2019 Self-Driving Safety Report

TUSIMPLE SAFETY REPORT

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CHAPTER 1
INTRODUCTION

OUR MISSION

- INCREASE SAFETY
- DECREASE TRANSPORTATION COSTS
- REDUCE CARBON EMISSIONS

ABOUT US

TuSimple was founded in 2015 with the goal of bringing the top minds in the world together to achieve the dream of an SAE level 4[1] autonomous truck driving solution. With a foundation in computer vision, algorithms, mapping, and artificial intelligence (AI), the TuSimple solution will allow freight to be moved with greater safety, improved cost efficiency, and fewer carbon emissions.

History

SEP 2015	Founded with headquarters in San Diego, CA
SEP 2016	Awarded ten world records for autonomous driving on the Karlsruhe Institute of Technology and Toyota Technological Institute (KITTI) and Cityscapes public datasets
AUG 2017	Opened testing and development facility in Tucson, AZ and began testing TuSimple's Autonomous Driving System (TADS) between Tucson, AZ and Phoenix, AZ
FEB 2018	Expanded to a new 50,000 sq ft production facility in Tucson, AZ to house our truck fleet
AUG 2018	Began hub-to-hub autonomous hauling for customers in Tucson, AZ

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SAFETY AND WORKFORCE ISSUES FACING THE TRUCKING INDUSTRY

TuSimple's autonomous truck solution can help address the driver shortage and improve safety.

The average age of truck drivers is **55** [2]
73% driver turnover rate at small carriers and **94%** turnover rate at large carriers[3]
By 2026 The shortage of truck drivers is projected to reach 175,000[4]
On average, there have been **3,513** fatal crashes and over **75,000** injury crashes per year involving large trucks since 2010[5]
On average there have been over **276,000** property damage only crashes per year involving heavy trucks since 2010[5]
At least one driver-related factor was recorded for the truck driver in nearly **1/3** of all fatal crashes involving trucks in 2016 [5]

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LANDSCAPE FOR SELF-DRIVING TRUCKS

Long-haul trucking, generally recognized as routes requiring goods to be delivered further than 250 miles from the truck's origin, is an essential and significant portion of the U.S. economy and is facing a number of safety and economic issues, ranging from accidents to worker shortages.

TuSimple believes that our autonomous driving solution can help the industry mitigate or eliminate some of the these most pressing issues in trucking, like driver retention and shortage, vehicle parking, traffic congestion and safety, while maintaining the cost and convenience advantages the trucking industry relies on to be America's preferred freight movement method.

GROWING FREIGHT DEMAND AND INCREASING COSTS

- Nearly 71% of all freight tonnage moved in the U.S. goes on trucks. [6]
- The annual shipping tonnage in America requires over 3.6 million heavy-duty Class 8 trucks and over 3.5 million truck drivers. [6]
- Freight volumes are projected to increase 35.6% by 2029.[7]
- Total tonnage may reach ~21.7 billion tons by 2029.[7]
- The median salary for truck drivers increased between 15-18% from 2013 to 2018 depending on their fleet and route status.[8]

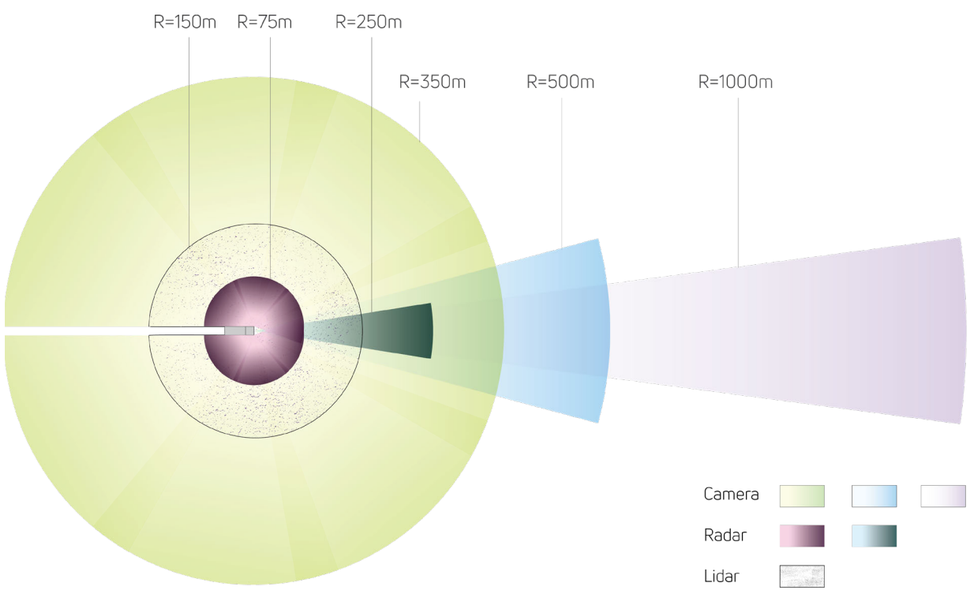
OUR SELF-DRIVING SYSTEM

TuSimple believes in utilizing cutting-edge perception technology to develop the world's safest self-driving truck. We're building a full-stack solution and enabling self-driving trucks to improve shipping times for goods and materials and to make highways safer and less congested. Our system utilizes an array of perception and localization sensors and data along with our proprietary deep learning detection algorithms to detect and track objects in real time and make pixel-level interpretations within the field of vision. With this technology, a truck can achieve a decimeter-level of positioning accuracy — even in a tunnel or under a bridge.

Using our sensor array and deep-learning algorithms, our proprietary artificial intelligence decision-making system can guide vehicles along a safe and fuel-efficient route based on terrain and real-time road conditions. Our solution has been purpose-built to provide a robust perception system, allowing

the decision-making AI to act with high confidence and detection reliability. Our camera-forward system operates more safely at highway speeds because the sensor array is optimized for use on Class 8 tractors and provides redundant secondary and tertiary perception, detection, and tracking data. To provide high confidence and reliable long-, medium-, and short-range perception, we use a variety of camera sensors that allow our system to detect and track objects at distances of up to 1000 meters. Our Light Detection and Ranging (LiDAR) sensors provide secondary perception and detection at medium- and short-range, while our RADAR sensors offer tertiary perception and detection at medium- and short-range.

Large trucks, like the Class-8 trucks our system is designed for and used on, require significantly more stopping distance and time than passenger vehicles. At 65 MPH, we believe a large truck perception system requires 300 to



500 meters of perception range, where perception means reliable detection, classification, localization, and tracking. Since a combined and integrated sensor suite that cannot reliably perceive the critical 300- to 500-meter range is not sufficient for a heavy vehicle traveling at highway speeds, we have designed our sensor array to perceive at a much larger distance of 1000 meters to ensure reliable determination in the critical safety range. Our 1000 meter perception range allows the self-driving software to make long-range, proactive, and strategic decisions to improve safety and efficiency beyond what other systems can achieve.

In addition to cutting-edge technology and advanced algorithms, it is important that self-driving systems are designed, manufactured, and utilized in accordance with exceedingly high safety standards. That is why we are building International Organization for Standardization (ISO) 26262 and Capability Maturity Model Integration (CMMI) Level 5 Controls (software) into every aspect of our system, hardware, software, purchasing, and production processes and are designing to meet the stringent ISO/PAS 21448 SOTIF (safety of the intended function). In support of these, we will be registered to International Automotive Task Force (IATF) 16949, the Automotive Quality Management System. IATF will include the required documented supporting processes.

This Voluntary Safety Self-Assessment describes our safety processes and features as well as the progress we've made implementing them. Our safety assessment follows the U.S. Department of Transportation (DOT) and National Highway Traffic Safety Administration (NHTSA) guidelines laid out in Automated Driving Systems 2.0: A Vision for Safety[9] and is organized in two parts. In this first chapter, we introduced TuSimple, our self-driving driving system, and our approach to safety. In the next chapter, we address the 12 safety elements that the DOT and NHTSA highlight in their guidelines.

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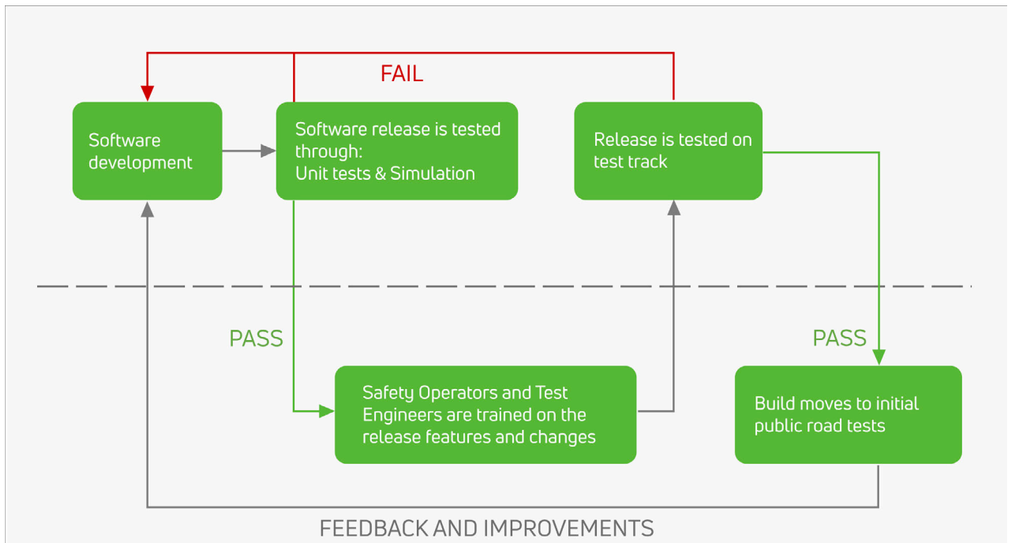
CHAPTER 2
ELEMENTS OF SAFETY

SYSTEM SAFETY

The primary goal of our self-driving system is to reduce the danger posed to humans around us. By removing the human operator from our commercial product, we can eliminate errors such as those caused by driver fatigue or distraction. We also continue to evaluate the performance of our system throughout the development and test cycle to identify improvements which are then tested, verified, and included in software updates on all of our trucks. Unlike self-driving systems that are designed for vehicles that carry passengers, our system will be capable of operating without human intervention. Because our system will operate without occupants, our design is primarily concerned with the safety of other drivers in its operational environment.



DEVELOPMENT AND TESTING CYCLE

We understand the importance of using a System Safety approach to eliminate unreasonable safety risks and to mitigate risks that cannot be fully eliminated. We've incorporated well-established standards and processes into the design of every element of our self-driving system. We utilize internationally recognized standards including relevant standards, recommended practices and guidance from the U.S. Department of Transportation, aerospace, and military to inform the design, sourcing, verification, and validation of every element of the self-driving system.

Standards we utilize

ISO 26262
Functional Safety – Road Vehicles

IATF 16949
Automotive Quality Management System

ISO /PAS 21488
Road Vehicles –
Safety of the Intended Functionality

Following the process outlined in ISO 26262 (Functional Safety – Road Vehicles), we begin by engaging in a requirements analysis to clearly develop the Item Definition. This becomes the basis for the Hazard Analysis and Risk Assessment (HARA) to identify Safety Goals and assign Automotive Safety Integrity Levels (ASIL) to every identified hazard and risk so that we can design, build, and implement mitigation, redundancy, and/or ASIL decomposition strategies that will avoid potential failure modes or mitigate the negative consequences of a potential failure.

Our Functional Safety and Quality team is led by safety experts with decades of experience in the automotive industry. This team is directly responsible for all safety-related issues and helps lead the engineering teams through detailed and rigorous fault-tree analysis, Failure Mode and Effects Analysis (FMEA), and all system testing and validation. For more information about our specific testing and validation strategies and practices, refer to the Validation Methods section in this document.

OPERATIONAL DESIGN DOMAIN

We are developing an automated driving solution for trucks that will operate at SAE Level 4 (L4). An L4 self-driving vehicle is able to operate autonomously without a driver present only within a well-defined operational design domain (ODD). Self-driving systems, much like human drivers, have limitations that affect how well they can perform in a variety of situations. The ODD for an L4 self-driving system defines its operating limitations and excludes scenarios and situations for which an effective technical solution has not yet been validated. For instance, a system may not be able to meet performance requirements on snowy, high-grade, mountainous roads, so the system would not be authorized to operate in that domain. ODDs can be extremely broad (e.g., interstate highways in clear conditions) or extremely narrow (e.g., a defined segment of a specific highway during certain hours), but they must be specific and use clear and unambiguous statements to define the limits under which the system is allowed to operate. ODDs must take into account road types and conditions, weather, topographic features, speed limits and traffic laws, as well as other jurisdictional regulations.

Our ODD definition includes highways and surface streets from depot to depot during night and day and during inclement weather. It also includes parameters for road types, geographic and topographic features, speed limits, and laws and regulations. Our commercially deployed self-driving system is intended to operate under a variety of conditions and will have an ODD that confines the system to previously mapped routes validated to the ODD.

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OBJECT AND EVENT DETECTION AND RESPONSE

Every driver relies on their senses to perceive the world around them. They use the information acquired through their senses, along with their previous experiences and knowledge, to predict the behavior of others on and around the road and to make driving decisions. Self-driving systems are no different. Our self-driving system utilizes sensor solutions to perceive and determine a safe and appropriate vehicle command. Our system detects, tracks, and predicts the behaviors of objects. Our system tracks and resolves dynamic objects to ensure that they are no longer associated with risks. These inputs are then used by our self-driving system to make appropriate driving decisions for the given situation.

Our self-driving system is capable of identifying and tracking various static and dynamic objects it encounters. We use an array of sensors including, high-definition cameras, Light Detection and Ranging (LiDAR), radar, ultrasonic sensors, GPS, inertial measurement units (IMUs), and audio sensors for long-distance sensing in a high-speed environment under a variety of conditions. The distance penetration and clarity of our sensor solution is necessary to provide the time and space for a tractor trailer to safely and smoothly complete maneuvers. In addition to the high-integrity detection in the 300 to 500-meter range that our sensor suite provides for safety at highway speeds, our 1000 meter forward camera extends our system's range by an additional 500 meters which allows our planning system to operate strategically, enabling our self-driving system to engage in and plan for the safest and most efficient behaviors possible.

We collect massive amounts of real-world sensor data from our trucks which we use to train the self-driving system to detect and classify objects it may encounter and to anticipate the behaviors of detected objects. Our robust prediction system considers future actions of every detected object in the environment. It assigns probabilities to each potential action for each detected object and uses this set of predictions to choose and execute a trajectory that maximizes the probability of a safe outcome. This allows us to have the safest possible course of action available to the self-driving system, depending on the actions of other drivers and pedestrians and the surrounding infrastructure.

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FALLBACK (MINIMAL RISK CONDITION)

No automated driving system can be entirely free from faults, potential failures, or changes in conditions that might place it outside of its operational design domain. Our automated driving system is designed to identify and safely react to these events. To safely react to situations that limit the self-driving system's capabilities or changes in roadway, weather, or other conditions outside the system's operational design domain, the system must be able to detect the critical event or change in conditions and to perform a fallback, or minimal risk condition (MRC), maneuver in response. Our system constantly monitors the health of every safety-critical component and validates all data and timestamps through checks and redundancies in order to detect scenarios in which an MRC maneuver is required.

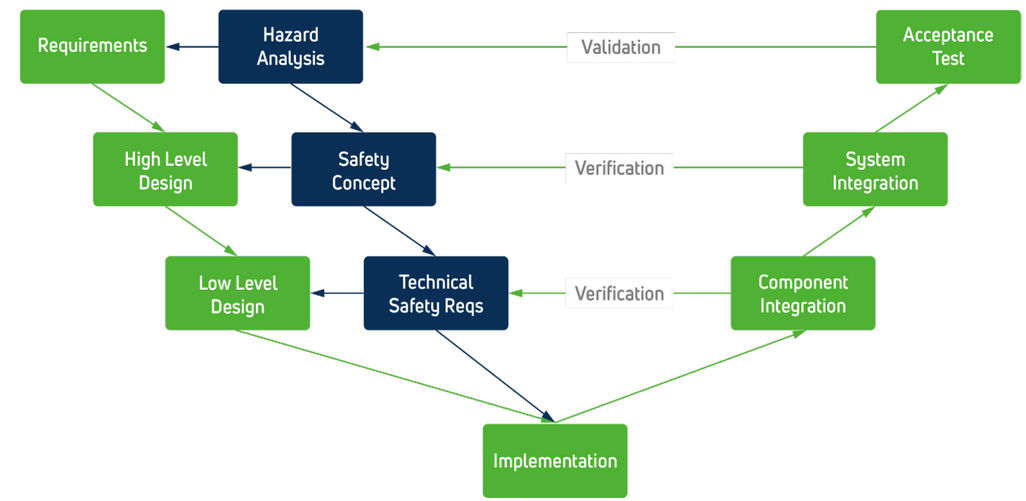
During the development phase, our automated driving system will recognize and attempt to perform most MRC maneuvers, but in some cases the Safety Operator will be asked to assume control of the vehicle. TuSimple's Safety Operator program, which includes training, testing, continuous education, monitoring and strict policies, combined with the design of TuSimple's development phase automated driving system, help to ensure that this is a highly controllable disengagement of the self-driving system. After the system is functionally complete, automated MRC maneuvers have met functional safety goals, and the system has been validated, the Safety Operator will not be required. Instead, our commercial-intent self-driving system will detect both internal system faults and external conditions to provide input to the Functional Safety module which will choose an appropriate Functional Safety response and, when necessary, perform appropriate actions to achieve an MRC ranging from logging an event for degradation analysis through performing a safe emergency stop and park. With fail-operational functionality, our system can determine whether to continue to operate under more restricted operational parameters or if it must stop operating immediately.

We're building fault-tolerance and fail-operational capability into our self-driving system by using proven practices and frameworks developed for automotive, aerospace, and military applications to improve the reliability and safety of our self-driving system. To reduce the likelihood of system failure, we design for reliability, self-diagnostics, self-correction, and redundancy where necessary. We perform extensive testing to evaluate the reliability of every component of the system and implement 3-tier redundancy whenever possible. We also perform fault analysis to develop a fault mitigation plan that covers the risks identified in our HARA. All safety mechanisms, faults, and fault tolerances are validated as is required to meet our functional safety goals.

VALIDATION METHODS

Throughout the system design process, we identify functional performance requirements and the hazards and risks that could result from misbehaving functions. We perform full Design Verification Plan and Reports (DVP&R) of functions, maneuvers, scenarios, and degradation scenarios. Electrical/electronic (E/E) devices receive full rational automotive tests, including electronic emissions. To limit public exposure to unnecessary risk, we use computer simulation testing first, before moving to test track/proving ground testing, then finally moving to road level testing with Safety Operators once the system has passed the previous two phases of testing. Data from each testing phase is analyzed and used to develop further improvements to the system.

Hardware components, including sensors, motherboards, graphics processing units (GPUs), and central processing units (CPUs), are tested for their reliability and their performance before being integrated into our on-vehicle system. Similarly, each software module must pass rigorous regression tests including intensive simulation-based tests that verify the performance of the code against previous iterations before it is installed on our vehicles. Once the individual modules and components pass their respective unit tests, we perform a series of simulation and closed-road track tests to verify the performance of the system. Only after the system has successfully passed the unit, simulation, and closed-road track tests is it allowed to operate on public roads. All



VERIFICATION AND VALIDATION

We follow the design V-diagram with the design creation from system to component on the left side of the V and the verification and validation from the component to the system on the right side.

public road tests of our developmental systems are conducted by a team of our Safety Operators and test engineers. Whenever a new software release is made available to the TuSimple fleet, our Test Engineers and Safety Operators are provided with detailed system behavior-oriented release notes and face-to-face meetings are held with the development engineering teams to review the changes and discuss their implementation. To pass our verification and validation testing, each update to our system must achieve stringent reliability and confidence levels that are derived from well-developed automotive industry standards.

Safety Operators

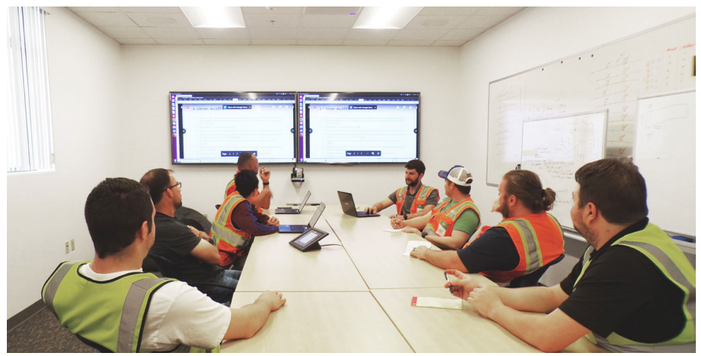
During the development period, our self-driving Class 8 trucks are operated by a 2-person team consisting of a trained Safety Operator and a Test Engineer. Our Safety Operators are all CDL Class A licensed drivers who are responsible for maintaining control of the vehicle at all times, disengaging the self-driving system when necessary, and manually operating the vehicle in the case of a self-driving system disengagement.

Whenever the system will be in Self-Driving mode, the Test Engineers are responsible for communicating road and system information to the Safety Operator, monitoring the self-driving system, and recording notes about system and road conditions by voice recording and a laptop.

Hiring and Qualifications

Before Safety Operators are hired, they must pass a background check, have a clean driving record, prove they possess a CDL Class A license, be Smith System[10] certified, and pass a road test administered by the Lead Safety Operator. Test Engineer's must also pass a background check, have a clean driving record, and pass a series of on-site interviews where they are asked to display their engineering and critical thinking skills by responding to a number of challenging scenarios.

Training and Testing



Test Engineers and Safety Operators, once hired, must complete a series of training activities that test their familiarity with the self-driving system as well as their ability to properly monitor and interact with the self-driving system. New Safety Operators spend their new hire period in classroom training to learn about the self-driving software and hardware. At the end of the course they must pass a written test.

Once Safety Operators have passed the classroom portion of the training course, they then move to behind-the-wheel vehicle training on a closed test track, where they must eventually pass a closed track road test that includes fault-injections and difficult self-driving scenarios. They must pass the closed track road test before they are allowed to engage in public-road tests.

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Continuous Education

Safety Operators and Test Engineers also attend debriefing meetings after road tests to discuss system performance, identify corner cases and unusual scenarios, and provide feedback to engineering teams. Similarly, whenever a new software release is made available to the fleet, Test Engineers and Safety Operators are provided with detailed, system behavior oriented, release notes and attend face-to-face meetings with the engineering teams to review changes and discuss their implementation.

Strict Policies and Monitoring

Safety Operators and Test Engineers are expected to follow all company safety policies. The cabin's audio and video recordings are constantly reviewed to ensure both Safety Operators and Test Engineers are following company policies. Violations of company safety policies or changes to driving records may result in disciplinary actions, ranging from training and testing to termination. For instance, Safety Operators may only use hands-free mobile devices while the vehicle is on the road, unless they are parked or immobilized and need to contact emergency responders. Additionally, Safety Operators must always keep their hands poised near the steering wheel and keep their feet poised near, but not on, the pedals.

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HUMAN MACHINE INTERFACE

When commercially deployed, our self-driving system is intended to function within its operational design domain without human intervention. Therefore, the most important aspects of our Human Machine Interface (HMI) are the external and public elements that will help other road users (including pedestrians, cyclists, law enforcement and first responders) interact with our self-driving trucks. We are designing an external-facing HMI that will be intuitive and easily understood by other road users.

Since our self-driving system is intended to be used on a variety of third-party Class 8 tractors, it relies on standard interfaces and indicators for other road users. The system uses the OEM installed tractor lights (cabin, hazard, head, turn, and tail). It also uses the same side and tail lights installed on the trailers it hauls. These signals are all readily understood by other road users and require no further training or education on the part of the public. The system does, however, have some unique indicators and interfaces on the exterior of the tractor. The commercial self-driving system will indicate to other road users that it is operating autonomously. We are working with regulators and other developers to standardize how the system will indicate its self-driving status. We are also working with regulators, state agencies, and other public safety entities to develop and improve the way first responders interface with the self-driving system, so they are informed about the system and prepared when they need to interact with the self-driving vehicle. We will also be publishing a detailed interaction guide for first responders and public safety officers.

During development, we provide an HMI for use inside the vehicle, intended for

use by the engineers and safety operators working on the self-driving system. Our development stage HMI is used to monitor the self-driving system and annotate recorded road and system data. The development stage HMI also provides passengers with the self-driving system's perception, prediction, and planning information. The HMI displays the detailed map, tracked objects and vehicles, and the predicted behaviors of other road users. It also audibly announces turns, lane changes, and other pertinent maneuver decisions.

During the development phase, the HMI allows the Safety Operator to disengage the self-driving system in any of the following ways:

- Pressing the Disengage button on the steering wheel
- Depressing either the accelerator or brake
- Turning the steering wheel
- Pressing the red emergency disconnect button on the dashboard

The development phase HMI includes a system that indicates the autonomous system's status to the Safety Operator, i.e., it indicates if the system is engaged, ready to engage, in an error or warning state, unable to engage, or disengaged. However, all other detailed system information comes from the Test Engineers, so Safety Operators are not monitoring the detailed HMI or at risk of on-screen distractions.

VEHICLE CYBERSECURITY

Cybersecurity is a critical element of our system safety approach. To protect our automated driving system from malicious attacks, we design in protections that will help prevent attacks and implement mitigation strategies to minimize the potential impact of any cyber-intrusion. We work with cybersecurity specialists to create security protocols that protect vulnerabilities in the self-driving system and all features, components, or tools that interact with the self-driving electronics.

Our cybersecurity protocols are designed to isolate and protect all onboard systems that communicate with the outside world through a variety of strategies, including physical isolation, firewalls, intrusion detection, and authentication. The self-driving system monitors itself for malfunctions and cy-

bersecurity attacks, responding to intrusions by activating an MRC maneuver once an intrusion is suspected. Remote monitoring services will also be notified of suspected attacks. In the event of any MRC maneuvers or detected software attacks, pertinent data is automatically recorded to electronic logs so that the system events can be reconstructed.

Any thorough approach to cybersecurity protections must also address the potential for physical attacks. To mitigate the risk of physical attacks against our self-driving system, we closely monitor and limit direct access to the system's hardware components, and our system is designed with physical enclosures that inhibit third-party access to hardware components, including physical tamper detection.

We work closely with security experts and our partners to review and approve all third-party libraries used in our software and hardware. We also review our internal processes and practices so that they align with the recommendations for cybersecurity from NHTSA and the Auto-ISAC.

CRASHWORTHINESS

When commercially deployed, TuSimple trucks are designed to haul freight without human intervention, therefore a human driver or other occupant will not need to be present in the vehicle when operating within the ODD. During the development phase, however, we do have safety operators, engineers, and other occupants in the vehicle and we anticipate that there will be times when commercially deployed trucks will be operated by a human driver outside of the ODD. To assure the safety of these vehicle occupants, we evaluate the crashworthiness and passenger safety implementations of our self-driving vehicles through

1) the crashworthiness and passenger protection features of the base vehicles; and 2) the crashworthiness and passenger protection features of our self-driving system and modifications.

CRASHWORTHINESS OF BASE VEHICLE

We are developing, testing, and validating our self-driving system on Class 8 trucks manufactured by Peterbilt and Navistar International. These tractor platforms comply with all applicable Federal safety standards and offer numerous supplemental safety features, including collision mitigation systems, radar-assisted rear end collision avoidance, Adaptive Cruise Control (ACC), lane departure warning, improved air disk brakes, and airbags and rollover seat protections.[11][12] We do not modify any of the existing safety or collision mitigation systems of our test vehicles and we work closely with our OEM suppliers to ensure that our system does not interfere with any of the intended functions of their systems.

CRASHWORTHINESS OF SELF-DRIVING SYSTEM AND MODIFICATIONS

We do not modify or disable any of the OEM installed safety features or functions. We only modify our self-driving vehicles to install and operate the self-driving sensors and system hardware. During the development and prototyping phase, we also modify selected test vehicles' sleeper cabins to accommodate additional passengers. The sleeper cab modifications to accommodate additional passengers will only be present during the development phase.

POST-CRASH ADS BEHAVIOR

Should a TuSimple truck operating in Self-Driving mode be involved in a crash, it will immediately initiate a fall-back, or MRC, maneuver appropriate to the severity of the incident. Depending on the severity of the incident and the vehicle's functional capabilities, the self-driving system will immediately and simultaneously complete the following actions, using redundant systems to complete the actions, if necessary:

1. Apply brakes and come to a complete stop or slowly move to the closest safe stopping area (like the shoulder on an interstate highway)
2. Activate the vehicle's hazard lights
3. Alert the TuSimple operations center and request assistance*
4. Automatically record detailed system and vehicle data surrounding the incident to an electronic log

*We are coordinating with regulatory bodies and first responders to develop an approperate notification protocol

We will provide emergency responders with all necessary information for them to safely interact with the self-driving vehicle at the scene of a crash as well as in normal operations. We will also set up a 1-800 hotline

for first responders and other road users so that they may communicate directly with company representatives regarding the self-driving vehicle's post-crash and normal operation.

In addition to the actions taken by the ADS in the event of a crash, we will initiate a fleet-wide response. During development, the fleet-wide response will be to immediately notify all Safety Operators to have them disengage the self-driving system and take manual control of the trucks they are operating. Post-development, TuSimple trucks in commercial operations will immediately notify our central management hub in the event of a crash, which will initiate an investigation into the root cause of the crash.

Finally, in the event of damage to one of our self-driving vehicles a complete system test will be performed before it is allowed to operate on the road again.

DATA RECORDING

During the development phase, our self-driving system records and logs all self-driving system, vehicle network (i.e., CAN-bus), and vehicle control data. This data is critical to the continued improvement of our self-driving system. The data we record is transmitted to teams of TuSimple engineers and backed up after every data collection or testing trip. This real-world data is then used to test and train the self-driving system on varying road, weather, lighting, and control situations. Since we record all sensor, vehicle control, and CAN-bus data, we can continuously run simulations with our self-driving software against previous real-world experience to ensure that the software continues to improve. Similarly, this data can be used to create and inform new simulation scenarios that we use to verify and validate the self-driving system.

Post-development, commercially deployed systems will record the same data that is being recorded during the development phase. We are working with other ADS developers and appropriate regulatory bodies to design and implement data recording standards that can be used for all self-driving vehicles, and our system will comply with any relevant data recording requirements.

CONSUMER EDUCATION AND TRAINING

The day-to-day experience for the general public who will interact with TuSimple's self-driving trucks will not be noticeably different from their current interaction with long-haul logistics carriers' manually operated trucks. To keep the public informed about self-driving trucks and address any concerns about how to properly interact with them, we will publish educational materials for public consumption as our self-driving system matures and becomes commercialized. These materials will be made available through traditional media outlets and through our website. (https://www.tusimple.com)

TuSimple is also working closely with our logistics partners to inform the employees who will interact directly with the self-driving system about the system's features and limitations. The loading and unloading of their trailers will remain unchanged and we will provide direct in-person and documented training for any changes that are required with regard to preparing the trailer for shipment. We are also partnering and working closely with a number of fuel, parking, and rest location operators to develop procedures for refueling and parking self-driving trucks.

FEDERAL, LOCAL, AND STATE LAWS

Our system safety approach requires that our self-driving system be capable of meeting or exceeding all federal, local, and state requirements and standards. We've also designed the self-driving system to follow all applicable laws. Our detailed ODD and capable OEDR system work in conjunction to cross-reference all road rules and ensure that the self-driving system follows the appropriate laws and rules of the road. We incorporate road sign information into our detailed maps, such that the map contains information that informs the self-driving vehicle's speed limit or lane assignment. This information is cross-referenced with ground-truth sensor data to ensure compliance with all applicable laws. For example, when our map indicates that the self-driving vehicle is operating in a lane with solid line lanes, the OEDR system confirms the presence of solid lane lines and the self-driving system knows that it cannot legally change lanes.

Any modifications we make to the base vehicle in our commercial system will meet all applicable Federal Motor Vehicle Safety Standards (FMVSS), or we will seek an exemption to the standard following the NHTSA process, which requires that we demonstrate that our system offers the same or greater level of safety as a vehicle meeting the standard. Similarly, we are committed to ensuring that our self-driving vehicles are correctly licensed, registered, insured, and maintained.

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APPENDIX

Glossary

TERM	DEFINITION
ACC	Adaptive Cruise Control
ADS	Automated Driving System
AI	Artificial Intelligence
ASIL	Automotive Safety Integrity Level
Auto-ISAC	Automotive-Information Sharing & Analysis Center
CAN	Controller Area Network
CDL	Commercial Driver License
CPU	Central Processing Unit
DOT	Department of Transportation
EDR	Event Data Recorder
FMVSS	Federal Motor Vehicle Safety Standards
GPS	Global Positioning System
GPU	Graphics Processing Unit
HARA	Hazard and Risk Analysis
HIL	Hardware-in-Loop
HMI	Human Machine Interface
IATF	International Automotive Task Force
IMU	Inertial Measurement Unit
ISO	International Organization for Standardization
KITTI	Karlsruhe Institute of Technology and Toyota Technological Institute
LiDAR	Light Detection and Ranging
MRC	Minimal Risk Condition
NHTSA	National Highway Traffic Safety Administration
ODD	Operational Design Domain
OEDR	Object and Event Detection and Response
OEM	Original Equipment Manufacturer
SAE	Society of Automotive Engineers
TADS	TuSimple Autonomous Driving System

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APPENDIX

End Notes

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

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