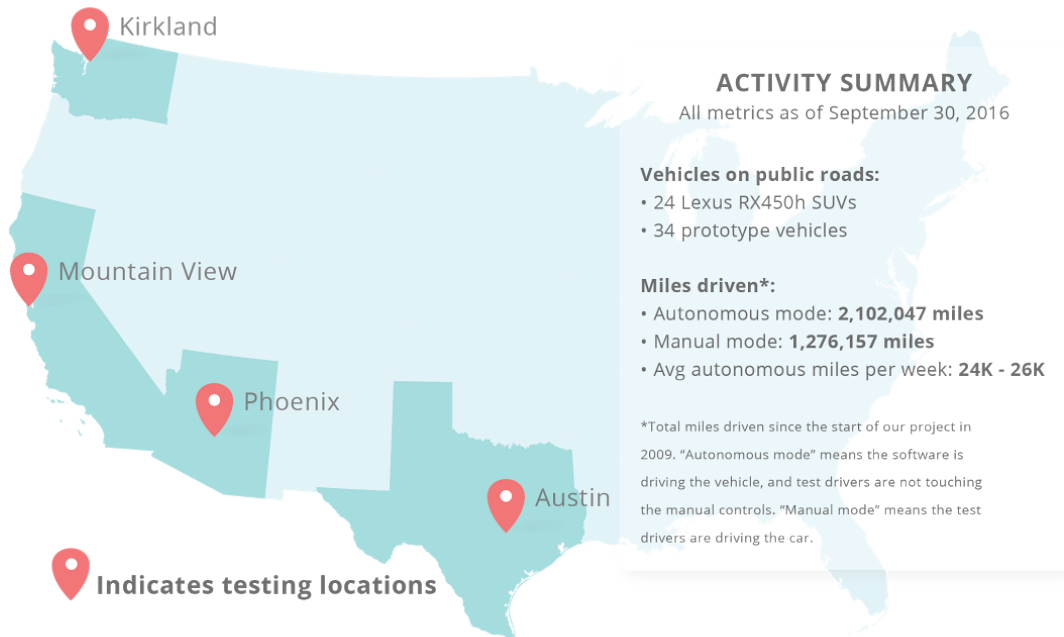


Google Self-Driving Car Project

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ON THE ROAD



TWO MILLION MILES CLOSER TO A FULLY AUTONOMOUS FUTURE

By Dmitri Dolgov, Head of Google's self-driving technology

When I first learned to drive, every mile I spent on the road was crucial. It was only through practice that I learned how to move with the flow of traffic, anticipate people's behavior, and react to unexpected situations. Developing a truly self-driving car is no different. A self-driving car that can get you safely from door to door has to understand the nuances of the road, which only comes with experience.

That's why our team has been focused on gaining real-world experience, and this month, we've reached a major milestone: we've now driven more than 2 million fully-autonomous miles on public roads. Put another way, if you consider the hours we've spent on the road, our cars now have the equivalent of 300 years of human driving experience.

What takes a self-driving car from concept, to demonstration, and finally to reality is this accumulated experience. Even in the early days of our project, it didn't take long before we could give a good demo ride in our self-driving car. That's because it's relatively easy to master the first 90% of driving where you're traveling on freeways, navigating light city-street traffic, or making your way through simple intersections.



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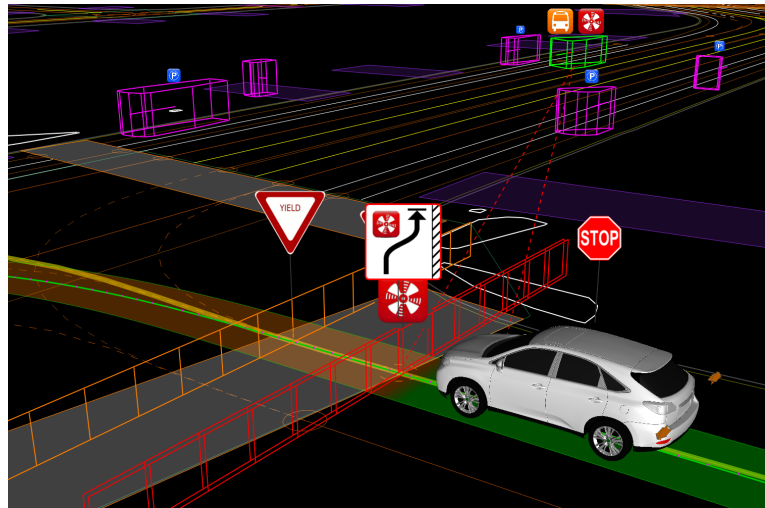
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But to create a truly self-driving car that can do all the driving, we knew we'd need experience in more challenging and interesting situations. That's why we now spend the vast majority of our time on complex city streets, rather than simpler environments like highways. It takes much more time to accumulate miles if you're focused on suburban roads; still, we're gaining experience at a rapid pace: our [first million miles](#) took six years to drive, but our next million took just 16 months. Today, we're taking a look at how our last million miles has brought us closer to making a truly self-driving car a reality.

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We've taught our cars a collection of advanced driving skills.

In the last few years, we've been focusing on the harder tasks of driving — the final 10% — that take much more time and experience to master. Our cars have gotten much better at detecting and responding to everything from crossing guards to emergency vehicles to construction zones. With these advanced driving skills, we can adjust to things like sudden changes in road conditions, such as closed lanes.



The ability to navigate smoothly on the road, while subtle, is also an important advanced driving skill that helps people feel comfortable whether they're inside or outside of the car. With each mile we drive, our test drivers provide feedback on the car's movements — things like how quickly we accelerate and brake, the distance we keep from other cars and pedestrians, or the speed and angle we turn. With each piece of feedback, our engineers tweak our software and calibrate our driving behavior, making our self-driving car feel more natural on the road.

We have a better understanding of the social side of driving.

Ultimately, being a good driver is about understanding other people — pedestrians, bikers and fellow drivers. Over the last year, we've learned that being a good driver is more than just knowing how to safely navigating *around* people, but also knowing how to *interact* with them.



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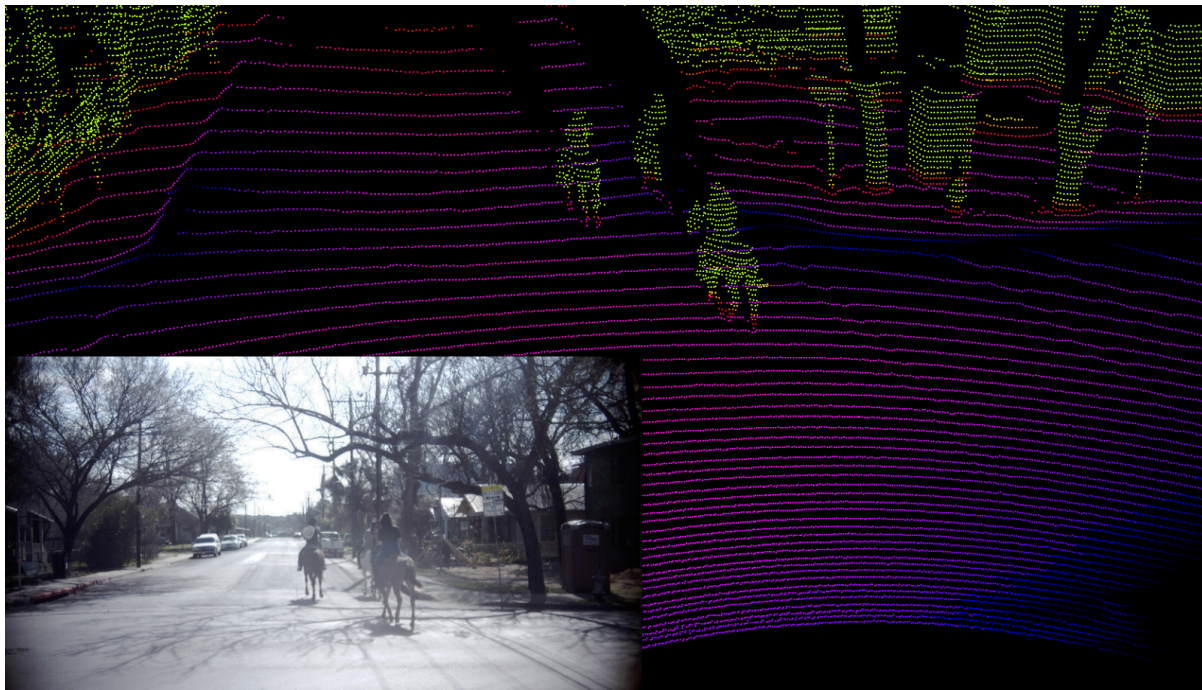
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In a delicate social dance, people signal their intentions in a number of ways. For example, merging into traffic during rush hour is an exercise in negotiation: *I'd like to cut in. May I cut in? If I speed up a little and move into the lane, will you slow down and leave me room, or will you speed up?* So much of driving relies on these silent conversations conducted via gentle nudge-and-response. Because we've observed or interacted with hundreds of millions of vehicles, pedestrians and cyclists, our software is much better at reliably predicting the trajectory, speed, and intention of other road users. Our cars can often mimic these social behaviors and communicate our intentions to other drivers, while reading many cues that tell us if we're able to pass, cut in or merge.

We've gained experience with rare and unexpected situations.

After 2 million miles of testing, our cars are more prepared to handle rare and unusual situations that human drivers may come across only once in a lifetime. In the last few months, we've seen everything from a horseback rider in the middle of the road, to a man wielding a chainsaw in the street (don't worry, he was trimming trees!), to a couple riding unicycles side-by-side. Today, our cars can confidently handle unusual situations like seeing a car (or three!) driving the wrong way down a road.



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When we first started the project 7.5 years ago, we saw the potential of this technology to help millions of people, making roads safer and improving quality of life. Today, our team is more confident than ever of a fully self-driving future. With every passing milestone — driving the [curves of Lombard Street](#), navigating [rain](#) and [dust](#) in four U.S. cities, building three [generations](#) of self-driving cars (with a [fourth](#) on the way) — we're even more committed to building that future.

TRAFFIC COLLISIONS INVOLVING AUTONOMOUS FLEET

Given the time we're spending on busy streets, we'll inevitably be involved in collisions; sometimes it's impossible to overcome the realities of speed and distance. Thousands of minor crashes happen every day on typical American streets, 94% of them involving human error, and as many as 55% of them go unreported. (And we think this number is low; for more, see [here](#).)

For collisions occurring in CA, the following summaries are what we submitted in the "Accident Details" section of form OL316 Report of Traffic Accident Involving an Autonomous Vehicle.

September 7, 2016: A Google prototype autonomous vehicle ("Google AV") proceeding westbound in autonomous mode on Nita Avenue in Palo Alto was involved in an accident. The Google AV came to a stop at the intersection of San Antonio Road, then, in preparation for making a right turn on San Antonio Road, began to gradually advance forward in order to gain a better view of cross-traffic. A 12-passenger shuttle van waiting immediately behind the Google AV then advanced forward at approximately 7 mph and collided with the rear bumper of the Google AV. The Google AV was travelling at approximately 3 mph at the time of the collision. The Google AV experienced minor damage to its rear bumper and hatch. The other vehicle experienced minor damage to its front bumper and right headlight. There were no injuries reported at the scene by either party.

September 14, 2016: A Google prototype vehicle ("Google AV") traveling eastbound in manual mode on El Camino Real in Los Altos was involved in an accident. As the Google AV was completing a lane change in autonomous mode from the far right lane to the middle lane of El Camino Real near the intersection of Showers Drive, a car stopped in traffic in the far left lane of El Camino Real abruptly changed lanes into the middle lane, immediately in front of the Google AV. The Google AV test driver took manual control of the Google AV and quickly merged back into the far right lane to avoid the vehicle. Another vehicle approaching from behind in the right lane of El Camino Real then struck the rear passenger side quarter panel of the Google AV at approximately 23 mph. The Google AV was travelling at approximately 14 mph at the time of the collision. The Google AV sustained minor damage to its rear passenger-side tire, quarter panel, and door. The other vehicle sustained moderate damage to its front bumper and front driver-side fender. No injuries were reported by the parties at the scene.



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September 20, 2016: A Google Lexus-model autonomous vehicle ("Google AV") traveling northbound in manual mode on Calderon Ave. in Mountain View was involved in an accident. As the Google AV began to make a right turn onto Dana St. in autonomous mode, two pedestrians walking northbound on the sidewalk on Calderon Ave. approached the entrance to the crosswalk across Dana St. The Google AV test driver disengaged the autonomous technology and began to bring the Google AV to a stop in order to yield to the pedestrians entering the crosswalk. A vehicle immediately behind the Google AV traveling at 4.5 mph collided with the rear bumper of the Google AV. The Google AV sustained minor damage to its rear bumper. The other vehicle sustained minor damage to its front bumper. There were no injuries reported at the scene by either party.

September 23, 2016: A Google Lexus-model autonomous vehicle ("Google AV") traveling northbound on Phyllis Ave. in Mountain View in manual mode was involved in an accident. As the Google AV proceeded through a green light at the El Camino Real intersection, its autonomous technology detected another vehicle traveling westbound on El Camino Real approaching the intersection at 30 mph and began to apply the Google AV's brakes in anticipation that the other vehicle would run through the red light. The Google AV test driver then disengaged the autonomous technology and took manual control of the Google AV. Immediately thereafter, the other vehicle ran through the red light and collided with the right side of the Google AV at 30 mph. At the time of collision, the Google AV was traveling at 22 mph. The Google AV sustained substantial damage to its front and rear passenger doors. The other vehicle sustained significant damage to its front end. There were no injuries reported at the scene by either party. However, the Google AV test driver later voluntarily went to a local hospital where he was evaluated by medical staff and released.

Note: Beginning next month, this section won't include collisions that occurred while our car was being manually driven. We will continue to include manual collisions that occur when the test driver takes control at the last moment.

WHAT WE'VE BEEN READING

Associated Press: [Tech may help steer older drivers down a safer road](#)
Washington Ideas Forum: [John Krafcik in conversation with James Fallows](#)
Pittsburgh Post-Gazette: [Barack Obama: Self-driving, yes, but also safe](#)
Consumer Reports: [Life in Google's Self-Driving City](#)

