Achieving Autonomous Driving **with Simulation & Testing**

By **Dr. Luca Castignani, Chief Autonomous Driving Strategist, MSC Software**

Self-driving is becoming more and more realistic. Every day, thousands of autonomous vehicles (Figure 1) are being tested on the roads by companies like Waymo, Cruise, Uber, Tesla, and some of those companies have accumulated millions of miles of road testing data, enhancing and validating their autonomous "brain", with the hope that in the near future, full automation can be achieved.

When the Pumpkins Take a Stroll

Today, everyone understands the importance of road testing for self-driving vehicles, and the industry is spending a fortune on it. On an average, a fully equipped autonomous vehicle can cost more than half a million dollars, so a small fleet of 20 vehicles would mean a 10-12 million dollars investment in the hardware itself, to perform the road testing for autonomous driving. However, is road testing really enough to help us reach level 5 autonomy in the foreseeable future?

To answer that question, first we need to understand: how many miles of testing is required to develop an autonomous driving system? The commonly accepted number among the industry is "one billion miles". So how many miles of road testing have we done so far? Waymo, the world's leading autonomous driving company in road testing, has accumulated an impressive 9 million miles in the past 9 years. However, even if we increase that effort by 10 fold, it would still take about 100 years for us to complete the validation of one self-driving system, if we solely rely on road testing.

As long as you only have to check a few use cases (in the range of tens), you can easily test them on real roads. However, in order to assure safety for Autonomous Vehicles, the number of conditions to

Figure 1. Autonomous Vehicle Testing Platform Developed by AutonomouStuff, Part of Hexagon

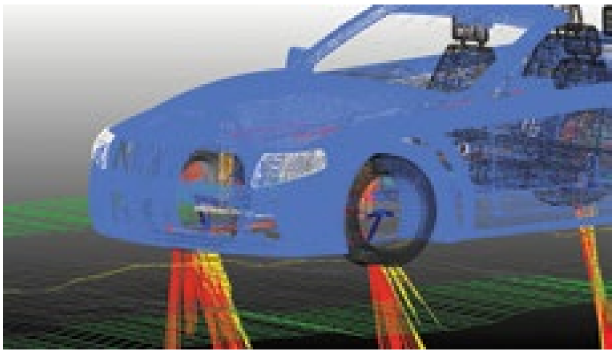

Figure 2. High-fidelity Vehicle Dynamics Model in MSC Adams, Part of Hexagon

be evaluated scales quickly to millions and there is no way to tackle it without simulations. For example: What if you want to know how the car will behave when the city decides to paint all the road signs in yellow instead of white? Or what happens when the trees planted today grow to a size that prevents the driver from seeing the pedestrians?

With simulation, it's also possible to create outlier scenarios for testing. Think of workers carrying a large mirror while crossing the street. Think of children dressed up as pumpkins, out for a walk on Halloween. Not many of these scenarios have been taken into consideration, but those are the realities.

How is Autonomous Driving Simulation Different than the Traditional Vehicle Simulation?

Computer-aided engineering (CAE) simulation has been a trusted tool leveraged by the automotive industry for dozens of years now. From vehicle handling & steering, ride & comfort (Figure 2), NVH, durability, aerodynamics, controls validation, all the way to manufacturing process simulation and advanced materials (composites) analyses, CAE companies like MSC Software (acquired by Hexagon AB in 2017) have been providing industry leading simulation solutions to help auto OEMs and suppliers refine the attributes of every newly developed vehicle model.

Engineers have been using CAE to improve the vehicle performance for a long time, so how is autonomous driving simulation (Figure 3) different than the traditional CAE simulation?

First of all, in an autonomous simulation environment, we need to capture more than the vehicle under design (the so called "Ego Vehicle"). Different types of participants need to be included in the scenario, for example, other vehicles, pedestrians, cyclists, animals (moose, deer, kangaroos) and so on.

Secondly, a realistic perception is crucial to accurate simulation. Unlike the vehicle models in a traditional CAE environment, the "Ego Vehicle" in an autonomous testing model doesn't always have a perfect understanding of its surroundings. Instead, it only knows what its sensors perceive, therefore it is important to accurately simulate those different types of sensors (cameras, RADAR, LiDARs…) and also how they function especially in adverse atmospheric conditions (sun glare, fog, snow, rain, evening light…).

These are just some examples that highlight how autonomous driving simulation is very different than a traditional CAE car simulation, and for those same reasons, not every traditional CAE solution provider is going to be a natural fit as an autonomous driving simulation partner.

Figure 3. Autonomous Driving Sensor Simulation Environment by Vires VTD (Virtual Test Drive), Part of Hexagon

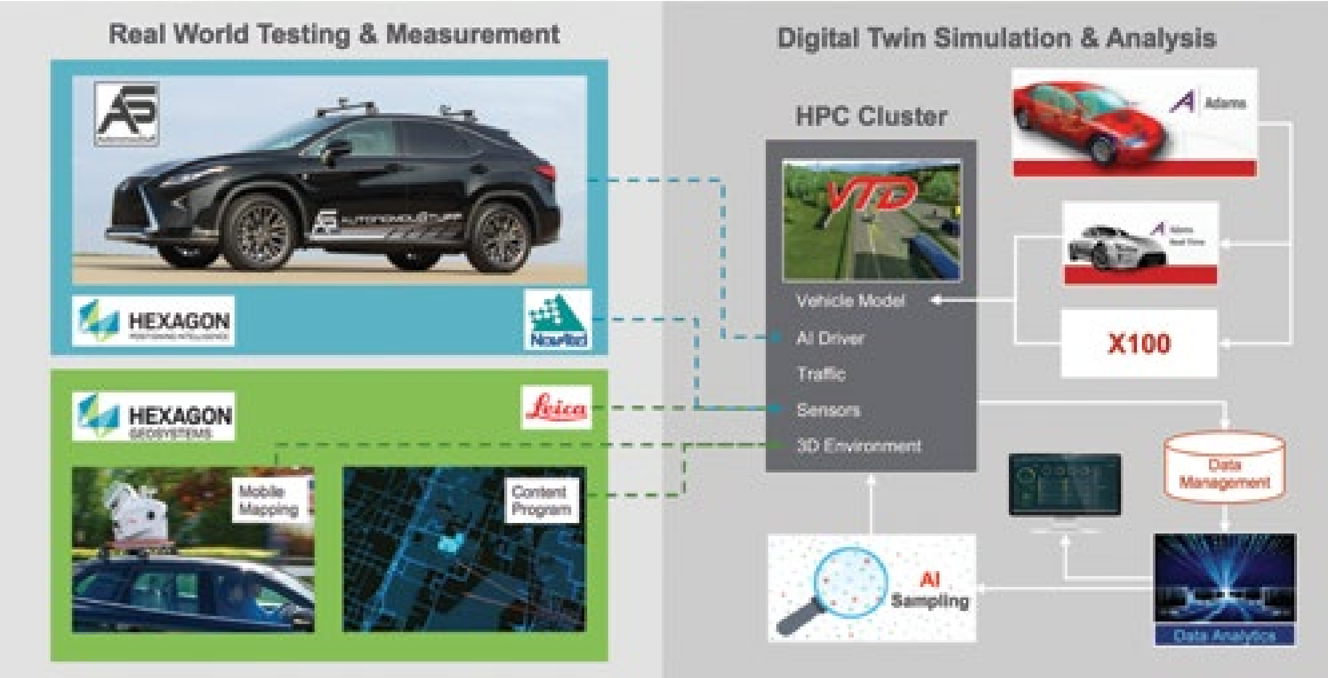

Figure 4: Hexagon's Complete Autonomous Driving Simulation & Testing Portfolio

A Comprehensive Strategy for Autonomous Driving Simulation and Testing

Through a series of acquisitions with MSC Software and VIRES VTD in 2017, AutonomouStuff in 2018, along with indigenous domain expertise in sensors, smart city and positioning intelligence solutions, Hexagon holds the leading edge in autonomous driving validation (Figure 4). This includes solutions for these domains: Vehicle CAE Modeling, Sensor Measurements and Modeling, 3D Environment modeling, Scenario Testing, Data Management, AI Driver and above all an open platform on which to integrate these.

A. Virtual Test Drive (VTD)

VTD is an open platform for creation, configuration, and animation of virtual environments for the testing and validation of Autonomous Vehicles. It acts as the coordinator for the domain segments mentioned above. It receives vehicle position and motions, rebuilds the 3D environment in real time (including traffic and pedestrians), computes the sensor perception, calculates the movements of all surrounding vehicles and so on. This stream of data can then be used to train the AI Driver at all levels (sensor fusion, object detection, path planning) or to assess its performance in terms of safety, comfort and efficiency.

B. Vehicle CAE Model

Depending on the scenario that the simulation needs to address, having vehicle models with different level of complexity can be handy. For example, for a common scenario such as emergency braking on a highway, a simplified model is preferred so a higher number of scenario permutations can be verified in a given amount of time. For a more dynamic scenario that perhaps involves a swift lane change to avoid a crash, a higher fidelity Adams Car model with a well-correlated suspension system is going to be essential. Not to mention that within an autonomous vehicle the riding comfort will become even more critical to the passengers such as to not suffer motion sickness while reading your favorite book or working with the laptop.

C. Sensors and Sensor Models

VTD has a complete set of sensors to replicate the physical sensors used in an autonomous vehicle: cameras (included infrared), LiDAR, RADAR and ultrasonic sensor. Each sensor can be represented

Figure 5. Creating Virtual 3D Environment in VTD from Metrology Road Measurements

with different levels of fidelity, from reproducing the intricacies of a laser beam reflecting over rough surfaces to simply capturing the basic sensor characteristics (in order to achieve the maximum simulation speed). To further enhance the fidelity and the variety of the sensor models, team VTD is also working with the world-leading sensor manufacturers like Leica and NovAtel (all part of Hexagon).

D. 3D Driving Environment

A 3D virtual environment can be generated either from inside VTD, or from scanning the actual roads. Creating the environment inside VTD gives you maximum control over all the details, while generating the 3D environment from measurements (LiDAR/camera) is more realistic and much faster. With Hexagon's new Leica Pegasus:2 mapping platform and its connection with VTD (Figure 5), engineers are expected to speed up the "Road Digitization" by a factor of 20 in the near future.

E. Scenarios and Data Management

With millions of scenarios to be evaluated at each step of the autonomous vehicle development, there is simply no way to manage everything manually. Indeed, Intel calculates that 1 Petabytes of data will be generated each day by an autonomous vehicle. That is where SimManager, the simulation management platform of MSC, comes into play to store the generated data and appropriately label them for easy access at any stage. With such a well-organized collection of data, to find out the "needle in the haystack" (such as "extract all simulations with rain") is like child's play and to compute meaningful performance indexes (such as "average time to collision") becomes a no-brainer.

F. Artificial Intelligence (AI) Driver

The AI Driver is the core of every autonomous system, and users can easily connect VTD to their own AI Driver to carefully validate them under all conditions, including sensor failure or misbehavior such as mud sputters covering a portion of a LiDAR. MSC Software is also working with its sister company, AutonomouStuff (both part of Hexagon), to connect AutonomouStuff's AI Driver to VTD so partners of AutonomouStuff can run their physical road tests and virtual tests with exactly the same AI brain.

In summary, today Hexagon owns many of the simulation and testing assets necessary for autonomous car projects: sensors and technology to manage smart intermittent sampling, HD maps from Hexagon Geosystems, and a turnkey platform for autonomous vehicle development from AutonomouStuff. Add in MSC Adams vehicle modeling, VTD to recreate the external environment and traffic, data management via MSC SimManager, and there is a very compelling turnkey autonomous vehicle solution toolset for both simulation and testing awaiting both OEMs and Start-ups around the world.