

TERESA FAVUZZI is a good driver; it's everyone else around her who is a maniac. Favuzzi's partner is legally blind, so the 54-year-old independent-living director from Sacramento, Calif., is used to taking the wheel of the family car. She makes full stops at stop signs, obeys

speed limits (mostly), and always looks both ways before entering an intersection. The responsibility of being the driver appeals to her, because then she generally knows what the outcome of her journey will be: a safe arrival at her destination.

She doesn't give up the wheel easily—"I'm a bit of a control freak," she says—but in May 2015, Favuzzi eagerly accepted an invitation to take a test ride in Google's prototype self-driving car on a parking garage rooftop of the software giant's Silicon Valley headquarters. Google has held several demonstration events for journalists and community organizations so that they can learn about, and experience firsthand, Google's self-driving technology.

The inside of Google's podlike vehicle is at once familiar and disconcerting. It has two forward-facing seats, seat belts, even cup holders. But there is no steering wheel, brake pedal, or any controls to speak of, save for a "go" button and a big, red emergency "stop" button. Engaging the go button is a leap of faith for any "driver." After that push, for the length of your journey you are at the mercy of a machine.

But as Favuzzi discovered, it's a cautious machine, maybe even more cautious than she is. The vehicle stopped for pedestrians, bicyclists, other cars, and obstacles in the road "almost as well" as she could have driven. The car was calm, courteous, patient ... careful to a fault, even. Favuzzi got used to the experience in a hurry, and never once had that panicked-passenger feeling. You know the one, where you smash your foot into the car's firewall, slamming on an imaginary brake pedal.

Instead, she got out feeling ... relaxed. She's now eagerly anticipating a day when

she can have a self-driving car of her own, one where she and her partner can chill out, chat, sit back, and enjoy the ride.

But she'll have to wait a while. The prototype (which still doesn't have an official name) that shuttled Favuzzi is Google's vision of the future, a world of cars that use lasers, radar, and cameras—and a significant amount of computer processing power—to “see” the road, and thus remove humans from the task of driving.

It's a compelling scenario: No texting drivers wandering into adjacent lanes. No aggressive road ragers cutting each other off. No tired, drunk, or just plain confused people in control of 2-ton vehicles. Just computers constantly analyzing the road and traffic conditions, always alert and making the safest, most logical decisions every time.

The fact that Google's vehicle works at all makes that vision seem tantalizingly within reach. And in some ways it is. Researchers at Google, as well as universities including Carnegie Mellon and Stanford, plus multiple car manufacturers, are working diligently on the technologies necessary to let cars drive themselves. Experts predict that we'll see some real-world deployments of self-driving car services in select cities within the next few years. Also, many systems

are available in cars right now that allow varying degrees of autonomy. Some production cars can even operate on their own for limited durations under specific circumstances.

But it's a leap of surprising complexity to go from a few sporadic implementations of self-driving technology to a get-in-the-backseat-and-take-a-nap world of robotic cars. In fact, many of the engineers and automotive executives we contacted can't even agree about a realistic time frame, or what will be necessary in terms of laws and standards. But most do agree that it will take decades to sort it all out and spread full-autopilot technology into dealerships countrywide.

Google Inside?

Chris Urmson, the director of Google's Self-Driving Car Project, is on the optimistic end of the spectrum. “My team here is working to make sure my 12-year-old son doesn't have to get a driver's license,” he says, “and we believe that.”

Google isn't looking to become a car manufacturer, though. Rather, the online-search company wants its software to be the electronic brains of cars built by established automakers.

Many of those automakers are urging patience. Matt Sloustcher, who handles advanced technology communications for

Honda, said his company doesn't have set date for when “ubiquitous, unmanipulated operation” will be achievable, but it won't be anytime soon. “There are many complexities involved from a regulatory liability, and infrastructural standpoint that are only just starting to be explored.

How that all rolls out is no small matter. If the move to self-driving vehicles is inevitable, then it will be the single biggest change in the relationship between cars and their passengers since the invention of the motor vehicle itself.

We are talking about letting computers make life-and-death decisions on our behalf, on a mass-scale. Whether it takes two years or 20, it is a transition that requires everybody understanding the basics of self-driving vehicles, and setting realistic expectations about what we can expect from the technology.

Consumer Reports has experienced some of the most advanced features currently on the market at our track in Connecticut, and we've also talked with scientists and engineers who are developing the next generation of self-driving technology.

Our goal has been to answer questions about what's possible, how safe it all will be, and when Teresa Favuzzi—and the rest of us—can realistically expect our cars to take the wheel.

Q: CAN I BUY A SELF-DRIVING CAR RIGHT NOW?

NO. WELL, NOT REALLY. But many cars on the road have the ingredients necessary for computer-controlled driving. Semiautonomous, or partially self-driving, tech has been available on cars for several years. Adaptive cruise control was first offered in the U.S. in the early 2000s on high-end models. The systems scan the road ahead using cameras, lasers, or radar, and can automatically apply the gas or brakes to maintain a set distance between your car

and the car in front of you.

Automatic emergency braking systems are an extension of the same technology. When the system sensors determine a collision is imminent with the car directly in front of you, your car will automatically apply the brakes to attempt to bring you to a safe stop.

Those systems will take control of the accelerator and brakes, and lane-keeping assist (LKA) systems will give your steering wheel a gentle nudge. Available on luxury

cars such as the Mercedes-Benz S-Class and Infiniti Q50 down to the Honda Civic econobox, LKA generally uses camera-based “machine vision” to monitor the lines on the road. When it senses that the driver is drifting without using a turn signal, LKA automatically corrects the path of the car to keep it within a given lane.

The trickle-down effect to mainstream cars is already being realized, with Honda spokesman Matt Sloustcher saying that advanced driver-assistance systems will become standard equipment on Honda products “in the near future.”

For truly futuristic tech, there's Tesla's Summon self-parking feature. That system allows the

Model S sedan to drive itself to enter or exit a narrow parking space ... without anyone in the car. It can travel up to 33 feet at a walking pace, and the operator must be within 10 feet of the vehicle, controlling it like a remote-control car via the key fob or a smartphone app.

Not only are those features designed to offer safety and convenience, but many of them also form the building blocks to self-driving cars.

Jennifer Stockburger, who oversees safety testing at Consumer Reports' Auto Test Center, says “Based on our experiences, we see a lot of safety potential with these systems, especially as they continue to be refined.”

Q: SO I WON'T BE PLAYING COMPUTER GAMES WHILE MY CAR CHAUFFEURS ME?

A FEW CARMAKERS already have systems that allow some aspects of an autonomous driving experience. None of those systems are designed, in theory, for true “Look, Ma, no hands!” driving. But they are a stepping-stone technology.

Tesla’s Auto Pilot lets the car drive without human input on highways with clearly defined lane markings. Once Auto Pilot is engaged, the car steers itself to keep within the lane. It even brings itself to a stop and can resume driving in stop-and-go traffic. If you hit the turn signal stalk, the car will change lanes for you, if the system determines the maneuver is safe.

Mercedes’ DISTRONIC Plus with Steering Assist will pilot the car down the freeway but will disengage if it senses your hands haven’t been on the steering wheel for more than 15 seconds. Tesla warns Auto Pilot is not meant to be hands-free, but keeping your hands off the wheel doesn’t actually disengage the system. Same with the Infiniti Q50, although the company is adamant that its Active Lane Control was designed to help you stay in your lane on the highway, not

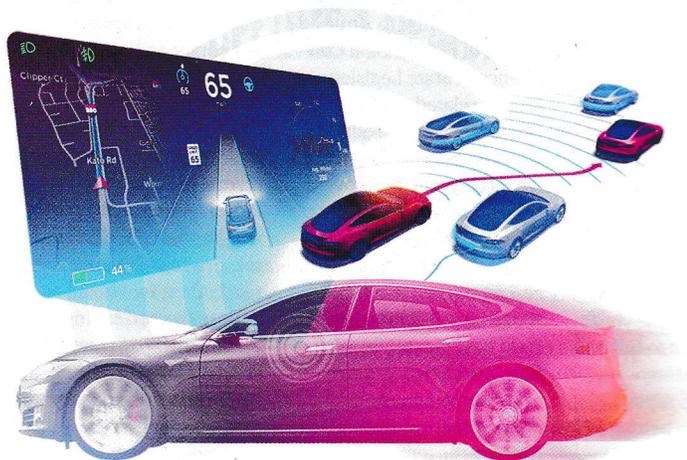
to do all of the steering for you.

Volvo has a forthcoming system called Pilot Assist II that will debut on the 2017 S90 sedan, allowing the car to accelerate, brake, and steer itself up to 80 mph, as well as come to a complete stop—although at least one hand must be on the steering wheel at all times.

Cadillac’s all-new CT6 sedan will have a system called Super Cruise available in 2017 that’s meant for truly hands-free operation on highways. But you can’t just zone out.

“At this point in time the technology is not good enough for you to not pay attention,” says John Capp, GM’s director of global vehicle safety. The system will monitor not only the behavior of the vehicle but also the driver’s face and eyes for attentiveness.

Both Nissan and Ford are working on autonomous drive systems that will operate in slow-moving traffic situations, taking over steering, throttle, and braking during city driving and traffic jams to save you from accidents. Honda is looking to have a freeway-only self-driving system in place by 2020.



SELF-DRIVING TERMS YOU SHOULD KNOW

Much of the core technology for self-driving cars is available on cars today. Here’s a guide to the key features and terms:

AUTONOMOUS VEHICLE

A car capable of sensing its environment and driving itself from point to point without needing input from a driver.

SEMI-AUTONOMOUS VEHICLE

A car that has limited capabilities, such as being able to steer, accelerate, brake, stop, change lanes, and park itself. The driver will need to stay alert to potential missteps and crisis situations.

ARTIFICIAL INTELLIGENCE

Machines with the ability to learn and make decisions on their own. The question that remains to be asked: Can a learning machine become self-aware?

FORWARD-COLLISION WARNING

Lasers, radar, or cameras assess the possibility of impact with a vehicle ahead and alert the driver to pay attention. We want this feature to be standard on all vehicles as soon as possible.

AUTO EMERGENCY BRAKING

Can sense an imminent forward collision and slam on the brakes if you don’t react in time. It’s *deus ex machina* for the inattentive driver. We want this feature to be standard on all cars as soon as possible.

LANE-KEEPING ASSIST

Induces mild steering input to keep your car in its lane. It works best on straight roads but can be overly intrusive on curvy two-lanes. Advanced versions allow for hands-off moments.

ADAPTIVE CRUISE CONTROL

Automatically adjusts your car’s speed to the vehicle ahead; some systems come to a full stop, then start again. You have but one job: steer.



Q: WILL SELF-DRIVING CARS MAKE OUR ROADS SAFER?

IF YOU ASK GOOGLE and the automakers why we need self-driving cars, they say the main reason is safety. Sure, letting a computer handle the driving will be a huge convenience. But consider that more than 90 percent of car crashes are the result of human error, something that, presumably, wouldn't be a problem for autonomous cars.

"We have 1.2 million people killed worldwide, 33,000 killed in the U.S. per year; that's incredible," says Google's Chris Urmson. "The 33,000 number is comparable to a 737 falling out of the sky almost five days a week, which would be completely unacceptable in air travel."

Active safety features, such as forward-collision warning with automatic emergency braking, are already reducing accidents. The Insurance Institute for Highway Safety says the combination of those two technologies has proven to reduce rear-end crashes by about 40 percent. Further safety aids such as rear-collision-alert systems, pedestrian detection, and blind-spot monitors will only serve to help.

In the far distant future, there's little debate that self-driving cars have the potential to drastically reduce, or possibly even eliminate, crashes. In the

interim, as self-driving cars navigate traffic alongside unpredictable human drivers, things will be murky.

Such a situation became clear in February, when a Google self-driving prototype collided at low speed with a municipal bus. The Google car's software wasn't programmed to react intuitively when the car's progress was blocked by sandbags in the road, just as it was attempting a right turn on a busy boulevard. The Google car then merged back into traffic, calculating that the bus following behind would yield. But the bus did not yield, and the two vehicles collided.

Google, firmly on the side of heading straight to full autonomy, worries that inviting drivers to tune in and out of the task of driving could be a serious problem; give people the option to pay even less attention to their driving, and many of them are bound to bury their head further into their smartphone or laptop.

To suddenly require a clocked-out human to re-engage with driving at a critical moment will probably not end well, according to driving simulations conducted by Stanford University.

In a 2013 interview with *Automotive News*, the late Stanford professor Clifford Nass explained:

"You look away to read *The New York Times* or watch 'Les Miz,' and traffic got crowded, the road surface changed, and it started raining. You have to be responsible for taking over the car. That is a phenomenal mental transition problem."

Volvo's case against going completely autonomous is based on its survey of more than 10,000 respondents to date—with 92 percent of drivers still wanting a car equipped with a steering wheel, with the ability to take over the driving at any moment. The summary: The luxury of driving manually must be preserved. Volvo says its goal for the future is not to remove driving but rather to support the driver when the task is less fun—for example, during the daily commute or a traffic jam.

A recent survey by AAA shows that 84 percent of respondents who do not want semi-autonomous features on their next vehicle said they trust their own driving skills more than the technology.

Mark Rosekind, head of the National Highway Traffic Safety Administration, responded to the dilemma of straight-to-full-automation vs. the step-by-step process by saying, "We would lose by betting on one or the other path."

Q: ARE AUTONOMOUS CARS EVEN LEGAL?

WHEN EACH STATE WROTE its driving laws, a car that drove itself wasn't a consideration. Back in 2012, University of South Carolina assistant professor of law Bryant Walker Smith took on the daunting task of reading the traffic codes in every state to find legal provisions that could complicate or prohibit self-driving cars.

He basically found only one, a provision in New York state that says, "no person shall operate a motor vehicle without having at least one hand ... on the steering mechanism at all times when the motor vehicle is in motion."

Beyond that, Smith said he found pretty much zero unambiguous red flags, prompting him to title his research paper "Automated Vehicles Are Probably Legal in the United States." And even that New York law, he says, is open to interpretation because it could be argued that, with a self-driving car, no "person" is actually driving it, so therefore there is no conflict.

But that's not to say states aren't busy enacting legislation related to autonomous cars. According to Anne Teigen of the National Conference of State Legislatures, 32 bills related to self-driving cars have been introduced in 2016 or are still active from last year's carryover.

Nevada was the first state to authorize the operation of self-driving cars, in 2011, and since then five other states plus Washington, D.C., have passed legislation. And Arizona's governor signed an executive order directing agencies to support the testing and

operation of self-driving cars.

The bills have ranged from authorizing the use of self-driving cars on public roads—under certain safety and testing conditions—to defining what a self-driving vehicle is to requiring a licensed driver in the driver's seat. North Dakota simply asked for a study of autonomous vehicles, and Tennessee's bill prohibits local governments from banning their use.

Despite the debate, Teigen says no state has introduced legislation that specifically prohibits the testing or development of self-driving technology, although Smith argues some have certainly muddied the waters.

For now, the federal government seems to support the move toward autonomous cars. Transportation Secretary Anthony Foxx recently said he was "personally asking automakers to submit more regulatory interpretation requests so that we can work with your progress, not hold it back."

That means systems such as Tesla's Auto Pilot and Cadillac's Super Cruise are legal to use, except in New York state. Because those types of systems are not considered self-driving (the driver needs to pay attention), the driver rather than the automaker will be responsible in the case of an accident. Things are less clear concerning what will happen once fully self-driving cars are on the road. Already, Volvo has gone on record saying it will assume liability when an accident is caused by a Volvo running in fully autonomous mode, as long as the system isn't being abused.



TRANSPORTATION OF THE FAR, FAR-OFF FUTURE

The Connected Highway

The utopian road—where cars, trucks, buses, bicyclists, pedestrians, and traffic signals all talk to each other through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication—has been envisioned for decades. Such a plan could

virtually eliminate accidents, massively reduce congestion, and improve efficiency. Although a completely connected vehicle fleet will take decades to implement, it doesn't have to come all at once. Frank Paluch, president of Honda R&D Americas, suggests it could start with a single, dedicated highway lane

for automated vehicles, for instance on Interstate 5 in California. Picture cars traveling at speeds of more than 180 mph, inches apart, in perfect uniformity: Los Angeles to San Francisco in about 2 hours.

The End of Car Ownership

A single highway lane for self-driving cars might not be all that far off and is fairly plausible. But eventually, owning a car could be mostly for hobbyists. For car enthusiasts, it's hard to imagine such a

future, but to the pragmatic the concept makes sense. Why spend so much money on an item that, in truth, sits idle the majority of the time? In the future you'll simply summon the car of your choice to your door, on demand, from a network of self-driving vehicles.

Fly, Don't Drive

We know, it's not a car, but it's hard to ignore the single-person Autonomous Aerial Vehicle (AAV). The Chinese-built Ehang 184 self-piloted mini-helicopter is powered

by eight electric motors and can fly for 23 minutes at an average speed of 62 mph before needing a 2- to 4-hour recharge. It has a 220-pound load capacity. Although the Federal Aviation Administration will have a field day regulating such a vehicle, Ehang says the drone-copter will go on sale in China this year for private use for around \$250,000. The "Blade Runner" dreamers can envision autonomous helicopters as the potential ride-sharing service of the future.

Q: WHEN WILL FULLY AUTONOMOUS CARS BECOME A REALITY?

YOU'LL PROBABLY HAIL an autonomous taxi long before you'll have the opportunity to buy your own self-driving car.

Alan Hall, who handles technology, research, and innovation communications for Ford, expects that the first application of the technology will be in automated taxis in certain cities.

The idea would be similar to the way ride-sharing services work now. You'd summon your ride with

a smartphone, and it would send a car to your location, then deliver you to your destination. Except, no driver.

That is, provided your destination was within the city. Hall says that early implementations of self-driving cars would work only "in a defined area that is mapped, in appropriate weather, in a city environment."

Experts agree that it will be a very long time before autonomous

vehicles will have free rein over every road in America. Before that happens, every road, highway, byway, bridge, and obstacle needs to be mapped. And we're not just talking the ordinary maps currently in your car's navigation system. According to Google's Chris Urmson, autonomous cars need detailed 3D maps that capture all features of the road, including lane markers and traffic signs.

Weather is also a big concern. Snow covers up the lane lines that cars' cameras use to find their way. To counteract that, Ford has been testing cars at Mcity, a 32-acre simulated urban driving environment at the University of Michigan. The cars use high-resolution 3D maps,

which provide information about road markings, signs, geography, landmarks, and topography. The goal is that when the Ford can't see the actual road, it will still be able to detect above-ground landmarks to orient itself on the map.

A self-driving car's software has to be ready for even the most bizarre circumstances and be ready to temporarily violate traffic laws—say, if a police officer or traffic worker waves the car into oncoming traffic lanes to avoid an obstacle. Could a car know to stop at a green traffic signal to avoid hitting a person chasing their dog into the street? Imagine the billions of lines of software code needed to accomplish that.