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UNIVERSITY OF MICHIGAN

DRIVING PROGRESS

2019 ANNUAL REPORT

HUEI PENG
MCITY DIRECTOR

ROGER L. McCARTHY PROFESSOR
OF MECHANICAL ENGINEERING
UNIVERSITY OF MICHIGAN

As we begin 2020 and prepare to celebrate Mcity's fifth anniversary, it is an appropriate time to review our accomplishments of the past year and consider the challenges ahead. Launched as the Mobility Transformation Center in 2014, we remain committed to our original vision of bringing together industry, government, and academia to improve transportation safety, sustainability, and accessibility for the benefit of society.

ACHIEVEMENTS

Mcity-funded research continues to drive progress. White papers highlighting our research results have received positive and widespread attention, fulfilling our commitment to education and outreach. White papers published in 2019 featured work such as a technique for measuring motion sickness in driverless cars, and a test concept called the Mcity ABC Test that assesses driverless vehicle safety prior to testing on public roads.

Additionally, Mcity's Legal, Liability and Insurance Working Group has been working closely with six law firms to study issues important to the commercialization of connected and automated vehicles.

With 17 active pooled research projects, where the learnings and results are shared among our members, Mcity's research is producing significant results. See "Research" for details

Mcity's test facility for connected and automated vehicles continues to drive progress.
In 2019 we made great advances in the technological capabilities of the test facility. To support highly repeatable testing, we released a software interface for automated control of the test facility's features, such as traffic lights, rail crossings, and our always-patient robotic deer.

Leadership Circle partner Verizon upgraded our existing 5G network to the 3GPP commercial standard and installed a mobile edge computing (MEC) center to enable research of low-latency computing value for transportation applications. Partnering with Econolite, they are developing a 5G-connected camera system for use at intersections to help prevent collisions.

Eight simulation companies have built "digital twins" of the Mcity test facility, enabling validation of real-world test results remotely via software simulation versus real-world testing on site.

The capabilities of the Mcity Test Facility are currently unmatched worldwide, and we will continue to evolve to meet the research and development needs of those using the facility.
More on "Advanced Capabilities" and "5G/Edge Computing"

Mcity's living labs allow us to drive progress through learning by doing. The more than 50 million miles of data we have collected from the Ann Arbor Connected Environment (AACE) have helped us learn how, where, and when people drive, facilitating the development of a microscopic mobility model for the City of Ann Arbor. This model can provide insight into the overall traffic flow of the city and be the basis from which other municipalities can learn.

The data collection phase of the Mcity Driverless Shuttle research project concluded in December. Two NAVYA Autonom Shuttles were deployed on U-M's campus over an 18-month period, with 16,000 trips completed. In collaboration with Affiliate member J.D. Power, insights gained will be shared in early 2020. Learn about the "Driverless Shuttle"

Following our driverless shuttle deployment at U-M, the Michigan Mobility Collaborative, of which Mcity is a member, received a $7.5 million grant from the U.S. Department of Transportation (USDOT) to conduct an automated vehicle deployment in Detroit to demonstrate the potential societal value of this technology. This deployment will allow us to add to the Mcity Data Garage, which now houses more than 50 datasets, one of which is Level-4 AV data from our NAVYA fleet. The award will also enable continued development of the Mcity ABC Test, as well as research into various issues related to accessibility. More about "Mcity to Detroit"

With U-M's Transportation Research Institute (UMTRI) we are now providing near real-time data from the entire Ann Arbor Connected Environment, using data from 2,500 connected vehicles and 70 connected intersections. We are using the same software interface that is already available for the test facility. This is a one-of-a-kind asset for researchers and our partners, not available anywhere else. See "Near Real-Time Data"

CHALLENGES

While great progress has been made, challenges remain. Uncertainty in the safety-critical communication spectrum and related connected technologies continues to grow. Should the Notice of Proposed Rule Making, recently approved by the Federal Communication Commission, result in the loss of exclusive access to the safety band for transportation safety, Mcity and other

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Collection and sharing of data has always been critical to Mcity's mission. Our focus is now expanding to analysis, to help generate insight and knowledge."

HUEI PENG
MCITY DIRECTOR

leaders in dedicated short-range communication (DSRC) deployments will be faced with the decision to migrate or decommission. Not only will Mcity, industry, and state and local governments be hurt financially, the delay of potential safety benefits will negatively impact us all.

Meanwhile, for automated vehicle (AV) technologies, the lack of consensus for defining standards and procedures to ensure human safety and assign responsibility remains a key challenge. We need to move faster from concept to implementation by working with Mcity partners, industry, and government in an open collaboration. In addition, Mcity will continue to address non-technological challenges in areas such as accessibility, liability, and public policy.

OUTLOOK

We are now two-thirds through our current three-year membership term. Mcity has completed all of the deliverables defined in the current membership agreement a full year early. We are proud of this accomplishment, and we resolve to use the year ahead to build on this success through data insights, renewed focus on the societal impacts of CAV technology, and additional capabilities in our labs. We will apply our learnings from our AV deployments in Mcity and the U-M campus to the cities of Ann Arbor and Detroit.

In this time of rapid evolution in transportation, Mcity is committed to upholding our position as one of the most advanced mobility research centers in the world.

We look forward to continuing to collaborate with our partners on the work ahead and drive progress for the benefit of all.

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Highly automated vehicles must be developed in a responsible way to fully benefit society."

HUEI PENG
MCITY DIRECTOR

ADVANCED CAPABILITIES

IN THE FUTURE, TEST FACILITIES WILL need to be significantly smarter than they are today to adequately test the "brains" of ever-more-capable transportation systems. To support this, Mcity built a new software interface, OCTANE, which allows users to control many aspects of the Mcity Test Facility infrastructure from a phone, laptop or vehicle computing platform. The OCTANE API (application programming interface) is a common language that other applications and users can use to interact with the facility. This one system allows researchers and test engineers to design and script complex test scenarios and coordinate actions in the facility with a high degree of repeatability.

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This new API has lowered the barrier to entry for conducting complex tests. It's a single centralized, well-documented place to create and orchestrate tests either through code or with the simple click of a mouse."

TYLER WORMAN
MCITY DATA ARCHITECT
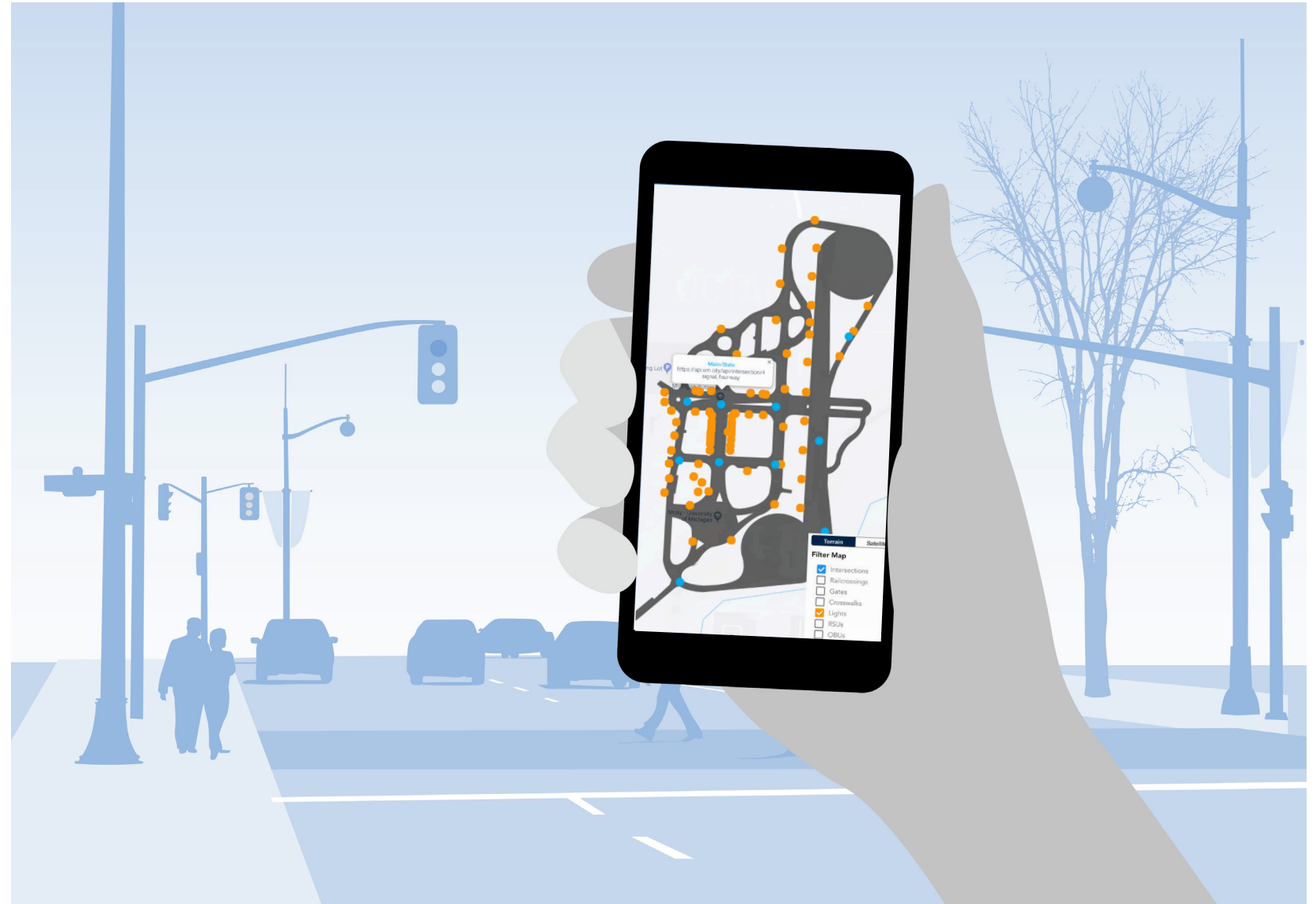
5G/EDGE COMPUTING

MCITY'S TEST FACILITY IS the perfect place to deploy and research cutting-edge technologies that can improve the mobility of people and goods. 5G, one of the most promising wireless technologies currently available, improves bandwidth and reduces latency. Mcity Leadership Circle member Verizon has brought a full standards-compliant 5G system to the test facility, allowing researchers and members to develop next-generation applications before scaling them in the real world. To run those applications with maximum benefit, Verizon has also provided an "edge" computing cloud, further reducing data transmission and processing delays and costs.

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Our collaboration with Mcity serves to drive the development and deployment of new 5G technologies that will transform the way we live, work and play."

ANDRÉS IRLANDO
VERIZON SENIOR VICE PRESIDENT;
PRESIDENT PUBLIC SECTOR AND VERIZON CONNECT

DRIVERLESS SHUTTLE

MCITY HAS PUBLISHED MORE THAN 50 DATASETS.
Nearly half of them have relevance for automated
vehicle research and development. One example
is the Mcity Driverless Shuttle research project
launched in June 2018 on the public roads of U-M's
North Campus. This project enabled us to collect
Level 4 AV data. At its conclusion in December 2019,
data had been collected from more than 16,000 trips
and 500 riders were surveyed. The engineering data
captured behavior of pedestrians, cyclists, and drivers
on the road, as well as dynamic motion of the shuttles.
It will allow us to analyze manual takeovers by the
safety conductors, unexpected brakes/stops,
interactions at crosswalks, onboard rider behavior,
and more. The survey data will help us understand
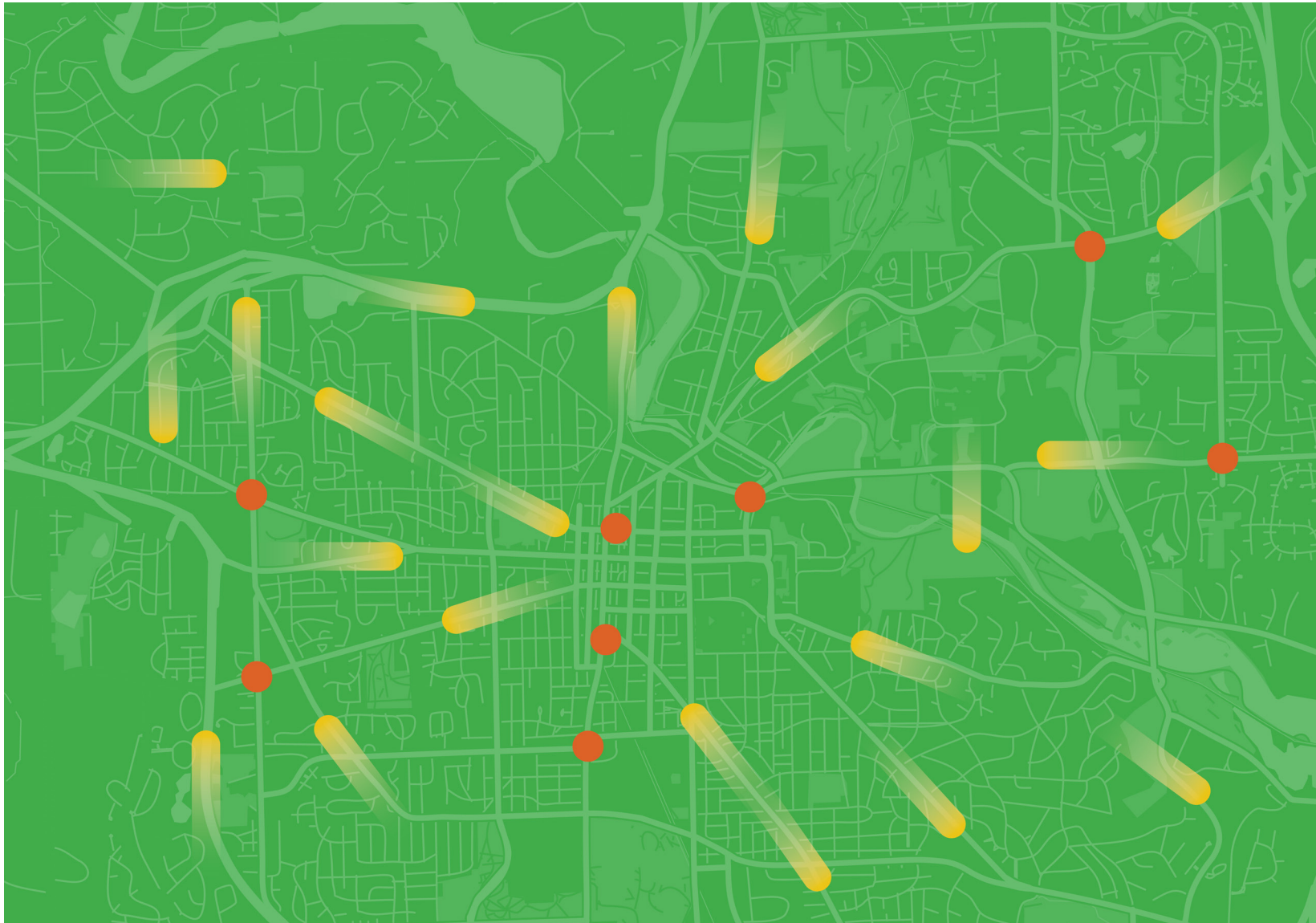usage patterns, trust, and overall rider experience.

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**The Mcity Driverless Shuttle
consumer research demonstrates
the importance that exposure
plays in generating future interest
in driverless technology."**

KRISTIN KOLODGE
J.D. POWER EXECUTIVE DIRECTOR OF DRIVER INTERACTION
AND HUMAN MACHINE INTERFACE
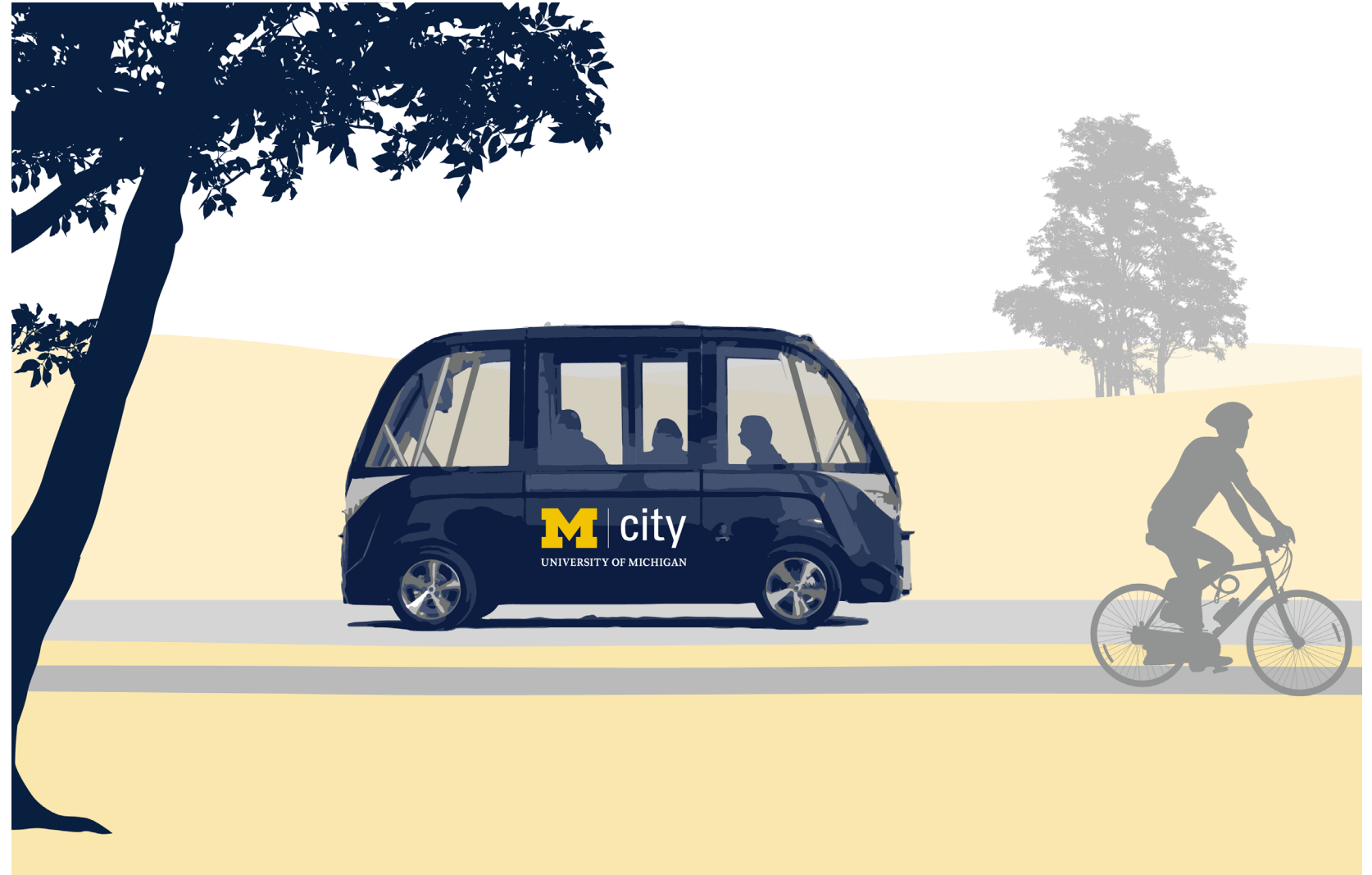
NEAR
REAL-TIME DATA

MCITY MEMBERS AND RESEARCHERS now have access to near real-time data collected from the Ann Arbor Connected Environment (AACE). With more than 70 key intersections online, and 2,500 vehicles broadcasting safety messages, AACE is a real-world living lab environment that supports testing of a variety of applications – from safety to fuel efficiency to dynamic routing. This unique view into the AACE network helps our partners substantially reduce research and development time.

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Ann Arbor and the University of Michigan have partnered to create a living laboratory that is incredibly unique; unique in its thinking, unique in the data it produces, and unique in the opportunities for transportation it unlocks."

GREG McGUIRE
MCITY ASSOCIATE DIRECTOR

MCITY
TO DETROIT

A $7.5 MILLION GRANT was awarded by the U.S. Department of Transportation (USDOT) to the Michigan Mobility Collaborative in October 2019. This state-wide group is led by the City of Detroit and supported by Mcity, the University of Michigan Transportation Research Institute, the American Center for Mobility, Wayne State University, Ford, and Verizon. Mcity's experience in conducting automated vehicle safety tests and managing the on-road deployment of driverless shuttles was critical in securing this grant. The project goal is to improve access to mobility for Detroit's senior population. Mcity will assist in the driverless vehicle deployment plan, conduct safety tests, and analyze the performance of the driverless vehicles.

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This critical funding from USDOT is further proof that Michigan continues to be the home of the global auto industry and advanced mobility technologies."

DEBBIE DINGELL
U.S. REPRESENTATIVE

MOTOR CITY

QLINE DETROIT

RESEARCH

HUEI PENG
LEAD RESEARCHER

GREG McGUIRE
LEAD RESEARCHER

Mcity ABC Test

When public perception of highly automated vehicles was negatively affected following two widely publicized fatalities in 2018, Mcity Director Huei Peng responded by presenting a test concept that would assess driverless vehicle safety in a controlled environment before vehicles go out on public roads. This concept could emerge as a voluntary standard.

The Mcity ABC Test is a three-tiered strategy that assesses autonomous vehicle safety. The three components are **A**ccelerated evaluation, **B**ehavior competence, and **C**orner cases, each of which achieves a different evaluation outcome.

Accelerated evaluation focuses on the most common risky driving situations, behavior competence in demonstrating the ability to be safe in a wide array of scenarios, and corner cases on pushing the limit toward the boundary (corners) of the automated vehicle performance and technology.

Mcity's leadership in conducting safety tests and advancing the Mcity ABC Test protocol was instrumental in securing U.S. Department of Transportation funding for the Michigan Mobility Collaborative, which aims to develop driverless shuttles to improve the quality of life for the senior population in Detroit. The Mcity ABC Test will be used to evaluate the safety of the selected automated driving system, from simulation to test tracks.

MARK PETERS
LEAD RESEARCHER

Key Management System Specification Project

Digital security keys ensure that when downloading software to a vehicle or one of its components, it's the correct software coming from the right place. Managing all of those keys has become increasingly complex, so Mcity researchers investigated creating a single, objective key management standard for car makers and suppliers.

Mark Peters, director of business development for Qualcomm and one of the project's leaders, began the research with a survey of the many different key standards and products being used throughout the industry. The next step was to create a protocol of interoperability by developing a list of use cases calling for key management. Using the Key Management Interoperability Protocol (KMIP) first released in 2010 by the Organization for the Advancement of Structured Information Standards (OASIS) as the foundation, Mcity researchers were able to augment existing KMIP profiles to include auto-industry-specific objects, attributes and operations.

Mcity's research jump-started the otherwise years-long standards process. The new specifications were sent to the Society of Automotive Engineers (SAE) for further development through the Vehicle Security Credentials Interoperability Task Force. The goal is to adopt a universal key management standard, creating an efficient and secure interface for generating and sharing keys without requiring suppliers and manufacturers to accommodate many different approaches.

ANOUCK GIRARD
LEAD RESEARCHER

ILYA KOLMANOVSKY
SHAN BAO
CO-RESEARCHERS

Modeling Human Behavior

Self-driving cars will likely be the first large-scale experiment in human-robot interaction as autonomous cars will have to interact with human-driven cars. Mcity researchers are developing a model of human drivers for self-driving cars to use for prediction, validation, and control.

Anouck Girard, Associate Professor of Aerospace Engineering at the University of Michigan, is modeling human drivers using hierarchical reasoning, or level-k game theory: drivers are grouped into levels and at each level are trained to behave in a way that gives them an advantage over the previous level. For example, level-0 drivers might behave more conservatively; using machine learning, level-1 drivers are trained to optimize their actions over level-0 drivers, such as learning to pass. Level-2 drivers learn to optimize their actions over level-1 drivers, and so on. The trained levels are then validated against naturalistic driving data, which shows that actual human driving behavior does match the levels, even the higher ones. The data can be used in a simulator with up to dozens of vehicles interacting in scenarios for testing and validation of automated vehicles, and for evaluating a vehicle's energy consumption.

Girard and her two co-principal investigators, Shan Bao and Ilya Kolmanovksy, have shown that using the game theoretical model results in vehicles that do not behave in pre-scripted ways, leading to traffic behavior that yields realistic driving patterns.

RESEARCH AWARDED IN 2019

SAFETY

Interactive Human–Autonomous Vehicle Dynamics in Traffic: Modeling, Simulation, and Control
Anouck Girard, Ilya Kolmanovsky, Shan Bao
CONNECTED & AUTOMATED TECHNOLOGY

Mcity ABC Test: Develop and Implement 16 Behavior Competencies
Huei Peng, Greg McGuire
CONNECTED & AUTOMATED TECHNOLOGY

Security Analysis of Machine-Learning-Based Sensing in CAV Systems
Qi Alfred Chen, Z. Morley Mao
CYBERSECURITY

Mcity Augmented Reality Testing Environment Development: Phase II
Yiheng Feng, Henry Liu
SIMULATION & TESTING

ACCESSIBILITY

Accessible Autonomous Shuttles: Human Factors, Challenges, and Design Solutions
Clive D'Souza
HUMAN FACTORS

COMMERCIAL/ ECONOMIC VIABILITY

Security Credential Management System (SCMS) 2.0
David LeBlanc, André Weimerskirch, Debra Bezzina
CYBERSECURITY

Standard Scenario Definition, Test-Case Generation, and Validation: Data Collection to Accelerate the Adoption of Simulation Software of HAVs
Huei Peng, Greg McGuire
SIMULATION & TESTING

IN THE COMMUNITY

Wheels & Heels at Mcity

In May 2019, Mcity was host to Ann Arbor Public Schools' A2 STEAM's first-ever Safe Routes to School bike and pedestrian training program, Wheels & Heels at Mcity. The event featured activity stations highlighting the many aspects of how to safely navigate the urban environment on foot or on a bike.

Students learn to safely cross the street during a Safety Routes to School session hosted by Mcity.

The initiative is part of the Safe Routes to School (SRTS) movement with a goal to make it safe, convenient, and fun for children – including those with disabilities – to bicycle and walk to school. When routes are safe, walking or biking to and from school is an easy way to get regular physical activity that children need for good health. SRTS programs also help ease traffic jams and air pollution, unite neighborhoods, and contribute to students' readiness to learn in school.

Trying Out Mobility Solutions

Wheelchair and scooter users visited Mcity in late March to try out the first installation of QUANTUM, a virtually autonomous wheelchair securement station being tested on 10 Ann Arbor Area Transit Authority (AAATA) buses. The devices, manufactured by Q'Straint, allow riders to independently secure their wheelchairs on public buses without assistance from drivers. Each device takes just 25 seconds to activate and lock.

The QUANTUM wheelchair stations are funded through the $8 million Michigan Mobility Challenge, a grant program through the Michigan Department of Transportation that addresses transportation needs for seniors, veterans and people with disabilities.

AAATA is the first urban transit agency in the state to test this technology on multiple vehicles. The acceptance of this system could have wider implications for mobility access in the disability community across the state.

AAATA passenger Kathleen Mozak-Betts tests QUANTUM securement technology.

Matching Students with Startups

TechLab at Mcity advances entrepreneurship and student careers by pairing mobility startups with engineering students. Interns gain experience in developing cutting-edge technology

Melinda Kothbauer's experience in TechLab helped her obtain a position at May Mobility.

at early-stage companies in the connected and automated vehicle industry, while obtaining real-world problem-solving skills that prepare them for post-graduation careers. Melinda Kothbauer, a recent Computer Engineering graduate, used her TechLab experience with the company Zendrive to obtain her current role with May Mobility as a robotics engineer.

Melinda's TechLab experience provided her with valuable skills in a variety of technical areas, such as data analytics, consumer product development, and vehicle-generated data. However, what she found even more valuable were the soft skills she gained through project management in a fast-paced environment, collaborating with various internal and external entities, and insight into the workings of a successful startup. Because of TechLab at Mcity, Melinda was well prepared to be an effective and impactful engineer. TechLab is managed by Michigan Engineering's Center for Entrepreneurship, in partnership with Mcity.

BY THE NUMBERS

51
Datasets available for researchers and Mcity members

59
Industry partners collaborating with Mcity on future mobility solutions

16,000
Mcity Driverless Shuttle trips from which data was collected

9,000
Hours of testing and engagement logged at the Mcity Test Facility since January 2017

1
Schoolbus located in the Mcity Test Facility

500
People from the general public who engaged in Mcity's Self-Driving Cars Teachout

120+
U-M graduate and undergraduate students involved in Mcity activities

50
U-M faculty across campus involved in Mcity-funded research

$28.2 million
Invested in research, development and deployment projects

24
Mcity-funded research projects active at this time

534
U-M students engaged in Mcity projects

1
Robotic deer in the Mcity Test Facility
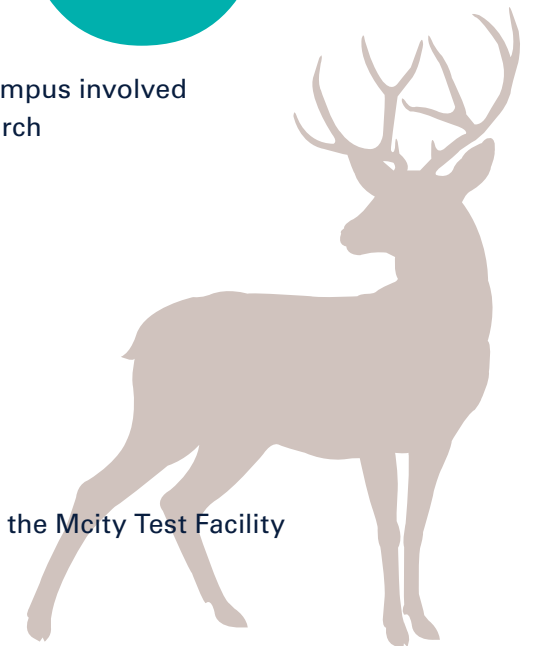
LEADERSHIP CIRCLE

AFFILIATES

· A P T I V ·

DENSO

●ECONOLITE

Ford

GM

HONDA
The Power of Dreams

intel

●LG
Life's Good

State Farm

TOYOTA

verizon

3M	Hitachi, Ltd.	Siemens
AISIN Group	Isuzu Technical Center of America, Inc.	Subaru
Analog Devices, Inc.		Swift Navigation
BMW	J.D. Power	Veoneer (formerly Autoliv Electronics)
CARMERA	Latham & Watkins LLP	
Changan Automobile	Lear Corporation	Visteon
Covington & Burling LLP	Magna International Inc.	Voxel51
Daikin America, Inc.	Marathon Petroleum Corporation	Warner, Norcross & Judd LLP
Danlaw, Inc.		Zenuity
Deloitte Consulting LLP	Mechanical Simulation Corporation	ZF
Desjardins General Insurance Group, Inc.	Metamoto	
Dow Coating Materials (A business unit of The Dow Chemical Co.)	Miller, Canfield, Paddock and Stone, PLC	
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Dykema	Nexteer Automotive	
EdgeConneX	NovAtel	
Fortive	OnBoard Security	
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	Progressive Casualty Insurance Company	
Harada Industry of America, Inc.	RAB Lighting Inc.	
Harman International Industries, Inc.	SAIC Motor Corporation Limited	
HERE Technologies	SF Motors, Inc.	

**Mcity Leadership Circle and
Affiliate Members as of December
2019**
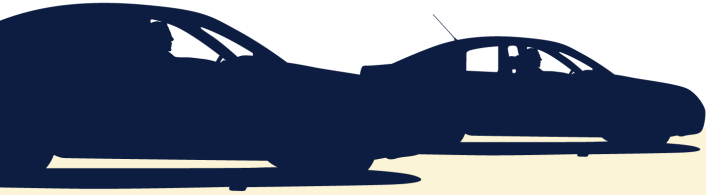
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