HISTORY OF INTELLIGENT TRANSPORTATION SYSTEMS

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16. Abstract ITS capabilities have matured significantly over the past 25 years since the ITS Joint Program Office was created, and this document celebrates the advances in this field and explore its exciting future, while also serving as a guide for future ITS research programs. Our nation stands now at the cusp of revolutionary changes to our transportation system, including connected and automated vehicles, making it a particularly apt time to look back at the history of ITS and reflect on what we can learn to help shape the future.		
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EXECUTIVE SUMMARY

At this moment, our nation stands at the cusp of some of the most revolutionary changes to our transportation system in decades. Connected and automated vehicles are closer than ever to being part of our everyday world, and the decisions we make regarding these and other advanced technologies could profoundly affect the future of transportation. As we move toward a more intelligent and connected transportation system, it is important to reflect on the history of the field, recognize lessons learned, identify trends and their historical implications, and acknowledge both the successes and the failures that have brought us to our current point in the evolution of intelligent transportation systems (ITS).

> **"The history of ITS was greatly influenced by specific champions who pushed the branding of ITS and created a much-needed consciousness of what ITS can do.**
>
> —Scott McCormick, President of the Connected Vehicle Trade Association

ITS is an operational system of various technologies that, when combined and managed, improve the operating capabilities of the overall system. According to a recent national survey conducted by the University of Iowa, there are very large gaps in the public's knowledge about ITS.[1] Many people have little knowledge of "formal" ITS, yet they benefit from its existence every day. ITS technology is the phone application that you use to determine how long to wait before walking to catch the next bus. It is your car's advanced braking system that monitors wheel speed and adjusts brake pressure

1 http://www.sltrib.com/home/2929434-155/survey-shows-big-gaps-in-knowledge

so that you can stop quickly and safely without losing control of your vehicle. ITS allows you to drive at highway speeds through toll collection kiosks, and helps you determine the exact location and delivery date of your online purchase with just a few clicks of the mouse. Moreover, ITS technologies (such as GPS use for mapping and positioning) and operational advancements (such as coordinated traffic management centers) allow quick and efficient mobilization of responders to an incident by providing real-time traffic, route, weather, and even hazardous material information across agencies.

Without question, ITS technology has made transportation safer and more efficient. While many think improving our nation's transportation system solely means repairing aging infrastructure or building new roads, the future of transportation lies not only in these efforts, but also increasingly in implementing ITS technologies. The benefits of ITS are wide reaching and applicable to urban and rural populations; commuters and commercial truck drivers; and pedestrians, bikers, and public transportation system users. Building on decades of ITS research and deployments, the very near future will likely include vehicles that can talk to one another and roadside infrastructure to avoid collisions, improve congestion, and recognize environmental benefits. ITS will enable automated vehicles to interact with the transportation system—a concept that has captured the human imagination for decades, and is closer than ever to widespread deployment.

> “We are not just in the transportation business. We are in the quality of life business.
>
> – James Pol, Technical Director, Federal Highway Administration Office of Safety Research and Development

ITS technology has already had a significant impact on the current transportation environment. We are now on the verge of greater benefits and impacts due to advances in technology. For example, connected vehicle technology research indicates that vehicle-to-vehicle safety systems may address up to 80 percent of collision-based accidents where the driver is not impaired. Fully automated vehicles may offer even greater safety benefits. As research, development, and deployment marches on, these advanced solutions will increasingly yield even more mobility, environmental, safety, and other benefits.

Over time, the ITS field has evolved, not only technologically but also in the area of public and private interactions. The relationship between industry and the government has progressed into an essential partnership, which has catalyzed the development of new technologies. This partnership is critical to the success of ITS. This report will highlight both public and private agency investments and advances, often achieved through collaborations between the two.

The United States Department of Transportation (USDOT) Intelligent Transportation Systems Joint Program Office (ITS JPO) commissioned this report in part to celebrate the convergence of three milestone anniversaries occurring in 2016—the USDOT's 50th anniversary, the ITS JPO's 25th anniversary, and the 60th anniversary of President Eisenhower signing the Federal-Aid Highway Act. In addition to celebrating these milestones, the ITS JPO wants to highlight the history and future of ITS developments and how these technologies have shaped our current environment and will influence our future.

The *History of ITS* report is organized chronologically, starting with early ITS history (prior to 1980). Each successive chapter covers a one-decade span, from the 1980s to the present day; the final chapter discusses the future of ITS. The chapters explore the socio-economic environment, policy and programs, and research and technology developments specific to each time period.

Experts from a variety of professional backgrounds were interviewed:

Total number of interviewees: 32

Interviewees from the public sector: 19

Interviewees from the private sector: 6

Interviewees from associations: 5

Interviewees from academia: 2

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CHAPTER 1

Photo Source: General Motors

THE EARLY HISTORY

The Socio-economic Environment

The promise of a future with technologically advanced transportation options has occupied the collective American imagination for decades. The tagline of the 1939-1940 New York World's Fair promised to show visitors "the world of tomorrow." Arguably, the most popular feature was a ride called Futurama in the General Motors Pavilion. Futurama attracted huge audiences; many waited in line for hours to experience possible life in the then-distant future year 1960.

The Futurama ride carried visitors past miniature yet realistic landscapes that focused on what transportation might look like in 20 years. Simultaneously, a narrator described this futuristic utopia forged by sophisticated transportation planning. Highways ran through rural farmland before moving into well-ordered cities. Automated vehicles had radio controls to help them maintain a proper distance from one another.

In 1939, there was no interstate freeway system, and many people did not own a personal vehicle. The audience left this exhibit with new ideas of what was possible and particularly new visions for the future of transportation, setting the stage for a period of incredible transportation advancement.

Pre-1980

- ITS was a "champion"-driven vision among public, private, and academic institutions.
- Transportation professionals recognized the limits on surface transportation capacity.
- ITS research during this time focused on specific in-vehicle navigation and route guidance systems.
- Technology was developed opportunistically, and there was little original equipment manufacturer (OEM) interest.

Futurama 1939 New York World's Fair "To New Horizons" 1940 General Motors:

https://www.youtube.com/watch?v=1cRoaPLvQx0

https://www.youtube.com/watch?v=-JFgpxYaeJQ

The American car culture began to form during the early 20th century. The first three-colored traffic signal was deployed in 1914, and the first parking meter was installed in 1935. In the 1920s alone, the number of passenger cars registered in the United States nearly tripled, from 8 million to 23 million.[2] Automobile sales slowed during the 1930s and early 1940s, due to the Great Depression and World War II. Around 30 million motor vehicles (cars, trucks, and buses) were registered in 1937.[3] The number of vehicles grew only slightly over the next several years, from about 32 million in 1940 to 33 million in 1946.[4]

After World War II, the United States experienced economic growth and increased land development. Factories, which were previously supplying wartime needs, switched to producing automobiles. Automobile sales accelerated again in the mid-1940s, partly because many middle-class families left cities for the new suburbs. By 1950, the number of registered vehicles had risen to 49 million.[5]

In 1956, Congress passed the Federal-Aid Highway Act, which led to the creation of the U.S. interstate network. The 41,000-mile system was planned to reach every metropolitan area with a population larger than 100,000.[6] Interstates opened up more land for development, and suburbs continued to expand from city edges. By 1960, the number of vehicles on the road totaled nearly 75 million.[7] Over the ensuing decades, as speed and congestion increased, so did the prevalence and severity of collisions.

Throughout the 1950s, commuting standards changed as more workers moved to the suburbs. The suburbanization of retail and the rise of the shopping mall followed the suburbanization of residences. Starting in the 1970s, businesses followed suit. Highways exceeded capacity with people commuting from one suburb to another.

On October 15, 1966, an act of Congress established the United States Department of Transportation (USDOT). Prior to this, the Under Secretary of Commerce for Transportation administered many of the functions that are now associated with the USDOT. Safety had been a recognized automotive issue since the mid-1930s, but government agencies began setting vehicle and highway safety standards starting in the 1960s. Seat belts, padded dashboards, standard bumper heights, and dual braking systems became mandatory for new cars in 1967. Later, standards such as air bags and child car seats were implemented. The Highway Safety Act of 1970 established the National Highway Traffic Safety Administration (NHTSA). Concepts for the use of advanced technologies on the nation's transportation system emerged at this time, but pre-dated a national ITS program. During this early period, the roots of ITS can be seen in research initiatives and deployments undertaken by states and regions, academic institutions, and the automotive industry.

2 http://www.ushistory.org/us/46a.asp

3 Kaszynski, William. *The American Highway: The History and Culture of Roads in the United States.* eBook. Google Books. Page 111.

4 Lukacs, John. A New Republic: *A History of the United States in the Twentieth Century.* eBook. Google Books. Page 109. Rose, Mark H. & Raymond A. Mohl. *Interstates: Highway Politics and Policy Since 1939.* eBook. Google Books. Page 31.

5 Rose, Mark H. & Raymond A. Mohl. *Interstates: Highway Politics and Policy Since 1939.* eBook. Google Books. Page 31.

6 http://www.econedlink.org/lessons/projector.php?lid=725&type=educator

7 http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1623457

Safety, decreased congestion, and improved mobility were the key driving forces behind ITS. The public sector has historically focused more on safety and environmental benefits. Private sector research and development, particularly during these early years, focused more on convenience and mobility. While coming at these various issues and technologies from different places, the two sectors have often converged in their approaches over time, resulting in joint projects and investments that have provided a variety of benefits.

Research and Technology Developments

Navigation and Mapping Technologies

U.S. research into proximity beacon navigation started with General Motor's Driver Aided Information and Routing System (DAIR) in the mid-1960s.[8] A car with DAIR could send an emergency message to a service center, including information on road conditions. The system relied on magnets buried at regular intervals along the road (generally between 3 to 5 miles apart) and used binary code to communicate location information. DAIR included a display panel on the car's dashboard that would show warning messages regarding road hazards and had a system that could guide a driver along a pre-determined route. General Motors installed this technology in two 1966 vehicles and tested it at their testing center in Detroit, Michigan. Ultimately, General Motors could not muster the resources necessary to deploy the system. The two DAIR-equipped cars were never tested outside General Motors' facilities.

U.S. Interstate Highway construction in Seattle, Washington, in 1963.

Photo Source: Federal Highway Administration

Interstate Growth/ Density Map:

http://www.fhwa.dot.gov/interstate/densitymap.cfm

The DAIR project was closely followed by the Bureau of Public Roads (now the Federal Highway Administration) Experimental Route Guidance System (ERGS) in the late 1960s. ERGS transmitted radio communications between the vehicle and roadside units. Several organizations under contract to the Office of Research and Development of the Bureau of Public Roads, including General Motors and Philco-Ford, investigated the system concept. Several prototype ERGS roadside units were installed at intersections around the eastern United States, including two in Washington, DC.[9] In the 1970s, the project was ultimately discontinued due to the expensive infrastructure required, but similar approaches were deployed during this timeframe in Germany and Japan.

New communications approaches and the development of map-matching algorithms gave rise to alternatives to the proximity-beacon approach. Map-matching algorithms were first developed in the 1970s and supplemented existing technology in early navigation systems. Networks of roads were modeled in a digital map database, in which a particular route could be programmed mathematically. An onboard computer was used to analyze dead reckoning[10] inputs and match the vehicle's path to the programmed routes. Robert L. French developed the first map-matching

8 http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=1623457

9 *Popular Science*, 1969. https://books.google.com/books?id=GSoDAAAAMBAJ&pg=PA102&lpg=PA102&dq=electronic+route+ERGS+public+roads&source=bl&ots=OfWo7zeEPO&sig=IsGrGCAngWuyD3a7DXqRmKdU5qY&hl=en&sa=X&ved=0ahUKEwjXttiukOfLAhVEqR4KHZ1SDiwQ6AEIQjAJ#v=onepage&q=electronic%20route%20ERGS%20public%20roads&f=false

10 Dead reckoning is the process of calculating one's current position by using a previously determined position, and then using estimated speeds, as well as elapsed time and course information, to advance that position (http://www.britannica.com/technology/dead-reckoning-navigation) system, called the automatic route control system (ARCS), in 1971[11]. First developed for a newspaper delivery route, it used map-matching technology paired with real-time route guidance. A pre-recorded voice message played at appropriate points in the route. For this technique to work, the vehicle was generally assumed to follow a predetermined road, but there was uncertainty when the vehicle traveled off-road because there was no way to correct for errors. A second version of ARCS gave route directions visually by using a plasma display panel and simple graphics.

Starting in the 1970s, transit agencies in North America were the first adopters of an early generation of bus automatic vehicle location (AVL) mapping technology using wayside signpost beacons as a location tracking method. Early AVL systems essentially provided simple vehicle position confirmation. One of the first techniques involved burying magnetized strips of metal in the roadbed. As a transit vehicle passed over the magnetized strip, a pickup coil on the vehicle detected a coded pattern, which was used to identify the vehicle location. This system was very costly and required significant maintenance. Present-day AVL systems offer sophisticated real-time vehicle location tracking and schedule monitoring using more advanced technology.

A dynamic message sign alerts drivers of an incident ahead.

Photo Source: https://en.wikipedia.org/wiki/Variable-message_sign#/media/File:MN_Changeable_Message_Sign.jpg

Loop Detectors

Loop detectors have become the most widely used sensors in incident detection systems. Loop detectors can estimate vehicle speed as well as measure flow and occupancy. Inductive loop detectors consist of one or more loops of wire embedded in the pavement and connected to a control box. When a vehicle passes over or rests on the loop, the change in current flow (or inductance) of the loop indicates the presence of a vehicle. Vehicle detection loops are often used at traffic lights to detect the presence of traffic waiting at the light and are used to activate a traffic control device, thus reducing the green-signal phase time for empty roads.

Dynamic Message Signs

A dynamic message sign (DMS) is an electronic traffic sign that provides information and warnings to travelers. These signs can be used for a variety of messaging purposes, including informing drivers of traffic congestion, upcoming accidents, roadwork zones, or changing speed limits. First deployed in the 1960s, DMS continue to provide helpful information on the roadways today. The signs have been instrumental in non-traffic-related applications including providing the foundation for the AMBER Alert system, which relays vital child abduction notifications.

Poorly designed and managed freeway entrance ramps can have significant adverse mobility and safety impacts on nearby freeways and arterials.

Photo Source: http://www.greencarreports.com/news/1095932_milan-pays-drivers-to-leave-cars-at-home-take-public-transit

Ramp Management

The 1950s brought research into ramp management techniques as a potential solution to highway safety concerns. In 1963, the first ramp meters were deployed along Chicago's Eisenhower Expressway. An onsite traffic enforcement officer manually controlled these early meters.[12] Over the next several years, subsequent ramp meters were successfully deployed in Detroit and Los Angeles. In 1967, Los Angeles implemented the first known ramp closure. In 1972, Minneapolis introduced a bus bypass lane at its metered ramp to promote the use of mass transit.[13] Since this

11 https://www.researchgate.net/publication/3155668_Automatic_route_control_system

12 https://www.oregon.gov/ODOT/HWY/ITS/pdfs/benefitsofits/rampmeteringstatus1995.pdf

13 http://ops.fhwa.dot.gov/publications/ramp_mgmt_handbook/manual/manual/1_1.htm

time, ramp management strategies have evolved and thrived. Today, ramp metering strategies are commonplace in jurisdictions across the United States and are shown to have safety, mobility, and environmental benefits.

Poorly designed and managed freeway entrance ramps can have significant adverse mobility and safety impacts on nearby freeways and arterials.

Integrated traffic management centers are the center of most modern freeway management systems.

Photo Source: http://sdotblog.seattle.gov/2011/11/04/traffic-responsive-operations-reduce-delays-during-viaduct-shutdown-and-beyond/

Traffic Management Centers

The first North American traffic management centers (TMCs) were deployed in the late 1960s. The TMC is the hub or center of most freeway management systems. The TMC collects and processes data about the freeway system such as weather, speed, congestion, incidents, and special events. This data is fused with other operational and control data and distributed to stakeholders such as the media, other agencies, and the traveling public. TMC staff use the information to monitor and manipulate freeway operation. TMCs are an operational epicenter where agencies can coordinate their responses to traffic situations and incidents. The role of a TMC often goes beyond the freeway network, functioning as the key technical and institutional hub to bring together the various jurisdictions, modal interests, and service providers. Together, these entities can focus on their common goal of optimizing the performance of the entire surface transportation system.

Global Positioning Systems

The global positioning system (GPS) consists of a network of satellites that transmit signals to GPS receivers. The signals carry a time code and geographical data that allow users to pinpoint their exact speed, position, and time. GPS was originally designed for military and intelligence purposes during the 1960s, at the height of the Cold War. In the 1980s, GPS was released for use in civilian applications.

During the 1990s, civilian use of GPS became more available and affordable. Today, millions of users rely on GPS to navigate with great accuracy whether on land, air, or sea. Drivers can use in-vehicle portable navigation devices to find the most efficient route, find traffic detours, and even receive traffic alerts or warnings regarding safety camera locations.

Top Photo: The first hand-held consumer GPS device was the Magellan NAV 1000.

Photo Source: https://timeandnavigation.si.edu/multimedia-asset/magellan-nav-1000-gps-receiver-1988

Bottom Photo: This equipment was the basis of a federal experimental emergency response system from 1995. The system was tested in Colorado and relied on GPS data, cellular telephone connections, and map databases. Ford's Remote Emergency Satellite Cellular Unit and General Motor's OnStar superseded this test system.

Photo Source: https://timeandnavigation.si.edu/multimedia-asset/emergency-vehicle-location-system

GPS-based AVL systems were generally adopted by many transit agencies in the late 1990s. GPS enables geographic information systems (GIS), which store, analyze, and display geographic information. GIS is used to monitor vehicle location, which keeps transit vehicles on schedule and informs passengers of precise arrival times. Mass transit systems use this capability to track rail, bus, and other services to improve on-time performance. This technology also enables efficient response to emergency scenarios.

GPS is an essential element in the future of ITS because it offers increased efficiencies and safety for highways, streets, and mass transit systems. Many new capabilities are possible due to GPS, such as instant carpools that match riders with nearby vehicles in real time.

Early Mobile Robotics

In the late 1960s, the Defense Advanced Research Projects Agency (DARPA) funded a project at the Stanford Research Institute to create the first mobile robot with the ability to perceive and reason about its own actions. The robot, named Shakey, was designed to perform navigation and exploration tasks using various sensors, range finders, and a TV camera. *LIFE* magazine featured Shakey in a 1970 issue, referring to the robot as the "first electronic person."[14] Shakey was considered a failure at the time for never reaching autonomous operation. However, the project established functional and performance baselines for mobile robots.[15]

Robotics research has been instrumental in the development of many ITS technologies. The navigation, sensory, and exploration functions that mobile robots use have been developed and transferred into technologies such as connected and automated vehicles.

In 1960, an engineering graduate student originally developed the Stanford Artificial Intelligence Laboratory Cart to study the potential of controlling a moon rover from a control station on Earth. Over the next 46 years, the Stanford Cart was reconfigured multiple times to serve in different capacities. In 1979, the Stanford Cart made mobile robotic history when it autonomously traveled across a room filled with chairs. The travel time for this historic feat? Approximately 5 hours.[16]

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14 https://www.sri.com/work/timeline-innovation/timeline.php?timeline=computing-digital#!&innovation=shakey-the-robot

15 http://www.dtic.mil/dtic/tr/fulltext/u2/a422845.pdf

16 http://www.wired.com/2012/02/autonomous-vehicle-history/

CHAPTER 2

THE 1980s

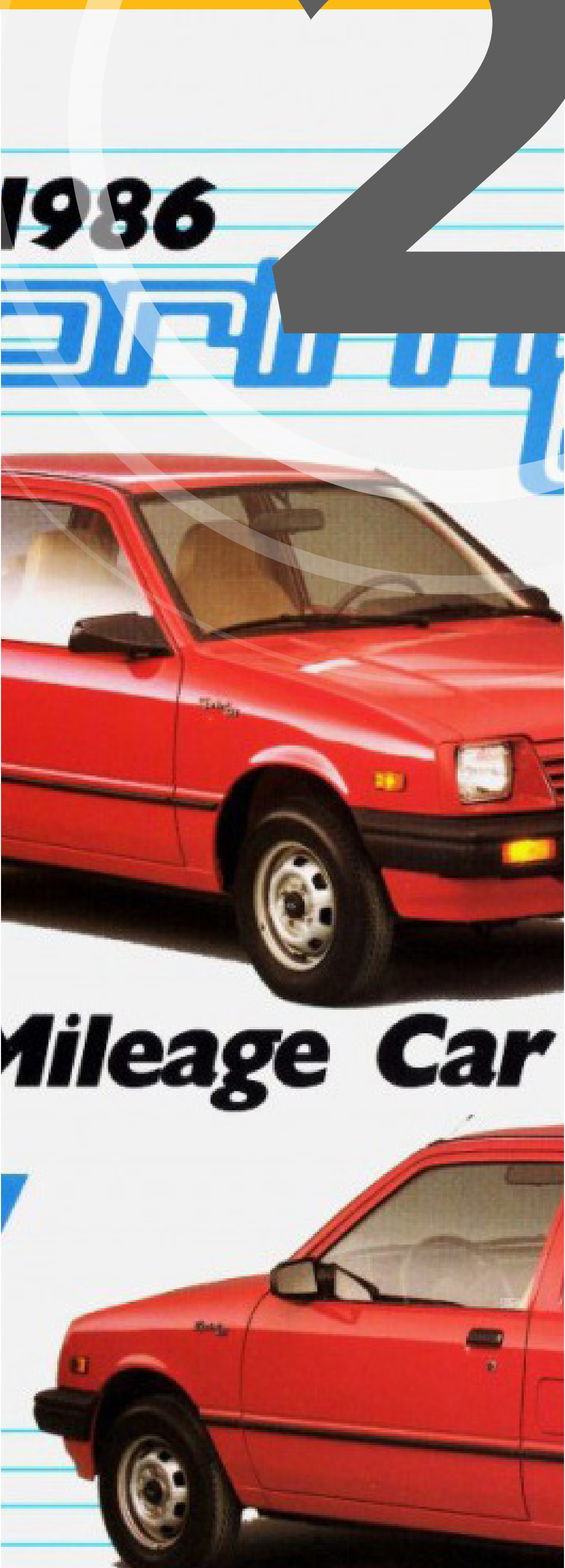

Photo Source: www.autosbunch.com

The Socio-economic Environment

During the 1980s, major changes appeared to be on the horizon. Legacy transportation programs, long in place, began to appear less suitable for the future, and Americans started to reconsider their relationship to transportation. Safety and environmental concerns became the increasing focus of transportation policy. There were 51,091 highway fatalities in 1980, and gas shortages in the 1970s led to a Congressional mandate that required new vehicles to get a minimum number of miles per gallon of fuel.[17] In addition, widespread concern about air pollution and the environment led Congress to start regulating automobile emissions.

During the 1980s, in the midst of these concerns, technology became cheaper and smarter—and technologies supporting improved traffic management emerged. Government agencies saw new possibilities for information, sensing, communication, and controls technologies to solve the environmental and safety problems associated with transportation. The transportation industry recognized new highway infrastructure-based technologies as a competitive business opportunity that would add value to their products. New technological developments—microprocessors, computers, sensors, new communications technologies, and GPS—were emerging with direct transportation implications.

This decade coined the term intelligent vehicle highway system (IVHS), which described a group of technologies (including information processing, communications, control, and electronics) that connect vehicles to infrastructure to improve the safety and efficiency of transportation systems. During this decade, there was no formal national IVHS program. However, much of the work in the 1980s set the stage for the current and future state and evolution of ITS, and enabled the development and implementation of advanced technologies across transportation areas in subsequent decades.

17 http://www.statisticbrain.com/car-crash-fatality-statistics-2/

In 1981, the first commercial car navigation system, the Honda Electro Gyro-Cator, was made available.

Photo Source: http://jalopnik.com/the-first-commercially-available-car-navigation-system-1574754802

Policy and Programs

Three significant trends were evident in the 1980s:

1. Public interest and state/local organizations formed a coalition to develop new Federal-aid transportation program proposals.
2. In the United States, Europe, and Japan, industry research focused on potential ways to apply new technology to transportation in the form of IVHS concepts.
3. State, federal, and university researchers organized meetings to discuss the potential of advanced technology.

During this decade, several universities started formal research programs focused on advanced technology in surface transportation. The California Program on Advanced Technology for the Highway (PATH)[18] was one of the most visible of these programs. PATH was founded in 1986 as a collaboration between the University of California at Berkeley and the California Department of Transportation (Caltrans), and is still an active and leading-edge research institution.

At the same time, the USDOT funded a modest program of university research and in-house "automated vehicle highway systems" research. The ERGS program started in the early 1970s and evolved into ARCS. ARCS was the first autonomous route guidance system that used an on-board computer with digitized maps, map-matching software, and a dead-reckoning subsystem. The Federal Highway Administration (FHWA) Traffic Systems Division collaborated with several universities on and conducted other small-scale exploratory projects in freeway management, advanced traffic control, computer simulation, and driver information systems. At the same time, visible, well-funded programs in Europe and Japan spurred global interest in the potential of related technology applications.

In a few areas around the United States, "pioneer" applications of advanced technology emerged in major arterial traffic control, traffic conditions information sharing, and electronic tolling. At the end of the decade, industry leaders who were interested in these new technologies organized a series of increasingly formal meetings. This group dialogue evolved into Mobility 2000, formed as an advocacy group in 1989 to represent the new technology perspective in policy formation. Mobility 2000 was predominantly a volunteer activity and had no formal authority. However, it played an important role in bringing together advocates from a variety of institutions, including state and federal governments, industry, consulting, and academia to represent the new technology perspective in policy formation. Mobility 2000 mobilized support for a national IVHS effort and sponsored the first National Leadership Conference on IVHS. The organization was essential in determining a conceptual definition for IVHS and promoting the formation of IVHS America (now called the Intelligent Transportation Society of America, or ITS America), a Utilized Federal Advisory Committee to the USDOT.

18 Later renamed Partners for Advanced Transit and Highways before combining with the California Center for Innovative Transportation to form the California Partners for Advanced Transportation Technology.

This development paralleled efforts on the part of a coalition of 12 surface transportation interest groups—led by the American Association of State Highway and Transportation Officials (AASHTO) and the Highway Users Federation (HUF)—to consider future broad directions for the Federal-Aid Highway Program, which faced reauthorization in 1991. This included a programmatic approach to developing the role of new technology. The first congressional hearing related to the potential of new IVHS technology was held in 1989, the first step in what would become a key focus of almost all subsequent transportation appropriations bills and areas of interest for Congress and other federal agencies.

Research and Technology Developments

Automated Traffic Surveillance and Control System

The Los Angeles Automated Traffic Surveillance and Control System installed in 1984 was the first to integrate vehicle detectors, closed-circuit television, and coordinated signal timing.

Operation Greenlight

Operation Greenlight was a joint effort between the Illinois Department of Transportation and other regional transportation agencies to reduce vehicle congestion in the region. Operation Greenlight started in 1989 and had two main goals—to reduce demand on the region's existing highway network and to increase capacity.[19] The project relied on input from the private sector, including the different modes of the freight community—trucking, rail, marine terminals, airlines, and freight associations.

Fuel-Efficient Traffic Signal Management

California's Fuel-Efficient Traffic Signal Management (FETSIM) program started in 1983. At the time, traffic signal retiming was a suggested means of improving traffic operations and reducing fuel consumption and emissions, but few local agencies had been able to fund such an operation. FETSIM was one of the first statewide programs to provide funding, training, and technical assistance to local agencies to retime their signal systems for greater operating efficiency.[20]

During the 11 years that this program was active, over 160 cities and counties retimed 12,245 signals. Retiming these signals reduced vehicular delays by 14 percent, decreased stops by 13 percent, decreased overall travel times by 7 percent, and cut fuel consumption by 8 percent. The FETSIM program also supported a number of research and development activities that improved analysis tools for traffic signal management. These tools were used nationwide, and the FETSIM program served as a model for several statewide signal management programs around the country.[21]

19 http://www.fhwa.dot.gov/planning/freight_planning/archive/chicago.cfm

20 http://trid.trb.org/view.aspx?id=288542

21 http://trid.trb.org/view.aspx?id=451797

Photo on the Right: The 12-foot tall DARPA ALV drove through the Colorado hills in 1985 without human intervention.

Photo Source: http://paleofuture.gizmodo.com/darpa-tried-to-build-skynet-in-the-1980s-1451000652

DARPA Autonomous Land Vehicle

The DARPA-sponsored artificial intelligence demonstrations that began in the 1960s with Shakey resurfaced in the early 1980s with the DARPA Autonomous Land Vehicle (ALV). The ALV was built on an all-terrain vehicle with sensors ranging from video cameras to laser scanners. The ALV contained six racks of computers programmed with algorithms and using images from the rooftop camera to steer safely along the road without need for human assistance. The ALV demonstrations began in 1985 at a speed of 3 kilometers per hour over a 1-kilometer straight road.[22] Over the next 2 years, the ALV was modified to be able to navigate longer courses at faster speeds with varying curves and pavement types, while avoiding obstacles.

TRANSCOM

TRANSCOM is a coalition of 16 transportation and enforcement agencies in New York, New Jersey, and Connecticut, with the mission of a cooperative, coordinated approach to incident notification, regional incident management, and construction coordination. TRANSCOM was established in 1986 as the Transportation Coordinating Committee for the region to ensure a common approach for developing solutions, including technology-based solutions, to the region's problems. In its early years, TRANSCOM was important for recognizing the institutional dimension to technology development and deployment. Since that time, TRANSCOM's role has expanded to include a multi-agency testbed for implementing ITS technologies.

National Cooperative Highway Research Program 03-38(1)

The National Cooperative Highway Research Program (NCHRP) project 03-38 (1), "Assessment of Advanced Technologies for Relieving Urban Traffic Congestion," which began in 1987, researched and assessed advanced technologies based on their ability to improve urban traffic operations, including capacity and traffic flow. For the most promising of these technologies and systems, researchers formulated a plan for research, development, testing, and demonstration.

NCHRP 03-38 (1) reviewed traveler information systems, traffic control systems, and automatic vehicle control systems. The study also reviewed urgent steps underway to develop a national IVHS program, concluding that there was an urgent need for a national program for developing, demonstrating, and implementing advanced transportation technologies.[23]

22 http://www.dtic.mil/dtic/tr/fulltext/u2/a422845.pdf

23 https://books.google.com/books?id=5o5DPPfnop8C&lpg=PP5&ots=Ks4aSzszKO&dq=Project%203-38(1)&pg=PP5#v=onepage&q=Project%203-38(1)&f=false

Heavy Vehicle Electronic License Plate Program

The Arizona and Oregon Departments of Transportation (DOTs) established the Heavy Vehicle Electronic License Plate Program (HELP) in 1984 to conduct research on commercial vehicle weigh-in-motion and automated vehicle identification (AVI) technologies. The program grew into a consortium of U.S. and Canadian federal, state, and local agencies and motor carrier organizations that conducted a multi-state demonstration of truck pre-screening and pre-clearance approaches at weigh stations between Texas and British Columbia, known as the Crescent Demonstration Project.

The HELP Program ultimately led to the creation of HELP, Inc., a non-profit, public/private partnership, and the launch of its PrePass service. Today, PrePass represents North America's largest truck safety pre-clearance service and the nation's largest vehicle-to-infrastructure (V2I) program.[24]

A 1984 depiction of a screening site with an electronic license plate reader and automated vehicle identification technology.

Photo Source: http://www.bing.com/images/search?q=heavy+vehicle+electronic+license+plate+program+help+in+1984

Benefits of Electronic Screening:

- Time savings are estimated at 1.5 to 4.5 minutes per bypass.
- Carriers with good safety records will have fewer inspections.
- Weigh station traffic is reduced.
- Inspectors can focus their efforts on high-risk carriers.[25]

24 http://www.helpinc.us/

25 http://fresno.ts.odu.edu/newitsd/ITS_Serv_Tech/freight_oper/freight_operations_summary4.html

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CHAPTER 3

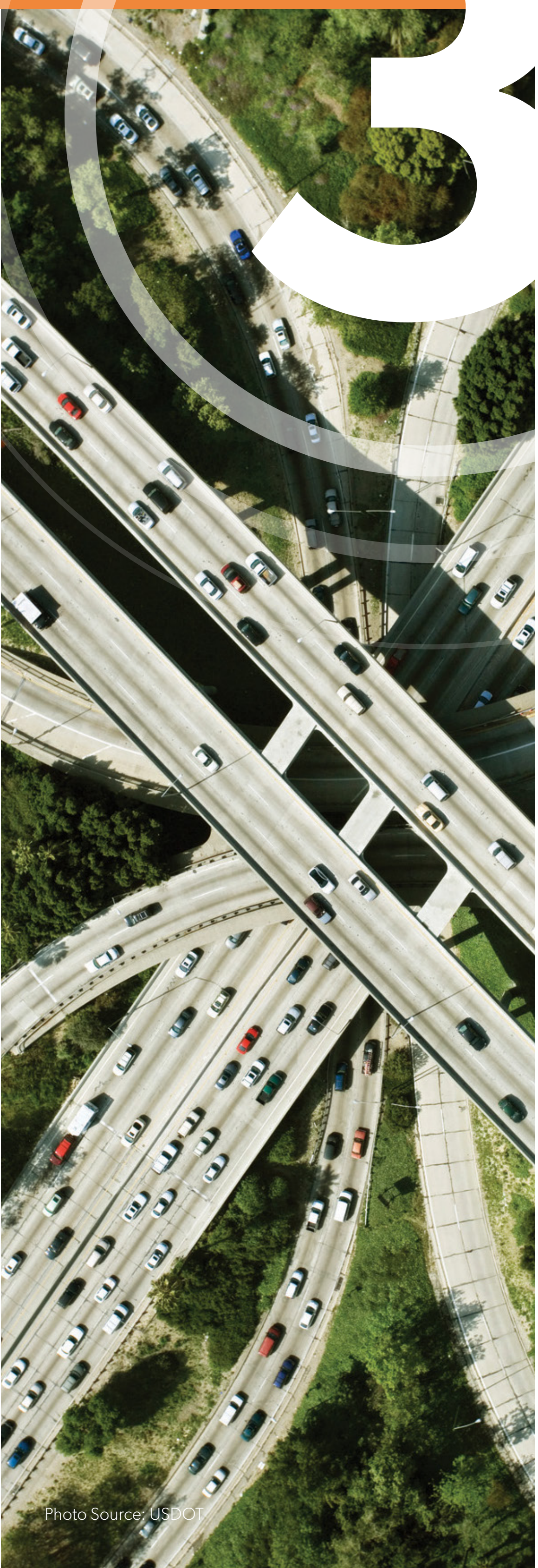


Photo Source: USDOT

THE 1990s

The Socio-economic Environment

In 1990, the United States was on the cusp of a technological revolution. The Interstate Highway System, considered the centerpiece of conventional transportation improvement, was complete and new directions to improve transportation were sought as part of the impending reauthorization of the Federal-Aid Highway Program.

> **"Surface transportation in the United States is at a crossroads. The mobility we prize so highly is threatened. Many of the nation's roads are badly clogged. Congestion continues to increase, the conventional approach of the past—building more roads—will not work in many areas of the country, for both financial and environmental reasons.**
>
> —Intelligent Vehicle-Highway Systems Strategic Plan, prepared by IVHS America (1992)[26]

1991 marked the end of the Cold War and the fall of the Berlin Wall. The United States experienced peace dividends through significant growth in the industrial, transportation, and healthcare sectors. The World Wide Web was invented just before the turn of the decade, and in the United States (as well as in Europe and Japan), attention increasingly focused on the potential of new technical developments both within and outside of transportation. Rapidly improving technology suggested new possibilities for a safer and more efficient transportation system through advances in sensing and computing technologies. This decade's key challenge was how to realize the value of and implement new advances in technology into such a large and multifaceted transportation system.

Dialogue among committed transportation champions and stakeholders brought the concept of IVHS into the mainstream of transportation policy discussions. The 1991 reauthorization of the Federal-Aid Highway Program made a significant

26 http://ntl.bts.gov/lib/jpodocs/repts_pr/1823.pdf

public commitment to institutionalize IVHS. This crucial step established the foundation for the Federal-aid ITS program and the public-private partnerships that have continued to this day. This advancement solidified the role and importance of ITS in maintaining, improving, and growing our transportation systems.

Since its founding, ITS America has grown significantly. Its membership includes public agencies, private companies, and academic and research institutions. ITS America is "dedicated to advancing the research, development, and deployment of Intelligent Transportation Systems (ITS) to improve the nation's surface transportation system."[27] ITS America has been instrumental in many aspects of ITS. They petitioned the Federal Communications Commission to set aside the frequency for dedicated short-range communications, which is now the foundation for connected vehicle technology. The organization also played a key role in the national traveler information system, or 511, by conducting a study that found that over 300 phone numbers just on the east coast of the United States were needed to determine road conditions.

Policy and Programs

Mobility 2000, the informal interest group of academics, stakeholder groups, and USDOT researchers, had been meeting since the late 1980s and pushed forward the idea that the USDOT needed to engage key players in the broader transportation community. Also informing the group were representatives from the Prometheus Program in Europe. In late 1990, this HUF-led discussion resulted in the creation of the 501 (c) (3) membership association IVHS America. IVHS America, now called ITS America, was founded in 1991 by a few innovative individuals at the National Leadership Conference. AASHTO, the Transportation Research Board (TRB), the Institute of Transportation Engineers, and HUF signed on as founding members. IVHS America's first annual meeting was held in Reston, Virginia, in 1991 and had approximately 500 attendees.

Parallel to the founding of IVHS America in 1991, the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) was signed into law by President George H.W. Bush. ISTEA was regarded as the first transportation bill of the post-Interstate era and established policies that recognized the shift in focus from the building of a surface transportation system to the operational management and maintenance of that system and the importance of encouraging the development and application of ITS advanced technologies. ISTEA included a requirement that the USDOT designate a federally utilized advisory committee to provide advice and assistance in the area of IVHS. Soon thereafter, the USDOT designated IVHS America as its federally utilized advisory committee for IVHS, and executed a contract with the new association to carry out specific tasks and provide advice.

ISTEA established an IVHS program with a budget of $660 million and an initial timeframe of 6 years.[28] The program began as a three-pronged effort that fostered the development of ITS through:

1. Basic research and development

27 http://www.itsa.org

28 http://ntl.bts.gov/DOCS/ste.html

2. Operational tests that served as the bridge between basic research and full deployment

3. Various technology transfer activities that facilitated the implementation of ITS technologies. There were designated priority corridors that received funding to develop an operations test program.

These test programs focused on research including the development of systems architecture, standards, and protocols for five IVHS user service components (advanced traffic management systems, advanced traveler information systems, commercial vehicle operations, advanced public transportation systems, and advanced vehicle control systems). The legislation also called for the establishment of a program plan to guide and support the development of an automated highway system. The plan would serve as a template for a future fully automated highway system concept that would support and stimulate the improvement of vehicle and highway technologies.

The IVHS program funded a series of operational tests during the early 1990s that blazed the way forward for new systems and technologies. Some of the most notable projects include Automated Highway Systems, TravTek, Pathfinder, Advanced Driver and Vehicle Advisory Navigation Concept (ADVANCE), Guidestar, INFORM, the Denver Smart Bus Project, FAST-TRAC, and HELP.

In February 1994, the USDOT established a Joint IVHS Program Office (JPO) to coordinate intermodal policy in the implementation of the IVHS program. With policy direction from the Office of the Secretary and Modal Administrators, the Joint IVHS Program Office was located within FHWA. The Office provided overall management and oversight of the IVHS program, including those of FHWA, the Federal Transit Administration (FTA), NHTSA, and the Research and Special Programs Administration (RSPA). In the autumn of 1994, the national IVHS program was renamed the Intelligent Transportation Systems (ITS) Joint Program Office, to clarify the multimodal intent.

> In 1994, the USDOT officially sanctioned the term "ITS" as a replacement for IVHS, recognizing the multimodal nature of the activity and de-emphasizing the focus on technologies for vehicle guidance.

One key activity of the ITS JPO during this period was to establish a degree of standardization within ITS. In the mid-1990s, the ITS JPO, drawing on aerospace experience, developed and standardized a national systems architecture and standards to promote interoperability and a coordinated national approach. The systems architecture has three layers:

- The communications layer provides for accurate and timely exchange of information between systems.
- The transportation layer defines transportation solutions in terms of the subsystems and interfaces, as well as the underlying functionality and data requirements for each transportation service.
- The institutional layer includes institutions, policies, funding mechanisms, and processes that are required for effective implementation.

The National ITS Architecture provides the framework that ties the transportation and communication worlds together into specific applications. Applications are oriented toward a specific user service—such as traveler information, sign messages, ramp metering, electronic tolling, or vehicle safety systems. In any given setting, ITS are combined with specific real-time agency actions to comprise transportation systems management and operation projects and programs. In addition, ITS technology provides much of the technological heart of the new transportation frontier of vehicle automation and connected vehicles, which provide significant mobility and safety benefits.

The USDOT established the ITS Standards Program in 1996 to encourage the widespread use of ITS technologies in our nation's surface transportation systems. The ITS Standards Program has worked with standards development organizations and public agencies to accelerate the development of open communications interface standards. These standards define how intelligent transportation components and systems interconnect and exchange information to deliver ITS services within a multimodal network. The consistent and widespread use of ITS standards will permit data and information sharing among public agencies and private organizations. Currently, nearly 100 standards have been published and are ready to use in ITS deployments.[29]

In 1996, the USDOT announced three major ITS deployment initiatives—the Metropolitan Model Deployment Initiative (MMDI), the Advanced Rural Transportation System, and the Commercial Vehicle Information Systems and Networks (CVISN) Model Deployment Initiative (MDI). The USDOT selected four locations for the MMDI. The four model deployments were the Seattle Smart Trek, the San Antonio TransGuide, the Phoenix AZTech, and the New York-New Jersey-Connecticut iTravel. Under MMDI, true partnerships between public agencies and private companies formed to create regional transportation management systems that provided improved operations, faster emergency response, and better incident management. Each of the four ITS metropolitan model deployment sites addressed the challenges of developing an integrated, multimodal intelligent transportation infrastructure in different ways, but all the sites focused on a common vision of providing more efficient transportation systems and better traveler information.

> "There has been enormous value in creating a National ITS Architecture. It has generated a recognized forum for stakeholders to come together and talk about what outcomes they need in order to truly improve our transportation system.
>
> – Interviewee

First conceived in 1996, CVISN was envisioned as a program through which the necessary open standards and technical framework could be developed to link ITS and commercial vehicle operations (CVO) elements into a single architecture that could be shared by the states participating in the pilot study and ultimately, of course, by all CVO interests in North America. The CVISN Program is a collection of information systems, communications networks, and ITS that support CVO. Through a dedicated CVISN Grant Program, established in 1999, the Federal Motor Carrier Safety Administration (FMCSA), formerly affiliated with FHWA, supports states in the deployment and evaluation of advanced technologies in the program areas of safety information exchange, electronic credentialing, and electronic screening. The CVISN MDI in 1996 demonstrated the technical and institutional feasibility, costs, and benefits of CVISN user services and encouraged further deployment. The initial participants included two prototype states (Maryland and Virginia) and eight pilot states (California, Colorado, Connecticut, Kentucky, Michigan, Minnesota, Oregon, and Washington).

29 https://www.standards.its.dot.gov/LearnAboutStandards/ITSStandardsBackground

The Transportation Equity Act for the 21st Century (TEA-21) passed in 1997 and retained ISTEA's essential features while boosting highway construction investments. TEA-21 provided a total of \$1.282 billion for fiscal years 1998 through 2003 to fund the ITS Program. Of this total, \$603 million was targeted for research, training, and standards development; \$482 million for metropolitan and rural systems; and \$184 million to deploy a commercial vehicle ITS infrastructure.[30,31] TEA-21 moved the USDOT's ITS Program from a moderate research program to a program that both researches and deploys ITS technologies.

In response to the new IVHS priority corridors program, two multi-state coalitions formed to capitalize on the potential of IVHS and corridor systems management. The I-95 Corridor Coalition formed as a partnership of transportation agencies, toll authorities, public safety, and related organizations. Initially, it spanned from the State of Maine to the State of Virginia, but, over time, the I-95 Corridor Coalition successfully expanded down the entire east coast to the State of Florida. Similar alliances formed in other parts of the United States, such as the Gary-Chicago-Milwaukee Corridor Coalition.

Starting in the 1980s and particularly increasing under ISTEA, the transportation sector saw a dramatic growth in earmarking, a practice in which Congress designates funds or resources to a particular project or purpose. While many observers are very critical of earmarks, some were successful for ITS, including FAST-TRAC, Guidestar, and the I-95 Corridor Coalition.

ITS research and deployment today heavily focuses on connected and automated vehicles. This focus is rooted in a range of activities that occurred in the mid-1990s:

- ISTEA mandated the development of an automated highway system to serve as the prototype for future fully automated IVHS systems. The USDOT carried out this ambitious program by sponsoring a competitive process to form the National Automated Highway System Consortium (NAHSC) in late 1994. NAHSC was comprised of nine core organizations, both public and private—General Motors, Bechtel Corporation, Caltrans, Carnegie Mellon University, Delco Electronics, Hughes Electronics, Lockheed Martin, Parsons Brinckerhoff, and the University of California-Berkeley. The consortium researched a range of options for the automated highway demonstration that could ultimately provide safer and more convenient travel. Ultimately, it was decided to combine specially equipped lanes on limited access roadways where communication, sensor, and obstacle-detection technologies were used to automatically control vehicle throttle, steering, and braking. The vehicles and the highway collaboratively coordinated vehicle movement, successfully avoiding obstacles and improving traffic flow. NAHSC's work culminated in the Demo '97, where more than 20 fully automated vehicles operated on 1-15 in San Diego, California. While the demonstration showed the potential of combining intelligent vehicles with intelligent highways, budget pressures and a change in focus to near-term safety systems led to the project's cancellation as part of subsequent legislation. This project is an important ancestor of today's focus on automated and connected vehicles.
- A key step toward making connected and automated vehicles a reality was the Federal Communications Commission (FCC) decision in 1999 to allocate 75 megahertz (MHz) of spectrum

30 https://www.fhwa.dot.gov/tea21/sumarat.htm

31 https://www.fhwa.dot.gov/publications/publicroads/98septoct/tea21.cfm for transportation services that improve highway safety and efficiency. The 5.850 to 5.925 gigahertz (GHz) band was allocated for a variety of dedicated short-range communications (DSRC) uses as a part of the national ITS program. DSRC systems provide a wireless link to transfer information between vehicles and roadside systems. The allocation of bandwidth for DSRC catalyzed the ITS JPO's focus on connected vehicle research. DSRC is essential in many present-day research initiatives with goals of improving traveler safety; decreasing traffic congestion; and facilitating environmental benefits, such as the reduction of air pollution and conservation of fossil fuels.

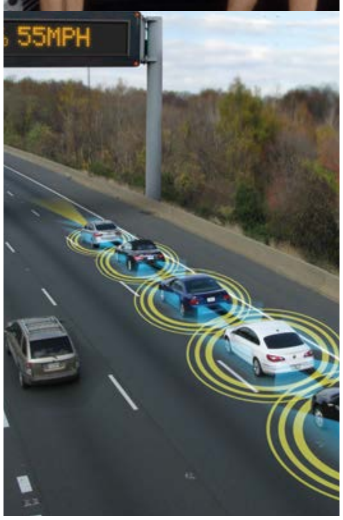
- A related milestone in the movement toward connected and automated vehicles was the development of the Crash Avoidance Metrics Partnership (CAMP). Ford and General Motors formed CAMP in 1995 to accelerate the implementation of crash avoidance countermeasures to improve traffic safety. This partnership has proven invaluable in its ability to provide a way for vehicle manufacturers and various other stakeholders to collaborate on pre-competitive crash avoidance research projects of mutual interest. Much of today's intelligent vehicle research has been a direct result of this partnership.
- Another precursor to automated vehicles was the project called "No Hands Across America." Researchers from Carnegie Mellon University drove a specially outfitted 1990 Pontiac Trans Sport from Pittsburgh to Los Angeles. The car, which the researchers called the NavLab5, drove 98.2 percent of the trip as a completely autonomous vehicle.[32] The remaining percentage of time, the car needed help with tasks such as obstacle avoidance. The longest portion of the drive where the car was able to operate in a fully autonomous fashion—with no help from human operators—was approximately 70 miles.

At the current time, CAMP has Cooperative Agreements with NHTSA on vehicle-to-vehicle technology and with FHWA on V2I technology:

- Ford, General Motors, Honda, Hyundai-Kia, Mazda, Nissan, and Volkswagen/Audi are currently working with NHTSA.
- Ford, General Motors, Honda, Hyundai-Kia, Mazda, Nissan, Volkswagen/Audi, Fiat Chrysler Automobiles, Subaru, and Volvo Truck are working with FHWA.

Video on the '97 Automated Highway Demonstration:

https://www.youtube.com watch?v=C9G6JRUmg_A



Top Photo: During the 1995 "No Hands Across America" demonstration test, the NavLab5 drove 98.2 percent of the 2,849-mile trip as a completely autonomous vehicle.

Photo Source: http://www.ri.cmu.edu/news_photo_view.html?news_id=418&menu_id=239

Bottom Photo: During the '97 Automated Highway Demonstration, more than 20 fully automated vehicles operated on the I-15 in San Diego, California.

Photo Source: USDOT

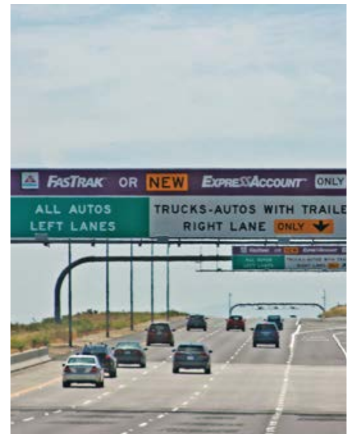
32 http://www.cs.cmu.edu/afs/cs/usr/tjochem/www/nhaa/nhaa_home_page.html

Research and Technology Developments

FAST-TRAC

FAST-TRAC was established as a testbed for a small-scale traffic control system. FAST-TRAC integrated advanced traffic management systems (ATMS) and advanced traveler information systems. The project originated in 1992 in Oakland County, Michigan, about 15 miles from Detroit. In the late 1980s, Oakland County local governments were increasingly concerned with traffic congestion. The local governments could not afford traditional road construction to handle the demand, so instead they adopted the plan proposed by the Road Commission for Oakland County (RCOC) to use an ATMS.

In 1992, the FAST-TRAC program was invoked as a major ITS operational test. Over the years, the project has expanded and evolved. Oakland County officials were successful in securing federal earmarks under ISTEA legislation. Since the program's inception in the early 1990s, RCOC, the USDOT, and the Michigan Department of Transportation have jointly funded different FAST-TRAC components, such as field tests and systems design and integration.



Signs on the roadway assist motorists in making safe lane changes prior to approaching toll collection kiosks.

Photo Source: http://thetollroadsblog.com/2014/07/02/the-toll-roads-update-all-electronic-toll-collection/

TravTek

TravTek was an in-vehicle traveler information system and navigation device that was developed specifically for the TravTek IVHS operational field trial, conducted from 1992 to 1993 in Orlando, Florida. The field trial was a joint project with both public and private sector entities contributing, including the American Automobile Association (AAA), FHWA, the Florida Highway Department, the City of Orlando, and General Motors. The primary objective was to obtain field data on driver acceptance and use of an in-vehicle navigation and information system.

TravTek Navigation System of the Future (circa 1992):

https://www.youtube.com/watch?v=AGrxur7dMh8

General Motors equipped 100 Oldsmobile Toronados with the system—including a 6-inch, touch-sensitive dashboard screen—to provide navigation (based on dead reckoning and map matching with a GPS), route selection and guidance, real-time traffic information, local "yellow pages" and tourist information, and cellular phone service. Data communications between the equipped vehicles and the TMC were conducted through a specialized mobile radio. AAA selected the test subjects including rental users through Avis, and operated a TravTek Information and Services Center that was accessible via cellular telephone. The City of Orlando, in conjunction with FHWA and the Florida Department of Transportation, operated a TMC that consolidated traffic data from various sources, including probe data consisting of road segment travel times received from the equipped vehicles themselves.[33]

Pathfinder

The Pathfinder In-Vehicle Information System project was conducted in 1990 along the Santa Monica Freeway Corridor (I-10) in Southern California. The freeway is one of the most traveled roadways in the country. The Pathfinder project aimed to assess communications technology for route guidance and in-car traffic navigation in response to incidents and traffic congestion. Like TravTek, Pathfinder evaluated strategies for providing route guidance and in-vehicle navigation to drivers. It also demonstrated that equipped vehicles could act as roving "traffic probes," and send travel time information back to a traffic information center.

33 https://www.fhwa.dot.gov/publications/research/operations/its/jpo99038/fotatis.pdf

Guidestar

In 1992, the Guidestar program was established between the Minnesota Department of Transportation and the University of Minnesota Center for Transportation Studies to research and deploy IVHS technologies initially in the Twin Cities and ultimately statewide. An early activity was the Genesis project, which was supported by FHWA as one of the original projects under the IVHS operational test program. Conducted in the Twin Cities area, this test used wireless personal communications devices to send drivers alphanumeric text travel information. A total of 492 participants were recruited to become Genesis users. These users provided the primary data input for the system effectiveness test, the user perception test, and the human factors evaluation.[34]

Advantage I-75

Advantage I-75 is a partnership of public and private interests along the Interstate 75 (I-75) corridor. The goal of the partnership is to reduce congestion, increase efficiency, and enhance the safety of motorists and other users of I-75, including its connections in Canada, using ITS. I-75 passes through six different states—Florida, Georgia, Tennessee, Kentucky, Ohio, and Michigan. Project partners include FHWA, the six I-75 states, the province of Ontario, the Canadian Ministry of Transport, U.S. and Canadian trucking associations, and various trucking companies. The Advantage I-75 partnership can be traced back to a conference held in June 1990, in Lexington, Kentucky, to discuss the feasibility of conducting an ITS project for CVO on I-75. Conference participants endorsed the concept and formed a policy committee to guide development of this ITS project.

Since that time, the Advantage I-75 partnership has worked to identify areas where ITS technologies can be applied quickly to achieve immediate benefits. The Advantage I-75 program aims to incorporate existing technologies into an ITS operational setting to help the nation's highway system adapt to increasing demands. The Advantage I-75 Mainline Automated Clearance System operational test permits transponder-equipped trucks to travel any segment of the I-75 and Highway 401 corridor at mainline speeds, while being cleared to bypass the weigh stations along the corridor.

INFORM

The INFORM (INformation FOR Motorists) project in Long Island, New York, demonstrated the impact of changeable message signs by presenting traffic flow and alternate routing information to drivers. The INFORM advanced traffic information system covered Long Island's 35-mile central corridor, comprising the island's major east/west highways and their busiest north/south connecting routes. The Long Island Traffic Information Center, operated by the New York State Department of Transportation, was at the center of this project. The prime source of information came from some 2,400 electronic sensors embedded in each roadway lane at half-mile intervals. When a vehicle moved over a sensor, it sent an impulse to the traffic information center where three INFORM computers continuously measured and analyzed changing traffic conditions. Traffic information coordinators could immediately spot delays, using data from computer monitors to determine the volume and speed of

34 http://www.dot.state.mn.us/guidestar/1996_2000/genesis/genexecsum.pdf traffic on different sectors of the highways. The coordinators would then transmit appropriate motorist advisories to any of the 74 traffic message signs located at key points throughout the corridor. The traffic information coordinators would also notify the appropriate police and emergency organizations of traffic incidents to facilitate a quick response and resolution to problems.[35]

Smart Bus

The Denver Smart Bus Project formed through a partnership between FTA and the Denver Regional Transportation District. The project demonstrated the use of GPS technologies to improve the management of a transit fleet and ensure on-time service and quick response to incidents.

Dedicated Short-Range Communications

DSRC is a two-way wireless communications capability that permits very high data transmission critical in communications-based active safety applications. DSRC technologies were developed specifically for vehicular communications and have been closely associated with the connected vehicle initiative and its predecessors. In 1997, ITS America petitioned the FCC to allocate 75 MHz of spectrum in the 5.9-GHz band. In 1999, as mentioned earlier, the FCC allocated the spectrum for DSRC use. In 2004, the FCC published a Report and Order that established standard licensing and service rules for DSRC in the ITS Radio Service in the 5.850 to 5.925-GHz band (5.9-GHz band), to be used for the purpose of protecting the safety of the traveling public. Connected vehicle applications using DSRC have the potential to significantly reduce many of the most deadly types of crashes through real-time advisories alerting drivers to imminent hazards—such as veering close to the edge of the road, vehicles suddenly stopped ahead, collision paths during merging, the presence of nearby communications devices and vehicles, sharp curves, or slippery patches of roadway ahead.[36]

Electronic Toll Collection

An electronic toll collection (ETC) system electronically debits registered car owners' accounts without requiring them to stop. This saves drivers time and decreases congestion near toll plazas. While manual toll collection lanes handle about 350 vehicles per hour and automatic coin machines can handle approximately 500 vehicles per hour, an ETC lane can handle up to 1,800 vehicles per hour in an all-electronic tolling configuration.[37]

Under Moving Ahead for Progress in the 21st Century Act (MAP-21), all ETC facilities in the United States must become interoperable by October 1, 2016.

In the 1960s and 1970s, free-flow tolling was tested by mounting transponders underneath vehicles and installing readers just under the surface of the highway.[38] In 1986, ETC was introduced in Europe. The United States followed suit shortly after. In 1991, the Oklahoma Turnpike Authority's Pikepass became the first ETC system in the United States. Since this time, ETC has become widespread across the United States.

35 http://assembly.state.ny.us/comm/CritTran/20030401/

36 http://www.its.dot.gov/factsheets/pdf/JPO-034_DSRC.pdf

37 Persad, Khali and Walton, C. Michael. *Toll Collection Technology and Best Practices*. Austin: Center for Transportation Research, 2007. Project 0-5217.

38 http://fee.org/freeman/roads-in-a-market-economy/

ETC systems save drivers time, reduce pollution, and cost less to operate and maintain than manual and coin tollbooths.

Photo Source: https://en.wikipedia.org/wiki/E-ZPass

ETC systems can provide cost savings of over $40,000 per lane for equipment costs and $40,000 per lane in annual operating and maintenance costs compared with automatic coin machines, and $135,000 per lane in annual operating and maintenance costs compared with manual tollbooths.[39] ETC lanes can also help to decrease emissions.

E-ZPass

In 1991, the E-ZPass Interagency Group (IAG) was created to develop an interoperable tolling system that would work for seven independent toll agencies throughout New York, New Jersey, and Pennsylvania. E-ZPass was first deployed in August of 1993 at the New York State Thruway.[40]

Currently, there are 27 toll agencies spread across 16 states that make up the IAG.[41] All member agencies use the same technology. This allows travelers to use the same E-ZPass transponder throughout the IAG network. Various independent systems were integrated into the E-ZPass system, including Illinois' I-Pass and North Carolina's NC Quick Pass. Although E-ZPass has greatly expanded over the years, E-ZPass transponders are not compatible with many other ETC toll roads.

> **"E-ZPass illustrates the degree of interagency cooperation necessary for interoperability…The IAG faced numerous institutional and organizational issues during the development of the E-ZPass specification. These included separate procurement procedures and requirements of the participating agencies, differences in agency missions, the pace of technological change, and parallel standard-setting efforts at the national level. In the large-scale procurement of cutting-edge technology, the IAG's regionally cooperative effort is unprecedented and provides valuable insights into the conflicts that occur and how they can be resolved.**
>
> – Gifford, J. L., L. Yermack, and C. Owens[42]

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39 Cost-Effectiveness Analysis of AVI/ETTM for Florida's Turnpike System, Center for Urban Transportation Research, University of South Florida-Tampa, 1992.

40 http://e-zpassiag.com/about-us

41 http://www.e-zpassiag.com/

42 "E-ZPass: A Case Study of Institutional and Organizational Issues in Technology Standards Development." *Transportation Research Record*, no. 1537 (November 1996): 10–14.

CHAPTER 4

THE 2000s

The Socio-economic Environment

The first decade of the 21st century saw significant growth in communication technologies. In 2000, the number of cellular subscribers in the United States per 1,000 people was 388. By 2010, the number had shot up to 946.[43]

The number and speed of Wi-Fi networks also grew immensely during this time. Although Wi-Fi existed prior to the new millennium, the different wireless technologies were incompatible, limiting benefits. In 2000, after the development of an industry-recognized technical standard, the first generation of Wi-Fi products had a maximum data range of 11 megabits per second (Mbit/s) and operated in the 2.4 GHz band. By 2009, a new standard was brought to market, having a maximum connect rate of 600 Mbit/s and able to use both 2.4 GHz and 5 GHz bands.[44]

The USDOT's Research and Innovative Technology Administration (RITA) was created in 2005 to advance transportation science, technology, and analysis. In a report titled, *Research Activities of the Department of Transportation: A Report to Congress*, Transportation Secretary Mineta promoted his vision for RITA as an "administration that combines research-driven innovation and entrepreneurship to ensure a safe and robust transportation network."[45] In 2014, the U.S. Congress transferred all RITA programs into the Office of the Secretary of Transportation (OST) to provide opportunities for increased research collaboration and coordination. The ITS JPO was included under RITA and is now organized under the Office of the Assistant Secretary of Research and Technology (OST-R).

Photo Credit: USDOT

43 Peterson, Michael. *Mapping in the Cloud*. https://books.google.com/books?id=mNcfAwAAQBAJ&printsec=frontcover&dq=isbn:1462510418&hl=en&sa=X&ved=0ahUKEwjp68GRlO7MAhUEGx4KHcsmCEAQ6AEIHDAA#v=onepage&q&f=false

44 Gratton, Dean A. *The Handbook of Personal Area Networking Technologies and Protocols*. eBook. Google Books. https://books.google.com/books?id=1aE0AAAAQBAJ&pg=PA249&lpg=PA249&dq=first+generation+of+Wi-Fi+2000+11Mbit/s&source=bl&ots=aQalKI2Xib&sig=Yv80ncxFSJtrXzoxPWORStS3s_A&hl=en&sa=X&ved=0CB0Q6AEwAGoVChMI472izLTZyAIVx3s-Ch07SgvQ#v=onepage&q=first%20generation%20of%20Wi-Fi%202000%2011Mbit%2Fs&f=false

45 http://www.rita.dot.gov/sites/default/files/publications/research_activities_of_the_department_of_transportation_a_report_to_congress/html/section_02.html

Cloud technology also became more prevalent during this decade. The term "the cloud" first popped up in technology circles in the mid-1990s to describe a third-party system that houses digital information on remote servers. However, during the 2000s, cloud computing became more streamlined, widespread, and affordable, allowing for significantly larger data sets to be collected and analyses to be performed.

Technological innovations that occurred during this decade have propelled ITS forward, by automating and connecting technologies and increasing opportunities for travelers to gather transportation information through social networking and smartphone applications. The need to provide and manage private sector data became increasingly important as end user expectations rose and transportation infrastructure operators and the traveling public required more accurate and timely road condition and performance data. Historically, the public sector primarily invested in infrastructure such as vehicle sensors and cameras, and would distribute free information to end users, including agencies and private data providers. Private sector companies recognized the business opportunity in providing not only more accurate and timely data but also more data—people would pay for information. For example, NAVTEQ (registered TM), was able to make a profitable business model by providing customers with geographic information system data and base electronic navigable maps. The growth of smartphone technology and the impact on real-time information access has created further opportunities to monetize transportation-related information. Smartphone platforms currently support many traffic applications, including INRIX Traffic. Similarly, the end user is empowered more than ever before to collect and share information.

Policy and Programs

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was signed into law by President George W. Bush in August 2005. SAFETEA-LU was a transportation funding and authorization bill that focused on federal surface transportation spending. The measure designated $286.4 billion to improve and maintain the surface transportation infrastructure in the United States. In general, the bill continued the ITS research program as indicated in TEA-21, but modified the language to make technical changes and reflect new programmatic priorities. Research priorities included enhancing mobility and productivity; utilizing interdisciplinary approaches; addressing traffic management, incident management, toll collection, and traveler information; enhancing intermodal use of ITS for diverse groups; and facilitating the integration of intelligent infrastructure, vehicle, and control technologies. The bill required the development of a National ITS Program Plan, an ITS Advisory Committee, National Architecture and Standards, Rural Interstate Corridor Communications Study, Road Weather Research and Development Program, and Multistate Corridor Operations and Management. Congress renewed its funding formulas 10 times after its expiration date, until eventually replacing the bill with the Moving Ahead for Progress in the 21st Century Act (MAP-21) in 2012. SAFETEA-LU affirmed the growing return on ITS investment and contained provisions to embed ITS into the mainstream of transportation planning and deployment processes, as well as to increase general awareness of improved operations brought about by the adoption of ITS applications.

After the allocation of 75 MHz of spectrum for use by ITS in 1999, the USDOT's ITS Program and its partners became more acutely interested in the tremendous potential of vehicle-to-vehicle (V2V) and V2I technologies to address highway safety problems and other transportation challenges. The USDOT launched the Vehicle-Infrastructure-Integration (VII) Program in 2003. The VII vision was to use wireless communication with and between vehicles to achieve dramatic safety and mobility improvements. In 2005, the USDOT initiated a program to develop and test a 5.9 GHz-based VII proof of concept (POC). This effort was a continuation of the automated vehicle control systems (AVCS) as envisioned in Mobility 2000. These communication capabilities are used to exchange safety messages and improve traffic flow. The ITS JPO sponsored VII as a public-private partnership between the USDOT, state and local governments, the automobile manufacturers, and other private entities, such as technology and telecommunications providers and consultants.

> **"The smartphone was important to the history of ITS because it gave the broad public a means of envisioning technologies such as connected vehicles or automated vehicles becoming a reality within their lifetime.**
>
> — Interviewee

USDOT conducted a POC test to investigate the technical feasibility of V2V and V2I applications. The POC was conducted in 2008 and 2009 in testbeds located in Michigan and California. The first DSRC multi-channel radios were built for the test vehicles, and the first instrumented roadside equipment was installed at the testbed sites. The POC testing determined that the concept was technically sound and feasible.

The VII Program progressed into commercial testing around the same timeframe as the commercial explosion in mobile communication devices, including smartphones and 3G networks. The ITS JPO realized it needed to expand its scope to explore the potential applications of the new wireless technologies.

In 2006, the USDOT collaborated with CAMP to develop and test prototype V2V safety applications. The overarching goal was to determine whether this technology would work better than existing vehicle-based safety systems, like adaptive cruise control, to address imminent crash scenarios. Sound, robust data, such as that generated from CAMP's research, was required for NHTSA to make an informed decision on the future of V2V and V2I safety communications systems. In addition to drawing information from previous tests and modeling, the Connected Vehicle Safety Pilot was a major source of robust data. This empirical data was critical to supporting the 2013 NHTSA agency decision on vehicle communications for safety.

The Mobility Services for All Americans (MSAA) initiative began in 2005 as a result of the Executive Order on Human Service Transportation Coordination (#13330) issued by President George W. Bush. MSAA aims to improve transportation services and access to employment, healthcare, education, and other community activities through a coordinated effort enabled by various ITS technologies and applications.

The MSAA initiative was built on several past and current USDOT-led activities, including the United We Ride Program, to increase mobility and accessibility for the transportation disadvantaged and the general public and achieve more efficient use of federal funding resources through technology integration and service coordination. The key to effective and efficient coordination under MSAA is integrating ITS technologies into a physical or virtual traffic management and control center that networks all parties together and uses ITS technologies that have demonstrated significant benefits and return on investment. These technologies include fleet scheduling, dispatching, and routing

The ITS JPO launched the MSAA initiative to provide a coordinated effort and apply technological solutions to the barriers to accessibility and mobility for the transportation disadvantaged.

Photo Source: USDOT

systems; integrated fare payment and management (payment, collection, and processing) systems; better traveler information and trip planning systems, particularly for customers with accessibility challenges; advanced geographic information systems; and demand-response systems to provide door-to-door service.

Research and Technology Developments

Driver Assistance Systems

Each year, over 6 million crashes occur on U.S. highways. They kill more than 42,000 people, injure approximately 3 million others, and cost more than $230 billion per year. Driver error is the leading cause of highway crashes. The USDOT's Intelligent Vehicle Initiative (IVI) Program was established in 1998 to help reduce the number and severity of these crashes through the development and commercialization of driver assistance products that warn drivers of dangerous situations, recommend actions, and even assume partial control of the vehicles to avoid collisions. The USDOT also established the Integrated Vehicle-Based Safety Systems (IVBSS) initiative to develop and test integrated safety systems on both light vehicles and commercial trucks through partnerships with private vehicle industries.[46]

> The USDOT's investment in crash prevention technologies will profoundly impact human lives.
>
> — Christine Johnson, Former ITS JPO Director

Under the IVBSS initiative, in November 2005, the USDOT entered into a cooperative research agreement with a private consortium led by the University of Michigan Transportation Research Institute (UMTRI) to build and field test an IVBSS designed to prevent rear-end, lane change, and run-off-road crashes. The prototype vehicles provided forward collision warning, lane departure warning, lane change warning, and curve speed warning functions. During the first 2 years of the program, the industry team designed, built, and conducted tests to verify the prototype systems on passenger cars and heavy trucks. The prototype vehicles underwent a series of closed-course track tests aimed at ensuring that the integrated system met the performance requirements. During the second phase, the industry team built a vehicle fleet of 16 passenger cars and 10 heavy trucks for use in the field test.[47]

This initiative directly led to the collision warning and driver assistance systems that appear today on a wide range of vehicles. These features include lane departure warning, blind spot monitoring, and collision avoidance systems. Most of these systems use either cameras or sensors mounted around the car to determine whether vehicles are near the equipped car, or where the equipped car is in relation to other objects. Beginning around 2007, these features were introduced on luxury cars and have now expanded to mainstream cars. In 2014, based on the promising results of this research, NHTSA mandated back-up cameras in all vehicle built in or after May 2018.

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46 http://www.its.dot.gov/ivbss/#sthash.PnGAKcdl.dpuf

47 http://www.nhtsa.gov/Research/Crash+Avoidance/Program+Description

511: National Traveler Information Telephone Number

On March 8, 1999, the USDOT petitioned the FCC to designate a nationwide three-digit telephone number for traveler information. On July 21, 2000, the FCC designated 511 as the single traffic information telephone number to be made available to states and local jurisdictions across the country.[48] The first 511 traveler information system was launched in the Cincinnati-Northern Kentucky metropolitan area in June 2001. The first statewide 511 traveler information system was launched in the State of Nebraska in October 2001. In the first 5 years after 511 was launched, more than 50 million 511 calls were made. The unexpected invention and growth of smartphones and traveler information apps eventually inhibited the relevance and long-term popularity of 511. However, the 511 coalition was categorically successful in encouraging states to establish collaborative working relationships with an eye toward technology deployment.

Clarus

Clarus is a USDOT initiative that provides clear, relevant information on roadway conditions to all transportation managers and users. The *Clarus* initiative was established in 2004 to reduce the impact of adverse weather conditions on surface transportation users. *Clarus* developed an integrated surface transportation weather observing and data management system that was designed to enable various public agencies to more accurately assess weather and pavement conditions, as well as their impacts on maintenance and operations. Such knowledge is critical for planning, conducting, and evaluating the effectiveness of activities such as winter road maintenance, weather-responsive traffic management, traveler information dissemination, safety management, transit vehicle dispatching, and flood control. *Clarus* featured data ingest that was very low impact for the participating U.S. state and local DOTs and Canadian provinces. The USDOT built metadata that was highly configurable for each participant to "screen" how data came in and what data was available through the interface. All the data were quality checked for reasonableness using sensor ranges, climate ranges, step tests, and spatial tests against nearby stations and the National Weather Service (NWS) Automated Surface Observing System to demonstrate the validity of the road weather instruments. The data were made available through multiple methods including a map with current observations, on-demand requests, and subscriptions. When the *Clarus* system retired in June 2014, there were 36 state and 5 local DOTs and 4 Canadian provinces providing observations, which represented 2,437 environmental sensor stations, 388 connected vehicles, and 54,251 individual sensors. Government agencies (federal, state, provincial, and local), academic institutions, weather service providers, television stations, and private sector firms used *Clarus*. The *Clarus* initiative has transitioned into two tracks: 1) Operational—NOAA's Meteorological Assimilation Data Ingest System; and 2) Research—FHWA's Weather Data Environment.

Top Photo: Roadside signs advertise the availability of 511 traveler information services.

Photo Source: http://news.fl511.com/images/511-sign/

Bottom Photo: Advanced traveler and roadway condition information can improve safety and assist maintenance vehicles during adverse weather conditions.

Photo Source: USDOT

48 https://www.fhwa.dot.gov/trafficinfo/511what.htm

DARPA Grand Challenge

The DARPA Grand Challenge was a first-of-its-kind race to stimulate the development of self-driving vehicles. Fifteen vehicles competed in the inaugural challenge, which took place outside of Barstow, California, on March 13, 2004. The long-term goal of this project was to accelerate the development of technology for autonomous vehicles that could ultimately replace men and women in hazardous military operations. Ultimately, none of the vehicles finished this course—the top-scoring vehicle traveled only 7.5 miles—and the $1 million cash prize went unclaimed.

Photo on the Right:
The DARPA Grand Challenge 2004 stimulated the development of self-driving vehicles.

Photo Source: http://archive.darpa.mil/grandchallenge04/Web_Photos/Sat/index.htm

One day after the first challenge ended, DARPA announced it would hold a second Grand Challenge in the fall of 2005. This time, five vehicles from out of the 195 teams that entered successfully, completed a 132-mile course in southern Nevada. Stanford University's entry finished first with a time of 6 hours and 53 minutes and won the $2 million prize.

> "That first competition created a community of innovators, engineers, students, programmers, off-road racers, backyard mechanics, inventors, and dreamers who came together to make history by trying to solve a tough technical problem. The fresh thinking they brought was the spark that has triggered major advances in the development of autonomous robotic ground vehicle technology in the years since.
>
> —Lt. Col. Scott Wadle, DARPA's liaison to the U.S. Marine Corps[49]

In 2007, DARPA conducted the Urban Challenge, which featured driverless vehicles navigating an intricate city course in Victorville, California. Six out of 11 teams successfully completed the course, and the Carnegie Mellon University team won the first-place prize. DARPA has continued to conduct more competitions building on the Grand Challenge prize-based competition model,

49 http://www.darpa.mil/news-events/2014-03-13

including the 2014 Spectrum Challenge, the 2015 DARPA Robotics Challenge, and the upcoming Cyber Grand Challenge. Like the first Grand Challenge, these competitions aim to encourage innovation, commercial investment, and more affordable advanced technologies. Significantly, many of the engineers and scientists who competed in the DARPA Grand Challenges have gone on to work for famous private automated vehicle development projects.

Next Generation 911

NG911 Timeline: http://www.911.gov/historyof911.html

In 1968, the first 911 system in the United States was installed in Haleyville, Alabama. Similar systems were rapidly adopted across the nation. However, over time, it became clear that enhancements were needed to create a faster and more flexible system that allows 911 to keep up with communication technology.

In 2005, NHTSA and the National Telecommunications and Information Administration established the National 911 Program Office. By coordinating the efforts of states, technology providers, public safety officials, 911 professionals, and other groups, the program seeks to ensure a seamless, reliable, and cost-effective transition to a 911 system that takes advantage of new communications technologies to enhance public safety nationwide. The National 911 Office has released a Next Generation 911 (NG911) system architecture design and successfully used this architecture to conduct a NG911 POC demonstration. By capitalizing on recent technology advances, the USDOT's ITS program has delivered a design and a transition plan for the NG911 system that, when implemented, will enable 911 calls from a variety of networked devices, and provide quicker delivery and more accurate information to responders and the public alike.

Several states have already begun the transition to NG911 infrastructure and others are preparing for this transition. NG911 enables the public to transmit text, images, video, and data to the 911 center. NG911 will establish more flexible, secure, and robust 911 center operations with increased capabilities for sharing data and resources, as well as more efficient procedures and standards to improve emergency response.

Integrated Corridor Management

ICM Video: https://www.youtube.com/watch?v=c9nqWXL5avo

> **"Now traffic management decisions are based on both current and predicted traffic conditions, a capability that has so far been missing [...] I believe we are creating one of the most comprehensive and intelligent decision support systems in the industry today.**

—Alex Estrella, Senior Transportation Planner and ICM Functional Project Manager at the San Diego Association of Governments (AimSun Online), discussing the San Diego ICM system

In 2006, the USDOT launched an integrated corridor management (ICM) initiative. During the second stage of this initiative, the USDOT partnered with three U.S. cities—Dallas, Texas; San Diego, California; and Minneapolis, Minnesota—all of which have congested multimodal transportation corridors. To achieve effective coordination between freeways, arterials, and transit operations, this initiative has required special analysis, modeling, and simulation (AMS) to explore whether applying ICM strategies could improve performance. The ICM project's pioneering decision support system used strategies such as network traffic prediction, online microsimulation analysis, and real-time response strategy assessments to more fully inform system managers about the current and predicted corridor performance. System managers can now anticipate problems before they arise and take preventative action using ICM strategies such as coordinated ramp metering, traffic light synchronization, and transit/bus priority. This allows for optimized capacity and efficiency, reducing delays and obtaining more reliable journey times without the need for investment in additional infrastructure. AMS findings in all three corridors suggested that ICM would increase reliability while reducing travel time, delays, fuel consumption, and emissions. Benefit-to-cost ratios for ICM ranged from 10 to 1 to more than 20 to 1 over the life of the ICM system.[50] In 2010, ICM deployment demonstrations in both San Diego and Dallas were implemented. The USDOT then funded 13 deployment-planning sites to help them get over the hurdle of research to implementation. This USDOT effort set the stage for widespread deployment.

TMCs and system managers can anticipate problems and take preventive actions using ICM strategies.

Photo Source: http://sunguide.info/sunguide/index.php/gallery/transportation_management_center_tmc#

Congestion Initiative

> Congestion is not a fact of life. We need a new approach, and we need it now.
>
> —Former Secretary Norman Y. Mineta, 2006

In 2006, the USDOT launched the National Strategy to Reduce Congestion on America's Transportation Network, known as the Congestion Initiative. The Congestion Initiative serves as a blueprint for federal, state, and local officials to address needs resulting from congestion in their localities. While tolling, transit, telecommuting, and ITS have served to alleviate congestion for years in many metropolitan areas, the Congestion Initiative aimed to demonstrate the effectiveness of deploying these strategies in combination, instead of in isolation.

In the late 2000s, the ITS JPO spent approximately $100 million on this initiative. Two elements of the Congestion Initiative are the Urban Partnership Agreements (UPA) program and follow-on Congestion Reduction Demonstration (CRD).[51] The Congestion Initiative includes a six-point plan to: (1) relieve urban congestion; (2) unleash private sector investment resources; (3) promote operational and technological improvements; (4) establish a "corridors of the future" competition; (5) target major freight bottlenecks and expand freight policy outreach; and (6) accelerate major aviation capacity projects and provide a future funding framework.[52] From 2007 to 2008, the USDOT awarded grants to several metropolitan areas for implementation of congestion reduction strategies under the UPA and CRD programs—Atlanta, Georgia; Los Angeles, California; Miami, Florida; Minneapolis/St. Paul, Minnesota; San Francisco, California; and Seattle, Washington.

50 http://www.its.dot.gov/factsheets/icm_factsheet.htm

51 http://www.its.dot.gov/congestion/#sthash.ncRDAfVI.dpuf

52 http://www.ops.fhwa.dot.gov/speeches/i95coalitionmtg06/index.htm

CHAPTER 5

THE PRESENT DAY (AFTER 2010)

Photo Source: USDOT

The Socio-economic Environment

A variety of forces has shaped the present state of ITS technology. The economic downturn in the 2000s focused increased attention on making the most efficient use of the highway system and vehicle fleet. At the same time, communications and information technology, systems, and applications have evolved at a rapid rate. These factors ultimately led to innovative research initiatives and an explosion of new transportation apps, often combining the use of vehicles as probes with enhanced geographic location and mapping systems in the form of user-friendly mobile and in-vehicle user interfaces. Increasingly, ITS applications are considered in two contexts—for automated purposes and/or for connected vehicle purposes.

Automated vehicles are those in which at least some aspect of a safety-critical control function (e.g., steering, throttle, or braking) occurs without direct driver input. Automated vehicles may be autonomous (i.e., use only vehicle sensors) or may be connected.

Statistics from the *2010-2011 ITS America Annual Report*:

- 70% of the population is covered by 511 systems (38 states).
- Thousands of miles of highway and arterial roads are now managed and under surveillance by TMCs.
- New model vehicles now include a wide array of safety technology not previously available (e.g., lane departure warnings, collision warning and avoidance systems, and adaptive cruise control).
- The private sector ITS market has grown: $48 billion in end-use sales; 180,000 in end-use jobs.[53]

53 http://www.itsa.org/aboutus/annual-report

Photo on the Right: Automated vehicles contain in-vehicle sensors, cameras, and mapping technologies to operate safely without driver input.

Photo Source: USDOT

Connected vehicles use wireless technology to connect vehicle information and location to other vehicles (V2V); to infrastructure (V2I); or to other modes, such as internet clouds, pedestrians, and bicyclists (V2X). The wireless technology typically used for connected vehicles is DSRC, but some functions may use cellular or other types of communication.

The USDOT has prioritized connectivity as an important input to realizing the full potential benefits and broad-scale implementation of automated vehicles.[54] In automated vehicles, in-vehicle sensors, cameras, and mapping allow for many safety features to function without direct driver input or interference. NHTSA has defined five levels of automation that range from no automation to full, self-driving automation. Automated vehicles on this spectrum are beginning to enter the vehicle fleet.

Autonomous vehicle development focuses primarily on potential safety benefits. Connected vehicles offer additional functions related to roadside devices and fleet-level information. Connected vehicles bring additional mobility and environmental benefits that cannot be achieved through automation alone. The ITS JPO shares the goal of advancing automation with many automotive and technology industry partners. Google, Mercedes-Benz, Tesla, and Volvo are all testing driverless vehicles across the world, and the top auto parts suppliers are researching and developing different technologies to meet the large demand for specialized systems that a self-driving car would need.

In addition to these technologies, commercial applications based on geolocation and cell phones, such as Waze and Uber, are influencing the ITS market and are part of a larger trend of shared mobility. Shared mobility—the shared use of a car, bicycle, or other low-speed mode of transportation—is one aspect of the sharing economy and enables users to obtain short-term access to transportation modes as needed, rather than requiring ownership.

54 http://www.its.dot.gov/automated_vehicle/index.htm#sthash.lRp2YnQ4.dpuf

Policy and Programs

President Obama signed MAP-21 into law on July 6, 2012. MAP-21 funded surface transportation programs at over $105 billion for fiscal years 2013 and 2014 and created a performance-based surface transportation program that builds on many of the highway, transit, bike, and pedestrian programs and policies established in 1991 under ISTEA. MAP-21 continued support for the ITS program by restoring the ITS research budget to $100 million per year and establishing a Technology and Innovation Deployment Program for $62.5 million per year. MAP-21 changed the focus of ITS activities by directing the Secretary of Transportation to encourage deployment of ITS technologies that will improve the performance of the national highway system.

Statistics from *Deployment of ITS: A Summary of the 2010 National Survey Results*[55]:

- 98% of toll collection lanes offered ETC.
- 66% of fixed-route buses were equipped with AVL.
- 88% of demand-responsive vehicles were equipped with computer-aided dispatch (CAD).
- 3% of bus stops display dynamic traveler information.
- 35% of fixed-route buses are equipped with electronic real-time monitoring system components.
- 8% of arterial miles are covered by surveillance cameras.
- 50% of freeway centerline miles were covered by closed-circuit television.

In August 2014, NHTSA released an advance notice of proposed rulemaking (ANPRM) and a supporting comprehensive research report on V2V communication technology. The report included analysis of the Department's research findings in several key areas including technical feasibility, privacy, and security, as well as preliminary estimates on costs and safety benefits. The estimates show that two safety applications—Left Turn Assist and Intersection Movement Assist—could prevent up to 592,000 crashes and save 1,083 lives per year.[56]

> “Safety is our top priority, and V2V technology represents the next great advance in saving lives. This technology could move us from helping people survive crashes to helping them avoid crashes altogether—saving lives, saving money, and even saving fuel thanks to the widespread benefits it offers.
>
> —U.S. Transportation Secretary Anthony Foxx[57]

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55 https://www.hsdl.org/?view&did=713134

56 http://www.nhtsa.gov/About+NHTSA/Press+Releases/NHTSA-issues-advanced-notice-of-proposed-rulemaking-on-V2V-communications

57 Ibid

V2V technology can be combined with existing vehicle safety features to make crash avoidance safety systems more effective. It also has the potential to serve as a building block for a driverless vehicle. Although the primary goal is safety, vehicles equipped with V2V technology also have many environmental and mobility benefits. V2V technology can lessen transportation's impact on the environment by reducing fuel use and emissions and improve mobility by reducing delays and congestion, enhancing traffic flow, and making it easier for people to plan travel.

Research and Technology Developments

Connected Vehicle Safety Pilot

The Connected Vehicle Safety Pilot Model Deployment occurred from 2012 to 2013 in Ann Arbor, Michigan. It was the largest real-world test of connected vehicle technology to date, with over 2,700 participating vehicles using wireless safety technology to help everyday drivers avoid crashes as they traveled along their normal routes. Safety applications warned drivers with alerts such as braking vehicles ahead, vehicles in their blind spots, or impending red light violations.

After analyzing data from the pilot program, NHTSA estimated that V2V technology could prevent more than half a million accidents and save more than 1,000 lives each year if implemented across the United States. This success prompted further actions and decisions within the USDOT. Then, in August 2014, NHTSA released an ANPRM and a supporting comprehensive research report on V2V communications technology. As noted previously, the report includes analysis of the Department's research findings in several key areas including technical feasibility, privacy, and security, as well as preliminary estimates on costs and safety benefits, while the ANPRM seeks public input on these findings to support the Department's regulatory work to eventually require V2V devices in new light vehicles.

Connected Vehicle Pilot Deployment Sites

A major success within the world of connected vehicles occurred in September 2015 when the USDOT announced the selection of three connected vehicle deployment sites as participants in the Connected Vehicle Pilot Deployment program. The three sites include using connected vehicle technologies to improve safe and efficient truck movement along I-80 in southern Wyoming, exploiting V2V and intersection communications to improve vehicle flow and pedestrian safety in high-priority corridors in New York City, and deploying multiple safety and mobility applications on and in proximity to reversible freeway lanes in Tampa, Florida. Since September, the connected vehicle pilots have been smoothly moving forward, and we should see deployment plans for these pilots by next summer.

The USDOT's goals for the Connected Vehicle Pilot Deployment program are straightforward—accelerate deployment, measure impact, and uncover the technical and non-technical barriers to deployment in a hands-on way. The Connected Vehicle Safety Pilot was primarily a V2V communication demonstration. The regional connected vehicle pilots will feature more V2I applications that go beyond safety to address additional promises of connected vehicles such as improving mobility, transit connections, pedestrian safety, fuel savings, speed harmonization, and much more. This pilot deployment program will take the findings from the Safety Pilot to the next level.

The USDOT's pilot deployments encourage partnerships between multiple stakeholders (e.g., private companies, states, transit agencies, commercial vehicle operators, and freight shippers) to deploy applications using data from multiple sources (e.g., vehicles, mobile devices, and infrastructure) across all elements of the surface transportation system (i.e., transit, freeway, arterial, parking facilities, and tollways) to support improved system performance and enhanced performance-based management. The pilot deployments are also expected to support an impact assessment and evaluation effort that will inform a broader cost-benefit assessment of connected vehicle concepts and technologies.

Washington State Department of Transportation Active Traffic Management

In August of 2010, Washington State Department of Transportation (WSDOT) launched the active traffic and demand management (ATDM) system to reduce collisions associated with congestion and blocked lanes. The system uses overhead lane signs to provide advanced notice of traffic conditions, variable speed limit signs to direct drivers to reduce speeds, symbols to indicate a lane is blocked, and overhead message signs to warn drivers of traffic ahead. WSDOT is one of the first state transportation agencies to use this type of ATDM system in the United States. These advanced notice technologies decrease dangerous, panicked braking and avoidance maneuvers, which are primary factors that contribute to collisions.

Environmental Research

The USDOT's Applications for the Environment: Real Time Information Synthesis (AERIS) research program develops advanced vehicle applications that reduce transportation's impact on the environment. More specifically, the AERIS research program generates and acquires environmentally-relevant real-time transportation data to support and facilitate "green" transportation choices. The AERIS research program employs a multimodal approach and encourages the development of technologies and applications that reduce fuel use and resulting emissions.

One application that was successfully developed by the AERIS research program is GlidePath. The GlidePath application uses cooperative adaptive cruise control and wireless communications with traffic signals to control a vehicle's approaching and departing speed in an eco-friendly manner. The FHWA's Saxton Transportation Operations Laboratory recently implemented and successfully demonstrated the GlidePath prototype application. Initial testing results indicate that the automated GlidePath prototype application provides up to a 22-percent fuel improvement over an uninformed driver.

Private Companies Investing in Automation

Private companies investing in automation technologies vary greatly in both their background and their approach to automation. In the race to automation, traditional automobile companies are joined by tech giants like Google and Apple and less traditional auto companies like Tesla Motors. Many of the automobile companies investing in this space have faith in an incremental solution. They have researched and implemented software and mechanics that allow for level 2 and level 3 automation (see sidebar on the following page for a description of the NHTSA levels of automation). At these levels of automation, the driver must remain alert for instances where they must take over (including situations like roadwork, lane alterations, and emergency vehicles). This incremental approach allows for a new relationship between the driver and car, one that is collaborative with shared responsibilities, rather than continuous control.

Google's Self-Driving Car project started in 2009. Originally, they outfitted existing vehicles, including the Toyota Prius and the Lexus RX450h. However, Google now has a new self-driving vehicle prototype that they designed from the ground up, exploring options such as removing the steering

Autonomous vehicles will allow drivers to become passengers and engage in other activities while commuting, such as reading or catching up on work assignments.

Photo Source: http://i.kinja-img.com/gawker-media/image/upload/t_original/jasqyosijhfrshkbz2vl.png

wheel and pedals. They are currently testing and refining their technology in different cities around the United States and their cars have self-driven over one million miles.[58] Google's self-driving car is one of the most widely known initiatives in the automated vehicle space and has a dramatically different goal than the incremental approach discussed above. Although the current self-driving model is an example of level 3 automation, it also has a removable steering wheel and is anticipated to reach level 4 automation. Google has focused on one of the more difficult realms in the automation world—city driving. Google relies on intricate and complex maps that take into account every eventuality on a city road, from a cyclist passing to a parked car opening its door into a traffic lane.

There is an important distinction between Google's drastic self-driving approach and the more incremental automated vehicle approach. Volvo, BMW, Toyota, General Motors, and other auto companies are investing in automated cars that will look like the vehicles we drive today, taking control of the vehicle from the driver under certain circumstances. Both the automated car and the self-driving car implement the same system of sensors, radar, and GPS mapping, but self-driving cars go a step further. The steering wheel will disappear completely, and the vehicle will be solely responsible for driving.

In 2013, NHTSA adopted the following levels of vehicle automation:

- **No-Automation (Level 0)**: The driver is in complete and sole control of the primary vehicle controls (brake, steering, throttle, and motive power) at all times.
- **Function-specific Automation (Level 1)**: Automation at this level involves one or more specific control functions. Examples include electronic stability control or pre-charged brakes, where the vehicle automatically assists with braking to enable the driver to regain control of the vehicle or stop faster than possible by acting alone.
- **Combined Function Automation (Level 2)**: This level involves automation of at least two primary control functions designed to work in unison to relieve the driver of control of those functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.
- **Limited Self-Driving Automation (Level 3)**: Vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The Google car is an example of limited self-driving automation.
- **Full Self-Driving Automation (Level 4)**: The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but will not be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.

58 http://www.google.com/selfdrivingcar/

CHAPTER 6

Photo Source: USDOT

THE FUTURE

> We know that connected vehicles and automated vehicles are coming. How will they interact with our current transportation environment and the current generation of ITS technologies? That is the key question. There will be a period of time where automated vehicles, connected vehicles, and the vehicles we drive today are going to co-exist. This will happen and we have to embrace it.

—Jeff Loftus, Chief, Technology Division, Federal Motor Carrier Safety Administration

In 2008, civilization crossed a landmark—over half of the global population lived in urban areas. Comparatively, in 1950, approximately 30 percent of the population lived in urban areas, and a century ago, only 10 percent did. In 2050, it is predicted that 66 percent of the world's population will be urban. North America is one of the most urbanized regions in the world, with 82 percent of its population living in urban areas in 2014.[59]

As populations migrate to urban areas, cities face new transportation challenges including traffic congestion, inadequate infrastructure, and pollution. ITS technology is poised to become even more necessary as these population shifts occur. Widespread deployment of connected vehicles will increase traveler safety and environmental benefits, while alleviating congestion issues. Partially and fully automated vehicles will become available to the general public, further increasing mobility and safety for road users. Furthermore, technology applications such as traveler information or traffic and demand management will decrease burdens on roadways. The growth of shared-use mobility applications will also decrease roadway burdens.

There is growing evidence in the United States that attitudes toward driving are shifting, and our cities are undergoing a dramatic shift in urban mobility. The Millennial Generation, those born between 1982 and 2003, is the largest

59 United Nation. 2014. *World Urbanization Prospect: The 2014 Revision*. New York: United Nations. http://esa.un.org/unpd/wup/

generation in American history. They are also the first generation to begin to reject car ownership. Millennials are living through times of economic dislocation and technological change. This generation is already driving trends and will continue to do so for the foreseeable future. Millennials prefer living in urban areas, are frequent users of public transportation and shared-use mobility options, and are experienced with and heavily reliant on technology. Each of these preferences have the ability to make significant impacts on future transportation trends, particularly the future of ITS—and combined, the impact can be dramatic.

> **"History shows that the combination of technological change, such as the advent of smartphone technology, television, or radio, combined with macro forces that shape behaviors, such as the Great Recession, the Great Depression, or World War II, can lead to societal change that can last generations.**
>
> — American Public Transportation Association/ Transit Cooperative Research Program Report, *Millenials & Mobility*[60]

Technology is enabling society to engage in new forms of sharing, revealing attitudinal preferences that were previously unseen. App-based, on-demand ride services (e.g., Lyft, Sidecar, Uber) connect riders to nearby drivers using their mobile devices. As of July 2014, there are over 1.3 million carsharing members in the United States sharing 19,000 vehicles.[61] Americans will likely continue to rely on shared-use mobility and public transportation. Thus, there will be pressure on public and private sectors to respond to these preferences with more public transit and shared-use mobility options, particularly in urban areas.

Connected vehicles can exchange data including vehicle location information, which can be used to identify ridesharing and transit information for system users.

Photo Source: USDOT

Multimodal tripmaking has created a new demand for improved integration among transportation options. At present, the vast majority of transportation systems require travelers to use transit smartcards, bikesharing key fobs, and carsharing mobile apps to access modes independently. There is a demand for and a likely move toward an integrated platform that enables users to seamlessly access and pay for different transportation services. Smartphones and apps that aggregate shared-mobility service options and enable users to find the closest vehicles available will play a growing role in urban mobility in the future.

In 2015, the ITS JPO released the ***ITS Strategic Plan 2015-2019***. The plan presents the next set of priorities, strategic themes, and program categories under which ITS research, development, and adoption activities will take place. Building on the momentum and success of prior and current research of the previous decade, the plan defines two primary strategic priorities—realizing connected vehicle implementation and advancing automation. These priorities are in line with overall USDOT strategic priorities that focus on increasing safety, enhancing mobility, limiting environmental impacts, and promoting innovation and information sharing.

60 http://www.apta.com/resources/reportsandpublications/Documents/APTA-Millennials-and-Mobility.pdf

61 *Understanding Travel Behavior: Research Scan*. Booz Allen Hamilton.

The plan includes program categories to provide the necessary structure for research, development, and adoption of ITS technologies, including:

- Adoption and eventual deployment of connected vehicle systems including NHTSA plans to issue a proposal by 2016 on V2V safety messaging and V2V communications based on DSRC technology
- Research on other connected vehicle technologies and communications that are enabled by either DSRC or other networks, such as cellular, Wi-Fi, or satellite and how various technologies and communications media will interact and operate
- Research about automated road-vehicle systems and related technologies that transfer some amount of vehicle control from the driver to the vehicle and enable smooth and safe introduction of automated features
- Tracking of emerging capabilities that demonstrate the potential to transform transportation, while also protecting consumer privacy
- Enterprise data management focused on capturing, managing, and integrating "big data" from the range of ITS enabled technologies
- Focus on ensuring interoperability within increasing complex technical systems by evolving standards and architectures to ensure that technological advancements are reflected and the required backward compatibility and interoperability are maintained
- Focus on accelerating deployment to ensure a smooth transition from research and development to widespread deployment.

In September 2015, President Obama announced a new Smart Cities Initiative that will invest over $160 million in federal research and leverage more than 25 new technology collaborations to help local communities tackle key challenges such as reducing traffic congestion, encouraging economic growth, managing environmental effects, and improving city services. A smart or connected city is a system of interconnected systems, including transportation, residencies, employment, healthcare, retail/entertainment, public services, and energy distribution. The entire city is connected by information and communications technologies that transmit and process data about many different active city component.

As a part of the President's Smart Cities Initiative, the USDOT is using funds from the ITS Program to launch the Smart City Challenge—a national competition to implement bold, data-driven ideas that make transportation safer, easier, and more reliable in that city. The USDOT is partnering with Paul G. Allen's Vulcan Inc. and Mobileye to provide the winning city with up to $50 million plus collision avoidance technology on every city bus. U.S. Transportation Secretary Anthony Foxx announced the seven Smart City Challenge finalists in March 2016 at the C3 Connected Mobility Showcase held during the South by Southwest Interactive Festival and Conference. The finalists are Austin, Texas; Columbus, Ohio; Denver, Colorado; Kansas City, Missouri; Pittsburgh, Pennsylvania; Portland, Oregon; and San Francisco, California. Each of the finalists will receive $100,000 in funding to help refine and finalize their proposals for the final selection process.

Connected Vehicles: The Future of Transportation Video:

http://www.its.dot.gov/library/media/15cv_future.htm

On December 4, 2015, President Obama signed into law the Fixing America's Surface Transportation (FAST) Act. It is the first law enacted in over 10 years that provides long-term funding certainty for surface transportation. This will allow state and local governments to move forward with critical transportation projects with confidence that they will have a long-standing federal partner. The FAST Act includes the *Transportation for Tomorrow Act* of 2015, which will fund critical research and accelerate the adoption of technologies to address safety, traffic congestion, mobility, infrastructure condition, and other transportation challenges.

The FAST Act contains many provisions to encourage innovation and accelerate the research and deployment of ITS technology, including $100 million per year for ITS research with an expanded role to enhance the national freight system and assist in developing cybersecurity standards. The FAST Act also creates a new $60 million per year Advanced Transportation and Congestion Management Technologies Deployment Program to provide competitive grants to develop model deployment sites. Between 5 and 10 grants will be awarded each year to deploy a wide range of ITS technologies. The FAST Act authorizes $67.5 million per year for a Technology and Innovation Deployment Program designed to accelerate the deployment of new technology and innovations and analyze federal, state, and local cost savings; project delivery time improvements; and fatalities and congestion impacts.[62]

Most likely, the future of ITS will not be a "one size fits all" solution. Transportation systems will be tailored to solve regional and local environments. Electric connected or automated vehicles would work well in urban cities or small towns where people generally commute shorter distances and carry light loads. However, an all-electric vehicle may not be appropriate for those who commute very long distances and carry large loads, such as freight.

62 http://www.itsa.org/component/content/article/1-general/1756-its-america-statement-on-the-house-and-senate-passing-the-fixing-americas-surface-transportation-fast-act-five-year-reauthorization

KEY TRANSPORTATION LEGISLATION FUNDING BILLS

- **1956: The Federal-Aid Highway Act was signed.**
  - The act funded the creation of the U.S. interstate network.
  - The 41,000-mile system was planned to reach every metropolitan area with a population larger than 100,000.
- **1991: The Intermodal Surface Transportation Efficiency Act (ISTEA) was signed into law by President George H.W. Bush.**
  - ISTEA included a requirement that the USDOT designate a federally utilized advisory committee to provide advice and assistance in the area of IVHS (ITS America was designated as the advisory committee).
  - ISTEA was the first transportation bill of the post-Interstate era and established policies that recognized the shift in focus from the building of a surface transportation system to the management and maintenance of that system.
  - The act encouraged the development and application of ITS advanced technologies to establish a safer and more efficient transportation system.
  - Under ISTEA, an IVHS Program was established, with approximately $660 million authorized for the 6-year authorization period.
- **1997: Transportation Equity Act for the 21st Century (TEA-21) was passed.**
  - TEA-21 retained ISTEA's essential features while boosting highway construction investments.
  - TEA-21 withdrew financial support from the National Automated Highway System Research Program (NAHSRP).
  - Through TEA-21, $1.282 billion was provided for fiscal years 1998 through 2003 to fund the ITS Program.
- **2005: Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was signed into law by President George W. Bush.**
  - The measure designated $286.4 billion to improve and maintain the surface transportation infrastructure in the United States.
  - In general, the bill continued the ITS research program as indicated in TEA-21, but modified the language to make technical changes and reflect new programmatic priorities.
  - SAFETEA-LU affirmed the growing return on ITS investment and contained provisions to embed ITS into the mainstream of transportation planning and deployment processes, as well as to increase general awareness of improved operations brought about by the adoption of ITS applications.
- **2012: Moving Ahead for Progress in the 21st Century Act (MAP-21) was signed into law by President Obama.**
  - MAP-21 funded surface transportation programs at over $105 billion for fiscal years 2013 and 2014 and created a performance-based surface transportation program that builds on many of the highway, transit, bike, and pedestrian programs and policies established in 1991 under ISTEA.
  - MAP-21 continues support for the ITS Program by restoring the ITS research budget to $100 million per year and establishing a Technology and Innovation Deployment program for $62.5 million per year. MAP-21 changed the focus of the use of funds for ITS activities by directing that the Secretary of Transportation encourage deployment of ITS technologies that will improve the performance of the national highway system.
- **2015: Fixing America's Surface Transportation (FAST) Act was signed into law by President Obama.**

APPENDIX A. ACKNOWLEDGMENTS AND INTERVIEW TRACKER

Acknowledgments

We would like to extend our appreciation to the following stakeholders for their support, collaboration, and contributions to the USDOT ITS JPO over the years.

AAA

AAMVA - American Association of Motor Vehicle Administrators

AASHTO - American Association of State Highway and Transportation Officials

Alliance of Automotive Manufacturers (Auto Alliance)

AMPO - Association of Metropolitan Planning Organizations

AMS - American Meteorological Society

APTA - American Public Transportation Association

ASTM - American Society for Testing and Materials

ATA - American Trucking Associations

Auto Care Association

CAMP - Crash Avoidance Metrics Partnership

CVTA - Connected Vehicle Trade Association

CTIA - Cellular Telephone Industries Association

CVSA - Commercial Vehicle Safety Alliance

GHSA - Governors Highway Safety Association

Global Alliance of Automakers

IBTTA - International Bridge, Tunnel and Turnpike Association

IEEE - Institute of Electrical and Electronics Engineers

ITS America - Intelligent Transportation Society of America

ITE - Institute of Transportation Engineers

NACE - National Association of County Engineers

NARC - National Association of Regional Councils

NEMA - National Electrical Manufacturers Association

NENA - National Emergency Number Association

NRITS - National Rural Intelligent Transportation Systems

OmniAir Consortium, Inc.

SAE - Society of Automotive Engineers

TRB - Transportation Research Board

TSAG - Transportation Safety Advancement Group

Interview Tracker

This report provides a brief yet comprehensive review of policies, research, technologies, and societal influences that have shaped the history and future of ITS. In researching and writing this report, it was critical to engage a number of ITS professionals and experts who truly understand how these developments unfolded. Throughout the research and drafting stages, the team engaged and interviewed a diverse group of individuals to ensure that this report captures the many facets of ITS.

The *History of ITS* development team would like to extend our appreciation and thanks to the following individuals that were instrumental in providing their input on the history and future of ITS.

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