A MATTER OF TRUST

FORD'S APPROACH TO DEVELOPING SELF-DRIVING VEHICLES

OUR MISSION

FORD MOTOR COMPANY WAS BUILT ON THE BELIEF THAT FREEDOM OF MOVEMENT DRIVES HUMAN PROGRESS. IT'S A BELIEF THAT HAS ALWAYS FUELED OUR PASSION TO CREATE GREAT CARS AND TRUCKS. AND TODAY, IT DRIVES OUR COMMITMENT TO BECOME THE WORLD'S MOST TRUSTED COMPANY, DESIGNING SMART VEHICLES FOR A SMART WORLD THAT HELP PEOPLE MOVE MORE SAFELY, CONFIDENTLY AND FREELY.

TRUST IS OUR GUIDING PRINCIPLE

At Ford, we value the trust our customers place in us. We respect the fact that trust is earned over time. And we've been building trust, customer by customer, serving millions of people since 1903.

Today, technology is changing how we get around.

Transportation, or "mobility" as it's often called, is no longer just about owning a car or catching a train. Now we've got new options, like the ride-hailing services of today or the self-driving vehicles of the near future.

But, at Ford, trust is still at the heart of what we do. One of the reasons customers trust Ford is because we prioritize people as we design our vehicles. That might seem like common sense, but when new technology comes to market, it can be all too easy to design with technology as the priority.

We don't believe that the central challenge in the development of self-driving vehicles is the technology. It's trust. Trust in the safety, reliability and experience that the technology will enable.

For all of us, self-driving technology is brand new. There's a lot of talk about it, but it's not yet clear how it will impact our lives.

Ford has spent the past century earning trust by designing and manufacturing safe, quality vehicles at high volumes that meet the needs of people around the world.

In our pursuit of new mobility solutions, including self-driving vehicles, we understand the importance of earning the same level of trust. That's why we're sharing our approach to development of the technology in this Voluntary Safety Self-Assessment Report.

In this report, you will learn how we always prioritize safety at Ford and how we're working closely with industry and government partners to apply this technology to solve the challenges our cities face. Our goal is to provide a sense of the new services that will soon be available to our customers and how it could impact their lives.

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WHY TRANSPORTATION NEEDS TO EVOLVE

In this rapidly changing world, cities are growing fast. With urban centers dealing with record levels of traffic and pollution, the United Nations has identified increasing urbanization as one of the defining trends of the 21st century.

This growth is also causing a shift from individual vehicle ownership to the use of shared mobility options such as ride-hailing services. Most of our infrastructure was built to meet the needs of individually used vehicles. However, most of those vehicles sit idle about 95% of the time. As a result of this, as much as 30% of the real estate in city centers is devoted to parking.[1]

At Ford, we see this as an opportunity to design smart vehicles for a smart world. If applied correctly, new technologies can enable solutions to help city transportation systems improve the quality of life for everyone. That's why we're approaching these opportunities in a holistic way. We recognize that just injecting new mobility technologies and services into a city or neighborhood won't solve their existing challenges and may even make them worse.

Therefore, we created a City Solutions team dedicated to working closely with cities and communities to address these challenges. We're learning how each city works, what its needs are and how our technology can adapt and support each city's unique transportation system. We're developing a portfolio of solutions that can help a city improve its transportation system through better orchestration of traffic, transit and the ever-growing mobility options emerging every day.

Self-driving vehicles are one of the solutions to help enable this future. Ford is designing them to operate as a productive, safe and valuable part of a city transportation system to help make people's lives better.

[1] Keeping the Nation Moving: Facts on Parking. RAC Foundation, 2012, www.racfoundation.org/wp-content/uploads/2017/11/parking_fact_sheet.pdf

WHAT OUR SELF-DRIVING VEHICLES WILL ENABLE

To understand the potential ways to use self-driving vehicles, we at Ford must first think about them in a different way from how most of us use cars and trucks today. Initially, self-driving vehicles will work best in a different business model: one where vehicles are accessed and shared versus owned and driven. They will operate as part of a mobility service accessed through a smartphone app for either moving people or delivering goods.

There are many ways for people to get around in cities. Taxis were the original "on-demand" service as all it took was a wave of the hand for a taxi to pull over to the curb. Now, new technology is improving taxi service, and there are also ride-hailing and sharing services available that offer even more options for customers. We think self-driving vehicles can enhance these services and help extend their availability and affordability – with a particular focus on operating in areas that are underserved by transit options – and support people that may not be able to drive themselves due to age or disability.

In the realm of goods delivery, we see opportunity to help the increasing demand generated by the convenience of ordering from large online retailers. There is also potential to support small and medium-sized local businesses that may want to take advantage of delivery services but don't have the ability to tap into complex and expensive logistics systems. We can help small businesses that may not be able to afford a dedicated delivery vehicle or medium-sized businesses that may have an underutilized vehicle that is a financial burden on their operations. These types of businesses could choose to use our autonomous vehicles instead.

Self-driving vehicles can transform cities in countless ways. While we plan to have them complement and integrate with the many available modes of transportation, there is potential to deliver unique value to customers. People will hail self-driving ride shares to avoid parking costs and traffic frustrations. Shoppers will seek efficient, effortless delivery via self-driving services. We believe that people and packages can move faster and more affordably in the self-driving future.

To learn about the potential of self-driving vehicles to enable goods delivery, we're working with Postmates to research an on-demand delivery platform. Our Postmates pilot is currently underway in Miami and Miami Beach with more than 70 local businesses participating. We designed a Transit Connect for this pilot program with a locker system to secure the deliveries and allow us to serve multiple customers on one delivery route. The focus of our research is on the first and last mile of the delivery experience, testing how businesses and consumers interact with a self-driving vehicle. We put the customer experience at the forefront of our thinking so self-driving vehicles can one day improve the lives of people, the operations of our partner companies and mobility within our communities.


LET'S GET
TO THE POINT

FREQUENTLY ASKED QUESTIONS ABOUT SELF-DRIVING VEHICLES

What does Ford mean by self-driving vehicle?

We use the term "self-driving vehicle" to refer to a vehicle that meets the definition set by the SAE International for Level 4 automation. That means the vehicle is capable of operating autonomously, without the need for a driver, within a specific geographic area and during appropriate weather conditions. When the vehicle is in "autonomous" mode, it has full responsibility for the task of driving.

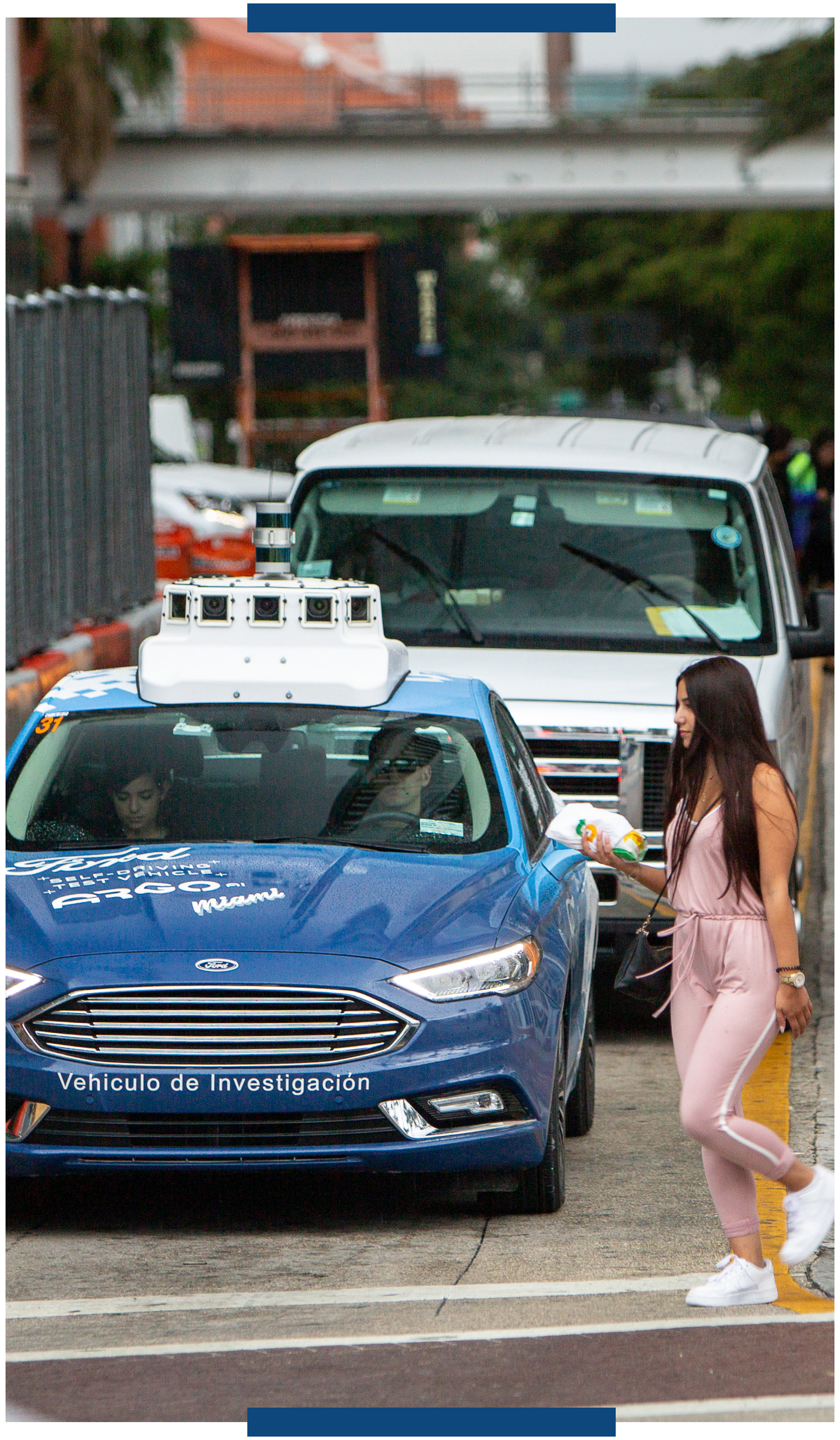
Will Ford's self-driving vehicles be truly driverless?

Yes, our self-driving vehicles will operate without the need for a driver. In fact, the purpose-built self-driving vehicle we plan to introduce in 2021 is designed to operate without a steering wheel, gas or brake pedals. We can do this because we're applying the technology in the way it is designed to operate, such as using self-driving vehicles for a ride-hailing service within a specifically-defined area of a city and only when the weather is good enough for the sensors to work properly.

When am I going to be able to experience Ford's self-driving vehicles?

Ford is currently developing self-driving vehicles. You might read about or see one operating on city streets for testing, but they won't be available to customers until we achieve specific milestones in the development process that indicate they're ready to do so. We are not in a race to be first to offer self-driving vehicles to the public. Our focus is on doing it correctly.

Over the next three years, we will have growing fleets of test vehicles in several cities, with a goal to begin manufacturing a purpose-built self-driving vehicle in 2021. At that point, we expect to be operating in multiple cities, where our self-driving vehicles will provide ride-hailing and goods delivery services.



Today, customers can benefit from automated features that enhance safety or convenience in cars they can buy now. We call these features driver-assist technology because they are designed to help improve the driving experience for a human driver. You may have heard of some of these features such as blind spot monitoring, lane keeping assist and adaptive cruise control. To be clear, these are not "self-driving" or "autonomous" – and we'll never refer to them as such – because they require the driver to supervise and maintain control of the vehicle.

Can I buy a Ford self-driving vehicle in 2021?

No, our self-driving vehicles won't initially be sold to customers in the way that cars are today. You'll be able to experience these vehicles through multiple means, including commercial fleets in mobility services such as ride-hailing and goods delivery. We believe we can offer the best value to our customers by providing the technology through a fleet service, similar to the way Ford currently offers specially-engineered vehicles for taxi and police fleets.

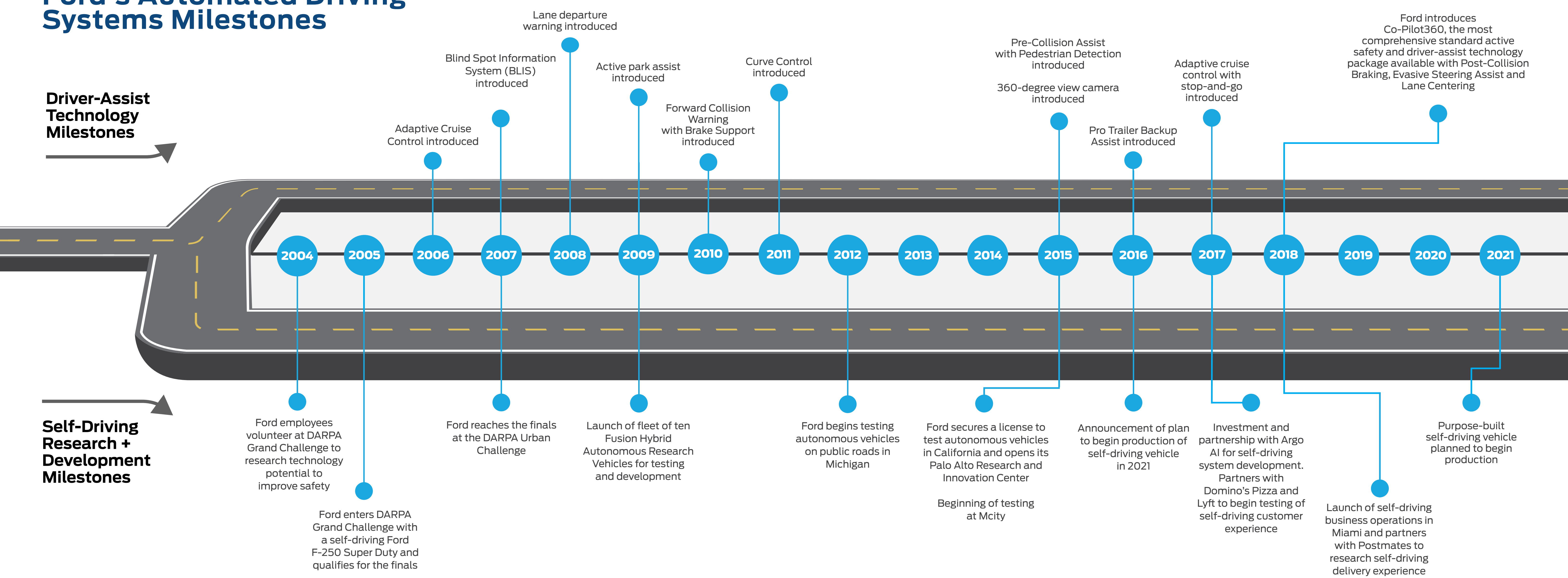
We are currently using Ford Fusion Hybrid sedans as the basis for our self-driving test vehicles. There are fleets of vehicles testing on public roads in Miami, Fla., Pittsburgh, Pa. and Dearborn, Mich. All of our test vehicles have a two-person safety operations team in them while operating in autonomous mode to monitor the road ahead as well as the performance of the computing and sensing systems.

FREQUENTLY ASKED QUESTIONS ABOUT SELF-DRIVING VEHICLES

What is Ford's history with automated vehicle technologies?

Ford has a long history of research, development and commercialization of automated driving systems, although we've clearly split them into dual pathways depending on how the technology is applied for customers. While this report is focused on describing our approach to self-driving or autonomous vehicle systems – defined by SAE International as Level 4 Automation – the timeline below shows our extensive portfolio of driver-assist technologies. We use the term driver-assist technology to describe features that assist drivers with convenience or safety benefits, but they are not autonomous because they require the human driver to always remain engaged and available to take control of the vehicle. These features are defined by SAE International as Levels 0-2 of Automation and leverage technology to augment a human driver but not replace them. For instance, the blind spot information system uses radar technology to detect if there is a vehicle in a driver's blind spot thus augmenting their ability to look and see for themselves.

Ford's Automated Driving Systems Milestones



FREQUENTLY ASKED QUESTIONS ABOUT SELF-DRIVING VEHICLES

I love to drive. Why would I want an autonomous vehicle?

We love to drive, too. Building cars and trucks that are fun to drive is at the heart of what we do, and we're not going to stop any time soon. But let's face it, owning and driving a vehicle can be a challenge in cities, due to traffic congestion and the cost and hassle of parking. And all of us are human, which means we can get tired, distracted, or otherwise impaired – or just have days when we'd like to do something else with our time other than drive. Self-driving vehicles can alleviate many of these challenges. But they may not be for everybody, and that's perfectly fine.

Will self-driving vehicles save lives?

Today, more than 37,000 people die in vehicle-related fatalities each year in the U.S. We believe that both the safety technology that we offer on our vehicles today and the self-driving vehicles of the future have the potential to reduce accidents and injuries and save lives. But while we see tremendous potential in these technologies, they are not our only solutions.

We continue to improve upon the design of our vehicles to ensure maximum protection of all our passengers. We offer technologies to reduce distractions, like SYNC, and enable life-saving emergency services, like 911 Assist, which can help connect you to emergency services when you need it. And we work to improve road safety through driver education and training, like our Driving Skills for Life program.

[2] Traffic Safety Facts 2016. National Highway Traffic Safety Administration, 2018, https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812554

Will self-driving cars "solve" congestion in our cities?

There's no one silver bullet for the problem of urban congestion, so we're working on comprehensive solutions rather than thinking self-driving vehicles will solve traffic congestion alone. We believe self-driving vehicles have the potential to be part of that larger solution. For instance, we think that self-driving vehicles have the potential to increase the number of shared rides, decreasing the number of vehicles required on the road to move the same amount of people. In addition, their ability to access road information in real-time could help them choose more efficient routes.

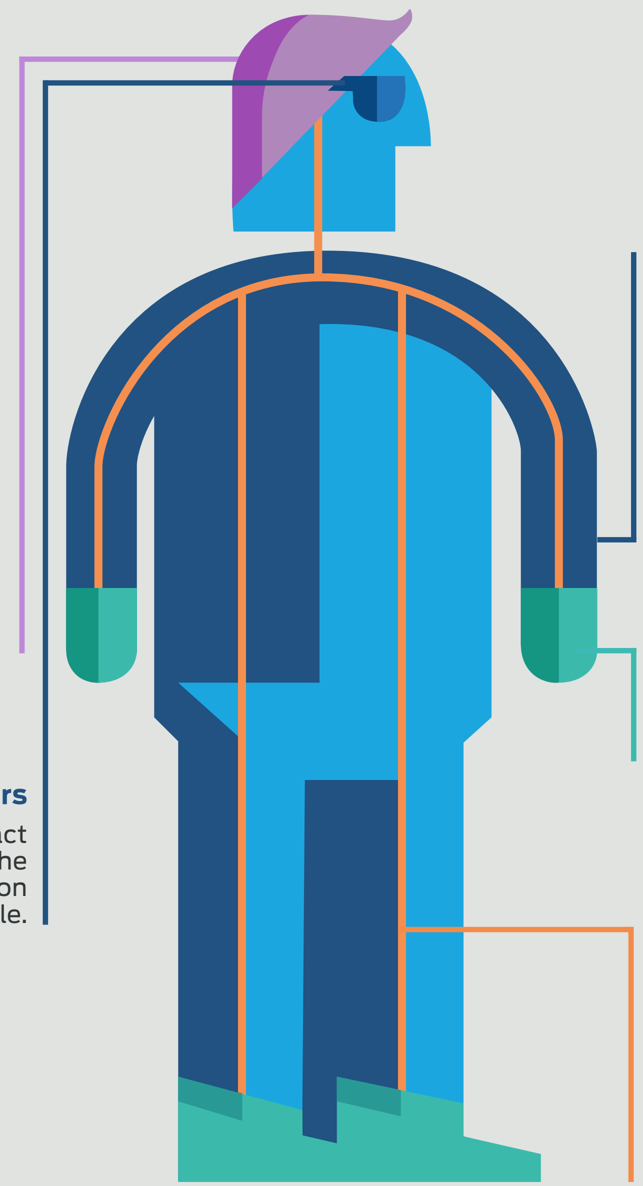
I heard of a self-driving test vehicle that struck and killed a pedestrian. How can Ford be sure that won't happen with their vehicles? Will I be safe if I live in a city with self-driving cars?

Any death on the road is terrible news. And the recent accident involving a self-driving test vehicle has raised serious questions for all of us working in the field. We are confident in our safety processes and procedures, which we've refined over decades of engineering and testing the vehicles we manufacture. We follow our proven safety strategies, including extensive computer simulations and driving on closed-course tracks, before we allow any self-driving test vehicles on public roads.

We also put our vehicle operators through extensive training, so they are familiar with everything from vehicle dynamics and the local roads to the capabilities of the self-driving system all before they take a vehicle out for a test. And all our vehicle operators currently work in two-person teams with the driver monitoring the road ahead and the passenger monitoring the self-driving system via a laptop computer as you can see in the photo below.

The two-person safety operations teams in our self-driving test vehicles are comprised of a driver and co-pilot. The driver focuses on the road ahead with their hands positioned around the steering wheel, so they are poised to take manual control as appropriate. The co-pilot monitors the performance of the self-driving system via a laptop computer. They remain in constant communication sharing information about what they see to ensure safety when out on the road.

Human anatomy can help explain self-driving vehicles



The technology must mimic the most miraculous, complex creation of all time: the human body. We are designed to sense, think and move. And while our senses, brain and muscles get most of the credit for our ability, it takes the structure and connectivity provided by the skeletal and nervous systems to make it all work together.

HOW SELF-DRIVING VEHICLES WORK

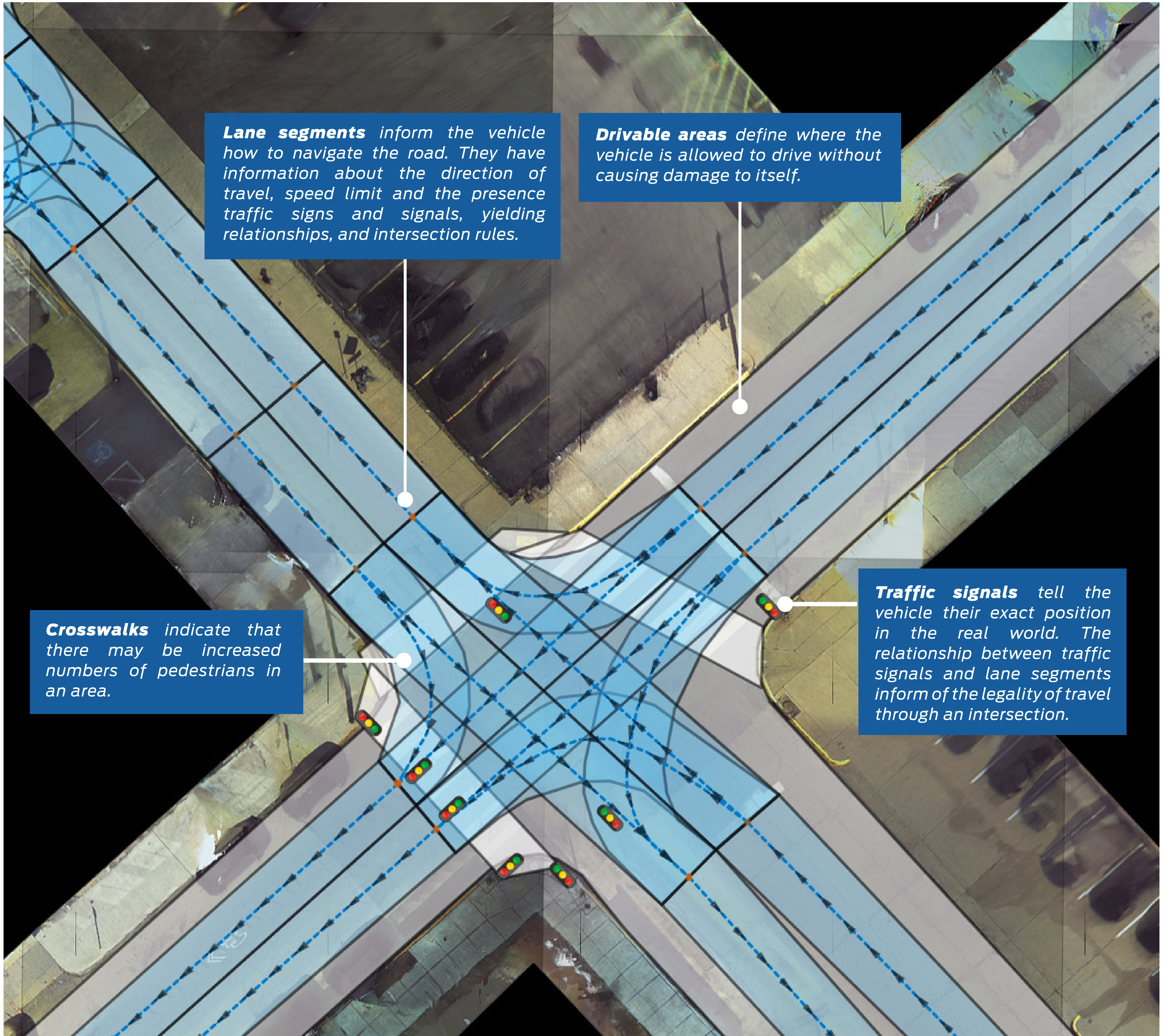
For a self-driving system to achieve similar capabilities as a human, our test vehicles are fit with the latest in cutting-edge sensing and computing technology. Yet, the components that make up the vehicle itself such as the suspension, brakes and electrical system are also critical because, just like a human body, a self-driving vehicle must be designed and developed as an integrated system that works in unison, otherwise we're not able to achieve maximum capability, reliability and performance. Today, we're using Ford Fusion Hybrid sedans as our self-driving test vehicles.

Each vehicle is modified with the components that make up the self-driving system and are responsible for the core capabilities of perception, motion planning and controls, which together enable the vehicle to drive itself.

The perception system is made up of sensors – cameras, radar and LiDAR – to take in the traffic scene all around the vehicle. The motion planning system is a sophisticated computing system that acts as the brain by combining the sensor information into a comprehensive understanding of the traffic situation. Then, the controls system directs the engine, braking, and steering systems to guide the vehicle accordingly.

Let's take a deeper look into each of those areas:

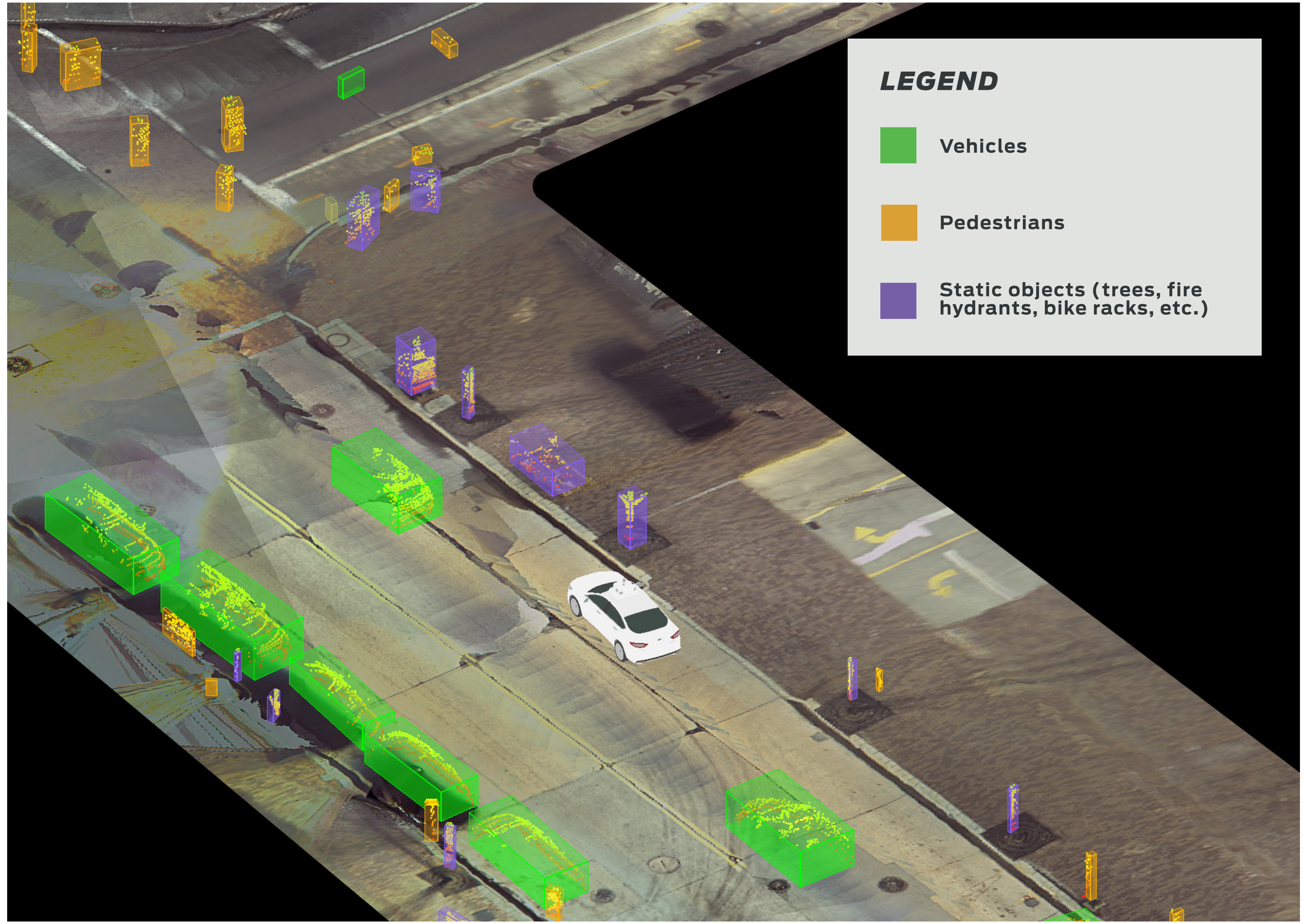
PERCEPTION: Just like human drivers, self-driving systems need information to operate. Self-driving systems take sensor data from the cameras, LiDAR and radar to infer what is happening in the world around the vehicle. They observe other road actors, such as vehicles, pedestrians and bicyclists, noticing how they move and what their likely intended actions are. The self-driving system also detects road debris that the vehicle must avoid and, of course, detects the state of traffic lights relevant to the vehicle motion. Achieving human-level perception is a tremendous challenge and requires bringing state-of-the-art machine learning techniques to bear on the problem. The self-driving system combines information from all sensor sources in a carefully designed and thoroughly tested architecture that provides redundant sensing 360º around the vehicle. Redundancy is essential because different sensors have different failure modes.

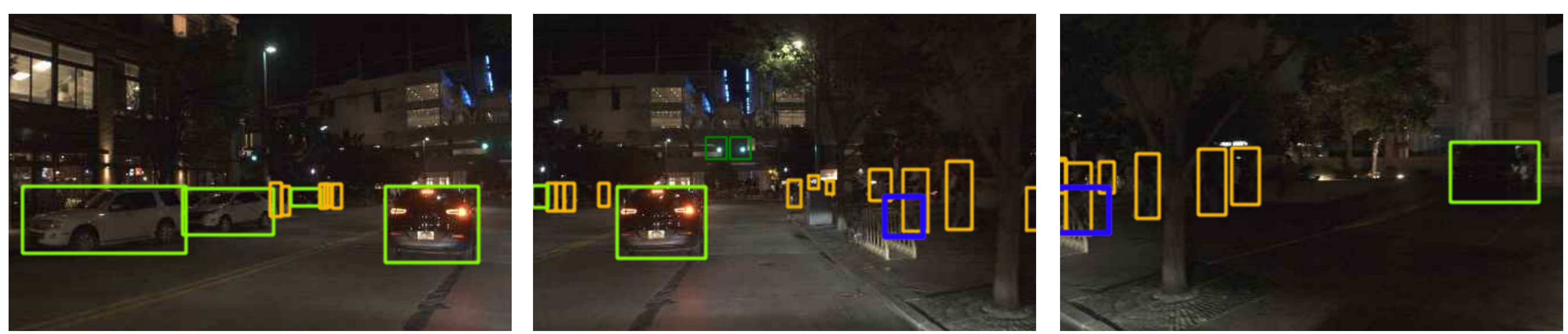


MOTION PLANNING: Many of our cities have tremendously challenging intersections and other unique traffic patterns and behaviors that visitors to a city struggle with and locals typically learn. By building and maintaining a highly accurate and richly detailed map of the environment, self-driving vehicles can gain superhuman abilities to understand the shape of the road around a corner. This will allow self-driving vehicles to know precisely where to look for traffic control measures or anticipate where to slow down (because pedestrians typically jaywalk or streets are congested). Using such a map effectively requires localizing within the map both precisely and reliably and enables the vehicle to execute with very high reliability.

In order for a self-driving vehicle to work, it first needs a map of the roads on which it will be operating. The map that a self-driving vehicle uses is unlike the types of maps that a person typically uses to navigate from one place to the other. In fact, the map imagery is created by the self-driving vehicle's sensors as our safety operators manually drive our test vehicles throughout a city. During these initial drives, sensors built in to the vehicle scan the roads, sidewalks and buildings allowing for the creation of a 3D map. The base map is annotated with all the relevant traffic regulations and guidance, including road edges, directions of travel, speed limits, traffic signals, stop signs, crosswalks and yielding relationships. This map forms the basis of a complex system of perception and tracking, so the on-board computing system can use it to understand the static world before it even starts driving autonomously.

CONTROLS: At the core of self-driving is decision making. In order to drive, the self-driving system needs to continually receive information from the perception system, evaluate and select from a range of driving actions and execute those precisely to enable it to drive efficiently and safely. The vehicle has to choose the actions that allow it to drive in a natural way, conveying clear intent in a human-like way that is consistent with local social norms. This allows other drivers to predict how the self-driving vehicle will behave more accurately and prevent bad situations before they occur.





The top image is a visualization of how the self-driving vehicle identifies and classifies objects as static (such as fire hydrant) or dynamic (such as pedestrian) along the route. The bottom three images are examples of the real-world scene from the video cameras mounted on the roof of the vehicle. The boxes indicate that an object has been identified and the color signifies the classification (light green for vehicles; orange for pedestrians; blue for bicycles; and traffic lights with the box color signifying the state, such as dark green as pictured here for a green light). As you can see here, our self-driving vehicles have impressive vision capability at night. With that camera data plus the available LiDAR and radar data, our self-driving vehicles have a robust view of the world no matter the time of day.

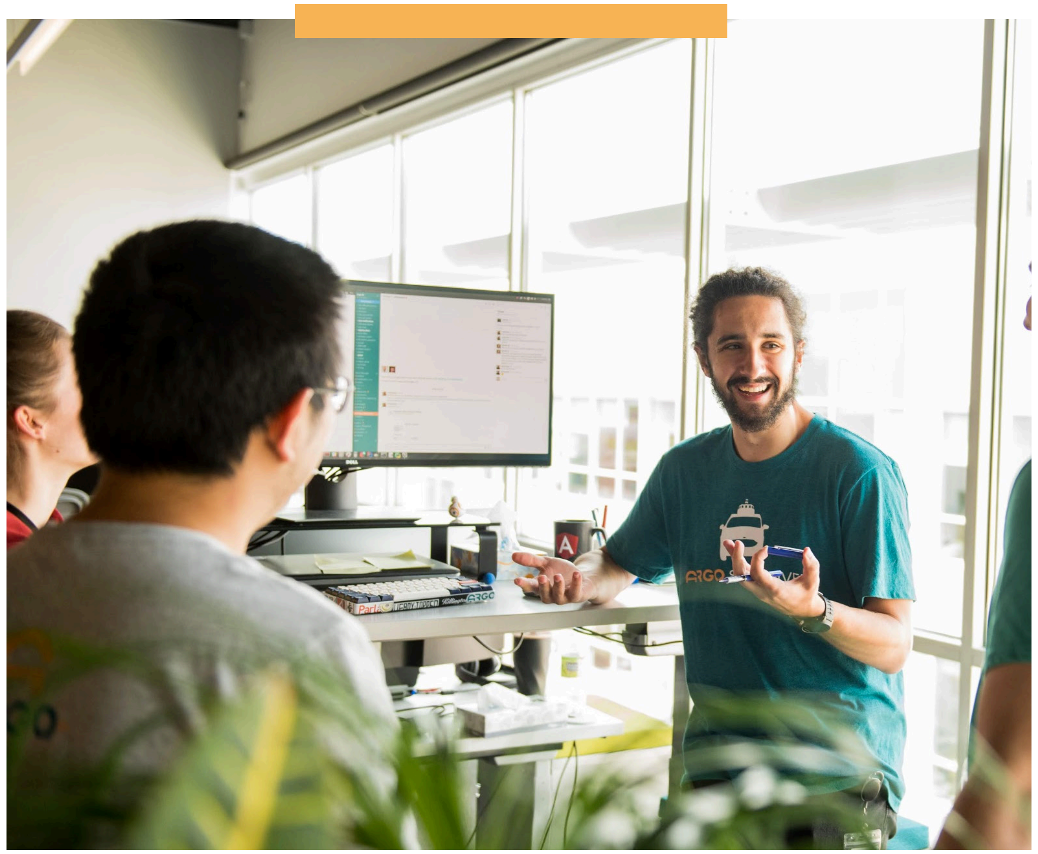
BEST IN CLASS PARTNERS: WORKING WITH ARGO AI

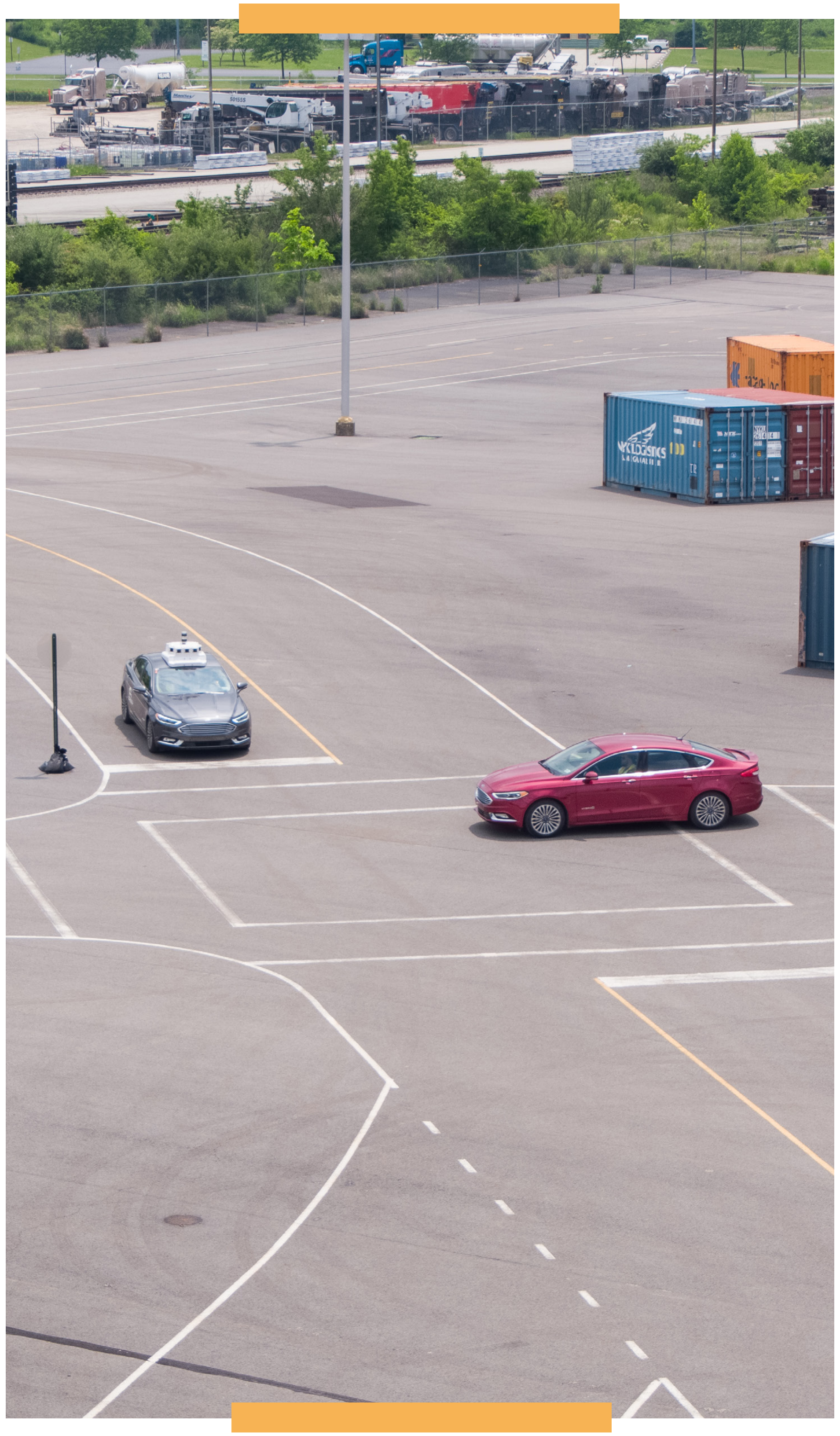
Argo AI is an artificial intelligence and robotics company, led by some of the industry's most experienced self-driving vehicle experts. Ford has partnered with Argo AI to develop the "brains and senses," or what we refer to as the Virtual Driver System, for our self-driving vehicles.

Argo AI is applying the latest advancements in computer vision and machine learning to help build safe and effective self-driving vehicles. The team also has extensive experience in commercializing robotics and sensing technologies with a history of designing and deploying integrated systems.

Headquartered in Pittsburgh, with engineering centers in Mountain View, Calif., Dearborn, Mich. and Cranbury, N.J. the more than 350 people on staff come from diverse educational backgrounds with a high concentration of Masters and PhD degrees. To foster continued learning and enable the roboticists of tomorrow, Argo AI has formed research collaborations with Carnegie Mellon University and Georgia Institute of Technology.

Argo AI's ability to build a scalable software architecture with production quality code from the start plus Ford's expertise with vehicles integration and manufacturing give us the confidence to build high-quality self-driving vehicles. This partnership uniquely unites the benefits of a technology startup with the experience and discipline of an automaker.





HOW WE EARN TRUST

SAFETY
RELIABILITY
VALUABLE EXPERIENCE

TRUST

As we develop our self-driving vehicles, we are focused on three ideals that we believe are crucial to earning trust: safety, reliability and valuable experiences.

Safety is a top priority in developing the processes we use for designing, testing and manufacturing our vehicles. We believe that the safety processes we have developed and proven throughout Ford’s history are key to the trust we have earned. We’re applying those time-tested processes to the development of self-driving vehicles. And, we’ve created additional, new safety processes for self-driving technology.

We design for reliability through durability testing, using our extensive experience in building dependable vehicles that operate day after day, in hot or cold weather and under all different road conditions.

Our end goal, as everything we’re developing comes together, is to create an experience that people enjoy and find valuable.

APPLYING SAFETY PROCESSES

Self-driving vehicles will be very different from cars and trucks on the road today, but the method for engineering and manufacturing them shouldn't be. While the field of self-driving vehicle development may only be a decade old, Ford brings more than a century of experience in vehicle safety processes to the table. In partnership with Argo AI, Ford is integrating decades of vehicle safety experience with the latest advancements in artificial intelligence to integrate both vehicle hardware and system software into a safe, efficient and enjoyable experience for our customers.

At Ford, we've already proven trusted processes for product testing and quality assurance. We're using those same robust disciplines to develop the autonomous vehicle of the future as Argo AI works with us to build a scalable software based on code that is production quality from the start.

SAFETY OPERATOR TRAINING

Throughout the development period, we will be utilizing safety operators in our test vehicles. We currently have two-person teams – a safety driver and a "co-pilot"– in all our test vehicles. Also, before we put anyone in the driver or passenger seat of our test vehicles, they go through rigorous training and certification.

The goal of our training, defined with our partner Argo AI, is to develop a standard professional framework for safety operators through a program that improves manual-driving skills in the classroom and then verifies those skills driving on closed courses. Safety operator training also provides education on self-driving technology. The training program is designed to be difficult and requires candidates to pass tests to advance through each phase.

Our test vehicles make it easy for safety operators to override the self-driving system in any situation. If the safety operator controls the vehicle in any way, by steering, throttle or braking, the vehicle returns full control with notification to the driver. The safety operator can also disconnect the self-driving system or disable the powertrain completely by pressing a failsafe button in the center console.

Once our safety operators complete training, they continue to work in teams of two with the driver focused on the road ahead and the co-pilot monitoring the performance of the self-driving system via a laptop computer. Safety operators can't use a cell phone unless the vehicle is in "Park."

We also subscribe to a philosophy of continuous education and learning. There are mandatory pre- and post-shift daily briefings to share information amongst the teams, and there are regular classroom sessions to educate about new software releases and capabilities.

Argo AI deploys a three-phase training program for safety operators:

PHASE 1
MANUAL DRIVING TRAINING AND CALIBRATION

Reintroduction of Proper Driving Etiquette

- Proper anatomical positioning
- Mirror adjustments, spatial awareness and blind-spot corrections
- Smooth accelerating and braking
- Turning trajectories and profiles
- Comfortable and correct stopping distances
- Acclimation to testing area streets

PHASE 2
ADVANCED DRIVER TRAINING AND INTRODUCTION TO AUTONOMY ON CLOSED COURSE

Development of Autonomous Mode Operations

- Advanced Driver Training
  - Car control drills
  - Accident avoidance
- Autonomous mode engagement / disengagement
- Autonomous mode fault injection training
  - Steering
  - Acceleration / deceleration
  - Emergency disengagement

PHASE 3
PUBLIC ROAD AUTONOMOUS MODE OPERATIONS AND CERTIFICATION

Supervised Application of Autonomous Mode

- Trainee ride-alongs with certified operators
- Graduated exposure to road scenarios
- In-vehicle and classroom evaluations

DESIGNING FOR RELIABILITY

For autonomous vehicles to be accepted by the public, we need to establish that they can be trusted. People tend to gain trust in something when they can predict what it will do. So part of earning the public's trust is to drive the vehicle in ways that other motorists, cyclists and pedestrians expect. Each city has its own culture and expectations for how vehicles should drive. That's why we drive extensively in the actual cities where we will eventually deploy our fleet before we allow the vehicles to drive by themselves. In this way, we learn the roads, the challenging intersections and the local behaviors, so we can develop the system to operate as people expect.

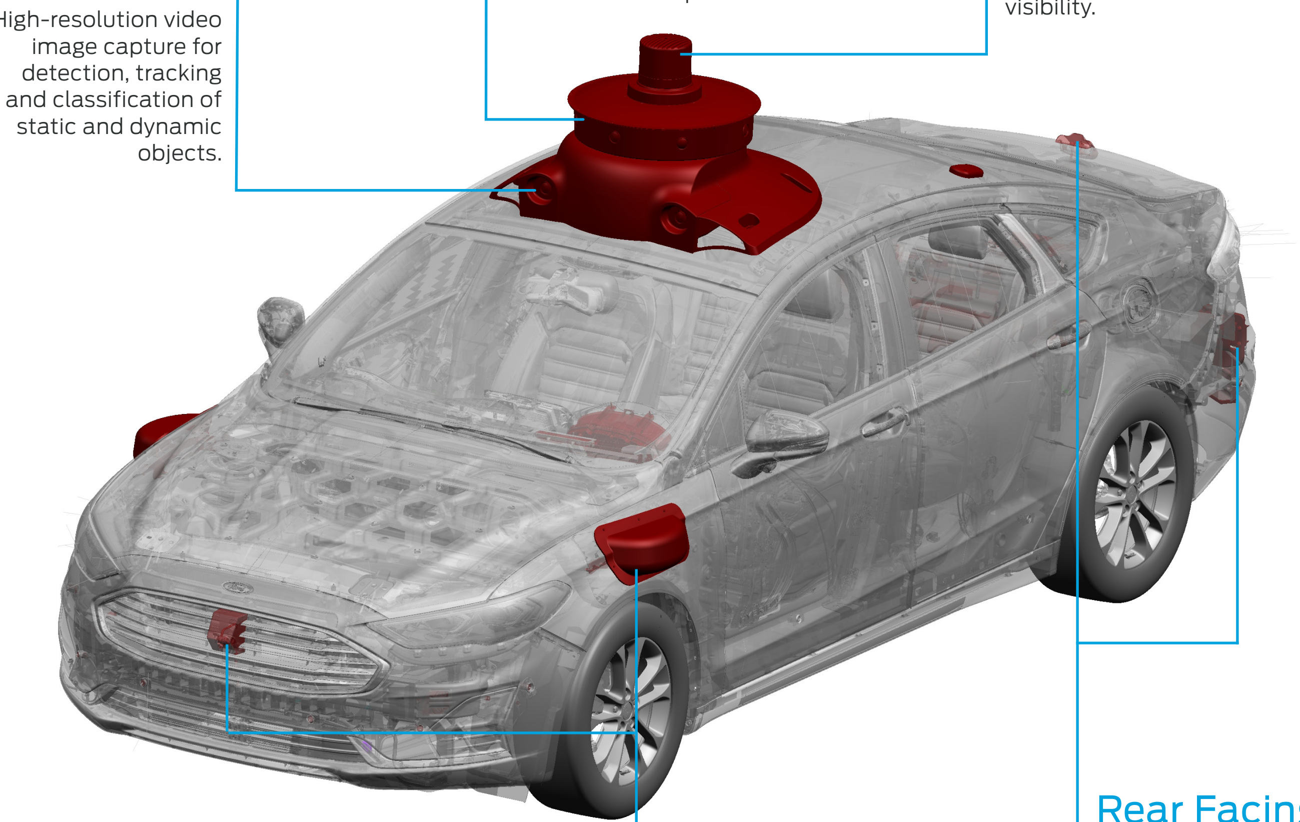
As a company, we're known for delivering dependable vehicles that meet and exceed customer expectations: in both private vehicle sales and fleet sales, like police, taxi and commercial trucking services. And we are bringing that same focus on reliability to our self-driving vehicles.

To make our vehicles capable of self-driving, we are making changes or modifying many parts of the vehicle. We have added several new sensors and computing systems to understand the traffic around the vehicle and make decisions for what to do next. We call this group of components the Virtual Driver System. We also modified the traditional components to allow the Virtual Driver System to control the vehicle with its computer-generated commands. We call this adapted set of traditional components the Autonomous Vehicle Platform, and it's designed to be applied to a broad range of different vehicles types.

VIRTUAL DRIVER SYSTEM

What do we mean by Virtual Driver System? Well, to make SAE-defined Level 4-capable autonomous vehicles, which do not need a driver to take control, the car must be able to perform what a human can perform behind the wheel. Our Virtual Driver System is designed to do just that. It includes:

- Sensors—LiDAR, cameras and radar to "see" all around the vehicle
- Algorithms running on powerful computers to determine the traffic situation all around the vehicle and plan where to go next
- Highly detailed 3D maps
- Precise inertial measurement systems

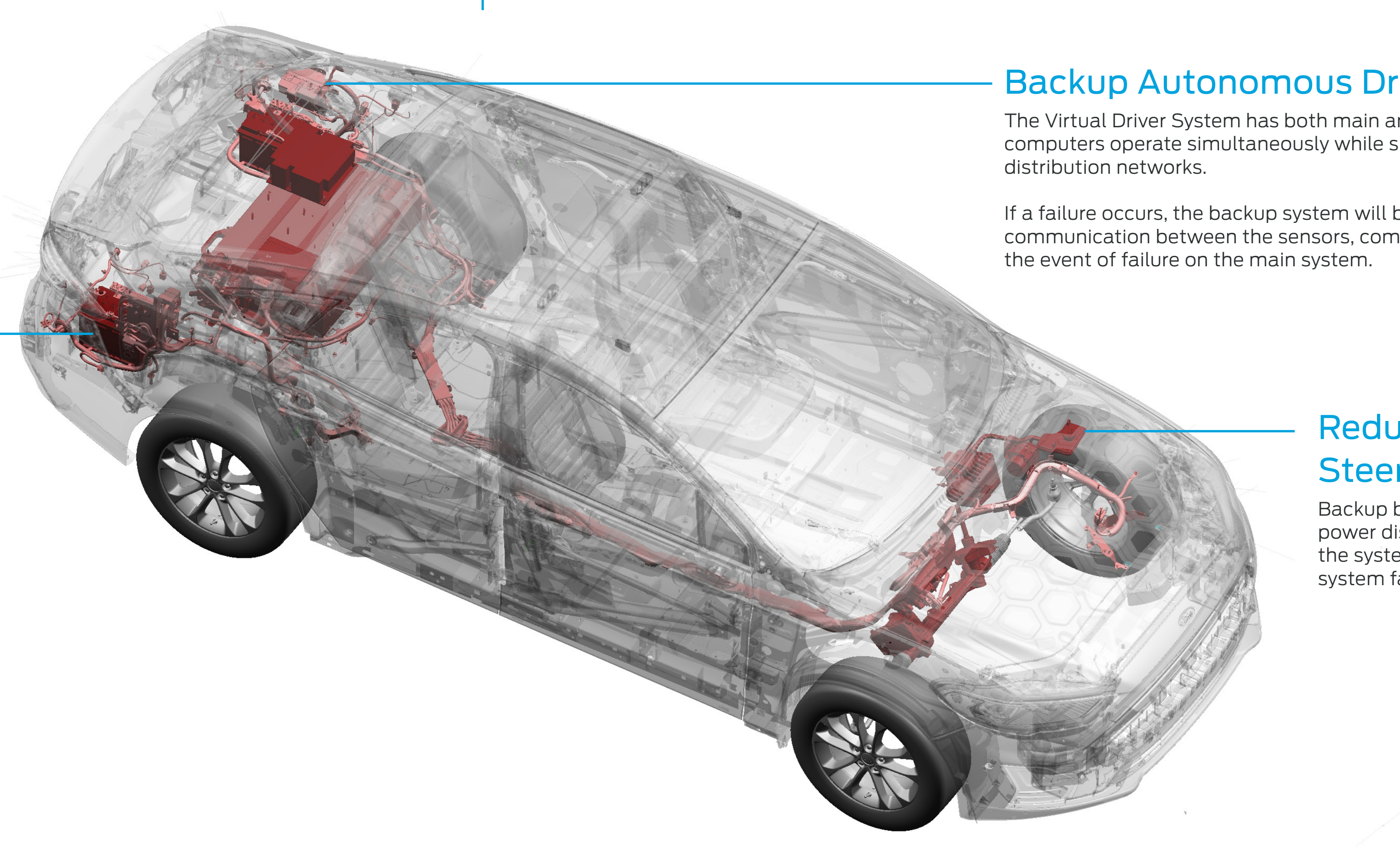


AUTONOMOUS VEHICLE PLATFORM

Contrary to what some might think, building an autonomous car isn't as easy as putting sensors and a computer into an existing car. The vehicle's traditional components must be developed and engineered to work with the software, for hardware and software need to work together to deliver the self-driving experience. The end result needs to be a high-quality, energy-efficient vehicle people trust to serve their needs — just as they trust Ford vehicles today.

Here's one of the challenges we face: in today's cars, if the 12-volt power experiences a rare failure, the driver is still able to mechanically push the brake pedal and steer to bring the vehicle to a controlled stop. In our self-driving vehicle, we are designing redundant power, brakes and steering systems, so if there is a loss of operation in one system, the second system is able to guide the vehicle to a controlled stop.

We also need to ensure that the all-new components required for a self-driving vehicle (LiDAR, camera and radar sensors plus the computer that processes all the data) are ready for the rigors of the car's lifetime.



Diagnostics and Vehicle Health Monitoring

A sophisticated vehicle health monitoring strategy employs diagnostics integrated across multiple systems within the vehicle to determine vehicle health and perform fallback maneuvers when needed.

In addition to diagnostics, we also monitor the vehicle to determine its readiness, such as if all doors are closed.

Electrical Power Systems

While main power to the vehicle is provided from the high voltage battery, there are backup electrical power sources and distribution to several critical components. In the case of a power failure, the backup powernets are able to provide low voltage power to the computers, sensors, braking and steering systems to bring the vehicle to a controlled stop.

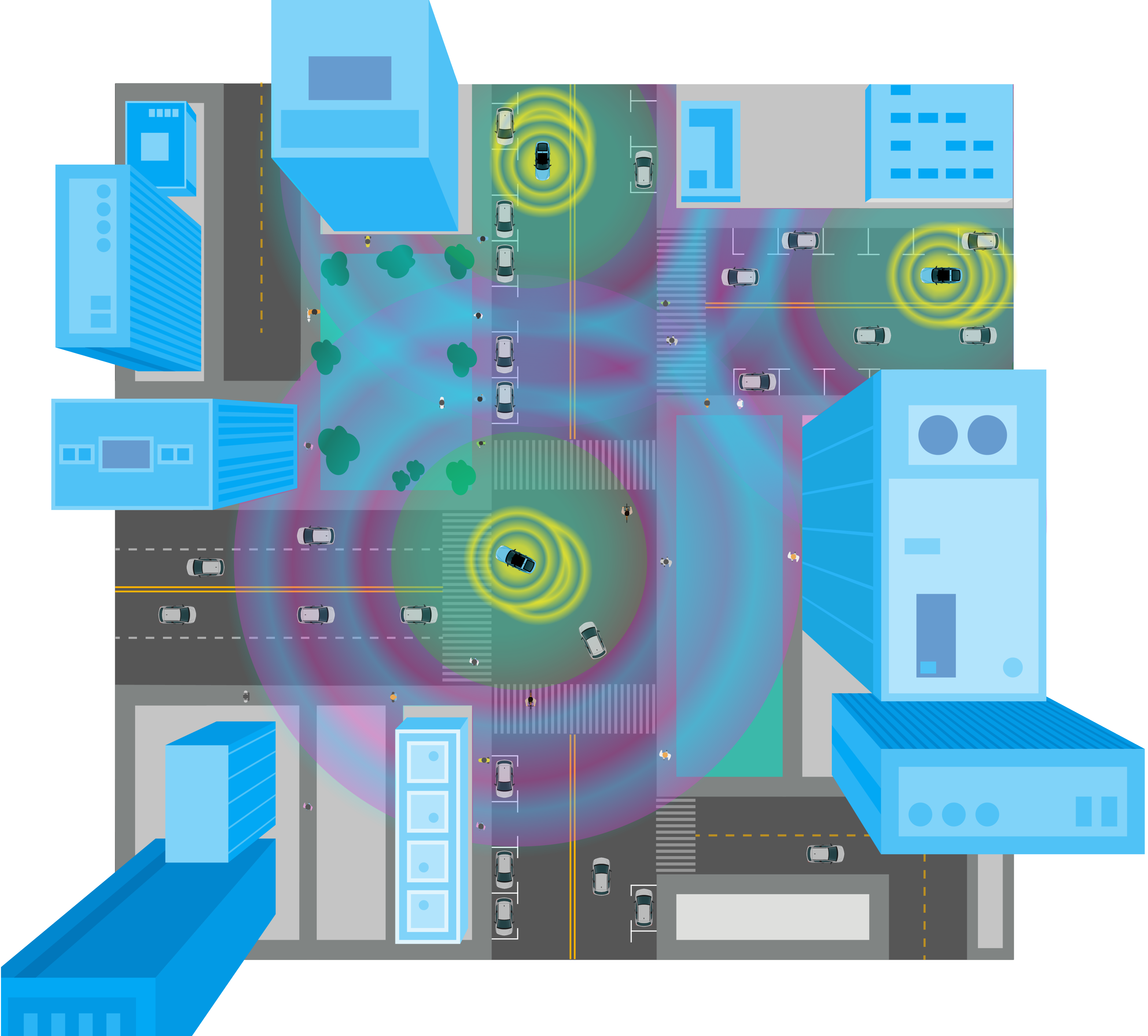
Backup Autonomous Driving System

The Virtual Driver System has both main and backup computing systems. These two computers operate simultaneously while sharing information yet are on separate power distribution networks.

If a failure occurs, the backup system will bring the vehicle to a controlled stop. In addition, communication between the sensors, computers, and actuators have an alternate path in the event of failure on the main system.

Redundant Braking and Steering Systems

Backup braking and steering systems exist on separate power distribution networks. This redundancy allows the system to bring the vehicle to a controlled stop if a system fails.



Sensing the Road Ahead... and All Around

Ford's self-driving vehicles have a set of sensors that provide 360º of monitoring of the environment in which they operate. The LiDAR sensors can see more than 250 meters, which is almost three football fields in length. The radar helps identify objects and the rate of speed of other vehicles. The cameras can recognize, classify and track objects including pedestrians and bicyclists. In a city environment, these sensors give a self-driving vehicle the view they need to operate safely amongst other road users.

Sensor Types

- **LiDAR**
- **Radar**
- **Far-Field Camera**
- **Near Field Camera**

Sensor ranges are approximations and for illustrative purposes only.

DESIGNED FOR PURPOSE

We're taking a different path than others that are racing to bring self-driving vehicles to market.

We are designing an all-new, purpose-built vehicle with self-driving technology. Our plan is to have this self-driving vehicle ready for production beginning in 2021. We've conducted extensive customer research and will continue to do so to understand our ride-hailing and delivery partners' needs, so we're able to design both the vehicle and the services that will improve their business operations and the customer experience.

Building on one of the strengths of our company, we're going to leverage our experience in engineering vehicles that serve police and heavy-duty service fleets. From today's Transit van and Super Duty pickup, we know how to build vehicles that thrive in heavy-duty, high-mileage commercial operations. What this means is that our self-driving vehicles will have upgraded components such as brakes, wheels and body structures that can withstand more extreme work cycles, and they will undergo more rigid durability testing before they hit the road.

Our commercial fleets are known for their lower cost of ownership and durability. We're applying this knowledge and experience to our self-driving vehicles, so they will be ready to meet the needs of both ride-hailing and delivery businesses operating in tough urban environments. Customers will only benefit if our vehicles are on the road, versus in the shop, so this is a critical component for a successful business. Another strength we have is in developing hybrid vehicles, including engineering them for use in commercial operations such as taxi fleets.

Applying hybrid-electric technology to our self-driving vehicles delivers several benefits to our service partner companies, including maximum vehicle mileage to keep fleets on the road. Plus, hybrids help provide the required amount of electrical power for self-driving sensors and computing systems without having a significant impact on the mileage.

As we get closer to 2021, we look forward to sharing more information and providing a first look at our purpose-built self-driving vehicle.

DELIVERING A VALUABLE CUSTOMER EXPERIENCE

Self-driving technology has tremendous potential to change people's lives and the communities in which they will operate. In addition to developing the technology in a safe and reliable manner, we are making sure it is being applied in ways that will deliver experiences that are valued.

As we design the ride-hailing and goods delivery services that self-driving technology will enable, we strive to put people at the center of our thinking.

We want to ensure that self-driving technology works to enhance people's lives.

To do this, we're beginning to design and test customer experiences in parallel with our efforts to develop the technology. With our goal in mind to build services enabled by self-driving vehicles, we can answer a lot of questions about what that will look like before the technology is ready.

We're taking an innovative approach to engaging consumers to better understand how they will respond to self-driving vehicles. Working with partner companies, such as Domino's Pizza and Postmates, we're conducting pilot programs that simulate the self-driving delivery experience. The vehicles that we're using are dressed up to look like they are self-driving, although they are driven by humans, so we can concentrate on evaluating the interaction between the customer and the vehicle.

This type of testing is giving us significant insight into how to design our purpose-built self-driving vehicle with interior and exterior features that will improve everything from business operations to the delivery and ride experience.

We're conducting these tests in cities where we're hoping to ultimately launch a business. Through engagement with city officials, and sharing our learnings with them, we're able to work together to resolve challenges that are identified early in the testing process.

Chariot, our microtransit ride sharing service, is helping commuters, businesses and cities improve transportation by pooling up to 14 passengers per van. Our testing shows that each van-load of passengers could remove approximately 10 private vehicles from the roadways thus contributing to improved improving traffic flow.

We've also launched GoRide, a new service for non-emergency medical transport, in the Detroit area with plans to expand. GoRide serves a population that is often overlooked but has a fundamental need to get around as a matter of their health and well-being. We're using Transit vans and experienced drivers to assist people in getting from their homes to medical appointments with easy scheduling and on-demand availability.

COMMUNICATING INTENT: DEVELOPING A SELF-DRIVING LANGUAGE

Today, pedestrians and bicyclists can look into a car and make eye contact with the driver to assure themselves that they are seen. A driver usually nods their head or waves a hand to indicate it's okay to cross the road. But, what about in a driverless future?

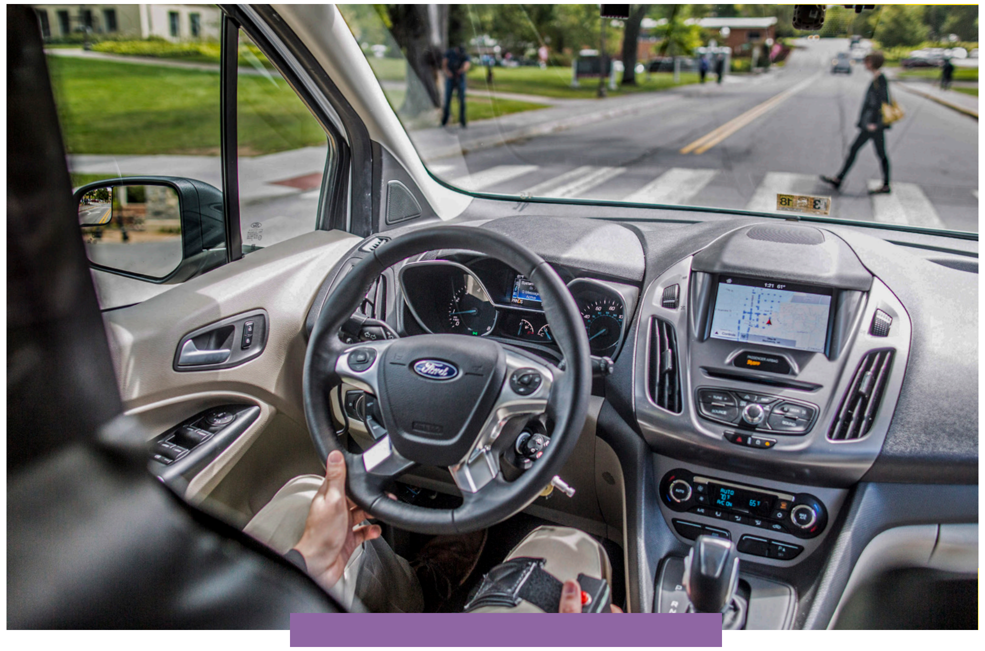
We believe there needs to be a standard way for autonomous vehicles to easily communicate their intention to people on the streets where they will operate in order to help communities trust and interact with the technology.

So, we set out to develop a common language that self-driving vehicles can share with other road users. To communicate with people outside the car, we designed a light bar to fit near the windshield. The placement of the light bar is just about where a pedestrian or cyclist would look to make eye contact with a human driver.

As the car drives, the light bar signals its intent with different patterns. A white light passes back-and-forth slowly when the vehicle is yielding. When the vehicle is stopped and preparing to move, the light blinks rapidly to get people's attention.

Communicating effectively with limited assumptions on common language, or symbology, is very challenging. There are thousands of languages throughout the world, and many countries have more than one official language, which makes it nearly impossible to ensure text-based signals can effectively communicate with the greatest number of people.

Second, human-driven vehicles typically communicate what they are doing – not what others, such as pedestrians, should do. Red brake lights indicate a vehicle is slowing or stopped. A turn signal indicates it is turning right or left. So, it's important to build off the current applications of light communications on vehicles today.



Third, many regulators around the world restrict what colors can be used for lighting on the front of a vehicle, so white or amber is the best option.

To test out the signal patterns in the real world, we worked with the Virginia Tech Transportation Institute to create a "simulated" autonomous vehicle. The vehicle looked like it was self-driving but actually had a driver dressed up in a "seat suit," effectively camouflaging them, so it looked as if nobody was behind the wheel.

Through our testing, which to-date encompasses more than 180 hours and approximately 2,300 miles in a dense urban area, we have results that suggest there may be a societal benefit to creating a standardized communications method.

Our light signals still need to undergo a significant amount of research, but we believe development and adoption of a global standard is critical to support eventual deployment of self-driving vehicles. That's why we are working with several industry organizations, including the International Organization for Standardization (ISO) and Society of Automotive Engineers (SAE) International and inviting other autonomous vehicle companies to join our work.

COMMUNICATING INTENT: DEVELOPING A SELF-DRIVING LANGUAGE

Signal Patterns | Driving: SOLID | Yielding: ROTATING | Preparing to drive: BLINKING

DELIVERY OF THE FUTURE: DESIGNING SELF-DRIVING VEHICLE CUSTOMER EXPERIENCES

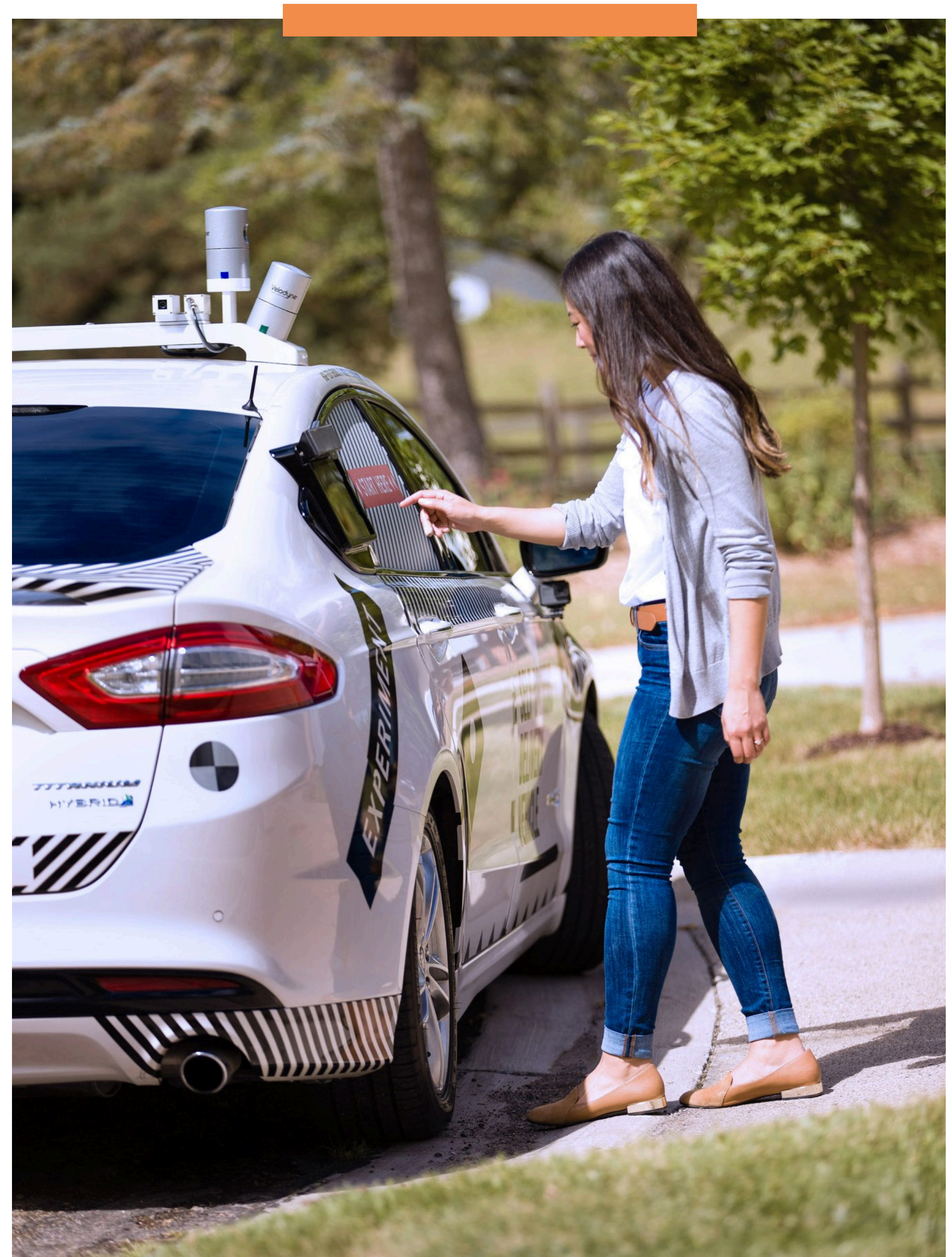
What do people think about getting their pizza delivered by a self-driving car? We partnered with Domino's Pizza to understand the role self-driving vehicles can play in food delivery.

The focus of our research is what's sometimes referred to as "the last mile" or in this specific case "the last 50 feet," which is the transfer of the pizza to the customer. What that means is we will be looking at how customers respond to this new experience, which will require them to interact with the self-driving car instead of a delivery person — walking out to the vehicle instead of just walking to answer their front door.

We conducted an observational study, looking at how people respond to and interact with a self-driving vehicle when it arrives with their pizza. Will they be willing to walk out to the curb, or do we need to park in their driveway? Will people be able to determine on which side of the vehicle they should collect their pizza? How should they be notified upon arrival since there won't be a delivery person knocking on their door? What's the best way to guide people through the process of getting their pizza?

Some of the initial findings were promising. We found significant interest from customers as a vast majority opted-in for self-driving delivery when offered. Post-delivery interviews revealed that customers enjoyed the spoken instructions played from external speakers that explained how to get their pizza out of the vehicle. In fact, as the car "talked" to them, many people talked back and even said "Bye!" as the car drove away. We also identified opportunities to overcome such as the difficulty of finding curbside parking spots in dense urban areas as self-driving vehicles won't be programmed to double park.

We are developing solutions to these questions and concerns in ways that are customer-friendly and easy-to-use.



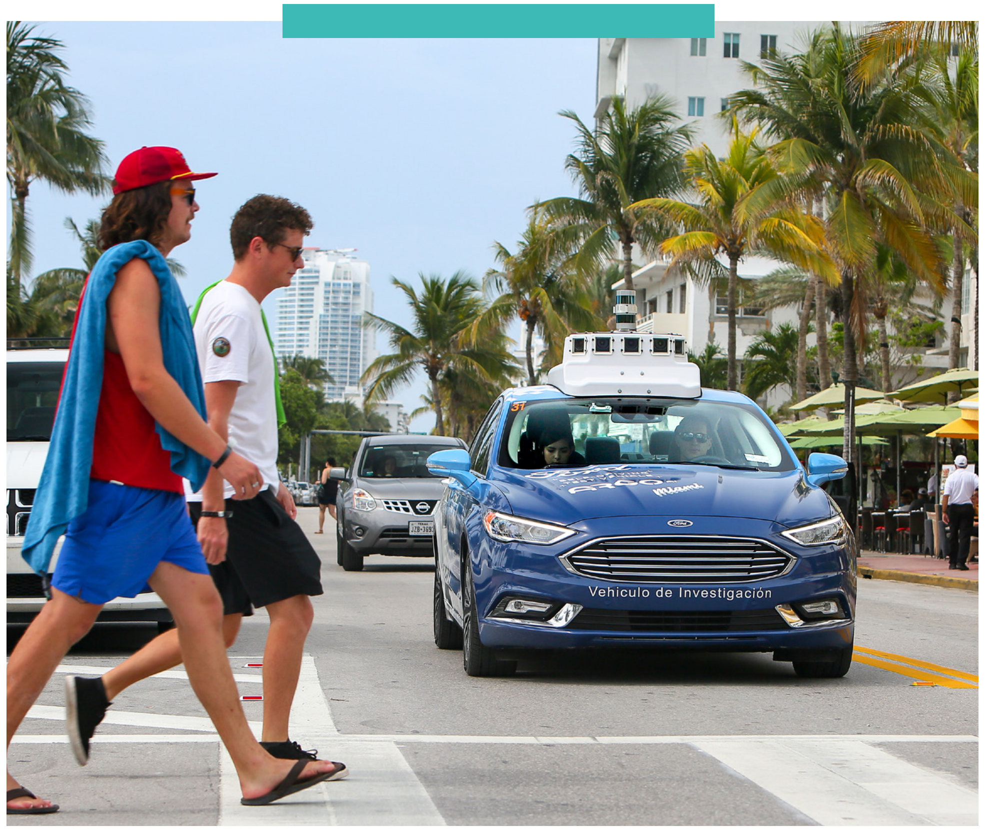
CITY SOLUTIONS: GETTING TO KNOW THE STREETS OF MIAMI-DADE COUNTY

Realizing that cities will be where transportation innovation is needed most, we formed a team of urban mobility experts called City Solutions. Our initial meetings with cities quickly pointed out that we need each other. City leaders were thankful for us spending the time to listen to them and taking a collaborative approach to helping their transportation systems. While there is still a lot to learn about one another, we're already talking and sharing insights that are leading to solutions for the benefit of all.

Our City Solutions team has had the opportunity to speak with the mayors of many cities along with other government and business leaders. Many are interested in exploring how new mobility solutions could help residents get around, but we found a particular champion in Miami-Dade Mayor Carlos A. Giménez. He's on the forefront of thinking about the future of transportation, leading a county that already offers a diverse set of transportation modes ranging from ride-hailing services and rail, to buses and bike sharing. He understands the potential of self-driving vehicles and how they can fit in, interact with and enhance all of those modes and more.

So, with the help of Miami-Dade County, we've set up operations in Miami to prove our autonomous vehicle business model, expand technology testing and development and even set up a terminal for fleet management.

Creating a self-driving business in any city requires a comprehensive understanding of local laws and the unique driving habits of residents, which is where Ford's partner, Argo AI, excels. With the support of county officials, Argo has a fleet of test vehicles on Miami streets, mapping roads and accumulating miles that will help us improve the ways self-driving vehicles navigate cities.



Customer behaviors are also unique city to city, so it's important that we learn about them in order to craft services that will be accepted and valued. We are now conducting customer experience pilot programs with our partners, including Postmates, to find the best way for self-driving vehicles to serve local businesses.

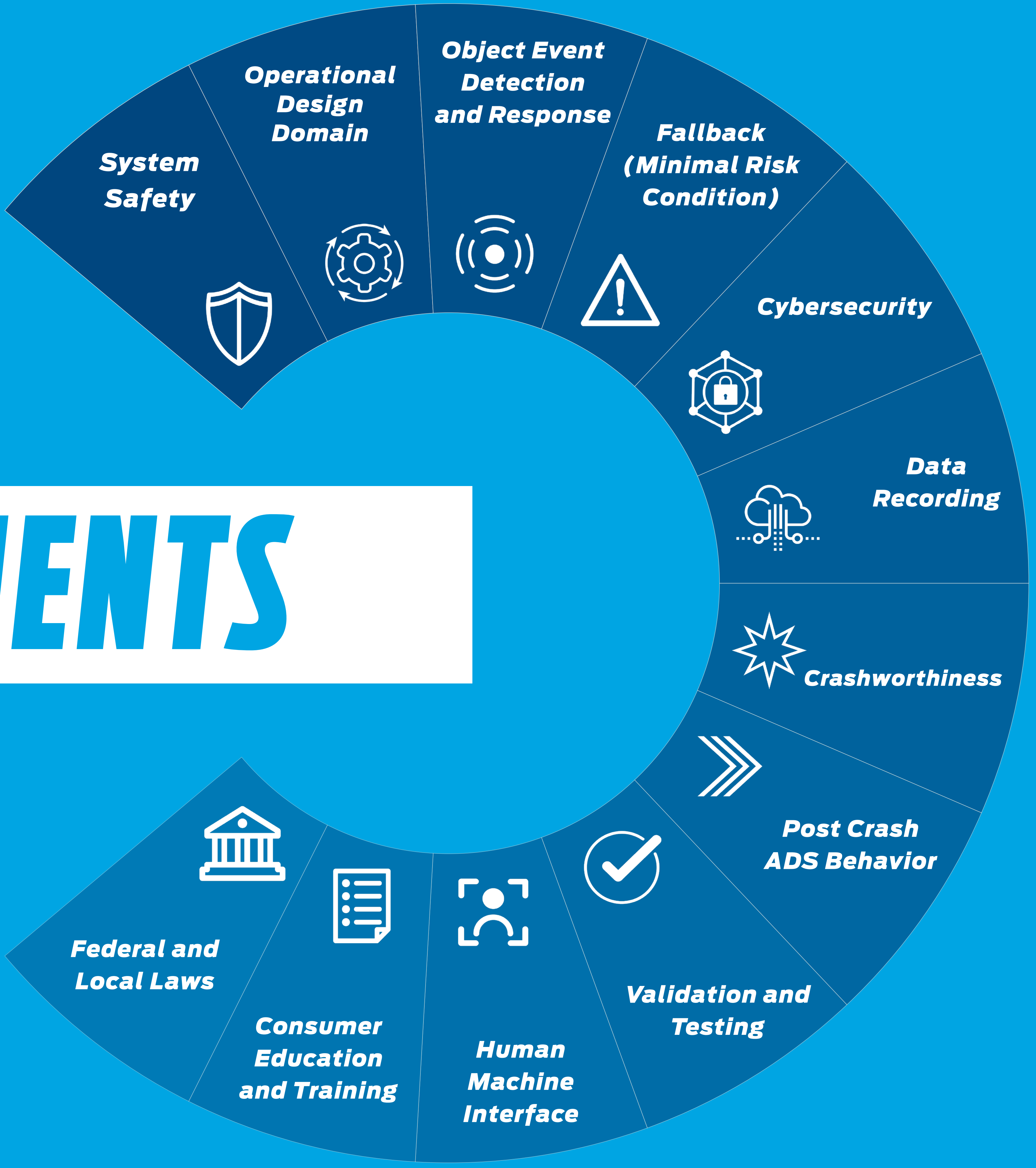
We've also established our first autonomous vehicle operations terminal in Miami. It will be the base from which we'll develop vehicle management processes and house our test fleet. The vehicles will be cleaned and maintained there, including troubleshooting problems that arise and more.

Additionally, we will work closely with our extensive dealer network in the area, looking for ways to integrate and incorporate their operations and capabilities into our terminal. Before thousands of self-driving vehicles can hit the streets, we have to be prepared to manage large, high-tech fleets efficiently, and the steps we're taking in Miami represent a significant development in that process.

Self-driving vehicles may transform the way we move people and goods, but it doesn't change Ford's way of doing business, namely by working together so our customers and their communities benefit. We're looking forward to connecting with the people of Miami-Dade County and becoming part of their community as we build a service they can rely on, day in and day out.

SAFETY ELEMENTS

Safety is our first concern at every step in our development of our self-driving vehicles. In this section, we will address the twelve safety elements in the National Highway Traffic Safety Administration's policy guidance, Automated Driving Systems 2.0 – A Vision for Safety.



SYSTEM SAFETY

System Safety refers to the holistic strategy to minimize failures and prevent unreasonable safety risks throughout the design, validation and testing processes.

Safety doesn't mean a sensor will never fail or an automated driving system will never err. It's about a holistic strategy to reduce the risk of failures and protect people in case something does go wrong.

At Ford, we place safety at the heart of the process and build the entire system – vehicle, software, testing and training – around it. System Safety drives our entire development approach, guaranteeing overall safety even in the unlikely event a component fails or the vehicle suffers a problem – how, when and where our vehicles operate.

At every stage of design and testing, Ford's engineers use systems engineering tools and processes and supplement them with lessons from the aerospace industry's long history of automation and safety.

Our functional safety process is strongly aligned with the industry automotive safety standard (ISO 26262). For the autonomous vehicle application, we also integrated and applied hazard analysis techniques, such as Systems-Theoretic Process Analysis (STPA), along with aspects of the Safety of the Intended Functionality (SOTIF) draft Standard.

From this process, we generate safety requirements for the vehicle's Operational Design Domain (ODD) (see page 32), Object Event Detection and Response (OEDR) (see page 33) and Minimal Risk Condition (MRC) (see page 34), along with associated safety verification and validation procedures. These requirements, in turn, guide the creation of a vehicle design that meet the goals defined at the outset. As testing reveals limitations of the current requirements, these lessons are fed back into the design process, becoming more robust over time.

This means designing systems that can continue to function even when experiencing faults that would have previously required driver intervention. This requires designing for fallback scenarios to ensure a vehicle can come to a controlled and safe stop.

Our resulting self-driving vehicle will fail safely or fail functionally depending on the type of the malfunction. Fail-functional systems include braking, steering, electrical low voltage power and the Virtual Driver System. Our self-driving vehicle includes an in-depth diagnostics strategy that analyzes and activates fallback solutions to bring the vehicle to a controlled stop when necessary. Our self-driving vehicles will constantly make decisions about how to interact with the world around them, including with traffic, weather and the rules of the road. All of these challenges go beyond hardware failures, such as cameras blinded by sunlight, and reducing these risks requires methods that go beyond traditional failure mode analysis.

Ford was engaged at the early stages of the original ISO 26262 standard development and has now been selected to lead the United States Technical Advisory Group (USTAG) for the development of the Safety of the Intended Function (SOTIF) ISO standard. Our engineers apply SOTIF to design self-driving vehicles capable of safely navigating the world. For example, we design software that knows when to change lanes, navigate intersections, see through inclement weather or handle the unexpected; and knows what failing safely means in these contexts.

Our self-driving vehicles are governed by robust safety requirements, including a tightly-defined ODD, that are developed through rigorous testing. In other words, we provide the vehicle with the programming required to respond appropriately to simple and complex situations.

SAFETY STRATEGY

How does Ford design safety into every self-driving vehicle? We have an established systems safety process integrated into our technology and product development processes. This promotes a systems approach for cross-functional collaboration to identify and develop a design that meets our safety requirements.

Safety operators are a crucial part of our development process, and our prototype vehicles are designed to ensure that a trained safety operator can always intervene. We design the intervention capability in many different components, such as placing limits on the self-driving system, which is programmed to always cede control to the human driver rather than the computer.

Backup systems in our production intent vehicles will provide fail-functional operations in our self-driving vehicles. This means a secondary braking system will ensure the vehicle can come to a controlled stop even if the primary braking system fails. In addition, the steering system has the ability to maneuver if one of the steering systems fails. The self-driving computer system is designed so that it can bring the vehicle to a safe state in the event of a failure in the primary or secondary computing hardware.

Since power is crucial to every critical system, our self-driving vehicle is also designed with independent power systems, which allow the vehicle to continue safe operation even after a single power failure or disturbance.

VERIFICATION AND VALIDATION OF SAFETY REQUIREMENTS

In more than a century of manufacturing, Ford has developed a repository of tests designed to measure performance, quality and safety.

After developing a system design, our teams verify and validate the functions against the safety requirements. Our self-driving vehicles will undergo rigorous testing, including verification of requirements through Model in the Loop (MIL), Software in the Loop (SIL), Hardware in the Loop (HIL) and fault injection at every level. MIL provides virtual testing in the absence of hardware. SIL provides target code testing in a simulated environment. HIL provides complete component and subsystem hardware testing. Fault injection purposely introduces faults into systems to test the robustness of the safety strategy to random failures. This provides a holistic, multi-layered approach to fault identification and elimination.

In addition, validation includes rigorous simulation and real-world testing to cover a variety of use cases and scenarios that self-driving vehicles will encounter.

As we test our system, we will continually improve our software through our engineering processes, which include machine learning and testing the software against our safety and performance requirements.

SAFETY OPERATOR TRAINING

At this stage in developing our self-driving vehicles, we believe safety operators play a critical role in the event of an error or malfunction. Their training is a core feature of our overall system safety.

Mirroring our validation and testing process of hardware and software, drivers proceed through three levels of instruction. First, they become familiar with the test vehicle and city through classroom and in-vehicle training. Second, they practice in a simulated urban environment at a closed-course facility, growing more comfortable with the vehicle's performance and Virtual Driver System as well as the ODD.

At this stage, safety operators are expected to remain constantly attentive to system performance as well as monitor other road users. They are specifically instructed to never consume media, talk or text on their phones and are continually evaluated on their ability to apply corrective input in a wide variety of driving scenarios, including random fault injections.

In the training program's third and final phase, safety operators begin to run start-to-finish autonomous missions on public roads. Monthly spot checks of the safety operators help ensure high standards.

At this stage in developing our self-driving vehicles, we believe safety operators play a critical role in the event of an error or malfunction.

Even after training is complete, ongoing daily briefings keep operators up to speed on new features; their feedback on testing is vital for teaching our safety engineers how to refine their designs for the next batch of improvements.

OPERATIONAL DESIGN DOMAIN

Operational Design Domain (ODD) describes where, when and under what conditions our self-driving vehicles will be designed to operate.

Most human drivers have a comfort zone. Some prefer to avoid highways and stick to local roads when possible; others would rather not drive at night or in bad conditions, such as during snow or ice storms. These driving routines and decisions can be considered a comfort zone.

The difference between most drivers and Ford's self-driving vehicles is that our comfort zone is set in code. Our Virtual Driver System only works within its Operational Design Domain (ODD), which prescribes which areas, streets, speeds, weather and time of day our vehicles can safely operate. Emerging from the requirements generated by our System Safety processes, the ODD defines the vehicle's area of operation. As the capabilities of our vehicles improve, we expect the ODD will expand in size and scope over time.

Our production-intent self-driving vehicles are being designed to operate at typical speeds for urban streets (e.g. boulevards and collector roads) within strictly mapped geo-fenced areas. The vehicles will be equipped with technology designed to detect and respond to static external environments, such as road structures and features (e.g. curbs, lane markings and barriers), roadside objects (e.g. trees and debris), dynamic objects (e.g. cars, trucks, motorcycles and bicycles) as well as pedestrians, first responders and animals. Our vehicles will operate day and night under a variety of light conditions as well as during precipitation capped at light rain.

Our intended ODD represents a convergence of our vehicles' expected capabilities and our projected business model, which includes ride-hailing and goods delivery along urban streets. It's important to note that, while the ODD includes a geo-fenced boundary, its operations within are constrained by its ability to operate safely. For example, our vehicles will be programmed to stay within the ODD. This may include in some circumstances avoiding highways, complex intersections and any other considerations exceeding its ODD.

Our Virtual Driver System only works within its Operational Design Domain, which prescribes which areas, streets, speeds, weather and time of day our vehicles can safely operate.

In the event that driving conditions sufficiently change to violate the ODD's conditions, our vehicles will implement the protocols defined by the Minimal Risk Condition (MRC).

OBJECT EVENT DETECTION AND RESPONSE

Object Event Detection and Response (OEDR) describes the capacity of the self-driving vehicle to detect and respond to environmental stimuli, both on and off of the road.

Driving is a feedback loop of identification, prediction, decision-making and execution. Once behind the wheel, we find ourselves constantly asking questions. What is our speed? Is it too fast? Is that car changing lanes? Is that person waiting to cross the street? And is that a plastic bag lying in the road or something more? In each case, we decide whether and how to take action: to speed up, slow down, signal, stop or evade.

Human drivers make decisions through a combination of intuition and experience. Our self-driving vehicles do much the same using sensors, software and onboard computing systems.

Human drivers make decisions through a combination of intuition and experience. Our self-driving vehicles do much the same using sensors, software and onboard computing systems.

These capabilities comprise the vehicle's Object Event Detection and Response (OEDR) system, which is responsible for perceiving conditions around the vehicle, choosing a path, recognizing objects and other road users, predicting their behavior and responding accordingly.

Our vehicle's OEDR is designed to be a match for environments prescribed by the Operational Design Domain (ODD). When driving conditions exceed its abilities, or the vehicles encounters a problem for which it has no response, it defaults to the Minimal Risk Condition (MRC).

To achieve this, Ford's self-driving vehicles employ a diverse set of sensors, combined with dynamically updated maps of the ODD. Redundancy is critical to our approach right now — overlapping sensors, backup steering and braking systems and (during development) human safety operators.

Our validation and testing uses an iterative process of simulation, closed-course testing and real-world testing to refine the OEDR system's capabilities and validate results from previous steps. There's no substitute for real-world driving experience. Our vehicles learn this as surely as any human driver does.

FALLBACK (MINIMAL RISK CONDITION)

In the event of a system malfunction, the self-driving vehicle will transition to a minimal risk condition (MRC) to assess the problem.

Decision-making for human drivers when things go wrong is not always easy or clear. But, for our self-driving vehicles, the next steps are written clearly in their code.

In the event of a technical malfunction affecting the Object Event Detection and Response (OEDR) system's ability to perform, Ford's production-intent vehicles will fall back to a Minimal Risk Condition (MRC). Depending on the severity of the problem, the vehicle will transition to an appropriately safe state, ranging from a diagnostic report to stopping as soon as possible.

In doing so, our vehicles rely on a comprehensive, robust diagnostics strategy, including a main Virtual Driver System and backup system sharing information. Each system conducts its own onboard diagnostics (no Internet required), as do critical subsystems such as braking and steering, allowing each to not only monitor themselves but each other. Redundant networks, controllers and actuators ensure continued operation in the case of a fault, enabling the vehicle to continuously plan fallback measures and execute them.

When a malfunction occurs, the vehicles dynamically sort potential responses into one of any number of fail-functional or fail-safe states. Minor faults not affecting the ability to drive are flagged for later resolution while more serious conditions might entail the decision to securely stop at a waypoint a short distance away, on the shoulder at the next opportunity or immediately.

Depending on the severity of the problem, the vehicle will transition to an appropriately safe state, ranging from a diagnostic report to stopping as soon as possible.

While connectivity isn't essential for vehicle health monitoring, our self-driving vehicles will transmit diagnostics information and vehicle states to its cloud platform for better customer service. As part of its leadership on safety, Ford is working with its industry partners in the Crash Avoidance Metrics Partnership (CAMP), as well as with NHTSA and SAE, to define an industry standard for MRC conditions requiring vehicle stops.

CYBERSECURITY

Cybersecurity is designed to protect the self-driving vehicle and the riders within from unauthorized access.

Cybersecurity is an important part of the world in which we live. Ensuring the integrity as well as the safety of our self-driving vehicles is a top priority. Autonomous vehicles present a unique challenge in terms of cybersecurity, combining unprecedented sophistication in a vehicle with frequent software updates.

Ford has sought to mitigate these inherent vulnerabilities by building security into the heart of our System Safety process. Our cybersecurity strategy extends not only to the vehicles' electronics, sensors and Virtual Driver System but also to any feature connected to them, such as data ports, mobile apps and customer service systems.

We recognize that no single part of the system may be perfectly secure. We employ the industry-standard defense in depth approach of layering security across multiple overlapping systems working together. Our system is designed to reduce the possibility of entry into a vehicle's network by using component isolation techniques, memory protection and access controls on any embedded systems, especially with external interfaces or safety functions. Our system also reduces the ability of a compromised device to affect behavior through message authentication, verification and credential provisioning. Additionally, our system minimizes the impact of any breaches via network segregation and physical and virtual partitioning, among other measures. Our validation techniques help ensure no single corrupted component jeopardizes the health of the overall system.

Not content to assume the security of our own solutions, our cybersecurity team works with partners and suppliers to help ensure our self-driving ecosystem and supply chain is also secure. Regular engineering testing, red team exercises and monitoring by our fleet managers adds an additional layer of redundancy to our approach. Various communication channels are used to document, report, share and communicate critical information to shareholders both internally and externally. Outside security assessments are conducted at various points to help ensure that security issues are found and resolved.

Our cybersecurity strategy extends not only to the vehicles' electronics, sensors and Virtual Driver System, but also to any feature connected to them, such as data ports, mobile apps and customer service systems.

Due to the ever-changing nature of the cybersecurity landscape, current design features are rigorously tested against our library of threats and attacks. This library is constantly updated, cross referencing Common Vulnerability and Exposure (CVE) alerts from the National Institute of Standards and Technology (NIST) and other threat sources. Ford is a founding member of the Auto-ISAC and chairs some of the SAE Cybersecurity work groups, and our efforts are aligned with the NHTSA Cybersecurity Best Practices for the Modern Vehicle.

DATA RECORDING

Data from self-driving vehicles feed powerful analytical tools that can be used to maximize the safety potential of self-driving vehicles.

Learning to drive requires both practice, experience and memory. Every driver carries an expectation of how their vehicle and others should behave on the road. We rely on experience to vet these hunches and know what to do in unique situations, but, for that, our self-driving vehicles need data.

Our development teams record terabytes daily from simulations and test vehicles with the latter providing performance data from onboard systems such as braking and steering in addition to sensor and camera data as well as the Virtual Driver System.

The ability to recreate actual events in simulations helps us to refine our approach and build better systems.

As we approach commercial deployment, our recording practices will increasingly shift from continuous to event-driven. In practice, this means events rising to a predetermined threshold will automatically trigger data recording. In addition to collisions and near misses, this list will also include any fault requiring a fallback into a Minimal Risk Condition, disengagement by the Virtual Driver System, cyberattacks and may also include rider initiated events and customer service interactions.

Our production-intent self-driving vehicles will use conventional Event Data Recorders (EDR) compliant with the regulatory standards for data recording during crash events. In addition, an autonomous vehicle data storage device will log information from onboard systems and the Virtual Driver System. Onboard storage will be capable of storing data-rich events that can be read during scheduled maintenance.

The ability to recreate actual events in simulations helps us to refine our approach and build better systems.

In addition, we are currently working with NHTSA and the Virginia Tech Transportation Institute to establish best practices in the sharing of data from edge cases and impact events that would be helpful to the industry at large.

CRASHWORTHINESS

Crashworthiness refers to the ability of the self-driving vehicle to protect its occupants in the event of an accident or crash.

Ford has more than a century of innovation in crashworthiness and occupant protection, including pioneering the use of rear inflatable seat belts and the development of detailed human body models with internal organs such as the brain, kidneys and spleen used in biomechanics research. We're leveraging our experience to ensure our self-driving vehicles can meet all applicable federal, state, and local regulations. And just as our stringent internal guidelines add stricter scrutiny to multiple types of crashes and pedestrian impacts, our production-intent self-driving vehicles will not only meet these same requirements, but new requirements may also be developed arising from unique situations from the addition of roof-mounted sensors and secondary braking, steering and power systems.

Ford's crashworthiness process comprises computer-aided modeling, engineering assessments, component testing, subsystem / sled testing and full vehicle system evaluations. Our approach to safety focuses on reducing the accelerations and loads occupants experience during a crash through the optimization of restraints (e.g. seatbelts and airbags) and structural elements such as bumpers, rails and pillars while maintaining the structural integrity and mitigating intrusion into the occupant compartment. For hybrid-electric vehicles, including our development and production-intent self-driving vehicles, the battery's housing structure is designed to perform well in a crash.

We are currently researching issues especially relevant for self-driving vehicles, including changes in kinematics from the distribution of sensors around the vehicle and guidelines for the new and non-conventional seating configurations and storage racks for our ride-hailing and goods delivery businesses. Ford is also working with the University of Michigan Transportation Research Institute to research how onboard sensor and diagnostic systems might be used to enhance passenger safety, such as airbag pre-deployment ahead of a detected collision, and with the Virginia Tech Transportation Institute to better understand the risk of passenger injuries arising from deployable restraint systems developed for unique seating configurations.

We're leveraging our experience to ensure our self-driving vehicles can meet all applicable federal, state, and local regulations.

Our self-driving vehicle crashworthiness process will reevaluate the base vehicle's crashworthiness performance and validate all of these updates through simulation and testing. And because Ford safety tests each vehicle independently, our crashworthiness tests will also validate that more standard elements like airbags and seatbelts meet Federal Motor Vehicle Safety Standards (FMVSS).

POST CRASH ADS BEHAVIOR

After a crash, the self-driving vehicle will return to a safe state to protect the riders.

In the event of a crash in one of Ford's production-intent vehicles, the vehicle immediately enters a minimal risk condition (MRC), coming to a safe stop. If necessary, backup steering, braking and power systems ensure the vehicle is able to stop under its own power. Depending on the severity of the crash, as judged by the self-driving vehicle's diagnostics, the following will happen simultaneously:

- The self-driving vehicle will use its embedded modem to call 911 and notify first responders.
- If necessary, the main battery will disconnect power for the safety of occupants and first responders while secondary power unlocks doors and turns on hazard lights.
- Data from the crash will be logged automatically, using its Event Data Recorders (EDR) and autonomous vehicle data recording device. Details such as airbag deployment, vehicle speed and seatbelt use can help us understand what happened.
- A service representative subsequently will call the vehicle to check on the occupants' health and safety and to help communicate with first responders.
- Depending on the severity, the service representative might also dispatch one of several self-driving vehicles: a second autonomous vehicle to complete the customers' trip, technicians to examine and repair the vehicle if possible or towing equipment if necessary. In all cases, the self-driving vehicle's Virtual Driver System will remain disabled until post-crash system checks are cleared.

VALIDATION AND TESTING

Our validation and testing methods ensure that the self-driving vehicle minimizes risks during operation.

At the beginning of Ford's self-driving vehicle development, our System Safety process identified safety risks, created a robust architecture to mitigate them and generated requirements to satisfy those conditions. Our Validation and Testing procedures close the loop on this process, using data from testing to vet and improve system, sub-system and component performance as we steer our self-driving vehicles toward deployment on public roads.

Ford uses a proven three-step method for validation: simulation, closed-track testing and real-world testing. Simulation techniques include Hardware-in-the-Loop (HIL) and Software-in-the-Loop (SIL) to create virtual sandboxes for component and sub-system testing.

In closed track testing, safety operators are placed behind the wheel on a simulated urban course and subject the vehicles to edge cases and difficult situations. Deliberate fault injection into fail-functional components, such as braking and sensors, tests the system's ability to transition to a Minimal Risk Condition during malfunctions with safety operators able to retake control at any time. Also, during this phase, our vehicles endure Electromagnetic Compatibility Testing (EMC), durability testing and environmental testing to validate the robustness of the Object Event Detection and Response system.

In the final stage, real-world testing generates the miles logged and near misses encountered to either validate system safety or to refine requirements with fresh data for simulations. In later phases of development, we will test the vehicle's ability to independently perform safety fallback maneuvers with the goal of removing safety operators when the Virtual Driver System is ready.

Continuous testing and system improvements using multiple sources will help to ensure our self-driving systems are safer.

Not all mileage is created equal: with millions of miles available for training sets from our partners at the Virginia Tech Transportation Institute, we are working to collect novel data while working with the industry to create baseline datasets for simulation. Going forward, data collection will be in accordance with our event-driven storage and retention policies as defined in Data Recording (above). Continuous testing and system improvements using multiple sources will help to ensure our self-driving systems get even safer.

HUMAN MACHINE INTERFACE

The human machine interface (HMI) refers to the design of interactions between the self-driving vehicle and people, both inside and outside of the vehicle.

It all seems so natural: the driver's seat, the steering wheel, the brake and the accelerator. But what it means to drive a car is the product of more than a century's worth of design and engineering decisions. So, what will happen when drivers become passengers? Thoughtful consideration of the Human Machine Interface (HMI) of self-driving vehicles will help foster the public acceptance of them.

Trust depends on many things, and communication is key. How our self-driving vehicles welcome customers and relay information about their trip or delivery will play a large part in the acceptance of self-driving vehicles. The same is true for safety: how the vehicle communicates its status and intentions in case of a fault and fallback to an MRC is a critical consideration. As we test our self-driving vehicles potential business models ahead of commercial service in 2021, we are already at work creating an interface that inspires trust at every step.

That interface begins, as nearly all trips will, with hailing a ride or placing a delivery order through a thoughtfully designed, intuitive mobile app. In a ride-hailing experience, when the vehicle arrives, customers are welcomed inside after their identities are confirmed by the app. Once inside and briefed on both the trip ahead and safety features, including a reminder to buckle up, passengers will press a button in a touchscreen accessible from each row of seating that indicates they're ready to go. Most information will be delivered visually via text and graphics with occasional audible commands.

For our production-intent vehicle should someone decide an unplanned stop is necessary, a pull over request button will be available for each row. Pressing it will trigger a stop at the next secure waypoint within the vehicle's ODD, and depending on the context may also prompt a call from a customer service representative to inquire about the matter. Should the vehicle experience a malfunction or crash and fall back to a fail-functional or fail-safety mode, the vehicle will explain if an emergency stop is necessary or if it cannot complete the trip. At this point, the vehicle will call a customer service representative who will be able to provide more detailed responses.

Once the vehicle arrives at its destination, passengers have an option to either dismiss the vehicle via their app or onboard touchscreen, or asking it to "hold" for a few minutes while they retrieve children, luggage, and or groceries. A "secure hold" feature locks the doors until unloading is completed.

In the case of deliveries, Ford is currently testing vehicles equipped with secure, private lockers. For a food delivery, a restaurant employee would type an access code into a touchscreen mounted on the exterior of the vehicle, then place the order inside. When the vehicle arrives at its destination, the customer receives a text notification indicating their order is ready for pickup. Upon meeting the vehicle at the curb, consumers enter their own access code into the touchscreen, and the appropriate locker opens. Audio prompts direct the interaction and lights will illuminate the designated locker.

HUMAN MACHINE INTERFACE

Self-driving vehicles have enormous potential to improve vehicle safety and personal mobility for those whose needs may not be easily met by existing transportation services. We are engaged in many research initiatives to understand how we can address the unique needs of all of our customers.

Self-driving vehicles have enormous potential to improve vehicle safety and personal mobility for those whose needs may not be easily met by existing transportation services.

Learnings from these studies are informing the ways in which we are developing our vehicle interfaces, including the audible and visual cues provided in our apps and in-vehicle displays, which will help customers with visual and hearing impairments. And we will continue to partner with other members of our communities to learn about the diverse needs of our customers to understand if we can provide new mobility solutions to address any additional challenges they are experiencing.

How Ford's self-driving vehicles interact with pedestrians and other road users is just as important if not more so than how they relate to customers. Driving contains any number of implicit behaviors — glances, nods or a simple wave convey unspoken understandings as to when to yield and when to proceed. We are investigating a similarly unspoken language for self-driving vehicles using a bar of lights fitted near the windshield to alternately flash, strobe or pulse in order to indicate vehicle intent — including yielding, accelerating from a stop, and driving. (Ford is currently working with organizations such as ISO and SAE to develop a global standard for signaling intent analogous to turn signals and brake lights.)

CONSUMER EDUCATION AND TRAINING

Proper education and training are essential throughout the deployment of our self-driving vehicles.

As of yet, there's no such thing as a commercially available self-driving vehicle service. Bringing self-driving vehicles to market will require a thoughtful and sustained effort to teach customers how they work, why they're safe and how to use them.

Ford isn't waiting until our production self-driving vehicles are ready in 2021. We already have cars on the road with a variety of automated technology features, including our Ford Co-Pilot360™ suite of driver-assist technologies debuting with the 2019 Ford Edge. And we educate our customers about these capabilities through our website (https://www.ford.com/dat/), sales brochures and other printed materials, instructional videos and programs such as Ford Driving Skills for Life, which teaches newly-licensed drivers how to use these features.

Given that consumer research by Kelley Blue Book, Autotrader and others demonstrate exposure to driver-assist technologies potentially increases acceptance of self-driving vehicles, we believe our efforts are paving the way for their successful Introduction.

While we continue to test and refine our self-driving vehicles, we'll strive to share information about their development milestones through various communication channels, including our blog (https://medium.com/self-driven), traditional media outreach and social media platforms including Facebook, Twitter, LinkedIn and Instagram.

Bringing self-driving vehicles to market will require a thoughtful and sustained effort to teach customers how they work, why they're safe and how to use them.

As we approach commercial deployment, we'll develop the appropriate materials to teach customers how to request a ride, how to order and interact with delivery vehicles, what to expect during the experience and how our self-driving vehicles work, including safety.

FEDERAL, STATE AND LOCAL LAWS

The System Safety process ensures that our vehicles can meet all federal, state and local laws as well as local regulations and rules of the road.

Ford's production-intent self-driving vehicles are designed from the ground up through our System Safety process to be capable of meeting all applicable federal, state and local laws as well as follow all local regulations and rules of the road. For example, our Object Event Detection and Response system (OEDR) guarantees compliance by cross-checking traffic signs and signals detected by onboard sensors against map data as well as recognizing other road users and acting appropriately, such as stopping for pedestrians.

Ford will also continue its commitment to the environment with self-driving vehicles that meet or exceed all applicable fuel economy and emissions regulations.

As mentioned earlier, we take safety seriously, including our obligations to meet Federal Motor Vehicle Safety Standards (FMVSS). Our vehicles will comply with all applicable requirements. In some cases, existing standards are not easily applied to self-driving cars, and for those, especially ones pertaining only to human drivers, we will seek exemptions or interpretations.

In their place, we will demonstrate how we intend to provide the same (or better) level of safety through new approaches. We are currently working with NHTSA, VTTI and other stakeholders to update FMVSS regulations in light of self-driving vehicles' unique features.

In addition to following the rules of the road, we understand self-driving vehicles will also need to follow and interact with the commands of law enforcement, EMS and other safety personnel. Ford has worked with the Michigan State Police to better understand edge cases unique to first responders and will incorporate their feedback into designing HMI for those encounters. Ford is also working with the industry and university alliances to supplement our knowledge on this topic.

Ford will also continue its commitment to the environment with self-driving vehicles that meet or exceed all applicable fuel economy and emissions regulations.

COMMITTED TO EARNING YOUR TRUST AS WE BUILD THE FUTURE.

WE KNOW TRUST IS THE CENTRAL QUESTION ON THE MINDS OF PEOPLE AS THEY THINK ABOUT A FUTURE OF SELF-DRIVING VEHICLES. CAN WE TRUST THIS NEW TECHNOLOGY? CAN WE TRUST THE COMPANIES THAT PROVIDE IT?

FORD HAS BEEN WORKING TO EARN THE TRUST OF OUR CUSTOMERS FOR MORE THAN A HUNDRED YEARS. AND WE'LL KEEP WORKING TO EARN THAT TRUST AS WE MOVE INTO THE SELF-DRIVING FUTURE.

WE AREN'T JUST BUILDING A NEW KIND OF CAR. WE SEE THIS AS AN OPPORTUNITY TO BE PART OF IMPROVING THE TRANSPORTATION SYSTEMS IN OUR BIGGEST CITIES AND THE LIVES OF MILLIONS.

AND EVEN AS WE CREATE THESE POWERFUL NEW TECHNOLOGIES, OUR CUSTOMERS WILL ALWAYS BE AT THE CENTER OF OUR DESIGN: TO MAKE SURE THAT EVERY TIME YOU USE A FORD VEHICLE OR SERVICE, YOU FEEL CONFIDENT AND SAFE.

THAT'S HOW WE'VE EARNED YOUR TRUST FOR YEARS. AND AS WE BUILD THE FUTURE TOGETHER, IT'S OUR COMMITMENT TO YOU.

Ford