WAYMO

Application

Driverless Autonomous Vehicle Tester Program
April 2018

Introduction

Waymo, formerly known as the Google Self-Driving Car Project, is a self-driving technology company with a mission to make it safe and easy for people and things to get around. We're determined to improve transportation for people around the world, building on software and sensor technology developed in Google's labs since 2009. We're committed to developing fully self-driving vehicles because we believe that this is safer and better for everyone.

Annually, over 1.2 million people die on our roadways. In the US alone, traffic collisions kill over 37,000 people a year and that number is rising. In the U.S., 94% of crashes involve human error or choice, and this is one place where we believe we really can bring technology to bear. Fully self-driving cars could also help people who can't drive—whether they're elderly, blind, or disabled—to get around and do the things they love.

After nearly a decade of working on this technology, 5 million miles driven on public roads, more than a billion miles simulated every year, and thousands of comprehensive tests, Waymo has introduced fully self-driving ("driverless") vehicles without a test driver in metro Phoenix and will do so in other jurisdictions moving forward. When the automated driving system[2] of these vehicles is engaged, all occupants, including Waymo employees and members of the public, are passengers only.

These driverless vehicles travel within a defined geographic area in the local jurisdictions where they have already been tested extensively. Separately, Waymo also continues to have a separate fleet of self-driving vehicles with test drivers.

The documents below supplement the overview of how we design, test, and validate our technology in the *Waymo Safety Report*.

[2] AUTOMATED DRIVING SYSTEM. The hardware and software that are collectively capable of performing the entire dynamic driving task on a sustained basis, regardless of whether the ADS is limited to a specific operational design domain.

Table of Contents

I. Waymo's Application for Driverless Testing to be Submitted to the California Department of Motor Vehicles

Application content enclosed on the following page.

STATE OF CALIFORNIA DMV DEPARTMENT OF MOTOR VEHICLES
A Public Service Agency

DMV USE ONLY	
AVT NUMBER	
NAME	
DATE PERMIT ISSUED	DATE PERMIT EXPIRES
TOTAL FEE	RECEIPT NUMBER

AUTONOMOUS VEHICLE TESTER (AVT) PROGRAM APPLICATION FOR MANUFACTURER'S TESTING PERMIT DRIVERLESS VEHICLES

APPLICATION TYPE:

- [x] Original $3,600
- [ ] Renewal $3,600
- [ ] Modification $70
- [ ] Additional Vehicle Permits $50

CHECK THE APPROPRIATE BOX:

- [ ] Address Change
- [x] Vehicles

INSTRUCTIONS:

- Please complete online or print and complete by hand using black or blue ink.
- **Submit completed and signed form and fees to:** Department of Motor Vehicles, Autonomous Vehicle Program P.O. BOX 932342, MS L224, Sacramento, CA 94232-3420

SECTION 1 — AUTONOMOUS VEHICLE TESTER INFORMATION

NAME OF MANUFACTURER: Waymo LLC

BUSINESS NAME: Waymo LLC — SECRETARY OF STATE ENTITY NUMBER: 6073396

BUSINESS NAME LICENSED BY DMV: Waymo LLC — TELEPHONE NUMBER: (650) 253-0000

STREET ADDRESS	CITY	STATE	ZIP CODE
1600 Amphitheatre Parkway	Mountain View	CA	94043

MAILING ADDRESS (IF DIFFERENT FROM STREET ADDRESS)	CITY	STATE	ZIP CODE
100 Mayfield Avenue	Mountain View	CA	94043

SECTION 2 — DRIVERLESS VEHICLES EQUIPPED FOR TESTING *List all vehicles in fleet.*

Number of vehicles in fleet 52

PLATE NUMBER	STATE ISSUED	VIN NUMBER	YEAR	MAKE	MODEL
85716G2	CA	2C4RC1K71HR534642	2017	Chrysler	Pacifica PHEV
7XCW003	CA	2C4RC1K73HR534643	2017	Chrysler	Pacifica PHEV
85718G2	CA	2C4RC1K78HR534637	2017	Chrysler	Pacifica PHEV
85719G2	CA	2C4RC1K7XHR534641	2017	Chrysler	Pacifica PHEV
85720G2	CA	2C4RC1K74HR534652	2017	Chrysler	Pacifica PHEV
7XJT285	CA	2C4RC1K75HR534644	2017	Chrysler	Pacifica PHEV
7XJT286	CA	2C4RC1K74HR534635	2017	Chrysler	Pacifica PHEV
85728G2	CA	2C4RC1K79HR534680	2017	Chrysler	Pacifica PHEV
85727G2	CA	2C4RC1K73HR534691	2017	Chrysler	Pacifica PHEV
7XJT289	CA	2C4RC1K7XHR534669	2017	Chrysler	Pacifica PHEV

PLATE NUMBER	STATE ISSUED	VIN NUMBER	YEAR	MAKE	MODEL
7XJT281	CA	2C4RC1K74HR534683	2017	Chrysler	Pacifica PHEV
85734G2	CA	2C4RC1K77HR534676	2017	Chrysler	Pacifica PHEV
85729G2	CA	2C4RC1K7XHR534686	2017	Chrysler	Pacifica PHEV
85730G2	CA	2C4RC1K71HR534690	2017	Chrysler	Pacifica PHEV
85731G2	CA	2C4RC1K78HR534699	2017	Chrysler	Pacifica PHEV
85732G2	CA	2C4RC1K79HR534663	2017	Chrysler	Pacifica PHEV
85735G2	CA	2C4RC1K74HR534666	2017	Chrysler	Pacifica PHEV
85733G2	CA	2C4RC1K76HR534703	2017	Chrysler	Pacifica PHEV
7ZUY446	CA	2C4RC1K78HR534704	2017	Chrysler	Pacifica PHEV
7ZUY447	CA	2C4RC1K70HR534678	2017	Chrysler	Pacifica PHEV

PLATE NUMBER	STATE ISSUED	VIN NUMBER	YEAR	MAKE	MODEL
85721G2	CA	2C4RC1K74HR534697	2017	Chrysler	Pacifica PHEV
85722G2	CA	2C4RC1K76HR534698	2017	Chrysler	Pacifica PHEV
85723G2	CA	2C4RC1K75HR534658	2017	Chrysler	Pacifica PHEV
7XJT379	CA	2C4RC1K75HR534708	2017	Chrysler	Pacifica PHEV
85726G2	CA	2C4RC1K76HR797337	2017	Chrysler	Pacifica PHEV
85724G2	CA	2C4RC1K74HR797370	2017	Chrysler	Pacifica PHEV
85725G2	CA	2C4RC1K71HR833838	2017	Chrysler	Pacifica PHEV
CK75116	AZ	2C4RC1K72HR534701	2017	Chrysler	Pacifica PHEV
CK75117	AZ	2C4RC1K7XHR534672	2017	Chrysler	Pacifica PHEV
CK60793	AZ	2C4RC1K77HR534709	2017	Chrysler	Pacifica PHEV

PLATE NUMBER	STATE ISSUED	VIN NUMBER	YEAR	MAKE	MODEL
CK60751	AZ	2C4RC1K70HR695693	2017	Chrysler	Pacifica PHEV
CK60752	AZ	2C4RC1K7XHR695703	2017	Chrysler	Pacifica PHEV
CK60753	AZ	2C4RC1K70HR695709	2017	Chrysler	Pacifica PHEV
CK60754	AZ	2C4RC1K78HR695697	2017	Chrysler	Pacifica PHEV
CK60755	AZ	2C4RC1K74HR695700	2017	Chrysler	Pacifica PHEV
CK60756	AZ	2C4RC1K75HR695690	2017	Chrysler	Pacifica PHEV
CK60757	AZ	2C4RC1K77HR695691	2017	Chrysler	Pacifica PHEV
CK60758	AZ	2C4RC1K74HR695695	2017	Chrysler	Pacifica PHEV
CK60759	AZ	2C4RC1K73HR695705	2017	Chrysler	Pacifica PHEV
CK60760	AZ	2C4RC1K75HR695706	2017	Chrysler	Pacifica PHEV

PLATE NUMBER	STATE ISSUED	VIN NUMBER	YEAR	MAKE	MODEL
CK75120	AZ	2C4RC1K73HR534674	2017	Chrysler	Pacifica PHEV
CK60796	AZ	2C4RC1K73HR534688	2017	Chrysler	Pacifica PHEV
CK60797	AZ	2C4RC1K73HR534657	2017	Chrysler	Pacifica PHEV
CK60799	AZ	2C4RC1K78HR534668	2017	Chrysler	Pacifica PHEV
CK74902	AZ	2C4RC1K71HR534687	2017	Chrysler	Pacifica PHEV
CK74903	AZ	2C4RC1K78HR534685	2017	Chrysler	Pacifica PHEV
CK74905	AZ	2C4RC1K75HR534661	2017	Chrysler	Pacifica PHEV
CK74907	AZ	2C4RC1K75HR534692	2017	Chrysler	Pacifica PHEV
CK74921	AZ	2C4RC1K72HR534696	2017	Chrysler	Pacifica PHEV
CK74926	AZ	2C4RC1K77HR534693	2017	Chrysler	Pacifica PHEV

PLATE NUMBER	STATE ISSUED	VIN NUMBER	YEAR	MAKE	MODEL
CK60761	AZ	2C4RC1K71HR695699	2017	Chrysler	Pacifica PHEV
PLATE NUMBER	STATE ISSUED	VIN NUMBER	YEAR	MAKE	MODEL
CK60762	AZ	2C4RC1K79HR695708	2017	Chrysler	Pacifica PHEV
PLATE NUMBER	STATE ISSUED	VIN NUMBER	YEAR	MAKE	MODEL
PLATE NUMBER	STATE ISSUED	VIN NUMBER	YEAR	MAKE	MODEL
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PLATE NUMBER	STATE ISSUED	VIN NUMBER	YEAR	MAKE	MODEL

DMV USE ONLY
AVT NUMBER
NAME

SECTION 3 – APPLICANT ACKNOWLEDGEMENT

INITIALS

1. The autonomous vehicle has been tested under controlled conditions that simulate as closely as practicable, each operational design domain in which the manufacturer intends the vehicle to operate and the manufacturer has reasonably determined that is safe to operate the vehicle in each operational design domain. CCR 227.18(b)
2. Written notification that includes all of the requirements identified in CCR 227.38(a) has been provided to local authorities, as defined in Vehicle Code section 385, within the jurisdiction where the vehicle will be tested.
3. The autonomous test vehicle has a communication link with the remote operator to provide information on the vehicle's location and status, and allow continuous two-way communication between the remote operator and any passengers if the vehicle experiences any failures that would endanger the safety of the vehicle's passengers or other road users or otherwise prevent the vehicle from functioning as intended, while operating without a driver. CCR 227.38(b)(1)(A)
4. There is a process to display or communicate vehicle owner or operator information as specified in Vehicle Code Section 16025 in the event that the vehicle is involved in a collision, or if there is a need to provide that information to a law enforcement officer for any reason. CCR 227.38(b)(2)
5. The autonomous vehicle complies with all relevant Federal Motor Vehicle Safety Standards, Title 49 Code of Federal Regulations, Part 571, and the California Vehicle Code, Division 12 (Equipment of Vehicles), or the manufacturer is exempt from such requirements pursuant to 49 U.S.C. §30112(b)(10), or an exemption has been approved by the National Highway Traffic Safety Administration and provided as an attachment to this application. CCR 227.38(b)(3)
6. The autonomous vehicle is capable of operating without the presence of a driver inside the vehicle and the autonomous technology meets the description of a level 4 or level 5 automated driving system under SAE International's *Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*, standard J3016. CVC 227.38(c)
7. A copy of a law enforcement interaction plan will be submitted to the California Highway Patrol within 10 days of application approval, and the internet web site address where the law enforcement interaction plan may be accessed will be provided to all other law enforcement agencies, first responders, fire department and emergency medical personnel within the vicinity of the operational design domain of the autonomous vehicle. CCR 227.38(e)
8. Remote operators have completed training sufficient to enable him or her to safely execute the duties of a remote operator and possesses the proper class of license for the type of test vehicle being operated. CCR 227.38(f)
9. Passengers that are not employees, contractors, or designees of the manufacturer will be notified of what personal information, if any, may be collected and how it will be used. CCR 227.38(h)
10. Upon receipt of a Manufacturer's Testing Permit to conduct the testing on public roads of a vehicle that does not require a driver, data related to the disengagement of the autonomous mode will be retained for the purposes of submitting an annual report to the department. CCR 227.50(a)
11. Any collision originating from the operation of the vehicle on public roads that resulted in the damage of property or in bodily injury or death shall be reported to the department, within 10 days. CCR 227.48
12. Autonomous test vehicles will not be permitted to operate on public roads when members of the public that are not employees, contractors, or designees of the manufacturer are charged a fee or the manufacturer receives compensation for providing a ride to members of the public. CCR 227.26(f)

DMV USE ONLY
AVT NUMBER
NAME

SECTION 4 — ATTACHMENTS

INITIALS

1. Evidence of Insurance, Surety Bond (OL 317), or Application for Self-Insurance (OL 319) in the amount of five million dollars ($5,000,000). CCR 227.04(c)
2. Copy of written notification to local authorities, as defined in Vehicle Code section 385, for each jurisdiction where the vehicle will be tested that includes all of the items identified in CCR 227.38(a).
3. Description of how the manufacturer will monitor the communication link. CCR 227.38(b)(1)(B)
4. Explanation of how all of the vehicles tested will be monitored. CCR 227.38(b)(1)(C)
5. Describe/inform the department of the intended operational design domain of the autonomous vehicle. CCR 227.38(d)
6. Copy of law enforcement interaction plan. CCR 227.38(e)
7. Copy of course outline and description of the remote operator training program and the date each remote operator completed the program and includes all of the items identified in CCR 227.38(f).
8. For manufacturers that have publicly disclosed an assessment demonstrating their approach to achieving safety, a copy of that assessment. CCR 227.38(g)
9. **If applicable**; evidence of an exemption approved by the National Highway Traffic Safety Administration for manufacturers exempt from such requirements pursuant to 49 U.S.C. 30112(b)(10). CCR 227.38(b)(3)

SECTION 5 — CERTIFICATION

I certify (or declare) under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

I further certify that I am the authorized Administrator of the program for the above named employer.

PROGRAM DIRECTOR/AUTHORIZED REPRESENTATIVE PRINTED NAME AND TITLE		DRIVER LICENSE NUMBER	
Shaun Stewart, Director		[redacted]	
SIGNATURE		DATE SIGNED	
X		04/12/2018	
STREET ADDRESS	CITY	STATE	ZIP CODE
1600 Amphitheatre Parkway	Mountain View	CA	94043
EMAIL ADDRESS	FAX NUMBER	TELEPHONE NUMBER	
autollc@waymo.com	( )	(650) 253-0000	

II. Waymo Contact Information

<table>
<tr><td colspan="4">Name of Manufacturer

WAYMO LLC</td></tr>
<tr><td colspan="3">Business Name

WAYMO LLC</td><td>Secretary of State Entity Number
6073396</td></tr>
<tr><td colspan="3">Business Name Licensed by DMV

WAYMO LLC</td><td>Telephone Number

650-253-0000</td></tr>
<tr><td>Street Address

1600 AMPHITHEATRE PKWY</td><td>City

MOUNTAIN VIEW</td><td>State

CA</td><td>Zip Code

94043</td></tr>
<tr><td>Mailing Address (If Different From Street Address)

100 MAYFIELD AVE</td><td>City

MOUNTAIN VIEW</td><td>State

CA</td><td>Zip Code

94043</td></tr>
</table>

III. Supplemental Attachments

A. Evidence of Insurance

Application content enclosed on the following page.

CERTIFICATE OF LIABILITY INSURANCE

ACORD

DATE (MM/DD/YYYY) 02/23/2018

THIS CERTIFICATE IS ISSUED AS A MATTER OF INFORMATION ONLY AND CONFERS NO RIGHTS UPON THE CERTIFICATE HOLDER. THIS CERTIFICATE DOES NOT AFFIRMATIVELY OR NEGATIVELY AMEND, EXTEND OR ALTER THE COVERAGE AFFORDED BY THE POLICIES BELOW. THIS CERTIFICATE OF INSURANCE DOES NOT CONSTITUTE A CONTRACT BETWEEN THE ISSUING INSURER(S), AUTHORIZED REPRESENTATIVE OR PRODUCER, AND THE CERTIFICATE HOLDER.

IMPORTANT: If the certificate holder is an ADDITIONAL INSURED, the policy(ies) must have ADDITIONAL INSURED provisions or be endorsed. If SUBROGATION IS WAIVED, subject to the terms and conditions of the policy, certain policies may require an endorsement. A statement on this certificate does not confer rights to the certificate holder in lieu of such endorsement(s).

PRODUCER MARSH RISK & INSURANCE SERVICES 345 CALIFORNIA STREET, SUITE 1300 CALIFORNIA LICENSE NO. 0437153 SAN FRANCISCO, CA 94104 Attn: Michael Pessy (Michael.Pessy@marsh.com) 102394-STND-GAWU-17-18	CONTACT NAME: PHONE (A/C, No, Ext): FAX (A/C, No): E-MAIL ADDRESS:	
	INSURER(S) AFFORDING COVERAGE	NAIC #
	INSURER A : Old Republic Insurance Co	24147
INSURED Alphabet Inc. and all subsidiaries including Waymo LLC Attn: Business Risk and Insurance 1600 Amphitheatre Parkway Mountain View, CA 94043	INSURER B : National Fire & Marine Insurance Co	20079
	INSURER C : Safety National Casualty Corp.	15105
	INSURER D :	
	INSURER E :	
	INSURER F :	

COVERAGES **CERTIFICATE NUMBER:** SEA-003534447-09 **REVISION NUMBER:** 2

THIS IS TO CERTIFY THAT THE POLICIES OF INSURANCE LISTED BELOW HAVE BEEN ISSUED TO THE INSURED NAMED ABOVE FOR THE POLICY PERIOD INDICATED. NOTWITHSTANDING ANY REQUIREMENT, TERM OR CONDITION OF ANY CONTRACT OR OTHER DOCUMENT WITH RESPECT TO WHICH THIS CERTIFICATE MAY BE ISSUED OR MAY PERTAIN, THE INSURANCE AFFORDED BY THE POLICIES DESCRIBED HEREIN IS SUBJECT TO ALL THE TERMS, EXCLUSIONS AND CONDITIONS OF SUCH POLICIES. LIMITS SHOWN MAY HAVE BEEN REDUCED BY PAID CLAIMS.

INSR LTR	TYPE OF INSURANCE	ADDL INSD	SUBR WVD	POLICY NUMBER	POLICY EFF (MM/DD/YYYY)	POLICY EXP (MM/DD/YYYY)	LIMITS	
A	X COMMERCIAL GENERAL LIABILITY			MWZY310510	06/01/2017	06/01/2018	EACH OCCURRENCE	$ 10,000,000
	CLAIMS-MADE [X] OCCUR						DAMAGE TO RENTED PREMISES (Ea occurrence)	$ 10,000,000
							MED EXP (Any one person)	$ 10,000
							PERSONAL & ADV INJURY	$ SEE ATTACHED
	GEN'L AGGREGATE LIMIT APPLIES PER:						GENERAL AGGREGATE	$ 15,000,000
	X POLICY [ ] PRO-JECT [ ] LOC						PRODUCTS - COMP/OP AGG	$ 15,000,000
	OTHER:							$
A	AUTOMOBILE LIABILITY			MWTB310509	06/01/2017	06/01/2018	COMBINED SINGLE LIMIT (Ea accident)	$ 10,000,000
	X ANY AUTO						BODILY INJURY (Per person)	$
	OWNED AUTOS ONLY / SCHEDULED AUTOS						BODILY INJURY (Per accident)	$
	HIRED AUTOS ONLY / NON-OWNED AUTOS ONLY						PROPERTY DAMAGE (Per accident)	$
								$
B	X UMBRELLA LIAB [X] OCCUR			42UMO10024004	06/01/2017	06/01/2018	EACH OCCURRENCE	$ 5,000,000
	EXCESS LIAB CLAIMS-MADE						AGGREGATE	$ 5,000,000
	DED [X] RETENTION $ 10,000							$
C	WORKERS COMPENSATION AND EMPLOYERS' LIABILITY Y/N			LDS4052990 (AOS)	06/01/2017	06/01/2018	X PER STATUTE / OTH-ER	
C	ANY PROPRIETOR/PARTNER/EXECUTIVE OFFICER/MEMBER EXCLUDED? (Mandatory in NH) [N] If yes, describe under DESCRIPTION OF OPERATIONS below	N/A		PS4052991 (WI)	06/01/2017	06/01/2018	E.L. EACH ACCIDENT	$ 10,000,000
							E.L. DISEASE - EA EMPLOYEE	$ 10,000,000
							E.L. DISEASE - POLICY LIMIT	$ 10,000,000

DESCRIPTION OF OPERATIONS / LOCATIONS / VEHICLES (ACORD 101, Additional Remarks Schedule, may be attached if more space is required)
EVIDENCE OF INSURANCE

CERTIFICATE HOLDER	CANCELLATION
Alphabet Inc. and all subsidiaries Including Waymo LLC Attn: Business Risk and Insurance 1600 Amphitheatre Parkway Mountain View, CA 94043	SHOULD ANY OF THE ABOVE DESCRIBED POLICIES BE CANCELLED BEFORE THE EXPIRATION DATE THEREOF, NOTICE WILL BE DELIVERED IN ACCORDANCE WITH THE POLICY PROVISIONS.
	AUTHORIZED REPRESENTATIVE of Marsh Risk & Insurance Services Jennifer D. Loveall *Jennifer D. Loveall*

AGENCY CUSTOMER ID: 102594
LOC #: San Francisco

ACORD®

ADDITIONAL REMARKS SCHEDULE

AGENCY		NAMED INSURED
MARSH RISK & INSURANCE SERVICES		Alphabet Inc. and all subsidiaries Including Waymo LLC Attn: Business Risk and Insurance 1600 Amphitheatre Parkway Mountain View, CA 94043
POLICY NUMBER		
CARRIER	NAIC CODE	EFFECTIVE DATE:

ADDITIONAL REMARKS

THIS ADDITIONAL REMARKS FORM IS A SCHEDULE TO ACORD FORM,
FORM NUMBER: 25 FORM TITLE: Certificate of Liability Insurance

* PERSONAL INJURY/ WITH LIMITATION ENDORSEMENT, POLICY NUMBER: MW2Y310510 (06/01/2017 - 06/01/2018), OLD REPUBLIC INSURANCE CO., LIMIT: $10,000,000

* ADVERTISING INJURY LIMIT: EXCLUDED

B. Copy of Written Notification to Local Officials

Notification content enclosed on the following page.

Re: Waymo | Los Altos contact

1 message

Zaid Hassan m> | Thu, Apr 12, 2018 at 3:50 PM

Reply-To: [redacted]
To: cjordan@losaltosca.gov
Cc: Ellis Casson <[illegible].com>
Bcc: [redacted]

Hi Chris,

As outlined by Ellis, we wanted to share an important update for you from the team at Waymo.

As you know, we started as the Google Self-Driving Car Project in 2009, with our headquarters in Mountain View, and since then have been working on our self-driving technology to improve safety and mobility on our roads.

During that time, we have self-driven millions of miles on California's public roads with our professionally-trained test drivers on board, tested extensively on closed courses, and completed billions of simulated driving miles all in order to validate the capability and safety of our technology. In October 2017, we began a driverless testing pilot program with our fully self-driving vehicle on public roads in metro Phoenix, where we plan to launch a public driverless ride-hailing service later this year.

After careful consideration, Waymo will be submitting an application to the California DMV's Driverless Autonomous Vehicle Tester Program, which they will receive tomorrow, April 13. As a part of that application, we have described an interest to bring this technology to the San Francisco Bay Area, including Los Altos's roads.

Attached, you will find key portions of the information Waymo is submitting to the California DMV, including the capabilities of our technology, how and where it will operate, and the Safety Report we submitted to the U.S. Department of Transportation in October 2017.

While Los Altos is named in our application, this does not mean that fully driverless cars will be arriving in your city immediately. If the DMV approves our application, we expect to take the necessary steps of 3D roadway mapping via manually driving our vehicles, conducting appropriate testing with a test driver on board before conducting driverless testing. Before we put any of Waymo's driverless vehicles on Los Altos's roads, we will notify you directly.

Over the next few weeks, we will send you the Waymo Law Enforcement Interaction Protocol and supplemental training information for your police and first responders. We would be happy to organize specific trainings on this information if needed.

As next steps, we're actively working to schedule an open-house / community engagement event, where residents from Los Altos will be able to learn more about Waymo, our test program, see our cars in-person, and get their questions answered. We will keep you apprised of this specific event.

In the interim, if you have any questions regarding our DMV application or testing plans, please feel free to reach out to Ellis, copied here, who would be more than happy to answer your questions, and will serve as your main point of contact moving forward.

Thank you,
Zaid

Zaid Hassan

Re: Waymo | Los Altos Hills contact

1 message

Zaid Hassan <[redacted]> | Thu, Apr 12, 2018 at 3:52 PM

Reply-To: [redacted]
To: ccahill@losaltoshills.ca.gov
Cc: Ellis Casson <[redacted]>
Bcc: [redacted]

Mr. Cahill,

As outlined by Ellis, we wanted to share an important update for you from the team at Waymo.

As you know, we started as the Google Self-Driving Car Project in 2009, with our headquarters in Mountain View, and since then have been working on our self-driving technology to improve safety and mobility on our roads.

During that time, we have self-driven millions of miles on California's public roads with our professionally-trained test drivers on board, tested extensively on closed courses, and completed billions of simulated driving miles all in order to validate the capability and safety of our technology. In October 2017, we began a driverless testing pilot program with our fully self-driving vehicle on public roads in metro Phoenix, where we plan to launch a public driverless ride-hailing service later this year.

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Attached, you will find key portions of the information Waymo is submitting to the California DMV, including the capabilities of our technology, how and where it will operate, and the Safety Report we submitted to the U.S. Department of Transportation in October 2017.

While Los Altos Hills is named in our application, this does not mean that fully driverless cars will be arriving in your city immediately. If the DMV approves our application, we expect to take the necessary steps of 3D roadway mapping via manually driving our vehicles, conducting appropriate testing with a test driver on board before conducting driverless testing. Before we put any of Waymo's driverless vehicles on Los Altos Hill's roads, we will notify you directly.

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In the interim, if you have any questions regarding our DMV application or testing plans, please feel free to reach out to Ellis, copied here, who would be more than happy to answer your questions, and will serve as your main point of contact moving forward.

Thank you,
Zaid

Zaid Hassan
[redacted]

Waymo | City of Mountain View

1 message

Ellie Casson [redacted]
Reply-To: [redacted]
To: Dan.Rich@mountainview.gov, Alex.Andrade@mountainview.gov, "Tsuda, Randy" <randy.tsuda@mountainview.gov>
Bcc: [redacted]

Thu, Apr 12, 2018 at 4:05 PM

Dear Dan, Alex, and Randy,

Per our discussion yesterday, we wanted to share an important update for you from the team at Waymo.

As you know, we started as the Google Self-Driving Car Project in 2009, with our headquarters here in Mountain View, and since then have been working on our self-driving technology to improve safety and mobility on our roads.

During that time, we have self-driven millions of miles on California's public roads with our professionally-trained test drivers on board, tested extensively on closed courses, and completed billions of simulated driving miles all in order to validate the capability and safety of our technology. In October 2017, we began a driverless testing pilot program with our fully self-driving vehicle on public roads in metro Phoenix, where we plan to launch a public driverless ride-hailing service later this year.

After careful consideration, Waymo will be submitting an application to the California DMV's Driverless Autonomous Vehicle Tester Program, which they will receive tomorrow (April 13). As a part of that application, we have described an interest to bring this technology to the San Francisco Bay Area, including Mountain View's roads.

Attached, you will find key portions of the information Waymo is submitting to the California DMV, including the capabilities of our technology, how and where it will operate, and the Safety Report we submitted to the U.S. Department of Transportation in October 2017.

While Mountain View is named in our application, this does not mean that fully driverless cars will be arriving in your city immediately. If the DMV approves our application, we expect to take the necessary steps of 3D roadway mapping via manually driving our vehicles, conducting appropriate testing with a test driver on board before conducting driverless testing. Before we put any of Waymo's driverless vehicles on Mountain View roads, we will notify you directly.

Over the next few weeks, we will send you the Waymo Law Enforcement Interaction Protocol and supplemental training information for your police and first responders. We would be happy to organize specific trainings on this information if needed.

As next steps, we're actively working to schedule an open house / community engagement event, where residents from Mountain View will be able to learn even more about Waymo, our test program, see our cars in-person, and get their questions answered. We will keep you apprised of this specific event.

In the interim, if you have any questions regarding our DMV application or testing plans, please feel free to reach out to me and I would be more than happy to answer your questions.

Thank you,
Ellie

--
Ellie Casson

Head of Local Policy
Waymo
[redacted]

Waymo | City of Palo Alto

1 message

Ellie Casson [redacted]
Reply-To: [redacted]
To: James.Keene@cityofpaloalto.org, joshuah.mello@cityofpaloalto.org
Bcc: [redacted]

Thu, Apr 12, 2018 at 4:17 PM

Dear Mr. Keene and Mr. Mello,

Thank you so much for taking time to speak with me by phone this afternoon. I look forward to this being the start of a longer and more in-depth conversation.

As promised, I wanted to share an important update for you from the team at Waymo.

As you know, we started as the Google Self-Driving Car Project in 2009, with our headquarters in Mountain View, and since then have been working on our self-driving technology to improve safety and mobility on our roads.

During that time, we have self-driven millions of miles on California's public roads with our professionally-trained test drivers on board, tested extensively on closed courses, and completed billions of simulated driving miles all in order to validate the capability and safety of our technology. In October 2017, we began a driverless testing pilot program with our fully self-driving vehicle on public roads in metro Phoenix, where we plan to launch a public driverless ride-hailing service later this year.

After careful consideration, Waymo will be submitting an application to the California DMV's Driverless Autonomous Vehicle Tester Program, which they will receive tomorrow (April 13). As a part of that application, we have described an interest to bring this technology to the San Francisco Bay Area, including the City of Palo Alto's roads.

Attached, you will find key portions of the information Waymo is submitting to the California DMV, including the capabilities of our technology, how and where it will operate, and the Safety Report we submitted to the U.S. Department of Transportation in October 2017.

While the City of Palo Alto is named in our application, this does not mean that fully driverless cars will be arriving in your city immediately. If the DMV approves our application, we expect to take the necessary steps of 3D roadway mapping via manually driving our vehicles, conducting appropriate testing with a test driver on board before conducting driverless testing. Before we put any of Waymo's driverless vehicles on Palo Alto's roads, we will notify you directly.

Over the next few weeks, we will send you the Waymo Law Enforcement Interaction Protocol and supplemental training information for your police and first responders. We would be happy to organize specific trainings on this information if needed.

As next steps, we're actively working to schedule an open house / community engagement event, where residents from Palo Alto will be able to learn even more about Waymo, our test program, see our cars in-person, and get their questions answered. We will keep you apprised of this specific event.

In the interim, if you have any questions regarding our DMV application or testing plans, please feel free to reach out to me and I would be more than happy to answer your questions.

Thank you,
Ellie

--
Ellie Casson

Head of Local Policy
Waymo

Waymo | City of Sunnyvale
1 message

Ellie Casson <[redacted]> Thu, Apr 12, 2018 at 4:24 PM
Reply-To: [redacted]
To: Connie Verceles <CVerceles@sunnyvale.ca.gov>
Bcc: [redacted]

Dear Connie,

Thank you so much for making time to speak with me just now.

As promised, I wanted to share the important update for you from the team at Waymo.

As you know, we started as the Google Self-Driving Car Project in 2009, with our headquarters in Mountain View, and since then have been working on our self-driving technology to improve safety and mobility on our roads.

During that time, we have self-driven millions of miles on California's public roads with our professionally-trained test drivers on board, tested extensively on closed courses, and completed billions of simulated driving miles all in order to validate the capability and safety of our technology. In October 2017, we began a driverless testing pilot program with our fully self-driving vehicles on public roads in metro Phoenix, where we plan to launch a public driverless ride-hailing service later this year.

After careful consideration, Waymo will be submitting an application to the California DMV's Driverless Autonomous Vehicle Tester Program, which they will receive tomorrow (April 13). As a part of that application, we have described an interest to bring this technology to the San Francisco Bay Area, including Sunnyvale's roads.

Attached, you will find key portions of the information Waymo is submitting to the California DMV, including the capabilities of our technology, how and where it will operate, and the Safety Report we submitted to the U.S. Department of Transportation in October 2017.

While Sunnyvale is named in our application, this does not mean that fully driverless cars will be arriving in your city immediately. If the DMV approves our application, we expect to take the necessary steps of 3D roadway mapping via manually driving our vehicles, conducting appropriate testing with a test driver on board before conducting driverless testing. Before we put any of Waymo's driverless vehicles on Sunnyvale roads, we will notify you directly.

Over the next few weeks, we will send you the Waymo Law Enforcement Interaction Protocol and supplemental training information for your police and first responders. We would be happy to organize specific trainings on this information if needed.

As next steps, we're actively working to schedule an open-house / community engagement event, where residents from Sunnyvale will be able to learn even more about Waymo, our test program, see our cars in-person, and get their questions answered. We will keep you apprised of this specific event.

In the interim, if you have any questions regarding our DMV application or testing plans, please feel free to reach out to me and I would be more than happy to answer your questions.

Thank you,
Ellie

--
Ellie Casson

Head of Local Policy
Waymo

C. Waymo Two-Way Communication Link Monitoring

Every Waymo vehicle has a two-way cellular communication link, with redundant cellular service, for connecting with our Fleet Response and Rider Support Agents.[3] In certain emergency situations, the Fleet Response Specialists notify the Rider Support Agents to connect to the passengers. In these situations, the Rider Support Agents are trained to promptly initiate communication with the passenger. The Rider Support Agents are also notified of irregular trip situations through the Rider Support tool, and are trained to connect with the passenger upon receiving said notifications.

In addition, if at any time the passenger is looking for assistance, the passenger can press a button inside the Waymo vehicle's second row or by calling or chatting with our Rider Support team via our mobile app. Rider Support Agents are trained to rapidly connect with passengers and initiate real-time voice communications to assist passengers in the vehicle. If the Rider Support Agents cannot connect through the car, the Rider Support Agents trained to reach out to the passenger's cellular phone. Passengers' cellular phone numbers are stored in the Rider Support tool.

D. Waymo Fleet Monitoring Overview

Before deploying our fully driverless vehicles, a Waymo technician ensures that each vehicle is ready for operation and puts the vehicle into driverless mode. Waymo has two separate teams that continuously monitor our fleet while in operation.

First, our Fleet Response Specialists possess valid drivers licenses and are responsible for monitoring the status of our vehicles in real-time as they travel on public roadways. Using a virtual tool, they monitor Waymo vehicles during all self-driving testing, including testing both with and without a human driver.

Additionally, our Rider Support team, which provides customer support functionality for passengers, is available to communicate with passengers at any point in their trip.

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[3] The definition of "remote operator" in the California DMV's *Driverless Testing and Deployment Regulations (CCR 227.02(n))* allows (but does not require) operators to "perform the dynamic driving task for the vehicle" - otherwise known as "remote driving" or "teleoperation." For safety reasons, and because Waymo's vehicles already handle the entire dynamic driving task at SAE Level 4, Waymo neither has such functionality today, nor do we intend to moving forward.

E. Intended Operational Design Domain of Waymo's Vehicles During Driverless Testing and Operation

A duplicate of the information is provided in the Waymo Law Enforcement Interaction Protocol.

The operational design domain refers to the conditions under which a self-driving system can safely operate. Waymo's domain includes geographies, roadway types, speed range, weather, time of day, state and local traffic laws and regulations, and other conditions.

An operational design domain can be very limited: for instance, a single fixed route on low-speed public streets or private grounds (such as business parks) in temperate weather conditions during daylight hours. However, Waymo intends to have a broad operational design domain to cover everyday driving. We're developing self-driving technology that can navigate roadways in a variety of conditions within broad geographic areas. Our vehicles are designed with the capability to drive in inclement weather, such as light to moderate rain, and can operate in daytime and at night.

Waymo's system is also designed so each vehicle will not operate outside of its approved operational design domain. For example, passengers cannot select a destination outside of our approved geography, and our software will not create a route that travels outside of a "geo-fenced" area, which has been mapped in detail.

Level of Automation	Waymo's vehicles validated for driverless testing include a Level 4 automated driving system under SAE International's Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles, standard J3016 (SEP 2016). This system is what enables the capabilities of our fully self-driving vehicles. Our Level 4 system includes the software and hardware that, when integrated into the vehicle, perform all driving functions. Waymo's self-driving system is designed to perform the entire dynamic driving task [4] within a defined operational design domain[5] and has the capability to achieve a minimal risk condition[6]: the ability to bring a vehicle to a safe stop, without any expectation that a human driver take over. In contrast, systems at a lower-level of automation, at SAE Levels 1, 2, or 3, are required to have a human driver take over from the system when necessary.

[4] DYNAMIC DRIVING TASK. Means all of the real-time functions required to operate a vehicle in on-road traffic, excluding selection of final and intermediate destinations, and including without limitation: object and event detection, recognition, and classification; object and event response; maneuver planning; steering, turning, lane keeping, and lane changing, including providing the appropriate signal for the lane change or turn maneuver; and acceleration and deceleration.

[5] OPERATIONAL DESIGN DOMAIN. A description of the specific operating domain(s) in which an automated driving system is designed to properly operate, including but not limited to geographic area, roadway type, speed range, environmental conditions (weather, daytime/nighttime, etc.) and other domain constraints.

[6] MINIMAL RISK CONDITION. A low-risk operating mode in which a fully self-driving vehicle operating without a human driver achieves a reasonably safe state, such as bringing the vehicle to a complete stop, upon experiencing a failure of the vehicle's automated driving system that renders the vehicle unable to perform the entire dynamic driving task

Minimal Risk Condition Overview	If the Waymo vehicle can no longer proceed on a planned trip, Waymo's vehicles are designed to be capable of performing a safe stop, known as achieving a "minimal risk condition" without any need for human intervention, which is a requirement for an SAE Level 4 automated driving system. This includes situations when Waymo's fully self-driving vehicle experiences a problem that prevents the automated driving system from continuing the driving task 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, steering and braking. Our vehicle's response 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 can determine an appropriate response to keep the vehicle, its passengers,[7] and other road users safe.
Roadway Type	During driverless testing, the intended operational design domain of Waymo's vehicles will include the following roadway types: • Freeways, highways,[8] city streets, rural roads, and other roadways. • Parking lots
Speed Range	During driverless testing, the intended operational design domain of Waymo's vehicles will include roadways with posted speed limits up to 65 miles per hour.
Inclement Weather	During driverless testing, the intended operational design domain of Waymo's vehicles will include the following inclement weather situations: • Light Rain • Fog
Time of Day	During driverless testing, the intended operational design domain of Waymo's vehicles will include all times of day and night.
Geographic Area for Driverless	Waymo will provide local jurisdictions with information regarding the geographic area where our vehicles are involved in driverless testing.

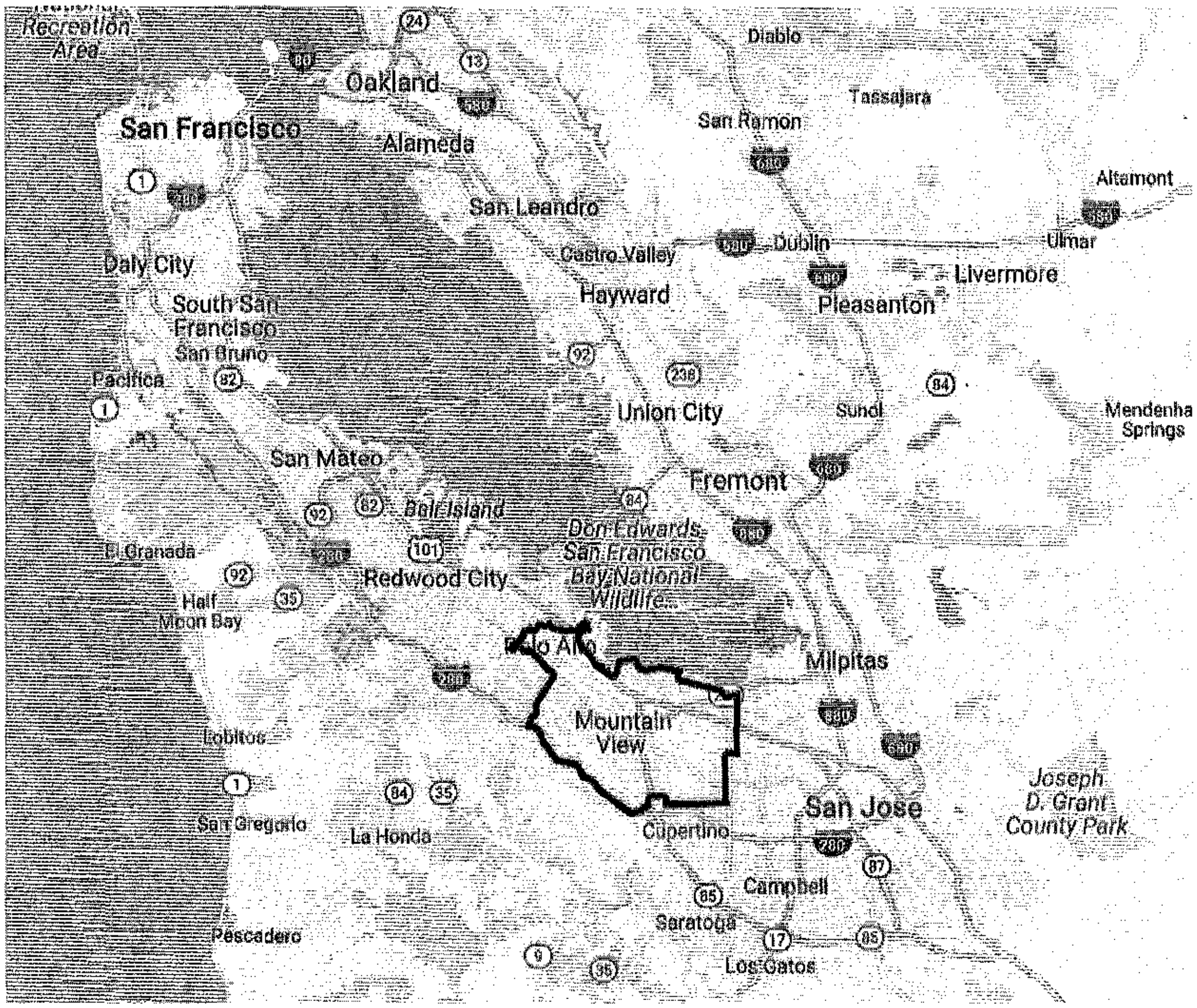
[7] PASSENGER. An occupant of a vehicle who has no role in the operation of that vehicle when the autonomous technology is engaged. A passenger may summon a vehicle or input a destination, but does not engage the technology, monitor the vehicle, or drive or operate the vehicle. A member of the public may ride as a passenger in an autonomous test vehicle if there are no fees charged to the passenger or compensation received by the manufacturer.

[8] See California Vehicle Code § 360: "Highway" is a way or place of whatever nature, publicly maintained and open to the use of the public for purposes of vehicular travel. Highway includes street.

Testing	
Types of Passengers During Driverless Testing	During driverless testing, Waymo's vehicles may transport the following categories of passengers: • Waymo employees, contractors, or agents. • Alphabet employees, contractors, or agents. • Alphabet affiliate company employees, contractors, or agents. • Members of the public as passengers during testing, without any fee charged.
Domain Constraints	Waymo's intended operational design domain will not initially allow for driverless testing under the following conditions: • Snow/icy conditions • Heavy rain • Flooded roadways • Offroad • One-way mountain roadways During driverless testing, if any of these conditions are encountered, Waymo's vehicles are designed to be capable of achieving a minimal risk condition without any human intervention. Controlling the operating domain of its driverless vehicles is a part of Waymo's dynamic testing program. For the purpose of driverless testing, Waymo may choose to change domain constraints for some or all of its vehicles at various times. For example, driverless testing may be limited to: • Certain times of day • Roadways of slower posted speed limits than 65 miles per hour • Certain validated roadway features (including freeway ramps, merge lanes, turn lanes, intersections, construction zones, roundabouts, cul de sacs, roundabouts, covered parking lots, restricted speed zones, and rail and light transit crossings) • Non-inclement weather conditions.

F. Geographic Area for Driverless Testing (California)

Waymo plans to conduct driverless testing[9] on roads within the California Bay Area communities outlined in the boundary map below with the vehicles described in Waymo's application. These geographies are part of Waymo's current operational design domain. Each of the covered communities will be notified of the date of driverless testing, prior to the start of such testing in the respective community. Additionally, any expansion of this territory during testing will be preceded by a notification to such covered communities before it is submitted as an amendment for review to the California Department of Motor Vehicles:



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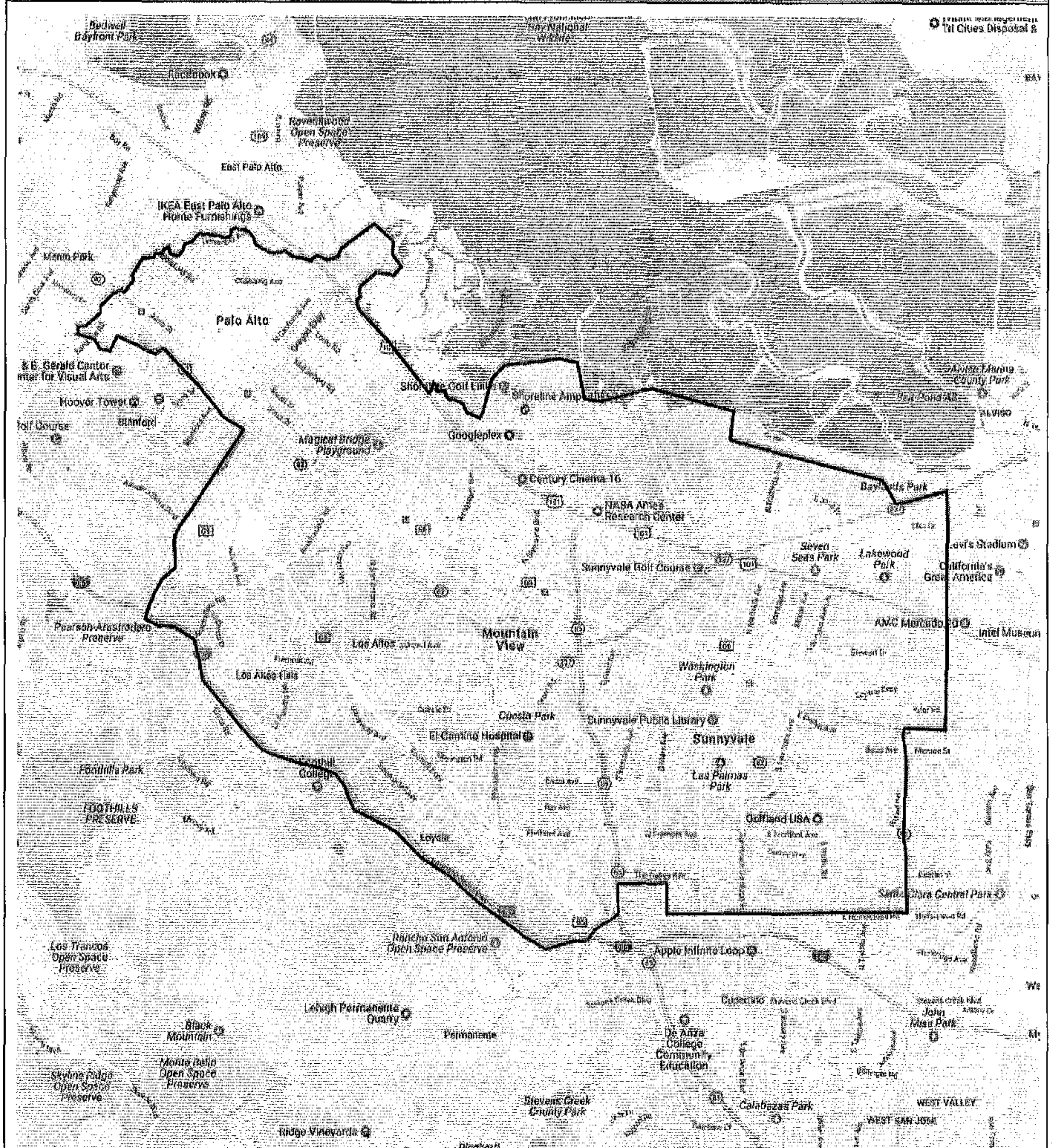
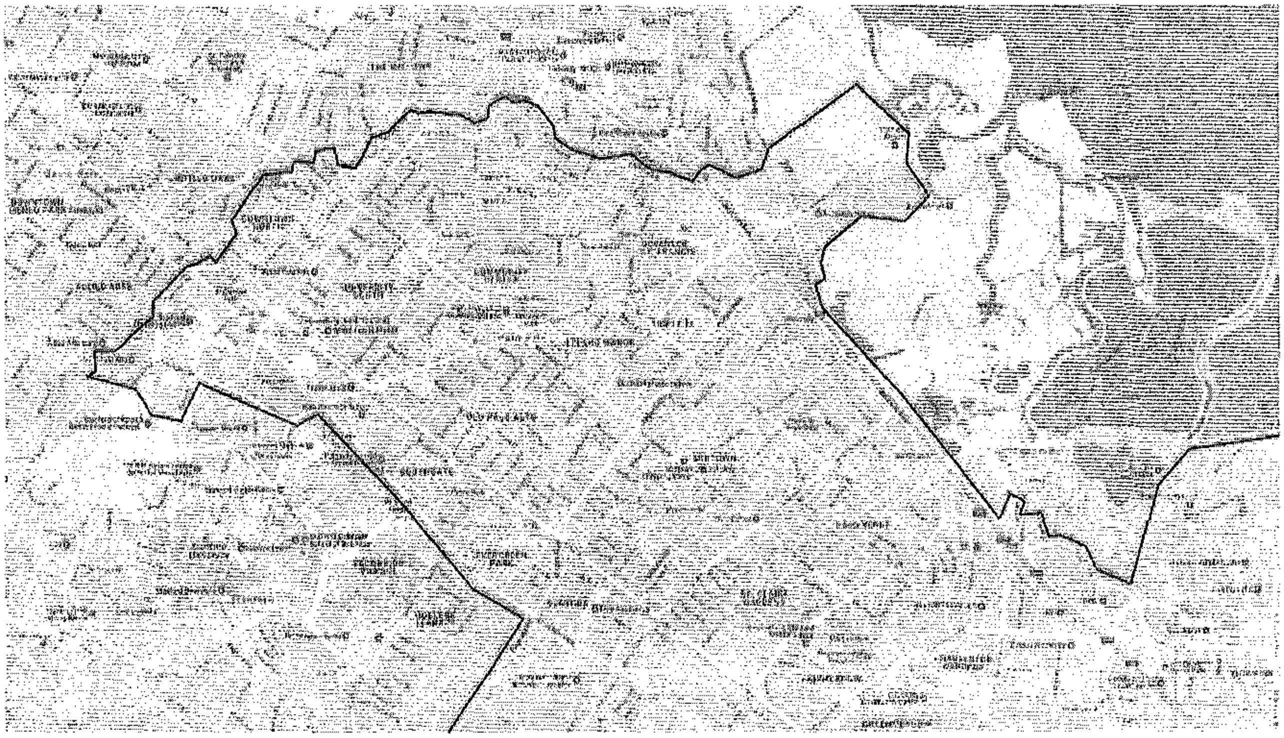
[9] TESTING. The operation of a self-driving vehicle on public roads by employees, contractors, or designees of a manufacturer for the purpose of assessing, demonstrating, and validating the automated driving system's capabilities.

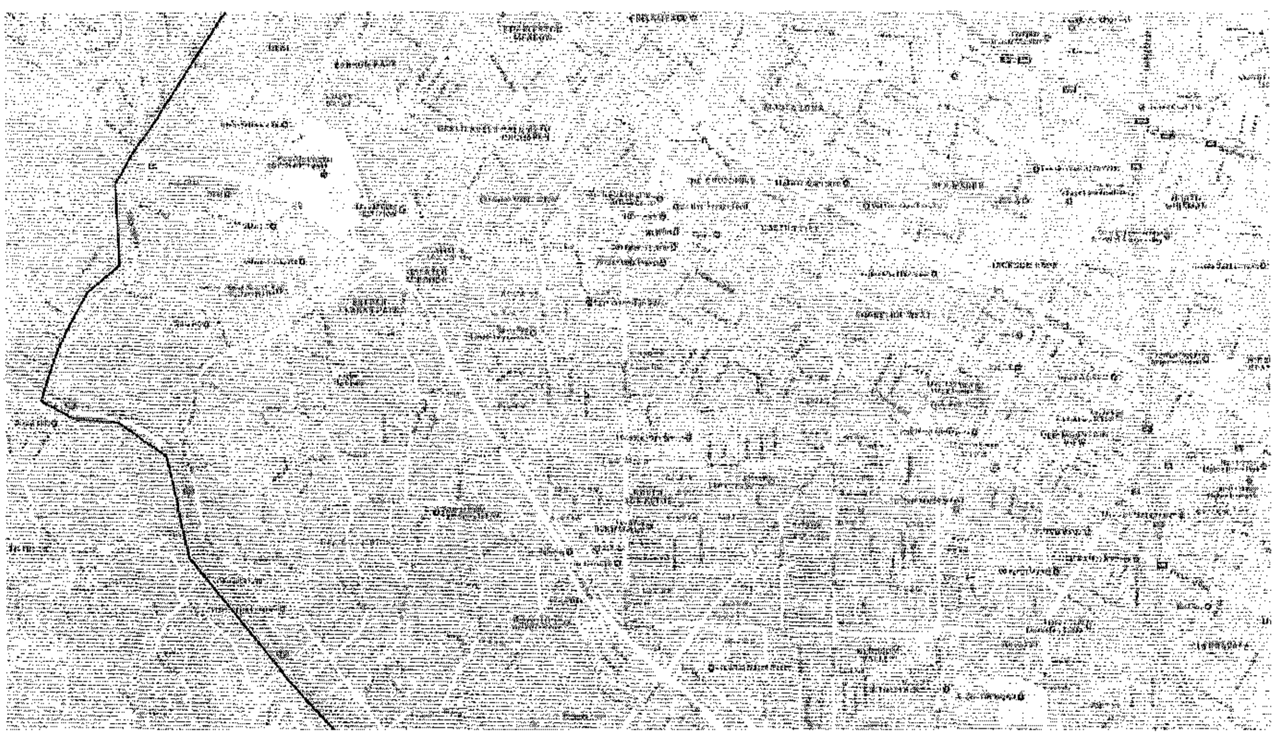
Expanded View 1



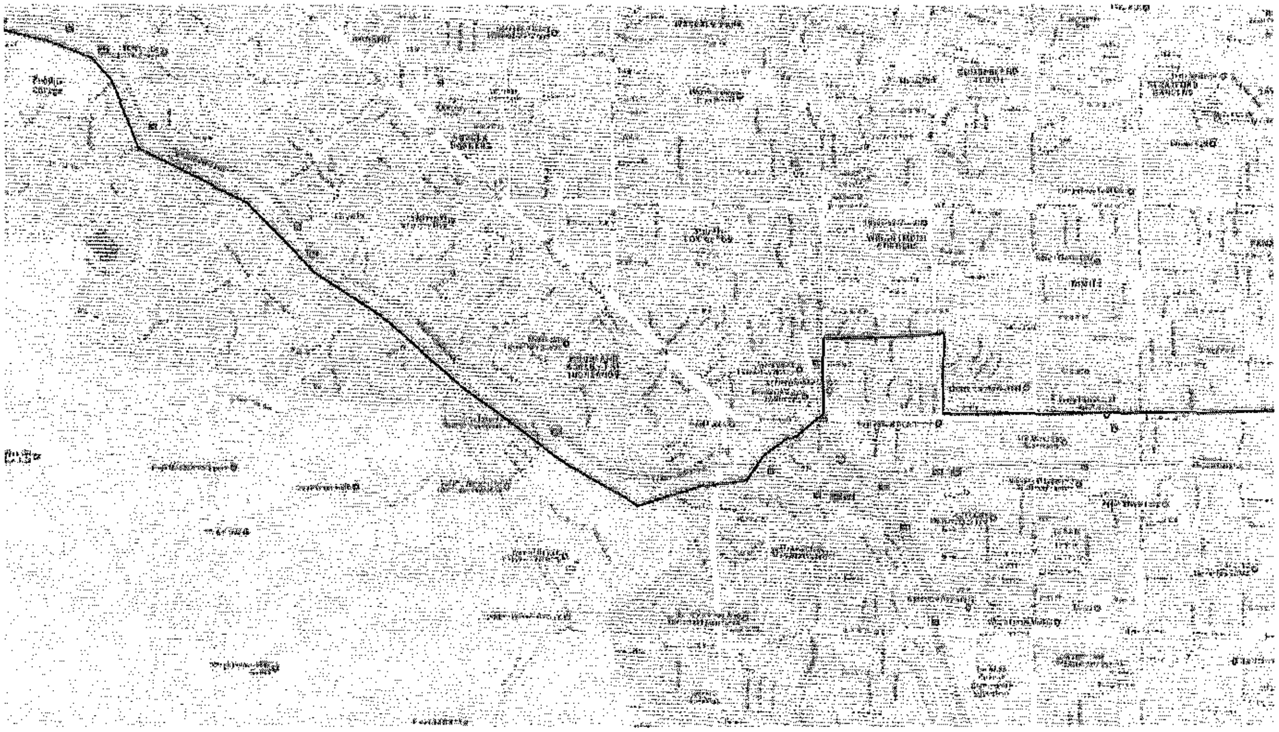
Expanded View 2



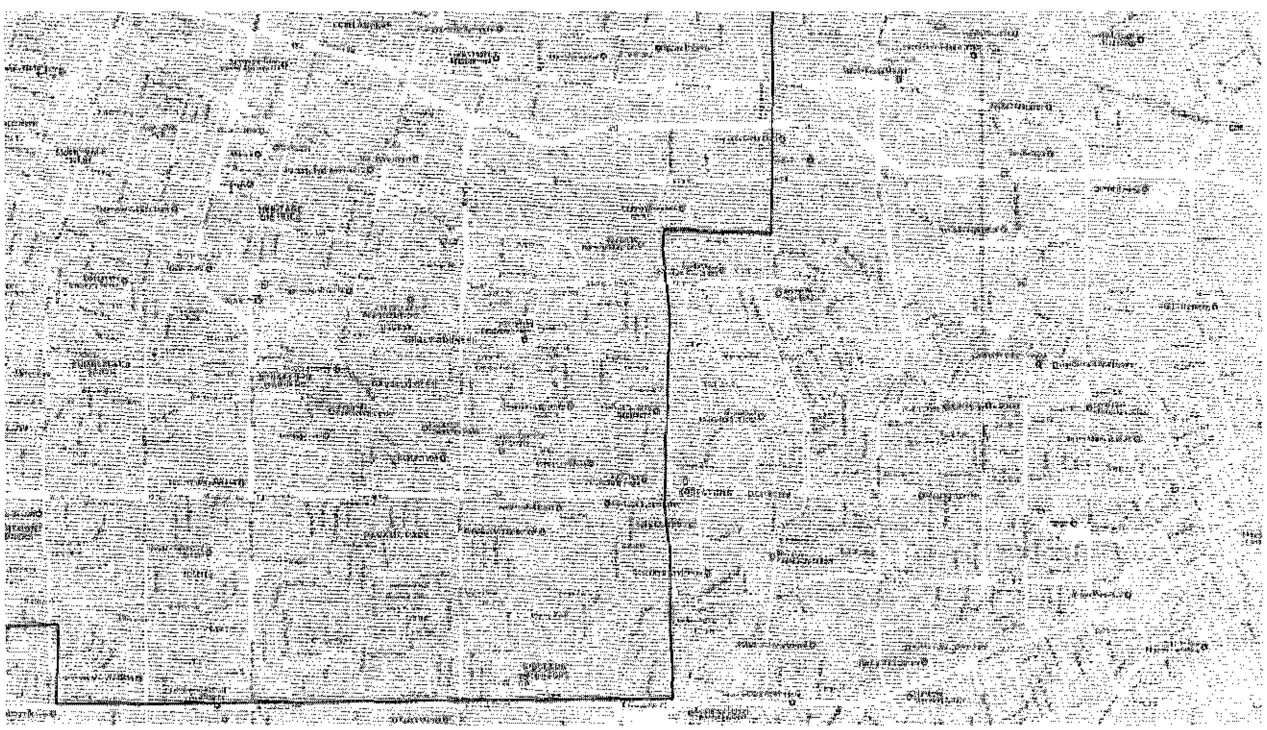
Expanded View 3



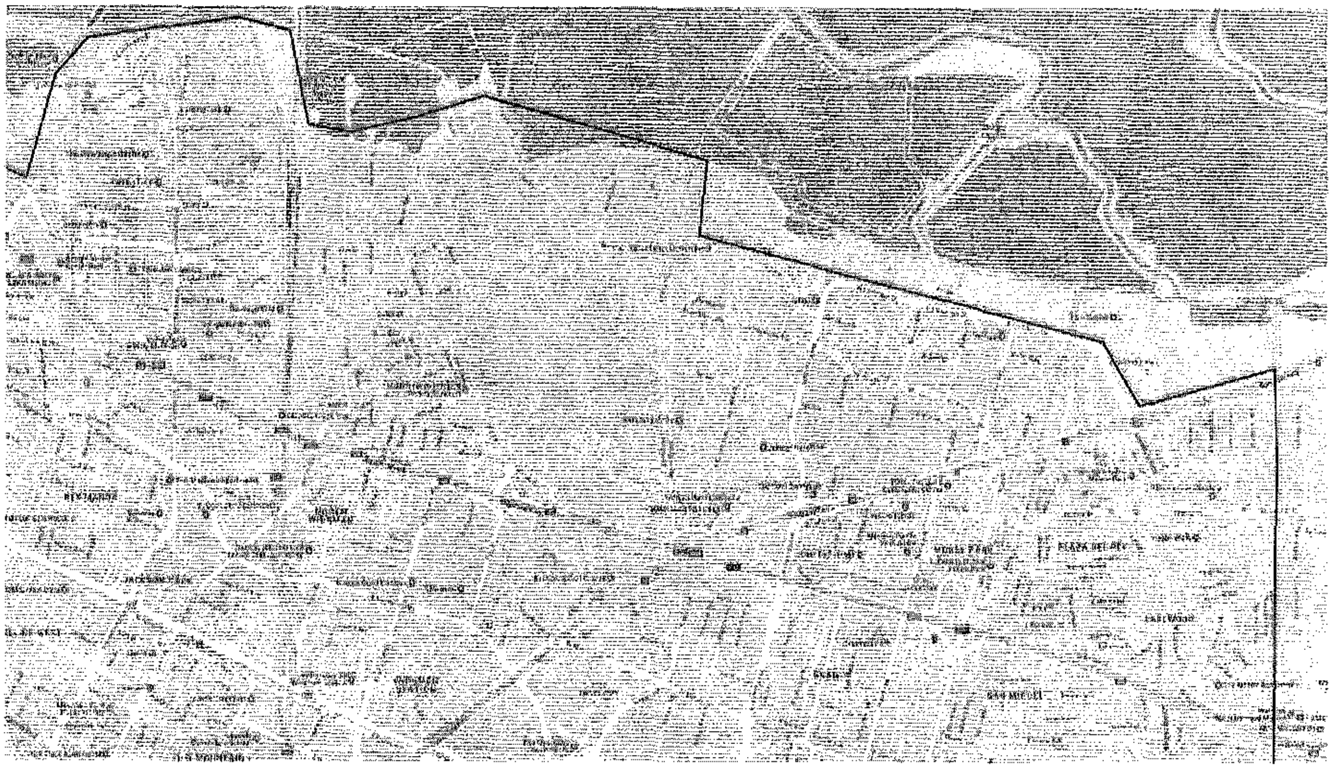
Expanded View 4



Expanded View 5



Expanded View 6



G. Law Enforcement Interaction Protocol

Protocol enclosed on the following page.

WAYMO

Waymo Law Enforcement Interaction Protocol

After nearly a decade of working on this technology, self-driving over 4 million miles on public roads, conducting tens of thousands of comprehensive tests during closed course testing, and driving billions of miles in simulation, Waymo introduced fully self-driving ("driverless") vehicles without a test driver in the driver's seat, in parts of the Phoenix metro area in October 2017. These vehicles travel within a defined geographic area where they have already been tested extensively with Waymo's test drivers. Later this year, Waymo intends to deploy these vehicles for commercial use, consistent with applicable federal and state statutes, regulations, guidance, and other applicable criteria.

In this Law Enforcement Interaction Protocol, Waymo outlines the procedures that we will follow with police, firefighters, and other first responders for driverless testing and operation in every jurisdiction. This Protocol supplements the overview of how we design, test, and validate our technology in the Waymo Safety Report. Waymo will review this protocol on a regular basis and update it as changes are needed or at least on an annual basis.

Waymo Law Enforcement Interaction Protocol

1. **Communication With Waymo Rider Support Through Dedicated Telephone Hotline Established for Police, Firefighters, and Other First Responders During Vehicle Operation**

   A. Waymo has established a toll-free telephone hotline dedicated to allowing police, fire departments, and other first responders to communicate directly with Waymo's Rider Support specialists and is available at all times when our driverless testing is taking place on public roads. This phone number is provided by Waymo directly to state and local police, fire departments, and other first responders.

      a. Waymo has created a Rider Support team to help answer questions for our early riders. These specialists can be reached, by either our passengers or police, with a button-press inside the vehicle's second row 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.

2. **Where, in the Waymo Vehicle, to Obtain Owner information, Vehicle Registration, and Proof of insurance in the Event of a Collision or Traffic Violation Involving the Vehicle**

   A. Law Enforcement and other first responders can obtain owner, registration, and insurance information for each Waymo fully self-driving vehicle by calling our dedicated toll-free hotline. Additionally, each vehicle will have physical copies of this information stored inside. One copy of the documents will be stored in a container affixed to the front passenger-side sun visor, and a second copy will be stored in a container affixed to the front driver-side sun visor.

3. **How to Safely Remove the Waymo Vehicle From the Roadway**

   A. If, for any reason, one of Waymo's vehicles needs to be removed from the roadway, then we will arrange for a towing service.

   B. Alternatively, police can follow standard towing procedures with the vehicles, after disabling the Self-Driving Mode and turning the vehicles off, in accordance with the Waymo Emergency Response Supplement, which is separately being provided directly to state agencies and local police, firefighters, and other first responders. After disabling Self-Driving Mode, the vehicle may be towed. If in manual mode, the vehicle can be towed like any conventional rear drive vehicle. Otherwise, the vehicle should be placed on a flatbed truck for removal.

Waymo Law Enforcement Interaction Protocol

4. How to Recognize Whether the Vehicles are Self-Driving While on Public Roads

A. During driverless testing and operation, Waymo's vehicles would not have any person in the driver's seat either steering or otherwise controlling the vehicle.

5. How First Responders, Firefighters, and Law Enforcement Can Deactivate the Self-Driving System and Ensure that it has Been Deactivated

A. Detecting and Responding to Police and Emergency Vehicles

a. Each of Waymo's fully self-driving vehicles uses its sensors to identify police or emergency vehicles by detecting how they look, their sirens, and their emergency lights. Once police and emergency vehicles are detected, the Waymo self-driving car is designed to yield as appropriate to these emergency vehicles no matter which direction they are headed.

b. If a Waymo fully self-driving vehicle detects that a police or emergency vehicle is behind it and flashing its lights, the Waymo vehicle is designed to pull over to the side of the road and stop when it finds a safe place to do so.

B. Detecting and Responding to a Law Enforcement Traffic Stop

a. After the Waymo fully self-driving vehicle pulls over to the side of the roadway, it will have the ability to unlock the doors and roll down the windows for our Rider Support team to communicate with law enforcement if needed.

b. Waymo's Rider Support specialists can also be reached by pressing the Help button in the interior console accessible from the second row passenger seating area.

c. Waymo's Rider Support specialists will have protocols for interacting with any vehicle passengers in the event of the vehicle being pulled over, or involved in a collision, by providing information through in-vehicle speakers, on the in-vehicle displays, and communicating with passengers through in-vehicle telecommunications capabilities. A Waymo support team will be dispatched to provide on-scene support, when needed, for passengers and first responders.

C. Detecting the Waymo Fully Self-Driving Vehicle was Involved in a Collision

a. The Waymo vehicle is capable of detecting that it was involved in a collision and will brake until it reaches a full stop. The vehicle will immediately notify Waymo's Fleet Response specialists.

i. Waymo's Fleet Response will then call 911 if the circumstances warrant (e.g, where there is a significant collision in which police may be needed because of injuries, vehicles blocking traffic, etc).

ii. A Waymo support team will be dispatched to provide on-scene support for passengers and first responders.

iii. The Waymo fully self-driving vehicle will react differently depending on the collision severity. In the event an airbag is deployed, the vehicle, by design, will become immobile.

b. Local police and other first responders will be able to take the appropriate steps to detect if the vehicle is immobilized or otherwise take appropriate steps to further immobilize and safely avoid physical hazards associated with the high voltage electric (lithium ion battery) powertrain by following our Waymo Emergency Response Supplement, which will be made available to law enforcement in jurisdictions where we are testing, for each type of Waymo Vehicle tested:

i. **Waymo Chrysler Pacifica PHEV:** All information provided in the Base 2017 Chrysler Pacifica Hybrid PHEV Emergency Response Guide ***("Base Guide")*** [https://www.nfpa.org/Training-and-Events/By-topic/Alternative-Fuel-Vehicle-Safety-Training/Emergency-Response-Guides/Chrysler] is applicable to the Waymo fully self-driving Chrysler Pacifica Hybrid minivans and supplemented by information in the Waymo Emergency Response Supplement, which is separately being provided directly to state agencies and local police, firefighters, and other first responders.

6. How First Responders, Firefighters, and Law Enforcement Can Safely Interact With Waymo's Electric and Hybrid Vehicles After Being Deactivated

A. **Waymo Chrysler Pacifica PHEV:** All information provided in the Base 2017 Chrysler Pacifica Hybrid PHEV Emergency Response Guide ***("Base Guide")*** [https://www.nfpa.org/Training-and-Events/By-topic/Alternative-Fuel-Vehicle-Safety-Training/Emergency-Response-Guides/Chrysler] is applicable to the Waymo fully self-driving Chrysler Pacifica Hybrid minivans and supplemented by information in the Waymo Emergency Response Supplement, which is separately being provided directly to state agencies and local police, firefighters, and other first responders.

7. Description of the Operational Design Domain of Waymo's Vehicles

The operational design domain refers to the conditions under which a self-driving system can safely operate. Waymo's domain includes geographies, roadway types, speed range, weather, time of day, state and local traffic laws and regulations, and other conditions.

An operational design domain can be very limited: for instance, a single fixed route on low-speed public streets or private grounds (such as business parks) in temperate weather conditions during daylight hours. However, Waymo intends to have a broad operational design domain to cover everyday driving. We're developing self-driving technology that can navigate roadways in a variety of conditions within broad geographic areas. Our vehicles are designed with the capability to drive in inclement weather, such as light to moderate rain, and can operate in daytime and at night.

Waymo's system is also designed so each vehicle will not operate outside of its approved operational design domain. For example, passengers cannot select a destination outside of our approved geography, and our software will not create a route that travels outside of a "geo-fenced" area, which has been mapped in detail.

Level of Automation	Waymo's vehicles validated for driverless testing include a Level 4 automated driving system under **SAE International's Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles, standard J3016 (SEP 2016)**. This system is what enables the capabilities of our fully self-driving vehicles. Our Level 4 system includes the software and hardware that, when integrated into the vehicle, perform all driving functions. Waymo's self-driving system is designed to perform the entire dynamic driving task[1] within a defined operational design domain[2] and has the capability to achieve a minimal risk condition[3]: the ability to bring a vehicle to a safe stop, without any expectation that a human driver take over. In contrast, systems at a lower-level of automation, at SAE Levels 1, 2, or 3, are required to have a human driver take over from the system when necessary.
Minimal Risk Condition Overview	If the Waymo vehicle can no longer proceed on a planned trip, Waymo's vehicles are designed to be capable of performing a safe stop, known as achieving a "minimal risk condition" without any need for human intervention, which is a requirement for an SAE Level 4 automated driving system. This includes situations when Waymo's fully self-driving vehicle experiences a problem that prevents the automated driving system from continuing the driving task 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, steering and braking. Our vehicle's response 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 can determine an appropriate response to keep the vehicle, its passengers[4], and other road users safe.

Waymo Law Enforcement Interaction Protocol

Roadway Type	During driverless testing, the intended operational design domain of Waymo's vehicles will include the following roadway types: • Freeways, highways[6], city streets, rural roads, and other roadways. • Parking lots
Speed Range	During driverless testing, the intended operational design domain of Waymo's vehicles will include roadways with posted speed limits up to 65 miles per hour.
Inclement Weather	During driverless testing, the intended operational design domain of Waymo's vehicles will include the following inclement weather situations: • Light Rain • Fog
Time of Day	During driverless testing, the intended operational design domain of Waymo's vehicles will include all times of day and night.
Geographic Area For Driverless Testing	Waymo will provide local jurisdictions with information regarding the geographic area where our vehicles are involved in driverless testing.
Types of Passengers During Driverless Testing	During driverless testing, Waymo's vehicles may transport the following categories of passengers: • Waymo employees, contractors, or agents. • Alphabet employees, contractors, or agents. • Alphabet affiliate company employees, contractors, or agents. • Members of the public as passengers during testing, without any fee charged.

Domain Constraints

Waymo's intended operational design domain will not initially allow for driverless testing under the following conditions:

- Snow/icy conditions
- Heavy rain
- Flooded roadways
- Offroad
- One-way mountain roadways

During driverless testing, if any of these conditions are encountered, Waymo's vehicles are designed to be capable of achieving a minimal risk condition without any human intervention.

Controlling the operating domain of its driverless vehicles is a part of Waymo's dynamic testing program. For the purpose of driverless testing, Waymo may choose to change domain constraints for some or all of its vehicles at various times. For example, driverless testing may be limited to:

- Certain times of day
- Roadways of slower posted speed limits than 65 miles per hour
- Certain validated roadway features (including freeway ramps, merge lanes, turn lanes, intersections, construction zones, roundabouts, cul de sacs, roundabouts, covered parking lots, restricted speed zones, and rail and light transit crossings)
- Non-inclement weather conditions

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[1] DYNAMIC DRIVING TASK. Means all of the real-time functions required to operate a vehicle in on-road traffic, excluding selection of final and intermediate destinations, and including without limitation: object and event detection, recognition, and classification; object and event response; maneuver planning; steering, turning, lane keeping, and lane changing, including providing the appropriate signal for the lane change or turn maneuver; and acceleration and deceleration.

[2] OPERATIONAL DESIGN DOMAIN. A description of the specific operating domain(s) in which an automated driving system is designed to properly operate, including but not limited to geographic area, roadway type, speed range, environmental conditions (weather, daytime/nighttime, etc.) and other domain constraints.

[3] MINIMAL RISK CONDITION. A low-risk operating mode in which a fully self-driving vehicle operating without a human driver achieves a reasonably safe state, such as bringing the vehicle to a complete stop, upon experiencing a failure of the vehicle's automated driving system that renders the vehicle unable to perform the entire dynamic driving task.

[4] PASSENGER. An occupant of a vehicle who has no role in the operation of that vehicle when the autonomous technology is engaged. A passenger may summon a vehicle or input a destination, but does not engage the technology, monitor the vehicle, or drive or operate the vehicle. A member of the public may ride as a passenger in an autonomous test vehicle if there are no fees charged to the passenger or compensation received by the manufacturer.

[5] See California Vehicle Code § 360: "Highway" is a way or place of whatever nature, publicly maintained and open to the use of the public for purposes of vehicular travel. Highway includes street.

H. Fleet Response Specialist and Rider Support Agents Training Program

1. Fleet Response Specialist Training Outline:

Waymo's Fleet Response Specialist training program is designed to match the level of training to the complexity of the scenarios the vehicle might encounter during driverless testing. Each of the following training modules is conducted by an experienced Fleet Response Specialist and trainees must pass a post-training evaluation with an instructor.

Fleet Response Specialist training is a combination of classroom time, use of a Fleet Response tool, guided observation, hands-on practice, supervised time on the live tool, and a final assessment. Fleet Response Specialist trainees are trained by experienced instructors and Fleet Response Specialists. Trainees will not be permitted to perform the Fleet Response Specialist role independently until they have successfully completed the Fleet Response Specialist training program including passing the evaluation.

During our three-week program, Fleet Response trainees are constantly being evaluated by instructors to determine when they're prepared for the next stage of instruction. In the third week of the program, once our training team determines that the trainee has reached a sufficient level of proficiency, the trainee will take a final assessment that evaluates the candidates for all necessary skill sets. The timing of the assessment during the second week thus varies per individual depending on the individual's subject proficiency. If unforeseen circumstances warrant a trainee's course of study to be paused (e.g., an illness) for a few days, the trainee can return to the program and complete the remainder of the third week training before taking the final assessment. Further details of the three-week Fleet Response training program are below.

Week 1: Classroom Training, Guided Observation, Fleet Response Specialist, Daily Assessment

a. **Classroom Training.** Trainees attend classroom trainings. Throughout these classroom sessions, trainees learn the intricacies of Waymo's self-driving system and how to use the Fleet Response Specialist tool to communicate with the self-driving cars. Video analysis of real-world scenarios combined with detailed explanation of both the self-driving system and the Fleet Response Specialist tool aids in the development of Fleet Response Specialist knowledge. Fleet Response Specialists also learn how to properly respond to scenarios the vehicles are expected to encounter.
b. **Guided Observation.** Trainees observe an experienced Fleet Response Specialist perform the Fleet Response Specialist role. During this time they observe the pace and flow of tasks and have the opportunity to ask questions and observe a Fleet Response Specialist respond to real-time tasks.

c. **Daily Assessments.** Every day, Fleet Response Specialists have time to study and review the new information they've learned throughout the day and week independently and with instructors in week 1. Instructors work with trainees to assess their progress on learning and retaining the new material they are learning to ensure steady growth.

B. Week 2: Classroom Presentations, Emergency Procedures, Supervised Fleet Response Specialist Practice, Daily Assessment

a. **Classroom Training.** Trainees complete a series of classroom presentations. Throughout these classroom presentations trainees learn the details needed to understand the operation of the self-driving system and how to use the Fleet Response Specialist tool to assist the self-driving cars. Video analysis of real-world scenarios combined with detailed explanation of the self-driving system and Fleet Response Specialist tool aids in the development of Fleet Response Specialist knowledge throughout these presentations. Fleet Response Specialists also learn how to properly respond to each scenario the vehicle encounters.

b. **Emergency Procedure.** Trainees study and practice the procedures for responding to possible collision alerts. Trainees learn the proper steps to evaluate possible collisions and quickly escalate true positive collisions.

c. **Supervised Fleet Response Specialist Practice.** Fleet Response Specialists in training week 2 working directly with an instructor or experienced Fleet Response Specialist practicing responding to real world scenarios on the Fleet Response Specialist tool. The instructor or experienced Fleet Response Specialist is there to support their practice, answer questions, provide feedback and guidance in order to hone the skills of the Fleet Response Specialist in training.

d. **Daily Assessment.** During week 2 Fleet Response Specialist trainees take a written assessment to evaluate their training progress and provide feedback in areas they need to continue to work on. After the assessment, instructors review the results and provide role related feedback to the trainees.

C. Week 3: Supervised Fleet Response Specialist Practice, Escalation Simulation, Final Assessment

a. **Supervised Fleet Response Specialist Practice.** Fleet Response Specialists in training work directly with an instructor or experienced Fleet Response Specialist practicing responding to real world scenarios on the Fleet Response Specialist tool. The instructor or experienced Fleet Response Specialist is there to support their practice, answer questions, provide feedback and guidance in order to hone the skills of the Fleet Response Specialist in training. By then end of week 3, Fleet Response Specialists should be able to demonstrate their ability to perform their role with only limited engagement from their instructor or experienced Fleet Response Specialist.

b. **Escalation Simulation.** Fleet Response Specialist trainees practice their escalation procedures in preparation for their final assessment, to ensure they're fully prepared to escalate complex scenarios per Fleet Response Specialist escalation procedures.
c. **Final Assessment.** Fleet Response Specialists in training must complete a final assessment where their overall Fleet Response Specialist competency is evaluated. A passing score on the final assessment means the Fleet Response Specialist is certified to perform the role independently. A trainee is not certified to complete the role without supervision until he/she receives a passing score on the final assessment.

D. Ongoing Training and Notable Training Tools/Methods

The following exercises and methods are intended to help our Fleet Response Specialists maintain the highest standard while assisting our cars in the real world. This continuous training program also helps our Fleet Response Specialists stay up to date on changes to Waymo's self-driving system and the Fleet Response Specialist tools and functionality.

A. **Operator feedback during training.** Instructors leave feedback on Fleet Response trainees after each training session to share progress of trainees. This helps instructors focus and improve on a trainee's strengths and weaknesses.
B. **Team scenario review.** Reviewing "play-back" videos of difficult Fleet Response Specialist scenarios experienced in the real world throughout the day/week. This gives the Fleet Response Specialist the time to analyze difficult situations without having to experience them first-hand. This exercise helps flag difficult areas and teach Fleet Response Specialists how to respond should they encounter these same situations.
C. **Shift Manager check-ins**. Periodically, shift managers will observe our Fleet Response Specialists to ensure continued high quality performance. During these check-ins, Shift Managers identify and discuss areas where Fleet Response Specialists may need to improve their performance by reviewing scenarios each Fleet Response Specialist has encountered in their daily operation.
D. **Debrief Meetings.** Fleet Response Specialists have a daily meeting with their Shift Managers to discuss updates, trends, scenarios or other issues that have been identified as important to discuss at the debriefs.

2. Rider Support Agent Training Outline

Waymo's Rider Support team is made up of agents that are trained over a two-week period to communicate with the passengers of self-driving cars. The Rider Support team is responsible for overseeing the two-way communications link and connecting with occupants for general support, high stress situations, and interacting with law enforcement via a toll-free number. The training is comprised of classrooms, shadowing current agents, supervised call-handling, and a final assessment.

During our two-week program, Rider Support trainees are constantly being evaluated by instructors to determine when they're prepared for the next stage of instruction. In the second week of the program, once our training team determines that the trainee has reached a sufficient level of proficiency, the trainee will take a final assessment that evaluates the candidates for all necessary skill sets. The timing of the assessment during the second week thus varies per individual depending on the individual's subject proficiency. If unforeseen circumstances warrant a trainee's course of study to be paused (e.g., an illness) for a few days, the trainee can return to the program and complete the remainder of the second week training before taking the final assessment. Further details of the two-week Rider Support training program are below.

Week 1:

- **Classroom Training**: During various classroom presentations, new agents are introduced to the Rider Support tools and the cues from the self-driving systems that signal that the passenger will be needing assistance.
- **Introduction to the Rider Support Guidebook**: It is the central resource for the agents' workflows, processes, and knowledge base of information.
- **Shadowing**: New Rider Support members shadow managers and advanced support agents while handling calls, chats, and emails from passengers of the self-driving system.

Week 2:

- **Supervised call handling**: Rider Support agents begin to take calls, chats, and emails under supervision of trainers.
- **Assessment that measures adherence to the Rider Support Guidebook**: Specialists must pass an assessment that covers process adherence, classroom materials, and scripts.

Ongoing training:

- **Emergency procedure adherence**: Rider Support agents participate in weekly drills to ensure that the specialists are prepared for emergency situations.
- **Quality assessments**: Managers will listen to a random selection of calls from the previous week and score calls from each specialist. Managers coach the agents on scripts and process adherence.
- **Weekly team meetings**: Managers hold weekly team meetings to discuss process and script updates.

3. Waymo Fleet Response Specialist and Rider Support Agent Training Certifications

Fleet Support Specialist (Initials)	Training Start Date	Certification Date
AS	1/29/2017	2/14/2017
CM	5/15/2017	6/1/2017
EM	5/15/2017	6/5/2017
JM	5/15/2017	6/8/2017
CM	6/5/2017	6/26/2017
BH	6/5/2017	6/29/2017
IL	6/12/2017	6/30/2017
LV	6/12/2017	6/30/2017
AP	6/26/2017	7/19/2017
TR	6/26/2017	7/20/2017
MR	7/10/2017	8/8/2017
TW	8/14/2017	8/30/2017
BE	8/14/2017	8/31/2017
MW	8/14/2017	8/31/2017
KD	8/14/2017	8/31/2017
CS	8/14/2017	9/1/2017
WD	8/14/2017	9/1/2017
SM	9/18/2017	10/5/2017
IP	9/18/2017	10/5/2017
WB	9/18/2017	10/5/2017
JS	9/18/2017	10/6/2017
GG	10/30/2017	11/17/2017
TB	10/30/2017	11/20/2017
MM	11/6/2017	11/22/2017
MT	11/6/2017	12/13/2017
AA	11/20/2017	12/12/2017
EH	11/20/2017	12/12/2017
CW	11/20/2017	12/12/2017
AM	11/20/2017	12/13/2017
BA	11/20/2017	12/14/2017
GM	11/20/2017	12/14/2017

DH	11/27/2017	12/13/2017
JR	1/8/2018	1/25/2018
SS	1/8/2018	1/25/2018
AC	1/8/2018	1/26/2018
GS	1/8/2018	1/26/2018
LM	1/8/2018	1/26/2018
BC	1/8/2018	2/15/2018
CR	1/8/2018	2/15/2018
AS	1/29/2018	2/14/2017
JA	1/29/2018	2/15/2018
SR	1/29/2018	2/15/2018
MC	1/29/2018	2/20/2018
RB	1/29/2018	2/21/2018
CB	1/29/2018	2/23/2018
HV	1/29/2018	2/25/2018
CZ	2/26/2018	3/16/2018
EC	2/26/2018	3/16/2018
ES	2/26/2018	3/16/2018
NK	2/26/2018	3/16/2018
RG	2/26/2018	3/16/2018
RM	2/26/2018	3/16/2018
CS	2/26/2018	3/21/2018
AO	3/19/2018	4/4/2018
AB	3/19/2018	4/4/2018
KF	3/19/2018	4/5/2018
AL	3/19/2018	4/5/2018
SC	3/19/2018	4/6/2018
CS	3/19/2018	4/6/2018
PF	4/9/2018	4/25/2018
AR	4/9/2018	4/25/2018
AL	4/9/2018	4/25/2018
FV	4/9/2018	4/26/2018
DD	4/9/2018	4/26/2018
GO	4/9/2018	4/27/2018

RW	4/9/2018	4/27/2018
JL	4/9/2018	4/27/2018
MS	4/9/2018	4/27/2018

Rider Support Agent (Initials)	Training Start Date	Certification Date
SD	7/31/2017	8/14/2017
DB	7/31/2017	8/14/2017
NW	7/31/2017	8/14/2017
SH	7/31/2017	8/14/2017
JS	8/7/2017	8/21/2017
RJ	8/7/2017	8/21/2017
NK	8/7/2017	8/21/2017
MG	8/7/2017	8/21/2017
JB	8/14/2017	8/28/2017
BP	8/14/2017	8/28/2017
MM	8/14/2017	8/28/2017
BV	8/21/2017	9/4/2017
BT	8/21/2017	9/4/2017
SB	8/21/2017	9/4/2017
KR	8/28/2017	9/11/2017
KT	9/25/2017	10/9/2017
DM	9/25/2017	10/9/2017
AR	11/27/2017	12/11/2017
MH	2/12/2018	2/26/2018
BL	2/12/2018	2/26/2018
DF	2/12/2018	2/26/2018
AM	2/12/2018	2/26/2018
RT	2/12/2018	2/26/2018

I. Waymo Safety Report

The Waymo Safety Report was submitted to the U.S. Department of Transportation on October 12, 2017. The report contains information responsive to the U.S. Department of Transportation's new Voluntary Guidance – Automated Driving Systems 2.0: A Vision for Safety, released on September 12, 2017. Section I of the Guidance outlines 12 safety design elements, and encourages companies testing and deploying self-driving systems to address each of these areas.

The Report summarizes how Waymo is considering and broadly addressing these specific safety areas, and includes additional details on other aspects of our safety program including safety features, the processes we've established to design and validate our technology to ensure safety, and our comprehensive testing program.

The DOT's 12 safety design elements have been considered during product development of our fully self-driving vehicles and are addressed across the four chapters of the Report:

Our "Safety by Design" Philosophy: How Waymo takes a comprehensive approach to system safety.

- *System safety*: Our System Safety Program builds on widely accepted industry practices, using a systems engineering approach to identify, analyze, and mitigate risks associated with our self-driving vehicles.

How the Vehicle Works: What our fully self-driving vehicle is and how it is designed to work safely without a human driver.

- *Object and event detection and response*: How our vehicles' sensors observe the world, predict actions of other road users, and provide the data our system needs to make safe decisions.
- *Operational design domain:* The conditions (e.g., speed, weather conditions, geography) within which our vehicles can operate, and how we ensure they do not operate outside those conditions.
- *Federal, state, and local laws*: How our vehicles incorporate rules of the road and other applicable laws.
- *Minimal risk condition (fallback)*: How our vehicle detects and responds to system faults or other problems that reduce functionality, while retaining the ability to achieve a safe stop.
- *Data recording*: How our vehicle records data useful for crash reconstruction, which we analyze for possible improvements to our system.
- Post-Crash Behavior: How our vehicle returns to a "safe state" after a collision, and our process for responding to safety incidents.
- *Cybersecurity*: How our cybersecurity program works to address threats and vulnerabilities.

The Testing Process: How we test our fully self-driving vehicles to demonstrate their capability and safety.

- *Validation methods*: How we employ on-road testing, closed-course testing, computer simulation, and other testing methods to ensure that our system is capable of safely handling both everyday and unexpected driving situations.
- *Crashworthiness:* How vehicles that Waymo uses protect their occupants in crashes, and how our system is designed to preserve those protections.

Building Public Trust: Additional measures we take to ensure safe interactions with our passengers and other road users.

- *Human-machine Interface*: How our system interface enhances communications and interactions with passengers in our vehicles.
- *Consumer education and training*: Our work to inform consumers and new users about our fully self-driving vehicles.

Waymo Safety Report

On the Road to Fully Self-Driving

WAYMO

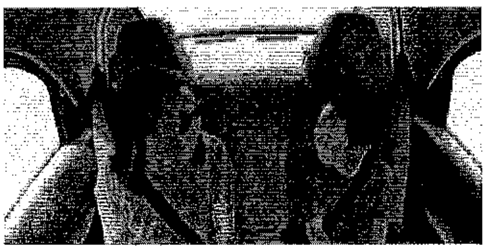
OUR MISSION

Waymo's mission is to bring self-driving technology to the world, making it safe and easy for people and things to move around. We believe our technology can improve mobility by giving people the freedom to get around, and save thousands of lives now lost to traffic crashes.

WAYMO

INTRODUCTION

We're Building a Safer Driver for Everyone



Self-driving vehicles hold the promise to improve road safety and offer new mobility options to millions of people. Whether they're saving lives or helping people run errands, commute to work, or drop kids off at school, fully self-driving vehicles hold enormous potential to transform people's lives for the better.

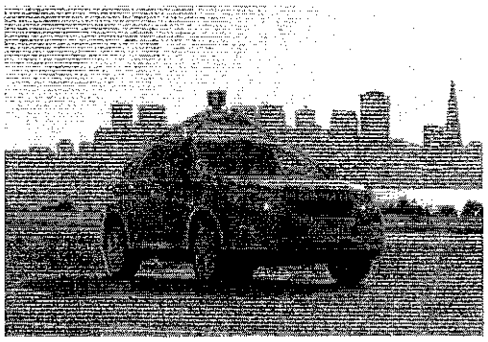
Safety is at the core of Waymo's mission—it's why we were founded over eight years ago as the *Google self-driving car project.*

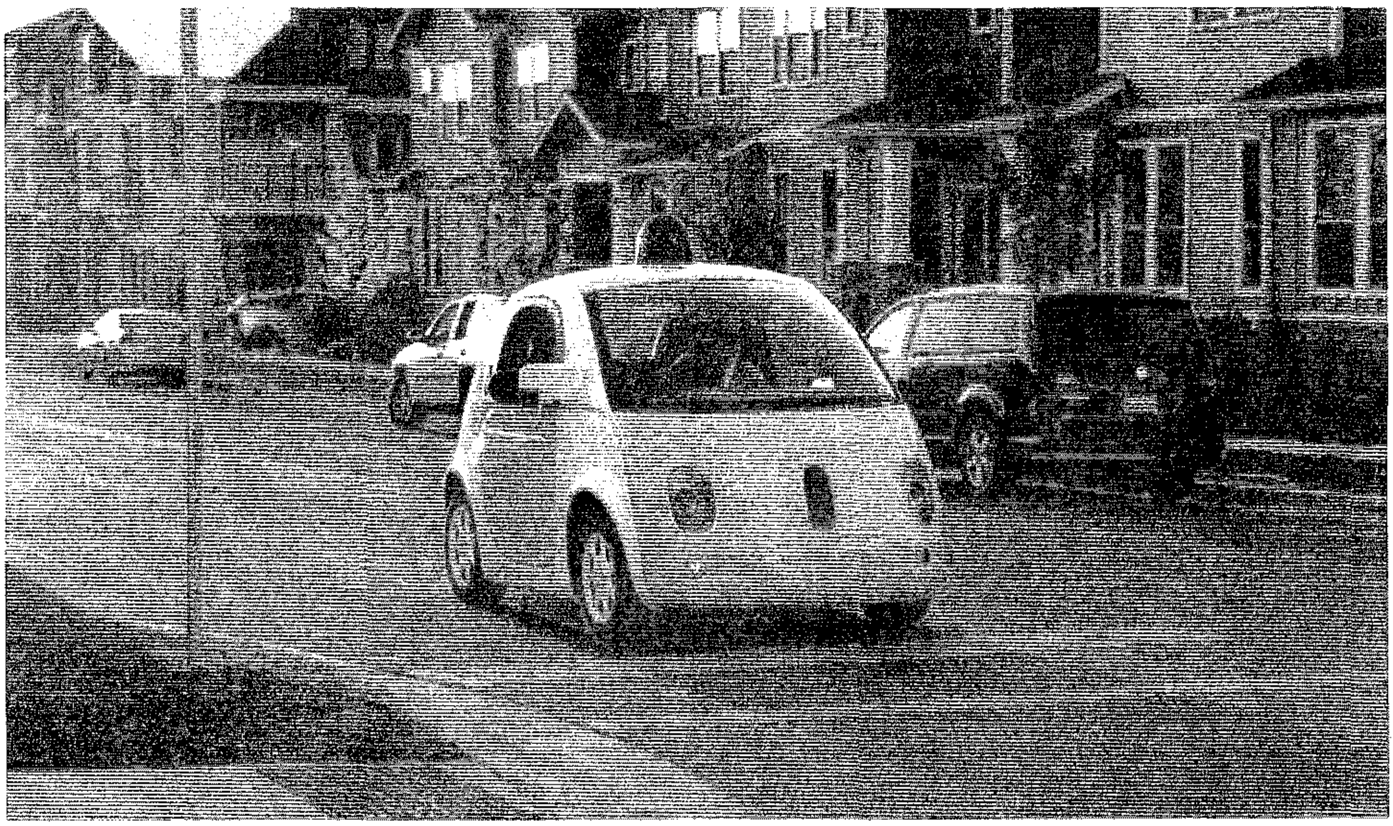
Every year, 1.2 million lives are lost to traffic crashes around the world, and in the U.S. the number of tragedies is growing. A common element of these crashes is that 94% involve human error. Driving is not as safe or as easy as it should be, while distracted driving is on the rise. We believe our technology could save thousands of lives now lost to traffic crashes every year.

Our commitment to safety is reflected in everything we do, from our company culture to how we design and test our technology. In this, our first Safety Report on Waymo's fully self-driving technology, we detail Waymo's work on—and our commitment to—safety. This overview of our safety program underscores the important lessons learned through the 3.5 million miles Waymo's vehicles have self-driven on public roads and through our billions of miles of simulated driving.

Waymo's Safety Report also addresses the U.S. Department of Transportation (DOT) federal policy framework for autonomous vehicles: *Automated Driving Systems 2.0: A Vision for Safety*. The DOT framework outlines 12 safety design elements, and encourages companies testing and deploying self-driving systems to address each of these areas. Over the course of our Report, we will outline the processes relevant to each safety design element and how they underpin the development, testing, and deployment of fully self-driving vehicles.

Fully self-driving vehicles will succeed in their promise and gain public acceptance only if they are safe. That's why Waymo has been investing in safety and building the processes that give us the confidence that our self-driving vehicles can serve the public's need for safer transportation and better mobility.





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The World Around Us

Safety

94
PERCENT
of U.S. crashes involve human error. [1]

1.2
MILLION
deaths worldwide due to vehicle crashes in 2013. [2]

37,461
ROAD DEATHS
in the U.S. in 2016 and 2.4 million injuries in 2015. [3]

2
OUT OF 3
people will be involved in a drunk driving crash in their lifetime. [4]

Society

$594
BILLION
in harm from loss of life and injury each year. [5]

$277
BILLION
in annual economic costs. [6]

$160
BILLION
in gas burned and time lost each year. [7]

Mobility and Quality Of Life

3
MILLION
Americans age 40 and older are blind or have low vision. [8]

79
PERCENT
of seniors age 65 and older living in car-dependent communities. [9]

42
HOURS
wasted in traffic each year per person. [7]

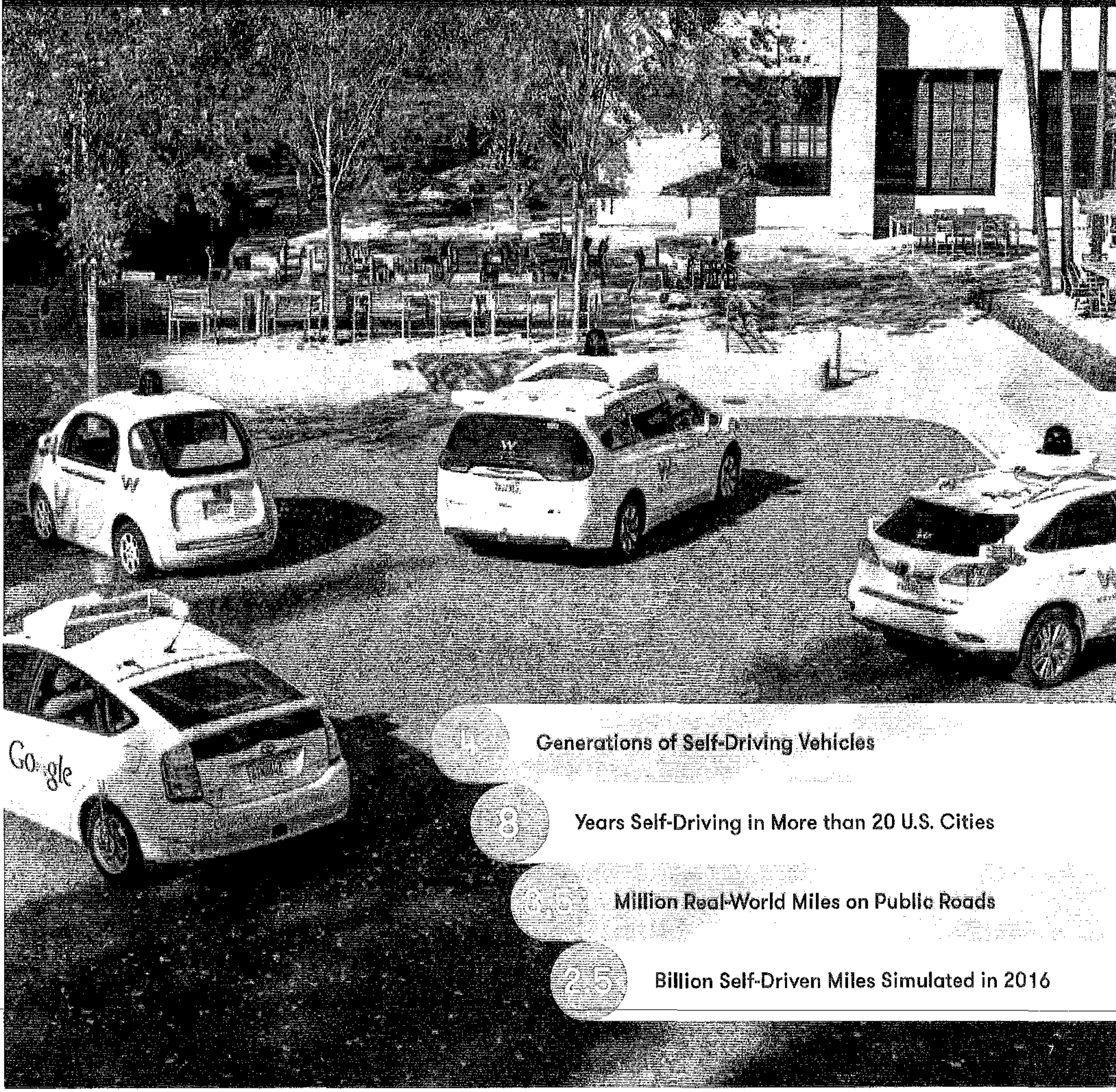
Self-Driving Technology Can Save Lives and Improve Mobility

At Waymo, we're designing fully self-driving vehicles that make it safe and easy for everyone to get around.

WAYMO

Building the World's Most Experienced Driver

Every mile, in every car, is shared with the entire fleet, giving every Waymo vehicle more experience for the next mile.



4 Generations of Self-Driving Vehicles

8 Years Self-Driving in More than 20 U.S. Cities

3.5 Million Real-World Miles on Public Roads

2.5 Billion Self-Driven Miles Simulated in 2016

How Our Self-Driving Vehicle Sees the World and How it Works

At the most basic level, human drivers need to answer four questions: "Where am I?" (perceiving the environment around you), "What's around me?" (processing that information), "What will happen next?" (predicting how others in that environment will behave), and "What should I do?" (making driving decisions based on that information). Self-driving vehicles need to answer those questions, too.

A Waymo vehicle's onboard map view of the intersection of W. Middlefield Road at Rengstorff Avenue, Mountain View, CA.

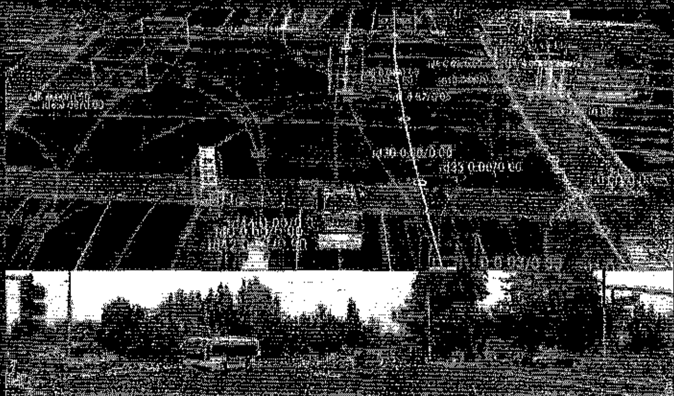
1. Where Am I?

Before our cars drive in any location, our team builds our own detailed three-dimensional maps that highlight information such as road profiles, curbs and sidewalks, lane markers, crosswalks, traffic lights, stop signs, and other road features. Rather than rely on GPS, Waymo's vehicles cross-reference their pre-built maps with real-time sensor data to precisely determine their location on the road.

In this example, our vehicle has detected vehicles (depicted by green and purple boxes), pedestrians (in yellow), and cyclists (in red) at the intersection—and a construction zone up ahead.

2. What's Around Me?

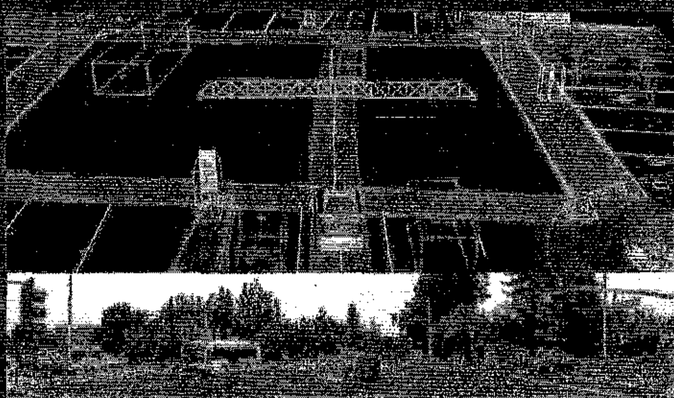
Our sensors and software scan constantly for objects around the vehicle—pedestrians, cyclists, vehicles, road work, obstructions—and continuously read traffic controls, from traffic light color and railroad crossing gates to temporary stop signs. Our vehicles can see up to 300 meters away (nearly three football fields) in every direction.



The simulated imagery shown demonstrates how our software assigns predictions to each object surrounding our vehicle—other vehicles, cyclists, pedestrians, and more.

3. What Will Happen Next?

For every dynamic object on the road, our software predicts future movements based on current speed and trajectory. It understands that a vehicle will move differently than a cyclist or pedestrian. The software then uses that information to predict the many possible paths that other road users may take. Our software also takes into account how changing road conditions (such as a blocked lane up ahead) may impact the behavior of others around it.



The green path indicates the trajectory through which our vehicle can proceed ahead. The series of green fences indicate that the self-driving vehicle can proceed, and that the vehicle has identified the vehicles ahead and understands it has to maintain certain headway.

4. What Should I Do?

The software considers all of this information as it finds an appropriate route for the vehicle to take. Our software selects the exact trajectory, speed, lane, and steering maneuvers needed to progress along this route safely. Because our vehicles are constantly monitoring the environment, and predicting the future behavior of other road users in 360 degrees around our vehicles, they're able to respond quickly and safely to any changes on the road.

Our System Safety Program

SAFETY BY DESIGN

As the first company to complete a fully self-driving trip on public roads, Waymo has had to write its own playbook.

In the earliest days of our company, we established our System Safety Program, which documented practices that would ensure safety in the testing and development of our technology. Today, that program is a comprehensive and robust approach we call *Safety by Design.*

Safety by Design means we consider safety from the ground up and incorporate safety at every system level and every development stage, from design to testing and validation. It is a multi-pronged approach that builds upon best practices from a variety of industries, including aerospace, automotive, and defense (including aspects of MIL-STD-882E [10] and ISO 26262). [11]

In line with these practices, each individual component of our self-driving vehicle is tested robustly to ensure that all subsystems perform safely when integrated as a complete self-driving system. This approach also helps us validate that the vehicle works safely as a fully self-driving vehicle on the road, and understand how a change or failure in any part of the system—component, subsystem, or otherwise—causes changes throughout the rest of the self-driving system.

This process has led to many of Waymo's key safety features, including redundant critical safety systems, which enable the vehicle to come to a safe stop in the event of a technology failure, the use of complementary sensors with overlapping fields-of-view, and our extensive testing program which has helped us make rapid improvements in our technology.

Areas Addressed by Waymo's System Safety Program

Our System Safety Program addresses five distinct safety areas: behavioral safety, functional safety, crash safety, operational safety, and non-collision safety. Each aspect requires a combination of testing methods that, taken together, allow us to validate the safety of our fully self-driving vehicles.

Behavioral Safety:

Behavioral safety refers to the driving decisions and behavior of our vehicles on the road. Just as for human drivers, our vehicles are subject to traffic rules and must safely navigate a variety of scenarios, both expected and unexpected. Waymo uses a combination of functional analysis, simulation tools, and on-road driving to fully understand the challenges presented within our operational design domain, and to develop safety requirements and a multi-pronged testing and validation process.

Functional Safety:

Functional safety seeks to ensure that our vehicles operate safely even when there is a system fault or failure. That means building in backup systems and redundancies to handle the unexpected. For example, all of our self-driving vehicles are equipped with a secondary computer that can take over in the event of a main computer failure, bringing the vehicle to a safe stop (i.e. a minimal risk condition). Each of our vehicles also has backup steering and braking, along with many layers of redundancies throughout the system.

Crash Safety:

Crash safety, or crashworthiness, refers to the ability of vehicles to protect passengers inside the vehicles through a variety of measures, ranging from a structural design that shields people inside, to features like seat restraints and airbags that mitigate injury or prevent death. Crash safety in the U.S. is covered by the Federal Motor Vehicle Safety Standards (FMVSS), which are issued by the National Highway Traffic Safety Administration (NHTSA). Vehicle manufacturers must certify that their base vehicles meet applicable FMVSS requirements.

Operational Safety:

This refers to the interaction between our vehicles and passengers. With operational safety, we can ensure that consumers have a safe and comfortable experience in our vehicles. Our approach to building a safe product is informed by our hazard analyses, existing safety standards, extensive testing, and best practices from a variety of industries. For example, through initiatives like our early rider program (further described in section 4), we have developed and tested user interfaces so that passengers can clearly indicate their destination, direct the vehicle to pull over, and contact Waymo rider support.

Non-Collision Safety:

We address physical safety for the range of people who might interact with the vehicle. For example, this includes electrical system or sensor hazards that could cause harm to occupants, vehicle technicians, test drivers, first responders, or bystanders.

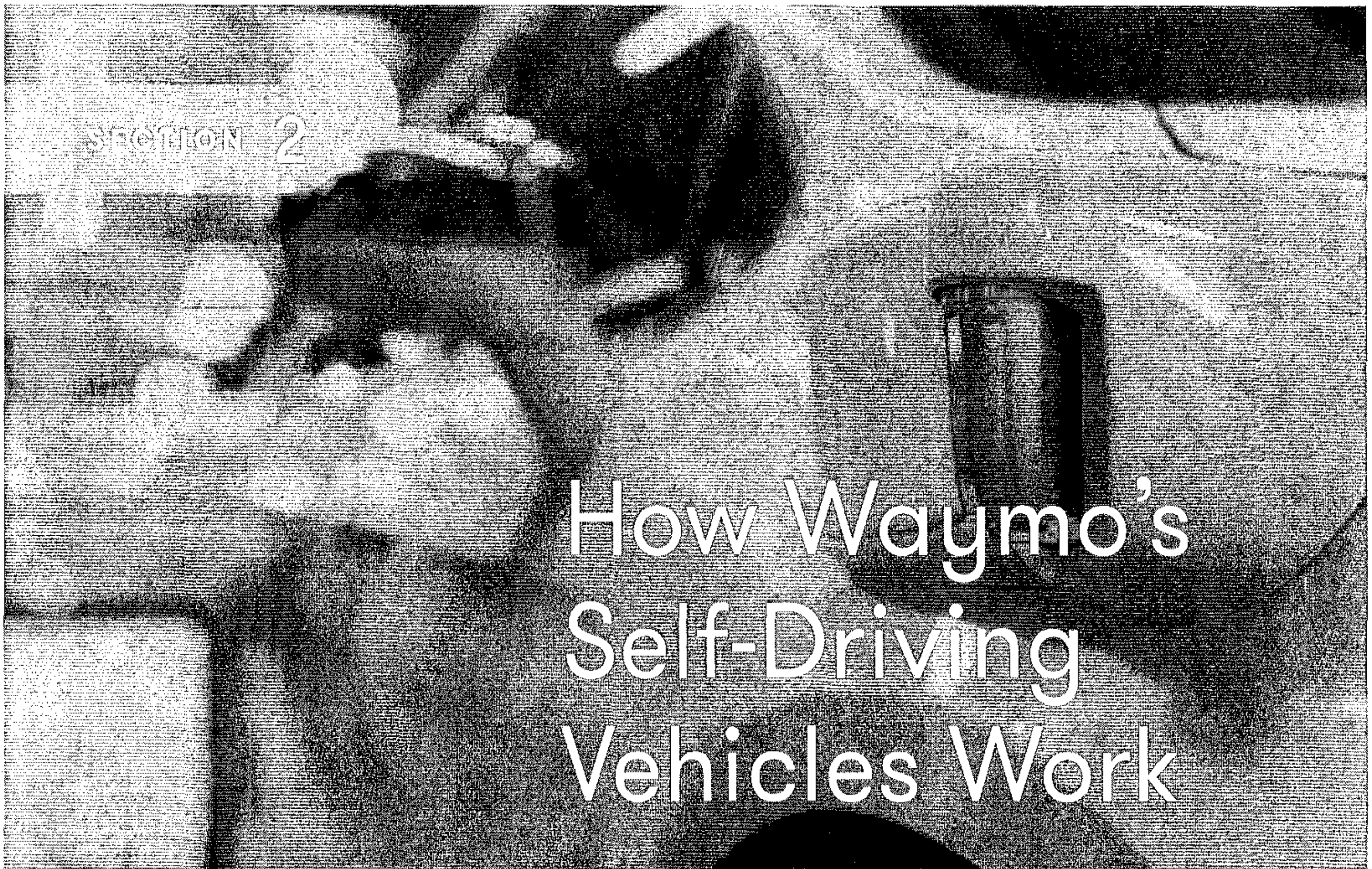
Safety Processes

Waymo organizes the processes we use to keep our vehicles safe through our System Safety Program. Safety requirements needed to reduce the risk of potential hazards are captured internally, addressed in design, and then verified and validated to demonstrate that safety risks have been reduced to the levels identified in the analyses.

Our approach starts with identifying hazard scenarios and potential mitigations that can be implemented to reduce risk. These mitigations may take various forms such as software or hardware requirements, hardware or software design recommendations, procedural controls, or recommendations for additional analyses. We use various hazard assessment methods such as preliminary hazard analysis, fault tree, and Design Failure Modes and Effects Analyses (DFMEA). This continuous process goes hand-in-hand with ongoing engineering and test activities and safety engineering analyses.

The hazard analysis process helps identify requirements for our self-driving system architecture, subsystems, and components. These safety requirements are developed from the use of a series of subsystem and system analysis techniques, various systems engineering processes, and Federal and State laws and regulations. The analysis also supports the development of requirements for our behavioral safety testing, and how our system detects and handles faults.

With our system architecture and requirements defined, Waymo then conducts extensive testing on public roads, a closed course, and in simulated driving. We use information gathered from this testing, as well as research into national crash data and naturalistic driving studies [12], to provide additional insights into potential hazards. The combined knowledge derived from these various tools plays a major role in our understanding of our system's readiness. Drawing on this understanding, we're able to comprehensively analyze and evaluate the safety of our system before we permit fully self-driving operation on public roads.



SECTION 2

How Waymo's Self-Driving Vehicles Work

The Case for Full Autonomy: Allowing Passengers to Stay Passengers

Advanced driver-assist technologies were one of the first technologies our teams explored. In 2012 we developed and tested a Level 3 system that would drive autonomously on the freeway in a single lane but would still require a driver to take over at a moment's notice. During our internal testing, however, we found that human drivers over-trusted the technology and were not monitoring the roadway carefully enough to be able to safely take control when needed.

As driver-assist features become more advanced, drivers are often asked to transition from passenger to driver in a matter of seconds, often in challenging or complex situations with little context of the scene ahead. The more tasks the vehicle is responsible for, the more complicated and vulnerable this moment of transition becomes.

Avoiding this "handoff problem" is part of the reason why Waymo is working on *fully* self-driving vehicles. Our technology takes care of all of the driving, allowing passengers to stay passengers.

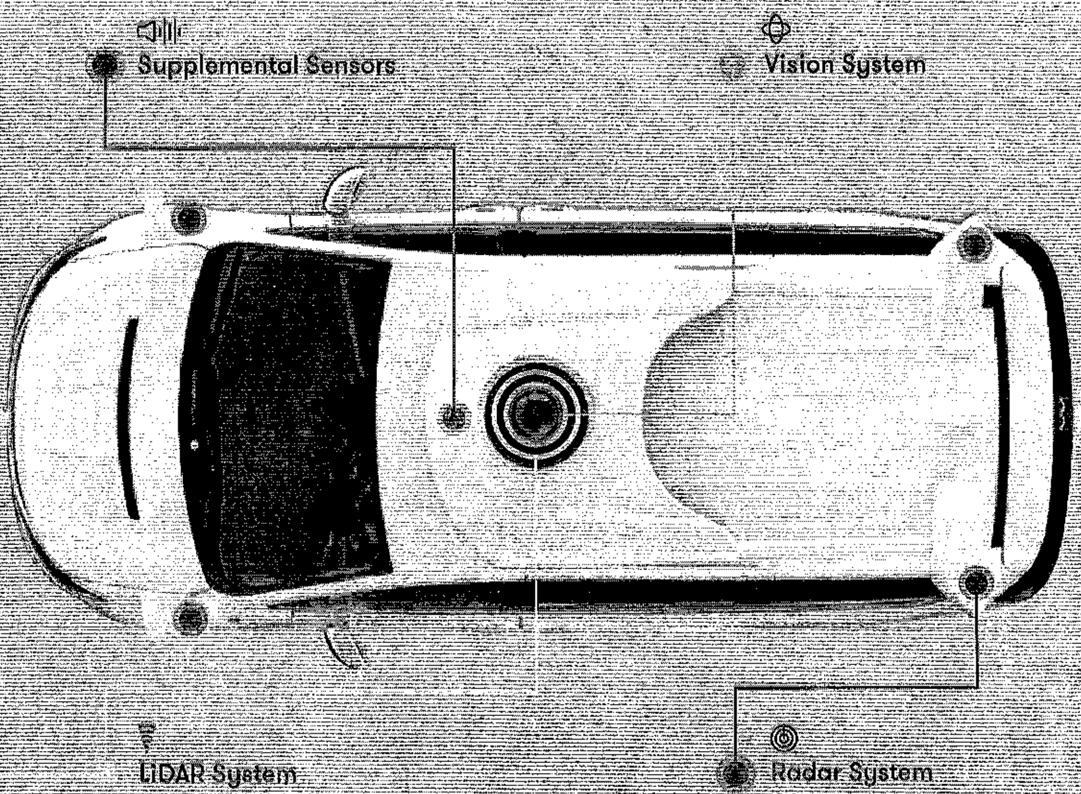
The Self-Driving System

Our fully self-driving system is designed to operate without a human driver, unlike technologies sold in cars today such as adaptive cruise-control or lane-keeping systems which require constant monitoring by the driver. Our system includes the software and hardware that, when integrated into the vehicle, perform all driving functions.

In self-driving jargon, Waymo's self-driving system is designed to perform the entire dynamic driving task within a geographic area and under certain defined conditions, without the need for a human driver. This type of technology falls under SAE International's definition of a Level 4 automated driving system, as our technology also has the ability to bring a vehicle to a safe stop (i.e. a minimal risk condition) in the event of any system failures. Unlike autonomous systems at lower levels (Level, 1, Level 2, and Level 3), a Level 4 system also has the ability to bring a vehicle to a safe stop (i.e. achieve a minimal risk condition) in the event of any system failures, without any expectation that a human driver take over. [13]

Object and Event Detection and Response: Our Vehicle Sensors

To meet the complex demands of autonomous driving, Waymo has developed an array of sensors that allow our vehicle to see 360 degrees, both in daytime and at night, and up to nearly three football fields away. This multi-layered sensor suite works together seamlessly to paint a detailed 3D picture of the world, showing dynamic and static objects including pedestrians, cyclists, other vehicles, traffic lights, construction cones, and other road features.



LiDAR (Laser) System

LiDAR (Light Detection and Ranging) works day and night by beaming out millions of laser pulses per second—in 360 degrees—and measuring how long it takes to reflect off a surface and return to the vehicle. Waymo's system includes three types of LiDAR developed in-house: a short-range LiDAR that gives our vehicle an uninterrupted view directly around it, a high-resolution mid-range LiDAR, and a powerful new generation long-range LiDAR that can see almost three football fields away.

Vision (Camera) System

Our vision system includes cameras designed to see the world in context, as a human would, but with a simultaneous 360-degree field of view, rather than the 120-degree view of human drivers. Because our high-resolution vision system detects color, it can help our system spot traffic lights, construction zones, school buses, and the flashing lights of emergency vehicles. Waymo's vision system is comprised of several sets of high-resolution cameras, designed to work well at long range, in daylight and low-light conditions.

Radar System

Radar uses wavelengths to perceive objects and movement. These wavelengths are able to travel around objects like rain drops, making radar effective in rain, fog, and snow, day or night. Waymo's radar system has a continuous 360-degree view, so it can track the speed of road users in front, behind and to both sides of the vehicle.

Supplemental Sensors

Waymo vehicles also have a number of additional sensors, including our audio detection system that can hear police and emergency vehicle sirens up to hundreds of feet away, and GPS to supplement our vehicles' extensive understanding of their physical locations in the world.

Our Self-Driving Software

Our self-driving software is the "brain" of our vehicle. It makes sense of the information coming from our sensors, and uses that information to make the best driving decisions for each situation.

Waymo has spent eight years building and refining our software, using machine learning and other advanced engineering techniques. We've trained our software through years of careful design and testing, billions of miles of simulated driving, and more than 3.5 million miles of on-road driving experience.

Our system possesses a deep, contextual understanding of the world; this is a key part of what differentiates Level 4 technology. Our self-driving software doesn't just detect the presence of other objects; it actually understands what an object is, how it's likely to behave, and how that should affect our vehicle's own behavior on the road. This is how our vehicles safely navigate roads in fully autonomous mode.

While our software is made up of many different pieces, here we detail three main components: perception, behavior prediction, and planner.

PERCEPTION

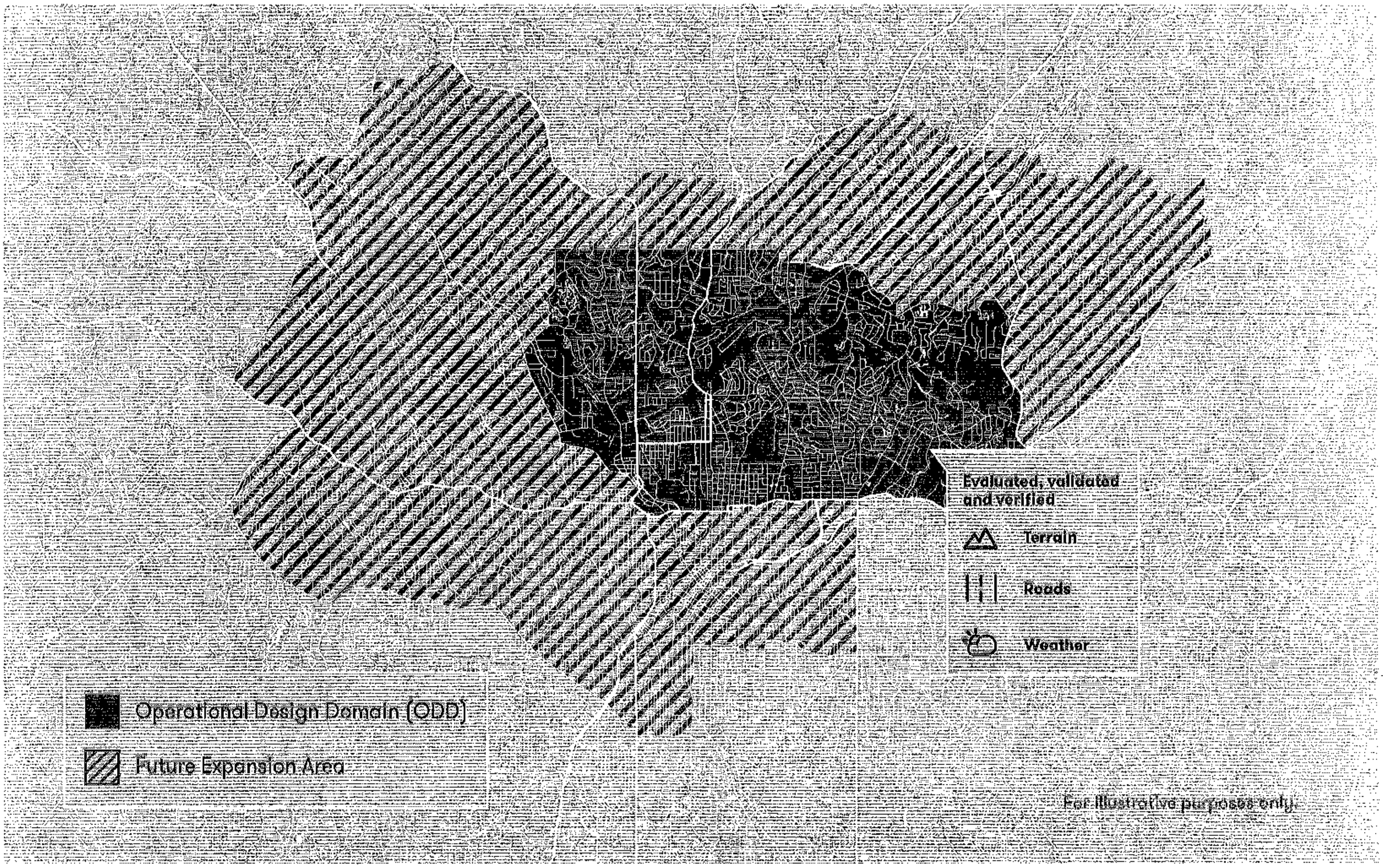
Perception is the part of our software that detects and classifies objects on the road, while also estimating their speed, heading, and acceleration over time. Our self-driving software takes the myriad of details coming from Waymo's sensors and turns them into a cohesive real-time view of the world. Perception helps our vehicle distinguish pedestrians, cyclists, motorcyclists, vehicles, and more. It also distinguishes the color of static objects such as traffic signals. For these kinds of objects, perception enables our system to semantically understand the situation around our vehicle—whether a light is green and clear for the vehicle to proceed, or whether a lane is blocked because of the many cones in front of it.

BEHAVIOR PREDICTION

With *behavior prediction*, our software can model, predict, and understand the intent of each object on the road. Because Waymo has millions of miles of driving experience, our vehicles have highly accurate models of how different road users are likely to behave. For example, our software understands that, though pedestrians, cyclists, and motorcyclists may look similar, their behavior can vary dramatically. Pedestrians move more slowly than either cyclists or motorcyclists, but they can change direction more suddenly.

PLANNER

Our *planner* considers all the information our software has gathered from perception and behavior prediction, and plots out a path for our vehicles. In our experience, the best drivers are the defensive drivers. That's why we've baked in defensive driving behaviors, such as staying out of other drivers' blind spots and leaving extra room for cyclists and pedestrians. Waymo's planner can also think several steps ahead. For example, if our software perceives that an adjacent lane ahead is closed due to construction, and predicts that a cyclist in that lane will move over, our planner can make the decision to slow down or make room for the cyclist well ahead of time. Using our on-road experience, we're also refining our driving so our movements on the road are smooth and comfortable for passengers inside our vehicles, and natural and predictable for other road users.



Operational Design Domain: Ensuring Our Vehicles Operate Safely Under Specific Conditions
The operational design domain refers to the conditions under which a self-driving system can safely operate. Waymo's domain includes geographies, roadway types, speed range, weather, time of day, and state and local traffic laws and regulations.

An operational design domain can be very limited: for instance, a single fixed route on low-speed public streets or private grounds (such as business parks) in temperate weather conditions during daylight hours. However, Waymo aims to have a broad operational design domain to cover everyday driving. We're developing self-driving technology that can navigate city streets in a variety of conditions within broad geographic areas. Our vehicles are designed with the capability to drive in inclement weather, such as light to moderate rain, and can operate in daytime and at night.

Waymo's system is also designed so each vehicle does not operate outside of its approved operational design domain. For example, passengers cannot select a destination outside of our approved geography, and our software will not create a route that travels outside of a "geo-fenced" area, which has been mapped in detail (see "How We Build a Map for a Self-Driving Vehicle"). Similarly, our vehicles are designed to automatically detect sudden changes (such as a snowstorm) that would affect safe driving within their operational design domain and come to a safe stop (i.e. achieve a "minimal risk condition") until conditions improve.

We design our vehicles to be capable of complying with federal, state, and local laws within their geographic area of operations. [14] Legal requirements, and any changes in those requirements, are identified and built into our system as safety requirements, including relevant speed limits, traffic signs, and signals. Before our vehicles drive in a new location, our team works to understand any unique road rules or driving customs, and we update our software so our vehicles are capable of responding safely. For example, California and Texas (home to two of Waymo's test cities) have differing rules for how to make right turns in the presence of a bike lane.

Waymo's operational design domain continues to evolve. Our ultimate goal is to develop fully self-driving technology that can take someone from A to B, anytime, anywhere, and in all conditions. As our system's capabilities grow and are validated, we will expand our operational design domain to bring our technology to more people.

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]

Our Vehicles' 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

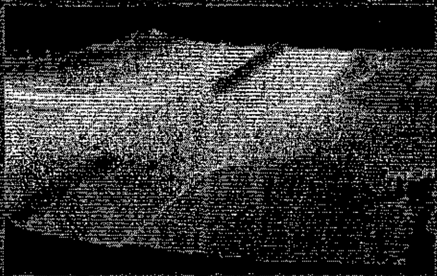
Multiple backup systems—including independent collision avoidance systems—constantly scan the road immediately ahead and behind the vehicle for objects such as pedestrians, cyclists, and other vehicles. These redundant systems slow or stop the vehicle in the rare event that the primary system does not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

How We Build a Map for a Self-Driving Vehicle

Before our vehicles are introduced on the road, our mapping team first uses our sensors on test vehicles to create highly detailed 3D maps. These maps are distinct from basic satellite imagery or online maps. Instead, Waymo's maps provide our vehicle with a deep *understanding of the physical environment:* road types, the distance and dimensions of the road itself, and other topographical features.



We take this data and add salient information that includes traffic control information such as the lengths of crosswalks, the locations of *traffic lights, and relevant signage.*

With our maps installed onboard our vehicle, our system can then focus on the parts of the environment that change dynamically around it, such as other road users. Our system can detect when a road has changed by cross-referencing the real-time sensor data with its on-board 3D map. If a change in the roadway (e.g., a collision up ahead that closes an intersection) is detected, our vehicle can re-route itself within the system's operational design domain and alert our operations center so that other vehicles in the fleet can avoid the area. In this case, the maps not only serve as an added reference point to our software, but also provide important feedback to our system.

These detailed custom maps give us a comprehensive understanding of the conditions in every location where we drive. When coupled with our deep knowledge of the capabilities of our system, they help us ensure that our vehicles operate only within their *operational design domain.*

Data Recording and Post-Crash Behavior

Waymo's self-driving technology never stops improving. Waymo has a robust system for collecting and analyzing data from encounters we have on the road. [16] Anything we learn from the experience of one vehicle, we apply to our entire fleet.

Waymo's system can detect when it has been involved in a collision and will notify our Waymo operations center automatically. There our trained specialists can initiate post-crash procedures, which include procedures for interacting with law enforcement and first responders, and for sending members of our team on location. Our operations center also has rider support specialists, who can communicate directly with our passengers through our in-vehicle audio system.

Following a collision, we're able to analyze all available data, including video and other sensor data, to evaluate factors that may have contributed to the incident, and we're able to make any appropriate software changes and update every vehicle in our fleet accordingly. Any damage our vehicles sustain in a collision is repaired and the vehicles are tested for safety before they return to the road.

Self-Driving Vehicle Cybersecurity

Waymo has developed a robust process to identify, prioritize, and mitigate cybersecurity threats. Our security practices are built on the foundation of Google's Security processes and are informed by publications like the NHTSA Cybersecurity Guidance and the Automotive Information Sharing and Analysis Center's (Auto-ISAC) Automotive Cybersecurity Best Practices. To help develop future security best practices, Waymo has also joined the Auto-ISAC, an industry-operated initiative created to enhance cybersecurity awareness and collaboration across the global automotive industry.

Waymo's Approach to Security

1. Build Verifiable Software and Systems
2. Encrypt and Verify Channels of Communication
3. Build Redundant Security Measures for Critical Systems
4. Limit Communication Between Critical Systems
5. Provide Timely Software Updates
6. Model and Prioritize Threats

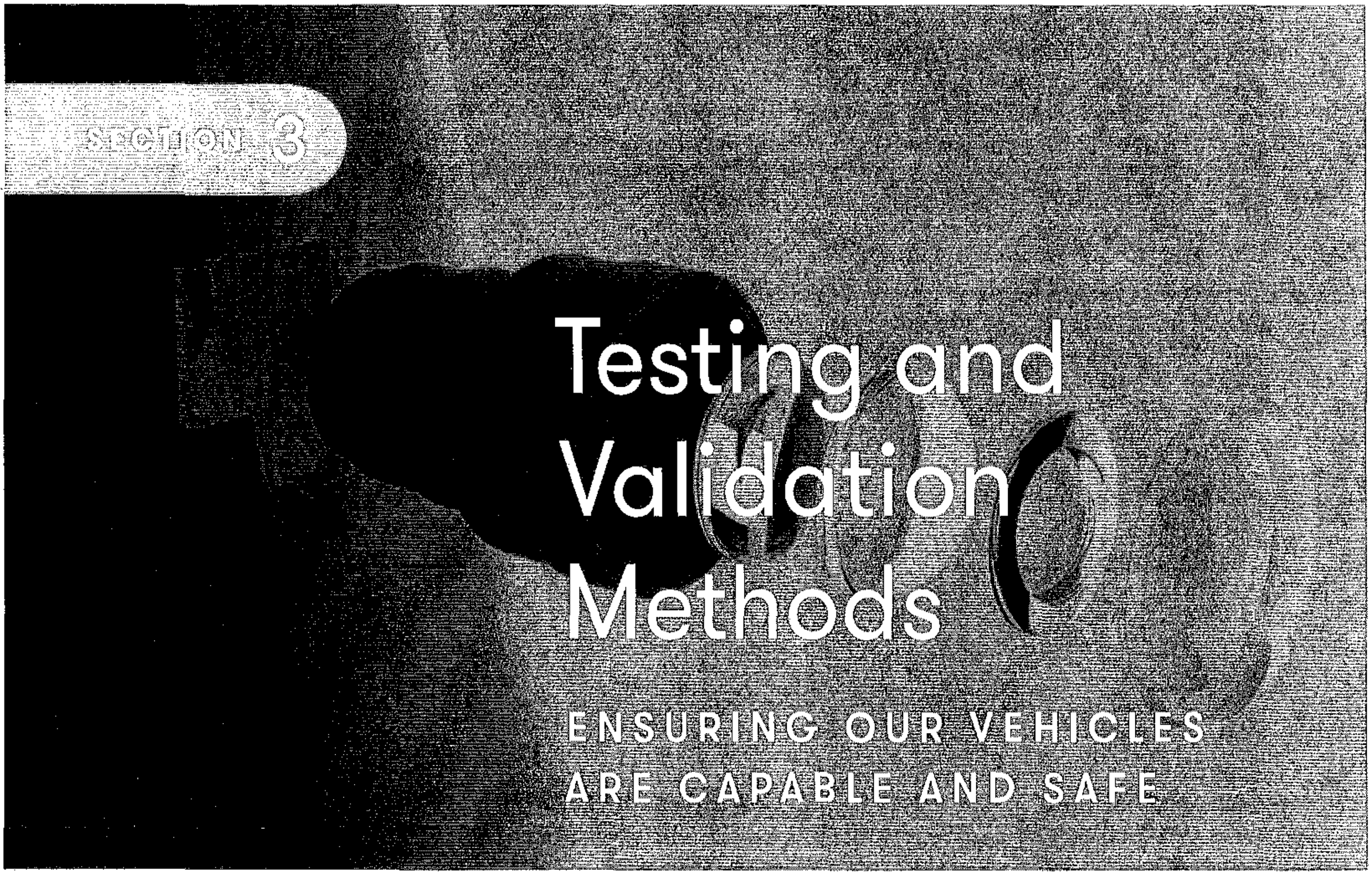
We complete a comprehensive review of all potential security access points to our self-driving system from both the interior and exterior of the physical vehicle, and take steps to limit the number and function of those access points.

This begins by collaborating with our OEM partners at the onset to identify and mitigate vulnerabilities of the base vehicle. Our software and vehicle design processes take full account of known threats to ensure that our system and vehicle designs are protected against them. New software releases go through an extensive peer review and verification process. Our hazard analysis and risk assessment processes have been designed to identify and mitigate risks that might affect safety, including those related to cybersecurity.

In our design, safety-critical aspects of Waymo's vehicles—e.g. steering, braking, controllers—are isolated from outside communication. For example, both the safety-critical computing that determines vehicle movements and the onboard 3D maps are shielded from, and inaccessible from, the vehicle's wireless connections and systems.

We also consider the security of our wireless communication. Our vehicles do not rely on a constant connection to operate safely. While on the road, all communications (e.g., redundant cellular connections) between the vehicles and Waymo are encrypted, including those between Waymo's operations support staff and our riders. Our vehicles can communicate with our operations center to gather more information about road conditions, while our vehicles maintain responsibility for the driving task at all times.

These protections help prevent anyone with limited physical access to our self-driving vehicles, whether passengers or malicious actors nearby, from impairing or altering their security. We have diverse mechanisms for noticing anomalous behavior and internal processes for analyzing those occurrences. Should we become aware of an indication that someone has attempted to impair our vehicle's security, Waymo will trigger its company-wide incident response procedure, which involves impact assessment, containment, recovery, and remediation.



SECTION 3

Testing and Validation Methods

ENSURING OUR VEHICLES ARE CAPABLE AND SAFE

Waymo's technology undergoes extensive testing—on the road, in closed courses, and in simulation—so that every part of our system is capable, reliable, and safe when operating within its design domain.

Waymo's self-driving vehicles consist of three primary subsystems that are individually and rigorously tested:

1. The base vehicle, as certified by the OEM
2. Our in-house hardware, including sensors and computers
3. Our self-driving software that makes all the driving decisions

Each of these subsystems is then combined to form a fully integrated self-driving vehicle, which is then further tested and validated. Collectively testing the hardware and software ensures that our overall self-driving vehicle meets all the safety requirements that we have set for our system.

Building a Safe and Reliable Supply Chain

Waymo works directly with our suppliers and subcontractors on the performance, safety, quality, and reliability requirements of system components. We include those suppliers in the Failures Modes and Effects Analysis (FMEA) and risk assessment processes as we work to identify potential risks associated with manufacturing processes, stand-alone components, or components when integrated with other subsystems. We monitor the performance of components in our products during manufacturing, and conduct ongoing reliability testing to make sure they meet design expectations and safety requirements before being integrated into our vehicles.

Testing At Every Level

Our multi-layered approach to safety is influenced by the same systems engineering processes used by NASA to launch the *Mars Rover* – a self-driving vehicle that operates millions of miles from Earth.

This approach means we analyze and test our system at the lowest component level to ensure the performance and reliability of our most critical systems. For example, our vision (camera) system alone is subjected to over a hundred separate tests in our labs before a single vehicle with this technology leaves our garage.

First we perform tests on every component: we examine the individual cameras that will make up the vision system, as well as parts like cables and connectors, to determine that each works to designed specifications. Then we test again once the cameras are fully integrated. Each camera is assembled into a ring formation and we calibrate them to work together, checking that the angle and orientation of each camera combines to give a complete 360-degree view. Then we test the vision system as a whole. The assembled camera ring is added to the self-driving system and our engineers run tests to ensure our different sensors work cohesively as one.

Before we operate a single vehicle on public roads with this new vision system, we perform another level of tests, confirming that the vision system is doing its job, performing tasks like seeing traffic lights in a variety of lighting conditions, detecting pedestrians, and spotting construction cones.

Only then is this vision system, as part of our self-driving vehicle, ready for the road.

Base Vehicle Safety

Waymo's current generation self-driving vehicle is a modified version of the 2017 Chrysler Pacifica Hybrid Minivan, into which we have integrated our self-driving system. The modified 2017 Chrysler Pacifica Hybrid Minivans that Fiat Chrysler Automobiles ("FCA") has sold to us have been certified by the manufacturer as compliant with all applicable Federal Motor Vehicle Safety Standards (FMVSS), which standards regulate the safety performance requirements for motor vehicles or items of motor vehicle equipment in the U.S.

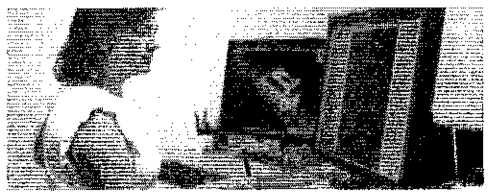
Self-Driving Hardware Testing

Through a technical collaboration between FCA and Waymo, we engineered and integrated Waymo's self-driving system, including our self-driving sensors and hardware, with the modified Chrysler Pacifica Hybrid Minivans provided by FCA. To ensure that we have properly integrated our self-driving system into the Chrysler Pacifica Hybrid Minivans that make up our fleet, Waymo has performed thousands of additional tests on top of those completed by FCA. These tests are completed at our private test tracks, in our labs, and in simulation, and are used to evaluate each safety function of the vehicle, from brakes and steering to physical vehicle controls like locks, headlights, and doors. With these tests, we can ensure that the vehicle operates safely in manual mode, self-driving mode with a test driver at the wheel, and fully self-driving mode without a person inside the vehicle. Overall, this testing seeks to ensure that our vehicle continues to function safely after the addition of our self-driving system.

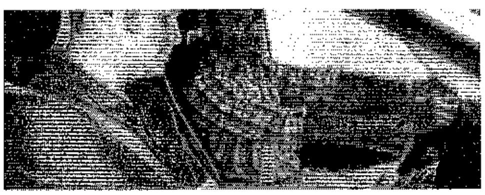
Self-Driving Software Testing

Like our hardware, our self-driving software is guided by our *Safety by Design* philosophy. We constantly and rigorously test the individual components of the software—including perception, behavior prediction, and planner—as well as the software as a whole.

Our technology is constantly learning and improving. Each change of our software undergoes a rigorous release process. We update our software regularly for different operational design domains. Each update is tested through a combination of simulation testing, closed course testing, and driving on public roadways:



Simulation Testing:
In simulation, we rigorously test any changes or updates to our software before they're deployed in our fleet. We identify the most challenging situations our vehicles have encountered on public roads, and turn them into virtual scenarios for our self-driving software to practice in simulation.



Closed-Course Testing:
New software is pushed to a few vehicles first so that our most experienced drivers can test the new software on our private test track. We can use different releases of software for different vehicles so that we can test new or specific features within different operational design domains.

Real-World Driving:
Once we confirm that our software is working as intended, we begin introducing the new software to our vehicles on public roads. We start small—our self-driving vehicles must show they can safely and consistently travel a predetermined route—and then we push the software update to our entire fleet. The more miles we travel on public roads, the more opportunities to monitor and assess the performance of software.

As we drive more road miles, we continue to further refine our driving and update our software. This continual feedback loop allows us to build confidence that our software reacts and responds appropriately in the operational design domain, enabling our vehicle to operate at SAE Level 4 safely.

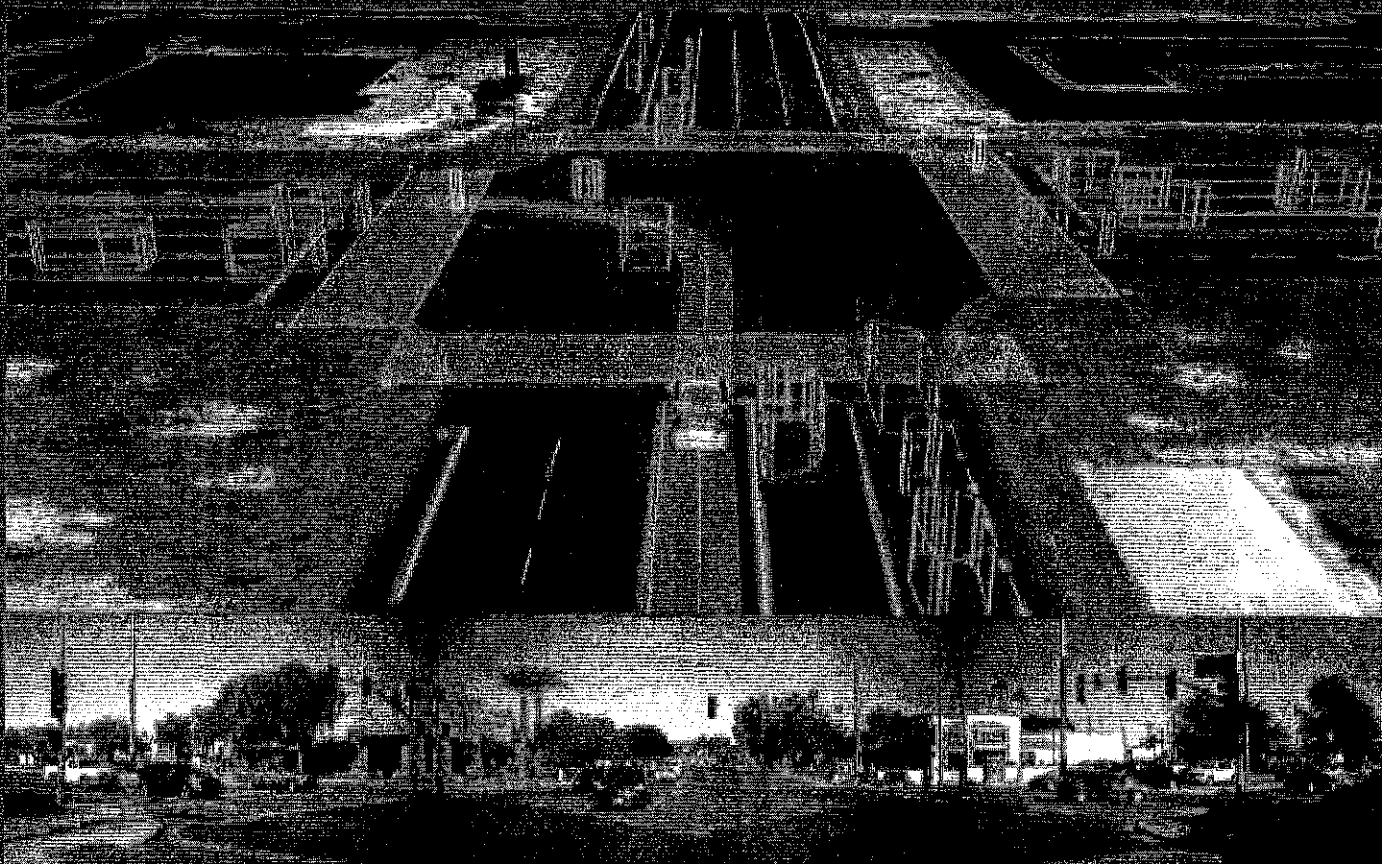
Simulation: How the Virtual World Helps Our Cars Learn Advanced Real-World Driving Skills

Waymo's simulator can replay the real-world miles we have driven with each new software version, but also can build completely new realistic virtual scenarios for our software to be tested against. Each day, as many as 25,000 virtual Waymo self-driving vehicles drive up to eight million miles in simulation, refining old skills and testing out new maneuvers that help them navigate the real world safely.

For example: at the corner of South Longmore Street and West Southern Avenue in Mesa, Arizona, there's a flashing yellow arrow for left turns. This type of intersection can be tricky for humans and self-driving vehicles alike—drivers must move into a five-lane intersection and then find a gap in oncoming traffic. A left turn made too early may pose a hazard for oncoming traffic; a turn made too late may frustrate drivers behind.

Simulation lets us turn a single real-world encounter like this into thousands of opportunities to practice and master a skill.

Waymo engineers build virtual scenarios that allow our self-driving vehicles to drive up to 8 million simulated miles each day.



Our self-driving vehicle encounters a flashing yellow left turn arrow in Mesa, Arizona.

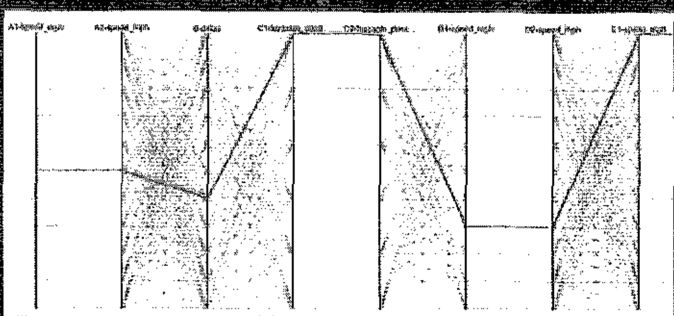
How Simulation Works

We can recreate a highly-detailed, realistic virtual version of the East Valley.

Step 1: Start with a Highly-Detailed Vision of the World
Using a powerful suite of custom-built sensors, we build a virtual replica of the intersection, complete with identical dimensions, lanes, curbs, and traffic lights. In simulation, we can focus on the most challenging interactions—flashing yellow signals, wrong-way drivers, or nimble cyclists—rather than on monotonous highway miles.

In simulation, we can practice driving the same intersection, in the same driving conditions thousands of times, with different vehicles from our fleet. In this image, we're simulating driving the intersection with one of our Lexus vehicles.

Step 2: Drive, Drive, and Redrive
With this flashing yellow left turn now digitized in our virtual world, our software can practice this scenario thousands of times over. Every time we update the software, we can test the change at the same intersection in a variety of driving conditions. That's how we were able to teach our vehicles to naturally inch forward at that flashing yellow light, and slot in after oncoming traffic. What's more, in simulation we can practice this new skill on every flashing yellow arrow we have ever come across, in order to improve our software even faster.



Through a process called fuzzing, we can alter the speed, trajectory and position of objects on these virtual streets.

Step 3: Create Thousands of Variations
Next, we can multiply this one tricky left turn to explore thousands of variable scenarios and "what ifs?" Through a process called fuzzing, we alter the speed of oncoming vehicles and the timing of traffic lights to make sure our vehicles can still find a safe gap in traffic. The scene can be made busier and more complex by adding simulated pedestrians, motorcycles "splitting the lane," or even joggers zig-zagging across the street—all to see how that might change our driving.

To make a scene more complex, we can add vehicles, pedestrians and cyclists that never existed in the original scene.

Step 4: Validate and Iterate
Success: Our self-driving vehicle has learned how to turn confidently at a flashing yellow arrow. That new skill becomes part of our permanent knowledge base, shared with every vehicle across the fleet. In turn, we'll use real-world driving and our private closed course testing facility to validate our simulated experience. And then the cycle begins again. Each of these eventful simulator miles is guiding us to what everyone wants: billions of safe and uneventful miles in the real world.

Field Tests at Our Closed-Course Facility

Waymo has set up a private, 91-acre, closed-course testing facility in California specially designed and built for our own unique testing needs. This private facility, nicknamed "Castle," is set up like a mock city, including everything from high-speed roads to suburban driveways to a railroad crossing. Our team uses this and other closed-course facilities to validate new software before it's released to our fleet of vehicles on the road, and also to stage challenging or rare scenarios so our vehicles gain experience with unusual situations.

On our closed course, we're able to conduct thousands of "structured tests" which recreate specific scenarios for learning and testing. To power our simulator, we've developed more than 20,000 simulation scenarios at Castle. Each recreates a driving situation we want to practice—an aggressive driver barreling out of a driveway, or a pedestrian suddenly emerging from a parked car—that might take hundreds of thousands of driving miles to encounter on public roads. We've staged people jumping out of canvas bags or porta potties on the side of the road, skateboarders lying on their boards, and thrown stacks of paper in front of our sensors. This "structured testing" is key to accelerating the progress of our technology and ensuring safety of our vehicles in both everyday and challenging driving situations.

Behavioral Competencies for Normal Driving

A fully self-driving vehicle must be able to handle all the everyday driving tasks expected of human drivers within the same operational design domain. This means self-driving systems need to demonstrate they have the adequate skills—or "behavioral competencies"—required for the intended locations and conditions of operation.

The U.S. Department of Transportation has recommended that Level 3, Level 4, and Level 5 self-driving vehicles should be able to demonstrate at least 28 core competencies adapted from research by California Partners for Advanced Transportation Technology (PATH) at the Institute of Transportation Studies at University of California, Berkeley. DOT also encourages companies "to consider all known behavioral competencies in the design, test, and validation" of a self-driving system.

Waymo's safety program has expanded the 28 core competencies in both breadth and depth, for which we test thousands of scenario variations—ranging in complexity—ensuring that our system can safely handle the challenges of real-world environments. In addition, we have identified further categories that expand upon the initial 28 core competencies. [17] (For a subset of Waymo's behavioral competencies, see Appendix A.)

For each competency, Waymo's team creates a wide variety of individual tests to run on our closed course facility and in simulation. For example, to test our ability to make unprotected left turns, we stage dozens of real-life situations and test to see if our vehicles respond appropriately. We include challenging variations of this common road maneuver, including using multiple lanes of oncoming traffic, obstructing our vehicle's field of view with a large truck, or providing a short green traffic light to make the turn.

For each of these scenarios we then use our simulator to create hundreds of different variations of the same encounter. With our virtual world testing, we can also create entirely new scenarios of unprotected left-hand turns so we can test this skill further. As we expand our operational design domain, the number of core competencies may grow (for example, to drive in northern U.S. states year-round, our system must be able to safely drive in snow) and the number of tests within each category may expand with more unique or complex scenarios.

While this type of scenario testing can demonstrate our software's core driving skills, these competencies need to translate out into the real world. That's why this acts merely as a starting point: our validation then moves onto testing our vehicle, hardware, and software as an integrated fully self-driving vehicle on public roads, where it demonstrates these competencies daily in real traffic situations.

Testing the Fully Integrated Self-Driving Vehicle

After testing the base vehicle, the self-driving system, and the software individually, we then test the fully integrated self-driving vehicle. This includes closed-course collision avoidance testing, reliability and durability testing, and on-road testing with trained test drivers at the wheel.

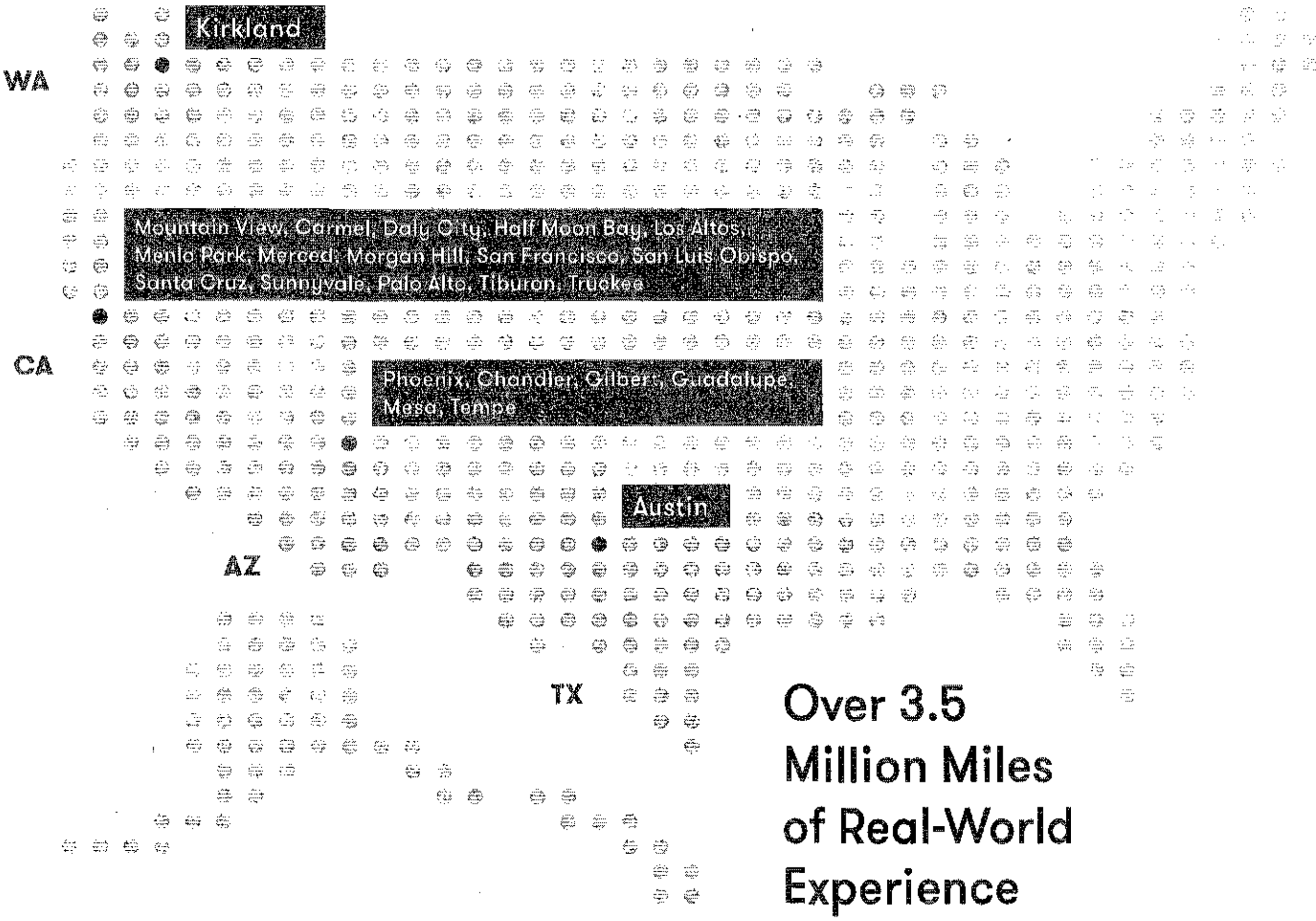
Testing on Public Roads

Waymo has a comprehensive on-road testing program that has been improved and refined continuously over our eight-year history. It's a critical step that allows us to validate the skills we have developed, uncover new challenging situations, and develop new capabilities.

The safety of our on-road testing program begins with highly-trained drivers. Our test drivers undergo extensive classroom training, learning about the overall system and how to monitor the vehicle safely on public roads, including taking defensive driving courses. After this training, our drivers are responsible for monitoring the system and if needed, taking control of the vehicle while we test on public roads.

Our on-road testing program drives tens of thousands of weekly miles that are used to evaluate our software. We monitor our systems to ensure they demonstrate our behavioral competencies, and we look for situations where we can build on these competencies and enable smoother driving.

Real-world testing provides a continuous feedback loop that lets us refine our system continually. Our engineers observe real-world situations, make adjustments to the software to refine our driving, and then implement those changes. This iterative approach to testing and public-road validation helps us safely scale our capabilities as we expand our operational design domain and the capabilities of our vehicles.



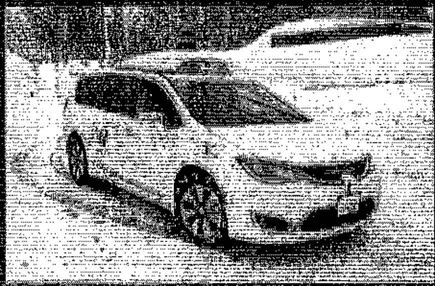
Over 3.5 Million Miles of Real-World Experience

Real-World Experience

Over the last eight years, Waymo has tested our vehicles in four U.S. states and self-driven in more than 20 cities—from sunny Phoenix, AZ to rainy Kirkland, WA—accumulating more than 3.5 million autonomous miles in the process. As we expand to new locations, we're able to gather a wider variety of experience with different road environments, streetscapes, and driver habits.

For example, driving in Phoenix has allowed us to test our sensors and software in desert conditions, including extreme temperatures and dust in the air. We learned how to navigate more confidently around new types of vehicles, like watering trucks that move 3 mph on 45 mph roads while spraying plants in road medians. Austin provided horizontal traffic signals for the first time, while Kirkland gave us more wet weather practice.

In every new city, we meet people who aren't used to seeing self-driving cars every day. That lets us also hear fresh perspectives from diverse populations—how people want to use self-driving vehicles, what they think of our driving, and more—who together inform how we develop and refine our self-driving technology.



Self-Driving in Extreme Temperatures

Our self-driving vehicles need to operate reliably and safely in extreme cold and oppressive heat. Waymo engineers have developed both our self-driving hardware and software in-house to create a complete system that can work reliably in the toughest environments.

Heat poses challenges for all modern technology. Everyday electronics like cell phones can overheat and switch off when used in the bright sun. However, our self-driving system needs to operate safely even in hot conditions. Our cars are equipped with a special cooling system that lets them operate under very hot temperatures, even with an engine running at full power and systems at full capacity.

Our engineers perform extensive testing in a wind tunnel that can mimic almost any weather condition, including the hottest temperatures ever recorded on Earth.

In addition to wind tunnel testing, we have tested our self-driving vehicle in three of America's hottest places: Las Vegas, Davis Dam, and Death Valley. The Davis Dam, on the Arizona and Nevada border, has long stretches of steep desert road for us to drive under the hot sun. The Las Vegas Strip lets us test our systems in countless busy lanes of stop-and-go city traffic under intense heat. Death Valley holds the record for the highest officially recorded temperature on Earth of 134°F.

During testing we closely monitor our systems, taking over 200 different measurements per second to confirm that our in-house sensor suite and compute keeps working as intended.

Testing Crash Avoidance Capabilities

In addition to testing core behavioral competencies, our engineers also conduct crash avoidance testing across a variety of scenarios. (To view a subset of Waymo's crash avoidance test scenarios, see Appendix B.)

Waymo has completed thousands of crash avoidance tests at our private test track. Each of these individual tests recreates a distinct driving scenario and allows us to analyze our vehicles' response. We then use our simulator to test these scenarios further and improve our overall software capabilities.

We draw from a variety of sources to learn which collisions to test against. They include our own analysis of sources such as NHTSA's fatal crash data base, and use of our extensive experience operating self-driving vehicles to expand on NHTSA's 37 pre-crash scenarios. We also test situations in which other road users create potentially dangerous situations, such as vehicles suddenly pulling out of driveways, large vehicles cutting across target lanes, motorcyclists weaving through traffic, and pedestrians jaywalking.

In 2015, NHTSA published data showing the distribution of the most common pre-crash scenarios. For example, just four crash categories accounted for 84% of all crashes: rear end crashes, vehicles turning or crossing at an intersection, vehicles running off the edge of the road, and vehicles changing lanes. Therefore, avoiding or mitigating those kinds of crashes is an important goal for our testing program. [18]

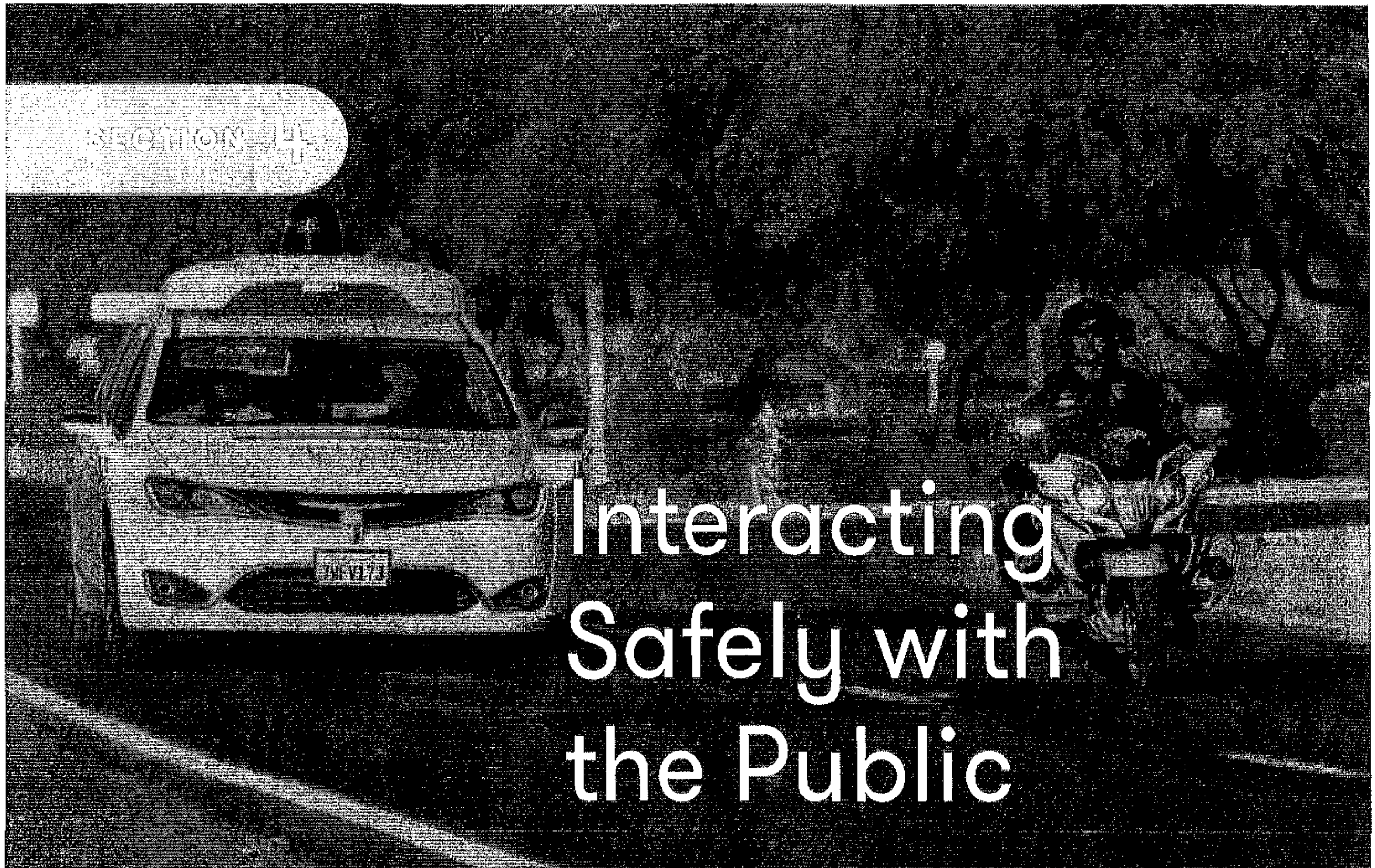
Crash avoidance testing at Waymo's closed course testing facility, Castle.

Hardware Reliability and Durability Testing

Self-driving vehicles, like their conventional counterparts, must operate reliably. That means the vehicle and each of its individual components must function under extreme environmental conditions and over the lifetime of the vehicle.

Waymo engineers design unique stress tests. Using our knowledge of the physics of failure to accelerate environmental stresses on our vehicle and its individual components, we compress years of real-world use into days and weeks of testing.

We blast our components with ultraviolet radiation, bombard them with powerful water jets, dunk them into nearly freezing vats of water, corrode them in chambers full of salty mist, shake and shock them with powerful vibrations, and heat and freeze them for weeks at a time in temperature and humidity chambers. We analyze any failures and make design improvements to increase the reliability of our components. We monitor the health of each sensor, and the vehicle itself, so we can identify and fix potential failures before they occur.



SECTION 4

Interacting Safely with the Public

Waymo's Early Rider Program

We want to learn how a self-driving vehicle could fit into people's every day transportation needs—whether that's as a personal use vehicle, as a ride-share, or to make public transit more accessible. That's why in April 2017, we launched our early rider program, the first public trial of our self-driving vehicles, in the Phoenix metropolitan area.

Our riders come from all walks of life, from families with teenage kids to young professionals. They're using our vehicles for everyday activities—from commuting to work to taking the kids to soccer practice. Educating our early riders on how to use our vehicles is critical. Our research team works with each new rider to provide them with information about the program and how to use our vehicles, and also how to provide feedback.

For the last 100 years, vehicles have been designed with a human driver in mind. The experiences of our early riders will teach us about how people want to interact with our vehicles, and what it's like to ride as a passenger instead of a driver. Their experiences will help us create an in-car experience that is even more intuitive and easy-to-use.

Our vehicles are designed to drive themselves, so our user interface focuses on passengers, not drivers.

That's why we've developed specific in-car features and user interfaces that help our passengers understand what our vehicles are doing on the road and let them do things like set a destination, ask the vehicle to pull over, and get in touch with Waymo support staff as needed. We also understand the transportation challenges that exist today, especially around accessibility, and we are working to develop solutions that work for riders of all abilities.

In addition to creating a safe and intuitive everyday ride for our passengers, Waymo has also developed procedures in case of emergency. For example, not only are our vehicles designed to detect collisions and respond appropriately to emergency vehicles on the road, but we have also conducted trainings with law enforcement and first responders who may come into contact with our vehicles.

Finally, the potential of self-driving cars will only be realized by growing public awareness and acceptance of this technology. In October 2017, Waymo helped to launch *Let's Talk Self-Driving* (letstalkselfdriving.com), the world's first public education campaign about fully self-driving vehicles. Working in partnership with national and local safety, mobility, and seniors groups, the initiative hopes to engage and educate the public about how this technology works and the enormous benefits self-driving technology could unlock.

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.

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.

Rider Experience

Waymo's user experience is guided by four main principles: give passengers the information they need for a seamless trip; help passengers anticipate what's next; proactively communicate the vehicle's response to events on the road; and help passengers engage safely with the vehicle.

Audio and visual information provided to passengers helps them know what to expect, reminds them of safety features such as seat belts, and permits them to communicate with Waymo's rider support personnel.

We also want our passengers to be aware of what the vehicle is perceiving, and why it is taking specific actions. Each vehicle also provides occupants with useful visual and audio information throughout the trip, to help them understand what the vehicle and other road users around it are doing. In Waymo's self-driving minivans, the in-vehicle screens are used to provide visual ride information, such as destination, current speed, and the route the vehicle intends to take. An audio system provides audible notifications and cues to all riders.

In the event of a safety-critical event, the screens and audio system are designed to provide the occupant with specific visual and audio cues depending on the nature of the event. We've designed multiple ways for our riders to interact with our vehicle, whether it's through the pressing of physical buttons, a mobile app, or by speaking with a Waymo rider support specialist.

Accessibility Features In Development

An Accessible Mobile App:

We're building our mobile app to be intuitive and accessible. It's designed for use with Android TalkBack, iOS VoiceOver, and other accessibility services.

Audio Cues and Tools:

Visually impaired riders may need help locating our vehicles at their pickup locations. We're exploring specific "wayfinding" features, including ways that these riders can ask their vehicle to make a sound to help guide them to the vehicle. Additional audio cues can be turned on in the mobile app and will be available in the vehicle to keep the rider informed of their journey.

Braille Labels:

The ride buttons in our self-driving vehicles are accompanied by Braille to allow vision-impaired riders to start the ride, pull over the vehicle, or call to speak to an operator who can provide further assistance and information. These buttons are also available in the mobile app.

Visual Display:

Through every phase of the ride, deaf and hearing-impaired riders will have access to on-screen visual cues of what is happening around the vehicle.

Accessible Rider Support:

Our chat-based rider support will be available to all riders of all abilities through visual displays or audio inside the vehicle.

Accessibility: Unlocking Opportunities for Those Who Cannot Drive Today

We believe our technology holds the potential to improve safety and mobility for people around the world. From the start, Waymo has been listening to and working with the disability community. We continue to learn about the unique needs of different riders, and what we learn will inform new features that will make the experience accessible to people who have historically had to rely on others to get around.

We also know we can't reach our goals alone. Waymo is committed to working with our partners to identify vehicle platforms and solutions that can serve a broader set of individuals.

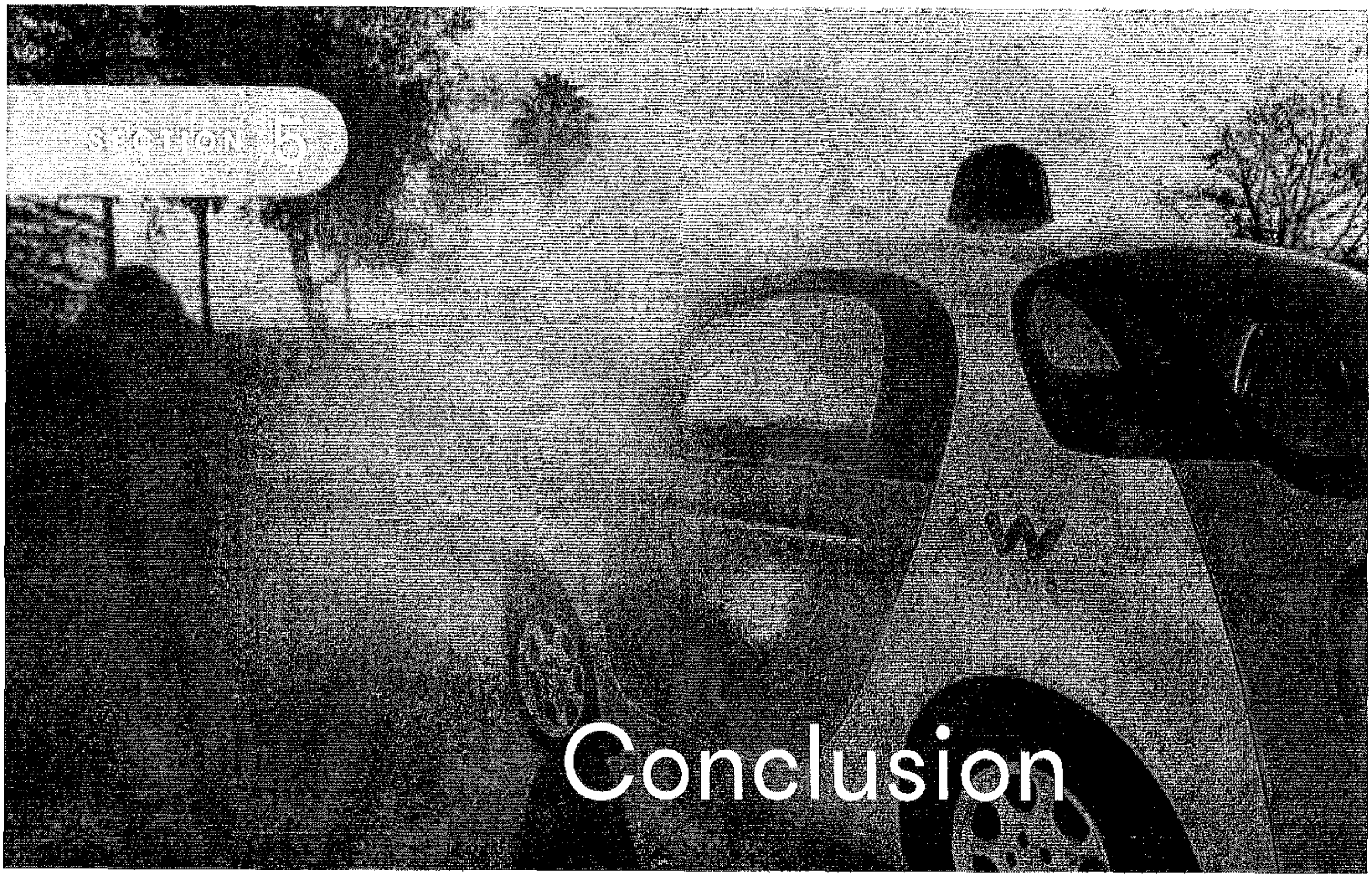
Testing with the Chandler Arizona Police Department

We've collaborated with the Chandler Police and Fire departments in Arizona to conduct emergency vehicle testing with our self-driving minivans. Our powerful suite of sensors, including our long-range audio detection system, observed local police vehicles, motorcycles, ambulances, firetrucks, and undercover vehicles as they trailed, passed, and led our vehicles. Our sensors collected samples at various speeds, distances, and angles—building up a library of sights and sounds that will help our vehicles respond safely to emergency vehicles on the road.

Emergencies and Interacting With Law Enforcement and First Responders

Our self-driving vehicles are designed to interact with law enforcement and first responders safely on road. Using our suite of custom-built sensors, including an audio detection system, our software can identify a nearby fire truck, detect its flashing lights, and hear sirens up to hundreds of feet away. Our audio sensors are designed to discern the direction sirens are likely coming from, improving our vehicles' ability to respond in both a safe and timely manner. Once an emergency vehicle is detected, our vehicle can respond by yielding, pulling over to the side of the road, or coming to a complete stop.

Waymo also briefs local authorities in every city in which we test, and offers a line of communication for further engagement. In some cities, Waymo has also conducted on-site training to help police and other emergency workers identify and access our vehicle in emergency situations. We plan to continue conducting these on-site trainings, while expanding the scope of the training program as our vehicles become more capable and our operational design domain expands.



SECTION 5

Conclusion

For more than eight years, Waymo has focused on one thing: bringing fully self-driving technology to the world. We are committed to *Safety By Design*, and we have built a culture that puts safety, and open communication about safety, at its core. All of us at Waymo are committed to the goal of making it safe and easy for people and things to move around.

This report summarizes our efforts to ensure the safe deployment of fully self-driving vehicles that use Waymo technology. We are excited about the potential this technology holds to improve road safety and provide new mobility options for the world. For further information about Waymo's self-driving technology, please visit www.waymo.com.

APPENDIX

Scenario Types Used for Testing and Validation

Waymo tests our vehicles comprehensively to ensure that they are capable of operating safely in reasonably foreseeable scenarios that could present a safety hazard.

The following types of scenarios are illustrative of the breadth of our testing program and are designed to ensure our vehicles have: 1) basic behavioral competencies and 2) the ability to avoid or mitigate crashes in common crash scenarios.

Appendix A. Basic Behavioral Competency Testing

We believe that our fully self-driving vehicles should be able to successfully demonstrate competency in a variety of reasonably foreseeable traffic situations that are within the vehicle's operational design domain. Our system can recognize and stay within its design domain, and the set of competencies expands or shrinks in accordance with the scope of each operational design domain. For each behavioral competency shown in the table below, we test a wide range of scenarios with variations in factors such as road configuration, the speed of our vehicle or other vehicles, and lighting conditions.

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

Appendix B. Avoidance or Mitigation of Common Crash Scenarios

Certain types of crashes account for a substantial percentage of all crashes. Avoiding or mitigating those kinds of crashes, therefore, is an important goal for our vehicle development program. In late 2015, NHTSA published data showing the distribution of pre-crash scenarios. [19]

Four scenarios accounted for the vast majority of crashes:

- 29 percent of the vehicles were involved in rear-end crashes
- 24 percent of the vehicles were turning or crossing at intersections just prior to the crashes
- 19 percent of the vehicles ran off the edge of the road
- 12 percent involved vehicles changing lanes

Therefore, these scenarios figure prominently in the evaluation of our vehicles. The table below illustrates just a few of the test scenarios we employ to determine our vehicle's ability to avoid or mitigate crashes in these all-important situations, as well as in other crash situations.

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

However, we evaluate those capabilities in many more situations than those shown here. We have developed many additional test scenarios based on NHTSA's overall pre-crash scenarios, our analysis of additional sources such as NHTSA's fatal crash data base, and from our own extensive experience operating self-driving vehicles. [19]

Behavioral Safety. An aspect of system safety that focuses on how a system should behave normally in its environment to avoid hazards and reduce the risk of mishaps: for instance, detect objects and respond in a safe way (slow down, stop, turn, lane change, etc.).

California Partners for Advanced Transportation Technology (PATH). A research and development program of the University of California, Berkeley, with staff, faculty, and students from universities worldwide and cooperative projects with private industry, state, and local agencies, and nonprofit institutions. See www.path.berkeley.edu.

Crash Safety. An aspect of system safety that focuses on reducing the consequences of collisions by reducing the severity of the event as experienced by vehicle occupants or other road users.

Dynamic Driving Task. All of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding strategic functions such as trip scheduling and selection of destinations and waypoints.

Fault. An abnormal condition in the system. A fault might be triggered by hardware failures, software error detection, detection of off-nominal system performance, or other conditions defined within the diagnostics capability of the system.

Functional Safety. An aspect of system safety that focuses on how the system should detect and respond to failures, errors, or off-nominal performance of the self-driving system (e.g., fail operational, fail safe, or transition to a minimal risk condition).

Hazard. Any real or potential condition that can cause injury, illness, or death to personnel; damage to or loss of a system, equipment or property; or damage to the environment. (MIL-STD-882E).

Hazard Analysis. A process of identifying or recognizing hazards that may arise from a system or its environment, and analyzing their potential causes for the purpose of assessing risk and initiating actions necessary to reduce the risk to acceptable levels. Results of hazard analyses are also used to develop verification and validation approaches and procedures to demonstrate that hazard risks have been mitigated to acceptable levels.

Manufacturer. An individual or company that manufactures self-driving vehicles or equipment for testing and deployment on public roadways.

Minimal Risk Condition. A low-risk operating mode in which a fully self-driving vehicle operating without a human driver achieves a reasonably safe state, such as bringing the vehicle to a complete stop, upon experiencing a failure of the self-driving system that renders the vehicle unable to perform the entire dynamic driving task.

Mishap. An event or series of events resulting in death, injury, illness, or damage to property.

Mishap Risk. See Definition for Risk.

Object and Event Detection and Response. The perception by the system of any circumstance that is relevant to the immediate driving task, as well as the appropriate driver or system response to such a circumstance.

Operational Design Domain. A description of the specific operating conditions in which a self-driving system is designed to properly operate, including but not limited to roadway types, speed range, environmental conditions (weather, daytime/nighttime, etc.), and other domain constraints.

Operational Safety. An aspect of system safety that focuses on the interaction between our vehicles and passengers.

Non-Collision Safety. An aspect of system safety that focuses on physical non-collision hazards.

Requirement. A general term used to describe the set of statements that identifies a system's functions, characteristics, or constraints.

Risk. An expression of the possibility and impact of a mishap in terms of hazard severity and hazard probability of occurrence. It routinely reflects conditions such as personnel error, environmental conditions, design characteristics, procedural deficiencies, or subsystem or component failure or malfunction.

SAE J3016. "Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles," published by SAE International in September 2016.

Safety. Freedom from those conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment. (MIL-STD-882E).

Safety Requirement. 1) A system or subsystem requirement that is associated with a hazard mitigation or reduces the risk of an identified hazard. 2) A regulatory safety requirement generated from a governing agency. 3) Safety requirement derived from an industry standard or published best practice.

Self-Driving System. A Level 4 or 5 system which has hardware and software that are collectively capable of performing the entire dynamic driving task, without a human driver. This distinguishes it from Level 1, 2, or 3 systems that require a human driver.

Fully Self-Driving Vehicle. A vehicle equipped with a self-driving system designed to function without a human driver as a level 4 or 5 system.

Subsystem. 1) A grouping of items satisfying a logical group of functions within a particular system. (MIL-STD-882E) 2) A major part of a system which in itself has the characteristics of a system, usually consisting of several components.

System. 1) An integrated composite of people, products, and processes that provide a capability to satisfy a stated need or objective. (MIL-STD-882E) 2) The organization of hardware, software, material, facilities, personnel, data, and services needed to perform a designated function within a stated environment with specified results.

System Safety. 1) The application of engineering and management principles, criteria, and techniques to achieve acceptable mishap risk, within the constraints of operational effectiveness and suitability, time, and cost, throughout all phases of a system life cycle. (MIL-STD-882E). 2) The optimum degree of safety within the constraints of operational effectiveness, time, and cost attained through specific application of system safety engineering throughout all phases of a system (McGraw Hill Dictionary of Technical Terms).

System Safety Engineering. 1) An engineering discipline that employs specialized professional knowledge and skills in applying scientific and engineering principles, criteria, and techniques to identify and eliminate hazards, in order to reduce the associated mishap risk. (MIL-STD-882E) 2) An element of systems management involving the application of scientific and engineering principles for the timely identification of hazards, and initiation of those actions necessary to prevent or mitigate hazards within the system.

END NOTES

[1] "Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey." National Highway Traffic Safety Administration, February 2015. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115

[2] "Global Status Report on Road Safety 2015." World Health Organization, 2015. http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/

[3] "2016 Fatal Motor Vehicle Crashes: Overview." National Highway Traffic Safety Administration, October 2017. https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812456; "Quick Facts 2015." National Highway Traffic Safety Administration, May 2017 (updated). https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812348

[4] "The Economic and Societal Impact Of Motor Vehicle Crashes, 2010." National Highway Traffic Safety Administration, May 2014, DOT HS 812 013. https://www-nrd.nhtsa.dot.gov/Pubs/812013.pdf

[5] "The Economic and Societal Impact Of Motor Vehicle Crashes, 2010." National Highway Traffic Safety Administration, May 2015 (revised). https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812013

[6] ibid.

[7] Schrank, D., Eisele, B., Lomax, T., and Bak, J. "2015 Urban Mobility Scorecard." The Texas A&M Transportation Institute and INRIX, August 2015. https://static.tti.tamu.edu/tti.tamu.edu/documents/mobility-scorecard-2015.pdf

[8] "Quieter Cars and the Safety Of Blind Pedestrians: Phase I." National Highway Traffic Safety Administration, April 2010. https://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2010/811304rev.pdf

[9] Rosenbloom, Sandra. "The Mobility Needs of Older Americans: Implications for Transportation Reauthorization." The Brookings Institution, July 2003. https://www.brookings.edu/wp-content/uploads/2016/06/20030807_Rosenbloom.pdf

[10] "MIL-STD-882E: Standard Practice: System Safety." U.S. Department of Defense, 11 May 2012.

[11] "ISO 26262: Road Vehicles – Functional Safety." The International Organization for Standardization (ISO), 15 Nov 2011.

[12] "Description of the SHRP 2 Naturalistic Database and the Crash, Near-Crash, and Baseline Data Sets." Virginia Tech Transportation Institute (VTTI), April 2016. https://vtechworks.lib.vt.edu/bitstream/handle/10919/70850/SHRP_2_CrashNearCrashBaselineReport_4-25-16.pdf?sequence=1

[13] "SAE J3016. Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles." SAE International, September 2016.

[14] "Federal Automated Vehicles Policy." National Highway Traffic Safety Administration, September 2016. (See Safety Assessment notes on page 15.) https://www.transportation.gov/AV/federal-automated-vehicles-policy-september-2016

[15] As NHTSA has noted: "A minimal risk condition will vary according to the type and extent of a given failure, but may include automatically bringing the vehicle to a safe stop, preferably outside of an active lane of traffic." (See Automated Driving Systems 2.0 on page 8.)

[16] Crashes are reported consistent with state law and we cooperate with law enforcement under established legal process.

[17] "Input to NHTSA's Development of Guidelines for the Safe Deployment and Operation Of Automated Vehicle Safety Technologies." Google, Inc., May 2016. https://drive.google.com/file/d/0Byq-WVq3Y4HEcWVvVjc3TXEwOEE/view?usp=sharing

[18] "New Car Assessment Program (NCAP), 80 Fed Reg 78522 at 78552, December 16, 2015) https://www.federalregister.gov/documents/2015/12/16/2015-31323/new-car-assessment-program

[19] Our test scenarios are derived from multiple sources, including: Najm, W. G., Smith, J. D., and Yanagisawa, M. "DOT HS 810 767: Pre-Crash Scenario Typology for Crash Avoidance Research." National Highway Traffic Safety Administration, April 2007. https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/pre-crash_scenario_typology-final_pdf_version_5-2-07.pdf
Data from the NHTSA's Fatality Analysis Reporting System (FARS) database https://www.nhtsa.gov/research-data/fatality-analysis-reporting-system-fars and hazardous situations Waymo has encountered during our eight years of driving experience.

J. Copy of Waymo's Corporate Information Filed with the Secretary of State

Application content enclosed on the following page.

17-314799

Secretary of State
Statement of Information
(Limited Liability Company)

LLC-12

FILED
Secretary of State
State of California
FEB 22 2017

376/350/20/cc

IMPORTANT — Read instructions before completing this form.

Filing Fee – $20.00

Copy Fees – First page $1.00; each attachment page $0.50;
Certification Fee - $5.00 plus copy fees

This Space For Office Use Only

1. Limited Liability Company Name (Enter the exact name of the LLC. If you registered in California using an alternate name, see instructions.)

Waymo LLC

2. 12-Digit Secretary of State File Number	3. State, Foreign Country or Place of Organization (only if formed outside of California)
201704810253	Delaware

4. Business Addresses

	City (no abbreviations)	State	Zip Code
a. Street Address of Principal Office - Do not list a P.O. Box: 1600 Amphitheatre Parkway	Mountain View	CA	94043
b. Mailing Address of LLC, if different than item 4a			
c. Street Address of California Office, if item 4a is not in California - Do not list a P.O. Box		CA	

5. Manager(s) or Member(s) If no managers have been appointed or elected, provide the name and address of each member. At least one name and address must be listed. If the manager/member is an individual, complete items 5a and 5c (leave item 5b blank). If the manager/member is an entity, complete items 5b and 5c (leave item 5a blank). Note: The LLC cannot serve as its own manager or member. If the LLC has additional managers/members, enter the name(s) and addresses on Form LLC-12A (see instructions).

a. First Name, if an individual - Do not complete item 5b	Middle Name	Last Name	Suffix

b. Entity Name - Do not complete item 5a
Waymo Holding Inc.

c. Address	City (no abbreviations)	State	Zip Code
1600 Amphitheatre Parkway	Mountain View	CA	94043

6. Service of Process (Must provide either Individual OR Corporation.)

INDIVIDUAL – Complete items 6a and 6b only. Must include agent's full name and California street address.

a. California Agent's First Name (if agent is not a corporation)	Middle Name	Last Name	Suffix

b. Street Address (if agent is not a corporation) - Do not enter a P.O. Box	City (no abbreviations)	State	Zip Code
		CA	

CORPORATION – Complete item 6c only. Only include the name of the registered agent Corporation.

c. California Registered Corporate Agent's Name (if agent is a corporation) – Do not complete item 6a or 6b
Corporation Service Company Which Will Do Business In California As CSC-Lawyers Incorporating Service C1592199

7. Type of Business

a. Describe the type of business or services of the Limited Liability Company
self-driving technology

8. Chief Executive Officer, if elected or appointed

a. First Name	Middle Name	Last Name	Suffix
John		Krafcik	

b. Address	City (no abbreviations)	State	Zip Code
1600 Amphitheatre Parkway	Mountain View	CA	94043

9. The information contained herein, including any attachments, is true and correct.

Date	Type or Print Name of Person Completing the Form	Title	Signature
2/22/2017	Christine Flores	Asst. Sec.	[signature]

Return Address (Optional) (For communication from the Secretary of State related to this document, or if purchasing a copy of the filed document enter the name of a person or company and the mailing address. This information will become public when filed. SEE INSTRUCTIONS BEFORE COMPLETING.)

Name:
Company:
Address:
City/State/Zip:

I hereby certify that the foregoing transcript of 1 page(s) is a full, true and correct copy of the original record in the custody of the California Secretary of State's office.

FEB 23 2017

Date: ____________

ALEX PADILLA, Secretary of State