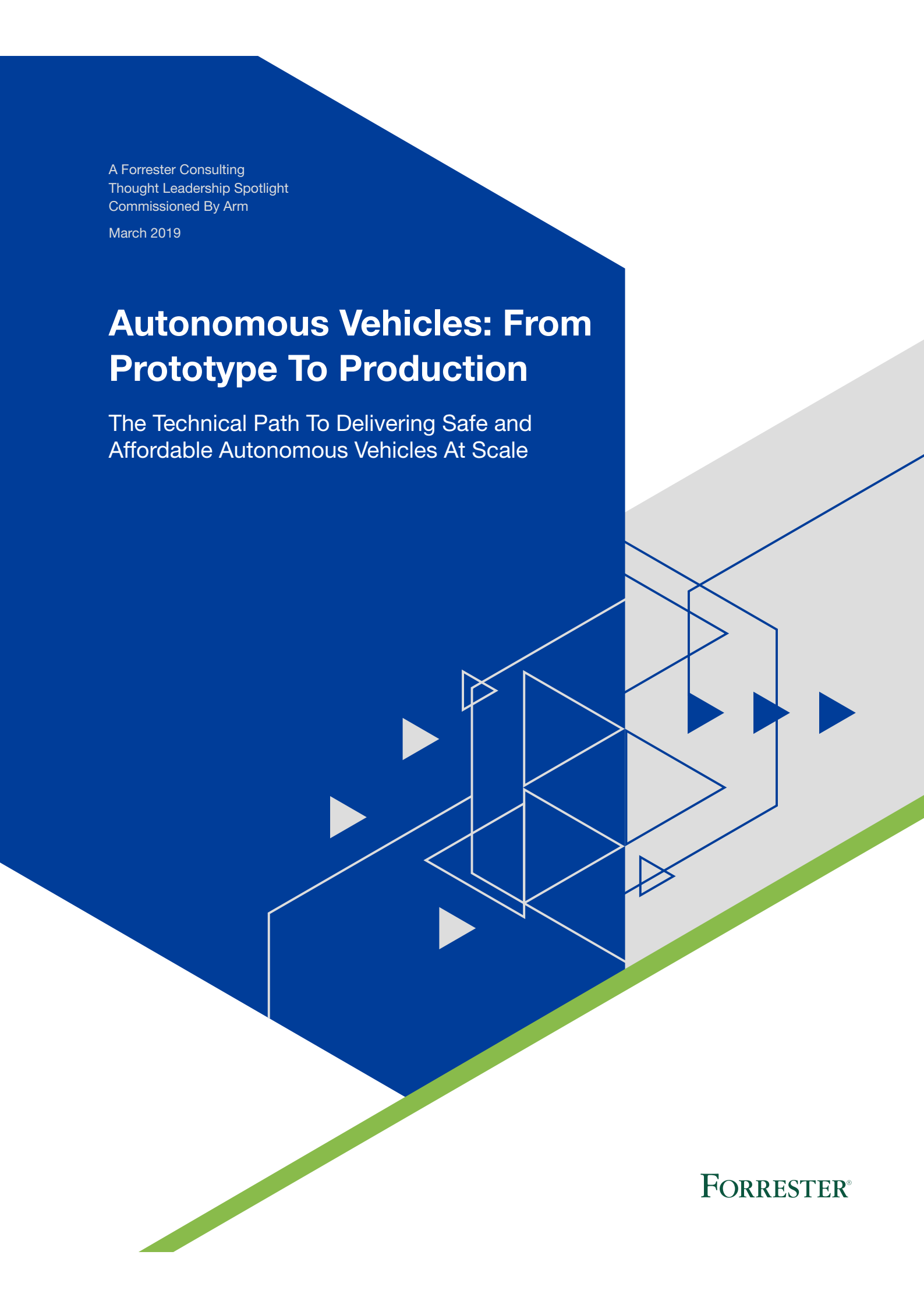
A Forrester Consulting
Thought Leadership Spotlight
Commissioned By Arm

March 2019

Autonomous Vehicles: From Prototype To Production

The Technical Path To Delivering Safe and Affordable Autonomous Vehicles At Scale



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Introduction

Companies of all descriptions are vying to take the lead in the emerging autonomous vehicle (AV) market; those born in the digital age and those born in the industrial age. Yet, whatever the age or type of company, the automotive industry as a whole faces huge technology challenges in order to fully realize the promise of autonomous driving technologies. To deliver on what is possible, automotive leaders must make future development leaps in safety, reliability, cost, compute performance and the power profile of in-vehicle AV technologies and systems.

Ultimate success will require more partnership, and while driver assistance technology is already saving lives, a world full of autonomous drive vehicles will only become real if there is a degree of industry-wide collaboration. To gauge the industry's progress towards that collaboration goal, and the challenges that lay ahead, Arm engaged Forrester Consulting to survey key players in the automotive world. Forrester asked the probing questions that teased out where the technology pinchpoints are today and the innovation that still needs to be made.

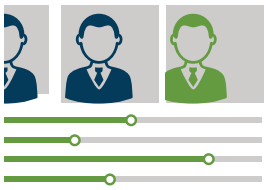
Forrester conducted 54 online surveys with global AV practitioners. Respondents were distributed evenly across the Society of Automotive Engineers (SAE) Levels of autonomous driving: More than 90% worked for companies developing vehicles in the SAE Level 1, 2, 3, and 4 categories — with an even split across each SAE level. The rest were focused on the most advanced Level 5 vehicles. Additionally, Forrester conducted five in-depth qualitative interviews with engineers and leaders of autonomous development departments at OEMs and Tier 1 suppliers across the globe. Forrester found that despite an overall enthusiasm for AV systems, there remain multiple challenges that organizations must overcome before automotive-grade level 5 AV systems will become technically viable and deployable at scale.

KEY FINDINGS

- **Organizations are eagerly exploring AV systems.** However, while most have developed prototypes, many are struggling to translate prototypes into safe, secure and affordable production-level designs.
- **Firms primarily face three main challenges.** Developing higher precision sensors and compute, producing automotive quality systems, and compliance with safety certification standards and regulations that are not yet decided.
- **Partners are key to bridging hardware and software obstacles.** Firms are working with software and hardware partners through joint ventures to help them overcome the discrete challenges they are facing in developing truly production-ready AV systems.

Despite Enthusiasm, AV Engineers Face Numerous Challenges In Developing Production-Ready AV Systems

Almost all automotive companies are now racing to develop AV systems and components —sensors, controllers, software, and computers — that are necessary to the safe autonomous operation of a vehicle. While they are investing heavily in the research and development (R&D) needed to create a complete AV system, many are still in the early stages of product engineering for mass production-ready designs. In fact, only 20% of surveyed respondents noted that they have a reliable prototype being prepared for production. Many of the interviewees noted that the path to full-scale production — i.e., dependable systems optimized for mass-production manufacturing — is long. Practitioners recognize the wide variety of important criteria necessary to creating a truly production-ready AV system — from reliability to safety and compute speed (see Figure 1).

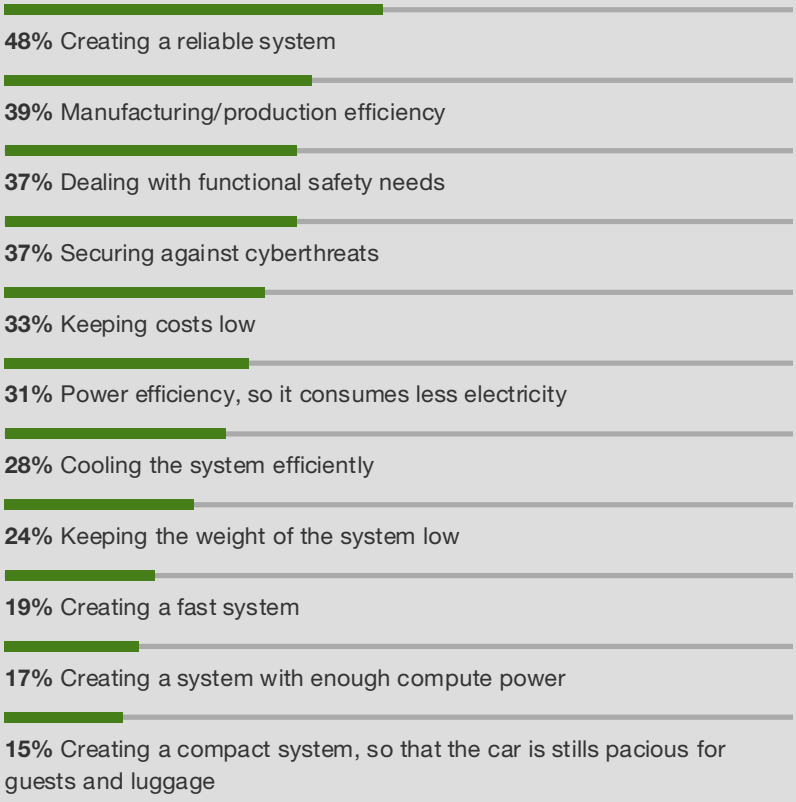


Development of production-ready AV systems is "not going to be a light switch. It's going to be a slow continuum of further capabilities."

US-based director of automated driving programs and testing at an Asia Pacific (AP) OEM R&D unit

Figure 1

"Which of the following criteria have you or your team identified as the most important for a production-ready design?" (Select up to five)



Base: 54 practitioners and above from engineering profiles in the automotive sector who are decision makers on tech investments
Source: A commissioned study conducted by Forrester Consulting on behalf of Arm, December 2018

For production designs, respondents are focused on system reliability, costs, and safety, more so than they are on hardware criteria.

They chose an average of three criteria, rather than maxing out with five choices.

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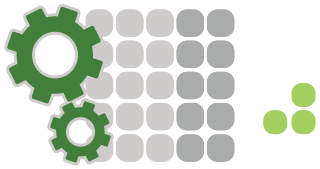
Based on our analysis of both the survey data and the interviewees' comments, teams face three core challenges when developing production-ready AV systems:

- Component and sensor issues.
- Designing and validating production-ready, automotive-grade systems.
- Upgrading regulatory and certification frameworks.



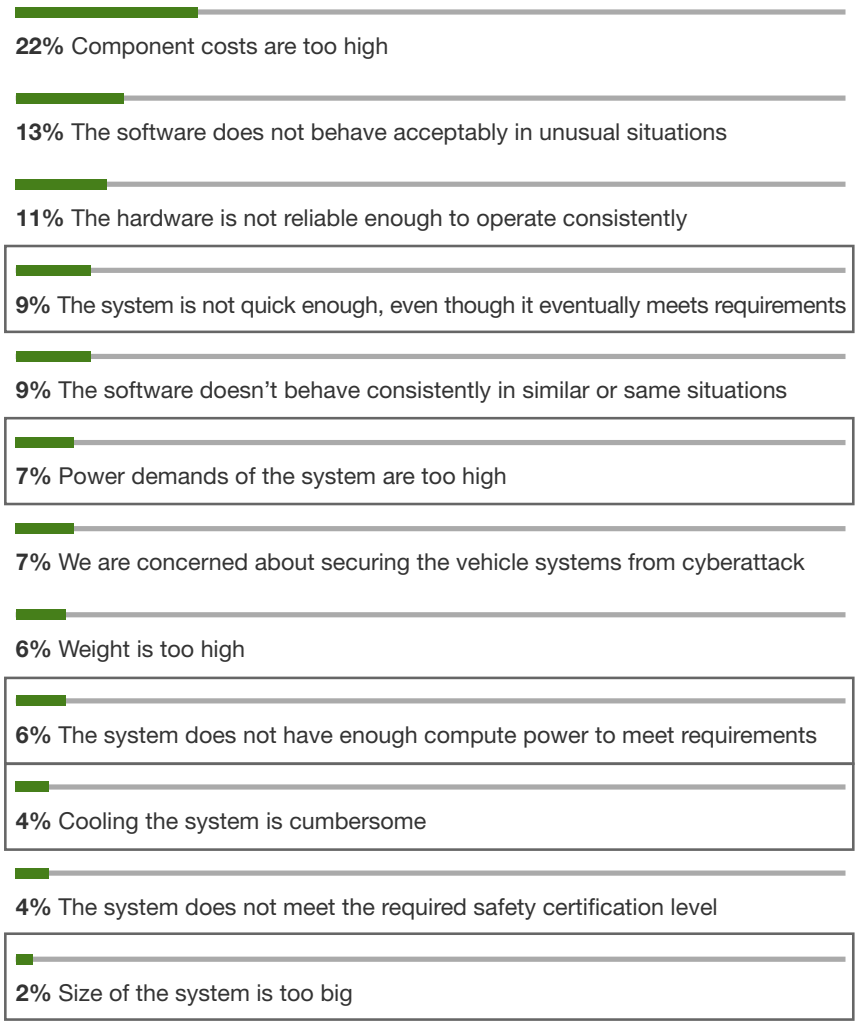
COMPONENT AND SENSOR ISSUES

Firms recognize the wide range of challenges they face with prototype AV systems — and the new challenges they will encounter as they develop functionally-safe production-ready designs.

- **Primary challenges when developing prototype AV systems are software, component costs, and security.** More than a third of respondents note that they are concerned with software that is not behaving acceptably in universal situations, the high cost of components, and securing the vehicle systems from cyberattacks.
- **Though costs are the biggest single challenge at 22%, hardware and compute challenges combined rank as the top priority for 28% of respondents.** We asked about system speed, power demands, compute power, system cooling, and system size as specific challenges as all are important characteristics of electronic performance and value. More than a quarter (28%) chose one of these as their toughest challenge (see Figure 2).
- **Sensors and compute are seen widely as not yet ready for production-level prime time.** Many of the engineers we spoke to during the qualitative interview phase said that the sensor technology needed for production-ready AV systems is still nascent. As one director of automated driving programs put it, the challenge in going from Level 4 to Level 5 automation is that the "sensor technology doesn't exist. Computing horsepower and algorithms don't exist yet. The amount of human judgement in driving in boundless conditions is such that it will take over 10 years before a computer can make all of the judgments in a guaranteed safer way than a human in all situations. The computer is going to have to be at least a factor of 10 better than what a human can do before the public will accept it."

Figure 2

"Of the challenges you're facing with your prototype AV system, which has been the most challenging to overcome?" (Select one)



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28% of respondents are primarily concerned with hardware/ compute challenge characteristics, when these variables are combined (power demands, compute power, cooling, size, and speed).

DESIGNING AND VALIDATING PRODUCTION-READY, AUTOMOTIVE-GRADE SYSTEMS

For engineers developing production-ready AV systems, a key goal is to meet the unique requirements for long-lasting road vehicles used by the public. They have to be simple to use, safe to operate in all weather conditions and remain in functional use for decades potentially.

- **Keeping costs low remains the top challenge when creating production-ready designs.** Forty-one percent of respondents note that costs will remain the biggest barrier when moving from prototype designs to production-ready designs, a fact that many interviewees echoed (See Figure 3). As one EMEA-based machine learning and perception engineer said: "Production-ready Level 5 vehicles will be more than 10 years [out]. And they will definitely only be in premium cars for a long time after that."
- **Efficiency is the No. 2 production-ready challenge, especially for creating a new level of automotive-grade components.** Thirty-one percent of respondents state that manufacturing/production efficiency is their top challenge when moving to production-ready designs. This concern was echoed by a number of interviewees, including a director of automated driving programs and testing: "The major players in sensor technology haven't done high volume production for the most part. There's going to be a lot of handholding by the OEMs because these tech companies have to learn how to get things into production. And to survive 10 years and 150,000 miles — the industry is going to have issues they didn't think of."

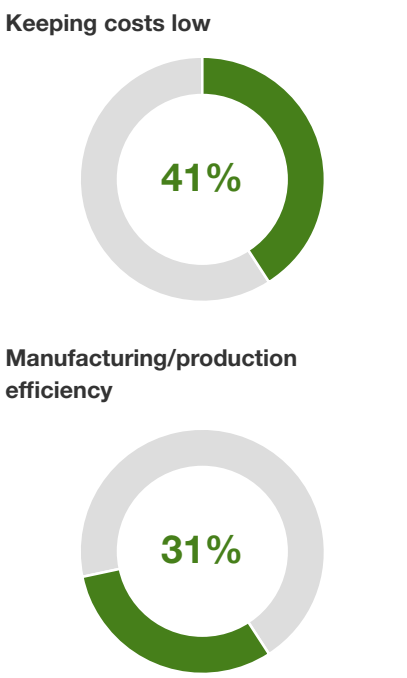
UPGRADING REGULATORY AND CERTIFICATION FRAMEWORKS

Many respondents note that regulatory and certification uncertainty is a key roadblock to having production-ready AV systems ready for mass production.

- **Engineers struggle with the lack of certification standards.** One EMEA-based interviewee noted: The safety standards are "completely individualized. There is no centralized standards or methods and tools to follow to validate the systems." Echoed a US-based interviewee: "NIST [National Institute of Standards and Technology] is nowhere near the capability of certifying this stuff themselves. They're looking to the industry to develop best practices that evolve into standards over time." A third interviewee stated that engineers are working with outdated standards that have not been fully considered for production-ready AV systems, "Everyone wants to have their algorithm certified, according to [the ISO 26262] standard — [but] that standard does not contain anything about deep learning."
- **Beyond the lack of clear certification standards, many respondents are concerned about securing functional safety for their AV systems.** As one US-based engineer at an OEM mentioned: The regulation and certification question is "something we're thinking about and nervous about— we don't know what we're going to run into. How resistant do the sensors have to be to weather conditions? How do you even derive a safety test for an autonomous vehicle? Which scenario do you run it through? A lot of people are trying to leverage simulation. Simulation works, but you can't simulate everything." Because of the complex algorithms that power AV systems, certifying functional safety in all situations is all but impossible for regulators.

Figure 3

"What challenges have you experienced as you create a production-ready design, or what challenges do you anticipate experiencing? (Select all that apply)



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> "The components have to be almost military-grade robust. It's the part of the vehicle that's not really where it needs to be, especially when it comes to reliability and fault tolerance."
>
> *US-based autonomous vehicle perception engineer at an NA OEM*

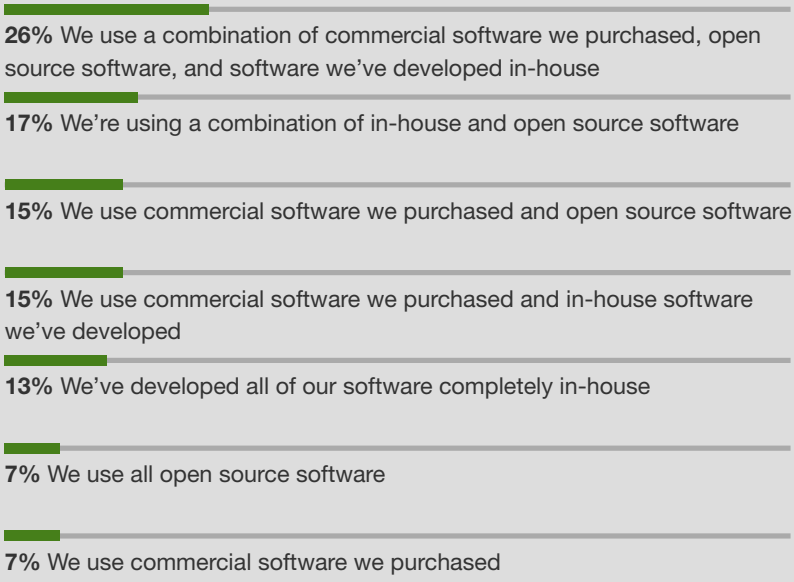
Partners Are Seen As The Key To Bridging Hardware And Software Challenges

Many automotive firms are looking to partners for help in overcoming the challenges in developing production-ready AV systems. Partners can help firms bridge the gaps many face in hardware as they've mostly focused on autonomous software. By combining their software with partner-supplied hardware, automotive firms can achieve the integration and fusion of software and hardware that is needed to succeed with complex autonomous systems.

- **Software development is the key component of AV systems.** As one interviewee said, "Software is the secret sauce." To that end, firms recognize that they must look for the best and the brightest to help them develop their AV software. Eighty-five percent of respondents plan on, or are already, working with software development partners.
- **Partners are bridging the gaps between automotive experience and software experience.** As one EMEA-based engineer noted, "Everybody wants to hire people with automotive experience and software skills — that's difficult." Because of this skills gap, respondents are looking to partners for help on the software and hardware side of things — only 13% noted that they were developing their software completely in-house (see Figure 4). And on the hardware side, firms are looking to joint ventures for help in tying internal expertise together with external experience on many of the top challenges they face in creating production-ready AV designs — from creating a fast system to keeping system weight low and dealing with functional safety.

Figure 4

"For your autonomous driving software, which of the following best describes it?" (Select one)



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65% of respondents say they're using open source software to some degree.

"Everyone uses some kind of open source libraries."

AP-based 3D perception engineer at a Tier 1 supplier

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Key Recommendations

Automotive companies are just beginning the product engineering work to convert prototype AV hardware into compact, power-efficient, and powerful production-ready systems for mass production. Forrester's survey and interview research with automotive industry autonomous engineers and leaders revealed that in order to succeed, firms must:

Develop hardware and software in tandem, with functional safety and security top of mind. Much of the autonomous systems work to date has focused on building sensors and software that can deliver increasing levels of autonomy. Now that systems are demonstrating the potential for SAE Level 4 autonomy, it's time to shift from prototypes to pre-production hardware. From this point, the industry should design software and hardware together as a unit to meet the performance, safety, and security requirements of autonomous vehicles.

Start optimizing silicon now to get to automotive-grade OEM hardware. The advanced AI and sensor data analysis needed to drive autonomous systems will benefit greatly from optimized silicon. It's time to start exploring and testing partner and in-house options to find practical approaches that will work in automotive-grade, production-ready systems.

Look broadly at partner collaboration for software and hardware. Only a few firms have the resources to go it alone entirely. Almost all firms should seek suppliers and partners to round out proprietary and specialized in-house technology with complementary professional services, software, sensors, and compute designs.

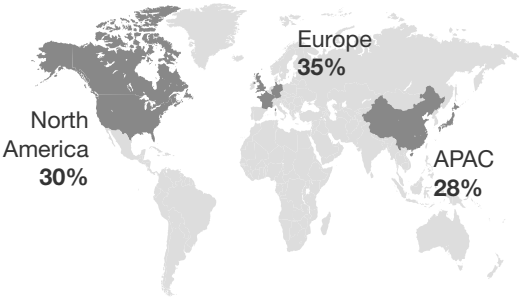
Work toward consistent regulations backed by certification frameworks that ensure global AV safety. Even if automotive firms get the technology right, today's industry certification standards and governmental regulatory frameworks don't address autonomous vehicles. Automotive industry executives must accelerate development of these new standards. If regulations and certification procedures aren't standardized by 2020, the automotive industry and insurers will face regulatory gaps or conflicts that may limit or entirely block plans to launch Level 4 AVs in 2021.

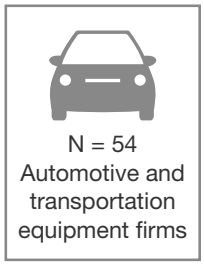
Appendix A: Methodology

In this study, Forrester interviewed five engineers at OEM and Tier 1 organizations in the US, EMEA, and AP. Additionally, Forrester surveyed 54 practitioners across the globe. Questions provided to the participants asked autonomous development system strategies, challenges, and concerns. Respondents were offered a small incentive as a thank you for time spent on the survey. The study was completed in December 2018.

Appendix B: Demographics/Data

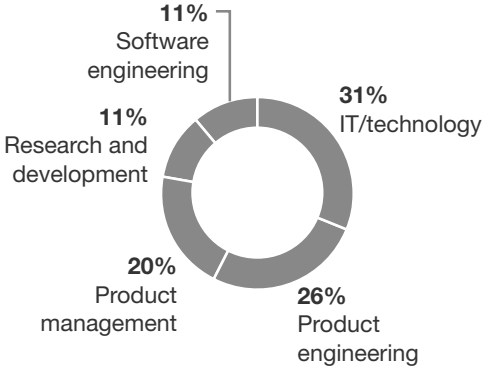
COUNTRY



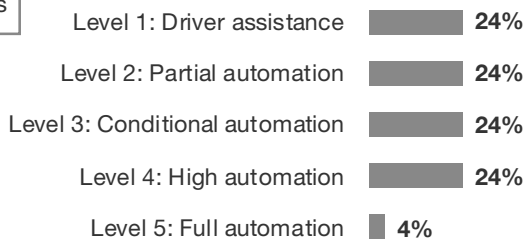


COMPANY SIZE

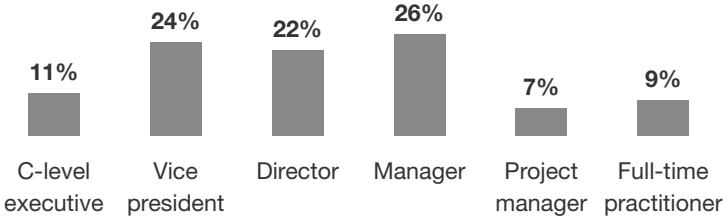
RESPONDENT DEPARTMENT



SAE LEVEL



RESPONDENT LEVEL



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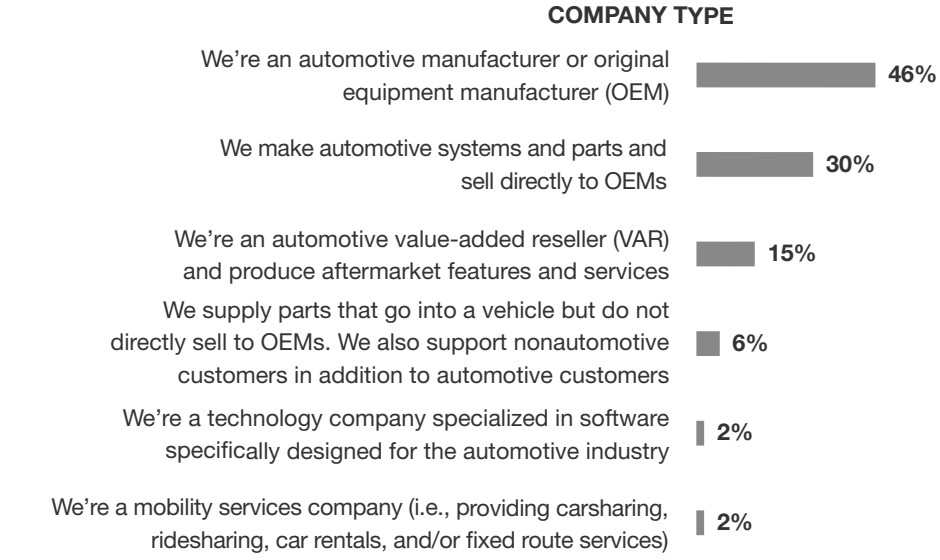

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Forrester's CIO research group

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