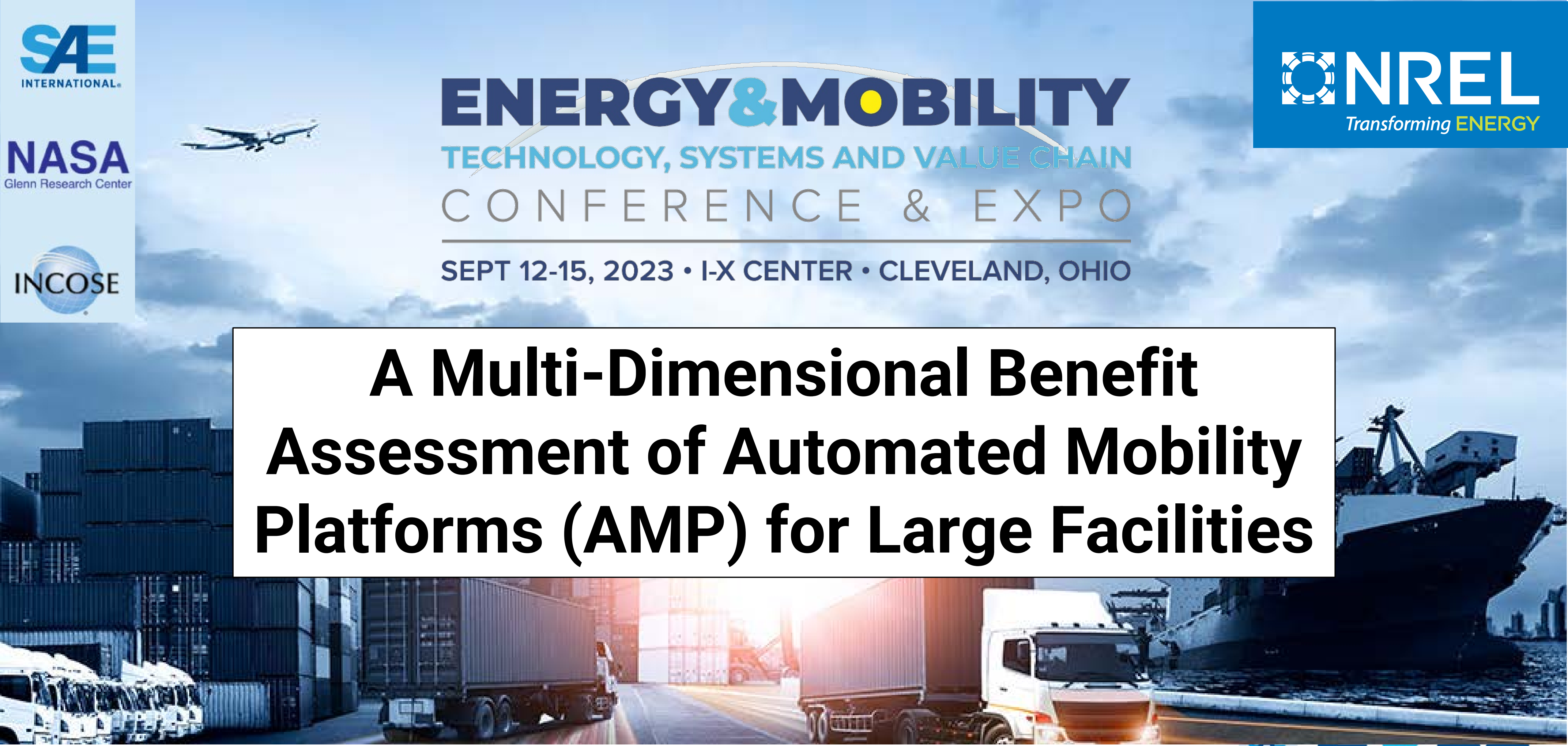


A Multi-Dimensional Benefit Assessment of Automated Mobility Platforms (AMP) for Large Facilities

09/14/2023

Stanley E. Young, PE, PhD
National Renewable Energy Laboratory

TECHNOLOGY, SYSTEMS AND VALUE CHAIN
CONFERENCE & EXPO
SEPTEMBER 12-15, 2023
CLEVELAND I-X CENTER

Outline

1. Background (air travel trends & challenges)
2. Framework for Multi-Dimensional Benefit Analysis (MDBA)
3. Results
4. Discussion & Conclusions

Air Travel Trends & Challenges

- Projected air travel growth
- Equity & efficiency
- Facility expansion

NREL Transforming ENERGY

E&M TECHNOLOGY, SYSTEMS AND VALUE CHAIN CONFERENCE & EXPO
SEPTEMBER 12-15, 2023
CLEVELAND I-X CENTER

Mobility Gaps in Large Facilities

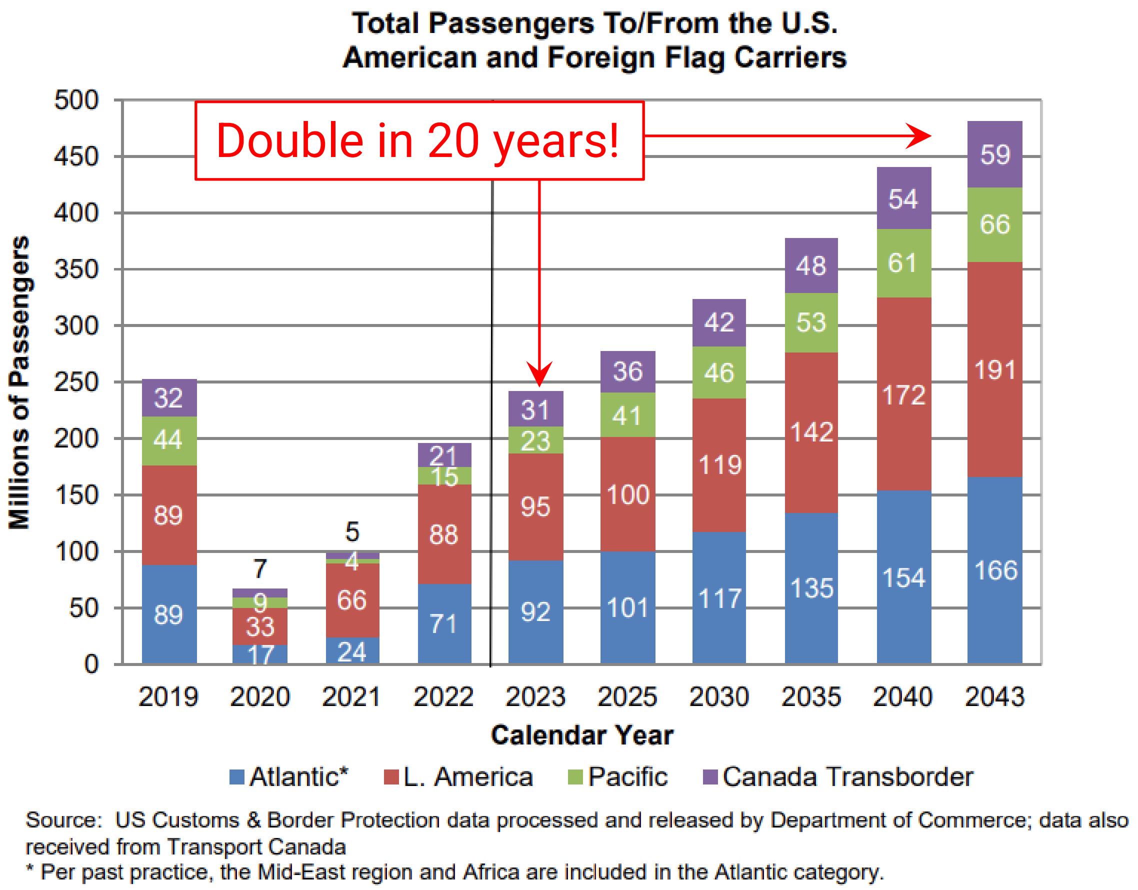
Problem/Objective:

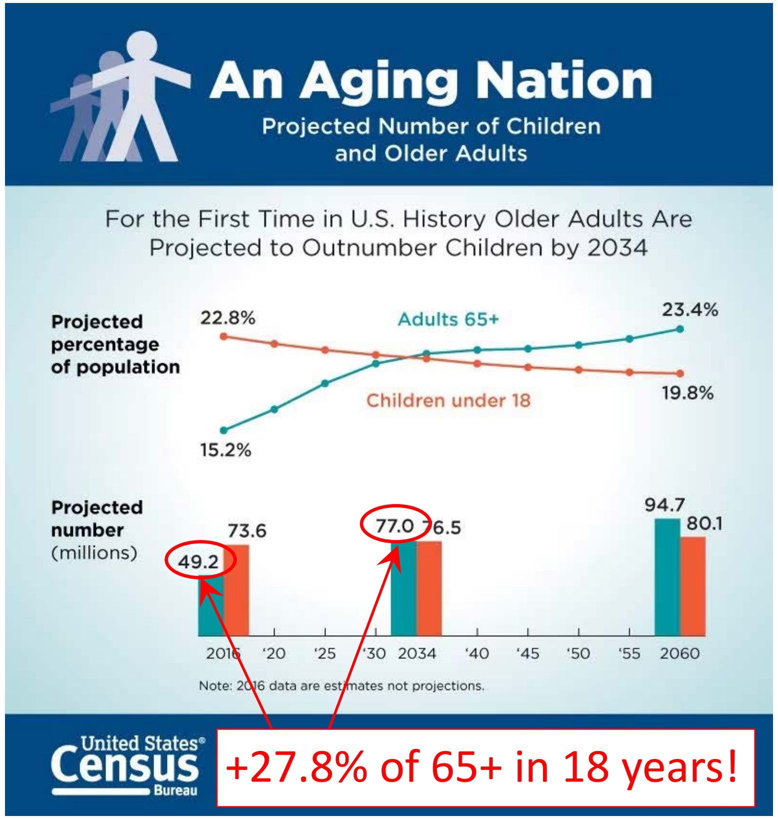
Gaps in transportation exist in large facilities. Especially for the elderly, obese and anyone living with a disability, or injury. As facilities increase in size, this impacts more travelers, decreases efficiency, creates inequities.

Facility automated systems address:

- Long wait times
- Customer frustration / way-finding
- Energy and mobility inefficiencies
- Equity for People with Reduced Mobility

Air Travel Trends





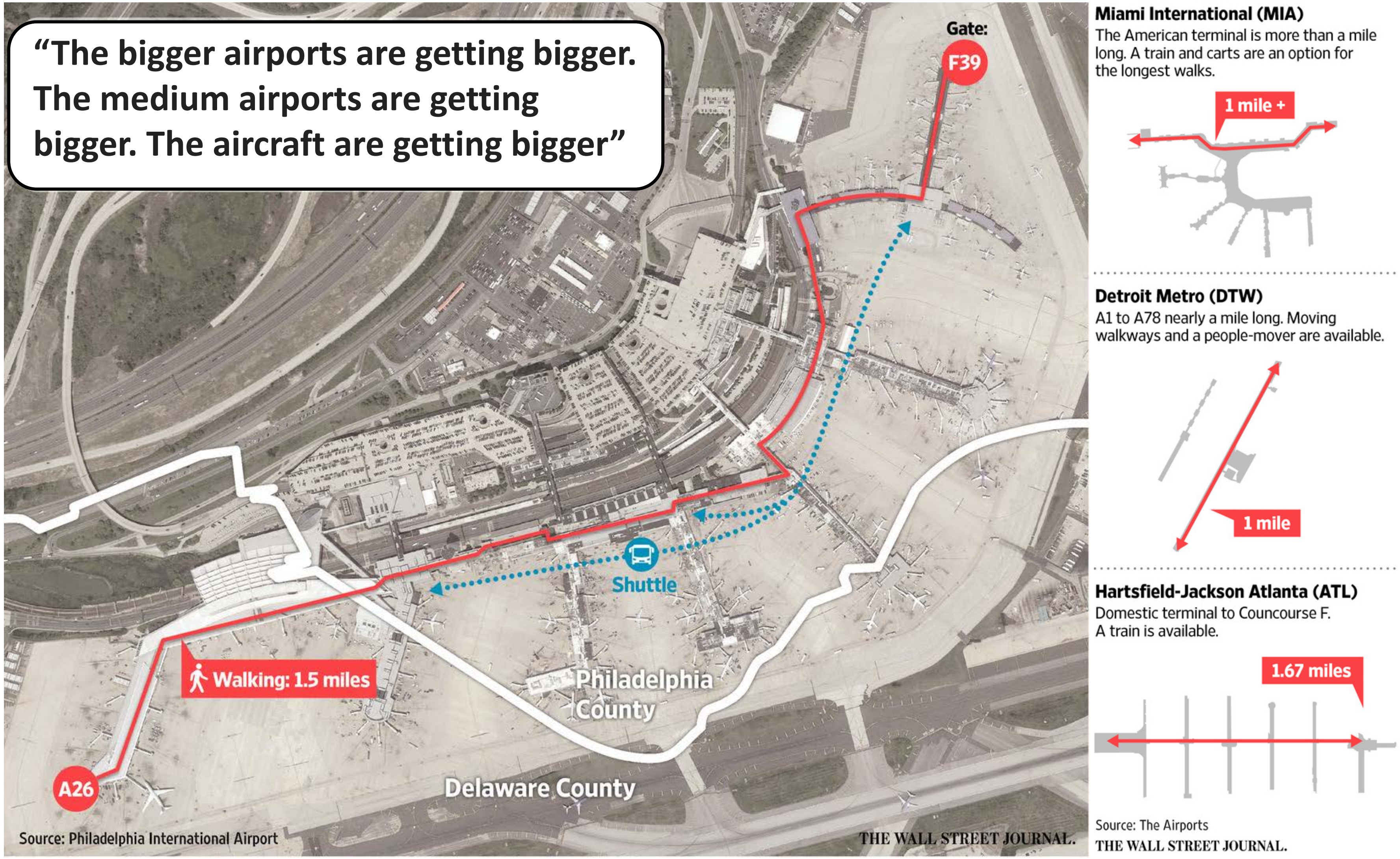
Elderly air travelers is a rapidly growing segment

SEPTEMBER 12-15, 2023
CLEVELAND I-X CENTER

Airport Expansions

NREL
Transforming ENERGY

“The bigger airports are getting bigger. The medium airports are getting bigger. The aircraft are getting bigger”



SAE INTERNATIONAL
NASA Glenn Research Center
INCOSE

E&M
TECHNOLOGY, SYSTEMS AND VALUE CHAIN
CONFERENCE & EXPO
SEPTEMBER 12-15, 2023
CLEVELAND I-X CENTER

Airport Mobility for PRMs

NREL
Transforming ENERGY

Current Solution → Airport Escorts

- Long hours, lower-wage, difficult conditions
- Labor shortage
- Challenging staff planning with “flight banks”
- Limited access to amenities for travelers

Novel Solution → Automated Mobility Platform (AMP)

- Independent mobility solution → access all amenities
- Empty wheelchairs can reposition
- Wayfinding
- Real-time data collection, processing, and decision-making

NREL
Transforming ENERGY

Multi-Dimensional Benefit Assessment

- Mobility
- Energy
- Equity
- Facility Management

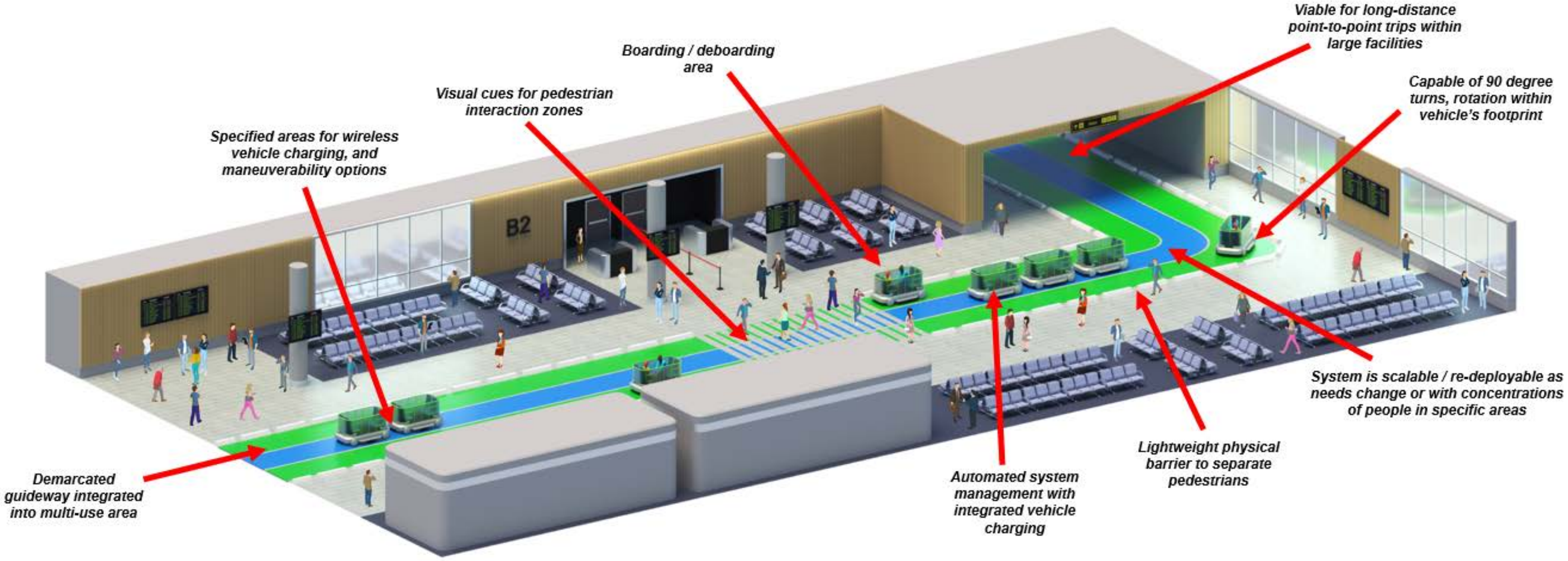
SAE International
NASA Glenn Research Center
INCOSE
E&M
TECHNOLOGY, SYSTEMS AND VALUE CHAIN
CONFERENCE & EXPO
SEPTEMBER 12-15, 2023
CLEVELAND I-X CENTER

Automated Mobility Platform (AMP)

Define:

Mobility systems/services that leverage:

Automation, Sensing, Communications, Optimization/Analytics, Electric Propulsion



SAE INTERNATIONAL

NASA Glenn Research Center

INCOSE

E&M TECHNOLOGY, SYSTEMS AND VALUE CHAIN CONFERENCE & EXPO

SEPTEMBER 12-15, 2023

CLEVELAND I-X CENTER

Mobility Gaps in Large Facilities

NREL
Transforming ENERGY

Mobility

- Wait time
- Travel time
- Reliability

Environment

- GHG Emissions
- Energy consumption

Equity

- Accessibility
- LOS across populations
- Wayfinding, tech adoption

Built Environment

- Operational Flexibility
- Architectural Versatility
- Scalability
- Digital Integration

Findings

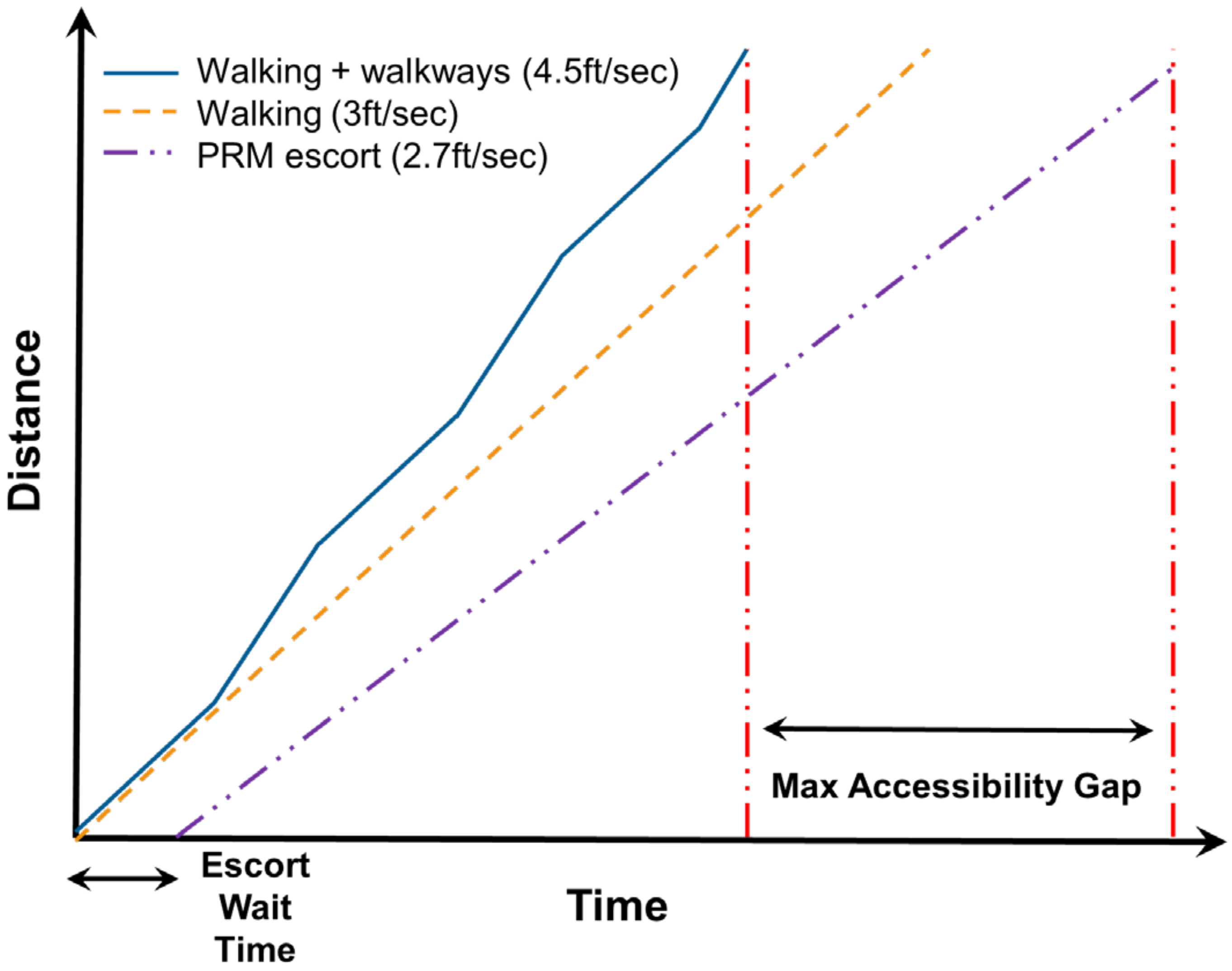
- Mobility
- Environment
- Equity
- Built Environment
- Mobility Energy Productivity (MEP)

NREL Transforming ENERGY

SAE International
NASA Glenn Research Center
INCOSE

E&M
TECHNOLOGY, SYSTEMS AND VALUE CHAIN
CONFERENCE & EXPO
SEPTEMBER 12-15, 2023
CLEVELAND I-X CENTER

Mobility



Quantifying the Accessibility Gap:

Assumed Escort Delay:

5 min → +56% increase in travel time
15 min → +150% increase in travel time

Not uncommon to see delays between 15-30 minutes during peak periods!

Environment

Moving Walkways:

<u>Energy use * power ratio (depending on loading) * 1000 (W) / hourly passengers</u>

<u>100% occupancy</u>: 120–240 kWh × 1,000/5,400 passengers/h = **22–45 Wh/pax-mile**

<u>25% occupancy</u>: 120–240 kWh × 0.5 × 1,000/1,350 passengers/h = **45–90 Wh/pax-mile**

<u>10% occupancy</u>: 120–240 kWh × 0.3 × 1,000/540 passengers/h = **60–120 Wh/pax-mile**

AMP autonomous wheelchair:

100-150 Wh/pax-mile ← Does not consider system level benefits of optimization

Utility Vehicle:

50-2000 Wh/pax-mile ← Depending on load

Key takeaway: AMPs on par with other options from energy consumption perspective

E&M Technology, Systems and Value Chain Conference & Expo
September 12-15, 2023
Cleveland I-X Center

Equity

Escorts for PRMs are unreliable (leading to large wait times) for several reasons:

- Supply/demand mismatch during peak periods
- Large variations in demand → leads to poor reliability
- Do not use system-level information for decision-making
- Limited access to airport amenities (often straight to gate)

AMPs for equity and inclusive design:

- Provide independent forms of mobility (travelers can experience airport similar to ambulatory population)
- Reposition to reduce wait times / improve reliability
- Intelligent, digital integration for improved performance

Built Environment

NREL Transforming ENERGY

Conveyance	Operational Flexibility	Versatility Across Domains	System Scalability	Intelligence/ Wayfinding
AMP	Centrally controlled system capable of real-time decision-making	Yes (landside, airside, elevators, re-deployable)	Additional vehicles, swarm intelligence, improved efficiency as system scales	Communication capabilities, over-the-air updating, wayfinding
Walking	–	Depends, walking distance constraints (max. 0.25–0.5 miles)	–	No (utility maximizing; not system optimal)
Moving walkway	Fixed capacity (designed for peak), continuously running	No; indoors, long straightaways	Fixed capacity, new walkways can be added to straight terminals	No communication capabilities with other systems
Utility vehicle	Require labor; shifts planned in advance for peak demand	Issues arise in tight spaces (elevators)	Requires additional labor and vehicles	Human-to-human communication, wayfinding, limited communication with other systems
Wheelchair (escort)	Require labor; shifts planned in advance for peak demand	Yes (landside, airside, elevators)	Requires additional labor and wheelchairs	Human-to-human communication, wayfinding, limited communication with other systems

Mobility Energy Productivity (MEP)

Terminal Conveyance	MEP Primary Dimension				
	Energy (Wh/pax-mile)		Cost ($)	Travel Speed (Relative to Walking Speed)	
	25% Occupancy	100% Occupancy		Fully Ambulatory	PRM
AMP vehicle (single passenger)	n/a	100–150	$7.5k/vehicle/year	1x (non-dedicated guideway) – 3x (dedicated guideway)	
Walking	n/a	n/a	n/a	1x	n/a
Moving walkway[a]	45–90	22–45	$50k–$75k/walkway/yr	0.5x (1.5x if walking)	Restricted
UTV (multiple passenger)	125–200	25–50	$80k–$100k/vehicle/yr	1x (non-dedicated guideway) – 3x (dedicated guideway)	
Wheelchair (with escort)	n/a	n/a	$70k–$90k/escort/yr	n/a	<1x walk speed + waiting time + transfer time

Discussion & Conclusions

- Costs/benefits of AMPs in large facilities
- Equity/inclusive design with AMPs

Overall Summary of Performance

NREL
Transforming ENERGY

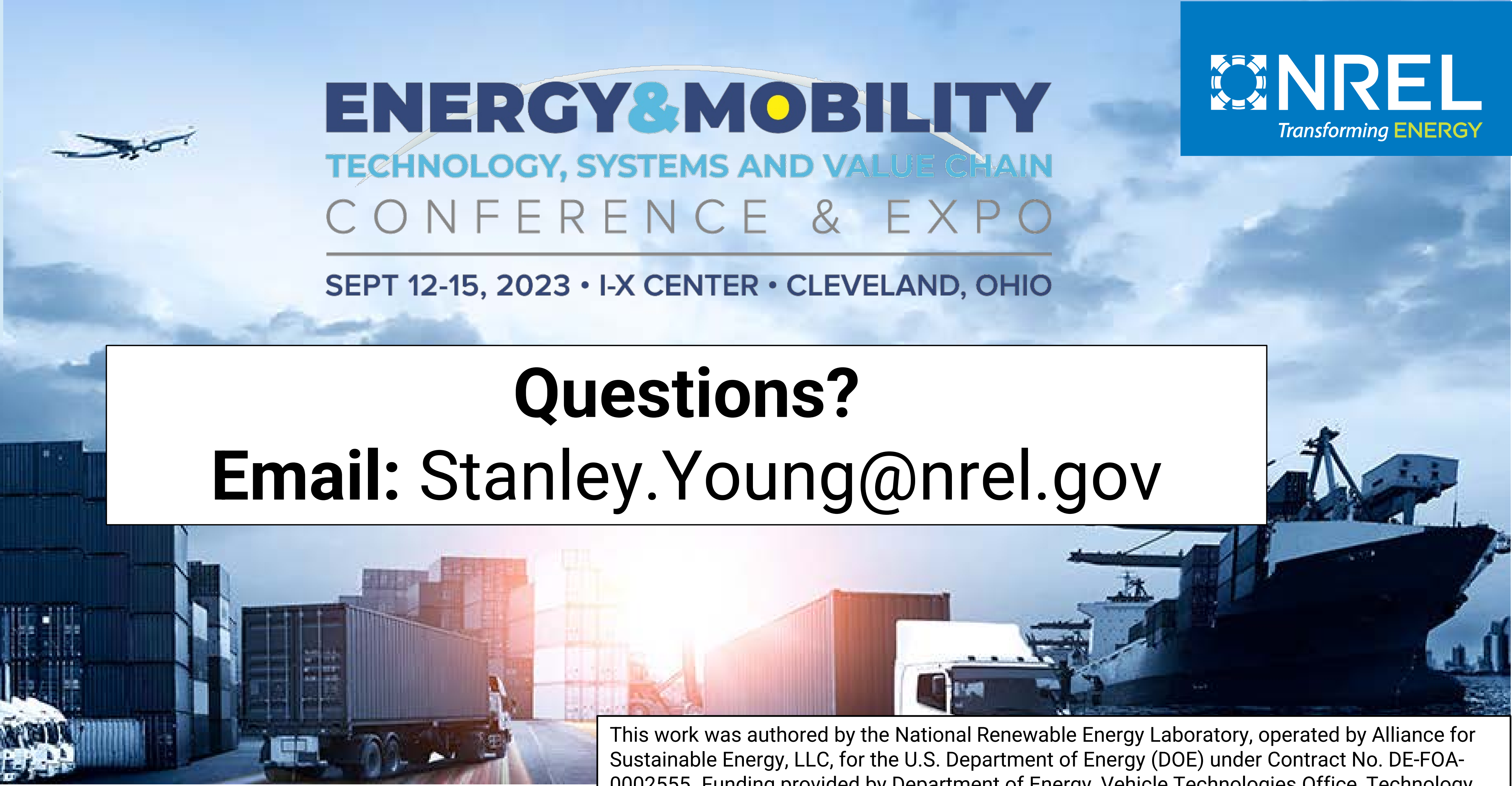
	Mobility (Public/PRM)		Environment	Equity	Built Environment	MEP	Total
AMPs	1	1	0	1	1	1	5
Walking	0	-1	1	-1	1	-1	-1
Moving Walkways	0	-1	0	-1	-1	0	-3
UTVs	-1	1	0	1	0	0	1
Wheelchair (escorts)	-1	0	1	1	0	0	1

Performance along given dimension →
1=Good, 0=Neutral, -1=Poor

SAE International
NASA Glenn Research Center
INCOSE
E&M
TECHNOLOGY, SYSTEMS AND VALUE CHAIN
CONFERENCE & EXPO
SEPTEMBER 12-15, 2023
CLEVELAND I-X CENTER

Key Takeaways

- **Airport ecosystem growing rapidly**, yet, highly uncertain (demand, technology, policy)
- Leveraging **systems/services** (e.g., automation, real-time communications and decision making) that are **flexible, adaptable, and efficient** can help **hedge against future uncertainty**
- **AMPs are highly flexible, intelligent, efficient, and cost-effective**
- **AMPs can serve all population groups**, which ensures equity and inclusivity of autonomous technologies



Questions?

Email: Stanley.Young@nrel.gov

Stanley E. Young, PE, PhD
National Renewable Energy Laboratory

NREL/PR-5400-87358

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-FOA-0002555. Funding provided by Department of Energy, Vehicle Technologies Office, Technology Integration. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government.