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Cruise Safety Report

2022

In 2022, Cruise took a small but historic step toward a driverless future by offering our first fully driverless ride to public passengers in San Francisco. This was the culmination of years of focus, intention, design, and execution; and with each passing day, we continue to expand our driverless capabilities and performance to tap into the true potential of our Cruise technology.

At Cruise, we believe that the potential societal benefits of Autonomous Vehicles (AVs) will be realized according to the scale of deployment. Upon the initial deployment of our driverless service, our AVs produced incremental benefits to transportation safety. We believe as we continue to expand into a full-scale, mature deployment, that the Cruise Driverless Fleet will yield proportional benefits to transportation safety and the communities we serve at large.

Our approach to achieving this objective responsibly is to start small, learn quickly, and scale over time. This Safety Report lays out the foundations for safely providing a driverless service on public roads. We based our decision to launch using a framework inspired by safety findings across multiple industries and engineering disciplines, and supplemented with hundreds of thousands of engineering-hours and millions of miles of on-road testing.

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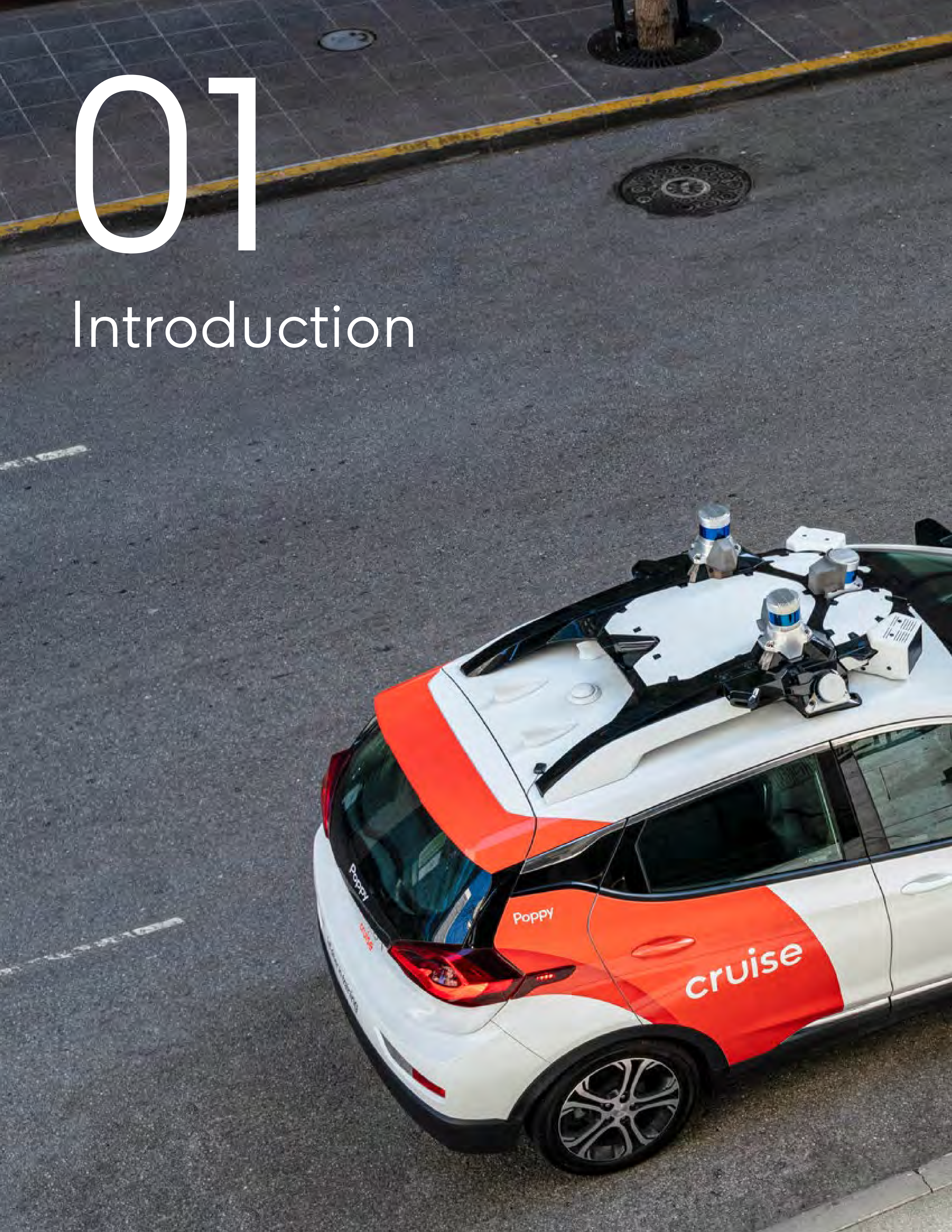
01 Introduction



At Cruise, safety is our north star. We hope that this Safety Report illustrates the depth of our commitment to safety. Our passengers, communities, and regulators can trust that the frameworks and processes defined in this Safety Report are embodied in every Cruise AV and Cruise Origin they encounter on the road. Together, we will drive forward to a safer future.

By leveraging the synergistic partnership between Cruise's state-of-the-art expertise in autonomous driving systems and General Motors' 100 years of safety and vehicle development expertise as an original equipment manufacturer (OEM), Cruise and GM have implemented an integrated approach to autonomous vehicle development.

Our autonomous driving ecosystem harmoniously integrates three key elements: the base vehicle, our unique driverless technology, and operational controls. We started our driverless service with the Cruise AV, a fully-integrated autonomous vehicle derived from the Chevy Bolt EV platform, and will apply the same safety technology and methodologies to the next generation of purpose-built Cruise Origins.

Through this Safety Report, Cruise and GM strive to further educate the public and garner their trust by laying out the details of our safety approach. We encourage the public to examine this report, ask questions, and engage in active dialogue to promote driverless safety.

1.1 Safety Mission and Safety Claim

Today's transportation status quo is broken. In 2021, 42,915 people lost their lives on U.S. roads — the highest loss of life in nearly 15 years — with worrying increases in impaired driving, distracted driving, and pedestrian and cyclist deaths. Additionally, over 2 million people are injured every year in motor vehicle collisions.[1]

Meanwhile, a rapid transition to electric vehicles will help significantly reduce carbon emissions across the United States and help make a significant impact on climate change and the avoidable health impacts that may particularly affect low-income communities and communities of color. Lastly, the design of our transportation system is fundamentally inequitable, inaccessible, and exclusionary, with 26% of Americans identifying as having a disability and many experiencing transportation as their single largest barrier in their daily lives.

These structural issues highlight the urgent need to reimagine how we collectively approach transportation. And the salience of this need has never been higher — U.S. Department of Transportation Secretary Pete Buttigieg starkly laid out this reality in October 2022, stating: **"We live in an era when it is safer to fly in an airplane 30,000 feet above the ground than it is to walk down the street."**[2]

Driving is not a zero-risk activity, as evidenced by transportation safety statistics and observed by Secretary Buttigieg. Cruise models our safety thinking across many established industries with safety-critical technologies, including aviation operation. The Safety Management System (SMS) framework is a tried and true system safety methodology leveraged by aviation operators to achieve state-of-the-art safety performance. Identifying, characterizing, and managing the exposure of systems or operations to safety risks that may result in injury or harm is a key aspect to achieving systematic safety in any safety context. Risk management is key to achieving broader systems safety.[3] Cruise's driverless service of autonomous vehicles provides the opportunity for Cruise to manage driving risks systematically.

42,915

total US road deaths in 2021

26%

Americans identifying as having disability

To meaningfully improve on the current state of transportation safety with utmost focus and expediency, Cruise has defined a Safety Mission and Safety Claim to guide our approach:

Our **Safety Mission** is to responsibly deploy the world's most advanced driverless service, and safely connect the communities we serve to the places, things, and experiences they care about.

Our **Safety Claim** is that we achieve this Safety Mission by identifying and classifying the safety risks of operating a driverless service and mitigating them to acceptable levels.

Cruise achieves this Safety Claim through 5 core actions:

01

Promote Safety
Build a company-wide Safety Management System to develop a robust safety culture in which employees can report safety concerns without fear of retaliation. Establish safety as the overriding priority for the company and its driverless operations. Make critical and timely safety decisions using an established risk assessment and execution framework.

02

Build Up Capabilities
Start small and expand as we observe performance improvements.

03

Drive Down Risks
Identify, catalog, characterize, prioritize, and minimize the safety risks that may emerge in our driverless operations.

04

Iterate Quickly
Develop a continuous feedback loop throughout our Cruise AV's development life cycle and throughout our driverless operations. Apply findings to our systems and processes to iterate efficiently, incorporate improvements, and maintain safety.

05

Respond Live
Provide live support during driverless operations to ensure safe and swift response to on-road events.

1.2 Continuous Evolution of the Safety Report

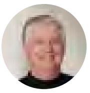
This Safety Report outlines Cruise's holistic approach to safely and responsibly deploying our driverless service.

To ensure that our safety approach is thoughtful, reasonable, and state-of-the-art, Cruise has established an Independent Review Board composed of experts from automotive safety, aviation safety, and academia.

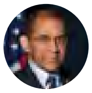
The members of our Independent Safety Review Board are:

Azad Madni
Ph.D., University Professor and Director of Systems Architecting in Engineering, University of Southern California

Carol Flannagan
Ph.D., Research associate professor in University of Michigan Transportation Research Institute Biosciences Group, Director of Center for the Management of Information for Safe and Sustainable Transportation ("CMISST")



Charles Justiz
Ph.D., Founder and Managing Director of JFA Inc., former NASA Aviation Safety Chief



Christopher Hart
J.D., M.S.E., Former Chairman of NTSB, Founder of Hart Solutions LLC

These Review Board members provide an independent, external perspective on our programs, processes, and procedures to evaluate and inform our approach to safety.

[1]National Highway Traffic Safety Administration. "Traffic Safety Facts Annual Report Table". National Statistics. June 2022. https://cdan.nhtsa.gov/tsftables/National%20Statistics.pdf.

[2]U.S. Department of Transportation. "U.S. Department of Transportation Marks the Start of National Pedestrian Safety Month, Stresses the Need to Protect Vulnerable Road Users." October 3, 2022. https://www.transportation.gov/briefing-room/us-department-transportation-marks-start-national-pedestrian-safety-month-stresses.

[3]From the context of a driverless transportation service, system risks are not limited to product defects. The vast majority of road collisions today are caused by external elements such as exposure to inclement weather or driver distraction, rather than product defects in the vehicle driven.

02
Safety Philosophy

Cruise's Safety Philosophy is based on findings from the current state-of-the-art in safety thinking, which informs our tailored approach to safety.

We begin by acknowledging the state of transportation safety, and the safety thinking and standards currently present in the AV industry. We highlight the potential benefits of driverless technology by highlighting the fundamental differences between human and autonomous driving.

Finally, we outline our Build-Up approach of starting small, and expanding; our Drive-Down approach of identifying safety risks and applying appropriate mitigations; and our Safety Management System that sets the stage for safety culture and decision making at Cruise.

2.1 Current State of Transportation Safety

Evolution in vehicle design and the adoption of driving regulations have positively impacted transportation safety trends throughout the hundred years span of the automotive industry. However, safe driving performance has been limited by inexperienced or poor drivers who perform the driving task with varying degrees of proficiency.

While researchers may disagree on the contribution of human driver errors to collisions, there is no ambiguity that human driving mistakes are one of the most substantial factors causing roadway injuries and deaths:[4,5,6]

38,824
total US road deaths in 2020

42,915
total US road deaths in 2021

13% & 5% increase
in pedestrian and pedalcyclists deaths respectively in 2021

5% increase
in police-reported drunk-driving fatalities in 2021[7]

5% increase
in speeding-related deaths in 2021*

3% increase
in fatalities involving unrestrained occupants in 2021*

>3,142
deaths due to distracted driving in 2020

633
deaths from fatigued driving crashes in 2020

Many of these lives are lost to the least controllable safety factor in each vehicle: the human driver. Cruise rigorously engineers safety into our autonomous driving technology, just as automotive safety technology was engineered and improved over time. We offer the prospect of greatly reducing human driver errors on the road, thereby reducing the dangerous situations, on-road collisions, and harm that result from these errors.

2.2 Human vs Autonomous Driving

Cruise envisions using our autonomous driving technology to make a positive impact on transportation safety in the following ways:

Safety Factor	Automobile Status Quo	Cruise AV Capability
Speeding	• Speeding was a contributing factor in 11,258, or 27%, of all traffic fatalities in 2020; up 17% from 2019.[8] Speeding-related fatalities continued to grow in 2021, increasing 5%.	• Cruise AVs are designed to obey speed limits and other road traffic rules.
Distraction	• Distraction-affected crashes led to 3,142 traffic fatalities in 2020, 8.1% of the total.[9]	• Cruise AVs cannot be distracted.
Impairment	• Alcohol-impaired fatalities totaled 11,654 in 2020 - 30% of traffic fatalities that year.[10] This represents a 14% jump from 2019 year over year, with a 5% increase reported year over year in 2021 as well. • Approx. half of US drivers admit to getting behind the wheel while tired.[11]	• Cruise AVs cannot be substance-impaired or fatigued.

Safety Factor	Automobile Status Quo	Cruise AV Capability
ODD Handling	• Human drivers drive in all driving conditions (whether or not they are capable of handling the driving conditions).	• Cruise defines a catalog of driving conditions and measures Cruise AV performance to determine whether the AV is capable of safely handling such conditions. • Controlled Cruise Driverless Fleet operations in ODD ensures that the Cruise AV only operates in conditions that it is designed to handle. • Cruise AVs accommodate limitations in constrained driving conditions with alternative behaviors, such as identifying an alternative driving route in advance.
Unmatched Potential for Improvements in Driving Capability	• Physiological caps to driving capabilities, such as field of view or reaction time. • Driving capability varies significantly by individual human driver.	• Cruise continuously improves and upgrades hardware components that affect driving capabilities, such as sensors that affect object detection, computes that affect processing time, and actuators that affect vehicle maneuverability. • Cruise continuously improves and matures driving scenarios and AV driving behaviors. • Driving capability is uniform across Driverless AVs operating in the production fleets within a defined ODD.

Safety Factor	Automobile Status Quo	Cruise AV Capability
Fleet-wide driving capabilities and controls	• Each driver has a learning curve driven by individual experience (e.g., teen drivers are more likely to crash than older, experienced drivers).[12] • In the US, the fatal crash rate per mile for 16-19 year-olds is nearly three times the rate for drivers aged 20 and over.[13] • Limited information sharing between drivers.	• Cruise AVs operate using standardized hardware and software. • Cruise AVs exhibit uniform driving behavior across the fleet. • Cruise AVs share real-time information across the Driverless Fleet. • If needed, Cruise has the ability to control and ground the entire Driverless Fleet.
Vehicle Upkeep and Maintenance	• Individuals must recognize and respond to maintenance indicators, e.g., "check engine" lights, tire pressure, etc. • Limited to no oversight (more than half of states do not require periodic safety inspections[14]). • More than 55 million vehicles and motor vehicle equipment were impacted by vehicle safety recalls in 2020. 25% go unrepaired.[15]	• Cruise conducts regular fleet inspections to ensure Cruise AVs are operation ready. • Trained professionals perform regular service and maintenance checks on every Cruise AV. • Cruise AVs are built with automatic behavioral responses (e.g., pulling over) upon detecting and confirming issues with the autonomous systems. • Centralized fleet operation ensures safety recall repairs, if any, are completed for all Cruise AVs.
Occupant Protection	• 45.7% of passenger vehicle occupant fatalities were unbelted in 2020, with occupant ejection-related fatalities up 21% from 2019.[16] The trend of unrestrained occupant fatalities continued to grow in 2021, increasing by 3%.	• Cruise rides are designed to help enforce proper seat belt usage prior to starting the ride.[17] • Cruise AVs feature sensors for each seating position that can detect and notify passengers when their belt is not buckled.

2.3 Autonomous Vehicle Standards

While there are many standards that apply to elements of the AV industry, there is no singularly accepted framework or definition to measure the safe operations of an AV.[18] Additionally, Cruise believes that while existing standards provide helpful guidance, a direct and literal application of all existing standards would not be sufficient for achieving a safe driverless service in a complex and dynamic operating environment. As an alternative, Cruise has drawn from best practices across multiple industries to develop a multi-layered approach to safety, designed to encompass principles from several authoritative standards in parallel with our own real-world findings.

2.3.1 Society of Automotive Engineers - Levels of Autonomy

The Society of Automotive Engineers (SAE) has produced some of the most commonly known automotive safety standards. Under the SAE's levels of autonomy framework,[19] **Cruise's driverless system is an SAE L4 high automation system**; that is, it requires no input from a human driver within its Operational Design Domain (ODD) to perform the Dynamic Driving Task (DDT) or to achieve a Minimal Risk Condition (MRC) in the event of a failure or ODD exit of the driverless system.

- 05 Full automation
- 04 **High automation**
- 03 Conditional automation
- 02 Partial automation
- 01 Driver assistance
- 00 No automation

2.3.2 ISO 26262 and ISO/PAS 21448

Certain automotive industry standards, such as ISO 26262[20] and ISO/PAS 21448,[21] are a common focus of AV safety discussions. ISO 26262 focuses on mitigating failure risk, and ISO/PAS 21448 focuses on assuring the safety of nominal performance, identifying unknown hazards, and mitigating foreseeable system misuse. Cruise has adopted the broad principles of these standards, such as risk evaluation, integrity levels, identification of foreseeable misuse, and eradication of unreasonable risk to our application and technology.[22]

2.3.3 NHTSA's 12 Safety Elements

Cruise has incorporated the goals and vision of the National Highway Traffic Safety Administration (NHTSA) guidelines into our safety approach, with special attention to the twelve elements of safety highlighted by NHTSA in AV 2.0. We have also pursued ongoing interactions and engagement with regulators on our approach to vehicle and systems safety.[23]

The table below highlights the sections in which this report describes Cruise's approach for each of NHTSA's 12 Safety Elements.

NHTSA Elements of Safety	Safety Report Topic
System Safety	• Operational Design Domain • Safety Approaches • High Level Architecture and System Design • Requirements Management • Release Process Overview • Hardware and Firmware Verification • Supporting System Verification • Test Scenario Development • Alternative Verification Methods • Immersive Incident Exercises

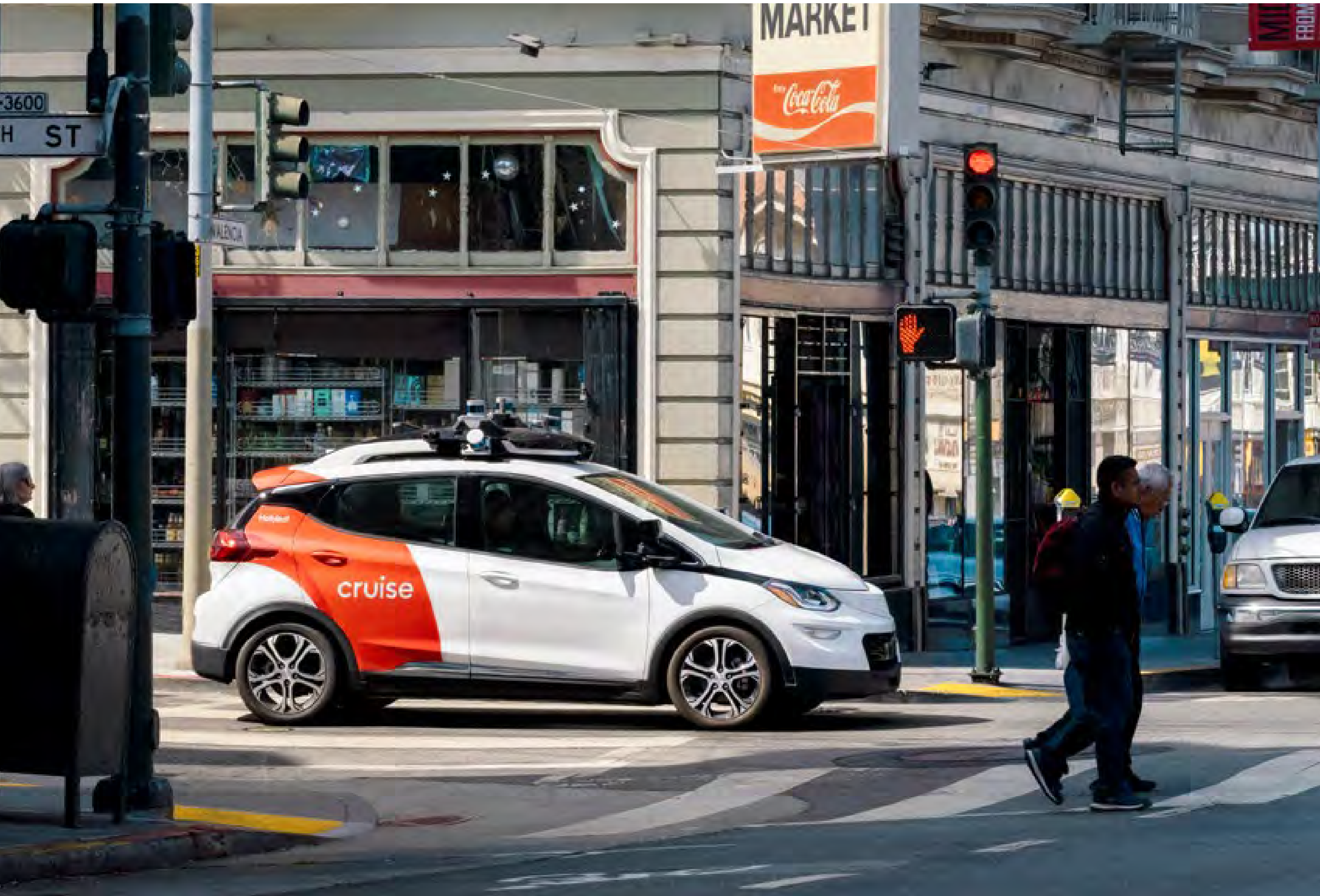
NHTSA Elements of Safety	Safety Report Topic
Operational Design Domain	• Operational Design Domain
Object and Event Detection and Response	• High Level Architecture and System Design • Test Scenario Development • Live Incident Response • Incident Response Scenarios • Appendix D: Actors and Systems
Fallback (Minimal Risk Condition)	• High Level Architecture and System Design • Incident Response Scenarios
Validation Methods	• Release Process Overview • Hardware and Firmware Verification • Supporting System Verification • Test Scenario Development • Alternative Verification Methods • Immersive Incident Exercises
Human Machine Interface	• Safety Approaches • Supporting System Verification • Operational Readiness • Passenger Education • Multi-Way Communications • Fleet Monitors • Remote Operators • In-Person Operators • Live Incident Response • First Responder Interaction • Fleet Actions

NHTSA Elements of Safety	Safety Report Topic
Vehicle Cybersecurity	• High Level Architecture and System Design • Incident Response Scenarios
Crashworthiness	• Safety Approaches
Post-Crash ADS Behavior	• High Level Architecture and System Design • Inspections and Deployment • Fleet Monitors • Remote Operators • In-Person Operators • First Responder Interaction • Incident Response Scenarios • Feedback Loops
Data Recording	• Feedback Loops
Consumer Education and Training	• Operational Readiness • Passenger Ridehail Policy • Passenger Education • Multi-Way Communications • First Responder Interaction • Feedback Loops
Federal, State, and Local Laws	• Regulatory Requirements

2.3.4 UL 4600

Beyond NHTSA and ISO, other entities have attempted to design AV safety standards, including Underwriters Laboratories (UL) and Edge Case Research — both of which have recommended UL 4600[24] as a means to assess AV safety. This standard was meant to encompass AVs and other applications, and uses a novel claim-based approach which prescribes topics that must be addressed in creating a safety case.

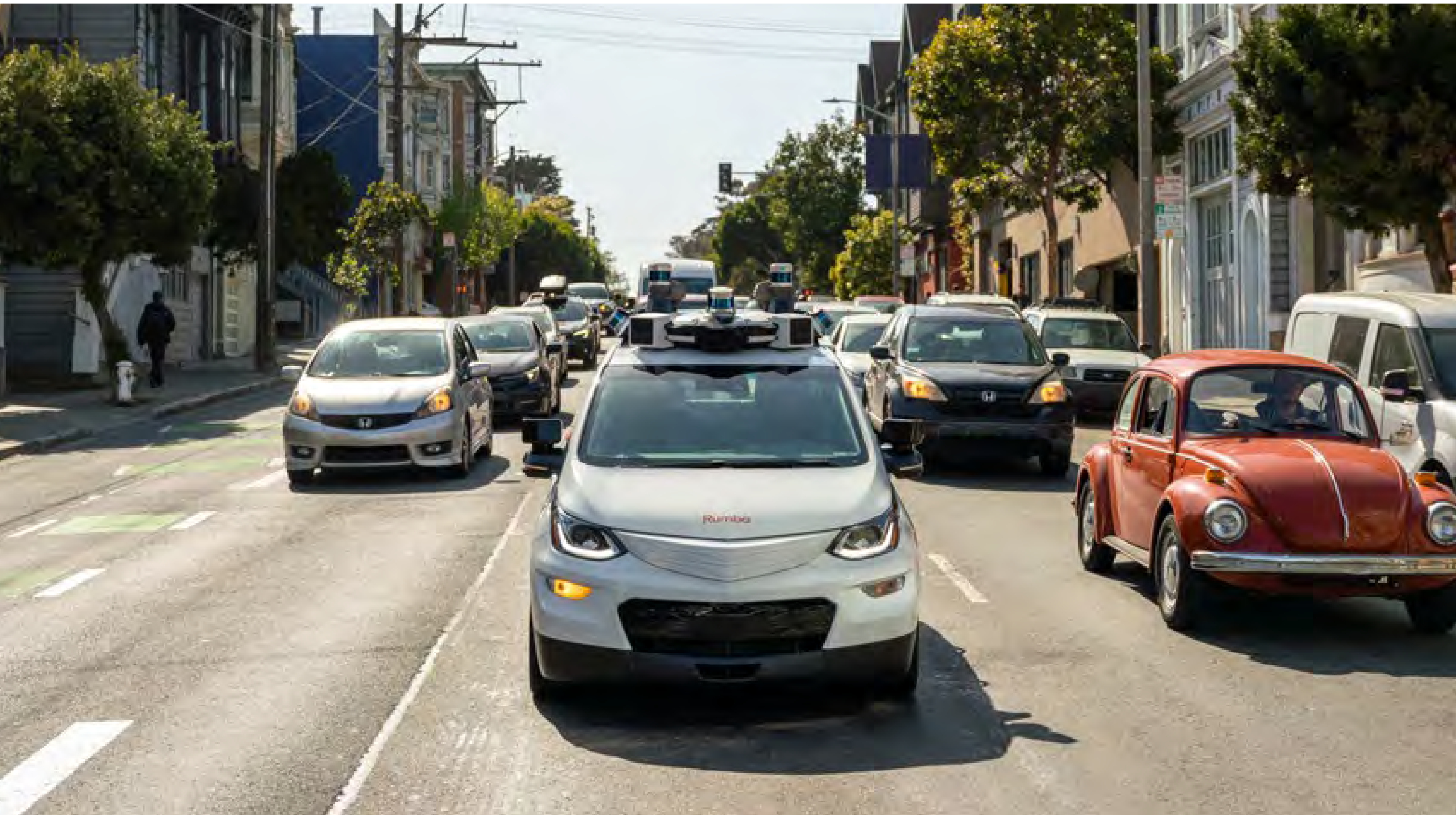
However, UL 4600 does not prescribe performance criteria or define pass/fail criteria for safety; instead it seeks to characterize how safe performance and intended behaviors are achieved based on AV health state and the dynamic operating environment.[25] Cruise has applied relevant elements of the standard in our approach.



2.4 Build-Up Approach

To achieve Cruise's safety mission of safely and responsibly deploying a driverless service, we start small and learn quickly to expand our capabilities over time. Through this approach, Cruise contains the risks that we have not yet encountered, characterized, or mitigated to a reduced level of operational exposure, while rapidly learning and iterating our driverless systems before we expand to scale.

The Build-Up Approach, otherwise known as envelope expansion, is a widely accepted means for improving the confidence and certainty of safe operation. **Put simply, our Build-Up approach starts with lower risk conditions and expands risk parameters as we achieve and maintain performance targets. This approach is common in aerospace, the medical device industry, and other safety-critical industries.**[26]



We have applied the Build-Up approach to several operational variables:

Constraint Types	Example Constraint Tiers
Geofence Constraints	Fixed route driving Limited geofence driving Expanded geofence driving Full geofence driving
Operational Hour Constraints	Low traffic hours Expanded traffic hours Full operational hours (i.e. 24/7)
Passenger Constraints	Test Operators No Passengers Internal Employee Passengers Public Passengers
Fleet Size Constraints	Single Driverless AV Operations Pilot Fleet (e.g., 10-15 Driverless AVs) Limited Fleet (e.g., 50+ Driverless AVs) Commercial Fleet (e.g., 500+ Driverless AVs)

Cruise has methodically controlled the expansion of our exposure to new risk profiles by leveraging the Build-Up Approach, which applies the principles of safety risk management,[27] and gates expansion decisions on detailed operational readiness meetings called Launch Readiness Reviews (LRR).[28]

2.5 Safety Management System

Cruise's Safety Management System (SMS) provides a systematic approach to ensure that responsible safety decisions are made throughout Cruise's product development and driverless operations processes.

SMS is an established safety framework required in safety-critical industries such as aviation operations and nuclear energy. It is also commonly implemented in the Oil & Gas industry, as well as military applications, because of its effectiveness in achieving meaningful safety improvements and sustaining overall safety performance. A core principle of SMS is to assign any safety-related decision to the people who are accountable for the safety outcomes of the decision; and control the resources used to manage that risk. Such resources can include engineering resources to build new features or improve on existing ones; or operational resources to control the hours or scale of operation. Safety risks are managed through characterization, and subsequent acceptance, reduction, or elimination.

At Cruise, every employee has a role to play in contributing to the SMS.

- A chief executive provides the highest level of organizational ownership of SMS.
- Senior leadership promotes SMS and participates in SMS processes. Several layers of management manage risks at their respective levels.
- Individual contributors act as subject matter experts to help characterize risks and identify potential mitigations.
- A dedicated SMS team provides guidance on SMS processes to ensure that risk ownership and risk resolution are performed consistently and according to clearly defined safety policies.

By embedding safety ownership into cross-functional roles and responsibilities, Cruise's SMS empowers each Cruise employee to integrate safety into their everyday activities. This ensures that a positive company-wide safety culture is well-established and continuously enhanced.[29]

Cruise's SMS consists of four core pillars:

01 Safety Policy

Safety Policy refers to a company's documented plans for establishing and maintaining a highly functional safety culture. This is achieved by identifying our safety values, defining our company-wide safety commitments, outlining our safety expectations of employees and stakeholders, and highlighting the resources available to our employees to effectively fulfill their SMS responsibilities. At Cruise, the Chief Operations Officer (COO) is assigned as Accountable Executive for the success of the SMS, and is also responsible for safety decisions comprising the highest risk. Additionally, every Cruise employee is empowered to provide insight and visibility into any potential safety concerns through the Safety Information Reporting & Escalation Network (SIREN) or Compliance Assurance Reporting System (CARS) reporting platforms.

02 Safety Risk Management

Safety Risk Management refers to the systematic identification, evaluation, and mitigation of the potential risks present in a system in its defined ODD, so that any such risks are known, cataloged, and sufficiently reduced to acceptable levels or eliminated outright. Inputs to Safety Risk Management include safety analyses processes such as Systems Theoretic Process Analyses; simulation and closed-course test results; inputs and risk assessments through reporting platforms like SIREN and CARS; and data from on-road events in supervised and driverless operations. Cruise has established a special safety-focused risk governance organization called the "Safety Council" which has authority to address potential safety-related risks including mitigation measures, with the opportunity to escalate to the Accountable Executive as necessary.

03 Safety Assurance

Safety Assurance refers to the measurement of safety risk controls. Safety Assurance characterizes the appropriateness and efficacy of risk mitigation actions that have taken place to further the company's safety objectives. This includes the design and implementation of Safety Performance Indicator metrics (SPIs), such as the time it takes for Cruise to respond to and mitigate a raised safety concern, that are regularly monitored as measurements of our SMS success. To further invest in our SMS, Cruise has worked with third party SMS experts to audit our existing systems. The audit has acknowledged our key areas of strength– namely our strong safety culture and management commitment to safety, as well as our dedicated and experienced team of SMS experts in-house– while providing us with insights into improvement opportunities, such as improved documentation management.

04 Safety Promotion

Safety Promotion refers to the promotion of a strong safety culture at an organization. At Cruise, this is achieved through a number of techniques. Cruise leadership regularly communicate their vocal support for SMS and safety in All Hands meetings and company emails. A dedicated safety and SMS course is part of Cruise employees' annual compliance training. Psychological safety, or the principle that employees can freely share safety concerns without fearing negative consequences, is regularly promoted as a company value (#staysafe). Through such initiatives, training, and communications, Cruise empowers each individual to be an active agent of safety.

In sum, Cruise leverages our SMS as a powerful tool to manage potential safety risks and help maintain safety. Cruise is committed to developing, implementing, and continuously improving our SMS strategies, systems, and processes so that each action and decision made by Cruise leaders and employees reflects our safety values.

[4]National Highway Traffic Safety Administration. (2022, March). Overview of Motor Vehicle Crashes in 2020. NHTSA Traffic Safety Facts Annual Report. https://crashstats.nhtsa.dot.gov/Api/Public/ ViewPublication/813266. National Highway Traffic Safety Administration. (2022, April). Early Estimate of Motor Vehicle Fatalities in 2021. https://crashstats.nhtsa.dot.gov/Api/Public/ ViewPublication/813283.

[5]National Highway Traffic Safety Administration. (2022, April). Early Estimate of Motor Vehicle Fatalities in 2021. https://crashstats.nhtsa.dot.gov/Api/Public/ ViewPublication/813283.

[6]National Highway Traffic Safety Administration. (2022, May). Early Estimates of Motor Vehicle Traffic Fatalities and Fatality Rate by Sub-Categories in 2021. https://crashstats.nhtsa.dot.gov/Api/Public/ ViewPublication/813298.

[7]Denotes 2021 annual fatality total for this category is still higher than pre-pandemic levels of 2019.

[8]Id.

[9]National Highway Traffic Safety Administration. (2020, December). Overview of the 2019 Crash Investigation Sampling System. NHTSA. https://crashstats.nhtsa.dot.gov/Api/Public/ ViewPublication/813060.pdf. =

[10]Id.

[11]National Safety Council. (2020). Drivers are Falling Asleep Behind the Wheel. NSC. https://www.nsc.org/road-safety/safety-topics/fatigued-driving#:%7E:text=According%20to%20the%20National%20Sleep,once%20in%20their%20driving%20careers.

[12]National Highway Traffic Safety Administration. (2020, October). 2018 Data: Young Drivers. NHTSA. https://crashstats.nhtsa.dot.gov/Api/Public/ ViewPublication/812968.

[13]Insurance Institute for Highway Safety. (2021, March). Fatality Facts 2019 - Teenagers. NHTSA. IIHS.org/topics/fatality-statistics/detail/teenagers#population-and-mileage-rates.

[14]AAA. (2021). Safety Inspection. AAA Digest of Motor Laws. https://drivinglaws.aaa.com/tag/safety-inspection/.

[15]National Highway Traffic Safety Administration. (2021). Vehicle Safety Recalls Week. NHTSA. https://www.nhtsa.gov/recalls/vehicle-safety-recalls-week.

[16]Id.

[17]Ride start is based on weight sensors and buckling sensors. Passengers can override for scenarios such as luggage triggering a weight sensor.

[18]NHTSA itself has noted that “[as] automated driving technologies evolve at a rapid pace, no single standard exists by which an entity’s methods of considering a safety design element can be measured.” Automated Driving Systems 2.0. A Vision for Safety at 7 Retrieved from https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/13069a-ads2.0_090617_v9a_tag.pdf.

[19]SAE International. (2021, April 30). Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. SAE. https://www.sae.org/standards/content/j3016_202104.

[20]International Organization for Standardization. (2018). Road vehicles — Functional safety — Part 1: Vocabulary (ISO Standard No. 26262-1). https://www.iso.org/standard/68383.html.

[21]International Organization for Standardization. (2019). Road vehicles — Safety of the intended functionality (ISO/PAS No. 21448). https://www.iso.org/standard/70939.html.

[22]See more details in Safety Approaches.

[23]General Motors. (2018). 2018 Self-Driving Safety Report (Published as a NHTSA Voluntary Safety Self Assessment). https://www.gm.com/content/dam/company/docs/us/en/gmcom/gmsafetyreport.pdf.

[24]Underwriters Laboratories. (2020). Standard for Safety for the Evaluation of Autonomous Products (UL4600). Retrieved from https://ul.org/UL4600.

[25]Id.

[26]In aerospace, new aircraft are initially limited to a conservative performance envelope. As the aircraft accumulates flight hours, the performance envelope is expanded slowly, following strict safety checks, until it reaches its full performance envelope.

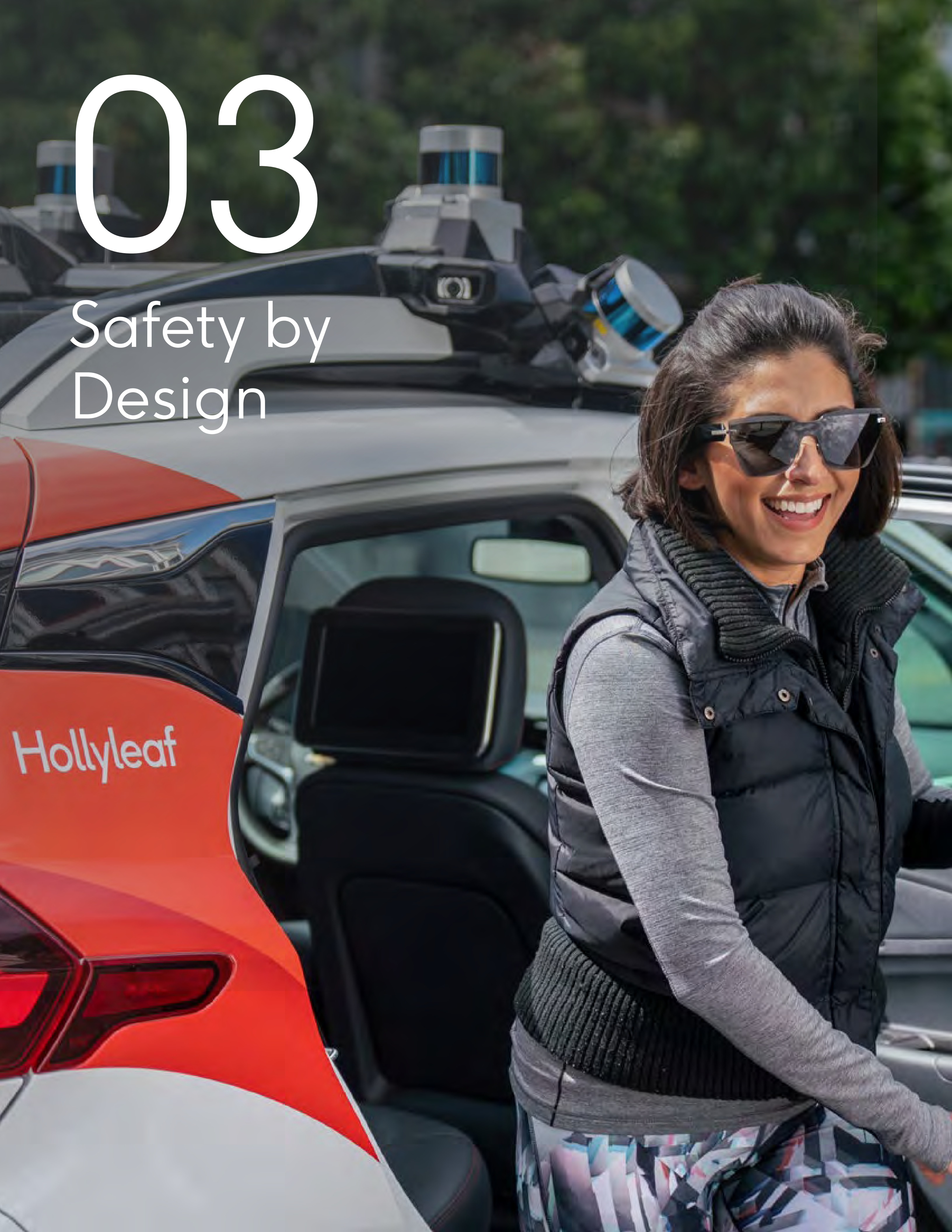
[27]See more details in Safety Management System.

[28]See more details in Launch Readiness Review.

[29]While an overview of the Cruise SMS framework is outlined in this Safety Report, specific processes, procedures, and best practices are captured in a Cruise SMS manual.

03

Safety by Design



We design Cruise AVs with safety in mind throughout the product development life cycle.

First, we identify the Operational Design Domain to specify the environment that our system and services are designed for. Then we derive regulatory requirements and safety approaches from a diverse set of sources and perspectives.

With these top-down inputs, we develop high-level designs and architectures using a requirements management process to trace stakeholder requirements to high-level architecture design and corresponding test documentation.

3.1 Operational Design Domain

As defined by SAE's Automated Vehicle Safety Consortium (AVSC), an Operational Design Domain (ODD) refers to the "Operating conditions under which a given driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics."[30]

As a first step to designing the Cruise AV's safety approach, Cruise constrained its Driverless Fleet to specific locations, conditions, or hours until we determined that our Driverless AVs met defined performance thresholds in expanded locations and conditions.

Cruise chose San Francisco as its first representative location for commercial operations because the dense, complex urban environment of the city provided a highly challenging yet efficient method of learning quickly and expanding capabilities that are needed for future commercial locations.

To ensure that driverless operation was accomplished safely, Cruise placed operational limits on its driverless operations while testing, enhancing, and improving its capabilities in a Limited Operational Design Domain (LODD). The LODD was iteratively expanded to include areas, hours, and conditions in which the Cruise AV fleet demonstrated its ability to operate safely with initial operator supervision.[31]

The Cruise AV has been optimally designed to operate within its specific ODD. If the Cruise AV detects that it has exited the bounds of its ODD, it is designed to transition out of the DDT to achieve an MRC, i.e., perform a driving maneuver that will allow it to reach a safe, low-risk state.

The Cruise AV is designed with the following ODD controls in place:

1. Avoid exiting the ODD through the use of controllable factors, e.g., geofence, routing logic, speed limitations, operational practices, etc.[32]
2. Continuously monitor for ODD exit events for environmental conditions that cannot be avoided, e.g., weather conditions.
3. Upon detecting that it has exited its ODD, dynamically respond with the objective of achieving an MRC.[33]

3.1.1 ODD Enforcement

Cruise uses a number of mechanisms to constrain driverless operation to the defined ODD:

ODD Enforcement Mechanism	Controlled Category	Example Control[34]
Design Restrictions	Vehicle Speed, Special Maneuvers	The Cruise AV is designed to adhere to respective posted legal speed limits.
Geographical Considerations	Road Surface Conditions, Weather Conditions	San Francisco has a very low occurrence of snow, sleet, or dust storms.
Geofence	Boundary of operational domain (city, county)	The Cruise AV is designed to navigate to destinations within the defined geofence.
Operational Hours	Road Actors, Special Zones	Cruise is able to constrain operational hours to limit exposure to specific ODD elements, such as time-dependent lanes.

ODD Enforcement Mechanism	Controlled Category	Example Control[34]
Road Constraints[35]	Road Geometry, Roadway Types, Intersection Types, Special Lane Types	Cruise is able to apply road constraints to prevent the Cruise AV from encountering ODD elements that are initially restricted, such as roundabouts, highways, bridges, or roads with posted speed limits above the approved ODD.[36]
Operational Controls	Weather Conditions	Cruise is able to monitor live weather conditions and determine whether to deploy AVs for driverless operations; and during operations, whether to summon AVs to return to facility.
Exit ODD Response	Weather Conditions	The Cruise AV is designed to detect heavy rain or fog and pull out of traffic to a safe location.[37]

The combination of preventative mechanisms and detection-and-response mechanisms ensure that the Cruise Driverless Fleet operates within its designated ODD.

3.2 Regulatory Requirements

Regulatory requirements regulate the safe and responsible operation of vehicles on public roads. Regulatory requirements can include requirements on the vehicle build, such as crashworthiness and equipment requirements. They can also include rules of the road requirements for driving behaviors that are shared across the community of drivers, pedestrians, and other road users. Cruise navigates the federal, state, and local regulatory requirements in the US as a key part of designing and operating our Driverless Fleet.

For example, the fully-integrated Cruise AV built using the Chevy Bolt platform fully complies with all applicable Federal Motor Vehicle Safety Standards (FMVSS).[38] Safety and FMVSS standards have also guided the development of Cruise and GM's next-generation purpose-built vehicle, the Cruise Origin.[39]

Cruise also incorporates roadway regulations as critical inputs in our behavioral designs. Within the context of our San Francisco driverless operations, Cruise developed these behavioral designs[40] to comply with every applicable element of the California Vehicle Code (CVC) and San Francisco Transportation Code that relates to the rules of the road, except as necessary to enhance the safety of the vehicle's occupants or other road users as permitted by California law.[41] We update our designs as needed to reflect any updates or changes to the rules of the road and pertinent regulations.

Further, Cruise's mapping operations enable a robust method for tracking roadway designs and managing lawful behavior on road. Roadway features like traffic lights, stop signs, lane merges, and lane markings are embedded in the Cruise AV's high-definition (HD) map, and detected real time by its onboard perception systems, such that the Cruise AV anticipates, detects, and obeys them. Cruise's mapping operations team keep the HD map up-to-date using a combination of fully automated and human-assisted systems, so that our Driverless Fleet maintains current information on road markers and signals.[42]

Finally, we have designed our Cruise AVs and fleet operations to satisfy all AV-specific permitting requirements in the markets in which we operate.

For example, consistent with California permit requirements, we have trained and certified remote operators who are available to monitor our Cruise AV fleet at any time, communicate with the vehicles and any passengers or third parties, and assist in the event that remote assistance is needed.[43]

These permits also require Cruise to attest that we conducted testing and validation of our vehicles and reasonably determined that we are safe to operate on public roads in California.

The requirements of these AV permitting regimes guide our approach to safety and promote the safe operation of our vehicles on public roads.

3.3 Safety Approaches

Cruise applies safety considerations as we conceptualize the design and intended operations of the Cruise AV system within its ecosystem of supporting systems and operators.[44]

Because managing a fleet of Driverless AVs is highly complex, Cruise has taken a multi-pronged approach to build safety into each and every step of product development and driverless operation.

Cruise constructs a holistic safety approach across all aspects of AV development and operations, covering:

1. Safety of the Intended Function (SOTIF)
2. Functional Safety (FuSa)
3. Physical Safety/Crashworthiness
4. Passenger Safety
5. Operational Safety

We design the Cruise AV to exhibit safe driving behaviors in both nominal and contingency driving situations within its defined ODD. Cruise has broken down the problem of safe driving into the following steps:

- Apply a systems engineering approach to characterize the goals of our overall system and decompose them into corresponding system functions
- Measure our AV's driving performance in a low-risk setting, e.g., a supervised setting
- Identify an appropriate ODD and Operational Safety measures to contain the level of safety risk exposure
- Establish a feedback loop to transform unknown safety risks to known safety risks
- Derive and apply solutions to further contain safety risks to acceptable levels

This overall approach to systems safety is inspired by the SOTIF framework defined in ISO/PAS 21448.

Developing complex systems requires accounting for the various failure modes that emerge from our systems and subsystems. Cruise uses the methodologies of hazard analyses, failure analyses, and failure-resilient solutions such as redundancy and diagnostics to ensure that the AV retains its ability to achieve a safe state in the event of a failure. Our approach to functional safety has been inspired by the FuSa framework as defined by ISO 26262.

The Cruise AV is an integrated suite of host vehicle and autonomy technology hardware and software that is collectively capable of autonomous driving. This integration relies on GM's decades of experience in automotive safety to ensure that the Cruise AV is built to help protect occupants in crash scenarios. This integration also depends on our systematic identification and analysis of expected human-machine interfaces between the Cruise AV, our supporting systems, and our operators, passengers, and third-party actors to help ensure that each interaction takes place as designed.

Cruise leverages each safety framework to identify and manage potential safety risks present in our driverless operations.

3.3.1 Safety of the Intended Function (SOTIF)

SOTIF is a framework that identifies and mitigates unreasonably risky and potentially hazardous behaviors caused by system limitations. The SOTIF framework determines whether the system as designed and implemented is capable of performing adequately in its defined operational design domain.

In accordance with the SOTIF framework, we define the ODD[45] of our driverless service and validate our ability to safely handle ODD elements that are in scope. We also validate our ability to limit exposure to ODD elements that are out of scope.

We also design our system to be resilient to human interactions in the absence of in-person operator supervision, including interactions with passengers, malicious actors, or first responders. We regularly expose our driverless systems to real world driving scenarios using a combination of supervised on-road testing and extremely realistic simulations. We also target stressing scenarios that we may not easily encounter through mileage accumulation to discover any unknown edge cases that may result in hazardous driving behavior.

Many of Cruise's known driving scenarios are captured in our high level design documents, such as the ODD, Concept of Operations (ConOps), and behavioral designs,[46] which inform our approach to test scenario coverage.[47] Our methodology of accounting for unknown use cases is built into our Build-Up Approach,[48] using a tightly controlled ODD with iterative expansions as we increase functionalities or improve performance;[49] and is also built into our release process[50] and continuous feedback loops,[51] which provide a continuous iteration cycle that allows Cruise to convert unknown use cases into an expanding knowledge base of known use cases over time.

3.3.2 Functional Safety (FuSa)

FuSa is a framework that identifies and mitigates safety hazards due to electrical and electronic-based malfunctions. The FuSa framework provides a methodical approach to identifying failure modes and corresponding hazards resulting from respective failures, such that each system, subsystem, and component is developed with appropriate measures of failure detection and failure mitigation, e.g., failure resilience.

Cruise applies elements of FuSa that are well suited for our application, such as risk evaluation and assignment of integrity levels during our electronic hardware development, verification, and validation processes.[52] A key differentiating factor that has informed our approach to functional safety and design is GM's decades of experience in component and functional testing. Our partnership with GM allows us to build on a robust foundation of established vehicle safety improvement processes that integrate deeply throughout the AV development process.

Notably, the FuSa framework is focused on the deterministic electronic component domain. The application of the FuSa framework for aspects of our system that are based on probabilistic functions, such as our perception and prediction software, is still under exploration. ISO 26262 makes the foundational assumption of the presence of a human driver in its framework,[53] which limits its application to non-deterministic functions traditionally performed by the human driver.

For the system applications which do benefit from a direct FuSa application, Cruise applies two key design principles: fail operation and health monitoring.

Cruise designs all critical systems with redundancy, including computers, brakes, sensors, and power systems, such that the Cruise AV retains sufficient safety performance in the event of plausible single-point hardware or software failures. This design, alongside the Cruise AV's robust diagnostics system that monitors vehicle health under various conditions, employs established safety design principles from the automotive sector.

Upon detection of a system malfunction, the Cruise AV either switches to a backup system or performs a maneuver to achieve an MRC.[54] Diagnostic areas span all functions that are safety critical and that need fault detection to enable Degraded State (DS) functionality.[55]

3.3.3 Occupant Protection and Crashworthiness

While Cruise strives to avoid collisions altogether where possible, Cruise and GM have designed an AV that minimizes the risk of occupant injury in the event of a collision. Our Driverless AVs meet or exceed NHTSA's applicable crashworthiness and occupant protection standards.

Built upon GM's decades of experience in crash safety and occupant protection, our current fleet of Cruise AVs is built on a Chevy Bolt vehicle platform with a five-star safety rating in the US New Car Assessment Program (NCAP).[56] This NCAP rating incorporates frontal crash testing, side crash testing and a rollover resistance test that measures the risk of rollover in a single-vehicle, loss-of-control scenario.

The base vehicle platform also has a "good rating" in connection with the following Insurance Institute of Highway Safety (IIHS) tests:

- Moderate overlap front test results
- Side impact test results
- Rear crash protection results
- Roof strength test results
- Small overlap front driver test results
- Front crash prevention results[57]

The unique hardware necessary for driverless operations was added to the Chevy Bolt vehicle platform and accompanied with targeted testing to preserve the same level of crashworthiness and occupant protection performance.[58]

Timely rescue can also greatly reduce the chance of fatality after a severe crash.[59] The Cruise AV is equipped with GM's state-of-the-art emergency assistance call system. Specific emergency events, such as a crash that triggers airbags or seat belt pretensioners, will automatically trigger a voice call with specialists trained in emergency assistance.[60]

3.3.4 Passenger Safety

In addition to occupant protection and crashworthiness, our driverless service is designed with the passenger in mind. Each scenario involving passenger interaction with the Driverless AV is characterized in high-level design documentation,[61] and are accompanied with hazard analyses that consider possible use and misuse scenarios that may result in passenger harm and injury. This includes nominal interaction scenarios, such as picking up and dropping off a passenger at their requested destination, or passenger requests for ending their ride early. This also includes contingency scenarios such as attempts to tamper or interruptions to a passenger ride.

Our Driverless AVs feature an in-vehicle touchscreen to instruct passengers, caution passengers to be careful, or provide live information about their trip; and in-vehicle and in-app buttons that allow the passenger to reach out to Customer Support or request an early end to their trip.[62] Cruise has designed the driving and interaction functions of the driverless service to promote a safe passenger experience in any situation the passenger may encounter.

3.3.5 Operational Safety

Cruise's driverless service is supported by a network of human operators, and we design our supporting systems with operational safety elements in mind, including human factors, safety and quality management, fleet risk monitoring and controls, and emergency preparedness.

Understanding the role of human factors in crash causation and designing to reduce risk of human error are essential for a human-supported driverless service. For any safety critical process or interface involving a human operator, Cruise assesses the defining characteristics of a human operator task, such as mental load, required equipment and interfaces, and potential for errors.

We also use Systems Theoretic Process Analyses (STPAs) on select operator activities and tools requiring in-depth systematic human-machine interface analysis due to the level of operational complexity and risk present in the interaction. We use this information to develop safety and operational requirements that our engineering and operations teams integrate into interface tools, training, and processes.[63]

Equally important to safe system design are the processes that ensure that our operators are trained and well-equipped to perform their functions. This includes training and certifications, process and documentation change management, and supporting system designs with clear communication of situational context.[64]

Cruise uses a combination of automated and operator-initiated risk monitoring to ensure that the risks that we encounter during driverless operations are escalated, addressed, and mitigated appropriately. This includes the fleet monitoring system used by our operators to observe fleet health and receive incident notifications;[65] operator escalations of observed safety issues across R&D and production fleets;[66] and fleet actions that our operators are able to perform in order to immediately mitigate and contain risks to an appropriate level.[67]

Finally, Cruise provides special training to operators who interact with first responders, such as Customer Support, Incident Experts, and Field Support Representatives,[67] to prepare operators for emergency response. Additionally, Cruise performs immersive incident exercises to prepare operators, engineers, and key decision makers for a possible high-severity incident,[68] which begins with the initial detection and containment of an event, to longer-term investigations and mitigations of safety risks. These training and exercise programs allow Cruise to be response-ready and to improve our operational responses to any potential high-severity incidents.

3.4 High Level Architecture and System Design

Cruise uses established design practices to ensure the proper design and validation of our Driverless AV's intended functions. In particular, Cruise uses enterprise-level design documents such as ConOps and behavioral designs to create a direct and traceable link between top-level stakeholder requirements and high level system design.[70]

3.4.1 Concept of Operations

Cruise has developed ConOps based on the NASA Systems Engineering[71] framework to characterize system interactions and responses across various scenarios the Driverless AV may encounter during driverless operations.

ConOps identify a triggering event (e.g., collision detection) and outline the various actors and systems that take actions or perform functions to bring the event to a proper resolution. Actors featured in the ConOps include human operators that interact with the Driverless AV using operator tool systems, as well as automated backend systems. By defining these high-level interactions, ConOps ensure that technical and non-technical stakeholders have a clear understanding and alignment of functional designs.

Cruise creates ConOps for reasonably foreseeable scenarios that the AVs may encounter on the road, and acknowledges the nominal and contingency events that may emerge in each scenario, to robustly identify the functionalities required in each technical system. These functionalities are allocated to lower-level system designs to provide traceability to the requirements and use cases their systems are designed to meet.

3.4.2 Behavioral Designs

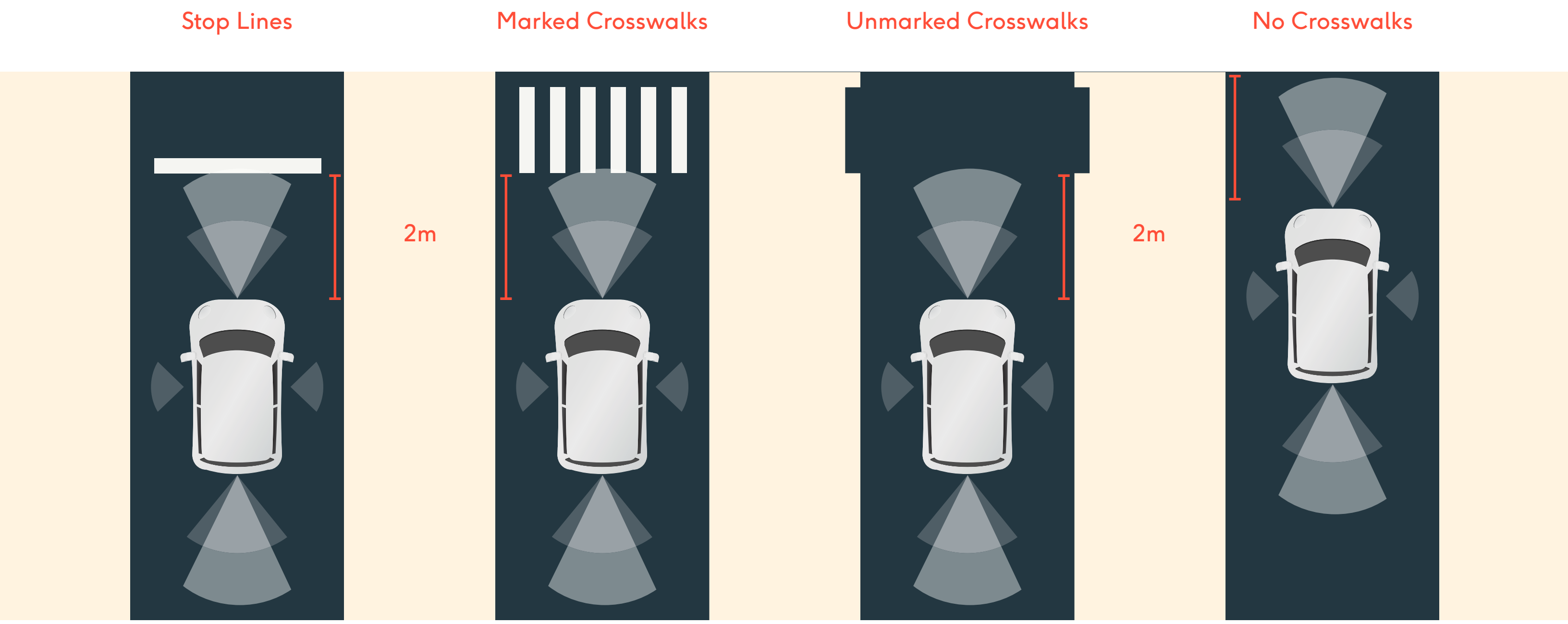
Cruise has developed behavioral designs that specify driving behaviors for a broad variety of driving scenarios that are described in regulatory requirements or otherwise encountered by the Cruise AV.[72]

An example behavioral design requires the Cruise AV to come to a stop at a distance of 2 meters from the stopping location. Furthermore, the behavioral design specifies 4 example types of stopping locations: **Stop Lines, Marked Crosswalks, Unmarked Crosswalks, and No Crosswalks**.

In each example, the behavioral design indicates where the 2 meter measurement begins: behind the stop line, behind the marked crosswalk, behind the curb transition of an unmarked crosswalk, or from the intersection entrance if there is no crosswalk.

The behavioral design combines the variety of traffic demarcations with the fundamental principle that the AV should stop with a buffer distance from the stopping location, to ensure that the AV maintains a safe distance at stopping locations from fellow road users such as pedestrians.

Because driving is a highly contextual behavior, the framework of behavioral designs serves as foundational building blocks in achieving safe driving in nominal driving contexts.[73]



3.4.3 Fallback and Minimal Risk Condition

Cruise AVs are designed to safely react to situations in which their ability to drive autonomously is impaired, such as exiting their defined ODD or detecting a system failure. This is achieved by performing a driving maneuver with residual driving capabilities to achieve a minimal risk condition (MRC), i.e. a state in which the Cruise AV has minimized safety risks to the extent possible within the driving context. The specific fallback maneuver, such as coming to an immediate stop, pulling over out of lane of travel, or pulling out of traffic after exiting an intersection, is highly dependent on the driving context as well as the Cruise AV's residual driving capabilities.

For example, if the Driverless AV detects the presence of inclement weather conditions, the Driverless AV may initially attempt to return to a Cruise facility. If conditions worsen, the Driverless AV may look for a place to pull out of the lane of traffic and wait for weather conditions to improve. In extreme cases, the Driverless AV may have to await in-person retrieval.

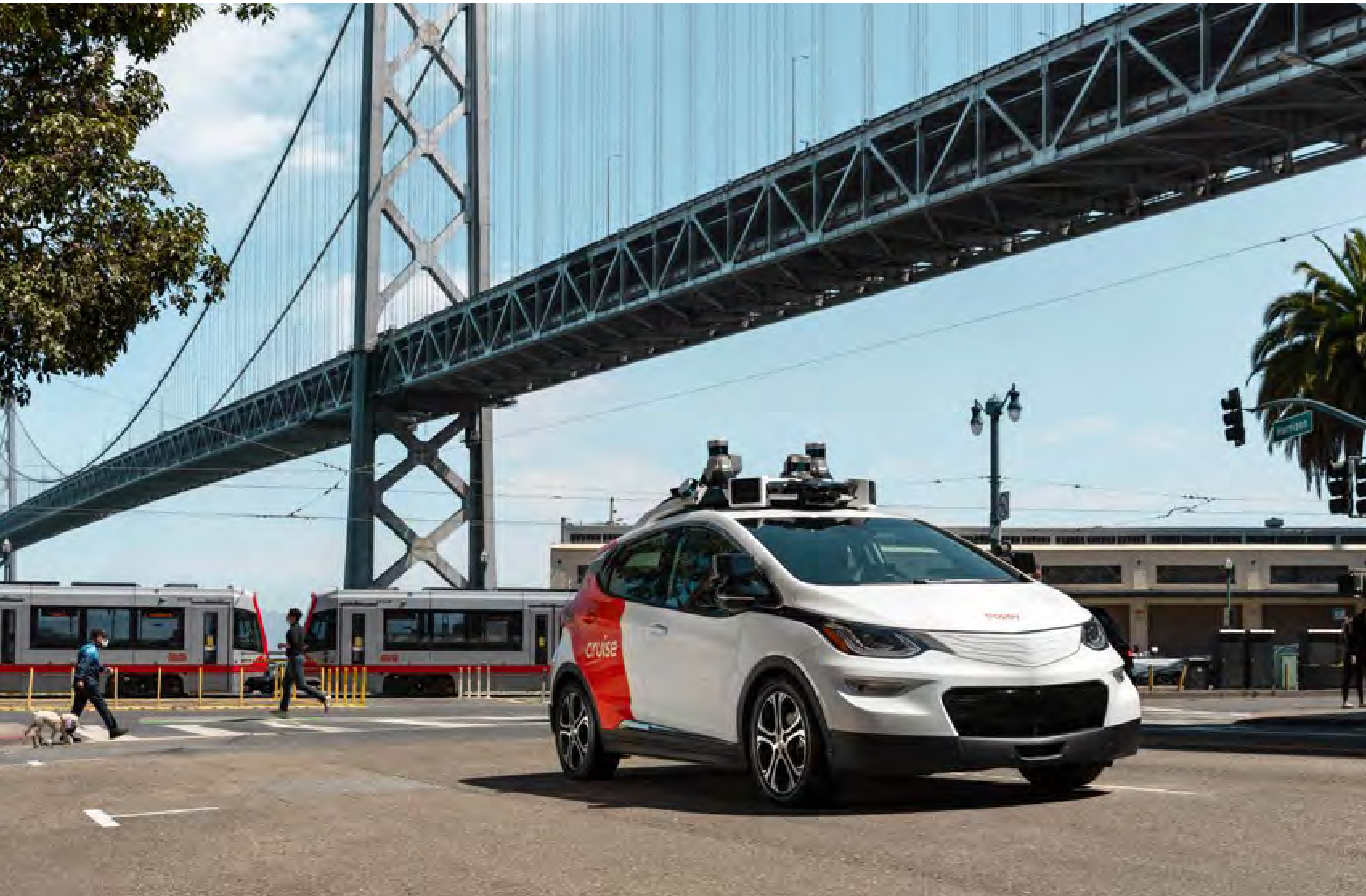
Alternately, in the unlikely event of a multi-sensor failure, the Driverless AV may need to come to a stop-in-lane or be remotely navigated to a safe location as the safest possible maneuver with the residual driving capabilities available to the Driverless AV, since its ability to autonomously change lanes while maintaining a safe distance from other road users may be compromised.[74]

In each instance, the means of achieving an MRC is dependent on situational context, but the end state of having achieved an MRC is similar: the Driverless AV attempts to move out of lane of traffic when possible and come to a stop; applies redundant mechanisms to ensure that it remains stationary; and activates communications signals such as hazard lights to ensure other road users have visibility into and awareness of its stopped state.

3.4.4 AV Health Monitor

Cruise AVs are designed with a health monitor that tracks the health of their hardware and software modules to determine when a fallback response to achieve an MRC is necessary. The Cruise AV features redundant hardware and software systems to maximize their ability to achieve an MRC in the presence of a potentially hazardous system fault. Cruise categorizes the presence of one or more latched failures as a degraded state, or DS, which correspond to the residual driving capability that the Cruise AV has to achieve an MRC.

Cruise's DS taxonomy[75] assigns higher numbers for a degraded state with less residual driving capabilities. Cruise supplements the Cruise AV's autonomous response with human-in-the-loop customer support, field support, and RA teams[76] to aid the safety of our passengers and other road users during events in which the Cruise AV has encountered a DS.



3.4.5 Cybersecurity

Cruise has developed a comprehensive and dynamic security program to identify, prioritize and mitigate cybersecurity risks. To protect our Cruise AVs from external threats, we perform ongoing threat modeling to identify the highest cybersecurity risks. Cruise uses the outputs of the modeling to prioritize our efforts around our security posture, such as algorithmically monitoring networks and software, developing bespoke security solutions, improving existing architecture, and hardening hardware and software cybersecurity controls.[77] We continuously improve our security systems by monitoring for emergent threats and improving our system resilience in response.

As with our strict standards for hardware and software development, we use various industry cybersecurity standards and frameworks to guide and mature our Security program, including the National Institute of Standards and Technology CyberSecurity Framework (NIST CSF),[78] International Organization for Standardization/International Electrotechnical Commission Information Security Management (ISO/IEC 27001:2013), and NHTSA Vehicle Cybersecurity guidance.[79]

In addition to our adherence to these standards, we have also implemented security measures that go beyond the established requirements for cybersecurity proscribed in these programs. These measures include technologies like host-based anomaly detection and prevention software, which enables Cruise's security team to monitor, alert, and react in real-time to potential threats in the main vehicle computer and base vehicle system.

Furthermore, our close partnership and integration with GM provides additional benefits to vehicle security, such as the ability to actively design and test security controls for systems and components in close conjunction with GM's tier-1 suppliers. Additionally, our partnership with GM affords the opportunity to participate in and collaborate with critical industry organizations working towards more secure vehicle systems, such as the Automotive Information Sharing & Analysis Center (Auto-ISAC).

3.5 Requirements Management

Requirements management and traceability are the foundation of robust and responsible product development.

Requirements management at Cruise is a hybrid of aerospace-inspired, top-down systems engineering, and a tailored development process that allows us to apply relative levels of requirements development and validation rigor according to the priority and criticality of system functionality.

3.5.1 High Level Requirements and Design

At the enterprise level, Cruise manages stakeholder requirements such as regulatory, safety, and security requirements to serve as inputs for developing high-level designs. Development teams look to upstream high-level design resources to develop Cruise AV systems and supporting systems that exhibit the desired behaviors and functions. Operational teams refer to high-level designs to develop processes and training materials that prepare the operator to perform their designated tasks and responsibilities. The implemented systems and processes undergo corresponding closed-course tests, simulation tests, or analyses at the driverless service level of integration for complete validation of stakeholder requirements.[80]

3.5.2 Low Level Requirements and Design

Because hardware and platform functionality precede autonomy behaviors or functions, the product development process for hardware and platform takes place in advance of, or sometimes in parallel with, the development of behaviors and functions.

Cruise applies hardware and platform best practices informed by decades of collective engineering experience and expertise to protect for the behavior and functionality expansions of future program phases. As an example, the thermal and mechanical shock testing we perform on our Origin vehicle far exceeds the San Francisco ODD, as our future-facing ODDs will extend to locations with a variety of weather and road roughness conditions. Cruise leverages our in-house hardware expertise to define high-level best practice engineering requirements or compliance requirements that we then use to derive downstream component and component driver requirements. These requirements link to corresponding downstream test cases, for which each test run is captured and recorded.

3.5.3 Review, Publication, and Change Control Process

Cruise uses a requirements management system (RMS) for formally documenting and tracing design artifacts such as ConOps and behavioral designs, requirements such as system requirements and hardware component requirements, and test results and report documentation. We also leverage the RMS for the systematic review and approval of design and requirement documents.

After creating and tracing items in the RMS, a review owner is able to initiate a review of pertinent items for stakeholder review and approval. The review owner addresses comments and publishes new revisions to drive the review to completion and gain stakeholder approval. Comments and formal approvals are captured and retained in the RMS, and reviews are always accessible through version history.

Once the items have been approved, the review owner publishes the items, resulting in the item being transitioned into a locked state. Any and all changes to the item with the RMS are captured in the item's version history. Such changes are able to be inspected using the RMS's version comparison tool, and any item is able to be restored to a previous version as needed.

[30]SAE International. (2020, April 30). AVSC Best Practice for Describing an Operational Design Domain: Conceptual Framework and Lexicon.

[31]See Build-Up Approach for more details on Cruise's expansion strategy.

[32]See ODD Enforcement for more details.

[33]Fallback and Minimal Risk Condition are discussed in more detail in the High Level Design section.

[34]These examples are meant to be illustrative, and are not comprehensive of the full list of controls.

[35]Cruise is able to designate areas on the map for Cruise AVs to avoid driving through. Road constraints may be temporary or longer-term.

[36]ODD enforcement mechanisms allow us to control exposure to ODD elements that we plan as expansions but have not yet been validated.

[37]See more details in High Level Architecture and System Design and Incident Response Scenarios.

[38]See more details in Safety Approaches.

[39]In February 2022, Cruise and General Motors submitted a part 555 petition to NHTSA seeking approval to deploy the Origin commercially. The petition embodies our extensive efforts to incorporate vehicle safety standards. The petition is the culmination of years of research, development, and testing to ensure that the Origin provides an equivalent or greater overall level of safety to existing FMVSS, and it transparently describes those efforts in detail.

[40]See more details in High Level Architecture and System Design.

[41]13 CCR §228.06(a)(9).

[42]If the Cruise AV detects a roadway change that has not yet been mapped, it is designed to automatically identify the deviation, maneuver autonomously, or in some cases request pathing assistance from a RA Advisor. In severe cases, the Cruise AV may trigger a temporary road constraint until the roadway is updated on Cruise's HD map.

[43]See more details in Appendix C: Actors and Systems.

[44]See more details in Appendix C: Actors and Systems.

[45]See more details in Operational Design Domain.

[46]See more details in High Level Architecture and System Design.

[47]See more details in Test Scenario Development.

[48]See more details in Build-Up Approach.

[49]See more details in Launch Readiness Review.

[50]See more details in Release Process Overview.

[51]See more details in Feedback Loops.

[52]See more details in Hardware Verification.

[53]For example, the variable of controllability in FuSa's risk assessment assumes that there is a human driver who needs to take control of the system.

[54]See more details in High Level Architecture and System Design.

[55]Diagnostic areas also span functions that are not directly safety critical but share computing resources with safety critical applications.

[56]National Highway Traffic Safety Administration. (2021). Car Safety Ratings. https://www.nhtsa.gov/ratings.

[57]Insurance Institute for Highway Safety. (2020). 2021 Chevrolet Bolt 4-door hatchback vehicle rating. IIHS-HLDI Crash Testing and Highway Safety. https://www.iihs.org/ratings/vehicle/chevrolet/bolt-4-door-hatchback/2021.

[58]For example, the compute hardware is intentionally positioned in the Chevy Bolt AV to help ensure that critical post-crash functions such as emergency calling remain fully functional.

[59]Byrne, J. P., Mann, N. C., Dai, M., Mason, S. A., Karanicolas, P., Rizoli, S., & Nathens, A. B. (2019). Association Between Emergency Medical Service Response Time and Motor Vehicle Crash Mortality in the United States. JAMA Surgery, 154(4), 286. https://doi.org/10.1001/jamasurg.2018.5097.

[60]See more details in Appendix C: Actors and Systems.

[61]See more details in High Level Architecture and System Design.

[62]See more details in Passenger Education.

[63]See more details in Supporting System Verification.

[64]See more details in Operational Readiness.

[65]See more details in Fleet Monitors.

[66]See more detail in Release Process Overview.

[67]See more details in Fleet Actions.

[68]See more detail in Remote Operators and In-Person Operators.

[69]See more details in Immersive Incident Exercises.

[70]See more details in Appendix C: Actors and Systems.

[71]https://www.nasa.gov/connect/ebooks/nasa-systems-engineering-handbook

[72] As an example, the state of California provides regulations in California Vehicle Code Division 11 - Rules of the Road.

[73]There are situational instances when deviating from nominal behavioral designs is necessary for safety or to avoid impeding traffic. The Cruise AV is designed with both nominal and contingency behavioral designs.

[74]Note that safe driving behaviors are highly context-dependent, and must be designed with situational considerations in mind. For example, a stop-in-lane maneuver in a low-speed urban environment may require a different safety hazard trade-off than a stop-in-lane in a highway environment.

[75]See more details in Appendix A: Degraded States.

[76]See more details in Incident Response Scenarios.

[77]See more details in Appendix B: Cybersecurity Controls.

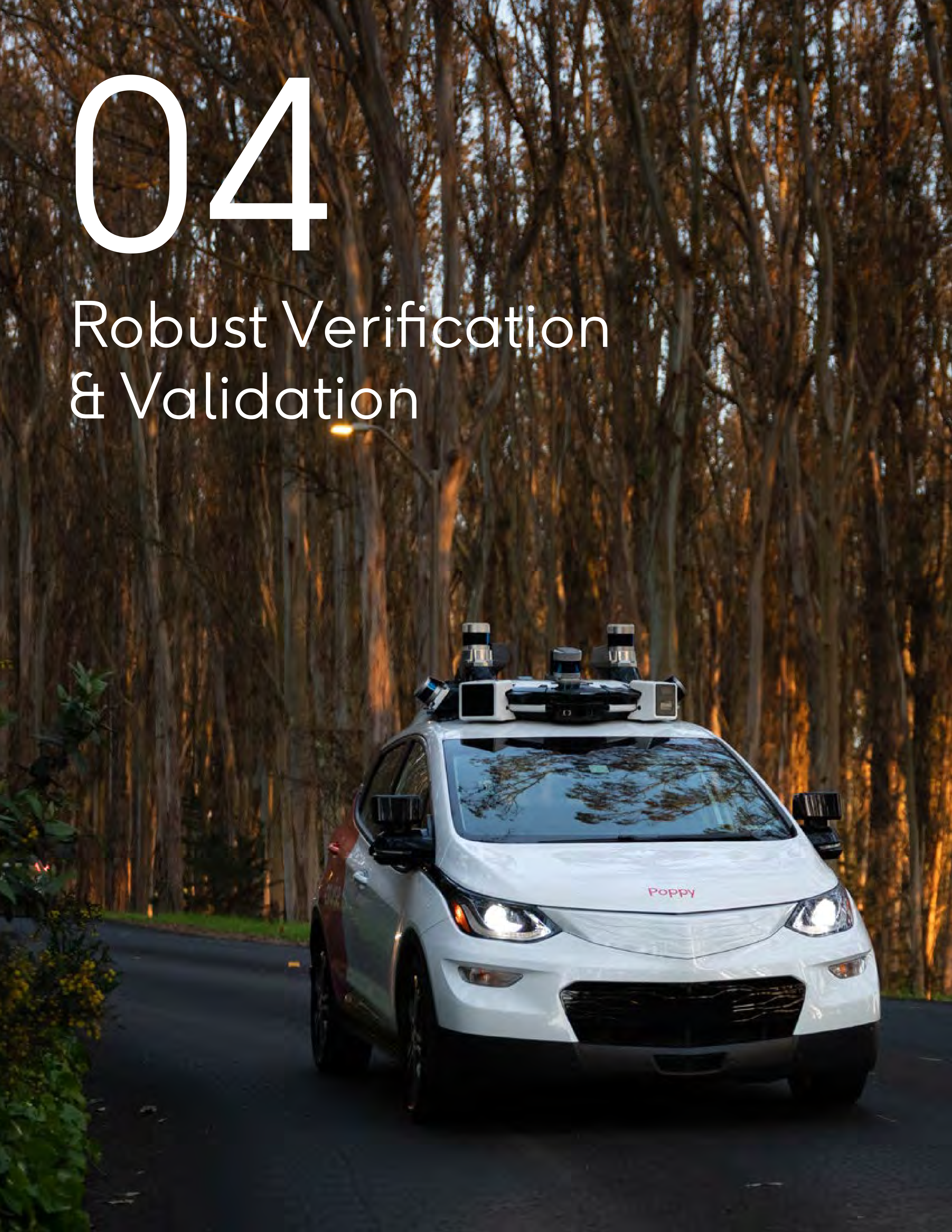
[78]National Institute of Standards and Technology. (2018, April 16). Framework for Improving Critical Infrastructure Cybersecurity (Version 1.1). https://doi.org/10.6028/NIST.CSWP.04162018.

[79]National Highway Traffic Safety Administration. (2020). Cybersecurity Best Practices for the Safety of Modern Vehicles. https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/vehicle_cybersecurity_best_practices_01072021.pdf.

[80]See Robust Verification & Validation chapter for details on Cruise's verification and validation process.

04

Robust Verification & Validation



Beyond the design stage, and after implementation, Cruise enforces a robust driverless release process to approve new code and hardware to enter driverless operations.

Key elements of the release process include software verification; hardware verification; and supporting systems verification. We also exercise non-test verification methods, such as inspection and analysis.

In addition to our layered verification framework, Cruise develops a robust set of test scenarios derived from high-level design, on-road events, and automotive safety best-practices. We also perform immersive incident exercises to measure whether Cruise is sufficiently prepared to encounter and appropriately respond to high-urgency events.

4.1 Release Process Overview

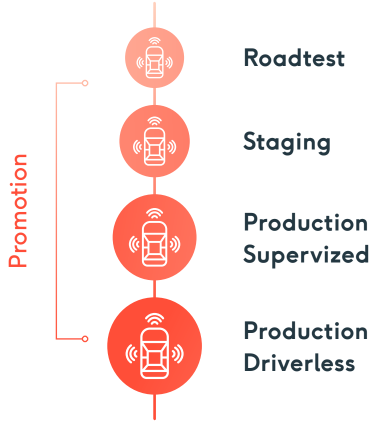
Cruise recognizes that it is important to establish proper processes and tools to promote robust verification, performance evaluation, quality control, and continuous improvement in our Driverless AVs and supporting systems.

Cruise's release process includes the management, planning, scheduling, and deployment of new or modified software or hardware to our Cruise AVs. Cruise's release process for validating each new release is performed in two stages: **the Supervised Release Process, and the Driverless Release Process.**

Supervised Fleets are operated with an Autonomous Vehicle Test Operator (AVTO) in the driver's seat. While Cruise AVs operate autonomously in Supervised Mode, the AVTO is able to take manual control at any time by performing a Take-Over (TKO) action, such as taking control of the steering wheel, pressing on the brake pedal, or pressing on the accelerator pedal. Supervised Operations gives Cruise the opportunity to observe the effects of hardware or software changes earlier in the release process, and tests the robust integration of hardware, software, and supporting systems in a representative ODD while mitigating safety risks via human supervision.

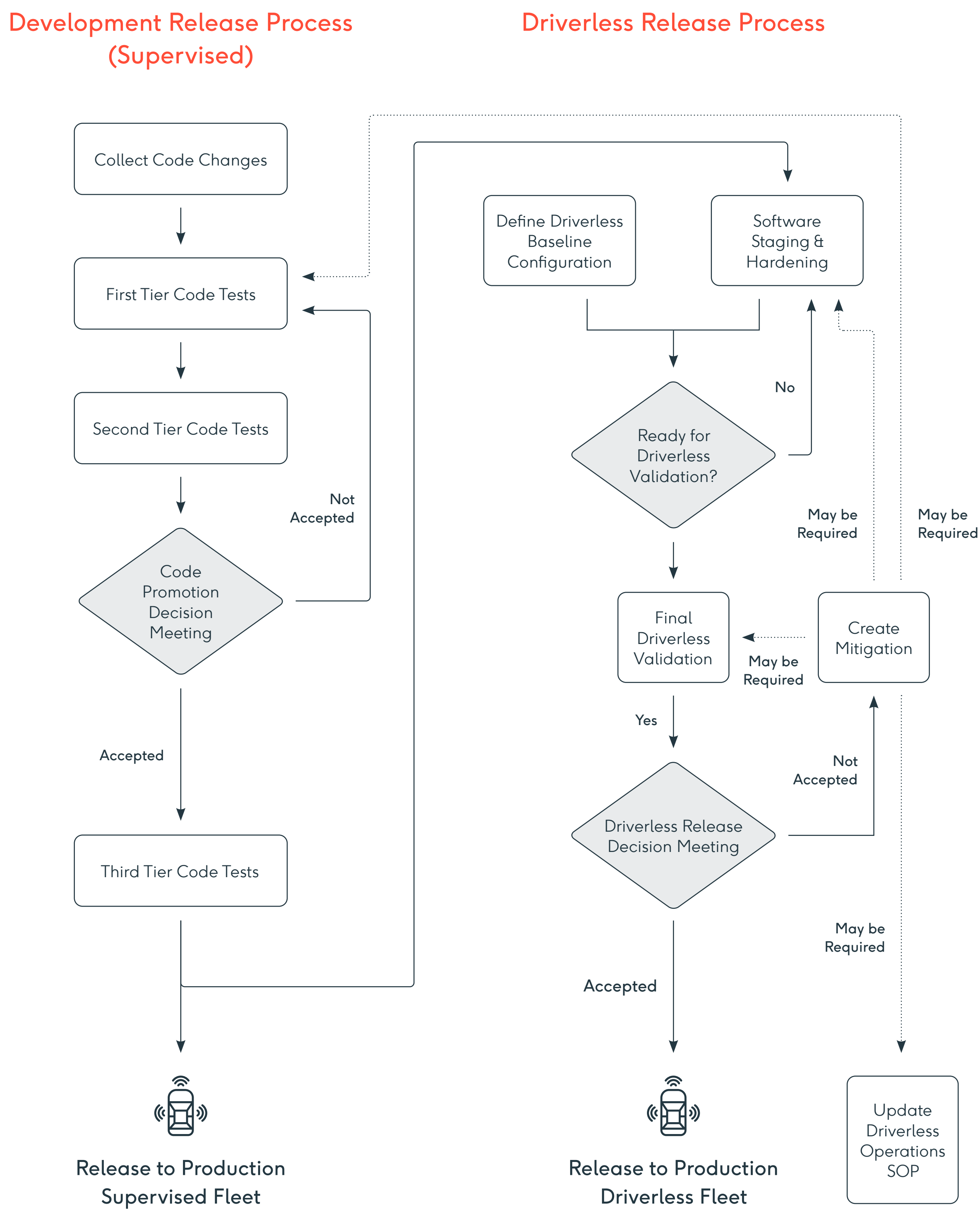
The staging phase of the Supervised Release Process exposes and matures code to a limited number of Supervised Research and Development (R&D) AVs, which allows Cruise to collect on-road data on code performance while maintaining operator supervision over the Cruise AV. As the code matures and passes its performance gates, it is exposed to on-road driving on a progressively increasing number of Supervised R&D AVs until it is finally promoted to the full-sized Supervised Production Fleet. Matured code from the Supervised Release Process is used to initiate the Driverless Release Process.

Driverless Fleets are operated without an AVTO in the Cruise AV. The Driverless Fleet is operated within the LODD, which may initially be bounded by operational hours and a subset of the full map.[81] The Driverless Fleet is only operated in a fully-validated production fleet, which means the code must undergo the highest level of validation rigor before being released on public roads.



Both the Supervised and Driverless Release Processes rely on a combination of the following mechanisms to evaluate whether the software and hardware are ready to be promoted to the next stage of release maturity and ultimately allowed to release onto production fleets:

1. Code change control
2. Simulation tests
3. Operability tests
4. On-road tests
5. Closed-course tests
6. Decision meetings & approvals


Development Release Process (Supervised)
Driverless Release Process
Collect Code Changes
First Tier Code Tests
Second Tier Code Tests
Not Accepted
Code Promotion Decision Meeting
Accepted
Third Tier Code Tests
Release to Production Supervised Fleet
Define Driverless Baseline Configuration
Software Staging & Hardening
No
Ready for Driverless Validation?
May be Required
May be Required
Final Driverless Validation
May be Required
Create Mitigation
Yes
Not Accepted
Driverless Release Decision Meeting
May be Required
Accepted
Release to Production Driverless Fleet
Update Driverless Operations SOP

4.1.1 Code Change Control

Code is change-controlled in Cruise's code repository to ensure that all changes undergo code review and approval before being allowed to merge into the collective code branch that is installed into a Cruise AV.

This is crucial in a rapid code development environment where multiple software development teams are working in parallel to deliver various features that are likely to affect driving behavior. Individual development teams are responsible for inspecting their own respective code change requests, i.e. pull requests (PRs), to ensure that the code submitted for review is well-understood, well-designed, sufficiently tested using static analyses and unit tests, and follows engineering best practices.

As the code branch progresses in maturity throughout the release process, it undergoes increasing numbers of tests to identify and mitigate regressions in functionality or performance before the code is promoted to the next code branch. Failures in automated test suites result in automatic rejection from subsequent promotion, until the failure is resolved. Failures in manually-performed test suites or inspected on-road performance are surfaced at the release decision meeting.

4.1.2 Simulation Tests

Simulation tests are automated test suites that are run with varying levels of scenario coverage to measure improvement or regressions in driving performance before allowing code branches to be promoted.

The Supervised Release Process features four tiers of simulation tests:

- Pre-integration Test Suite
- Build Test Suite
- Standard Integration Test Suite
- Full Integration Test Suite

01 The **Pre-integration Test Suite** ensures that any individual PR meets the minimum requirements for merging into the collective code branch before being evaluated for operability. This test suite is kept lightweight to allow the merging of hundreds of PRs multiple times a day while reducing the likelihood of failed subsequent promotion gates and delayed mitigation actions. The Pre-Integration Test Suite comprises thousands of unique simulation tests.

02 The **Build Test Suite** includes a robust set of unit tests, framework tests, network integration tests, and code performance tests that promotes general code performance quality before the collective code branch is promoted to a more stable collective code branch.

03 The **Standard Integration Test Suite** represents a more robust set of simulation tests that measure driving performance before new code is allowed on-road for the first time. It is an intermediary between the light-weight Pre-Integration Test Suite and the heavy-weight Full-Integration Test Suite respective to the amount of exposure that the code has in the limited number of Supervised R&D AVs. The Standard Integration Test Suite comprises tens of thousands of unique simulation tests.[82]

04 The **Full Integration Test Suite** represents the most robust set of simulation tests that measure driving behavioral performance before the Cruise AV is allowed in the expanded Staging Supervised Fleet. The Full Integration Test Suite currently comprises close to a quarter million unique simulation tests. Once the code branch passes the Full Integration Test Suite, it is baselined for use in the Driverless Release Process.

4.1.3 Performance Tests

In addition to running simulation tests that determine whether the code produces appropriate driving behaviors in a broad range of scenarios, Cruise also runs performance tests to ensure that the Cruise AV is otherwise operations- and road-ready.

Performance tests include specific computing resource-intensive integration tests, such as scenarios with dense crowds. They are run on hardware benches that test the code's ability to launch on the Cruise AV computer with acceptable performance in latency, compute processing, and network load.

Cruise also performs calibration tests that ensure that the new code has not compromised our ability to properly calibrate the Cruise AV's sensors. Performance tests gate the promotion of new code based on its impact to fleet operations, in parallel with the safety considerations covered in the simulation, on-road, and closed-course tests.

4.1.4 On-Road Tests

Once the new code has undergone the necessary simulation and operability tests, it is installed in an expanding number of Supervised AVs that allow Cruise to collect performance data on the Supervised AVs under the supervision of a highly-trained AVTO.[83] Currently, the fleet ranges across tens of vehicles, and the amount of on-road exposure ranges from hundreds to thousands of miles per day.

Typically, a given code change will have on-road exposure of tens of thousands of miles upon completing driverless validation. Additionally, due to the sequential steps in the release process, features that are introduced to the Driverless Fleet for the first time undergo significant amounts of simulation, on-road, and other testing. Cruise continuously calibrates the size of the fleet and mileage to ensure each validation step is effective in capturing any material regressions.

4.1.5 Closed Course Tests

Closed-course tests allow Cruise to observe the Driverless AVs in a controlled setting. This helps us build confidence in the Driverless AVs' ability to operate safely on public roads. Cruise performs closed-course tests on a dedicated track at GM's Milford Proving Grounds, as well as closed-course locations in California.

The closed-course tests involve scenario-based regression tests to ensure that every release maintains strict and ever-increasing performance standards. These tests include nominal operational scenarios such as passenger pick up and drop off, as well as contingency operational scenarios such as exiting the ODD, degraded states, collisions, and defined crash avoidance scenarios.[84]

Additionally, Cruise performs targeted safety performance tests to evaluate the Driverless AV's crash avoidance performance around vulnerable road users, such as pedestrians and cyclists.

4.1.6 Decision Meetings

Cruise holds promotion and release decision meetings as a regular part of the Supervised and Driverless Release Processes.

For the Supervised Release Process, Cruise holds a promotion decision meeting that uses inputs from on-road performance data, calibration regression tests, and simulation tests to determine whether a code candidate is mature, stable, and sufficiently validated to be promoted to a larger fleet. Code that is promoted to the supervised production fleet is eligible for the Driverless Release Process, and is exposed to a much larger fleet of Supervised AVs, making the staging promotion meeting a critical decision meeting.

Cruise additionally holds a supervised release promotion decision meeting that takes on-road performance data from the staging fleet to determine whether code can be promoted to the Production Supervised Fleet. The code used on the Production Supervised Fleet is the most matured code used in a Supervised setting, and can support ridehail services to internal and public riders under the supervision of an AVTO. Additionally, data from the Production Supervised Fleet informs the Driverless Release decision.

For the Driverless Release Process, Cruise holds a driverless release promotion decision meeting that uses inputs from operability performance tests, the staging fleet on-road performance, the Production Supervised on-road performance, closed-course tests, and safety risk analyses. Given that the Production Driverless Fleet is operated without an AVTO in the vehicle, this particular release decision meeting receives the highest amount of scrutiny through the collective Supervised and Driverless Release Processes.

Once the code is promoted to be the official Production Driverless release, it is installed on the Production Driverless Fleet, securely signed, and verified on launch.[85] This code is the most mature and robustly validated autonomous driving software that Cruise operates on public roads, and allows our fleet of Driverless AVs to provide the Cruise driverless ridehail service to internal and public riders alike.

4.2 Hardware and Firmware Verification

The Cruise AV integrates dozens of electronic hardware components assembled together to enable the driverless functionalities that Cruise AVs exhibit on the road. The hardware components needed for performing the driving task include sensors, computers, network switches, telemetry modules, and vehicle actuators. Given the complexity inherent in the Cruise AV's hardware architecture, Cruise performs verification in multiple stages to ensure that the components, subsystems, and systems are capable of performing their respective required functionalities.

Cruise follows a multiphase Product Development Process (PDP) framework to continuously optimize hardware verification, using a standard set of phase gate reviews for hardware development and verification across the dozens of components Cruise supports.

At the component level, each vendor is responsible for providing evidence that their component design and manufacturing process is systematic and robust according to the designated Automotive Safety Integrity Level (ASIL) rating of their component.[86] Cruise performs additional component level sensor characterization to evaluate sensor performance in challenging scenarios.

As our driverless hardware platform evolves, Cruise continuously performs integration tests at the component, subsystem, and system level with Hardware in the Loop (HIL) testing benches. Cruise configures the HIL bench with the expected configuration of component firmware and simulated integrated environment to perform functionality tests, performance tests, and requirement verification tests. These tests are performed to onboard new components, test software updates introduced by the vendor, and test new software configurations introduced in the simulated integrated environment. HIL tests are crucial for verifying a component integrated into its subsystem before allowing a component, new component software, or new configurations to be installed at scale across our fleet.

Because Cruise operates different fleets with several configurations of R&D and production hardware, it is crucial for any subsystem integration impacted by lower-level changes to be tested at higher-level integrations that Cruise operations teams support and ensure minimal disruption to R&D and production operations. Once the component, component software, or new configuration is verified with HIL tests, it is installed in batches in R&D fleets and undergoes small-scale roll-out until any residual issues are resolved.

Throughout the various stages of integration, Cruise monitors fleet performance and attributes failure modes to its root causes, which may include hardware failures, software failures, or operator errors. Based on the hardware failure rates observed in the field, Cruise creates additional test cases to produce a more robust testing framework.

In particular, the release processes that span the Supervised and Driverless Production fleets assume a stable hardware configuration starting from the very earliest stages of code release. At the time of initiating the Driverless Release Process, a Driverless Baseline Configuration is identified for performing all closed-course full-integration testing. Preliminary verification at the component and subsystem levels, and integration testing at the small Supervised Fleet levels, reduce residual hardware failures and streamline the final integration testing performed in Driverless Validation closed-course tests prior to final Driverless Operation.

4.3 Supporting System Verification

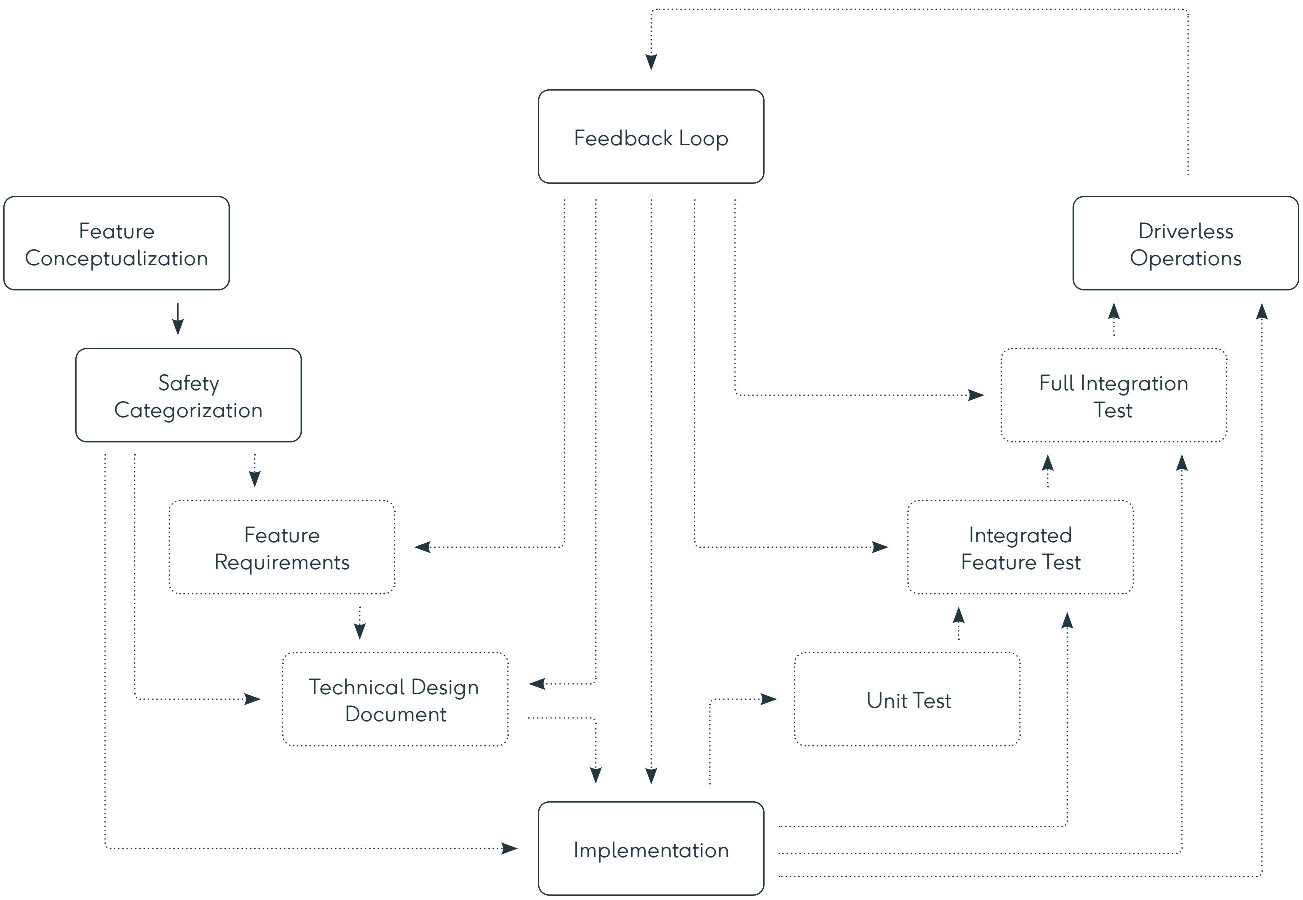
Beyond the software and hardware, the Cruise AV works within an ecosystem of supporting systems including operator tools and fully automatic systems to provide business services, report statuses, and receive assistance.[87] This ecosystem supports the Cruise AV's ability to provide a driverless service, including driving, receiving assignments, and interacting with passengers.

While supporting systems are crucial to driverless operations, they undergo unique verification steps that rely heavily on integration testing. Supporting systems generally exert less influence over the Cruise AV's ability to drive autonomously, and often require fewer controls and risk mitigations compared to core autonomous driving features. Cruise has built verification pipelines that exert a proportional and appropriate amount of safety controls, including feedback loops for identifying safety and quality issues encountered on road.

Supporting systems provide many functionalities, such as:

- Providing the Cruise AV with additional situational context to assist with its driving task
- Engaging in live voice communications with passengers inside the Cruise AV
- Providing a camera view of the Cruise AV cabin and areas surrounding the vehicle for remote inspection[88]
- Optimizing driving routes for Cruise's business service
- Managing the Cruise AV's road constraints on a shared fleet map
- Displaying situational context or instructions to passengers during a ride

Supporting system features undergo a version of the verification process illustrated below. This includes various feature development and verification stages proportional to the safety risk it represents before being released to Driverless Operations.[89]



Based on the complexity and safety criticality of the feature, Cruise develops feature requirements and technical design documents to define the intended implementation. Design analyses such as STPA and Human Factors Analyses (HFA) may be performed to identify hazards, generate requirements, and generate test cases, particularly for operator tools that rely on a human-in-the-loop who must make clear and informed decisions.

Once a new feature is implemented or an existing feature is modified, developers create unit tests to confirm that their feature functions as expected and improve the feature's likelihood of passing integration tests. The amount of testing performed at the unit test level varies by individual systems and their testing frameworks.

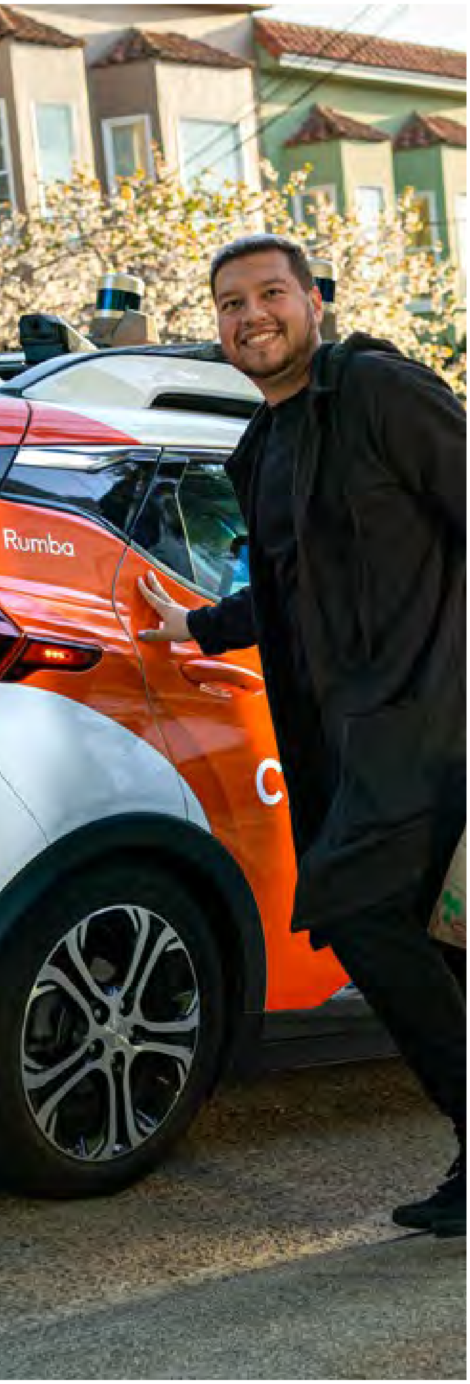
Integrated feature tests assess a feature's readiness for entering the Driverless Release Process. Most integrated feature tests are operated in a closed-course setting that include the Cruise AV, supporting system(s), and human operator-in-the-loop as applicable. These tests ensure that system dependencies between all actors in the ecosystem are functional prior to full scenario-based testing. These tests also provide the opportunity to exercise a broader range of system functionalities beyond what is exercised in targeted integration testing.

Full integration tests are a key part of the Driverless Release Process and represent the final gate for safety-critical and safety-informing features to be tested within the context of targeted test scenarios before being released to driverless operations.[90]

Once a feature is released to driverless operations, it is observed using Cruise's feedback loop mechanisms[91] that ingest and prioritize issues seen on the road. As an example response, Cruise is able to restore a prior proven release to resolve observed anomalies in performance or functionality. Alternately, Cruise ingests the feedback to revise feature requirements and technical design documents, or inform additional feature integration and full integration tests, to ensure that the issue is addressed and resolved.

The amount of verification necessary for a supporting system is determined by the feature's safety criticality, which is measured by the amount of risk the feature would introduce given the possibility of malfunction. Safety-critical supporting system features undergo the full development and verification cycle to apply the greatest amount of control and gain the greatest amount of confidence in the feature before release to driverless operations. Issues across all features, safety-critical and non-safety critical alike, are surfaced and triaged through Cruise's feedback loop mechanisms.

4.4 Cybersecurity Validation



Cruise leverages a number of cybersecurity strategies and controls from traditional software engineering to continuously validate our components, subsystems and overall system. We use software that verifies and analyzes vehicle components and firmware to detect regressions prior to putting any Cruise AV on-road. Test suites are available for all critical Cruise AV components to validate security controls.

To verify that the code running on components is genuine and has not been manipulated, we perform cryptographic verification of firmware and configurations. We only sign firmware that has been proven to not contain any known security deficiencies. This process is also designed to be automated, abrogating any potential manual processing errors.

Cruise's cybersecurity validation strategies, much like our software engineering development processes, are fundamentally iterative in nature. In traditional settings and applications, security components are often only validated once, and are rarely looked at again. In contrast, Cruise employs automated methods to validate components, subsystems, and systems for security flaws and failures on a continual basis.

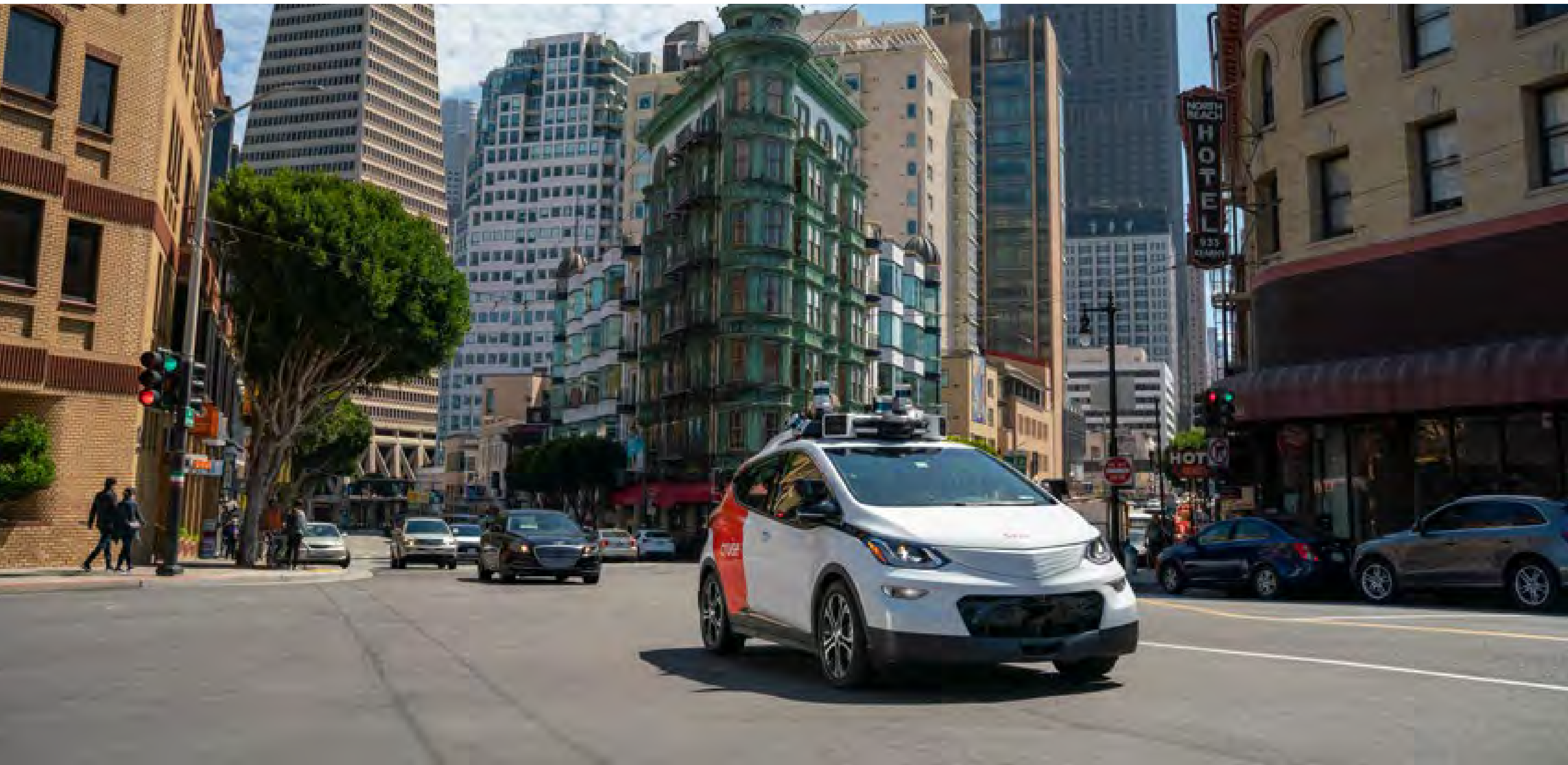
In addition to manual and automated validation processes, Cruise performs real-time cybersecurity checks each time a Cruise AV is powered on. These checks ensure that every component of each Cruise AV in the fleet has the most stringent cybersecurity standards in-place, and that these systems and components have not deviated since last use. If a cybersecurity variance is detected, the vehicle automatically initiates a degraded state response to prevent its operation on-road and ensure that the variance is resolved.

4.5 Test Scenario Development

Every journey in a complex urban operating environment like San Francisco represents a unique combination of possible scenarios that the Driverless AV may encounter in providing its driverless service. Cruise accounts for this variability by methodically deriving test scenarios to ensure that our Driverless AV functions and behaves as designed.

Cruise develops tests using the following sources:

1. Driverless functionality tests derived from ConOps, including achievement of an MRC
2. Nominal driving behavior tests derived from behavioral designs and on-road data
3. Targeted hazard tests derived from on-road data
4. Targeted imminent collision avoidance tests derived from automotive best practices



4.5.1 Driverless Functionality Test Scenarios

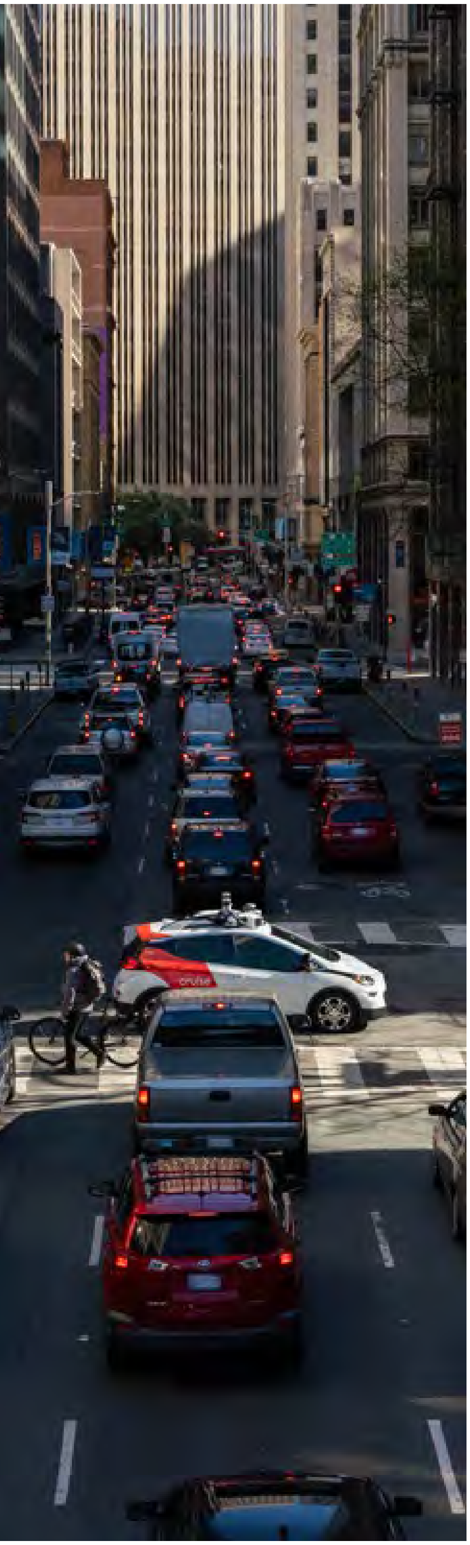
Cruise develops ConOps to ensure that our driverless service is prepared to encounter a variety of situations requiring interaction with an operator, the passenger, or a third party. **Example ConOps include nominal passenger interactions with the Driverless AV, interactions with the passenger during a ride interruption or emergency, collisions, and more.**

Each ConOps documents the various decision paths that can emerge in a given scenario, which generates a broad set of scenario permutations. **Example variations in permutation include the presence of passenger; varying types of autonomous event detections, such as degraded state or tampering detections; and the presence of operator inputs, such as operator confirmation of a collision event.**

These permutations also include various scenarios in which the Driverless AV must achieve an MRC, and may need to cease autonomous driving.

Test scenarios derived from ConOps allow Cruise to verify that each system, including the Driverless AV, is functioning correctly as documented in the ConOps, and that each operator is equipped to perform their tasks in their designated tool system in a fully integrated context.

4.5.2 Nominal Driving Behavior Test Scenarios



Given the large amount of variability in driving scenarios that the Cruise AV may encounter on the road, **Cruise uses two sources to derive driving behavior test scenarios that identify foundational driving competencies: behavioral designs and on-road driving data.**

01

Behavioral designs

02

On-road driving data

Cruise develops behavioral designs that exhibit safe driving and adhere to the rules of the road. Cruise uses scenarios identified in regulatory requirements and drivership[92] guidelines to develop behavioral designs and test coverage that is comparable to the guidance provided to comparable human drivers. Cruise develops permutations of driving behavior test cases that account for variability of driving condition parameters, such as vehicle driving speed and road signage, to produce robust test coverage.

As a complement to the top-down driving scenarios identified by regulatory requirements, Cruise observes on-road autonomous miles to identify the maneuvers and driving situations that the Cruise AV encounters most frequently. This allows Cruise to prioritize the driving behaviors that are most relevant to the Cruise AV in a given ODD, and also allows us to develop simulation tests using historical data to develop highly-relevant driving scenario simulations.

Using the outcome of these tests, Cruise is able to monitor driving performance of a broad set of driving scenarios far beyond the physical road miles driven for a release. The changes observed in these test suites are discussed as part of the release process to ensure that our driving performance is progressing compared to the previous release. Each release is assessed for gaps in simulation test coverage using new road data as part of the continually improving release process.

4.5.3 Hazard Test Scenarios

Cruise leverages our rich on-road data pipeline to identify hazard scenarios in addition to nominal driving scenarios. These scenarios are sourced from predicted or real-world collisions,[93] probabilistic model scores,[94] operator escalations of observed behavioral issues, or SIREN tickets submitted by Cruise employees.[95]

These scenarios can also be discovered through the accumulation of targeted supervised miles collected in stressing scenarios that challenge the Cruise AV's known driving capabilities and identify previously unknown failure modes. Similarly to nominal driving behavior tests, sources of observed behavior provide opportunities for Cruise to develop simulation tests using historical data to measure behavioral improvements.[96]

Cruise uses the frequency of on-road events encountered for a given hazard scenario with the corresponding severity of risk to identify necessary driverless operations constraints where applicable, and drive engineering prioritization of hazard scenario behavioral performance improvements. **Discovering hazard scenarios using our rich supply of on-road data allows Cruise to dynamically increase test coverage of hazard scenarios based on occurrence rate and severity until performance expectations are satisfied.**

4.5.4 Imminent Collision Avoidance Test Scenarios

Cruise complements its use of on-road data with structured collision-avoidance tests to ensure that scenarios with low occurrence rates and high severity have robust test coverage. Cruise leverages relevant scenarios defined by US NCAP,[97] EuroNCAP,[98] and IIHS[99] tests to validate system performance for collision imminent scenarios involving a pedestrian, a bicyclist, and other vehicles, and demonstrate our safety performance across known automotive best practices.[100]

Cruise initially tested these collision-imminent scenarios in a specialized closed-course setting to simulate on-road Cruise AV performance. We then used data gathered from closed-course testing to reinforce areas in our simulation framework and test coverage which is regularly exercised in our release process.[101] **Leveraging these resources across the automotive industry's best practices allows Cruise to build confidence and robustness in our collision-imminent and collision avoidance testing framework.**

4.6 Alternative Verification Methods

While testing is Cruise's primary, and most heavily exercised, method of verification, we apply the alternative verification methods of analyses and inspection in specific applications:

- Structured Design and Supplier Integrity
- Behavioral Verification
- Continuous Performance Monitoring

These alternate methods of verification allow Cruise to evidence verification in areas where testing verification benefits from being supplemented, e.g., the testing framework needs further maturation; the testing coverage is incomplete; or testing is otherwise impractical.

4.6.1 Structured Design and Supplier Integrity

Cruise applies principles of ISO 26262, such as the ASIL risk classification schema, to minimize the risk of systematic failures and establish the software and hardware integrity of our components. We closely monitor suppliers' progress through continuous collaboration and inspection to help ensure that both parties continue to be aligned, and ensure that the supplier's verification documentation is sufficient to meet our defined requirements and specifications.

4.6.2 Behavioral Verification

The real world poses an unlimited permutation of driving scenarios that are not easily captured in a testing framework. To supplement the base testing coverage of behavioral driving scenarios we perform as part of our regular release process,[102] Cruise uses the Analyses and Inspection methods of verification as described below.

Cruise analyzes on-road data in addition to aggregated simulation data to characterize our compliance rate with our behavioral designs. This allows Cruise to continually measure how the Cruise AV is performing against behavioral designs in Supervised and Driverless operations. Analyses, especially analyses of aggregate Cruise AV behavior observed over a broad range of scenarios, can often provide a more robust and comprehensive signal.

For example, a simulation test may define an AV-pedestrian interaction in which the simulation framework assumes that the pedestrian behaves in a reasonable manner.[103] However, pedestrians in the real world do not always behave in an expected or predictable manner, for various reasons that can include pedestrians who are confused, inebriated, distracted, or hostile. Cruise's suite of simulation tests cover for some variations in pedestrian behavior and physical characteristics such as the pedestrian's size or speed of movement, but we additionally use on-road data to gain a more holistic understanding of potential scenarios that we are exposed to in our designated ODD.

Findings from these analyses reveal target scenarios that we subsequently use for targeted expansions of our test frameworks.[104] Over time, Cruise expects to leverage a robust simulation framework for rapid verification and validation across future vehicle platforms, and in future city expansions.[105]

Additionally, Cruise inspects implementation features such as mapping and router features to ensure that our systems are designed to adhere to our defined requirements. An area that benefits from inspection is the Cruise AV's adherence to our definition of the ODD.

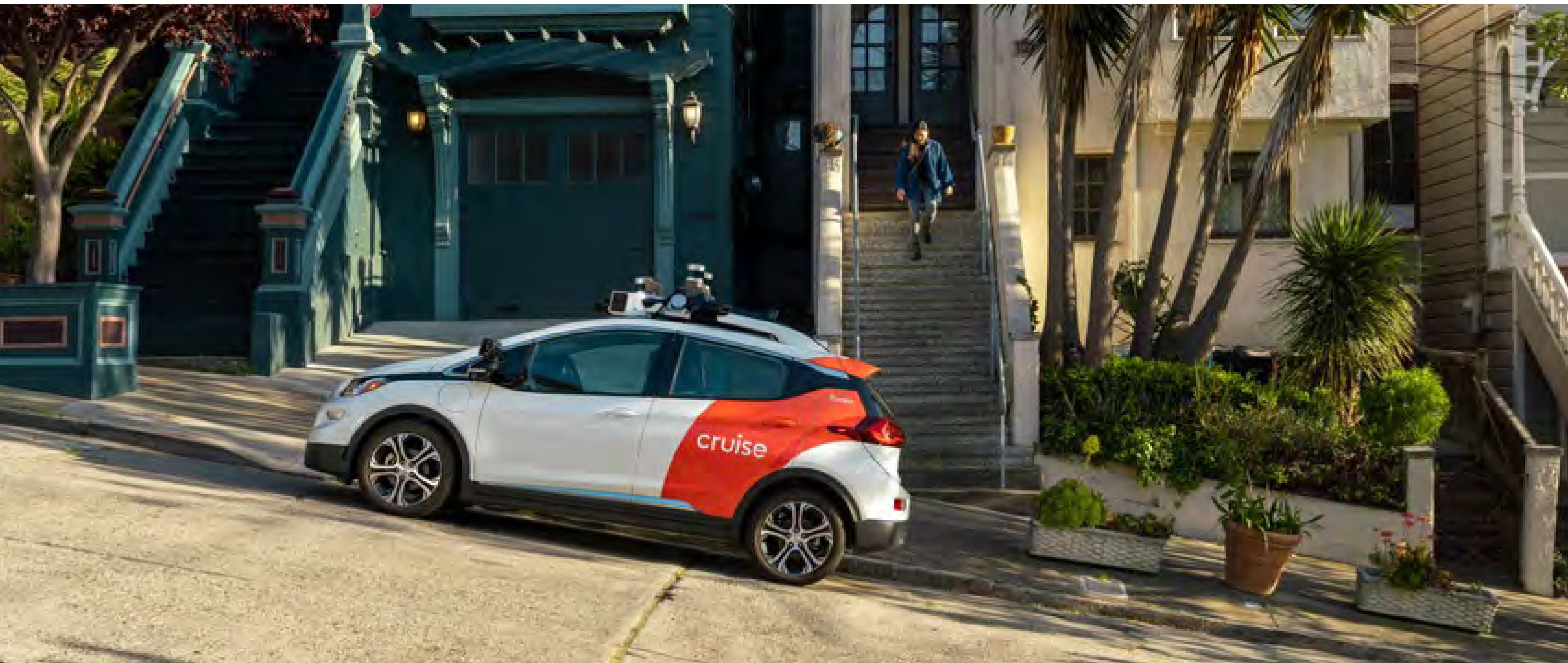
For example, our ODD definition excludes bus-only lanes from the Cruise AV's nominal driving area. To ensure that the Cruise AV does not route through bus-only lanes in nominal driving conditions,[106] Cruise establishes traceability between the ODD requirements and its corresponding behavioral design, and then inspects the corresponding implementation to identify the applied constraints levied by the behavioral design.[107] Verification by inspection allows Cruise to observe the absence of constrained behaviors, such as "not driving through bus-only lanes," with confidence that the Cruise AV will not perform such an action at the time of inspection.[108]

4.6.3 Continuous Performance Monitoring

Cruise develops performance dashboards to continually measure the Cruise AV's driving performance using targeted exposure data or operational data.

For example, Cruise monitors the Driverless AV's ingress into and egress from our Cruise Facility per release to ensure that the Driverless AV's ability to exit and enter its Cruise facility meets performance requirements in each new release. Because this capability is dependent on facility-specific driving variables such as the level of visual occlusion or the type of maneuver required to exit and enter the Cruise facility, the performance of Driverless AV ingress and egress is monitored per instance of ingress and egress, and can additionally be filtered by Cruise facility.

These performance measurements inform Cruise release decisions and LRR decisions, may affect our decision to release new or modified code, or enable a new facility, and may result in subsequent improvement initiatives to achieve acceptable performance.



4.6.4 Investing in the Future of Driverless Validation

While alternative methods of verification allow Cruise to exercise a continuous and iterative release process, they also provide Cruise a method of validating our existing testing framework and coverage to strengthen verification through testing. This will become increasingly more critical as we transition from driverless operations supported on our existing Chevy Bolt vehicle platform, which includes driver controls and allows for an AVTO; to our purpose-built Origin vehicle platform, which does not feature any driver controls.[109]

Cruise strives to evolve beyond validation with a human-in-the-loop serving as the defining precursor to driverless operation, given the future of ever-expanding autonomy performance data, as well as our vision for a future of purpose-built AVs. Cruise continually invests in reinforcing our testing verification methods, with a strong emphasis on simulation testing, to unlock this potential. Alternate verification methods are key in validating our testing framework to ensure that our tests are sufficiently robust, complete, and adequate to support greater levels of driverless automation and scale.

4.7 Immersive Incident Exercises

While Cruise's primary focus is the design and validation of the Driverless AV's autonomous response to any incident, Cruise recognizes that the corresponding operational response following an incident is critical to make appropriate fleet-wide mitigations and support internal and external investigations.

In support of this effort, Cruise performs regularly-scheduled Immersive Incident Exercises, i.e. a simulation of high-urgency incidents, to evaluate our company-wide preparedness.

Our response actions include:

- Immediate autonomous response
- Diagnostics and root-cause analyses
- Operational response
- Post-incident actions

4.7.1 Immersive Incident Exercises Overview

The intent of the Immersive Incident Exercise is to evaluate Cruise's existing processes, procedures, and operational execution in response to a high-urgency incident.

These steps include initial response, continual evaluation of the event, determination of the most appropriate course of action, and operational execution of the plan of action. It also includes post-event analyses such as the collection of documents and retrospectives on improvement opportunities.

The table below describes the high-urgency incident response in four phases:

Phase	Description	Timeframe
Phase 0 — Identify and Mobilize	Detection of an issue and initial notification, including automated notifications and manual alerts to required parties	Time of issue detection
Phase 1 — Stabilize Scene	Initial response to the reported issue	First hours after the incident
Phase 2 — Assess and Identify	Deep dive investigation into the event, decisions on operational impact, reporting and engagement with regulators and impacted parties as needed	Following hours and days after the incident
Phase 3 — Recover	Assessment of crisis resolution performance, collection of information, support to regulatory investigation (as required), identification of process improvements	Throughout the days and weeks after the incident

4.7.2 Benefits of Immersive Incident Exercise

The Immersive Incident Exercise provides a representative end-to-end test of the processes, interactions of parties, and tools that are used to enable Cruise's response to a potential high-urgency incident.

The parties involved in incident response may include the boots-on-the-ground operators with initial response and collection of situational context; engineers and managers responsible for evaluating and triaging the severity and impact of the event; and mid- and senior-level leadership receiving the briefings and making executive decisions regarding the appropriate response.[110] The parties operate with limited information throughout the exercise and are tested on the tools and training they need to collect more information or make decisions.

The success of such an exercise is measured in the following ways:

- Whether the diagnosis, risk evaluation, and resulting operating decisions and communications were made in a timely and effective manner
- The number of issues identified that affected or compromised Cruise's ability to make effective and timely decisions
- The severity and impact such issues had on the final outcome of the decision, and on similar decisions that may need to be made in the future
- Evaluation of the exercise itself to determine whether the Critical Severity exercise as performed was sufficiently representative

Immersive Incident Exercises help prepare the extended team for real world events, and maintain the process execution muscle memory needed to enable quick response and decision making within a limited time frame, and with limited contextual information. An additional benefit to the Immersive Incident Exercise is the tangible experience of responding to a high-urgency event with the full weight of the risk and the consequences of their decisions.

Immersive Incident Exercises are increasingly crucial as the ODD and the number of Driverless AVs on the road expand.

As Cruise progresses in our product development maturity, we are committed to continually improving our ability to efficiently, productively, and safely handle high-urgency incident situations.

[81]See more details in Operational Design Domain.

[82]See more details in Test Scenario Development.

[83]Our AVTOs undergo a training course and certification that covers AV education, the take over (TKO) process, autonomous driving procedures, rules of the road, and defensive driving through in-class, at car, in-car, private environment, and public environment stages.

[84]See more detail in Test Scenario Development.

[85]See more detail in Operational Readiness.

[86]See more detail in Alternative Verification Methods.

[87]See more details in Appendix C: Actors and Systems.

[88]Note that the camera view becomes available to the operator as situationally needed.

[89]See more details in Release Process Overview.

[90]See more details in Test Scenario Development.

[91]See more details in Feedback Loops.

[92]The use of this term is used as a non-gendered alternative to RAND's terminology, "roadsmanship." Fraade-Blanar, L., Blumenthal, M. S., Anderson, J. M., & Kalra, N. (2018). Measuring Automated Vehicle Safety - Forging a Framework (RR-2662). RAND Corporation. https://doi.org/10.7249/RR2662.

[93]See more details in Root Causing and Prioritization.

[94]See more details in Root Causing and Prioritization.

[95]See more details in Feedback Loops.

[96]Scenarios derived from non-observed sources, such as SIREN tickets, may require top-down derivation of test cases as an alternative to simulation tests re-created with historical data.

[97]https://downloads.regulations.gov/NHTSA-2015-0006-0025/attachment_1.pdf

[98]https://cdn.euroncap.com/media/56143/euro-ncap-aeb-c2c-test-protocol-v302.pdf

[99]Version 1: https://www.iihs.org/media/a582abfb-7691-4805-81aa-16bbdf622992/REo1sA/Ratings/Protocols/current/test_protocol_aeb.pdf

Version 2: https://www.iihs.org/media/f6a24355-fe4b-4d71-bd19-0aab8b39aa7e/TfEBAA/Ratings/Protocols/current/test_protocol_pedestrian_aeb.pdf

[100]https://www.sae.org/standards/content/j3016_201806/- Section 3.10

[101]See more details in Release Process Overview.

[102]See more details in Release Process Overview.

[103]Cruise considers this a sensible assumption in a simulation testing framework because the range of "pedestrians behaving in unreasonable manners" is extremely broad.

[104]See more details in Test Scenario Development.

[105]See more details in Cruise Origin: The Next Generation of Autonomous Vehicle and Expansion Beyond San Francisco.

[106]There may be contingency situations in which it is necessary to route through bus-only lanes, e.g., as a safety-critical driving response.

[107]Inspections can be accompanied with routing or exposure analysis for more robust verification.

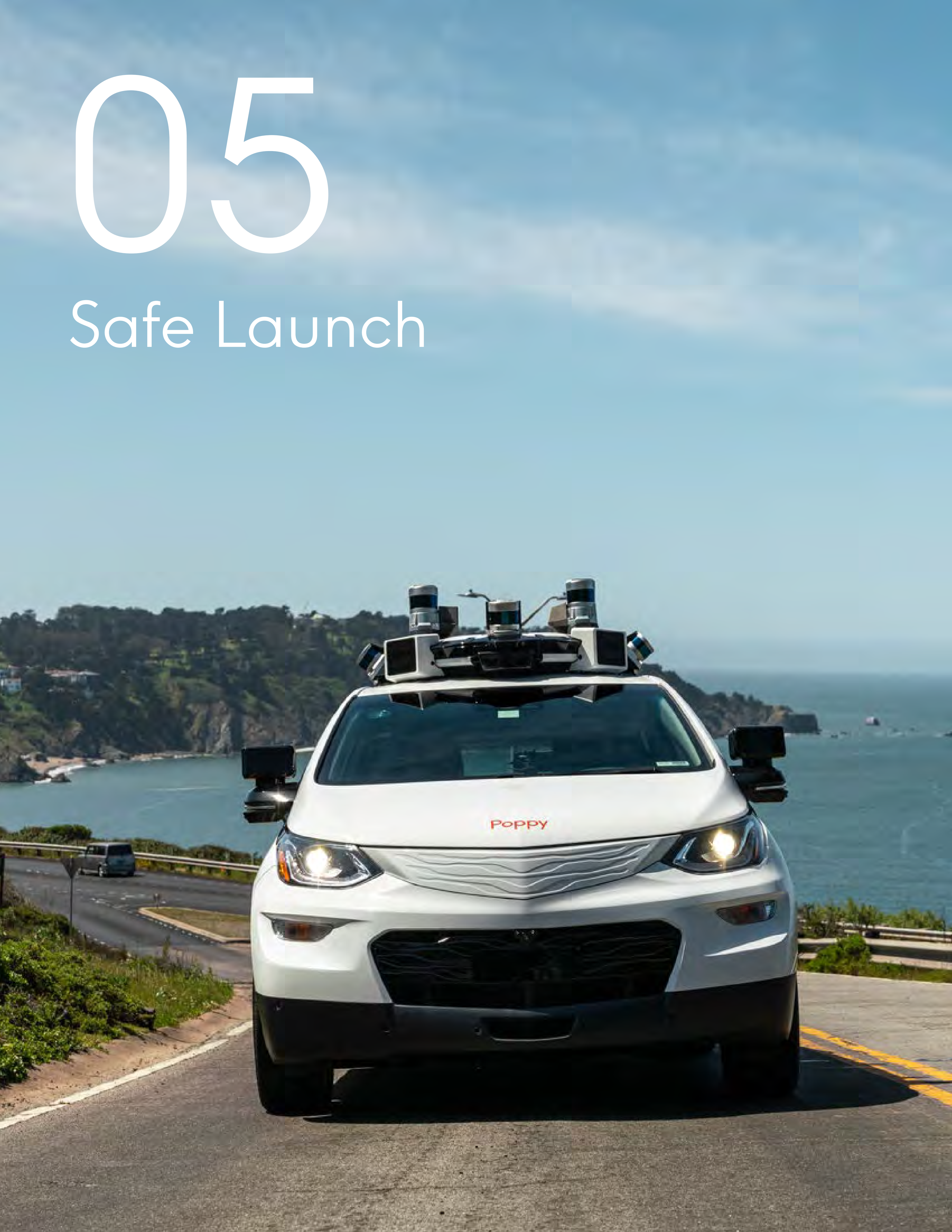
[108]See more details on how deviations observed on road are mitigated and resolved in Feedback Loops and Root Causing and Prioritization.

[109]See more details in Cruise Origin: The Next Generation of Autonomous Vehicle.

[110]Depending on the circumstances of the event, both Supervised and Driverless Fleets across multiple operational areas may be affected by the outcome of such a decision.

05

Safe Launch



Beyond verification and validation, Cruise takes additional steps to ensure our driverless service is fully operations-ready.

We start with an LRR to determine, based on the evidence of the AV's performance and any remaining residual risks, whether we are ready to expand the parameters of our driverless service. Beyond the launch decision, we take steps to train our operations teams and prepare them to provide live support; process and inspect each vehicle in the Driverless Fleet to ensure it is properly registered and configured for driverless operations; and perform critical inspections and deployment checks prior to deployment to ensure that our Driverless Fleet is operating at optimal operational health.

5.1 Launch Readiness Review

Cruise holds LRRs as key safety decision meetings for evaluating whether our Driverless Fleet is ready for a proposed program expansion.

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Program expansions can touch on a number of variables, including but not limited to:

- Geofence area
- Hours of operation
- New environmental elements
- Size of driverless fleet

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To make these determinations, Cruise considers safety performance indicators, which include:

- Cruise AV safety performance
- Cruise AV reliability performance
- The completion, integration, and verification status of new features
- Risks captured in the Cruise Safety Risk Register

As fitting to our safety approach of continuous improvement, the LRR process itself has evolved and matured alongside our driverless technology. Moreover, each subsequent LRR has introduced unique elements, such as the type of expansion proposed in the LRR, or new performance measurements, that have required a highly tailored approach.

However, the core of what Cruise strives to achieve through the LRR remains the same:

01 Process all pertinent information regarding Driverless Fleet safety functionality and performance in a centralized forum of critical stakeholders

02 Identify whether our Driverless Fleet is ready to enter a new risk exposure profile

03 Take any remedial actions as necessary to address outstanding safety risks or concerns

04 Decide whether to authorize or delay program expansion

Cruise performed its first official LRR in September 2021 to decide whether our Cruise AV was prepared, from a technical and safety perspective, to operate driverlessly on public roads. Each subsequent LRR has presented Cruise with a unique opportunity to evaluate our readiness to expand to new horizons of operation. This includes a continuous expansion of LRR considerations beyond safety, including factors such as reliability and customer experience.

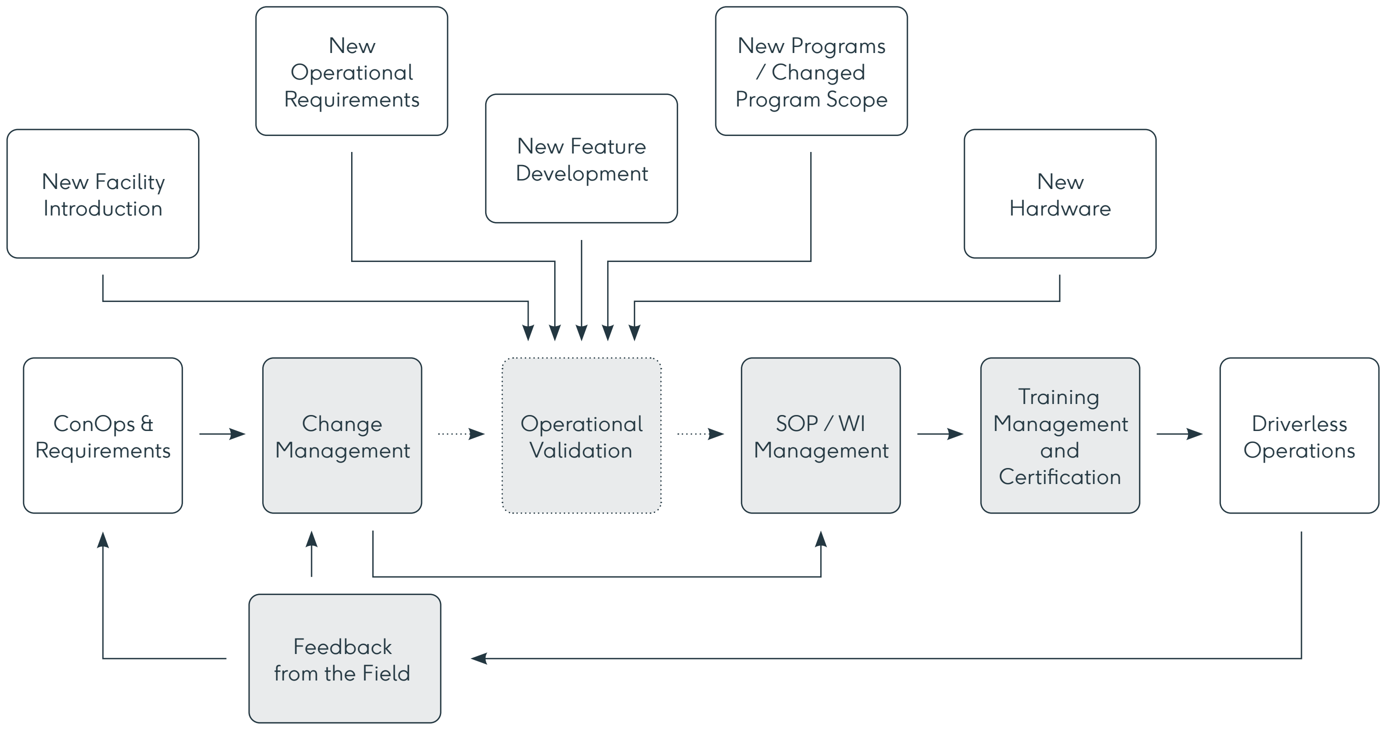
Cruise has approached each LRR decision with careful consideration, and each LRR decision asks our accountable Risk Owners and Accountable Executive to decide whether to expand our program upon careful consideration of the risk portfolio.

5.2 Operational Readiness

Cruise's live operators provide crucial support to our Driverless AVs, passengers, first responders, and third party interactions, making Operational Readiness key to Cruise's driverless operations.

Cruise establishes operational readiness for driverless operations in five stages:

1. Change Management
2. Operational Validation
3. Standard Operating Procedure (SOP) and Work Instruction (WI) Management
4. Training Management and Certification
5. Feedback from the Field



5.2.1 Change Management

Every significant change on the Cruise AV or in the operational processes undergoes a review by a change review board composed of members from operations, maintenance, training and safety teams. Instances of new changes requiring operational validation may include the introduction of new or modified: ConOps; Cruise Facilities; operational requirements; features in operator tools and downstream systems; programs or changed program scope; vehicle components or equipment, which may include the roll-out of new hardware retrofits or vehicle platforms.

Tool interface changes for vehicle operators go through a special review by a human factors safety engineer in addition to standard feature testing so that potential causes of human error are reduced or eliminated out of the design or processes, and vehicle operators are properly trained on the use of the new or changed tools.

5.2.2 Operational Validation

Operational Validation describes the process of ensuring that any steps designed for the operator are able to be performed and optimized before formalizing the outcome into documentation.[111]

Operational Validation objectives include confirming that tool interfaces are clear and accessible to the operator; performing the operational steps with all systems integrated so that the end outcome of a given step is functional and as expected; and walking through the steps in sequence to make sure that it makes sense in the operator environment. Operational Validation can be performed as a dry-run of operator procedures to identify any necessary adjustments before the documentation and training is rolled out to operators.

5.2.3 Document Management

SOP and WI Management describes the process of documenting each scenario that the Cruise operator(s) may encounter, including step-by-step procedural descriptions and clear identification of the operator responsible for each step. Depending on the feature developed, this may require the creation of a new SOP for new scenarios, such as introducing a new interaction between the Driverless AV and an ODD element with an operator in the loop; or the revision of an existing SOP to accommodate modifications to an existing flow, such as identifying an alternative operator to take on an existing task.

SOPs can be updated based on new Operational Validations or as a result from feedback from the field, and undergo a document change control process to ensure that all changes to the formal plan of record are understood, approved, and rolled out consistently throughout all impacted documents.

5.2.4 Training Management and Certification

Training Management describes the process of developing training materials based on the SOPs for individual operators. This can include additional documentation, classroom exercises, quizzes, and live drills. Because the training materials are developed based on the plan of record documented in the SOPs, training development and updates depend heavily on SOP documentation change control.

All operations roles require some degree of specialized onboarding and on-the-job training due to the novel nature of our work and our Cruise AV technology. All vehicle operators spend time in a mix of classroom and hands-on courses to learn about Cruise AV fundamentals, as well as the specifics of their role and tasks.

Certain roles require special certifications and, in some cases, individual permits issued by local authorities. Cruise manages all of this training through a formal course structure with standardized curriculum and knowledge checks that are based on industry best practices in safety training management. Cruise maintains a formal record of operator certifications to ensure that each operator is well-prepared to fulfill their duties.

5.2.5 Feedback from the Field

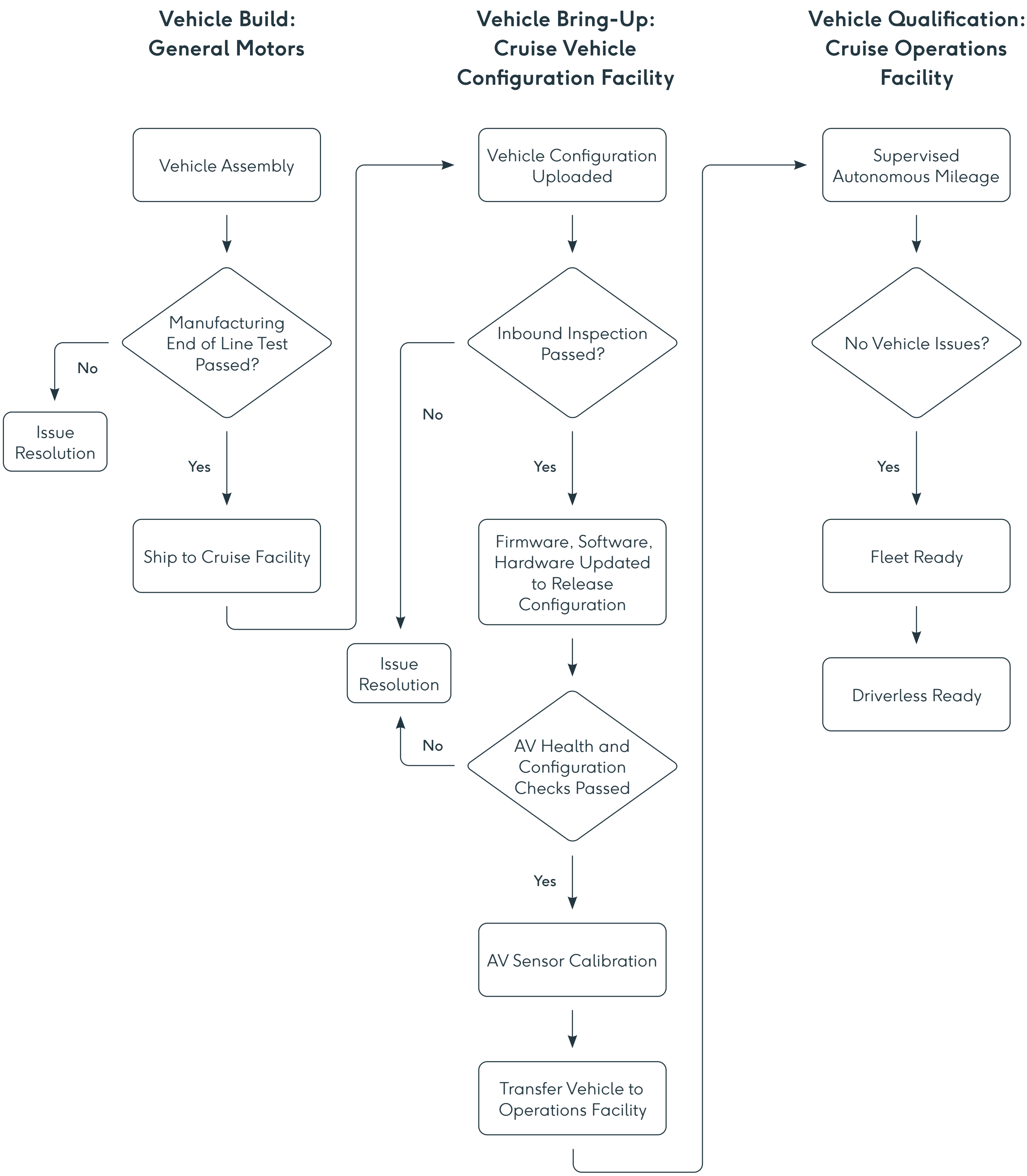
Feedback from the Field describes the process of collecting operator feedback or monitoring operator performance during Driverless Operations to identify changes needed in the SOPs. Example changes may include flow optimization requests, addition of operational steps to ensure that operational requirements are met, or adjustments of operator responsibilities.

This feedback allows individual Cruise operators to surface issues that have the biggest impacts on operator efficiency and adherence to operational requirements, and represents a key source of updates to the ConOps, SOPs, WIs, and trainings that are managed through the change control process.

5.3 AV Bring-Up and Qualification

AV Bring-Up and Qualification describes the process by which Cruise processes and registers a new AV as a valid driverless vehicle; perform a series of inspections and checks to ensure that the appropriate hardware, firmware, and software are installed on the vehicle; and formally approve the Driverless AV as being operations-ready before allowing its operations on public roads.

Below is a diagram that illustrates the AV Bring-Up and Qualification process of a Driverless AV.



The Cruise AV is assembled at GM's Orion facility on a vehicle assembly line in accordance with GM's defined best practices and standard procedures, allowing inspections and tests to occur throughout the vehicle build process.

Prior to shipment to the Cruise vehicle bring-up facility, Cruise AVs go through a final manufacturing end-of-line test to ensure satisfactory vehicle assembly and component operation, and also undergo a final inspection to ensure overall vehicle quality. Checks throughout the build include visual inspections, measurements of component positioning, and automated alignment checks, as well as confirming the absence of unexpected error codes.

Once the Cruise AV is received at the Cruise Vehicle Configuration Facility, Cruise technicians perform a series of visual and operational safety inspections as part of the vehicle receipt process. Cruise technicians then upload preliminary vehicle configuration information into the Cruise vehicle configuration system. Any discrepancies identified are shared with GM to drive resolution or identify any process or quality improvements needed as part of the vehicle build process.

The Cruise technicians subsequently perform all required firmware and software updates based on the latest released vehicle configuration, install additional equipment, and update documentation needed for driverless operations, such as the in-vehicle touchscreens and tamper-protection barriers. Cruise technicians then perform health checks and sensor calibrations before approving the Cruise AV to operate on the road.

Once the Cruise AV is transferred to a Cruise Operations Facility, the Cruise AV is sent on initial qualification drives, which are supervised autonomous drives with an AVTO; or, in the case of the driverless Cruise Origin vehicle, are performed in a closed-course setting with operator supervision. Qualification drives are reviewed to ensure no vehicle issues are apparent prior to approving the Cruise AV for driverless operations. After the Cruise AV receives any necessary regulatory approvals, it is promoted and added to the Driverless Fleet.[112]

5.4 Inspections and Deployment

5.4.1 Regular Maintenance Inspections

As part of our safety processes, Cruise performs recurring maintenance and inspections of our Cruise AVs. These inspections are derived from a combination of standard inspections required for commercial vehicle fleets and inspections based on years of findings from on-road autonomous fleet operations. Oversight includes detailed human inspections as well as automated system checks performed by the vehicle, occurring at varying frequencies.

In addition to meeting regulatory inspection requirements, inspection frequency is based on a continual reassessment informed by live fleet operational data, which is a method used by aviation operators.[113]

Cruise developed our vehicle maintenance plan in collaboration with GM, with input on projected and observed component reliability data derived from validation testing. Our reliability data allows us to plan for timely inspections, proactively replace components as needed, and ultimately reduce unplanned failures on the road.

5.4.2 Pre-Deployment Checks

Before deployment, each Driverless AV undergoes a daily inspection consisting of automated health checks, physical inspection checks, and operational equipment checks.

Automated software checks ensure that the Driverless AV is healthy and ready for driverless operations. The Driverless AV is designed with protective features to prevent driverless operations unless all software health checks successfully pass. This includes the clearance of any latched fault conditions.[114]

Physical inspections ensure that the vehicle itself is in good shape for operations. These checks include inspecting for damage or signs of tampering in the vehicle body, tires, windows, interior cabin features, and passenger safety mechanisms such as airbags and seat belts. This also includes inspecting the sensor suite for any damage or obstructions.

Operational equipment checks ensure that any equipment needed for driverless operations is properly installed or stored. This can include anti-tampering equipment; documentation needed for driverless operation; and the Field Responder packet that instructs any in-person operator of incident response protocols.

Once these pre-deployment checks are successfully passed, the Operations Coordinator[115] is authorized to deploy the Driverless AV into the field.

5.4.3 Weather Checks and Operational Pause

Based on our defined ODD limitations around heavy rain and fog, **Cruise uses a combination of weather forecasting and weather detection capabilities of the Supervised Fleet to limit our Driverless Fleet's exposure to weather-related exit ODD conditions.**[116]

Cruise AVs in both the Supervised and Driverless fleets continuously monitor for weather conditions that exceed our ODD thresholds for rain and fog. This allows us to collect observed weather data throughout our San Francisco operational map in real-time, which is accessible to the Operations Coordinator via the fleet monitoring tool in the time leading up to our driverless operations hours.[117]

Based on this input, the Operations Coordinator is able to limit the number of Driverless AVs deployed onto the road, or enact an Operational Pause command that restricts all Driverless AVs from being deployed.[118]

[111] Operational Validation is performed for first-time procedures, new changes with broad impact, or on a periodic cadence to test operational efficiencies; but is not always performed for small iterations.

[112]See more details on software release versioning in Release Process Overview.

[113]This method was developed and optimized over four decades by the Maintenance Steering Group of Airlines for America. MSG-3, The Intelligent Maintenance | Aviation Pros.

[114]See more details in High Level Architecture and System Design.

[115]See more details in Fleet Monitors.

[116]Live AV response to Exit ODD events is detailed in Incident Response Scenarios.

[117]See more details in Appendix C: Actors and Systems.

[118]See more details in Fleet Actions.

06
Passenger Experience

As part of our driverless service, Cruise provides a comprehensive passenger experience that encompasses passenger-facing features, messaging, and support.

Upon first engagement with a new Cruise passenger, we establish service agreements between the passenger and Cruise. Then we provide a multi-platform educational experience using introductory emails, the Cruise mobile app, and live feedback via the in-vehicle touchscreen to ensure that the passenger is prepared for a truly unique experience: a fully driverless ride.

Finally, we have live customer support through in-vehicle buttons or asynchronous support through the mobile app, which have been designed with a variety of accessibility needs in mind.

6.1 Passenger Ridehail Policy

6.1.1 Service Policy

To ensure that passengers are fully aware of the expected and appropriate behavior in Cruise's ridehail service, customers are required to agree to Cruise's Terms of Service[119] before creating an account to use Cruise's service.[120]

Accompanying the Cruise Terms of Service are the Cruise Community Rules[121] that cover our expectations for passenger conduct and safety behaviors during use of our service. Many of these rules are directly passenger safety related:

- Wear a seatbelt
- Do not bring illegal substances, hazardous materials, highly flammable materials, or any kind of weapon into the Cruise AV
- Safely enter and exit our Cruise AVs; watch out for other passengers, pedestrians, cyclists, and other road users

Some of these rules also guide positive and cooperative interactions with others:

- Cooperate with first responders
- Interact with Cruise customer support specialists via the in-vehicle help button, Cruise mobile app, or other Cruise AV interface
- Refrain from threatening, confrontational, discriminatory, harassing, disrespectful, offiensive, or inappropriate behavior towards others

Passengers are clearly informed that any violation of the Cruise Terms of Service or the Cruise Community Rules are grounds for suspension or termination of a passenger's account and their ability to use our service.

6.1.2 Accessibility Features

Cruise understands the need to factor accessibility into the design of our driverless service, and acknowledges that accessibility can benefit the safety and ease of use of all Cruise passengers, including those with disabilities. **Our Driverless Deployment Program complies with legal accessibility obligations, including accommodations for service animals and other means of supporting access.**

Additionally, to help us achieve the goal of designing and building an accessible service, we have developed strong relationships with organizations and advocates across the disability community to receive input from a broad range of voices and perspectives.

For example, we have engaged with organizations across the accessibility spectrum, including with partners from the National Federation of the Blind and the San Francisco Lighthouse for the Blind, to understand existing challenges in the ridehail experience, such as locating the ridehail vehicle at pickup and understanding route progression during a ride. This collaboration has been instrumental to our efforts to build and operate a more accessible and inclusive ridehail service that minimizes safety concerns for any and all passengers who choose our driverless service.

To date, we have incorporated a number of accessibility features that are designed to support a wider range of passengers using our service, **including those who are blind or have low vision; are deaf or hard of hearing; or have limited mobility.**

Through further engagement with advocacy groups and users with disabilities, Cruise is committed to building on this work by continuing to advance and improve on accessible features that allow us to serve more communities.

6.1.2.1 Mobile App

The Cruise mobile app is compatible with iOS VoiceOver, which provides blind and low vision users with auditory feedback if they cannot visually access the mobile app.

This allows users to:

- Receive real-time updates through audio notifications
- Navigate to the Cruise AV through the mobile app's audio-based navigation systems
- Interact entirely through the mobile app to start ride, end ride, and call for assistance

This design was based on our findings from organizational partners, external user studies, and our own internal user studies, which concluded that blind and low vision passengers prefer using their personal mobile phones compared to less familiar interfaces. Additionally, the mobile app provides assistance to deaf and hard of hearing passengers by providing multiple methods of communication with Customer Support, including Real-Time Text (RTT) support as an alternative to a voice call.

6.1.2.2 In-Vehicle Touchscreen

The Cruise in-vehicle touchscreen provides visual and audio prompts from the moment passengers enter the vehicle, creating a multi-sensory experience that is accessible to all passengers. **The in-vehicle touchscreen features a visual display with touch screen interaction to allow users to customize their ridehail experience, including the ability to toggle the display between daytime and nighttime modes.** The in-vehicle touchscreen also produces audible alerts with real-time updates about the ride, such as an audio alert once the Cruise AV arrives at its destination.

6.1.2.3 In-Vehicle Buttons

The Cruise AV features physical buttons with distinct tactile indicators designed to help passengers to identify their desired button. The two buttons currently supported inside the cabin are the **End Ride button**, which allows the passenger to request an early end to their ride; and the **Help button**, which initiates a call to Customer Support.

6.1.2.4 In-Vehicle Wheelchair Accessibility

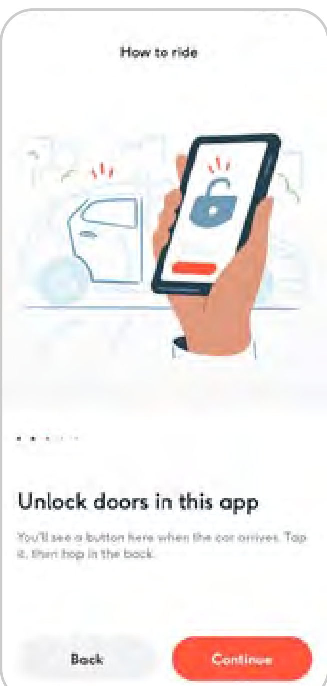
Cruise's initial driverless service operates with the Chevy Bolt Cruise AV. The Chevy Bolt Cruise AV can securely fit a foldable wheelchair on the rear floor or backseat with one passenger. The rear floor and backseat can also accommodate similar sized foldable walkers and foldable scooters, in addition to other smaller assistive devices such as crutches and canes.

In future driverless fleets, Cruise will provide driverless rides in our purpose-built vehicle, the Cruise Origin. **Cruise is currently developing a wheelchair-accessible model of the Origin.** We are working closely with the disability community to receive feedback, counsel, and guidance on this model and have engaged in user testing of early prototypes.

6.2 Passenger Education

Many passengers will experience a fully driverless ride for the first time when they participate in Cruise's ridehail service. Cruise is invested in making sure that every ride is safe and easy-to-understand for passengers from the very first stages of providing our driverless service. **Prior to initiating a ride, passengers will have access to educational onboarding materials through many communication channels, including the mobile app and email, that will address ride safety.** These onboarding materials will help passengers understand what to expect during their ride, including support options available and how to use them.

6.2.1 Passenger Education Materials



Before their first ride, passengers receive onboarding materials that explain the basics of how our Cruise AVs safely navigate on public roads.

First, passengers learn how the Cruise AV is built to operate safely without a human driver. Passengers learn that they should never assume the role of a driver or attempt to take operational control of the Cruise AV at any time. Passengers are also educated in how Cruise's Driverless AV works, from rapidly synthesizing information collected by the sensors, to characterizing and understanding its surroundings, to making driving decisions. This orientation enables passengers who are new to driverless technology to better anticipate their first driverless ride.

Upon completion of this orientation, passengers are asked to accept the Cruise Terms of Service in the mobile app.

6.2.2 Pre-Ride Passenger Safety Checks

The mobile app guides passengers to properly hail, identify, and enter the Cruise AV.

At the start of a ride, Cruise provides passengers with easy-to-understand reminders to help increase their safety, comfort and awareness of how to fully enjoy our driverless service. After requesting a Cruise AV through the mobile app, passengers are able to identify their designated Cruise AV through the user interface in the mobile app, which displays the Cruise AV location, name, and estimated time of arrival at pickup.

If there is not a suitable location for the vehicle to stop at the requested pickup location, the Cruise AV selects a suitable location nearby.[122] The mobile app conveys this change to the passenger as they await their ride, and passengers are able to enable audible wayfinding cues as desired to navigate to the Cruise AV.

The passenger identifies an approaching Cruise AV by our orange branding and the Cruise emblem visible on the exterior of the vehicle. Once the Cruise AV is near, the passenger confirms that this is their assigned vehicle by matching the Cruise AV name in the mobile app with the displayed name on the vehicle. Passengers are able to reach out to Customer Support for questions or concerns through the mobile app. Once the Cruise AV arrives, only authorized passengers are able to start the ride through the mobile app or in-vehicle touchscreens.[123]

To promote in-vehicle passenger safety, the Cruise AV reminds passengers via in-vehicle touchscreen and the mobile app to close all doors and fasten seat belts.[124] Once the passenger satisfies these conditions, the in-vehicle touchscreen and mobile app allow the passenger to start the ride.

6.2.3 Real-Time Contextual Awareness

The Cruise AV features in-vehicle contextual cues that provide passengers real-time situational awareness about the ride and expectations for passenger actions. These contextual cues make our driverless service and passenger experience more accessible and intuitive.

During the ride, passengers are able to access this information through the mobile app, as well as visual and audio alerts from the in-vehicle touchscreen. Passengers can follow trip progress through the in-vehicle touchscreen or the mobile app, and important live trip updates, such as changes to their trip route or a necessary stop, are provided using audio and visual cues. If a passenger feels the need, they are able to change their destination or request to end their ride early using the in-vehicle button or the mobile app.

Once the Cruise AV arrives at its destination or heeds a passenger's request to end their trip early, the mobile app and in-vehicle touchscreens will provide guidance on how to safely exit the vehicle with consideration for other road users. If a passenger attempts to exit the Cruise AV before it is pulled over in a safe location, the Cruise AV will respond by coming to a stop and establishing a call connection with a remote operator.

6.3 Multi-Way Communications

To ensure that passengers have access to live support at all times throughout their Cruise trip, Cruise has built in Customer Support request features through the mobile app and an in-vehicle button.

After getting matched with a Cruise AV and throughout their trip, the passenger is able to use the in-app voice communication to communicate with Customer Support in real time. Customer Support can assist with passenger support requests such as unlocking doors, helping the passenger locate their Cruise AV, or attending to possessions left behind in the vehicle.

While the passenger is in the Cruise AV, they can access the in-vehicle Help button, which is lighted for ease of accessibility and visibility in day- or night-time lighting conditions. This button also features tactile indicators to help passengers, including blind or low-vision customers, identify and differentiate the Help button and End Ride buttons.

Once connected to Customer Support, the passenger can express their concerns and communicate if they are encountering an emergency event. Customer Support can expand the voice call at any time as needed to engage Incident Expert and Emergency Advisors for live emergency support.

The Incident Expert is able to command the Cruise AV to pull over, and the Emergency Advisor is specially trained to handle passenger medical emergencies and dispatch first responders to the scene as needed.[125] The multi-way communications link remains active between Cruise and the passenger throughout the escalation process. All teams that support passenger safety undergo rigorous, specialized training and continued education to best perform their specific functions.[126]

In addition to accommodating passenger-initiated requests for communications, the Cruise AV also features automated call initiators to accommodate situations requiring proactive communication.[127]

For example, if the passenger does not start the ride after entering the Cruise AV, or does not exit the Cruise AV at the end of a ride, an automated Customer Support call will initiate to allow Customer Support to reach out and check in with the passenger. Additionally, in instances where the Cruise AV has encountered an event that interrupts the ride, such as a degraded state, exiting ODD event, or collision, an automated call will initiate accompanied by automated notifications in the in-vehicle touchscreen to reassure the passenger that Cruise is aware of the event and is reaching out to provide assistance.[128]

[119]https://getcruise.com/terms

[120]The Cruise Terms of Service is also available to our customers at any time through the mobile app.

[121]https://www.getcruise.com/terms/us/ridehail/community-rules

[122]Cruise AVs are designed to adhere to constraints on permissible pullover locations that take legal and safety considerations into account. While there are specific circumstances in which the AV may not be able to adhere to these constraints, e.g., in the event of a failure or a detected collision event, Cruise is working to improve our Driverless AV's ability to consistently pull out of lane. If a passenger identifies a stopping location in which they do not feel safe to enter or exit the vehicle, they can raise their concerns to our Customer Support Representative at any time.

[123]Cruise Passenger Safety Plan (2021, Nov.). Page 15. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/consumer-protection-and-enforcement-division/documents/tlab/av-programs/phase-i-av-deployment-program-al-status/2021-11-05-advice-letter---cruise-application-for-driverless-deployment-permit.pdf.

[124]See more details in Human vs Autonomous Driving, footnote 7.

[125]See more details in Remote Operators.

[126]See more details in Operational Readiness.

[127]When any of the automated call initiators are created for deaf or hard of hearing users, Cruise will utilize our integrated Real-Time Text (RTT) support to effectively communicate with these users.

[128]See more details in Incident Response Scenarios.

07
Live Operational Support

The Cruise Driverless Fleet is supported by a team of human operators who continuously monitor fleet health for issues, assist individual Driverless AVs and passengers, and provide in-person support.

These operators include fleet monitors, remote operators, and in-person operators. Cruise operators are always available to keep the Driverless Fleet operational and respond to any individual or fleet-wide incident.[129]

In response to any on-road incident, Cruise applies an Incident Triage and Escalation policy to identify appropriate short-term operational responses while initiating longer-term investigations in parallel. Possible response includes fleet actions to manage the affected Driverless AVs in the field.

7.1 Fleet Monitors

7.1.1 Pit Crew Operator

The Pit Crew Operator works in the Cruise facility and is primarily responsible for ensuring that each Driverless AV is prepared for driverless operations.

The Pit Crew Operator's responsibilities include:

- Performing fleet maintenance tasks, such as charging, cleaning, and initiating data offload
- Manually operating the Cruise AV between and within the Cruise facilities
- Performing necessary inspections, and escalating issues for troubleshooting and resolution
- Deploying and receiving the Driverless AV in the Cruise Facility

The Pit Crew Operator works with a checklist of methodical visual, software, and equipment inspections for each Driverless AV to check for irregularities or issues that would prevent deployment. Depending on the nature of the issue, the Pit Crew Operator is able to resolve the issue directly, or else escalate more serious or complex issues to a technician or Troubleforce Operator.

If the Driverless AV passes all inspections, the Pit Crew Operator commands the Driverless AV to engage and depart autonomously from the Cruise facility onto the public road. The Pit Crew Operator also receives each Driverless AV returning to the Cruise Facility to process each vehicle, offload data, confirm the vehicle's designated operability status, and position the vehicle for receiving technical attention as necessary.

7.1.2 Operations Coordinator

The Operations Coordinator is the central node of communication between cross functional operations teams and is responsible for the Driverless Fleet as a whole.

The Operations Coordinator's responsibilities include:

- Monitoring the driverless fleet health
- Monitoring weather conditions within the defined ODD geofence; tracking reported Driverless AV incidents to ensure end-to-end resolution across functional teams
- Making or escalating decisions affecting the Driverless Fleet based on situational context
- Initiating fleet actions to one or more Driverless AVs to pause operations, pull over, or return to facility
- Dispatching Field Support Representatives to Driverless AVs that require in-person assistance

The Operations Coordinator's responsibility starts prior to driverless operations hours, when they observe the map display via the fleet monitoring tool to watch for reported weather detections or receive any input from external teams on any fleet-wide issues. The Operations Coordinator has the ability to enact an Operational Pause at any time, which systematically prevents Driverless AVs from being commanded to deploy until the Operational Pause is lifted.[130]

Once the Driverless Fleet is deployed onto the field, the Operations Coordinator monitors the fleet monitoring tool to see incoming reports of Driverless AV incidents. Upon being notified of an active incident, the Operations Coordinator tracks its progression to identify whether further operational intervention is needed. The Operations Coordinator is able to access information such as autonomous mode, connection with a remote advisor, and passenger occupancy using the fleet monitoring tool to aid their situational assessment.

The Operations Coordinator's response to an incident can vary depending on the progression of the incident. They can dispatch an in-person Field Support Representative or Safety Escalation Team to the Driverless AV; summon the Driverless AV back to facility; or escalate any incidents requiring immediate attention to the appropriate stakeholder parties. They can also observe that the incident has been successfully resolved by a remote operator, such that the Driverless AV has returned to driverless operations and does not need further intervention.

In addition to individual incidents that take place in the field, the Operations Coordinator may be informed by external teams of an event that requires a fleet action response, such as a fleet-wide issue, or reports of an event taking place within the operational domain (e.g., large public gatherings such as protesting, riots, etc). The Operations Coordinator may receive specific guidance of the Driverless AVs' operability, and determines which fleet action is most appropriate for the incident.

7.1.3 Troubleforce Operator

The Troubleforce Operator is responsible for providing triaging and troubleshooting support for reported Cruise AV health issues.

The Troubleforce Operator's responsibilities include:

- Receiving reports of Cruise AV health issues, triaging the issue and recommending immediate response
- Characterizing whether a Cruise AV is suitable for continued operations
- Removing a Cruise AV that is not suitable for operations from the fleet
- Troubleshooting known issues with technicians to drive issue resolution
- Characterizing and cataloging unknown or newly encountered issues
- Providing input to the operations teams if any action is required at the fleet level beyond any individual Cruise AV

The Troubleforce team receives reports of Cruise AV health issues from both the Supervised and Driverless Fleet; and the support they provide can take place before, during, and after driverless operations.

If the support takes place before operations, the Troubleforce Operator works with the Pit Crew Operator and technician to characterize the issue and attempt to resolve it. If the issue requires extensive investigation, the Troubleforce Operator may pull the Cruise AVs from deployment for specialized resolution attempts.

If support takes place during operations, the Troubleforce Operator takes the additional step of triaging the issue and recommending immediate action, such as retrieving the Driverless AV to a Cruise facility or performing troubleshooting actions in the field, before diving into further investigation. The Troubleforce Operator is also able to place, evaluate, and remove road constraints from the Driverless Fleet's shared map as needed for operational response.

7.2 Remote Operators

7.2.1 Remote Assistance Advisor

The RA Advisor is responsible for providing driving task assistance to the Cruise AV.

The RA Advisor's responsibilities include:

- Confirming Cruise AV detections, such as the presence of an emergency vehicle
- Confirming whether the Cruise AV's intended path is obstructed
- Providing the Cruise AV guidance on a recommended path

The RA Advisor has access to live data from the Cruise AV, including occupancy state, AV health status, the Cruise AV's perception of its surroundings, and the Cruise AV's video feeds from external-facing cameras. Using this information, the RA Advisor is able to provide confirmation upon request of a Cruise AV's initial detection, such as object classification.

The RA Advisor is also able to bolster the Cruise AV's sensor detection as a supplementary input, such as a visual confirmation of object presence or non-presence. Additionally, the RA Advisor is able to perceive the Cruise AV's intended path and provide input on potential alternative paths to help the Cruise AV progress from its initial obstruction.

7.2.2 Customer Support Specialist

The Customer Support Specialist is responsible for handling all interactions with the passenger, providing customer support, and escalating to other remote operators as appropriate.

The Customer Support Specialist's responsibilities include:

- General customer support
- Assisting the passenger with locating and accessing their Cruise AV, or with available passenger actions such as requesting Remote Assistance support, changing destinations, or requesting End Ride
- Escalating to another operator such as an Incident Expert or an Emergency Advisor as situationally appropriate
- Receiving passenger feedback about the ridehail experience

Upon receiving a call, the Customer Support Specialist is able to access the Cruise AV's name, vehicle occupancy, vehicle location, whether there is an Incident Expert or Emergency Advisor on the call, and whether there is a RA Advisor providing assistance. The Customer Support Specialist is also able to access a live stream of the interior cabin cameras as situationally necessary. This information provides situational context that supplements any verbal communication the Customer Support Specialist is able to have with passengers, if any are present. Based on this information, the Customer Support Specialist makes support decisions which can include operator escalation or dispatch of Field Support Representatives.

In the case of a passenger emergency, the Customer Support Specialist escalates to an Incident Expert and Emergency Advisor as needed, and defers to the Emergency Advisor as the primary communicator to let them assess any emergency situations that are taking place. In the event that a Field Support Representative is dispatched in response to an event and arrives on scene, the Customer Support Specialist confirms to the passenger and any operators on the line that the in-person Field Support team has arrived, and transitions communications to the in-person team from that point forward.

The Customer Support team additionally has the ability to communicate to external third parties or first responders by commanding the Chevy Bolt Cruise AV windows open and raising the volume of the in-vehicle voice call system speakers, such that they can communicate the autonomy status of the Cruise AV, heed any instructions from first responders, or communicate with third parties to gain additional situational context.[131]

7.2.3 Incident Expert

The Incident Expert is responsible for receiving and responding to reports of incidents with the AV that require advanced response and live verbal context from the passenger.

The Incident Expert's responsibilities include:

- Collecting situational context on an incident to determine the appropriate course of action
- Authorizing or rejecting the Driverless AV's continued operation
- Commanding a Driverless AV to perform a MRC[132]

The Incident Expert may receive a variety of incident response requests requiring their input. They can be asked to confirm whether the Driverless AV is authorized to continue its autonomous operation; receive a verbal assistance request from Customer Support on the passenger's behalf; command the Driverless AV to perform a MRC or disengage from autonomous mode; and classify a detected collision event to determine the appropriate resolution after initial autonomous response. The Incident Expert is given specialized training to handle each of these distinct incident scenarios to ensure that the incident resolution action is appropriate for the situational context.

7.2.4 Emergency Advisor

The Emergency Advisor is responsible for providing emergency passenger assistance as needed upon receiving a voice call escalation, or receiving an Automatic Crash Response[133] detection.

The Emergency Advisor's responsibilities include:

- Taking on primary interactions with the passenger or involved third parties to assess the nature of the emergency
- Requesting 9-1-1 dispatch of first responders as situationally appropriate

Customer Support Specialists and Incident Experts are trained to defer to the Emergency Advisor as the primary point of communications during emergency situations, and Emergency Advisor support is available 24/7 to receive emergency calls or escalations at any time. If the passenger is unresponsive, an Emergency Advisor is able to interact with the Customer Support Specialist and Incident Expert to collect situational context of the Driverless AV's surroundings or cabin interior.

At any time the Emergency Advisor deems necessary, they can request the dispatch of first responders, at which point the Customer Support Specialist dispatches a Cruise Field Support Representative in parallel to work with the first responders and public safety officials, and offer in-person Driverless AV support.

7.3 In-Person Operators

7.3.1 Field Support Representative

The Field Support Representative is responsible for providing in-person support to Driverless AVs in the event that other recovery methods have not been successful, and the AV is not capable of returning autonomously to the Cruise Facility.

The Field Support Representative's responsibilities include:

- Attending to incidents in person
- Interacting with passengers, third parties, and first responders
- Manually operating the Cruise AV as needed

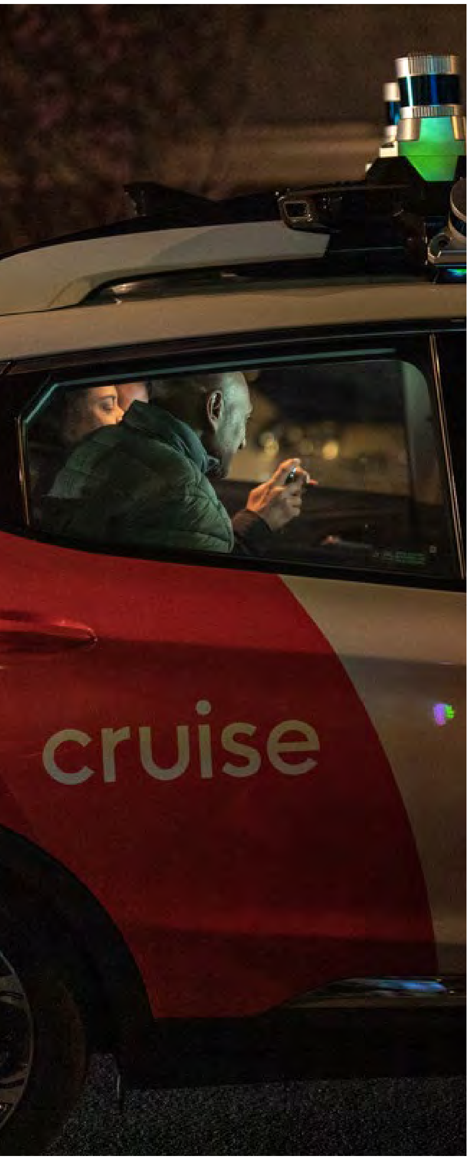
The Field Support Representative is requested by Customer Support Specialists at any time throughout driverless operations. Teams of Field Support Representatives are distributed throughout the operational map for broad dispatch coverage. Any remote communications with passengers, third parties, or first responders are handed off to Field Support Representatives once they are confirmed to have arrived on the scene, and Field Support Representatives are able to access the driving controls in the front of the vehicle[134] to manually operate the Cruise AV as needed.

7.3.2 Safety Escalation Team (SET)

The Safety Escalation Team (SET) member is responsible for providing in-person support for instances of passenger or third-party aggression or non-cooperation. This includes situations of Driverless AV vandalism, unauthorized cabin activity, occupants refusing to exit the Driverless AV, or unwanted public interactions, which require a level of interaction and de-escalation techniques beyond the domain of the Field Support Representative. The SET is composed of experienced off-duty or retired law enforcement officers who are Police Officer Standard Training certified and highly trained to resolve situations requiring de-escalation.

7.4 Live Incident Response

While the Driverless AV may encounter many different types of incidents on the road, the same basic steps take place for incident response.



First, the Driverless AV initiates an event detection. This can take place through the use of the Cruise AV's external sensor suite; signals from the vehicle cabin such as doors or actuator controls; or from the driving software itself. Then, the Driverless AV performs a stopping response maneuver appropriate to the detected event.

For example, the Driverless AV may perform a pullover maneuver in response to a heavy rain detection event, or a hard stop-in-lane maneuver in response to the detection of a potential high severity collision. In parallel, the Driverless AV establishes a voice call connection with the Incident Expert and Customer Support Specialist to communicate with any passengers, first responders, or involved third parties present and collect situational context. The Incident Expert additionally uses the RA System to monitor the Driverless AV's state and its surroundings.

Equipped with situational context and available inputs from the passenger, the Incident Expert makes a decision as to whether the Driverless AV can resume operations, or should stop.[135] The Customer Support Specialist can escalate to an Emergency Advisor if they perceive that a passenger present in the Cruise AV is injured or unresponsive.

The Incident Expert can approve the Driverless AV to resume operations using the RA System, and the Customer Support Specialist can close out communications with the passenger or third parties to ensure any remaining assistance needs are addressed. If the Incident Expert decides that the Driverless AV is not allowed to resume operations, the Customer Support Specialist informs the passenger that their trip is interrupted and dispatches Field Support Representatives to the scene. The Customer Support Specialist and Incident Expert remain connected with the passenger and any third parties until the Field Support Representative arrives on scene.

7.5 Incident Response Scenarios

As part of driverless operations, the Driverless AV may encounter a variety of incident scenarios that require a mixture of autonomous and operator-driven response.

Most instances are able to be resolved with the Driverless AV returning to driverless operations. Some instances are not able to be resolved, such that the Driverless AV must initiate a Vehicle Retrieval Event (VRE) to receive assistance from a Field Support Representative.

The determination of whether an AV is able to continue driverless operations is highly dependent on the situational context, and can be determined automatically by the Cruise AV if it knows in advance that its operational thresholds are exceeded, such as specific ODD exit or degraded state scenarios; or determined manually by an assisting Incident Expert if human interpretation of a scene is required, such as collision confirmation or unwanted public interaction. The operational thresholds for the scenarios that the Cruise AV can recover from autonomously are continuously expanding as we collect more data and make improvements in our driverless technology.

The following sections provide details on the various scenarios that the Driverless AV may encounter for illustrative purposes.[136] As our driverless technology and capabilities evolve, the specific incident response designs will also change over time.

7.5.1 Exit ODD

The Cruise AV is designed to avoid ODD exit scenarios where possible by monitoring for weather conditions levels, reporting rising weather detection trends, and preemptively returning to the Cruise facility as needed. However, in circumstances in which extreme weather conditions overtake the AV, the Driverless AV is able to detect the weather event, attempt to pull over out of traffic, and remain stationary until the weather conditions subside or it is manually retrieved. While the Driverless AV performs its stopping maneuver, the Customer Support Specialist automatically connects to the Driverless AV to inform the passenger that the Driverless AV is experiencing an interruption to the trip. A Driverless AV that has exited its ODD may need to be manually retrieved back to the facility by the Field Support Representative depending on subsequent weather conditions.

7.5.2 Degraded State

The Driverless AV is designed to continuously monitor its health and detect instances of failures that compromise its ability to drive autonomously. Based on the failure encountered and the Driverless AV's residual driving functionality,[137] the Driverless AV performs a stopping maneuver to achieve an MRC and evaluate whether it will cease operations altogether or attempt to reset functions to restore functionality.

While the Driverless AV is performing its stopping maneuver, the Customer Support Specialist is connected to the Driverless AV to inform the passenger that the Driverless AV is experiencing an issue. If the Driverless AV attempts to reset, the Customer Support Specialist advises the passenger to remain in the Driverless AV until the reset attempt is complete. If the Driverless AV is unable to recover or experiences a failure that does not allow recovery, the Customer Support Specialist informs the passenger that the Cruise AV is no longer able to complete its trip. A Driverless AV that has encountered an unrecoverable failure must be manually retrieved back to the facility by the Field Support Representative.

7.5.3 Cybersecurity Attack

The Cruise AV is designed with intrusion detection mechanisms to detect cybersecurity attacks.[138] Upon detection, the Driverless AV initiates a degraded state, performs an appropriate stopping maneuver, and achieves an MRC, to protect against situations in which its driving capability is compromised.

In parallel to the immediate AV response, detection of a cybersecurity intrusion notifies Cruise cybersecurity personnel, who evaluate the nature of the threat and notify the operations teams of any fleet-wide responses that are necessary. As a result, both the individual Driverless AV encountering the cybersecurity attack and the greater Driverless AV fleet are able to respond to cybersecurity threats in real time.

7.5.4 Tampering

Tampering describes an event in which an occupant interacts with the Driverless AV in an unauthorized way. This may range from attempting to enter the front of the vehicle cabin through the front doors, to interacting with the vehicle actuator controls such as the steering wheel or brake pedal.[139] Cruise addresses tampering risks in two ways: **preventative controls and protections, and detection and response mechanisms.**

Preventative controls include:

- Authentication mechanisms to ensure that the occupant in the Driverless AV is an authorized passenger
- Ridehail policy to limit passenger access to the rear seats, away from driving controls
- Physical barriers to discourage access to the front of the cabin
- Physical covers over controls

Tampering detection mechanisms include:

- Front door activity detection
- Front seat belt detection
- Actuator control detections
- Vehicle hood, hatch, and charger port detection

These mechanisms help the Driverless AV identify active tampering attempts that may lead to unauthorized input into the Driverless AV actuators. Based on the type of tampering detection, the Driverless AV performs a stopping maneuver to safely achieve an MRC and allow a Customer Support Specialist to communicate with any occupants and evaluate the situation.

7.5.5 Unwanted Public Interaction

An unwanted public interaction (UPI) is an event in which an external third party initiates an undesirable interaction with the Driverless AV. Examples of UPIs can include obstructing the Driverless AV's path of driving; initiating physical contact with the Driverless AV; or harassing the occupants of a Driverless AV.

UPIs are unique in that they take place in many forms, and are highly dynamic and unpredictable situations that may require human operator intervention to determine the appropriate course of action. Depending on the nature of the interaction, a persistent UPI may force the Driverless AV into a situation in which it must achieve an MRC and subsequently initiate a VRE requiring onsite-assistance.

A UPI can be detected autonomously through an obstructed path or physical contact, or manually through passenger communications outreach. Once detected, the Incident Expert is able to monitor the situation and determine what actions, if any, will enable the Driverless AV to leave the scene. A Customer Support Specialist can additionally escalate the call to an Emergency Advisor if they assess there is risk to passenger safety, or dispatch the Safety Escalation Team (SET) to provide on-site de-escalation.

Throughout the unwanted public interaction, the Customer Support Specialist and Incident Expert remain connected at all times, and are able to track the Driverless AV's location and access the internal and external video stream to maintain situational awareness.

7.5.6 Collision

The Cruise AV uses a fused hardware and software approach to reliably detect contact of varying intensities with the exterior of the vehicle. Upon detecting a potential collision, the Driverless AV performs a stopping maneuver according to the detected severity of the collision. An Incident Expert is automatically connected to evaluate video clips preceding the collision detection and confirm whether there was a collision event, and characterize the nature of the collision. A voice call is also automatically connected with the Customer Support Specialist and Incident Expert to communicate with any passengers or external third parties if present.

If the Incident Expert reviews the data and concludes that the collision is a false positive detection or a negligible event without damage, the Incident Expert can authorize the Driverless AV to continue operation. If the Incident Expert concludes that there was a collision, the Incident Expert commands the Driverless AV to cease operations and the Customer Support Specialist dispatches Field Support Representatives to attend to the Driverless AV in person.[140]

The Cruise AV is additionally equipped with an Automatic Crash Response system that automatically alerts our Customer Support Specialist, Incident Experts, and Emergency Advisor in the event of a high-severity collision. Upon receipt of an Automatic Crash Response notification, the Emergency Advisor is trained to immediately notify 9-1-1 dispatch, and the Customer Support Specialist is trained to request a Field Support Representative, without awaiting passenger initiation or input. This protects for situations in which there is no passenger in the Driverless AV, and also for situations in which a passenger is non-responsive. The remote operators remain on the line to communicate with the passenger or third parties and observe the scene until the arrival of the Field Support Representative.

Upon arrival at the scene, the Field Support Representative communicates with the passenger and exchanges information with any third parties and with law enforcement as needed. The Field Support Representative also documents the scene and condition of the involved vehicles before manually retrieving the Driverless AV to a Cruise Facility, if possible. In parallel, Cruise reports the confirmed collision according to regulatory requirements while Cruise engineers analyze the collision incident data remotely transmitted by the Driverless AV and work to identify causal factors. The findings of this analysis can inform immediate fleet level response, kick off a high-urgency incident response depending on the severity of the collision,[141] or drive engineering work to prevent the occurrence of similar collisions in the future.

7.6 First Responder Interaction

In the event of an incident or medical emergency, Emergency Advisors work with our Incident Experts to provide support for passengers and coordinate with first responders as necessary.

The Cruise AV also has the ability to detect and respond to emergency vehicles and law enforcement officers, including law enforcement vehicle lights and sirens, to identify situations in which a law enforcement officer is initiating a traffic stop.

During first responder interactions, such as a traffic stop, first responder dispatch request, or a collision event, Cruise personnel are able to interact with first responders in the following ways:

01 Remote operators are able to lower windows and raise the volume of the internal audio system to communicate with a first responder standing near the Driverless AV.

02 First responders are able to call the Cruise Critical Response Line at any time to interact with an Incident Expert and communicate about a specific Driverless AV, whether they are standing near the Driverless AV or want to request Incident Experts to pull a specific Driverless AV over.[142] The Cruise Critical Response Line number is provided by Cruise in advance via the Law Enforcement Interaction Plan (LEIP).[143]

03 Once the Field Support Representative arrives on scene, they are able to communicate with the first responder and provide information and documentation as needed.

Cruise's goal is to develop Driverless AVs that improve road safety, and we are committed to supporting the crucial work of public safety officials.

We have conducted multiple training sessions with first responders to provide them with the information they need to safely identify and interact with the Driverless AV. Based on these interactions, we developed a LEIP that is designed to equip public safety officials with the information they need to safely interact with the Driverless AV in multiple scenarios. The LEIP includes information about National Fire Protection Association (NFPA) standards[144] for interacting with the vehicle battery, if needed.

7.7 Incident Triage and Escalation

As the Cruise Driverless Fleet operates on the road, Cruise AVs, Cruise operators such as Pit Crew Operators, Operations Coordinators or RA Advisors, or external actors may report an issue involving compromised AV health or driving behavior issues requiring specialized attention. All inquiries are centralized to the Troubleforce team, who provide 24/7 support to help triage, troubleshoot, and escalate Cruise AV issues, to ensure that each issue is resolved as appropriate.

7.7.1 Standard Triaging Process

Troubleforce Operators respond to live notification of Cruise AV health or driving behavior issues by referring to our centralized issues database. For issues that are known and documented, they are able to provide guidance on defined responses that resolve the problem, or else remove the Cruise AV from the operational fleet. For unknown issues, they provide guidance using the Event Risk Classification (ERC) framework.

The appropriate action for an issue on the road may be limited to downing a single Cruise AV, such as a Cruise AV experiencing sensor damage which affects its ability to drive autonomously.

The recommendation may also involve a fleet action to multiple Driverless AVs, or even the entire fleet of Driverless AVs,[145] such as a notification from the Security team of a potential cybersecurity threat that affects multiple Driverless AVs.

In triaging and troubleshooting issues, Troubleforce are able to send live notifications to on-call engineering teams to assist in the triaging effort. Troubleforce's database of issues may identify the tools and teams who can identify appropriate short-term actions. Fleet-wide health issues such as tool outages may merit immediate fleet actions in addition to paging a broad number of engineering teams to resolve the outage and determine appropriate actions moving forward.

Generally, most issues encountered on the road are known and documented in the issue database. A few known issues may be context specific or complex, requiring immediate escalation to on-call engineering teams. The remaining unknown issues undergo the ERC process which assesses the degree of risk represented by the issue, and identifies mitigations. Depending on the degree of severity, Troubleforce determines the appropriate response, which may involve issue logging, targeted fleet actions, or an investigation.

7.7.2 Post-Troubleforce Investigations

Once the appropriate live response is determined, Troubleforce can create follow-up tickets with the RIM (Release and Issue Management) team to identify whether the reported issue is a repeat instance of a known issue, or triggers investigation of a new issue.

Based on the outcome of the investigation, the RIM team can expand the issue database to transform unknown issues into known issues. **The Troubleforce issue database is enriched from a number of different sources, including:**

- Engineering documentation of new features
- Supervised Operations
- Driverless Operations

Using the Incident Triage and Escalation process, the Driverless Fleet always has guidance in response to known and unknown issues encountered on the road.

7.8 Fleet Actions

Cruise can wield a number of fleet actions in response to the various events that Driverless AVs may encounter in the field. The actions below represent the commands that the Operations Coordinators are able to initiate to command a range of Driverless AVs, from a single Driverless AV, to multiple Driverless AVs, to the entire Driverless Fleet, based on situational context.

7.8.1 Summoning

The Driverless Fleet may encounter situations in which the Driverless AV must return to a Cruise facility, but is allowed to return autonomously.

Example situations include:

- Passenger reporting a cabin cleanliness or damage issue to Customer Support
- The operations team being notified that a Driverless AV is running low on battery charge or disk space for data storage
- The operations team wants to reduce the number of Driverless AVs on the road

In each of these instances, the Operations Coordinator is able to summon one or more Driverless AVs to return autonomously to a Cruise Facility.

7.8.2 Downing and Operational Pause

The Driverless Fleet may also encounter situations in which the operations team must constrain one or more Driverless AVs from deploying into the field.

Example situations include:

- The Supervised fleet has observed ODD-exit weather conditions, and the operations team delays deployment of the Driverless fleet until weather conditions improve
- The operations team has been notified of a broad city-wide event, such as a parade, and limits the number of Driverless AVs on the road
- A Driverless AV has a health issue or vehicle damage issue that prevents driverless operation until further troubleshooting, maintenance, or repairs are completed

An Operational Pause prevents deployment of Driverless AVs on the road. A downing action prevents deployment of a specific Driverless AV.

Note that it is possible for Operational Pause to be used in tandem with other fleet actions (e.g., Summoning) to reduce the size of the operating Driverless Fleet, and maintain the fleet at a smaller size.

7.8.3 Grounding

The operations team may identify a situation in which one or more Driverless AVs must be commanded to stop (e.g., be grounded).

Example situations include:

- An externally reported issue requiring a Driverless AV to be manually retrieved
- Request from Troubleforce team to respond to a health, behavioral, or security issue affecting one or more Driverless AVs
- Catastrophic event requiring an immediate response, such as an earthquake

Once the Operations Coordinator commands a Driverless AV to ground, the Driverless AV performs a stopping maneuver and achieves an MRC. The Driverless AV is then retrieved by a Field Support Representative. This action can be applied to one or more Driverless AVs, and can be used in combination with other fleet actions to control the number of Driverless AVs requiring manual retrieval at once.

7.8.4 Road Constraints

Operations Coordinators monitoring the fleet, and RA Advisors monitoring specific Cruise AVs, may identify issues or hazards that require immediate intervention to prevent additional Cruise AVs from entering a particular geographic area or road. These operators are able to request the placement of a road constraint to remove a road section from the autonomous fleet's routing logic. Placement of a road constraint results in immediate communication across all Cruise AVs in the operational fleet, and allows swift containment of Cruise AVs from geographic areas that are problematic or high-risk for Cruise AV travel until the road constraint is removed.

[129]A summary of operators is provided in Appendix C: Actors and Systems.

[130]See more details in Fleet Actions.

[131]While lowering windows is necessary in the Chevy Bolt vehicle platform for communicating with actors outside of the AV, the Origin vehicle platform features external speakers and microphone systems that obsolete this functionality.

[132]Similar to a RA Advisor, an IE does NOT remotely operate the AV.

[133]See more details in Incident Response Scenarios.

[134]Manual driving controls at the front of the vehicle are specific to the Chevy Bolt Cruise AV. The Cruise Origin does not support built-in driving controls and will feature an alternative means of manual operation.

[135]There may be incidents that do not require Incident Expert input, such as instances of degraded state in which the AV self-evaluates its own driving capability; or severe collisions, in which the AV self-determines that it must cease operation.

[136]Note that the descriptions of manual retrieval are specific to the Chevy Bolt Cruise AV, and may have alternative actions to accommodate the Cruise Origin.

[137]See more details in High Level Architecture and System Design.

[138]See more details in High Level Architecture and System Design.

[139]Note that actuator control tampering represents a risk for the Cruise AV Chevy Bolt, but does not represent a risk for the Cruise Origin, which does not feature actuator controls for manual driving.

[140]The Incident Expert is able to reposition the vehicle as situationally appropriate to clear the lane of travel or reduce the level of hazard present in the scene of the collision.

[141]See more details in Immersive Incident Exercises.

[142]The Cruise Critical Response Line number is provided by Cruise in advance via the Law Enforcement Interaction Plan (LEIP) and is available here: getcruise.com/firstresponders. The Cruise Critical Response Line number is also displayed on the in-vehicle touch screens upon AV disengagement.

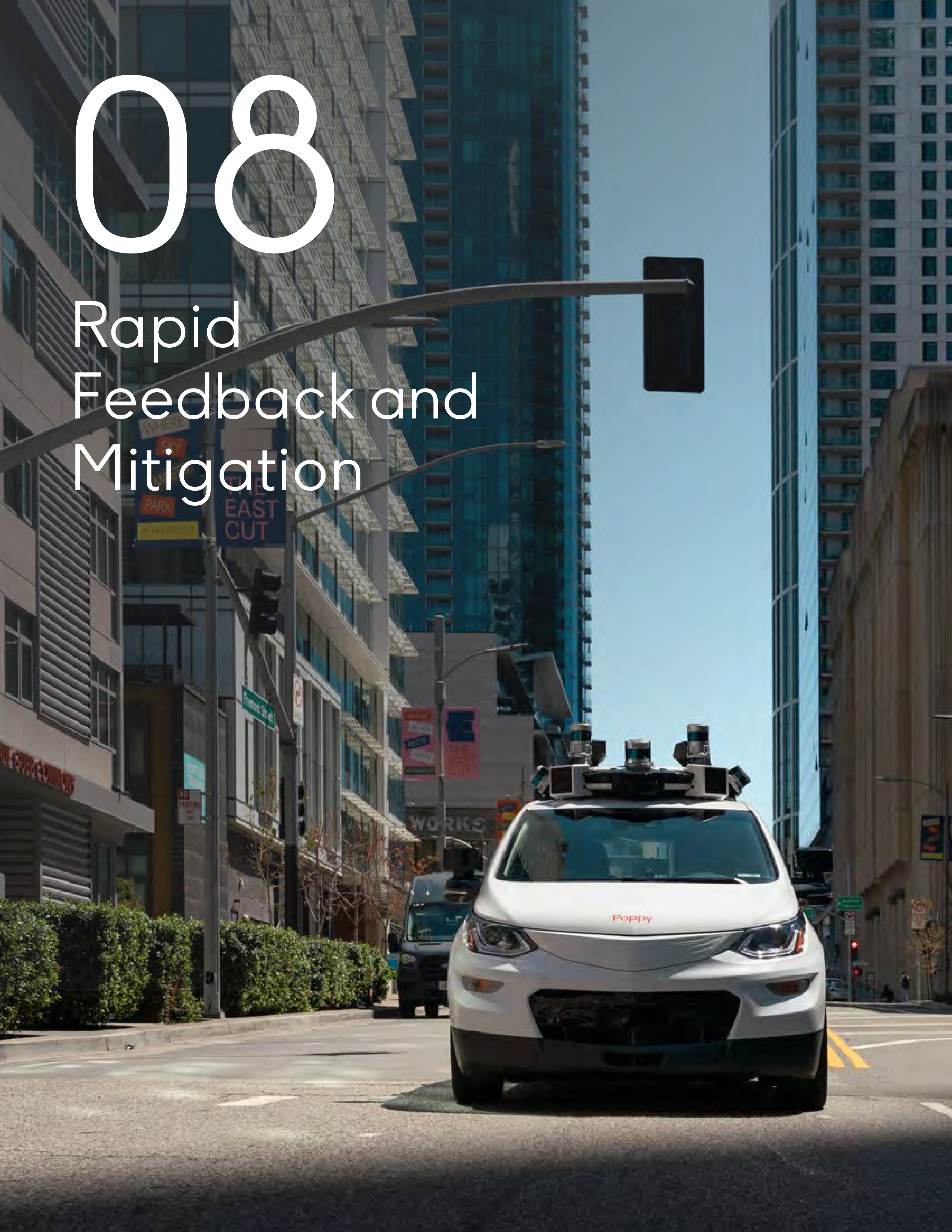
[143]https://getcruise.com/firstresponders

[144]https://www.nfpa.org/-/media/Files/Training/AFV/Emergency-Response-Guides/Chevrolet/Chevrolet-Bolt-EV-2017-2019-QRG.ashx

[145]See more details in Fleet Actions.

08

Rapid Feedback and Mitigation



Cruise collects inputs from every stage of product development to ensure that we are continuously improving our operations, systems, and processes.

Sources of risks, gaps, and improvement opportunities include automated data collection from the road; externally reported data; operational feedback; and internal feedback. Once we receive the feedback, the feedback processing pipeline identifies the outlets best suited to drive improvements, and prioritizes high-criticality inputs with the appropriate resources and level of urgency to resolve any outstanding safety risks.

8.1 Feedback Loops

Feedback is at the heart of continuous improvement at Cruise. We pipe feedback from various sources into a prioritization framework to quickly triage all incoming feedback and identify the urgency and priority of response. Our feedback sources include automated notifications from the Cruise AV, and feedback from external, operational, and internal sources.

8.1.1 Automated Event Notifications

Cruise is notified of Driverless AV incidents in real time, including ODD exit, degraded state, cybersecurity attack, tampering event, unwanted public interaction, and collision.

In each of these events, operators are notified in real-time to provide immediate resolution, while prioritizing the safety of the passengers above all else.[146] Cruise tracks these events to determine whether the Driverless AV behaved appropriately and did not encounter unexpected safety or driving behavior issues. Cruise ensures that collision-specific sensor data necessary for collision investigations are protected and immediately accessible in accordance with regulatory requirements.[147]

Upon detection of a collision event, Incident Experts can access a subset of over-the-air Cruise AV data to inspect the situation, make a determination of collision classification, escalate to an Emergency Advisor, and enable an internal investigation as needed. Upon return to a Cruise facility, Cruise can access additional data to evaluate the nature of the collision in more detail and identify any additional operational actions that are necessary in response.

8.1.2 External Feedback

Cruise is able to receive feedback from external sources through our passengers, third parties that interface with our Cruise AVs, the general public, and local municipalities and regulators.

Passengers can provide feedback at any time through three main avenues:

1. The in-vehicle multi-way communication link[148]
2. The mobile app
3. Email through support@getcruise.com

These communications can take place live during a ride, or asynchronously outside of a ride. These channels are monitored 24/7 by the Customer Support team, who flag potential safety concerns for internal review and real-time escalation as necessary. Passengers can also provide feedback through the post-trip feedback survey.

Third parties and the general public can contact Cruise by emailing community@getcruise.com, which is monitored by the Customer Support team. Alternatively, community or neighborhood concerns are routed to relevant internal teams, such as the Public Affairs team. The public can also provide safety feedback via social media, such as Twitter, Facebook and Instagram, which are monitored by the Customer Support and Social Media teams and escalated accordingly.

Cruise also engages with law enforcement to provide guidance on how to safely interact with the Cruise AV and ensure an effective feedback loop with officers. Public safety officials are equipped with contact information on how to reach Cruise in emergency and non-emergency situations in its LEIP, which is available through links on Cruise's Resources for First Responders webpage.[149] **Officers are directed to call Cruise at 888-662-7103 in urgent scenarios and email firstresponders@getcruise.com in non-urgent scenarios.**

Local municipalities and regulatory bodies can reach out to their Cruise Government Affairs point of contact to make any requests or escalate any concerns. Cruise is committed to having regular, open, transparent, and meaningful conversations with our regulators.

Because the level of detail provided by these inputs may vary, Cruise teams initially engage in dialogue with these parties to collect further information before feeding information to the RIM team or specialized subject matter experts for further investigation.

8.1.3 Operational Feedback

All Cruise operators are able to raise any issues or concerns that they observe with a Driverless AV or supporting systems to the Troubleforce team, which is available to provide support 24/7.

Upon receiving an issue, the Troubleforce Operator initiates the established Incident Triage and Escalation process, which include, as appropriate:

- Recommending real-time response with an isolated AV, such as summoning or downing the Driverless AV
- Recommending real-time response with a broader subset of Driverless AVs or the entire fleet of Driverless AVs, such as summoning or retrieving the Driverless AVs; or escalating to the RIM Team for deeper internal investigations[150]

8.1.4 Internal Feedback

Every Cruise employee and contractor has the ability to report safety concerns that they have, whether explicitly through SIREN or anonymously through CARS. SIREN and CARS can be used to report safety incidents that have already occurred, safety concerns that may result in an unsafe situation, or proactive suggestions for improving safety.

8.2 Root Causing and Prioritization

In order to ensure that urgent safety-critical events and behaviors are properly prioritized, Cruise triages and performs a root-cause analysis for events received through the feedback pipeline.

Sources for such events include:

- Predicted and real-world collision events from Supervised and Driverless Operations
- Probability modeling from Supervised Driving
- Operational escalation of observed issues from Troubleforce, AV Operations, or AVTOs

8.2.1 Predicted and Real-World Collision Events

While real-world collision events may take place during Cruise's Driverless and Supervised Operations, Cruise additionally identifies predicted collision events during Supervised Operations.

Predicted collisions are detected through the use of the AVTO's takeover (TKO) mechanism during Supervised Operations. Each TKO is manually reviewed to determine if the Supervised AV's planned path as projected forward in time from the TKO would have led to a collision had autonomous operation continued.[151] If it is determined that a collision would have occurred without vehicle operator intervention, we classify the occurrence as a potential collision. Cruise investigates the combination of potential and real-world collisions to measure Cruise AV safety performance in Supervised Operations prior to approving the promotion of a new release to the Driverless Fleet.[152]

Given the serious nature of predicted and real-world collisions, these events have the quickest support turnaround by the RIM team. Upon notification of a collision, the RIM team uses an established taxonomy of known failure modes to sort the incoming events and identify relevant technical subject matter experts.[153]

A live communications channel is established to centralize all discussions throughout the root-causing process, which can include inspecting Cruise AV data collected at the time of the incident, as well as inspecting the code that could have informed particular behavioral responses. The subject matter experts are also able to involve additional parties needed to perform a thorough investigation.

The RIM team reports out the initial problem statement describing the cause of the event. This problem statement can conclude one of two outcomes, based on the situational context:

- The Cruise AV could not have changed its behaviors to avoid the predicted or real-world collision event, and there is no further action required.
- The Cruise AV could have mitigated or avoided the predicted or real-world collision event. The scenario will be used to improve the AV development and fleet operation.

Operational actions taken to contain risk of a recurring event can include restoring the Driverless Fleet with software with proven performance attributes; operational limitations to the ODD or fleet size; or road constraints placed on specific roads. In parallel, responsible engineering teams are identified to define the intended engineering mitigation.

Note that the chosen response may differ significantly depending on when in the release process that a predicted or real-world collision event is encountered. The exposure may be limited to a few Supervised AVs, or it may apply to the entire Driverless Fleet. Cruise tailors our operational and engineering response to contain the safety risk efficiently and effectively.

8.2.2 Probabilistic Modeling

Predicted and real-world collisions are statistically rare, even in a complex urban environment like San Francisco. To overcome the sparsity of data in the predicted and real-world collision metric, we developed a machine-learned model trained on our millions of miles of driving data to model the probability of a predicted or real-world collision in any driving scenario. This model is continually retrained using the latest data from our fleet, and cross-validated with real-world incident data for accurate predictions across the full ODD.

Using this model, Cruise identifies scenarios using the model's calibrated threshold to identify potentially unsafe driving behaviors which are neither predicted nor real-world collision events. Cruise uses these potentially safety-affecting driving behaviors as proactive inputs to drive engineering improvements in holistic safety performance.

8.2.3 Operational Escalations

Cruise operators are able to escalate observed issues to Troubleforce and RIM teams for triaging and root-cause investigations, including observed issues with driving behavior, and issues in supporting systems that are not directly associated with a predicted or real-world collision.

The RIM team triages and investigates these issues to identify the appropriate course of action depending on the severity of the reported event. This allows engineering teams to resolve safety-affecting issues outside of predicted and real-world collisions. Operators can report all issues with tool functions whether they are safety-critical issues or not. Customer Support Specialists are also able to escalate reported safety issues from passengers.

Each source of reported issues allows Cruise to complement our immediate mitigation of predicted and real-world collisions with a continuous improvement roadmap.

8.2.4 Resource Prioritization

Cruise uses safety metrics derived from predicted and real-world collisions, probability modeling, and operator escalations in supervised and driverless operations to determine operational and engineering prioritization of identified safety mitigations.

Safety risks, characterized as scenarios with a high-likelihood of serious injury identified through predicted collisions, real-world collisions, or probability modeling, receive maximum prioritization at Cruise regardless of whether the Cruise AV is deemed to be responsible for the event. Cruise evaluates these events with utmost scrutiny to identify any engineering or operational mitigation needed to prevent future instances, and take immediate action to contain the safety risk.

For scenarios with a lesser-likelihood of serious injury, Cruise makes a secondary determination to identify whether the Cruise AV had control over the event, and is capable of avoiding such a situation with a given operational or engineering mitigation. If Cruise determines that such a capability could be designed and implemented, Cruise prioritizes resourcing these efforts over resourcing efforts for scenarios in which the Cruise AV was not able to directly mitigate the event.

For scenarios with low or no likelihood of injury, and in which the Cruise AV is not able to mitigate the event, Cruise addresses these events according to their respective priority. Cruise is committed to reducing the total frequency of predicted collisions, real-world collisions, probability modeling-identified driving behaviors, and operational escalations over time.

This approach of resource prioritization ensures that the most important and safety-critical problems are solved with maximum intent and urgency, while allowing Cruise to address its lower-priority, non-hazard issues over time.

[146]See more details in Incident Response Scenarios.

[147]In California, regulatory requirements for collision investigation are outlined in CVC 38750(c)(1)(G), CCR 227.28, and CCR 227.50. Federal regulatory requirements are outlined in Standing General Order 2021-01: Incident Reporting for Automated Driving Systems ("ADS") and Level 2 Advanced Driver Assistance Systems ("ADAS").

[148]See more details in Multi-Way Communications.

[149]https://www.getcruise.com/firstresponders

[150]See more details in Incident Triage and Escalation.

[151]Predicted collisions are subsequently analyzed to account for potential divergence in the scenario between the simulation and a counterfactual physical world, such as the other vehicle reacting to the vehicle operator's driving rather than the AV's planned path.

[152]More information can be found in the Release Process Overview section.

[153]Real-time response to a collision is performed by live operators, as described in detail in the Incident Triage and Escalation section.

09

Next Generation of Safety

In addition to the processes we have established in our existing safety approach, Cruise maintains a vision for what's ahead.

The purpose-built Cruise Origin will allow Cruise to further its goals of achieving new levels of safety, scalability, and accessibility. Today's driverless ODD begins in San Francisco, but we plan to safely and responsibly deploy our service to additional cities in the near future.

We are confident that, with safety as our north star, our driverless service can make a resounding impact on the safety, access, and culture of transportation in the communities we serve.

9.1 Cruise Origin: The Next Generation of Autonomous Vehicle

The Cruise Origin is the first American-made purpose-built vehicle for autonomous ridehail and delivery. It is designed to improve overall road safety by meeting existing safety standards or their equivalent, and also by leveraging Cruise's fleet management mechanisms that allow Cruise to control, adapt, and improve our Driverless Fleet.

The Origin builds on the six years that Cruise has spent designing, developing, testing and refining our advanced automated driving technology, throughout nearly 5MM of driving. Achieving the safety objectives set forth in the Vehicle Safety Act[154] and related regulations is an essential element of this work.

The Origin is roughly the size of a modern SUV, but it fundamentally innovates on vehicle design. From the sensor pods placed along the four corners of the Origin roof to the dual sliding subway-style doors, the Origin reimagines what an autonomous vehicle should be through its exterior and interior design. The Origin is purpose-built as a shared ride vehicle, with two rows of inward-facing seats that optimize passenger space and enables easier ingress and egress.

The Origin is equipped with a buckle-to-ride feature that ensures that the passenger's seat belt is buckled prior to allowing the passenger to start the ride. It is equipped with buttons that allow passengers to request start and early stop of a ride or call for help, and is also equipped with in-cabin information displays. These functions are also provided in the mobile app for ease of access and customizable user experience.[155]

The Origin is equipped with seating and airbags that are designed and crash tested to provide maximum comfort and occupant protection in the event of a collision. It will not be equipped with manually operated driving controls, because it will not be operated by a human driver; rather, the Origin will be operated exclusively by its autonomous driving technology, which has benefitted from the extensive product development and operations processes described throughout this report.[156]

The Cruise Origin is the next step in the journey toward Cruise and GM's vision of a future with zero crashes, zero emissions, and zero congestion.

9.2 Expansion Beyond San Francisco

While Cruise focused our first driverless operations in the complex urban environment of San Francisco, our vision for the future of driverless transportation extends to many other cities in the United States and beyond.

Our approach to expanding our driverless services beyond San Francisco revolves around the same Safety Claim we applied when launching in our first city: **identifying and classifying the safety risks of operating a driverless service and mitigating them to acceptable levels.**

We plan to expand our existing framework of risk identification and risk management to new markets, which we have broken down into three risk areas:

01 Known Safety Risks

Have we identified a catalog of known safety risks that are present in the new market? Are there performance improvements or operational mitigations that we need to apply to reduce these risks to an acceptable level?

02 Unknown Safety Risks

How do we efficiently discover potential unknown safety risks? How do we transform potential unknown safety risks into known safety risks given limited exposure? How do we estimate that the number of potential unknown safety risks is at an acceptable level?

03 Residual Risks

What evidence do we have to indicate that the risk level present in the new market is acceptable?

We plan to address these three risk areas by characterizing our baseline safety performance in the new market; defining an initial ODD in the new city with an acceptable risk profile, and progressively expanding; and discovering, characterizing, and mitigating the residual risks that we encounter along the way. The same approaches of building up[157] capabilities and driving down[158] risks apply to new city expansion.

Cruise will take these actions in parallel with Cruise's already-established design, verification, and risk management frameworks and processes. In accordance with our SMS framework,[159] Cruise will develop a portfolio of safety performance evidence and present it to corresponding risk owners and the Accountable Executive during a new market LRR prior to any expansion into a new market.[160]

9.2.1 Known Safety Risks

Cruise plans to leverage the rich data and performance measurements we've collected in San Francisco over the past 6 years, through which we have derived a catalog of known safety risks, to apply in any new market we consider for operational expansion. We plan to augment our known risk catalog in two directions: top-down analysis to identify a new market's unique driving environment features and driving behaviors; and a continuous bottom-up risk discovery pipeline that is able to surface risks that are not captured by the top-down analysis.

During initial considerations of a new market, Cruise's domain experts will decompose the measurement of safe driving performance into its respective elements:

- ODD elements such as weather, driving speeds, unique driving maneuvers, road geometries, and static elements (e.g., road signage)
- Rules of the road as defined by local driving regulations and observed behaviors
- Subsystem performance sensitivities in new markets, such as perception and localization performance

Upon identifying these elements, Cruise will initiate targeted data collection[161] to expedite our understanding and characterization of these new safety risks in the new market.

Cruise will simultaneously evaluate the risk levels across the existing full known risk catalog in the new environment using a combination of supervised on-road driving, large scale end-to-end simulation test suites, and targeted closed-course tests and subsystem tests, to determine whether the risks need additional characterization or mitigation. The outcomes and actions of this risk catalog and corresponding risk levels will be considered in a new market LRR.

While risk mitigation may be achieved through performance improvements, it can also be achieved through the various ODD risk controls we levy for risk avoidance, such as map geofence definitions, road constraints, limit operational hours, etc.[162] These controls allow us to constrain our initial ODD to one that most closely matches the ODD risk profile of our existing market to achieve safe driverless operations in an ODD portfolio in which we have the highest levels of confidence and evidence.

9.2.2 Unknown Safety Risks

Cruise plans to mitigate unknown safety risks of a new market by using a combination of on-road driving with existing and proven feedback loops to discover new safety risks. Cruise will transform any potential unknown safety risks discovered in this process into known safety risks by labeling and analyzing the data collected from the road to extend the risk catalog.

New markets introduced into our driverless services represent a new source of Cruise AV performance data and corresponding expansion of known risk areas. We therefore expect that the portfolio of potential unknown safety risks will reduce over time with each subsequent new market introduction, with the subsequent rate of discovery of new risks correspondingly decreasing over time. This rate of new risk discovery will form our metric for estimating the comprehensiveness of the risk catalog.

9.2.3 Residual Risks

Beyond managing the known risk register and risk discovery pipeline, Cruise will define residual risk of expanding to a new market by comparing the safety performance and coverage of the new markets' risk catalog, e.g., our rate of discovering new safety hazards per mile driven, to that in existing and established market risk catalogs. This process enables us to limit the level of unobserved risks when compared to a city with much greater exposure, data, and testing.

Any gaps in risk discovery will be addressed partially through targeted driving of stressing scenarios to discover remaining unknown failure modes, and heavily through simulation. Performance across the known risk areas in the new market compared to existing markets, the estimated risk coverage in the new market, and any identified risk discrepancies, will be presented at the new market LRR.

[154]49 USC Sec. 301

[155]See more details in Passenger Education.

[156]In-depth technical information on the Origin vehicle platform is provided in the General Motors LLC Petition for Temporary Exemption from Provisions of Certain Federal Motor Vehicle Safety Standards.

[157]See more details in Build-Up Approach.

[158]See more details in Safety Management System.

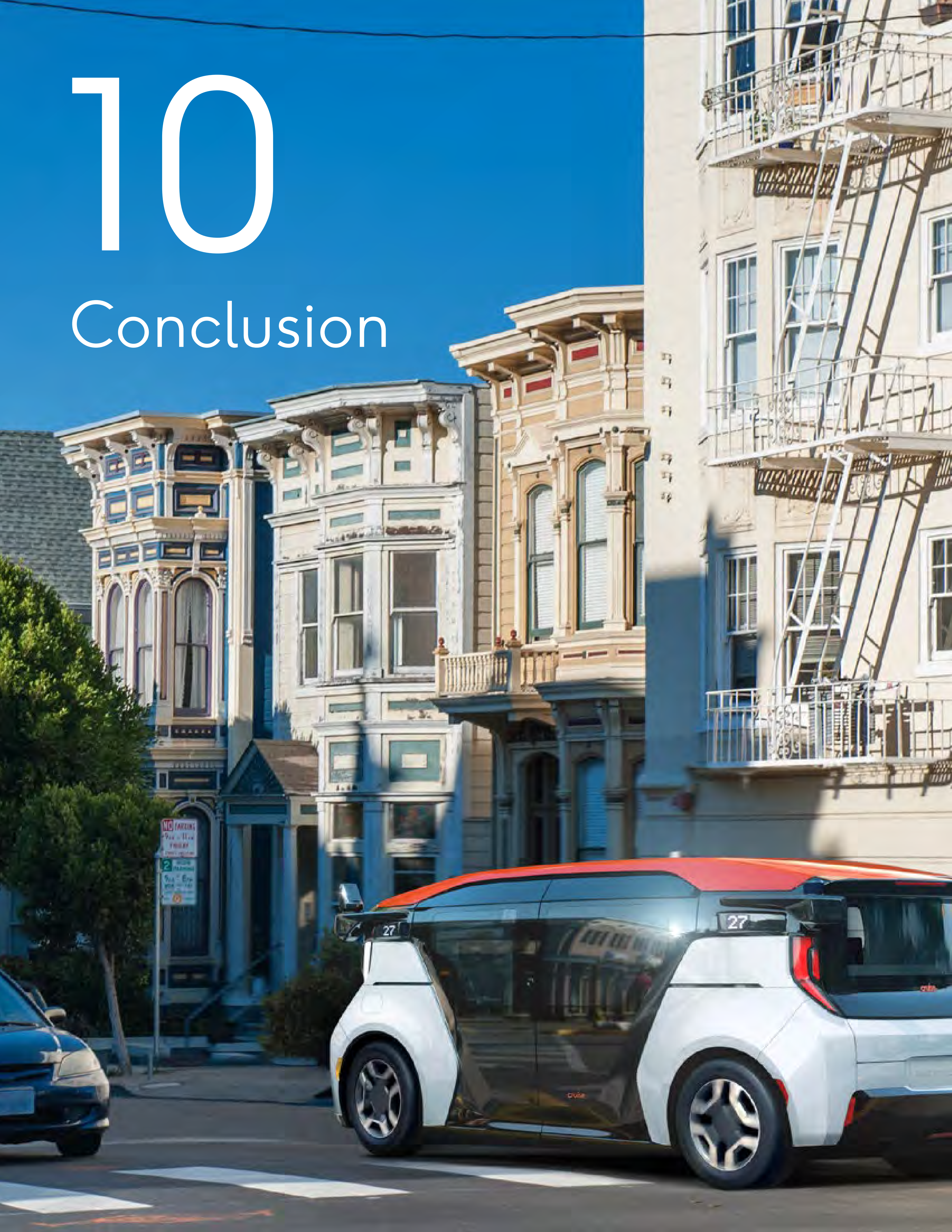
[159]See more details in Safety Management System.

[160]See more details in Launch Readiness Review.

[161]Data sources include manual driving data collected for measuring subsystem performance, or supervised driving data collected for measuring integrated system performance. Data sources can additionally include established 3rd party data sources that enrich our understanding of a new market.

[162]See more details in Operational Design Domain.

10
Conclusion



At Cruise, we believe that the future of transportation is driverless.

We believe Cruise can make the greatest positive societal impact by deploying our Driverless AV technology at scale as safely and quickly as possible. The humble beginnings of Kitty Hawk, NC in 1903 changed the world with its promise of safe, quick, and reliable travel over long distances, and served as the predecessor to today's massive commercial aviation industry.

Our all-electric fleet of Driverless AVs has the same potential to improve transportation safety, transition on-road miles from fossil fuels to sustainable energy, and improve transportation access to customers of all demographics.

Everything we do at Cruise is driven by our belief that our driverless technology will help realize these benefits. Cruise works every day to achieve these outcomes by:

1. Applying a multi-faceted approach to safety
2. Incorporating safety into every aspect of our product and service design
3. Gating our product release on robust verification and validation steps to ensure that our product is built well, and built for unprecedented safety
4. Conscientiously making safety-critical decisions, ranging from daily deployments to operational expansions
5. Designing driverless service with our passengers and customers in mind
6. Creating a network of support operators who are available to assist our AVs and passengers every step of the way
7. Building a continuous feedback loop to strengthen our iterative learning processes
8. Envisioning the future of safety and transportation

While our safety approach represents the accumulation of years of work and findings, it is never finished. Cruise leverages both on-road performance and simulation tools to assess and improve the driving performance of our vehicles in commonly occurring scenarios, and also to minimize the risk of rare yet high-severity events we might otherwise not observe.

By adopting iterative approaches and leveraging fleet learning, we will promote the continuous improvement and evolution of our driverless technology over time. We are committed to continuously refining our safety methodology as we expand into new markets and geographies across the nation, and across the world.

At Cruise, safety is at the foundation of every choice we make. Cruise recognizes that the successful deployment of our transformative driverless service requires us to earn the trust of our communities, our regulators, our customers, and the public. We wrote this Safety Report out of our commitment to achieving safety and promoting open safety dialogue.

We strive every day to achieve our Safety Mission:

to responsibly deploy the world's most advanced driverless service, and safely connect the communities we serve to the places, things, and experiences they care about.

cruise

Appendix

Appendix A

Degraded States

As illustrated in the table below, Cruise's Degraded State taxonomy assigns higher numbers for a degraded state with less residual driving performance. In other words, Degraded State 1 has the highest remaining driving capability, whereas Degraded State 5 has the lowest remaining driving capability.

Degraded State	Description
DS1	The Cruise AV has a benign latent malfunction indicating the need for service and maintenance attention. The Cruise AV maintains full capability to perform the dynamic driving task ("DDT") and dynamic driving task fallback ("DDT-F"). The malfunction does not lead to a hazard so normal vehicle use until the end of the day (or until the next vehicle power cycle) is expected. The Cruise AV can continue all on-road operations for the remainder of the shift.
DS2	The Cruise AV has a tolerated malfunction in a safety system and maintains the capability to perform the DDT and DDT-F and return to the fleet service facility for repair. The Cruise AV is capable of completing the current mission by falling back to stricter driving constraints or limitations as needed, to help maintain an acceptable level of performance until the Cruise AV returns to the fleet service facility and the issue is resolved. The Cruise AV is recovered by the Field Support team at the fleet service facility for repair. No new fleet operations will be assigned to the Cruise AV in this state.

Degraded State	Description
DS3	The Cruise AV has a system malfunction that results in degraded vehicle performance risking the ability to perform the DDT or DDT-F. The Cruise AV is capable of pulling over to a safe location at the side of the road, followed by engaging Park state and activating hazard flashers. The Cruise AV is retrieved by a Field Support team and returned to a fleet service facility for repair. No new fleet operations will be assigned to the Cruise AV in this state.
DS4	The Cruise AV has partial loss of primary autonomous driving functionality, requiring fallback to the secondary autonomous driving functionality to perform the DDT-F. The Cruise AV is capable of gradually slowing to a stop while steering to a safe location out of high risk areas such as intersections, followed by engaging its transmission in "Park" and activating its hazard flashers. The Cruise AV is retrieved by a Field Support team and returned to a fleet service facility for repair. No new fleet operations will be assigned to the Cruise AV in this state.
DS5	The Cruise AV has a total loss of primary Autonomous Driving functionality. The Cruise AV can quickly slow down to a stop in its lane of travel, followed by engaging its transmission in "Park" and activating its hazard flashers. The Cruise AV is retrieved by a Field Support team and returned to a fleet service facility for repair. No new fleet operations will be assigned to the Cruise AV in this state.

Appendix B

Cybersecurity Controls

To ensure the safest operation of our Cruise AVs, we have implemented a number of security controls that both improve our fleet's security posture, and minimize the risk and severity of any attack should one occur.

Example controls include controlled access to our firmware, required reporting of various system security states to a centralized, onboard logging service, and required secure boot and updates for all critical autonomous components and subsystems to cryptographically guarantee code has not been tampered with or modified. We also segment our security architecture to prevent an attacker from compromising a vehicle through a single component.

In addition to these layered security tools, we require on-board data volume cryptographic verification. This ensures that file systems used by components are legitimate and have not been manipulated. We also utilize multiple security domains and varying levels of trust for different vehicle components depending on use case — including whether a component can access the Internet or if customers can interact with it. We protect each more-trusted domain from any components within or from a less-trusted domain.

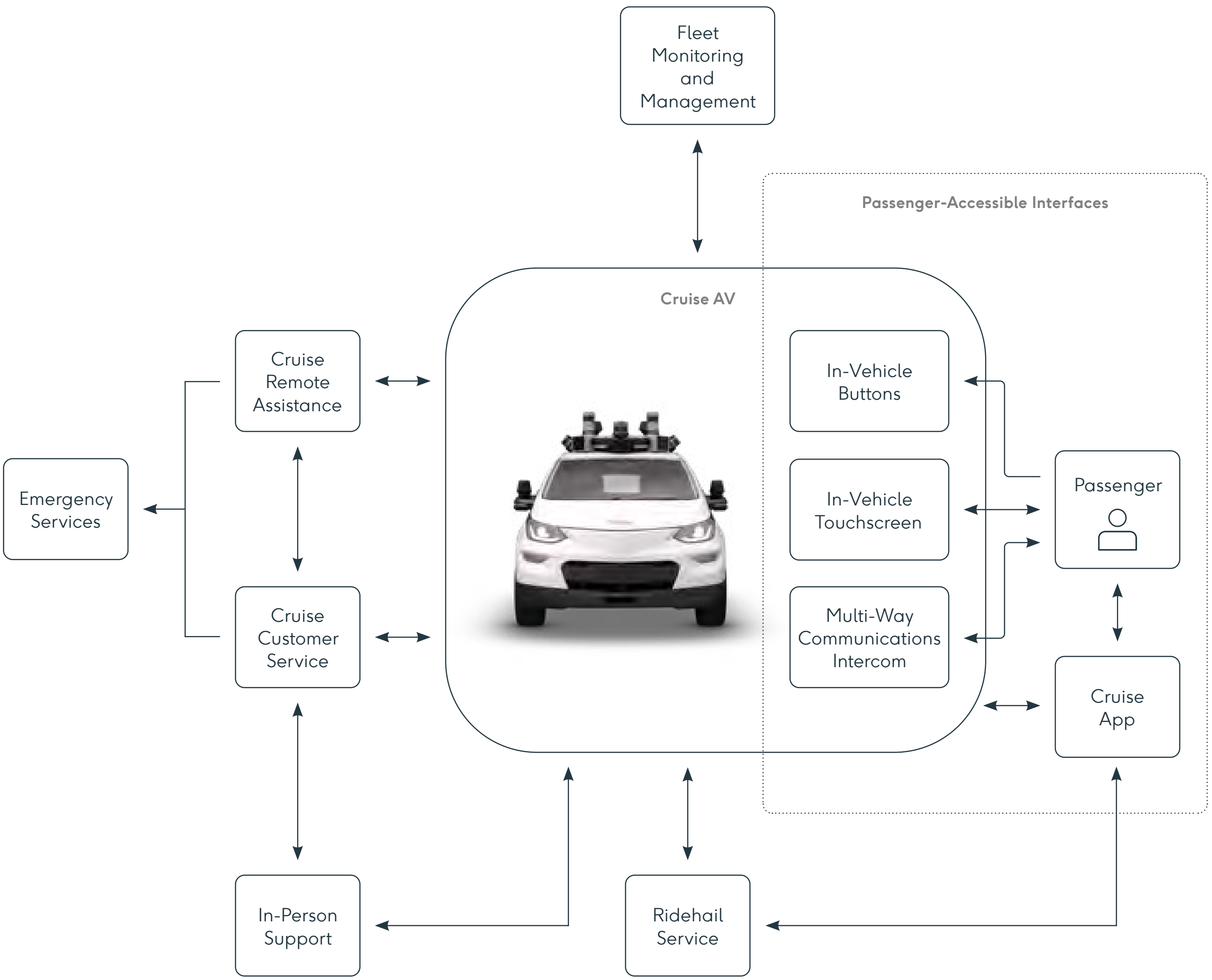
We also use managed communication protocols that limit attack surfaces for hostile parties. To mutually authenticate and encrypt communications within the Cruise AV or between the Cruise AV and back office components, we use mutual transport layer security connections to provide encrypted streams for end-to-end secure streaming communications.

Finally, intrusion detection and prevention mechanisms are used to help detect and react to attacks. Our on-board software monitors traffic patterns, message counts, and attributes, and alerts the Cruise AV and backend systems when potential security incidents are detected. In instances in which these detected instances affect the Cruise AV's control of the vehicle, the Cruise AV is designed to initiate a Degraded State 4 to achieve a minimal risk condition. All of these initiatives help detect, defend against and respond to cyber-attacks, unauthorized intrusions, or false vehicle control commands.

Appendix C

Actors and Systems

Cruise's driverless operations take place in a complex ecosystem of a fleet of autonomous vehicles that are inspected, deployed, assigned, assisted, monitored, and commanded by a collection of Cruise operators and backend systems.



Actors

Actor	Description
Autonomous Vehicle (AV)	Autonomous vehicle that performs the autonomous driving task. May receive inputs from operators, automatic systems or other roadway actors that affect its driving behavior, e.g., operator input to pull over; emergency vehicle interaction; operator classification of road elements; operator application of road constraints.
Pit Crew Operator	AV Operations crew member responsible for inspecting, preparing, and deploying the Driverless AV for driverless operations.
Operations Coordinator	AV Operations crew member responsible for monitoring the Driverless Fleet within the mapped geofence and commanding one or more Driverless AVs to perform specific tasks, e.g., pulling over, returning to facility.
Customer Support Specialist	Operator providing live support for any event in which an interaction with a passenger or third party is necessary.
Remote Assistance Advisor	Operator providing live input and assistance to a Cruise AV as requested to perform a specific driving task. Example assistance tasks are classification confirmation and assisted pathing.
Incident Expert	Remote Assistance Advisor with special training responsible for responding to any incident events such as collision, actuator tampering, and unsecure cabin states.

Actor	Description
Emergency Advisor	Trained operator responsible for attending to passengers and interfacing with first responders in the event of an emergency such as passenger emergency or collision with injury.
Field Support Representative	In-field operator responsible for attending to a Driverless AV requiring in-person assistance. Field Support Representatives are also able to attend to stranded passengers in the event that their active ride is interrupted.
Troubleforce Operator	Operator responsible for providing triaging and troubleshooting support for reported health issues. Troubleforce Operator can support incoming inquiries from the Cruise AV, Operations Coordinator, RA Advisor, Incident Expert, or external parties. Troubleforce Operators can recommend operational responses based on their understanding of the issue's severity and scale.

Cruise AV Systems

The following is a catalog of the various systems involved in autonomous driving, which include a combination of hardware and software systems.

Hardware Systems	Description
Sensors	A suite of multiple sensor modalities that provide raw data input to the Cruise AV to process and interpret. The sensors provide the Cruise AV with context of its surrounding environment, and include LiDAR, Radar, Camera, microphones, Inertial Measurement Units (IMUs), and tactile sensors. The sensors also provide the Cruise AV with its own inertial motion measurement to help the Controls software execute its intended motion.
Computers and Networks	The processing units and network connectors that allow the Cruise AV to receive data from various inputs (sensors, other computers, Cruise back-end services) and store software to interpret its context, derive the appropriate driving behavior, and command its actuators. See Software Systems table below for more information on specific software functions performed in the compute system.
Telemetry Module	The data transmission module that allows the Cruise AV to be connected with the Cruise back-end service to receive information such as assignments, commands, and transmit health status, as well as guidance from Remote Assistance.
Vehicle Actuators	The vehicle actuation controls that receive commands from the Cruise AV to perform the dynamic driving task. Actuators include brakes, propulsion, steering, and transmission.

Software Systems	Description
Embedded Software	Software that allows for transmission and receipt of data across hardware systems and their corresponding software.
Platform and Health Monitor	Software that acts as the central data messaging center between software nodes. This software monitors all software nodes to control execution timing, receive diagnostics, and set appropriate system health states as needed, triggering a corresponding behavioral response.
Perception	Software that receives inputs from the sensors to develop environmental awareness of the objects and actors around the Cruise AV.
Localization	Software that matches the Cruise AV perception inputs with an internally stored map to locate the Cruise AV's physical position within its greater world.
Prediction	Software that tracks each object and actor around the Cruise AV and interprets its observed actions into a trajectory of expected (predicted) actions.
Planning	Software that translates the Cruise AV's assigned mission and the Cruise AV's environmental context into the autonomous driving path.
Controls	Software that receives the Cruise AV's intended path and continuously observes the Cruise AV's actual state of motion to perform the intended driving task.

Operator Tools

The following is a catalog of the tools that Cruise operators use to interface with the AV in performing their tasks. These tools are a mix of proprietary, custom tools, and off the shelf systems with Cruise specific enhancements.

Tool Systems	Description
Fleet Management Portal	Software that stores Cruise AV configuration, inspection, and maintenance records. Software that tracks the Driverless AV fleet within the map geofence and provides visibility into Driverless AV health and map weather conditions. This software also allows an operator to deploy each Driverless AV, and command one or more Driverless AVs in the Driverless Fleet to perform a task, such as pulling over, grounding, or returning to facility.
Remote Assistance System	Software that allows for a RA Advisor to gain contextual information about the Cruise AV and its surrounding driving condition, and provide assistance to the Cruise AV to complete its autonomous driving task.
Customer Service Tool	Software that connects voice communications between Cruise operators and the passenger inside the Driverless AV. This software allows for voice communications with Emergency Advisors or any third-party (e.g., first responders) that are standing outside of the Driverless AV. This software includes some non-driving cabin controls that a Cruise operator can use to assist a passenger or interact with a third party, e.g., unlocking doors, opening windows, etc. Software that provides Cruise operators with assignments and context for providing in-field support. This includes the location of the Driverless AV; whether the Driverless AV is currently supporting a passenger; and any situational context provided by remote Cruise operators.

Back-End Services

The following is a catalog of the back-end services that support the Driverless Fleet.

Back-End Services	Description
Ridehail Backend	Back-end service that processes passenger requests and updates from the mobile app and sends assignment requests to the centralized Cruise AV dispatch management service.
Dispatch Management Service	Back-end service that receives all requests from Ridehail Backend and Fleet Management tools and translates them to assignments to available or specified Cruise AVs.
Centralized Back-End Service	Centralized back-end service that receives and stores Cruise AV status data, and communicates outputs such as commands or assignments to the Cruise AV.

Glossary

Glossary Term	Description
AV Test Operator	A human operator who is permitted to manually operate the Cruise AV, and who provides human supervision while the Cruise AV is operating in supervised mode. The AVTO performs the same function as a human driver under SAE J3016 (2021), defined as a "a user who performs in real time part or all of the DDT and/or DDT fallback for a particular vehicle."
Build-Up Approach	A risk-control approach that initially establishes acceptable levels of risk exposure using limited ODD controls, then continually expands as the system demonstrates performance improvements. In exercising the Build-Up Approach, Cruise is able to deploy its Driverless Fleet within an acceptable risk exposure profile.

Glossary Term	Description
Drive-Down Approach	A risk-reduction approach for surfacing and identifying risks, assessing risk levels, developing mitigation actions, and deciding whether to continue, modify, or pause operations. In exercising the Drive-Down Approach, Cruise is able to identify, prioritize, and mitigate identified risks to an acceptable level according to the risk owner's resources and judgment.
Cruise AV	The fully integrated autonomous vehicle designed by GM and Cruise from the Chevy Bolt platform. Cruise AV is able to be operated manually, in supervised mode, and in driverless mode. The Cruise AV can be operated autonomously in a supervised autonomous mode under the supervision of an AVTO as a **Supervised AV**. An AVTO is able to take manual control of a Supervised AV at any time through the use of vehicle actuator command inputs, such as the steering wheel, brakes, etc. The Cruise AV can be operated autonomously in a driverless autonomous mode without the presence of an AVTO as a **Driverless AV**.
Degraded State	A degraded health state in which the Cruise AV's driving capabilities or other autonomy functionalities are compromised. The degraded state assignment determines the degree to which the Cruise AV's driving capabilities are compromised, ranging from DS1 (lowest level of degradation) to DS5 (highest level of degradation).

Glossary Term	Description
Dynamic Driving Task	All of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints, and including, without limitation, the following subtasks: 1. Lateral vehicle motion control via steering (operational). 2. Longitudinal vehicle motion control via acceleration and deceleration (operational). 3. Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (operational and tactical). 4. Object and event response execution (operational and tactical). 5. Maneuver planning (tactical). 6. Enhancing conspicuity via lighting, sounding the horn, signaling, gesturing, etc. (tactical).[163] A modification of the Dynamic Driving Task is the **Dynamic Driving Task Fallback**, which refers to the response to either perform the DDT or achieve a minimal risk condition (1) after occurrence of a DDT performance-relevant system failure(s), or (2) upon operational design domain (ODD) exit, or the response by an ADS to achieve minimal risk condition given the same circumstances.[164]
Functional Safety	A safety framework that identifies and mitigates safety hazards caused by electronic-based malfunctions.
Operational Design Domain	Operating conditions under which a driving automation system or feature thereof is specifically designed to function, including, but not limited to, environmental, geographical, and time-of-day restrictions, and/or the requisite presence or absence of certain traffic or roadway characteristics.[165] A modification of the Operational Design Domain is the Limited Operational Design Domain, which describes a subset of the full Operational Design Domain leveraged for interim operations until sufficient performance is achieved by the system to unlock the full Operational Design Domain.

Glossary Term	Description
Minimal Risk Condition	A stable, stopped condition in which a user or an ADS may bring a vehicle after performing the DDT fallback in order to reduce the risk of a crash when a given trip cannot or should not be continued. The Minimal Risk Condition that is achievable by the autonomous vehicle is variable depending on the circumstances and residual driving capabilities of the autonomous vehicle.
Predicted Collision	A hypothetical event in which a Supervised AV's planned path as projected forward in time from a TKO would have led to a real-world collision, had manual intervention not taken place.
Safety Management System	A structured approach to ensuring safety throughout product development and operations processes. Cruise's Safety Management System provides a comprehensive picture of our safety strengths and vulnerabilities, and ensures that our safety decision-making and the continuous improvement of safety initiatives are well-structured. Our SMS assigns risks to distributed accountable risk owners who control the resources needed to act on, and mitigate or resolve, each particular risk.
Safety Mission & Safety Claim	Cruise's **Safety Mission** is to responsibly deploy the world's most advanced driverless service, and safely connect the communities we serve to the places, things, and experiences they care about. Cruise's **Safety Claim** is that we achieve this Safety Mission by identifying and classifying the safety risks of operating a driverless service and mitigating them to acceptable levels.
Safety of the Intended Function	A safety framework that identifies and mitigates unreasonably risky and potentially hazardous behaviors caused by system limitations. **SOTIF is formally defined in ISO/PAS 21448 (2022) as:** ...the absence of unreasonable risk due to a hazard caused by functional insufficiencies, i.e.: • The insufficiencies of specification of the intended functionality at the vehicle level; or • The insufficiencies of specification or performance insufficiencies in the implementation of electric and/or electronic (E/E) elements in the system.

Acronyms

AE	Accountable Executive
ASIL	Automotive Safety Integrity Level
Auto-ISAC	Automotive Information Sharing & Analysis Center
AV	Autonomous Vehicle
AVSC	Automated Vehicle Safety Consortium
AVTO	Autonomous Vehicle Test Operator
CARS	Compliance Assurance Reporting System
ConOps	Concept of Operations
COO	Chief Operating Officer
CVC	California Vehicle Code

DIA	Development Interface Agreement
DDT	Dynamic Driving Task
DDT-F	Dynamic Driving Task, Fallback
DS	Degraded State
ERC	Event Risk Classification
FMVSS	Federal Motor Vehicle Safety Standards
FUSA	Functional Safety
GM	General Motors
HD	High-Definition
HFA	Human Factors Analysis
HIL	Hardware-in-the-Loop
IIHS	Insurance Institute of Highway Safety
LEIP	Law Enforcement Interaction Plan
LODD	Limited Operational Design Domain
LRR	Launch Readiness Review
MRC	Minimal Risk Condition
NTSB	National Transportation Safety Board
NCAP	New Car Assessment Program

NFPA	National Fire Protection Association
NHTSA	National Highway Traffic Safety Administration
NIST CSF	National Institute of Standards and Technology Cybersecurity Framework
ODD	Operational Design Domain
PDP	Product Development Process
PR	Pull Request
RA	Remote Assistance
R&D	Research and Development
RIM	Release and Issue Management
RMS	Requirements Management System
RTT	Real-Time Text
RWG	Risk Working Group
SAE	Society of Automotive Engineers
SE	Safety Executive
SET	Safety Escalation Team
SIREN	Safety Information Reporting & Escalation Network
SMS	Safety Management System
SOP	Standard Operating Procedure

SOTIF	Safety of the Intended Function
SPI	Safety Performance Indicators
SRM	Safety Risk Management
STPA	Systems Theoretic Process Analysis
TKO	Take Over
UL	Underwriters Laboratories
UPI	Unwanted Public Interaction
VRE	Vehicle Retrieval Event
WI	Work Instruction

cruise