DIGITAL REPORT

VSI Labs

Ecosystem Analysis:

The Building Blocks of Automated Vehicles

AV Ecosystem Analysis: The Building Blocks of Automated Vehicles

Table of Contents

Introduction

Developing automated vehicle systems is a complex endeavor for anyone trying to compete in this space. OEMs and traditional automotive suppliers have been very active through tie-ups, investments, and acquisitions designed to improve their strategic position. Large tech companies are also very active in developing complete platform strategies as well as aggressive investments through their venture funds.

Beyond traditional auto and big tech companies, there are literally hundreds of other companies vying for a piece of the AV ecosystem. Many are startups with fresh rounds of capital are feverishly pursuing technology breakthroughs in the areas of sensing, processing, data handling, and software/algorithms. Meanwhile, well-established

companies have been entering the AV space from adjacent sectors such as geosciences, robotics, and artificial intelligence, while others are entering from industries such as aerospace, defense, and logistics.

The purpose of this report is to decompose the ever-changing AV ecosystem by looking at the latest version of VSI's infographic, which reflects the major players within the value chain for autonomy. The report provides a high-level analysis of the global AV landscape by explaining each domain of the AV ecosystem.

VSI AV Ecosystem Infographic: The Building Blocks of Automated Vehicles

The AV ecosystem is a vast array of companies both large and small, that offer products and technologies to support active safety (ADAS) and automated driving. Making sense of this complex and evolving ecosystem is an ongoing task.

VSI has been mapping the ecosystem of automated driving since 2014 and has been distributing the VSI Infographic: *AV Ecosystem - The Building Blocks of Automated Vehicles* since 2016.

VSI's AV ecosystem map is rather high level, and beneath it lie many categories and subcategories. Thus, VSI has also built an AV/ADS taxonomy for our database records system. The method for researching the companies and organizations that make up the ecosystem as well as the technical insight into their products and technologies led us to launch a dynamic and interactive infographic generator, the Ecosystem Examiner, in 2019, as part of the VSI portal subscription service.

In order to invite broader AV community members, we also opened the Ecosystem Examiner infographic generator to the public, for which are based on our company-product relational database organized by our product database taxonomy.

While the Infographics in the Ecosystem Examiner represent more than 1,000 companies and over 1,500 products, this VSI Infographic is VSI's selection of only the top AV companies in each domain of the value chain.

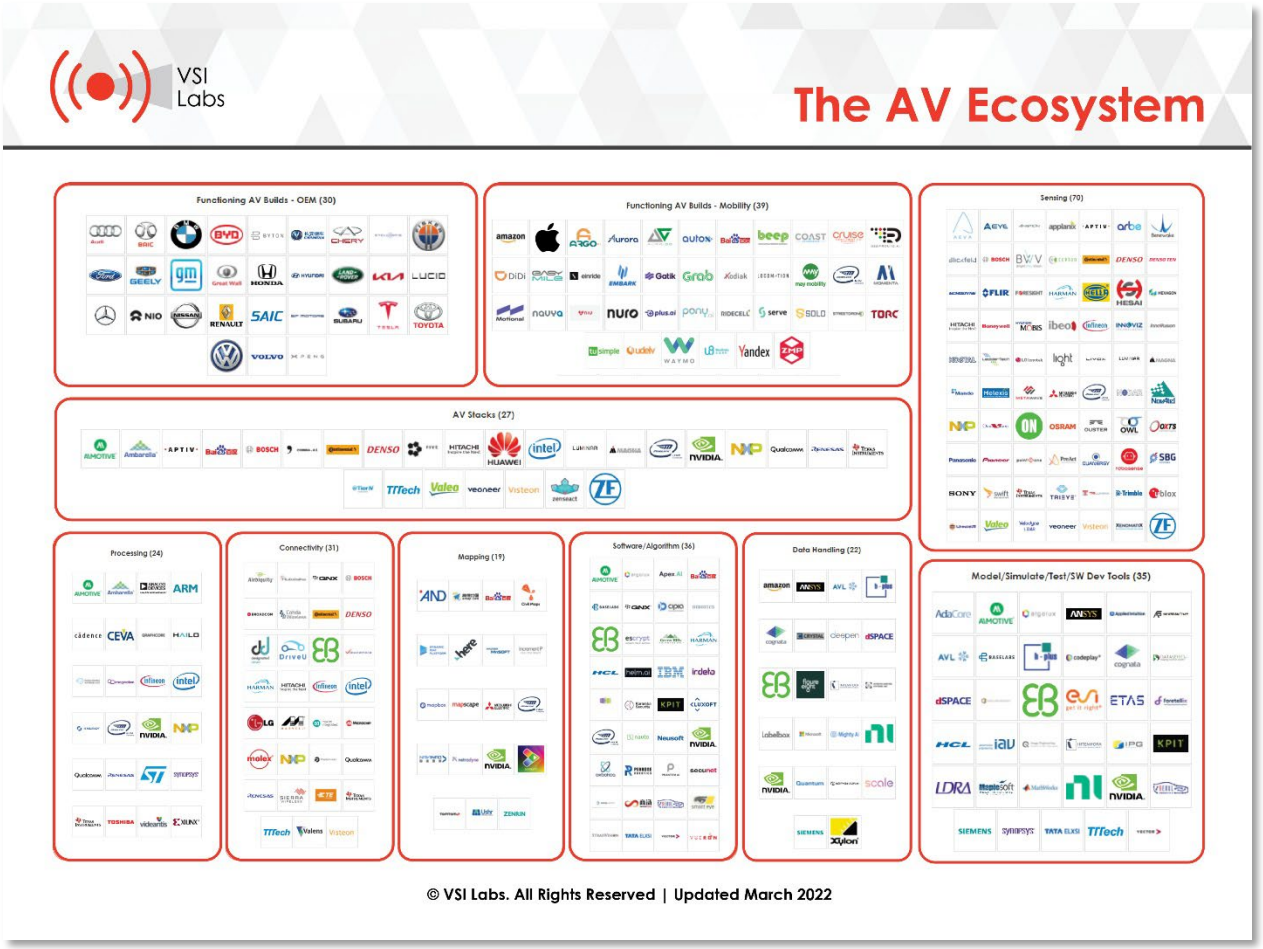
Selection Criteria:

- Companies featured in this infographic are chosen based on their known products or evidence of their commercialization strategy. A company operating in stealth mode does not necessarily qualify them to be on the chart unless we know precisely what they are doing and where their capital is coming from. Thus, industry visibility such as media/industry conference exposure is important to be considered, although the companies making the most progress are sometimes the ones making the least noise.
- VSI analysts receive analyst briefings from these companies routinely and gather insights by asking quality questions. Often we talk to each and every company in

an AV ecosystem domain, enabling us to assess who has a more competitive advantage. Our in-house lab engineers who perform applied research on AV technologies also help us build more objective and deeper technical insights on the technologies and products of these companies.

- Clarity of strategy, partnership span and ecosystem influence are also considered.

The VSI Infographic is updated regularly to reflect the dynamic nature of the ecosystem: mergers and acquisitions, internal business expansions, the emergence of new domains and the demise of business entities.



Latest Landscape of AV Technology

Let's decompose the ecosystem by examining the companies and their associated categories within the infographic. The following sections discuss the categories, the compositions of each category, and what type of products are included. Based on observed trends in each domain, the leading companies are called out as well.

Functioning AV Builds - OEM

The Functioning AV Builds category represents companies that are building complete vehicle platforms with AV functionality. This field is also divided into two sub-categories; OEM and Mobility.

The companies that are represented in the OEM category are traditional automotive OEMs that are actively developing ADAS/AV technologies for their production models. Their end goal is to build their own ADAS/AV vehicles and/or sell them to AV service operators or fleet operators.

To qualify for AV Builds, the OEM may offer automated features at the production level (typically L2 or L2+) and/or are developing L4 consumer AVs. These are typically separate business units, as OEMs rarely consolidate their automated activities into one group. Furthermore, the L4+ track is typically based on a new mobility service model which has huge implications in terms of timelines and go-to-market strategies.

There are several "hands-free" L2 ADAS systems on the market from **General Motors, Nissan, Toyota, Honda** in the U.S. and/or Asia. BMW, Volkswagen and Audi's L2 systems in Europe are rather "hands-on" L2 systems due to the regulatory environment. There are many upcoming hands-free L2 ADAS systems from OEMs including **Ford** and **Stellantis**.

2022 will see more L2+ premium ADAS systems and the emergence of "door-to-door hands-free" navigation systems. Door-to-door hands-free navigation systems include **Tesla** FSD Beta and many Chinese EV manufacturers' systems such as Mobileye's SuperVision-equipped **Zeekr** (EV unit of **Geely**) Autonomous Driving (ZAD), **Xpeng's** Xpilot, **Nio** Autonomous Driving (NAD), and **Arcfox's** (EV unit of **BAIC**) Huawei Inside (HI) in 2022. **General Motors** will join later with the Ultra Cruise in 2023. Chinese OEMs are especially interesting as China is collectively achieving an affordable local ADAS and AD ecosystem and supply chains are moving fast.

The public will start to see a few L3 systems in limited geographic areas, pending maturity of legal frameworks in each region. **Mercedes-Benz's** shipping of the L3 (low-speed Traffic Jam Pilot) Drive Pilot system-equipped S-classes (which is type-approved in Germany) is imminent as of March, not limited by production volume or to leasing models like the **Honda** Legend L3 system that launched last year. **BMW** and **Hyundai** will follow suit later this year. This doesn't make 2022 a year of L3, but there is growing

evidence that L3 commitment from the OEMs is getting serious. **Volvo's** announcement from CES 2022 also shows their firm commitment to L3 system launch starting in the US.

Few OEMs are talking about L4 consumer (personal) AVs. At CES 2022, **General Motors** teased a Cadillac personal AV (concept), while Mobileye highlighted its first design win of a consumer L4 platform from **Zeekr** (EV unit of **Geely**), whose SOP (Start of Production) will be early 2024. Traditional OEMs' consumer vehicles can and should benefit from their robotaxi operations. However, going from a robotaxi technology stack to a consumer AV will be a challenge because most OEMs' robotaxi units have made all design and development decisions separately from their consumer vehicles.

Functioning AV Builds – Mobility

The Mobility category includes companies that are developing and testing complete AVs for future mobility target markets such as the robo-taxi, low-speed automated shuttle, robo-delivery vehicle and autonomous truck. Many companies in this space retrofit current production vehicles and integrate systems from multiple suppliers coupling that with their own self-driving technology stack. Their end goal is to operate AV mobility services for the general public and commercial fleets.

Many of these companies develop full AV stacks in-house with a mobility service operation network in mind, but others may outsource either designing the AV system, integrating the software platform and/or compute platform.

Year 2022 will be a year for robotaxis, and VSI believes that there will be major milestones despite not a huge growth. VSI believes **Cruise** will get the 6th and final permit for robotaxis in California, as it already started opening up fully driverless robotaxis to the public in San Francisco (SF) in limited fashion. Meanwhile, **Waymo** may expand Waymo One without safety drivers in SF, possibly also expanding borders of driverless service in Phoenix.

We will also see some demos and pilot programs from **Amazon (Zoox)**, **Motional**, **Argo AI** and **Aurora** in 2022. **Mobileye** also boasts its progress with mobility companies in supplying turn-key "Mobileye Drive" systems and its robotaxi efforts in 6 cities (Israel, Detroit, NYC, Tokyo, Munich, and Paris). Mobileye will start robotaxi service with safety driver and no fees in Germany, Paris, and possibly in Israel as well.

These robotaxi and Mobility-as-a-Service full-stack AV technology suppliers do not build cars/EVs, and they are at the mercy of getting OEM deals to build vehicles for them.

Therefore, each of these companies either has ties with one or two traditional OEMs who acquired its stakes via financial investments, or has developed strategic partnerships to secure vehicle fleets.

The Chinese robotaxi deployment speed is quite impressive if you look at their milestones and launches in major dense urban cities, despite being small scale and regional. However, collectively, there are many major companies that also are doing drivered and driverless testing in California, being more focused on R&D rather than commercial deployment.

Meanwhile, the mobility industry has seen continuous consolidation. Uber, Lyft, and Voyage sold their AV units to Aurora, Toyota Woven Planet and Cruise, respectively. In low-speed autonomous shuttle markets, Optimus Ride was acquired by Magna recently, followed by ZF's acquisitions of Bestmile in 2021 and 2getthere in 2019. Low-speed shuttles or people movers operating on a fixed route or clearly defined geographic area did not attract as much investment as robotaxis, trucking, or delivery solution providers in the U.S. especially during the COVID era. Local Motors, the US-based creator of the "Olli" self-driving shuttle also went out of business.

However, **Navya, May Mobility, Easy Mile, Beep,** etc. have done many pilot projects in restricted areas and are nearing commercial operations. Robo-delivery companies such as **Nuro, Serve Robotics, Starship Technologies** are still attracting investments, while some other full-stack AV technology solution suppliers who have been only focused on robotaxi applications started piloting such delivery services as well.

Such full-stack AV technology solution suppliers are also turning their attention to autonomous trucks. The race to put self-driving vehicles on public roads took an unexpected turn in recent months, with autonomous trucks taking the lead position. These companies are concentrating on the hub-to-hub trucking segment, also called middle-mile trucking. This long-hall segment is primarily focused on highway driving, which is easier to deploy using current technology and safety features. **Waymo** and **Aurora** joined autonomous truck full-stack technology solution specialists and AV truck fleet network operators such as **TuSimple, Embark, Gatik, Kodiak, Locomation, Torc/Daimler Trucks, Plus, Einride,** etc.

Gatik's two "driverless" vehicles haul Walmart goods from big distribution centers to retail locations on short, fixed routes in Bentonville, Arkansas, where their headquarters

are. **TuSimple** has also recently made several "Driver Out" (no human in the truck) runs in Arizona. The design cycles in creating new technology in these trucks take a long time, which is why truck OEM partnerships are vital for the solution companies just like in other mobility sectors.

AV Stacks

The AV Stacks category includes companies that offer AV full-stack systems, or compute and/or software platforms that can handle the tasks of perception, decision, and control. These companies are developing AV platform technologies to control multiple domains of AV functionality. Most companies in this space also have their own research AVs for testing purposes only and do not operate such fleets. Their end goal is to provide their AV hardware and/or software stacks to OEMs and mobility service operators developing functioning AV builds – complete vehicles.

Intel/Mobileye, Nvidia, Qualcomm, NXP, AMD/Xilinx, Texas Instruments and some tier ones (**Hitachi, Denso, Bosch, Continental, Valeo, ZF, Magna,** etc.) lead the supply of AV compute platforms or ADAS/AV domain controllers. Automotive ADAS/AD applications are increasingly using a processor "platform" approach. The heterogeneous processors in such platforms are used for signal processing, image recognition, sensor fusion and machine learning to implement ADAS and AD functions. Especially for high-end ADAS and autonomy, the chipset vendors are all moving toward "centralized" compute platforms.

OEMs will start to work more directly with semiconductor and software companies to drive innovation. Chipset vendors are increasingly offering solutions with elements outside of silicon itself, such as development boards, design tools, reference designs, and even relevant free or licensable IP cores that primarily reside in the fabric but that provide SW functionalities and comprehensive pipelines of ADAS/AD applications.

VSI believes that specialized microcontroller-based distributed architectures will phase out and major chipset vendors as mentioned above will move toward central compute platforms as the level of autonomy increases for these systems. Recently, **Ambarella** joined this group by launching its latest CV3 domain controller SoC family.

Meanwhile, several "full-stack" AV platform suppliers such as **Five AI** pivoted to AV "SW" platform suppliers. Similar SW platform supplier includes **AiMotive** and **Zenseact**. They usually provide onboard software (algorithmic SW, framework SW and operating system), off-board software and data infrastructure (data processing, operations, mapping, maps), rather than licensing individual software components.

Sensing

The Sensing category is the largest category, to no surprise. Sensing is a large piece of the AV stack and the components here include all formats from sensor signal/image processing ICs to optics components and antennas, to complete sensing modules.

Although not shown in our high-level infographic, the sensing category is further defined by sensor types including RGB camera, radar, LiDAR, ultrasonic, IR/NIR (or thermal), GPS/GNSS, IMU (Inertial Measurement Unit) and INS (Inertial Navigation System).

No sensor can work alone for any highly automated systems (L3 and above), but camera-only (i.e., **Mobileye** SuperVision) and lidar-centric (i.e., **Luminar** Sentinel) systems are emerging with advanced perception software to power more reliable applications. Meanwhile, radar has been indispensable for its advantages.

Forward-facing cameras have been the most essential environmental sensor in ADAS/AD systems and will be in the future because they have better lane detection/tracking and color recognition capabilities than any other sensor. With computer vision and deep learning-based perception software, camera systems can further enhance object detection, object classification, object edge precision, semantic segmentation, traffic sign recognition, and perform subsequent object tracking very reliably.

However, one of the most inherent caveats of visible cameras is adverse weather, low-light performance, and operation in the dark. To overcome this, active sensor cameras leveraging Near Infrared (NIR) and Short-Wave Infrared (SWIR) are emerging. In the case of living object detection and classification, a Far Infrared (FIR) or Long-Wave Infrared (LWIR) thermal camera can be used. Companies addressing these challenges include **Brightway Vision**, **TriEye**, **AdaSky**, and **Teledyne/FLIR**.

Another inherent challenge for cameras is depth/range estimation from 2D images. Stereo systems from **Foresight** and **Nodar** can address solutions to such challenges, while there are a few companies tackling depth estimation from 3D camera perception platform such as **Light** and **Owl Autonomous Imaging**.

Today, we see automotive markets talking about 4D sensors - 4D FMCW lidars and 4D imaging radars. Lidar point clouds already have rich 3D information, but the fourth dimension the upcoming FMCW lidars are bringing is "velocity." Such FMCW lidars will be brought by companies like **Intel/Mobileye**, **Aeva** along with a company like **Aurora** who acquired another FMCW lidar makers like Blackmore and Ours and manufactured its own FMCW lidar.

Still, the 3D Time-of-Flight (ToF) lidar manufacturers are the major incumbents in the lidar markets, such as **Valeo**, **Luminar**, **Innoviz**, **Velodyne**, **Ouster**, **Cepton**, **AEye**, etc., all of which went public in stock markets. Although industrialization of some of these startups are lagging, the use cases for some of the lidars include low-speed Traffic Jam Pilot systems and upcoming full-speed L3 highway pilot. Lately, lidar systems see their use cases even in active safety applications, such as enhanced AEB.

Chinese lidar companies are also taking advantage of lidar for these use cases. For example, Xpeng Xpilot's **Livox** lidars improve the vehicle's ACC. These affordable Chinese EVs leverage relatively cheaper local lidars (Robosense, Innovusion, etc.) for basic ADAS even if they don't explicitly call it out.

Texas Instruments, **NXP**, **Infineon**, **ST Microelectronics**, and **Analog Devices** have been the leaders in contemporary mmWave 3D FMCW radar chipsets. Now, many new 4D imaging radar developers are leveraging this completely new antenna design on top of such radar chipsets. 4D imaging radar is a relatively new technology that uses a large Radio Frequency (RF) channel array to detect the relative speed, distance, and azimuth of items in the roadway, as well as the height of the objects above the road (the fourth dimension). Now, the incumbent imaging radar leaders like **Arbe**, **Uhnder**, **Metawave** are joined by new entrants including major tier ones (**Aptiv**, **Magna**, **Continental**) and numerous startups. Some of them are specialized in software only which can process rich imaging radar point cloud data to unlock the potential of the novel sensor.

GPS positioning is vital for AVs because they require absolute location, but GPS by itself does not provide the precision necessary, so many AV developers rely on enhanced GNSS receivers that rely on ground-based transponders to improve GPS accuracy down to a few centimeters.

Another sensor vital to AV functionality is Inertial Measurement devices (IMUs). When coupled with wheel odometry, IMUs can predict the AV's position through dead reckoning, especially in areas where GPS signals are compromised. INS devices typically come with both GPS and IMUs, along with positioning engine and correction services. Major suppliers include **Trimble**, **Swift Navigation**, **OxTS**, **Novatel/Hexagon**, and **Point One**.

Processing

The Processing category includes companies that offer processing logic or licensed IP. The processor technologies and types represented in this domain typically include digital signal processing (DSP), field-programmable gate array (FPGA), graphics processing unit (GPU), microcontroller, and a system on a chip (SoC). There are also application-specific integrated circuits (ASICs) which are essentially customized instruction sets coupled and optimized for a specific computing function. This category would also include processors optimized for computing and AI-based inference model.

Within the context of automation, these processing technologies are used for the areas of perception, localization, prediction, planning, control, AI inferencing, connectivity, security, and safety. Most of the major semiconductor companies in the automotive industry offer solutions (i.e., nodes) for the various domains within active safety and autonomous control. Some silicon providers provide physical chips while others may offer licensable instruction sets for some custom configuration.

Many companies in this category also appear in AV Stacks as an AV Compute platform supplier, while this category highlights more component-level players, for example, suppliers of neural network (vision) accelerators (ASIC or IPs only) such as **AImotive**, **Horizon Robotics**, **Hailo**, etc.

Data/Connectivity

The Connectivity category includes companies that offer hardware/software solutions that support the movement of data along the in-vehicle networks or via wireless networks outside the vehicle. Some of the companies are Tier 1 suppliers that make connectivity modules (i.e. gateways or connectivity controller/ECUs) that can handle data traffic, compressing/decompressing or encrypting messages where needed.

Others in the space produce network interfaces and switches that may be a component within the network architecture of the vehicle.

Moreover, companies that make external communication modules such as V2X devices and telematics control units (TCUs) are also included in this category. These companies are vital members of the data connectivity stack as future AVs must communicate with other vehicles and infrastructure. Furthermore, the AV must maintain connectivity to service providers and monitoring centers for various applications including the maintenance of vehicle software assets (Over the Air Software update), or remote teleoperation. Tele-operation companies included in this version of the VSI Infographic are **Designated Driver, Phantom Auto** and **DriveU.auto**.

Mapping

Mapping assets used for automated vehicle functions are vital for performance and safety. Maps for AVs are highly detailed and include a precision lane model so the vehicle can operate when lane lines are not visible. Furthermore, Maps for AVs contain landmarks and other physical structures from which the AV can localize against. Lastly, mapping assets contain other data including speed limits, curve warnings, lane closures and the like.

This category includes map companies that provide digital map data for AVs. These map companies harvest, process, and update map data and provide them to OEMs and other AV companies. Some of the companies provide full maps-as-a-service while others offer mapping-as-a-service.

The Mapping industry has experienced the biggest changes of all categories in recent months, leaving very few third-party independent mapping service companies or map data suppliers. Deepmap, Carmera, Atlatec, Mapper, and Mapilary were acquired by Nvidia, Toyota Woven Planet, Bosch, Velodyne, and Facebook.

Mobileye's seemingly most efficient and scalable mapping program appears to be lagging for some reason. The adoption of the full "REM" program (harvesting-updating/aggregation-localization) in production is limited to several strategic partners.

Nvidia has shown its mapping stack (Localization, MapStream, MapServices) in DRIVE AV software architecture along with other software stacks like Perception and Planning, which have been opened to 3rd party mapping companies and full-stack developers. Nvidia is now leveraging DeepMap's expertise in building a streamlined infrastructure of creating and updating geo-spatial intelligence and localization.

Maintaining a map is exponentially more complicated than creating it. Not only does the data need to be good, it also needs to be fast and cheap to produce. In the future, AV companies will need maps more like Mobileye's REM-RoadBook than a lidar-based Waymo map, because sensor capabilities got better and more reliable enough that the AV does not need ultra-accurate and over-specified HD maps. A Medium-Definition (MD) or a good enough HD map has a balance in these geometric and semantic attributes where the maintenance can be easier and would just assist the sensor/perception stack, only where more reliability is needed when line-of-sight perception is missing.

VSI also sees the trend of internalizing mapping assets in vertically integrated OEMs for L2+ (urban ADAS) and L3 system development and mobility companies for higher-level ADS. You will need to have a closed loop system where map data sent from the OEM fleet is also consumed in the fleet and not necessarily sent to anywhere else.

Software/Algorithm

The Software/Algorithm category is very broad and includes companies which offer operating system, middleware, run-time software, application software, and AI inference model. Among the onboard software suppliers, many are the suppliers of operating systems and middleware, while others are specialized in AV framework software.

Unlike AV software platform players in the AV Stacks category, some of these companies tend to license individual algorithmic software or application software such as ADAS perception/sensor fusion software (e.g., **Helm.ai, Stradvision, Phantom AI**, **BaseLabs,** etc.), driver monitoring applications (**Cipia, Jungo, Seeing Machines, Smart Eye** etc.), and security solutions (**escrypt, IBM, Secunet, ir.deto, Karamba**, etc.)

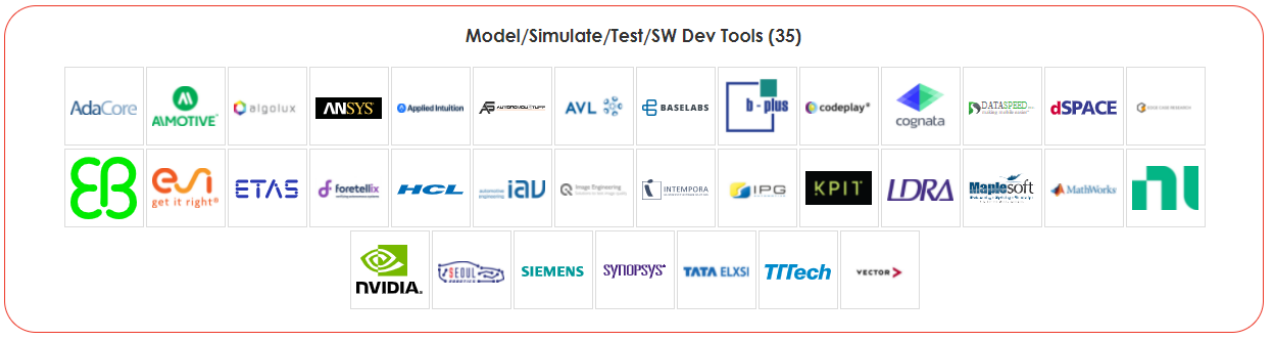
The biggest trend in this category is that over time, third party independent perception software companies are disappearing, unless they are also producing sensor hardware. Perception system developers need to clearly define and set the bar for the

minimum needed performance from all sensors that may end up in the "sensor suite," including resolution, false detection rate, range, latency, and sensitivity.

The question here is how much sensor companies should prepare perception software for their clients. VSI feels that many traditional OEMs and tier ones may lack skills and knowledge on the best ways to develop software to leverage the new sensor. Therefore, new sensor companies probably would benefit from doing their own software to sell the novel sensors to traditional OEMs and tier ones. 3rd party lidar perception companies like **Seoul Robotics** and **Vueron**, which provide 3D sensor perception software independently across many lidar sensors or other 3D sensors, are rare but valuable to the industry, even more so for 4D sensors like FMCW lidar or imaging radar. **Oculii** was such a company for imaging radar but it is now part of chipset company Ambarella.

Model/Simulate/Test/SW Dev Tools

The Model/Simulate/Test/SW Dev Tools category includes companies that offer software development tools for algorithms, code generation, development environment/kits, network/signal analysis, and debug/compilation. There are also companies that offer tools for simulation, modeling, prototyping, recording/examination, and validation/ verification.

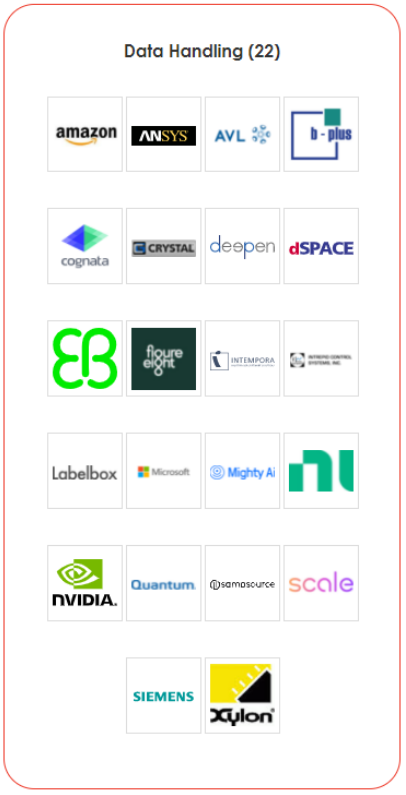


These development tools are vital for designing sophisticated AV systems. Modeling comes into play early in the development cycle followed by various stages of simulation to test the performance against a virtual environment where scenes, actors, sensors, and physics can be modeled. Some of the simulations offer the ability to test individual components, while others are used to test the performance of algorithms.

Simulation software and testing system suppliers continue to prove their solutions as important tool chains in AV development. **Ansys**, **AVL**, **Applied Intuition,** and **Foretellix** have been active in this area and Applied Intuition recently acquired Mechanical Simulation Corporation, a provider of vehicle dynamics simulation software. Building a full stack simulation tool chain is common among vertically integrated robotaxi companies, while traditional OEMs are still relying mainly on these 3rd party software companies to simulate their ADAS/AD software.

Data Handling

This is a category for data processing and management companies. Data Handling companies include data storage/logger suppliers, data logging/ management/ annotation/ visualization tool companies, testing automation tool suppliers, and data annotation service companies. The data logging/ management/ annotation/ visualization tool companies only include tools that manage massive data from environmental sensors and create sensor fusion algorithms for ADAS and AV application development, rather than tools for small-sized data (position, sensor/vehicle bus signals, and other measurement data) processing and test management.



Companies specializing in data annotation have become critical to the autonomous driving ecosystem and value chain. Companies like **Scale AI**, **Deepen AI, etc.** can provide quality training datasets from the raw data AV companies collected, who want to develop and commercialize algorithms based on labeled datasets as quickly as possible.

Calibration is about fixing/maintaining sensor accuracy - configuring a sensor to provide results that are within an acceptable range while minimizing the factors that could lead to inaccurate measurements. Moreover, calibration is a prerequisite for building accurate annotation. The user might want to collect some data and start labeling and annotating their own interesting scenarios. It is crucial for them to have calibrated data so their efforts do not go to waste.

Deepen AI is a company that primarily does annotation tasks for its clients while at the same time providing calibration tools for autonomous vehicles' raw sensor data to maintain higher annotation accuracy.

Data loggers or more sophisticated automotive development computer suppliers (**b-Plus, Crystal Group, Intrepid Control Systems, Quantum, Xylong**, etc.) have also become critical in the AV development processes. Especially these data storage and ruggedized computers made for harsh vehicle environments are increasingly in demand.

Autonomous vehicle development and deployment requires the ability to collect, store, and manage massive amounts of environmental data, high-performance computing

capacity, and advanced deep learning techniques, along with the capability to do real-time processing in the vehicle.

In the AV DevOps area, **Amazon** and **Microsoft** are becoming very important players of the AV ecosystem, as they not only provide massive data storage and efficient ingestion tools into the cloud, but also offer powerful computing resources, ML/AI algorithm development framework and simulation/validation environments in the cloud along with their AV development toolchain partners.

Conclusions

The AV Ecosystem Infographic reflects dramatic changes in the companies coming and going. Functioning AV Build – Mobility added many more players from the AV Stacks category as they started building and operating fleets, while some existing ones disappeared via active M&As throughout COVID.

The sensing category has seen many new entrants addressing new challenges in existing sensors. Such new technologies include not just new hardware designs but also novel perception software.

The mapping category has experienced the biggest consolidation as the trend of internalizing mapping assets in vertically integrated OEMs and mobility companies continue. Additionally, the data Handling category continues to be important as more and more companies build the infrastructure to manage fleet data for iterative development processes.

To capture this fast-moving and growing market, VSI offers its Ecosystem Examiner, where users can create custom infographics for all product categories out in the market, powered by VSI's ADSAS/AV product taxonomy. The VSI Infographic represents VSI's selection of top AV companies. Any changes to the AV industry landscape will be dynamically updated every year.

About VSI Labs:

Founded in 2014, VSI Labs has become a leading provider of research and advisory to companies that develop or supply into the automated vehicle space. VSI is unique in that it conducts applied research using its own fleet of test vehicles. Through this hands-on research, VSI provides thought leadership at the technology level like no other research or advisory firm out there.

From high-level componentry to deep decomposition of AV applications, VSI's services save companies time and money. VSI Insights and its AV ecosystem research are ideal for suppliers looking to break into the AV space or want to sharpen their competitive positionings or improve their technology planning. For AV developers looking to speed up their development, VSI Pro offers a thorough decomposition of AV functions and

applications. VSI Pro also offers code base necessary to build bridges between the different systems or functions within the AV software stack.

For more information about VSI Labs or to schedule a meeting, please contact us (info@vsi-labs.com) or visit our website (www.vsi-labs.com).