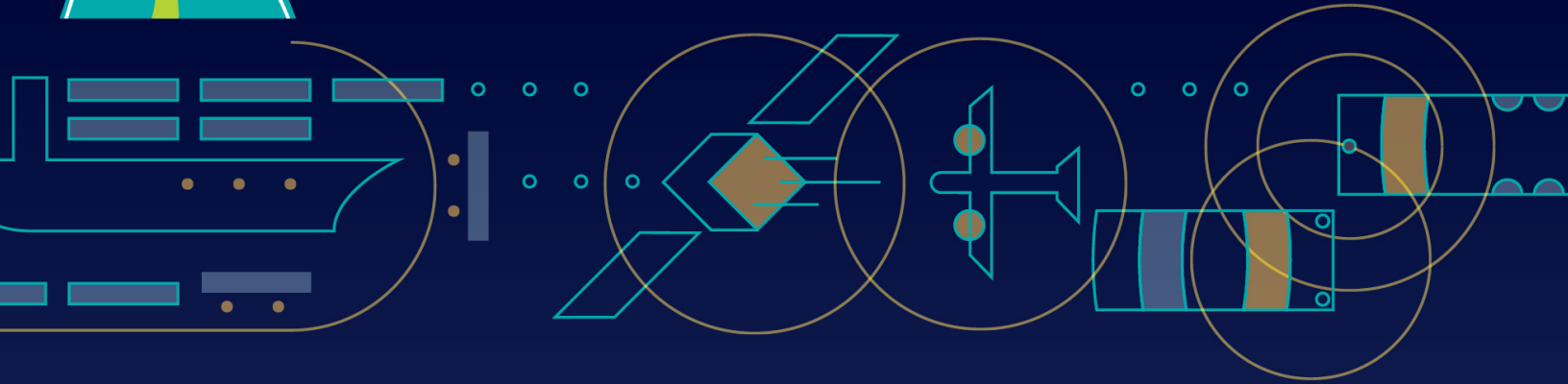# Beyond Traffic 2045

U.S. Department of Transportation

Reimagining Transportation
Technology, Disruptive Innovation, and the Future of Transportation

A Thought Leadership Speaker Series at Volpe

Notice

REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	**2. REPORT DATE** June 2016	**3. REPORT TYPE AND DATES COVERED** Final Report

4. TITLE AND SUBTITLE

Beyond Traffic 2045 Reimagining Transportation: Technology, Disruptive Innovation, and the Future of Transportation

5a. FUNDING NUMBERS

YP350/G228A

6. AUTHOR(S)

Bahar Barami, Ph.D., and Clark Merrefield

5b. CONTRACT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Office of Strategic Initiatives for Research and Innovation
U.S. Department of Transportation
John A. Volpe National Transportation Systems Center
55 Broadway
Cambridge, MA 02142-1093

8. PERFORMING ORGANIZATION REPORT NUMBER

DOT-VNTSC-16-01

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Department of Transportation
John A. Volpe National Transportation Systems Center
55 Broadway
Cambridge, MA 02142-1093

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

 Prepared under the direction of Ellen Bell, Director of Strategic Initiatives for Research and Innovation, Volpe

12a. DISTRIBUTION/AVAILABILITY STATEMENT

 This document is available to the public on the Volpe website: http//www.volpe.dot.gov.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

This report summarizes key findings from the *Beyond Traffic 2045 Reimagining Transportation* thought leadership speaker series held at Volpe, The National Transportation Systems Center, in the fall and winter of 2015.

14. SUBJECT TERMS

Beyond Traffic, innovation, planning, reimagining transportation, thought leadership, Volpe, Department of Transportation, future, transportation, automation, decision making, disruptive innovation

15. NUMBER OF PAGES

16

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** Unlimited

Contents

"Beyond Traffic is more than a document. We want it to be part of a
national conversation about transportation, and the choices we need to make in the 21st
century. This Volpe speaker series is a valuable part of that conversation."

Anthony R. Foxx
U.S. Secretary of Transportation

Imagining Our Transportation Future

Transportation innovation is happening at an unprecedented pace. We're seeing advances in communication, connected automation, data, navigation, robotics, and smart cities that just a few years ago would have seemed like pure science fiction.

We're entering a transportation landscape rich with possibility, and full of challenges. The next 10 years could bring more change to transportation and to the transportation workforce than we saw over the past century. A nation on the move must be a nation that is looking forward.

In 2015, U.S. Transportation Secretary Anthony R. Foxx released *Beyond Traffic 2045: Trends and Choices*, a comprehensive report on the major forces impacting our nation's transportation systems. The report frames critical policy questions by identifying trends that are shaping our transportation future.

We're poised to see major changes in car ownership, freight movement, population growth patterns, urbanization, vehicle miles traveled, and transportation-focused technologies. We're going to face significant challenges related to aging infrastructure, energy use, highway safety, network congestion, rising greenhouse gas emissions, and more powerful weather events.

The U.S. must always have a safe, reliable transportation system that can compete globally, but that won't be possible unless we answer some big questions. How do we build and pay for **infrastructure and capacity needs**? How can we do a better job **maintaining infrastructure**? What strategies can we use to **reduce emissions**? How can technology **enhance safety and efficiency**? How do we ensure our transportation system connects people to **economic opportunities**?

With *Beyond Traffic*, Secretary Foxx has identified the trends that will shape transportation in the U.S., and the challenges our nation will face. We can also now begin to understand the technologies that will help us meet those challenges.

Beyond Traffic 2045: Reimagining Transportation, a Volpe thought leadership speaker series, advances the conversation that Secretary Foxx's *Beyond Traffic* report started. This speaker series brought together top thinkers in business, technology, and transportation research to offer their perspectives on our transportation future.

Advancing the Conversation Beyond Traffic

Volpe's thought leadership speaker series, *Beyond Traffic 2045: Reimagining Transportation*, kicked off in fall 2015 with introductions from Secretary Foxx and Assistant Secretary for Research and Technology Gregory D. Winfree. They discussed obstacles to safe and efficient transportation, and how innovation may make tomorrow's transportation networks almost unrecognizable.

"Beyond Traffic highlights some big challenges we face as a country," Secretary Foxx said. "Of course, our infrastructure is aging and struggling to meet current demand. And in the next 30 years our country will have **70 million more people** competing for the use of our roads, transit and rail networks, and airports, putting even more pressure on an already constrained system."

Advances in automation, navigation, communication, and robotics coupled with a surge in transportation data will dramatically change how we move and deliver goods and services, Winfree added.

Throughout the series, distinguished experts explored the emerging technologies and disruptive innovations that will shape the next 30 years of transportation in the U.S. The underlying theme for each speaker was that innovations lead to tangible benefits only when we understand new technologies and how to use them.

Our U.S. transportation system can be safer, more efficient, resilient and environmentally sustainable, but long-term success demands new approaches.

-Gregory D. Winfree

Building off that underlying theme, the series addressed:

- **Innovation and Decision Making.**
  How we benefit from transportation breakthroughs will be determined by how well we plan for, invest in, regulate, and monitor new technologies.

- **Safety and Mobility.**
  Breakthroughs in automation, communication, and data collection will lead to significant improvements in traveler safety and system efficiency.

- **Sustainability.**
  Emerging research, strategies, and technologies can reduce the risks of climate change.

These are issues critical to the future of transportation in a nation moving beyond traffic.

Distinguished Experts

Innovation and Decision Making

Andrew McAfee, Ph.D.

Massachusetts Institute of Technology

Ken Gabriel, Ph.D.

Draper

Safety and Mobility

Surface Transportation

Chris Urmson, Ph.D.

Google

Anthony Townsend, Ph.D.

Rudin Center, New York University

Harry Lightsey

General Motors

Donald Fisher, Ph.D.

Volpe, The National Transportation Systems Center

Air Transportation

Edward Bolton

Federal Aviation Administration

John Cavolowsky, Ph.D.

National Aeronautics and Space Administration

Sustainability

John Heywood, Ph.D.

Massachusetts Institute of Technology

Innovation and Decision Making

Andrew McAfee
Massachusetts Institute of Technology

The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Transportation

Along the ever-upward curve of Moore's Law, computing power is at an inflection point where the curve is going to start to bend a lot, according to McAfee.

With extraordinary computing power poised to let machines perform fundamentally human tasks—such as driving a car—we are entering what McAfee calls, "a **second machine age**," in which, "key building blocks are already in place for digital technologies to be as important and transformational to society and the economy as the steam engine."[1]

So far, though, there isn't a computer that can think for itself. Will technology ultimately assist and augment us, or will it take over things we are used to doing for ourselves?

The answer is clear for McAfee: machines are much better at complex tasks than we perhaps ever thought they would be, but people still have an edge in common sense and creativity. How we strike a balance between **tasks** and **inspiration** will depend on whether we accept our limitations.

Humans are better than machines at pattern recognition and understanding context, but we also have a number of biases and glitches that hamper good decisions, McAfee said.

Decisions need to be based on sound data and not gut reactions, because data-driven decisions lead to demonstrably better outcomes. Or, as McAfee put it during his talk: trust the geeks, flee the HiPPOs—the highest paid person's opinions—which tend to favor gut reactions over quantitative analysis.

The goal is not to replace humans with machines, or to limit machines from doing what they can do better than humans—it's about finding the right mix.

> *There is a coming war to assist or replace human decision making. This is a war we will see play out not just in the transportation sector. I can't think of any corner of the economy that is going to be immune from this very deep question: Will technology assist and augment us, or will it take over things we are very used to doing ourselves?*
>
> -Andrew McAfee

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[1] Erik Brynjolfssson, Andrew McAfee, *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*, W.W. Norton & Company, 2014.

After the inflection point, the trendline of growth in advanced technologies is heading in the right direction and societal benefits are increasing significantly, McAfee said. However, he concluded that while the second machine age is making the pie of societal and economic benefits larger, how that pie will be divided is still a very open question.

"It is the choices we make as communities and as a society that will determine things like how wealthy we are as a group, the things we have access to, and how we share the bounty that's coming," McAfee said.

Dr. Andrew McAfee is co-founder of the Initiative on the Digital Economy at the Massachusetts Institute of Technology, and with Erik Brynjolfsson is author of *The Second Machine Age: Work, Progress, and Prosperity in a Time of Brilliant Technologies*.

Kaigham (Ken) Gabriel
Draper

Innovation…It's More Than a Buzz Word

Innovation is not a linear process with defined outcomes achieved through a single path, Gabriel said. How an innovation comes about can be as unique as the innovation itself. Teams of creative and dynamic researchers rarely reach breakthrough innovations and solutions by executing a preplanned roadmap.

Teams that do achieve breakthroughs have three key things in common, Gabriel said. First, innovative teams have the best employees, or "**jumpers**," who may come from other organizations or industries and are attracted by the chance to work on big, bold projects.

Second, innovative teams are independent from organizational constraints and micro-oversight, giving them the intellectual room to uproot common knowledge.

Third, they don't sit on their hands. A competing linear model that is at least 20 years out of date assumes that we should follow a prescribed roadmap to achieve innovation, Gabriel said. Because it is so prescriptive, team leaders working within this model rarely encourage ideas that run counter to accepted wisdom.

If you're going to have a significant impact on the 32,000 people killed every year in accidents, it's not going to happen from a technology roadmap. If you want to do something that is going to make a significant impact, it's going to go through something that defies this process.

-Ken Gabriel

Gabriel provided details on successful innovation from his experience as deputy director of Google's Advanced Technology and Projects Group (ATAP). At ATAP, Gabriel had only about a half-dozen employees on staff, but partnered with more than **40 organizations** in academia and in the public and private sector. This collaboration with companies big and small across four continents gave ATAP staff the flexibility to drive toward the next big thing.

"If we had had to hire that capability into Google, hiring 400 people and getting them facilities and equipment, we would still be pulling that project together," Gabriel said. "That's a really important part of getting these things done: not doing it all yourself, but to drive and manage it yourself."

Dr. Ken Gabriel is President and CEO of Draper. Previously, he was deputy director of Google's Advanced Technology and Projects Group, and a senior official at the U.S. Defense Advanced Research Projects Agency.

Chris Urmson
Google

Realizing Self-Driving Vehicles

A driver's brain processes an enormous amount of information every second. Drivers make the best decisions they can, based on all that input. Urmson explained that people, when they have their eyes on the road, are indeed good at recognizing and adapting to unusual situations.

For instance, if a driver approaches orange cones surrounding a road crew using jackhammers, he knows that it's time to switch lanes. Self-driving cars need to have enough information—enough driving experience through real-world and simulation testing—to do the same, he said.

To mimic this innate human capability, Urmson said Google equips its automated cars with detailed maps and sensors, to detect unusual patterns and understand the unexpected.

Just like human drivers, Google's self-driving car will come across situations it has never seen before: a bird that flies right in front of a windshield, a bicycle built for a half-dozen people, cars crossing lanes without warning, and vehicle doors suddenly opening into traffic.

"What our software has to be able to do is be able to say, 'This is not normal. This is what we call an anomaly,'" Urmson said. "And, just give [the anomaly] a little more space."

The one saving grace we have is that 94 percent of accidents are caused by human error. We have an opportunity through building software and systems that are going to pay attention 100 percent of the time, and are going to be able to respond quickly, to try and reduce accident rates.

-Chris Urmson

Google's self-driving car program does its real-world testing on the roads of Mountain View, California. Its cars travel **more than 10,000 miles** every week. In addition to road tests, the program includes extensive computer simulations, with more than **3 million miles** of simulation testing daily, Urmson said.

As part of the simulation program, the Google team focused on testing unexpected scenarios for roadway events. The team thought up abnormal situations—such as a pedestrian holding a giant rubber ball crossing in front of a self-driving car—to test the car's ability to recognize unexpected events.

Urmson emphasized that fatalities can be reduced dramatically in a world where self-driving cars are the norm. But, he added that there is still the human element to consider. Just because a technology is plausible does not mean it will be broadly accepted. Roads full of self-driving cars will only become a reality if there is a wholesale rethinking of what it means to drive.

"The idea is that you'll get in [self-driving cars], tell them where you want to go, they'll take you there and then get out," Urmson said. "You effectively are moving people from being the helmsman to the captain of the ship, which we think is empowering."

Dr. Chris Urmson is director of the self-driving car program at Google.

Anthony Townsend
Rudin Center, New York University

Re-programming Mobility 2030:
Scenarios of Digital Transformation in Metropolitan America

In major cities there are a range of players coming together to address challenges—like congestion, highway bottlenecks, and inadequate public transit—using *programmable mobility*, Townsend said. Congestion pricing, on-demand ridesharing services, and usage-surge pricing are all examples of innovations that can pick up where political will leaves off.

Drawing on *Re-Programming Mobility*, a report Townsend wrote with colleagues at New York University's Rudin Center, he identified four broad scenarios for the nation's transportation future: **growth**, **collapse**, **constraint**, and **transformation**. He identified the chain of policy choices and investment decisions that are likely to culminate in each of the four outcomes by 2045.

For the **growth** scenario, Townsend described a trajectory of urban development that would involve persistent, exponential growth in the economy and technological innovation. This scenario would be represented by developments in a city like Atlanta. By 2028, Atlanta would respond to growing traffic congestion through more sprawl. The scenario envisions advanced technologies that make alternative energy the main source of power for electric vehicles on automated highways. Demand for transportation, however, would not decrease, transit would not increase, and the automobile would remain the dominant mode of transport.

> *Our method is based on an inductive method that assumes pretty much any story that you can tell about the future falls into one of these four archetypes. The purpose of these scenarios is to get people out of what we saw as one-dimensional narratives for the future.*
>
> -Anthony Townsend

In the **collapse** scenario, Townsend outlined a set of possibilities in which traffic conditions would significantly deteriorate, as represented in a city like Los Angeles. In Los Angeles in 2030, cheap automated cars make up more than one-third of the vehicle fleet, but the influx of vehicles and congestion is not paralleled by regulatory oversight and standards. Some cars are programmed to be aggressive, while others are passive. Instead of parking their cars, owners send them to drive in loops, exacerbating urban congestion. The Los Angeles surface transportation system collapses from too much innovation, and too little oversight.

In the **constraint** scenario, there is a key resource that limits growth and leads to potentially unexpected innovations, Townsend said. Using New Jersey as his example, Townsend hypothesized that physical limitations mark the end of sprawl and the last major developable tract of land is sold in 2018. By 2029, New Jersey is a model of transit-oriented development. People live and work in dense clusters and get around by autonomous bus. Shared electric bike systems and automobile bans free up land that was used for parking for other development.

Finally, in the **transformation** scenario, Townsend envisioned change driven by high-tech innovation, with Boston as his prototype. Boston in 2032 would be, "a tale of two cities: a city of stuff and a city of people," Townsend said. Boston's large student population is drawn to small modular apartments that can be moved around the city. Goods are brought to these apartments at the press of a button on a wall screen. Possessions are stored remotely, and the small apartments receive up to a dozen shipments daily. At night, a logistics network of automated vehicles springs to life to deliver goods.

Townsend acknowledged that his scenarios are broad, but that they are designed to capture overarching visions with details that are not yet clarified. His intention for building these scenarios is to encourage the public and urban planners to examine the outcomes they find desirable and feasible for their networks.

"[The transformation scenario] is one that I think people gravitate to," Townsend said. "This is really the Silicon Valley narrative that allows us to grow even better with fewer externalities than before."

Dr. Anthony Townsend is a senior research fellow at New York University's Rudin Center for Transportation Policy & Management.

Harry Lightsey
General Motors

Industry Disruption: How Connectivity is Redefining Personal Mobility

Technological advances are not only poised to change how we move. With connected vehicles already making our traveling lives safer than ever before, they are poised to change how we *think* about how we move, Lightsey said. The focus is shifting from making cars safer during crashes to making cars that will avoid crashes entirely.

Lightsey identified four foundational changes that are making the auto industry and consumers rethink what a personal vehicle looks like, and how personal vehicles are operated.

The first change in automobile technology is the profusion of sensors, GPS location devices, and **information and communications technologies** embedded in every car. Sensors enhance driver awareness of risks inside and outside the vehicle, "inching our cars along a continuum toward successful crash avoidance," Lightsey said.

The second change is around **intelligence**. Vehicles today are incredibly intelligent computing platforms, with dozens of electronic computers that help while driving. Smart cars are changing how we interact with our vehicles, with screen displays and Internet access right on the dashboard.

The third change is that we are better **connected**. Sensors, smart computing platforms, and wireless communications are connecting vehicles to each other, to infrastructure, and to drivers and passengers. The move toward greater connectivity through wireless communication alone is accelerating at a great pace across the auto industry. More than 80 percent of cars by 2019 will be wirelessly connected in some way, Lightsey said.

The final change is that a greater diversity of engines is transforming **mobility** and offering environmental sustainability. Greater power train diversity has enabled the electric and hybrid-electric cars that complement the current fleet of internal combustion vehicles.

Lightsey predicted that the auto industry will be in a fundamentally different place in 10 years. Just as the telecom industry was upended by outside forces, Lightsey suggested that the automobile industry is undergoing foundational changes that may not come entirely from one of the major auto makers.

> *We've gone from an era of knowing crashes were going to happen and engineering and designing vehicles to withstand the crashes. But we have a huge pivot in our industry now where we know the best crash is the one that doesn't happen. So we're going from crash survival to crash avoidance.*
>
> -Harry Lightsey

"[In telecom] there was this guy from a different industry that said, 'We can create an $800 phone that people will stand in line to get,'" Lightsey said. "And it happened. I think that's the great thing about disruptive technology and technology transformation: it happens in ways that nobody expects."

Mr. Harry Lightsey is executive director of Global Connected Customer Experience for Public Policy at General Motors.

Donald Fisher
U.S. Department of Transportation
Volpe, The National Transportation Systems Center

User and Machine: Secrets to a Harmonious Marriage

After decades of declining road fatalities, during the first six months of 2015 there was a nationwide increase in traffic fatalities of **14 percent**, and a **30 percent increase** in traffic injuries, Fisher said.

"Beyond Traffic 2045 has as an imperative that we do something about automobile safety," he said.

To understand how automation will impact traffic safety within the next 30 years, we'll need to ask several key questions:

- Where will the car of tomorrow fall on the automation spectrum?

- Will our vehicles be fully automated, where we as drivers are completely out of the loop?

- Or, will the car of the future act as a safety net, leaving drivers in control but applying the brakes when we're not paying full attention?

Looking at the present, at the growing use of in-vehicle screens, audio-visual guidance, and numerous mapping and routing devices, we're already seeing a marriage between car and driver, Fisher said. With short-term traffic fatalities rising, the state of that marriage does not look very promising.

Looking at automation innovations to come, Fisher said there needs to be a shared vision, common goals, and transparent communication between manufacturers and drivers. These parties must have similar goals if we're going to have a future with cars that have various levels of advanced automation.

Right now, whether a shared vision is possible is still an open question.

"We still want to remain in control of our car. A University of Michigan Transportation Research Institute study indicated that 43.8 percent of drivers didn't want any autonomy," Fisher said. "It was only 15.6 percent who wanted full autonomy. What do the manufacturers of the future want? They want us out of the driver's seat. The vision doesn't seem to be a shared one."

To arrive at a shared vision, drivers and manufacturers will need to acknowledge a few questions that will arise as autonomous vehicle technologies progress, including:

- What are the liability issues at stake?

- In a crash involving a self-driving vehicle, who is at fault?

New technologies may dazzle, but they can also be harmful. Some heads-up displays, windshield-mounted navigation devices, and voice-recognition gadgets can create cognitive distraction, Fisher said. Your eyes might be on the road, but you might still miss a child walking in front of your car.

To find the right match between automation and our enhanced future well-being, safety, and convenience, Fisher suggested that we envision several other scenarios.

Rather than a future in which the car is the chauffeur, perhaps we should envision a future where the keys stay in our hands and the car serves as a lifeguard. In that future, driver-assistance technologies will help drivers avoid crashes, or reduce their severity, but drivers will still need to stay in control.

If there is one thing certain about the future, Fisher said, it is that it will be thoroughly unpredictable.

There's not just one marriage. There are going to be many, many, many marriages in the future. Marriages between autonomous, semi-autonomous, and non-autonomous vehicles, along with marriages between the driver, the pedestrian, and the bicyclist.

-Donald Fisher

Dr. Donald Fisher is a principal technical advisor in Volpe's Surface Transportation Human Factors division. He formerly served as head of the Department of Mechanical and Industrial Engineering at the University of Massachusetts Amherst.

Safety and Mobility: Air Transportation

Edward Bolton
Federal Aviation Administration

Leveraging Opportunities: Modernizing Our National Airspace System in an Evolving Environment

By 2030, air travel might not seem much different than it is today. We'll board a plane, go up to cruising altitude, and land at our destinations. The difference will be in what the average traveler doesn't see: more efficient routes that use less fuel, and flights that are even safer than they are today.

That's because behind the scenes the Federal Aviation Administration's NextGen program is already modernizing how pilots communicate with air traffic controllers, on the ground and in the air, Bolton said.

Across the national airspace, cockpit systems will provide satellite-based global positioning data on position, route, and engine health and performance. Digitization is also changing how control towers and pilots communicate, moving from voice-based to text-based messages. With satellite systems and improved communication, air traffic controllers are shouldering less of the burden for air domain surveillance and aircraft separation.

Built on a foundation of advanced avionics and satellite-based communications, by 2030 NextGen is expected to have generated **$134 billion in benefits** compared to $29 billion in costs, Bolton said. NextGen is so transformational and will generate such significant benefits in safety and efficiency, that there's only one historical comparison.

"In 1919, a young army lieutenant colonel was part of a cross-country convoy. It took 62 days," Bolton said. "Thirty-seven years later as president, Dwight Eisenhower was the father of the highway system. I would argue [NextGen] is the largest infrastructure transformation program this country has seen since the highway system."

Data sharing is another key benefit of the NextGen move to digital systems. NextGen already provides huge volumes of data not previously available to all players in aviation operations. Today about three dozen major airports already have the data-sharing platform that is the information backbone of NextGen, Bolton said.

> *Today we have the largest controlled, safest, most diverse, most complex airspace on planet Earth. But it's not a birthright. You've got to fight to keep it. We cannot handle the capacity that we're going to have in 20 years doing what we're doing today.*
>
> -Edward Bolton

Bolton stressed that there are still significant challenges to rolling out NextGen technologies across the entire national airspace. These include funding challenges, cyber security challenges, and safety risks associated with the entry of new players, novel aircraft modes, air space congestion and airport capacity constraints. New flight patterns—vertical as well as horizontal—could also pose challenges, Bolton said, and unmanned aerial systems will require major regulatory efforts to ensure safety.

But, known and unforeseen challenges are a given for a program as transformational as NextGen. Over the past decade the NextGen team has made progress by taking a measured approach, targeting bite-sized goals to achieve project milestones, Bolton said.

At the time of his talk, Mr. Edward Bolton was assistant administrator for the Federal Aviation Administration's NextGen modernization program.

John Cavolowsky
National Aeronautics and Space Administration

NASA's Strategy for Transformative Aeronautics

In just a few years the world of global aeronautics will face major disruptive challenges driven by three megadrivers, Cavolowsky said.

The first megadriver, **accelerated demand for air travel**, is spurred by economic growth in China and India, where urbanization and middle class growth are creating rapidly increasing demand for air travel. This growth will create intense wealth and population concentrations that will step up demand for rapid air and surface transportation, Cavolowsky said.

"Air transportation continues to be a critical global capability," Cavolowsky said. "An amazing statistic from the United Nations is that urbanization is occurring at a rate of seven Chicagoes a year."

Climate change is the next megadriver in transformative aeronautics. Through sustainable energy use and emissions controls, global demand for air travel must be met with new technologies that reduce emissions, Cavolowsky said.

The third megadriver, **new technologies and standards**, has created a convergence with the potential to bring together nano-, bio-, and cognitive technologies, Cavolowsky said.

This convergence is evident in advances in robotics, and in unmanned aerial vehicles (UAVs) used for transportation, commerce and manufacturing, Cavolowsky said. The automobile manufacturing industry, he said, is a driving force in technological convergences as it moves toward self-driving cars and on-demand transportation—and offers a framework to make on-demand aviation available to more people than ever before.

Although UAVs are not yet an integral part of freight service, their emergence is a critical development that must be monitored, Cavolowsky said. He speculated that the day may not be far off when UAVs are delivering packages and inspecting infrastructure and agriculture.

NASA will be a key player in making real the trillion-dollar potential of the unmanned aircraft industry, and will be looking to "provide an operational system where individual operators of these vehicles can subscribe to provide a proposed flight, to have that flight managed within a safe constraint to perform their business operations, whether public service or otherwise," Cavolowsky said.

Traffic management for unmanned aircraft will not look like traffic management for commercial aviation. Cavolowsky noted that NASA wants to provide an operational system for unmanned aircraft soon—but, "it has to be done safely."

Instead of rooms where human controllers monitor airspace, traffic management will be cloud-based with virtual perimeters based on the proposed path an aircraft will fly. By 2019, NASA expects a traffic management prototype will allow unmanned aircraft to fly, even in dense urban areas.

The lodestar for an aviation sector pursuing transformative aeronautics in the 21st century is to be inspired by an array of advanced automation partners who are working to make transportation safer and more efficient, Cavolowsky said.

What we need to do from the aviation side is to really connect with the broader community, the ground automation capabilities. They're developing standards for autonomous operations right now. How do we take advantage of that to leverage what they're learning?

-John Cavolowsky

Dr. John Cavolowsky is director of NASA's Airspace Operations and Safety Program.

Sustainability

John Heywood
Massachusetts Institute of Technology

Toward 2050: Options for Reducing Light-Vehicle Energy Use and GHG Emissions

Fossil fuels are the primary way we power vehicles that get people and goods where they need to go—and the transportation sector is the second-biggest source of greenhouse gases (GHGs) in the U.S.

Heywood identified a blueprint that the transportation sector can use to reduce GHGs: **improve** fuel consumption, **conserve** energy, and **transform** the nation's vehicle fleet.

To improve fuel consumption and reduce emissions, we'll need new vehicle propulsion technologies and consumer markets that demand more electric and hybrid cars and light trucks. Heywood estimated that the use of current internal combustion systems may drop over the next three decades, from 90 percent of cars and light trucks on the road to 50 to 60 percent, but that current alternatives to gasoline engines in themselves are not up to the task of drastically reducing GHGs. He noted that we're making strides in changing engine design and manufacturing but that our progress is slow, and emission reductions will not be enough.

Conserving energy will require changes in demand, Heywood said. We'll have to drive less and reduce vehicle use, so that less fuel is used overall. Reducing demand is an untapped area, he noted. It would require rigorous transportation planning and investment that curbs urban sprawl, creates greater density so that people don't have to drive far to work, and makes public transit more readily available.

> *Transportation is special in its energy needs in that the propulsion systems are almost all internal combustion engines today, and they fit what we want remarkably well. Except that their impacts are very unattractive, and we've got to change those impacts.*
>
> -John Heywood

Transforming the nation's vehicle fleet will rely on market-based pricing mechanisms that gradually move vehicles away from diesel-based engines and toward alternative fuels. These mechanisms could include a mix of market incentives that lower the price of alternative-fuel vehicles, and also introduce pricing penalties on GHG emissions through strategies such as emissions caps and higher fuel taxes, Heywood said. He cautioned that achieving significant impacts—with 25 to 30 percent of the national fleet equipped with engines that generate little or no GHGs—will be slow.

"These [strategies] all need to be worked on intensely. I'm not saying number one is more important than number three," Heywood said. "The challenge is that very few of us can focus on three things at
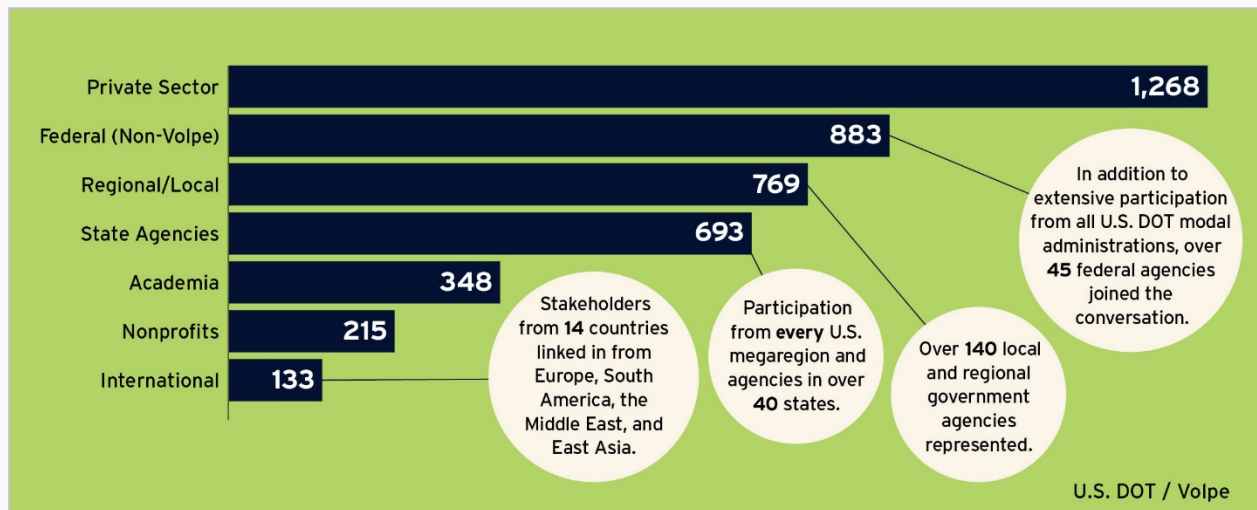
once—seriously focus. We've got to seriously focus on three things, not every one of us, but in our thinking and planning, we have to focus on these three."

Dr. John Heywood is a professor of mechanical engineering and is Sun Jae Professor, Emeritus, at the Massachusetts Institute of Technology.

How Volpe's Thought Leadership Engages Stakeholders

Beyond Traffic 2045: Reimagining Transportation engaged a range of stakeholders in government, industry, academia, and non-profit organizations in an important dialogue on the future of transportation in the U.S. This series built on Volpe's 2014-2015 thought leadership series, *Transportation and the Economy*. In addition to **1,200 seats filled** and standing-room-only for many of the speakers there were more than **4,700 online registrations** across both series. The graph below shows the number of audience members for both series by sector.

Private Sector: 1,268
Federal (Non-Volpe): 883
Regional/Local: 769
State Agencies: 693
Academia: 348
Nonprofits: 215
International: 133

Stakeholders from **14 countries** linked in from Europe, South America, the Middle East, and East Asia.

Participation from **every** U.S. megaregion and agencies in over **40** states.

Over **140** local and regional government agencies represented.

In addition to extensive participation from all U.S. DOT modal administrations, over **45** federal agencies joined the conversation.

U.S. DOT / Volpe

For More Information

For more information on Volpe's thought leadership programs, please contact:

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For feature stories, video highlights, speaker bios, and additional information from the *Beyond Traffic 2045: Reimagining Transportation* speaker series, please visit:
https://www.volpe.dot.gov/events/reimagining-transportation-speaker-series.