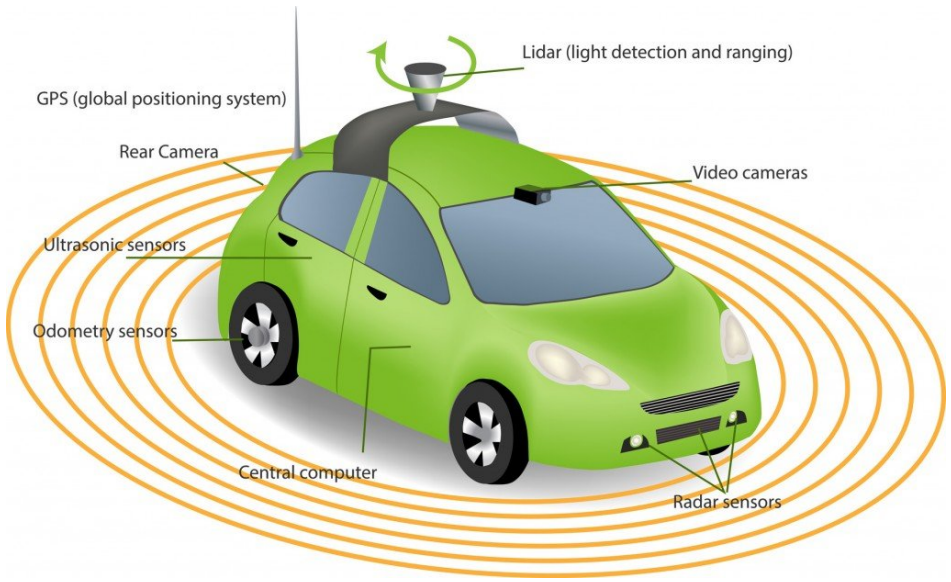
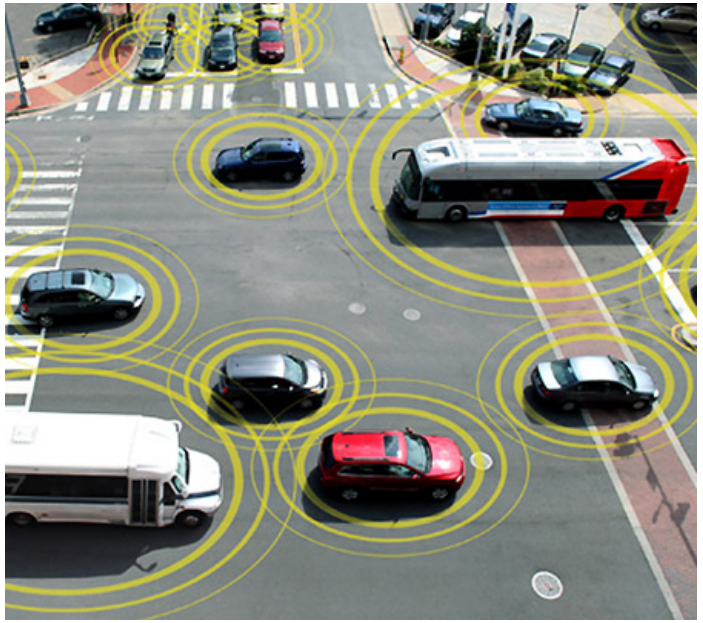
Autonomous Vehicles

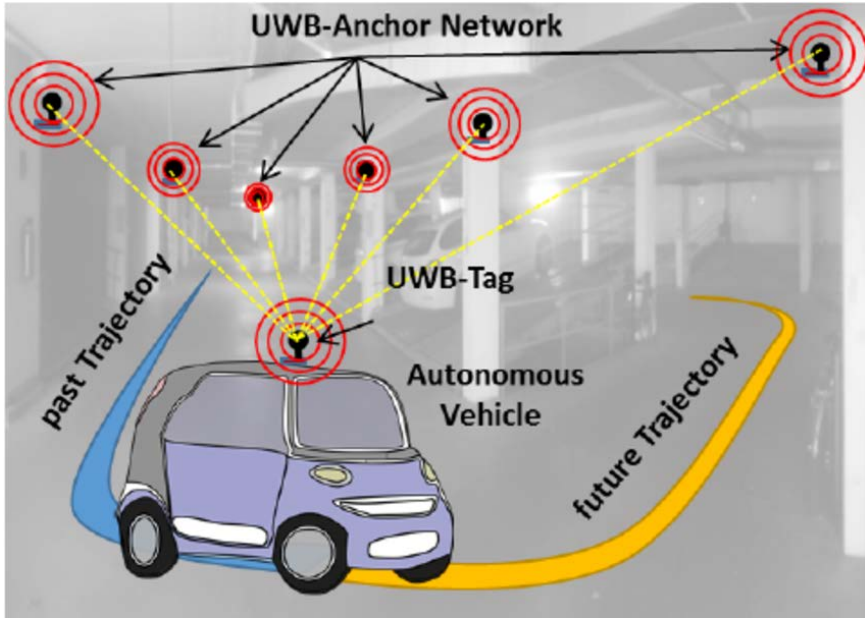
CV/AV Technologies



Autonomous Vehicles (AV)



Connected Vehicles (CV)

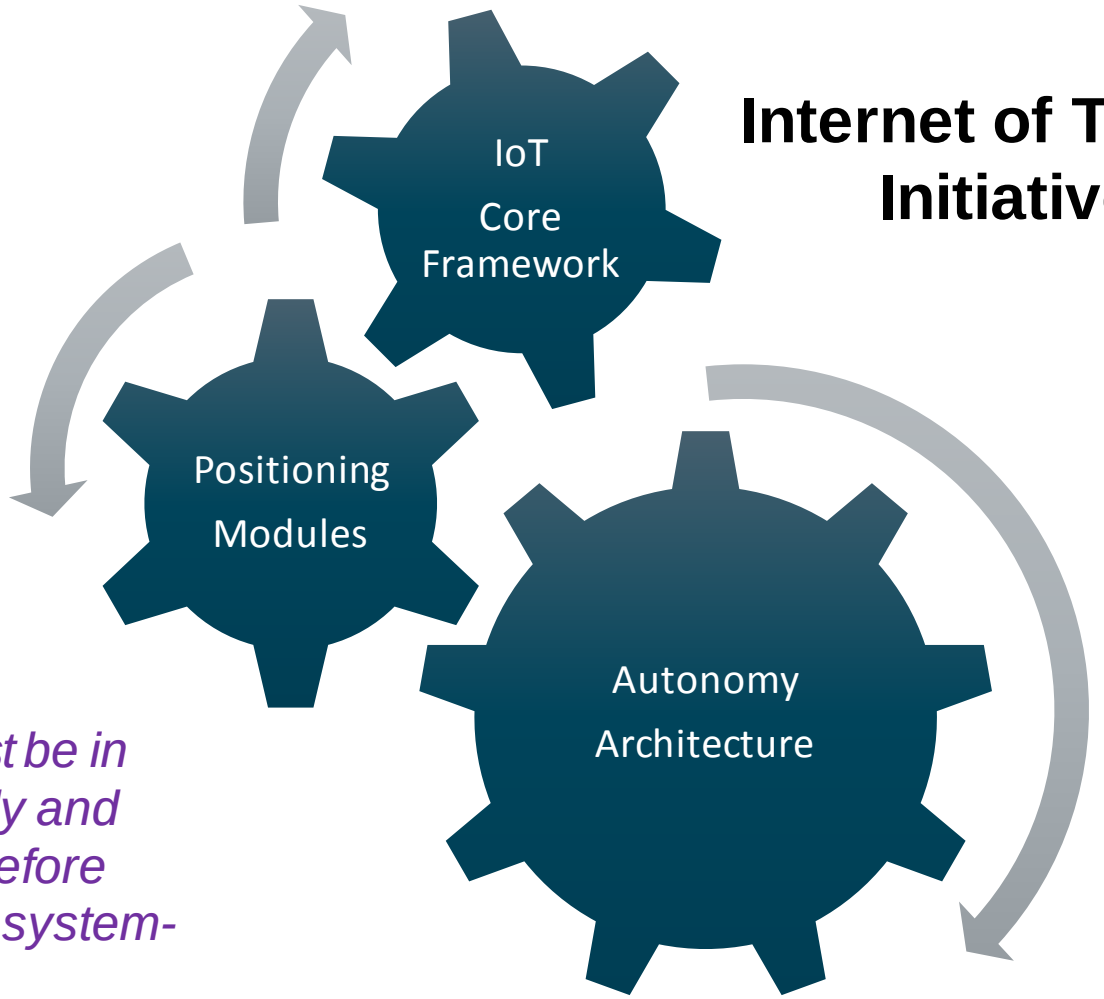


Ultra-Wideband (UWB)

Where Are We Going with Automated Vehicles?

- Near term (<2 years)
  - Advanced Driver Assistance System (ADAS) – ACC, EBS, LKAS
  - Low-speed, autonomous fixed route shuttles
  - High-speed, semi-dedicated connected facilities
  - Shorter Headway Automated People Movers
- Mid term (2-5 years)
  - Automated GSEs
  - Low speed, first/last mile on-demand shuttles
  - Automated vehicle guideways replacing rail APMs at airports
- Long term (5+ years)
  - Automated mobility on-demand
  - Automated parking garages

Underlying Architecture



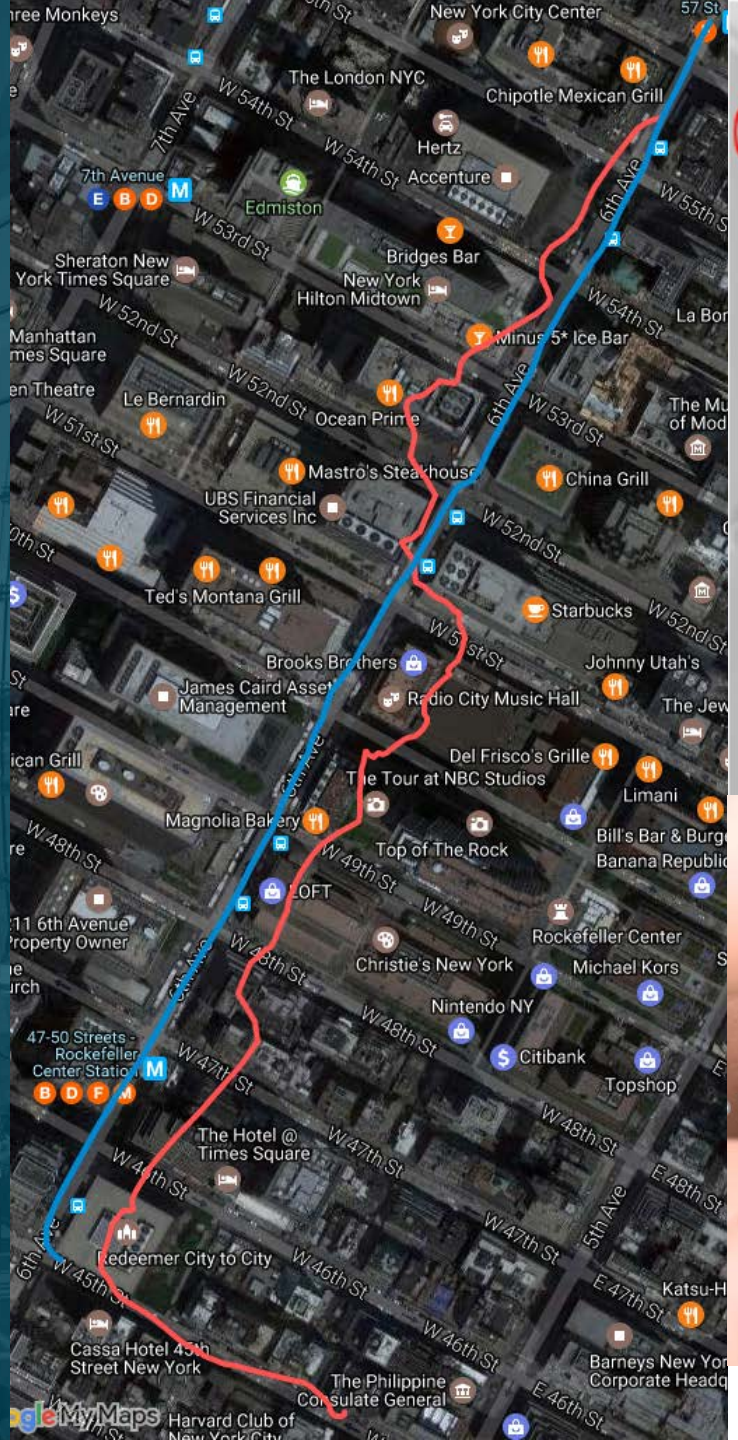
Internet of Things Initiative

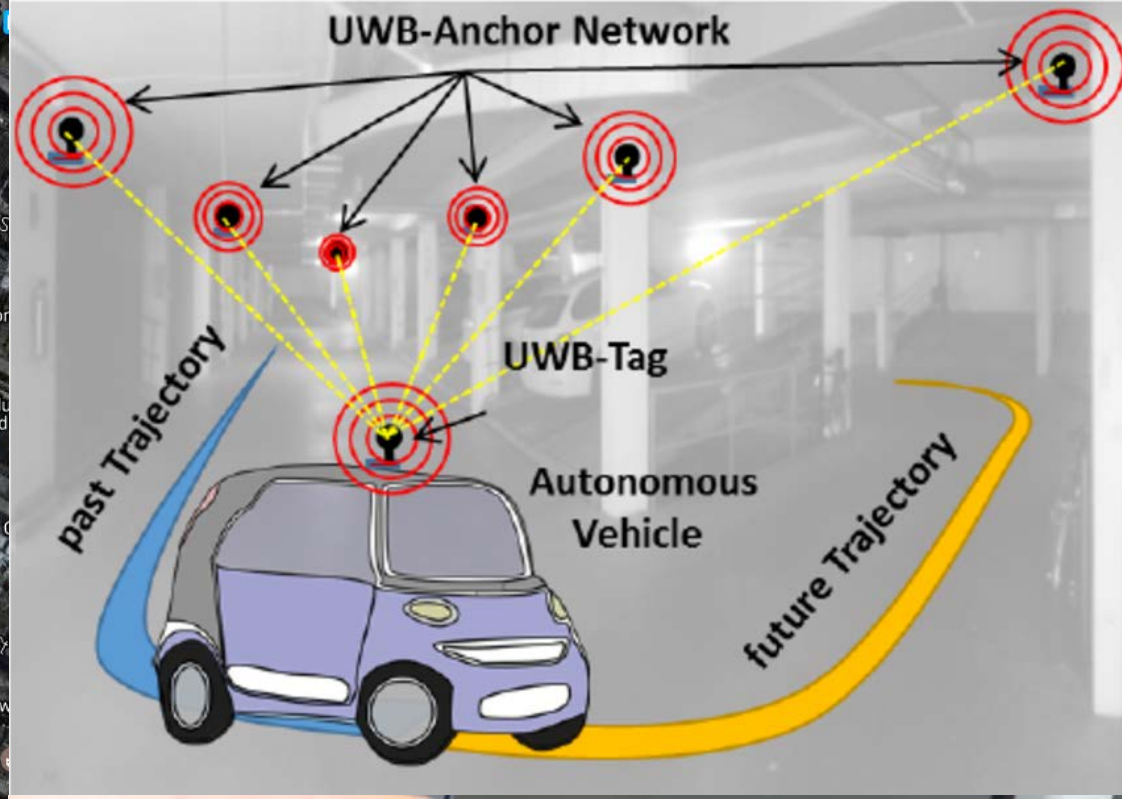
Asset Management Initiative

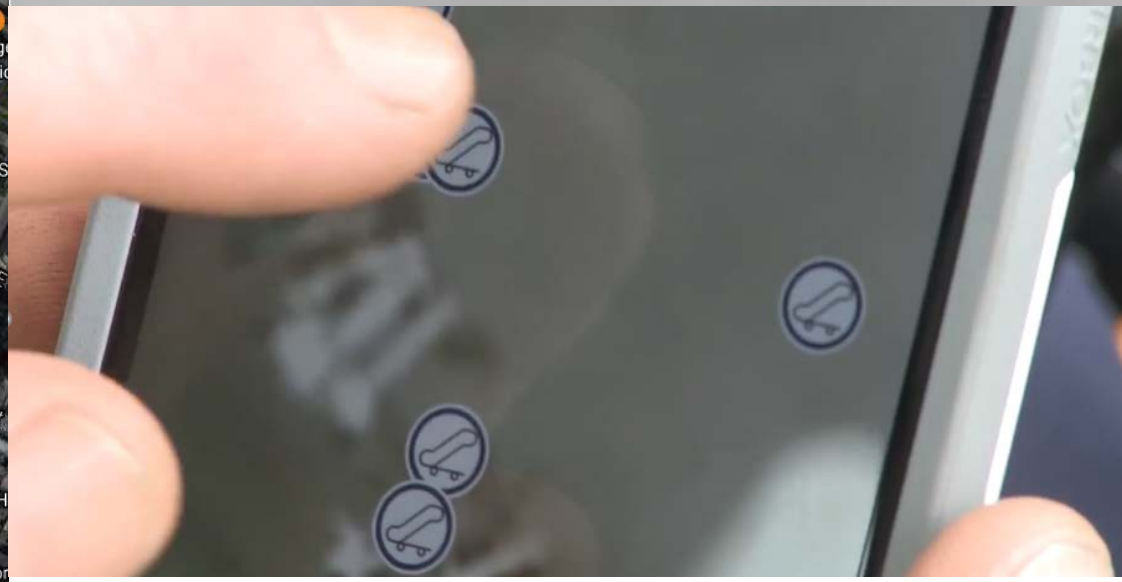
Autonomy Initiative

This framework must be in place technologically and programmatically before autonomy can provide system-level benefit

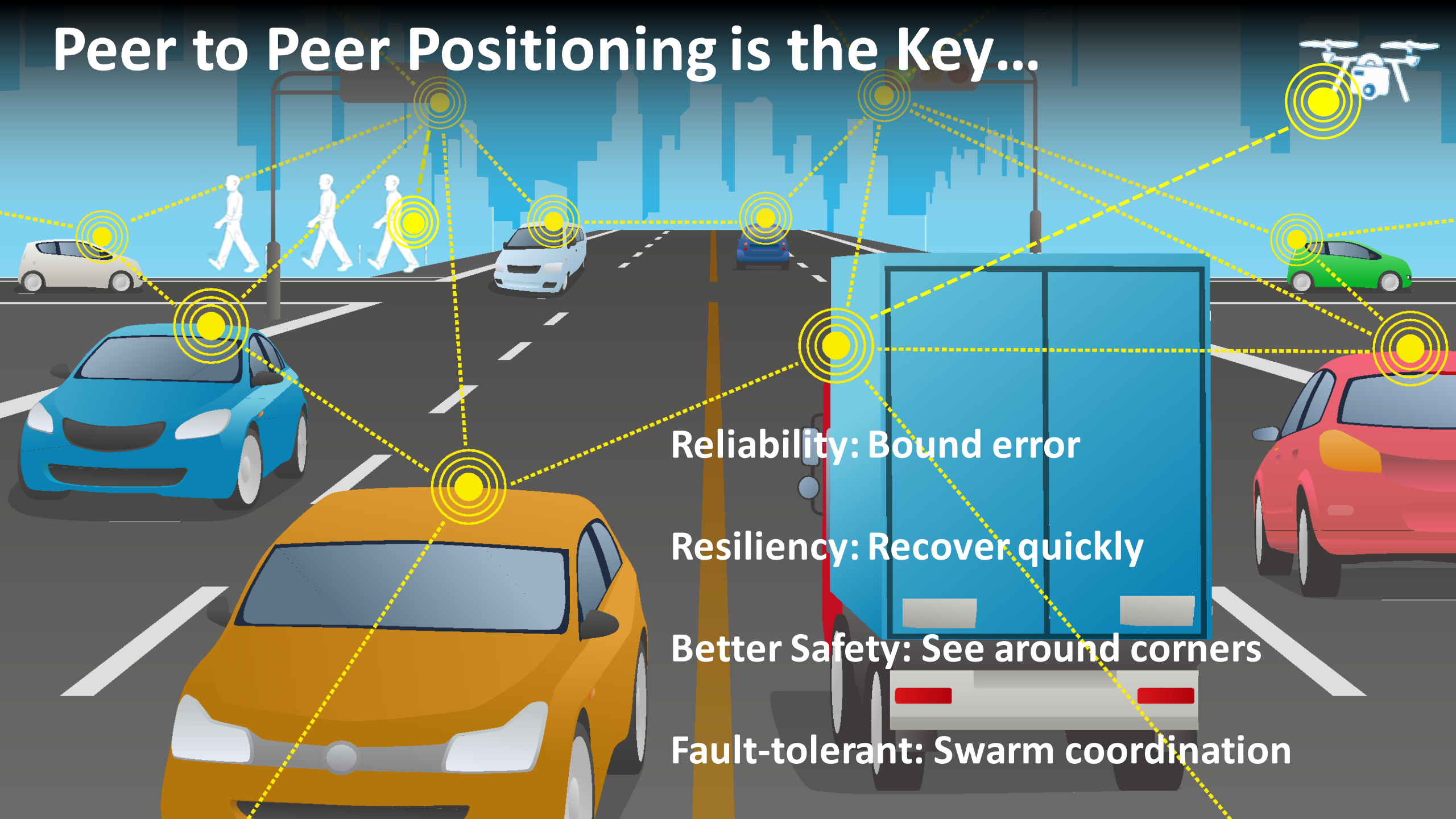
High-Accuracy Real-time Asset Tracking and Management







Peer to Peer Positioning is the Key…



Reliability: Bound error

Resiliency: Recover quickly

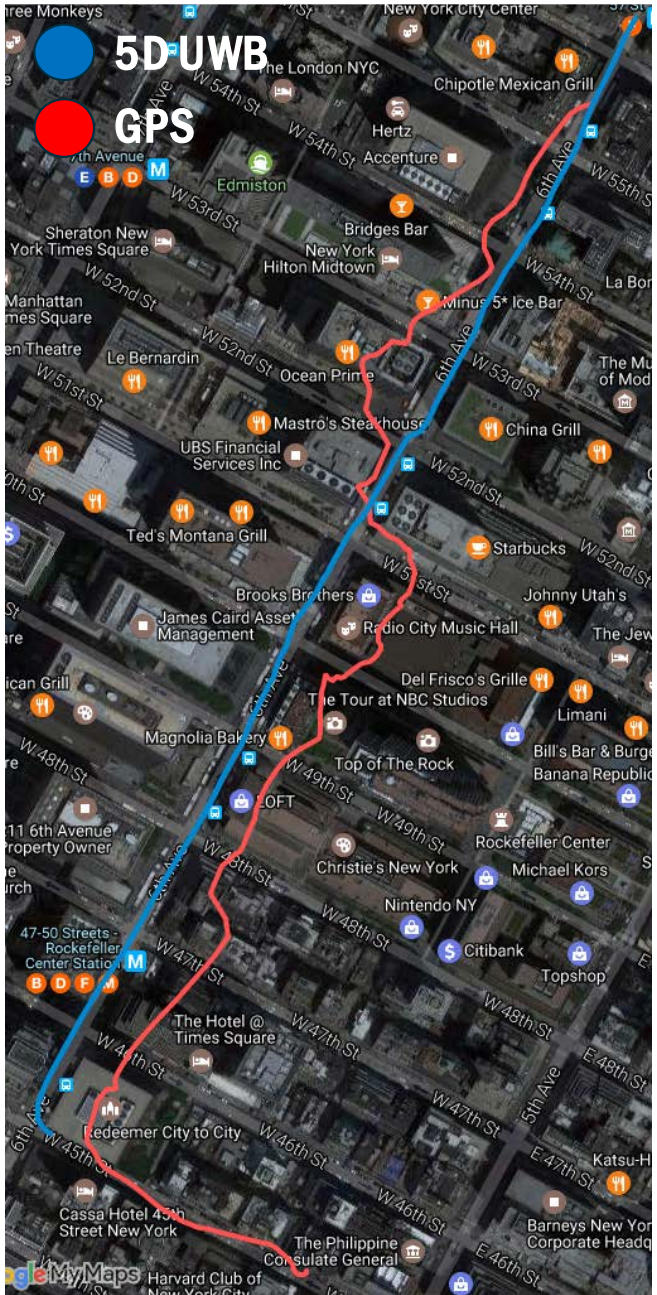
Better Safety: See around corners

Fault-tolerant: Swarm coordination

Choosing Tracking Technology

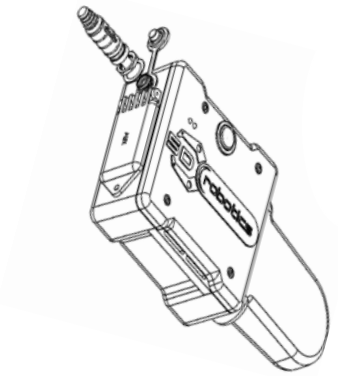
- GPS is not enough
  - Does not work indoors
  - Can be jammed
  - Accuracy not sufficient for automation
  - Requires radio/cellular communication to convey location data centrally
    - When multiplied by 10,000 to 35,000 units causes interference issues with other narrowband communications
- Beacons – Work with cellular, but very low position accuracy and shorter ranges
- Ultra-wideband found to be best for accuracy, no interference, jam proof

Asset Management



DOT accuracy requirement: **1.5m**
DOT accuracy objective: **10cm**

	GPS	5D UWB
Average	~10m	~5cm
Worst Case	~50m	~0.5m



Benefits of Asset Tracking and Management

- Reduced downtime, higher efficiency and assured safety result from a combination of contributing factors including:
  - Reduced idle time
  - Minimized fuel cost
  - Lower repair costs
  - Maximized productivity
  - Optimized GSE fleet size
  - Extended equipment life
  - Verified worker access
  - Enforced safety standards
  - Avoided equipment damage

GSE Location System Case Study

–After deploying a Vehicle Management System:

- An airline uncovered that out of 100 pieces of GSE (baggage tractors) monitored in their hub, less than 35 were ever used simultaneously at any given time over a four-month period. As a result, the airline canceled the purchase of new equipment and transferred the underutilized equipment to a new hub.
- Ramp accidents were reduced by nearly 75%
- GSE operator overtime was significantly reduced
- Preventative Maintenance costs reduced by 50%
- 30% reduction in GSE fleet size

Autonomous GSEs

TLD Autonomous GSEs with EasyMile

Automated Ground Support Equipment

CargoPod at Heathrow Airport

Mercedes Daimler AG Automated Snow Plows at Pferdsfeld airbase

More Automated GSEs

Improving automated baggage handling

Rotterdam The Hague Airport (RTHA) and Vanderlande

“An Uber-like service” on the airfield

Gatwick Airport (London)

Collaboration in Hong Kong

Hong Kong International Airport

- Airport luggage
- Movement of Universal Load Devices
- AutoPallet
- GeoDrone

Electric fly-by-wire Pushback

Why Automate GSEs

- Reduce human error
  - Safety consideration
  - Reduce damage/reporting damage
- Security concerns
  - Less people/less threats
- Many connections are standardized
- Operator requirements becoming more stringent

TLD Autonomous GSEs with EasyMile

Dubai Airport Automation

dnata mplementing airside automation demonstration by Nov 2019

- Automate turnaround functions
- Automate push back (and possibly taxi)
- Independent on-demand transport of ULDs and pallets
- Autonomous delivery of containers on “milk runs” and to staging areas
- Autonomous transport for passenger transport
- Autonomous on demand transport for staff

Autonomous Passenger Transport

AV Shuttle Vendors

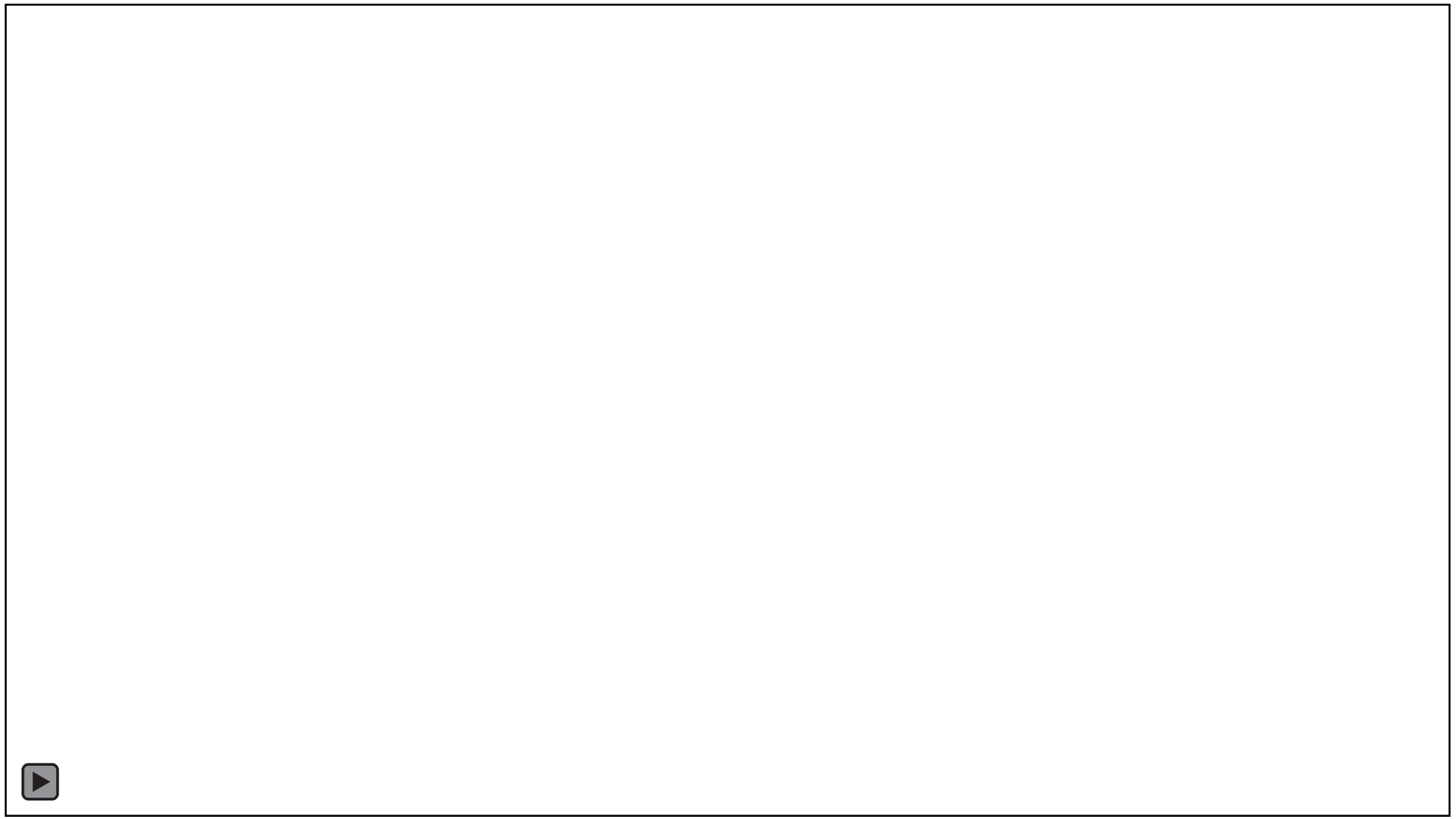
Mercedes Bus (2021)	
Ohmio Lift XT1 (2020)	
Toyota e-Palette (2021)	
2GetThere GRT2 - 3rd Gen (2 door)	
2GetThere GRT2 - 3rd Gen (1 door)	
EasyMile EZ10 Gen 3 (2020)	

Ohmio Lift	
Coast Automation	
2GetThere GRT	
EasyMile EZ10	
Navya/Softbank	
City Mobil2	

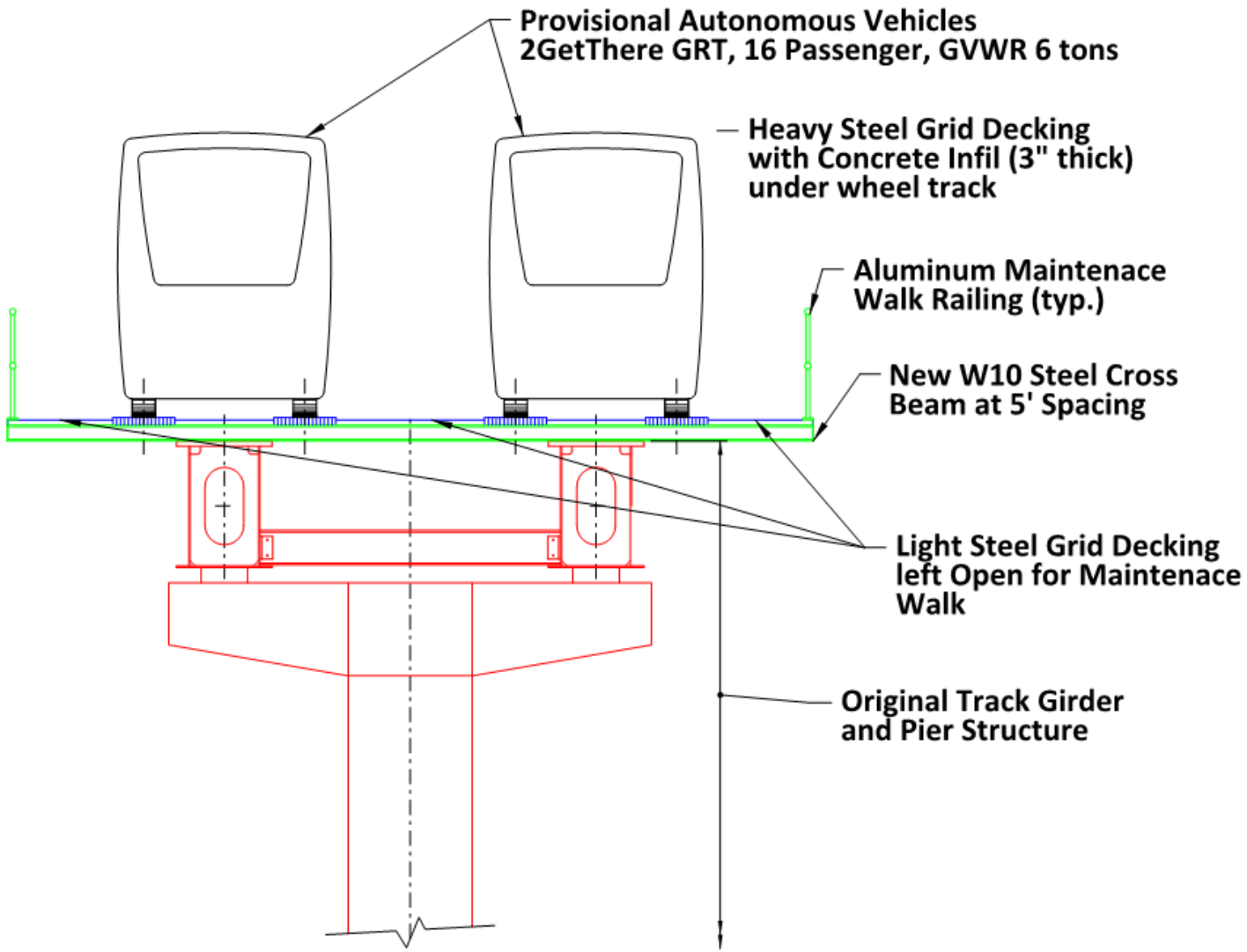
Improve Air Train Operation and Capacity

APM Replaced with Connected Automated Guideway

Repurposing Existing Infrastructure



Case Example – Monorail Replacement



Refit Concept for Monorail Guideway Structure
Twin Track at Stations shown

Preliminary engineering

- Cost savings
  ($200M vs. $1.8B)
- Time savings
  (2 years vs. 10 years)
- Expansion potential
- Vehicle flexibility

APM - CV/AV Comparison

	APM	CV/AV
Service Flexibility	Fixed Route and Schedule	On-Demand, Real-Time, Dynamic Schedule
Vehicle Fleet Flexibility	None	Mixed Vehicle Size
Vendor Options	Limited	Many
Tracks, Interlocking, Switches, Electrical Substations, Power	Required	Not Required
Longitudinal/Lateral Control	Tracks	Sensors and Algorithms
Aligned with Future Mobility Trends	No	Yes
Deployment Cost	High Infrastructure Cost	Minimal Infrastructure Cost
O&M Costs (Power Savings!)	High	Low
Construction Duration	High	Low
Deployments to Date	Multiple Deployments in US and Around the World	Mostly Short- and Long-Term Trials in US and Around the World

Questions/Discussion?

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