SIMULATION APPLICATIONS HELP SHAPE THE DESIGN OF CAR AUDIO SYSTEMS

Experts at HARMAN are building and distributing simulation applications to develop audio systems for cars that surpass customer expectations, improving their internal workflow in the process.

By **THOMAS FORRISTER**

TODAY'S LUXURY CAR MARKET is entering uncharted territory in its ability to meet customer preferences. Vehicles are designed to offer the ultimate driving and riding experience: massaging seats; heated steering wheels; stylish interiors; roomy cabins; and, of course, electronic entertainment. Over the past decade, the importance of the audio and multimedia system in cars has grown significantly, because the car has become an elemental component of many end consumers' lifestyles. Research suggests that the car is the number one place where people listen to music, while their expectation is to get the same high-quality listening experience they are accustomed to from their home audio system. However, designing such car audio systems presents some challenges.

From a system-engineering point of view, the various hard and soft surfaces that characterize the interior design, providing style and comfort, often interfere with sound, as reflections or sound absorption might occur. The even bigger challenge, though, is that the consumer expects new applications, new features, and new listening experiences in a car to be released in a similar frequency as that of new features becoming available for smartphones. The development cycles for consumer electronics (sometimes not even six months) are much shorter than for a car (five to six years). HARMAN International, a subsidiary of Samsung Electronics Co. Ltd, uses simulation software and builds applications that improve workflows, speed up product development, and help push the boundaries of what is possible for in-car audio technology.

➤➤ PROVIDING A PERSONALIZED IN-VEHICLE AUDIO EXPERIENCE

EVERY DAY, CONSUMERS SPEND a lot of time in their cars, commuting to work or driving around in urban areas. For many, the car is not just a means of transportation for getting from point A to B. They want to enjoy their ride to the fullest, getting a sense of freedom, adventure, and even escaping for a moment from their everyday routine.

To create this experience, a seamless integration between the consumer's devices and the vehicle is important, as well as the in-vehicle technologies. For instance, the different car displays, applications, and the audio system must work together in harmony.

"Today's consumers are demanding personalized solutions and experiences at home, on the go, and also in the car," says François Malbos, principal engineer at
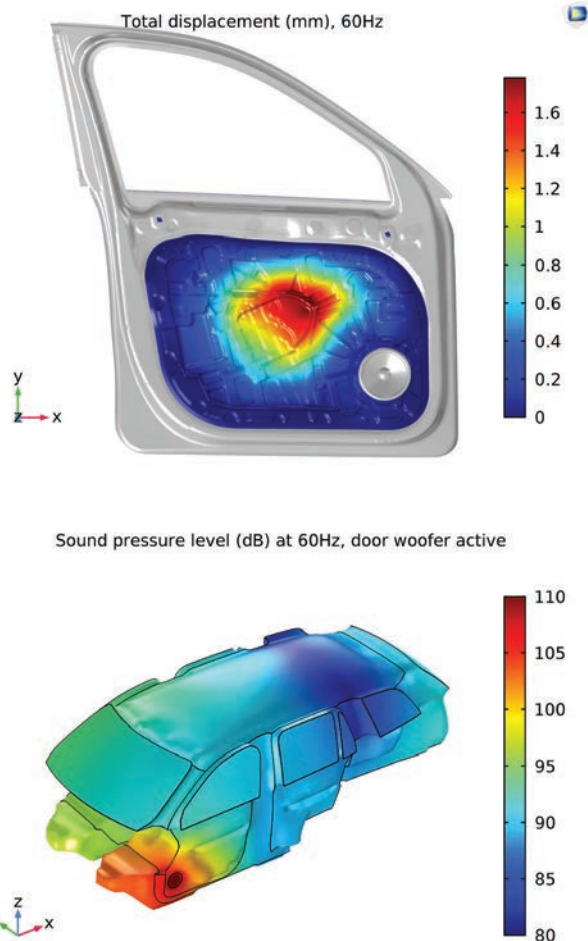

Figure 1. Top: Door stiffness analysis. Bottom: Car cabin simulation for different speaker placements.
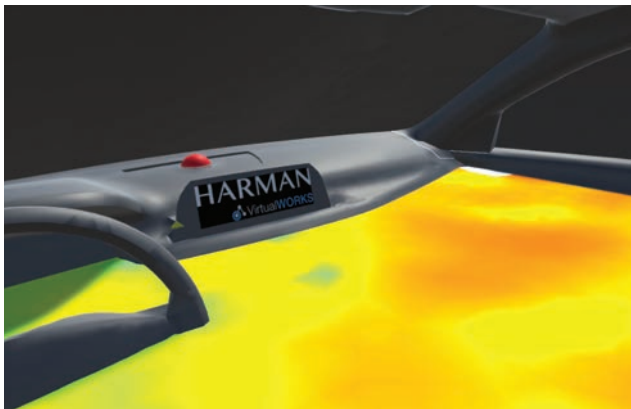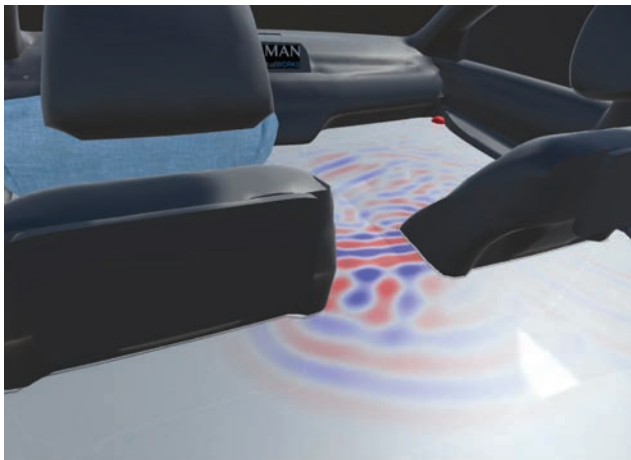
Figure 2. Acoustic sound field of the back seat (top) and right front speaker (bottom), augmented in the car environment.

HARMAN. "A luxury vehicle offers more technology, more speakers, and more sophisticated audio capabilities. On midrange vehicles, personalized features are more limited, and there might be less technology integrated. The larger and more capable the system is, the more complex and sophisticated it gets, so the interfaces must be simple and intuitive to use but also scalable."

It was not too long ago that a vehicle's value was measured by its mechanical performance and driving dynamics. With the emerging popularity of shared mobility and in-vehicle technology, value is now being measured by experience-per-mile. With more than seven decades at the forefront of introducing breakthrough developments in the audio industry, HARMAN is driving this shift to the experiences-per-mile paradigm, taking a consumer-centric approach in offering personalized audio experiences. One example is HARMAN's Virtual Venues technology, which acoustically transports the listener into world-famous music venues — concert halls, stadiums, a cozy jazz club, or a sound studio — by reproducing the sound of this

particular venue based on its acoustic fingerprint. HARMAN's Premium Communication Solutions, to name another example, leverages the latest advancements in smart audio and acoustic signal processing to personalize the sonic environment and provide clear, frustration-free communication for all vehicle occupants — whether it is with a voice assistant, someone on the other end of a phone call, or between passengers. Enhanced voice command capabilities also increase traffic safety by allowing drivers to keep their eyes on the road and their hands at the wheel when using their telephone or infotainment screens.

To balance the broad range of personalized features being built into luxury vehicles, the team of acoustics and simulation experts at HARMAN accounts for different components, acoustics, and unique configurations early on in the design system process (Figure 1). One way that these engineers "think outside the cabin" is by designing a car around the audio system, not the other way around. This helps the team adapt to customization requests at a moment's notice. There are also several factors influencing the acoustics of a car cabin; for example, the choice of trim level, which often involves changes in the interior design or different materials being used. The tuning of the system has

to compensate for such changes in the design to not compromise the sound quality. Aspects like the stiffness of a car door can change the car's acoustics, so the engineers would need to factor in extra bells and whistles.

The sensitivity of these audio system designs increases the complexity of product development, benchmarking of automotive solutions, and quality assurance processes. "Fortunately, HARMAN is uniquely poised to address these design challenges head-on. We can develop everything in house, from the initial design to the manufacturing stages, so that our systems are unique to market," says Michael Strauss, senior manager of virtual product development (VPD) at HARMAN.

To facilitate their workflow, HARMAN uses the COMSOL Multiphysics® software to accelerate design and production processes, predict and validate in-cabin test results, and ultimately enhance their designs.

›› THE ROADMAP TO ENHANCED AUDIO SYSTEMS INCLUDES SIMULATION APPLICATIONS

SIMULATION PLAYS A LARGE ROLE in product development at HARMAN, with the ultimate goal to perform fully virtual developments for transducers, packaging, car cabins, binaural playback, and more. Currently, the
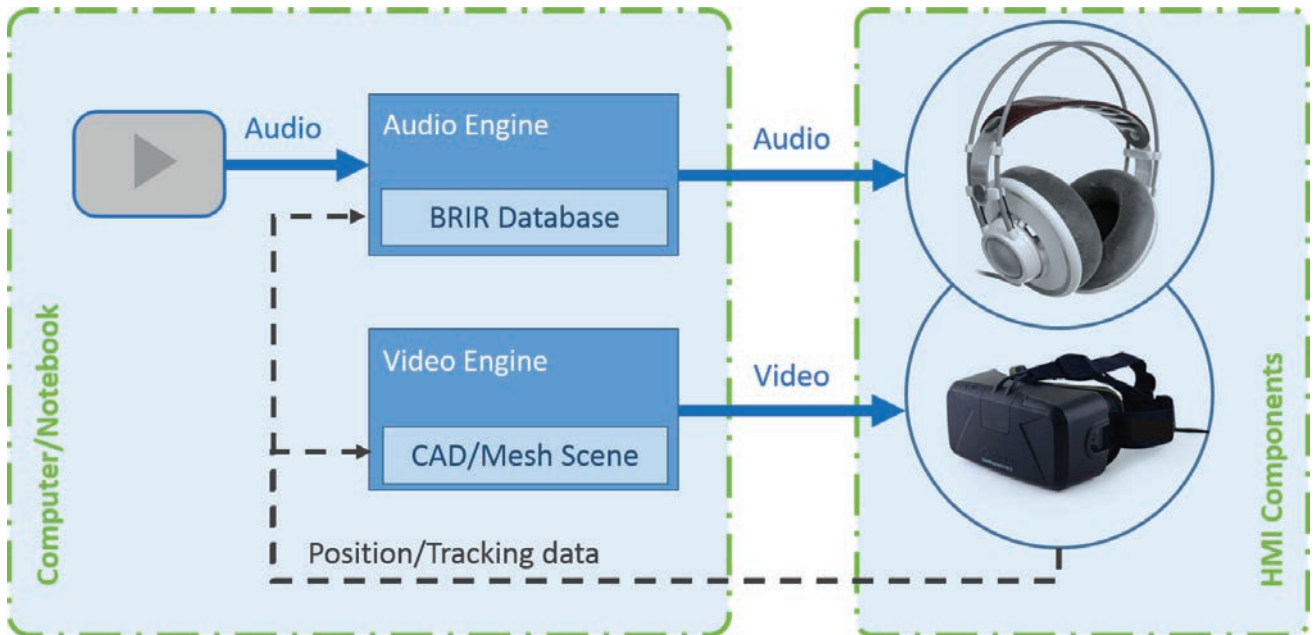
Figure 3. The VR setup at HARMAN.

VPD team combines physical experiments with numerical modeling. Moving forward, more *in situ* listening tests will be replaced with virtual tests. When virtually developing an audio system using COMSOL Multiphysics®, the HARMAN engineers can quickly make adjustments based on the different components and unique configurations of the cars being worked on. Furthermore, the results from physical car cabin tests can be compared to simulation results (Figure 2).

HARMAN has also explored ways to turn their models into digital twins and simulation applications. "All models are sensitive to changes in boundary conditions, and each simulation result is different in terms of defining interfaces between simulation and physics," says Michal Bogdanski, project leader in VPD at HARMAN. "With an app or digital twin, we do not have to worry about it as much because we can 'lock' certain boundary conditions. Those parameters are crucial for physics definitions and cannot be changed by the app user. Such an approach ensures that the results are in line with the measurements."

HARMAN simulation reference models are nowadays evaluated and proven during daily work. The VPD team established a simulation workflow to offer numerical support at any stage of a development project. With Industry 4.0 in mind, one of the objectives is to introduce simulation support and simulation applications into the legacy workflow and eventually transform it into a VPD workflow. With this application, users and simulation experts alike can work together companywide to make design changes much earlier in the process than before. To further accelerate their workflow, Malbos created a roadmap concept that helped HARMAN design a toolbox that any application user can access. This makes the use of applications better suited for long-term resource planning. "It has really improved our workflow. Not everyone can work at the same time, so the app concept helps keep track of the project status and drive it forward with the support of a global, cross-functional team," says Malbos. "Moreover, the app benefits other team members that are not necessarily fluent simulation experts," Strauss adds. "This helps in two ways, as on the one hand, the designer's workflow will become more

> " *Not everyone can work at the same time, so the app concept helps. It frees up resources so that the users have what they need and the simulation experts can focus on more advanced modeling. With apps, we can create a consolidated set of tools that is accessible to domain experts in my branch.*"
>
> **—FRANÇOIS MALBOS, SENIOR ACOUSTICS ENGINEER, HARMAN**

efficient and they will gain more insight into the product features. On the other hand, simulation experts can lift off some of their routine tasks and focus on more time- and resource-demanding projects."

The applications are constantly being improved based on feedback from the different user groups that help identify potential bugs, or make recommendations and suggestions on how they want to use the application. To provide the most value to the user groups, suggestions are discussed on a regular basis and then selected and implemented by the team.

Building trust in the capability of virtual simulations is another important part of application democratization. Each application user needs validated material parameters, accessible and high-quality data, and a balance of both innovative solutions and a quick delivery of results required for most of the processes. Furthermore, for advanced simulations, there needs to be accurate rendition and validation as well as communication so that the users understand the measurements.

"To help build trust and transparency with users, every app comes with a validation document. When you buy a pit microphone, for example, you get a sheet with specs. This validation doc is comparable to that," says Strauss. "The user can find a PDF and compare measurements with the app or twin."

Using COMSOL Server™, the VPD team put together a library of validated applications that other engineers can use to predict loudspeaker performance with a wide variety of configurations and under different conditions. The transducer engineering department at HARMAN was the first to use applications, but other departments, like acoustics engineering, became interested soon after. "Acceptance is growing," says Strauss.

Democratizing simulation via applications frees up resources — allowing the VPD team's simulation experts to focus on other projects, like virtual reality.

›› HARMAN VIRTUALWORKS MAKES WAY FOR VIRTUAL REALITY

HARMAN VIRTUALWORKS, one of HARMAN's audio development tools, has been recently expanded to include the HARMAN VirtualWORKS VR (Virtual Reality) Experience. With the interactive VR capability, customers get the same auditory experience as if they were sitting in an actual car. This is a critical advantage in the system design
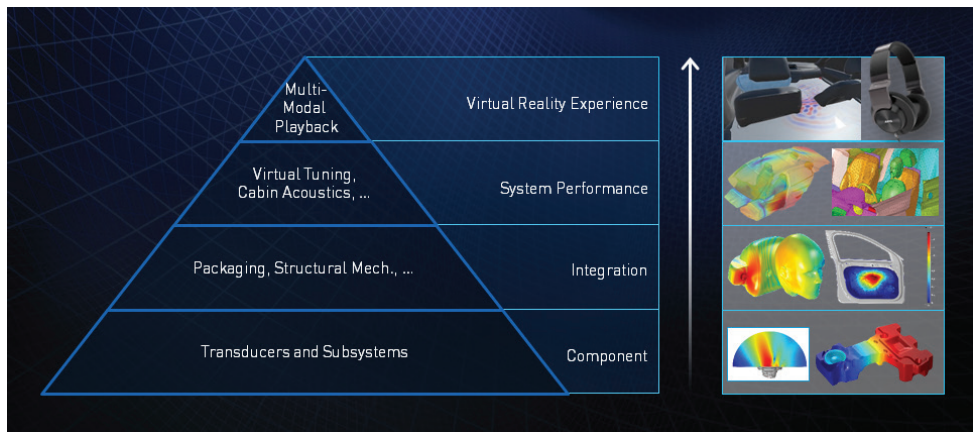

Figure 4. The numerical simulation workflow at HARMAN VirtualWORKS.

process together with the carmaker, as nonexperts could experience the performance of an audio system in a specific car without having to build a physical prototype.

"VirtualWORKS VR gives the user a chance to test the system and sound field of the cabin," says Bogdanski. "With a VR setup and glasses, customers can ride in the car and see and hear how the audio system performs. It helps, for example, OEM interior designers to understand that their idea to maybe shape the interior differently has a certain effect on the sound performance."

Strauss adds: "In particular, for the decision-making process internally but also with the OEM executives, it is sometimes hard to convince key stakeholders with numbers only. VirtualWORKS VR is a great instrument to illustrate and demo how the system would perform considering relevant factors and given a certain setup. And that is, like the apps

concept, another strong driver for achieving digital transformation of product development processes."

With the head-mounted display of the VR setup, audio cues make the listening experience visible through 3D movement and high-resolution graphics. This augmented reality gives users an in-car experience and helps them, for example, visualize the acoustic sound field of speakers for different configurations (Figures 3).

New products and technologies for luxury vehicles need to be both innovative and mature, yet they also need to keep up with the growing demand for personalization. HARMAN drives development for car audio systems forward by incorporating advanced tools into their engineering workflow that help them optimize designs (Figure 4). In the near future, they may be able to go fully virtual in their development cycle before ever building a prototype. ◎