Google Self-Driving Car Project
Monthly Report

March 2016

ACTIVITY SUMMARY

All metrics as of March 31, 2016

Vehicles:

- 21 Lexus RX450h SUVs currently self-driving on public streets: 13 in Mountain View, CA; 8 in Austin, TX
- 33 prototypes currently self-driving on public streets: 24 in Mountain View, CA; 7 in Austin, TX; 2 in Kirkland, WA

Miles driven since start of project in 2009

"Autonomous mode" means the software is driving the vehicle, and test drivers are not touching the manual controls. "Manual mode" means the test drivers are driving the car.

- **Autonomous mode:** 1,498,214
- **Manual mode:** 1,046,386
- We average around 10,000—15,000 autonomous miles per week on public streets

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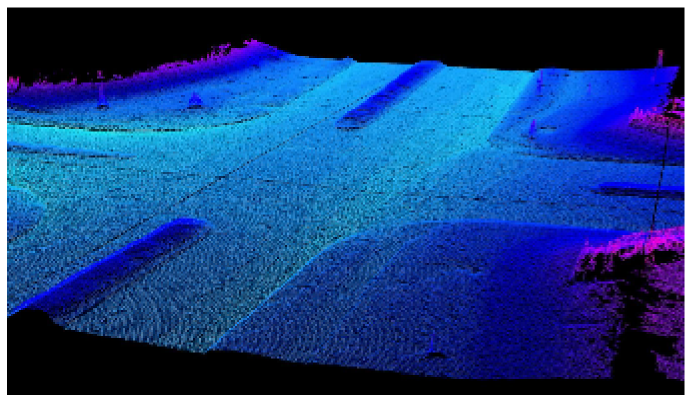
BUILDING MAPS FOR A SELF-DRIVING CAR



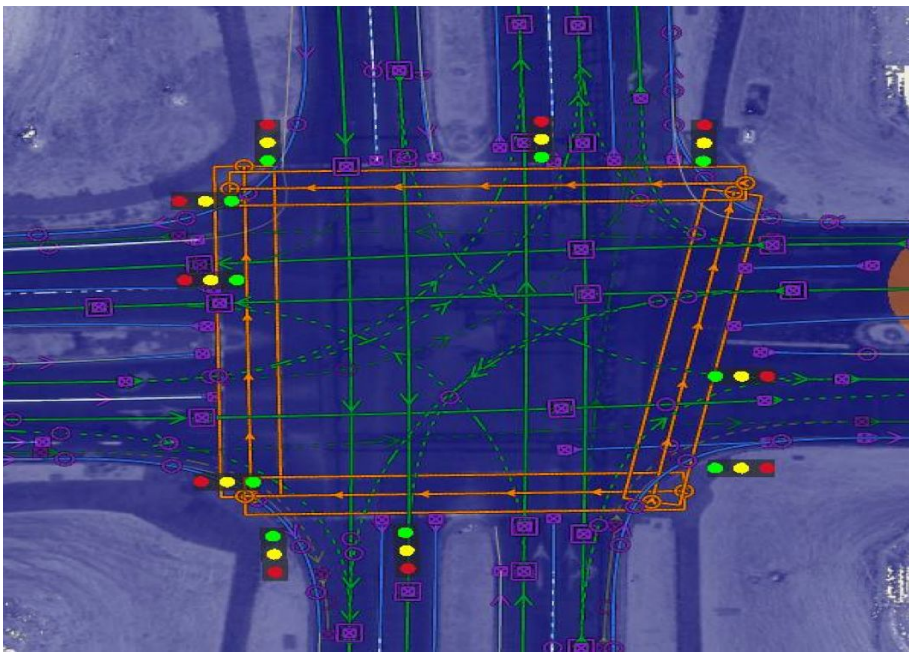
Elevation view of an intersection in Mountain View, CA. This information tells our car what to expect on the road so our sensors and software can spend more time processing moving objects, like cars and pedestrians.

We're often asked how we build maps specifically for a fully autonomous car. A map for self-driving cars has a lot more detail than conventional maps (e.g. the height of a curb, width of an intersection, and the exact location of a traffic light or stop sign), so we've had to develop a whole new way of mapping the world.

Before we drive in a new city or new part of town, we build a detailed picture of what's around us using the sensors on our self-driving car. As we drive around town, our lasers send out pulses of light that help us paint a three-dimensional portrait of the world. We're able to tell the distance and dimensions of road features based on the amount of time it takes for the laser beam to bounce back to our sensors (see image above). Our mapping team then turns this into useful information for our cars by categorizing interesting features on the road, such as driveways, fire hydrants, and intersections.

This level of detail helps our car know exactly where it is in the world. As our cars drive autonomously on the road, our software matches what the car sees in real-time with the maps we've already built, allowing the car to know its position on the road to within 10cm of accuracy. That means we don't have to rely on GPS technology, or a single point of data such as lane markings, to navigate the streets.

Another benefit of knowing permanent features of the road is that our sensors and software can focus more on moving objects, like pedestrians, vehicles, and construction zones. This allows us to do a better job of anticipating — and avoiding — tricky situations.



Self-driving cars can use a much greater level of detail than you'd find on Google Maps. Our mapping team highlights road features such as the length of a crosswalk, height of a traffic light, and the curve of a turn.

Of course our streets are ever-changing, so our cars need to be able to recognize new conditions and make adjustments in real-time. For example, we can detect signs of construction (orange cones, workmen in vests, etc.) and understand that we may have to merge to bypass a closed lane, or that other road users may behave differently.

To keep our maps up-to-date, our cars automatically send reports back to our mapping team whenever they detect changes like these. The team can then quickly update the map and share information with the whole autonomous fleet.

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SCENES FROM THE STREET
Each month we'll give examples of situations we encounter on the road

What do a 1980s Japanese arcade game and our self-driving car have in common? This month we showed a compilation of odd encounters we've recently had on the streets while out testing. One of these included half a dozen people leap-frogging through traffic in front of one of our self-driving cars (if you're finding that difficult to imagine, you can watch Chris Urmson show this encounter in his SXSW speech at 26:00).

Despite never encountering humans posing as an army of frogs, our car still knew how to behave safely (though your parents would probably tell you this is unsafe behavior anyway, so kids don't try this at home!). That's because rather than teaching the car to handle very specific things, we give the car fundamental capabilities for detecting other road users or unfamiliar objects, and then we give it lots of practice in a wide range of situations.

On our private test track, we've dreamt up and recreated hundreds of odd scenarios to gauge our car's response (e.g we even had someone jump out of a porta potty on the side of the road), but situations like these demonstrate why public testing of our self-driving cars is important to developing our cars for the road. We can try to come up with lots of wacky situations for our cars to handle, but the real world can defy even our wildest imaginations.

TRAFFIC COLLISIONS INVOLVING AUTONOMOUS FLEET

In this section, we detail any accidents our self-driving fleet has been involved in while testing on public roads. 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 accidents 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.)

March 14, 2016: A Google Lexus-model autonomous vehicle ("Google AV") travelling westbound on W. Anderson Ln. in Austin, TX in autonomous mode was rear-ended while stopped at a traffic light. The Google AV was stopped for approximately 3 seconds behind traffic waiting at a red light at Burnet Road, when a vehicle (Volkswagen Passat) approaching from behind collided with the rear bumper of the Google AV. The Google AV's speed at the time of the collision was 0 mph. The other vehicle's approximate speed at the time of the collision was 10 mph.

The driver of the other vehicle appeared disoriented to the Google AV test driver, so the Google AV test driver called 911, and the 911 dispatcher sent emergency vehicles to the scene. The Google AV sustained minor damage to its rear bumper. The other vehicle sustained moderate damage to its front bumper.

WHAT WE'VE BEEN READING

- **SxSW:** Watch Chris Urmson explain Google's self-driving car project [video] (March 2016)
- **Washington Post:** I rode in Google's self-driving car. This what impressed me the most. (March 2016)
- **The Verge:** Google's bus crash is changing the conversation around self-driving cars (March 2016)
- **USA Today:** Self-driving car leaders ask for national laws (March 2016)
- **AP:** Autonomous cars aren't perfect, but how safe must they be? (March 2016)