Modeling Coupler Angling

with Some Thoughts on Multiple Vehicle Models

2022 Vampire User Day

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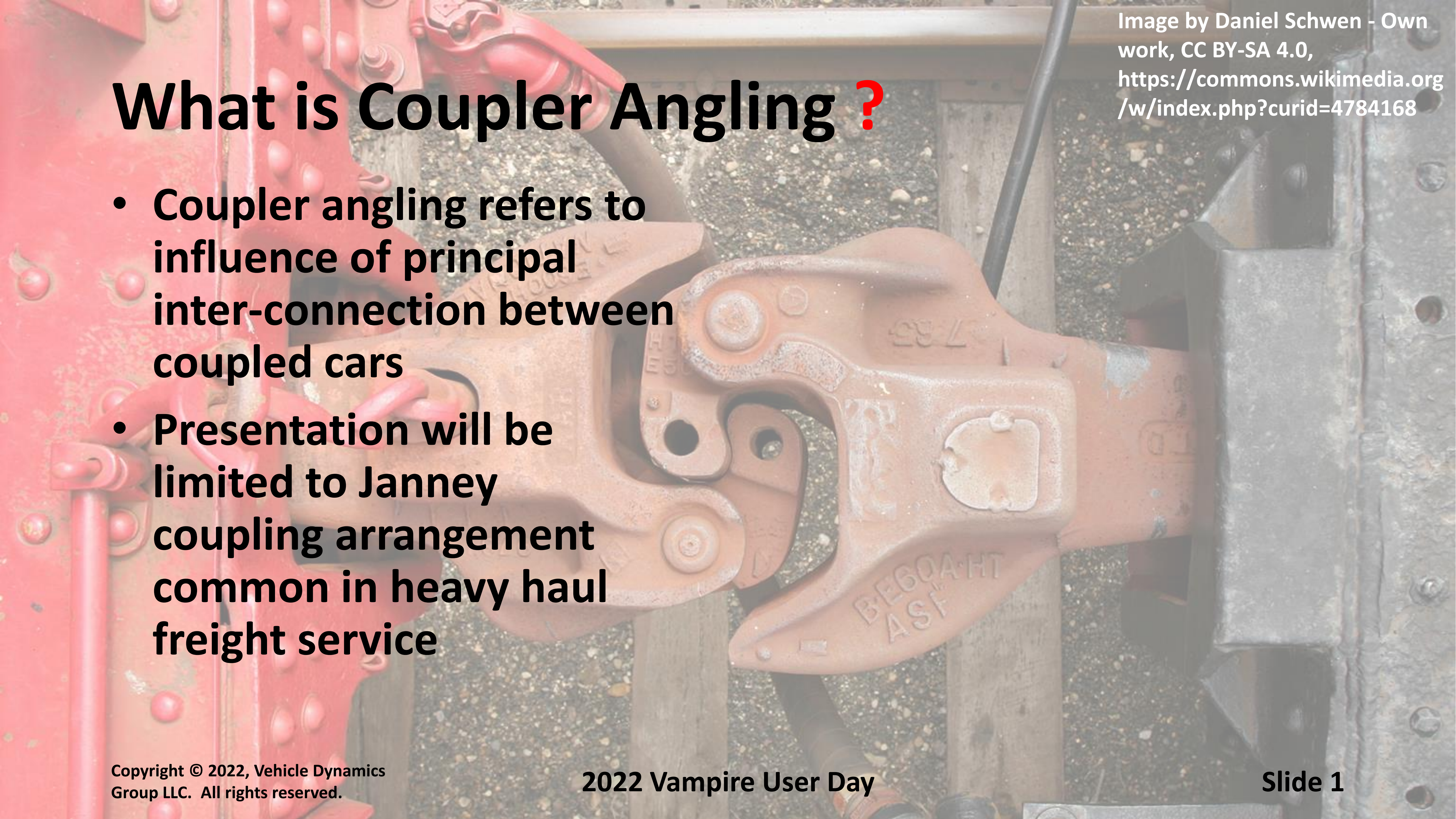
What is Coupler Angling ?



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- Coupler angling refers to influence of principal inter-connection between coupled cars
- Presentation will be limited to Janney coupling arrangement common in heavy haul freight service

When Might Coupler Angling Be Important ?

- **<u>In combination with in-train forces</u>**

  Coupler angling may create vehicle forces and moments leading to derailment

  - Buff forces (compression) cause jackknifing (buckling)
  - Draft forces (tension) cause string-lining

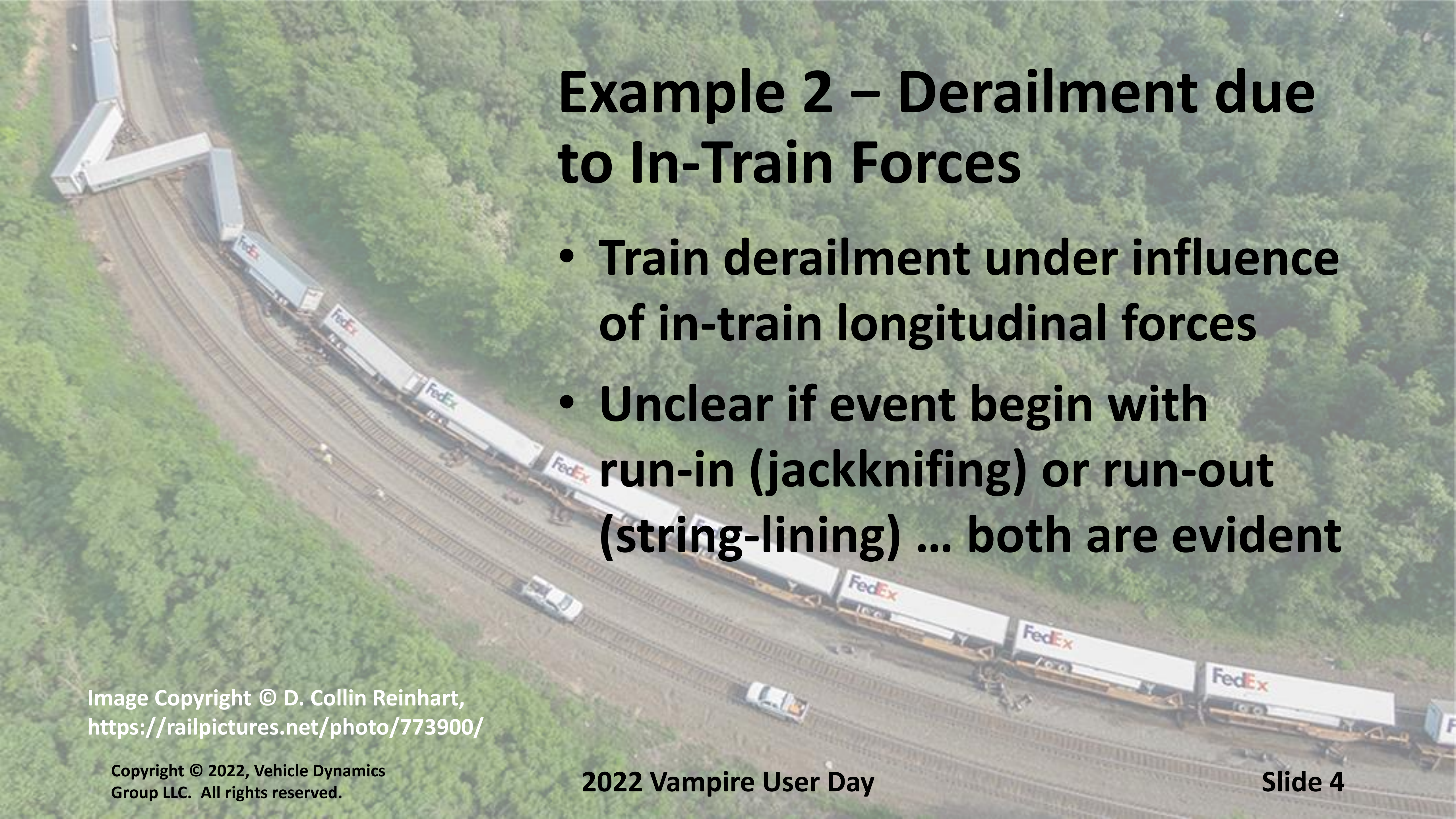
- **<u>Over specific track layouts</u>**

  Coupler angling may exceed vehicle geometry limits leading to structural damage or derailment

  - Long car-short car during curve entry or exit (especially without spiral)
  - Long car-long car in S-curves (especially with short tangents and no spiral) … crossovers can be critical

Example 1 – Locomotives without Alignment Control

- Dedicated move of short wheelbase locomotives without alignment control couplers
- Locomotives separated by intermediate cars to avoid jackknifing
- Previous move in manifest train without idler cars resulted in derailment



Example 2 – Derailment due to In-Train Forces

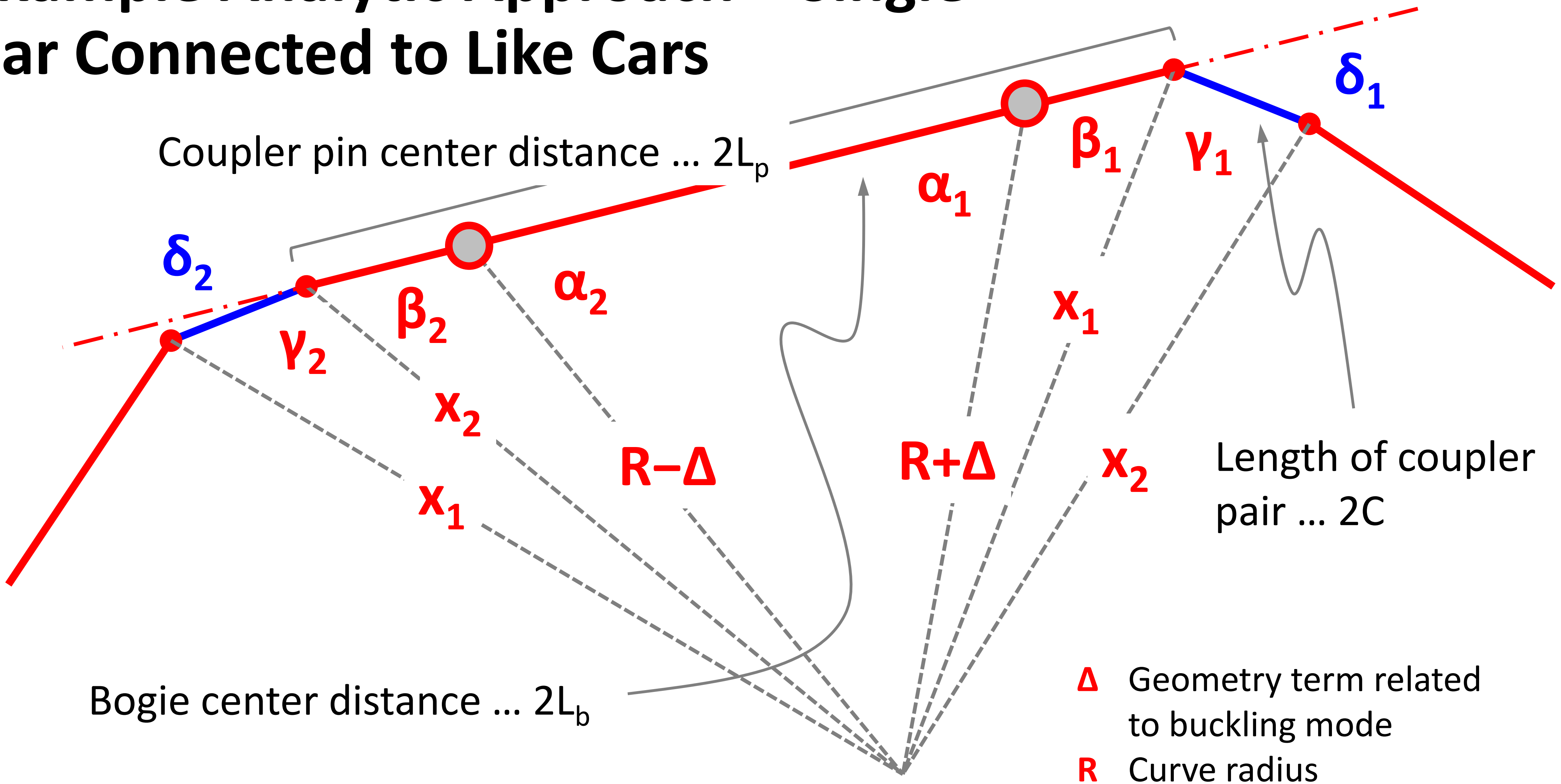
- **Train derailment under influence of in-train longitudinal forces**
- **Unclear if event begin with run-in (jackknifing) or run-out (string-lining) … both are evident**

Coupler Angling Calculation Options

- For complicated track geometry cases (other than constant radius curve) use multiple vehicle models
- For simple geometries such as constant radius curve, constant radius curve to tangent without spiral, and back-to-back curves without intervening spiral, **analytic solutions are possible**
- Analytic approach models coupled vehicles as linkage system (stick model) with assumption bogies must follow path defined by track layout

For more information on coupler angling calculation, see AAR MSRP Section C – Part 2, Volume 1 Chapter 2

Example Analytic Approach – Single Car Connected to Like Cars

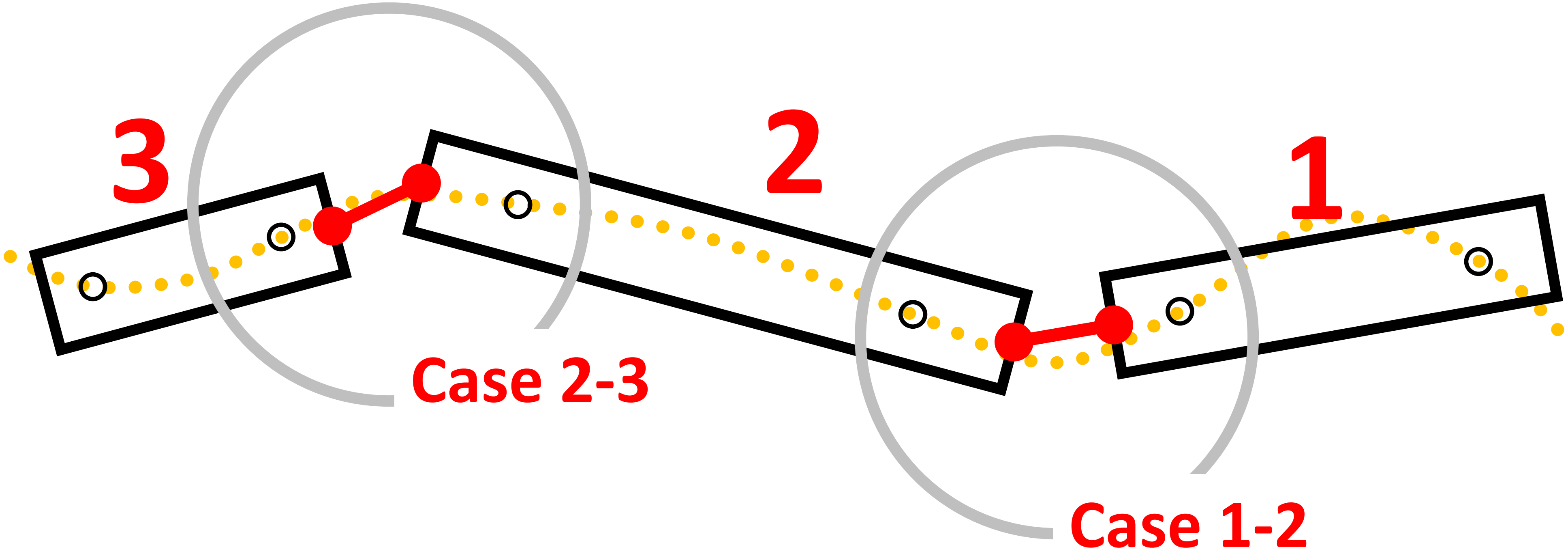


Δ Geometry term related to buckling mode

R Curve radius

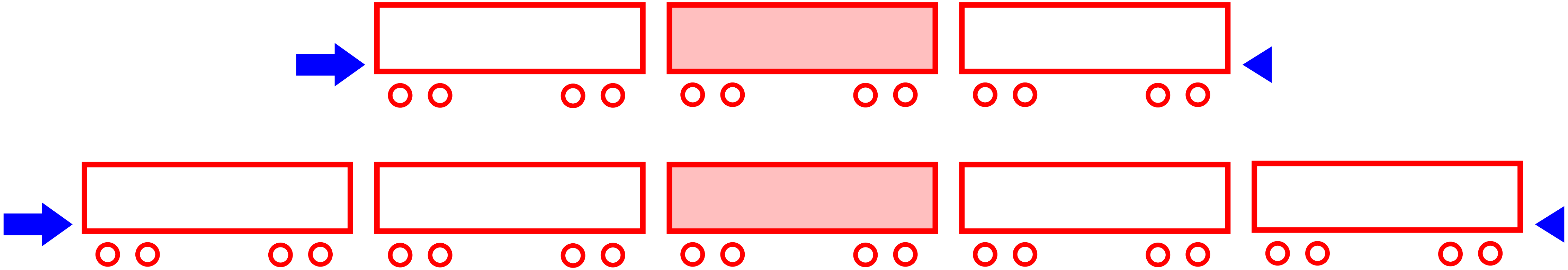
Coupler Angling as Geometry Problem

- If in-train forces can be ignored, then two-car model is acceptable
- Underlying assumption is that coupler angling is based on car-to-car geometry only



Coupler Angling under In-Train Forces

- Models typically involve odd number of cars, with center car of interest, so one car, or three cars, or five cars, etc.
- If more than one car is of interest, then these cars are preceded and followed by zero cars, one car, two cars, etc. at each end



Modeling Choices

Model	Force Input (see next slide)	Track Geometry
Single Vehicle	End coupler lateral force and yaw moment based on assumed curve geometry	Simple geometry only – constant radius curve plus assumed buckling orientation
	End coupler lateral force and yaw moment based on actual vehicle orientation	Simple geometry only with iterative refinement based on predicted vehicle position
Three Vehicles	Longitudinal only – Vampire model defines angling for center car	Any
	End coupler lateral force and yaw moment based on assumed curve geometry	Simple geometry only – constant radius curve plus assumed buckling orientation of end cars
Five Vehicles	Longitudinal only – Vampire model defines angling for center three cars	Any
	End coupler lateral force and yaw moment based on assumed curve geometry	Simple geometry only – constant radius curve plus assumed buckling orientation of end cars

Increasing accuracy ↓

Vampire Specifics

- Vehicle
  - To be covered in following slides
- Track geometry
  - Coupler angling is determined by horizontal geometry (tangents, spirals, curves)
  - Vertical curve negotiation can be important as well, but even more complicated
  - Critical cases include crossovers, S-curves, and any tangent-to-curve or curve-to-tangent transition with short spiral or no spiral
  - Track perturbations important in predicting derailment but unlikely to affect coupler angling
- External forcing (**if important**)
  - Steady-state longitudinal load (buff or draft)
  - Dynamic in-train forces
    - Run-in under buff conditions
    - Run-out under draft conditions

Force Input

Either – Longitudinal only

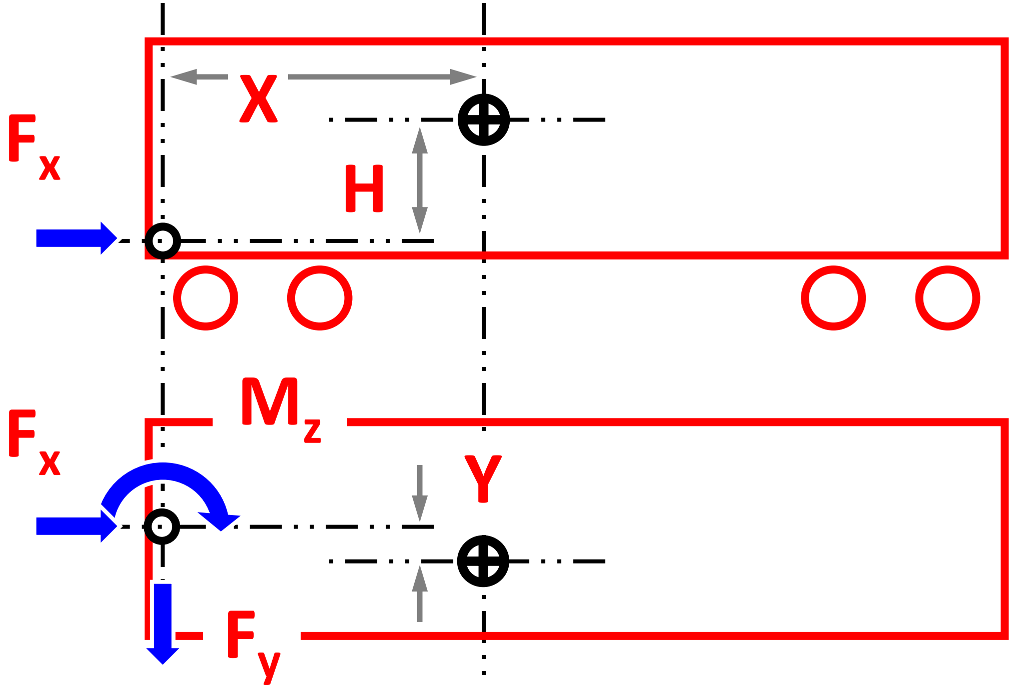
- Longitudinal force only at trailing vehicle trailing coupler pin either pushing (buff force case) or pulling (draft force case) against longitudinal restraint at leading vehicle leading coupler pin

Or – End coupler lateral force and yaw moment (coupler aligning moment) based on assumed curve geometry

- Longitudinal force as above
- Plus lateral force and yaw moment from analytic calculation applied to leading vehicle leading coupler pin and trailing vehicle trailing coupler pin

In both cases – External input applied via Forcing file as referenced in Run file

End of Car Inputs



- Longitudinal force F_x
- Lateral force F_y
- Potential yaw moment M_z due to alignment control
- Forces must be applied at carbody center of gravity
  - End-of-car **longitudinal force** results in center of gravity **longitudinal force** plus **pitch moment** (and possible **yaw moment**)
  - End-of-car **lateral force** results in center of gravity **lateral force** plus **roll moment** and **yaw moment**
  - End-of-car **yaw moment** results in center of gravity **yaw moment** only

Multiple Vehicle Files

- **… not so simple**
- No method currently to merge independent vehicle files
- However, well-organized single vehicle files can be combined to relatively quickly create multiple vehicle files
  - Perhaps 5 minutes per vehicle for identical vehicle types
  - Perhaps 30 minutes per vehicle for dissimilar vehicle types
- Requirements
  - **Organization**
  - **Counter variables** to handle connections
  - **Position parameter** to handle vehicle longitudinal offset

Organization

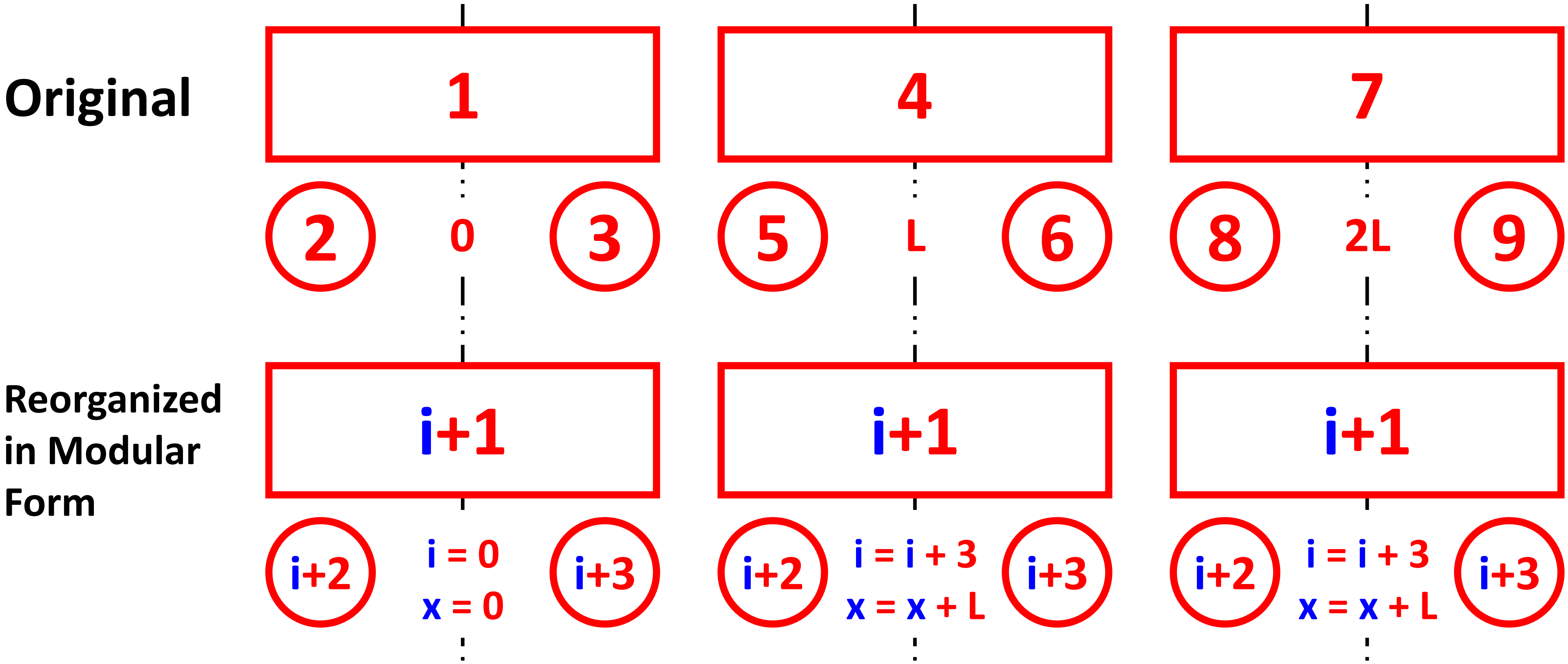
- Starting point is **properly organized** single vehicle file
- Single vehicle files are combined* to create multiple vehicle file

* With minor modification

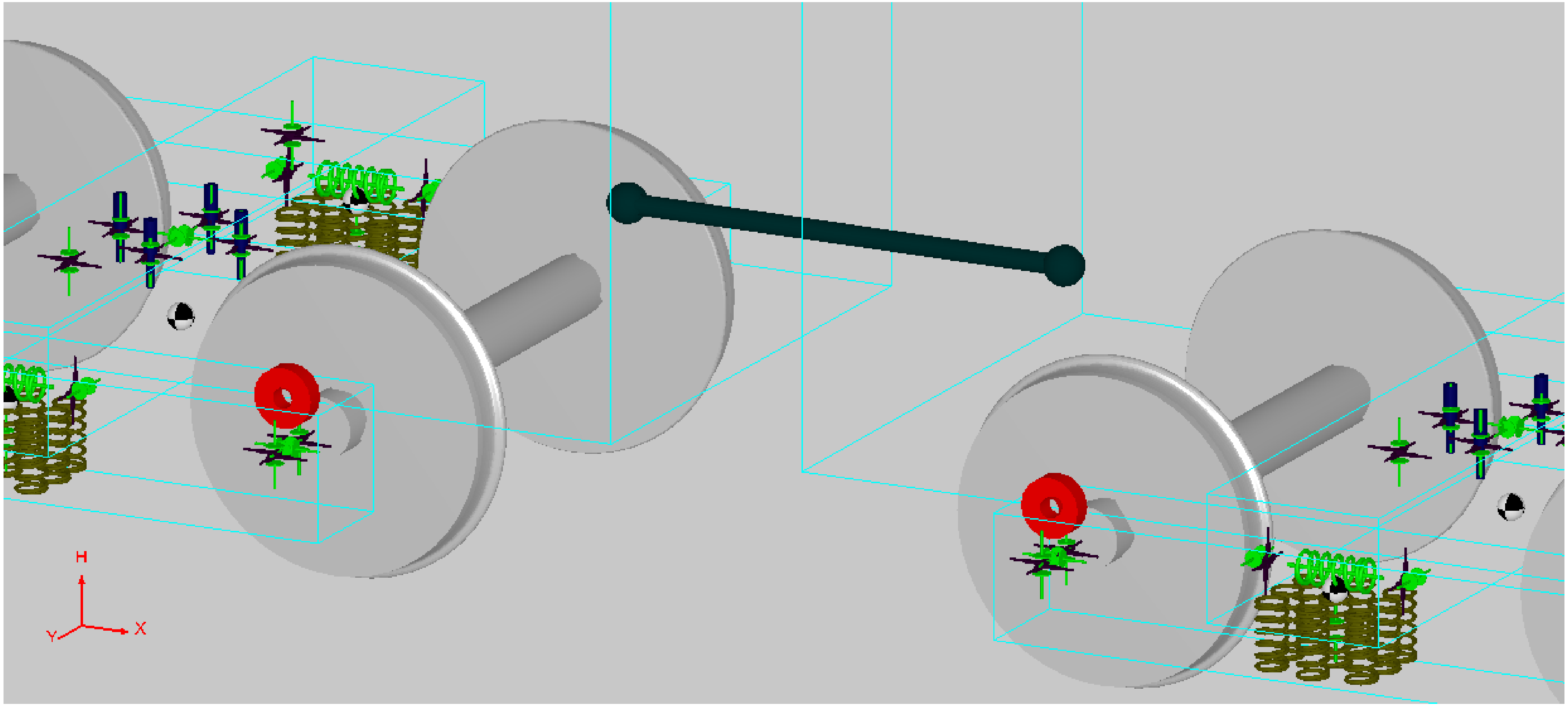
- Header and Parameters
- Carbody definition
- Leading Bogie definition
- Trailing Bogie definition
- Coupler

- Header Lines
- Vehicle 1
  - Carbody
  - Leading Bogie
  - Trailing Bogie
- Vehicle 2
  - Carbody
  - Leading Bogie
  - Trailing Bogie
- Vehicle 3
  - Carbody
  - Leading Bogie
  - Trailing Bogie
- Couplers

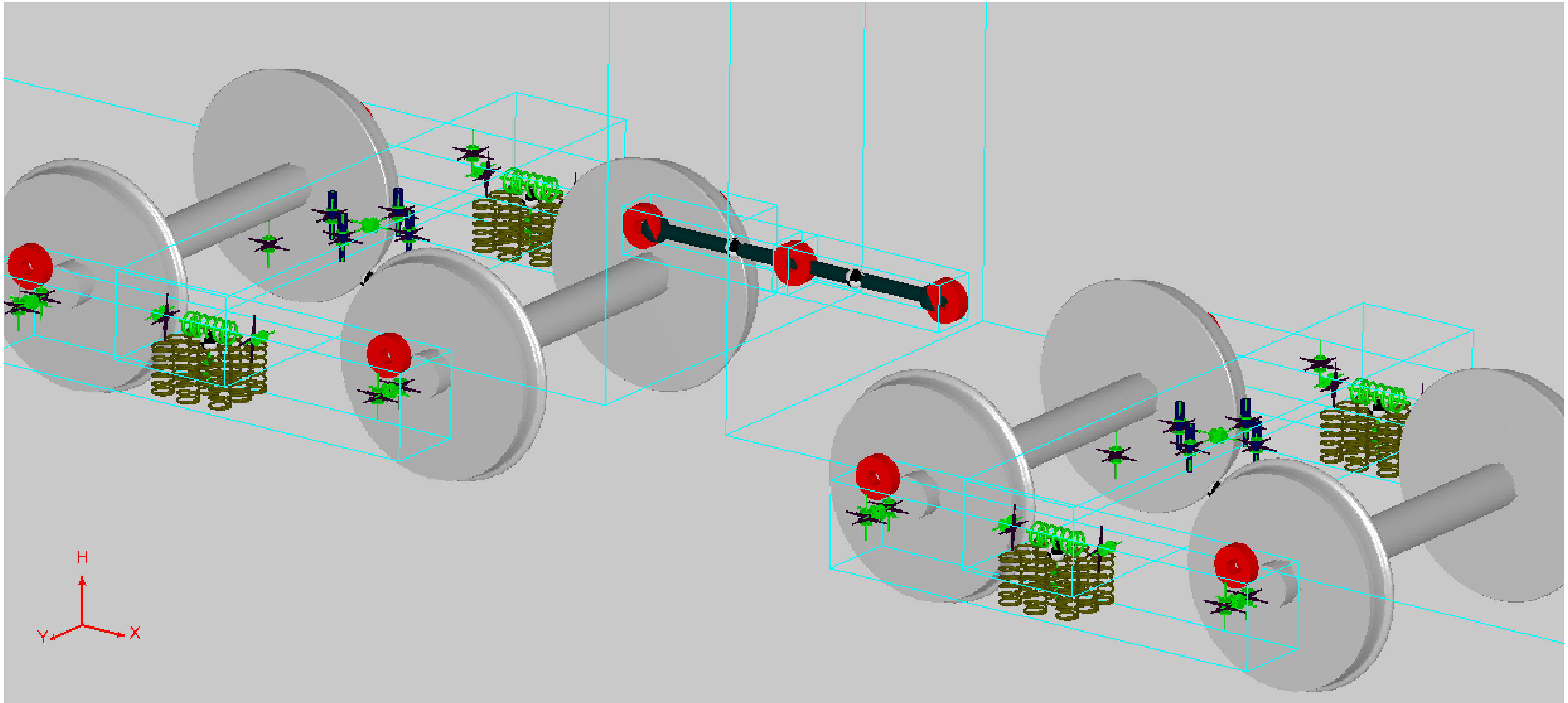
Counter Variables and Position Parameter



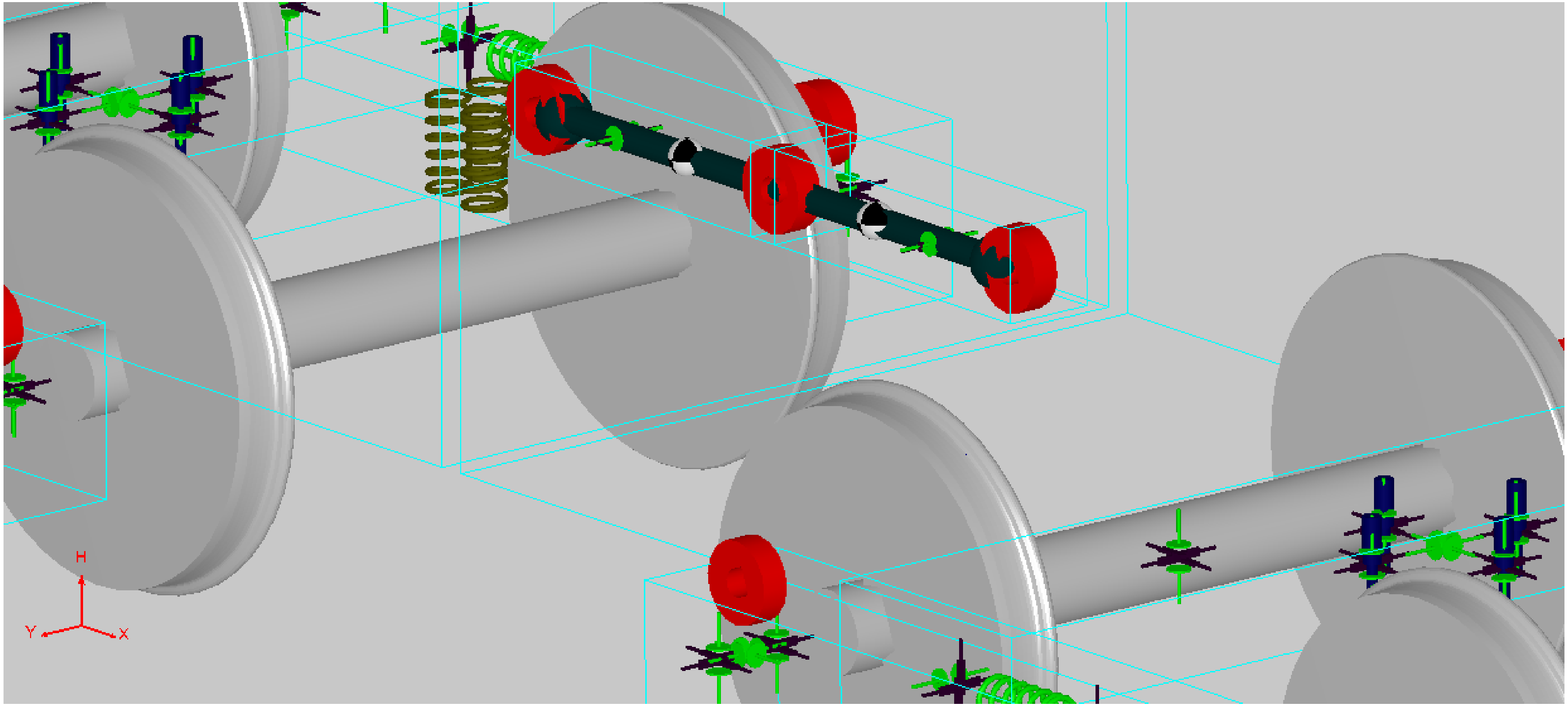
Inter-Car Connections – Pinlink Only



Mass Elements Added

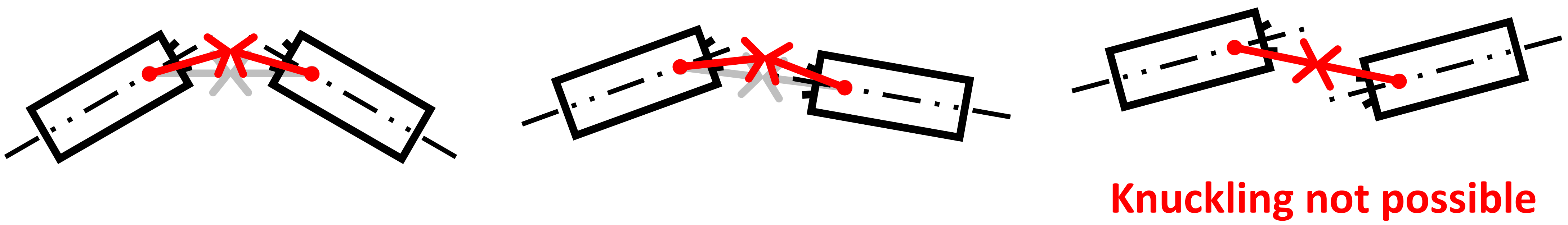


Alignment Control Elements Added



More Topics …

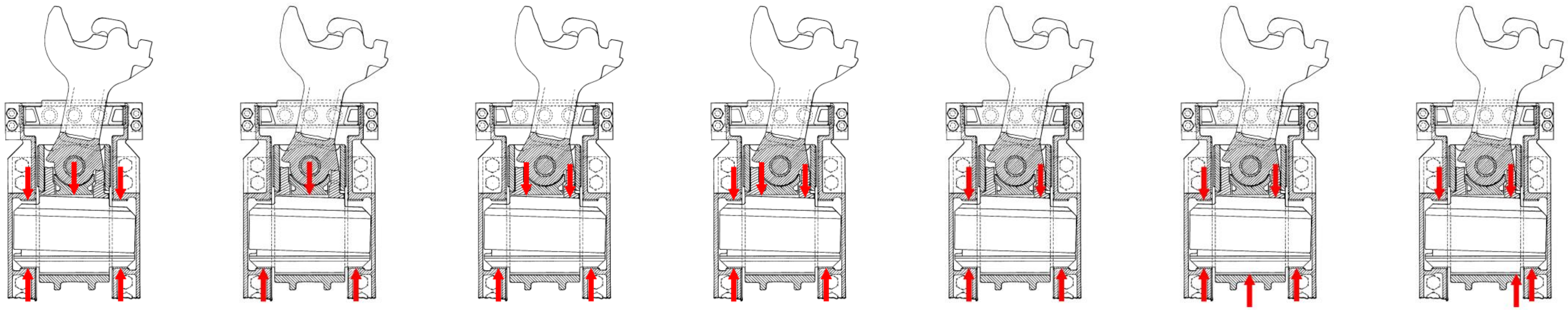
- Multiple axis systems
  - May be required for accuracy in complicated track layouts (tight curves)
- Coupler knuckling
  - Angling between couplers forced by striker contact, important in limiting cases



- Alignment control
  - Coupler end yaw moment, often longitudinal force-dependent, acting against coupler angling

More Topics … continued

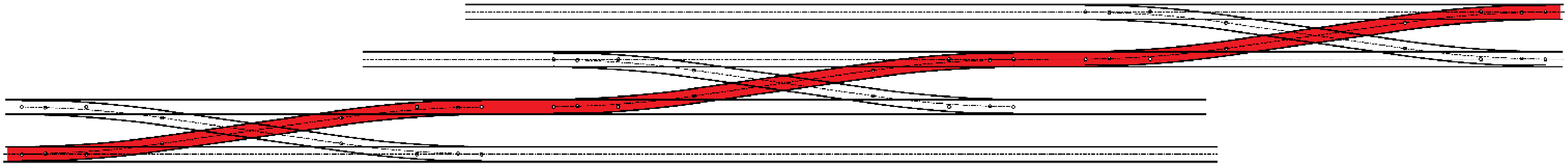
- Alignment control (continued)
  - Dependent on coupler geometry and potentially draft gear characteristic
  - Example load paths shown below for locomotive coupler arrangement as function of buff force and coupler angle (potentially programmed in User Subroutine)



- Vampire model size limits
  - Seven detailed freight cars are typically possible, but nine or more may not be possible due to connection and parameter limits
  - One solution is to reduce detail of **end** cars

Sample Results – Interlocking Study

- Project to replace double slip switches with conventional turnouts in passenger station entry
- Modeling examined response of three coupled cars



Example Coupler Angling Result