



Science.  
Applied to Life.™



3M Traffic Safety and Security Division

# 3M™ Connected Roads

Helping improve the safety of your road  
systems today and in the future.

# Driving a Transportation Evolution

More than 64 million kilometers of roadway cover the globe, connecting us to each other and allowing us to trade goods and services. The lane markings, highway signs, and traffic lights that help us navigate our roads are such a familiar sight that we almost take their presence for granted. But without them, we'd be lost.

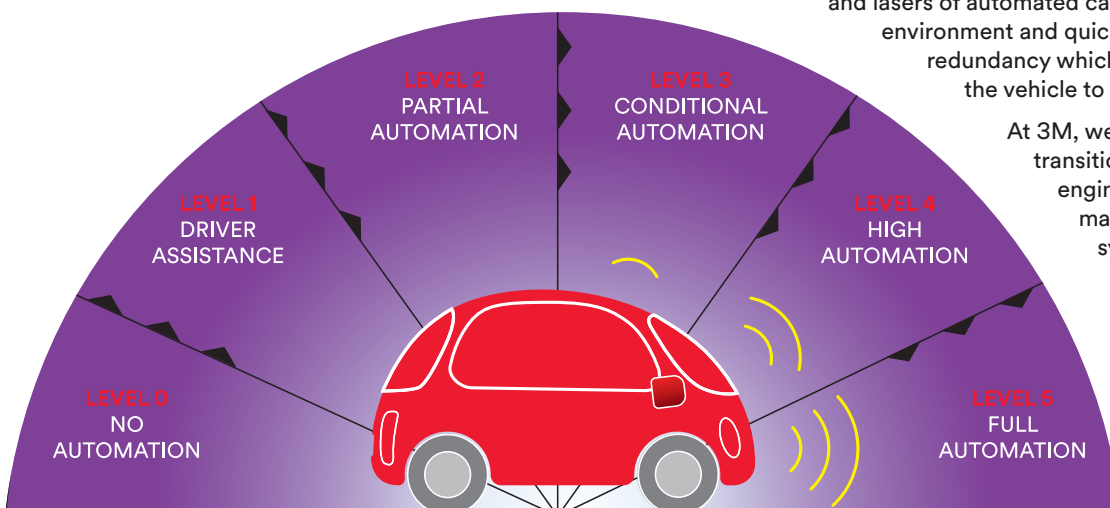
These roadways are soon to be the stage for a revolution. Self-driving vehicles, long dreamed of, are becoming a reality. The race to make a successful and safe autonomous car is on, with everyone from young tech companies to traditional auto manufacturers entering the competition.

Public attention follows Google, Tesla, and Uber as their autonomous vehicles go from strength to mishap and back again, but the reality is that leading automotive manufacturers around the globe will be producing driverless cars sooner than most would guess—think 2021.

Change is just around the corner. And it's going to bring huge benefits: freedom from the stress and loss of productivity associated with driving is just the start. The biggest—a possible end to nearly 90 percent of traffic fatalities, a public health triumph that could mean almost 30,000 lives saved a year in America alone, plus \$190 billion dollars in health care costs saved.<sup>1</sup>

In order for this evolution to take place, the environment surrounding the vehicle must evolve as well. The infrastructure must move from analog messages designed for human eyes to digital messages designed so the cameras, radar, and lasers of automated cars can interpret the surrounding environment and quickly respond, creating redundancy which increases the confidence of the vehicle to make critical driving decisions.

At 3M, we're playing a key part in this transition. Our expert scientists and engineers are developing new materials and designing innovative systems that will help to fuel mobility, improve safety, and work with the data-driven environment of tomorrow's cars and roadways.



◀ SAE J3016 Levels of Automation

1. <http://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-ways-autonomous-driving-could-redefine-the-automotive-world>

# Why 3M?

For more than 75 years, 3M has provided leading Roadway Safety Solutions that have drastically changed the way people move, connect, and operate.

We're a global science company that never stops inventing. Using 46 technology platforms, our integrated team of scientists and researchers work with customers to create breakthroughs. Our inventions have improved daily life for hundreds of millions of people all over the world.

We know that real innovation happens when experienced, committed, passionate minds come to together to rise to the challenge of improving infrastructure and mobility. That's why 3M is more than just a leading global company. We are a hub for collaborations that can help change the world.

How do we do this? We empower and build passionate experts, allowing for open innovation across business teams and groups. We work to build ambitious, pioneering solutions that have the ability to change the marketplace and how we live, connect, and commute. And we work—together—to become one of the world leaders in developing innovations that advance mobility and safety every day.

## Some of the innovative ways 3M has improved infrastructure and safety:



### Pavement Markings

3M innovations include durable Stamark™ tapes and microcrystalline beads that have changed how people navigate the roads every day. Our unique research and pavement marking solutions have helped improve visibility and durability for more than seven decades.

In the 1990s, 3M researchers began working to develop a bead with suitable refractive index to achieve useful and marketable wet reflective pavement marking performance. With conventional beads, rainwater reduces the apparent refractive index of the bead, so the headlight's illumination doesn't focus on the back of the bead and retro-reflect back to the driver. 3M researchers designed a new durable high refractive index bead that anticipates the light-bending quality of water.

Combining durable beads with multiple refractive index beads creates pavement-marking products that provide superior retroreflectivity in both dry and wet conditions.

### Retroreflective Sign Materials

3M breakthroughs in retroreflective science have been adopted around the world, which is what makes 3M a trusted industry leader providing ingenious solutions to help transportation agencies succeed.

3M Full Cube technology features nearly 100 percent efficient optical elements. This means the retroreflective elements in Full Cube technology reflect 58 percent of the light that strikes them.

When this technology is incorporated into 3M™ Diamond Grade™ DG<sup>3</sup> Reflective sheeting, it nearly doubles the average brightness of road signs using truncated cube technology.

### Fluorescent Technology

In the 1990s, 3M introduced fluorescent technology that would improve sign visibility during dawn and dusk. Combining fluorescent colors with Diamond Grade™ Reflective sheeting ensures maximum visibility for traffic control signs where and when they are needed the most.

Fluorescent orange is used to enhance work zone safety, and fluorescent yellow-green is used in school, pedestrian, and bicycle zones to warn drivers about non-motorized crossings.

Fluorescent yellow can be used in warning signs, bringing attention to something coming up, such as a curve or possible animal crossing. The materials' "light-shifting" capacity to provide maximum readability and visibility, helps to increase roadway and work crew safety.



# Improving Safety—Together

Today, as vehicles become increasingly automated and connected, we have an opportunity to help move transportation and safety even further.

Our unique ability to collaborate—and to innovate—bodes well for an industry that will require an ecosystem to work together.

At 3M, we are driven to think about what's next. That's why we're collaborating and partnering with thought leaders and leading organizations like the Center for Automotive Research, the University of Michigan Mobility and Transformation Center (MCity), Texas Transportation Institute (TTI), Stanford Center for Automotive Research (CAR), CLEPA European Association of Automotive Suppliers, and ERTICO ITS Europe and more, to pave the way for the roadways of the future.

It's through these unique collaborations that we can develop leading solutions:

- **What can we learn from automobile manufacturers, technology innovators, university research centers, and government agencies about what infrastructure and connectivity requirements are necessary to advance connected and automated vehicles?**
- **And how can 3M inspire innovation and provide solutions that can drive the future of transportation?**

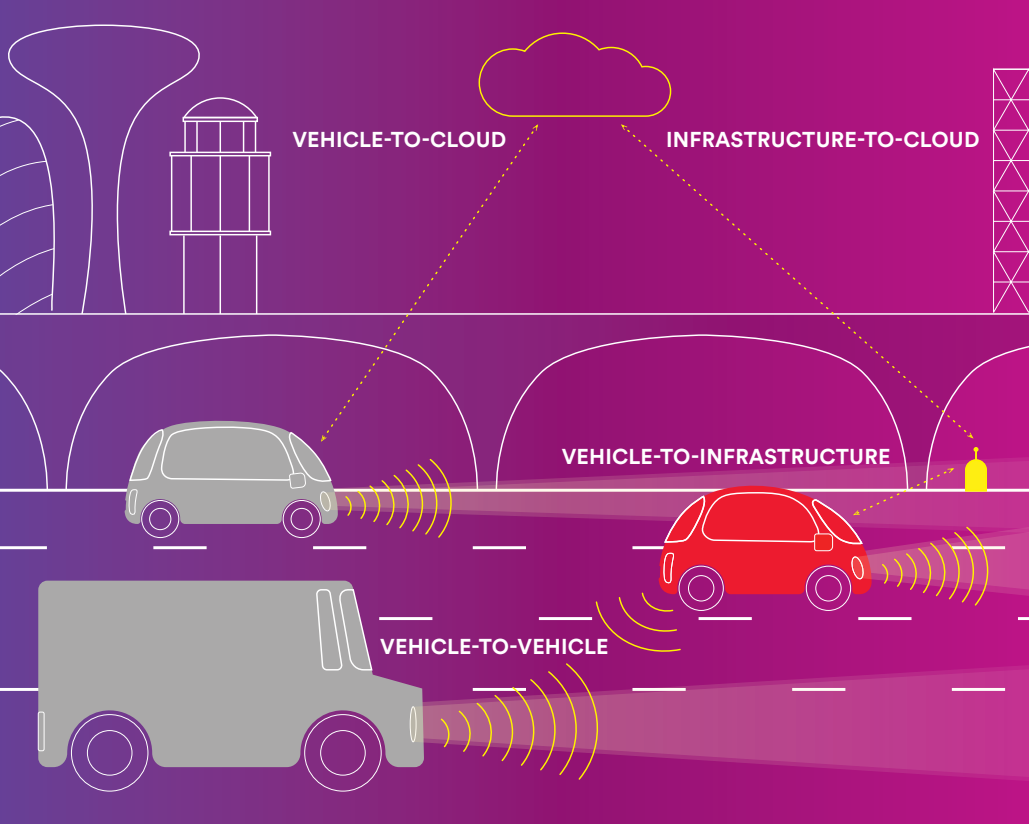
For more than 75 years, 3M has led the development of cutting-edge traffic safety advancements around the world. We've partnered with departments of transportation from all ends of the globe to help create new roadway technologies that enhance visibility and response time for drivers, protect work crews, and improve traffic safety for everyone. This is how we lead, and create safer roadways.

A more mobile future requires a more open ecosystem—leaders and innovators connecting, collaborating, and developing smart solutions that will keep us on the road ahead.

**“Everybody has some level of interest in the future of autonomous vehicles—insurance, OEMS, electronics, data, cell phone, infrastructure components, state and federal government—there aren't too many people who won't have their life impacted in some way, shape or form. Everyone will be impacted—it's just a question of how. It's not going to happen in isolation. Change will come from everywhere, simultaneously.”**

– James Sayer,  
University of Michigan  
Transportation Research Institute





▲ Ecosystem Simplified

**“There are questions and challenges being raised by government and academia and others that are focused on connected vehicles and safety. But we know we can solve the problem another way—through infrastructure.”**

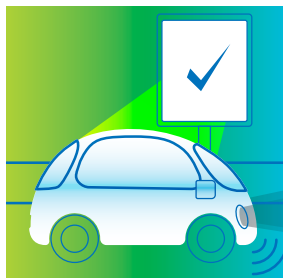
– Ben Watson, Innovation Leader, Technology and Innovation at 3M

# Driving Innovation

At 3M, we know we can drive innovation and improve safety through smarter infrastructure. First and foremost, connected and automated vehicles require environments that support them. But we have to move fast if we want to be successful.

Machine-vision is here. Fully connected vehicles, ones that communicate directly with infrastructure, are only a few years away. What we envisioned as space age is now right in front of us. Soon, infrastructure and driver systems will have to operate completely together, from partial automation—where we are today—to conditional by as soon as 2020.

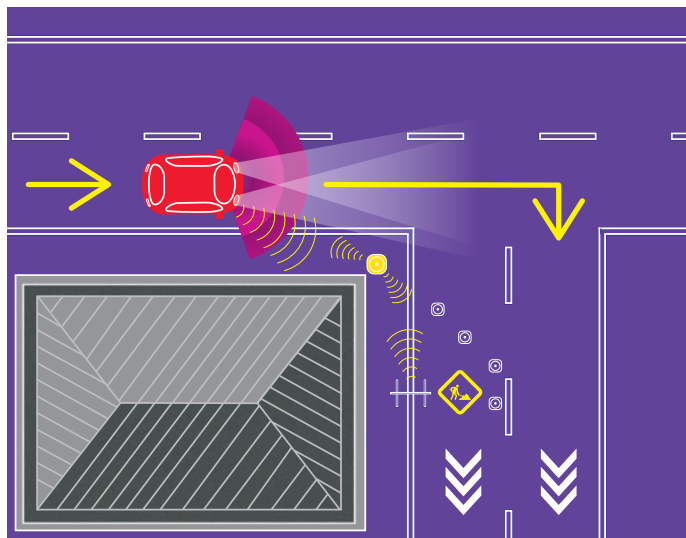
How can we navigate the road ahead? First and foremost, infrastructure will need to support both human and machine vision. We need pavement markings and directional signage that are visible to humans and machines in any road condition.



▲ Smart Signs

There is a need for increased redundancies—like state-of-the-art road signs, and enhanced road markings—that help drivers, cameras, and sensors more easily sense and decode rules of the road.

There is also a need for wireless communications that connect directly to vehicles, quickly helping identify construction zones and potential safety hazards so vehicle mobility and traffic flow can improve. It means sensors like LiDAR, and cameras working together can improve readability, helping drivers make decisions faster, and improve roadway safety for everyone.



▲ LiDAR Sensors

“Just imagine if all this works, what it’ll do to the auto industry? Or taxis? Or urban planning?” says Denny Lorentz, Lab Manager, Advanced Technologies at 3M. “The system has to work together. If you design each part with other parts in mind, the whole ecosystem can work better together.”



# Developing Solutions for the Road Ahead

At 3M, we're playing a key part in this transition. We're engineering new materials and designing systems that will fuel mobility, improve safety, and work with the data-driven environment of tomorrow's cars and roadways.

We know there are challenges on the road ahead, and our team of innovators is ready to meet them.

## 1. Building a Digital Infrastructure

As cars get smarter and computerized systems bear more of the driving burden, signs, pavement markings, and temporary traffic and vehicle identification must support machine vision. We've already taken the lead in this area, with pavement markings and signs supporting features like driver assistance, cruise control, and auto braking.

The next step is for vehicle systems to exceed the human driver's ability to recognize signs and lines accurately, reliably, and in any weather condition. That means signs, markings, and lines need to provide digital information as guaranteed back-up systems. Smart signs and pavement markings need to communicate with cars equipped to recognize optical character recognition.

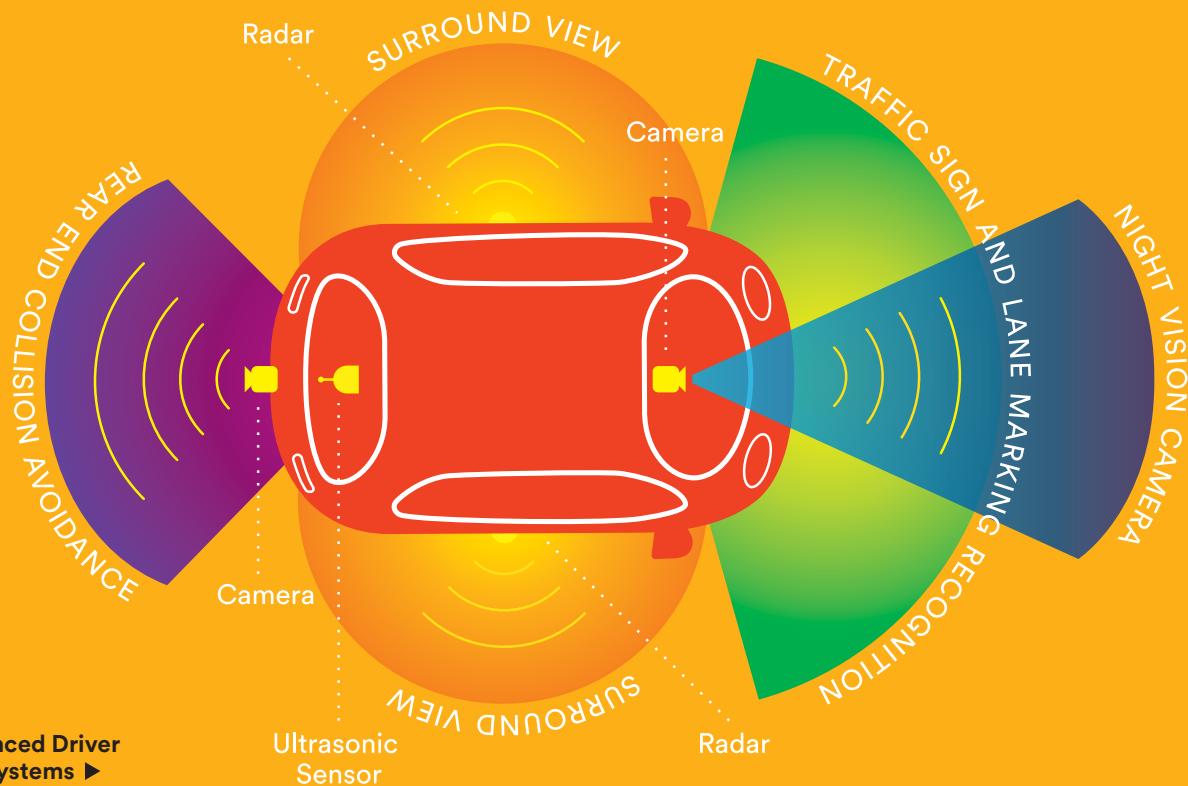
At 3M, we are developing materials and systems that support both human and machine vision, with safety as a top priority that can help drive us toward zero deaths.

"We've worked for 30 years to increase pavement marking durability, and making markings brighter for humans—it's a crucial safety factor for driving in bad weather," says Tom Headblom, 3M scientist, who has led human-factors research in retroreflective pavement markings.

"Now, we need to increase the durability, weather range, time, and distance that a machine or camera could 'see' the pavement markings even further. We're always asking ourselves: How do we bridge the gap from today to what'll be needed in the future?"

**“To get the full benefit of connected and automated vehicles, you need the infrastructure outfitted. Infrastructure can carry and share information about crashes, traffic jams, sharp curves, and with recommended speeds. You can also dynamically change recommended speed based on weather or other conditions.”**

– James Sayer,  
University of Michigan Transportation Research Institute



ADAS: Advanced Driver Assistance Systems ▶

## 2. Vehicle to Infrastructure (V2I)

As we leave behind the days when cruise control and assisted driving were the smartest operations the car could perform, we move into new levels of automation. Vehicle systems will take on more responsibility and the role of the driver will diminish.

To accomplish this, vehicle sensors will receive information from the ever-changing road environment. At this stage, humans will still be expected to keep an eye on the road, and be ready to take back control of the vehicle in specific situations. Until there are strong redundancies in these technologies, humans will still play a strong role as we evolve to fully automated vehicles.

In order to empower this vehicle evolution, infrastructure needs to be in place to allow vehicle sensors and wireless communication to continue advancing automation technology.

Some more ways we are helping to create redundancies that improve safety and propel us into the future of automation:

- **Advanced Road Markings:** Durable, removable magnetic pavement lane markings work with automated vehicle sensors to detect lines outside the vision-based spectrum, improving lane detection and traffic safety in even the most extreme weather conditions.
- **Smart Signs:** Retroreflective signs provide better readability, which results in more accurate navigation and faster decision-making for both drivers and automated vehicle systems. In addition, smart signs are compatible with traditional signage.
- **Wireless Communication:** 3M™ DSRC Multi-Channel Test Tool is an independent multi-channel listening device that provides vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications. The test tool is an unbiased 3<sup>rd</sup> party resource, used to decode standards and connected vehicle requirements; SAE J2735, IEEE 802.11p and IEEE1609.

## 3. Redundant Systems for Safety

No single system will guarantee safety. Safety will only increase if all vehicle systems are working together to improve the readability of pavement markings, traffic signs, temporary traffic control and help drivers navigate safely. Redundant systems take over when GPS isn't able to work, such as in a tunnel, or pavement markings aren't visible to the camera because of the sun's glare, the systems need to work together to operate effectively.

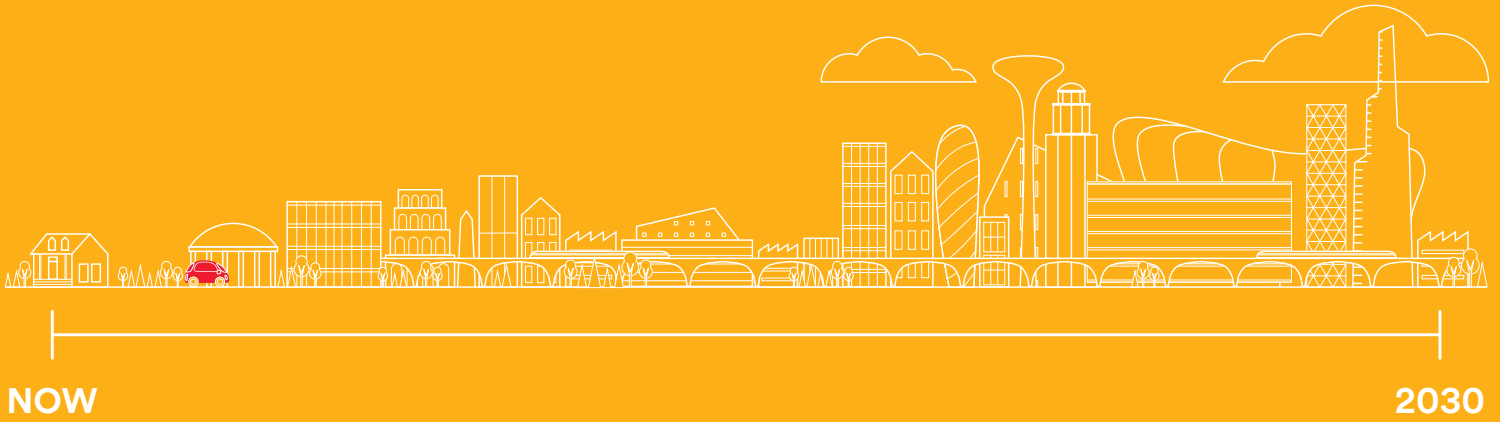
Think of systems working together to improve mobility and safety for everyone. If buildings are blocking a satellite and GPS isn't working, or if snow has covered pavement markings, a LiDAR sensor or camera will provide the redundancies necessary to keep traffic moving efficiently, improve drive time and vehicle safety. Congestion is greatly reduced. People are more mobile. People get where they need to go faster—and more safely. Yet this level of automation requires innovative, intelligent infrastructure that supports a digital ecosystem.

At 3M, we know state-of-the-art vehicles require state-of-the-art infrastructure. Improving infrastructure through redundancies is how we drive innovation, increase safety, enhance mobility, and create roadways of the future.



▲ A single system will not guarantee safety





# How Can You Drive an Evolution?

The future is always a moving target. We can't truly know our destination, but we can put our best efforts and biggest creative ideas into preparing ourselves for the road that will lead us there.

At 3M, we're working to ensure this journey is as swift—and safe—as it can possibly be. As leaders in the crucial area of infrastructure, we stand shoulder to shoulder with equipment and auto manufacturers and software-designers, playing an equal role in this extraordinary advancement in human society.

This seismic shift in mobility will depend on partnerships, collaborations, and tireless examination of safety standards and the ever-changing realities of the roadways. A data-rich driving environment will increase both efficiency and safety—and we'll make sure it's understood by both humans and machines.

As global leaders in roadway safety innovation, we are excited to partner with you to power a transportation revolution—and bring more people home safely, every day.



3M Traffic Safety and Security Division  
3M Center, Building 225-4N-14  
St. Paul, MN 55144-1000  
1-800-553-1380

Please recycle. Printed in USA.  
© 3M 2017.

3M, Diamond Grade and Stamark are trademarks of 3M. Used under license in Canada. All other trademarks are the property of their respective owners.