

A RESEARCH VISION FOR AN AMERICAN TRANSPORTATION FUTURE

"BY THE PEOPLE AND FOR THE PEOPLE"

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You've not met them yet, and they don't necessarily know each other, but you already know them. They will be your fellow community members, co-workers, colleagues, family members, and friends. You pass people like them on the street, sit across from them on a bus or a flight, or stand with them in line at the store. Jessica, Selma, "TJ" (don't ever call him Theodore James!), Alan, Ichiro, and Taylor are Americans just like you, and "Airie" is a familiar part of their world just as comfortable, natural, and essential for their lives as automobiles and telephones are for us today. Like you, their lives and livelihoods depend in critical ways upon having safe, reliable, and affordable access to transportation.

The seven of them, however, live in your transportation future, in the year 2050. They inhabit a world that has been transformed since the early 2020s by far-seeing infrastructure investments, innovative technological developments, and wise institutional reforms that have made transportation in their time more accessible and convenient, more efficient and environmentally responsible, more equitable, and safer than ever before.

Each has unique transportation requirements and preferences. **Alan**, for instance, is in his mid-80s with health challenges that give him specific mobility needs. He depends upon the transportation system to visit his doctors, and to ensure that his home care support worker arrives on time. Ichiro needs to travel internationally and up to space for his job, as well as to visit family overseas, but without worrying that his aging parents and pregnant wife will be unable to get around in his absence. For her part, Selma needs to make sure that inventory and supplies for her family's small business get where they need to go on time, while Jessica needs to visit her clients. Meanwhile, **TJ** also has to make sure he gets to work in time for his shift, while still making it to his widely-dispersed classes at the local university on time. Taylor, on the other hand, is a town council member who needs to address underserved local communities' transportation needs in a town far removed from any metropolitan area. Meanwhile, the autonomous Airie relies on being able to freely transit the nation's airspace in order to move essential consumer goods, supply chain components, and health care supplies that may be time sensitive or hazardous. The seven of them face different circumstances, and have varying mobility needs, but transportation is critical to livelihood and quality of life for all of them.

Fortunately, the U.S. transportation system of 2050 is able to meet all their individual mobility needs, while also addressing cross-domain (surface, aviation, maritime, and space) requirements for sustainability, equity, safety, and resiliency at the national level. In this future, Americans enjoy an integrated

PERSONA 1: TJ

DEMOGRAPHICS

- Early 20s, White, male Lives in rural area with low population density- Pigeon Forge, TN (Smoky Mountains)
- Bus Boy at local restaurant and local grocery store worker; inconsistent hours; grocery store job provides health insurance-shift worker
- Part-time student takes night

· Lives in a group house No private vehicle

- · Able-bodied
- Language(s): English
- · Values and Beliefs: Friends, Setting self-up for success, Choice, Cares about the environment

classes working toward a BA

REEDS FROM THE TRANSPORTATION SYSTEM

- · Get to work on time and to class on time, departing either from home or from work
- · Requires mode of transportation to move between work, home, and school (locations are not physically near each other and range in distance from 12-20 miles apart)
- · Certain modes of transportation don't make sense because they're not close to these locations
- · Requires mode of transportation for leisure such as time with friends or hobbies · Drones deliver his basic goods
- · Subsidized transit cost (as student/lower wage worker)
- Relies almost exclusively on applications on smart devices to move through the needs of his life (arrange for transit, appts, make orders)



Affordability	Low Cost	High Cost
ADA Accessibility	Limited ADA Accessibility	Full ADA Accessibility
Availability	Longer Wait Times (10-20+ min)	No Wait/On Demand (0-5 min)
Sustainability	High Carbon Emission	Low/No Carbon Emission
Risk Tolerance	Low Tolerance for Risk	High Tolerance for Risk
Reliability	Limited Reliability	High Reliability
Efficiency	Slow/Indirect	Fast/Direct
Personal Comfort		Individual/Mara Pareanalized
Privacy		
Tech Uptake	Low Adoption/Comfort	High Adoption/Comfort

transportation system that enables economic growth by supporting a reliable supply chain to enable prosperity across our country, provides personal mobility and convenience to underserved communities and busy individuals, bridges communities to bring the nation together, and ensures safety for all, including bystanders, passengers, and pedestrians.

This transportation system has evolved since the 2020s into a true enabler for quality of life and prosperity. It has become a seamlessly integrated nationwide system of diverse transport subsystems that ties America's diverse urban, suburban, and rural populations and communities together more effectively, accessibly, and affordably than ever before, and that provides safe, resilient, and "green" mobility more easily and equitably for **Jessica**, **Selma**, **TJ**, **Alan**, **Ichiro**, **Taylor**, and **Airie**—and for all Americans—than in past decades.

A SEAMLESS SYSTEM OF SYSTEMS

Thanks to infrastructure investments, technological developments, and institutional reforms, transportation for **Jessica**, **Selma**, **TJ**, **Alan**, **Ichiro**, and **Airie**—as well as for all the inhabitants of **Taylor's** town—is safe, reliable, affordable, equitable, environmentally sustainable, and resilient. Their transportation system is a highly interconnected system of systems, in which the specific details of the transportation infrastructure and its operations have become effectively invisible to its users, transcending geographic and operational boundaries of traditional rural, urban, surface, riverine/maritime, aviation, and space domains.

It may sound strange to speak of this interconnected transportation "supersystem" becoming "invisible," but this invisibility has made their lives immeasurably easier. For them in 2050, transportation has been transformed in ways comparable to how electronic commerce has revolutionized traditional shopping for us in the 2020s. Just as much of the machinery of commerce has today already effectively "disappeared" from our individual consciousness as consumers, so too have the various elements of travel logistics been folded into the unseen "background" of **Jessica, Selma**, **TJ**, **Alan**, **Ichiro**, **Taylor**, and **Airie's** individual experience.

For them, the point-to-point transportation of people and goods has become easy, simple, and functionally "invisible," for they can simply specify their own particular destination, itinerary, schedule, and preferences about how they wish to travel from any U.S. location, and trust both that the transportation system will safely and efficiently get them to A seamless integrated transportation system connects America's diverse communities, enabling economic prosperity and providing safe, personal mobility and convenience for all. their desired location via land, sea, air, or even space, and that their own personal privacy (and that of their data) will be protected all the while. And the movement of goods and people is itself all but frictionless for those using or moving within it, blurring the lines between modes of transportation.

These future Americans, for example, can leave their doorstep by one type of transport (e.g., an electric micromobility bicycle or scooter, a rideshare vehicle, an autonomous vertical take-off air taxi, a multi-passenger roadway bus responding automatically to customer needs on the basis of smart traffic management systems, or perhaps even the occasional "old school" personal automobile) and be whisked safely, securely, reliably, affordably, and comfortably between as many transportation subsystems as needed to get them to their chosen destinations. They can take advantage of a dizzying mix of transportation options that the system is able to make available-including self-driving shared surface vehicles on interstate highways or local roads, efficient magneticlevitation high-speed rail, air taxis, ferries, or water taxis to and from airports, stations, and ports, as well as efficient long-haul commercial aviation or maritime transit, or even transcontinental sub-orbital vehicles—to get them where they need to be.

Similar things can be said for the goods they and their communities enjoy and consume, and the materials used to build and maintain the physical world in which they live. In short, in 2050, mobility for both people and things is provided through a seamless nationwide system of interconnecting systems. These modes of transportation, moreover, continue to blend and blur, such as with ultrafast "hyperloop" subsurface links becoming cargo alternatives to pipelines.

Whatever travel they need or choose, moreover, **Jessica**, **Selma**, **TJ**, **Alan**, **Ichiro**, and **Taylor** will experience a customized private or voluntarily-shared electronic environment of entertainment, productive work opportunities, quiet rest, or whatever else they like. Travel for them no longer consists of "wasted time" from the perspective of either work or personal life, because their electronic connectivity to friends, family, co-workers, and their favorite corners of the Internet-based metaverse is maintained continuously and seamlessly as each transportation subsystem whisks them through and between the communications networks of the world outside.

While relaxing in this mobile environment, our seven individuals also take comfort in the fact that—due to things such as the use of renewable energy sources, data-driven traffic



PERSONA 2: Jessica

${eta}$ demographics

- 35-year-old female, bi-racial
- Lives in urban, coastal area Jacksonville, FL
 Retired military
- Works as a contractor in cybersecurity –
 hybrid worker
- Lives in a 3-bedroom condo with her husband and two children (ages 2 and 6)
- Children are in 1st grade and in daycare • One child uses durable medical device
- one child uses durable medical device for support, though is not fully encumbered
- Husband works for cruise
- industry as a hybrid worker • Children participate in
- evening/weekend activities • Lives an active lifestyle
- Language(s): English, French, Mandarin
- Values and Beliefs: Immediate & Extended Family, Health, Money to Provide for Family, Safety of Children

🖳 NEEDS FROM THE TRANSPORTATION SYSTEM

- Transportation mode to take children to/from school and daycare on time taking child to daycare; elementary-age child is getting picked up by bus/transit option
 - Partner with families in community for group rate and assurance for a direct route to/from school and home
 - Safety is paramount here and wants alternative modes of transportation that ensure that children are only being picked up and dropped off at known locations and with other children who are going to and from the same destination
- Transportation to/from client sites
- Husband needs to get to/from port and HQ to check in
- \bullet Leisure time with family likes to travel globally and provide enrichment for children
- Relies almost exclusively on apps on her smart device to move through the needs of her and her family's life (call for transit, appointments, orders)
 - She is concerned about how her personal/family data is being used. Her privacy concerns are balanced with the convenience of applications on her smart device to help her family
- Wants alternative modes of transport that fit family life the transportation vehicle must support individual or 2-person needs during the week and also family mode of travel on the weekend
 - Scooter option vs pod option
 - Amiable to water taxi options like duck boat, but knows that this alternative may not be reliable due to weather, like flooding during hurricane season

A EXPECTATIONS OF THE TRANSPORTATION SYSTEM

Affordahility		
Anordability	Low Cost	High Cost
ADA Accessibility		
	Limited ADA Accessibility	Full ADA Accessibility
Availability		
	Longer Wait Times (10-20+ min)	No Wait/On Demand (0-5 min)
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Efficiency	Chandle direct	Fut/Diret
	Slow/Indirect	Fast/Direct
Personal Comfort	Lever Orme II and Demonstrand	la di cita al Alexa Denana fina d
	Large Group/Less Personalized	individual/more Personalized
Privacy	Closed/Opting Out	Open/Opting In
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Tech Uptake	Leur Adentian (Comfort	Link Adaption/Comfact
	LOW Adoption/Connort	nigh Adoption/Comfort

management decision-making, real-time data exchanges among autonomous vehicles, supporting infrastructure and traffic management control systems, and new materials and construction methods-the interconnecting and intercommunicating systems behind such frictionless travel within and across transportation domains facilitate efficiencies that make it not just more environmentally responsible and sustainable than in their grandparents' day (our day!) but safer as well. And while the workings of the seamlessly interoperable system of systems of this transportation supersystem seem almost to have "disappeared" for Jessica, Selma, TJ, Alan, Ichiro, Taylor, and Airie, this intelligent infrastructure nonetheless facilitates an outwardly effortless flow of people and goods that enables them to meet their work, health, family, and educational needs and provides them and their communities with new opportunities for prosperity and engagement in an interconnected world.

OUR RESEARCH CHALLENGE

Jessica, Selma, TJ, Alan, Ichiro, Taylor, and Airie are able to take advantage of this seamlessly interconnected transportation supersystem in 2050 because U.S. public and private sector leaders in the 2020s invested in a bold agenda of research and development for the future transportation capabilities, processes, and skills needed to make such benefits available. This transformation of American transportation required adaptability, the adoption of new technology and development of innovative new use cases and mobility-related services facilitated, in part, by federal, state, and private investments in the enabling technologies for advances in vehicle, infrastructure, and information system design—as well as far-sighted planning, and creative system-of-systems integration.

This transformation also needed innovative new approaches and governance models that broke down the various regulatory, jurisdictional, institutional, bureaucratic, cultural, and conceptual stovepipes that previously divided the U.S. transportation system into stand-alone, non-interoperable, and separately regulated sub-components. Fortunately, America's leaders in the 2020s were able to provide these things, making it possible for the U.S. transportation system to come through a period of paralytic congestion, safety challenges, fragmentation, and decaying legacy infrastructure, and to evolve into the highly-integrated and interoperable supersystem that in 2050 enables **Jessica**, **Selma**, **TJ**, **Alan**, and **Ichiro**—as well as the previously underserved members of **Taylor's** town all to live productive, high-quality, high-mobility lives.



...a bold agenda of research and development for future transportation capabilities which includes the adoption of new technology and the development of innovative use cases to inform farsighted planning and creative system-of-systems integration.

1. Interconnected Community and Mobility through Information Sharing

So how do we get to that world of 2050? First and foremost, we will need better and massively scalable approaches to data sharing and management. Building a safe, secure, efficient, reliable, affordable, resilient, and environmentally responsible system of seamlessly interoperable transportation subsystems will depend upon the collection, aggregation, understanding, sharing, and protection of data on a greater scale and across more organizational, geospatial, and technological boundaries than ever before.

The interoperability of these transportation subsystems that will be the backbone of transportation's future will require high-volume, in-time to real-time exchange of data about such things as vehicle status and location, resource consumption, routing and destination, environmental conditions and impact, potential obstacles, infrastructure condition or repairs, hazards, delays, and other variables. This exchange of data will be needed between individual vehicles, between such vehicles and the transportation infrastructure itself, between vehicular and infrastructural elements and emergency response and repair institutions, and between all components and nodes of the system and smart traffic management systems and predictive modeling engines.

Such data-sharing becomes an enabler for making critical transportation related decisions regarding efficiency, planning, and safety when the available data is provided to the correct node in the transportation system in a timely manner. The space launch of hazardous goods and people that **Ichiro** experiences in his work, for instance, may require temporary suspensions or alterations of maritime, rail, or air operations or routing, which in turn will affect the timing and means by which Alan's pharmacy is able to deliver his medication, or Selma to move her inventory. A research agenda to support such ongoing systemic adaptation will explore methods for achieving greater efficiency through dynamic equitable access management for transportation, such as by using a shared knowledge of resource demands to identify unique alternatives for managing rush hour loads, spikes in traffic, or other fluctuations.

The transportation supersystem must balance equitable access to critical transportation resources with the growing demand for these same resources, and doing this effectively requires information. If all of these workings



PERSONA 3: Selma

${f lpha}$ demographics

- Mid-50s, female, LatinX
- Lives in urban area- Chicago, IL
- Owns family business with her husband Steve - S&S Company – sells the key secret, patented yet tasty ingredient needed to make burgers
- Lives in a single-family home with her husband and 1 of their 2 children (ages 15 and 19)
- 2 children 1 child in high school,
- 1 child in private college; 1 dog • Husband is co-owner of S&S Company-
- oversees Point of Sale • Hobbies: Photography, Theater, Travel
- Language(s): English, Spanish
- Values and Beliefs: Immediate & Extended Family, Entrepreneurship, Health, Worker Wellbeing

REEDS FROM THE TRANSPORTATION SYSTEM

- Need to be able to move inventory to big box stores; if doesn't move inventory, steep financial impacts
 - Inventory needs to move given the anticipated increase in demand around an upcoming major holiday, where grilling and barbeques are popular
- Efficiency for people and goods to get to their final destination
- Multi-modal transport to receive/ship goods
- · Employs 150 people at their warehouse who need to get to/from work
- ADA accessible to meet compliance needs
- Meeting green mandates
- Transport as advertising/marketing
- Seamless and efficient communication

 Travel to conventions to network and travel to vendors to view new materials and products (globally)



are to be transparent to **Jessica**, **Selma**, **TJ**, **Alan**, **Ichiro**, **Taylor**, **Airie**, and all their fellow consumers of mobility options in 2050, moreover, the innumerable components of this American transportation system of systems will need to be communicating with each other to share and exchange the information needed. Only such communication and interoperability can ensure that their needs are met and their transportation experience is as safe, seamless, and frictionless as possible.

Real-time data collection, sharing, and analysis across the transportation supersystem and its myriad sub-systems, for instance, will permit networked responses, including the routing of public transportation, autonomous vehicles, and privatelyowned but multi-user rideshare assets to meet each moment's shifting transportation needs. Nor is such sophisticated adaptation just for personal travel, which Selma will appreciate as she uses shipment transport data to coordinate a mix of alternative delivery methods—among them autonomous truck platooning from ports of entry to a warehouse, followed by the use of remotely-piloted electric aircraft from the warehouse directly to her storefront-and even to expedite deliveries based on traffic flow demands. For its part, Airie will use realtime data to understand potential constraints and bottlenecks as it determines safe and cost-effective routes to move hazardous goods from a port through hundreds of miles of highaltitude transit to each intended destination.

For both people and goods, data-informed predictive models will allow public and private transportation routes to be adjusted dynamically, turning physical infrastructure from a constraint into a dynamic resource. Such models will also drive deployments of novel adaptive streetlight and flexible street and lane capabilities, to make travel as rapid and efficient as possible and to smoothly and safely re-route travelers and shipments of goods around obstructions or other problems, thus reducing transportation's impact on the environment.

The large-scale collection, aggregation, and analysis of consumer-generated demand data across this system of systems will inform equitable infrastructure investments on an ongoing basis. Federal, state, and local transportation regulators, such as town council member **Taylor**, may use such data, along with input from community members and the output of local Planning and Development committees, to make transportation investments for underserved communities, factoring in the need for an adaptable nationwide infrastructure to be compatible with state and

Information across this system of systems will inform equitable transportation investments to support underserved communities ensuring they are compatible with state and local infrastructure and fiscally responsible. local infrastructure. These regulators will also need to coordinate this work with state and other local regulators to operationalize seamless and safe surface transportation alternatives for all town residents and to find appropriate balances between cost-effectiveness and the optimization of other performance criteria. With such information, policymakers can understand trends in and monitor the operational dynamics of the transportation system for safety and resource management, as well as track progress, anticipate future needs and opportunities, and prioritize ongoing transportation-related investment and research to ensure that the system benefits all Americans, regardless of geography and means, enabling them to thrive in a dynamic global economy.

Coupled with systemic modeling, aggregated data will support the actuarial understandings needed to make possible effective insurance coverage for travelers, vehicle manufacturers, infrastructure providers, and system operators alike. It will also facilitate ongoing monitoring and research into future infrastructure requirements and transportation needs, enabling all elements of the system to invest and modernize to meet demand and performance objectives on an ongoing basis.

Additionally, the generation and consumption of simulation data on a very large scale will enable the creation of "digital twins" of the entire transportation system, wherein scenarios that leverage simulated and historical operational data may be used by decision makers to evaluate various possible transportation outcomes and alternatives, such as in building a more efficient and resilient air transportation system. Effective data management at scale is critical to ensuring the safety of people and goods moving in through this interconnected supersystem, as well as of the general citizenry in a dynamic transportation environment in which largely autonomous vehicles will share and pass through three-dimensional physical space in an intercommunicating ballet of coordinated movement.

As of the early 2020s, however, the system-wide data standards and interoperability and security protocols for such dynamic mutual situational awareness have not yet been developed. These standards and protocols—including machine-to-machine safety controls—are essential and must be a critical focus for transportation research.



PERSONA 4: Alan

\otimes demographics

- 85-year-old, Black, male
- Physically Disabled Veteran
- Retired Nurse
- Lives in a small house in rural Missouri which he owns
- Lives with his 83-year-old wife who is a retired teacher
- Has 3 children and 7 grandchildren
 Lives within an hour of a basic services

• Avid birder

Active community volunteer

Relies on durable medical

equipment to get around

Language(s): English, Pashtu
 Values and Beliefs: Immediate
 & Extended Family, Community,
 Environment, Health, Faith
 Community

🛱 NEEDS FROM THE TRANSPORTATION SYSTEM

- Receives home care services every morning to help with their daily needs needs support person to be on time
- To be able to get to medical appointments
- To be able get to/from seeing grandchildren
- To be able to get to/from community events
- Relies on apps for basic needs, but prefers to talk with a human for more complex issues
- Relies on transportation for family vacation

🖉 EXPECTATIONS OF THE TRANSPORTATION SYSTEM



More broadly, for the transportation system to function and to generate the societal, economic, and environmental benefits it has the potential to provide, it will be necessary to build and to sustain public trust in the integrity of the data flows that represent the life-giving "circulatory system" of the country's future transportation architecture. Jessica, Selma, TJ, Alan, Ichiro, Taylor, and Airie may have different approaches to the utilization of new technology. Nonetheless, all of them will have to trust the transportation supersystem if it is to serve them and their diverse needs as it will have been designed to do. The data-driven analytics produced by this system, however, will allow it to be built to deserve this trust-and to do so demonstrably. It will also allow travelers such as our seven future individuals to identify the transportation alternatives that best meet their needs, and with which they are the most comfortable.

The future of transportation will thus require the development and deployment of new technologies, methods, and governance structures for ensuring digital trust throughout the system—not least with respect to ensuring appropriate degrees of privacy for the enormous volumes of data that such an interconnected and intercommunicating system will generate about user locations and behavior. Much new research is needed in devising data interoperability standards, in developing large-scale data aggregation, analytics, and modeling and simulation methods, and in acquiring the decision-support and situational awareness tools needed for effective operational oversight, performance monitoring, and regulation.

2. Integrated Safety and Cybersecurity for Land, Sea, Air, and Space Mobility

Safety will be a huge priority for **Jessica**, **Selma**, **TJ**, **Alan**, **Ichiro**, and **Taylor**, for they not only depend upon the transportation network for their livelihood and quality of life, but will also need to trust it with their lives and those of their families. Fortunately, if done properly, the adoption of advanced technology—including largely autonomous systems and other smart capabilities that take advantage of Artificial Intelligence/Machine Learning (AI/ML) for flow and route management, to meet performance outcomes, and to meet demands for mobility—will produce enormous safety benefits throughout the transportation system, not merely in reducing the incidence of accidents due to human error but also through the incorporation of improved vehicular



Future of transportation will require the development and deployment of new governance structures and methods for ensuring digital trust and privacy. and infrastructural designs and materials, and allowing technology, including **Airie**, to effectively team with human decision makers.

To ensure that safety is built into this system from the outset for Jessica, Selma, TJ, Alan, Ichiro, Taylor, and Airie, however, will require much more focus on "software" issues than just "hardware" questions. Safety in this transportation system must account for ensuring personal safety of passengers, drivers, pedestrians, and those on the surface who are not traveling. Safety controls and regulatory oversight must adequately mitigate risks, while also meeting the public's expectations for safety across aviation, maritime, surface, and space operations. To ensure that the drone delivering Alan's medicine avoids physical obstacles and terrain features, for example, a delivery company might need to comply with aerial separation standards the stringency of which has been informed not just by sound technical performance metrics but also by the need to accommodate public sensitivities about the potential for accidents occurring overhead. Similarly, autonomous vehicle manufacturers may need to be subject to uniquely rigorous performance standards grounded in the need to encourage public uptake of such novel technology use cases.

And this transportation transformation will require "designing" resiliency—as well as cybersecurity—into the system from a foundational level, to cope with natural and man-made disasters resulting from exogenous disruptions such as climate change and potential cyberattack. When frequent severe storms hit the coast near where she lives, for instance, Jessica may need to consider various alternative transportation modes and routes to help keep her business and family life on track. The integration of space travel options of the sort Ichiro occasionally needs to use will also require designed-in resilience to reduce risks to third parties who may live or be traveling underneath the launch or re-entry paths of spacelaunch vehicles. More broadly, data-driven analysis can also help "future-proof" the system against broader unanticipated events-including forecasting volatile climate effects such as the increased prevalence of severe hurricanes that affect overlapping modes of coastal transport, violent thunderstorms that impede air travel, or wildfires that create smoke obscuring surface and low-level aerial visibility—by allowing trends and challenges to be identified and understood as early as possible, and by facilitating any necessary policy interventions.

Building this future will also require careful analysis to understand the potential safety and cybersecurity implications



PERSONA 5: Ichiro

\otimes demographics

- 35-year-old, Asian, male • Chief Innovation Officer
- at an R&D firm
- Has a single family house in Washington, DC
- Lives with his parents and pregnant wife
 - Active in the Asian community and serving as a robotics coach for the local high school team
- Lives within walking distance of basic services
- Has had Lasik to improve eyesight and is able bodied
- Lives within proximity of several domestic/international airports
- Has a personal vehicle that is shared among the household
- Language: English, Japanese
 Values and Beliefs: family, safety, provider for immediate and

extended family

NEEDS FROM THE TRANSPORTATION SYSTEM

- To travel domestically and internationally quickly to make key meetings and events that are work related (these are not frequent given a more hybrid work environment)
- His work requires supporting material testing in space for materials that are too dangerous to test on Earth. He must travel to remote locations for launch, taking multiple modes to complete his trip
 - The material to be tested is hazardous, and requires special transportation from its warehouse to the launch site (surface) and then to space $% \left({\left[{{{\rm{s}}_{\rm{s}}} \right]_{\rm{s}}} \right)$
- Ichiro is concerned about the launch window and the dangers associated with the launch itself, including potential debris and impact on the public and the environment in the event of an incident/accident
- To travel to work located in the suburbs of Maryland from home personal vehicle is not a reliable source as there are others in his family who need to use the vehicle
- Has health concerns over his pregnant wife and aging parents, so he is health conscious
- To travel internationally with the family to see extended family in Asia

A EXPECTATIONS OF THE TRANSPORTATION SYSTEM

Affordahility		
Anordubility	Low Cost	High Cost
ADA Accessibility		
	Limited ADA Accessibility	Full ADA Accessibility
Availability	Learner Welt Trace (10,00 - min)	No. Weit/On Dermond (O. E. min)
	Longer Wait Times (10-20+ min)	No Wart/On Demand (U-5 min)
Sustainability		
	High Carbon Emission	Low/No Carbon Emission
Risk Tolerance	Law Televiser for Diel	Unde Televisier for Diele
	LOW TOIEFANCE TOF RISK	High Tolerance for Risk
Reliability		
	Limited Reliability	High Reliability
Efficiency		
	Slow/Indirect	Fast/Direct
Personal Comfort		
	Large Group/Less Personalized	Individual/More Personalized
Privacy	Cleand/Online Out	Onen/Onling In
	olosen/ohrling our	Open/Opting in
Tech Uptake		
	Low Adoption/Comfort	High Adoption/Comfort

of large-scale system integration and to build awareness of emerging risks and threats and concerns of privacy, as well as new approaches to certification and validation. Indeed, in this future transportation system, the integrity and security of this transportation system, including its data streams, become not just mission-critical and safety-critical, but also critical to national security. In such an interconnected environment, the country's ability to move people and goods—certainly on any scale, but perhaps at all—and its ability to preserve the integrity of its supply chain will depend fundamentally upon preserving this data against disruption, degradation, or manipulation. A customer who is relying on Airie to deliver sensitive goods, for instance, may be concerned about how Airie will protect the flight plan and track data as Airie traverses the nation's aerial highways. Moreover, in an era in which America's adversaries are reportedly planning to mount cyberattacks in time of conflict upon American Industrial Control Systems and other operational technologies, including our electric grid, in order to produce cascading failure effects in critical infrastructure, effective cybersecurity and network redundancy and resilience will be essential elements of the future transportation architecture.

Performance-based safety standards need to guide the development of technology for both vehicles and for the infrastructure, ongoing safety and cybersecurity-related behavioral research will be needed to inform regulatory and infrastructure investment decisions, and a concerted effort will be needed to ensure that safety and security processes and procedures are followed by industry and by the many skilled operators, inspectors, and maintainers who keep this system working. It will also be essential for the public both to understand the inherent risks associated with various transportation modes and to participate in an effective transportation safety culture built upon safetyrelated behaviors, norms, and expectations that have evolved in conjunction with transportation technology. The future transportation system of systems will require an enterprisewide approach to safety.

Aggregation of available data at the broader system level promotes an integrated approach to spotting and managing emerging risks, thus allowing earlier identification of potentially negative trends or unwanted behaviors—before the occurrence of any accident or incident—through timely analysis. Such data collection will also be essential to monitoring and anticipating the impact of future land, air, sea, and space transportation subsystems upon different The public must understand the inherent risks associated with the various transportation modes and participate in an effective transportation safety culture. segments of the American population, and in facilitating policy interventions that may be needed to ensure fairness, equity, and accessibility.

Systemic resiliency is a means to ensure a safe and secure transportation system, where there are planned and designed mitigations to hazards and threats. Data collection, analysis, and exchange at scale will allow the system to manage traffic flows and volumes in response to localized disruptions or outages, with redundant alternatives being presented to a traveler, who can choose from among them based on needs and preferences (e.g., safety, affordability, privacy, or speed), as a set of dynamic options in an integrated network that is always reconfiguring itself to meet demand and bypass problems when they occur.

Building and maintaining justified confidence in systemic safety will be critical to ensuring that our seven individuals and all Americans—trust and accept the future transportation network, particularly as uncrewed or autonomous vehicles increasingly become the dominant mode of transport for both goods and persons, and as data collection exchanges, including personal identifiable data, become more prevalent. Devising appropriate new software- and integration-focused safety and cybersecurity models and certification standards must therefore be a key priority for transportation research.

3. Sustainable Mobility

The transportation network has not traditionally made environmental responsibility a core value to guide its development, but that will need to change if **Jessica**, **Selma**, **TJ**, **Alan**, **Ichiro**, **Taylor**, and **Airie** are to get the value out of that network that they need and deserve, and if they are to be able to pass on that network to future generations. Fortunately, advances in technology and materials—in such things, for instance, as improved fossil fuel efficiency en route to phasing out non-renewable energy sources entirely, additive manufacturing, sustainable or renewable sources of electrical power, and lighter and more environmentally-friendly materials and construction methods for both transportation vehicles and components of the infrastructure itself—will make the transportation system of the future much more environmentally responsible.

Not only will the various components of the system each be intrinsically more energy efficient, but many of them will be used in more efficient or environmentally-responsible ways, allowing the transportation system to be more resilient, such



® DEMOGRAPHICS

- 47 years old gender nonconforming
 Has served 2 years of a 4-year term on the town council
 - As a member of the LGBTQIA+ community, Taylor understands the varying transportation needs of their community, as well as underserved communities in the town. Provides guidance and guardrails to ensure transportation is safe in the town's metro area and the surrounding county
- Municipality is not a major metropolitan area but a large town with urban transit needs. The town has a mixture of affordable and multimillion-dollar homes, and has a highly residential area with commercial and industrial zoning on the outskirts of the town
- Lives with their partner and 3 cats

 Has multiple personal vehicles which they rely on for personal transit, leisure activities, work, and council duties. Would prefer to take mass transit only if they felt safe on it

• Is abled bodied

🖳 NEEDS FROM THE TRANSPORTATION SYSTEM

- To understand the mobility and safety needs of the town and determine the best way to allocate municipal resources
- There is a heavy reliance on public transportation and movement away from personal/individual vehicles (even though they may be remote piloted/autonomous). However, members of the L6BTQIA+, low-income, disabled communities have expressed concerns about personal safety and comfort in taking public transit as well as other public amenities
- As a councilmember tasked to the transportation and environment (T&E) committee, Taylor wants to look beyond the individual needs of each town member to the broader population
- The town's growing population is increasingly mixed and requires multiple modes of transportation for surface and aviation. As a large, semi-dense town, accessibility, affordability, public safety, and sustainability are all priorities for which Taylor is very interested in finding solutions
- Currently, the town council is wrestling with how to address the needs of an aging transit system which requires additional funding for maintenance and repair. This includes dealing with the need to procure obsolete replacement parts from manufacturers
- The town is developing policies which recognize, affirm, and support the needs of a large and vocal LGBTQIA+ community and their unique needs regarding transit safety and access

The transportation needs include the physical infrastructure and respective control systems to enable transit operations

- The T&E committee is evaluating the cost to upgrade the transit systems and infrastructure
- Additive manufacturing exploration (cut down on costs, create replacement parts while short-circuiting supply chain, increase sustainability)

Acknowledge that benefits/return on investment will take time
 I acknowledge that benefits/return to take and fodoral regulations record

 Local government must adhere to state and federal regulations regarding transportation

- Requires coordination and collaboration with respective manufactures; infrastructure owners and operators; and third-party vendors to ensure that individuals are compliant with known regulations and standards, and are meeting the town expectations- there are **opportunities for public and private partnerships**
- Requires coordination and collaboration with county leadership and other town council members to ensure that transportation alternatives are integrated and not just town specific

Representations of the transportation system



as in handling maritime and aviation disruptions due to severe weather events that make traveling unsafe. Both environmental and cost-efficiency incentives, for instance, will blur functional distinctions between public and private, as increased reliance on public-private partnerships facilitates the widespread adoption of "transportation-as-a-service" models in which privately-owned vehicles of various sorts are never idle but instead shared and re-allocated more efficiently and in more environmentally-responsible ways on a dynamic basis among multiple users.

Actually making such advances, however, will require continued research funding and prioritization to bring such new technologies and materials to fruition. Essential to such progress, for instance, will be the inculcation of a new culture of green design and technology deployment—both for vehicles themselves and for America's underlying transportation infrastructure—that emphasizes environmental equities in meeting the so-called "triple bottom line" of sustainability for the people, the environment, and the economy.

4. Adaptable and Resilient Governance

To do all this effectively—at scale, and in the ways needed to integrate what is today a system largely disaggregated into separate road, rail, aviation, water, pipeline, and space components-will require the development of new, systemwide standards for interoperability: effectively a wholly new governance model. This model must transcend such traditional boundaries, but it should eschew heavy-handed regulation of the sort that could stifle innovation in the rapidly-evolving technologies that are revolutionizing transportation. Yet it must also set the basic public policy "guardrails" needed to ensure system-wide safety, interoperability, environmental responsibility, privacy, cybersecurity, and equity-and to allow U.S. transportation subsystems seamlessly to "plug in and hand off" to foreign ones—on a technology-agnostic and performance-based basis. Technology disruptors will also create new opportunities to collaborate and coordinate at a national and global scale, allowing the United States to foster global harmonization and provide leadership as the worldwide transportation enterprise evolves.

Doing this well will require a governance model that coordinates through close partnership relationships with the private sector, nonprofits, state and local governments, and foreign stakeholders, as well as across multiple U.S. Government agencies and agency components—all of whom will need to be engaged as important partners in a "whole The inculcation of a new culture of green design and technology deployment emphasizes environmental equities for people, the environment and the economy. of nation" challenge. Nor can America build and innovate the future of transportation in a vacuum, for engagement and partnership with key foreign stakeholders will also be necessary, giving the United States the opportunity to play a leadership role in transforming transportation on a global scale. Beyond specific questions of technology, therefore, developing such new models of cooperative regulation, oversight and standards must also be a key focus for transportation research.

Like the information-driven transportation system of systems itself, such reforms will be "invisible" to travelers in 2050 and indeed, these innovations will already have occurred by the time **Jessica**, **Selma**, **TJ**, **Alan**, **Ichiro**, **Taylor**, and **Airie** encounter the American transportation network. Governance must provide the necessary guardrails to ensure that these transportation subsystems that are owned and operated by public and private entities are operating in accordance with applicable performance standards while balancing the needs of being interoperable, accessible, "green", affordable, and safe. To ensure that this can happen, institutional changes must be a priority for us today in the 2020s.

The United States will also need a better federal model for funding the modernization and improvement of its transportation infrastructure. At present, such funding is at best episodic and unpredictable, and infrastructure spending is heavily dependent upon single-year funding when monies do become available. This not only impedes necessary ongoing maintenance of legacy infrastructure, but also undermines long-term strategic planning and handicaps the country's ability to develop and transition to the safer. resilient, more efficient, more environmentally sustainable, and more equitable infrastructure we need in the future. Solutions to this problem will require systemic changes, including multi-year funding, long-term consistency of vision, and approaches to sustain infrastructure innovation and modernization on a continuous basis as technologies, materials, and methods improve.

Such far-reaching governance reforms may not be easy to contemplate from the perspective of the 2020s, but they are essential to bringing transportation's future to life. Effective public and private partnerships between private industry and local, state, and federal agencies can help keep the transportation network safe, secure, reliable, affordable, and environmentally sustainable for all.



PERSONA 7: BJN-451 (aka: Airie)

${eta}$ demographics

 BleuSkii Airspace Transit Bot; version 3.1

- Headquartered in North Dakota, BleuSkii is a leading American company in the development of highaltitude and sub-orbital transit robots. The company's essential personnel are located at each port to support operations and maintenance of their transit robots
- "Lives" at the BleuSkii company hanger bay near the airport where it's assigned
- Has been in operation for 6 months: Airie is an AI airspace transit bot designed to pilot aircraft for suborbital and high-altitude consumer goods transit (organs for transplant, medical transit, volatile chemicals that can't be safely transported over surface)
- As a sentient Al bot, has concerns about public perception and biases associated with robots

- Likes the airport's dog teams (security and bird management); the shepherds for bird management are its favorite (finds the fluffiness of the fur fascinating)
- Airie is one of 500 such bots in the 3.1 lifecycle, an upgrade from the 2.1 version
- v3.1 upgrade empowers bots to pilot craft safely, thus ensuring the safety of itself and its cargo (this also allows the bot to belay orders from traffic management if the impacts result in negative outcomes for Airie's fragile cargo)
- Language(s): algorithm allows Airie to fluently speak multiple languages to maximize communication with airport operators to understand cargo needs and logistics; also "speaks" the language in which its algorithm is programmed to detect anomalies and report to BleuSkii's programming team

Reeds From the transportation system

- Relies on BleuSkii's micro-mobility system to transit to/from airport and hanger; and from hanger to upgrade center
- Understand transit expectations/concerns better
- \bullet Keeping cargo safe and ensuring it arrives undamaged to its next destination in the transit chain
- Making sure transit routes are clear
- Being empowered to make decisions while performing job (getting things from port to end-point without incident; efficiently)
- Reporting back on issues and potential implications associated with transport of specific goods
- Implementing safety protocols to protect self and others in the event of an emergency (e.g., chemical spill)

 Airie's data tracker is activated any time it is on the clock for security purposes; however, cargo Airie is carrying may be sensitive, so privacy protocols are of utmost importance





CONCLUSION

If we are able to act today with wisdom and forethought in the 2020s, a bold research and public policy agenda for transportation technology and governance can indeed ensure that **Jessica**, **Selma**, **TJ**, **Alan**, **Ichiro**, **Taylor**, and **Airie** will be able to enjoy the transportation supersystem they need and deserve in the 2050s. This future requires transportation to be safe, affordable, green, seamless, equitable, accessible, and resilient. Building that future will take time and hard work, but it is both essential and achievable. And getting there starts with being clear about our vision for that future, and about the considerable innovation and investment that will be needed along the way.

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SLIDING SCALE DEFINITIONS

Affordability cost of using transportation

ADA Accessibility

ease of use or service and features adapted to accommodate

Availability ease of obtaining for use within a window of time

Sustainability meeting long term needs without compromising the environment and/or natural resources

Risk Tolerance ability to withstand someone or something that increases the exposure to a hazard

Reliability ability to get to destination with minimal issue

Efficiency

ability to reach a destination without wasting time or energy

Personal Comfort preferences towards an individual's well-being

Privacy

freedom from unauthorized tracking by external parties

MITRE's mission-driven teams are dedicated to solving problems for a safer world. Through our public-private partnerships and federally funded R&D centers, we work across government to tackle challenges to the safety, stability, and well-being of our nation.

