Test Report – PE21-015 UPPAbaby Knox Child Seat Lateral Movement

Mason Richards

Vehicle Research and Test Center

11/14/2024

Requestor:	Taylor Collins (ODI)			Bruce York (ODI)
Investigation Information:	ODI #	PE21-015		UPPAbaby Knox Lateral Movement
	VRTC #	DCD2021		UPPAbaby Knox Lateral Movement
Test Members:	Mason Richards (NHTSA - Test Engineer, Report Author)			Dave Disinger (TRC –Vehicle Driver)
	Jared Dowdy (TRC – Instrumentation)			Andrew Bockheim (TRC – Instrumentation)
Test Dates:	8/09/2022		**TO**	5/31/2023
Testing Units:	2016 Chevrolet Tahoe			UPPAbaby Knox Seat – Original Base CRS
	Various Peer CRS			UPPAbaby Knox – Revised Base CRS
Test Instrumentation:	FDIX force gauge			Digital protractor
	IMC data acquisition			AB Dynamics Gyro
	GPS unit			Accelerometer
	Measurement scale			TRC skid pad
	Belt tension gauge			AB Dynamics steering / brake robot
Test Scope:	Scope 1: Dynamic Testing Scope 2: Static Testing			
Issue Background:	**Per ODI's Opening Resume:** The National Highway Traffic Safety Administration (NHTSA) Office of Defects Investigation (ODI) received a manufacturer communication, sent to subject 2020 UPPAbaby Knox Convertible Child car seat owners, that alerts them the seat can exhibit lateral movement when used in the rearward facing position. The lateral movement can occur despite secure installation. The communication goes on to instruct owners to stop using the subject car seat immediately and that if they continue to use the car seat it will be at their own risk. No fatalities have been reported. The manufacturer produced a reported 1,808 Knox Convertible Child car seats and as of late 12/18/2020, indicated 100% of purchasers were contacted but that 411 seats had not been returned. The manufacturer outreach to consumers involved a letter, in which UPPAbaby requested owners to refrain from using the car seat. A second letter provided instructions for owners on how to disable the seat from further use and receive a monetary refund for the seat plus a fifty-dollar incentive for doing so. ODI opened the investigation to evaluate the scope, frequency, and consequence of the alleged defect in the subject 2020 UPPAbaby Knox Convertible Child car seat because a safety recall was not filed for this issue. **At the request of ODI:** The Vehicle Research and Test Center (VRTC) was requested to obtain subject child restraints [Commonly referred to as child car seats] and conduct benchmark testing. Dynamic testing focused on lane change maneuvers, which would impart lateral motion into the child seats when installed per the owner's manual. Static testing focused on applying forces on the restraint to create the highest moment possible with equipment readily available.			

1. Test Findings Summary

TEST	TOP FINDINGS
ISO 3888-1 Double Lane Change Maneuver (45 MPH)	UPPAbaby Knox seat base has impact on lateral stability performance. Lateral stability difference exists between UPPAbaby Knox original base and peers benchmarked.
High Severity Single Lane Change Maneuver (35 MPH)	UPPAbaby Knox seat base has impact on lateral stability performance. Lateral stability difference exists between UPPAbaby Knox original base and peers benchmarked.
High Force Static Test	Increase in inward tilt reaction found in Knox seats compared to peers tested at all applied forces. Unknown correlation to real world data (i.e. side impact crash, vehicle driving kinematics). Quasi-Static force application only. Vehicle layout impact unknown. Performance correlation between dynamic testing and static testing unknown.

2. Test Plan

2.1 Scope 1: Dynamic Testing

2.1.1 ISO 3888-1 Double Lane Change Maneuver

Goal: Characterize the lateral stability performance of the subject seat vs. its peers.

Test Procedure:

Install child restraints per manufacturer instructions in a rear facing orientation.
Perform 3x ISO 3888-1 style double lane change maneuver.
Determine maximum tilt angle of seat during maneuver.

2.1.2 High Severity Single Lane Change Maneuver

Goal: Characterize the lateral stability of the subject seat vs its peers at maximum repeatable condition with test vehicle readily available.

Test Procedure:

Install child restraints per manufacturer instructions in a rear facing orientation.
Perform high severity single lane change maneuver.
Determine maximum tilt angle of seat during maneuver.

2.2 Scope 2: Static Testing

2.2.1 High Force Static Test

Goals: Characterize lateral stability of the subject seat vs its peers by applying the highest moment attainable with readily available equipment.

Test procedure:

Install child restraints per manufacturer instructions in a rear facing orientation.
Apply force slowly by hand to 100N / 200N / 300N.
Document tilt angle at each force setpoint.

3. Test Vehicle and Child Restraints

A 2016 Chevrolet Tahoe was used for testing due to availability and interior volume allowing for ease of instrumentation with the child restraints installed. All child restraints were installed in the middle row of the vehicle. The vehicle had the following interior measurements shown in Figure 1.



Figure 1 - Test Vehicle

For maneuver repeatability and accuracy, an AB Dynamics steering and brake robot was used for the dynamic test portions. The installed condition of this equipment in the vehicle can be seen in Figure 2.



Figure 2 – AB Dynamics Steering and Brake Robot

A variety of child restraints were readily available to VRTC for conducting these tests. With agreement from ODI, a focus was placed on all-in-one or convertible child restraints manufactured both before and after the subject restraints were manufactured. This process allowed for any outside influences from proposed regulations or industry changes to be effectively captured more fairly. All seats chosen had rear facing installation capability and were within the weight limits for the ballast dummy chosen. In

addition, a vaiety of base designs and seat features were included in the testing. A total of 13 versions of child restraints were tested, as shown in Figure 3.

	Manufacturer	Seat Name	CRS Type	Quantity	Model Number	Mfg. Date	Adjustable base?
1	Graco	4EVER	All in One	1	1906082	5/29/14	Yes
2	Britax	Boulevard	Convertible	1	E1A325Q	3/8/2017	Yes
3	Safety 1st	Air Protect	Convertible	1	CC114CLC	2/22/2017	Yes
4	Graco	My Ride 65	Convertible	1	*Not Recorded*	*Not Recorded*	No
5	Evenflo	Triumph LX	Convertible	1	38211713	8/28/2018	Yes
6	Cosco	Scenera Next	Convertible	1	CC145DEN	9/26/2018	No
7	Maxi-Cosi	Pria 85	Convertible	1	CC121CTF	1/10/2020	Yes
8	Evenflo	Tribute	Convertible	1	3812198	6/30/2021	No
9	Chicco	NextFit	Convertible	1	06 079853 950 070	6/1/2021	Yes
10	Uppababy	Knox Old	Convertible	1	1119-KNX-US-JKE	12/27/2019	Yes
11	Uppababy	Knox Revised	Convertible	1	NA - No Labels	NA - No Labels	Yes
12	Cybex	Sirona S	Convertible	1	519004435	07/2021	Yes
13	Nuna	Revv	Convertible	1	CS136000CN	4/14/2022	Yes



Figure 3 – Child Seats Tested

A comparison between the UPPAbaby Knox original base and the revised base can be seen in Figure 4 below.



Component	Measurement	Knox Old	Knox Revised
Base	Length	330mm	365mm
	Width	300mm	356mm
	Height	135mm	135mm

Figure 4 - UPPAbaby Knox Base Comparison

All testing was conducted with the same ballast dummy design. A 3YO Hybrid III dummy weighing approximately 36 lb. was installed in the child restraints. The child restraint harness tension was verified with the use of a force gauge. A summary of a typical ballast dummy attributes is found in Figure 5.

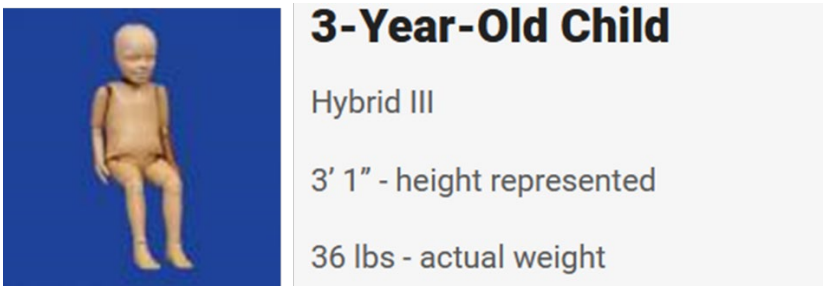


Figure 5- 3YO Hybrid III Dummy

4. Test Results

4.1 Scope 1: Dynamic Testing

4.1.1 ISO 3888-1 Double Lane Change Maneuver (45 MPH)

The restraints were evaluated with a robotically programed ISO 3888-1 style double lane change maneuver performed at 45 MPH. During the initial phase of dynamic testing, video recordings of the test setup were collected, and video analysis was conducted to determine the maximum inward or outward tilt of the child restraint. The maneuver was programmed to be repeated 3x per run for each child restraint. Due to the nature of how the steering and brake robot was programed, changes in weather and track conditions, some variation from the ISO 3888-1 profile was seen, however, a focus was placed on lateral acceleration values and repeatability. The ISO 3888-1 maneuver profile is illustrated in Figure 6.

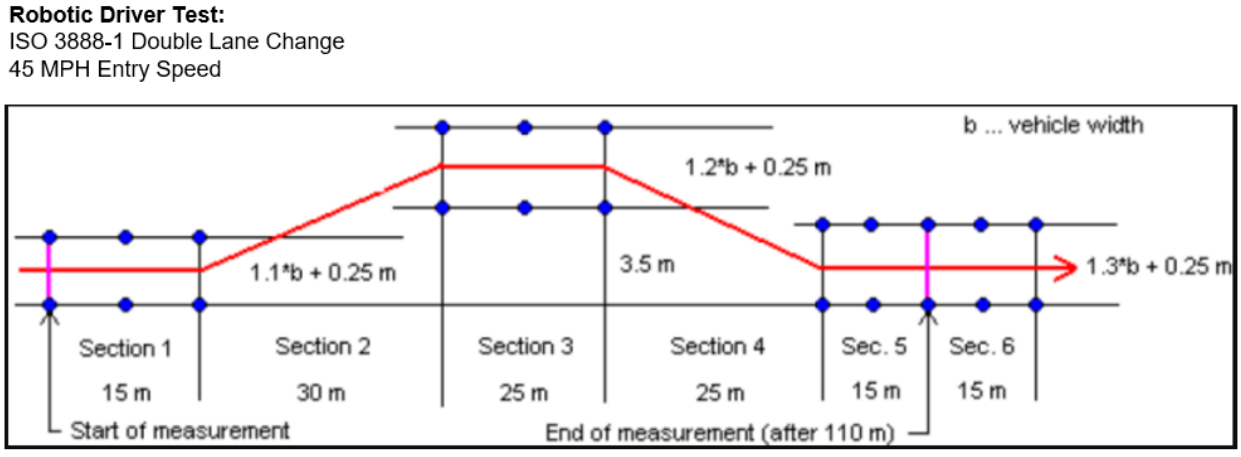


Figure 6- ISO 3888-1 Maneuver

The maneuver was verified to be acceptable through the analysis of three randomly chosen runs that were analyzed for lateral acceleration and for anomalies. These tests had a high level of repeatability. The resulting maneuver conducted is shown in Figure 7.

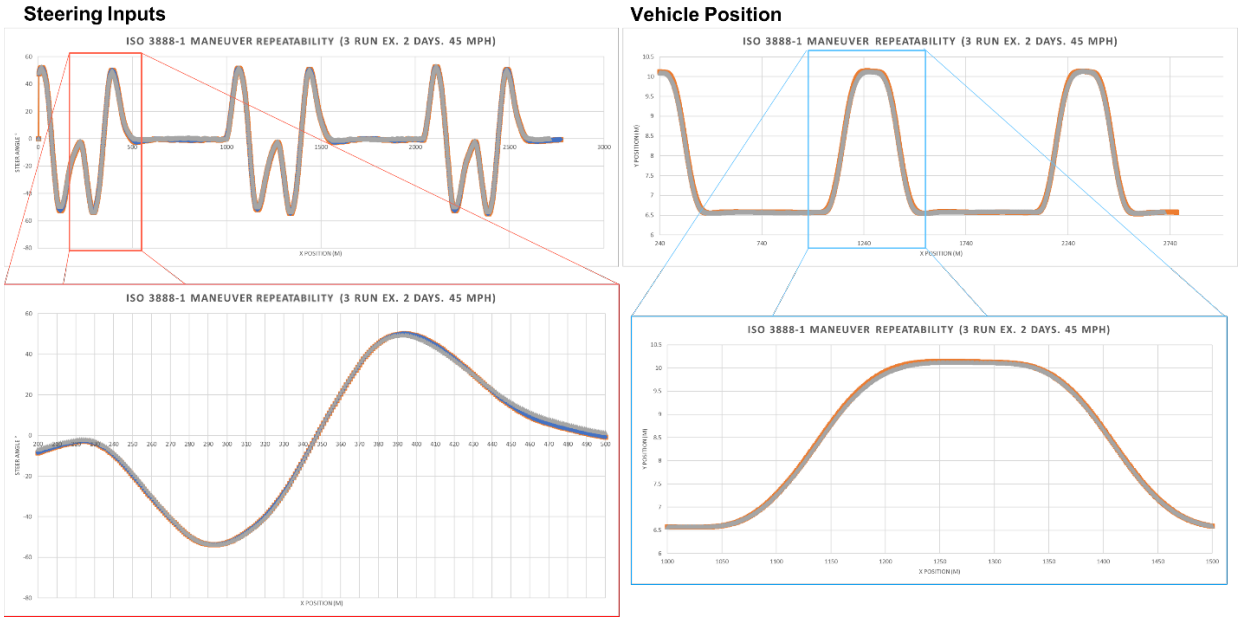


Figure 7 - ISO 3888-1 Maneuver (Actual)

This maneuver resulted in ~0.5g of maximum lateral acceleration as seen in Figure 8 below. In addition, confirmation of similar levels of lateral acceleration between runs was confirmed.

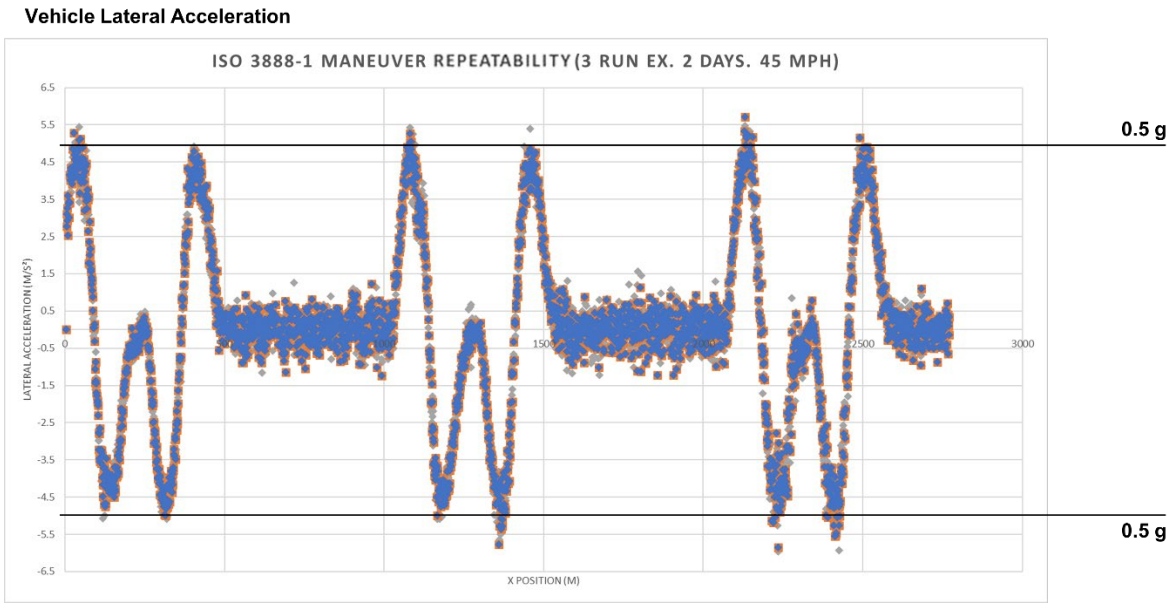


Figure 8 - Vehicle Lateral Acceleration

The observed maximum tilt of the restraints as a result of this maneuver is plotted in Figure 9, below. The maximum angle of tilt was extrapolated using video analysis and is deemed an estimate only due to distortion and potential camera mount movement during the test. Through this analysis, it was seen that the change in base design of the UPPAbaby Knox child restraints had an impact on its lateral movement performance.

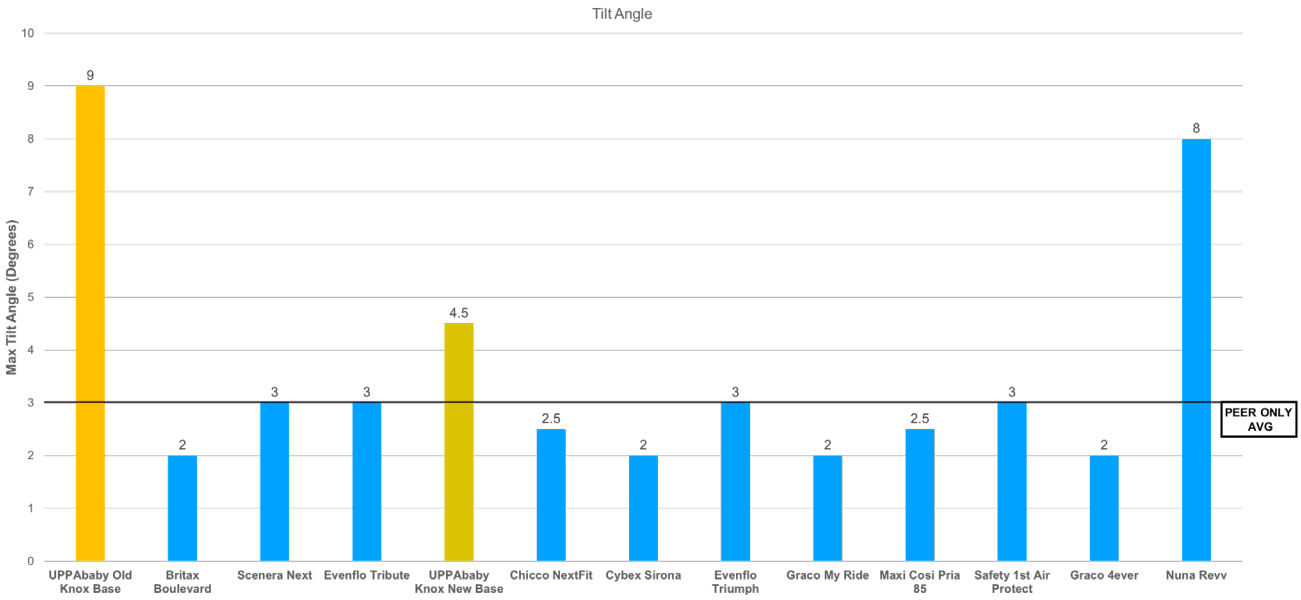


Figure 9 - Tilt Angle (Per Video Analysis)

Visual representations of these tilt angles are shown below in Figure 10 and Figure 11. The UPPAbaby Knox tests are included in both figures to aid in visual comparison. The maximum tilt angles noted on the images in Figures 10 and 11 were found through video frame extrapolation, which was done by comparing the targets placed on the ballast dummy's head at the start of the test and at the maximum tilt angle due to the maneuver. The images at these two points were then combined and overlayed to calculate the maximum tilt angle as shown by the red lines.

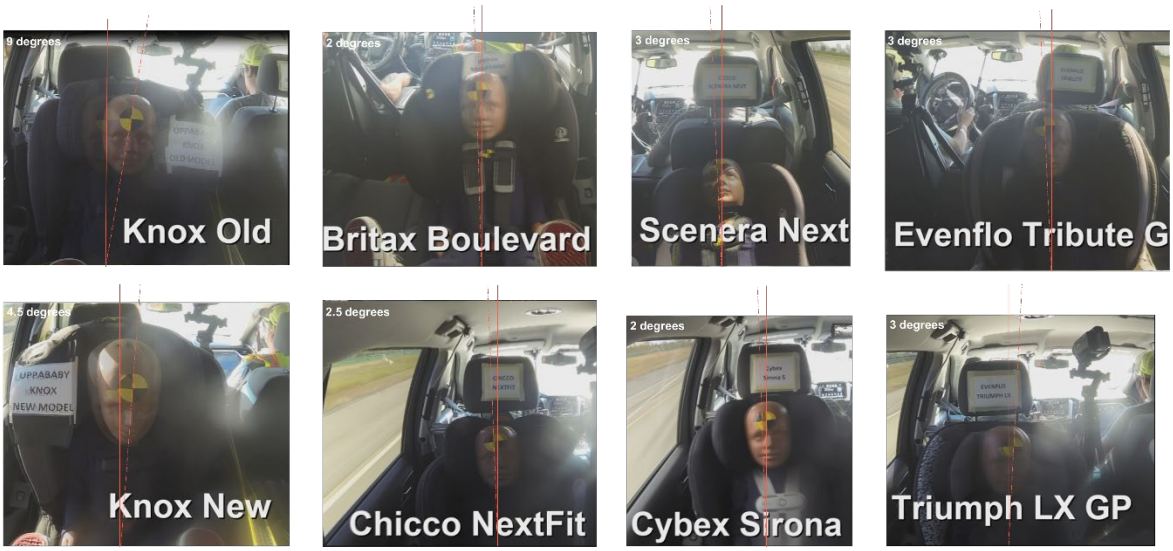


Figure 10 - Max Tilt Angle (1/2)

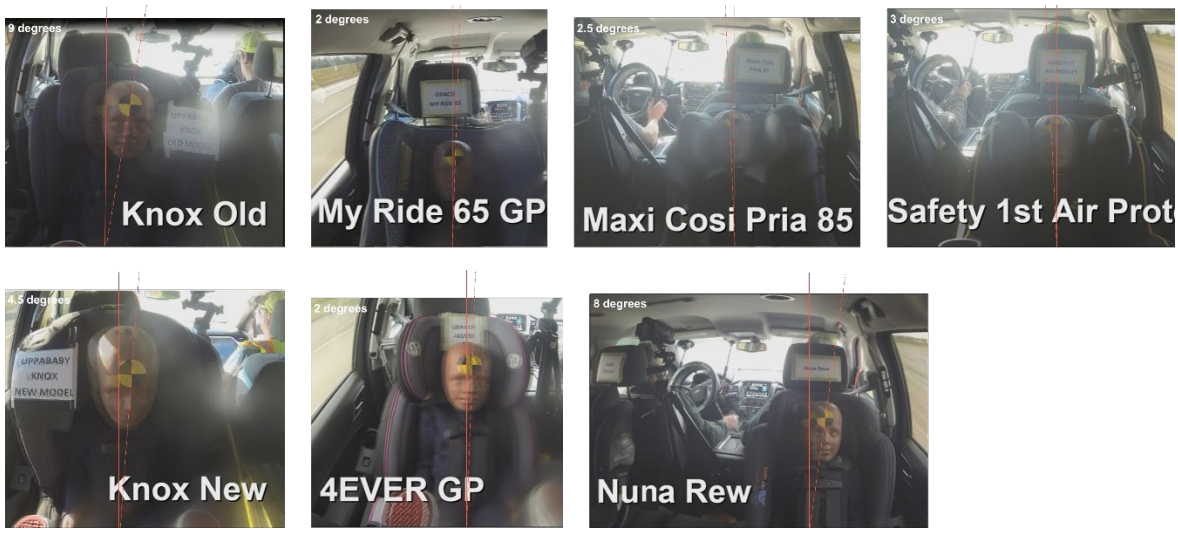


Figure 11 - Max Tilt Angle (2/2)

After the completion of the ISO 3888-1 maneuver, an analysis of the maneuver results and of ODI data was conducted to identify and select the poorest performing child restraints. With the selection of these restraints, it was determined that a higher severity maneuver was needed to determine if the performance gap between the child restraints increases at a higher lateral acceleration. In addition, test enhancements to better capture the child restraint movement were incorporated through the addition of a gyroscope for child restraint angle data collection. The following child restraints in Figure 12 were chosen for the higher severity dynamic testing.

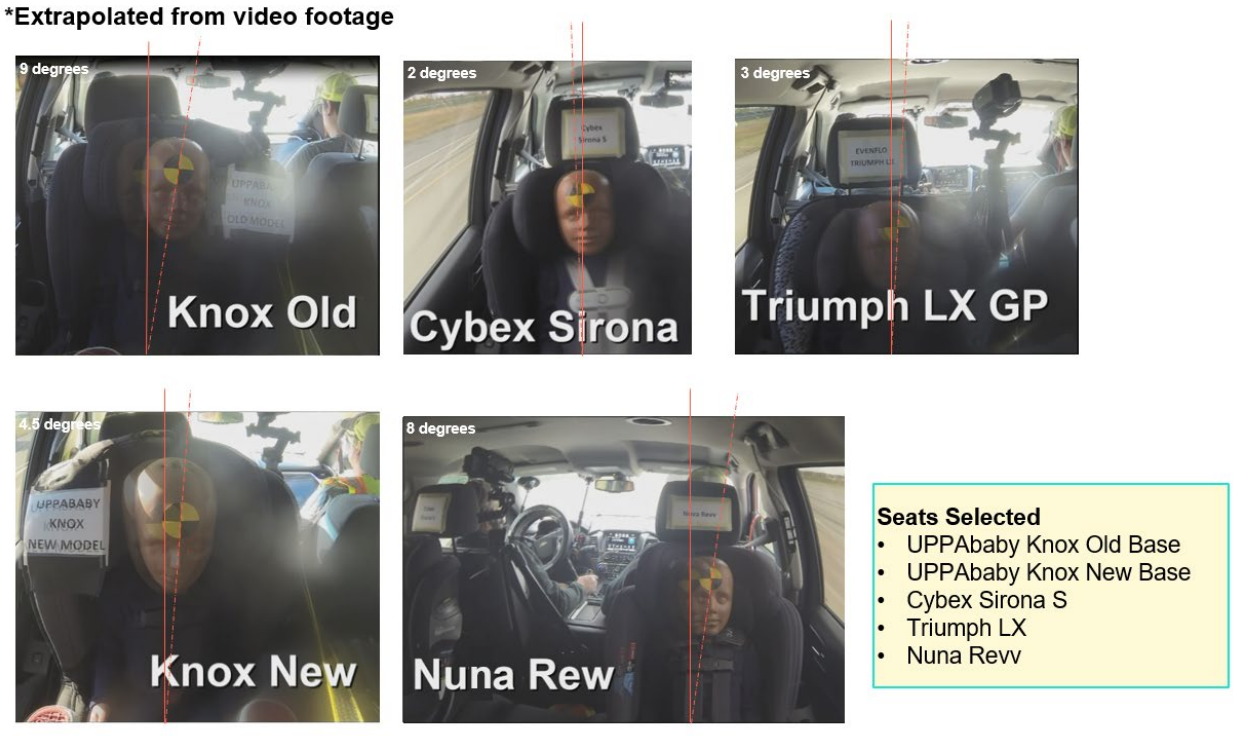


Figure 12 - Higher Severity Maneuver Seats

4.1.2 High Severity Single Lane Change Maneuver (35 MPH)

The ISO 3888-1 maneuver resulted in a maximum lateral acceleration of ~0.5g. An increase in vehicle speed for this maneuver was attempted as a method to increase the lateral acceleration, however, due to the steering robot calibration to the vehicle, the increased vehicle speeds did not result in a significant change to the maximum lateral acceleration. As a result, the steering robot was set to path following mode and higher severity single lane change maneuvers were developed by a test driver at lower speeds. The final maneuver chosen resulted in the greatest lateral acceleration without activating vehicle stability control. Figure 13 below shows the plotted final maneuver compared to the ISO 3888-1 style maneuver conducted in Section 4.1.1.

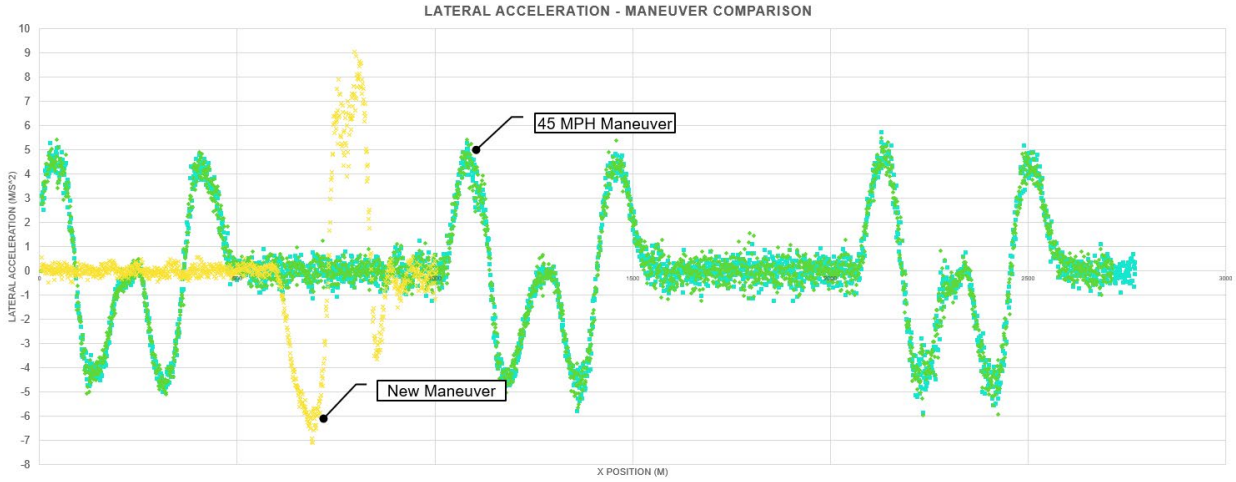


Figure 13 - High Severity Maneuver

The high severity maneuver was completed at a lower speed of 35 MPH and incorporates quicker steering inputs. When compared to the initial ISO 3888-1 dynamic maneuver at 45 MPH, the 35 MPH maneuver resulted in a higher lateral acceleration of ~0.9 g's whereas the 45 MPH maneuver resulted in a maximum lateral acceleration of ~0.5g. Repeatability of the maneuver was verified by comparing three random runs with the steering robot inputs and the vehicle GPS positioning shown in Figure 14 and Figure 15.

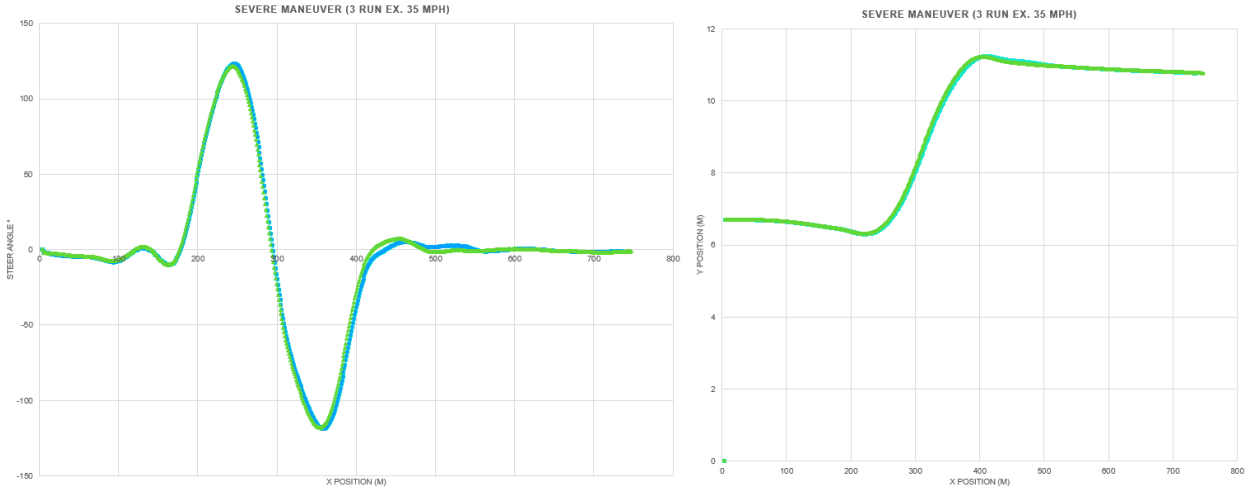


Figure 14 - High Severity Maneuver Repeatability

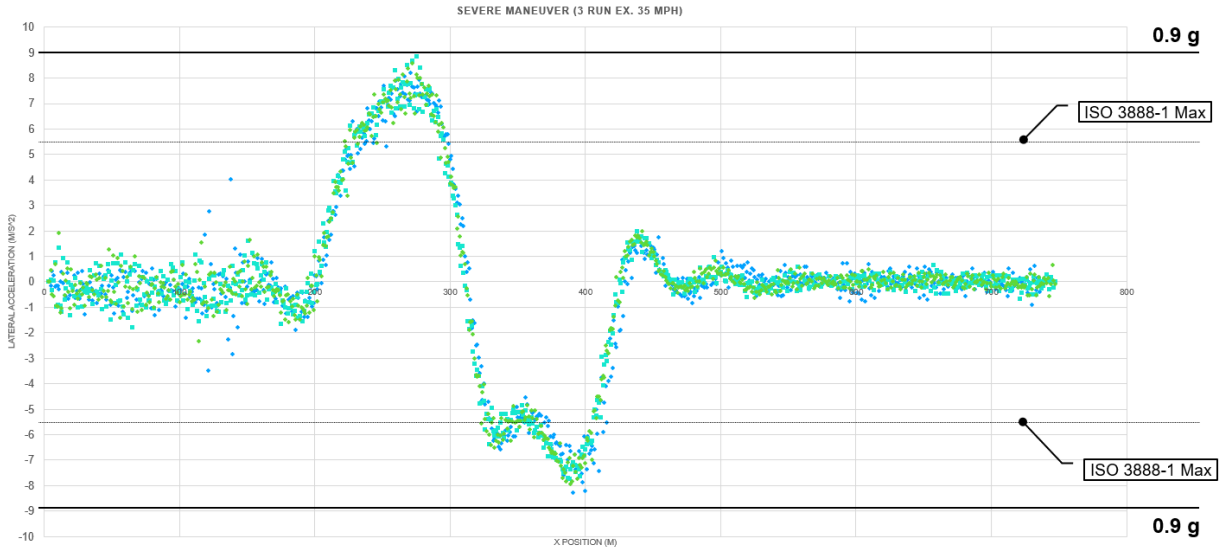


Figure 15 - High Severity Maneuver Repeatability

These tests were conducted under the same methodology as the initial dynamic testing was conducted. All tests used the same ballast dummy design, a Hybrid III 3-year-old ATD weighing ~36 lbs., which was installed in the restraints and the internal harness tension was verified with the use of a force gauge. All tests were conducted in the rear facing orientation and installed per the manufacturer instructions. An AB Dynamics gyro and mount was added to the side of the child restraint for additional data collection. The gyro and mount added a combined weight of 2.70 lbs. to each child restraint. A total of 10 tests were conducted (two runs per child restraint) during this testing phase. A summary of the seats and instrumentation is shown in Figure 16.

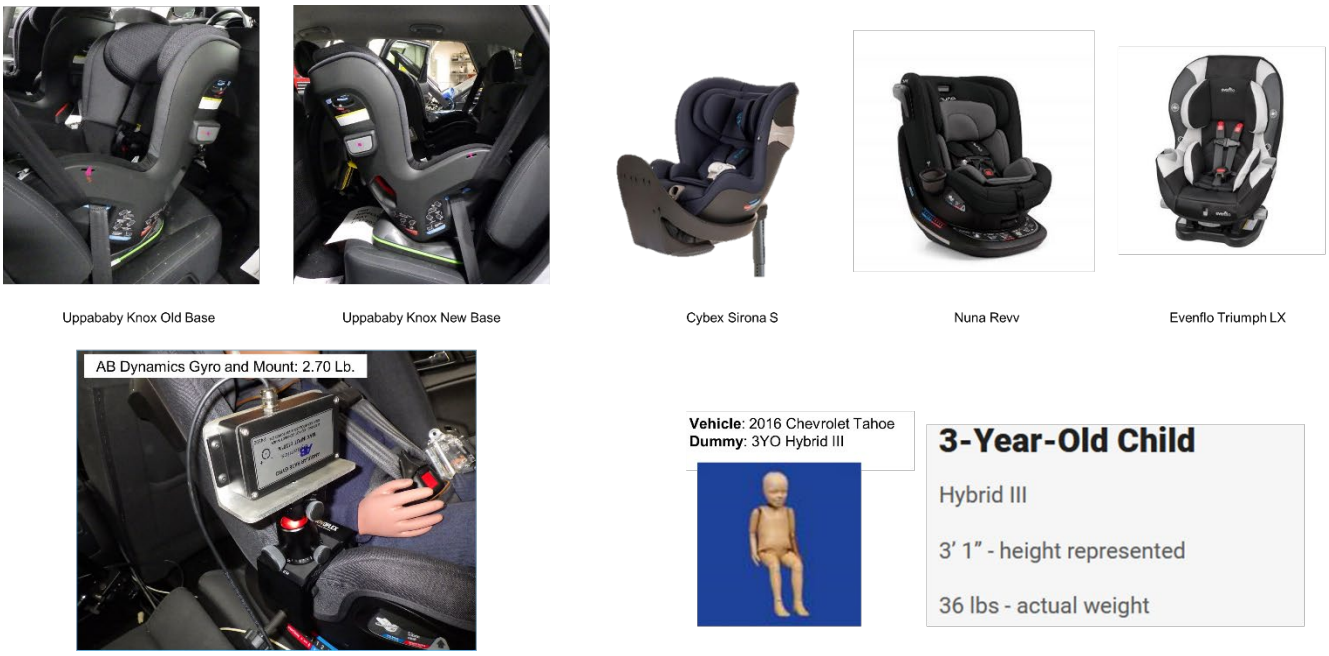


Figure 16 - High Severity Seats and Equipment

The degrees per second and maximum tilt angle were collected and analyzed from the AB Dynamics gyro (Figure 17). The maximum inward (toward the center of the vehicle interior) and outward (toward the vehicle door panel) tilt of each child restraint was analyzed independently to evaluate the impact of any interior components, such as the vehicle door arm rest (Figure 19). The total tilt range was also analyzed to determine maximum tilt movement of the child restraint throughout the test, which could result in a greater chance of head movement for a child in the child restraint (Figure 18). Video recordings of all runs were collected.

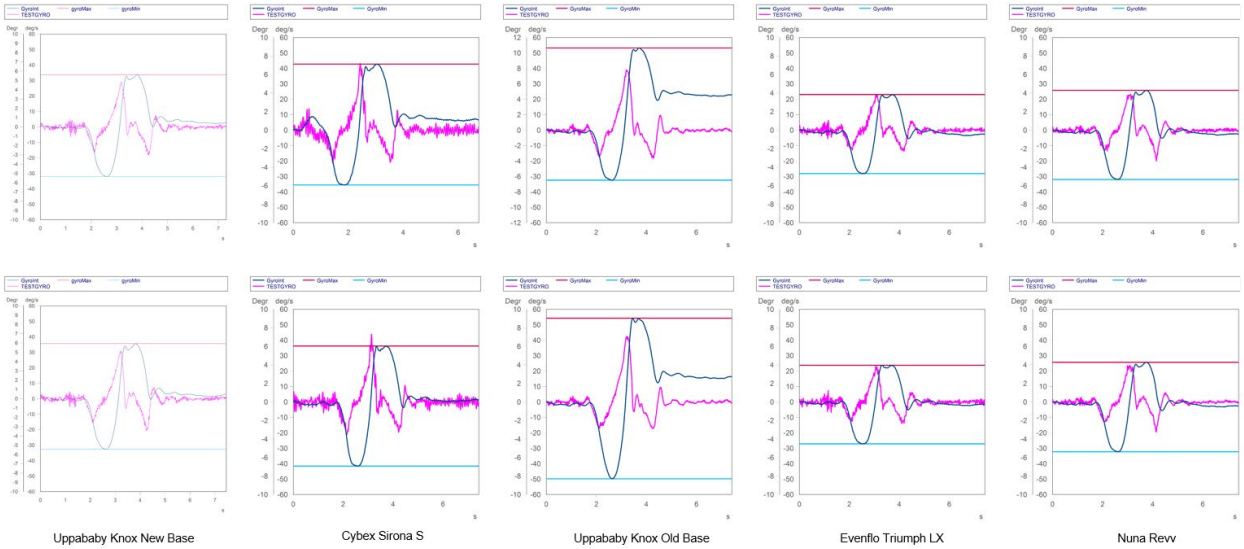


Figure 17 - High Severity Gyro Data (Two Runs Per CRS)

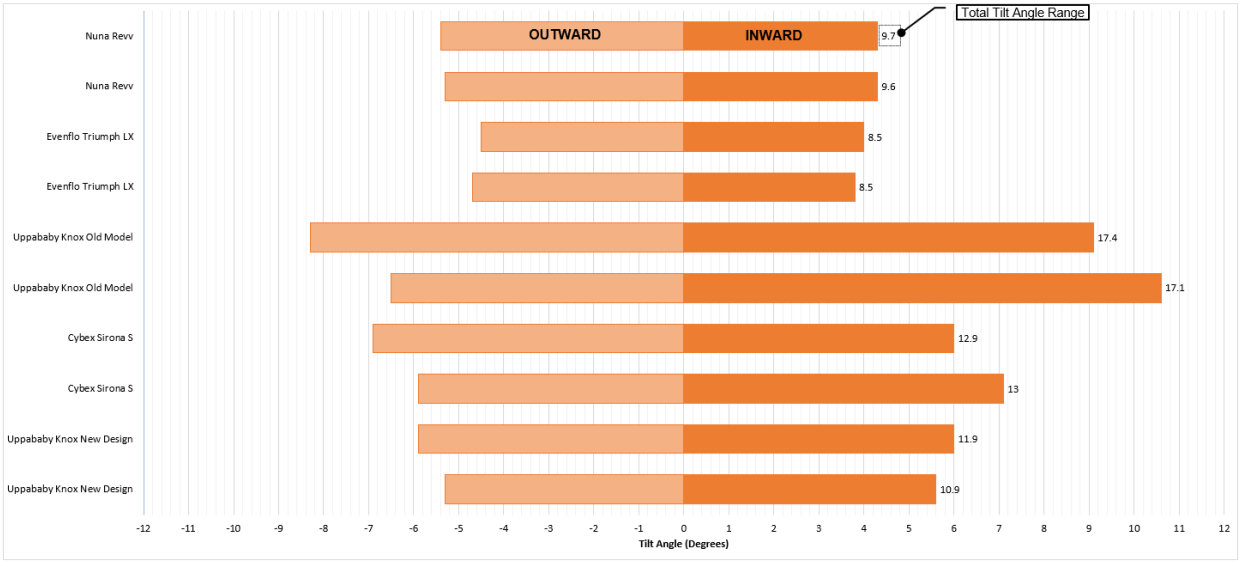


Figure 18 - High Severity Tilt Range (Two Runs Per CRS)

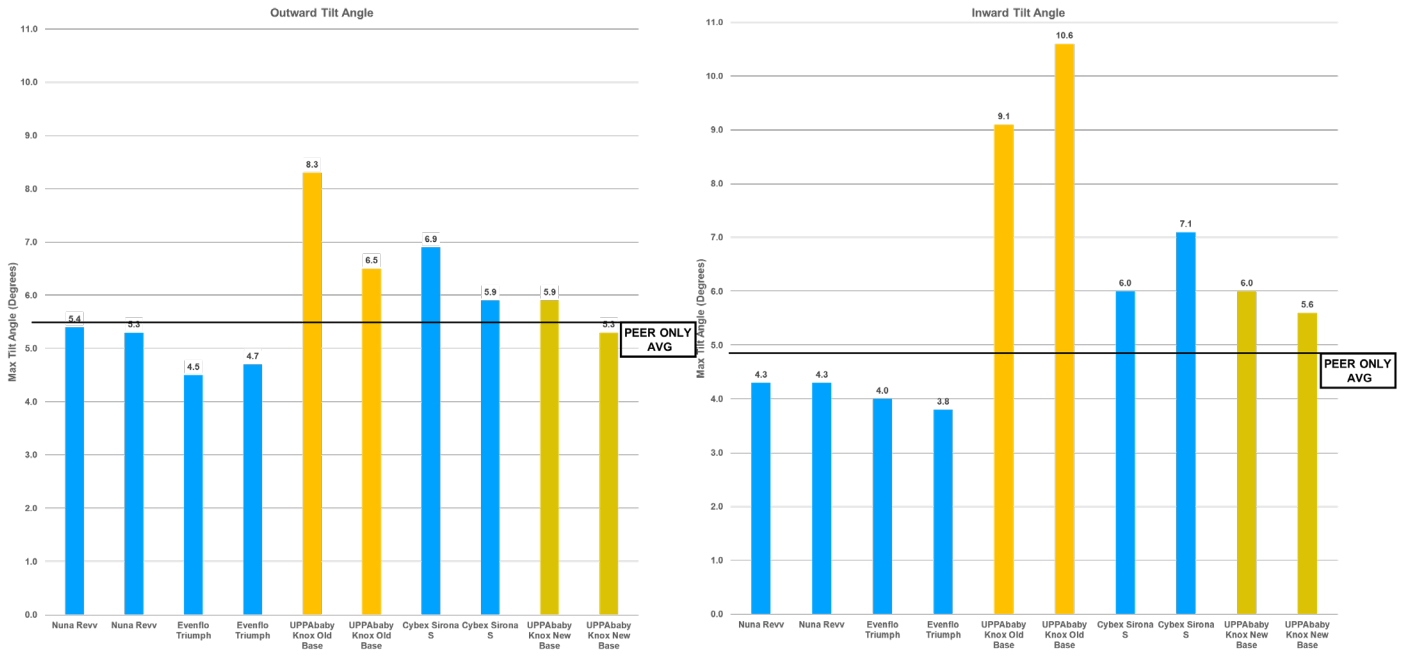


Figure 19 - High Severity Tilt Angle (Two Runs Per CRS)

The results of the higher severity tests show that the UPPAbaby Knox with the old base had the greatest overall tilt angle range, outward tilt angle, and inward tilt angle. The UPPAbaby Knox with the revised base had better performance in all aspects analyzed when compared to the original base. The UPPAbaby Knox with the revised base had either similar or better performance to the peer seats evaluated. The higher lateral acceleration of the maneuver resulted in greater child restraint movement for most seats tested. Due to vehicle limitations for higher lateral acceleration in excess of the single lane change maneuver, high force static testing was performed to determine the impact that larger moments on the child restraints would have.

4.2 Scope 2: Static Testing

Static testing focused on applying forces at locations on the child restraints to create the highest possible moment with test equipment that is readily available. The goal of these tests was to evaluate tilt angles of the child restraints under three static loads that are potentially greater than the forces that were applied to these restraints during the dynamic, vehicle-based maneuvers. The same 2016 Chevrolet Tahoe, child restraints, and ballast dummy that were used in dynamic tests were utilized for this static testing. The subject UPPAbaby restraints and two of the peer child restraints from the high severity maneuver tests were selected for initial viability testing. The test setup was as follows:

Test Setup:

-Rear facing seat installation – lap and shoulder belt used
-3YO Hybrid III Dummy – ~36 lbs. weight
-Belt and harness tension verified with force gauge
-Digital force gauge (FDIX Force One) and digital protractor used for force/tilt measurements
-100N / 200 N / 300 N forces applied to seat
-Seats chosen:

- UPPAbaby Knox old base
- UPPAbaby Knox new base
- Nuna Revv
- Evenflo Triumph

The following test procedure was then used for each seat tested:

Test Procedure:

1. Seat installed per child restraint instruction manual
2. Install ballast dummy into CRS per FMVSS No. 213
3. Verify belt and harness tension
4. Apply force slowly with force gauge to 100N / 200N / 300N
5. Document tilt angle at each applied force

To create the maximum moment on the seat, the farthest, stable points on the seats were chosen as measured from the belt path. The point chosen and a visual representation of the test setup can be seen in Figure 20.



Figure 20 - Static Testing Setup

After the completion of the tests, the final position of the child restraints were documented visually and can be seen in Figure 21 and Figure 22. Combined rotation of the base and tilt angle was visible in the child restraints.



UPPAbaby Knox Old Base **UPPAbaby Knox New Base**

Figure 21 - End of Test



Nuna Revv

Evenflo Triumph

Figure 22 - End of Test

The resulting inward tilt angle at each applied force setpoint is plotted in Figure 23. An increase in the inward tilt was observed in both UPPAbaby Knox seats when compared to the selected peers at all applied forces. Many test limitations were identified, and additional sampling and analysis was not pursued beyond these initial viability tests due to these limitations.

Test Limitations Identified:

- Unknown correlation to real world data (i.e. side impact crash, vehicle driving kinematics).
- Quasi-Static force application only.
- Impact with other vehicle layouts is unknown.
- Performance correlation between dynamic testing and static testing unknown.

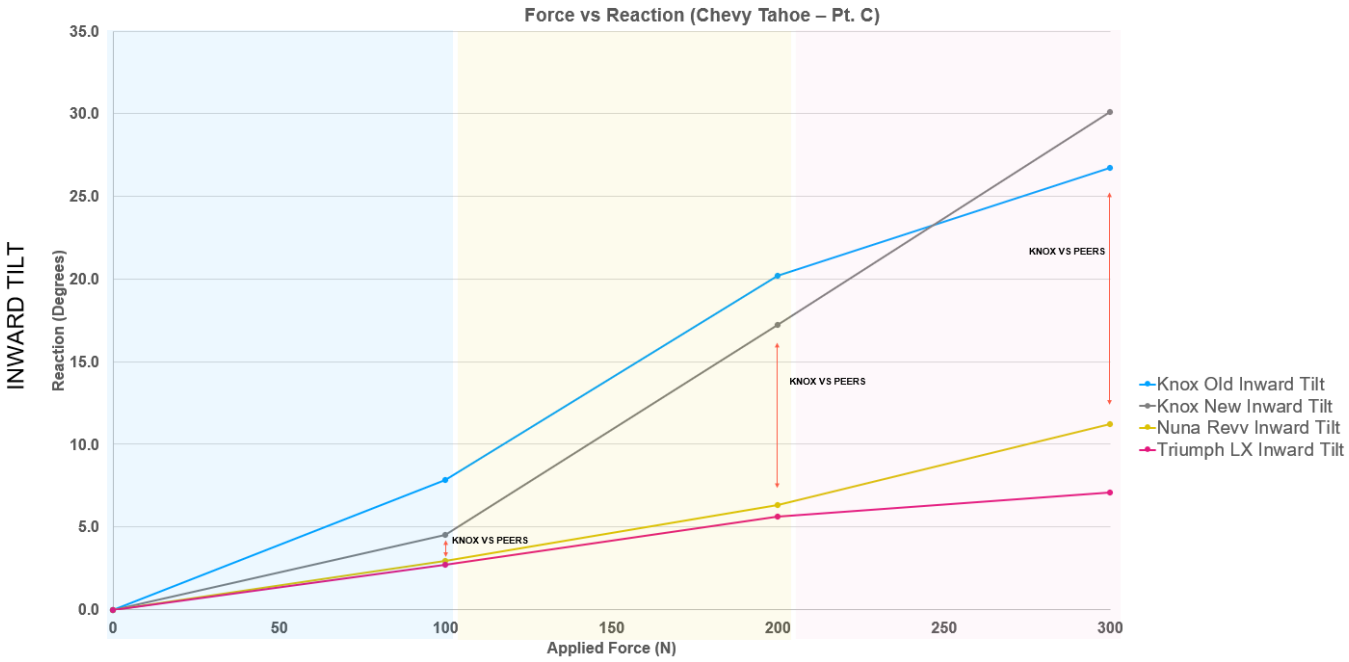


Figure 23 – High Force Static Testing