

VERIFICATION & VALIDATION REPORT of MGS Barrier Impact with 1100C Vehicle Using Toyota Yaris Coarse FE Model

CCSA VALIDATION/VERIFICATION REPORT

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Project: CCSA Longitudinal Barriers on Curved, Superelevated Roadway Sections
Comparison Case: 1100C Vehicle with MGS Barrier
Impact Description: 25.4 degree impact into barrier at 97.8 km/h (60.8 mph)
Governing Criteria: MASH TL-3
Report Date: July 2013

Table A – Information Sources:

General Information	Known Solution	Analysis Solution
Performing Organization	MwRSF	CCSA-GMU
Test/Run Number	2214NJ-1	130306b
Vehicle	2002 Kia Rio	CCSA 2010 Yaris_C V1h Model
Vehicle Mass (lb/kg)	2588 / 1174	2593 / 1176
Impact Speed (mph/kph)	60.8 / 97.8	62.1 / 100
Impact Angle (degrees)	25.4	25

Table B - Evaluation Parameters Summary:

Category	Subset	Values
Evaluation Method	MASH (V1, 2009)	
Hardware Type	Longitudinal	
Test Number	3-10	
Test Vehicle Required	1100C	
Criterion to be Applied	Structural Adequacy	A - Test article should contain and redirect the vehicle; the vehicle should not penetrate, under-ride, or override the installation although controlled lateral deflection of the test article is acceptable.
	Occupant Risk	D - Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians or personnel in a work zone.
		F - The vehicle should remain upright during and after the collision although moderate roll, pitching and yawing are
		H - The occupant impact velocity in the longitudinal direction should not exceed 40 ft/sec and the occupant ride-down acceleration in the longitudinal direction should not exceed 20 G's.
		I - Longitudinal & lateral occupant ridedown accelerations (ORA) should fall below the preferred value of 15.0 g, or at least below the maximum allowed value of 20.49 g.
	Vehicle Trajectory	For redirective devices the vehicle shall exit within the prescribed box.

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Table C – Analysis Solution Verification Summary

Verification Evaluation Criteria	Change (%)	Pass?
Total energy of the analysis solution (i.e., kinetic, potential, contact, etc.) must not vary more than 10 percent from the beginning of the run to the end of the run.	2.64	YES
Hourglass Energy of the analysis solution at the end of the run is less than 5 % of the total initial energy at the beginning of the run	1.70	YES
The part/material with the highest amount of hourglass energy at any time during the run is less than 5 % of the total initial energy at the beginning of the run.	2.05	YES
Mass added to the total model is less than 5 % the total model mass at the start of the run.	< 1%	YES
The part/material with the most mass added had less than 10 % of its initial mass added.	< 1%	YES
The moving parts/materials in the model have less than 5 % of mass added to the initial moving mass of the model.	< 1%	YES
There are no shooting nodes in the solution?	NA	YES
There are no solid elements with negative volumes?	NA	YES

Table D - RSVVP Results

Single Channel Time History Comparison Results		Time interval [0 sec - 0.5 sec]		
O	Sprague-Geer Metrics	M	P	Pass?
	X acceleration	21	29.6	YES
	Y acceleration	42.6	30.4	NO
	Z acceleration	110.2	43.5	NO
	Yaw rate	1.8	16.6	YES
	Roll rate	1.5	29.9	YES
	Pitch rate	85.7	43.6	NO
P	ANOVA Metrics	Mean	SD	Pass?
	X acceleration/Peak	2.74	20.94	YES
	Y acceleration/Peak	-1.88	44.09	NO
	Z acceleration/Peak	-3.3	71.18	NO
	Yaw rate	-10.25	20.02	NO
	Roll rate	-1.97	36.54	NO
	Pitch rate	6.35	53.36	NO
Multi-Channel Weighting Factors		Time interval [0 sec; 0.5 sec]		
Multi-Channel Weighting Method Peaks Area I Area II Inertial		X Channel	0.222365	
		Y Channel	0.236344	
		Z Channel	0.041289	
		Yaw Channel	0.412014	
		Roll Channel	0.052883	
		Pitch Channel	0.035101	
Sprague-Geer Metrics		M	P	Pass?
	All Channels (weighted)	23.1	25.5	YES
ANOVA Metrics		Mean	SD	Pass?
	All Channels (weighted)	-4.1	30.1	YES

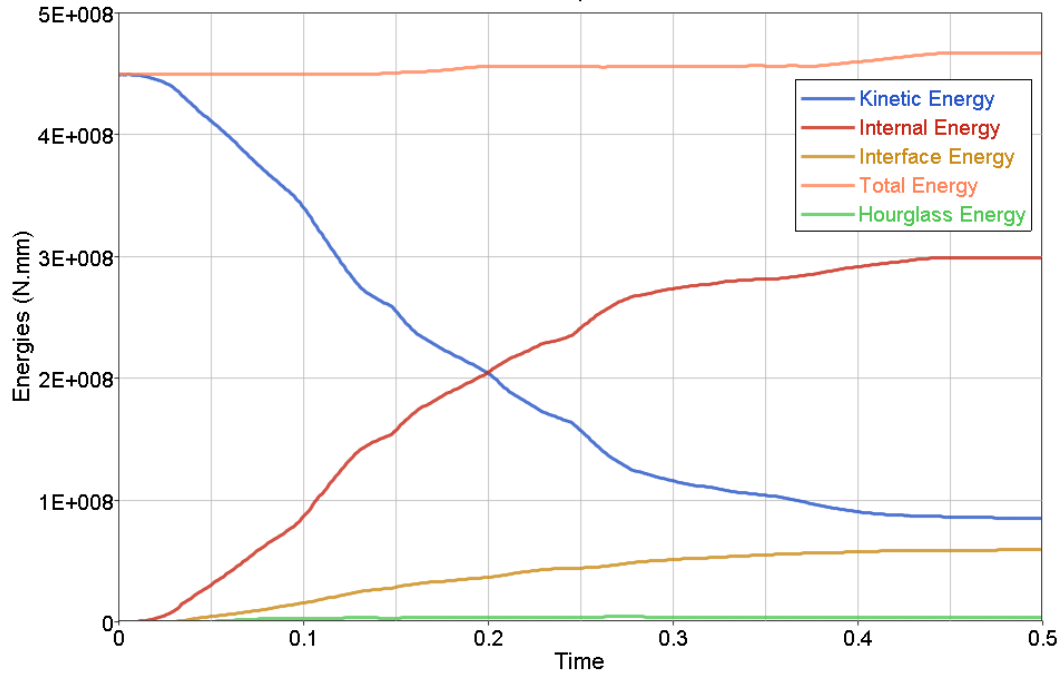


Figure 1: Simulations Energies

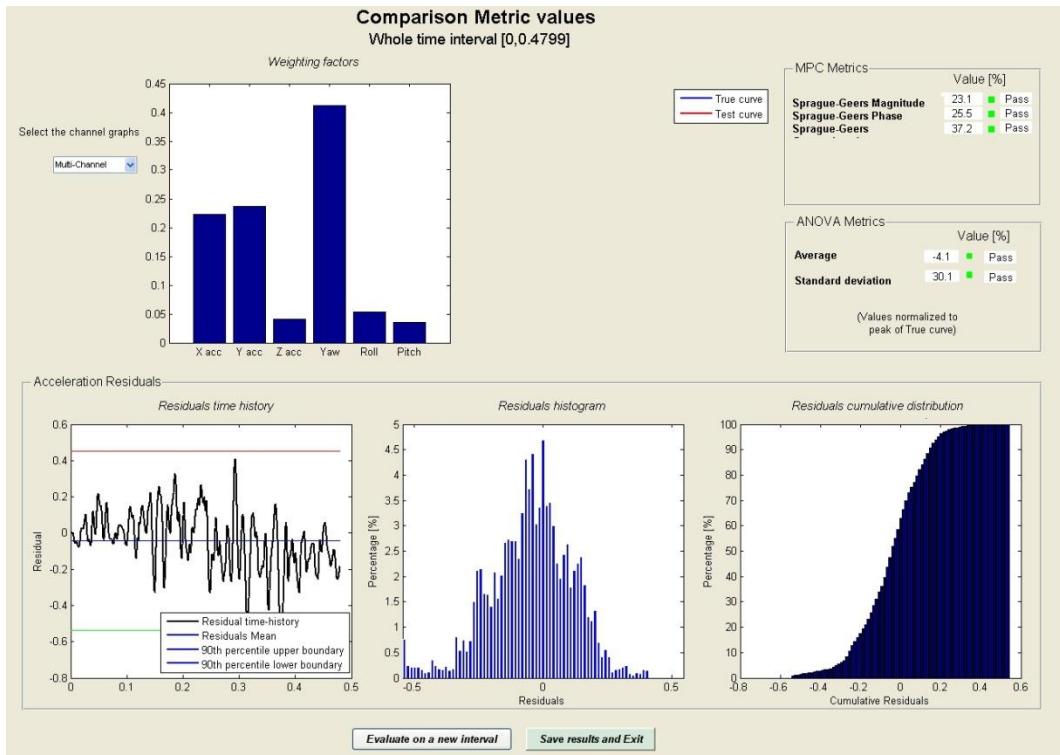


Figure 2a: RSVVP Results – All Channels

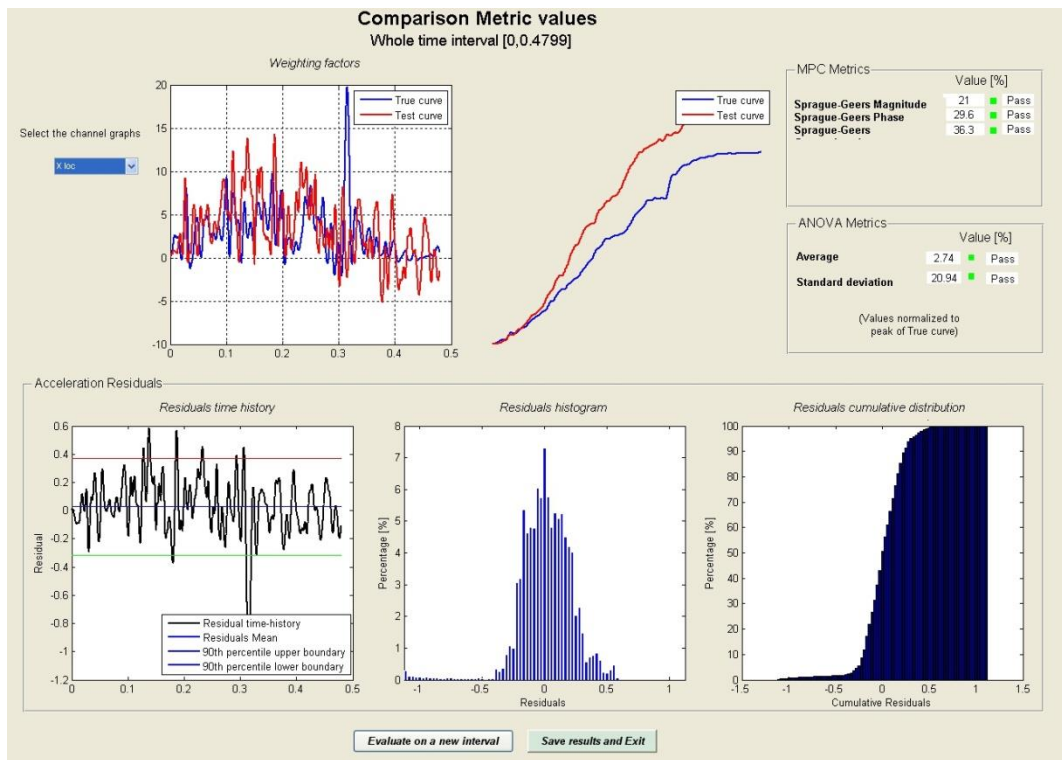


Figure 2b: RSVVP Results – Longitudinal Acceleration

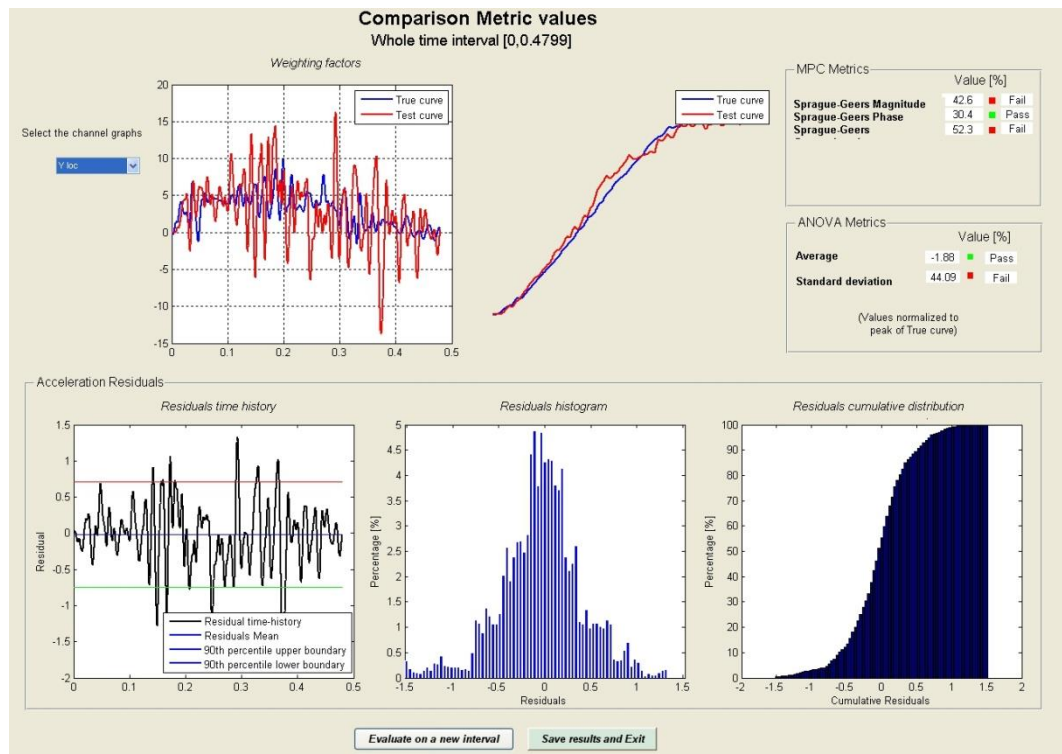


Figure 2c: RSVVP Results – Lateral Acceleration

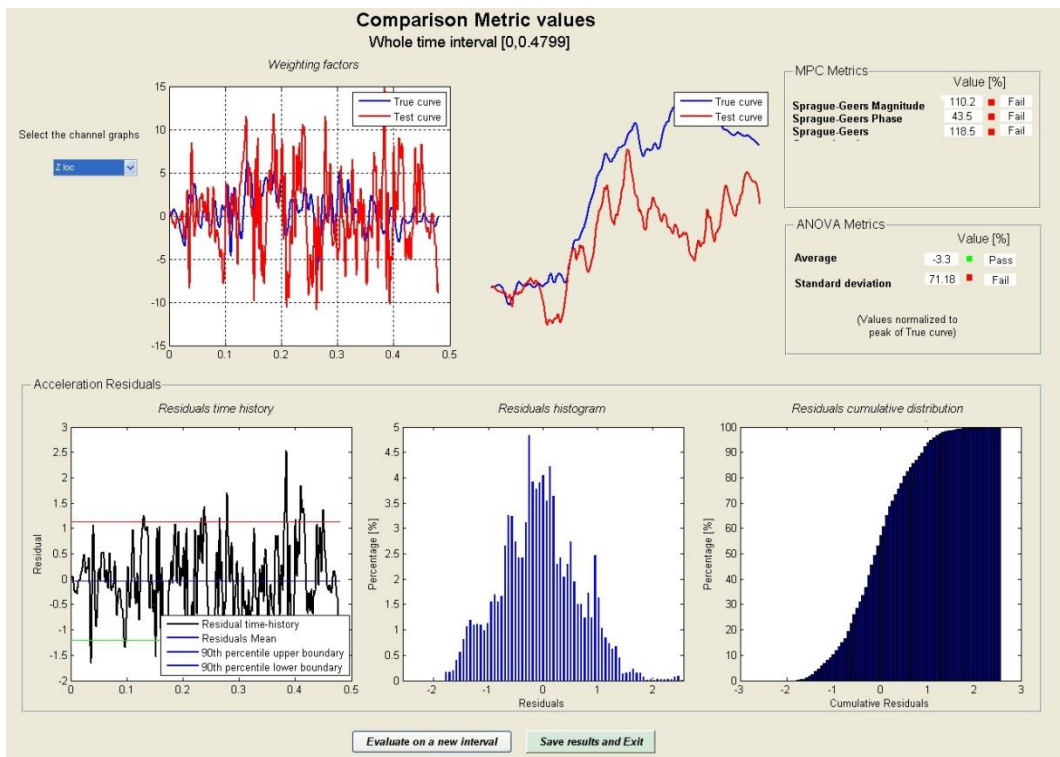


Figure 2d: RSVVP Results – Vertical Acceleration

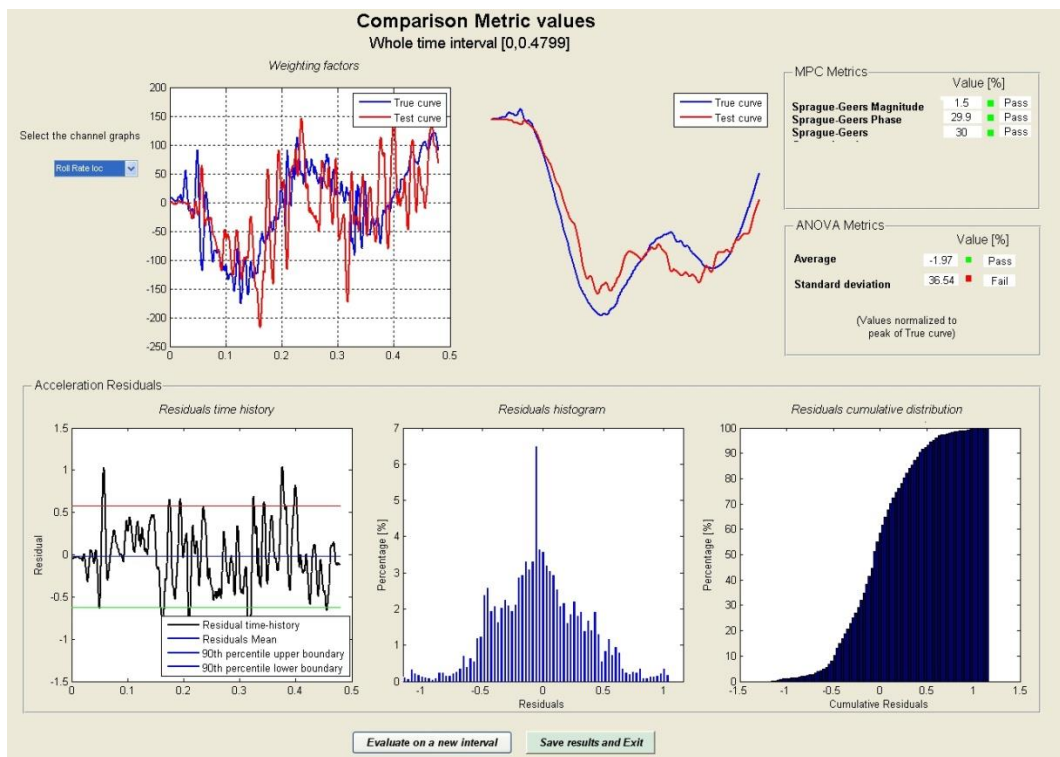


Figure 2e: RSVVP Results – Roll Angle

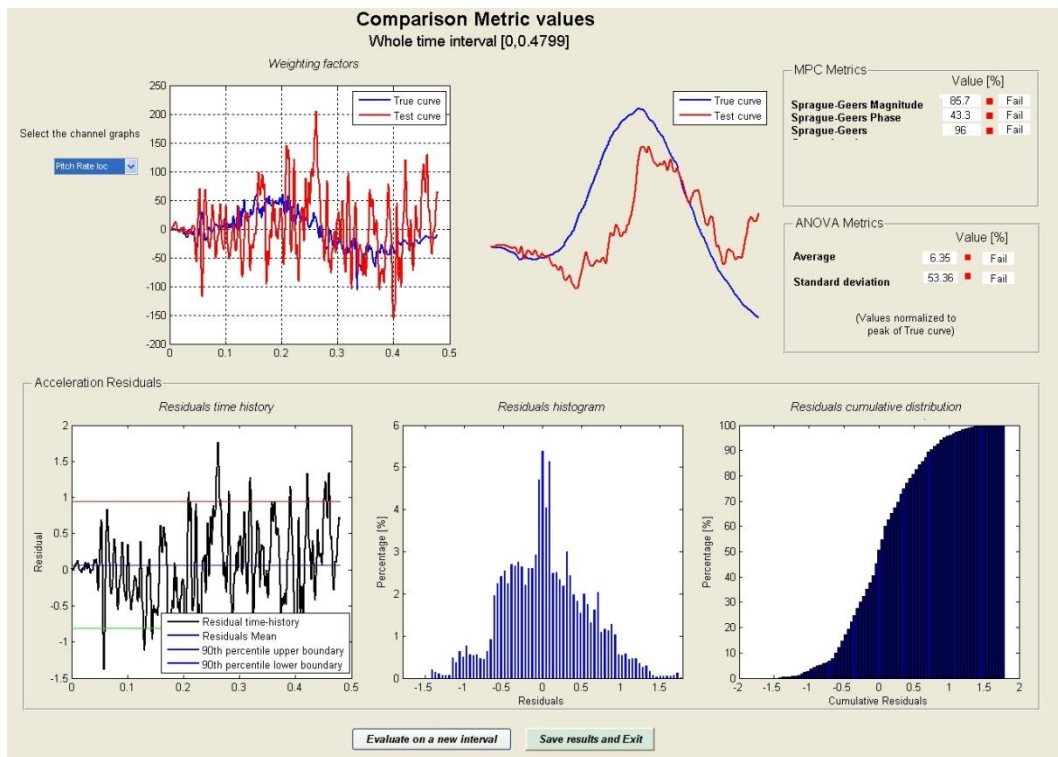


Figure 2f: RSVVP Results – Pitch Angle

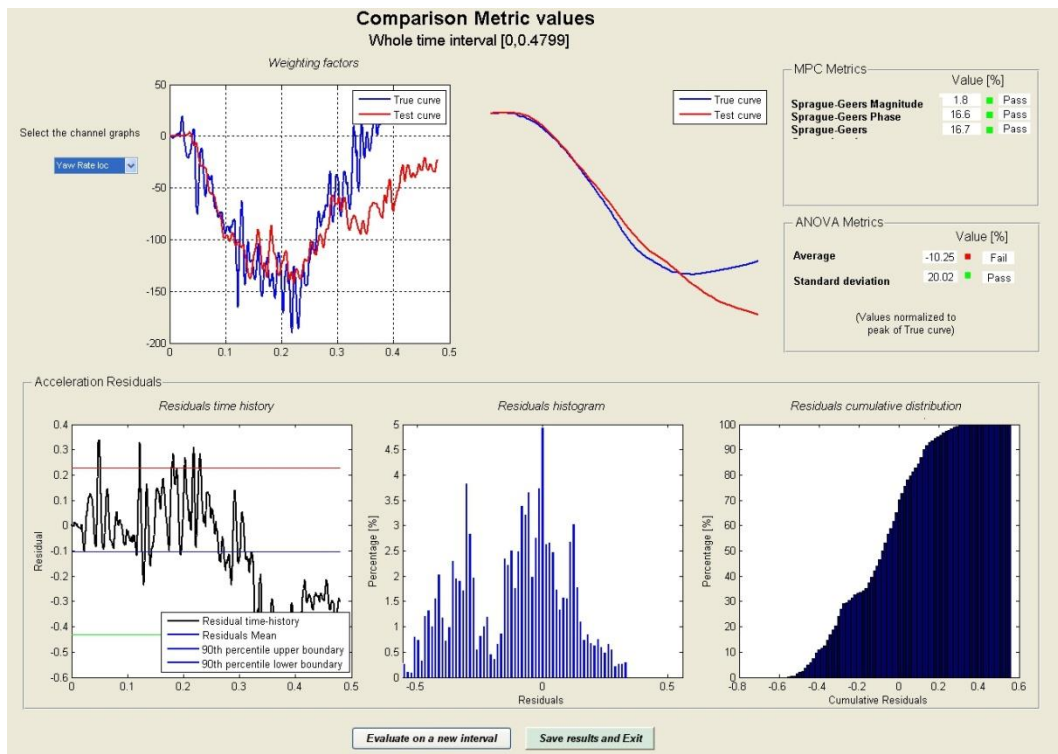


Figure 2g: RSVVP Results – Yaw Angle

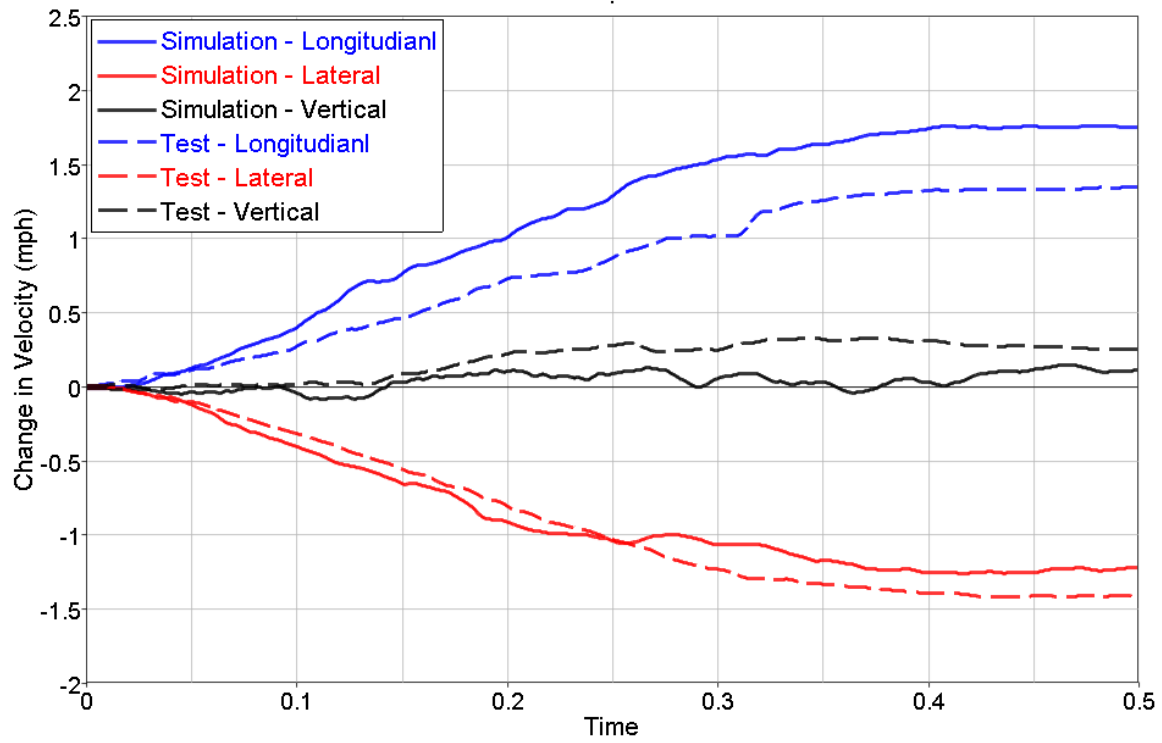


Figure 3: Change in Vehicle Velocities

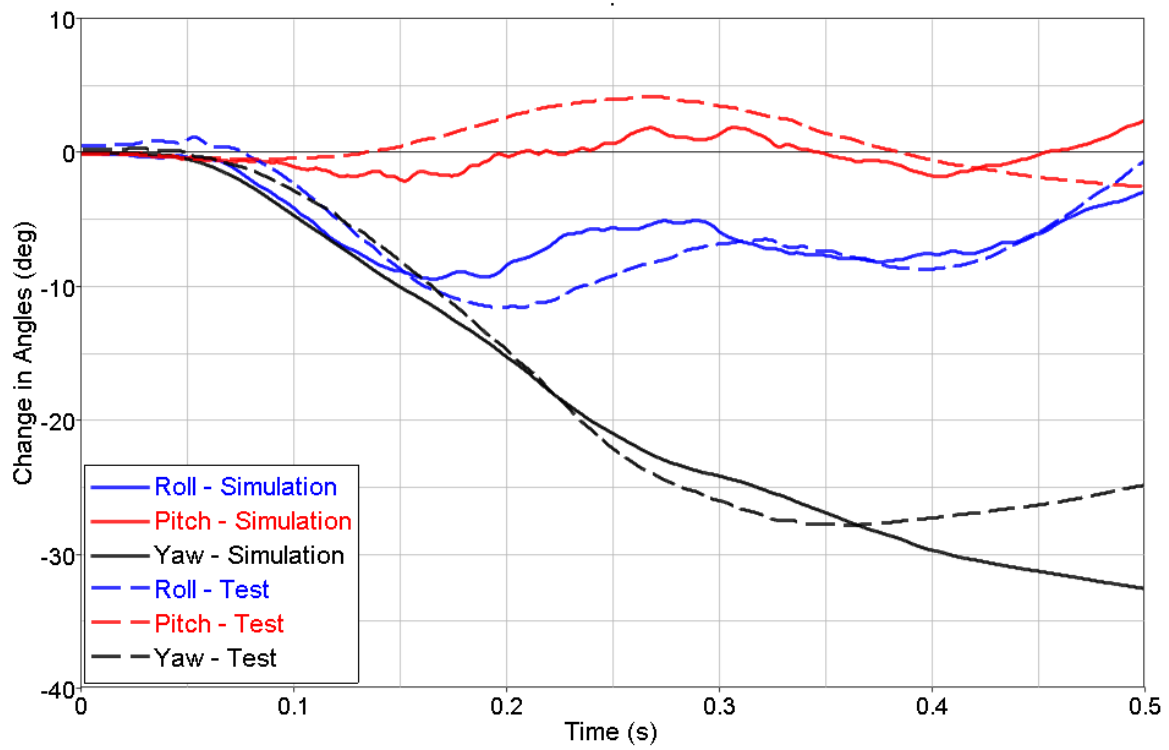


Figure 4: Change in Vehicle Angle

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Comparison Case: 1100C Vehicle with MGS Barrier

Table E - Roadside Safety Phenomena Importance Ranking Table (MASH Evaluation)

Evaluation Criteria				Known Result	Analysis Result	Relative Diff. (%)	Agree?	
Structural Adequacy	A	A1	Test article should contain and redirect the vehicle; the vehicle should not penetrate, under-ride, or override the installation although controlled lateral deflection of the test article is acceptable.	Yes	Yes		YES	
		A2	The relative difference in the maximum dynamic deflection is less than 20 percent.	0.91m	0.82mm	9.9%	YES	
		A3	The relative difference in the time of vehicle-barrier contact is less than 20 percent.	0.56s	0.50s	10.7%	YES	
		A4	The relative difference in the number of broken or significantly bent posts is less than 20 percent.	3	2		NO	
		A5	Barrier did not fail (Answer Yes or No).	Yes	Yes		YES	
		A6	There were no failures of connector elements (Answer Yes or No).	No	No		YES	
		A7	There was no significant snagging between the vehicle wheels and barrier elements (Answer Yes or No).	No	No		YES	
		A8	There was no significant snagging between vehicle body components and barrier elements (Answer Yes or No).	No	No		YES	
Occupant Risk	D		Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians or personnel in a work zone (Answer Yes or No).	No	No		YES	
		F	F1	The vehicle should remain upright during and after the collision. The maximum pitch & roll angles are not to exceed 75 degrees.	Yes	Yes		YES
			F2	Maximum vehicle roll – relative difference is less than 20% or absolute difference is less than 5 degrees.	11.70 (0.5s)	10.74 (0.5s)	8.20% 0.96	YES
			F3	Maximum vehicle pitch – relative difference is less than 20% or absolute difference is less than 5 deg.	5.33 (0.5s)	2.66 (0.5s)	50.09% 2.67	YES
			F4	Maximum vehicle yaw – relative difference is less than 20% or absolute difference is less than 5 deg.	27.94 (0.5s)	35.58 (0.5s)	21.47% 7.64	No
		H	H1	Longitudinal & lateral occupant impact velocities (OIV) should fall below the preferred value of 30 ft/s (9.1 m/s), or at least below the maximum allowed value of 40 ft/s (12.2 m/s)	Yes	Yes		YES
			H2	Longitudinal OIV (m/s) - Relative difference is less than 20% or absolute difference is less than 2 m/s	4.52	5.59	19.12% 1.07	YES
			H3	Lateral OIV (m/s) - Relative difference is less than 20% or absolute difference is less than 2 m/s	5.22	5.27	0.95% 0.05	YES
		I	I1	Longitudinal & lateral occupant ridedown accelerations (ORA) should fall below the preferred value of 15.0 g, or at least below the maximum allowed value of 20.49 g.	Yes	Yes		YES
			I2	Longitudinal ORA (g) - Relative difference is less than 20% or absolute difference is less than 4 g’s	16.14	11.43	29.1% 4.71	NO
			I3	Lateral ORA (g) - Relative difference is less than 20% or absolute difference is less than 4 g’s	8.37	12.72	34.19% 4.35	NO
Vehicle Trajectory		The vehicle rebounded within the exit box. (Answer Yes or No)	Yes	Yes	YES	Yes		

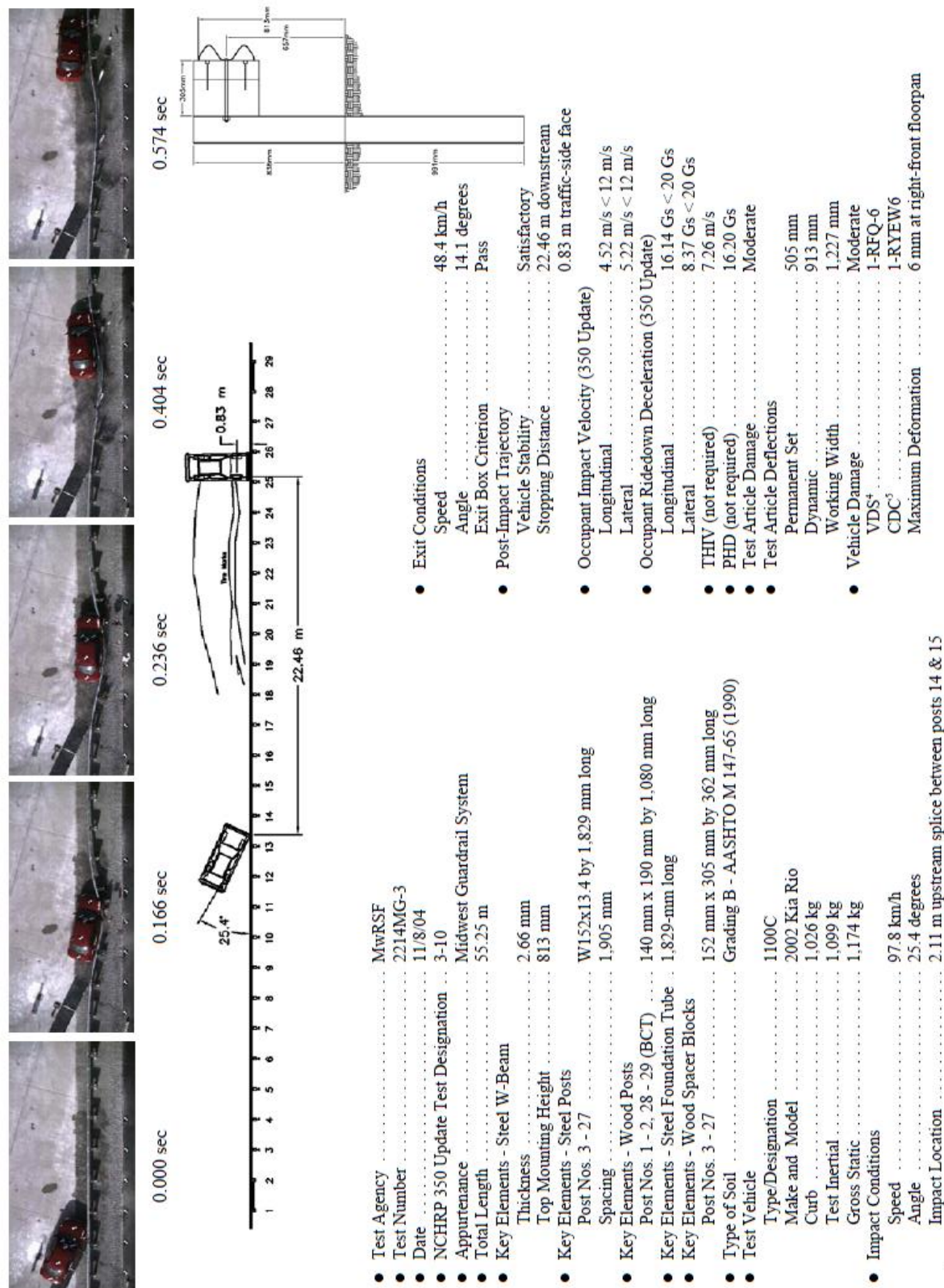


Figure 13. Summary of Test Results and Sequential Photographs, Test 2214MG-3

Figure 5: Full-Scale Test Summary

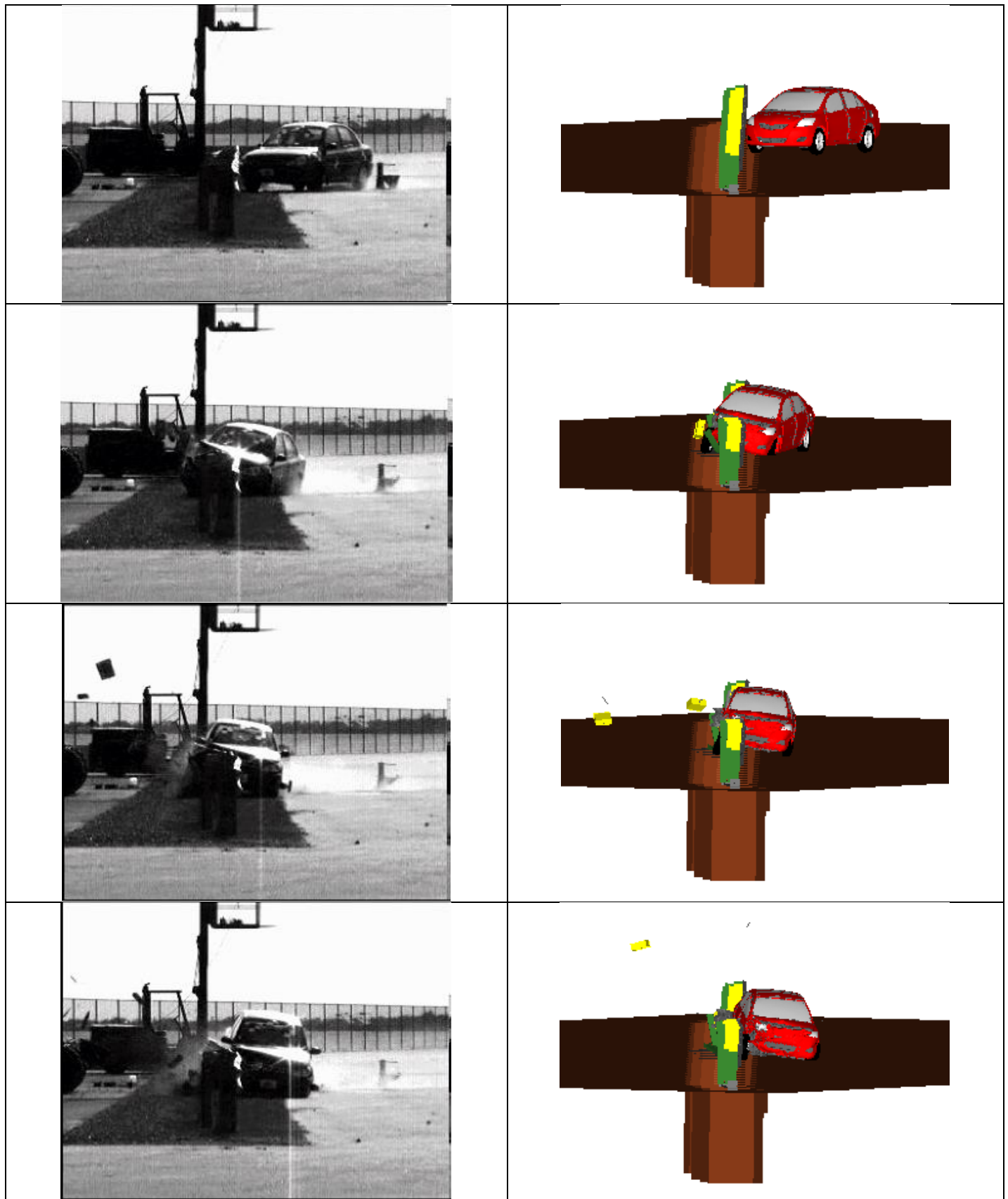


Figure 6a: Sequential Comparisons – Front View

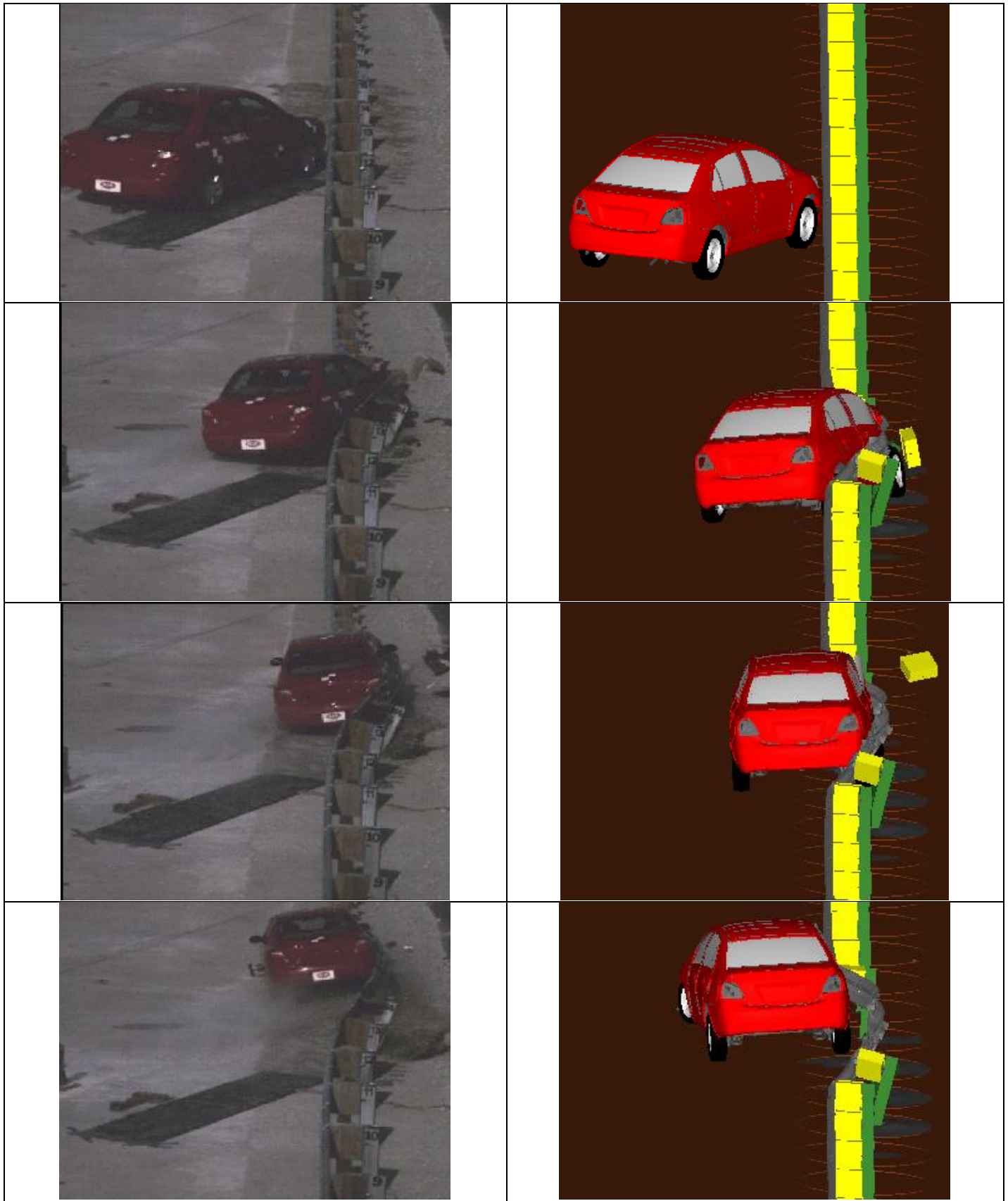


Figure 6b: Sequential Comparisons – Rear View

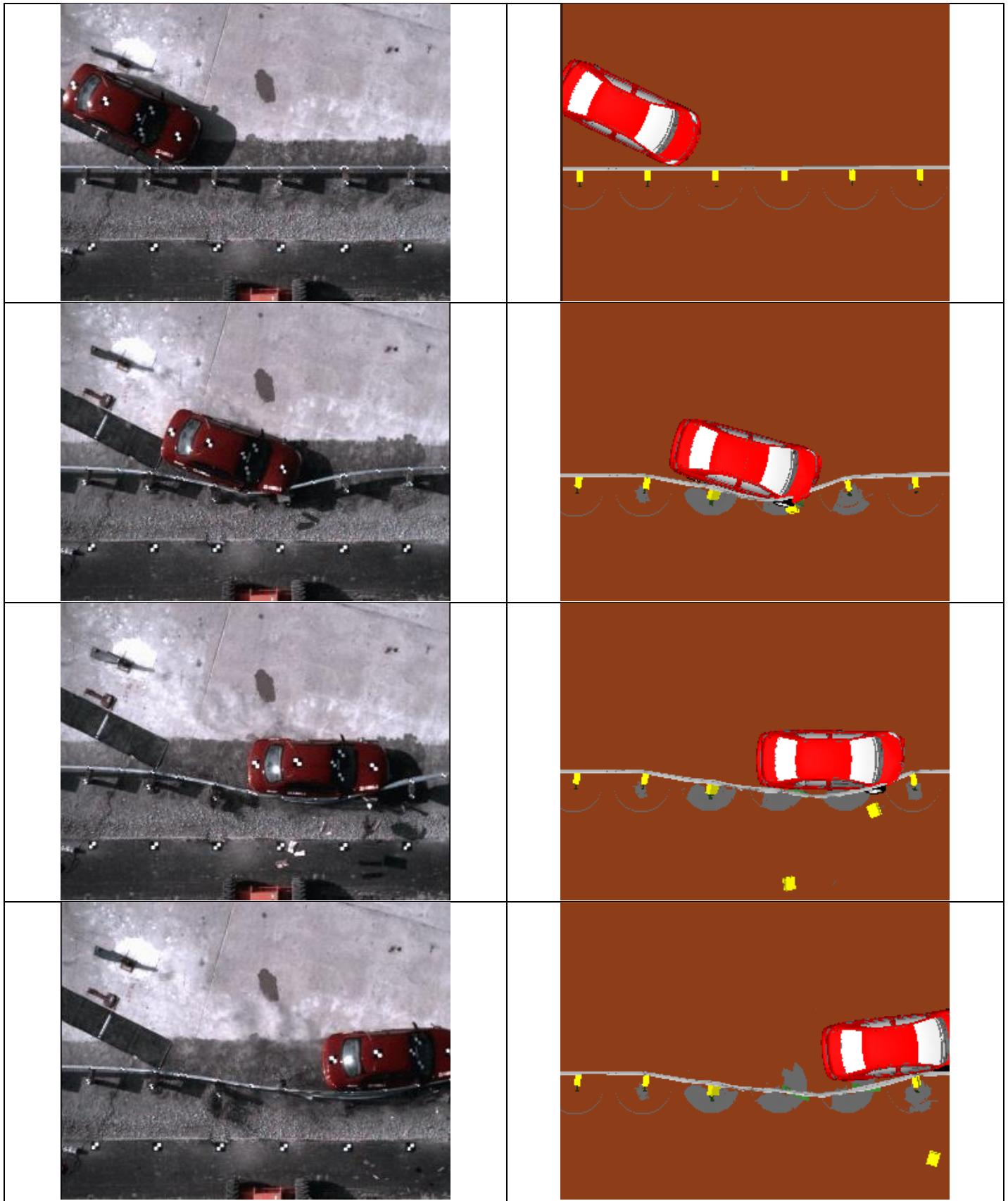


Figure 6c: Sequential Comparisons – Top View

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Comparison Case: 1100C Vehicle with New Jersey Safety Shape Barrier

Table F - Composite Verification and Validation Summary:

List the Report MASH08 Test Number		
Table C – Analysis Solution Verification	Did all solution verification criteria in table pass?	YES
Table D - RSVVP Results	Do all the time history evaluation scores from the single channel factors result in a satisfactory comparison (i.e., the comparison passes the criterion)?	NO
	If all the values for Single Channel comparison did not pass, did the weighted procedure result in an acceptable.	YES
Table E - Roadside Safety Phenomena Importance Ranking Table	Did all the critical criteria in the PIRT Table pass? Note: Tire deflation was observed in the test but not in the simulation. This due to the fact that tire deflation in not incorporated in the model. This is considered not to have a critical effect on the outcome of the test	NO
Overall	Are the results of Steps I through III all affirmative (i.e., YES)? If all three steps result in a “YES” answer, the comparison can be considered validated or verified. If one of the steps results in a negative response, the result cannot be considered validated or verified.	NO

NOTES:

The vehicle used in the test was a Kia Rio while the one used in the simulation was a Toyota Yaris. These two vehicles meet the MASH requirements and are similar in mass and overall geometry. The Yaris bumper however is higher which let some differences in the results between the test and simulation.