Securement of Wheeled Mobility Device Experiments on Locomotive Train-to-Train Test

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Next Generation Equipment Committee NGEC

The NGEC will provide national leadership in standardization, acquisition, financing and management of passenger rail equipment.

Presentation Outline

I. Improved Accessibility for Next Generation Passenger Rail Cars
   - Background
   - Accessibility Recommendations
   - Compartmentalization of Passengers Seated in WhMDs

II. Securement and Compartmentalization of Wheeled Mobility Device Experiments
   - Background
   - Test overview
   - Results
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III. Next Steps

I. Improved Accessibility for Next Generation Passenger Rail Cars

Background

- 2011 FRA awarded contract to Oregon State University
  - Develop universal and inclusive accessibility recommendations for next generation passenger rail cars
  - Worked with NGEC Technical Subcommittee to develop and vet the recommendations
    - PRIIA Accessibility Working Group – DOT, Amtrak, rail car manufacturers & suppliers, US Access Board staff, disability advocates
    - Spatial recommendations were incorporated into PRIIA bi-level specifications for cars procured by Caltrans and Illinois DOT
- 2018 FRA awarded contract to Volpe National Transportation Center to evaluate safety issue surrounding containment of wheeled mobility devices (WhMDs)

Spatial Accessibility Recommendations

- 800 lbs design load for carborne lift
- 30” x 54” clear space for lift platform
- 44” width in vestibule for 90° turn
- 32” x 59” accessible space
- 2 accessible seating spaces per car
- 35” x 60” clear interior space in accessible restroom
- 39” door opening for accessible restroom doors located on side
  - Power assist restroom door

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Additional Accessibility Recommendations

- Improved interior features of accessible restroom
- On-board accessible passenger information systems
- On-board evacuation chair for passengers using WhMDs
- Space for service animals

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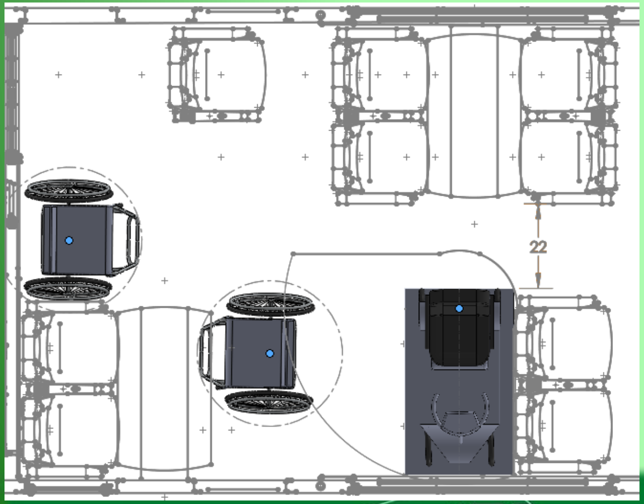
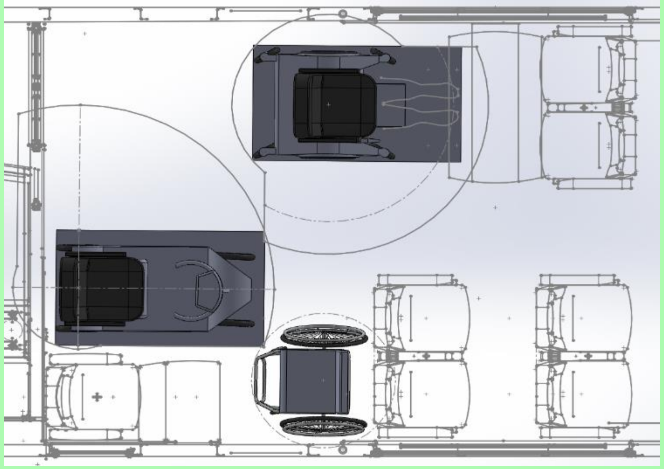
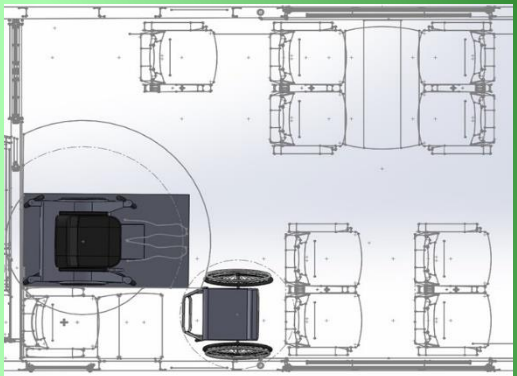
Containment of Passengers Seated in WhMDs

- Inclusion of two or more accessible spaces was investigated for impact on loss of revenue seats
  - Used large power base wheelchair, manual sports model wheelchair and scooter in study
- Some proposed layouts revealed lack of compartmentalization of passengers in WhMD

Layouts with Compartmentalization Issues







II. Securement and Compartmentalization of Wheeled Mobility Device Experiments

Background

- No securement requirements for wheeled mobility devices (WhMDs), or users, on trains
- Collision safety can be improved by limiting the motion of occupants and WhMDs during train collisions and derailments.
- Three experiments were conducted onboard a 24-mph train-to-train impact test using anthropomorphic test devices (ATDs), manual and surrogate wheelchairs, and restraint systems used on transit buses

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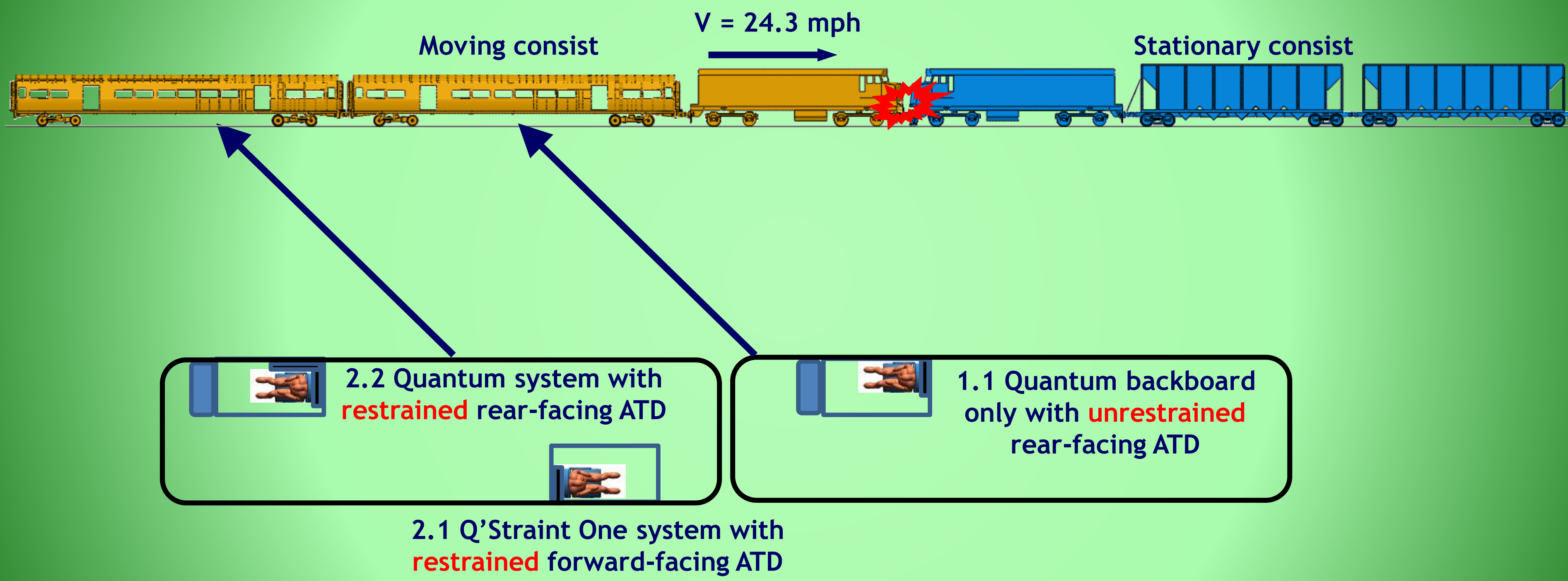
Locomotive Train-to-Train Test Overview

- 24.3 mph impact speed
- **Primary test objective:** evaluate performance of locomotive crash energy management features
- **Secondary test objective:** evaluate feasibility of transit bus restraint/securement devices on trains and the protection they may provide, i.e., proof-of-concept test

Experiment Locations



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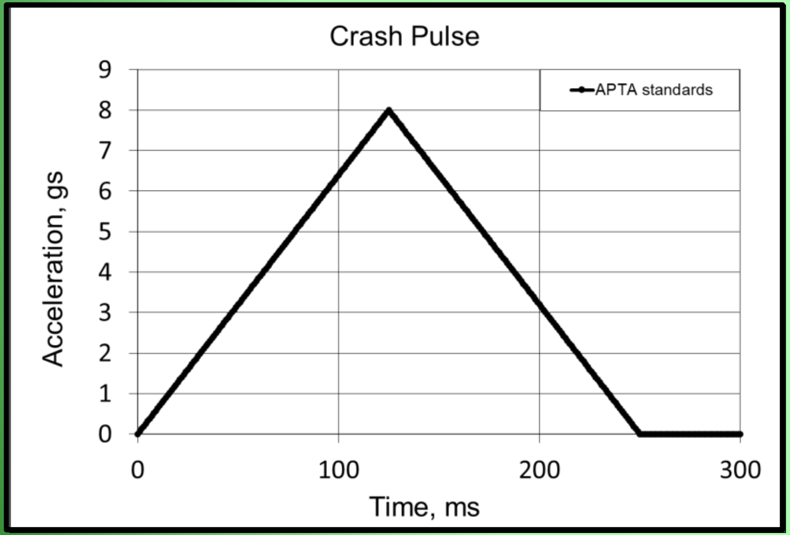
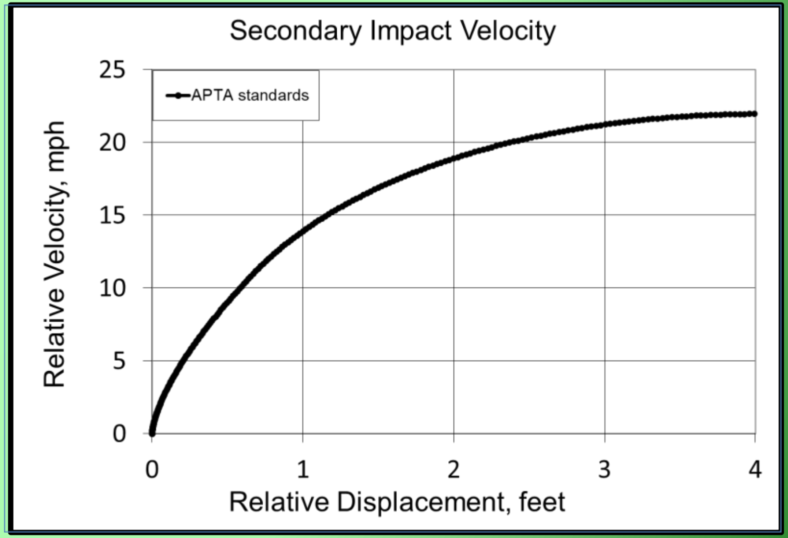
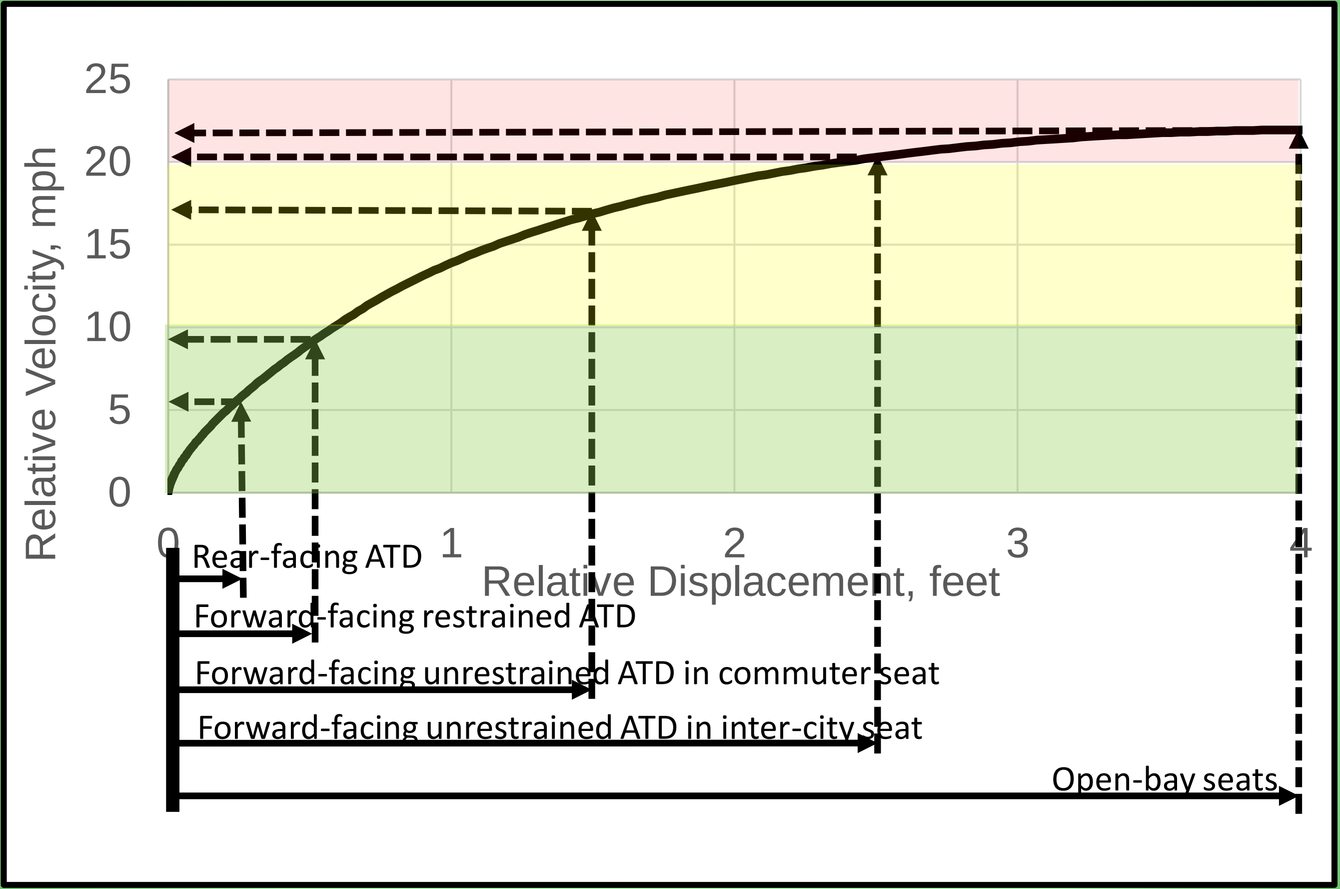
Secondary Impact Velocity (SIV)

- For a given acceleration pulse
  - Integrate once → relative velocity
  - Integrate twice → relative displacement
  - Cross-plot velocity vs. displacement





Secondary Impact Analysis



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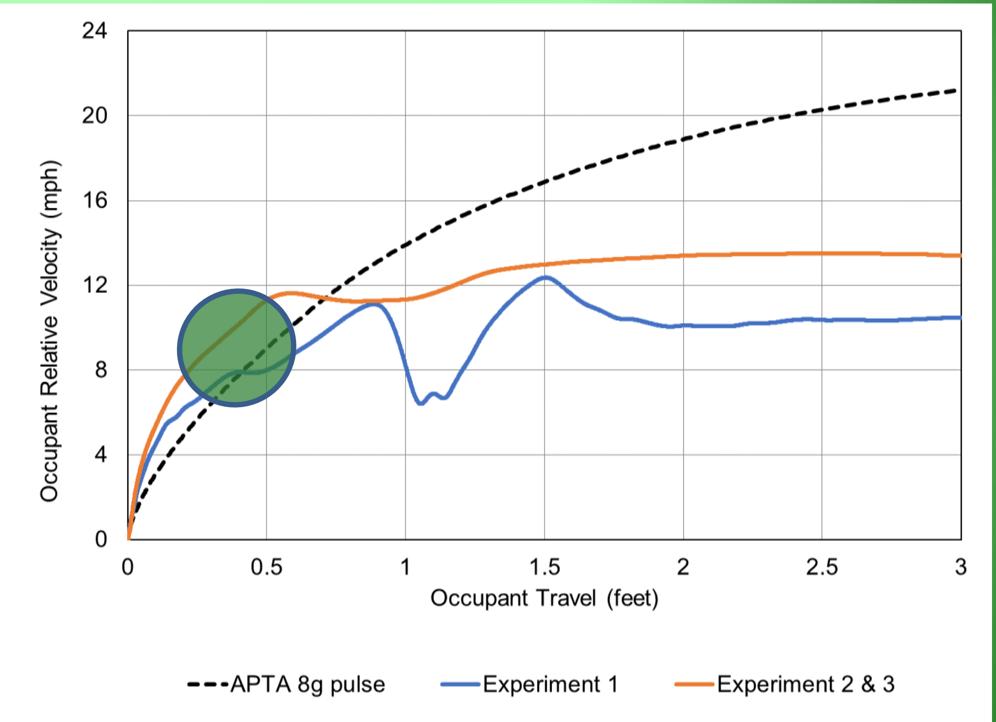
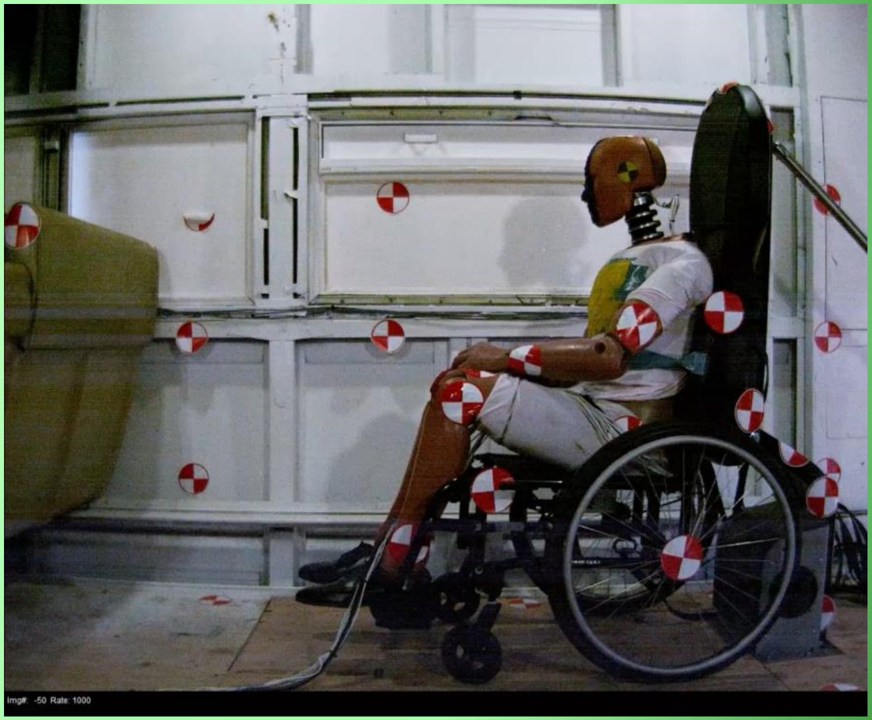
Secondary Impact Velocity

- The ATDs had less than a foot of travel before their motion was constrained by the backboard and/or the securement devices.
- The 24.3 mph train impact resulted in SIVs inside the two passenger cars that were very similar to the APTA 8g crash pulse
- The occupants inside the trailing car experienced higher secondary impact velocities (SIVs) than the middle car



Occupant Experiment 1.1 – Quantum® Backboard Only (Baseline)

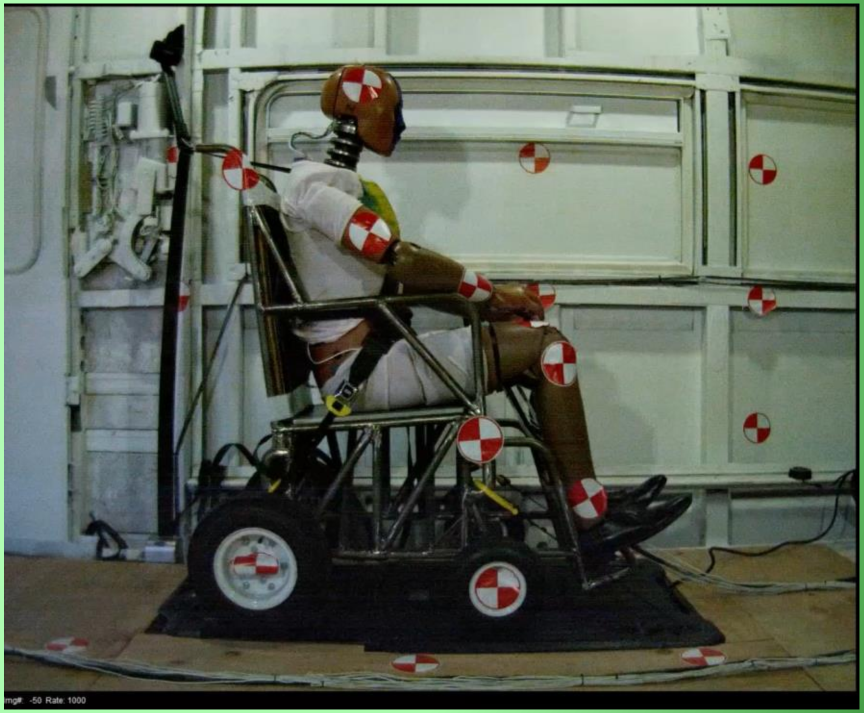
Direction of travel →



- Unrestrained commercial manual wheelchair
- Unrestrained rear-facing H3-50M ATD
- Adjacent rear-facing M-Style seat
- No assistance required for this passive restraint system

Occupant Experiment 2.1 – Q'Straint One™ System, Active System

Direction of travel →



- Surrogate test wheelchair, restrained to floor with 4 J-hooks
- Forward-facing H3-50M ATD, restrained with lap/shoulder belt
- Restraint system designed to resist the most severe transit bus crash pulse
- Assistance required; there is a trade-off between occupant protection and independence

Occupant Experiment 2.2 – Quantum® Restraint System

- Surrogate test wheelchair, restrained by active ‘grips’ on rear wheels
- Rear-facing H3-50M ATD, restrained with lap/shoulder belt
- Adjacent rear-facing M-Style seat
- No assistance required for wheelchair restraint; assistance may be needed for some users to reach and secure the lap/shoulder belt

Direction of travel

Active restraint system

Test Measurements

- H3-50M ATDs
  - Head and chest acceleration
  - Neck forces and moment
  - Chest displacement
  - Femur loads
- Carbody
  - Triaxial accelerations

Results were evaluated against performance requirements specified in APTA seat and table standards:

  - Component attachment
  - ATD Compartmentalization
  - Head, chest, neck, and femur injury

Injury Criteria	**Limit in APTA seat/table standards**
Head Injury Criterion (HIC15)	700
Peak Axial Neck Tension	4,170 N
Peak Axial Neck Compression	4,000 N
Nij	1.0
3-ms Chest Acceleration	60 g
Peak Chest Compression (63 mm)	63 mm
Peak Femur Compression (10 kN)	10 kN

Results

- All restraint devices remained attached to the carbody
- All ATDs were compartmentalized during and after the impact
- All experiments met the injury criteria requirements in APTA S-016 (seat) & S-018 (table) safety standards

Injury data normalized to respective limit			
Experiment #	**1.1**	**2.1**	**2.2**
Direction (Rear or Forward)	R	F	R
Restrained (Yes or No)	N	Y	Y
HIC15 (700)	3%	5%	2%
Peak Neck Tension (4,170 N)	12%	20%	8%
Peak Neck Compression (4,000 N)	6%	7%	24%
Nij (1.0)	15%	26%	26%
Chest Acceleration 3ms (60g)	18%	26%	35%
Peak Chest Compression (63 mm)	32%†	31%	9%
Peak Femur Compression (10 kN)	6%	4%	10%

† *Spike in chest compression due to signal noise*

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Observations

- Proof-of-concept experiments demonstrated that existing transit bus retention devices performed as intended:
  - ATDs were compartmentalized
  - Injury measurements were well below threshold values
- The neck loads could potentially be reduced by adding an adjustable headrest to the backboard in both the forward- and rear-facing experiments
- The ATDs experienced significant vertical motion due to the carbody moving on its secondary suspension. The vertical motion is more extreme in the last car in a consist.
  - Vertical motion could affect compartmentalization without a seatbelt.

Dissemination of Test results

- Published FRA Research Result (https://rosap.ntl.bts.gov/view/dot/64418)
- Two FRA test reports to be published in 2023
- Presented test results to industry stakeholders:
  - APTA Passenger Rail Equipment Standards Construction & Structural Working Group
  - Rail Vehicle Access Advisory Council (RVAAC), Amtrak, FRA
  - NGEC PRIIA Annual Meeting
- Conference paper TBD in 2023

Acknowledgements

- TTCI (now known as MxV Rail) – Planned and executed train-to-train test
- CAMX – Pre- and post-test computer modeling
- Q'Straint, Inc.
  - Donated and installed all Q'Straint restraint equipment
  - Provided CAD files
  - Supported pre-test planning
- NHTSA
  - Loaned ATDs free of charge
  - Supported pre-test planning
- Oregon State University – Katharine Hunter-Zaworski provided support related to regulations for wheelchair testing and issues affecting wheelchair users

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III. Next Steps

Input from Stakeholders Requested

- Collect feedback on test results
- Seek guidance on potential next steps:
  - Conduct additional research to improve WhMD safety
    - Computer modeling to evaluate APTA 8g crash pulse, additional ATD sizes, type of WhMD, etc.
    - 8G sled tests to further support proof of concept regarding structural integrity, compartmentalization, and human injury performance of the securement devices. Model validation would be a secondary benefit.
  - Develop recommended practices for rail operators interested in utilizing restraint systems
  - Develop potential regulations or industry safety standards
  - Other ideas?