GM Driving Automation: Supervised Test Operation

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Our Vision for Automated Driving

As one of the largest global automakers, GM is constantly redefining the driving experience. Now, we're aiming to lead the transformation of personal mobility at scale. Automated driving technology will transform the driving experience for everyone. We're building a future where autonomous vehicles are designed to help give precious time back to people and make driving safer, easier, and more enjoyable.

Hands-free, eyes-on driving is already mainstream: more than 800 million miles have been driven with GM's Super Cruise technology alone. Today's Super Cruise is a driver assistance system. Even while the assistance system is engaged, the human driver is responsible for driving safety at all times. GM's next-generation Super Cruise will be an Automated Driving System (ADS) that doesn't just help people drive better but safely drives the vehicle for them when engaged.

GM's next-generation Super Cruise must safely and reliably operate in dynamic, uncertain, and challenging environments. Our ADS will leverage some of the most complex technology applications of our time: advanced perception and decision-making capabilities built from large AI models, a comprehensive sensor suite, robust safety systems, and a system architecture that is designed with redundancy and built with confidence. To develop this technology, we're using our extensive experience and rich data across public road miles, closed-course testing, and large-scale simulation. We evaluate performance, identify risks early, and safely iterate as we advance towards personal autonomous vehicles that transport our customers at the touch of a button.

The following sections of this test operations Voluntary Safety Self-Assessment (VSSA) describes GM's approach to enabling supervised test operation on public roads as an important step in the development of our ADS. It outlines the steps we have taken in our Supervised Test Operation Safety Case to safely operate our supervised test operation fleet on public roads. This paper reflects GM's longstanding commitment to transparency, continuous improvement, and responsible development and deployment of new technology. We consider public trust an essential stewardship of GM and will continue to share safety information and updates on our testing and validation as we develop in service of earning and building trust.

Supervised Test Operation

One critical component to ADS development is using supervised test operation to help validate our driving automation system on public roads. Our testing fleet features modified production GM test vehicles that are supervised by trained test drivers. The supervised test operation vehicles are modified with advanced sensors, computers, and software specific to our data collection and testing needs. Trained test drivers are positioned in the driver's seat and able to take manual driving control of the test vehicle at any time. We plan to conduct supervised test operations in multiple geographic locations: we will begin in California and Michigan with a limited version of the system (i.e., SAE Level 2[1] driving automation) and expand our operational design domain (ODD) and system capabilities as we progress.

Our Supervised Test Operation Safety Case helps ensure the safety of our test systems by confirming that the system does not introduce hazards that a trained test driver cannot mitigate. Our test protocol also helps confirm that our trained test drivers can safely supervise the test system and remain attentive to the driving task throughout supervised test operation.

The supervised test operation vehicle is equipped with manual driving controls, such as steering wheel, throttle and brake pedals, and gear shift controls, which allow our trained test drivers to take manual driving control of (in other words, "take over") the test vehicle at any time while the driving automation system is engaged. The trained test driver may take over for any reason, including but not limited to following operational protocol, enforcing operation within the designated ODD, maintaining in-car comfort, or encountering uncertain situations on the road.

We will operate our supervised test operation vehicles with attentive human test drivers responsible for safe operation. Through testing, we will generate valuable data to develop, train, and inform the development of our ADS and the system's AI models.

[1] *See Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles J3016*, SAE International 1, 26 (Apr. 30, 2021), https://www.sae.org/standards/j3016_202104-taxonomy-definitions-terms-related-driving-automation-systems-road-motor-vehicles.

Building the Supervised Test Operation Safety Case

GM's Supervised Test Operation Safety Case is a structured argument supported by evidence that our supervised test operation is safe for public roads. In developing the Safety Case, we abide by the following principles:

1. **The Safety Case is a shared responsibility.** Subject matter experts (SMEs) at GM own claims across a broad range of disciplines to promote the strength and relevance of our Safety Case.
2. **The Safety Case is informed by industry best practices and standards.** While the Autonomous Vehicle industry continues to expand and mature, we remain committed to achieving state-of-the-art safety. We review and apply industry standards and literature to strengthen our Safety Case. We also participate in industry organizations like SAE's Automated Vehicle Safety Consortium to inform standards and best practices.
3. **The Safety Case is fundamental to the program.** Development of the Safety Case is incorporated from the beginning into program planning. Risks associated with the development, completion, and assurance of the Safety Case are reviewed, escalated, and resolved in a timely manner in cross-functional program forums. The success of the program relies on the completion of the Safety Case.
4. **The Safety Case is regularly monitored, assessed, and improved.** We are always working to maintain, evolve, and improve our Safety Case. We define core Safety Performance Indicators (SPIs) to monitor safety performance and recognize emerging risks. We identify and resolve safety concerns or gaps in a timely manner, and the Safety Case is kept up to date to reflect these activities.

Building the Supervised Test Operation Safety Case, Cont.

Our Supervised Test Operation Safety Case structure is built by our safety team and leverages standards and best practices. The evidence demonstrating the claim is produced by SMEs across the following domains, which are described in more detail in Supervised Test Operation Safety Case Topics.

- Operational Design Domain (ODD)
- Regulatory Compliance
- System Safety
- Cybersecurity
- Verification and Validation
- Safety Performance Indicators (SPIs)
- Test Driver Readiness
- Incident Response

Safety Case
Lifecycle

Our Safety Case is a living artifact. We have developed a Safety Case lifecycle that allows us to build, review, govern, monitor, evaluate, and evolve our Safety Case. This process is cyclical in nature: every step presents the opportunity to identify new learnings and continuously strengthen our Safety Case.

A centralized and independent Safety Case team works closely with domain-specific SMEs to confirm that Safety Case claims and evidence are robust, complete, and defensible. As part of the Safety Case lifecycle, we build our Safety Case from the beginning of product development; we continuously identify and mitigate safety and substantiation risks; and we launch with confidence.

An AV Safety Strategy forum of cross-functional senior leadership serves as the governing body for safety relevant aspects and regulatory compliance decisions related to automated driving from concept through product launch. Safety materials approved by the forum include safety strategies, Safety Case claims, safety findings, and safety mitigations proposed throughout the product development cycle. The forum also conducts a Safety Review to confirm safety case completeness and closure of all pertinent findings prior to the cross-functional readiness review.

As SMEs submit evidence to substantiate their claims in the Safety Case, a Safety Assurance Review Board of independent internal contributors regularly reviews the evidence to identify and escalate potential gaps or findings. The SME responsible for the claim and evidence addresses and resolves these in collaboration with a reviewer from the Safety Assurance Review Board. Further escalations are brought to the AV Safety Strategy forum as necessary.

At each major program gate, a comprehensive and cross-functional readiness review is held to assess technical, operational, and enterprise readiness for launch or expansion of supervised test operations. A baseline record of the Safety Case that supports launch serves as one of the core inputs to this broader readiness assessment.

Safety Case
Lifecycle, Cont.

Cross-functional teams define, implement, and monitor the driving automation system's safety performance using Safety Performance Indicators (SPIs). Emerging safety risks identified through SPI trends are investigated by the responsible cross-functional team to determine underlying contributors. Once identified, our teams take prompt corrective actions and improvement measures. In parallel, the cross-functional team highlights safety risks, trends, and solution proposals to the AV Safety Strategy forum.

The Safety Case team proactively assesses proposed changes that could affect the safety of our operations, including new software releases, revised ODD scope, or modified test vehicle platforms (e.g., transition to production intent vehicle platform). These assessments help identify any additional work necessary to maintain the safety performance of our supervised test operation fleet and produce corresponding updates to the Supervised Test Operation Safety Case. Proposed revisions and updates to the Safety Case undergo a change control process to allow for review by the Safety Case team and relevant SME.

Feedback systems such as call centers and reporting tools are available to employees, contractors, partners, and the public to collect concerns associated with GM's products, including our automated driving technology development. GM fully investigates these safety concerns to promote continuous improvement in our automated driving technology and development processes.

Supervised Test Operation

Safety Case Topics

The following sections describe the topics that comprise our Supervised Test Operation Safety Case. GM's supervised test operation features a trained test driver in the driver's seat who can take over at any time while the driving automation system is engaged. Our Supervised Test Operation Safety Case is comprehensive and centers on two key objectives: demonstrating that the trained test driver is capable and prepared to safely supervise the driving automation system, and confirming that the driving automation system does not introduce hazards that the trained test driver cannot effectively detect, manage, or mitigate.

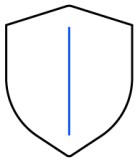
Operational Design Domain (ODD)

The initial focus of our supervised test operation ODD is limited-access highways. Our supervised test operation is performed only in weather conditions that allow our trained test drivers to maintain driving control and visibility of the road. Geographically, we operate in multiple locations starting with specific highways in California and Michigan. The trained test driver engages the driving automation system within the authorized ODD and can take over at any time they deem necessary, including exiting the authorized ODD.

Regulatory Compliance and Engagement

GM maintains an unwavering focus on safety and regulatory compliance in the responsible use of our data collection and technology testing on public roads. We proactively notify federal, state, and local stakeholders as appropriate about ongoing supervised testing operations and data-collection activities to keep policymakers informed of operations in their jurisdictions and proactively offer safety information through shared materials like this VSSA. GM also regularly communicates with the National Highway Traffic Safety Administration on our public road-testing plans and what we are doing to help ensure safe testing. A cross-disciplinary group of first responders – including leaders from 911 centers, law enforcement, EMS, and fire services – take part in the GM OnStar Public Safety Advisory Council to provide expert guidance on vehicle safety, emergency response protocols, and interaction plans.

System Safety



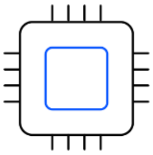
GM develops safety-critical systems with system safety processes to prevent and mitigate potential harm to our trained test driver, vehicle occupants, or other road users. For the supervised test operation, the focus for system safety is on protecting the ability of our trained test driver to safely take control of our test vehicles at any time.

GM's proven system safety processes leverage systems engineering and functional safety best practices consistent with industry standards and best practices. These processes identify, assess, and mitigate potential safety risks, such as random hardware failures, systematic software failures, or technology limitations, which may arise within our safety-critical systems. The test vehicle's safety-critical systems include vehicle actuator control systems such as steering, thermal and power systems, occupant safety features like seat belt restraints, and testing-specific systems such as the emergency stop system.

We also implement safeguard features using industry best practices to enable, enhance, or protect the trained test driver's ability to safely take over. Such safeguards include the takeover system, actuator control rate limits, and driver monitoring systems. GM develops Human Machine Interface (HMI), including those developed in the supervised test operation vehicle, according to industry best practices. The HMI system includes system state displays, takeover alerts, and takeover controls that allow the trained test driver to override the driving automation. Limitations to these systems are communicated to the test drivers through instructions and training, which promotes their ability to safely take over on the road.

Modifications to production vehicles, such as additional sensors, computers, interfaces, and other features necessary for supervised test operation, are made using GM's engineering best practices. These modifications are included in the safety case and reviewed by internal subject matter experts. Testing and analysis are completed according to engineering best practices to confirm that test vehicles are safe for public road usage.

Cybersecurity



As part of GM's cybersecurity approach for ADS development, we developed a threat model to identify cybersecurity vulnerabilities. This model accounts for unauthorized software attacks, remote attacks, and physical device attacks to protect the trained test driver's ability to take manual control of the test vehicle. The ADS's electronic control units protect against malicious software or firmware using restricted boot up and authorization keys. An automated firewall system blocks unauthenticated inbound connections. Critical messages on the automated system are authenticated by a cryptographic signature to protect against cybersecurity attacks made with a physical device.

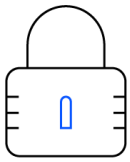
If the trained test driver observes unusual or hazardous situations, including those caused by a potential cybersecurity threat, they are trained to take over control of the test vehicle at any time.

Verification and Validation (V&V)

GM performs V&V activities including manual driving, simulation, and closed-course testing to evaluate the test vehicle's safety performance and readiness for on-road operations. GM follows a well-established systems development process to identify the necessary verification and validation activities. Unit tests are performed on software to demonstrate desired functionality and debug undesired results. Integration tests, including combinations of hardware-in-the-loop, software-in-the-loop, and tests with the test driver in-the-loop, are performed in controlled test environments to demonstrate integrated system functionality and performance. End-to-end integration tests are performed in closed course as a controlled emulation of the real-world driving domain.

These V&V activities are performed on a continual basis with each software release. Each software candidate undergoes robust integration tests. We regularly monitor and analyze performance test data to inspect and confirm the performance of our safety-critical systems. GM development and validation teams identify, escalate, and resolve potential gaps in requirements, tests and analyses, or SPIs. GM investigates internal and external feedback, including feedback relating to driving automation, as part of our commitment to continuous improvement.

Safety Performance Indicators (SPIs) and Application



GM defines SPIs and performance benchmarks using a range of reference points, including but not limited to naturalistic driving data, driving data from our trained test drivers, internal data from production and development systems, and engineering requirements. We use SPIs to measure and regularly monitor the safety performance of the driving automation system.

If an immediate safety concern such as dipping below a defined SPI threshold is identified, GM enacts its response policies which can include restricting or pausing the supervised test operation. Additionally, when emerging safety risks or trends are detected, they are escalated through the AV Safety Strategy forum. This process triggers a detailed review to ensure timely corrective actions.

For supervised operations, GM's SPIs are focused on monitoring driver controllability. Examples include the rate of test driver intervention, and the rate of driving controllability events such as hard brakes and swerves. GM also closely monitors potential traffic citations and crashes .

GM leverages this data-driven framework to monitor, maintain, and evolve our SPIs over time, and promote the ongoing safety and evolution of our Safety Case.

Test Driver
Readiness

The trained test driver is responsible for monitoring the test vehicle and taking over as needed. The test driver may take over to follow operational protocol, respond to ODD exits, protect against potentially hazardous situations on the road, and more. Our trained test drivers are expected to be capable, trained, and attentive throughout the supervised test operation.

We demonstrate the readiness of the trained test driver for supervised operations in several ways, taking guidance from *SAE J3018_202012 - Guidelines for Safe On-Road Testing of SAE Level 3, 4, and 5 Prototype Automated Driving Systems (ADS)*. Test drivers receive clear policies, work instructions, and classroom training to understand their roles and responsibilities. They receive an overview of the driving automation system and learn about hazardous situations that may emerge during supervised operation. Test drivers are given classroom and hands-on closed-course training, including emergency response and evasive handling techniques. New test drivers are paired with experienced test drivers during training and early operations to promote knowledge sharing and increase vigilance.

GM enforces a comprehensive fatigue management policy to reduce fatigue-related risks related to supervised test operation. The policy includes guidelines for schedules and work limits, driver monitoring, driver education, peer- and self-reporting, and strict driving requirements. The test vehicle is equipped with a driver monitoring system that identifies driver distraction, fatigue, and unsafe driving behavior s such as speeding violations. The system sends in-cabin warnings to the trained test driver and notifications to back-office operations teams to provide guidance and maintain safe operations. These events, along with traffic violations and crashes, are audited, reviewed, and escalated by an independent internal safety team as needed.

Incident Response

Preparation for incident response begins before an incident takes place. Trained test drivers and the incident management team are trained on the required incident response policies and procedures. Test vehicles are equipped with incident-readiness documentation and instructions to help ensure that the trained test drivers have the information and support they need during an event.

When an incident takes place, the trained test driver safely exits traffic when practicable (e.g., to the road shoulder) and activates the hazard lights. The trained test driver then follows established procedures for incident response aimed at quickly securing the appropriate help needed for all involved.

The GM OnStar safety, security, and connectivity service is available on all GM vehicles including supervised operation test vehicles for emergency support and response. In the event of a severe crash detection, or if the trained test driver manually initiates an emergency SOS call per protocol, an emergency-certified OnStar Advisor connects via live audio call. Based on the interaction and the information available, the OnStar Advisor can contact the appropriate emergency communications center to request dispatch of local first responders as needed. The trained test driver notifies the 24/7 live support incident management team of incidents and receives in-field support as needed.

The trained test driver cooperates with first responders if any are present and follows their directions. First responders can visually identify whether or not the driving automation system is engaged: a green light lamp on the test vehicle steering wheel indicates that the driving automation is engaged and a non-illuminated lamp indicates that it is disengaged. The trained test driver also interacts with third parties to exchange information and collect details for the incident response report.

After initial incident response is complete, the trained test driver completes incident documentation before leaving the scene. GM teams perform post-incident analyses including root-cause analysis, identification of potential learnings, and compilation of materials for regulatory reporting as applicable.

Conclusion

This VSSA outlines GM's approach to safely conducting supervised test operation. We are committed to responsibly developing our driving automation technology and we recognize the importance of sharing our safety approach with regulators and stakeholders.

Supervised test operation is a critical step in advancing and refining our driving automation technology. Autonomy has the potential to make driving safer, easier, and more enjoyable. Earning and building trust is an essential part of this journey. As our technology and safety practices evolve, we will update this document and provide supplemental safety information to offer continued transparency into our progress.

Appendix:
12 Elements of Safety

The following table provides references to the 12 Elements of Safety identified in NHTSA's 2017 publication, *Automated Driving Systems 2.0 - A Vision for Safety*.

Element	Heading
System Safety	System Safety
Operational Design Domain	Operational Design Domain (ODD)
Object and Event Detection & Response	System Safety, Test Driver Readiness
Fallback (Minimal Risk Condition)	System Safety, Test Driver Readiness
Validation Methods	Validation and Verification (V&V)
Human Machine Interface	System Safety, Test Driver Readiness
Vehicle Cybersecurity	Cybersecurity
Crashworthiness	System Safety, Verification and Validation (V&V)
Post-Crash ADS Behavior	Test Driver Readiness, Incident Response
Data Recording	Verification and Validation (V&V), Incident Response
Consumer Education and Training	Test Driver Readiness
Federal, State, and Local Laws	Regulatory Compliance and Engagement