

Automotive News

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The Malibu, shown, is GM's top-selling car for the first time since the Chevy Cruze arrived in 2010.

Chevy Malibu delivers at last for GM...

Sedan escapes its reliance on fleet sales and incentives

Nick Bunkley

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DETROIT — The Chevrolet Malibu is having its best year in decades, even as the market for traditional sedans is collapsing around it.

The Malibu, redesigned a year ago, is the only one of the eight most popular midsize cars to increase its U.S. sales in 2016. And unlike the case with the car's last four generations, the gains are not being driven by big discounts or bulk orders from rental-car companies.



Reuss: Malibu can top Camry.

In just the first 11 months of the year, Chevy had sold more Malibus to retail customers than in any year since General Motors revived the nameplate in 1996. It has displaced the Chevy Cruze as GM's top-selling car for the first time since the Cruze arrived in 2010.

"It's a serious competitor, there's no question," said Jake Fisher, director of auto testing at *Consumer Reports*. "They're really not just up there

see **MALIBU**, Page 37

... as Bolt zooms to the center of self-driving bid

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DETROIT — General Motors is making the Chevrolet Bolt the centerpiece of not only its electric vehicle portfolio but also of its work on self-driving technology.

Days after delivering the first Bolts to customers in California last week — and fulfilling CEO Mary Barra's promise to launch the vehicle by year end — GM revealed plans to start building a test fleet of autonomous Bolts in January on the same Michigan assembly line as the regular version of the car.

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WHO ARE STEERING SELF-DRIVING VEHICLES

They're mostly new to the auto industry and they're intent on changing it forever. Meet the visionary engineers and executives who are making autonomous vehicles a reality. | PAGES 21-31 |



The Big Bang that launched autonomous

The mad rush toward driverless cars started with a bucket of Pentagon money and a field of college researchers — and then the industry got it

Lindsay Chappell

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Unless you are living in an underground bunker and trying your best to ignore the auto industry, you are aware that the car business is now hurtling madly toward a future called "autonomous driving."

Automakers around the world, tech companies that want to be automakers, auto parts makers, municipal planners and even operators of deliv-

ery fleets and taxi companies all are marching toward a reality of cars and trucks that will steer themselves, brake when drivers are not paying attention, change lanes by themselves and, eventually, pick you up at your house and take you to work with nobody at the steering wheel.

You may have wondered: How in the world did all this start?

The answer surprises many.

There was a Big Bang on a Saturday in November 2007, and chances are

you missed it.

"That was the moment," agrees Red Whittaker, a leading robotics professor at Carnegie Mellon University in Pittsburgh who has spent his career exploring and patenting ways to automate mining, farming and industrial vehicles.

"That day in 2007 was the moment when concepts that had been around for years suddenly came out of the laboratory and into the world. And unless you were aware of the decades of research that had been going on, the whole thing probably came as a complete surprise to you."

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Automotive News

60 WHO ARE STEERING SELF-DRIVING VEHICLES

A GUERRILLA FORCE of inventors, engineers and executives instigated the self-driving revolution we have all witnessed this year. They are non-auto people for the most part, including many former academics, who have moved autonomous vehicles out of the realm of the theoretical by sheer force of will and genius.

They represent a new breed of thinker and enabler in the car business — visionaries who are changing the auto world and attracting brilliant young followers to an industry that has long fretted about losing talent to the tech giants. In effect, self-driving vehicles have been Silicon Valley's entry point into the auto industry.

Who are these people? Here are 60 standouts.



A remarkable group has helped make it real

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From driverless taxi pilot programs to cars equipped with self-driving hardware already on the market, autonomous technology has progressed at a remarkable pace in 2016.

As companies showcase technology with potential to improve safety, mobility and transportation costs for consumers, varying timelines have emerged as to when the driverless future will arrive. Some see mass deployment in as little as five years while others expect a slower rollout over the

next 20 years.

While the self-driving timeline takes shape, the next question to ask is who. Who will manufacture autonomous vehicles, operate self-driving fleets and facilitate widespread consumer acceptance of the new technology? Who will regulate and enforce regulations on these manufacturers? Who will profit from self-driving cars and who will be left behind?

With help from industry experts, *Automotive News* has compiled a list of 60 people who have contributed heavily to the development of autonomous vehicles.

They have applied their individual talents and expertise to make driverless vehicles a reality.

The list is long but far from complete. There are now hundreds of people tied to self-driving cars, and we have worked to identify the ones leading the charge.

Though some of these names are well-known automotive or technology veterans, others are relatively new to the space and on their way to becoming major figures in a changing industry.

Automakers, suppliers, tech giants, Silicon Valley startups, academics,

regulators and a variety of other fields are represented in this list. The group is also an international one, with entrants hailing from North America, Europe, Asia and Australia, demonstrating just how far-reaching autonomous technology has become.

The questions posed by the development of self-driving cars are far from being resolved, and more are sure to arise.

But we know there will be an autonomous future, and we hope this list helps identify the players who will make it happen. **AN**

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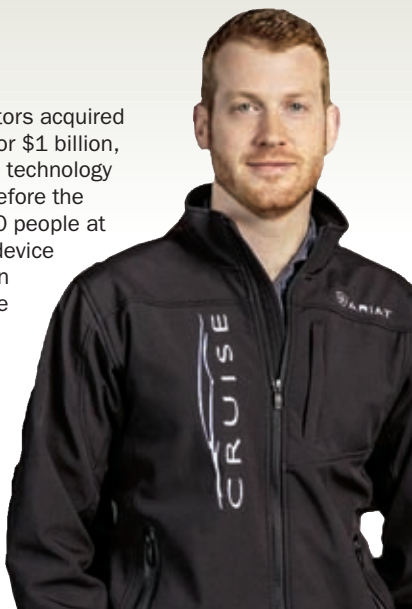
WHO ARE STEERING SELF-DRIVING VEHICLES

KYLE VOGT

CEO, Cruise Automation

● **Chosen because:** In March, General Motors acquired San Francisco startup Cruise Automation for \$1 billion, signaling a serious interest in autonomous technology and Silicon Valley's role in developing it. Before the acquisition, Kyle Vogt, 31, led a team of 40 people at Cruise to develop a \$10,000 aftermarket device that would enable self-driving capabilities in late-model Audis. Now, he and his team are spearheading the effort to develop autonomous capabilities in the upcoming Chevrolet Bolt, GM's answer to Tesla's mass-market Model 3 electric vehicle.

● **Quote:** "GM's commitment to autonomous vehicles is inspiring, deliberate and completely in line with our vision to make transportation safer and more accessible."



GILL PRATT

CEO, Toyota Research Institute

● **Chosen because:** Gill Pratt, 55, is responsible for Toyota Motors' \$1 billion research incubator, which has locations in Ann Arbor, Mich.; Cambridge, Mass.; and Silicon Valley. A robotics expert and former program manager at Defense Advanced Research Projects Agency, Pratt is spearheading Toyota's two-pronged autonomous vehicle initiative, which will begin with an advanced driver assist system — nicknamed Guardian — and transition to a semiautonomous technology, known as Chauffeur. Though Toyota's strategy is conservative compared with automakers such as Ford, which is focusing on delivering fully autonomous vehicles in the next decade, Pratt foresees cautious consumer acceptance of self-driving technology.

● **Quote:** "We want to make cars more fun to drive as well as safer to drive, as well as more convenient to drive, as well as more accessible to drive."



KAY STEPPER

Head of regional business unit, driver assistance and automated driving, Robert Bosch

● **Chosen because:** In leading Bosch's approach to self-driving cars, Kay Stepper, 47, has adopted an incremental strategy to ensure consumer acceptance. With a Ph.D.



in electrical engineering from the Technical University of Berlin, Stepper has been working on automation at Bosch since 1996. In his current role, Stepper is responsible for

product development of advanced driver assistance technologies. While many in the industry have predicted widespread adoption of this technology within the next decade, Stepper has been outspoken about the need to consider the conservative tastes and opinions of mass-market consumers.

● **Quote:** "It has to be an evolution, a step-by-step introduction of these technologies. Consumer acceptance of these features takes time."



JEN-HSUN HUANG

CEO, Nvidia

● **Chosen because:** Nvidia has become one of the major suppliers in the development of self-driving systems, producing artificial intelligence systems and infotainment displays for companies such as Audi, Tesla and Baidu. Jen-Hsun Huang, 53, has made it a primary initiative of his company, which also develops video game graphics, to put together the "brain" of autonomous driving systems. In September, Huang said Nvidia would work with Baidu to produce a fully integrated platform for self-driving technology.

● **Quote:** "That's the spirit of innovators, in a lot of ways. In your mind, you see things as solvable, or arguably solved, and a lot of it is really about getting there."

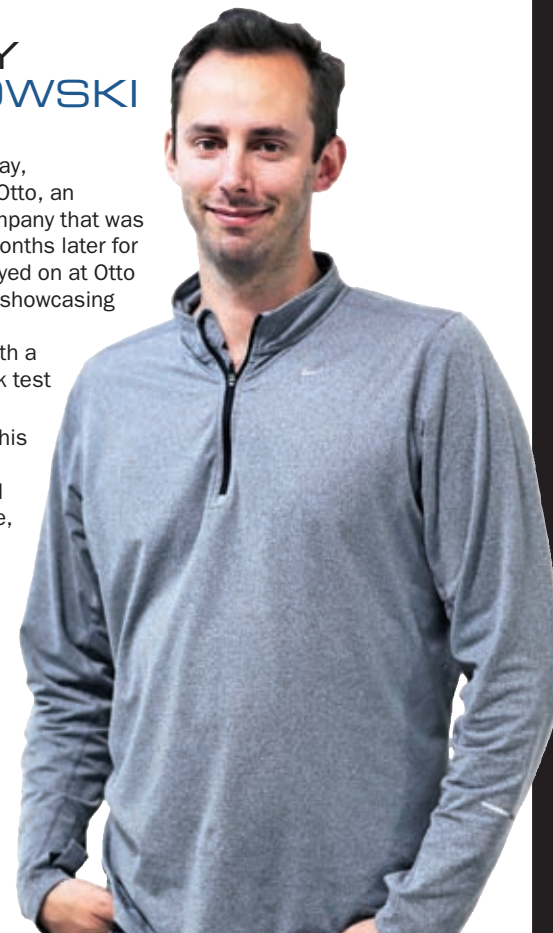
ANTHONY LEVANDOWSKI

Co-founder, Otto

● **Chosen because:** In May, Levandowski introduced Otto, an autonomous trucking company that was acquired by Uber three months later for \$680 million. He has stayed on at Otto under Uber's ownership, showcasing the startup's technology capabilities in October with a 120-mile self-driving truck test run in Colorado.

Levandowski, 36, began his career in autonomous vehicles when he entered his self-driving motorcycle, Ghost Rider, in the 2004 Defense Advanced Research Projects Agency Grand Challenge. He joined Google's Street View mapping project in 2007 and later helped launch the tech giant's self-driving car efforts.

● **Quote:** "This technology restores the freedom that people can't see."



MAARTEN SIERHUIS

Director, Nissan Research Center

● **Chosen because:** Maarten Sierhuis, 54, leads a team of engineers in Nissan's research lab in Sunnyvale, Calif. A former NASA research scientist, Sierhuis has transitioned to building autonomous and connected vehicles from developing an intelligent system for communication between the mission control center and the International Space Station. Sierhuis is focusing on producing vehicles with "deliberative" software, giving them the ability to assess traffic and road conditions rather than reacting to them. Nissan wants to market fully autonomous vehicles by 2020.

● **Quote:** "The folks in Silicon Valley are not automotive people. We're not used to the way this industry works. So we have to learn that."

RALPH LAUXMANN

Member of the management board, Chassis & Safety Division, Continental

● **Chosen because:** Oversees Conti's Automated Driving Project House, which has two projects — Cruising Chauffeur and Self-Driving Car. Cruising Chauffeur bundles all highway-related activities for automated driving; Self-Driving Car focuses on future forms of urban mobility.

Lauxmann, 52, has filed several patent applications related to driver assistance systems. He's bullish about the demand for assistance-related components. He said, "We expect to double our business within the next four years."

● **Quote:** "We believe it will be 2020 before the driver will be able to hand over the full driving task to the car. Even then this will not be on public roads. It will be in restricted areas where only similar cars will be allowed to drive."



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WHO ARE STEERING SELF-DRIVING VEHICLES

ROGER BERG

Vice president of wireless technologies, Denso International America

● **Chosen because:** To go driverless, vehicles must be able to communicate with each other and their surroundings — a challenge Roger Berg, 56, has been working on for more than 10 years. As Denso's vice president of wireless technologies, Berg oversees development of the supplier's connected technology and has been working with automakers and regulators on a federal program to aid in the development and deployment of connected vehicles. He has been a vocal supporter of connected technologies, touting their potential to save lives lost to traffic accidents and the vital role of aftermarket products in mass adoption.

● **Quote:** "The technology is here today, and it works."



BRIAN LOH

Vice president of active safety, ZF-TRW

● **Chosen because:** Since ZF acquired TRW Automotive Holdings Corp. in 2015 for \$12.9 billion and took a 40 percent stake in lidar producer Ibeo Automotive Systems GmbH, the supplier has become a self-driving technology powerhouse. Brian Loh, 37, heads up ZF's automated vehicle strategy and execution, developing a suite of cameras, radar, lidar and collision-avoidance software for small automakers such as PSA Peugeot Citroen. Through further acquisition and investment, Loh told *Automotive News* in November, the supplier is potentially pursuing more deals with automakers that don't have the resources to build the technology in-house.

● **Quote:** "ZF TRW's mission has long centered on safety, so I'm excited that the work we and the industry are doing on autonomous driving has the potential to significantly improve vehicle safety and the lives of drivers."



CAROL REILEY: 'Deep learning' expert's mission is protecting young drivers

Carol Reiley is president of Drive.ai, a Silicon Valley startup using "deep learning" — a machine's ability to continuously analyze and adapt to new situations — to build automated driving systems.

Reiley, 34, who holds a Ph.D. from Johns Hopkins, launched Drive.ai in 2015 after working as an engineer at Intuitive Surgical, which builds the robot-assisted da Vinci surgical system. She made the switch to automotive to continue applying the technology to saving lives.

"One of the biggest problems facing society today is human drivers," Reiley said. "I'm driven by problems that can help people at scale."

Specifically, she says she is working to reduce the number of accidents that young people are involved in. The rate of fatal car accidents for drivers between 16 and 19 is three times as high as the rate for drivers over age 20, according to the Insurance Institute for Highway Safety.

"If we can save even a small fraction of those lives, it's worth it," she said.

Drive.ai, whose board includes former General Motors Vice Chairman Steve Girsky, is developing a kit that can be retrofitted to cars on the road today. The kit uses LED signs



and speakers to signal to other cars and pedestrians and will be intended primarily for business fleets.

"We are using deep learning to power everything — from the sensors to the cameras, to the vehicle's decision-making, to the way the car communicates with people and things around it," says Reiley.

Communication and how it evolves with automated technology will be a key part of the development of self-driving cars, according to Reiley. She said she expects everything from the car horn, to brake lights, to rearview mirrors to be redesigned or deemed unnecessary in the upcoming generation of autonomous vehicles.

— Katie Burke

DAVID HALL

Founder and CEO, Velodyne Lidar

● **Chosen because:** Lidar debuted in the self-driving car conversation when autonomous prototypes began appearing with the spinning coffee-canlike sensors on their roofs. David Hall, 59, introduced the solid-state hybrid lidar technology during the Defense Advanced Research Projects Agency Grand Challenge 10 years ago. Under his company, Velodyne Lidar Inc., Hall has made the sensors available to Ford Motor Co., General Motors, Uber and Google, which are developing autonomous driving systems. Tesla deemed the laser radar too expensive and unnecessary for its self-driving cars. Hall's Velodyne has succeeded in lowering the cost of the sensors through a \$150 million investment from Ford and Baidu, a Chinese technology company.

● **Quote:** "Lidar continues to prove itself as the critical sensor for safe autonomous vehicle operation."



CHRISTOPH GROTE

Senior vice president electronics, BMW

● **Chosen because:** Christoph Grote, 49, has already played a central role in the development of connected car and highly automated driving systems at BMW. Now he is spearheading the company's push into advanced electronics.

A BMW veteran who started as an in-house consultant in 1997, he was vice president for strategy and innovation before taking up his current role this year. He is a theoretical physicist by profession who has worked at identifying the mobility needs of premium-car buyers. Technologies developed on his watch include gesture control, remote control parking and cross traffic warning. Grote has also contributed to the collaboration with HERE, the map and location service that was acquired by BMW, Audi and Mercedes in 2015.

● **Quote:** "The first big wave in connected car started in the mid-1990s, but just before it was about to happen a lot of people got nervous and withdrew. There were a few automakers that pulled it off ... including BMW, and we stuck with it and gradually ramped up our penetration to what is now around 90 percent of our cars being connected."



RICKY HUDI

Former head of electrics/electronics, Audi

● **Chosen because:** During almost two decades at Audi, Ricky Hudi accelerated the company's drive into autonomous driving and connected car technologies. He recently announced plans to leave Audi to set up his own technology and consulting firm.

Hudi, 48, was responsible for introducing Audi's user-friendly MMI (multimedia interface) into series production. He also led the development of Audi's electronics architecture, which sped up the introduction of more powerful processors for infotainment and driver assistance systems.

Born in Redwood City, Calif., in the heart of Silicon Valley, Hudi is an electrical engineer who started at BMW in the engine/transmission electronics department. He transferred to BMW Technik where he expanded his expertise in vehicle electronics.

● **Quote:** "Autonomous driving is complex. You cannot go to just one Tier 1 supplier and get everything you need. It requires a competent and experienced team to bring the best technologies and the best partners in the world together. ... For piloted driving you need to guarantee that information is where it should be. If one processor makes a miscalculation it is immediately recognized."



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WHO ARE STEERING SELF-DRIVING VEHICLES



JAN BECKER

Senior director of automated driving, Faraday Future

● **Chosen because:** Jan Becker, 46, has been developing automated vehicles for nearly 20 years, starting at the Technical University of Braunschweig in Germany. He earned a Ph.D. in control engineering and then spent 14 years at Robert Bosch GmbH focused on self-driving technology. While at Bosch, Becker worked with the Stanford University team headed by Sebastian Thrun that took second place in the 2007 Defense Advanced Research Projects Agency Grand Challenge. He is a lecturer on vehicle automation at the university. In January, he left Bosch to head the self-driving efforts at the electric vehicle startup Faraday Future.

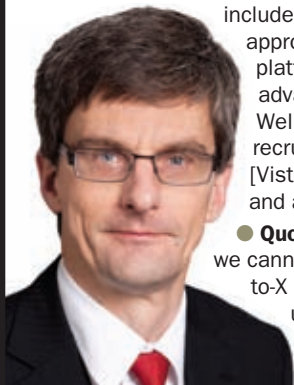
● **Quote:** "I have been working on autonomous driving for 19 years. It's amazing to see self-driving cars becoming reality now."

MATTHIAS SCHULZE

Head of advanced driver assistance system, Visteon

● **Chosen because:** Before his move to Visteon this month, Schulze, 54, spent 20 years with Daimler. He led research and engineering in environmental perception, advanced driver assistance system development and vehicular communications. Visteon says Schulze's role includes creating "a new centralized approach to domain controller and platform development" for the advanced driver assistance system. Wells Fargo analyst David Lim said recruiting Schulze "is a clear sign of [Visteon's] commitment to active safety and autonomous drive research."

● **Quote:** "For highly automated driving we cannot rely on the networking or a Car-to-X standard. The vehicle alone must ultimately be able to perceive its environment."



ERIK COELINGH

Senior technical leader for safety and driver support technologies, Volvo Cars

● **Chosen because:** Volvo has made considerable efforts in advancing driverless vehicles, including launching its Drive Me program to test 100 self-driving cars on public roads in Sweden, partnering with Autoliv to develop an autonomous vehicle system and pledging to take responsibility for any accident involving its technology. Erik Coelingh, 45, is a more than 15-year veteran at Volvo, and is spearheading the automaker's initiative to be a leader in autonomous vehicles.

Coelingh's approach focuses on a fail-operational system, in which each autonomous feature has multiple backups, similar to an airplane's autopilot technology.

● **Quote:** "It is relatively easy to build and demonstrate a self-driving concept vehicle, but if you want to create an impact in the real world, you have to design and produce a complete system that will be safe, robust and affordable for ordinary customers."



JOSH HARTUNG: Pushing automakers, suppliers to save cost and let software experts do the heavy lifting

Josh Hartung, 32, wants to make automakers' jobs easier — even if it means taking them out of their comfort zones.

Hartung is the founder of Portland, Ore.-based PolySync, whose software platform provides the back end of self-driving systems that automakers and suppliers can build upon. His goal is to drive widespread adoption of the software, saving companies time they would have spent building the code from scratch. That includes facilitating the flow of information among automakers that have traditionally shunned technology sharing.

"The auto industry is by default closed," Hartung said. "We want to allow them to share in spite of themselves."

As the chief technology officer at radar and lidar sensor distributor AutonomouStuff, Hartung said he watched automakers, suppliers and startups struggle to build software that could be scaled up to a mass-produced autonomous vehicle.

He founded PolySync — formerly known as Harbrick Technologies — in 2013 to allow automotive companies to "focus on what they need to focus on" and not get caught up with technology that the consumer will never directly interact with.

"We want to be the iOS or Android of automotive," Hartung said. "We're giving companies a base layer of autonomous driving

software."

Much like mobile apps on smartphones, automotive companies can build their own functionalities off PolySync. The software is flexible, allowing users to continuously tweak it for changing conditions such as cybersecurity threats and evolving consumer demand, he said.

Companies will need to save time and money where they can as they develop self-driving vehicles, Hartung said. To build safe systems, the car needs to have a number of costly mechanical backups in place in the case of a malfunction.

"We have to build systems that are more like aircraft systems, they need to be fail-operational and have some kind of backup," he said. "That will drive [bill of materials] costs through the roof. It will be difficult for the automotive industry to address."

Hartung wouldn't say which companies PolySync is working with. However, he said the industry is moving toward a model similar to that of mobile phones and cloud computing, where companies will all use the same open software platform and differentiate their products on a more detailed level.

"Eighty percent of capital in vehicles is completely duplicated across the industry," Hartung said. "Companies that focus on bringing value to the end consumer will outsource an open platform for everything else."

— Katie Burke



LAUREN ISAAC

Manager of sustainable transportation, WSP Parsons Brinckerhoff

● **Chosen because:** Self-driving cars won't exist in a bubble — they are expected to heavily influence the environment surrounding them. Isaac, 36, works on developing ways autonomous vehicles and other technologies can improve urban mobility at the engineering services firm. In 2015, she was named the William Barclay Parsons fellow, a Parsons Brinckerhoff sponsorship that allows engineers to pursue independent research projects. Under the fellowship, Isaac developed a guide for government agencies on how to approach and regulate a driverless transportation environment.

● **Quote:** "Government at all levels has the opportunity to proactively establish goals and policies that can continue to support the driverless vehicle revolution while keeping the traveling public safe and mobile."



SHERIF MARAKBY

Vice president of global vehicle programs, Uber

● **Chosen because:** Uber became one of the first companies to put self-driving cars on the road when it launched its pilot autonomous ride-hailing network in Pittsburgh in September. Sherif Marakby, 50, joined the San Francisco-based startup in April to help launch the Pittsburgh project after 25 years at Ford. At Ford, Marakby worked on developing hybrid and electrified vehicles before moving to a post in Europe. When announcing his departure, Marakby said he wanted to work on making self-driving cars a reality to help save lives.

● **Quote:** "A lot of us think of the technology as technology; we're thinking of technology as an enabler."



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WHO ARE STEERING SELF-DRIVING VEHICLES



SIMON JONES

Director, Unreal Engine Enterprise

● **Chosen because:** Video game developers have become surprising resources in the development of autonomous vehicles. Simon Jones' Unreal Engine Enterprise is a division of video game maker Epic Games, and builds 3-D virtual reality scenes that automakers use for mapping and testing. Unreal Engine Enterprise has provided Jaguar, BMW, McLaren Automotive and Toyota's Australian unit with its virtual reality technology. Jones, 45, has also provided his virtual reality experience to the aviation, architecture and medical industries.

● **Quote:** "An autonomous car is essentially building a picture of the scene around it. The more accurate that scene is, the more accurate and safer the vehicle will be."

BRYANT WALKER SMITH

Professor, University of South Carolina School of Law

● **Chosen because:** Bryant Walker Smith is one of the leading legal experts in autonomous vehicle deployment. He taught one of the first classes on the subject at Stanford University, before moving to the University of South Carolina School of Law in 2014. At Stanford, Walker Smith headed the legal efforts at the school's Center for Automotive Research and is an affiliate scholar at the Center for Internet and Society at Stanford Law School.

● **Quote:** "Given its limited resources and the speed of technological change, NHTSA cannot hope to come up with all the answers for automated driving in its many forms. But NHTSA can focus on asking the important questions."



BART NABBE

Director of strategic partnerships, Faraday Future

● **Chosen because:** Electric automaker Faraday Future still is refining its plans for the development of autonomous vehicles, according to media reports, and must deal with the cash problems of its backer, Chinese technology company LeEco. But it has added one of the technology's leading experts to its team. Bart Nabbe's resume includes Toyota and Apple, which he left in August after two years. The adjunct professor at Carnegie Mellon University specializes in autonomous navigation, artificial intelligence, computer vision and embedded systems, according to his LinkedIn profile.

● **Quote:** "My goal is to bring state-of-the-art artificial intelligence into everyday applications."

RAJ RAJKUMAR

Co-director, General Motors-Carnegie Mellon Autonomous Driving Collaborative Research Lab

● **Chosen because:** Raj Rajkumar, 53, has been working on autonomous vehicles for the past decade — he was part of the team that won the 2007 Defense Advanced Research Projects Agency Urban Challenge, a Pentagon-sponsored competition and one of the first significant projects involving self-driving vehicles in urban environments, and went on to research self-driving

technology under the sponsorship of General Motors. He has been a key ambassador for autonomous vehicles, taking members of Congress for a ride in his lab's self-driving Cadillac SRX crossover in 2014. As a researcher, Rajkumar has advised automakers and suppliers on effective development and implementation of autonomous technology.

● **Quote:** "It has taken literally decades for this technology to evolve. ... Researchers in academia are playing a significant part in finding some technologies that apply. You collect lots of data from the real world and try to learn from the data."

LAURA MERLING

Vice president of autonomous vehicle solutions, Ford Smart Mobility

● **Chosen because:** Ford Motor Co. tapped Laura Merling, 48, to head its self-driving car efforts in October, adding to its newly formed technology subsidiary, Ford Smart Mobility. Merling has an extensive background in connectivity, having been executive vice president of Internet of Things at SAP and vice president of enterprise digital transformation at AT&T. At Ford, she's working to meet the automaker's targets of having a fully autonomous vehicle operating in a ride-hailing or ride-sharing service by 2021 and such vehicles available to individual consumers by 2025.

● **Quote:** "I am excited by the opportunity to be part of the biggest change in transportation in more than a century."



IBRO MUHAREMOVIC: Sees full autonomy as way to prevent driver confusion

Ibro Muharemovic doesn't drive himself to work. He lets one of Continental AG's Cruising Chauffeur prototypes tackle most of the traffic on his 45-minute commute to Auburn Hills, Mich.

Muharemovic, 33, is the head of advanced engineering for Continental and leads the supplier's Cruising Chauffeur project, which equips vehicles with semiautonomous driving capabilities.

"You get used to these cars so much, it gives you quite a different freedom," he said.

Growing up in Germany, Muharemovic got his first taste of autonomous technology watching the American television series "Knight Rider," starring David Hasselhoff and an artificially intelligent car. He came to the U.S. to attend college, building a self-driving wheelchair for his senior project at Oakland University in Rochester, Mich.

After graduating in 2007, Muharemovic joined Continental as an engineer working on advanced driver assist systems.

Though initially attracted by the futuristic appeal of self-driving cars, Muharemovic's ultimate goal is to reduce the number of lives lost to traffic fatalities.

"My wife is a surgeon, we're having a competition to see who can save more lives," he said. "For me, it's more of a long game: How do I create an environment that puts her out of business?"

Muharemovic set his sights on developing fully autonomous vehicles after listening to a dealer oversell the capabilities of Continental's driver assist systems, he said. Rather than risk drivers misunderstanding driver assist technologies, Muharemovic said, it would be safer to focus on getting self-driving cars on the road.

"He told me the car could drive itself," though it was only equipped with emergency braking and other driver assist features, Muharemovic said. "That scared me. Since then the idea of self-driving cars has been stuck in my mind."

In 2011, he started working only on automated technologies, launching the Cruising Chauffeur project, a system designed to take over highway driving while still requiring human intervention. Muharemovic said this type of semiautonomous technology is a crucial step in garnering public acceptance of self-driving vehicles.

"The more you drive it, the more the car is able to handle intersections, highways and other situations, and you're less inclined to worry," he said.

Muharemovic said that working at a supplier, which typically has a more behind-the-scenes role in vehicle development than an automaker, has given him and his team more freedom to test new ideas such as the Cruising Chauffeur.

"If an idea grabs our attention, we're going to do it," he said.

— Katie Burke



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WHO ARE STEERING SELF-DRIVING VEHICLES

OGI REDZIC

Senior vice president of connected vehicles and mobility services, Renault-Nissan

● **Chosen because:** A former executive at Motorola and Nokia, Ogi Redzic, 45, was tapped to lead Renault-Nissan's autonomous vehicle efforts in January. In October, the alliance said it was forming a 300-person tech division under Redzic to develop and execute its mobility strategy and was planning to build fully autonomous vehicles by 2020. Redzic has taken a collaborative approach to self-driving cars, saying he is looking to partner with smaller technology companies to develop an autonomous system rather than build it in-house. In September, Renault-Nissan acquired French software company Sylpheed and partnered with Microsoft to develop a connected-car platform.

● **Quote:** "The industry is not just about selling cars but making mobility services relevant for people."



PADMASREE WARRIOR

CEO, NextEV U.S.

● **Chosen because:** Chinese electric vehicle startup NextEV claims to have the fastest electric supercar, besting Tesla Motors, and plans to tackle self-driving vehicles next. This year, it received an autonomous vehicle testing permit from the California Department of Motor Vehicles. At the helm of NextEV's U.S. operations is Padmasree Warrior, 55, a longtime Silicon Valley executive who joined the company in 2015 from Cisco Systems, where she had been chief technology officer. Warrior specializes in software development and user experience. She has been recognized by *Forbes*, the International Alliance for Women and the Aspen Institute for her work as a female executive in the technology industry.

● **Quote:** "The vision is not just about technology, but changing the experience."



BARRY NAPIER

CEO, Cubic Telecom

● **Chosen because:** Dublin-based Cubic Telecom has been quietly carving out a space for itself in connected — and eventually autonomous — vehicle telematics. Under the leadership of Barry Napier, 42, Cubic partnered with Audi AG in 2014 to power the Audi Connect infotainment system. The supplier specializes in providing an LTE-based platform for vehicle infotainment, a technology that will become vital as self-driving cars rely on over-the-air software updates and connect to their surrounding infrastructure. In April, Cubic was recognized by TU-Automotive for the quality of its cloud platform.

● **Quote:** "We are like the gel between automakers and local mobile operators."



RYAN EUSTICE

EDWIN OLSON

Co-directors of autonomous driving, Toyota Research Institute

● **Chosen because:** Toyota opened its Ann Arbor, Mich., research institute this year, tapping University of Michigan engineering professors Ryan Eustice, 40, and Edwin Olson, 39, for key roles. With Eustice and Olson's combined expertise in robotics, computer science and mapping, Toyota hopes to create a research environment that mimics the Silicon Valley "go fast, fail quickly" mentality to bring its autonomous technology to market in the next five to 10 years. Rather than source technology from suppliers, Eustice and Olson's team is working to build Toyota's autonomous systems primarily in-house.

● **Quote:** "We approach this very much like a Google or an Apple, a large-scale modern software company. ... This is new for Toyota."



KARL IAGNEMMA

CEO, NuTonomy

● **Chosen because:** In August, Cambridge, Mass., startup NuTonomy rolled out a self-driving taxi pilot program in Singapore one month before Uber launched a similar service in Pittsburgh. In November, NuTonomy brought its autonomous Renault Zoe electric vehicle to the streets of Boston for testing. Karl Iagnemma, 44, is a former research scientist at the Massachusetts Institute of Technology who launched NuTonomy with fellow MIT researcher Emilio Frazzoli. Iagnemma plans to introduce NuTonomy's autonomous taxi service in 2018 and has received investments from Ford Motor Co. Executive Chairman Bill Ford's venture capital firm, Fontinalis Partners.

● **Quote:** "NuTonomy's self-driving vehicle software unlocks access to a multi-trillion dollar global 'robotaxi' opportunity."

LOUAY ELDADA

CEO, Quanergy Systems

● **Chosen because:** Eldada's resume boasts academic, invention and entrepreneurial credentials, and he's using all three areas of expertise to develop and produce low-cost lidar sensors for autonomous vehicles. Eldada, 50, co-founded Quanergy in 2012 and has since received \$150 million in funding from investors, including Daimler AG, Delphi Automotive and Wardenclyffe Partners, a venture capital firm run by Tesla Motors co-founders Martin Eberhard and Marc Tarpenning. In January, the company introduced the S3, a lidar sensor for autonomous driving systems that will cost \$250 or less per sensor once it is in production.

● **Quote:** "The realization of autonomous vehicles is dependent on smart and capable sensing technology."



JOHN KRAFCIK

CEO, Waymo, Google's self-driving car company

● **Chosen because:** In September 2015, Google tapped the industry veteran to head its autonomous vehicle project, which spun off its own company, Waymo, last week. Since taking on his new role, John Krafcik, 55, has focused on forging partnerships with automakers. Google joined with Fiat Chrysler Automobiles in May on a plan to develop 100 autonomous Chrysler Pacificas. The former CEO of Hyundai Motor America also has been vocal in the push for autonomous vehicle testing legislation, submitting revisions to state and federal guidelines to ensure the inclusion of technology companies.

● **Quote:** "In the next stages of our project, we're going to be partnering more and more for sure. You can count on it."



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WHO ARE STEERING SELF-DRIVING VEHICLES



JING WANG

General manager of Autonomous Driving Unit, Baidu

● **Chosen because:** Chinese search engine company Baidu has been making significant investments in autonomous driving technology. Under Jing Wang's leadership, the company plans to roll out self-driving cars on a small scale by 2018 with mass deployment by 2021. Wang, 51, has an extensive

background in tech, working in executive positions at Google China, eBay China and Alibaba. Though it dissolved its partnership with BMW Group in November, Baidu has worked with chipmaker Nvidia Corp., Harman International and Tesla Motors, and it made a joint investment in Velodyne with Ford Motor Co.

● **Quote:** "I'm open for any partners; actually, I'm talking to many."



TIM KENTLEY-KLAY

JESSE LEVINSON

Founder and CEO, Zoox

● **Chosen because:** Self-driving technology startups have attracted much attention from the auto industry since General Motors agreed to acquire Cruise Automation for \$1 billion in March. Zoox, founded by Tim Kentley-Klay, and engineer Jesse Levinson, is one of the most highly valued startups after receiving more than \$250 million in funding this year for a valuation of \$1.55 billion. Though the company hasn't released many details on its technology, Kentley-Klay has said it is aiming to provide a fully autonomous taxi service similar to Uber. In March, Zoox became the 12th company to be granted a permit to test self-driving vehicles in California.

● **Quote:** "We think the future of mobility is actually a symbiotic relationship between the passenger and a robot." — Kentley-Klay

ALEX LIDOW

CEO, Efficient Power Conversion

● **Chosen because:** Alex Lidow, 62, is an entrepreneur and a physicist with a Ph.D. from Stanford University who wants to take the silicon out of Silicon Valley. His 9-year-old company in El Segundo, Calif., Efficient Power Conversion, is working to transition products reliant on silicon-powered chips — including lidar sensors — to faster, more efficient and less expensive gallium nitride chip technology. The result could lead to more powerful and cheaper lidar sensors, enabling automakers and suppliers to develop commercial autonomous vehicles faster.



● **Quote:** "Semiconductors fuel innovation, creating the backbone of technology advancement and subsequently, the economy at large."

GLEN DE VOS

Vice president of advanced and product engineering, Delphi Automotive

● **Chosen because:** In 2015, Delphi became the first company to complete a cross-country automated demonstration drive, collecting real-

world data to help develop advanced driver-assist systems and, eventually, fully autonomous technology. Glen De Vos, 56, has been working with automakers to phase in the



advanced driver-assist technologies that will help build consumer acceptance and the eventual adoption of self-driving vehicles. To De Vos, the greatest challenge to widespread acceptance is developing systems that are unaffected by weather conditions and that mimic normal driving behavior as closely as possible.

● **Quote:** "The biggest concern with these systems is they become an irritant, and people turn them off."

STEFAN KROENUNG

President, Autoliv Active Safety

● **Chosen because:** Level 2 collision-avoidance technologies such as automatic braking and seat-angle adjustment already are being incorporated in today's vehicles and are a steppingstone to a fully self-driving platform. Under Stefan Kroenung, 57, Autoliv has been developing a suite of such technologies and has developed self-driving prototypes to allow its customers, which include Tesla, Ford and General Motors, to test individual features. In September, the supplier said it was teaming up with Volvo to develop autonomous driving software, which is slated to be on the road by 2020, according to the automaker.

● **Quote:** "We want to become a leading supplier in the field of active safety, ADAS and automated driving."



PRI MUDALIGE

Research group manager, General Motors Global R&D

● **Chosen because:** Pri Mudalige's involvement with autonomous vehicles extends back to the 1990s. Back then he was a research scientist at CSIRO-Australia, the country's national science agency, developing autonomous underground vehicles and vision-based controls. Today, the 53-year-old Sri-Lankan American leads the Sensing, Perception and Behavior Systems Research Group at General Motors Global R&D. He has initiated several automated vehicle research programs at GM, collaborating with the National Highway



Traffic Safety Administration, Carnegie Mellon University and the University of California, Berkeley, and is the technical brain behind GM's Opel Insignia, EN-V and EN-V2 autonomous research vehicles. Before joining GM in 2004, Mudalige led Komatsu's autonomous haul truck crash avoidance system development.

● **Quote:** "This work is important because it will also improve productivity by allowing people to do other simple tasks while they are in bumper-to-bumper traffic and improve the utilization of infrastructure investment in

the future. I am confident that autonomous technology will have a significant societal benefit in the near future."

AMNON SHASHUA

Chief technology officer, Mobileye

● **Chosen because:** Israel-based Mobileye became a prominent name in the self-driving conversation when it partnered with Tesla Motors to provide camera sensors for its Autopilot semiautonomous driving technology. Though the companies dissolved their relationship in July, Mobileye and Amnon Shashua, 56, have continued to develop vision systems for autonomous vehicles, working with more than a dozen automakers to provide sensor technology. Shashua is also a computer science professor at the Hebrew University of Jerusalem, specializing in computer vision and machine learning.



● **Quote:** "The ingredients exist; now it is a matter of engineering."



ULRICH LAGES

CEO, Ibeo Automotive Systems

● **Chosen because:** Ulrich Lages, 48, has been involved with more than 20 patents and patent applications about object recognition and laser tracking for driver assistance and autonomous driving. In 1998, he co-founded Ibeo Automobile Sensor GmbH to develop time-of-flight range imaging technology for measuring distance. The firm in Hamburg, Germany, now called Ibeo Automotive Systems, has evolved into a major player in self-driving vehicles through its lidar expertise. This year, ZF-TRW took a 40 percent stake in Ibeo. The companies plan to market a solid-state lidar system by 2020 or 2021.

● **Quote:** "The vehicle of the near future will behave as the cooperative partner of all road users, especially of those which cannot protect themselves — like our children."

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WHO ARE STEERING SELF-DRIVING VEHICLES

RALF HERRTWICH

Senior vice president of automotive, Here

● **Chosen because:** Ralf Herrtwich, 54, joined real-time mapping company Here in October after leading Daimler AG's autonomous vehicle program. Herrtwich joined Daimler in 1998, working in infotainment before heading the research group on driver assistance programs in 2010. Three years later, he helped launch the Mercedes-Benz S500 Intelligent Drive project, which carried out an automated drive demonstration on public roads in Germany. Last year, Herrtwich estimated automated highway driving and parking would come before 2020, and that fully self-driving vehicles would follow within 20 years.

● **Quote:** "It is not just what we can provide to [autonomous] vehicles that genuinely excites me. It is also what these vehicles can add to our future maps through the sensors by which they observe their outside world."



TONY TETHER

Former director of the Defense Advanced Research Projects Agency

● **Chosen because:** Tony Tether, 74, led the Defense Advanced Research Project Agency from 2001 until retirement in 2009. Essentially the Defense Department's r&d division, DARPA turned its attention to self-driving technology in the early 2000s. The Pentagon-sponsored DARPA Urban Challenge in 2007 was a major test of autonomous vehicles in urban environments and accelerated research projects within the auto industry. Tether has been awarded the National Intelligence Medal and the Department of Defense Civilian Meritorious Service Medal.

● **Quote** (from 2005): "The DARPA Grand Challenge is about fresh thinking and new approaches to the tough technical problem of developing a truly autonomous ground vehicle."



THOMAS MUELLER

Vice president, chassis development, Audi

● **Chosen because:** While responsible for braking, steering and driver assistance systems since 2010, Thomas Mueller, 40, has driven Audi's autonomous vehicle strategy. Born and raised in Sao Paulo, Brazil, he studied mechanical engineering at the Technical University of Munich and joined Audi in 2001. Early in his career, Mueller led development of the ESC (stability control) Systems for the Audi A4, A6 and A8.

● **Quote:** "Based on the assumption that you'll have cities with mixed scenarios — you have old cars, new cars, autonomous cars — I think the first cities where it (autonomous driving) would work will be the end of the next decade."

JOHANN JUNGWIRTH

Chief digital officer, Volkswagen Group

● **Chosen because:** In November last year, Volkswagen Group named former Apple executive Johann Jungwirth to the new position of head of digitalization strategy. He reports to CEO Matthias Mueller.



The 43-year-old electrical engineer, who once led Mercedes-Benz Research & Development North America, oversees a key pillar of autonomous driving at VW. In February, the company

announced that design and digitalization would work together within three new Future Centers opening in Europe, Asia and California. Designers and digitalization experts work side by side, with a view to bringing autonomous vehicle technology to maturity.

● **Quote:** "Artificial intelligence and machine learning are emerging as key technologies in the automotive industry. Volkswagen plays a pivotal role in driving these topics forward."

EDZARD OVERBEEK

CEO, Here

● **Chosen because:** Mapping capabilities are crucial for self-driving vehicles to navigate and react to their environment. Edzard Overbeek, 49, left Cisco Systems Inc. in February to head up Here, a cloud-based, real-time mapping company jointly owned by Audi AG, BMW Group and Daimler AG. The company has partnered with Colorado and Iowa to enable connected technology on state highways, paving the way for autonomous vehicle testing on public roads.

● **Quote:** "The challenge is to understand how the maps of the future will look."



STERLING ANDERSON

Director of autopilot programs, Tesla Motors

● **Chosen because:** Tesla Motors CEO Elon Musk predicts fully autonomous vehicles will be on the road by the end of 2017, and the automaker is attracting top talent to make that prediction come true. Sterling Anderson, 33, received his Ph.D. in mechanical engineering from the Massachusetts Institute of Technology in 2012, going on to launch a technology company that develops intelligent vehicle systems and working at McKinsey & Co. before moving to Tesla in 2014. He was responsible for the launch of the Model X crossover and is overseeing the development of Tesla's semiautonomous driving software, Autopilot.

● **Quote:** "Since I began my work in vehicular autonomy nearly a decade ago, 10 million people have died and nearly half a billion others have been injured in traffic-related accidents. Automating the driving task — even in phases — is an imperative too urgent to wait for perfection."



SEBASTIAN THRUN

Founder, Udacity

● **Chosen because:** Google joined the autonomous vehicle conversation when it debuted its self-driving prototype in 2014. Though Sebastian Thrun has moved on to launch Udacity, an online education company, he helped found the Google car project nearly eight years ago as part of the Google X division. Thrun, 49, no longer is working on

Google's driverless cars — which recorded their 2 millionth mile on public roads on Oct. 5 — however, he launched a Udacity class for engineers to learn skills to work on autonomous technology and advises artificial intelligence projects at Stanford University.

● **Quote:** "I'm really looking forward to the time when generations after us look back at us and say how ridiculous it was that humans were driving cars."

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WHO ARE STEERING SELF-DRIVING VEHICLES

BOB MANSFIELD

Chief of Project Titan, Apple

● **Chosen because:** Though the tech giant has attempted to keep its automotive plans — nicknamed Project Titan — under wraps, Apple's foray into autonomous vehicle technology has been no secret. In July, *The Wall Street Journal* reported that longtime Apple engineer, executive and adviser Bob Mansfield had been tapped to take over the project from Steve Zadesky. Since Mansfield took over, there have been reports of layoffs in the department and a pivot from designing and manufacturing an entire vehicle to producing autonomous vehicle software. Before joining Project Titan, Mansfield helped bring other Apple products, including the iPad and Apple Watch, to market.



BRYAN SALESKY

Director of hardware development, Waymo, Google's self-driving car company

● **Chosen because:** The software engineer has been director of hardware development for Google's autonomous vehicle efforts for the past three years, splitting his time between Pittsburgh and Mountain View, Calif. Before Google, Salesky was at Carnegie Mellon University's Robotics Institute. Indeed, he was the software lead for the university's legendary victorious 2007 Defense Advanced Research Projects

Agency Urban Challenge team. At Google, he has worked with the California Department of Motor Vehicles on formulating flexible regulations for the development of autonomous vehicles.

● **Quote:** "Safety is built into the product from day one. It's something that is organic to what we do."

BJORN GIESLER: Wants self-driving tech to become faster and cheaper to manufacture

Bjorn Giesler joined Audi in 2005 to "build robots of actual use to people." More than 10 years later, he is still working toward that goal, as head of driver assistance at automotive software supplier Elektrobit.

Giesler, 44, who holds a Ph.D. in computer science from the Karlsruhe Institute of Technology in Germany, worked on hospital service robots before starting at Audi as the project lead for advanced driver assistance. In 2012, he was named head of the brand's autonomous driving initiative.

Despite the advances made in self-driving technology at the university level, Giesler found that progress to commercialize it had been slow when he entered the automotive industry.

"I joined Audi to do autonomous driving, but I was in for a pretty big disappointment," he said. "Autonomous driving had not yet reached the industry by far."

The primary obstacles at the time were convincing the industry to take it seriously and establishing a regulatory framework, Giesler said.

"We had to get the world to understand what autonomous driving means," he said.

He says it took automakers several years to warm to the idea. Meanwhile, in 2013, the Society of Automotive Engineers addressed the regulation question by establishing a classification system for levels of autonomous technology.

In the same year, Giesler's team introduced a self-driving Audi A7 prototype at the Consumer Electronics Show in Las Vegas.

Giesler moved to Elektrobit from Audi in 2015 to address a new problem — making self-driving technology faster and cheaper



to manufacture.

"You can't actually buy an autonomous system," he said. "OEMs have to do everything themselves, and it's costing them a ton of money."

At Elektrobit, Giesler is developing a "blockset" of autonomous software which automakers can use to build their own self-driving systems. He said the aim is to eventually have automakers use open-source technology to share and test driving data. Maintaining open lines of communication among automakers is crucial to developing effective and safe autonomous technology, Giesler said.

"Nobody talks about their architecture or how they're doing it. I would like to push for an industry-spanning discussion on what makes a vehicle safe and able to be on the road at a technical level."

Giesler's vision of developing robots that help consumers hasn't changed, and he sees autonomous vehicles as the way to achieve it.

"If you're in robotics today, you should be doing autonomous vehicles," he said. "That's where society is."

— Katie Burke

MISSY CUMMINGS: University research smooths the way for self-driving cars

Missy Cummings, head of Duke University's Humans and Autonomy Lab, is an expert in the relationship between humans and technology, and she has studied how people interact with cars for 15 years.

Before working at Duke, Cummings was a naval officer and military pilot for more than a decade. She began her automotive work when distracted driving caused by cellphones became an industrywide safety issue. She and her team studied human behavior to understand how cellphone distraction worked and developed telematics designs to help limit it.

When the auto industry began to seriously consider autonomous driving technology, Cummings had been working primarily with drones and automated aviation — a field that has been a guiding example for the auto industry.

"When driverless cars started to become an issue, people were turning to aviation to see if there were lessons to be learned," Cummings said. "There's so much overlap."

Particularly in areas such as ethics and human operation, Cummings has transferred her aviation expertise to autonomous vehicle development.

Though self-driving systems have advanced dramatically since Cummings began her work, university-level research will continue to be essential to the systems' development, she said. Issues such as sensor blind spots, pedestrian motion



detection, inclement-weather navigation and gesture recognition need to be resolved before fully autonomous vehicles available to consumers.

"Autonomous driving would not have happened if there had not been the work from universities," she said. "If universities are still producing significant research achievements, you have to wonder whether this field is ready to be commercialized."

Despite the limitations of current technology, Cummings said she expects some level of autonomy to be widely available in the short term, but it will be another 15 to 20 years before fully self-driving cars are on the road. In that time frame, however, Cummings said she hopes to have moved on to the next big trend in robotics.

"I'd like my role to diminish because it means we got the human interaction piece correct," she said. "I want these cars to be much more available than they are now."

— Katie Burke

KRISTIN SCHONDORF: Growing the talent pool as autonomous pace quickens

Much has changed in the world of autonomous vehicles since Kristin Schondorf began working on blueprints for self-driving cars nearly five years ago.

"When we started looking at the blueprints in early 2012, we thought of autonomous vehicles being out on the road in 20 to 30 years-plus,"

said Schondorf, 47, global automotive and transportation lead at EY. "No one predicted we'd be where we are today."

At the time, the Massachusetts Institute of Technology graduate was at Ford Motor Co., where she had worked in everything from powertrain to technology strategy and helped formulate Ford's original mobility vision. She joined EY in 2015 after a combined 23 years at Ford and Fiat Chrysler Automobiles.

Since 2012, Ford's plans for autonomous vehicles have accelerated significantly. The company expects to operate a fully self-driving ride-hailing service in 2021 and introduce commercial autonomous vehicles by 2025.

As a consultant, Schondorf is working with manufacturers to address the growing number of obstacles to deployment of self-driving

vehicles. That includes developing an engineering talent pool to compete with technology giants such as Google and Uber. After tech companies became interested in autonomous vehicles, Schondorf says, automakers have struggled to find the right people to work on the technology.

"This whole new world of tech has really opened up the playing field," she said. "The tech industry came into the game and bought up some great talent."

Schondorf says she worked to help develop a pool of experts with a "different mindset" than the traditional auto industry, creating a new source of employees.

Despite the challenges of regulations, ethics and consumer acceptance, Schondorf said she expects self-driving cars to be on the road much sooner than her original prediction of 20 to 30 years. Specifically, the rapid development of artificial intelligence has greatly accelerated autonomous capabilities, she said.

"There has been such an acceleration, and I think we're going to see it grow," Schondorf said. "It's really an exciting place to be."

— Katie Burke



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WHO ARE STEERING SELF-DRIVING VEHICLES



JOHN ABSMEIER

Vice president, Samsung Strategy and Innovation Center, Smart Machines initiative

● **Chosen because:** The former Marine — with a mechanical engineering degree from Purdue — set up Delphi Labs in Silicon Valley in 2012 and led development of the supplier's autonomous vehicle platform. The vehicle completed a coast-to-coast trip from San Francisco to New York City in 2015. Absmeier, 42, moved to Samsung that year, taking responsibility for open innovation, investment and new business creation in the areas of drones, robots and automotive.

● **Quote:** "We see technology — artificial intelligence, advanced sensing, high-power computing and connectivity — enabling a future of safe, connected and accessible mobility. Cars will perceive and react to situations better than humans. Accidents will be rare, congestion and gridlock will be distant memories, commutes will be convenient and comfortable."

LARRY PAGE SERGEY BRIN



Co-founders, Google

● **Chosen because:** Though Google's self-driving car project has gained more independence from its parent company under CEO John Krafcik, the program would not have advanced as quickly without the support of Google's co-founders, Larry Page and Sergey Brin. The project originally began under Google X, the company's laboratory for "moonshot" ideas, but it quickly developed beyond a futuristic product idea as autonomous Google cars began taking to Mountain View, Calif., roads.

Driverless cars may seem like a major departure for a company that began as a search engine, but Brin and Page — both 43 and now president and CEO, respectively, of Google parent Alphabet — have loftier goals, including eliminating traffic deaths and backing new mobility ventures, including flying cars.

● **Quote:** "Just like when we started nearly two decades ago, it is possible to create the technology that allows people to lead healthier, happier lives." — Brin



RED WHITTAKER

Fredkin professor of robotics, Carnegie Mellon University's Robotics Institute

● **Chosen because:** Red Whittaker, 68, is considered a pioneer developer of mobile robots for hazardous environments and has led projects that inspected the aftermath of nuclear accidents at Three Mile Island in Pennsylvania and Chernobyl in Ukraine. Whittaker's work has also crossed over to autonomous vehicles. In 1986 Navlab 1, a converted van, was the first full-sized vehicle to house researchers and computing, serving as a "test bed" for unmanned ground vehicle research. In 2007 Whittaker led Carnegie Mellon University's Tartan Racing to a first-place finish in the Defense Advanced Research Projects Agency Urban Challenge with a robotized 2007 Chevrolet Tahoe named Boss.

Not only did the Tahoe follow driving laws as it



navigated the course in a safe and stable manner, it finished 20 minutes ahead of the second-place finisher. Whittaker also had experience with two other DARPA challenges. He is the Fredkin professor of robotics at Carnegie Mellon University's Robotics Institute in Pittsburgh, which just so happens to be where Uber opened its Advanced

Technologies Center.

● **Quote:** "The technology of this trend in automotive is so inevitable that I don't have any doubts about its success. What matters going forward is how people understand the benefits that will come from it and appreciate it. People ask me where I see autonomous driving taking us — what will it look like? I'm 68. When I imagine driving across Pittsburgh on my 90th birthday, I believe I will be thinking about my birthday and I won't be thinking about the drive."

YUTAKA HIWATASHI

General manager, Subaru Engineering Division, Fuji Heavy Industries

● **Chosen because:** More than two decades ago, Yutaka Hiwatashi set out to develop an automatic brake system, the forerunner of the company's EyeSight driver assist technology.

He put a stereo camera-based safety device into commercial use, a feat that was considered impossible at the time. After EyeSight debuted in 2008, he continued to work to reduce the cost of what was once a pricey drive assist system. Hiwatashi, 56, is now head of the safety technology development at Fuji Heavy.

● **Quote:** "I'm honored that our EyeSight technology has been highly recognized. By further enhancing EyeSight's collision avoidance capabilities, we at Subaru aim to create driver-centered autonomous vehicles which provide a safer driving experience to customers."



YOICHI SUGIMOTO

Senior chief engineer, Honda R&D Co.



● **Chosen because:** Since joining Honda Motor Co. in 1986, Yoichi Sugimoto has focused on r&d of safety and driver assist technologies, including collision prevention brake systems. Sugimoto, 56, is now responsible for Honda's autonomous driving strategy.

In 2012, Sugimoto was assigned to Honda R&D Americas to work on intelligent transport systems. Two years later, the company introduced its Honda Sensing advanced safety driving assist technology that Sugimoto said combines cameras and radar to enable a higher level of driver assistance. He says further research in vehicle-to-infrastructure and vehicle-to-vehicle communications, personalization and computer self-learning will encourage the evolution of more intelligent cars.

● **Quote:** "Automated vehicle technology is not just about realizing the automated driving function. It is crucial for improving advanced driver assistance and active safety such as collision avoidance."

TETSUYA IJIMA

General manager, ADAS and Autonomous Driving Engineering Department, Nissan Motor Co.

● **Chosen because:** Iijima, 53, has led Nissan's efforts to develop advanced driver assistance systems and autonomous driving technologies, starting a decade ago when he worked at Nissan Technical Center North America. In 2015 Iijima and his team developed Piloted Drive 1.0, which enables vehicles to change lanes, pass other vehicles and merge onto and off of highways by themselves. In August Nissan launched a Serena minivan in Japan with semiautonomous technology called ProPilot, the first step toward the automaker's goal of putting fully self-driving cars on the market by 2020.

● **Quote:** "People will only begin to understand it [autonomous driving] once it is on the road. It will be a step-by-step process."



LAWRENCE BURNS

Consultant

● **Chosen because:** During his 1998-2009 stint as head of General Motors r&d, Lawrence Burns evangelized for the safety benefits of self-driving vehicles. Burns oversaw GM's role in the U.S. Defense Advanced Research Projects Agency self-driving vehicle challenge in 2007, won by a partnership between GM and Carnegie Mellon University. Today, Burns, 65, has several consulting roles, including adviser to Google on autonomous vehicles.

● **Quote:** "The acceptance of roadway fatalities for over a century is really amazing, if you think about it."



CHRIS URMSON

Former chief technical officer for Google self-driving cars; free agent

● **Chosen because:** Chris Urmson was the technical lead for Google's self-driving car project as it pulled the industry forward with its rapid progress in creating working vehicles and its audacity in testing them on public roads. Urmson became a leading advocate for fully autonomous vehicles; his 2015 TED

talk on the topic has more than 1.8 million views. Urmson quit his Google job last August and has been mum about his plans. However, the tech website Recode reported this month that Urmson plans to start his own company to develop autonomous-vehicle technology.

● **Quote:** "Developing a car that can shoulder the entire burden of driving is crucial to safety. Human drivers can't always be trusted to dip in and out of the task of driving when the car is encouraging them to sit back and relax."

DARPA

'There was a little more awareness' at 2007 race

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It was on a closed Air Force base in Southern California that day that the autonomous-driving industry was born. The U.S. Department of Defense — as in the Pentagon — had invited a couple hundred of the country's most advanced transportation science and computer problem-solving thinkers to conduct a 60-mile obstacle course race — primarily to make a point. The Defense Department wanted to demonstrate that it was possible, practical, safe and maybe even financially attractive to make automobiles drive through a city with nobody behind the wheel.

As the country's "real" auto industry geared up for its annual holiday season blowout sales, the California gathering was largely overlooked. But in the months and years that followed, future-minded thinkers realized that the race had been an auto industry game changer.

Into the light

The Nov. 3, 2007, contest was not the first of its kind. The Defense Department for years had been trying to nurture research on self-guided machines at big universities, including the Massachusetts Institute of Technology, Stanford University and Carnegie Mellon. Robots were seen as the next great battlefield tool in America's arsenal. Robotically guided vehicles might be used to approach suspicious cars in war zones. Robot devices might creep through caves or over mountain hideouts or along the seafloor looking for enemy combatants.

An independent Defense Department organization launched by the Eisenhower administration, called the Defense Advanced Research Projects Agency, or DARPA, was, by the 2000s, bent on bringing advanced transportation thinkers out of their laboratories and university computer rooms to compete in the light of day. The government had even granted DARPA special power to give away prize money to sponsor public contests to do it.

In 2004, DARPA offered a \$1 million prize to challenge participants to get a driverless vehicle to complete a 150-mile trek through the Mojave Desert. But like new Marine Corps recruits collapsing in basic training, not one of the participants finished the course, and no one claimed the prize.

A year later, DARPA tried again, this time offering \$2 million to challenge teams to complete a 132-mile Mojave course with driverless vehicles. And this time, five teams completed the race. A Volkswagen Touareg converted by Stanford University into a self-driving vehicle called Stanley won.

Two years later, DARPA doubled down, moving the contest to a mock urban landscape where driverless vehicles would have to navigate lifelike city traffic and unpredictable pedestrians.

Less cheerful times

At that late 2007 moment, the auto industry was not a happy place. Auto sales were falling. Pickups and SUVs, which had made the industry rich for a decade, were taking it on the chin as gasoline prices rose and the housing market teetered into trouble. The U.S. economy was looking sketchy. Americans were losing their jobs, and General Motors was losing money.

Among the teams for that race, Stanford was back with its VW partners. An MIT team had partnered with Land Rover. Virginia Tech worked with Ford Motor Co. Carnegie Mellon worked with GM.

"There was a little more awareness this time around," recalls Whittaker, who directed the Carnegie-GM team. "You could tell that some people were starting to watch this

activity a little closer. In the previous DARPA races, it had really been an off-road competition with a lot of rugged vehicles, like a dune buggy, an old Hummer and an autonomous motorcycle. But for the 2007 race, it was really about urban driving. It was really about ordinary passenger cars for the first time."

Attracting attention

Strolling through the racing grounds that Saturday were individuals who illustrated the growing awareness. Steve Wozniak, co-founder of Apple Inc., visited with the teams and introduced himself. At that time, Apple had no car venture.

Also in the crowd, observing the teams, were Google founders Larry Page and Sergey Brin. Google also had not declared its interest in automobiles. Microsoft, a company that had been at least supplying software products for Ford and other automakers for nearly a decade by then, also had representatives strolling the field.

Carnegie Mellon's converted Chevy Tahoe won the race, and Whittaker's team accepted the \$2 million. But Whittaker philosophically muses that "there was the prize money — and then there was the larger prize. We proved the technology worked out on real streets and could comply with traffic laws and compete with real cars."

"We ignited the industry's interest," he says. "OEMs had to start asking, 'How can we not participate in this technology?'"

Immediately, many companies saw it as a ground-floor opportunity. Race participants from that day became hot properties for computer tech companies and automakers that suddenly glimpsed a future of driverless cars. If a college professor knew how to make a sedan stop by itself to avoid an obstacle in the road, there were new fortunes to be made. If there were university computer science technicians who knew how to convert that behavior into computer code, they were valuable employees.

"A handful of companies immediately saw amazing potential in all this, and they began hiring everybody they could from academia," says one race participant who was recruited to help Internet giant Google get into the automated vehicle business and asks not to be identified. "But that's the great part of this story. An idea emerged from outside of the traditional auto industry, and companies like Google with their very fast-moving and creative culture got it. And as a result, the idea took flight far faster than it would have otherwise."

Google said as much itself three years lat-

er, in 2010, when the company revealed that it was planning to produce self-driving cars. A revealing blog post connected its work directly to DARPA.

"To develop this technology, we gathered some of the very best engineers from the DARPA Challenges, a series of autonomous vehicle races organized by the U.S. Government," the public statement said. "Chris Urmson was the technical team leader of the [Carnegie Mellon] team that won the 2007 Urban Challenge. Mike Montemerlo was the software lead for the Stanford team that won the 2005 Grand Challenge. Also on the team is Anthony Levandowski, who built the world's first autonomous motorcycle that participated in a DARPA Grand Challenge, and who also built a modified Prius that delivered pizza without a person inside."

The Google blog was attributed to a "software engineer" named Sebastian Thrun. But the academic world knew Thrun was far more than a software engineer. A renowned researcher in computer learning, the German-born Thrun was recruited to Google soon after running Stanford's racing team for DARPA in 2007. His team's converted Volkswagen Passat named Junior came in second behind Whittaker's Chevy. Thrun's Stanford team also had developed Stanley, the DARPA 2005 winner.

Thrun stepped down to an advisory role at Google in 2014.

It continues

But the degree to which academic talent was hired away after DARPA was a surprise, Whittaker says. He saw a number of colleagues and graduate students recruited to auto industry pursuits from Carnegie Mellon's Robotics Institute, where he has worked for 36 years. Urmson, for instance, an assistant research professor, had served as director of technology on Carnegie's winning DARPA 2007 car. He was recruited to direct Google's self-driving car project in early 2009. He left that Google post in August.

"I've spun off some 20 companies and organizations over the years from what we do here," says Whittaker, 68. "This is how it works in academic circles. But I really didn't see this one coming."

After the 2007 race, Whittaker, who drives home every day to a large farm where he raises some 200 head of cattle, turned his focus back to his earlier research work of automated industrial and farming vehicles. His career research has led to the development of massively large automated rock-hauling



Stanley, a modified VW Touareg, was Stanford University's winning entry in the 2005 DARPA Grand Challenge. Stanford race participants went on to populate the industry's autonomous-drive push.

Below, Carnegie Mellon's modified Chevrolet Tahoe, winner of the 2007 DARPA race that lit the fuse for today's autonomous driving frenzy



trucks, now being used in an Australian mine. His patents include the technology to let tractors plant and harvest rows of crops without a driver.

He believes that hugely important applications need to be developed outside passenger cars to automate dangerous vehicle jobs in construction, mining, farming and emergency fields. Those fields will be just as revolutionized as passenger cars by the advent of driverless technologies, he says.

Meanwhile, the autonomous Big Bang continues to pull talent out of universities such as Carnegie Mellon.

This year, the San Francisco-based ride-hailing company Uber opened an advanced technologies center in Pittsburgh, near Carnegie's campus. Uber hired away some 40 people from Carnegie's staff to bring driverless-car know-how to what is currently a taxi company.

John Bares crossed over from Carnegie Mellon to Uber. A research scientist who came to the university as an undergraduate, stayed to receive his Ph.D. and later became director of the National Robotics Engineering Center at Carnegie, Bares left last year to become director of Uber's new tech center.

Pioneers

"These people are pioneers, and this is inevitable now," Whittaker says. "What you start just keeps spreading out in new ways. You don't know where discoveries will take you. Do you think that when the Wright brothers first got their plane off the ground they had any idea that it would result in the technology to compare airline ticket prices online?"

There was a telling moment at the conclusion of the ceremonies of that November 2007 race, some participants recall.

The director of DARPA at that time, Tony Tether, was presenting the prizes and congratulating the teams. A team member asked him, "Tony, when is DARPA's next race, and what will it be next time?"

"There isn't another race," they recall Tether answering. "Mission accomplished. You've achieved what we hoped to achieve. That's it."

"Our job was to start the ball rolling," he said. "Now all of you have to go out and make something out of it." **AN**

"We ignited the industry's interest. OEMs had to start asking, 'How can we not participate in this technology?'"

Red Whittaker, Carnegie Mellon University