50 Years of Growth, Innovation and Leadership

Unlock the Power of Data to Fuel Your Advanced Driver Assistance Systems (ADAS) and Autonomous Driving (AD) Journey

ADAS and AD Systems Won't Work Unless R&D Unlocks Its Data

A Frost & Sullivan White Paper
In Partnership with Dell Technologies

FROST & SULLIVAN

DELL Technologies

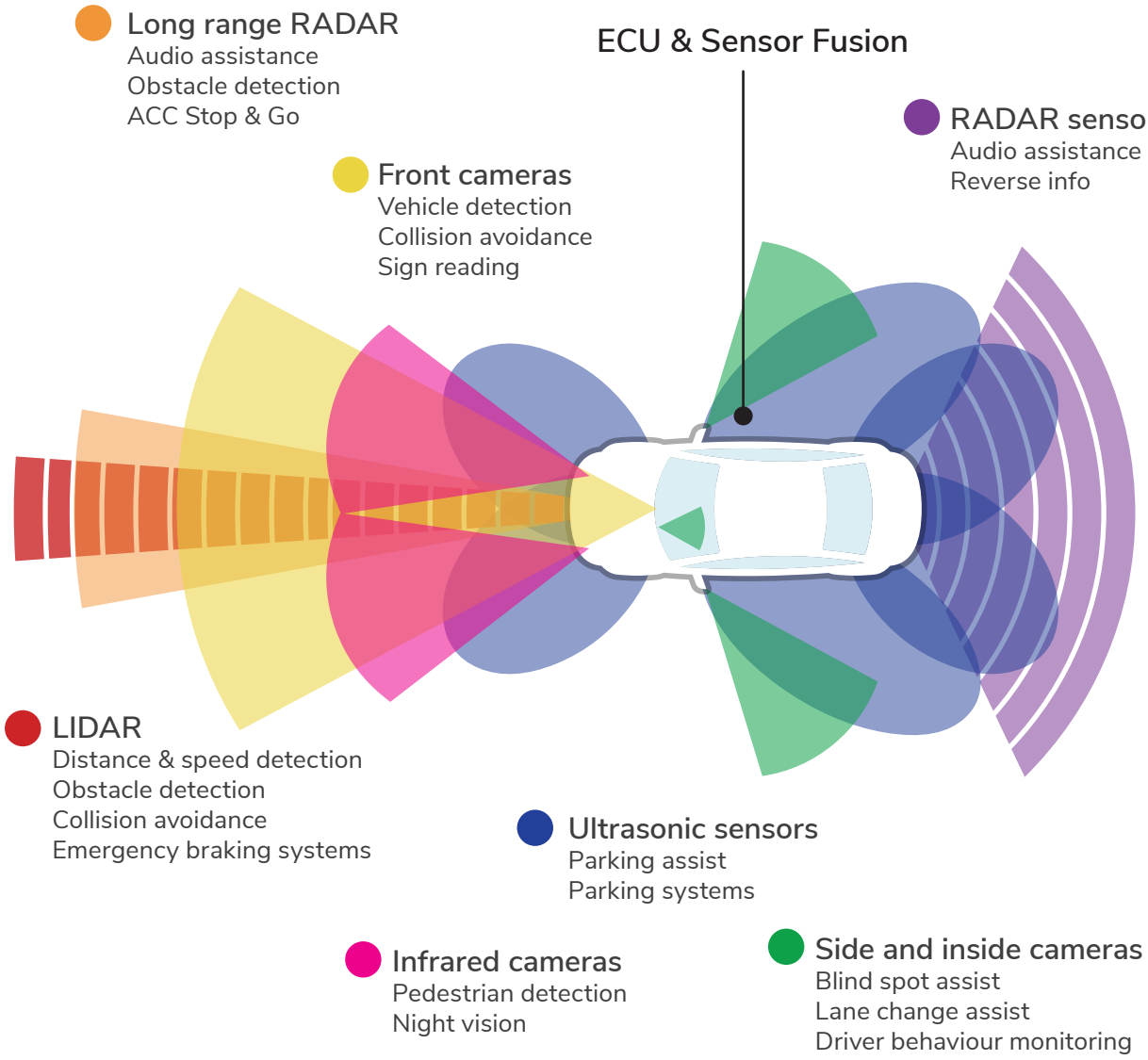
The automotive industry is amidst a period of transformation. A confluence of industry trends around safety and emissions, customer preferences, and technology advances is shifting focus on how products are developed by transport and mobility industry players. Among the most visible trends is the accelerating demand for Advanced Driver-Assistance Systems (ADAS) and Autonomous Driving (AD) systems, spurred by evolving safety standards and increased consumer interest. By 2030, 67% of vehicles sold globally will have at least level 2 and 3 autonomous driving capability. One quarter will have level 4 and under 5% will have level 5 full automation capabilities.

EXHIBIT 1: SAE LEVELS OF AUTONOMY

0	1	2	3	4	5
No Automation	Driver Assistance	Partial Automation	Conditional Automation	High Automation	Full Automation
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.

To ensure readiness, vehicle OEMs, Tier 1 suppliers and mobility providers are reprioritizing their investment in ADAS product development to fast-track innovations to market. To do so, they must optimize the way they ingest and manage the massive amounts of data generated by vehicles and the infrastructure that the current ADAS and AD test & development solutions rely on.

EXHIBIT 2: CURRENT LEVEL 1 ADAS VEHICLES USE 15–20 SENSORS AND ELECTRICAL CONTROL UNITS (ECUS), GENERATING OVER 1 TB OF DATA PER DAY



As ADAS solutions evolve from simple collision-avoidance systems to fully autonomous vehicles, these systems will combine complex sensing, processing, and algorithmic technologies. This vehicle-generated data is a critical component to improving ADAS systems, feeding into integrated test and development cycles (or development tool chains) for these systems. In addition to vehicular data, ADAS Test & Dev. systems in the next 3–5 years will also rely on inputs from infrastructure to support the growing scale of data movement, computing and storing required between the vehicles, across the edge, through the cloud and within on-premise environments. Such data will support ongoing modifications to current simulation, SIL, and HIL testing to improve the reliability of services after deployment.

However, before connected and autonomous vehicle providers can leverage the data, they must first solve the underlying complexities associated with creating data capital and value. Scaling and evolving ADAS systems will require a seamless data management process that is flexible enough to handle challenges such as:

- Future-proofing ADAS simulation and architecture, to adapt to changes in vehicle sensors and other environmental data points
- Managing data storage to comply with regulatory and privacy requirements, while addressing security and accessibility needs
- Analyzing massive volumes of unstructured data sets, to support analytical modelling and querying of ADAS data. This requires costly and time-consuming data preparation steps, such as labeling data for analysis.

In this report, Frost & Sullivan and Dell Technologies provide insight on how developers, engineers, and data scientists focused on ADAS/AD development can accelerate the value of data to help their firms win the ADAS race.

WHAT MATTERS MOST TO R&D

To ensure a successful ADAS/AD approach, engineers, developers and data scientists need to prioritize action items. Based on conversations with these ADAS/AD leaders, Frost & Sullivan sees the following as top initiatives:

Turn driver experiences into programmable information—An integrated and homogenized method of data storage enables developers to conduct tasks (such as localized data labelling, transcoding, compression, and integration of data blocks) that can empower collaborative training, simulation and referencing of data sets. This will ensure safe operation of the vehicle into the future.

> Today our biggest bottleneck in ADAS test and dev environment is data labelling. For some complex driving environments, the time delays between data ingest and modelling can be as much as two weeks, which we assign for data annotation and labelling.
>
> Sr. Director, Safety and Convenience, European Tier 1 Supplier

Determine what data is and isn't important. Develop predictive and prescriptive models to deal with the influx of sensory information—Labelled data will need to be trained on predictive and prescriptive models that developers will access for each use case. For complex models, users require on-demand resources to accelerate specific instances for workloads. With ADAS/AD systems now being regulated based on object sets,it is critical for developers to

prioritize models that meet all edge cases defined by safety standards, complying with the threshold of false positives and negatives acceptable in each system.

> The challenge today is to understand what data sets are relevant at what time and how much data and how many services will be required. We spend a significant amount of our scarce resources in object annotation and labelling, which is tedious yet critical for improving our algorithms.
>
> Chief Engineer, Fully automated driving and driver assistance Premium European OEM

Architect advanced data-driven solutions, models, statistical methods, prescriptive analytics and cognitive computing components to solve complex operations—To minimize resource consumption, developers use dynamic computing to run virtualization and simulation of the models. Virtual and SIL/HIL simulation is an essential step in a robust development framework for creating safety critical software. Developers prioritize compliance with ISO 26262 and its V framework for the ADAS and AD software stack, with a diverse set of combinations to support statistical methods and prescriptive analytical models to ensure validity of the ADAS/AD software.

> Key to resolving this issue and handling complex data handling operations is to develop agile workflow models capable of accelerating the fine tuning of our perception and path planning blocks, while ensuring to adhere to strict automotive system standards.
>
> CEO, AD Software Supplier

Continuously ideate and contribute to new business services based on data capacity and capability—Beyond development of ADAS/AD systems, the route to zero false positives and negatives is constantly pushing developers to create new and innovative means of improving ADAS/AD services. Developers are seeking more data sets from the environment and infrastructure that can be implemented into the test and development cycle, further advancing the reliability of ADAS/AD systems.

> We are now preparing for a future where in-vehicle sensors alone will not be sufficient to make ADAS systems robust enough. There will be a further influx of data from infrastructure and other nodes that will all need to be incorporated into our models to ensure we have an agile model for all future ADAS systems we roll out.
>
> Sr. Manager, ADAS Research & Development, European OEM

UNDERSTANDING THE ADAS/AD DEVELOPMENT LIFECYCLE THAT UNDERPINS DEVELOPMENT TEAM SUCCESS

In order for vehicle OEM, Tier 1 suppliers and mobility provider development teams to leverage their data, they must first solve the underlying complexities associated with the ADAS/AD development lifecycle that will create data capital and value. Scaling and evolving ADAS and AD systems will require a seamless test and development platform that has the capacity and flexibility handle workloads such as:

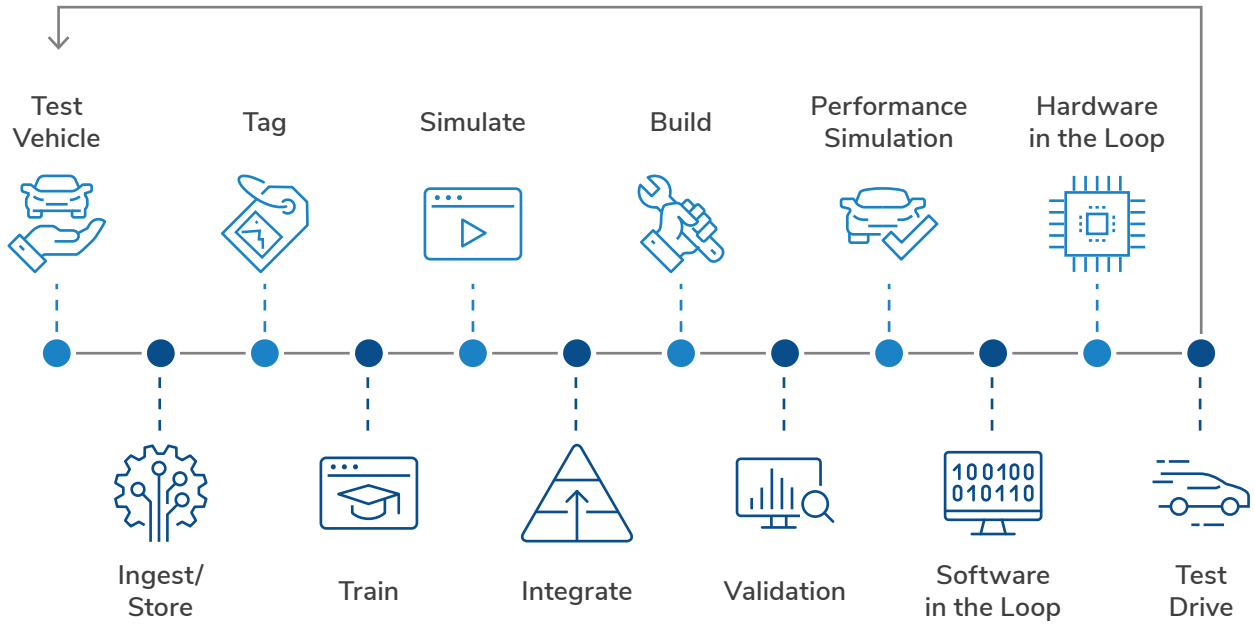
- Vehicle data acquisition, ingestion, movement and preparation of massive volumes (PBs to TBs/day) of unstructured data sets to support simulation (and ongoing re-simulation) of data against ADAS/AD test cases and models. This requires costly and time-consuming data preparation steps, such as trimming, decoding, data enrichment (labeling), processing, and adding metadata attributes

Design and development of ADAS/AD machine/deep learning models for sensor (smart cameras, lidar) and electronic control unit (ECU) system testing based on all possible corner cases, weather, and road/environment changes

- Re-simulations of tuned ADAS/AD models that are executed on models in the loop/hardware in the loop/software in the loop (MiL/HiL/SiL) test systems. This involves “replaying” the captured raw sensor data back through the test farm—usually with hundreds or even thousands of iterations running in parallel where high-concurrency is needed
- Analysis of results and ongoing support of a continuous improvement loop for the models, test cases and in-vehicle ADAS/AD sensor and ECU systems operation
- Archiving and managing data storage to comply with regional regulatory and contractual requirements (simulation data restoration time), while addressing security, accessibility and affordability needs

These steps are not time-sequential, but must all be conducted concurrently and continuously to ensure engineers, developers and data scientists within the development teams progress and create safe and accurate models, tests and outcomes.

EXHIBIT 3: DEVELOPMENT LIFECYCLE & TOOL CHAIN



Sources: Bosch and Frost & Sullivan.

ACCELERATE AND SCALE YOUR ADAS/AD DEVELOPMENT SUCCESS

The data management and computational demands underpinning the ADAS/AD test and dev environment are substantial and require solutions that is can accelerate time to market and scale to accommodate complexity and exponentially growing ADAS/AD data sets. Essential to helping ADAS/AD development teams unlock the data and create value is a high performance and high capacity platform that can provide the following:

A consistent, high throughput solution to ingest data from test vehicles while simultaneously delivering the test data into hundreds to thousands of concurrent streams to MiL/SiL/HiL servers, test stands and even deep learning training. It must also scale performance near-linearly, so performance isn't degraded as capacity is added—critical for ADAS development where sensor data ingest rates of 2 PB+ per week are becoming common.

A high performance and predictable storage solution that will scale and manage ADAS/AD data sets and workloads as they grow centrally and regionally. Essential elements of the

platform include an expandable single namespace, eliminating data silos by consolidating all globally collected ADAS/AD data; automated plug and play hardware detection and expansion that won't disrupt ongoing projects; automated policy-based tiering to reduce file server sprawl and performance bottlenecks; and file-object orchestration and encryption that will allow data movement between high performance network-attached storage and lower-cost private and public cloud options.

Distributed deep learning frameworks are core to unlocking data capital and foundational to ADAS and AD development. Because deep learning models are very complex and large, developers can benefit from using a deep learning framework— an interface, library or a tool that allows them to leverage deep learning easily and quickly, without requiring in-depth understanding of the underlying algorithms. These frameworks provide a clear and concise way for defining models using a collection of pre-built and pre-optimized components. Essential characteristics of well-designed deep learning frameworks, such as Tensorflow, Keras, PyTorch, and Caffe, include: optimization for GPU performance, easy to understand code, extensive community support, process parallelization to reduce computation cycles, and automatically computed gradients.

An optimized and scalable accelerator-based platform that has the capacity and ability to run AI in place as well as deep learning (training) and MiL/HiL/SiL workloads. Engineers and data scientists continuously manage massive data sets and compute-intensive workloads to run their ADAS/AD test and dev operations across departments and around the globe. A large capacity and distributed GPU-based compute and storage infrastructure gives development teams the ability to rapidly build, train and deploy test cases and AI models, predictive analytics, simulations and re-simulations.

Why Dell Technologies for ADAS and AD

While engineering and development teams look to accelerate time to market, Dell Technologies is increasingly working to automate, standardize, and cloud-deliver infrastructure layers to scale with agility, accommodate the complexity of exponentially growing ADAS/AD data sets and create both test & development and production-ready platforms.

Dell Technologies also continues to focus on delivering a balance of high performance, scalability, and ease-of-use while increasing efficiency and minimizing costs over time. This innovation mindset ensures a challenge to the status quo of how high-performance computing & storage are leveraged but more importantly why it is strategically integral to the future infrastructure and provides simplicity, performance, and future-proof infrastructures to support the massive data needs for ADAS/AD development.

We have deep expertise in ADAS/AD infrastructure deployment that powers the industry

Dell Technologies has been helping automotive OEMs and Tier 1 suppliers design and develop their ADAS and AD test & development platforms for over 8 years. Drawing upon 40+ customers engagements, our engineers and technologists share their extensive experience and expertise in the design, deploy and management of ADAS/AD infrastructureås. To date, we've deployed over 1+ exabyte to support ADAS platforms in the market.

We have an award winning, best in class infrastructure to accelerate ADAS and AD

To help development teams reduce time in data preparation and management, we maintain a scale-up, scale-out architecture that is unmatched within the industry. This includes:

- **Purpose-built ADAS/AD Solutions**
  To support massive datasets and mixed ADAS/AD workloads, Dell Technologies delivers the consistent, high throughput required to ingest data from test vehicles while simultaneously

delivering test data into hundreds to thousands of concurrent streams to MiL/SiL/HiL servers, test stands and even deep learning training

- **Scalable storage and compute**
  Our Unstructured Storage Division helps you combine multi-petabyte scale-out, global petabyte scale single namespaces, re-sim/re-read data SLAs within hours and more cost-effective, long-term data retention.
- **Hybrid and multi-cloud capabilities**
  Dell gives you access to a hybrid/multi-cloud specifically designed for ADAS/AD development workloads. Dell Technologies Cloud for Automotive creates the environment to manage a fully automated toolchain, end to end data movement and leverage public cloud(s) of choice. The future is hybrid-multi-cloud and we uniquely fill that need enabling the best of both worlds without compromise or excessive cost.

We provide versatility leveraging extensive partner ecosystem

Dell Technologies fosters critical relationships with automotive and mobility specific technology partners across the ADAS/AD development cycle. We understand no one technology provider can provide an end to end solution. We have a growing ecosystem of partners such as Siemens, Altair, IAV, Autodesk, Dassault Systems, it-RSC, PTC, Nvidia and continuously work with our customers to evaluate and select the other best in class data management, MiL/HiL/SiL, public cloud analytics, AI/ML partners to ensure a successful ADAS/AD journey.

We invest in innovation

We've invested 5.6% of total revenue (more than $4 billion) in research and development. That investment also includes the buildout of our Centers of Excellence labs staffed by world-class experts who partner with customers, design solutions and test- drive cutting-edge technologies.

Through Dell Technologies Capital we've invested more than $600 million in tech startups to help our customers make the most of emerging technologies.

FROST & SULLIVAN'S CONCLUSION

OEM and mobility provider engineers, developers and data scientists have a difficult job. They need to turn driver experiences into programmable information, determine what data is important, architect integrated development tool chains, train and retrain ADAS/AD models, and ensure they deploy highly accurate and scalable updates to their test and development vehicle fleets for further progression in the race for autonomy.

To do this, they need a high performing, highly scalable future-proof infrastructure platform and strategic partner with the vision, best in class solutions, capabilities and extensive set of ecosystem to unlock their data capital and fuel their ADAS and AD journeys.

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