Waymo Safety Report

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Waymo is a self-driving technology company with a mission to make it safe and easy for people and things to move around.

Our Journey

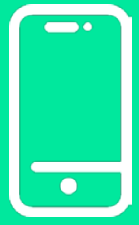
Speeding

Alcohol

94%

of crashes involve human choice or error in the US

Drowsiness



Distraction

2009


2012
6UEJ089


55

Driver Assist

1 Driver assistance

2 Partial automation

3 Conditional automation

Fully Self-Driving

4 High automation

5 Full automation

2012


RAIL ROAD CROSSING
RED LIGHT VIOLATION
$336
MINIMUM FINE
NO U TURN
Central Expwy
6YCT869
RX 450h
Google
self-driving car

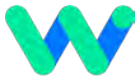

2015


2016
WAYMO


2017

Miles driven

160 X
around
globe



Most people think fully self-driving cars will be ready by 2020

ON THE ROAD TO FULLY SELF-DRIVING

Waymo Safety Report

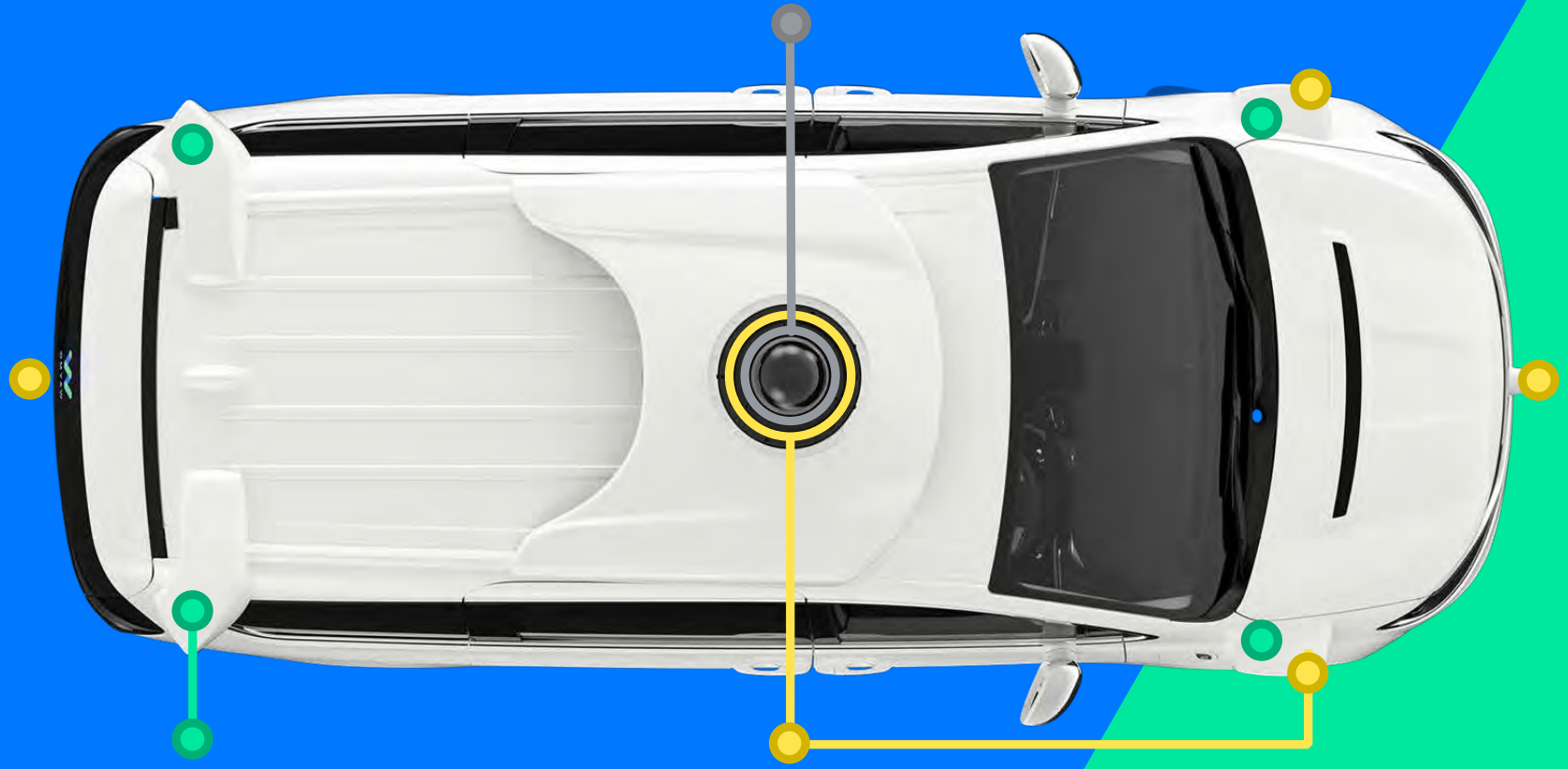
WAYMO

I. Waymo's System Safety Program: Safety-by-Design

- Behavioral Safety
- Functional Safety
- Crash Safety
- Operational Safety
- Non-Collision Safety

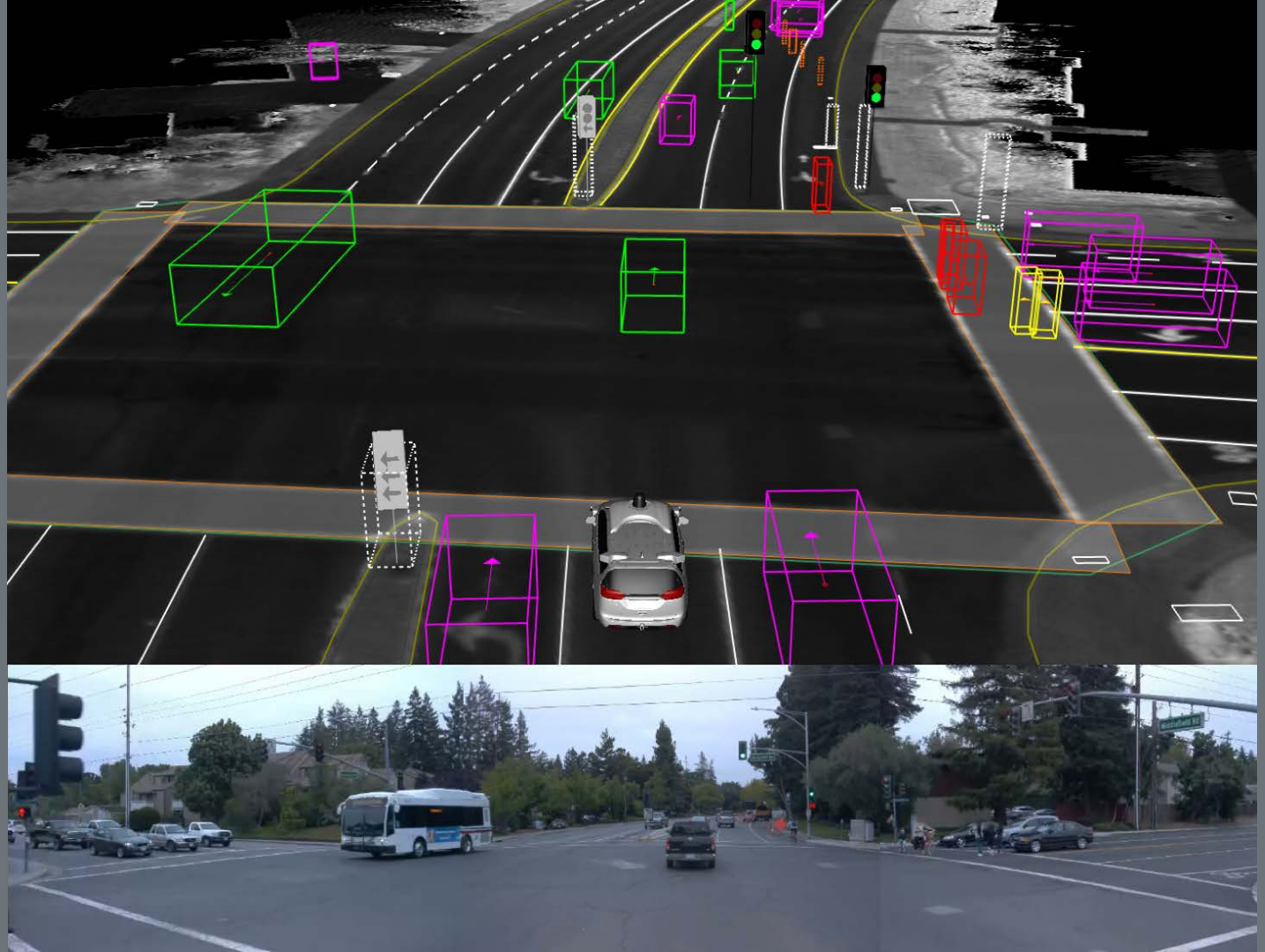
II. How Waymo's Self-Driving Vehicles Work

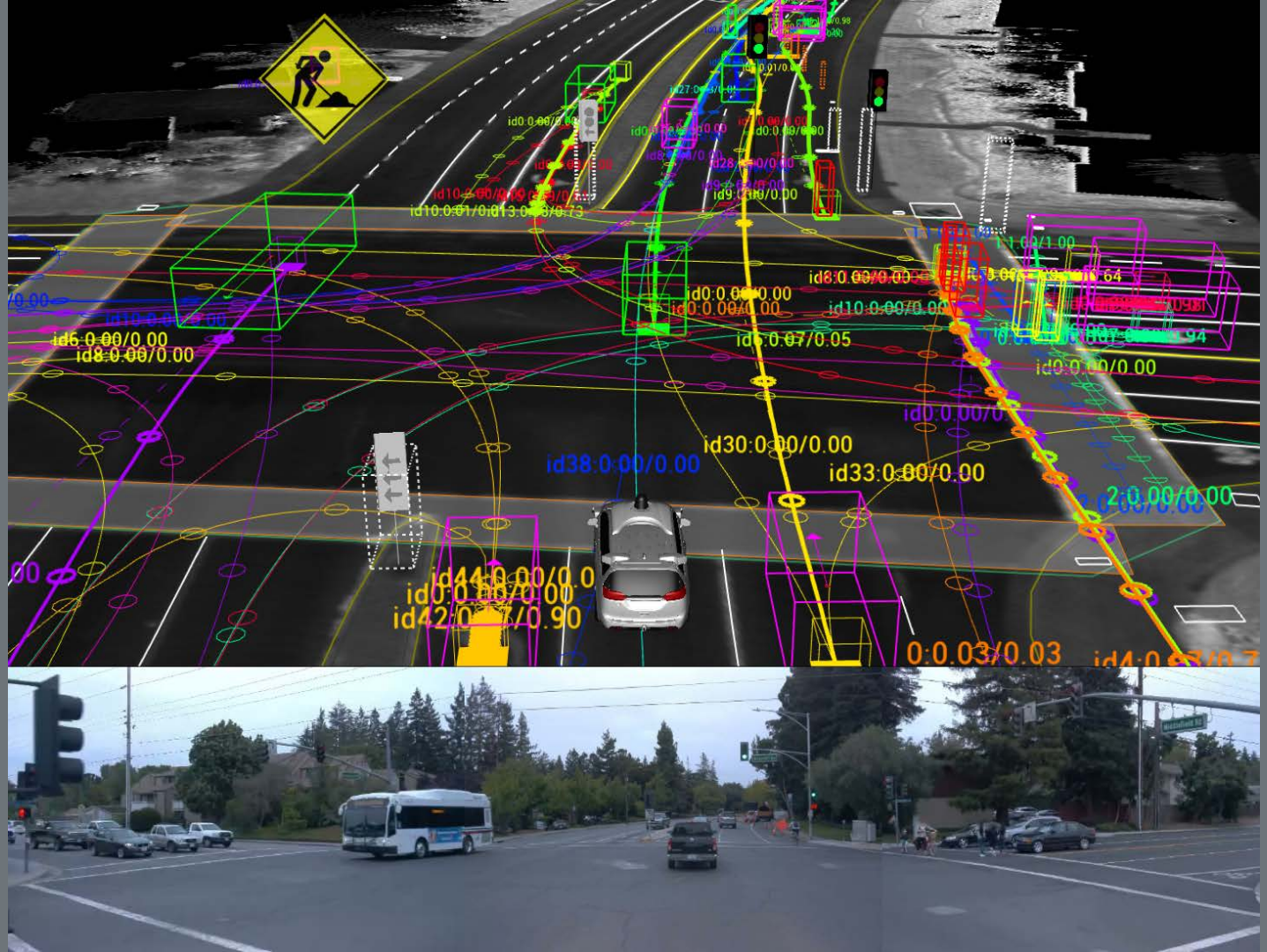
Vision system



Radar system

LiDAR system

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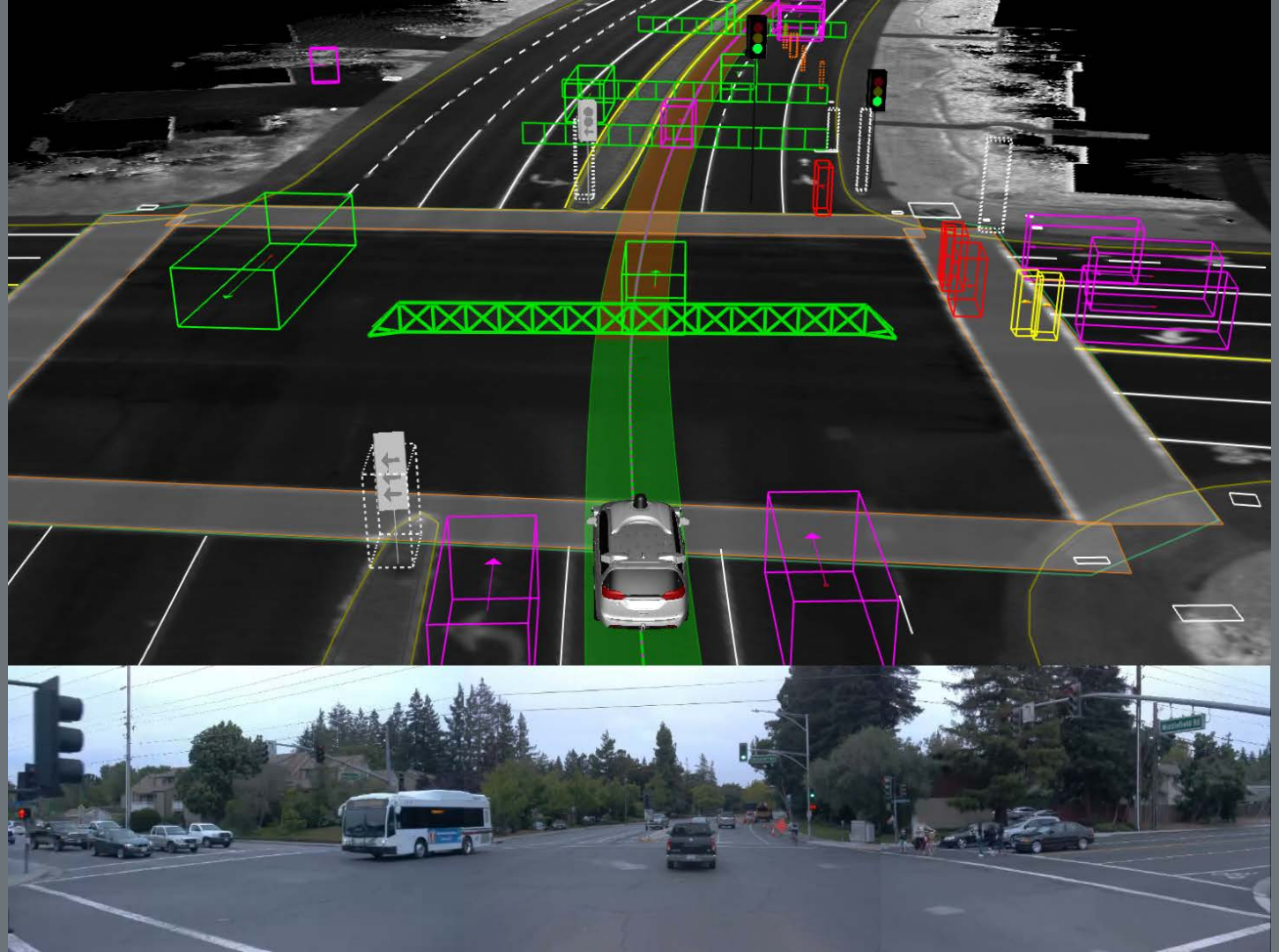


Minimal Risk Condition (Fallback): Ensuring the Vehicle Can Transition to a Safe Stop

Vehicles with lower levels of automation rely on a human driver to take back control if a situation on the road becomes too complex for the technology to handle, or if the technology itself fails. As a fully self-driving system, Waymo's technology must be robust enough to handle these situations on its own.

If our self-driving vehicle can no longer proceed on a planned trip, it must be capable of performing a safe stop, known as a "minimal risk condition" or fallback. This might include situations when the self-driving system experiences a problem, when the vehicle is involved in a collision, or when environmental conditions change in a way that would affect safe driving within our operational design domain.

Waymo's system is designed to detect each one of these scenarios automatically. In addition, our vehicles run thousands of checks on their systems every second, looking for faults. Our system is equipped with a series of redundancies for critical systems, such as sensors, computing, and braking. How our vehicle responds varies with the type of roadway on which a situation occurs, the current traffic conditions, and the extent of the technology failure. Depending on these factors, the system will determine an appropriate response to keep the vehicle and its passengers safe, including pulling over or coming to a safe stop. [15]

Redundant Safety-Critical Systems

Backup Computing

A secondary computer in the vehicle is always running in the background and is designed to bring the vehicle to a safe stop if it detects a failure of the primary system.

Backup Braking

If the primary braking system fails, we have a full secondary braking system that immediately kicks in. Either braking system can bring the vehicle to a safe stop if a failure occurs in the other.

Backup Steering

The steering system features a redundant drive motor system with independent controllers and separate power supplies. Either one can manage steering in the case that a failure occurs in the other.

Backup Power Systems

Independent power sources are provided for each of the critical driving systems. These independent power sources ensure that our vehicles' critical driving components remain online during single power failures or circuit interruptions.

Backup Collision Detection and Avoidance System

Multiple backup systems—including independent collision avoidance systems—constantly scan the road immediately ahead and behind the vehicle for objects such as pedestrians, cyclists, and other vehicles. These redundant systems slow or stop the vehicle in the rare event that the primary system does not detect or respond to objects in the path of the vehicle.

Redundant Inertial Measurement Systems for Vehicle Positioning

Redundant inertial measurement systems help the vehicle accurately track its motion along the road. These two systems cross-check each other and assume control from one another, if a fault is detected in either system.

III. Testing and Validation Methods: Ensuring Our Vehicles Are Capable and Safe

- Base Vehicle
- Self-Driving Hardware
- Self-Driving Software
  - Simulation
  - Closed-Course Testing
- Real-World Driving

Basic Behavioral Competency Testing

Set of Behavioral Competencies Recommended by NHTSA	
1	Detect and Respond to Speed Limit Changes and Speed Advisories
2	Perform High-Speed Merge (e.g., Freeway)
3	Perform Low-Speed Merge
4	Move Out of the Travel Lane and Park (e.g., to the Shoulder for Minimal Risk)
5	Detect and Respond to Encroaching Oncoming Vehicles
6	Detect Passing and No Passing Zones and Perform Passing Maneuvers
7	Perform Car Following (Including Stop and Go)
8	Detect and Respond to Stopped Vehicles
9	Detect and Respond to Lane Changes
10	Detect and Respond to Static Obstacles in the Path of the Vehicle
11	Detect Traffic Signals and Stop/Yield Signs
12	Respond to Traffic Signals and Stop/Yield Signs
13	Navigate Intersections and Perform Turns
14	Navigate Roundabouts
15	Navigate a Parking Lot and Locate Spaces
16	Detect and Respond to Access Restrictions (One-Way, No Turn, Ramps, etc.)
17	Detect and Respond to Work Zones and People Directing Traffic in Unplanned or Planned Events
18	Make Appropriate Right-of-Way Decisions
19	Follow Local and State Driving Laws
20	Follow Police/First Responder Controlling Traffic (Overriding or Acting as Traffic Control Device)
21	Follow Construction Zone Workers Controlling Traffic Patterns (Slow/Stop Sign Holders)
22	Respond to Citizens Directing Traffic After a Crash
23	Detect and Respond to Temporary Traffic Control Devices
24	Detect and Respond to Emergency Vehicles
25	Yield for Law Enforcement, EMT, Fire, and Other Emergency Vehicles at Intersections, Junctions, and Other Traffic Controlled Situations
26	Yield to Pedestrians and Bicyclists at Intersections and Crosswalks
27	Provide Safe Distance From Vehicles, Pedestrians, Bicyclists on Side of the Road
28	Detect/Respond to Detours and/or Other Temporary Changes in Traffic Patterns

Examples of Additional Behavioral Competencies Tested by Waymo	
29	Moving to a Minimum Risk Condition When Exiting the Travel Lane is Not Possible
30	Perform Lane Changes
31	Detect and Respond to Lead Vehicle
32	Detect and Respond to a Merging Vehicle
33	Detect and Respond to Pedestrians in Road (Not Walking Through Intersection or Crosswalk)
34	Provide Safe Distance from Bicyclists Traveling on Road (With or Without Bike Lane)
35	Detect and Respond to Animals
36	Detect and Respond to Motorcyclists
37	Detect and Respond to School Buses
38	Navigate Around Unexpected Road Closures (e.g. Lane, Intersection, etc.)
39	Navigate Railroad Crossings
40	Make Appropriate Reversing Maneuvers
41	Detect and Respond to Vehicle Control Loss (e.g. reduced road friction)
42	Detect and Respond to Conditions Involving Vehicle, System, or Component-Level Failures or Faults (e.g. power failure, sensing failure, sensing obstruction, computing failure, fault handling or response)
43	Detect and Respond to Unanticipated Weather or Lighting Conditions Outside of Vehicle's Capability (e.g. rainstorm)
44	Detect and Respond to Unanticipated Lighting Conditions (e.g. power outages)
45	Detect and Respond to Non-Collision Safety Situations (e.g. vehicle doors ajar)
46	Detect and Respond to Faded or Missing Roadway Markings or Signage
47	Detect and Respond to Vehicles Parking in the Roadway


SPEED
LIMIT
35


SPEED
LIMIT
25


Cruise
37
SPEED LIMIT
45


Cruise
SPEED UNIT
35

Avoidance or Mitigation of Common Crash Scenarios

Crash Avoidance Category	Example Test Scenario
Rear-end Demonstrate ability to avoid or mitigate crashes with lead vehicles.	Fully self-driving vehicle approaches stopped lead vehicle
	Fully self-driving vehicle approaches disabled vehicle
	Fully self-driving vehicle approaches lead vehicle traveling at lower constant speed
	Fully self-driving vehicle approaches lead vehicle traveling at slower speed and initiating strong braking
	Fully self-driving vehicle approaches lead vehicle accelerating
	Fully self-driving vehicle following a lead vehicle making a maneuver (e.g. cutting into lane or pulling out of driveway)
	Fully self-driving vehicle approaches lead vehicle decelerating
	Fully self-driving vehicle approaches other vehicle(s) reversing
	Fully self-driving vehicle approaches other vehicle(s) parking
Intersection Demonstrate ability to detect vehicle entering path at perpendicular angle and apply brakes.	Fully self-driving vehicle approaches protected intersection, Vehicle A approaches from right
	Fully self-driving vehicle approaches protected intersection, Vehicle A approaches from left
	Fully self-driving vehicle prepares to turn across unprotected intersection, oncoming Vehicle A approaches
	Crossing path collisions - other vehicle running red light
	Crossing path collisions - other vehicle running stop sign

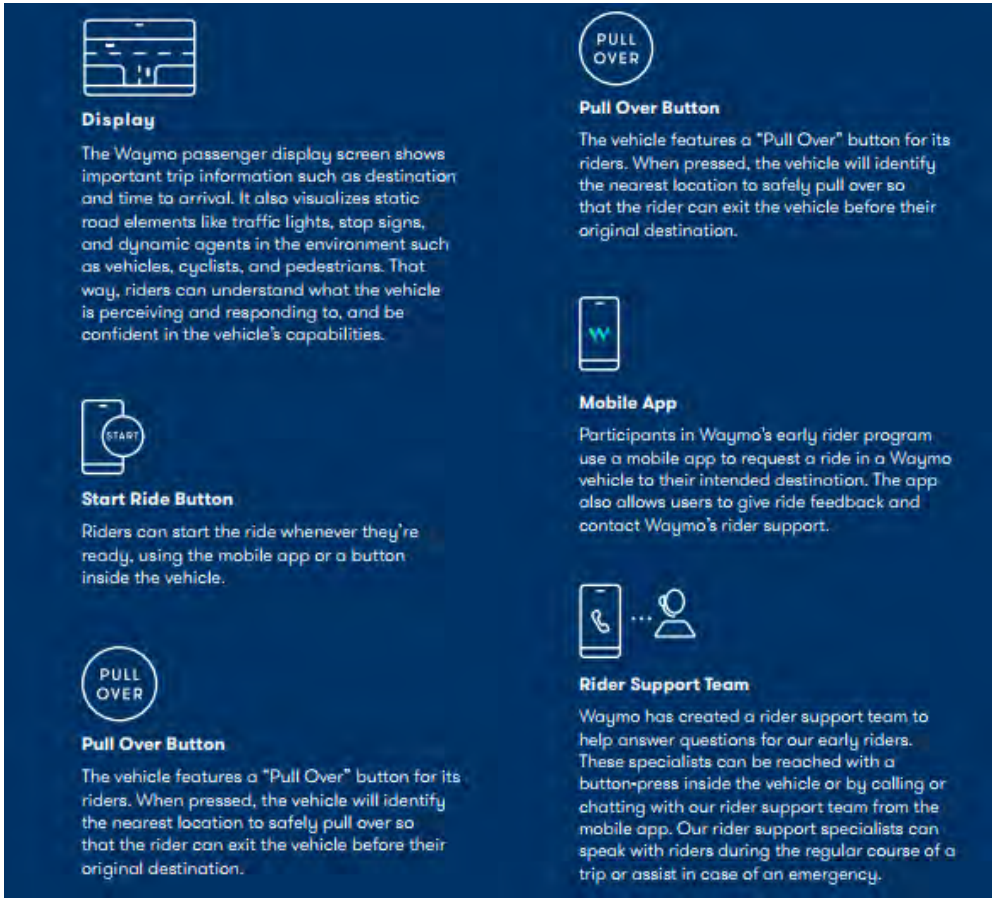
Crash Avoidance Category (continued)	Example Test Scenario (continued)
Road Departure Demonstrate ability to steer clear of roadway edge and stay within lane.	Fully self-driving vehicle travels down straight road (with or without prior vehicle maneuver)
	Fully self-driving vehicle travels down curved road (with or without prior vehicle maneuver)
	Fully self-driving vehicle travels down straight road with visible lane marking
	Fully self-driving vehicle travels down straight road with faded or missing lane marking
	Fully self-driving vehicle travels down curved road with visible lane marking
	Fully self-driving vehicle travels down curved road with faded or missing lane marking
	Fully self-driving vehicle travels down wet road with lane marking
	Fully self-driving vehicle approaches other vehicle(s) reversing
	Fully self-driving vehicle travels down wet road with faded or missing lane marking
Lane Change Demonstrate ability to avoid or mitigate crash when other vehicles make lane changes or merge.	Lane changes - other vehicles turning same direction
	Lane changes - other vehicles parking same direction
	Lane changes - other vehicles changing lanes same direction
	Lane changes - other vehicles drifting same direction
	Lane merges

IV. Interacting Safely With the Public

- Waymo's Early Rider Program
- Rider Experience
- Accessibility Features
- Emergencies & Law Enforcement


WAYMO

Making Waymo's Vehicles Easy to Use



Display

The Waymo passenger display screen shows important trip information such as destination and time to arrival. It also visualizes static road elements like traffic lights, stop signs, and dynamic agents in the environment such as vehicles, cyclists, and pedestrians. That way, riders can understand what the vehicle is perceiving and responding to, and be confident in the vehicle's capabilities.

Start Ride Button

Riders can start the ride whenever they're ready, using the mobile app or a button inside the vehicle.

Pull Over Button

The vehicle features a "Pull Over" button for its riders. When pressed, the vehicle will identify the nearest location to safely pull over so that the rider can exit the vehicle before their original destination.

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Mobile App

Participants in Waymo's early rider program use a mobile app to request a ride in a Waymo vehicle to their intended destination. The app also allows users to give ride feedback and contact Waymo's rider support.

Rider Support Team

Waymo has created a rider support team to help answer questions for our early riders. These specialists can be reached with a button-press inside the vehicle or by calling or chatting with our rider support team from the mobile app. Our rider support specialists can speak with riders during the regular course of a trip or assist in case of an emergency.


HELP
PULL OVER
START RIDE
Castro St
Castro St


9 Min Arrival
Yielding to pedestrians
45 MPH ZONE

What's Next

Waymo's driverless service