The Exploratory Advanced Research Program

EXPLORATORY ADVANCED RESEARCH

Novel Modes Workshop

WORKSHOP SUMMARY REPORT • DECEMBER 2–3, 2014

U.S. Department of Transportation
Federal Highway Administration

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16. Abstract

On December 2–3, 2014, the Federal Highway Administration's (FHWA's) Exploratory Advanced Research Program, with support from the John A. Volpe National Transportation Systems Center, convened the 2-day workshop "Novel Modes." It was held concurrently at FHWA's Turner–Fairbank Highway Research Center in McLean, VA; Federal Transit Administration's Region 9 Offices in San Francisco, CA; and via Web conferencing. The purpose of the workshop was to assess and document the state of technology for new modal systems, thereby providing FHWA, the U.S. Department of Transportation, and other government agencies with (a) an educated understanding of potential technological trends that could affect the current highway, transit, and rail systems; (b) a foundation for considering the appropriate government policy and research roles for novel modal systems; and (c) an opportunity to provide ongoing fair and open access to innovators in the business and academic sectors.

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Executive Summary

On December 2–3, 2014, the Federal Highway Administration's (FHWA's) Exploratory Advanced Research (EAR) Program, with support from the John A. Volpe National Transportation Systems Center (Volpe Center), convened the 2-day workshop "Novel Modes." The workshop was held concurrently at FHWA's Turner–Fairbank Highway Research Center (TFHRC) in McLean, VA; the Federal Transit Administration's Region 9 Offices in San Francisco, CA; and via Web conferencing. Michael Trentacoste, TFHRC Director and FHWA Associate Administrator for Research, Development, and Technology, provided a brief introduction describing the purpose of the novel modes project. Trentacoste explained that the project is part of FHWA's overall strategy of addressing national transportation challenges. He noted that the EAR Program focuses on higher risk, longer term research on breakthroughs and transformative improvements. Trentacoste highlighted that this novel modes project provides a complement to the EAR Program periodic technology scans, and the results are intended not just for FHWA, but also for a much broader set of stakeholders, including State and local governments and the private sector. He explained that this approach falls in line with FHWA's move away from the 1950s paradigm of simply building a highway system. Trentacoste added that an important part of this project is the ability to share information between and among innovators, the U.S. Department of Transportation (USDOT), and panelists from the public and private sectors.

Gregory D. Winfree, USDOT Assistant Secretary for Research and Technology, then provided some additional opening remarks. Winfree suggested that making transportation better (i.e., safer, more equitable, and more efficient) is part of improving overall quality of life and subsequently puts the United States in a stronger position for the future. He noted that there may be different opinions on how specifically to enhance the U.S. transportation system but that everyone agrees on the need to improve transportation in America. Winfree also highlighted some past transportation "game changers," such as the development of commercial aviation and the Interstate highway system, which fueled middle-class prosperity. Winfree explained that the Novel Modes workshop serves as an opportunity to stimulate ideas and fresh perspectives on how to improve the U.S. transportation system. He noted that USDOT's Small Business Innovation Research program is one example of how USDOT looks for innovative solutions but that innovators should not limit themselves to Federal funding. Winfree mentioned that there are other models worth exploring and that the USDOT encourages collaboration as part of an "all of the above" approach to facilitating innovation.

Winfree noted that connected vehicles and automated vehicles serve as a huge area for products and innovation. He mentioned that USDOT is focused on interoperability

of devices for cars, trucks, transit, motorcycles, bikes, and pedestrians to create a true platform for developers. He added that the broader point is transportation connectivity and the long-term trend toward automated operation, which is a bigger change than just the connected-vehicle platform itself. Winfree also noted that demographics, technology, and even weather will affect transportation in the future. He highlighted how USDOT wants to work in tandem with innovators, academics, and others parties to build the reliable and efficient transportation system that the American people deserve. Winfree concluded his opening remarks by stating that the Novel Modes workshop provides an opportunity for participants to share their vision of the future of transportation.

During day one of the workshop, participants observed presentations from expert speakers on past, present, and future transportation trends and challenges for innovation. Following this, a selection of request-for-information (RFI) respondents provided brief presentations on their transportation concepts for the future. These presentations took place over two sessions and were followed by a panel discussion in which experts provided feedback, identified themes and challenges, and took questions from the wider group of workshop participants. These discussion sessions are summarized in the following sections. Brief overviews of the RFI respondent presentations are presented in Appendix A.

On day two of the workshop, participants at TFHRC took part in a tour of the facility, during which FHWA researchers demonstrated some of the computer-modeling approaches, driving simulators, and other tools used to investigate the potential effects of technology and policy changes on highway traffic behavior and safety. Following the tour, David Kuehn, EAR Program Manager, welcomed participants. The second day included two discussion panels, two sessions of RFI respondent presentations, and a subsequent response panel. This final day of the workshop concluded with closing remarks from Bob Sheehan of the Office of the Assistant Secretary for Research and Technology's Intelligent Transportation Systems Joint Program Office.

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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List of Acronyms and Abbreviations

ATN	automated transit network
EAR	Exploratory Advanced Research
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
FY	fiscal year
ITS	intelligent transportation system
MTA	Maryland Transit Administration
P3s	public-private partnerships
PRT	personal rapid transit
R&D	research and development
RFI	request for information
RITA	Research and Innovative Technology Administration
ROW	right of way
SBA	Small Business Administration
SBIR	small business innovation research
STTR	small business technology transfer
TEV	tracked electric vehicle
TFHRC	Turner–Fairbank Highway Research Center
TTI	Texas A&M Transportation Institute
USDOT	U.S. Department of Transportation
VMT	vehicle-miles-traveled

Introduction

On December 2–3, 2014, the Federal Highway Administration's (FHWA's) Exploratory Advanced Research (EAR) Program, with support from the John A. Volpe National Transportation Systems Center (Volpe Center), convened a 2-day workshop on "Novel Modes" at the Turner–Fairbank Highway Research Center (TFHRC) in McLean, VA. The EAR Program held the workshop to assess and document the state of technology for new modal systems, thereby providing FHWA, the U.S. Department of Transportation (USDOT), and other government agencies with (a) an educated understanding of potential technological trends that could affect the current highway, transit, and rail systems; (b) a foundation for considering the appropriate government policy and research roles for novel modal systems; and (c) an opportunity to provide fair and open access to innovators in the business and academic sectors.

In fiscal year (FY) 2013, the EAR Program conducted a desk scan, and in FY 2014, the EAR Program posted a request for information (RFI) to identify current entities who were working on novel modal systems. A total of 34 entities responded and submitted information about their novel modal system concept. The EAR Program invited these respondents to the workshop to present their concepts, either in person or remotely. Respondents provided an overview of their system, highlighted the problem that they were trying to solve, proposed a solution, provided an update on their project's current status, and identified potential challenges.

The workshop included participants from government, academia, and the private sector. A team from multiple offices in Office of the Secretary of Transportation, FHWA, the Federal Transit Administration (FTA), and the Federal Railroad Administration (FRA) also participated. In addition to the TFHRC location, the workshop took place concurrently at FTA Region 9 Offices in San Francisco, CA, and remotely via Web access.

This workshop summary report captures highlights from the workshop and summarizes the discussions that took place. Brief overviews of the RFI respondent presentations are presented in Appendix A.

Part One:
Day 1 Overview

History of Modes of Transportation

Dr. Martin Wachs
University of California, Los Angeles, and the Rand Corporation

Overview

Dr. Martin Wachs provided a historical context for the workshop. He focused specifically on lessons that can provide insight for proponents of novel mode concepts today.

Summary

Dr. Wachs noted that technological change is almost always incremental, not revolutionary, and involves public and private participants in both contention and cooperation. He added that technological shifts in transportation have also required huge public investments. Dr. Wachs explained how the relationship between personal and goods movement and the movement of information has been a central element of technological changes. He highlighted how information originally traveled in the same way as people and goods. Starting with the telegraph, information could be transmitted more quickly than could material goods and could be used to track movements of items and integrated into transportation. Dr. Wachs noted that virtually every new transportation innovation links movement and information in a more integrated way.

Dr. Wachs explained how novel modes often start out as a component of, or addition to, existing transportation frameworks. Even so, he noted that substantial implementation of novel modes can take decades to occur as a result of the need for social conventions, human behavior, and institutional change to accommodate new technologies. Dr. Wachs also suggested that the role of government is to provide the context for transportation technology changes and to be a force for facilitating technological and social change. He emphasized Government's role in standardization and cited the case of the General Time Convention of October 1883, which set standard time zones for railway schedules.

Recent Changes and Future Directions in Travel Behavior

Nancy McGuckin
Travel Behavior Consultant

Overview

Nancy McGuckin focused on the current shifts in travel behavior toward lower per capita vehicle-miles-traveled (VMT) and lower "maintenance" travel (e.g., travel associated with errands).

Summary

McGuckin explained that some of the decline in travel can be attributed to societal and demographic shifts as millennials move to cities and purchase items online that are delivered directly to their doors, as gas prices rise over time (shown in figure 1), and as baby boomers age out of the working and commuting population.

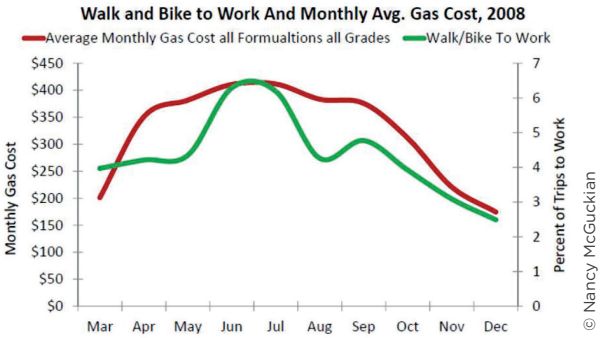

Figure 1.
The effect of rising gas prices on choice of mode.

Data: McGuckin's Analysis of 2009 National Household Travel Survey public files,[1] published by the Federal Highway Administration and Energy Information Administration public files,[2] published by the Department of Energy.

McGuckin noted that the United States should also anticipate decreases in "mandatory" driving (shown in figure 2), such as not having to commute as a result of teleworking and remote access to certain elements of medical care (e.g., telemedicine). She added, however, that discretionary travel continues to increase, particularly long-distance travel. McGuckin suggested that for people with many available choices, mode choice can change depending on the situation, rather than a person habitually using the same mode. This is in part because of technological changes.

During her presentation, McGuckin posed several questions to the workshop participants, including the following:

- In the future, if you do not have to travel for any particular daily needs, why would you travel?
- Who is bringing goods to you, and how is their travel changing?

McGuckin highlighted that technology has enabled "a million markets of one." She noted that this enables mass customization in areas such as navigation and mobility aids, pay-as-you-drive options, and multimodal traveler organization services. She added that, in some locations around the world, there are too few transportation options available. In the third world, for example, women and children may have to travel many hours every day for water and firewood. McGuckin noted that there are still many issues around the world associated with having limited transportation choices.

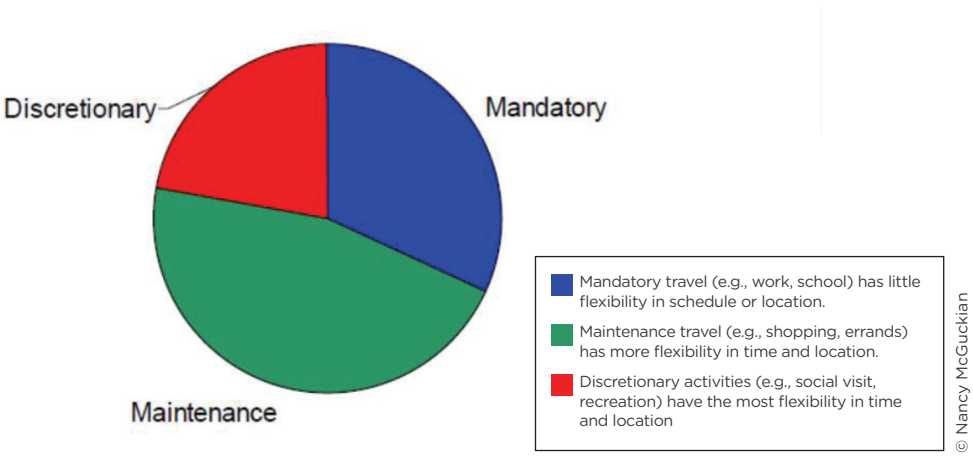

Figure 2. Proportion of daily trips by activity type.

Present Day Trends in Freight Movement

Professor Genevieve Giuliano
University of Southern California, Los Angeles

Overview

Genevieve Giuliano provided workshop participants with an overview of freight transportation. She focused in particular on the United States and the implications for innovation and novel modes.

Summary

Giuliano highlighted the fact that trade volumes and freight movements have been rising and that there has been a movement toward differentiation by mode. This means that heavy, low-value shipments usually travel by water or rail, whereas higher value products mostly travel by air or truck. She noted that water and air are mostly favored for longer distance shipments, whereas trucks manage shorter distance shipments, including almost all "last-mile" movements. Giuliano added that overall, trucks handle about 67 percent of freight in the United States by weight and 64 percent by value, whereas air is negligible by weight but handles 7 percent by value.

Giuliano described how the overall trend in freight has been to shift to faster modes of travel, reduce costs through economies of scale, and improve reliability. She noted that supply chains comprise the full set of activities associated with a product—from raw materials to production, distribution, consumption, and ultimately disposition. Giuliano described how supply chains have moved from a push model (i.e., producer driven) to a pull model (i.e., consumer driven). She noted the containerization of shipping and intermodal systems (i.e., using standardized containers that can be efficiently transferred from one mode of transport to another) have yielded enormous productivity improvements for freight. These improvements include lower freight costs, lower insurance and inventory costs, and improved service and reliability. Giuliano suggested that telecommunications and information technology have been a facilitating factor in these improvements. She also highlighted the automation of freight functions that is currently in progress. In addition to semi-automated movements at distribution centers, Giuliano highlighted demonstration projects involving fully automated forklifts and automated vehicles for container movements.

During her presentation, Giuliano identified several challenges that researchers face. She noted that for novel modes, an overall challenge is to improve transportation to be better, faster, cheaper, or more reliable than the existing transportation system. Giuliano also identified an energy challenge: She explained that alternative fuels are problematic because they have lower energy density than does diesel, and thus either reduce range or increase costs. She added that alternative fuels are also currently less widely available, which further raises refueling costs. Giuliano also identified a velocity challenge: She explained that new vehicle concepts must be more cost-effective than the current transportation method. Any transfer to a new transportation system will involve additional time and money, and a

system that is slower will increase transit times and thus increase inventory costs. She noted that vehicles that are smaller also entail higher labor costs per shipment as less product can be moved with each shipment. Giuliano identified infrastructure as the final challenge and explained that innovations usually build on an existing infrastructure framework rather than stemming from the development of an entirely new transportation system. She used containerization as a past example of building on an existing infrastructure and automation of freight transportation as a present example.

Making the Investment Decision for a New Technology

Bob Denaro
Motus Ventures

Overview
During his presentation, Bob Denaro discussed ways to acquire capital for novel mode development. He presented several key points, which are highlighted in the following summary section.

Summary
Denaro explained that it can be difficult to secure funding in the current financial climate and highlighted how approximately 50 percent of today's start-up companies start with investments from friends and family. In addition, he noted that there are also Government innovative research awards (e.g., the Small Business Innovation Research (SBIR) program), which have certain valuable features. Denaro explained that these awards enable developers to keep the rights to their inventions, but they may take longer to arrive and may incur additional overhead costs related to ongoing reporting conditions and other constraints.

Denaro also mentioned that corporate venture arms have "deep pockets" but do not usually engage in seed-round funding. Despite this challenge, he noted that corporate partners can serve as a good source of funding. Denaro also discussed how investment banking has many regulations and restrictions and may not serve as a good source of capital for workshop participants to pursue. He added that investors look for proposals that offer a big market, the ability to scale up, and a compelling value proposition (e.g., why people are compelled to buy a particular service or product).

Setting the Context and Wrap-up

Kevin Kesler
Federal Railroad Administration

Overview

Kevin Kesler thanked the speakers for establishing the overall context for the workshop. He then provided some additional summarizing thoughts related to the requirements for novel modes and the Government perspective on new modal systems, which are outlined in the following section.

Summary

Kesler noted that safety is a key public goal and that new transportation concepts must be as safe—or safer—than the mode that is being replaced. He suggested that passengers will demand an acceptable level of comfort from a new travel mode and that this in turn ties in to many different mode characteristics, such as available space, smooth acceleration movements, and temperature control. Kesler noted that cost must also be competitive and the efficiency and convenience of a new transportation mode must be favorable when compared with modal alternatives. In addition, he suggested that connections to existing modes are important and will yield the best public-transit cost–benefit analysis. Kesler also mentioned that standardization will help to promote growth and reduce cost. He noted that some innovators see standardization as negative because it can restrict innovation; however, he suggested that certain standards, such as guideway interfaces and control systems, can actually accelerate widespread implementation.

Day 1 Reaction Panel: Themes, Challenges, and Opportunities

PANELISTS

Bob Denaro
Motus Ventures

Nancy McGuckin
Travel Behavior Consultant

Henry Kay
Maryland Transit Administration

MODERATOR

David Kuehn
Federal Highway Administration

Overview

At the end of the first day, three expert speakers participated in a panel discussion and answered questions from the moderator and workshop participants. A summary of the panel discussion is outlined in the following section.

Impact of Automation on Operational Aspects and Costs

David Kuehn began the panel discussion by asking the three panelists how automation changes operational aspects and costs. In response, Henry Kay suggested that automated transit has been technologically possible for decades but has not really been adopted. He noted that there are some technical issues, but the lack of progress is mostly a product of a skeptical and litigious culture. Kay highlighted that society has a very high expectation for automated systems, and public agencies are risk averse, preferring systems that are simple and time-tested. Kay also noted the presence of some workforce issues meaning that public-transit agencies may not have the capacity to maintain highly sophisticated systems over the long term.

Nancy McGuckin added that it is important to keep in mind the advantages of the current U.S. transportation system. She highlighted the flexibility of the road infrastructure and how it can accommodate cars, pedestrians, bicycles, buses, and even new modes like Segways. McGuckin also explained that long-distance travel (i.e., journeys over 160 km (100 mi)) makes up approximately 15–20 percent of VMT and is already very cheap and flexible; therefore, it is difficult to compete with. She highlighted that at a fuel cost of $4 per gallon, and with a motor vehicle achieving an average fuel economy of 40 km (25 mi) per gallon, the out-of-pocket costs for a 160-km (100-mi) trip are only about $16 and offers the flexibility of also transporting children, pets, and luggage.

McGuckin noted that transit only has a small share of overall travel in the United States, so it is interesting to see that so many alternative transit systems are currently being proposed, such as personal rapid transit (PRT). McGuckin explained that fleet turnover tends to be gradual; thus, automated vehicles will need to be compatible with conventional vehicles for decades. She also mentioned that the future may also have more extreme weather events, so both existing and new infrastructure may need to become more resilient. McGuckin indicated that a concern with the day one presentations was that there was very little that addressed the passenger experience. She noted that considerations

such as the aesthetics of windows or seating can play a big part of mode choice and that users seem to be seeking out new transportation experiences.

Bob Denaro described how expensive new infrastructure is a tough sell compared with automated vehicles that use existing infrastructure. He noted that new infrastructure does have the advantage of being able to restrict and control access to the transit system. Denaro explained that automated vehicles are also costly at present because of sensor requirements and the need for redundant systems. He suggested that as automakers expand automation capabilities and the range of environments in which vehicles can operate in automated mode, the need for sensor technology, control systems, redundancies, and testing will drive up costs even further. In summary, Denaro noted that overall cost is a major barrier to implementation for new infrastructure and automated vehicles.

Government Role in Open Platforms and Interoperability

Next, Kuehn asked panelists whether Government could encourage open platforms and interoperability and whether this would reduce costs. Denaro responded that having the Government encourage open platforms and interoperability would not necessarily help reduce costs, particularly for safety–critical applications. He explained that the "agile" software development process is well-suited for consumer products but not necessarily for safety and control systems. Denaro suggested that a rapidly reconfigurable platform, with over-the-air software updates, is a more appealing model because mistakes can be fixed as customers discover problems. He noted this addresses the fact that, unlike traditional control systems, it is not possible to test every possible scenario. One workshop participant commented that the public seems to accept automated transit at airports and added that rail has inherent advantages because it involves primarily only longitudinal control. This same participant also suggested that automation allows for a much larger number of smaller vehicles to operate at a lower cost. Another workshop participant added that one community will need to be willing to be the first to adopt automation.

Modeling New Systems

David Kuehn then asked the panelists to discuss how to model demand and capacity for systems that do not yet exist. McGuckin explained how travel-demand modeling used to be easier when VMT was consistently rising. She noted that, with recent changes to personal travel patterns, travel-demand modeling has become more difficult. McGuckin added that several forecasts for toll-road performance have come up short of reality and that California's high-speed rail project is another example of how forecasts can prove to be controversial. Kay noted that some new systems would offer greater capacity; however, that capacity would come at a cost. He explained the reality is that capacity is only an issue for a few big city transit systems, but in most other places, the limits of transit capacity have not been tested, and higher capacity systems are not necessarily a good value.

Attracting Investors

Next, Kuehn asked panelists to discuss what they would need to demonstrate to generate potential interest in an investor. He asked whether people look at market forecasts and whether investors want something more than a simulation. Denaro noted that people want to see something more than a demonstration and that demonstrations are often expensive. He

suggested other avenues to pursue could be consumer surveys and expert analysis. He added that market research is difficult when the product does not exist, and respondents are not able to provide reliable information regarding something they have not yet seen. Denaro mentioned that systems need upfront capital, a business model, and a new customer base. He highlighted that these are almost all business or institutional issues and not technological issues. One workshop participant proposed California's high-speed rail project as an example of spending money on concepts before they are ready. This same participant also highlighted New York City's Second Avenue subway project and Boston's Big Dig as expensive projects that have used existing technology. Another workshop participant commented that the backlog in transit projects is due more to demand than to available funding. This participant suggested that more innovation is required to reduce costs. After further discussion, another participant noted that cost is not necessarily an issue if there is sufficient value, for example, safety is less of an issue in a closed system.

Managing Risks

David Kuehn then asked the panelists to consider risk management. He explained that for some transportation concepts there are only a few customers (e.g., government agencies), in contrast to a regular consumer product in which the user is the customer. He highlighted how this is a challenge that is also faced by the defense industry and one that presents large risks to both the buyer and seller. Kuehn asked panelists to discuss how these risks can be managed, and in response, one workshop participant suggested that more test systems are needed. Another participant questioned who the customer is and noted that transit systems are mostly built by State and local governments. The participant mentioned that there is currently no venture capital market for infrastructure and very few examples of successful private infrastructure projects. This participant also noted that Government projects can have high costs and low revenues and provided an example of how Japanese cities with expensive bullet trains have not eliminated congestion.

Kay added that many presentations at the workshop mentioned cost savings or cost-effectiveness. He noted that this would appeal to elected officials and the public sector in general. Kay explained that cost is always the first question, so having a more cost-effective system is an advantage. He also indicated that it is important to keep focusing on costs and methods to secure more reliable cost figures. In summary, McGuckin mentioned that the topics discussed at the workshop could be used to think about the future and to further refine concepts to be flexible and responsive to the user. Denaro added that the public and private sectors have to work together. He explained that most transportation investments have long payback periods, which can be problematic for a purely private investment, and noted that a public–private model allows private firms to make investments with public backing.

Closing Remarks

Matt Lesh
Federal Transit Administration

Overview
At the end of the first day, Matt Lesh thanked the respondents for their creativity, participation, and courage in sharing new ideas. Lesh then provided some closing thoughts, which are highlighted in the following section.

Summary
Lesh highlighted the importance of recognizing the history in this field. He suggested visiting the PRT system in Morgantown, WV. Lesh explained how existing and new systems can be leveraged in new settings. He noted that challenging environments require new tools for mobility but that not all operation strategies will be solved by one type of system or tool. He emphasized that a new focus on multimodal connectivity is vital.

Lesh mentioned that travel is about the individual. He urged workshop participants to consider the rider experience and to think about a future of on-demand mobility in which individuals have a variety of preferences, and mode choice is situational. Lesh also mentioned FTA's concept of a "systems of systems" and the integrated corridor management program. He explained that this means highway and transit are operated as a system, sometimes shifting travel from one to the other based on conditions. He noted that part of this concept is data interoperability. Lesh reminded workshop participants and panelists that ideas on facilitating last-mile, seamless connections are just as important as higher profile concepts like high-speed rail. He highlighted a need to leverage existing infrastructure with new first- and last-mile options and other new ideas, such as how to transfer travelers from a high-speed rail station to their final destination.

Part Two:
Day 2 Overview

Day Two Introduction

At the start of the second day of the workshop, several attendees participated in a tour of the TFHRC facility, during which FHWA researchers demonstrated some of the computer-modeling approaches, driving simulators, and other tools used to investigate the potential effects of technology and policy changes on highway traffic behavior and safety. After the tour, David Kuehn, EAR Program Manager, reconvened the workshop with an introduction and overview of the second day. The second half of the workshop included two panel discussions, two sessions of RFI-respondent presentations, a subsequent response panel, and some final remarks to close the workshop. A summary of these discussions, presentations, and remarks is included in the following sections.

Panel One: State and Local Perspectives on Transportation System Development

PANELISTS

Laura Stuchinsky
City of San José, CA

Christopher Poe
Texas A&M Transportation Institute

Henry Kay
Maryland Transit Administration

MODERATOR

Ed Fok
Federal Highway Administration

City of San José, CA

Laura Stuchinsky explained that the City of San José, CA, manages 3,900 km (2,400 mi) of streets and sidewalks, along with other public infrastructure and utilities. She noted that the city also handles land-use planning and coordinates with the regional transit provider. Stuchinsky noted that the city's goals for 2025 include a 50-percent reduction in single-occupant vehicle commuting and a fivefold increase in transit, walking, and bike trips. She added that the city has made innovation a key part of its approach, with several initiatives and examples as follows:

- Expedited the procurement process for demonstration projects (e.g., vehicle-charging stations) so that small-scale tests can proceed with many of the normal procurement provisions waived.
- Developed a "smart" light-emitting diode streetlight system with network control (shown in figure 3).
- Performed a study of an automated transit network (ATN) to operate from the airport and connect to the city.
- Partnered with BMW on connected vehicles that use vehicle-to-infrastructure communication at traffic signals.

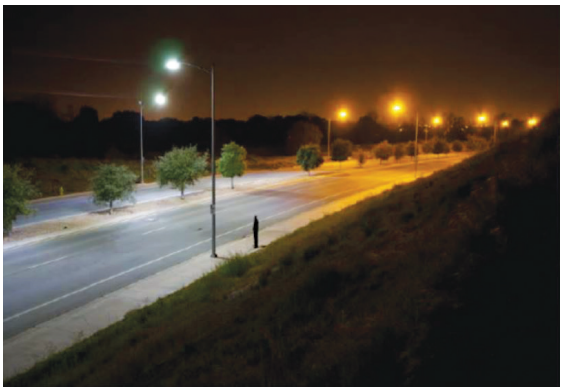

Figure 3. Smart streetlights in San José, CA.

The city is also creating a North San José transportation innovation zone, which may include various forms of sensors, monitoring, vehicle-to-vehicle and vehicle-to-infrastructure communication, and automated vehicles. Stuchinsky noted that even for a city like San José, which is intent on fostering innovation, there are some recurring constraints. During her presentation, Stuchinsky highlighted several constraints as follows:

- The city has a limited capacity to manage large and complex systems.
- The competitive public-procurement system is not well-suited to protecting proprietary information.

- The public sector likes to see independent verification and the use of industry standards, both of which may not be options for a truly cutting-edge technology.
- The environmental process requires an alternative analysis, which may present challenges for the evaluation of new modes.
- There is a need for independent, objective verification and validation of large, complex systems.

To respond to these challenges, some recommendations for transportation innovators include:

- Do not overreach—Play to the unique strengths of the system rather than describing it as a universal solution.
- Meet the needs of buyers.
- Build a strong business case.

Texas A&M Transportation Institute

Christopher Poe explained that some of the key constraints facing State and local governments are an aging infrastructure, financial constraints, limited operations and maintenance budgets, workforce turnover, long-time horizons for new and reconstructed infrastructure, and jurisdictional issues and the need for coordination. He noted that public-procurement processes can present a barrier to innovative ideas. Poe also highlighted that the past models are founded on a specifications-based approach that uses a design–bid–build approach, with the intent of choosing the lowest bidder who meets the specifications. Poe explained that these past models are ill-suited to new concepts and that some agencies are moving to a new, performance-based approach. He added that the newer approaches often make use of special delivery vehicles and other forms of public–private partnerships.

Poe mentioned that Texas has implemented several efforts to facilitate innovation in transportation and public services, including the Texas Technology Task Force, Texas Transportation Forum, and Accelerate Texas. Poe also described a new think tank that generates fresh ideas and helps the public and private sectors communicate on some of the largest issues facing Texas, such as transportation, water, and energy. He added that some of the current discussions on people movers in the north Texas area include first- and last-mile solutions for connecting the Dallas light-rail system to places such as office parks. Poe noted that there have also been discussions about a possible freight shuttle that would use shipping containers. He suggested that although certain aspects of the vehicle-highway system have changed only slightly over the past few decades (e.g., vehicle size and lane widths), the future is likely to require tighter integration between the vehicle, roadway, and driver. Poe added that the Texas Department of Transportation is moving forward with plans to allow some of its public roads to be used for testing new concepts.

Maryland Transit Administration

Henry Kay described the Maryland Transit Administration (MTA) as a typical transit operator because it is a State agency rather than a municipal or regional transit authority. As a planner, Kay mentioned that much of his attention has been focused on two "mega projects" for light-rail transit, each with budgets of $2–3 billion. He noted that light rail is a conventional technology that has been around for over 100 years, albeit

with improvements over time, and in this case it is mostly serving traditional urban land-use patterns, such as those in downtown Baltimore, MD.

During his presentation, Kay described several ways Government could become more open to innovation. He mentioned public–private partnerships (P3s) as one approach that offers additional flexibility. Kay noted that Maryland has already passed legislation that facilitates P3s but added that the public sector still needs to learn more about how P3s work and become comfortable with them. He mentioned that P3s are more common abroad and that MTA is learning from such overseas experiences to create a mechanism under which an innovator could work with a public agency more easily.

Kay next described how public-sector procurement processes tend to be stuck in a paradigm of defining precise specifications against which submissions are evaluated. He also mentioned that this approach is not amenable to new ideas. Moreover, Kay noted that the procurement process is designed to be fully transparent for fairness but that this works against the idea of safeguarding the intellectual property associated with new concepts. Kay agreed that the procurement process does need to be updated but suggested that innovators should also consider how to work within the current system. For example, there may be some parts of the system that could be competitively sourced, or non-proprietary technology could be used.

Kay suggested that innovators should also consider the perspective of public agencies and regulators, such as State public utilities commissions. He noted that they have a low-risk tolerance because of their mission to protect the public. Kay mentioned that innovative places, like the previous example of San José, CA, are really the exception to the rule and that most State and local governments perceive that they cannot afford to take any significant risks. He added that this is one reason why State and local governments prefer conventional, proven technologies, even when they arguably may offer less performance at greater cost when compared with more innovative options.

Kay also noted that public agencies may be concerned about the durability and complexity of assets associated with new transportation systems, in addition to their operation and maintenance costs. He explained that public budgets often endure lean periods when routine maintenance may be neglected. With this in mind, Kay stressed the importance of assets being robust to such neglect. For example, he highlighted how conventional road and rail systems can survive a certain degree of deferred maintenance and still provide acceptable, if somewhat degraded, performance. Kay added that if a system cannot function without perfect adherence to a maintenance schedule, then it is less likely to be considered a viable option. He noted that this relates to a point mentioned earlier in the workshop that systems requiring highly sophisticated maintenance regimes are also perceived as problematic because of employee turnover at transit agencies and other workforce issues. Agencies do not want to be stuck with systems that they lack the capacity to maintain.

In summary, Kay mentioned that innovators must consider the physical form and environmental impacts of infrastructure. When

implementing new projects, he highlighted that public agencies have a high level of accountability, such as environmental processes and regulations, that includes socio-economic and visual impacts. Kay stated that the primary function of public agencies is not research and development (R&D) and noted that those encouraging innovation within the public sector are often unique or have been empowered to assist innovation.

Panel Two: Financing and Business Models

PANELISTS

Jeff Olson
Alta Planning + Design

Nagesh Rao
Small Business Administration

Bob Denaro
Motus Ventures

MODERATOR
Heather Rose
Federal Highway Administration

Alta Planning + Design

Jeff Olson provided perspective from that of a successful transportation innovator and described Alta's focus on both the use of human power to improve community health and the promotion of a fun traveler experience. Olson emphasized that changes in society are enabling the establishment of new mobility models and posed a number of questions for the group to consider. He asked workshop participants to consider transportation, recreation, innovation, and short-distance travel and to think about how human power can be used to become a healthier society.

Olson highlighted Alta's focus on making travel fun and noted there have been 30 million rides on their bike-share systems so far. He added that Alta recently announced a major deal for new financing and the company has already used a variety of financing models that range from public funding (e.g., Washington, DC) to mixed public–private funding (e.g., Boston, MA; Chicago, IL; and San Francisco, CA). Olson mentioned that in New York City, Alta successfully leveraged sponsorship from Citibank for the "Citibike" program, which Citibank has seen as being very successful (shown in figure 4).

Olson highlighted that urban settings are providing many unique opportunities at this time. He noted that over 50 percent of the world's population now lives in urban environments and rapid changes in urban design are providing for many new opportunities, such as the use of Wi-Fi-based systems, mobile-transit stations,

Figure 4. Alta's bike-share bicycles in New York City.

and renewable energy systems (e.g., solar power). He added that large new urban projects now incorporate multiple modes, including complete streets and large greenway projects for walking, bicycling, and driving electric vehicles. Olson suggested that this represents a change in how people live, work, and play. He proposed the "72-hour street" in Curitiba, Brazil, which was reworked into a pedestrian walkway in just 3 days, as a representation of this type of shift.

When developing new systems, Olson highlighted the importance of asking what the next big thing is, what the next generation wants, and how to train people to work in industries that do not yet exist. He suggested working with a design professional to develop tools to facilitate use, ensure that new tools can be used by both an elderly person and a child, and ensure that tools are integrated so that people can move from mode to mode more easily.

Small Business Administration

Nagesh Rao highlighted how science, technology, and innovation priorities at the Federal level have resulted in a $135.4-billion budget for Federal R&D, as shown in figure 5; however, he noted that this funding is spread across many agencies. Rao explained that the Small Business Administration (SBA) provides advocacy on why small businesses matter. He noted that the SBA's SBIR program is commercially driven and provides seed funding for high-risk endeavors. Rao noted that some major companies have emerged as a result of SBIR funding.

Rao explained the importance of bringing something tangible and practical in nature to the SBA's SBIR and small business technology transfer (STTR) programs to successfully secure funding. He recommended not solely focusing on USDOT funding because there is funding available across the Government (shown in figure 6), and many new technologies may be relevant to other agencies, such as the Department of Defense or the National Aeronautics and Space Administration. He suggested that workshop participants think of "pivots" for a new technology and consider a range of applications. He mentioned to participants that the company iRobot now sells household vacuum cleaners but the original robotics application was in the field of bomb detection.

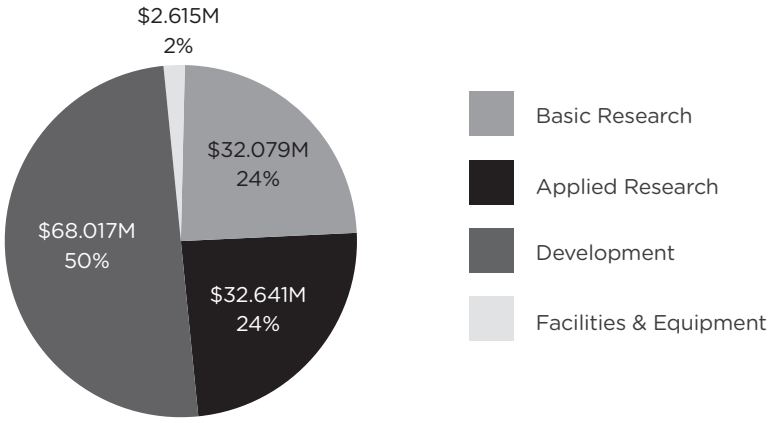

Figure 5. A breakdown of the $135.4-billion budget for Federal research and development.

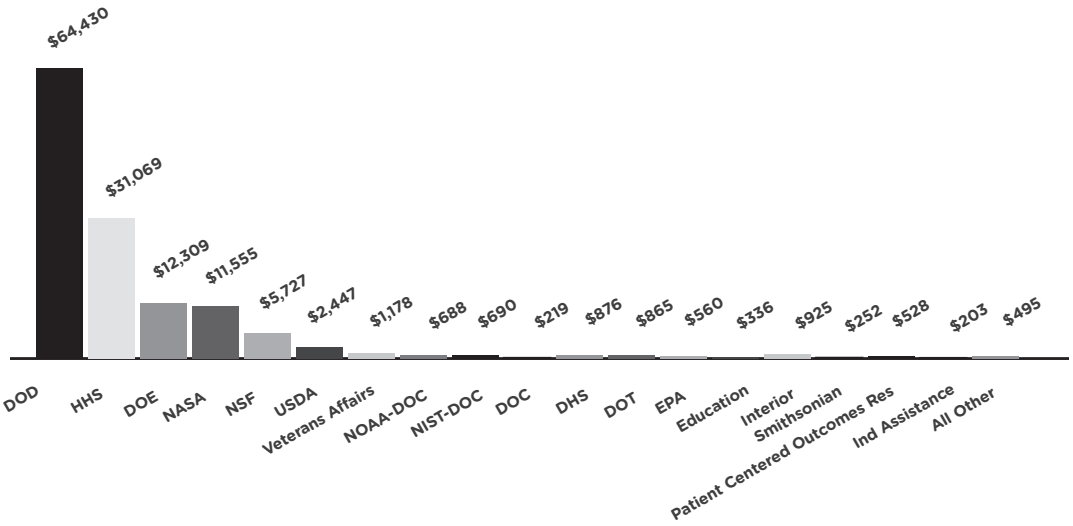

Figure 6. Budget breakdown by agencies in millions of U.S. dollars.

Rao also noted that venture capital is not the only place to go for financing. He mentioned that Government research programs can serve as a good source of funding, and although they may have additional procedural requirements, they also have the advantage of not diluting original ownership stake. Rao noted that, in transportation specifically, there are many legacy systems. He suggested that hybridization is one means of having people feel comfortable with a new concept (e.g., gas–electric hybrid vehicles) and might be considered as a way of gaining traction for a new idea. He also reminded participants to think globally about markets and suggested that there may be an application in the developing world or other countries beyond the United States. During his closing comments, Rao suggested that workshop participants work with local agency partners, universities, and community colleges to refine and test concepts and develop demonstrations and test beds. He noted that engineering students can be great partners in advancing an idea.

Day 2 Reaction Panel: Themes, Challenges, and Opportunities

PANELISTS

Christopher Poe
Texas A&M Transportation Institute

Nagesh Rao
Small Business Administration

Laura Stuchinsky
City of San José, CA

MODERATOR

Ed Fok
Federal Highway Administration

Overview

At the end of the second day, three expert speakers participated in a panel discussion and answered questions from the moderator and workshop participants. A summary of the panel discussion is outlined in the following sections.

Introducing New Technologies

Nagesh Rao asked workshop participants to consider how groundbreaking ideas can be executed and implemented in real time. He suggested looking for market traction and potential where one could build out a product. Rao congratulated workshop participants for pursuing grand challenges and reminded them to think globally about markets. Ed Fok then asked panelists to consider behavioral shifts and noted that end-user behaviors are often regional and localized. Fok asked how the successful transition from a hybrid system to a new mode, as seen abroad, can be achieved in the United States. Rao highlighted the importance of education and getting the next generation comfortable with the idea of transitioning over time to new technologies. He suggested introducing technology at a high-school level so that when a new technology emerges into society, it is already a social norm. Rao suggested working with local city partners, testing out technology within a 16-km (10-mi) radius, and working with universities and their engineering students.

Developing New Infrastructure

Fok asked panelists to consider why the majority of the systems presented at the workshop are elevated. He suggested that there may be an assumption that right-of-way (ROW) costs would be low. Fok asked if anyone has studied cost-per-mile for ROW acquisition as opposed to using existing options. One workshop participant explained that the main advantage to elevation is separation from other modes and pedestrians. This is why systems usually are constructed either underground or at elevated levels. The participant added that building an elevated system increases capital cost by approximately $1–2 million per mile. Another participant suggested that there is no other choice but to use elevated guideways.

Christopher Poe noted that an estimated two-thirds of the world's transportation infrastructure has not been built yet. He highlighted how some countries skipped landline telephone systems and progressed straight to cellular networks. Poe suggested that we may see similar jumps in transportation. He also suggested that it would be helpful to have in place some form of standardization. He explained that this way,

as agencies travel down a particular path, they will have some reassurance that they will be supporting multiple possible organizations and not just one single technology.

Laura Stuchinsky referenced Rao's earlier idea of companies working with local governments and noted that probably only a small handful of the workshop presentations would allow for a company to enter into an agreement with a local government, who could serve as a partner in system deployment. Stuchinsky suggested that a small experimental system might be acceptable but large elevated systems carrying people would be a very difficult sell. She noted that there would need to be answers to basic questions about the cost and safety of the system, with some objective or independent source of supporting information.

Identifying a Role for Government

Fok then asked the panelists to discuss any overarching needs the Government could fulfill. Fok also noted the importance of establishing system requirements or societal needs and asked panelists to consider the overall goal for society, for example, to eventually move to all-electric vehicles or to replace existing infrastructure. One workshop participant highlighted that all agencies want a prototype or pilot project and recommended seeking partnerships. Rao asked participants to consider the idea of developing a feeder system into research programs. Another workshop participant suggested that innovators could work with graduate students to perform an analysis of a system and provide a report for sponsors at Federal agencies to read. Rao noted that if there are opportunities to partner with local researchers at community colleges, then this could be a valuable option. He mentioned that STTR grants could help with this, but that there is room to do more to make this happen.

Implementing Automated Transit Networks

Ed Fok noted that ATNs and elevated systems move large numbers of people along a specific alignment; however, there are still last-mile issues to contend with. Jeff Olson noted that he would like to see partnerships with community planners and real-estate and community health professionals to identify what the city of the future should look like and how these innovative modes would make that happen. He asked participants to consider what places are being connected and question whether people would want to choose a new transit system to get there. Olson highlighted a need for broader thinking beyond engineering and design. He suggested that researchers engage students from fields such as architecture and landscape architecture to inform this process.

Laura Stuchinsky noted that one reason ATN is so attractive is to improve access. She highlighted that suburban areas are low density but that ATN can transform these areas into walking-, biking-, and transit-friendly environments. Stuchinsky suggested that the current problems are not necessarily technology-related or contingent on the speed of the vehicle but instead are more related to factors like station design, how people react to automated systems, and personal safety. She noted that there is a lot of potential but also a lot of unanswered questions.

Olson provided an example of a new aerial tramway system in Rio de Janeiro, Brazil, that connects hilltop favelas to improve access. He explained that the system was not hitting ridership targets because all of the stations were located at hilltops and people halfway down the hill did not want to walk uphill first thing in the morning. To avoid this uphill walk, users would walk downhill

and then take the system uphill at the end of the day. Olson noted that the system would be great for tourists, but it was not marketed to tourists. He highlighted this as an example of how system designers need to consider how people will use a system during different times of the day, during different seasons, for different purposes, and how it will be accessed. Olson added that the population being served will determine how mobility develops.

Standardization and Risk Mitigation

Kevin Kesler asked the inventors present at the workshop to provide their views on standardization. He asked whether a standard guideway and a standard control system would enable growth. One workshop participant responded that a standard guideway and control system would indeed enable growth and that all generational designs would follow. Another participant noted that ASTM International standards cover all aspects of technologies, although these standards are not mandatory. The participant suggested that if a new technology emerges that has not existed before, then new standards would need to be identified.

Ed Fok asked panelists to consider the issue of a failure mode and identify how the system responds when bad things happen. Fok also asked how risk can be mitigated so that any early failures do not kill innovation, particularly for ATN systems. Stuchinsky suggested that researchers conduct pilots or demonstrations that are outside of existing ROWs to establish that the system is safe. Olson highlighted that Alta's New York City bike-share project was hit by Superstorm Sandy while in predeployment storage at the Navy Yard. He noted that resiliency is now built into what they do. He suggested that, for systems involving elevated stations, researchers should consider what those stations look like, identify how people access the station, and verify that they are resilient in terms of flooding. Olson added that the first and last minutes of a trip are often the most critical. Poe noted that universities and government agencies are dedicating part of their infrastructure to performing testing on hybrid systems.

Looking to the Future

A workshop participant asked the panelists if they see value in systems that do not include or integrate with current automobile transportation systems. Olson noted that in 25 years, cars will differ from what they are today, with automation and different user models. He suggested that even if researchers do not use any of the guideway systems described at this time, changes are currently taking place that may alter how people think of transportation. Olson highlighted that in the United States, because of land-use patterns and suburbanization, people will be living in neighborhoods and wanting to travel significant distances every day. He noted that one of the issues facing fixed guideway systems is that filling that system will require working with the real-estate community and getting people to live near those systems.

A workshop participant then asked the panelists whether they believe that there is only one infrastructure system that will be predominant in the future. Olson suggested that this would not be the case because the world is too diverse, and cities and cultures vary. He highlighted how businesses adapt to local needs, conditions, and interests in the business world. Fok agreed that it is important to not put all proverbial eggs in one basket. He noted that this issue occurred when the Interstate system was being built, in that transit lines that were previously ripped out because of the new Interstate system are now desired to be reinstated.

Closing Remarks

Bob Sheehan
Intelligent Transportation Systems Joint Program Office

Nagesh Rao
Federal Highway Administration

Summary
Bob Sheehan noted that in his role at FHWA's Intelligent Transportation Systems Joint Program Office, he looks at maximizing the value of existing infrastructure and advancing the idea of mobility as a service. Sheehan then summarized some of the themes of the workshop. He noted that the overall goal is to make the "novel" the "normal," that is, to bring innovation to the mainstream. Sheehan noted that there are challenges to evolution and innovation, including the public sector process, but that there are also ways to mitigate these challenges, such as operational tests outside of the public ROW. He noted that it is important to consider integration of highways and transit with broader questions of land use. Sheehan added that different transportation objectives and new metrics also need to be considered, with transportation viewed as part of the overall quality of life. He suggested that transportation is changing as society is becoming more connected. With this in mind, he asked participants to consider the implications of the "connected city" concept, the National Highway Traffic Safety Administration's proposal for vehicle-to-vehicle safety communication, and vehicle automation. Sheehan noted that it is now important to identify the Government's role, to specifically identify the role of the Joint Program Office, and then to examine how to integrate exploratory research into more programs.

David Kuehn discussed next steps following the workshop. He noted that information from the RFI responses, the workshop, and other technology scans will go into a final summary report. He added that it will take time for all stakeholders to be consulted, including non-DOT Federal agencies and some State and local partners. Kuehn mentioned that some basic draft material will be circulated to confirm details of the RFI respondents' concepts and to share initial findings. Kuehn concluded by expressing his thanks to the workshop participants and noted that their innovative ideas are the reason for the workshop.

KEY THEMES AND TAKEAWAY MESSAGES

Several major themes emerged from the workshop. These themes and their relevance for novel surface transportation systems are summarized in the following sections.

Societal Context and Current Trends

- The history of transportation suggests that innovation has been mostly incremental rather than revolutionary and has involved interaction between the public and private sectors. New systems generally require substantial investment over long-time horizons, and their success is

often determined as much by institutional factors as by technical ones.
- Current road and transit systems offer high levels of mobility and convenience and are flexible enough to incorporate new concepts like bus rapid transit and bike-sharing. This means that competing concepts have a fairly high threshold to clear for widespread adoption.
- Both passenger and freight transportation are introducing partial automation, which offers efficiency improvements without the need for major new infrastructure.
- Personal travel patterns are currently in transition, with evidence of shifts from "maintenance" travel to other trip purposes, more situational mode choice, and overall moderation in the growth of travel demand.

Opportunities for Novel Modes

- Some State and local agencies, such as San José, CA, are actively pursuing new concepts with innovation zones and procurement changes.
- Changes in travel patterns are breaking the automobile "monoculture," and there is greater openness to new concepts like car- and bike-sharing, suggesting potential openness to other new modes as well.
- Novel modes and their underlying technologies may have other applications that would be of interest to Federal research programs outside of USDOT (e.g., Department of Defense, Department of Health and Human Services, and Department of Energy).
- University partnerships can help with research, modeling, and demonstrations.
- Standards-setting can accelerate innovation in some cases. The public sector does not need to set these standards but in some cases can serve as a convener.
- Novel-mode concepts may be more viable with a focus on specific applications or niche markets, such as certain trip types, customers, or geographies (including international and developing-country applications).

Challenges for Novel Modes

- New concepts will need to consider connections to existing transportation modes and the whole trip chain. Fixed guideway systems also need to address the first- and last-mile issue, particularly given the low-density land-use patterns in much of the country.
- Passenger comfort and the overall experience are also important factors in mode choice and deserve additional attention as new concepts are developed.
- There is a need for independent verification and validation of performance of novel modes.
- Forecasting travel demand and mode choice has become more difficult in general and even more so for novel modes.
- The balance between public and private investment in transportation has changed over time, but both are risk-averse and prefer time-tested technologies and systems that are easier to build, operate, and maintain. For the private sector, the key issues are the business model and the potential for a very long period before initial investments are paid back. For the public sector, there are many limitations affecting the ability to pursue novel concepts, including rigid procurement processes, workforce concerns, and fluctuating funding levels.
- For systems likely to be operated by the public sector, tolerance to deferred maintenance under times of limited operating budgets is key.

Potential Government Roles

Workshop participants also discussed several potential roles for the public sector. These roles ranged from direct funding of research and demonstrations of promising concepts to more indirect support, such as stakeholder outreach, assisting with the development of technical standards, providing guidance and technical assistance, and facilitating technology transfer. Workshop participants also suggested that government agencies offer access to their test beds and research facilities to enable research and testing.

Appendices

APPENDIX A: RFI RESPONDENT CONCEPT SUMMARIES

Project Title	CargoFish
Submitted by	Robert DeDomenico, CargoFish Physical Internet
Summary	• Initial phase: Track-based, underground, capillary network that delivers small payloads using small motor-driven traction drive track vehicles. • Secondary phase: Larger, heavier gauge arterial network is installed to move people and freight.
Status	Operational proof-of-concept prototype developed.
Project Title	**Low Cost Maglev Transportation using Electrodynamic Wheels**
Submitted by	Jonathan Bird, University of North Carolina at Charlotte and Electrodynamic Wheels
Summary	• Maglev transportation using electrodynamic wheels passive guideway.
Status	Sub-scale force and three-dimensional eddy-current analyses complete. Sub-scale vehicle demonstration complete.
Project Title	**Hybrid Personal Rail Transit System**
Submitted by	Thomas Pumpelly, Hybrid Personal Transit, Inc.
Summary	• Infrastructure: Elevated electrified monorail located in a freeway median. • Modified vehicles drive onto monorail from roadway access points. Vehicles can use existing infrastructure. • Dual mode. Vehicles can travel on existing streets.
Status	Conceptual drawings prepared. Preliminary engineering designs for system components done. Simulations conducted.
Project Title	**Electric Dual Mode Skyway**
Submitted by	Travis Knapp, Innov8Transport
Summary	• Automated high-speed road/rail. • Wheel-wing technology that enables existing vehicles (e.g., car, bus, and truck) to dock onto road/rail. • On/off-board at designated locations. • Automated platooning.
Status	Full-scale wheel-wing latches have been built and tested.
Project Title	**Hydrogen Super Highway**
Submitted by	Justin Sutton, Interstate Traveler Co., LLC
Summary	• Integrates elevated maglev transportation system with municipal conduit. • Solar-powered, converted to hydrogen power to self-sustain system. • Operating system will facilitate routing and position control.
Status	Computer simulations performed.

APPENDIX A: RFI RESPONDENT CONCEPT SUMMARIES, *cont'd.*

Project Title	**Comprehensive MagLev**
Submitted by	Joshua Levin, LeviCar Unlimited
Summary	• Vehicle body can attach to a road chassis for conventional driving or the maglev chassis/track for guideway transportation. • Dual mode. Vehicles can travel on existing streets.
Status	Hardware components built and tested together and functioned properly together as a prototype.
Project Title	**Hybrid Electric Roadtrains**
Submitted by	Bruce McHenry, Tommaso Gecchelin, and Dr. Tim Gordon, McHenry Enterprises
Summary	• "Combine" through mechanical coupling to form a single, train-like vehicle. • Hybrid-electric vehicles; range of the vehicle is not limited by storage of electricity. • Requires driver in the lead vehicle.
Status	Conceptual phase of development.
Project Title	**SkyTran Automated Transit Networks**
Submitted by	John Cole, SkyTran, Inc.
Summary	• An aircraft that "flies" within an elevated guideway system via magnetic containment. • Propulsion by "magnetic screw." Spinning magnet arrays within the tubular reaction rail induce eddy current forces that center and propel the magnet array axially within the rail. • Travels up to 241 km/h (150 mi/h) and can add up to three lanes of capacity.
Status	Working 1/5 scale prototype that demonstrates propulsion and levitation. Will soon demonstrate switching.
Project Title	**Beamways Adaptive ATN System**
Submitted by	Bengt Gustafsson, Beamways AB
Summary	• Automated transit network with adaptable vehicle size and platooning. • Vehicles suspended on elevated monorail system. • Solar-powered.
Status	Technology patented. Costing and guideway structural study completed. Simulation completed. University team working on system.
Project Title	**UltraLight Rail Transit**
Submitted by	Neil Sinclair, CyberTran International
Summary	• Small, light, autonomous, high-speed passenger rail vehicles for long-distance commuting.
Status	Near full-scale test deployments developed.

APPENDIX A: RFI RESPONDENT CONCEPT SUMMARIES, *cont'd.*

Project Title	**A Third Generation of Roadway**
Submitted by	Roger Davidheiser, Davidheiser Design
Summary	• Light-weight vehicles that interface with track infrastructure electrically and autonomously, providing high-speed travel. • Dual mode. Vehicles can travel on existing streets.
Status	Scale model constructed. Studies performed.
Project Title	**VECTORR™ High-Speed Passenger Rail**
Submitted by	Max Schlienger and John Reardan, Flight Rail Corporation
Summary	• High-speed, elevated guideway system that uses vacuum/pressure to propel a free piston, magnetically coupled to the vehicle, for propulsion. • Stationary power systems can use a wide range of fuels, including electricity.
Status	1/6 scale prototype constructed. Testing conducted.
Project Title	**Automated Transit Network**
Submitted by	Eugene Nishinaga and Peter Muller, Transit Control Solutions/ PRT Consulting Inc.
Summary	• New vehicular control algorithms implemented through Transit Control Solutions, which can integrate with existing commercial off-the-shelf products.
Status	1/32 scale model (45.72-m (150-ft track)) constructed. Tests conducted and findings are summarized in report. Software engineering currently in progress.
Project Title	**BeemCar**
Submitted by	Peter Lovering, BeemCar Ltd.
Summary	• Personal rapid transit system. • Lightweight pods suspended from a network of carbon fiber beams propelled by Linear Synchronous Motor and partly powered by solar energy.
Status	Seeking funding for demonstration.
Project Title	**Bubblemotion**
Submitted by	Asko Kauppi, BM Design Oy
Summary	• Automated personal rapid transit system. • Vehicles travel on elevated rail.
Status	Static track strength simulations and cost–benefit analysis completed.
Project Title	**Infrastructure System for Powering Vehicles while Driving**
Submitted by	Gunnar Asplund, Elways AB
Summary	• Conductive system feeds all vehicle types (e.g., electric vehicles) electricity through rail in road while driving. • Conductors placed beneath the surface and only energized when a vehicle passes.
Status	Technology patented and demonstration model built.

APPENDIX A: RFI RESPONDENT CONCEPT SUMMARIES, *cont'd.*

Project Title	**Speedway**
Submitted by	Christian Foerg, Lumod GmbH
Summary	• Long distance, electric propulsion for any vehicle. • Wandering magnetic field under the road powers vehicles and inductively charges their internal batteries.
Status	Initial technical test completed.
Project Title	**Aerial Highway**
Submitted by	Rodger L. Gibson, Airbornway Corporation
Summary	• Autonomous, freight/passenger car that runs on a light aerial cable from which it draws electricity.
Status	Proof of concept developed.
Project Title	**Drive on Drive off Truck Ferry**
Submitted by	Robert Pulliam, Tubular Rail, Inc.
Summary	• Expansion of the current national rail system to incorporate flatbeds (accommodating three to four trucks) into the rolling stock. • Trucks align on 18 m by 24 m (60 ft by 80 ft) flatbed perpendicular to movement of train • Supporting rails on either side of the main track 9 m (30 ft) from the center.
Status	Technology patented and demonstration model built.
Project Title	**OTG HighRoad and Silver Bullet**
Submitted by	William Owen, Owen Transit Group, Inc.
Summary	• Elevated, automated guideway with a T-shaped rail that supports two-way transportation. • Silver Bullet faster than HighRoad and designed for commuting.
Status	Engineering analyses, business plan, and ridership analysis complete.
Project Title	**Elevated Dual Mode High-Speed Rail**
Submitted by	Waldemar Kissel, Overland ATS, LLC
Summary	• Elevated steel rail infrastructure with electrified security rail in center. • Vehicles have bimodal wheels and multipurpose sensory saddle.
Status	Multiple patents issued and pending. Model and demonstration prototypes developed.
Project Title	**SkySMART**
Submitted by	Robert Laurence, SHWEEB US-Fl. Inc.
Summary	• Suspended, bi-directional, steel and hypercomposite guideway that operates above, below, or at ground level. • SMARTpods full automated. • Runs off of grid electric, solar, battery, and optional human power.
Status	Proof of concept completed. Final R&D in progress.

APPENDIX A: RFI RESPONDENT CONCEPT SUMMARIES, *cont'd.*

Project Title	**The TEV Project**
Submitted by	Will Jones and Caroline Jones Carrick, TEV Project
Summary	• Restricted, electrified highway lane. • Rubber tired electric cars, driverless minicabs and buses, and automated-vehicle platoons can draw electricity from the track.
Status	Design studies, animations, and technical report developed.
Project Title	**MonoCab VRT**
Submitted by	David Whittaker, MonoCab VRT
Summary	• Elevated guideways. • Propulsion by electrically powered drive trains at each end of vehicle, incorporates regenerative braking.
Status	Concept report and case studies prepared. Trailer mounted display model developed.

APPENDIX B: AGENDA

EAR Program Workshop : Novel Modes Workshop

Turner–Fairbank Highway Research Center, McLean, VA, and FTA Region 9 Offices in San Francisco, CA

Tuesday, December 2, 2014		
Time	**Topic**	**Speaker(s)**
12 p.m.	Welcome Introduction Opening Remarks: Workshop Interests and Goals	Michael Trentacoste, *Associate Administrator, Research, Development, and Technology, Federal Highway Administration* Gregory D. Winfree, *Assistant Secretary for Research and Technology, U.S. Department of Transportation*
12:30 p.m.	Keynote: History of Modes of Transportation	Martin Wachs, *University of California, LA, and RAND Corporation*
	Presentation: Recent Changes and Future Directions in Travel Behavior	Nancy McGuckin, *Travel Behavior Consultant*
	Presentation: Present-day Trends in Freight Movement	Genevieve Giuliano, *University of Southern California*
	Presentation: Making the Investment Decision for a New Technology	Bob Denaro, *Motus Ventures*
	Summary Remarks	Kevin Kesler, *Federal Railroad Administration*
2 p.m.	Break/Lunch	
2:10 p.m.	Presentations: RFI respondents (Day 1, Part I)	RFI respondents
3:30 p.m.	Break/Lunch	
4 p.m.	Presentations: RFI respondents (Day 1, Part II)	RFI respondents
5 p.m.	Panel Discussion: Themes, Challenges, and Opportunities	Panel Members Moderated by Ed Fok, *Federal Highway Administration*
5:45 p.m.	Wrap-up: Day 1	Matt Lesh, *Federal Transit Administration*
6 p.m.	End of Day 1	

APPENDIX B: AGENDA *, cont'd.*

Wednesday, December 3, 2014		
Time	**Topic**	**Speaker(s)**
10 a.m.	Optional Activity: TFHRC Facility Tour	
12 p.m.	Opening Remarks	David Kuehn, *Federal Highway Administration*
12:05 p.m.	Panel Discussion: State and Local Perspectives on Transportation System Development	Laura Stuchinsky, *City of San José, CA* Christopher Poe, *Texas A&M Transportation Institute* Henry Kay, *Maryland Transit Administration* Moderated by Ed Fok, *Federal Highway Administration*
12:50 p.m.	Presentations: RFI Respondents (Day 2, Part I)	RFI respondents
1:50 p.m.	Break/Lunch	
2 p.m.	Panel Discussion: Financing and Business Models	Jeff Olson, *Alta Planning + Design* Nagesh Rao, *Small Business Administration* Bob Denaro, *Motus Ventures* Moderated by Heather Rose, *Federal Highway Administration*
2:45 p.m.	Break/Lunch	
3:15 p.m.	Presentations: RFI Respondents (Day 2, Part II)	RFI respondents
4:15 p.m.	Panel Discussion: Themes, Challenges, and Opportunities	Panel Members Moderated by Bob Sheehan, *Intelligent Transportation Systems Joint Program Office*
5 p.m.	Workshop Closing Remarks	Vince Valdes, *Associate Administrator for Research, Demonstration, and Innovation, Federal Transit Administration*
5:15 p.m.	End of Day 2	

APPENDIX B: AGENDA, *cont'd.*

Day 1 RFI Respondent Presentations		
Time	**Speaker/Organization**	**Location**
2:10 p.m.	Robert DeDomenico, CargoFish	McLean, VA
2:20 p.m.	Jonathan Bird, Electrodynamic Wheels and University of North Carolina at Charlotte	McLean, VA
2:30 p.m.	Thomas Pumpelly, Hybrid Personal Transit, Inc.	McLean, VA
2:40 p.m.	Travis Knapp, Innov8Transport	McLean, VA
2:50 p.m.	Justin Sutton, Interstate Traveler Co., LLC	McLean, VA
3 p.m.	Joshua Levin, LeviCar Unlimited	McLean, VA
3:10 p.m.	Bruce McHenry, Tommaso Gecchelin, & Dr. Tim Gordon; McHenry Enterprises	San Francisco, CA
3:20 p.m.	John Cole, SkyTran, Inc.	San Francisco, CA
4 p.m.	Bengt Gustafsson, Beamways AB	San Francisco, CA
4:10 p.m.	Neil Sinclair, CyberTran International	San Francisco, CA
4:20 p.m.	Roger Davidheiser, Davidheiser Design	San Francisco, CA
4:30 p.m.	Max Schlienger and John Reardan, Flight Rail Corporation	San Francisco, CA
4:40 p.m.	Eugene Nishinaga and Peter Muller, Transit Control Solutions and PRT Consulting	San Francisco, CA

APPENDIX B: AGENDA, *cont'd.*

Day 2 RFI Respondent Presentations		
Time	**Speaker/Organization**	**Location**
12:50 p.m.	Peter Lovering, BeemCar Limited	Remote
1 p.m.	Asko Kauppi, BM Design Oy	Remote
1:10 p.m.	Gunnar Asplund, Elways AB	Remote
1:20 p.m.	Christian Foerg, Lumod Design	McLean, VA
1:30 p.m.	Ramesh Malla and Roger Gibson, University of Connecticut and Airbornway Corporation	Remote
1:40 p.m.	Robert Pulliam, Tubular Rail, Inc.	McLean, VA
3:15 p.m.	William Owen, Owen Transit Group, Inc.	Remote
3:25 p.m.	Waldemar Kissel, Overland ATS, LLC	McLean, VA
3:35 p.m.	Robert Laurence, SHWEEB US-FI. Inc	McLean, VA
3:45 p.m.	Will Jones and Caroline Jones Carrick, TEV Project	McLean, VA
3:55 p.m.	David Whittaker, MonoCab VRT	Remote

APPENDIX C: SPEAKER AND PANELIST BIOGRAPHIES

Bob Denaro

Bob Denaro is a private consultant in intelligent transportation systems (ITS) technology and strategy and a member of the Board of Advisors of Transportation Technology Ventures in Silicon Valley, CA. He was formerly Vice President of Nokia/Navteq where he led the development of Advanced Driver Assistance Systems and, before that, Vice President of Motorola where he developed the world's first Telematics products for Ford Rescu, Mercedes TeleAid, GM Onstar, and others. He also led Motorola's global positioning system business. Denaro is currently chair of the USDOT's ITS Program Federal Advisory Committee and chair of the Transportation Research Board's Joint Subcommittee on Challenges and Opportunities in Road Vehicle Automation.

Genevieve Giuliano

Professor Genevieve Giuliano conducts research on relationships between land use and transportation, transportation policy analysis, and information technology applications in transportation. Her current research includes analysis of regulatory policies aimed at reducing impacts of freight in metropolitan areas, development of metropolitan freight-flow models, and analysis of changes in metropolitan spatial structure. Giuliano has published over 130 papers. She serves on the Editorial Boards of *Urban Studies* and *Journal of Transport Policy*. She has participated in several National Research Council policy studies and is currently chairing the Committee on Funding Options for Freight Transportation Projects of National Significance. She is also founding Chair of the California Transportation Research and Technology Advisory Panel.

Henry Kay

Henry Kay is MTA's Executive Director for Transit Development and Delivery. Reporting to the MTA Administrator, he is responsible for planning, engineering, and construction of three new high-capacity transit lines with a total estimated value of $6 billion and total daily ridership of 150,000. Kay also served as MTA's Deputy Administrator for Planning and Engineering and Director of Planning. Kay holds a Bachelors degree from the University of California, Berkeley, and a Masters of City and Regional Planning from Cornell University.

Kevin Kesler

Kevin Kesler joined USDOT in 2009 as the Federal Railroad Administration's Chief of Rolling Stock R&D Division. He previously spent 38 years leading the development and application of technology for the railroad industry around the world and for USDOT. As Vice President at ENSCO, Inc., he was responsible for technology development and sales to the global rail and transit industry and the USDOT. He has served as Technical Advisor to the National MAGLEV Initiative and Amtrak Acela and has been awarded four patents for transportation technology.

APPENDIX C: SPEAKER AND PANELIST BIOGRAPHIES, *cont'd.*

Matthew Lesh
Matthew Lesh currently works as a Transportation Program Specialist in the Office of Mobility Innovation at the Federal Transit Administration. He previously worked for Arlington County, VA, and spent several years building a series of start-ups in the biotechnology sector. Among other responsibilities, he currently manages FTA's Transit Investment for Greenhouse Gas and Energy Reduction Program; works on transit access, bicycle, and pedestrian issues; and works closely within several department-wide programs developing ITS. Lesh also works on supporting the agency on subjects as diverse as bus rapid transit deployment, bike sharing, the shared economy, and transit-oriented development.

Nancy McGuckin
Nancy McGuckin is an independent consultant and nationally known expert in the interpretation and forecasting of travel behavior. She is best known for her ability to make meaningful analysis from complex data sources and her practical interpretation of research. She recently completed forecasts of travel by older Americans, migration and immigration patterns and trends, and forecasts of non-work travel for the National Surface Transportation Policy and Revenue Study Commission.

Jeff Olson
Jeff Olson is an architect, planner, and author who has been involved in greenways, open space, active living, and alternative mobility projects for more than 25 years. He has had a diverse career with national, international, and local experience in the public, private, and non-profit sectors. He has been a principal with Alta Planning + Design for more than a decade and was a co-founder of Alta Bicycle Share, the operator of bike-share systems in New York, Washington, DC, Toronto, Melbourne, Boston, San Francisco, and other cities. His experience was recognized in 2014 by the Association for Pedestrian and Bicycle Professionals with a Lifetime Achievement Award. His unique vision and leadership ability are important assets to projects ranging from regional planning to site-specific projects and programs. Olson teaches America's first university course in bicycle and pedestrian planning, and is Co-Director of the University at Albany Initiative for Healthy Infrastructure. His book, *The Third Mode: Towards a Green Society*, has created a new way of thinking about mobility and society. Olson is a frequent inspirational speaker at conferences, public meetings, and other events.

Christopher Poe
Dr. Christopher Poe is an Assistant Director at the Texas A&M Transportation Institute (TTI). In his current position, he is leading ITS, transportation operations, connected transportation, and toll-road research and implementation projects. Poe also serves as the Head of the Research and Implementation Division at TTI where he oversees 70 transportation researchers on a variety of projects in the TTI Dallas/Fort Worth, El Paso, Houston, and San Antonio offices. Poe has an extensive background in transportation management, traffic operations, ITS, and high-occupancy vehicle lanes.

APPENDIX C: SPEAKER AND PANELIST BIOGRAPHIES, *cont'd.*

G. Nagesh Rao

G. Nagesh Rao currently serves as Chief Technologist with the Small Business Administration's Office of Investment and Innovation. His portfolio of work includes the SBIR and STTR programs and coordination of the Fueling Small Business Innovation Interagency Policy Committee for the White House's Lab to Market Commercialization Agenda. He is a practicing technologist and commercialization strategist working at the intersection of applied science, law, business, and public policy from both domestic and international perspectives.

Laura Stuchinsky

As an Associate Transportation Specialist at the City of San José Department of Transportation, Laura Stuchinsky works to advance the city's sustainable transportation goals and illustrate San José's reputation for innovation. This includes managing the installation of electric-vehicle charging stations and overseeing the car share parking pilot program. She managed a study that evaluated the technical and financial feasibility of building an ATN to interconnect points within the Norman Y. Mineta San José International Airport and link it to transit lines on either side of the airport. More recently, she joined the city's newly-formed Transportation Options Program team, which will employ a variety of innovative tools and programs to encourage residents and employees to use transportation options. Prior to coming to the City of San José, Stuchinsky was the Director of Transportation and Land Use for the Silicon Valley Leadership Group.

Michael Trentacoste

Michael Trentacoste was named FHWA Associate Administrator for Research, Development, and Technology in January 2009. He also serves as the Director of FHWA's TFHRC in McLean, VA. He is responsible for leadership in the development and coordination of national research and technology partnerships, corporate facilitation and coordination of the delivery of technology and innovation, and the formulation, conduct, and evaluation of R&D. Prior to joining USDOT, Trentacoste held a variety of technical positions with the New York State Department of Transportation.

Vincent Valdes

Vincent Valdes is the Associate Administrator for Research, Demonstration, and Innovation at the Federal Transit Administration, where he manages the critical transit research program. The program provides research leadership to the transit industry and facilitates the development of transit technologies and techniques that support national transportation goals. Valdes has over 25 years' experience as a senior manager in public and private sector agencies, including the Washington, DC, Office of Planning, the World Bank, and the Inter-American Foundation.

APPENDIX C: SPEAKER AND PANELIST BIOGRAPHIES, *cont'd.*

Martin Wachs

Dr. Martin Wachs was a professor of civil and environmental engineering and professor of city and regional planning at the University of California, Berkeley, where he also served as director of the Institute of Transportation Studies. Prior to this, he spent 25 years at University of California, Los Angeles, where he served three terms as chairman of the Department of Urban Planning. He retired as senior principal researcher and director of the Transportation, Space, and Technology Program at the RAND Corporation.

Gregory Winfree

Gregory Winfree originally came to the USDOT's Research and Innovative Technology Administration (RITA) in March 2010, and was sworn in as its fourth Administrator on October 23, 2013. As directed in the Consolidated Appropriations Act (Omnibus) of 2014, RITA was elevated to the newly-created Office of the Assistant Secretary for Research and Technology, and on January 23, 2014, Winfree was sworn in as the Assistant Secretary. During his tenure, Winfree has also served as the agency's Chief Counsel, Deputy Administrator, and Acting Administrator and as chairman of USDOT's Innovation Council. As both an innovator with design and utility patents to his credit and an experienced intellectual property litigator, Winfree has a special affinity for USDOT's diverse transportation research, innovation, and knowledge-management mission.

APPENDIX D : RFI RESPONDENT PARTICIPANT LIST

Organization	First	Last
Elways AB	Gunnar	Asplund
Freedom Transit, Solar Transportation Technologies	Jim	Beregi
Electrodynamic Wheels	Jonathan	Bird
TEV (Tracked Electric Vehicle)	Caroline	Carrick
Davidheiser Design and Third Generation Roadway	Roger	Davidheiser
BiModal Glideway	William D.	Davis, Jr.
CargoFish Physical Internet	Robert	DeDomenico
SwiftTram	Becky	English
SkyTran and The Ferguson Group	Bill	Ferguson
Lumod GmbH	Christian	Foerg
Airbornway Corporation	Rodger	Gibson
Beamways AB	Bengt	Gustafsson
TEV Project	Will	Jones
TEV Project	Caroline	Jones Carrick
BM Design Oy	Asko	Kauppi
Innov8transport	Patrick	Kennedy
Overland ATS	Waldemar F.	Kissel Jr.
Magna Force, Inc., Lev X	Jo	Klinski
Innov8Transport	Travis	Knapp
SHWEEB-CAN	Robert	Laurence
Taxi 2000, SkyWeb Express	Mike	Lester
LeviCar Unlimited	Joshua	Levin
BeemCar Ltd.	Peter	Lovering
Airbornway Corp.	Ramesh B.	Malla
(Hybrid-) Electric Roadtrains	Bruce	McHenery
Tunnel Bus System	Li	Mingshen
PRT Consulting	Peter	Muller
Transit Control Solutions	Eugene	Nishinaga
ET3	Daryl	Oster
Owen Transit Group	William E.	Owen
Tubular Rail, Inc.	Robert	Pulliam
Hybrid Personal Transport, Inc.	Thomas	Pumpelly
Flight Rail Corporation	John	Reardan
Zetta Research	Kim	Rubin
VECTORR™ technology, Flight Rail Corporation	Max P.	Schlienger
CyberTrain International	Neil B.	Sinclair
Fastran	Ennis C.	Sullivan II
Interstate Traveler Co.	Justin	Sutton
MonoCab VRT	David	Whittaker
Advanced Transportation Technologies, New West Technologies	Gregory	Wilcox

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About the EAR Program

Federal legislation establishes an Exploratory Advanced Research (EAR) Program for transportation to address longer term, higher risk, breakthrough research with the potential for dramatic long-term improvements to transportation systems, improvements in planning, building, renewing, and operating safe, congestion-free, and environmentally sound transportation facilities. The Federal Highway Administration's (FHWA's) EAR Program secures broad scientific participation and extensive coverage of advanced ideas and new technologies through stakeholder engagement, topic identification, and sponsored research. The uncertainties in the research approach and outcomes challenge organizations and researchers to be innovative problem-solvers, which can lead to new research techniques, instruments, and processes that can be applied to future high-risk and applied research projects.

For more information, please visit the EAR Program Web site at http://www.fhwa.dot.gov/advancedresearch/.

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