Daimler's New Full-Scale, High-dynamic Driving Simulator – A Technical Overview

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Abstract – Based on 25 years experience with the optimization and successful operation of driving simulators as efficient tools for the development and assessment of driver assistant and chassis system for passenger cars, trucks and busses, we have built up a new driving simulator center at Daimler´s main research and development location in Sindelfingen. Beside three fixed-based simulators and a ride simulator a completely new designed high dynamic moving-base simulator was constructed. The new driving simulator center was taken into operation in the first half of 2010 and will be officially opened end of September. This paper gives an overview of the hard- and software components as well as of the performance of the new simulators.

Introduction

Driving simulators are intensively used since several years for the development of driver assistant systems (see e.g. [1,2,3]) and several research institutes and car manufactures have built up new simulator facilities lately (see e.g. [4,5,6]).

Since the first publishing of our moving-base driving simulators in 1985 [7], we have permanently improved and modified the motion system, as shown in Fig. 1.

The driving simulator first was based on a hydraulic hexapod motion system only, which was enhanced by an additional lateral hydraulic cylinder and a lateral rail system of 5.6 m length in 1994 [8]. In 2004 a further soft- and hardware upgrade was done. The simulator thereby more and more had improved in such a way, that it became an accepted efficient tool for drive dynamic assessments of digital prototypes [9]. But the Berlin simulator still has the limitation that typical drive dynamic maneuvers have to be scaled to about 70 % in motion range and dynamic. The hydraulic cylinder system and the aluminum dome structure are also limited to excitation well below 10 Hz.
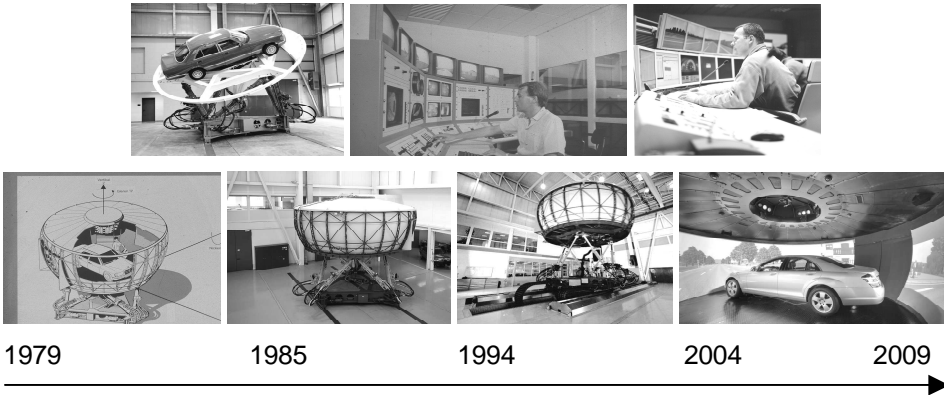
1979   1985   1994   2004   2009

Figure 1. History of Daimler´s moving-base driving simulator in Berlin

To improve the performance of our driving simulator further and to reach the future needs of our car and truck development departments, we started a research and development project to analyze various technologies and possible solutions to realize moving base driving simulators. As a result of this project we built up the driving simulator facility described in the following.

Driving Simulator Center

Due to the fact that driving simulators are used within the vehicle development process for a variety of applications – e.g. from simple use studies of control buttons to benefit studies of complex driver assistance systems or drive dynamic assessments - we first had to decide how many (different) driving simulators are necessary and cost efficient. Of course from a basic scientific or technical perspective a simulator with a real car cabin, a photorealistic 360° projection system and a motion system "as big and as dynamic as possible" or in other words a large moving-base simulator on a large x-y-sledge with an additional heave and all rotary degrees of freedom would be the best choice, because it could be used for all possible applications. But such an all-in-one device suitable for every purpose is technically not feasible and by far not cost efficient.

Therefore we

– consequently extrapolated our simulator strategy [1] and decided to build up a simulator center with simulators of different complexity, based - as far as possible - on a common hard- and software structure.
– carefully evaluated the real needs for a motion platform in terms of cost and benefits (see section Motion System).

As shown in Fig. 2, a moving-base handling simulator with a 360° projection, a fixed based simulator with a cylindrical 210 ° fron t projection and a flat rear projection, two fixed based simulators with flat front projections and a ride simulator are located in the new driving simulator center building. Additionally some further specialized labs within the Mercedes development center are connected to the facility.
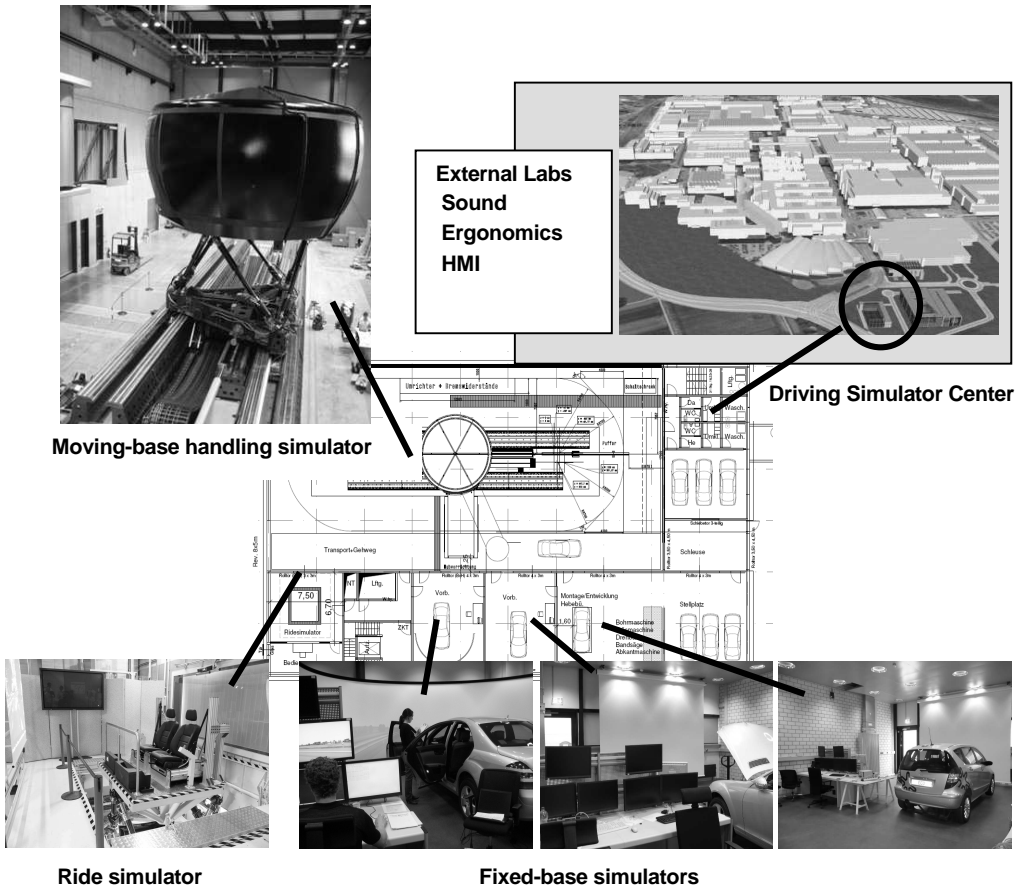

External Labs
Sound
Ergonomics
HMI

Driving Simulator Center

Moving-base handling simulator

Ride simulator   **Fixed-base simulators**

**Figure 2. Schematic of Daimler´s new driving simulator center
in Sindelfingen**

Common Simulator Hard- and Software

All driving simulators, except the ride simulator (which is only a comfort shaker without a driver in the loop) are based on the same simulation hard- and software platform as depicted in Figure 3.

As simulation servers we use iHawk 862 G servers with 2 Intel X 5482 Quadcore CPUs, one for each simulator, in sum 10 servers. As real-time operating system ReadHawk Linux is used.

In the past several years, IG technology has undergone significant changes. What was once only possible on large-chassis, special purpose computers, has become increasingly possible on commodity PC's. For our new simulator center, we recognized the need to move to a system non-reliant on special purpose modifications to drivers provided by chip manufactures. Therefore we use commercial-off-the-shelf Intel X 5570 Quadcore CPU with ATI FirePro 8750 Graphics board, one for each graphics channel, in sum 28 Image Generators.
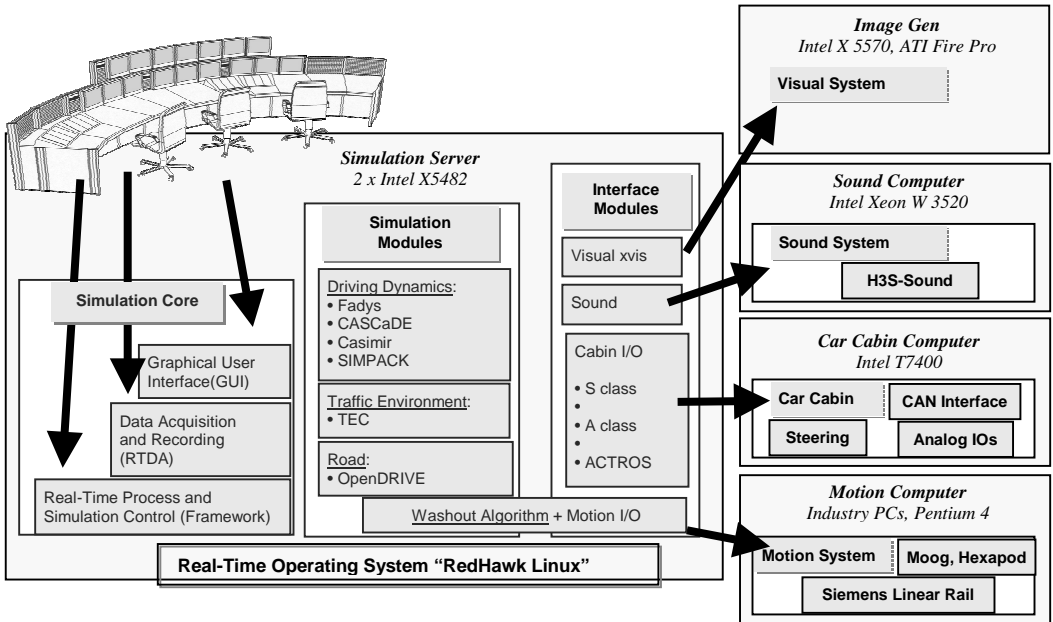
Figure 3. Schematic of hard- and software structure

The general software structure already used and optimized for our previous simulators is unchanged and we still use most of the simulation modules, namely the simulation core modules, the drive dynamics modules, OpenDRIVE [10] as road description and the H3S Sound System from Head Acoustics.

Only two new software developments were started, purchased and implemented: a new traffic and experiment control software and a new visual software.

Traffic and Experiment Control Software TEC

Our in-house developed and for many years successfully used experiment control and traffic simulation software MASTER was originally designed for simulator specialists as users. Additionally it has reached its performance limits, especially considering the realization of autonomous traffic on road networks or inner-city traffic. Therefore we decided to order completely new TEC software from Realtime Technology Inc. based on their existing SimVista Product line [11] and considering our experience with the MASTER software. The interface between TEC and the visual and road modules is realized via OpenFlight and OpenDrive respectively.

The new TEC software allows e.g. the generation of autonomous and deterministic traffic consisting of different kind of vehicles (cars, trucks, bicycles,..), control of all vehicle lights, selection of driver characteristics for the autonomous traffic, placement of obstacles on the road, generation and control of pedestrians, moving objects, traffic signs and traffic lights, chose of environmental conditions like fog or rain and many more. An example of inner-city traffic is shown in Figure 4.

A graphical user interface (GUI) allows controlling and monitoring the TEC-Modules also for e.g. simulator operators or experiment designers without very deep knowledge of the TEC module software itself.

Figure 4. Example of inner-city traffic generated with TEC

Visual Software Pixel Transit

We also implemented a new state-of-the art visual software, Pixel Transit [12] from BlueNewt Software LLC, to enhance the realism of the simulation.

Key features from the user perspective include:

– Dynamic Lighting
– Dynamic Shadows
– High Dynamic Range
– Diffuse, Bump, and Gloss-mapped Objects

With these key features, the implementation of visual system effects associated with realistic driving environments including

– Projected Custom Headlamps
– Articulated Illumination Model (blinkers, brakes, etc)
– Weather Effects (scattered sky attenuation, correct solar/lunar illumination, clouds, rain, snow, layered fog)
– Dynamic Vegetation
– Pedestrians

is realized.

The system software renders the scenes at no less than 60 frames per second without any distracting visible artifacts. This is achieved using Daimler´s already existing datasets and the above mentioned commercial-off-the-shelf PC's and graphics hardware. Examples of sceneries generated with Pixel Transit are shown in Fig. 5.

Figure 5. Example of shadows and brake light generated with Pixel Transit

Projection systems

The outputs of the image generators are connected via fibre optic dvi links to the video projectors.

For the fixed base simulators we use Viscon projection systems with Canon WUX10 projectors. One simulator is equipped with three front projectors using a cylindrical 210° front screen of 3 m radius and one rear projector. The other fixed-base simulators only have a single channel flat front projection.

The inner surface of the moving-base simulator dome is high gain coated (gain 2.5) and is used as 360° screen, illuminated by a Barco projection system based on 8 Sim7 LCOS projectors.

The exterior mirrors of the simulator car cabins are replaced by LCD displays and the mirror images are displayed directly on these displays.

Motion System

For an optimal and cost efficient design of the motion system we first analyzed the requirements coming from the two main application fields for our moving-base simulator: drive dynamic assessment with expert drivers and driver assistant system evaluation and development with the help of ordinary drivers.

For drive dynamic assessment a very realistic motion simulation without any scaling for e.g. slalom or lane change maneuvers is desirable, resulting in a necessary lateral moving space of about +/- 4 m, lateral acceleration dynamics of 1 g, roll and yaw angles of about 5° and 30°, respe ctively and a very high motion smoothness.

For experiments with ordinary drivers, motion is only one important topic out of many others (e.g. visual system, sound, realistic car cabin) to dupe a realistic driving feeling. For most of the application, experiments and studies the "old Berlin motion platform" without a linear motion space in longitudinal direction was sufficient both to generate a realistic driving feeling and to achieve an extremely low simulator sickness rate of only 2 % in the last years [13]. To induce a much better longitudinal motion sensation with a scaling factor close to 1:1 for all possible acceleration and deceleration scenarios even a several ten meter long sledge would not be sufficient, but would increase the technical and financial effort tremendously, especially when the above mentioned mandatory requirements for drive dynamic experiments have to be fulfilled.

Therefore we decided to stay with a hexapod platform mounted on a single 12 m long axis for linear motion. Additionally we use a quasi static 90° turn table inside the dome, which allows us to use the linear rail either for lateral (drive dynamic experiments) or longitudinal (e.g. stop and go traffic simulation) motion.

A schematic is shown in Fig. 6. With this configuration we are confident to reach nearly 90 % of the requirements needed for car and truck development with acceptable technical and financial efforts.
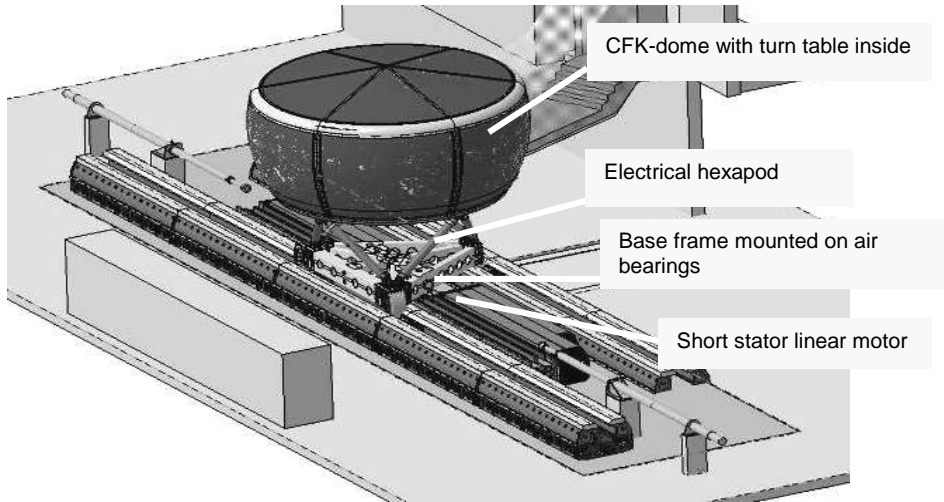
CFK-dome with turn table inside

Electrical hexapod

Base frame mounted on air bearings

Short stator linear motor

Figure 6. Schematic of motion system

All mechanical components of the motion system were specially designed and optimized [e.g. 14] together with our construction partner IMTEC GmbH "Innovative Maschinentechnik" and several specific suppliers for the various components.

Essential components and their most important typical values are

– **linear rail system:** high precision machined cast iron elements with a total lengths of 28 m,

– **air bearings** for friction less linear motion, air gap below 40 µm, air pressure below 9 bar, dynamic load bearing capacity between 200 kN and 400 kN

– **short stator linear motor** length 15.5 m, acceleration 1g, max. velocity 10 m/s, force 212 kN, scalable in length

– **electrical hexapod** actuator specs: length 1.5 m, velocity 1.25 m/s, acceleration 1 g platform moving space: + 1.4/-1.3 m longitudinal , ± 1.3 m lateral, ± 1.0 m vertical± 38 ° yaw, +24°/-19° pitch, ± 20 ° roll

– **Dom** spherical, weight and stiffness optimized CFK structure; inner diameter ca. 7.5 m, height ca. 4.5 minner surface high gain coating with gain 2.5

Summary

In summary we have installed a new driving simulator center at the main development facility of Mercedes in Sindelfingen. Within the center several fixed base simulators, a moving-base handling simulator and a ride simulator are installed, all optimized for various use cases within car and truck development.

The high dynamic motion system of the new handling simulator was especially designed to allow the usage of the simulator for a very efficient and realistic

assessment of digital chassis prototypes. In addition to the motion system we also co-developed, purchased and implemented new traffic simulation, new traffic control and new visual system software as well as new high resolution projection systems to improve the realism of the driving simulation further.

The new driving simulator center was completed in July 2010 and currently runs in test operation mode. The regular operation will start end of September.

Keyword: moving-base driving simulator, fixed-base simulator, visual system, traffic simulation, drive dynamics assessment, driver assistant systems, car development.

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