Predictive Simulations of Crash Impacts Using HPRC : The Short Radius Example

– Akram Abu-Odeh

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What are Roadside Safety Devices?

- Roadside Safety Devices: used to shield, contain and redirect vehicles away from roadside hazards

- Roadside Hazards include both fixed objects and non-traversable roadside features

Evaluation Methodologies

- Testing standards have evolved over the course of history based on crash test data
  - Vehicle fleet
  - Roadway Velocity
  - Departure/Encroachment angle
- The Manual for Assessing Safety Hardware (MASH) is the new state of the practice for the crash testing of safety hardware devices for use on the National Highway System (NHS)
- Federal Highway Administration (FHWA) has required that all new roadside safety hardware for which a Federal-aid reimbursement eligibility letter is sought be tested to MASH criteria*

*http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/policy_memo/memo111215/

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Develop a MASH Test Level-3 Short Radius System

- A short radius is a guardrail setup for intersecting roadways
- What do we need from a short radius
  - Containment
    - Vehicle capture and prevention of override or underride
  - Redirection
  - Deflection/Stoppage distance
  - Yet simple to construct

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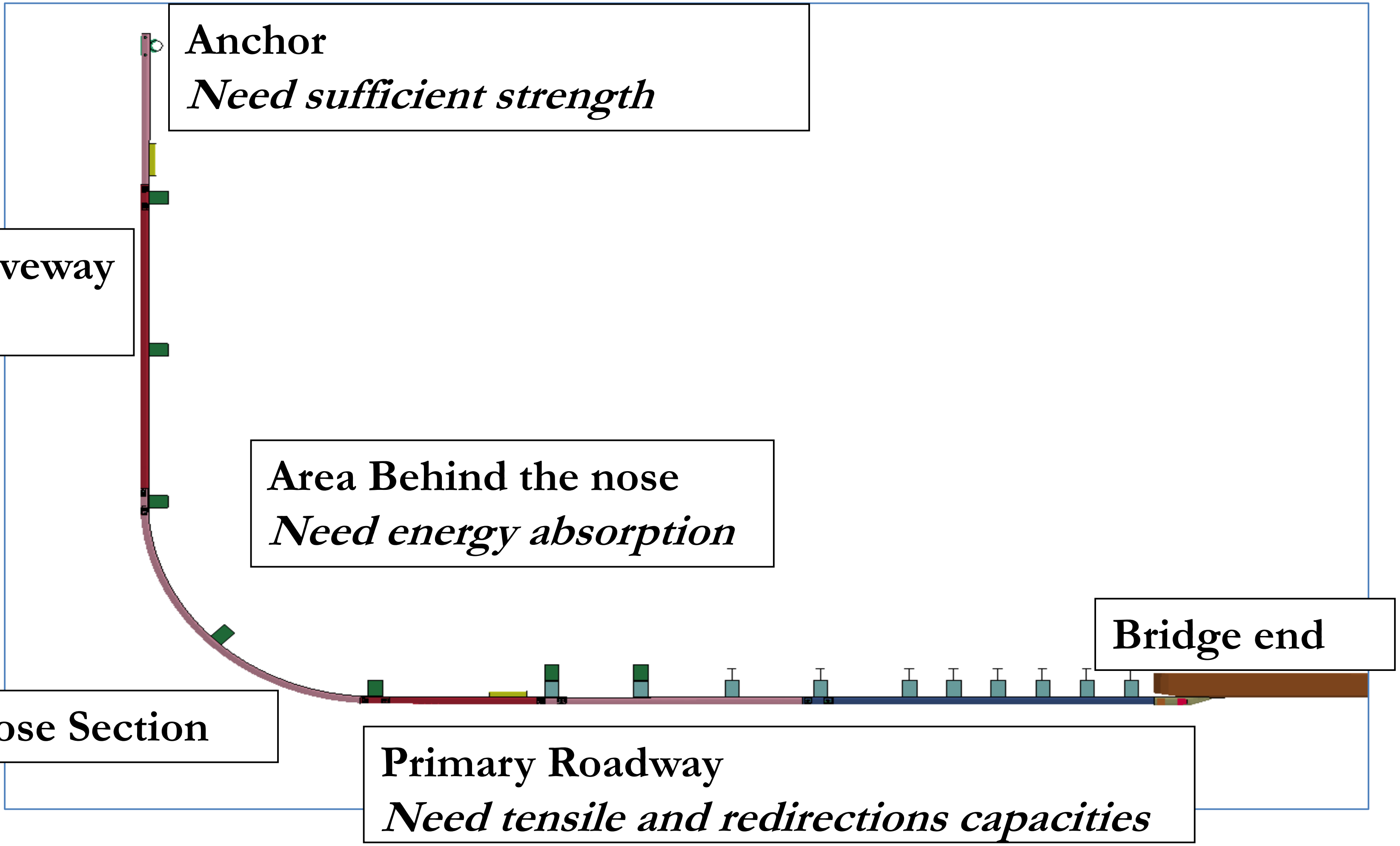
Short-Radius Project

Dissection of Short-Radius Functional Need



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Short-Radius Project

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Short-Radius – Previous Work

TTI-Thrie Beam System

Test 414424-2 (4400 lb pickup truck/62 mph/25 degrees)
(Failed to contain the test vehicle)

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Short-Radius – Previous Work

Midwest Roadside Safety Facility

- Full-Scale Testing – SR-1 (NCHRP Report No. 350)
  - 4400 lb pickup truck (2000P)/61.5 mph/19 degrees (failed – vehicle penetration)

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Finite Element Methodology

- Develop confidence in the model through
  - Material testing
  - Small component calibration
  - Full (previous) tests calibration
- Design safety device based on safety requirements defined in safety design manuals and based on previous research
- Multiple Simulation of concepts
- Choose best finite element model that represents the chosen design
- Run detailed finite element simulation to determine adequacy of new safety device for full-scale crash testing.

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Finite Element Methodology

- LS-DYNA® from Livermore Software Technology Corporation (LSTC)
  - Explicit and Implicit dynamic time step integration
  - Library of highly nonlinear materials and robust contacts
  - Highly scalable on HPRC (MPP using Intel MPI protocol)
  - Available vehicle models and variety of pre- and post-processing software

- Explicit modeling of the railing components were included in the models
- Material models include elastic-plastic behavior
- Materials used are steel (different grades, sand, wood and plastic)
- Sand is modeled using smooth Particles Hydrodynamics (SPH)
- Bolts are explicitly modeled and pre-tensioned to provide the physical clamping among parts

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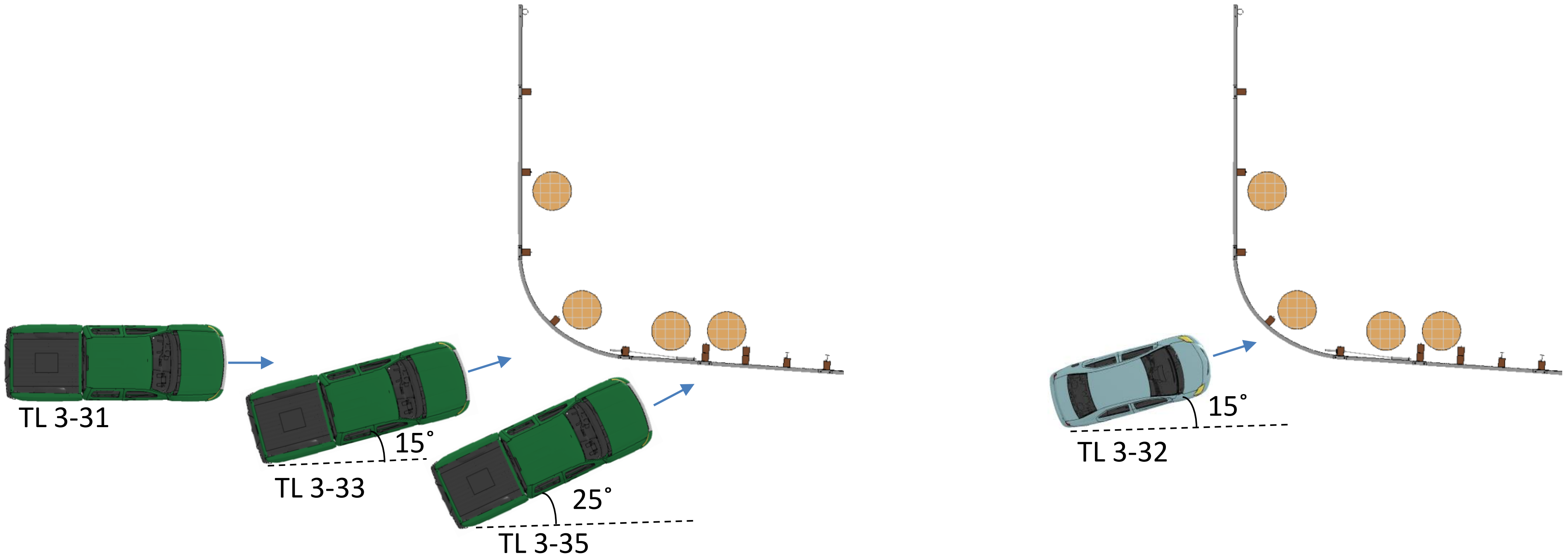
Short-Radius on Flat Terrain

Recommended Test Matrix



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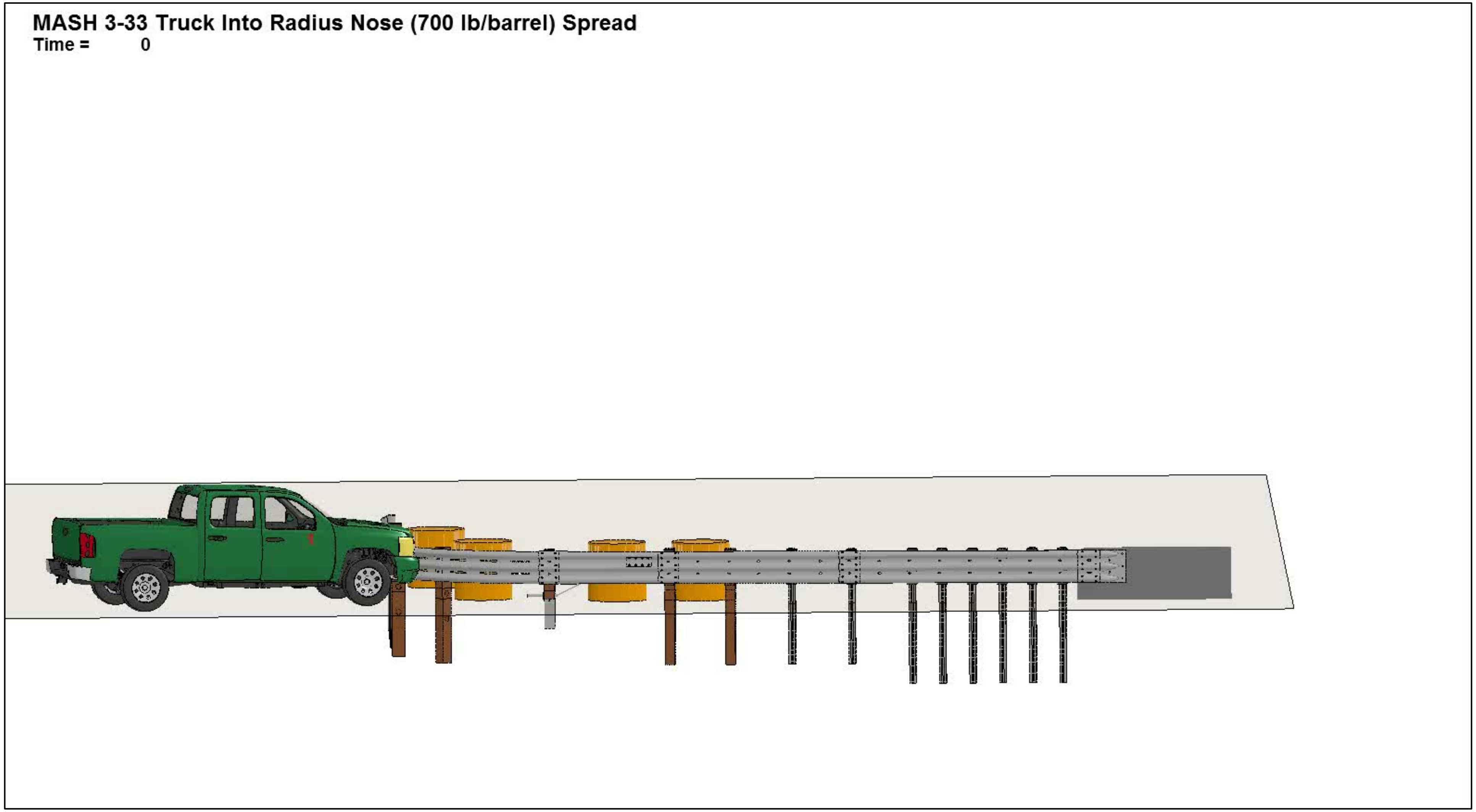
Truck TL 3-33: Flare and 700-lb Sand Barrels Spread Out



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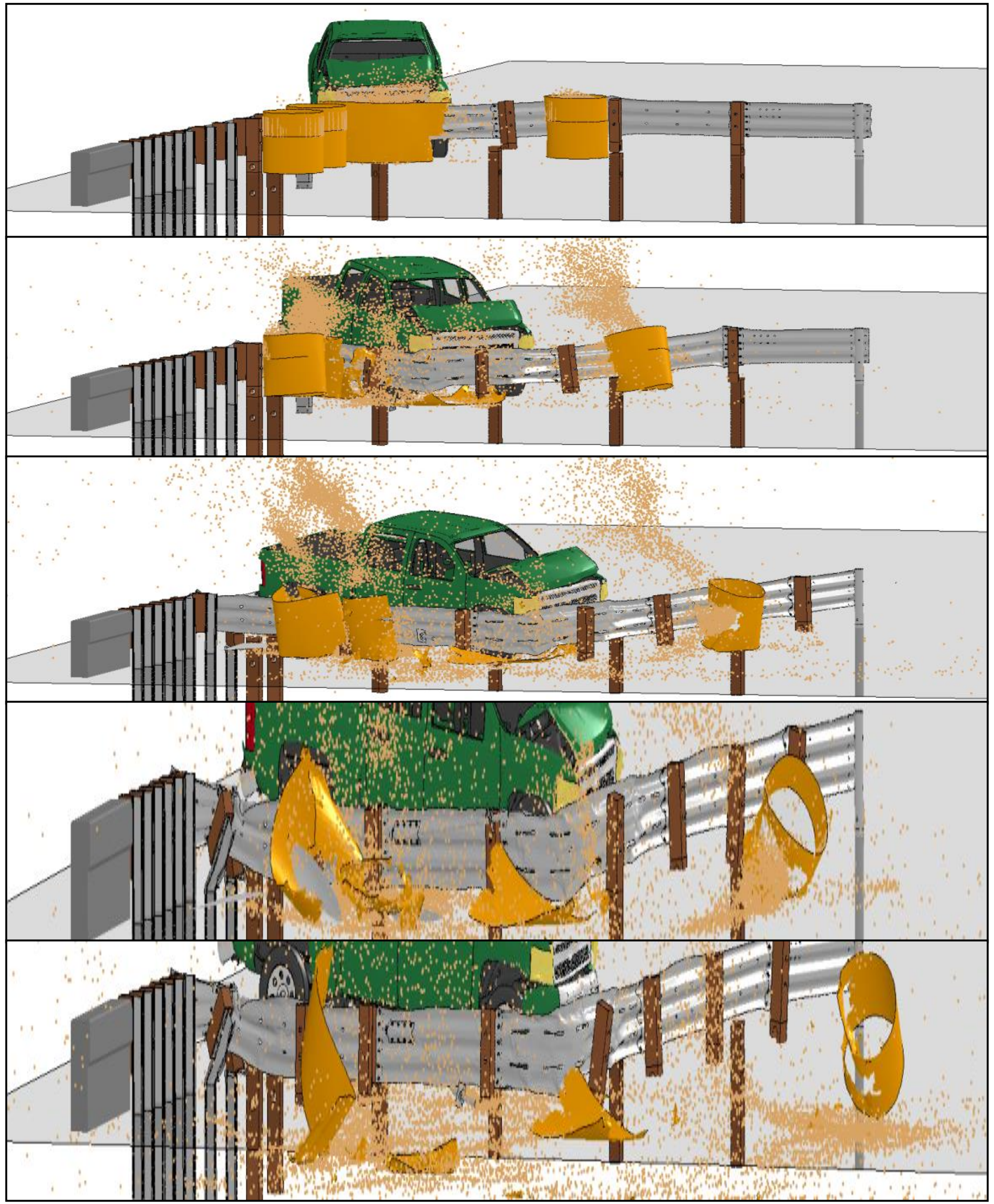

Time = 0.095 seconds

Time = 0.295 seconds

Time = 0.545 seconds

Time = 0.695 seconds

Time = 1.045 seconds

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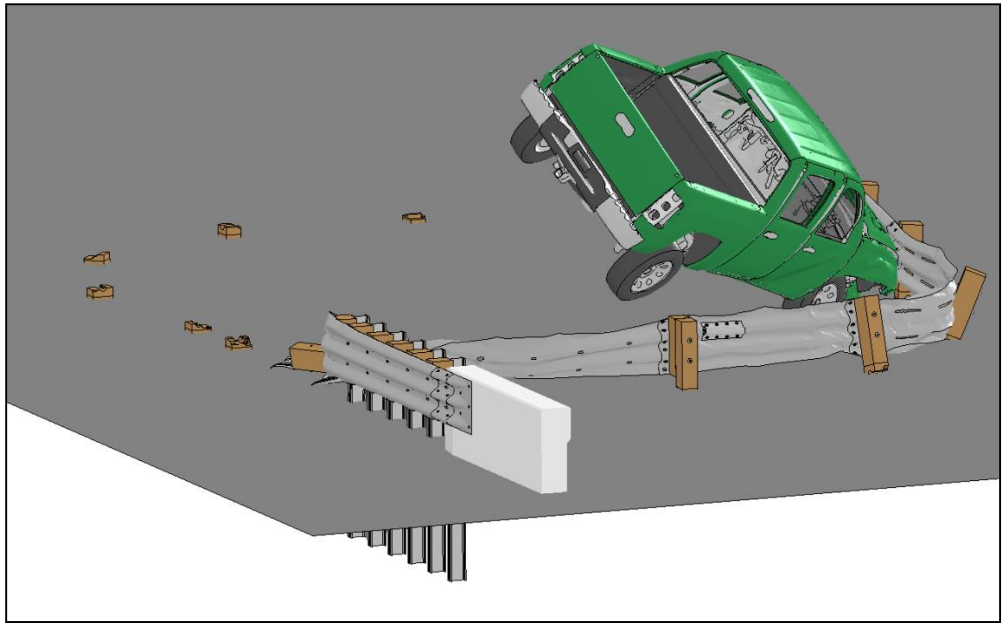
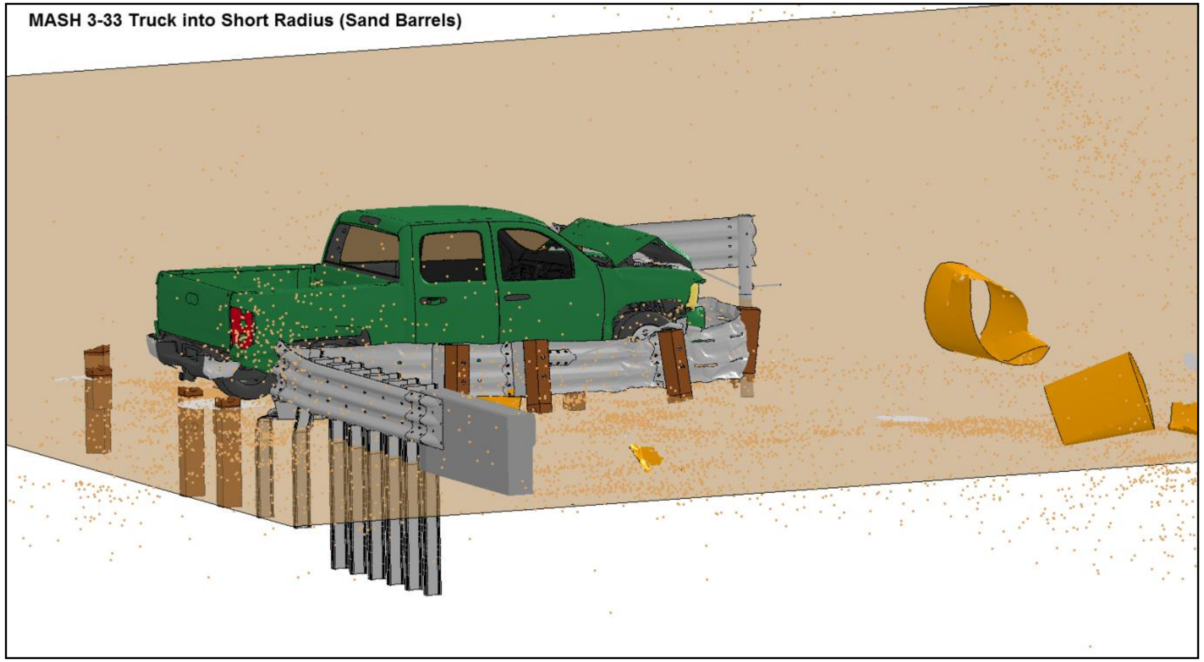
Sand Barrel Impact on Stability



No Sand Barrels



With Sand Barrels

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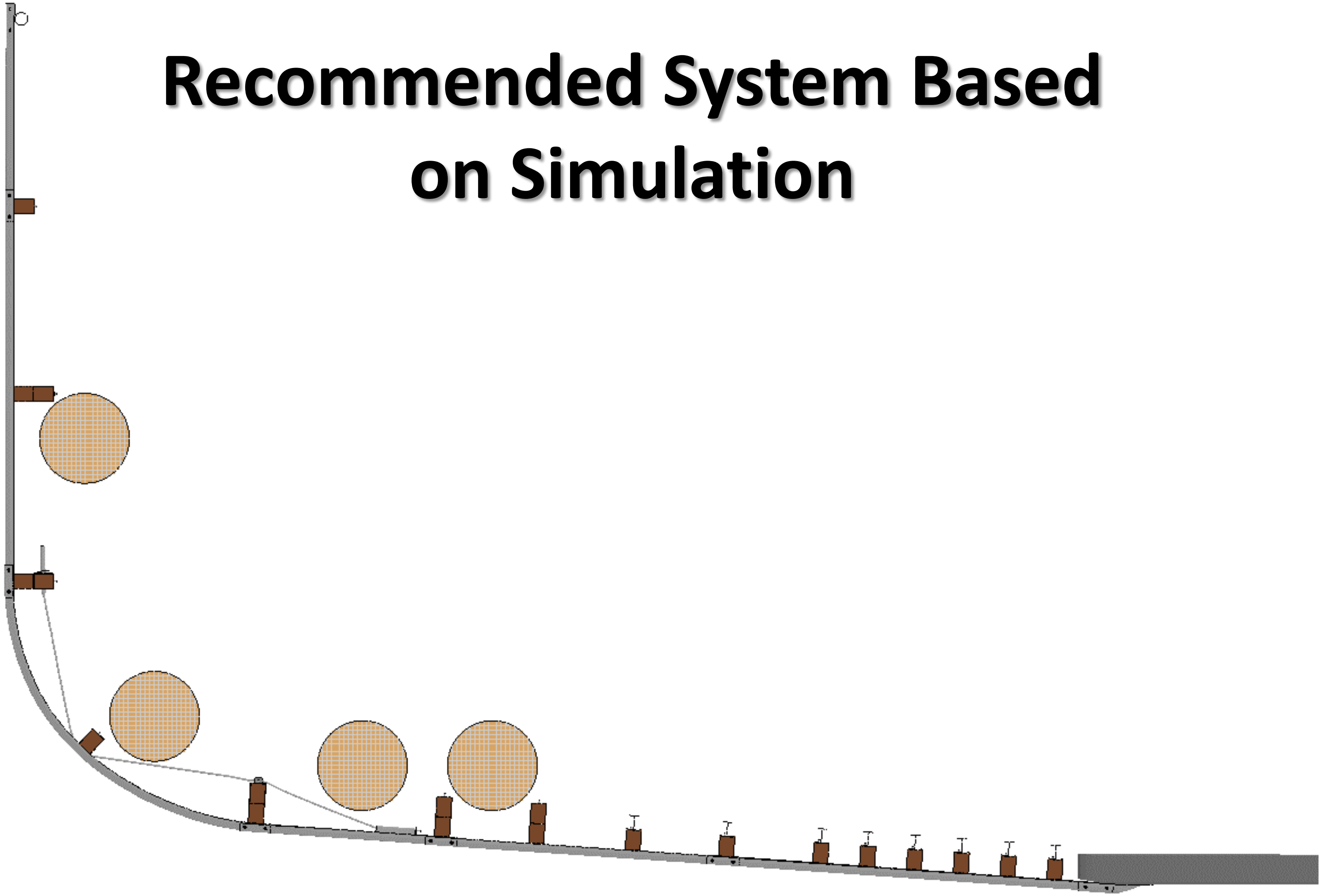
Recommended System Based on Simulation



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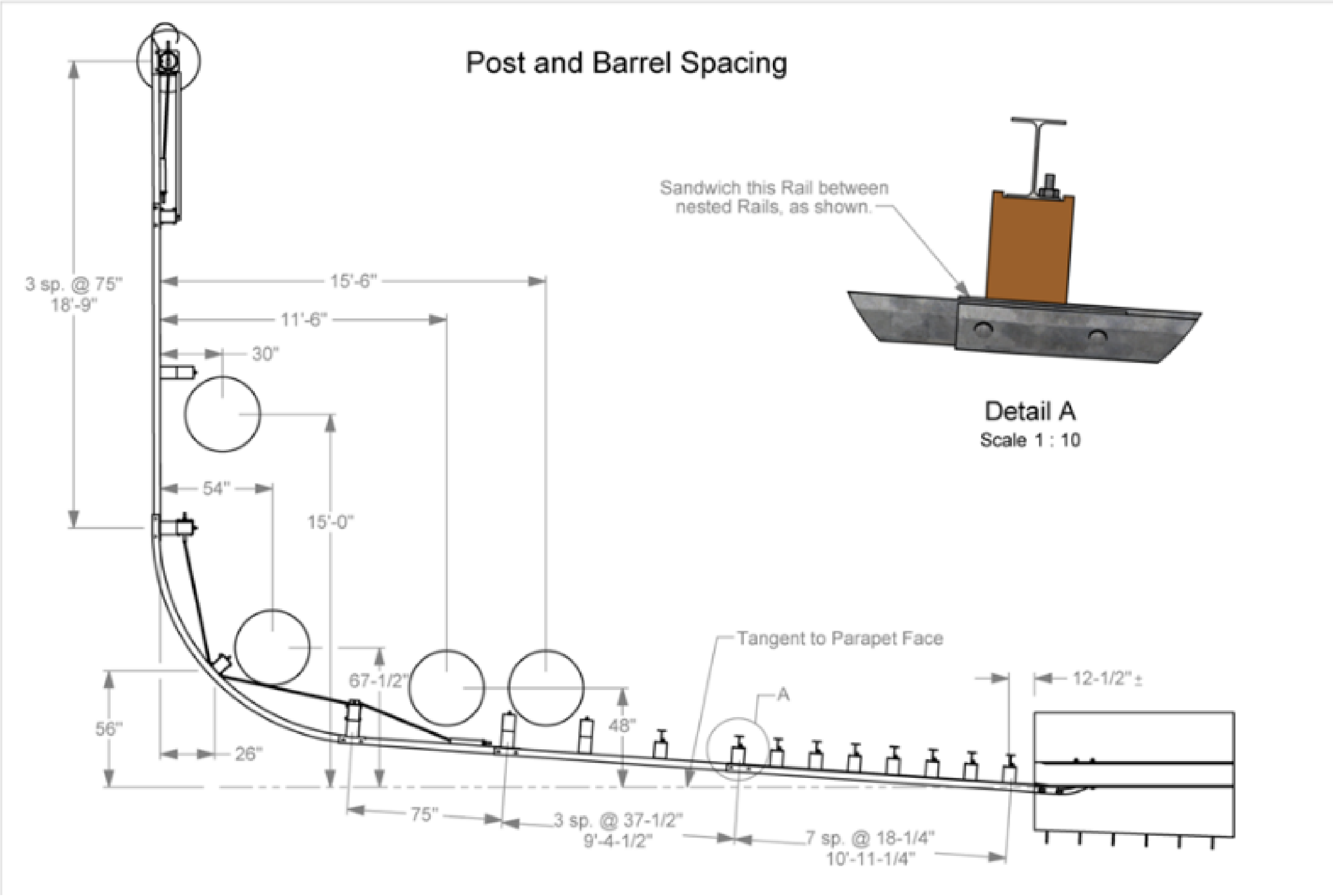
Recommended System Details



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System Installation
(based on the design developed by simulation)

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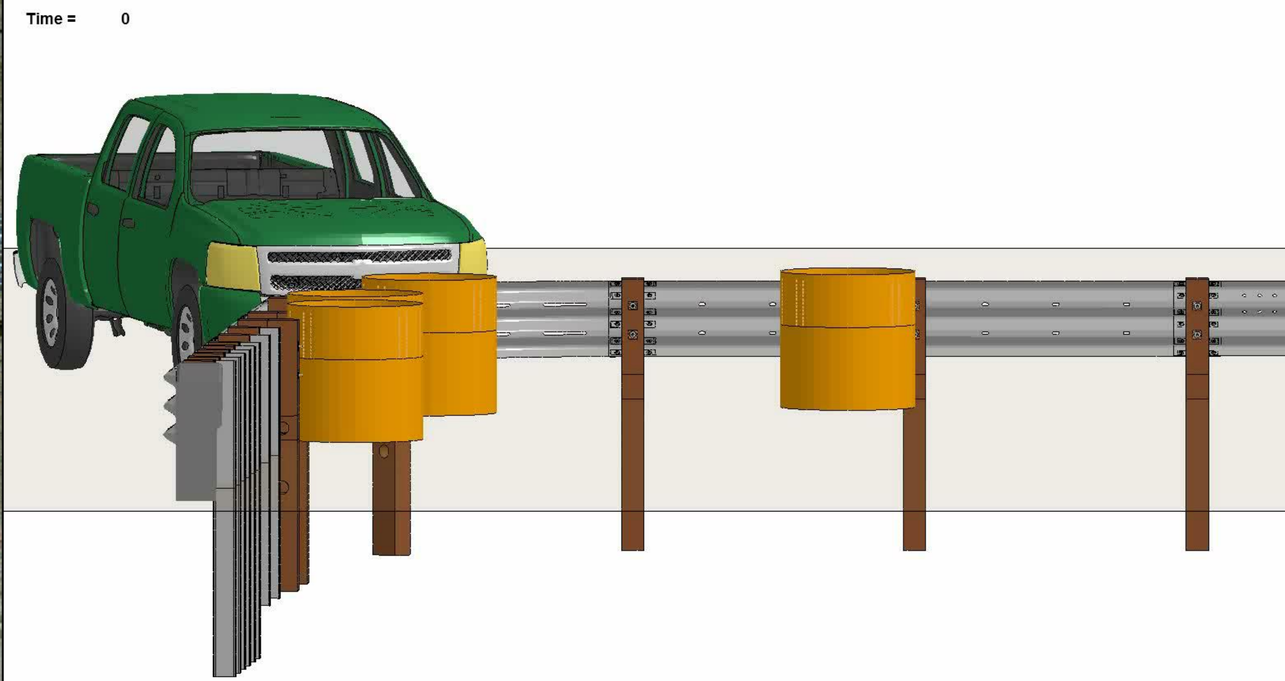
Truck TL 3-33: Predictive Simulation and Subsequent Crash Test



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Conclusion

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Finite Element Methodology

- Simulations were conducted on TAMU HPRC machines EOS and ADA using 32 cores to 100 cores per job
- Wall clock time ranges from 26 hours to 56 hours depending on the size of the model and the simulation termination time (0.8 seconds to 1.7 seconds)
- Domain decomposition is utilized for MPI scalability.
- Special decomposition for sand (SPH) was used to spread the simulation effort along equally across the utilized cores (along with the Lagrangian parts)

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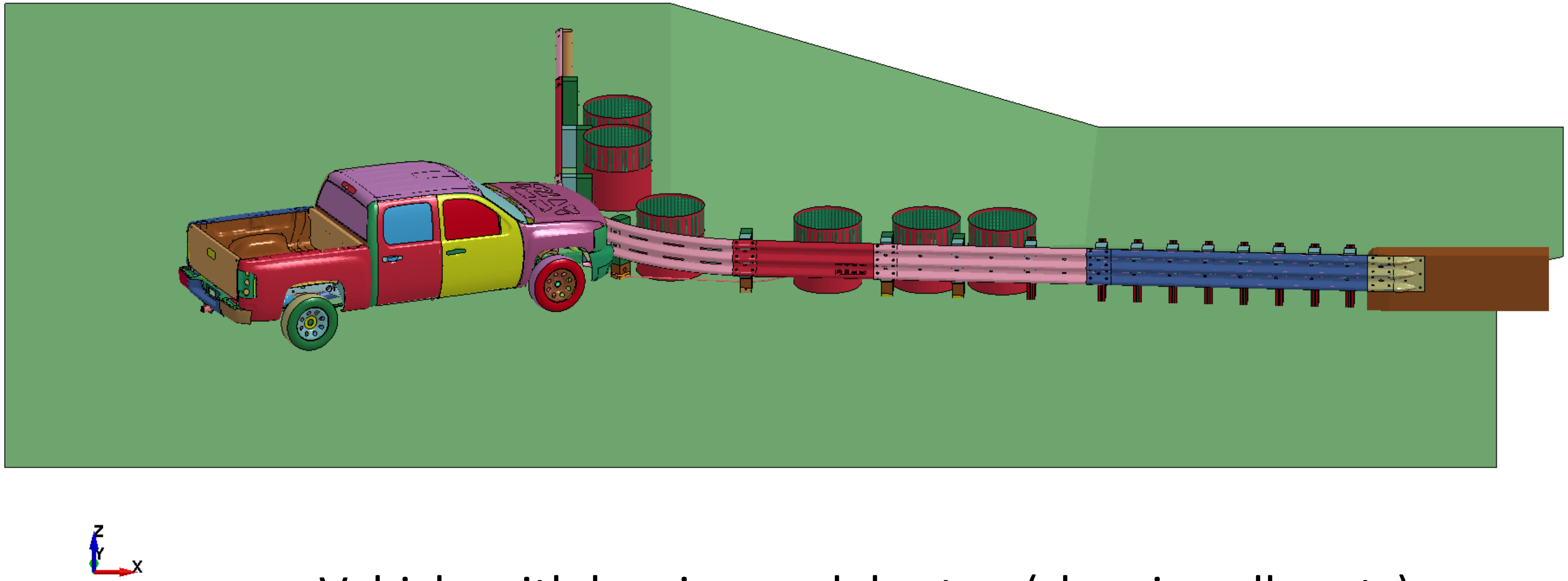
Finite Element Methodology



- Vehicle with barrier model setup (showing all parts)

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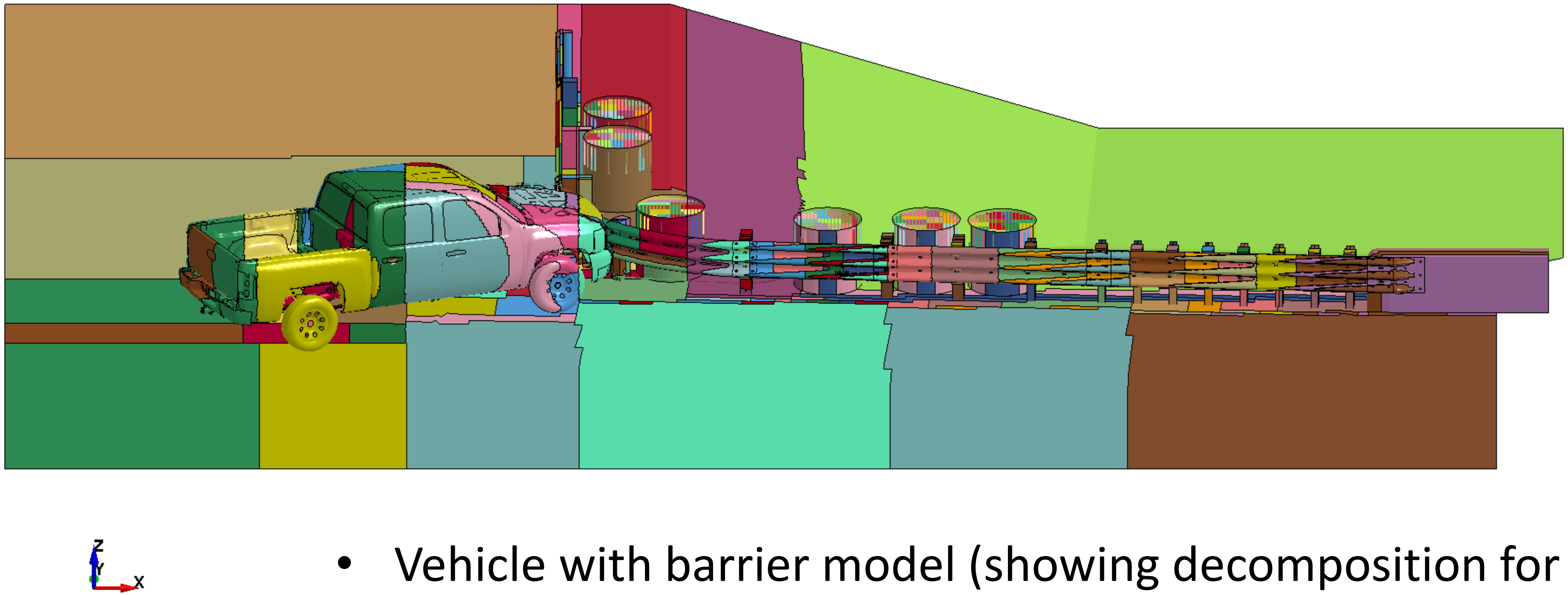
Finite Element Methodology



- Vehicle with barrier model (showing decomposition for 80-cores on ADA)

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Conclusion

- Predictive simulations on HPRC was used to design and test five impact scenarios of high speed vehicular tests on roadway barrier
- The barrier design for a short radius that has been elusive to achieve for many years
- A 3TO1 ditch what excavated one foot behind the barrels edge for the last two tests
- All these tests are considered pass according to MASH evaluation criteria.

Thank You!

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