paper Number 17-0221

ABSTRACT

This paper describes the new Technology Center for Vehicle Safety (TFS) at the Mercedes-Benz R&D location in Sindelfingen (Germany). The new crash test site was inaugurated in November 2016, replacing the former building from 1973. It is equipped with crash test areas, sled test facilities, and test rigs for component testing.

In order to design the new facility, requirements resulting from future regulations, internal test modes, and rating tests were analyzed. A special focus was set on the simulation of real life crash scenarios, such as vehicle to vehicle collisions under different angles. Those configurations had a major influence on the layout.

The dimensions of the building were defined by the maximum weight of test vehicles, the maximum desired speed, as well as the space requirements for a head-on collision with two moving vehicles. Therefore, the longest crash track measures around 245m (800ft) resulting in a building length of 279m (915ft). A large 90m x 90m (295ft x 295ft) indoor area without any pillars supplements the crash track to provide the required space for multiple moving test objects.

In order to get the necessary capacity of up to 900 full scale crash tests and more than 1,700 sled tests per year, it was necessary to implement additional test tracks inside the building. The final layout comprises three test tracks plus the angled test area in a highly configurable setup. Due to the space restrictions in the Sindelfingen plant, the tracks were positioned in a way that the ground space needed for the building was minimized without compromises in the performance of the crash facility. The maximum width of the TFS could be limited to 170m (560ft), resulting in a gross story area of 58.260m² (627,000ft²).

With the new building, the entire process from the test object entering the building, the preparation, the testing and the post processing was revised for highest efficiency. All steps can be done paperless with a high amount of automation. New three dimensional photogrammetric measurement techniques were implemented using an automatic laser surface scanning device while the vehicle is standing on a turntable. With that technology, deformation data from the crash can be directly processed in common CAE tools.

With respect to future drivetrain technologies, a highly sophisticated fire and explosion protection system was developed. Alternative drivetrains may include lithium ion batteries and/or for instance hydrogen or other gas tanks. The requirement was to provide a safety concept enabling full scale crash testing with fully loaded batteries or gas tanks.

Another field of innovation was the testing of higher vehicle automation systems and their sensing technology. The building should allow the assessment of interactions between active safety systems and new enhanced pre-crash systems, such as pre-deploying restraint components.

For this purpose, the TFS will allow fully programmable vehicle motion inside the crash hall. Specifically, the vehicle can move without a towing cable. With that technology, the test lab is designed to conduct full scale vehicle testing including the assessment of future crash avoidance/mitigation systems.

RESEARCH QUESTION / OBJECTIVES

Mercedes-Benz has a long tradition in vehicle safety development. The first crash test in the history of Mercedes-Benz took place on September 10, 1959, on open ground close to the plant in Sindelfingen, with a test car being driven head-on into a solid obstacle, *figure 1*.

figure 1: In the late 1950s, vehicle crash testing was conducted using a rocket propelled by hot steam [Daimler archive]

This opened a new chapter in safety research at Mercedes-Benz. It made it possible to study the crash behavior of vehicles and its occupants under realistic conditions using test cars and dummies.

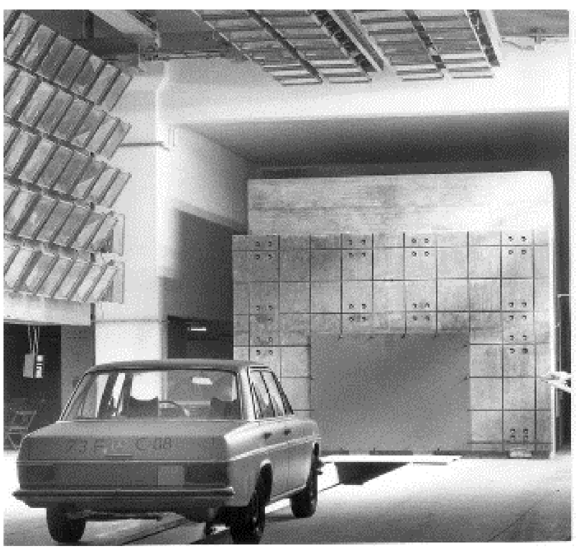

figure 2: The first indoor crash test facility in Sindelfingen opened in 1973 [Daimler archive]

Already then, the company's crash tests exceeded the legally required tests in amount and complexity. The current development program for new ready-to-produce models comprises around 15,000 realistic crash test simulations and roughly 150 crash tests. These include not just the approximately 40 different impact configurations required for ratings and worldwide vehicle homologation, but also special crash tests such as the roof-drop test that are additionally carried out. The thorough crash testing regime at Mercedes-Benz covers not just cars, but also vans, heavy-duty commercial vehicles and buses.

figure 3: 1980: S-Class W126 in a full frontal crash test in the Sindelfingen crash test facility [Daimler archive]

In1998, the crash test facility was revised and equipped with the latest measurement technology, introducing newly available digital camera systems.

figure 4: 1998-2016: Crash testing in the improved crash test facility [Daimler archive]

However, only approximately ten years after the revision, it became obvious that further improvements would be necessary to prepare for upcoming demands. Vehicle to vehicle testing started to get more and more relevant to study realistic accident scenarios. The layout of the 1973 crash hall did not take into account the additional space requirements for angular testing, for instance. In addition to that, the Mercedes-Benz product portfolio increased dramatically, requiring a higher number of crash test. That was the time when the idea of a new test center was born, giving the opportunity to rethink the entire process chain from preparing the vehicle up the conducting and post processing tests.

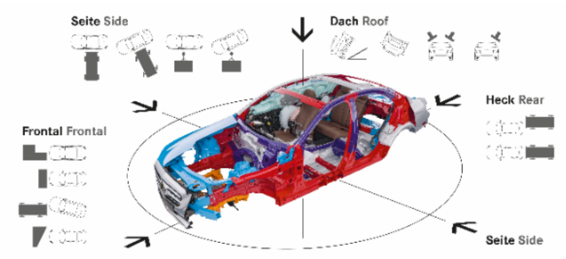

figure 5: A vehicle has to withstand multiple test modes [Daimler]

The main objective was to design a new crash test facility that would be able to cope with the demands of future ground vehicle testing, including possible interactions between active and passive safety systems. The layout of the new site had to be suitable for the next couple of decades. Therefore, many aspects from current testing requirements up to new future regulations had to be taken into account.

PLANNING THE TECHNOLOGY CENTER

After it was clear that the complexity of this project was too high to be managed by only one external company, a project management team was implemented. Daimler took the lead, supported by numerous external companies. Two major suppliers were chosen, one for the building and the other for the main technical testing equipment. The project team consisted of around 500 people.

figure 6: Start of construction, April 2014

The building planning included the following phases:

1. First draft layout
2. Competition for the architecture
3. Improvement of the concepts
4. Technical Specifications / Innovations for Testing Technology inside the building
5. Conzept freeze
6. Detailed planning
7. Setup of the building and the test facilites
8. Start of testing

In order to design the new test facility, requirements resulting from future regulations, internal test modes, and rating tests were analyzed. The goal was to create a test facility that can simulate realistic accident scenarios in addition to standardized testing.

THE INTEGRAL SAFETY CONCEPT

The Integral Safety Concept from Mercedes-Benz describes safety as part of four phases, figure 7. The new test facility was designed in a way that all phases of the Integral Safety Concept can be tested inside the building. This means that accident scenarios can be reproduced in a very realistic way.

figure 7: The Integral Safety Concept [Daimler]

Phase 1 "safe driving": Providing a safe driving environment helps to reduce the risk to get into an accident. Systems under this category include, for instance, enhanced lighting systems, drowsiness detection technology that is able to alert the driver before his or her state gets critical, and comfort features of advanced driver assistance systems (ADAS). As a prerequisite for driving a vehicle inside the crash hall, sufficient space was necessary. To achieve this, the open space for angular crash testing was equipped with a highly flexible on-floor propulsion system for crash tests that will only be mounted temporarily when needed. If it is not needed, the perfectly flat surface can be used for driving tests. Furthermore, the friction coefficient and the surface characteristics were tailored to normal conditions on typical roads.

Phase 2 "in a critical situation": When a critical situation occurs, the vehicle systems can warn the driver to react, for instance with a forward collision warning. If the driver reacts, the vehicle can assist and even prepare for a possible crash with PRE-SAFE® measures, such as activating the reversible electrical pretensioners of the motorized seat belts. If the driver fails to react, certain crash preventions systems can mitigate or even avoid the crash. The new facility is prepared to assess the performance of pre-crash restraint systems while the vehicle performs an autonomous emergency braking (AEB) or an evasive maneuver.

Phase 3 "during a crash": The classical field of passive safety deals with reducing the consequences of a crash, mainly for the occupant. For that purpose, the new TFS is equipped with
- a sled test area with four sled test facilities
- four main tracks for indoor crash testing
- angular track: a wide indoor area for multiple purposes, including vehicle to vehicle tests under adjustable angles

Further detail will be discussed in a later section of this paper.

Phase 4 "after a crash": The time directly after a crash is valuable for the occupant as well. Post-crash measures such as automatic emergency call and other systems can also be tested inside the facility. For specific market requirements, a fully operable foreign cell phone network can be temporarily installed under supervision of the appropriate authorities. Systems in this category can also activate the hazard warning lights, ventilate the interior, and even provide the rescue teams with important information about the vehicle systems.

CRASH TEST AREA

Crash testing is the main purpose of the new Technology Center for Vehicle Safety. The flexible and efficient crash facility concept in the new building not only allows for classic crash tests, but also provides the opportunity for completely new test configurations: vehicle-to-vehicle (Car2Car) collisions from all angles, the evaluation of PRE-SAFE® features, automated driving maneuvers with a subsequent crash, and even crash tests with heavy duty trucks and buses. All in all, around 70 different crash test configurations are possible.

The crash area consists of four main tracks and the angular track, which was built as a huge unobstructed open space inside the hall without any pillars to serve for vehicle-to-vehicle crash testing under adjustable angles.

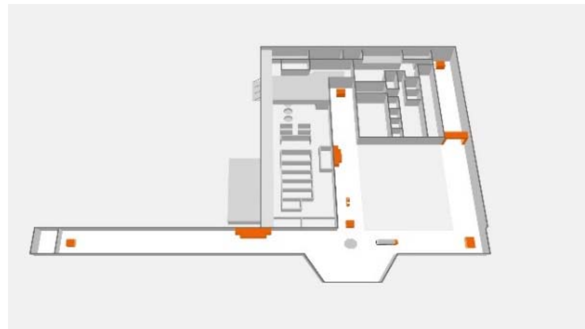

figure 8: Layout plan [Daimler]

The technology center for vehicle safety provides sufficient space and many innovations for future requirements.

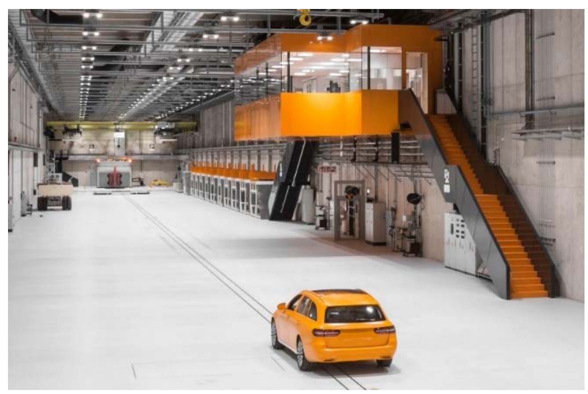

figure 9: crash track [Daimler]

The new facility allows for parallel testing on up to five tracks with a wide variety of test modes, including for instance:

- standard crash configurations (frontal, lateral/pole, rear impact)
- NHTSA oblique and equivalent
- Euro NCAP 2020 test configurations
- Rollover (new: using an embarkment ramp for ERA Glonas testing)
- heavy duty truck and bus testing on a rigid barrier or on a newly designed trailer barrier
- car2Car impact configurations with vehicles moving at different speeds and a fully configurable impact angle. The bullit

car typically starts in the large open space area, whereas the target starts on track 1
- special test modes for future vehicle concepts/alternative propulsion vehicles
- new test configurations to assess the safety benefit of future safety innovations

figure 10: examples for test configurations

There are five crash blocks, one of which is flexibly movable using an electric built-in drivetrain and another one that can be rotated around its vertical axis. For efficient operation, these two crash blocks are preconfigured with a different barrier on each of the four sides. Preprogrammed automated positioning of the new LED-lighting systems and new high speed cameras also make testing more efficient than before. Approximately 900 crash tests can be carried out each year, thanks to the new operating concept and the flexible system layout.

SUPPORTING SERVICES

All service areas are located around the test tracks in order to support efficient and safe testing.

Services include
- anthropomorphic test device certification area
- automated 3D-measuring rigs
- workshop areas
- emergency response equipment
- office space

The dummy laboratory is prepared to certify all types of anthropomorphic test devices, including the new THOR dummy. Modern In-Dummy measurement equipment is used for more efficient processes. The staff of the dummy laboratory is also responsible for the final positioning inside the crash vehicle.

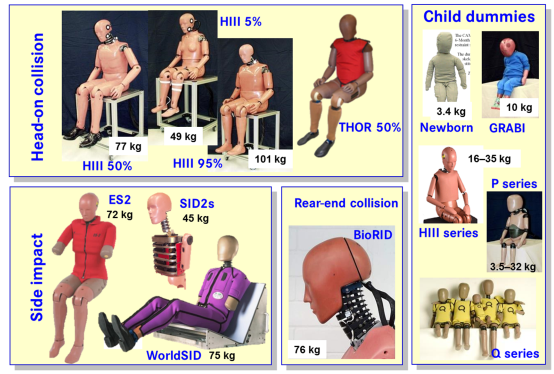

figure 11: dummy family [Daimler]

Depending on the crash mode and the nature of the test, different types of 3D-measurement tools are available. Figure 12 shows a spot measurement rig. For larger surface scans, the object can be mounted on a turntable and be scanned automatically using a laser tracker device.

figure 12: 3D spot measurement [Daimler]

The dimensions and location of the workshop areas were defined to serve the pre- and the post processing needs for the necessary amount of tests. Once again, to reduce the necessary ground space, the workshop was planned on different levels inside the building. Each vehicle follows a defined routine before a crash can be conducted.

The new facility is prepared for all kinds of future drivetrains. Consequently, new hazards may arise from vehicles with new battery technology, hydrogen or other gas tanks, and of course gas and diesel fuel. A lot of innovations were necessary to get official approval for those kind of tests from the appropriate authorities

Special emergency response equipment was developed to allow for efficient and safe testing. For instance, a special robot can be used to measure the concentration of certain gases if necessary, figure 13. The robot can also be equipped with a infrared camera.

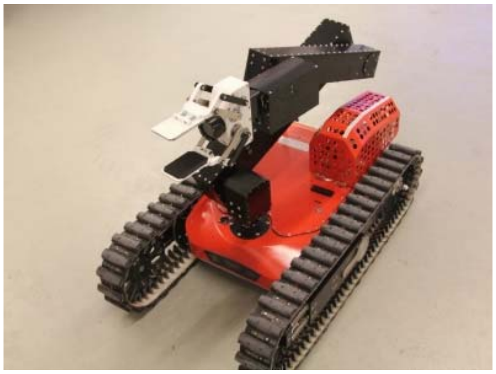

figure 13: exploration robot

Here is a list of measures to ensure safe testing:

- Conventional fire extinguisher at every crash location
- CO2 extinguishing systems at every crash location
- Smoke extraction flaps
- Gate and door concept for fire and explosion protection
- Depressurization openings for explosion protection in combination with a highly pressure-resistant building structure
- Jet nozzles at exposed crash points for extreme air mixtures to inhibit the formation of explosive mixtures of gasoline, hydrogen, etc.
- Remote-controlled measurement robots for safe detection of possible hazards
- Tailored telescopic Manitou loader for removing damaged cars
- Water basins for damaged vehicles containing Li-ion batteries
- High-voltage garages for safe, supervised storage of HV crash vehicles after crash testing

Further precautions include special handling and storage procedures for vehicles with fully loaded energy capacities. For that purpose, separate individual storage areas are included with direct access for fire response services from the outside of the building.

SLED TEST AREA

Four sled test facilities are situated in the TFS. The combination sled comprises two sleds which are used for acceleration testing (typical application: Whiplash testing) or component testing (typical application: destroying tests). The hydraulic crash sled is made for higher pulses such as in a severe frontal impact. The hydro brake is permanently installed on a crash track. However, it can be removed if further capacity for full scale vehicle testing is needed.

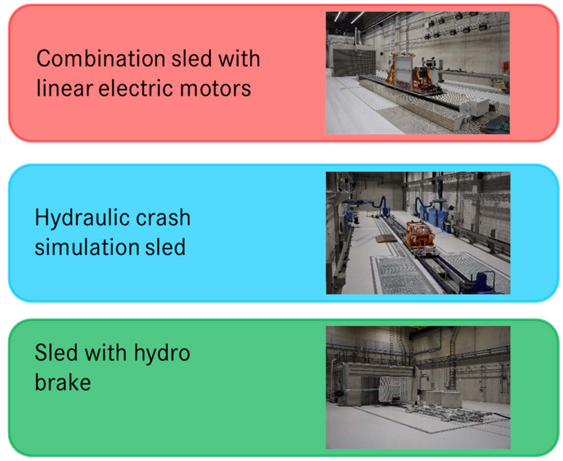

figure 14: sled test facilites

Figure 15 illustrates in a qualitative diagram the use cases for the different sled test facilites.

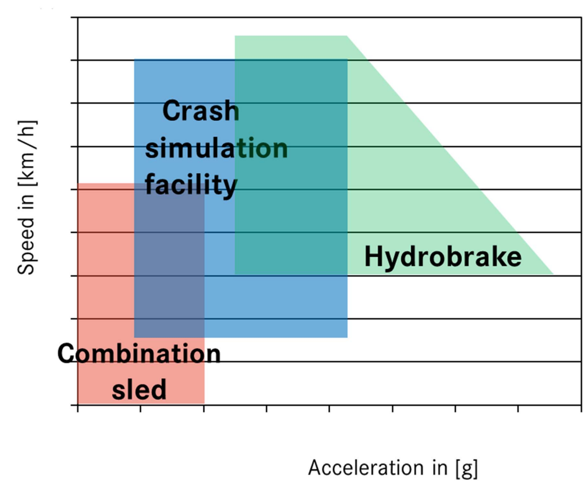

figure 15: acceleration sled tests

DISCUSSION AND LIMITATIONS

Active and passive safety testing can only simulate specific scenarios that are most common in the field. In the new test facility, realistic driving maneuvers can be conducted as well as complex crash configurations. However, accident research will continue to be an important part of the development to reach our goal of reducing the number of traffic related fatalities and injuries.

OUTLOOK

The TFS is prepared for fully programmable longitudinal and lateral vehicle motion inside the crash hall.

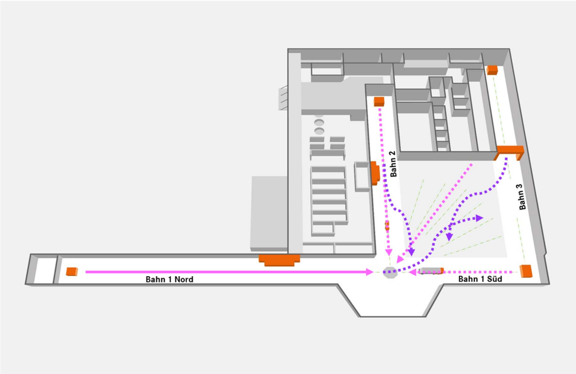

figure 16: prepared for vehicle motion without a towing cable system

Specifically, the car can be moved without a towing cable by operating the vehicle systems including steering, braking, and gas with an external controller. For that application, a special laser tracking device was installed to enable the vehicle to detect its position inside the facility. The idea is to be able to replicate even critical driving maneuvers with severe under- or oversteering before the collision.

With that technology, the test lab is designed to conduct full scale vehicle testing including the assessment of future crash avoidance/mitigation systems.

HIGHLIGHTS - TOP 10

This sections summarizes some of the most important highlights of the Mercedes-Benz Technology Center of Vehicle Safety in Sindelfingen.

- Highly flexible and efficient crash track concept
- Independent and simultaneous operation of all test tracks
- Unobstructed 90m x 90m area to enable testing of pre-crash scenarios
- Movable impact block for variable positioning
- Fully automated LED crash test illumination system
- 3D-measurement on turntable platforms for laser scanning
- Sled test facility with four specialized test areas
- Use of modern In-Dummy measuring technology
- Rollover tests using an embankment or rollover ramp
- Heating and cooling is using waste heat from the adjacent wind tunnel

CONCLUSION

Full scale vehicle testing will continue to be an important part in the vehicle development process. The TFS is designed to assess systems of all phases of the Integral Safety Concept, particularly the interactions between active safety systems and new enhanced pre-crash systems, such as pre-deploying restraint components and more.

However, with changing mobility demands, the trend towards higher vehicle automation and alternative propulsion, future car technology may dramatically change. With changing vehicle technology, testing methods may need to be adapted as well. Therefore, the new test lab was built to be prepared for all currently imaginable test modes.

The new Mercedes-Benz technology center for vehicle safety (TFS) is situated in Sindelfingen/Germany and started its operation in November 2016.