Update on Dynamic Rollover Crash Research

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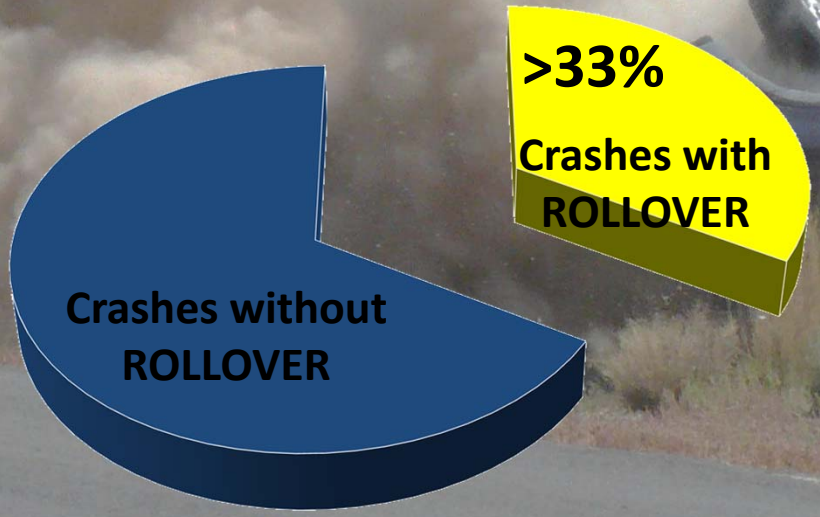
Problem: Rollover Crashes

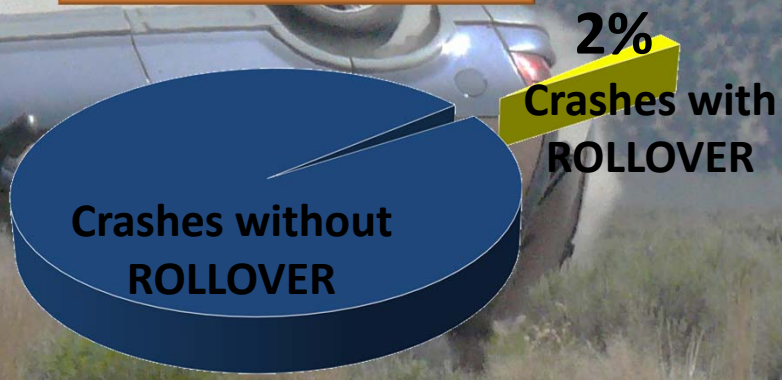
Since 2005:

Vehicle Occupant Fatalities

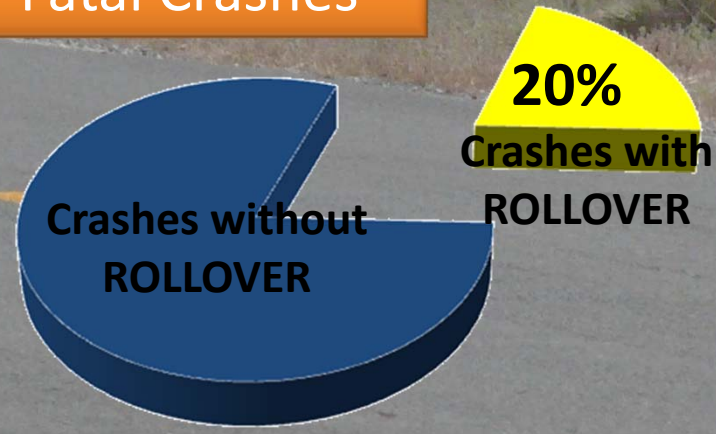


In 2010:

Vehicle Crashes



Fatal Crashes



Source: NHTSA Traffic Safety Facts 2010, FINAL Edition

NHTSA's Efforts

- FMVSS 126
  - Electronic Stability Control
- FMVSS 216
  - Roof Crush Resistance
- FMVSS 226
  - Ejection Mitigation

Criticism:
No dynamic test standard

Feasibility Undetermined

1. No repeatable dynamic rollover test procedure
2. No dummy biofidelity for rollover
3. Insufficient injuries, injury mechanisms, injury criteria

UVA Rollover Research 2009-Present

Long-Term Research Goals:

- Identify and investigate injuries, mechanisms, and sources
- Evaluate and improve dummy biofidelity
- Investigate potential for repeatability
- Determine what can be learned about vehicle crashworthiness by a dynamic test
- Develop a suite of computational models for modeling crashes, vehicles, and occupants.

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Dynamic **Ro**llover **T**est **S**ystem (**DRoTS**)

- Rollover crash test full-sized vehicles inside lab
  - mimic the dynamics of real crashes
- Accurate and detailed measurements
  - vehicle kinematics,
  - boundary conditions, and
  - deformations
- Wide variety of initial conditions
  - whatever can occur in the field
- Reliably prescribe initial conditions
  - Low tolerance for variability
- Expose crash occupant surrogates to the injury-producing conditions in real crashes

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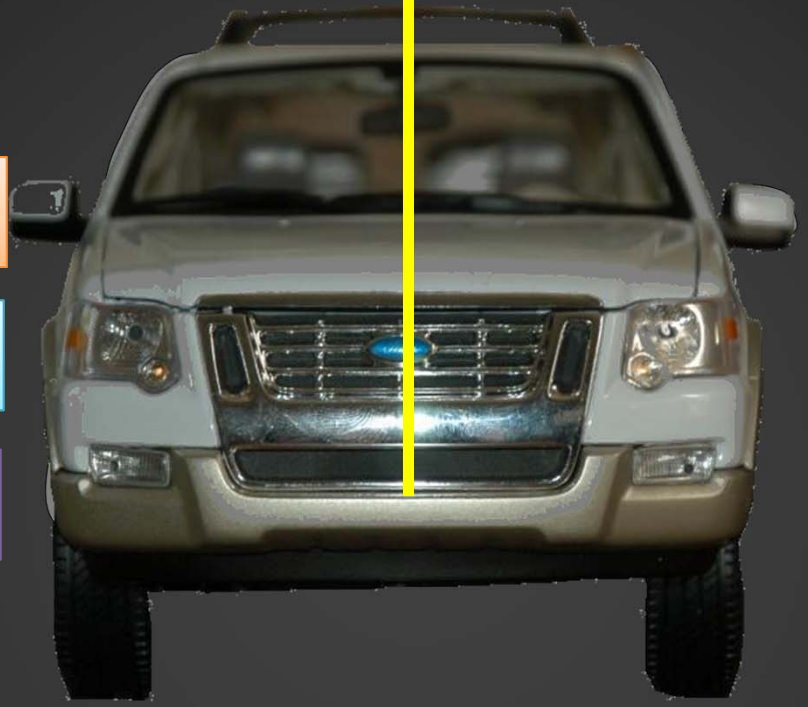
DRoTS Test Concept

PRE-TEST

TEST PHASE

POST-TEST



1) Rotated to Test Velocity and Test Angle

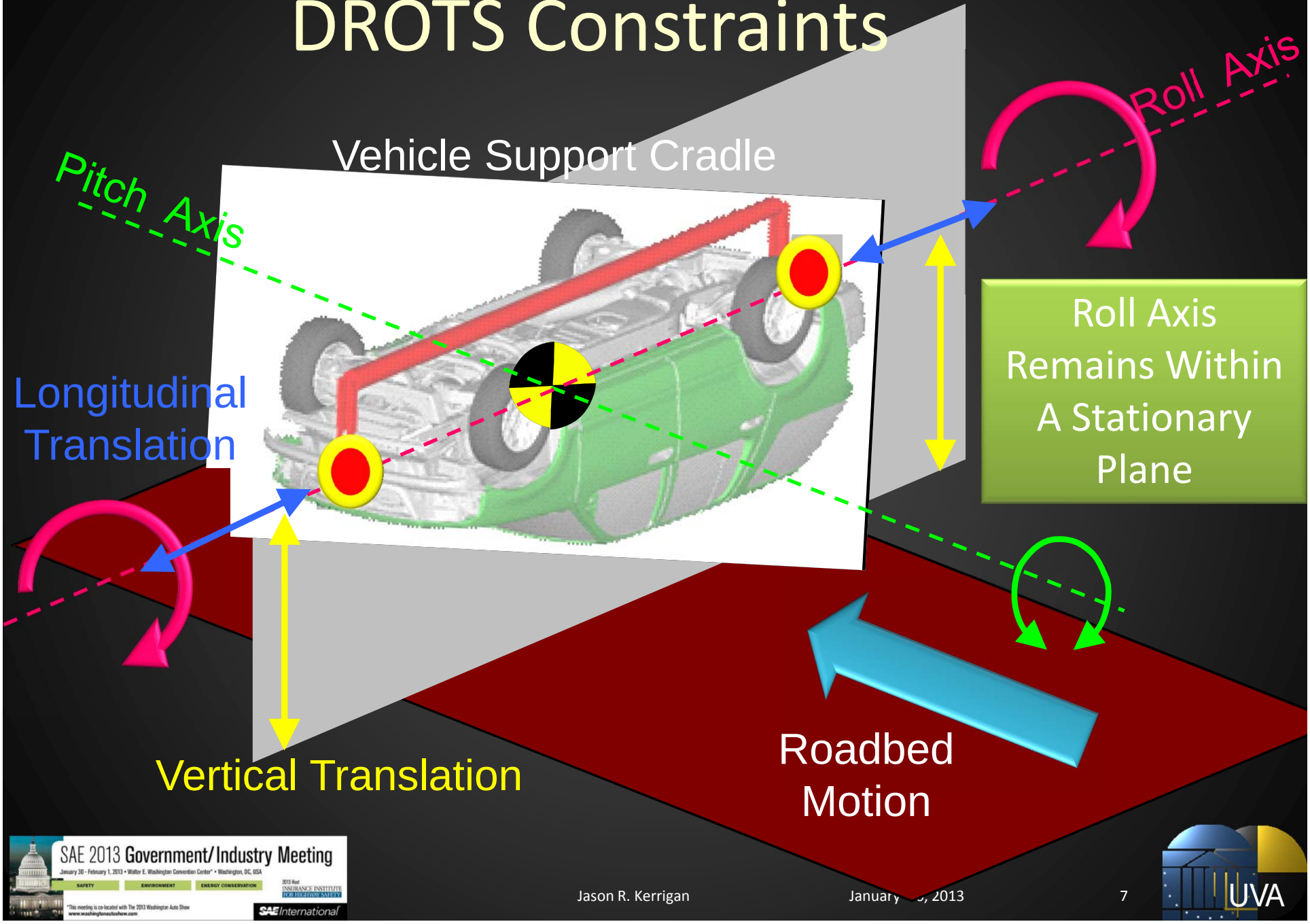
2) Dropped onto Moving Road Surface

3) Rolls Across Moving Road Surface

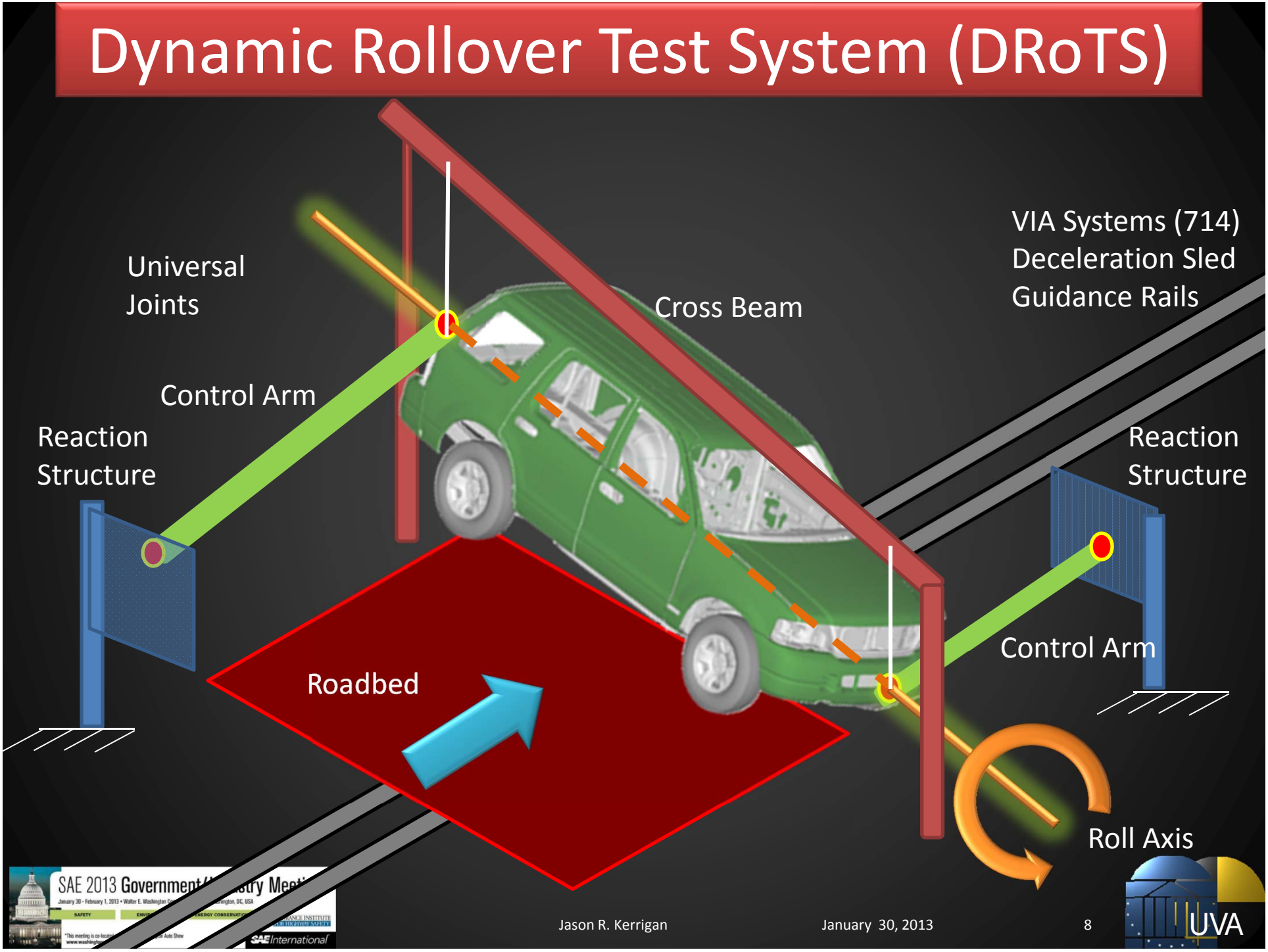
4) Vertical Motion Is Arrested

5) Rotational Motion is Arrested

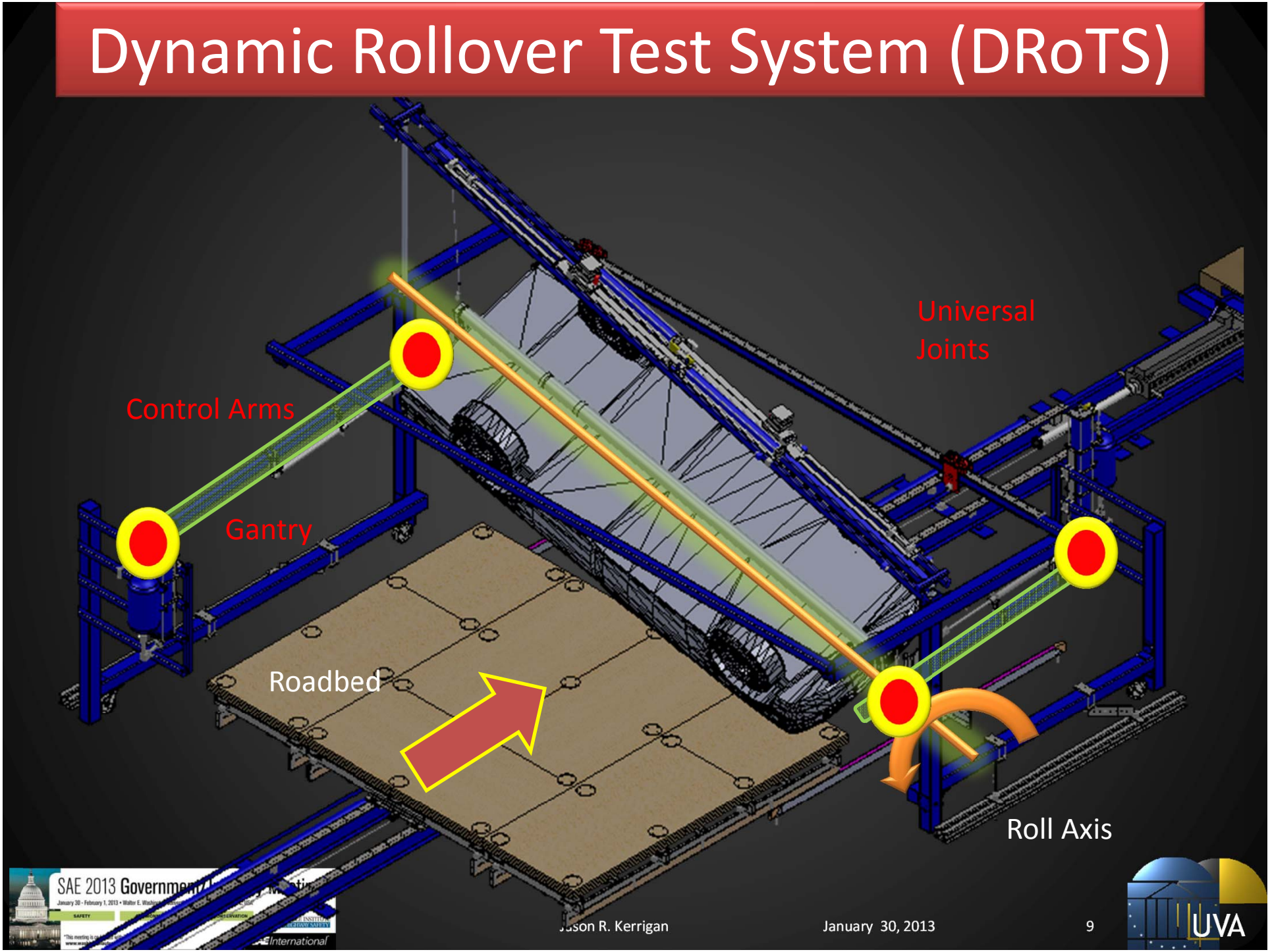
DROTS Constraints



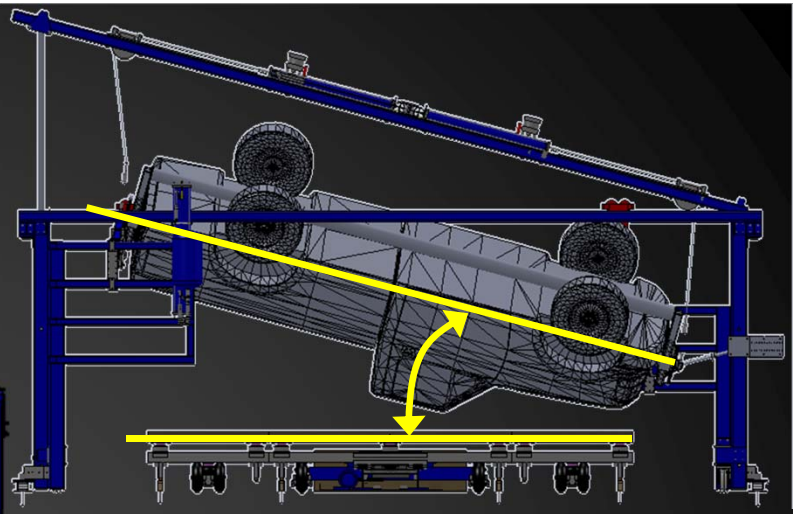
Dynamic Rollover Test System (DRoTS)

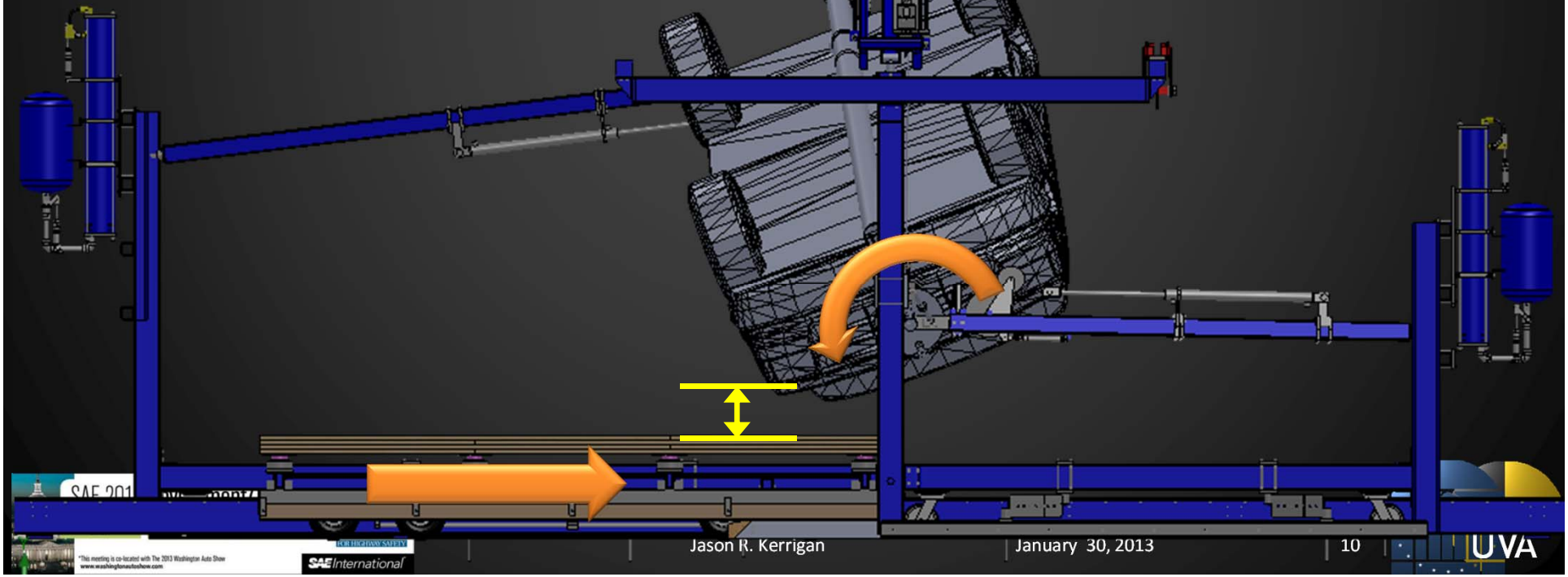


Dynamic Rollover Test System (DRoTS)



- Ford F-250 to Smart ForTwo
- Translational Speed: 4-17 m/s
- Drop Height: 0-30 cm
- Pitch Angle: 0-15 deg
- Roll Angle: 135-225 deg
- Roll Rate: 50-600 deg/s





Kerrigan JR, Jordan A, Parent D, Zhang Q, Funk J, Dennis NJ, Overby B, Bolton J, Crandall J. (2011) Design of a dynamic rollover test system. Society of Automotive Engineers (SAE). Paper Number 2011-01-1116. Warrendale, PA.

DRoTS Testing

- Commissioning
  - Five (5) Vehicles, Seven (7) Tests
- Repeatability
- Buck Development
- Biofidelity
  - Kinematics
  - Injury Prediction

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V1: 2006 Chevy Cobalt

Test 1-May 10,2011

Test 2-May 11, 2011

V2: 2007 Chevrolet HHR

Test 3-June 17, 2011

Test 4-August 2, 2011

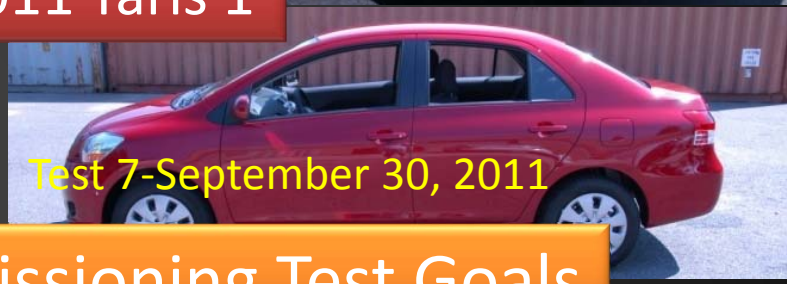
V3: 2007 Pontiac Torrent

Test 5-August 18, 2011

V4: 2002 Ford Explorer

Test 6-September 9, 2011

V5: 2011 Yaris 1



Test 7-September 30, 2011

Commissioning Test Goals

- Test methodology and instrumentation methods,
- Capabilities of fixture across a variety of initial conditions
- Accuracy of specified test parameters
- Identify problems with fixture, implement solutions

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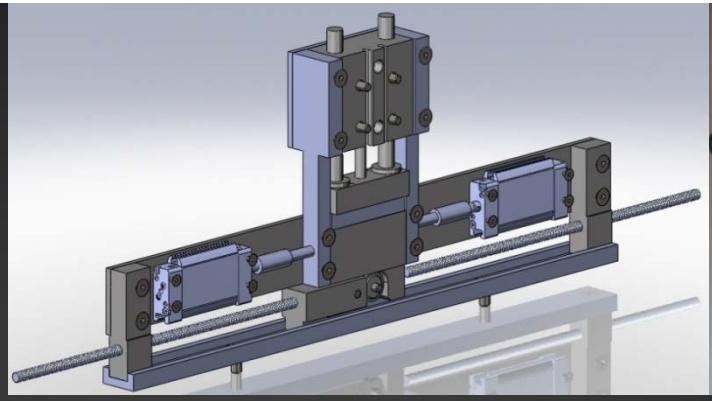
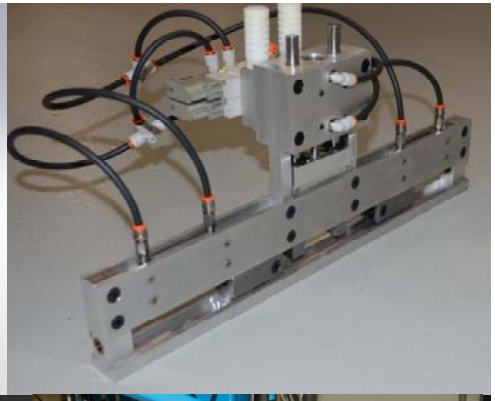
Result:

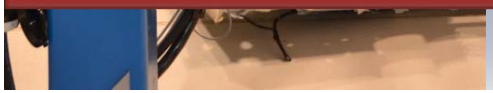
Numerous Changes Made

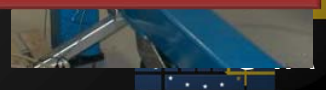




- Boost roll drive for faster rates with large vehicles
- Improve drop release to increase timing accuracy
- Structural Changes for Fixture Strength
- Instrumentation changes for improved documentation of tests

Kerrigan JR, Seppi J, Lockerby J, Foltz P, Overby B, Kim T, Dennis N, Crandall JR (2013) Test methodology and initial results from a dynamic rollover test system. Society of Automotive Engineers (SAE). Paper Number 2013-01-0468.





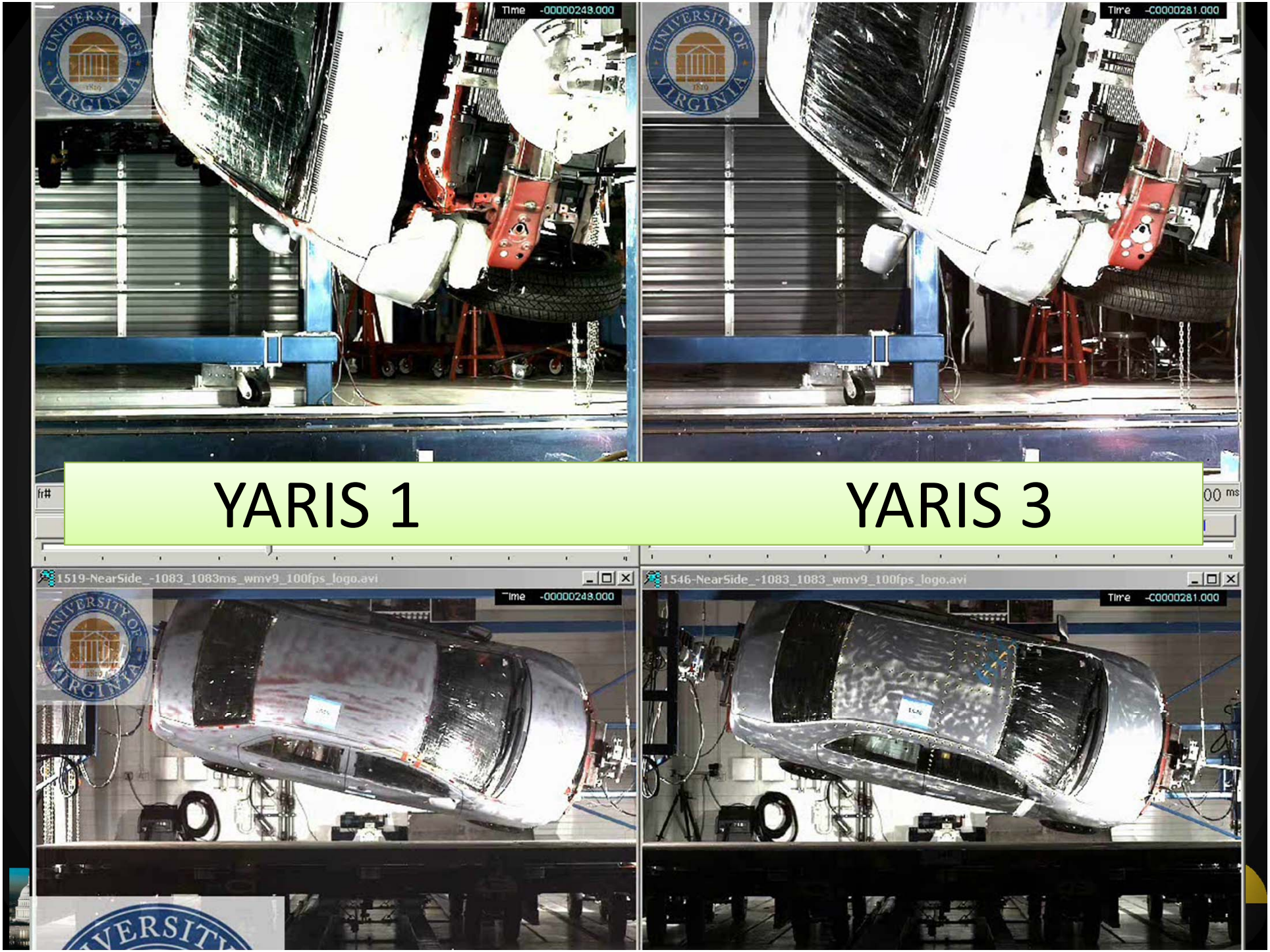
Repeatability Testing: 2011 Toyota Yaris

YARIS 1

YARIS 2

YARIS 3

Test Number	1519	1530	1546
MY	2010	2010	2010
Make	Toyota	Toyota	Toyota
Model	Yaris 1	Yaris 2	Yaris 3
Mass As Tested	1173.9	1173.4	1181.6
SWR	3.78	3.78	3.78
Angular Velocity (deg/s)	268	267	274
Roll Angle (deg)	181	199	181
Road Velocity (m/s)	8.38	8.48	8.52
Pitch Angle (deg)	-12.9	-13.6	-11.1
Pitch Velocity (deg/s)	-5.2	-11.9	0.8
Drop Height (m)	0.2277	0.1887	0.2277


YARIS 1
YARIS 3

87 ms


Time +00000208.000


Time +00000278.000


Time +00000175.000

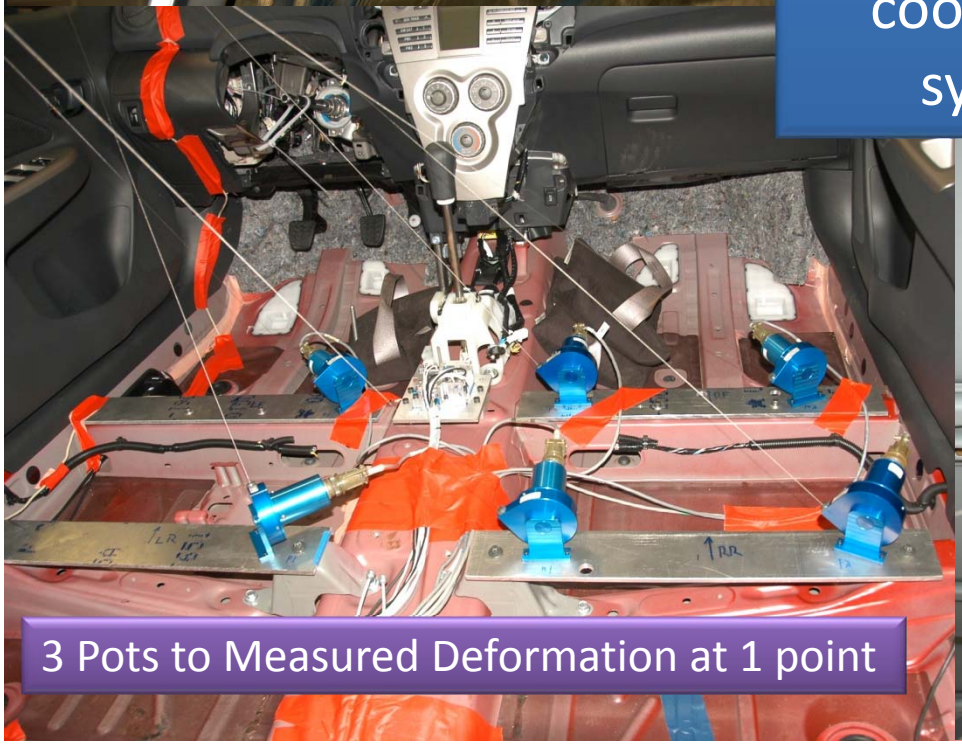

Time +00000208.000

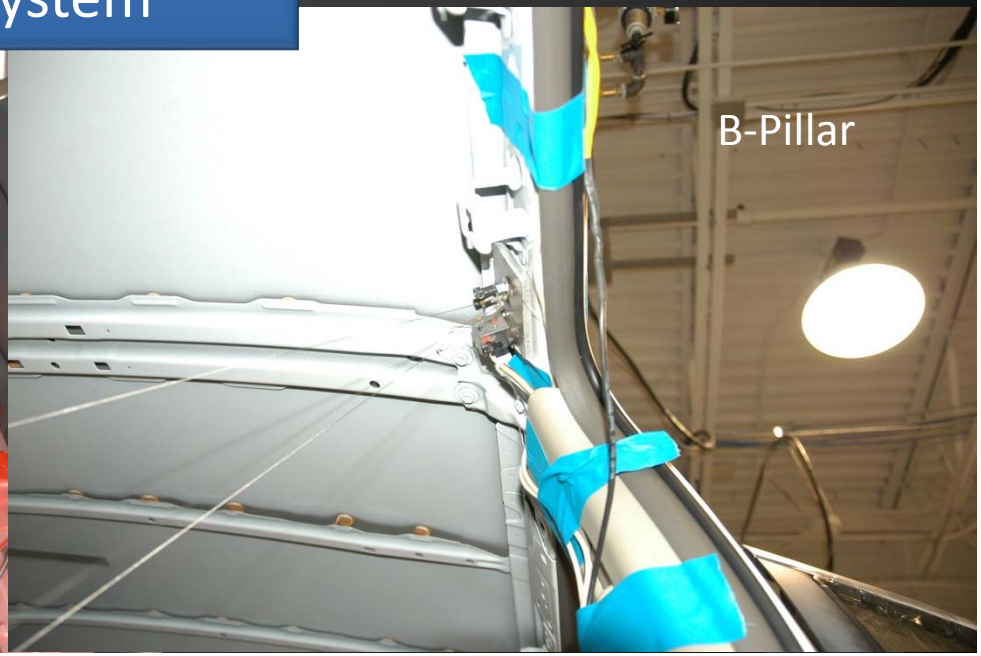

Time +00000278.000


Time +00000175.0

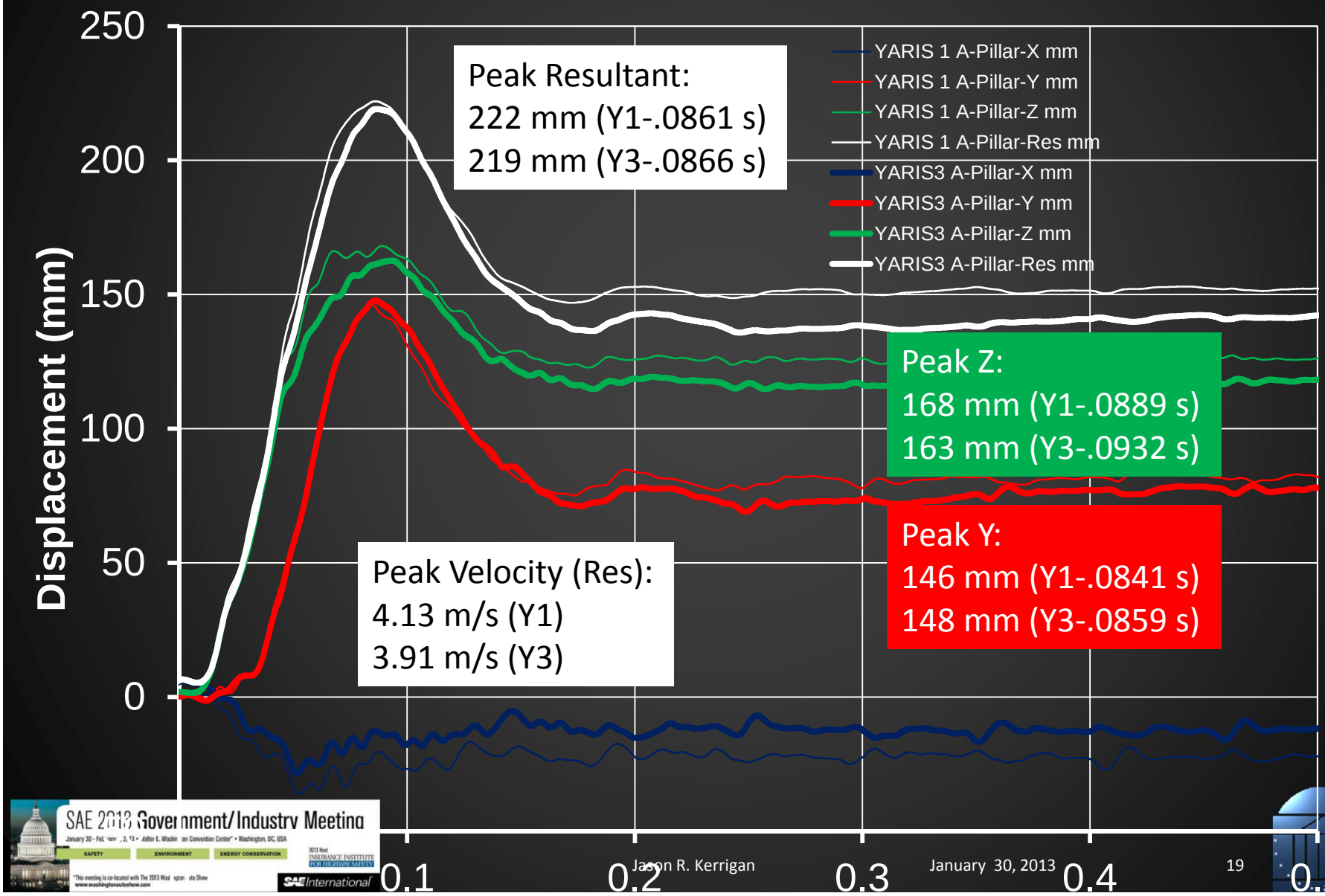
String Potentiometers for Deformation

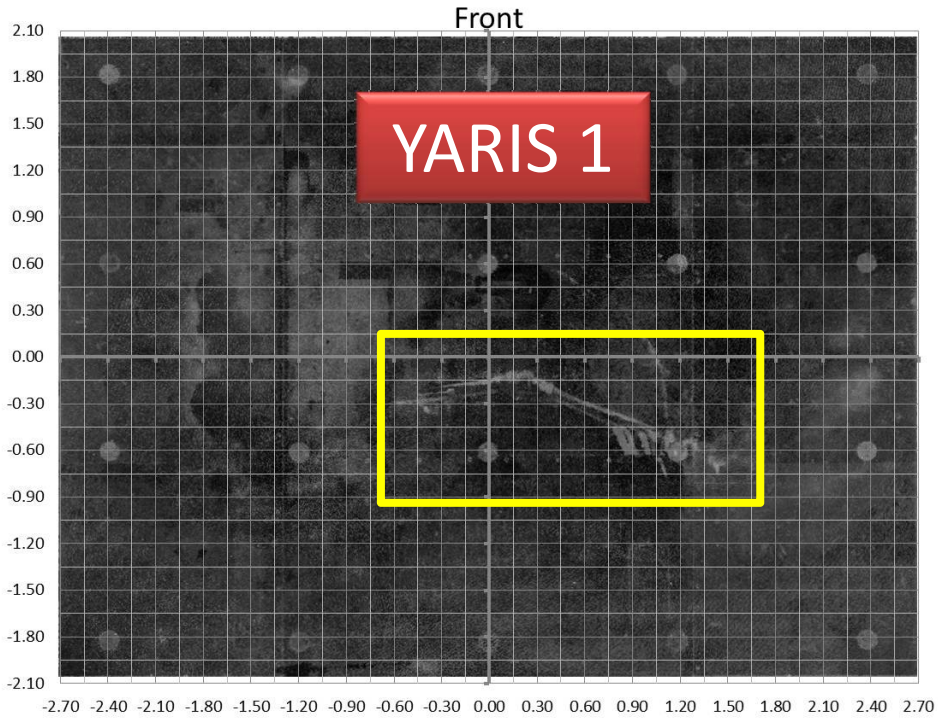
Trilateration to determine component-wise (X,Y,Z) deformations in vehicle coordinate system

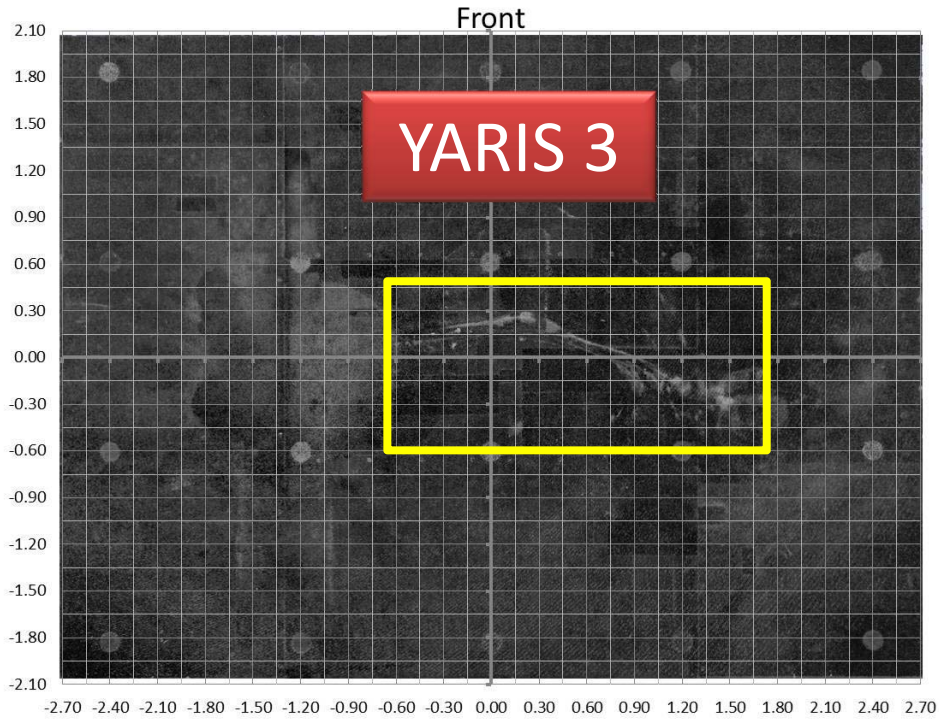




Yaris 1 vs Yaris 3 - APillar




Front
YARIS 1
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
-0.30
-0.60
-0.90
-1.20
-1.50
-1.80
-2.10
-2.70 -2.40 -2.10 -1.80 -1.50 -1.20 -0.90 -0.60 -0.30 0.00 0.30 0.60 0.90 1.20 1.50 1.80 2.10 2.40 2.70


Front
YARIS 3
2.10
1.80
1.50
1.20
0.90
0.60
0.30
0.00
-0.30
-0.60
-0.90
-1.20
-1.50
-1.80
-2.10
-2.70 -2.40 -2.10 -1.80 -1.50 -1.20 -0.90 -0.60 -0.30 0.00 0.30 0.60 0.90 1.20 1.50 1.80 2.10 2.40 2.70

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YARIS 1

YARIS 3

Test Number	1519	1530	1546
Peak Road Force (N)	94378	95581	84049
Time of Peak Load	0.0547	0.0754	0.0505
Roll Angle At Peak Load	195.9	222	195.3
Normalized Peak Load	8.19	8.3	7.25
Peak Roll Rate	332	447	424.8
Roll Angle At Peak	206	256	208
Time at Peak	0.0907	0.1586	0.0903

10 kN!

<1 deg

90 deg/s

2 deg

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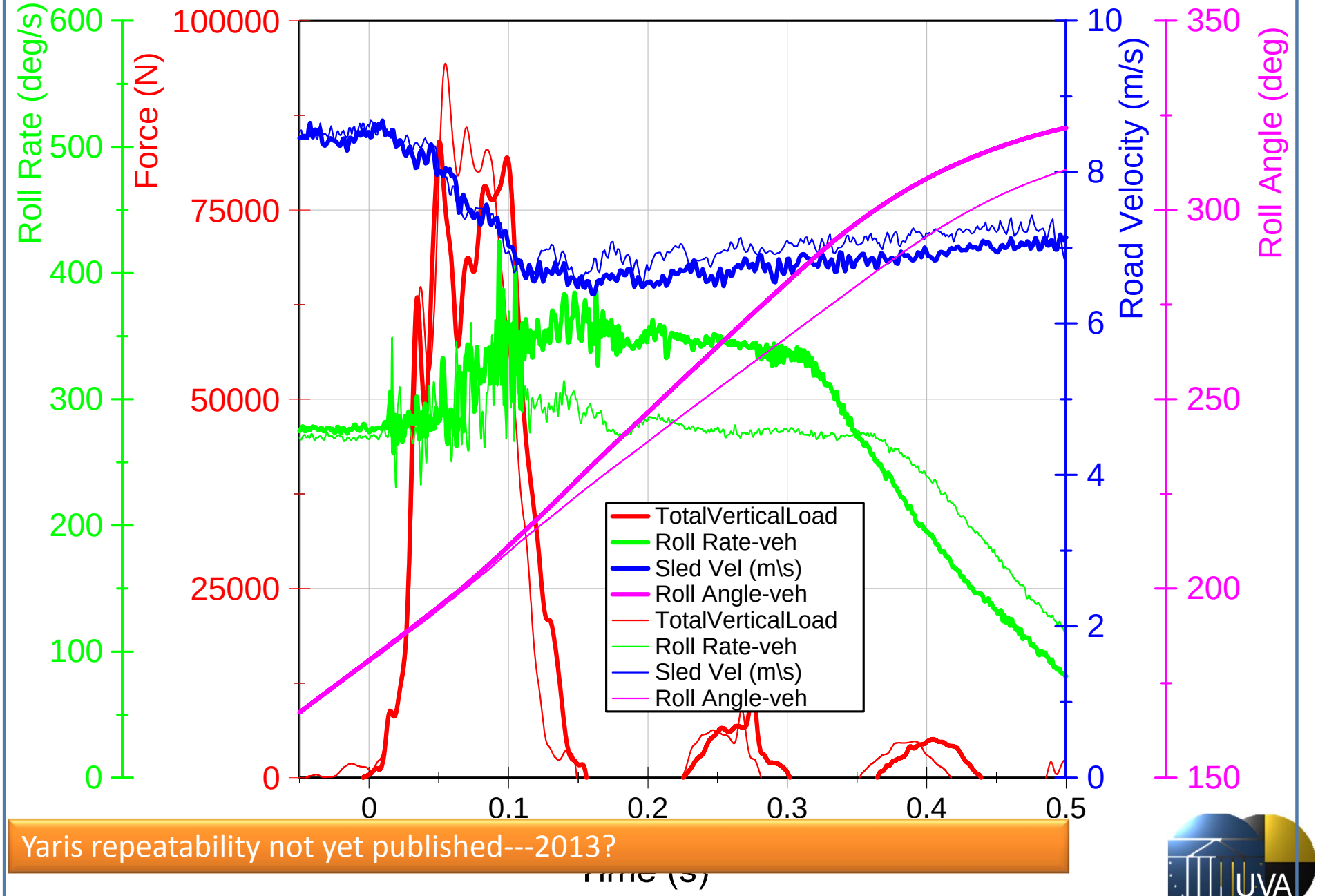
2011 Toyota Yaris-1(thin lines) vs. Yaris 3 (thick lines):

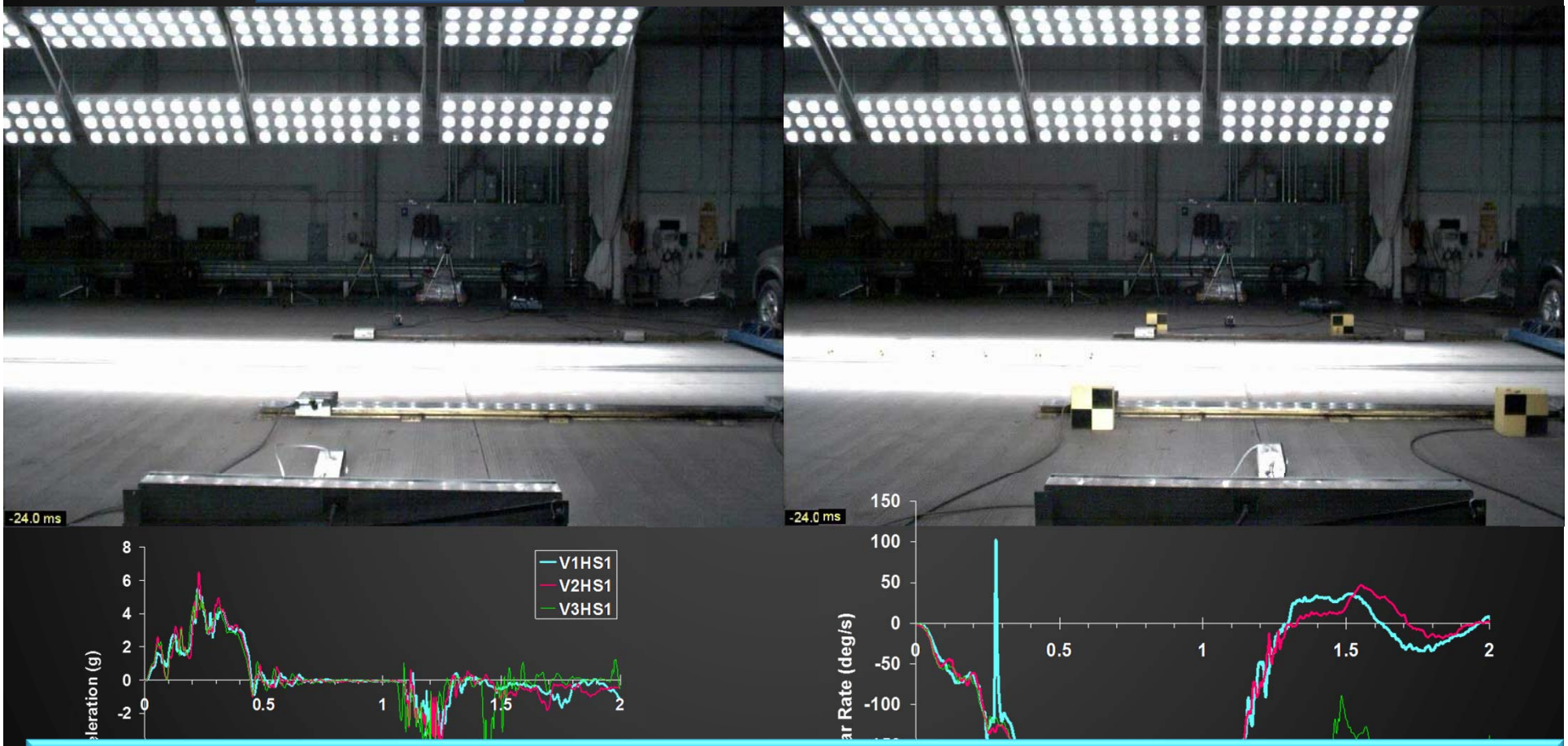


Yaris repeatability not yet published---2013?

Repeatability: Deceleration Rollover Sled Test

V1

V2



Kerrigan JR, Dennis NJ, Parent DP, Purtsezov S, Ash JH, Crandall JR, Stein D. (2011) Test system, vehicle and occupant response repeatability evaluation in rollover crash tests: the deceleration rollover sled test. International Journal of Crashworthiness. 16(6): 583-605.

Rollover Test Buck: WHY

- Parametric Analysis
  - Permits parameter separation
- Dummy Biofidelity Assessment
  - Future tests can be easily compared
- Measure Occupant Kinematics
  - 3-D optical motion tracking requires line of sight
- Computational modeling
  - Complex geometries and stiffnesses are difficult to model

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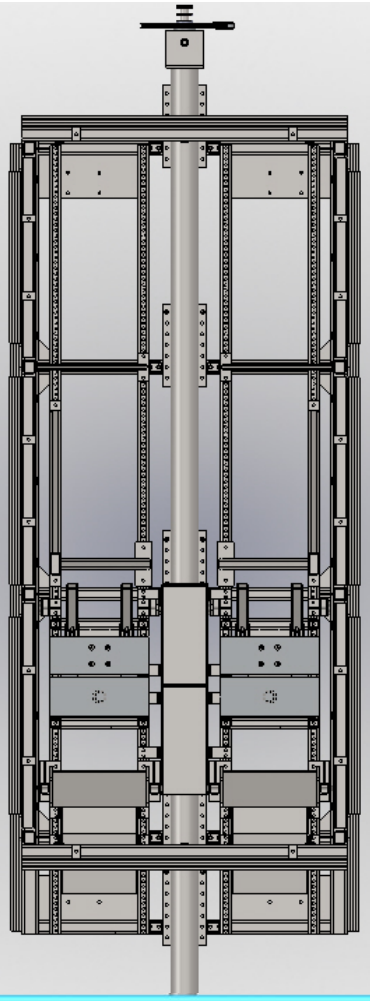
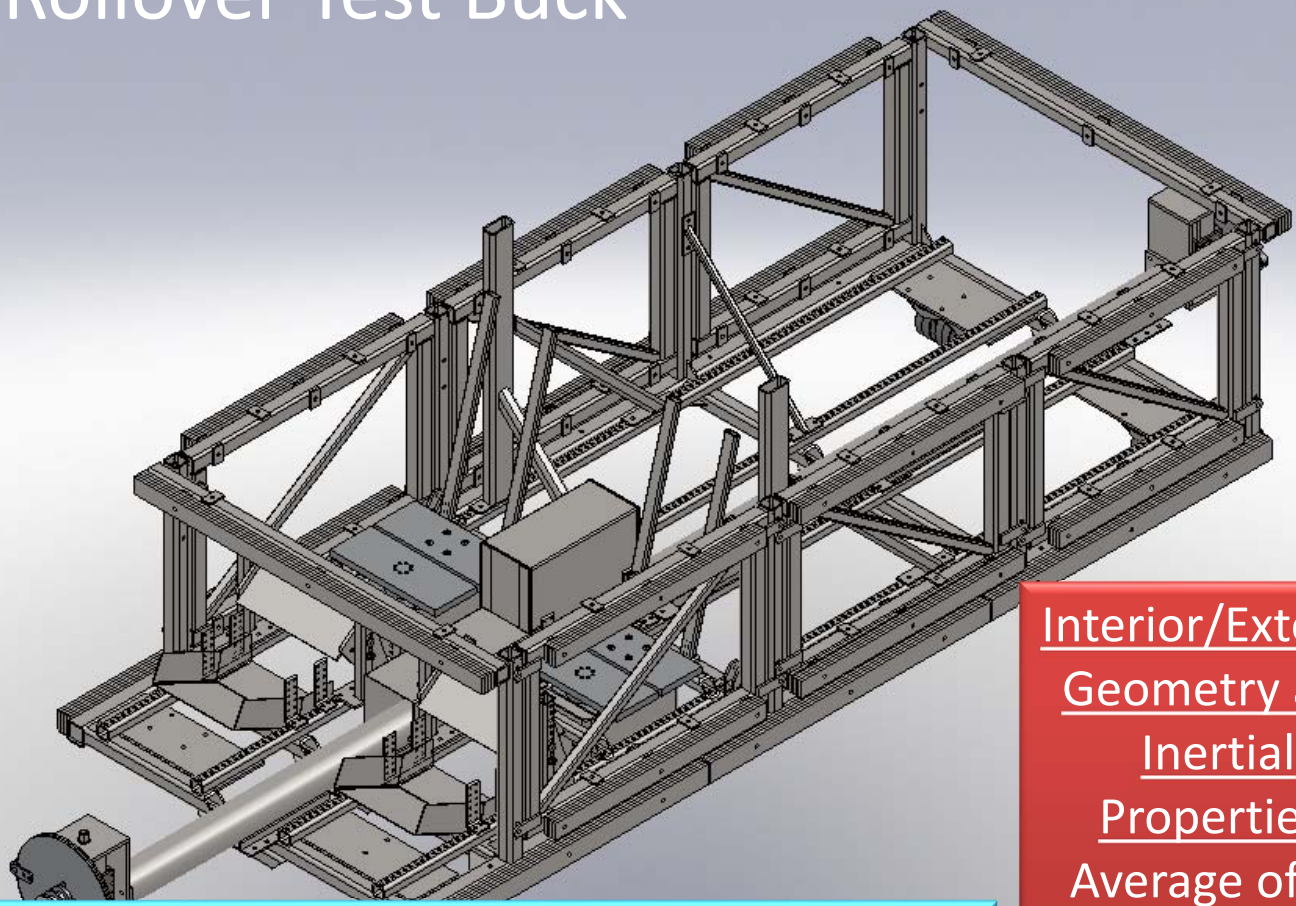
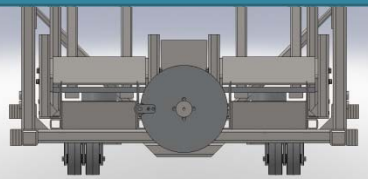
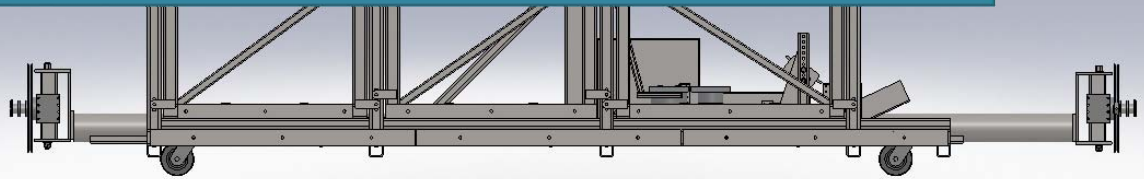
Rollover Test Buck









Foltz P, Kim T, **Kerrigan JR**, Crandall JR. (2011) Vehicle greenhouse shape analysis for design of a parametric test buck for dynamic rollover testing. Paper Number 11-0271. Proceedings of the 22nd International Conference on the Enhanced Safety of Vehicles (ESV).

Interior/Exterior Geometry and Inertial Properties: Average of 12 2011-2012 Full Size Crossover Vehicles

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Crash Dummy Biofidelity Analysis

- Step 1: Occupant Kinematics (no impact, no roof)
  - Roll tests
  - Drop tests (linear acceleration)
  - Roll + Drop Tests
- Step 2: Occupant Injury Risk
  - Full Rollover Tests
  - With Roof/Impact/Deformation

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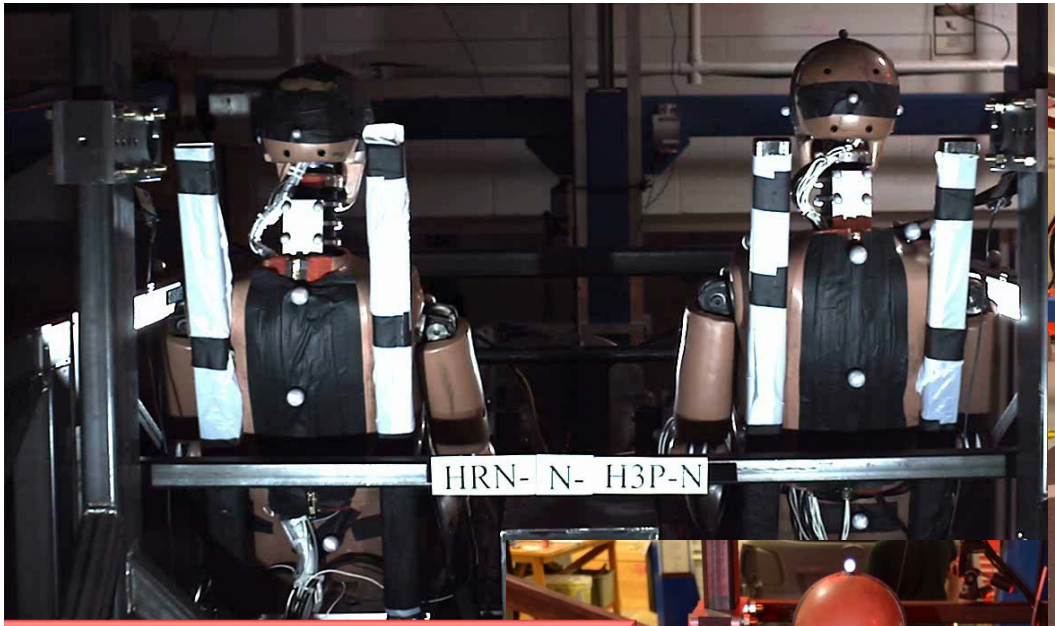
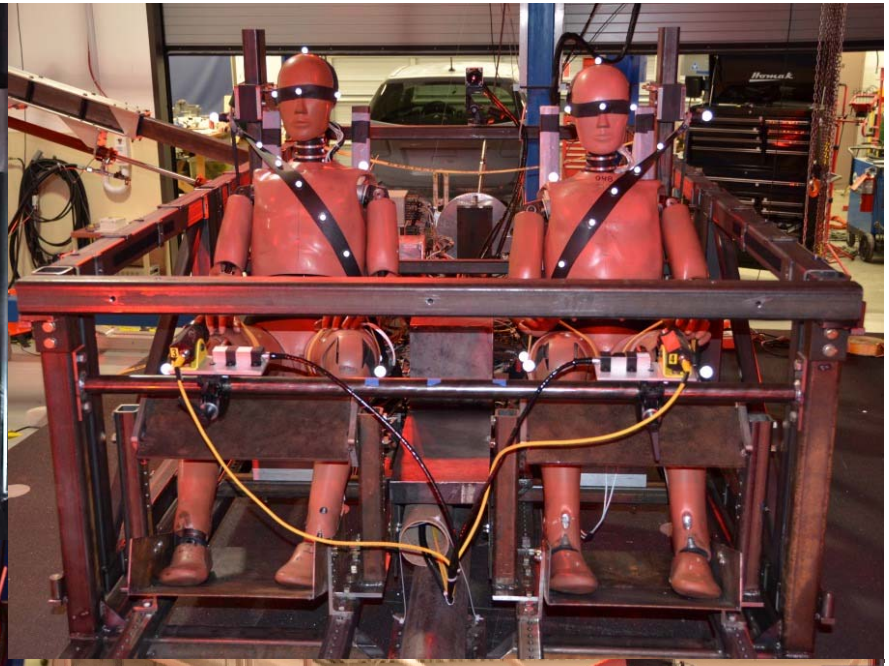
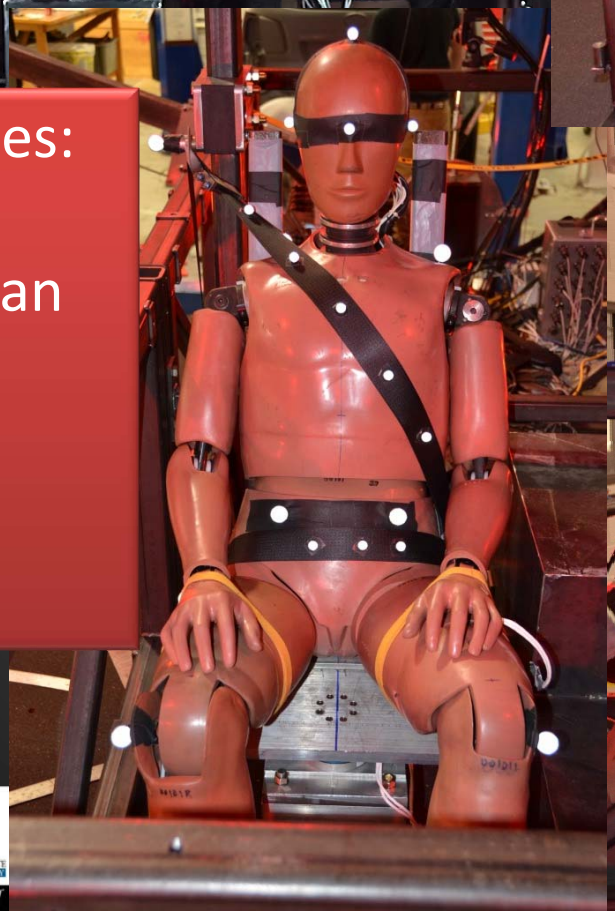






Occupant Surrogates:

-Hybrid III

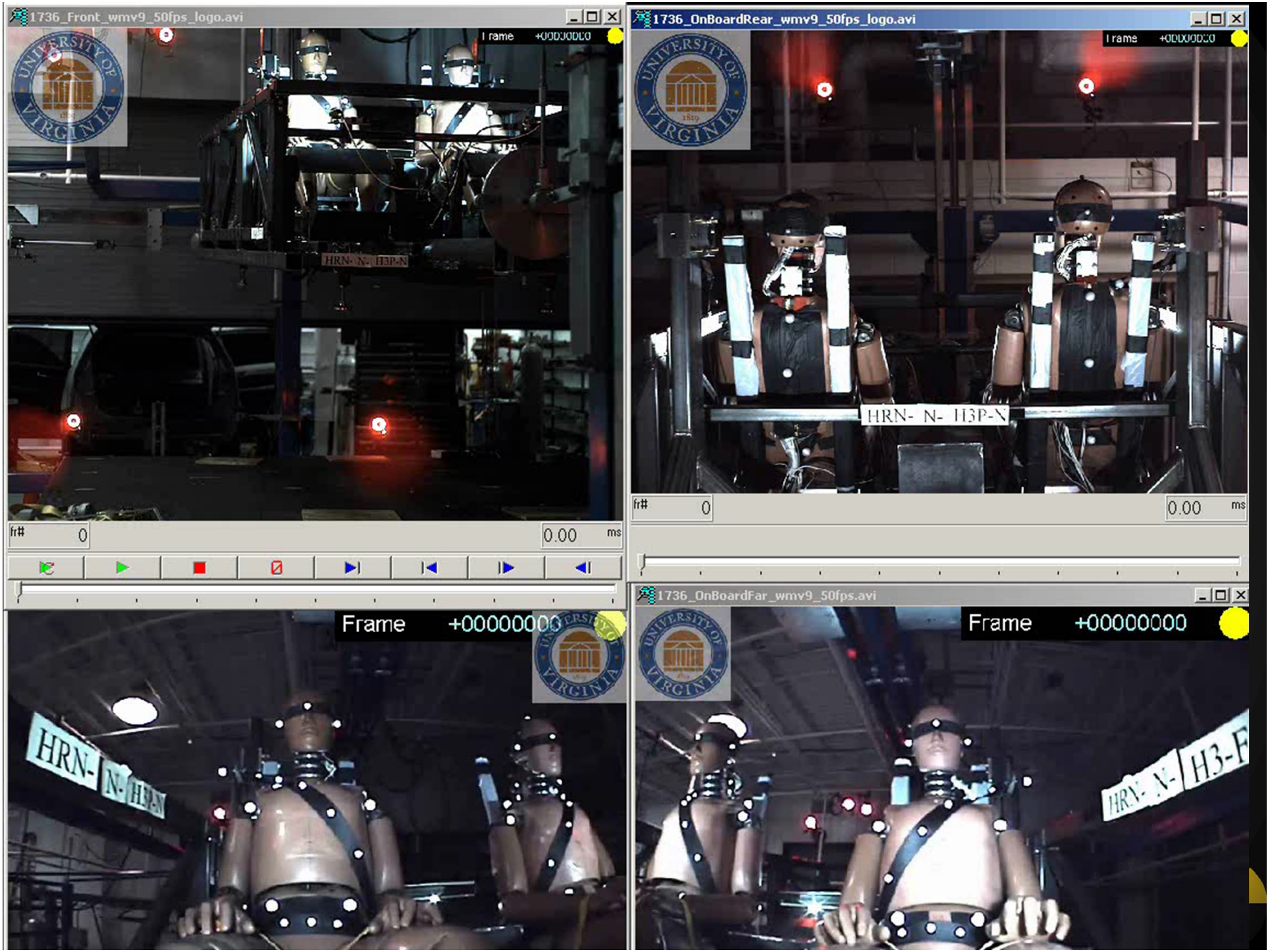
-Hybrid III Pedestrian

-THOR

-Polar II

-WorldSID

-Cadaver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Frame +00000000
HRN- N- H3P-N
fr# 0
0.00 ms
1736_OnBoardRear_wmv9_50fps_logo.avi
Frame +00000000
HRN- N- H3P-N
fr# 0
0.00 ms
Frame +00000000
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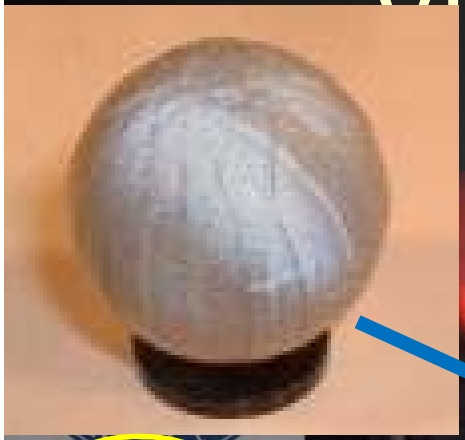
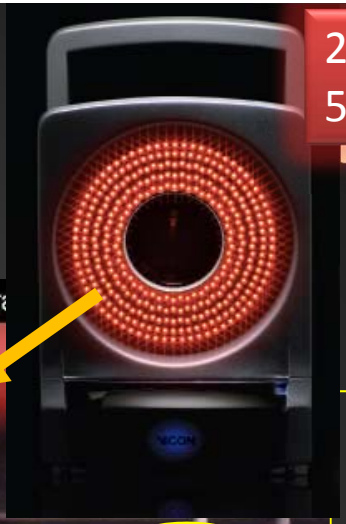
Frame +00000000
HRN- N- H3-F

VICON 3D Motion





26 Cameras @ 500 Hz

Tracking of Vehicle (@ CG)

Tracking of Head (@ CG)

Tracking of Thorax @ T1, T8 (CG), Shoulders

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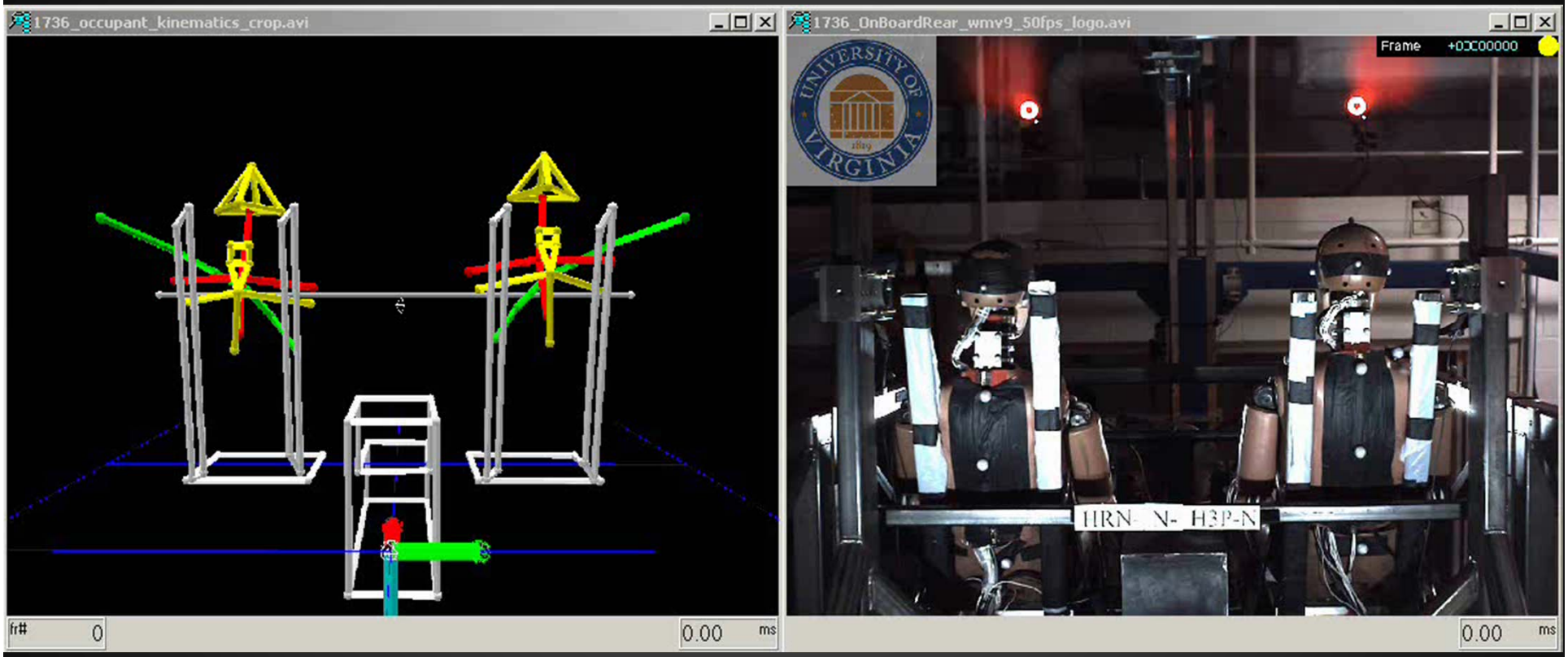
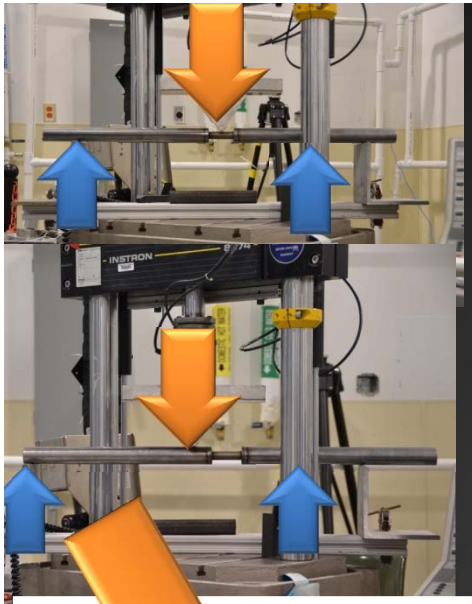
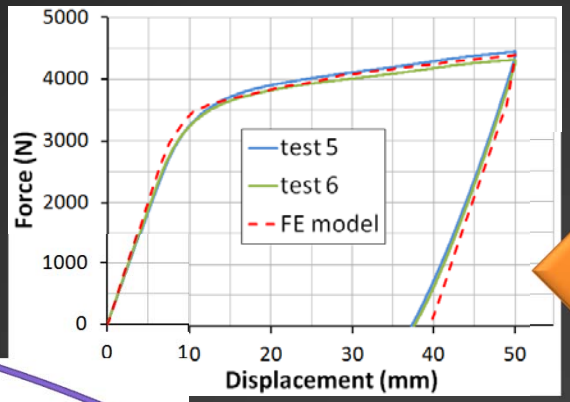
VICON 3-D Motion Tracking

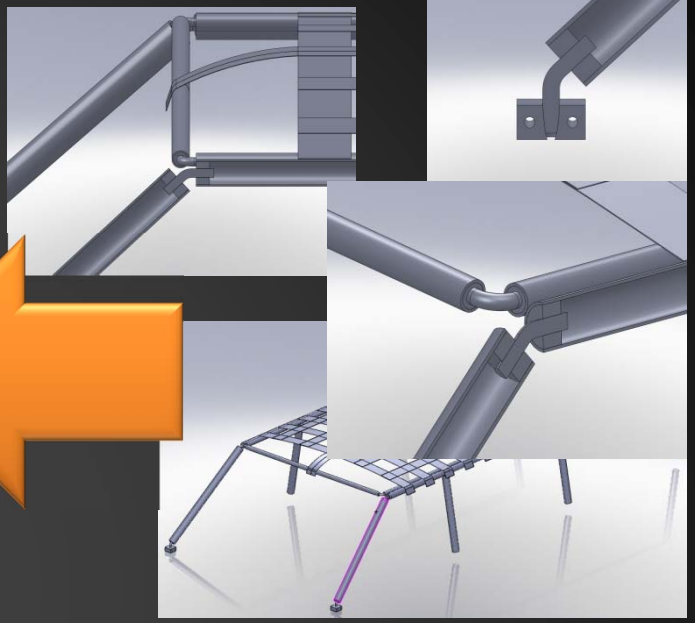


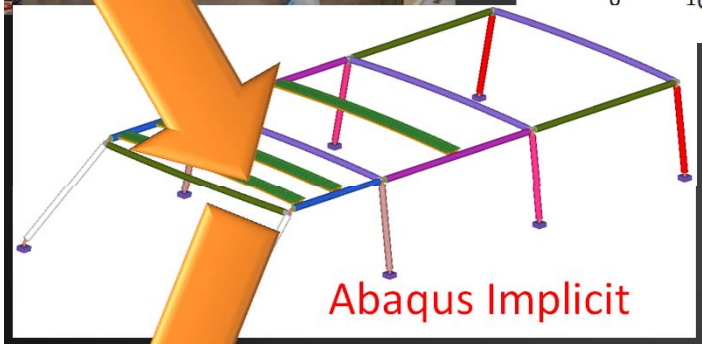
Zhang Q, Kerrigan J, Lessley D, Seppi J, Foltz P, Lockerby J, Overby B, Crandall J. (2013) Whole-Body Kinematics and Kinetics: Response comparison of the seated and pedestrian Hybrid III ATDs in DRoTS Rollover Tests. IRCOBI Conference. Gothenburg, Sweden.

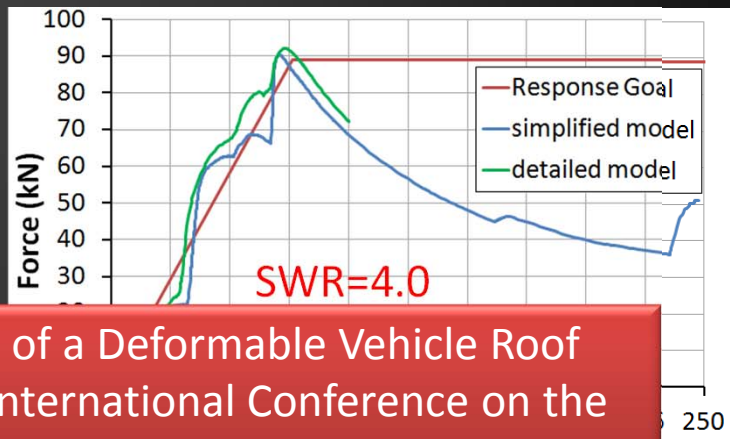
Buck Roof Modeling Procedure

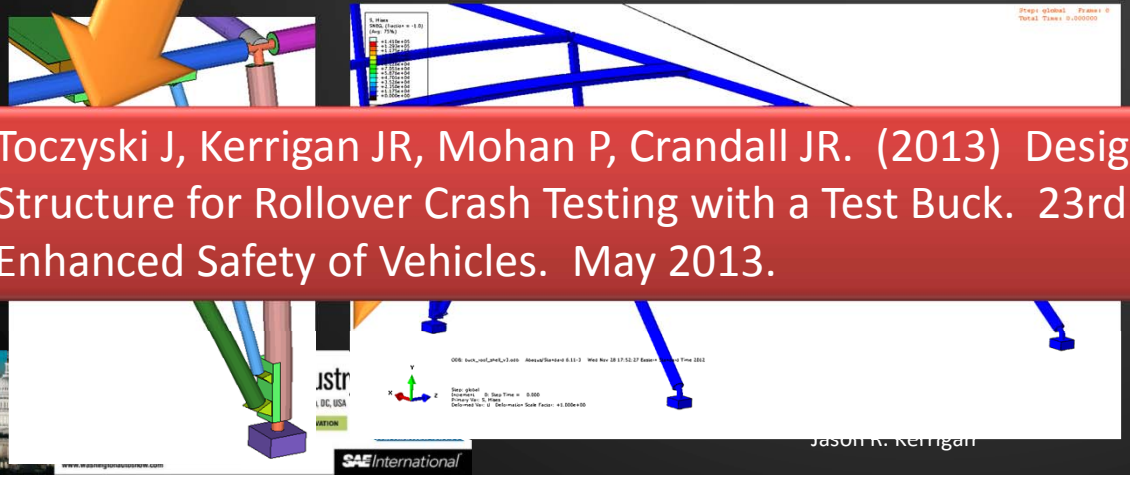






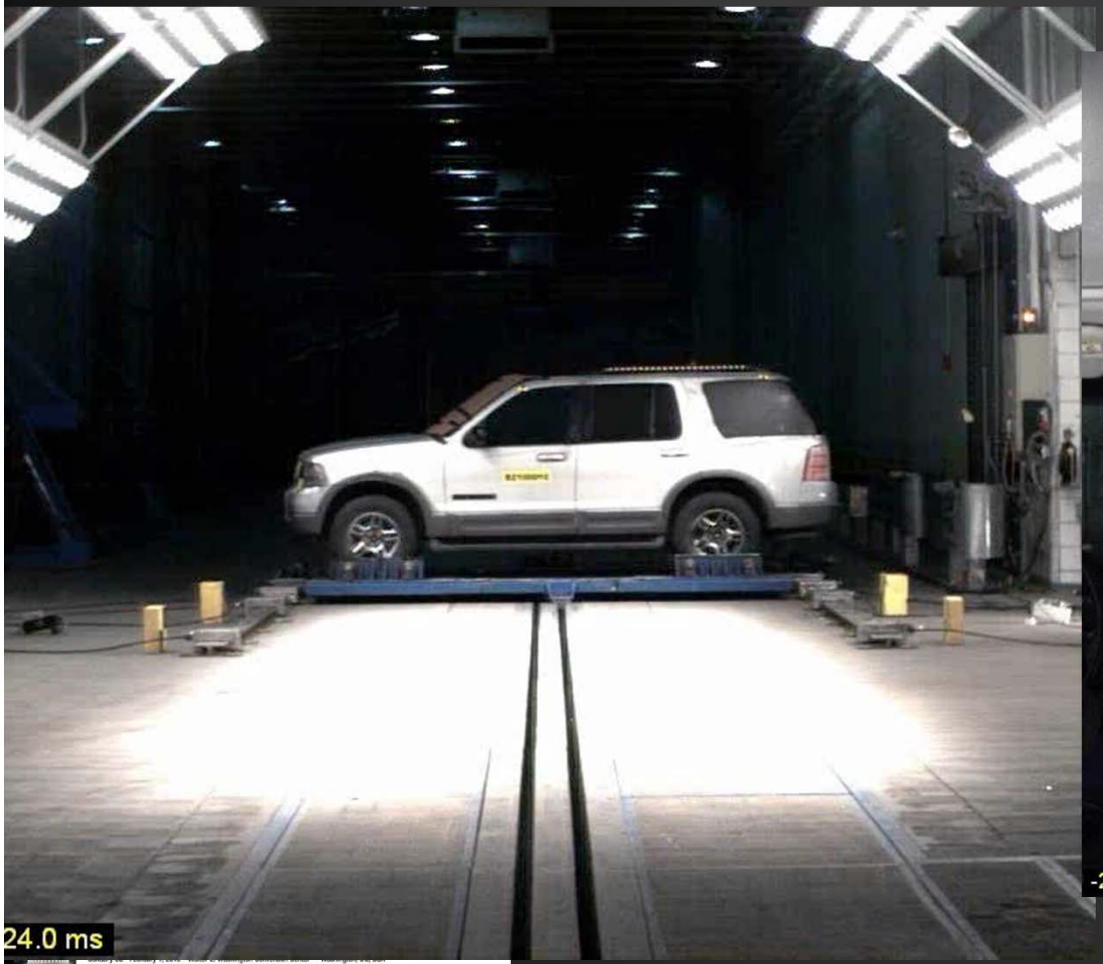


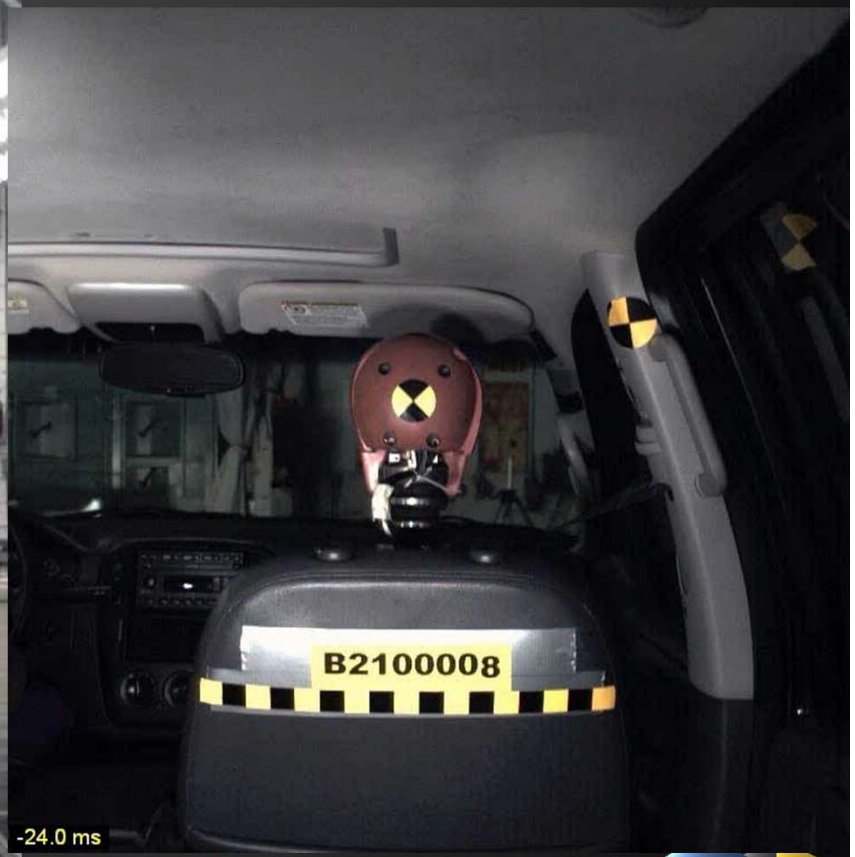




Toczyski J, Kerrigan JR, Mohan P, Crandall JR. (2013) Design of a Deformable Vehicle Roof Structure for Rollover Crash Testing with a Test Buck. 23rd International Conference on the Enhanced Safety of Vehicles. May 2013.

Rollover Initiation Test System (RITS) Development





Questions?

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