# Fact Sheet: LiDAR, the "eyes" of our self-driving car

In order to build a fully self-driving car, we rely on powerful sensors called **LiDAR** to help our car see shapes in three dimensions, detect stationary objects, and measure distance precisely. Waymo has been working for many years to design and build all of our LiDAR in-house, so we can create the safest, most reliable self-driving system for our vehicles.

How LiDAR Works

LiDAR, short for **Li**ght **D**etection **A**nd **R**anging, is a surveying method that measures distance to an object by using a pulsed laser. LiDAR bounces a laser off an object at an extremely high rate—millions of pulses every second—and measures how long the laser takes to reflect off that surface. This generates a precise, three-dimensional image of the object, whether a person, vehicle, aircraft, cloud, or mountain.
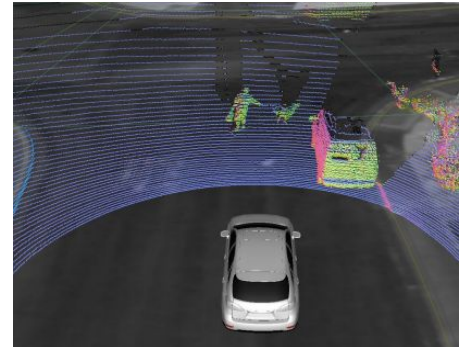
NASA has identified LiDAR as a key technology to "enable [the] safe landing of robotic and manned vehicles with a high degree of precision." LiDAR is routinely used in atmospheric mapping and meteorology, and increasingly in defense applications. At Waymo, we've built LiDARs for the specific task of fully autonomous driving.

Our In-House Suite of Technology

In the early days of our project, our hardware was comprised of sensors and compute systems from a multitude of suppliers. Not only were they limited in capabilities, they were also expensive. For example, a single LiDAR on top of the car cost more than the car itself! We soon realized that in order to reach what the Society of Automotive Engineers classify as Level 4 autonomy —and make it safe, reliable and accessible— we needed a fundamentally different approach. That's why we designed and built several generations of our own self-driving sensors, with every part manufactured to safely handle the complex task of full autonomy.

Having our hardware and software development under one roof is incredibly valuable. Our sensors are developed in close collaboration with our software experts who specialize in AI

techniques like machine learning. As a fully self-driving car, our system needs a more detailed view of the world than traditional LiDARs can offer. The detail we capture with our custom LiDAR is so high that we not only detect pedestrians all around us, but can tell which direction they're facing, so we can more accurately predict where someone will walk.

About Our Trio of In-House LiDARs:

Our self-driving Pacifica minivan has a complete system of three types of Waymo-built LiDARs that allows us to detect more objects and see them at a higher resolution. Two of these three sensors are completely new categories of LiDAR, designed and built by Waymo.

- **Short-range LiDAR:** A brand new type of LiDAR, our short range LiDARs are positioned to give the car an uninterrupted surround view—down, behind and next to its body—so the car can see small people and objects, no matter how close.
- **Long-Range LiDAR:** Our first-of-its-kind long-range LiDAR helps our cars understand subtle signals from far away, like hand gestures. It works with the primary LiDAR to quickly zoom 360 degrees around the car and can see incredible details -- like a cyclist waving to let us pass, two football fields away, while driving at full speed.
- **High-resolution LiDAR:** Coupled with short and long-range LiDAR, this high-resolution LiDAR allows us to send out millions of laser points every second to build an incredibly high-resolution 3D picture. This is needed to navigate the complexities of city driving: streets filled with cyclists, pedestrians and unexpected objects.

A Single Integrated System

All of the different parts of our self-driving technology work together seamlessly as a single integrated system. Like a person's five senses, our sensors are more useful and more powerful when we put them all together, allowing them to complement one another. Our LiDARs pick up where our radars and cameras leave off and vice versa.

Taken as a whole, our custom-built suite of sensors creates a virtuous cycle with our software. Better hardware gives us better data to develop our software; and as our software become more sophisticated, we get better at optimizing the most important aspects of our hardware. It's this tight integration that has made the entire suite more robust and more cost effective, bringing self-driving technology closer to reality for more people in more places.