Department of Energy
Transportation External Coordination Working Group (TEC)
September 20-21, 2005

Ruben D. Peña B.
Testing at the
Transportation Technology Center Inc.

Experience – Innovation - Solutions

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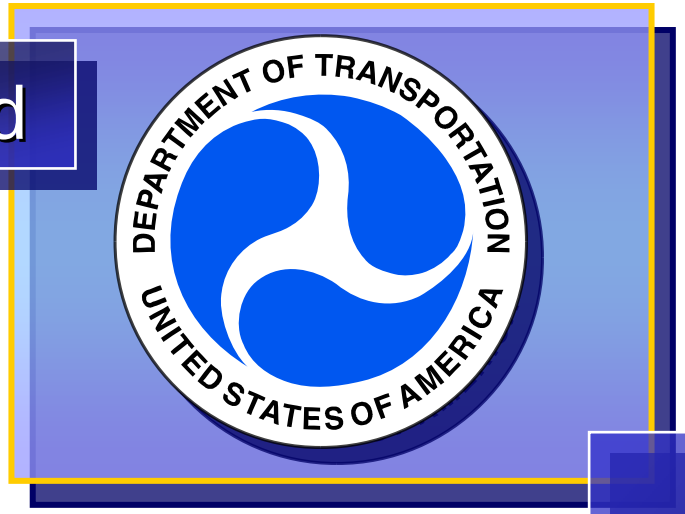
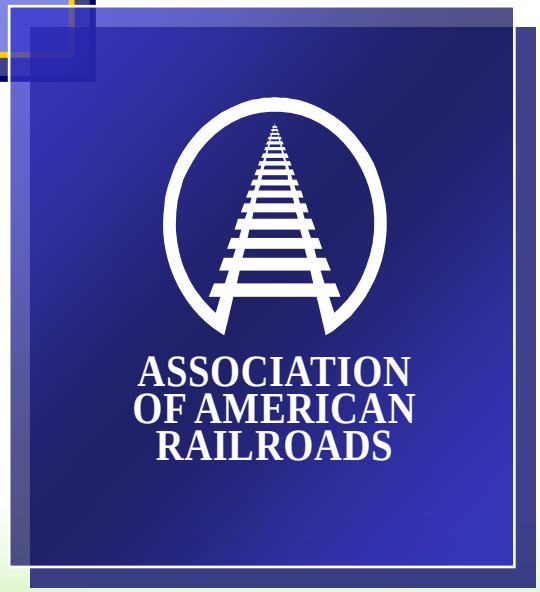
The Transportation Technology Center, Inc.

- Our Landlord



Our Owner



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Unique Facility with Worldwide Experience

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Roles & Capabilities

- **Roles**
  - Safety
  - Reliability
  - Efficiency
  - Independent Assessment
- **Capabilities**
  - Traditional R,D & T
  - Rail Security
  - Emergency Response Training
    - Passenger Training
  - Technology Development

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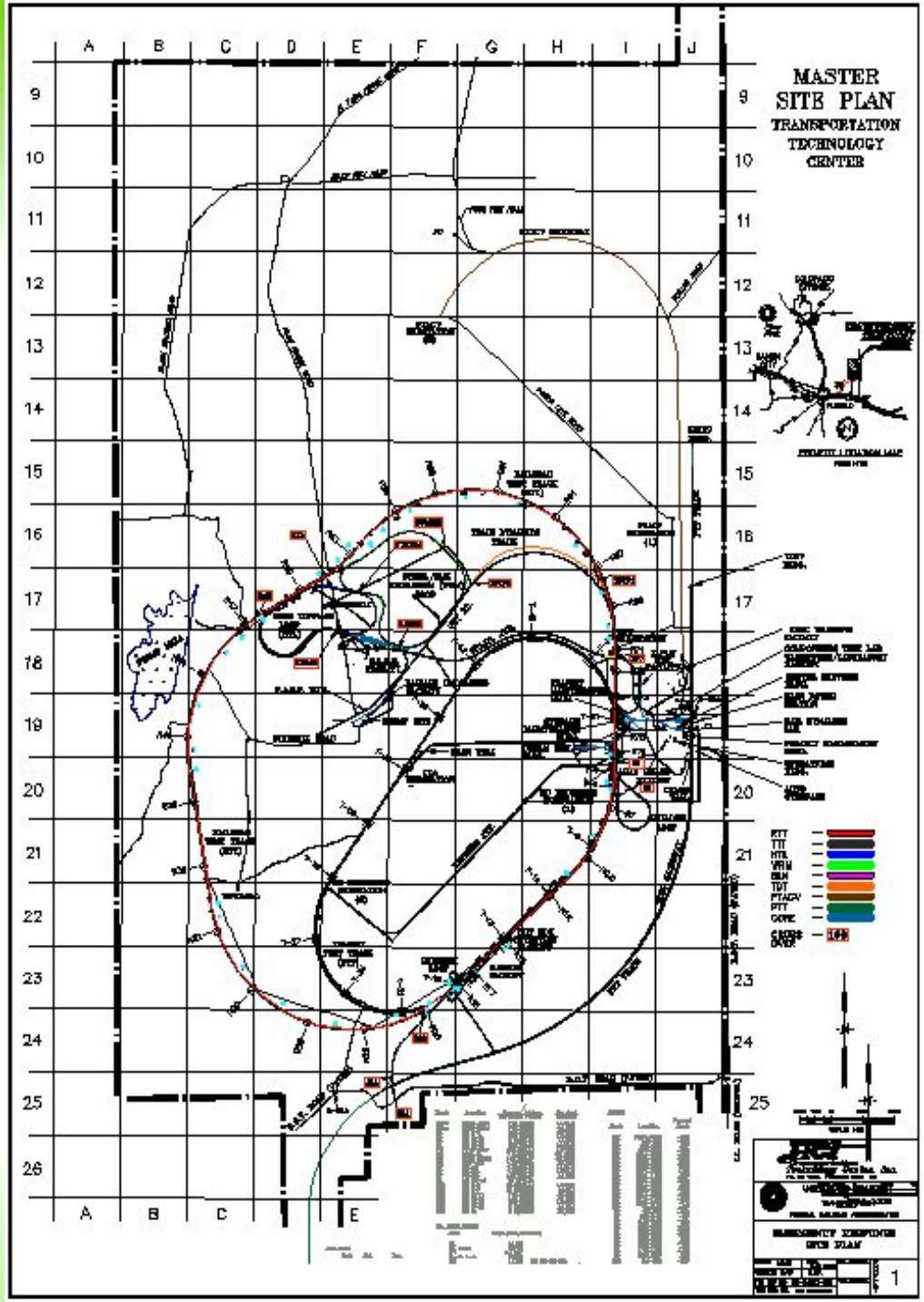
The Transportation Technology Center



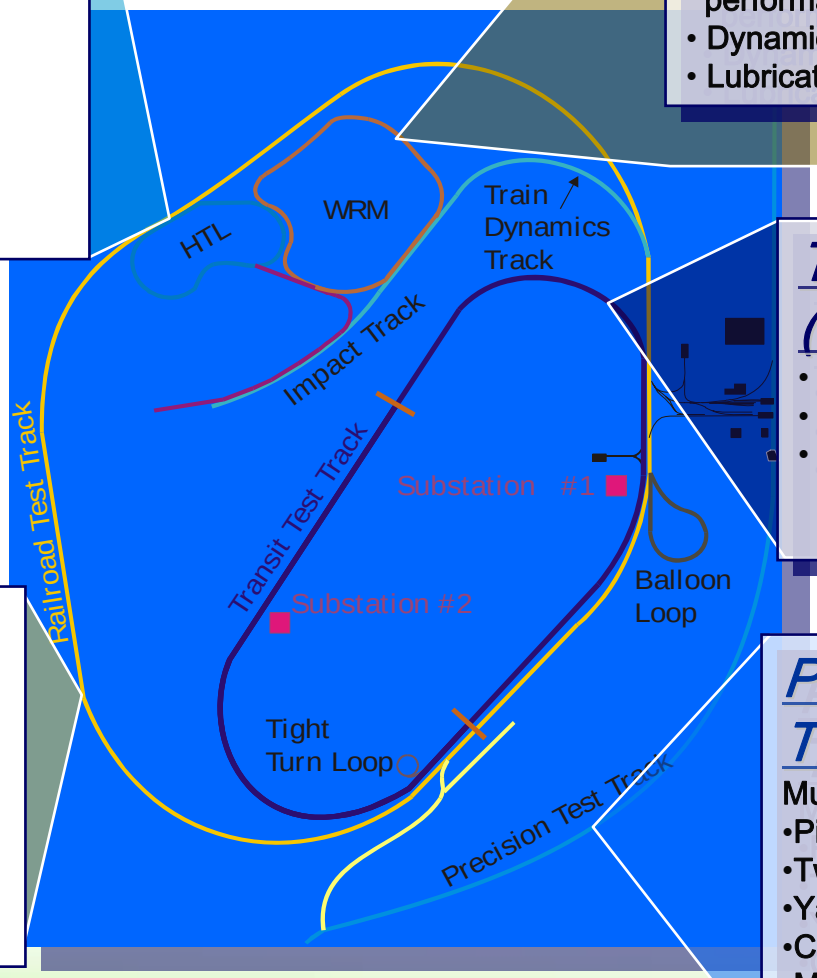
Engineered Facilities for Dynamic Testing

High Tonnage Loop (HTL)

- 2.7-mile loop, three 5° curves, one 6 ° curve
- Main use – HAL studies
- Test bed for various premium track components
- 25 MGT/month in controlled environment

Wheel/Rail Mechanism Track (WRM)

- 7.5°, 10°, and 12° curving performance tests
- Dynamic curving tests
- Lubrication studies



Transit Test Track (TTT)

- 9.1-mile loop
- 80 mph max speed
- DC electrified third rail
  - Up to 1150 volts
  - Up to 12,000 amps

Railroad Test Track (RTT)

- 13.5-mile loop
- 1°-15' curve and four 50' curves
- Main use – HAL studies
- Maximum speed 165 mph
- 12.5-, 25-, and 50-kV overhead catenary

Precision Test Track (PTT)

Multi-use track for railcar testing

- Pitch and bounce
- Twist and roll
- Yaw and sway
- Car impact
- Miscellaneous studies

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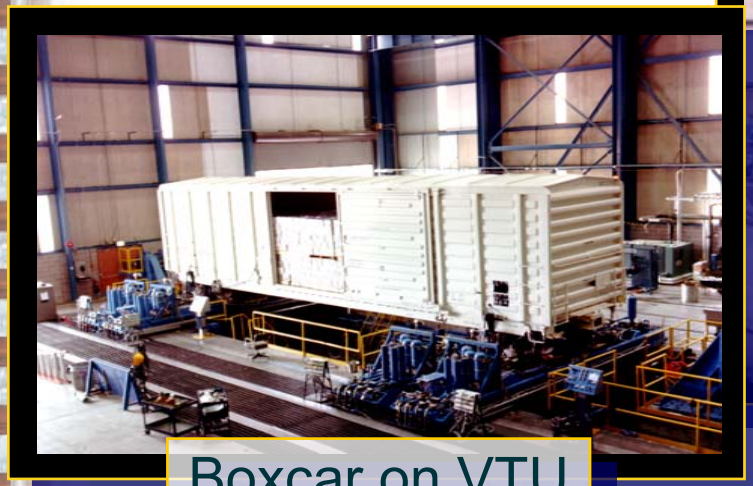
Full-Scale Laboratory Testing

- Vibration testing
- Used for characterizing rail vehicle suspensions and components
- VTU is also used to improve lading restraint systems This will:
  - Reduce lading damage problems in revenue service

Auto Rack on VTU



Boxcar on VTU

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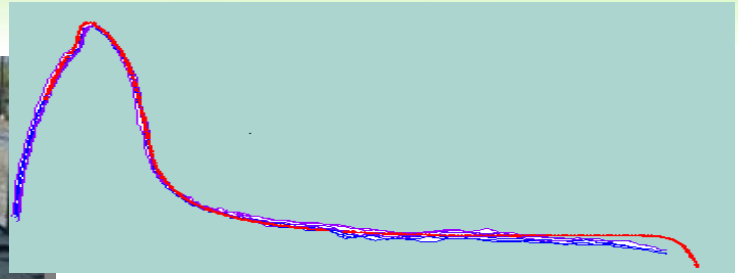
Wheel Profile Technology Used to Identify Hollow / Thin Flange Wheels

Sensor box with view of high speed cameras and lasers



Impact load detectors are widely used to identify and remove wheels with surface defects.

1.5 x 5 in. Shell, 106 k

TTC Testing of Impact Load Detectors

Electronic Equipment

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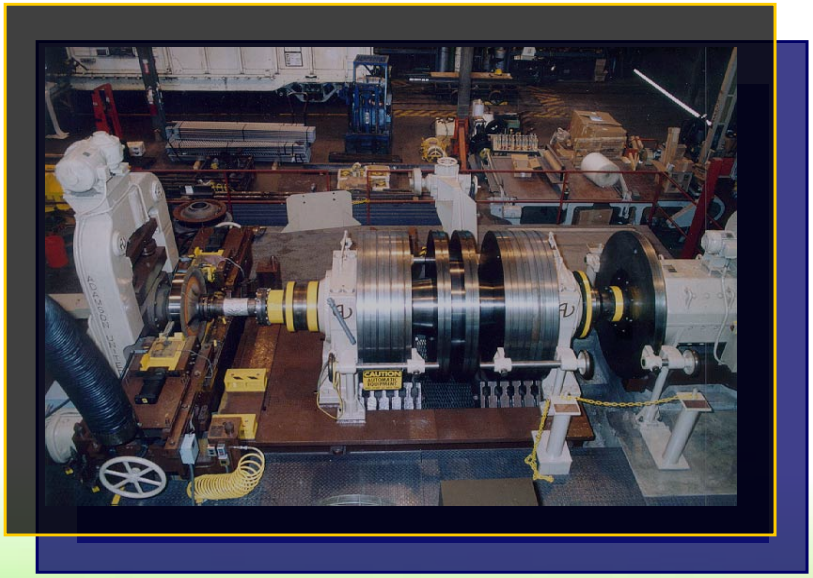
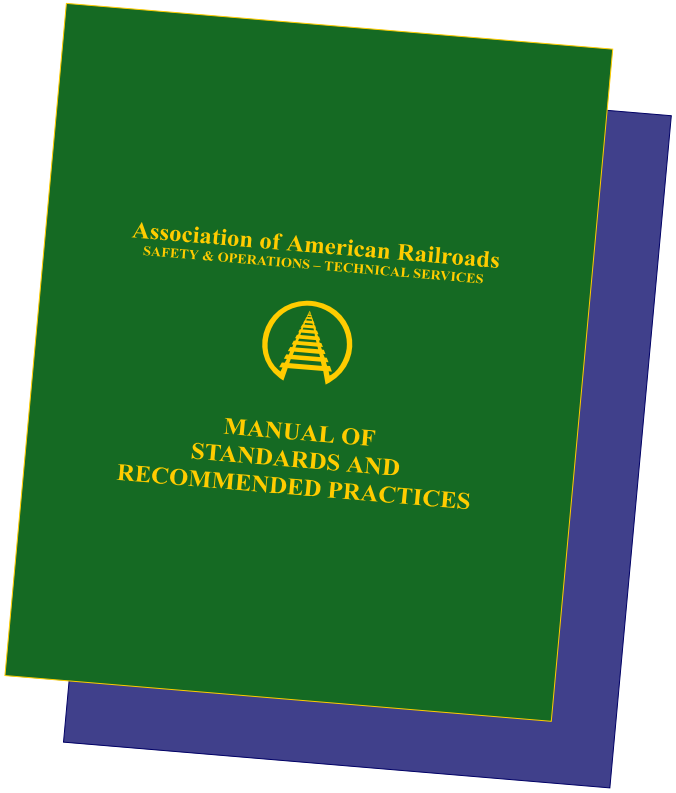
Standards Development & Certification

- **What are the elements of technical standards?**
  - AAR technical committees
  - Industry quality programs
  - Rules and standards policing
  - Certification testing





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Railcar Safety Criteria

- **What are the goals of railcar safety standards ?**
  - Provide an unbiased and consistent method to evaluate proposed designs
  - Publish evaluation regimes and success criteria
  - Shorten the time to introduce new products
  - Improve the efficiency & reliability of the fleet
- These tests & criteria
  - Used in derailment studies
  - Used in product development
  - Focus on past problem areas
- Freight railroad safety standards are established by committee
  - Equipment Engineering Committee (EEC)
  - Certification must be through this group
  - Action can only be at direction of EEC

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Railcar Safety Criteria

- Freight Car Safety Standards now in effect
  - Chapter XI –
    - Vehicle dynamics and derailment
    - Theoretical analyses and tests
  - M965 – 100 ton (263,000 pound) trucks only
    - Originally for supplemental snubbing devices
  - S286/M976 for 268,000 – 286,000 pound cars
  - Chapter VIII – intermodal cars
  - S2043 – Safety performance specifications for trains carrying High Level Radioactive Material
  - Chapter XI and S-2043 based on extensive practical test and analysis experience at TTCI

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Safety Performance Specifications

- **AAR Manual of Specifications and Recommended Practices**
  - Design specifications for freight cars
  - Chapter XI safety performance specifications
    - Vehicle dynamics and derailment
    - Theoretical analyses and tests
  - S-2043 safety performance specifications for trains carrying High Level Radioactive Material
    - More comprehensive and rigorous than Chapter XI
    - Extensive theoretical analysis required before construction and test of prototype vehicles
  - Chapter XI and S-2043 based on extensive practical test and analysis experience at TTCI

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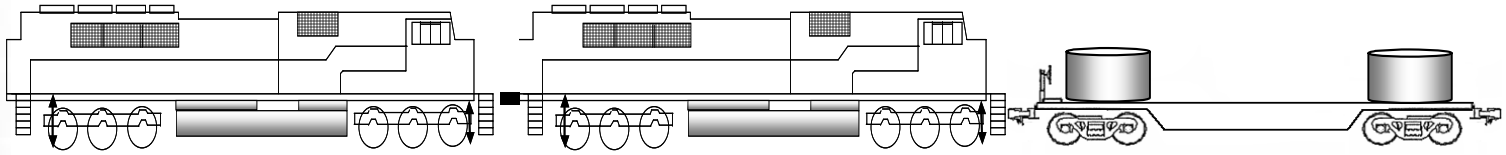
90 1034

DODX 39898
87 2121

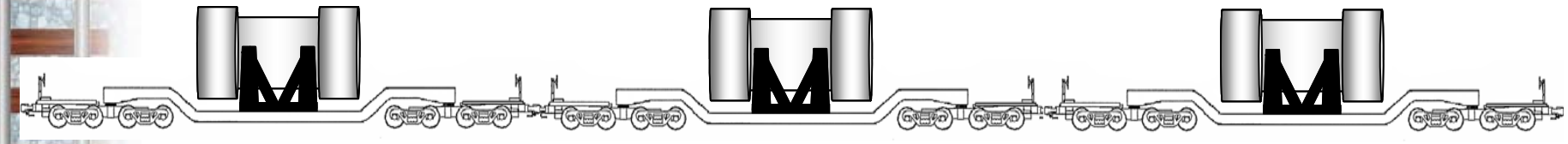
S-2043 - Performance Standard for Trains Used to Haul High Level Radioactive Material (HLRM)

4- or 6-Axle Locomotives with ECP Brakes

Ballasted Buffer Car



Cask cars weighing 425,000 each, including cask and cradle



Ballasted Buffer Car

Escort Car for Monitoring & Security

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S-2043 Goals

- Optimize train performance & reliability
  - Speeds to 50 mph (analysed & tested to 70 mph)
  - Excite rigid body modes
    - Method to handle unknown track conditions
  - Car to car interaction included
  - ECP brakes required
  - Onboard monitoring for every car
  - Crew onboard dedicated train
  - Buffer car between waste and people

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Application

- Applies to all rail equipment operating in HLRM trains except locomotives
- Standard Became Effective 9/1/00

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Anticipated Car Types

- Cask Car
- Buffer Car to Separate Cask Car from Occupied Vehicles
- Passenger Car for Security Personnel and Monitoring Systems

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Design Requirements

- Structural
  - Stress analysis preformed by FEA
  - Standard AAR freight car load cases
  - Additional crashworthiness requirements
  - Fatigue life analysis
- Non-Structural Static Tests
  - Truck twist equalization
  - Car body twist equalization
  - Truck warp restraint
  - Static curve stability
  - Curve negotiation
- Dynamic Analysis
  - Approved dynamic modeling software
  - Primarily Chapter XI track simulations
  - Criteria more conservative than Chapter XI

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Design Requirements, Continued

- Non-Chapter XI Dynamic Analysis
  - Perturbation wavelengths at truck centers
  - Single bump on tangent and curve
  - Curving with various lubrication combinations
  - Turnouts and crossovers
  - Ride quality
  - Buff and draft curving
  - Braking effect of curving
  - Worn component simulations
- Brake System Design
  - ECP required for higher braking rates for dedicated trains
  - Communication for train health monitoring
  - Brake shoe force variation limited to 8%
  - Jerk rates limited for crew protection
- System Safety Monitoring
  - Real time monitoring for derailment prevention
  - Remote monitoring to prevent performance degradation

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Single Car Test Requirements

- Vehicle Characterization
  - Tests designed to verify that components performance matches manufacturer specifications
  - Results aid designer in estimating performance that cannot be easily tested
- Non-Structural Static Tests
  - Truck twist equalization
  - Car body twist equalization
  - Truck warp restraint
  - Static curve stability
  - Horizontal curve negotiation
- Static Brake Tests
  - Force measurements per S-401
  - Single car air test
  - Electronically Controlled Pneumatic design compliance
- Structural Tests
  - Strain gages for critical areas and FEA verification
  - Standard Chapter XI structural tests
  - Cask securement system test

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Single Car Test Requirements

- Single Car Dynamic Tests
  - Chapter XI tests with more conservative limits
  - Pitch and bounce with perturbation wavelengths at truck center spacing
  - Single bump
  - Curving with single rail perturbation
  - Turnouts and crossovers
  - Ride quality

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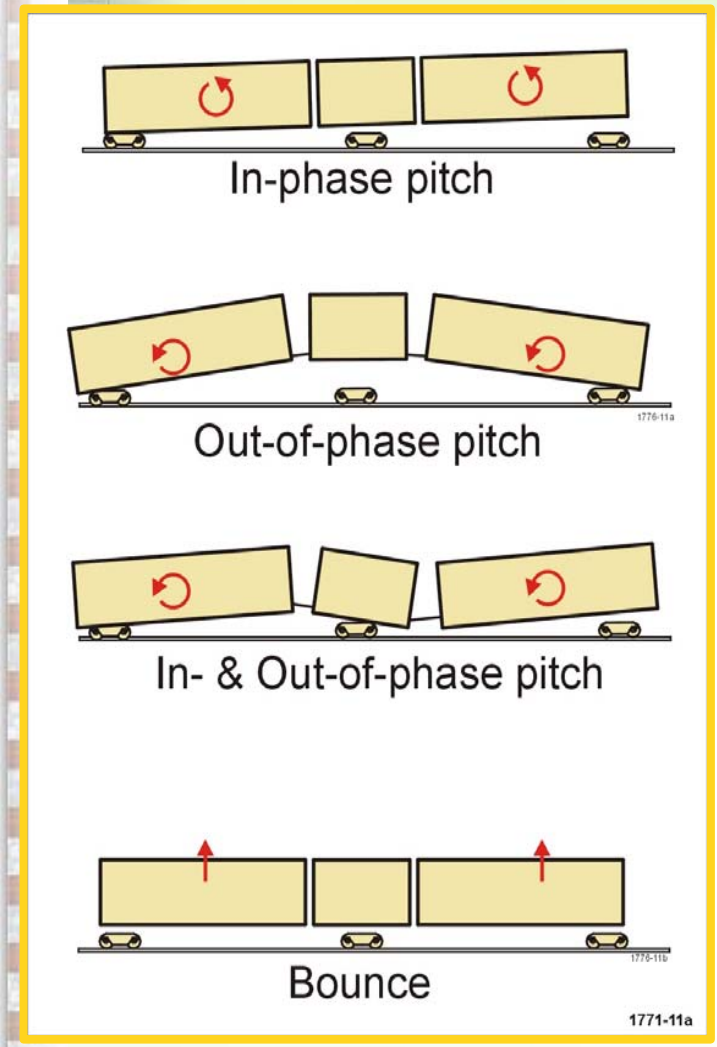
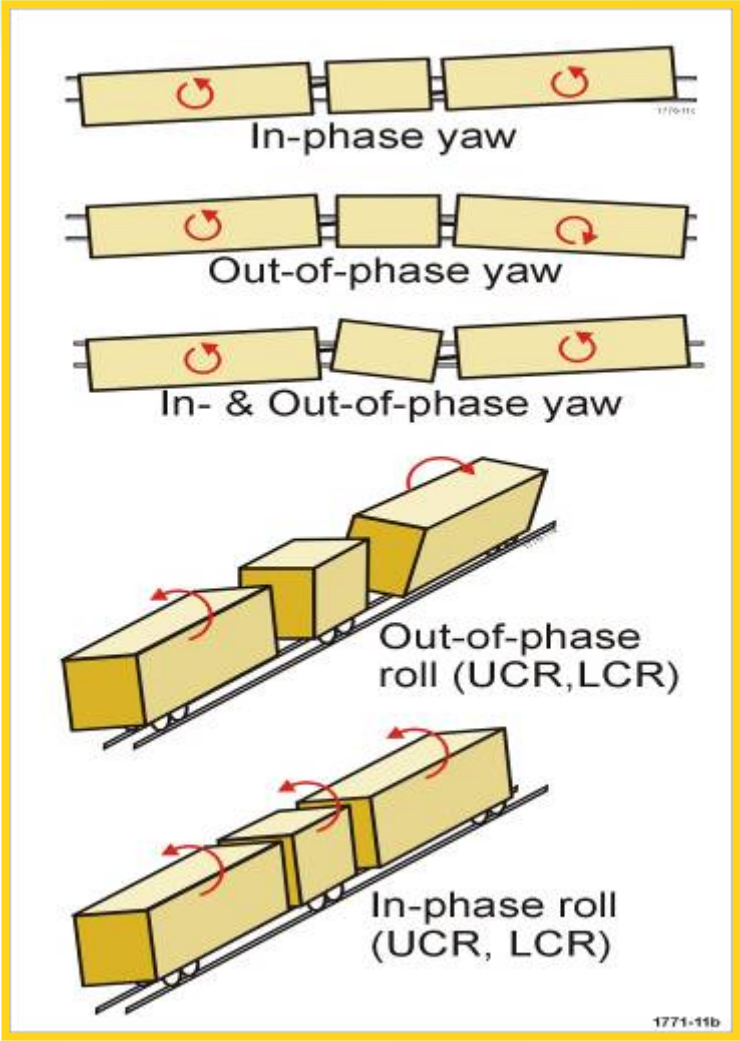
Articulated Car Rigid Body Modes





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Multiple Car Test Requirements

- Dynamic Tests at Controlled Test Site
  - Stop distance
  - Braking in curves
  - Buff and draft curving
  - System monitoring tests
- Revenue Service Tests
  - Turnouts and crossovers
  - Poorly maintained track
  - Ride quality
  - Operational demonstration

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TTCI experience with Nuclear Waste Transportation Standards and Safety Performance Issues

- **Development of S-2043 and other AAR standards**
- **On-going test and analysis support of USA Nuclear Waste transportation systems for:** DOE, Yucca Mountain, PFS
- **Extensive RR industry R&D**
  - Flange climb derailment mechanisms & derailment investigation
  - Vehicle and track dynamics
- **Vehicle/Track interaction**
  - Vehicle testing: freight and passenger
  - Simulation model development: NUCARS, TOES/STARCO, WRTOL

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TYPICAL VEHICLE PERFORMANCE EVALUATION PROCESS

- *Theoretical Simulations - NUCARS*
  - *NUCARS model - Design Optimization*
- Vehicle Characterization Tests
  - Verify vehicle characteristics
  - Update/revise NUCARS Simulations
- TTCI Tests – Track and Laboratory
  - Verify simulations
  - Conformance to specifications and safety performance standards
  - Structural, Fatigue
- Revenue Track
  - Verify simulations and lab tests
  - Ride Quality

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NUCARS™

A PC-based multi-body railroad vehicle dynamics simulation program designed to simulate *any railroad vehicle moving over any track.*

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New and Untried Car Analytic Regime Simulation (NUCARS)

Multi-body Vehicle/Track Dynamic Interaction Simulation

- 6-Rigid Body Degrees of Freedom (DoF) per body
- Up to 99 Flexible Modes per Body
- Fully non-linear
- Various type of suspensions
  - **Friction, load dependent, series and parallel spring and damper, air suspensions… and many, many more**
- Nearly any combination of worn wheel and rail profiles
- Solid and/or independent rotating axles
- Many options / types of track geometry inputs
- External force inputs (wind, longitudinal buff and draft)
- Braking or traction inputs
- Lubrication / dry track

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NUCARS™ Applications:

- Detailed analyses of vehicle/track dynamic interaction
- Detailed studies of derailment mechanisms
- Parametric studies
- Evaluation of specific vehicle design details and defects
- Evaluation of specific track design details and defects:
- Operational and environmental conditions
- Tool for learning details of vehicle/track interaction

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Why Use Computer Simulations to Evaluate Performance?

- Design optimization before building prototype
  - Evaluate design variations
- Evaluate effects of various operating conditions
  - Track geometry
  - Environmental conditions
  - Derailment Simulation
- Testing is expensive
  - Many simulations can be run for cost of one day of tests
  - Derailments in computers are easy to clear up
  - Testing can not duplicate all operational conditions
  - Use simulations to identify critical test run matrix

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Why Perform Tests to Evaluate Performance?

- Confirm and verify computer simulations
- Obtain empirical data to ensure accurate simulations
  - Performance data
  - Vehicle suspension and inertial characteristics
    - Design values sometimes incorrect or may not account for interaction with other components
    - Account for wear and defects
  - Measured track geometry, wheel and rail profiles
- Prototype design evaluation

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WHY PERFORM TESTS TO EVALUATE PERFORMANCE? (continued)

- Conformance to specifications
  - Ride quality
  - Safety performance
  - Braking and acceleration
- Structural fatigue performance
  - TTCI simuloader
  - Revenue service tests
- Derailment investigation

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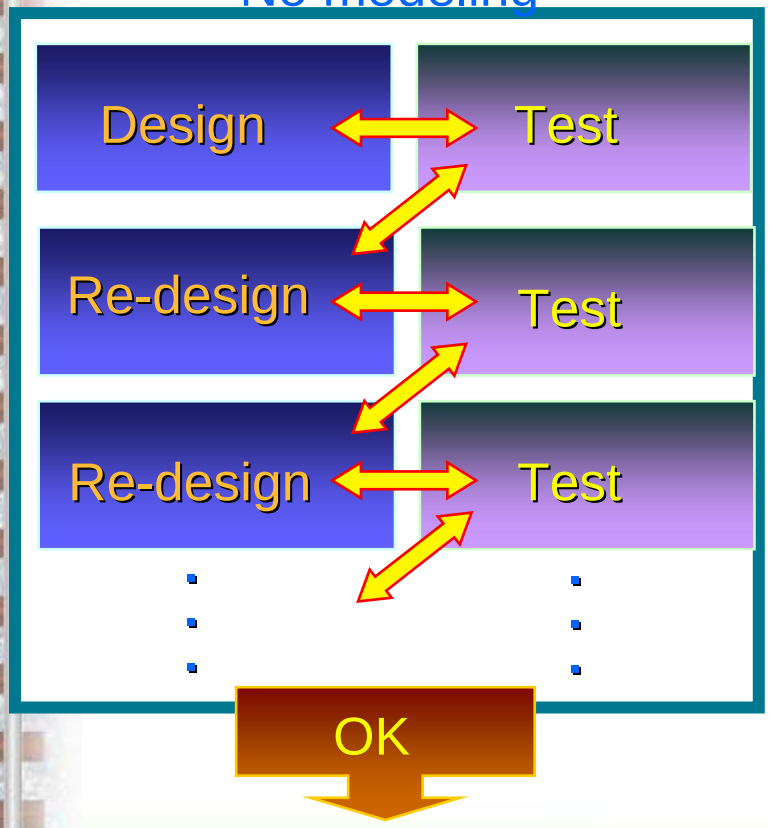
Combination of Simulation and Testing Provides Most Cost Effective Solution

No modeling



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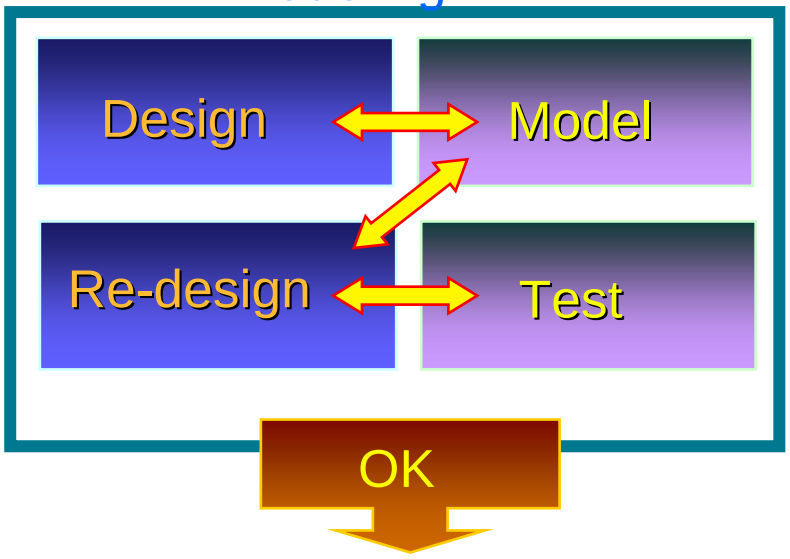
Modeling



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TTCI Technical Expertise

- Support development & implementation through:
  - Technical support for RR standards
  - Derailment investigation
  - Improvements to vehicles & components
  - Certification Testing
  - Simulations & analysis tools
  - Best practices for track & vehicle maintenance
  - Test-bed for endurance proof testing of vehicles & tracks
  - Research & development
  - New measurement and monitoring technologies
  - Full scale laboratories

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Conclusion

TTCI has the railway expertise and facility to safely implement test, evaluate new technologies and to prove performance and reliability.

Our worldwide network and international experience uniquely qualify us to provide support to the analysis and testing of trains carrying High level Radioactive Waste.

What we are and what we are not!

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Conclusion

Can provide support for developing railway standards

Able to provide support from Modeling to Testing

Can help developing and implementing training programs

One Test is Worth a Thousand Expert Opinions

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