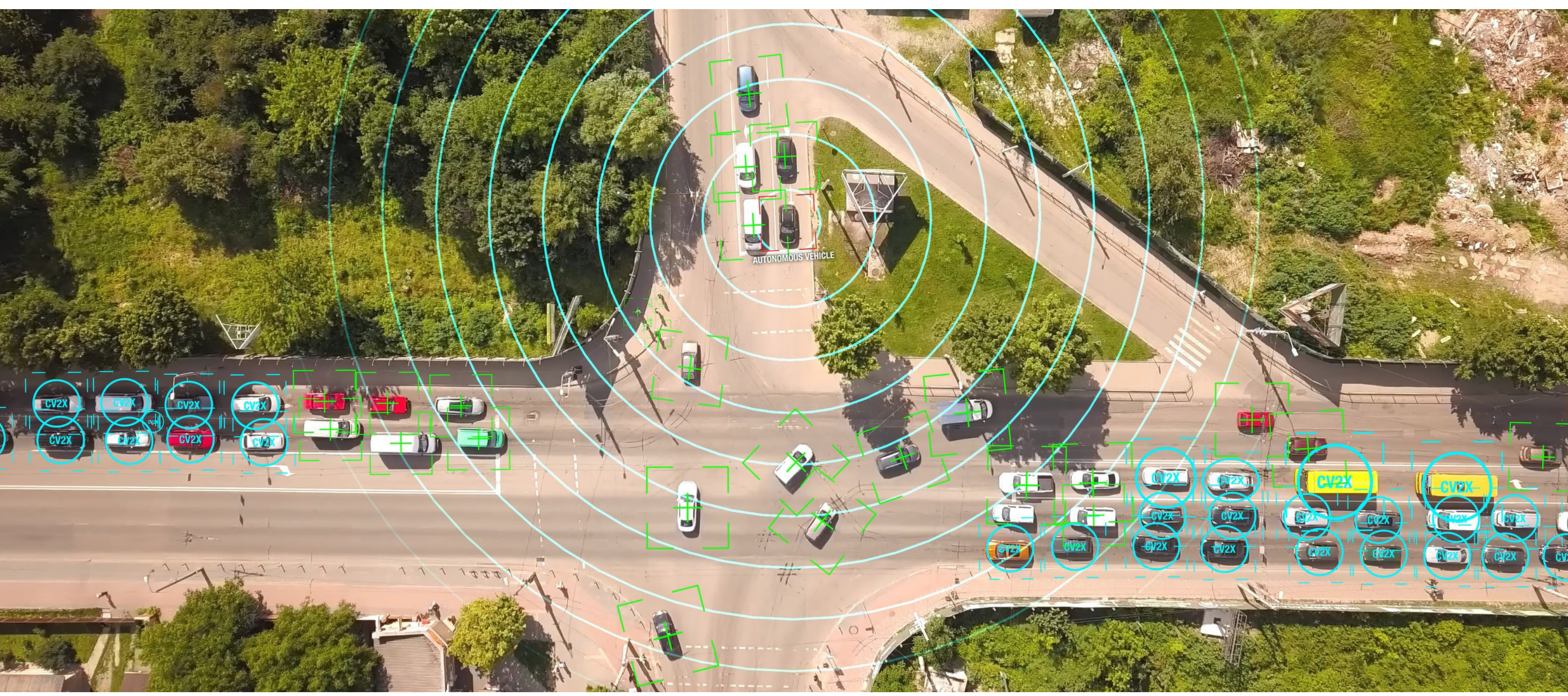
DATA SHEET

Radar Scene Emulator

See the Whole Picture

In vehicle autonomy, advancing through Levels 3, 4 and 5 demands unshakeable confidence in robust ADAS/AD[1] algorithms that are ready for road testing and, ultimately, deployment in real-world vehicles. Keysight's Autonomous Drive Emulation (ADE) platform is the environment emulator for in-lab testing using realistic roadway scenarios, from mundane to one-in-a-million.

Utilizing "total scene generation," the platform exercises your systems and algorithms by applying time-synchronized inputs to the actual sensors. Its open architecture also closes the loop with your existing hardware-in-the-loop (HIL) systems and 3D modelers. These capabilities create a solution that complements—and fills the gap between—software simulation and on-road testing.



1 Advanced Driver Assistance Systems and Autonomous Driving abbreviated throughout as ADAD/AD.

KEYSIGHT TECHNOLOGIES

See, Test, and Accelerate

Keysight's Radar Scene Emulator (RSE) is a core element of the ADE platform. It tests the performance and response of radar-based ADAS/AD software against complex scenarios in a lab environment that includes near and far targets across a contiguous field of view (FOV). The vehicle's decisions need to be made on comprehensive real-world scenes, not limited by what the test equipment allows them to see.

The RSE provides a deterministic environment for in-lab testing of complex scenes that today can be tested only on the road, if at all. With RSE's industry-first approach, you can accelerate the learning of your ADAS/AD algorithms by testing decisions earlier against complex, repeatable, high-density scenes, with objects either stationary or in motion.

To maximize the realism in every scene, the RSE delivers exceptional capability in four areas: field of view, minimum distance, points per object, and interference. For each of these, standard functionality supports the creation of highly realistic scenarios, and available enhancements add greater realism to ADAS/AD testing. It is now possible to emulate real-world driving scenes in the lab with every variation of environmental condition, traffic density, speed, and distance, with all scene objects represented.

Figure 1. The Keysight Radar Scene Emulator (RSE).

Close the Technology Gap With Realistic In-Lab Testing

In ADAS/AD development, one of the crucial goals is achieving confidence in the performance and safety of increasingly autonomous systems. Until now, the testing process has suffered from a gap between software simulation and on-road testing. Software simulation is useful and important, but it lacks the ability to properly emulate the responses of the actual sensors and their imperfections. Roadway testing is essential, but it's costly, nonrepeatable, and too risky to perform too early in the development process. Ultimately, the ability of ADAS/AD algorithms to ensure the safety of people and property is of the utmost importance. For that reason alone, it is critical to utilize all three approaches: software simulation, in-lab scene generation, and on-road testing.

The rendering of full 3D scenes in the lab, with the goal of testing the real sensor response, is the vision. Today, specifically in emulating radar targets, there is a technology gap.

- Limited number of targets and field of view
- Limited ability to test at close range
- Poor object resolution

Backed by more than 20 patents, the RSE fills this gap with the ability to emulate complex and detailed roadway scenarios in your lab. The key concept is total scene generation, applied consistently and repeatably across a contiguous field of view.

Create Scenarios That Range From Mundane to One-In-A-Million

Validating ADAS/AD radar detection routines against a small number of targets offers an incomplete view of the real world (Figure 2).

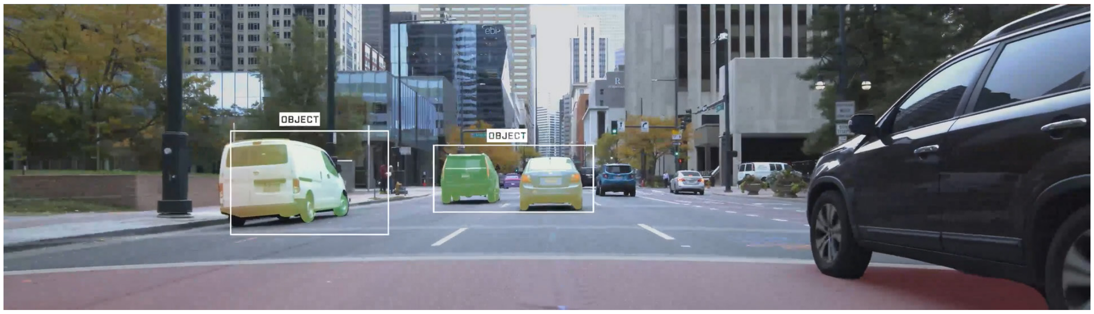


Figure 2. Example of targets simulated by one-point-per-target system. It is showing two objects, where the first target can be simulated only at 6+ meters from the ego vehicle, completely missing the car on the right and combining two targets that are close together.

The RSE allows you to create scenarios containing up to 512 point-targets with independent attributes: speed, direction, distance from the ego vehicle, angle, and more (Figure 3).

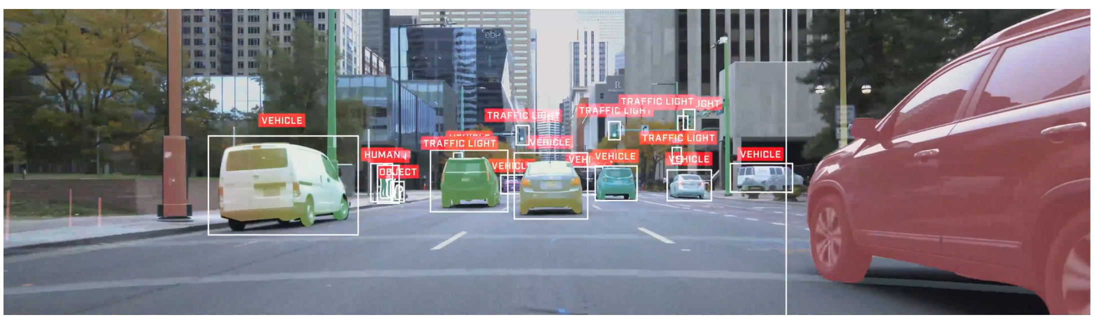


Figure 3. The exceptional resolution of the RSE produces a higher level of realism, emulating up to 512 point-targets, and at distances as close as 1.5 meters from the ego vehicle.

Table 1 captures some possible scenarios to be covered, ranging from current NCAP and NHTSA[2] test cases to common radar-based ADAS/AD features and functions. The RSE also supports the creation of corner-case scenarios from your in-house library of tests, ranging from a deer leaping onto a two-lane country road in the dark, to other high-risk situations.

Table 1. The Keysight RSE can cover mandatory and proprietary test cases for radar-based ADAS/AD functions.

NCAP/NHTSA	Common radar-based ADS functions/tests
• Safety Assist : Autonomous Emergency Braking (AEB) Car-to-Car • Safety Assist : Lane Support Systems (LSS) • Vulnerable Road User Protection : AEB Pedestrian • Vulnerable Road User Protection : AEB Cyclist	• Forward Collision Warning (FCW) • Lane Departure Warning (LDW) • Lane Keeping Assistance (LKA) • Active Cruise Control (ACC) • Evasive Steering Assist • Cross-Traffic Alert • Blind Spot Detection • Rear Automatic Braking

In addition to these test cases and features, there are many dangerous situations that, over the lifespan of a vehicle, have a non-zero probability of occurring. It is best to test these cases early on in the lab rather than when vehicle is in operation on the public roadways.

- Complex urban scene with buses, cars, pedestrians, e-scooters and mopeds
- Child running into the street in neighborhood
- Vehicle assessing height of overpass
- Animal entering road, daytime
- Animal entering road, nighttime
- Passing on two-lane country road
- Motorcycle approaching while passing
- Chair in the road (or another unexpected item)

The RSE allows you to test all these features and use cases, and more, in a repeatable, safe, environment.

2 NCAP – New Car Assessment Program and NHTSA – National Highway Traffic Safety Administration. There are other local and regional organizations that govern these standards, NCAP and NHTSA are only two of them.

Enhance Your Scenarios in Four Key Areas

In ADAS/AD systems, real-time decisions are made based on the complete situation, taking the inputs from cameras, radar sensors, lidar sensors and vehicle-to-everything (V2X) communication modules. Specific to radar, the RSE presents your system with an abundance of high-resolution objects that range from far to near. It can also help you assess the system's immunity from external interference.

Populate the field of view with dynamic realism

Inside the RSE enclosure, the test array creates a contiguous FOV that extends ±70 degrees in azimuth and ±15 degrees in elevation from the radar DUT's boresight. But realism is about more than just numbers: a continuous scene means every target, static or dynamic, can be present at every moment of a test.

This is possible because the RSE test array contains a wall of RF front-ends that echo back the signal modulated by the parameters needed for the system-under-test (SUT) to detect scene elements. It's a 64-by-8 array of "radar pixels" or "rixels" that create a dynamic radar environment (Figure 4). This implementation covers more cases in less time than systems that rely on mechanically moving parts. In addition, it is more stable, predictable, repeatable, and reliable.

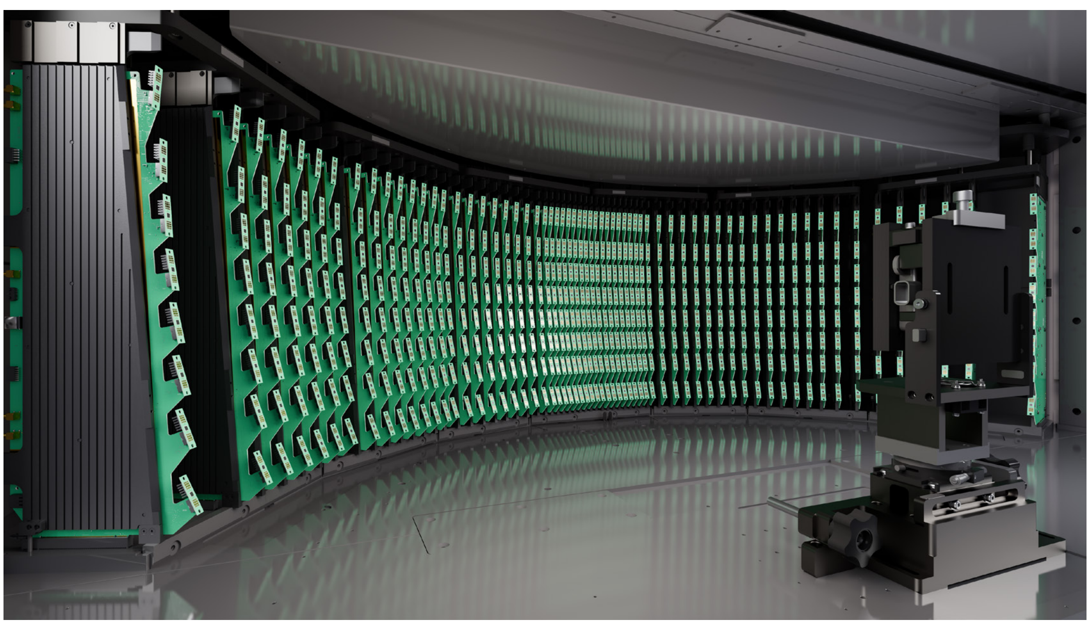


Figure 4. The 64x8 array of rixels creates a dynamic radar screen, physically placed less than 1 meter from the radar DUT and contained in an anechoic chamber that shields it from external undesired interference.

These miniaturized rixels are invisible to the radar sensor by design and activated by the 3D simulation software, replacing mechanical movement altogether. Each rixel in the array emulates an object's distance and echo strength (Figure 5). Multiple reflections, plus more — as objects get closer — allows for improved detection and differentiation of objects.

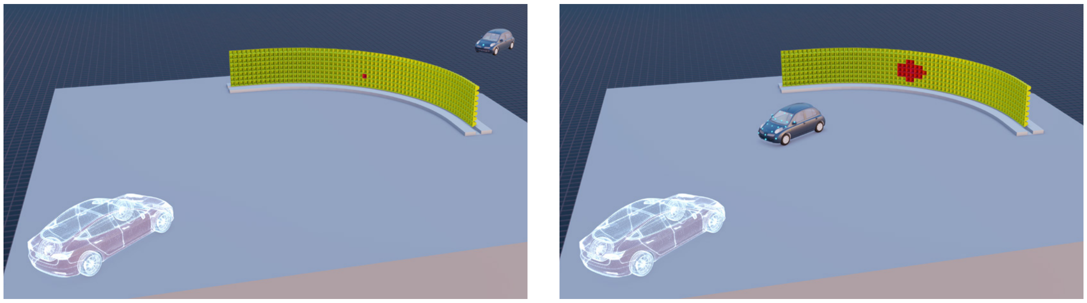


Figure 5. Each rixel on the wall represents an object's distance, speed, and echo strength. Multiple rixels can represent an object, depending on the distance from the DUT — showing more resolution and more points per object.

Validate crucial functionality down to 1.5 meters

Many test cases—AEB, FCW, LDW, LKA, and more—require emulation of objects that are very close to the SUT. For example, approaching a stop light, vehicles are typically less than 2 meters apart in every direction. In a moving scenario, a two-wheeler—bicycle, motorcycle, scooter—could swerve into the lane, or a pedestrian might suddenly step into the roadway.

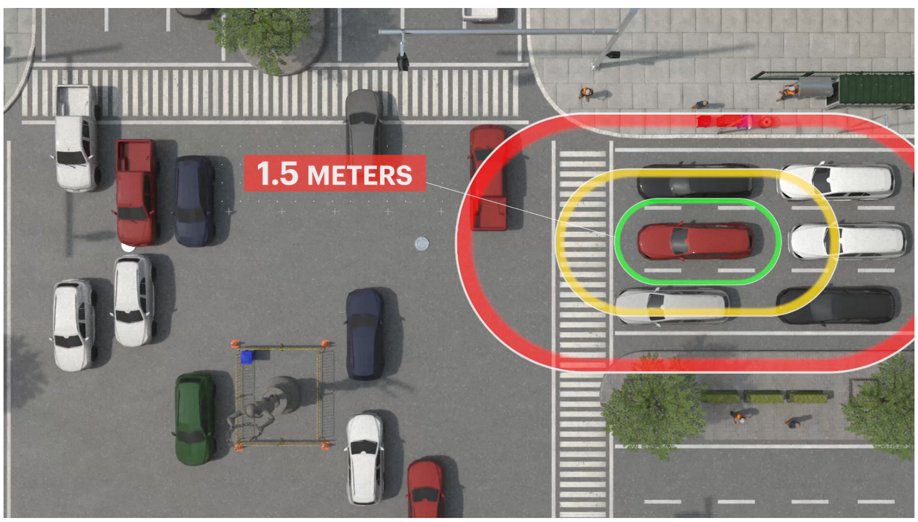


Figure 6. The green circle indicates the distance of 1.5 meters, meaning you can simulate objects in close proximity to the ego vehicle, to test important safety features.

Scenarios like these can be challenging to recreate in a lab environment. With its standard capabilities, the RSE can emulate objects as far away as 300 meters and as near as 6 meters or, with optional advanced capabilities, as close as 1.5 meters. Object velocities can range from –400 to 400 kilometers per hour.

Create greater realism in static and dynamic elements

State-of-the-art automotive radars that can detect closely spaced targets rely on high angular resolution to perceive the spatial characteristic of objects. Object separation, the ability to distinguish between obstacles on the road, is a major area that needs to be tested for a smoother and faster transition towards Level 4 and 5 autonomous vehicles.

In scenario emulation, too few points per object may cause a radar to erroneously detect closely spaced targets as a single entity. This makes it difficult to fully test not just the sensor but also the algorithms and decisions that rely on data streaming from the radar sensor.

Keysight addresses this technology gap using 3D point clouds, which bring more resolution for each object. This approach relies on ray tracing techniques to extract the relevant data from highly realistic views of modeled objects. This enables multiple points (rixels) to represent a single object, and provides improved detection and differentiation of objects.

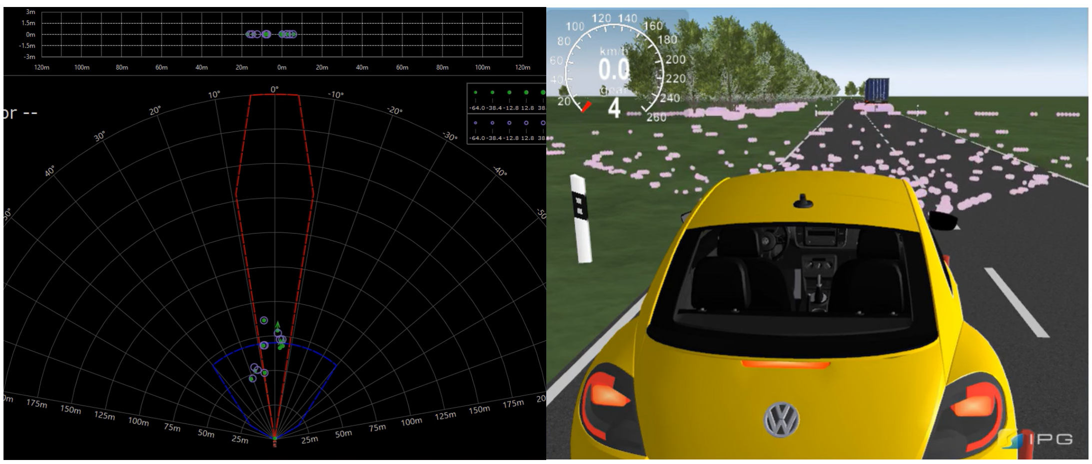


Figure 7. The Radar Scene Emulator uses ray tracing technology to extract the relevant point clouds from the simulated scene and render them to the rixel screen (left panel). The 3D simulation software can provide highly detailed scenes (note there are also reflections from the ground), representing objects as point clouds (right panel). Image from IPG CarMaker.[3]

Point clouds add details to the scene and give you the confidence to know that the algorithm you are testing can distinguish between two objects that are close together. While a traditional radar target simulator (RTS) will return one reflection, independent of distance, the RSE increases the number of reflections as the target gets closer. This type of "dynamic resolution" varies the number of points that represent an object as a function of distance.

3 IPG's CarMaker version 10.1 was used as an example. Other 3D simulation software could also be used.

Assess System Immunity From Interfering Signals

As more ADAS/AD systems are deployed on the roadways, the likelihood of interference from nearby vehicles grows in lockstep. To test and enhance system immunity from interference, the ability to emulate stray RF signals in dense downtown scenarios is crucial.

Optional hardware and software modules enable the validation of interference-mitigation designs by subjecting your SUT to a wide variety of signals, whether mandated by ETSI regulations or of your own choosing. The wide frequency range of the interference option module covers the automotive radar-specific 76-81 GHz band, along with out-of-band 60-90 GHz signals, with bandwidth of up to 5 GHz.

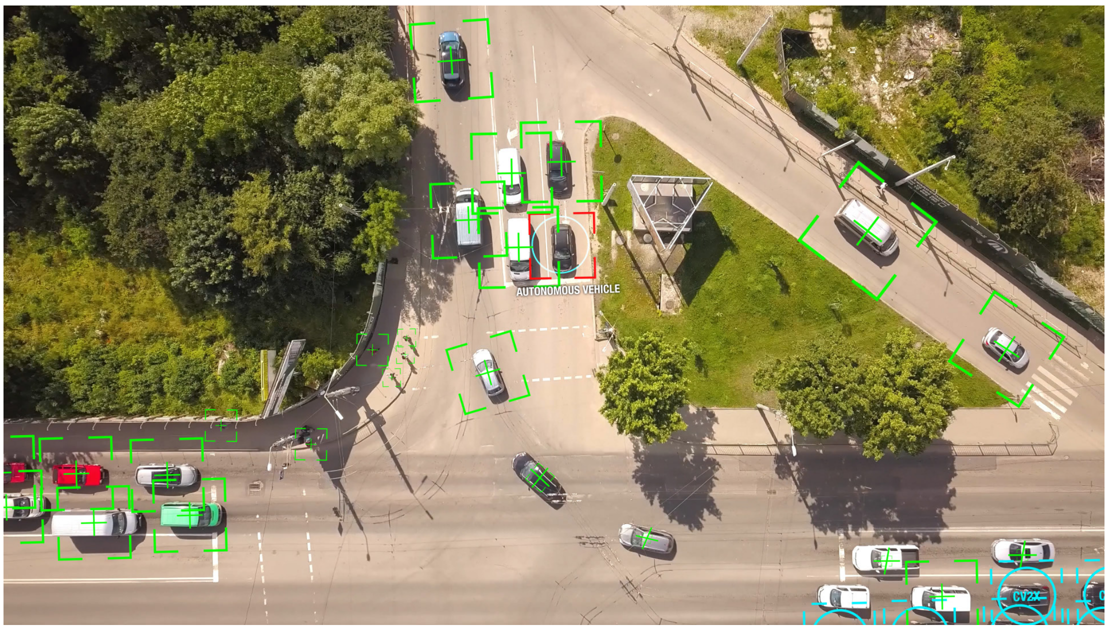


Figure 8. Each vehicle has several radars and each of those could be seen as an interferer to the ego vehicle.

Protect Your Investments in HIL Systems and 3D Modelers

Keysight's open ADE architecture reduces integration costs with the ability to leverage your existing test environment and workflow. You can also easily reuse your in-house library of test scenarios created in software simulators.

Utilizing total scene generation, the ADE platform exercises ADAS/AD software by applying time-synchronized inputs to the actual sensors and subsystems that will be used in vehicles. Our open architecture also closes the loop with your existing HIL systems and 3D modelers.

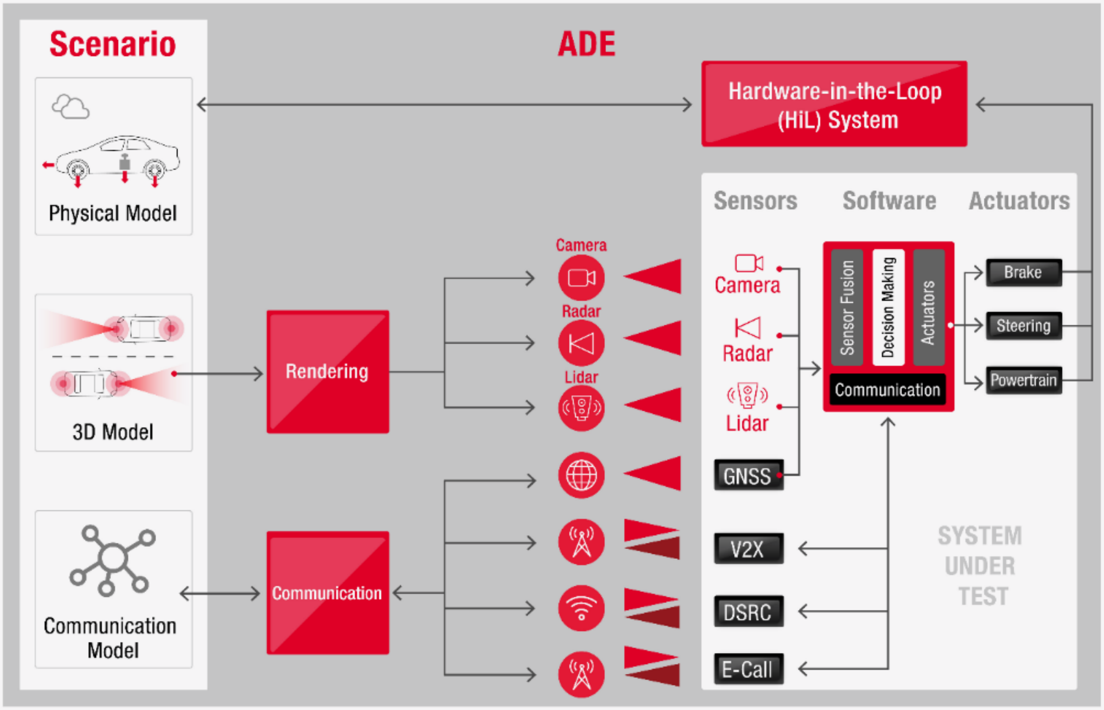


Figure 9. ADE architecture overview including V2X, GNSS, camera, radar and lidar.

Here's how it works. The real-time 3D engine creates a virtual environment that includes three key aspects:

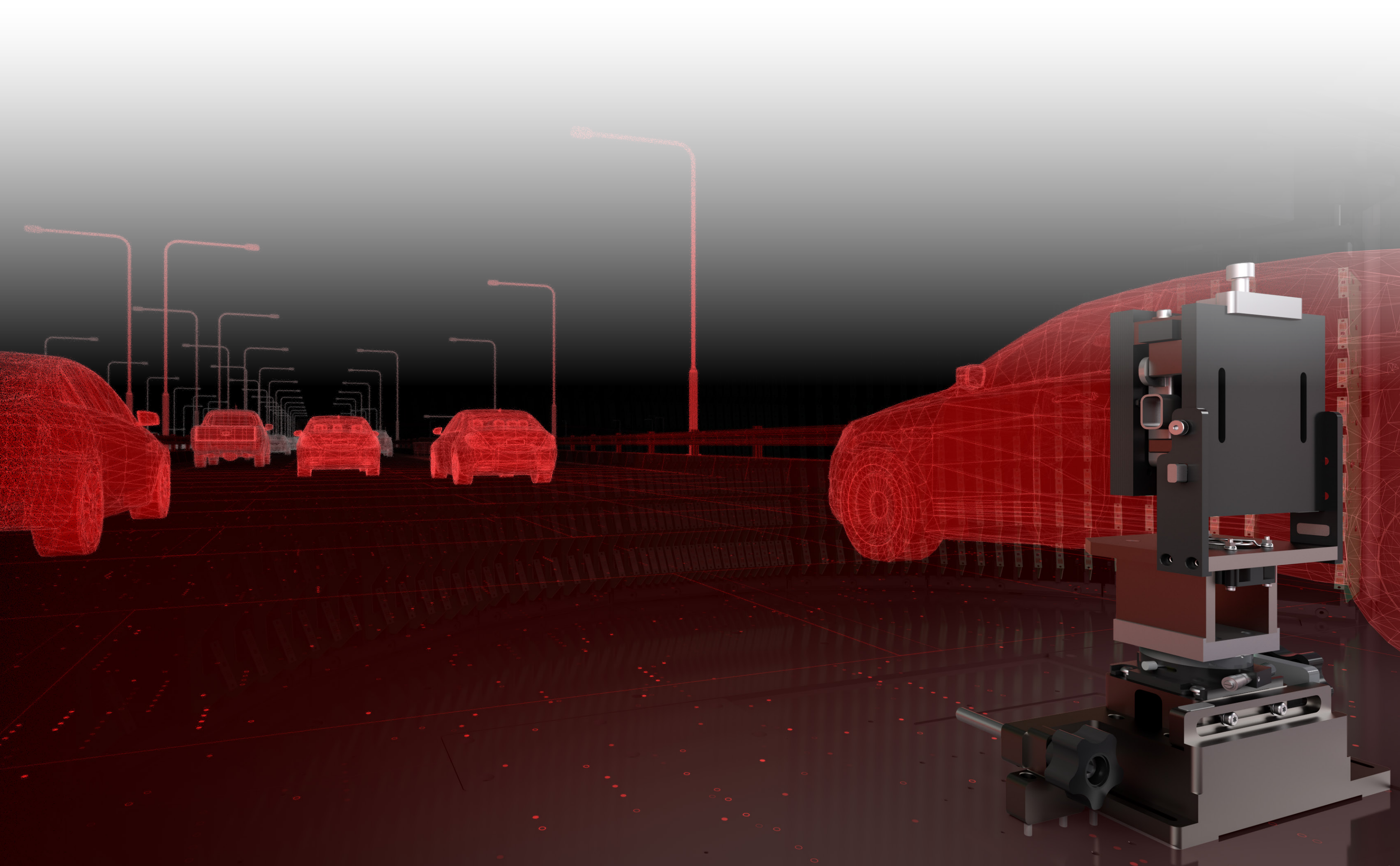
- Full-motion video, simulating highway, city and rural driving conditions
- Dynamic radar signals emulating moving or stationary targets
- Congested C-V2X scenarios, with 4G today and 5G NR in the near future

The unit-under-test responds with actions such as braking, steering and acceleration, just as it would on the road. By expediting testing and validation through cumulative hours, and miles, of environment emulation, the ADE platform provides new insights into ADAS/AD behavior.

Configure the Right Solution for Your Lab

Hardware configuration options
AD1011A with 64 rixels in 1 row
AD1012A with 512 rixels in 8 rows
Standard configuration includes
Field of view (FOV) Azimuth = ±10 degrees
Emulated distance beyond 6 meters
FOV Elevation ±6 degrees (in case of AD1012A)

Options
Extended FOV capability ±45 degrees
Extended FOV capability ±70 degrees
Extended minimum distance < 6 meters
Interference testing
Extended FOV capability ±15 degrees elevation (in case of AD1012A)



Get a Closer Look at the RSE's Capabilities

The goal of this overview is to give you a sense of what the Radar Scene Emulator can add to your lab. Keysight has prepared a series of videos that allows you to dive deeper into the RSE technology and contributions. We invite you to take a closer look: https://www.keysight.com/find/DiscoverRSE

Work With Us to Realize Your Vision of Mobility

As you continue to create what comes next, Keysight is ready with test solutions that can accompany you from concept to reality. Our goal is to help you excel—and accelerate—in those areas that are redefining future mobility: sensor systems, wireless links, in-car networks, batteries and cells, and beyond. It's all about getting there first and realizing your company's vision of mobility.

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