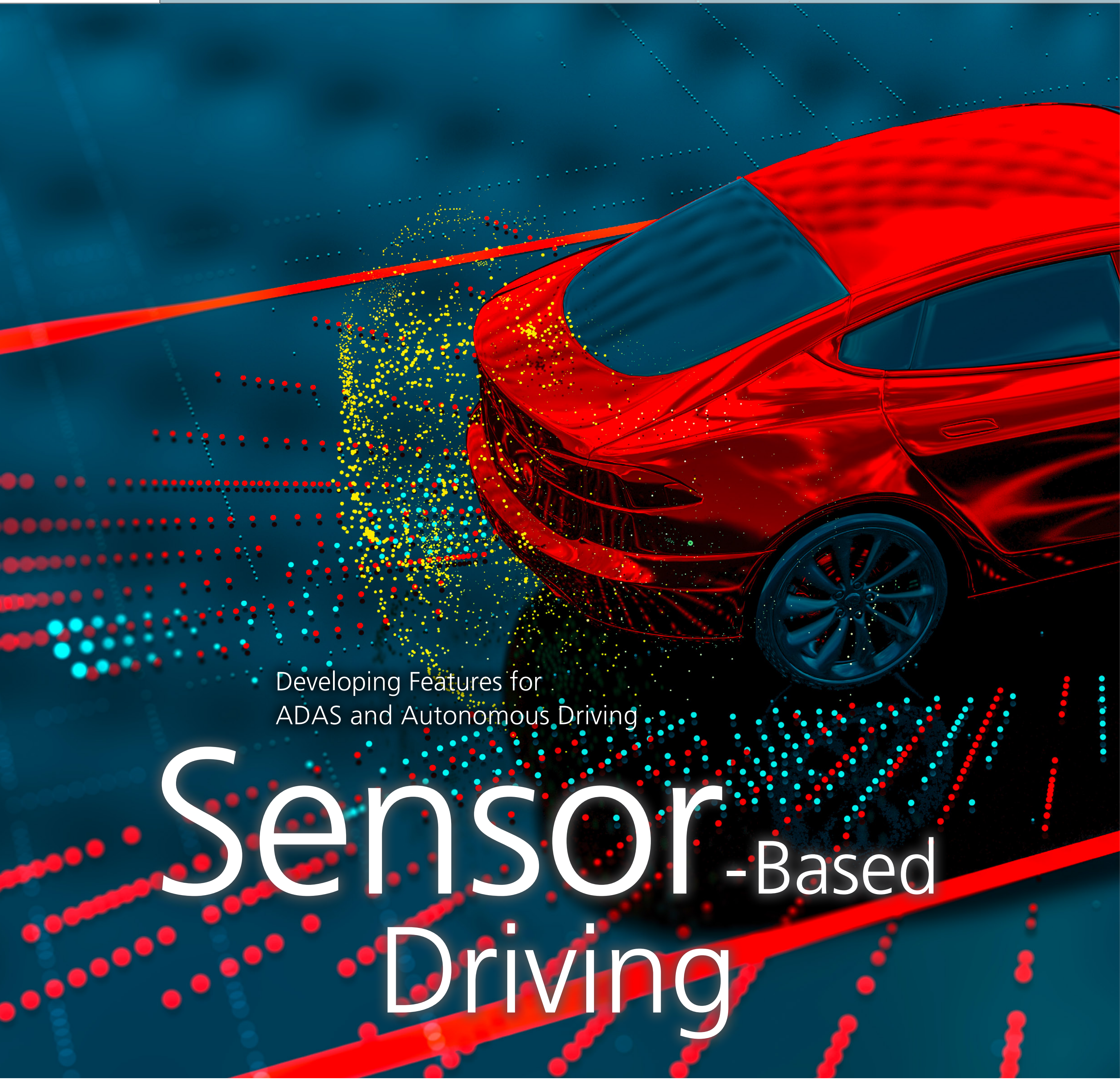
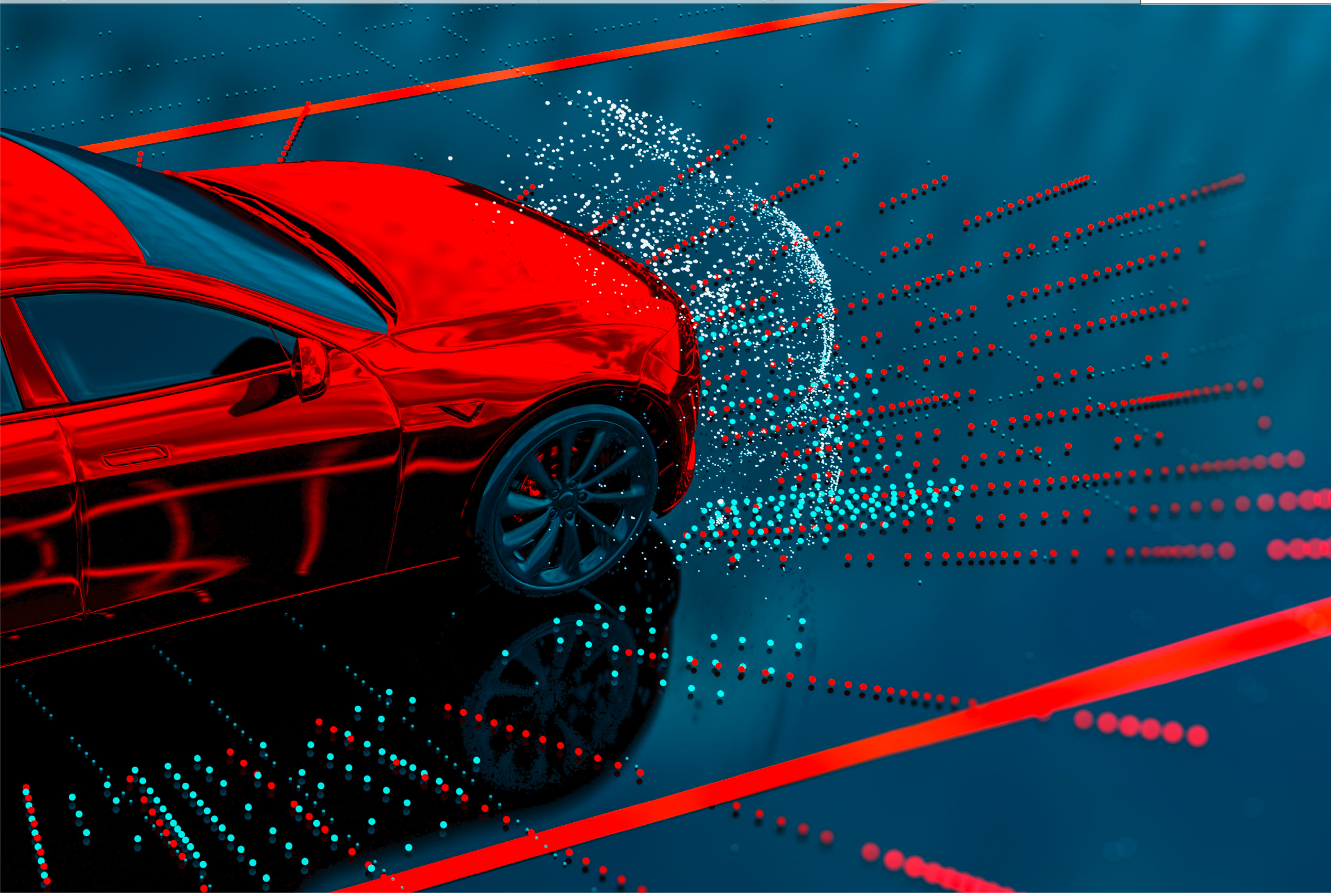


Developing Features for ADAS and Autonomous Driving

# Sensor-Based Driving

P3 has developed an Autonomous Data and Analytics Platform for Testing (ADAPT) to help customers evaluate the implementation of features for ADAS and autonomous driving. These include vision-based features and features for testing sensors as well as sensor configurations and algorithms. ADAPT leverages RTMaps software to verify and validate ADAS and algorithms for autonomous driving.



As emerging trends are ushering in a period of fundamental transformation across the transportation industry, P3 helps OEMs and suppliers prepare for the future by providing effective strategies. Their aim is to bring new connected services and technologies for autonomous driving to the marketplace. In the area of ADAS and the development of autonomous vehicles, P3 provides a range of services including:

- Development of technology roadmaps and business strategies
- Benchmarking for global products and mobility services
- Definition of functional system and subsystem requirements
- Functional safety analysis (ISO 26262)
- Rapid prototyping (HW/SW)
- Data strategy and data analysis
- Agile program management and launch

To demonstrate its capabilities in this area, P3 North America, a subsidiary of P3, recently unveiled its ADAPT vehicle, showcasing advanced driver assistance systems (ADAS) and features for developing autonomous vehicles. ADAPT stands for Autonomous Data and Analytics Platform for Testing.

### Considerations for Autonomy

P3's first step was to consider which sensors, software, and hardware would have to be tested in the future. The P3 engineers determined that tests must support a comprehensive range of sensors as they expected there might be various configurations of vehicles of SAE Level 3 or higher. They set a goal to create a modular vehicle that offers the option to mount a variety of sensors. P3's aim is to deliver real-time static and dynamic data in a robust and reliable setup – independently of the existing weather or traffic conditions. The P3 engineers conducted a benchmark study to review a variety of different sensor options, including a surround view camera, forward-looking camera, peripheral view camera, mid/long-range radar, lidar, short-range radar, and ultrasonic sensors. Additionally, they evaluated common communication interfaces (e.g., USB, Ethernet, CAN). For demonstration purposes, P3 decided to incorporate scanning and solid-state lidars, ultrasonic sensors, forward-looking cameras, and forward-looking radar in the vehicle, which did not have to be all-inclusive.

### Design Specifications

To conceptualize, design, and model desired ADAS features for the demo vehicle, P3 turned to model-based

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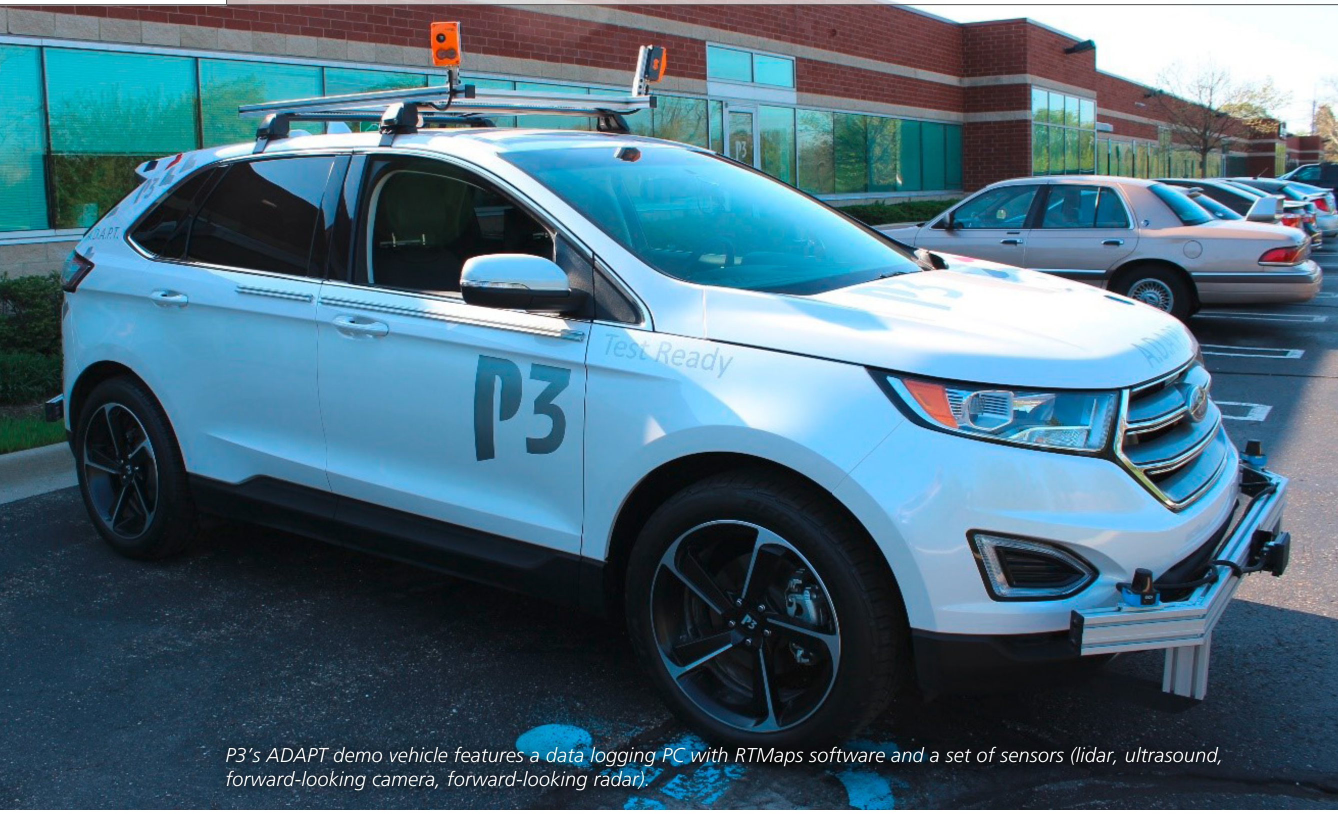


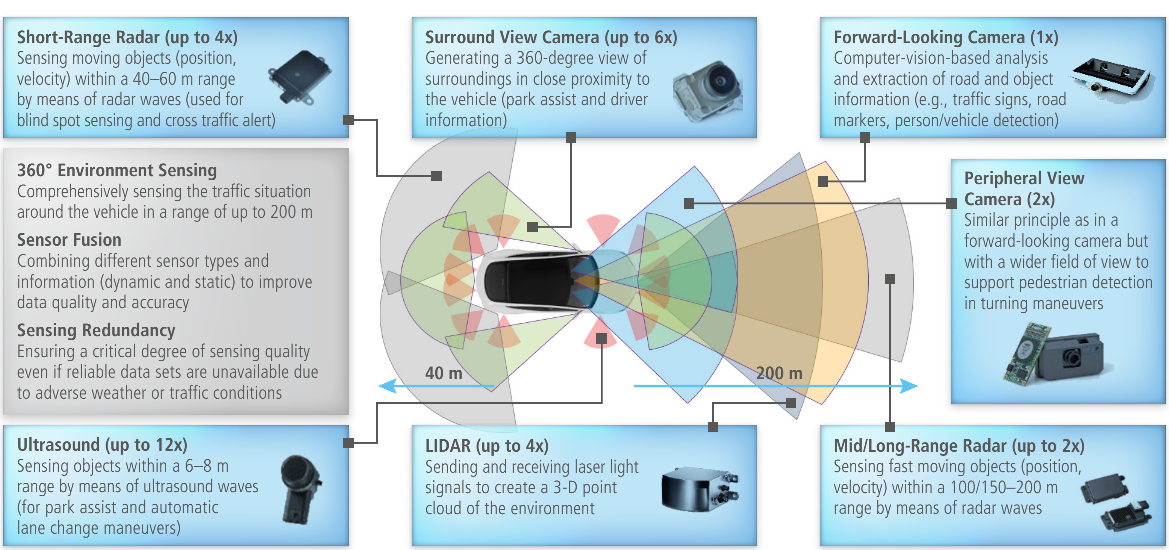

*P3's ADAPT demo vehicle features a data logging PC with RTMaps software and a set of sensors (lidar, ultrasound, forward-looking camera, forward-looking radar).*

systems engineering, which supports the development of system design specifications. This engineering approach included identifying functional and software testing requirements (i.e., model-in-the-loop [MIL], software-in-the-loop [SIL], hardware-in-the-loop [HIL], etc.), as well as creating the vehicle and feature architecture models. All of these aspects support the verification and validation of production software and hardware. P3 engineers identified hazardous scenarios and set appropriate system safety goals. From this initial assessment, engineers defined system and technical safety requirements for implementation.

## Equipping the Vehicle

With a good understanding of the functional safety requirements, P3 engineers began with installing the measuring and test equipment. They mounted the various sensors to the vehicle. They prepared sensor connectors and wiring according to the desired layout and interface elements, and they installed PCs to log data derived from the sensors. Some of the important aspects that they kept in mind while equipping the vehicle with the instruments included:

*Autonomous vehicle systems involve a complex suite of sensors, software, and hardware.*



Solid-state lidar mounted on the vehicle roof.


Power management, I/O, data logging, and processing units housed in the vehicle trunk.

- Incorporating sensors with common communication interfaces (e.g., USB, Ethernet, CAN)
- Creating a schema of the vehicle to consider all possible sensor locations and expansions that might be added
- Mounting sensors in both invasive (e.g., bumper rails) and non-invasive spaces
- Integrating the vehicle with reliable power management to support additional equipment and multiple configurations
- Expandable storage that supports the largest sensor packages and test scenarios
- Providing easy access to all equipment with enough space for expandability while keeping sufficient room for passengers and maintaining the safety and integrity of the vehicle
- Ensuring optimal cable routing that is resilient enough to handle environmental stresses and constant use but short enough to reduce data loss
- Preventing interference with existing sensors (e.g., blocking other sensors' fields of view, network interference, electrical noise)

## Setting up the Data Logging System

Gathering accurate real-time data is vital for the proper operation of ADAS and functions for autonomous driving. With this objective in mind, P3 engineers made a list of conditions they wanted to be conscious of when setting up their data logging system. Some qualities they sought to incorporate included:

- Understanding how the sensors interface and communicate with each other
- Enabling data processing for required live visualization (e.g., converting radar data from range, angle to (x,y,z))
- Synchronizing data handled in real time or according to the GPS clock
- Monitoring sensor communication (P3 uses RTMaps watchdog blocks to ensure data is captured)
- Saving raw data (for testing modified algorithms in a playback diagram)
- Saving processed data (to save time on playback after testing)
- Ensuring that sensors operate properly via component interaction (P3 uses RTMaps to provide necessary information, i.e., CAN messages, yaw rate, etc.)

## Managing Sensor Fusion

With a clear plan of how to set up the data logging system, P3's next step was to find a way to process

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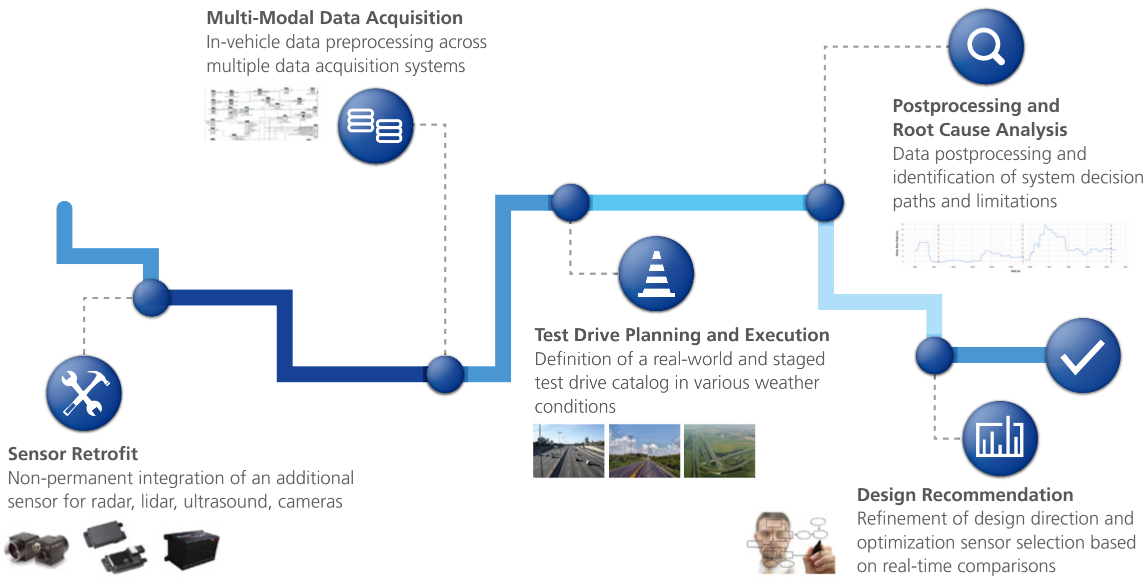
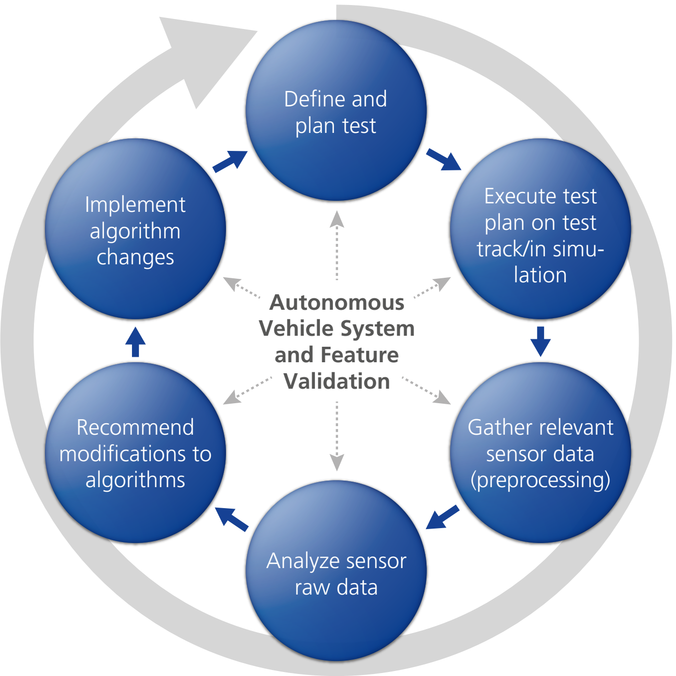
"We have been using and recommending dSPACE MicroAutoBox and ControlDesk to enhance the robustness of ADAS and autonomous driving prototypes. This allows prototype systems to operate in near-automotive-grade conditions."

*Modar Horani, Managing Principal of Systems Engineering at P3 North America*




*Milestones in setting up and refining an autonomous vehicle system.*

and manage the data collected from the various sensors. P3 set out to establish an in-vehicle data preprocessing system that can handle multiple data acquisition systems. The ADAPT platform is designed to accelerate the development of new autonomous driving (AD) and ADAS features as it combines everything that is necessary for the efficient, robust, and reliable testing of sensors, sensor configurations, and algorithms. This platform allows for gathering real-world data for benchmarking and data analytics purposes. It also enables OEMs and Tier 1s to test different configurations of hardware and software in real-time, dynamic driving conditions. ADAPT is equipped with RTMaps (Real-Time Multisensor applications), a software platform created by Intempora and distributed by dSPACE. RTMaps enables data collection in real time and testing of data processing algorithms. The platform's powerful real-time execution performance enables it to handle time coherency among numerous software tasks and the high bandwidth of raw data streams. Modar Horani serves as Managing Principal of Systems Engineering at P3 North America. He leads a team of systems engineers who support clients (OEMs and Tier 1s) in developing functional requirements for systems and subsystems, functional safety analyses (ISO 26262), and rapid prototyping (HW/SW). Horani explained that RTMaps allowed P3 to record data from a relatively large set of sensors




*Important steps for planning tests and analyzing data of autonomous vehicle systems.*

> "We are very pleased with the capabilities offered by RTMaps. The performance was seamless and logging was reliable."
>
> *Modar Horani, Managing Principal of Systems Engineering at P3 North America*

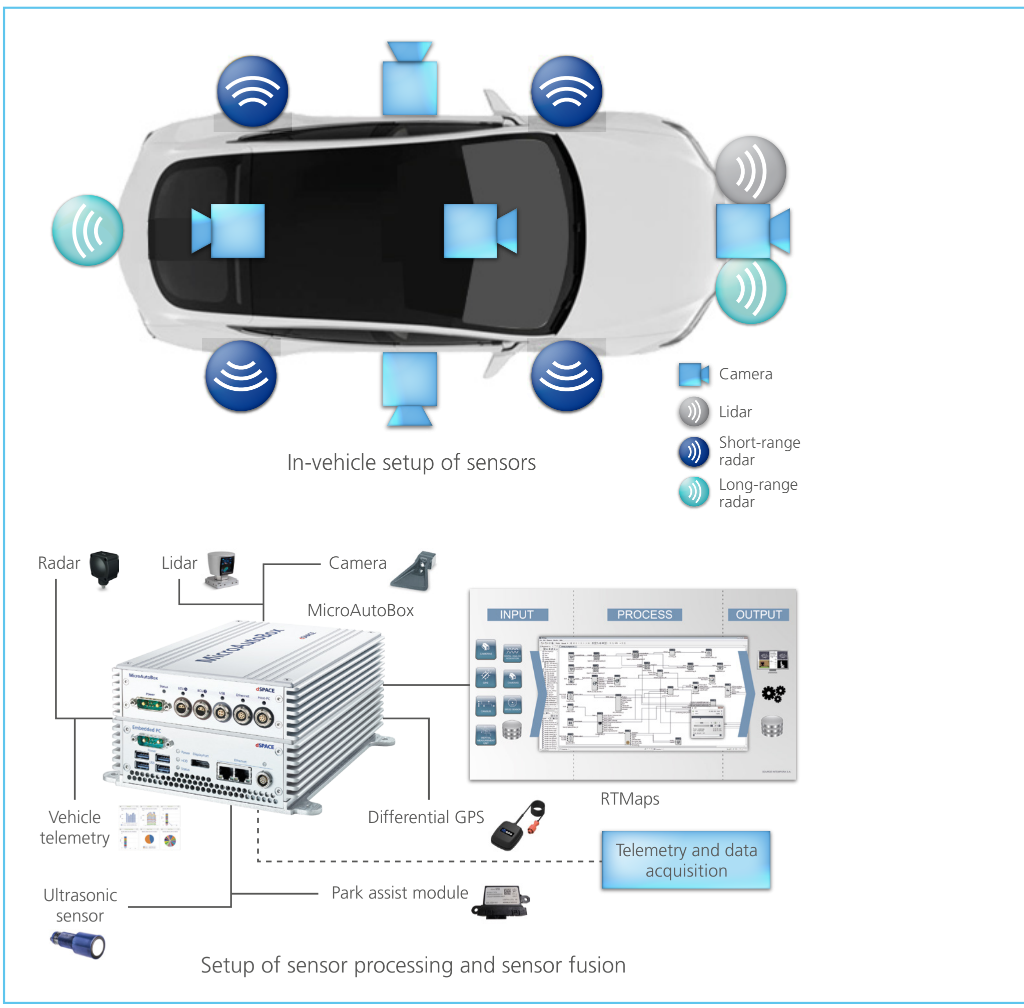
including cameras, lidar, radar, CAN, GPS, IMU, and ultrasound. He also stated that RTMaps connected well to the dSPACE tool chain. "Its simple interface makes it easy to use and you can rapidly modify the existing environment," Horani said. "To ensure the proper operation of sensors, RTMaps lets us send control signals to the sensors, and the built-in watchdog package helps to ensure valid data is being input to the logging diagram. Overall we are very pleased with the capabilities offered by RTMaps. The performance was seamless and logging was reliable."

### Test Planning and Analyzing Collected Data

Once their demo vehicle was successfully equipped with sensors and a data logging system, P3 set out to identify a series of driving tests to be executed, the final goal being test completion without errors. The test drives were designed to achieve the following goals:

- Confirming system readiness and sensor calibration
- Gathering data from various road, weather, and traffic conditions of interest
- Verifying the performance of certain algorithms under test

A careful design of experiments was performed to identify the most suitable experiment environment and variable factors. Some of the variations of interest included gathering sensor readings from normal to adverse weather conditions. For example, collecting data from sunny, rainy, snowy, and foggy days while driving on the same section of a highway. GPS tracking allowed for aligning the recorded data and identifying the corresponding challenges when dealing with adverse conditions. Some test drives were performed on a dedicated proving ground facility to establish verified ground truth. Ground truth data is required to calibrate both the sensor and algorithm outcome. P3 was able to collect significant streams of real- >>



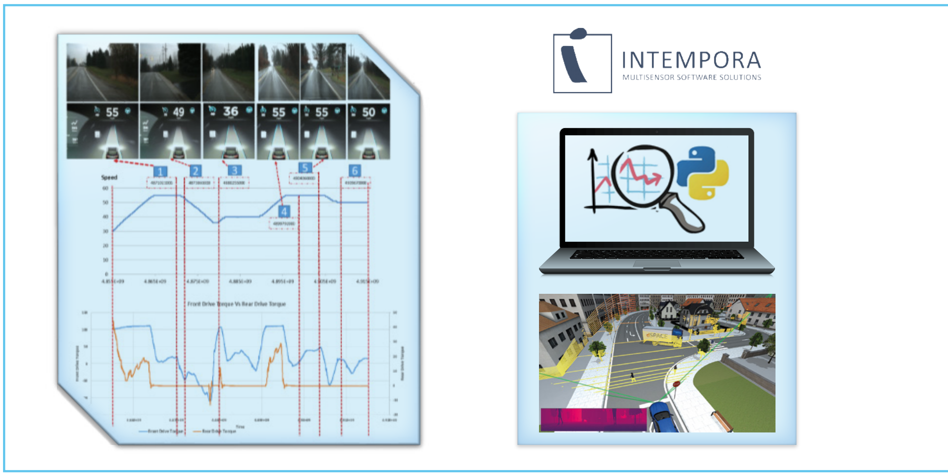

*To merge various sensor signals and perform the relevant processing algorithms in real time, RTMaps and MicroAutoBox took over crucial roles.*

time data from the various sensors to evaluate sensor functionality.

### Modifying Algorithms

Using the data collected from the demo vehicle sensors for various driving tests, such as forward and rear collision avoidance as well as lane departure warning, engineers initiated rapid prototyping to evaluate findings and their impact on system performance. They were able to identify errors and modify and implement various ADAS algorithms to improve the performance of the demo vehicle.

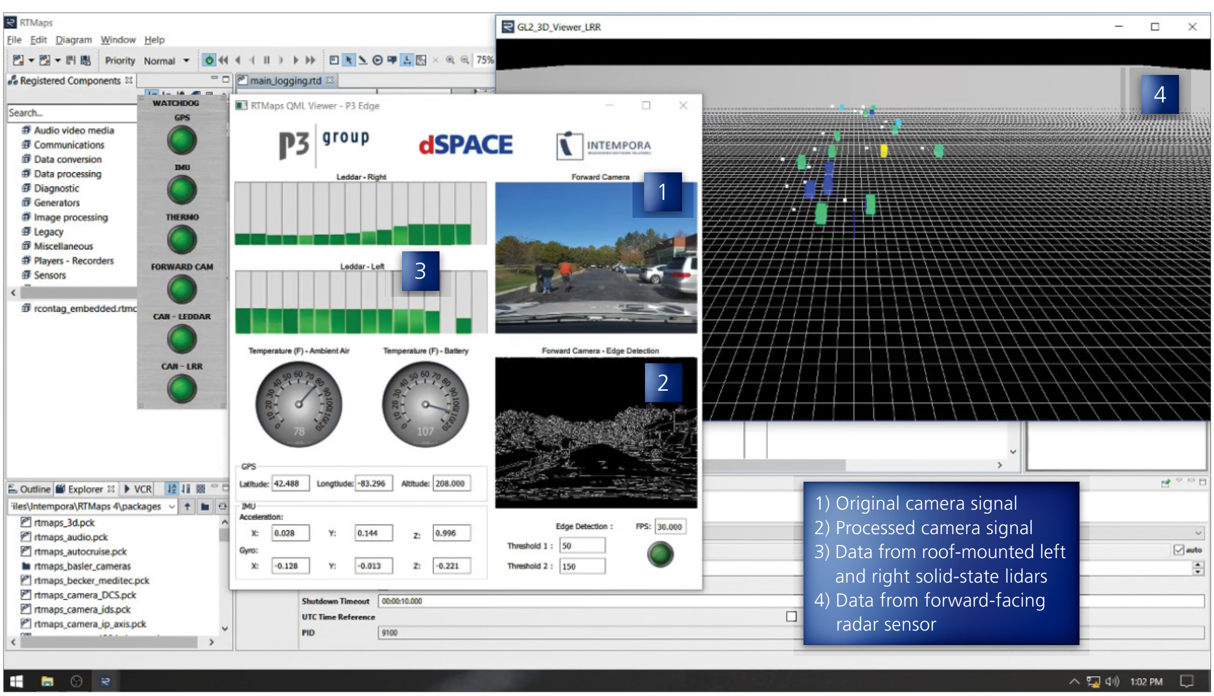
A dSPACE MicroAutoBox II prototyping unit and the dSPACE ControlDesk experiment software were among the tools used to modify and implement the ADAS algorithms. Horani explained that MicroAutoBox II was easy to use and integrated well with major model-based development tools (e.g., MATLAB®/Simulink®) to accelerate the implementation of new and innovative concepts. "We have been using and recommending dSPACE MicroAutoBox II and ControlDesk to enhance the robustness of ADAS/AD prototypes," Horani said. "This allows prototype systems to operate in near-automotive-grade conditions."




*Validation and verification with RTMaps and further solutions: Early confirmation by means of reviewing and analyzing whether all safety requirements are correctly implemented.*

### Using RTMaps

Beyond the demo vehicle, Horani said P3 had leveraged RTMaps for




*Data analysis of raw and processed sensor data with RTMaps.*

the verification and validation of ADAS algorithms in two scenarios:

1) On the road, where algorithms are running on the car's PC and live data is collected and visualized, and 2) in the lab, where the collected data is used as input to verify the performance of algorithms under development.

Additionally, Horani said RTMaps was helpful for several projects with algorithms that were developed in various programming languages (e.g., Python, C, MATLAB) and required integration. "RTMaps has a good native selection of packages for interfacing sensors," Horani explained. "However, customer requirements often dictate the use of proprietary sensors outside of the native packages. The tools provided by RTMaps facilitate the development of custom packages."

### What is Next for P3?

After validating its functional autonomous vehicle system, P3 is well positioned to work on future ADAS and autonomous vehicle development projects. The company is looking to expand the capabilities of its Autonomous Data and Analytics Platform for Testing (ADAPT) to include additional sensors for various applications, such as V2X communication. They are also evaluating implementations of vision-based ADAS features. P3 provides management consulting and innovative engineering solutions that accelerate the development of mobility products and services. Their combination of management support, consulting services, and engineering solutions enables them to understand what it takes to implement new technologies with speed and agility. In North America, their focus areas are autonomous, connected, and electric mobility in addition to new mobility services and digital transformation. P3 has almost 4,000 consultants and engineers across more than 40 locations worldwide working to develop and implement innovative solutions to today's complex technology challenges. The successful implementation of the ADAS evaluation platform extends P3's services and capabilities to support both the development and validation of features for ADAS and autonomous driving. The ease of use and modularity of the platform make it relevant to the complete development cycle from early research and prototyping to product development, integration, and validation. P3 is deploying this platform globally to accelerate the transition towards the future of autonomous mobility, which is safer, greener, and connected. ■

*With the kind permission of P3, Inc.*

## At a Glance

**The Task**

Setting up a demo vehicle that is based on a data and analytics platform for autonomous driving to help customers evaluate the implementation of ADAS and features for autonomous driving. The platform comprises vision-based features and the testing of sensors, sensor configurations, and algorithms.

**The Challenge**

Gathering accurate real-time data is vital to the proper operation of functions for ADAS and autonomous driving. Therefore, various sensor interfaces and communication protocols have to be supported and their signals must be processed in a synchronized manner. Monitoring sensor data, saving raw and processed data, and a flexible routing of signals are crucial to verify the performance of algorithms under test.

**The Solution**

P3 relies on RTMaps and MicroAutoBox to connect to and record data from a relatively large set of sensors, including cameras, lidar, radar, CAN, GPS, IMU, and ultrasound. RTMaps enables data collection in real time and testing of data processing algorithms. The platform's powerful real-time execution performance enables it to handle time coherency among numerous software tasks and the high bandwidth of raw data streams. The MicroAutoBox II prototyping unit was used in combination with ControlDesk to modify and implement the ADAS algorithms and perform them in the vehicle in real time.

*Watch the video demonstrating the data analysis with RTMaps. www.dspace.com/go/dMag_20181_P3*