



Highly Automated and Autonomous Vehicle Development with **Amazon Web Services**

How AWS is helping automotive customers accelerate Advanced Driver Assistance Systems and Autonomous Vehicle development



Autonomous technology is driving transformation in the automotive industry

There's widespread agreement on the inevitability of Autonomous Vehicles (AV) becoming an important and rich segment of the global mobility ecosystem. Autonomous vehicles hold the promise of a safe, efficient (for energy and operational cost savings), and accessible (for the disabled, elderly, and underserved) future that will minimize the dependency on—and eventually eliminate—the need for a human driver.

Nevertheless, it's also widely accepted that there's still a long and sometimes unmapped road ahead to getting autonomous technology precisely right—requiring innovations, commitment, creativity, capital, and abundant resources.

In this eBook, we'll explore how **four industry leaders in AV**—**Lyft**, **Toyota Research Institute**, **Momenta**, and **TuSimple**—are partnering with **Amazon Web Services** to innovate and accelerate their autonomous vehicle development as they look to transform themselves into mobility services providers.



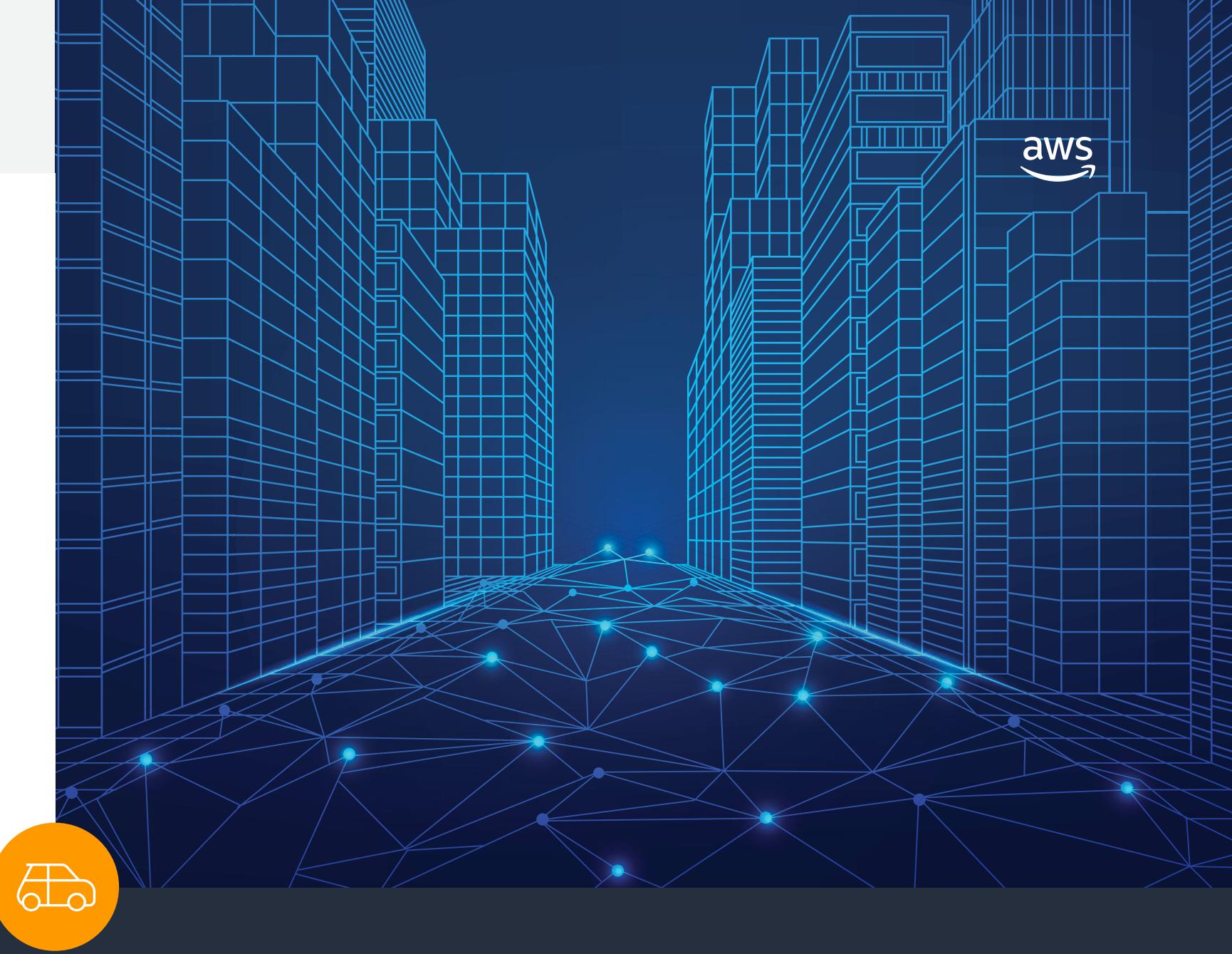
Near-term priorities shift from AV to Advanced Driver Assistance Systems

The realization of AV is complex and proving to be costly with more than \$13 billion spent in 2020 on Advanced Driver Assistance Systems (ADAS) and partially automated systems, including technologies such as machine learning, sensor, and software that will one day enable cars to effectively see and think for themselves.¹

Selective investments in AV picked up pace in the fourth quarter of 2020 after an AV-timeline shift and COVID-induced slowdown in the first three quarters of the year. Autonomous technology is not mature enough and the timeline predictions for a true Robotaxi future has shifted beyond 2030. Early autonomous adoption is expected to occur in goods delivery and geo-fenced mobility services.

While fully autonomous timelines are unclear, ADAS development and deployment will grow exponentially in the next decade due to regulations calling for mandatory ADAS features and driving customer demand.

By 2026, there will be more than 200 million passenger vehicles on the road globally with advanced driving assistance systems.¹



The road ahead

- ✓ The **current focus** of the industry is on advanced driver assistance systems (ADAS) with parallel ongoing efforts in AV.
- ✓ Regulations and customer demand will cause the number of ADAS programs to **accelerate** in the next decade.
- ✓ Fully autonomous vehicle timeline is unknown and is **unlikely** before 2030.
- ✓ Market-first autonomous use cases will be around **goods delivery** and **geo-fenced mobility services**.
- ✓ **China** is expected to be an early AV powerhouse.



Finding the **most experienced**
technology partner is
critical to success.

The cloud is accelerating AV breakthroughs and is foundational to scaling the technology

The massive data and computational intensity of AV makes it among the most demanding of endeavors. In important ways, it's about teaching AI to navigate our complex world. A single autonomous vehicle may generate up to 100 terabytes of data per day. This translates to petabytes of autonomous vehicle driving data that AV customers need to store, manage, and derive value from.

As many of the early leaders in AV development discovered, the limitations of on-premises data centers, including limited storage and compute, high CAPEX, and lack of continuous innovation and flexibility makes the cloud an essential element in a successful AV strategy.

AWS readily provides the scale, security, data compliance, and the latest in technology for AI and machine learning required to make AV development and deployment a reality in the years ahead.

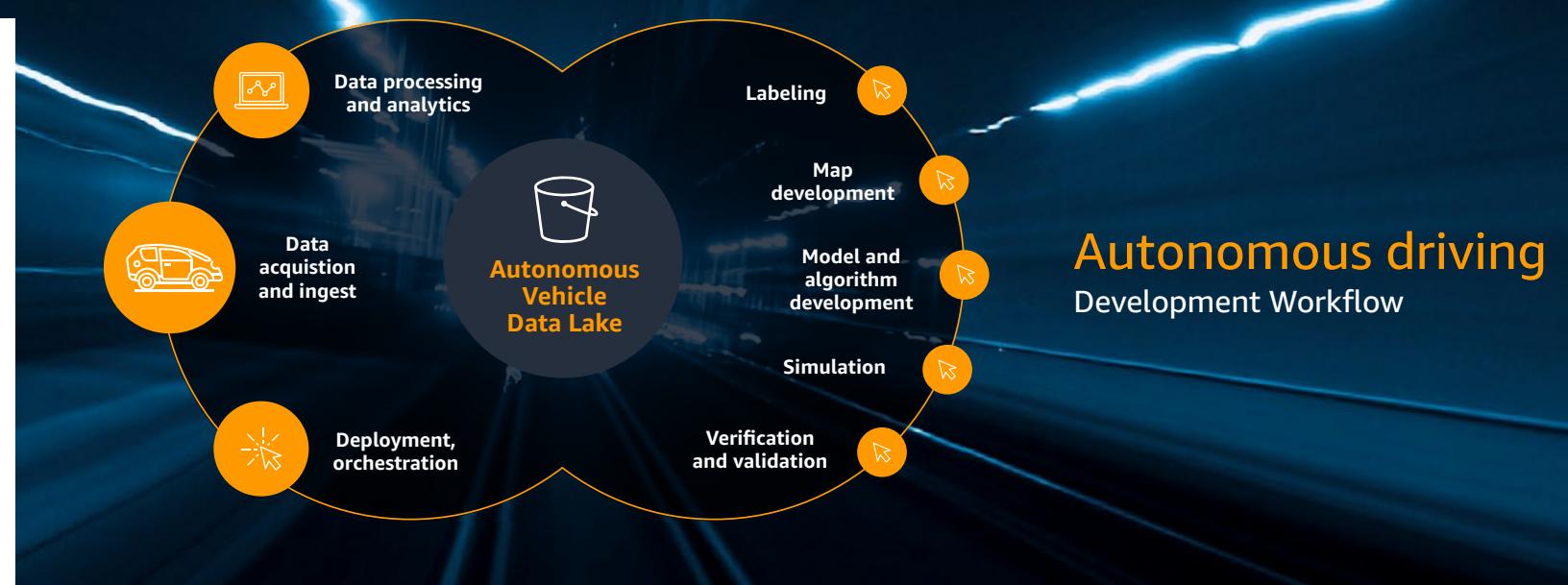
AWS and the AWS-enabled partner ecosystem can provide the required development tools and an environment that is adaptable, agile, and traceable for compliance and homologation (the process of certifying a product to indicate that it meets regulatory standards and specifications, including safety and technical requirements).

AWS is your trusted autonomous development technology partner

Even large data centers have limited capacity in contrast to the cloud, which offers virtually unlimited capacity and agility for scaling storage and computing to meet the needs of AV technologies. AV executives are finding the cloud to be significantly more cost-effective while protecting the flow of data to, from, and between autonomous vehicles and providing advanced data privacy and security services to meet core data and security and compliance requirements.

AWS is recognized as a cloud leader for the tenth consecutive year by Gartner. In addition to industry-leading technologies, AWS provides the highest standards for security and privacy with customers owning their data on AWS. Amazon has a 20-year history of innovations and continues to make investments in autonomous systems and machine learning. AWS has a versatile and powerful suite of technologies to enable ADAS and AV development across the toolchain: data ingestion, edge computing, data storage and management, training, simulation, verification, validation, and, finally, the iterative feedback loop with the vehicle through over-the-air updates.

The potential rewards in the AV space are tremendous but the barriers to achieving them are not inconsequential: AV companies need to build new systems and think differently in order to be successful. To help them meet and exceed their goals, they must choose the right cloud partner: One with the broadest set of services, a large geographical footprint, and enough capacity to meet the massive compute and storage needs of AV. TCO optimization using cloud requires scale and agility. AWS is best suited to serve the AV needs of our customers.



Key solutions include

- ✓ **AWS EC2** The broadest compute platform.
- ✓ **Amazon Simple Storage Service (Amazon S3)** An object storage service that offers industry-leading intelligence, scalability, data availability, security, and performance.
- ✓ **AWS ML Stack** The broadest and most complete set of machine learning capabilities.
- ✓ **AWS Sagemaker Ground Truth** A comprehensive data labeling service for machine learning.
- ✓ **AWS Direct Connect** A cloud service solution that makes it easy to establish a dedicated network connection from a customer's premises to AWS.
- ✓ **AWS Snow Family** Including **Snowball**, an edge computing, data migration, and edge storage device, and **Snowcone**, a portable, rugged, and secure edge computing and data transfer device.
- ✓ **AWS Outpost** A fully-managed service that offers the same AWS infrastructure, services, APIs, and tools to virtually any data center, co-location space, or on-premises facility for a truly consistent hybrid experience.

Lyft runs large-scale AV simulation and manages petabytes of data on AWS

Lyft, one of the largest transportation networks in the US and Canada, is on a mission to improve people's lives with the world's best transportation. Lyft launched its Level 5 autonomous vehicle division in 2017 as part of the effort to achieve this mission. Using petabytes of data gathered from its AV fleet, Lyft's engineers run millions of simulations each year to improve the performance and safety of its self-driving system.

But those simulations are compute intensive, and Lyft knew it needed massive computing power that could scale up and down to boost its compute capacity and lower costs.

The company, which has been using Amazon Web Services for its rideshare platform since the day it launched in 2012, turned to AWS again to boost its compute capacity and lower costs, ultimately choosing a combination of **Amazon Elastic Compute Cloud (Amazon EC2) Spot Instances** and **Amazon Elastic Kubernetes Service (Amazon EKS)** for its AV simulation workload.

Steep cost savings drive AV research advances

To manage the massive amount of data gathered from simulations and its AV fleet, Lyft relies on **Amazon Simple Storage Service (Amazon S3)** to store and access an ever-expanding dataset as Lyft increases the number of sensors on its test vehicles.

Transferring that amount of data directly to the cloud, as the Level 5 team did in the early days, was costly. To reduce costs, Lyft uses **AWS Direct Connect**, a dedicated network connection between its Level 5 engineering center and its cloud systems.

Running millions of simulations at a steep cost savings on AWS allows Lyft's engineering team to run its tests from inside its offices, enabling staff to gain confidence in software changes prior to taking physical vehicles out in the real world.

Using a combination of Amazon EC2 Spot Instances and Amazon EKS, plus other AWS services, Lyft is moving the world closer to a place where self-driving cars improve access to safe and reliable transportation.



"About 77 percent of our computing fleet is now on Amazon EC2 Spot Instances. We were able to scale up our computing capacity significantly while reducing the overall cost of operation."

Timothy Perrett, Senior Staff Engineer,
Lyft Level 5



Benefits of AWS

- ✓ **Reduced** compute costs by two-thirds.
- ✓ **Scaled up** computing capacity significantly.
- ✓ **Increased** velocity of development for AVs.

Toyota Research Institute accelerates automated driving with deep learning on AWS

Among the top priorities at Toyota Research Institute (TRI) is to apply the latest advances in artificial intelligence to produce self-driving cars that are safe, accessible, and environmentally friendly. To help achieve its goals, TRI turned to deep learning on AWS.

Using **Amazon EC2 P3 instances**, TRI is seeing a 4x faster time-to-train than the P2 instances it had used previously, reducing training time from days to hours. This gives researchers significant agility to optimize and retrain their models quickly and to deploy them in test cars or simulation environments for further testing.

In addition, the significant performance improvement in P3 instances over P2 instances, coupled with the AWS pay-as-you-go model, translates to lower operating costs for TRI.

Spinning up compute and storage resources

TRI needed an IT platform that can handle large amounts of data, has the required processing power to train machine learning models quickly, and can scale to meet its requirements. Using AWS, it gained the ability to spin up compute and storage resources on demand and couple them with higher-level management and orchestration services. This provides TRI's development teams the agility to enable a rapid R&D cycle that can run experiments on massive amounts of data.

TRI uses Amazon S3 to store and retrieve any amount of data from anywhere and **Amazon SQS** to coordinate data transfer to and from remote data collection sites. The core compute capability needed by TRI to accelerate the training of their machine learning models is powered by multiple Amazon EC2 P3 instances which feature NVIDIA's latest Tesla V100 GPUs. P3 instances are some of the fastest GPU instances available in the cloud.

Using deep learning on Amazon EC2 P3 instances, Amazon S3, Amazon SQS, and AWS networking services, TRI built a scalable solution to enable their development teams to make rapid progress and deliver on their grand vision of applying AI to help Toyota produce cars that are safer—and get closer to realizing a future without traffic injuries or fatalities.

*"Using the AWS Cloud and specifically Amazon EC2 P3 instances, we're able to build a **scalable and highly performant** applications stack to efficiently handle and process the huge amount of data that we collect."*

Mike Garrison, Technical Lead, Infrastructure Engineering,
Toyota Research Institute



Momenta builds the brain on AWS to make autonomous driving go

Momenta is positioned to build an autonomous driving brain. Its core technology is deep learning-based environment perception, high-precision maps, and driving decision-making algorithms. The company's strategy is to accelerate the mass production of autonomous driving technology and fully unmanned driving through data-driven algorithms and closed-loop automation.

A stable, reliable, high-performance, and easily expandable IT infrastructure is critical to the fast-growing Momenta. The company uses **Amazon Simple Storage Service (Amazon S3)** for storage, management, and access to tens and even hundreds of petabytes of data. By using Amazon S3, Momenta can safely store any amount of data, and the data durability can reach 99.99999999 percent.

Amazon S3 also provides a wealth of storage types. Without sacrificing performance, it performs hierarchical storage according to the value and life cycle of the data, thereby saving costs. For example, in the AWS China (Beijing) Region operated by Sinnet, **Amazon S3 Glacier** is used to store 1TB of data, and it costs only 3.4 Yuan (\$0.49) per month.

Performing bid data analysis

Amazon S3 has built-in functions and free services, which makes it possible for a direct query of data without copying or loading data into a separate analysis platform or data warehouse. At the same time, Amazon S3 can also perform big data analysis in conjunction with **Amazon EMR** to provide safe driving assistance decision services.


“In just two weeks, based on AWS IoT and AWS Lambda, we were able to **quickly build** the after-market, on-board IoT prototype, **complete** the verification of the scheme, and **open up** the entire closed loop. It would have taken at least two months to develop the necessary functional components completely independently.”

Dong Weishan, Research and Development Director, Momenta

In the future, Momenta's on-board data mining and monitoring platform may need to manage hundreds of thousands or millions of IoT devices. With the help of **AWS IoT Device Management**, Momenta can easily and securely register, organize, monitor, and remotely manage IoT devices at scale, conveniently—and visually manage permissions, monitor device functions, troubleshoot, inquire the status of any IoT device in the queue, and send firmware updates over the air (OTA).

In addition, in terms of data transmission, **AWS Snowball** can migrate large-scale data to the cloud safely and efficiently at a low cost, saving operation and maintenance costs and improving Momenta's developer efficiency.



Benefits of AWS

- ✓ **Innovation** cycles are faster, more stable, and more efficient.
- ✓ **Improved** development efficiency with reduced operation and maintenance costs.
- ✓ **Ability** to achieve rapid deployment through global AWS regions with access to support, including AWS technology sharing sessions, and AWS Marketplace.

TuSimple uses AI and AWS machine learning to train self-driving semis

Though self-driving passenger cars get most of the attention, there's another pressing problem that autonomous vehicle technologists are working to solve: bringing self-driving technology to long-haul trucks.

TuSimple, based in both San Diego and China, is at the forefront of solving this challenge by leveraging artificial intelligence to develop self-driving trucks. The company currently has vehicles making trips of about 100 miles in length to generate test data for its deep learning algorithms.

Getting a tractor-trailer to drive itself is no easy feat, with a truck's length and width representing two of the central challenges. For a 70-foot-long truck, every calculation about accelerating, stopping, and merging is extraordinarily complex. And with only 21 inches of room on either side of an interstate freeway lane (in the US, 12 feet wide by law), a tractor-trailer has an even smaller margin of error than when driving on a city street.

On board each TuSimple truck is a server loaded with up to 100 AI modules. Built primarily using the **Apache MXNet** deep learning framework on Amazon Web Services, these modules ingest a steady stream of data from the system of cameras, lidar, and radar on the truck.

When the trucks return to home base, the data is analyzed using the massive computing power of **AWS GPU-powered compute** in **Amazon EC2 P3 instances**. TuSimple is also relying on two recent AWS innovations: **AWS Snowball Edge**, a new edge computing device that can streamline the migration of data from the trucks to AWS cloud services and back, and **AWS Snowcone**, a small, rugged, secure edge computing, storage, and data transfer device.

TuSimple's fleet, supported by AWS machine learning services and data storage, is making meaningful progress towards achieving a degree of accuracy that will keep a self-driving truck, with loaded trailer, in the center of a lane on the highway within 5 centimeters of accuracy.



"A few hundred years ago we were using cows to help us plow the land. We're still looking for ways for human labor to be done by machine. This is really a natural **evolution of human civilization**."

Xiaodi Hou, President & CTO, TuSimple



Benefits of AWS

- ✓ **On-demand access** to the latest GPU instances and integrated deep learning frameworks reduces training time from days to hours.
- ✓ **Global collaboration** between test and development sites.
- ✓ **AWS Snowball Edge** for easy data transfer from the vehicle to the cloud.



Where success with autonomous systems and the cloud is homegrown

Amazon's mission to be the earth's most customer-centric company, and the culture of innovation for which it has become known globally, led the company to develop and invest in autonomous systems early on—to meet its promises to customers.

Today, Amazon fulfillment centers benefit from efficiencies of advanced autonomous systems, while the goal of getting goods to customers faster has led to development of the Scout robot and Prime Air drone delivery services. Similarly, Amazon first developed its cloud technologies and cloud capacity to support its own operations and serve its customers.

Now, Amazon is making some of its autonomous systems technologies and its cloud services available to customers that want to rise in their industry verticals as Amazon has succeeded across its businesses.

" Even when they don't yet know it, customers want something better, and your desire to **delight** customers will drive you to **invent** on their behalf."

Jeff Bezos, Amazon Founder and CEO



Amazon Web Services: The leading cloud platform



Amazon Web Services (AWS) is the world's most comprehensive and broadly adopted cloud platform, offering over 175 fully featured services from data centers globally. Millions of customers are using AWS to lower costs, become more agile, and innovate faster.

✓ Most functionality

AWS has significantly more services, more features and the deepest functionality within those services, than any other cloud provider.

✓ Most secure

AWS is architected to be the most flexible and secure cloud computing environment available today, backed by a deep set of cloud security tools, with 230 security, compliance, and governance services and features. Customers always maintain control and ownership of their data, which is never accessed or used by AWS for any purpose.

✓ Fastest pace of innovation

AWS is continually accelerating its pace of innovation to invent entirely new technologies you can use to transform your business. Amazon SageMaker, for example, is a fully managed machine learning service that empowers everyday developers and scientists to use machine learning—without any previous experience.

✓ Proven operational expertise

AWS has unmatched experience, maturity, reliability, security, and performance that you can depend on: the most operational experience, at greater scale, of any cloud provider.

✓ Global infrastructure

The most secure, extensive, and reliable cloud platform.

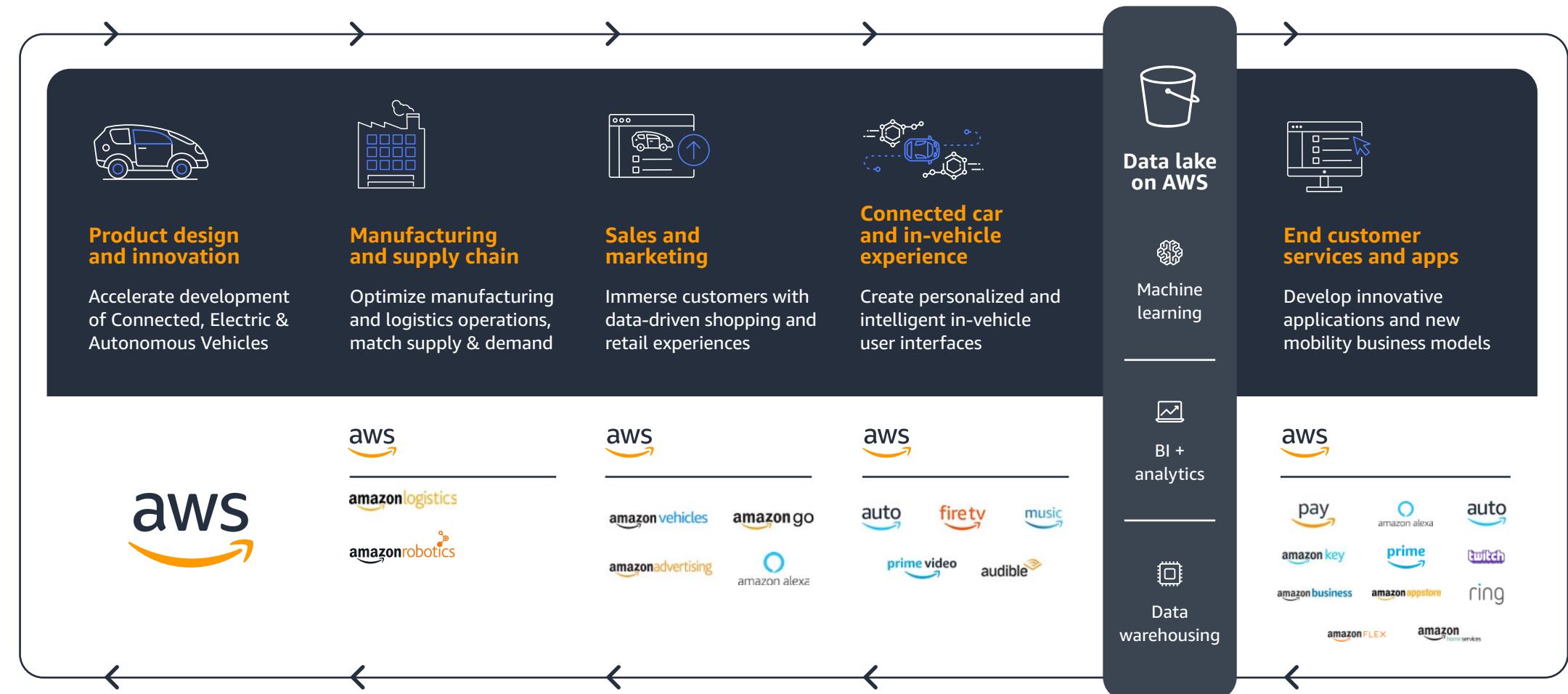
✓ Partner ecosystem

The largest and most dynamic community, with millions of active customers and tens of thousands of partners globally.

✓ AWS in China

AWS China (Beijing) Region operated by Sinnet and AWS China (Ningxia) Region operated by NWCD offer a technology service platform that is similar to other AWS Regions around the world.

AWS has a proven track record of delivering measurable business outcomes across the automotive industry value chain.





AWS Global Autonomous Development Team



Stephen Houghton

Head of Autonomous Vehicles GTM



Vijitha Chekuri

Autonomous Vehicle Business
Development Principal Specialist



Bryan Berezdivin

Worldwide Lead Specialist –
Autonomous Vehicles

To learn more about AWS for AV innovation, development, and deployment, go to
aws.amazon.com/automotive/autonomous-driving/

To schedule a virtual call, go to
aws.amazon.com/contact-us/