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Evaluation of LATCH Usability Tools Update

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16. Abstract

Federal Motor Vehicle Safety Standard No. 225, Child restraint anchorage systems, requires that nearly all motor vehicles be equipped with Lower Anchors and Top Tethers for Children (LATCH) anchors. NHTSA published a Notice of Proposed Rulemaking for FMVSS No. 225 in January 2015 that proposed three new requirements for LATCH lower anchors in vehicles: a minimum clearance angle, a maximum attachment force, and a maximum depth of the anchor in the seat bight. These requirements were proposed to improve lower anchor usability and promote correct installation of child restraint systems. After the comment period for the NPRM, NHTSA reevaluated the proposed tools and procedures. During this time, the Insurance Institute for Highway Safety released its rating protocol along with tools to assess the usability of the lower anchors with similar requirements. After an assessment of the comments received on the NPRM and of the IIHS tools and procedures, NHTSA made some modifications. NHTSA then contracted with the University of Michigan Transportation Research Institute to do a robust repeatability and reproducibility assessment with the modified tools and provide statistical analysis on the results of the usability of the toolsets. UMTRI made additional modifications prior to its analysis to improve the tools and procedures. Both the modified NHTSA and UMTRI toolsets were returned to NHTSA's Vehicle Research and Test Center for further evaluation. Additional modifications were made to the NHTSA tools based on observations from the UMTRI study. Both versions of the toolsets were tested during a VRTC usability study to compare with results from the UMTRI study. The results of these studies and descriptions of the modifications made to the tools and associated procedures are contained in this report.

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Table of Contents

List of Figures

List of Tables

Executive Summary

Federal Motor Vehicle Safety Standard (FMVSS) No. 225, Child restraint anchorage systems requires that nearly all motor vehicles be equipped with Lower Anchors and Tethers for Children (LATCH) anchors (49 CFR 571.225). LATCH anchors are a standard way of installing child restraint systems (CRSs) independent of vehicle seat belts. LATCH consists of two lower anchors and a top tether anchor. The intent of the LATCH requirements was to make it easier for CRSs to be installed in vehicles and to be installed correctly. In January 2015 the National Highway Traffic Safety Administration published a Notice of Proposed Rulemaking (NPRM) that proposed three new requirements for lower LATCH anchors of minimum clearance angle, maximum attachment force, and maximum depth of the anchor in the seat bight (80 FR 3744, 2015).

In response to the comments on the NPRM for FMVSS No. 225, NHTSA reevaluated the proposed tools and procedures. During this time, the Insurance Institute for Highway Safety (IIHS) released its rating protocol along with tools to assess the usability of the lower anchors with similar requirements. After an assessment of the comments received on the NPRM and of the IIHS tools and procedures, NHTSA made some modifications. The biggest changes made to the NHTSA tools were an update to the attachment force tool (AFT) to add a guide rod and updated instrumentation similar to the IIHS tool; the addition of a pulley bridge to apply a 67-newton (15-lb) force vertically and digital instrumentation to the clearance angle tool (CAT); and a change from reading the depth measurement at 30° from vertical to reading it at 20 to 40° from horizontal for the anchor depth tool (ADT).

NHTSA then contracted with the University of Michigan Transportation Research Institute (UMTRI) to do a robust repeatability and reproducibility assessment with the modified tools and provide statistical analysis on the results of the usability of the toolsets. UMTRI made additional modifications prior to its analysis to improve the tools and procedures. These included redesigning the ADT by adding a positioning view bar and scale to measure the depth, adding an actuator and support leg to the AFT, and making small modifications to the pully bridge used for the CAT (Klinich et al., in press).

Both the modified NHTSA and UMTRI toolsets were returned to NHTSA's Vehicle Research and Test Center (VRTC) for further evaluation. Additional modifications were made to the NHTSA tools based on observations from the UMTRI study. Both versions of the toolsets were tested during a VRTC usability study to compare with results from the UMTRI study. The results of these studies and descriptions of the modifications made to the tools and associated procedures are contained in this report.

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Background

FMVSS No. 225, Child restraint anchorage systems, requires that nearly all motor vehicles be equipped with LATCH anchors (49 CFR 571.225). LATCH anchors are a standard way of installing CRSs independent of vehicle seat belts. LATCH consists of two lower anchors and a top tether anchor. The intent of the LATCH requirements in vehicles was to make it easier for CRSs to be installed in vehicles and to be installed correctly.

NHTSA released an NPRM in January 2015 that proposed new requirements for the lower anchors in vehicles. The proposed tools described in the NPRM are the ADT, the AFT, and the CAT (Figures 1 to 3). These tools have associated proposed performance requirements as follows: ADT: a maximum depth of anchor in seat bight of 20 mm (0.8 inch); AFT: maximum attachment force of 178 newtons (40 lb), and the CAT: a minimum clearance angle of 54°. These tools were presented and discussed in a NHTSA report, *Evaluation of LATCH Usability Procedure* (Louden et al., 2014) released with the NPRM. These tools were based on the 2012 UMTRI study and evaluation that surveyed 98 vehicles (MY 2010 and 2011) that documented the characteristics of child restraint anchorage systems (Klinich et al., 2012).

Figure 1. NPRM Anchor Depth Tool, ADT

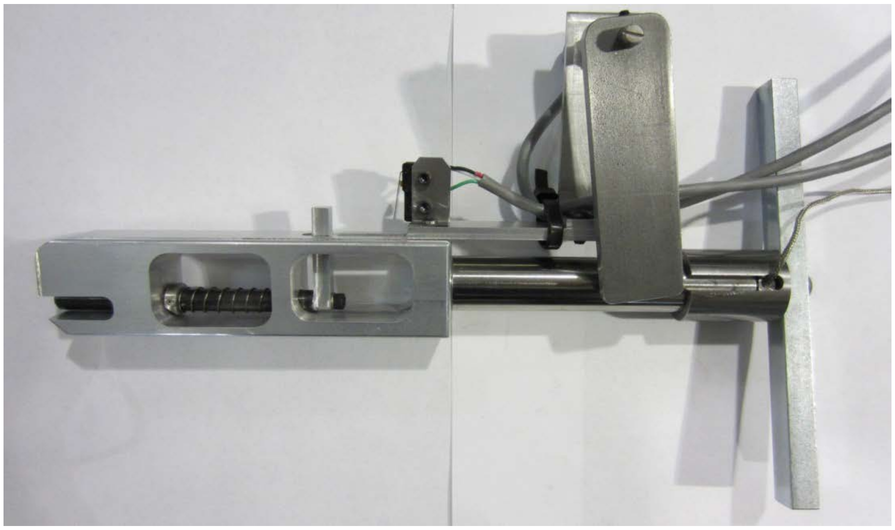

Figure 2. NPRM Attachment Force Tool, AFT

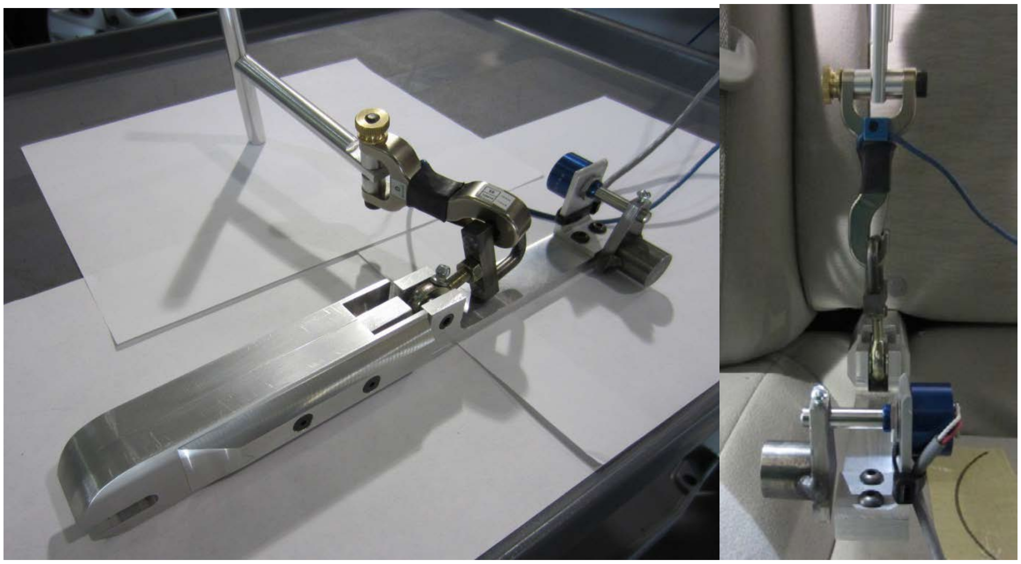

Figure 3. NPRM Clearance Angle Tool, CAT

This report documents the design changes to the proposed lower anchor usability tools and the different studies supporting the design changes. Revisions to the associated procedures were also made as a result of these studies, which are presented in this report.

Modification Discussion Post-NPRM

NPRM Comments

After the NPRM was released, comments from industry were presented to NHTSA on the tools and how they were performing in the field. Some comments stated that the proposed tools were bulky and had outdated instrumentation. Concerns were presented regarding the tools not being repeatable and ambiguities with all the tools, but there were larger concerns raised with both the force and depth tools. Some commenters found the tools to be difficult to use and operator dependently. In addition, users commented that NHTSA should harmonize or adopt the tools and procedures being used by the IIHS for consistency of evaluation on the lower anchor attachments.

Insurance Institute for Highway Safety LATCH Tools and Procedures

During the time of the NHTSA July 2014 initial evaluation of the tool design and since the release of the NPRM for FMVSS No. 225, IIHS was also working on assessing the rear anchors by using a variety of tools. It had developed its own tools based on the UMTRI LATCH Usability in Vehicles study (Klinich et al., 2012). IIHS released its own ease-of-use ratings with criteria that matched those proposed by NHTSA in June 2015.[1] However, although the IIHS tools were similar to those proposed in the NPRM, there were some differences. NHTSA therefore decided to evaluate the IIHS tools and procedures and compare them to the NPRM-proposed tools and test protocols.

The biggest difference between the NHTSA NPRM and IIHS tools was the incorporation of the depth measurement feature into the force tool. The IIHS force/depth tool added a guide rod with 2-cm colored depth increments to measure the depth and attempted to aid loading during the force measurement. The IIHS force/depth tool is shown in Figure 4.

Figure 4. IIHS Force/Depth Tool

The IIHS clearance angle tool was very similar to NHTSA's except it included a digital read-out force gauge. The IIHS clearance angle tool is shown in Figure 5.

[1] Currently the same toolsets as evaluated by NHTSA are being used at IIHS for rating the vehicles on the lower anchors.

Figure 5. IIHS Clearance Angle Tool

After the initial evaluation of the IIHS test procedures and tools, NHTSA determined that certain upgrades should be incorporated into the NPRM-proposed LATCH tools. In reviewing the IIHS test procedures, it was determined there was some subjectivity in its methods, which was also a concern some commenters had on the NPRM-proposed test methods.

Tool Modifications Based on IIHS Evaluation/Comments

Modifications were made to all the usability tools to improve their repeatability and ease of use. The next sections discuss these modifications. The IIHS force and depth tools were combined into one tool. However, NHTSA decided to evaluate them as separate tools, therefore they will be discussed as separate tools in this section.

Attachment Force Tool

NHTSA received comments about the repeatability and reproducibility of the NPRM AFT due to operator variability and the tool being too small to apply the load in a repeatable manner. The proposed procedure had the operator push on the back of the tool while maintaining a minimal force at different approach angles (beginning at 5° from horizontal and increasing in 10° increments to a maximum of 55°) (Figure 6). The angles were measured with a tilt sensor, and the force of engagement was recorded.

Figure 6. NPRM AFT With Force Being Applied at Initial Approach Angle

IIHS commented that the AFT measurement should be at the peak force from initial engagement with the seat cushion until full engagement of the tool on the lower anchor, and that the proposed tool does not account for vertical off-axis forces. NHTSA had observed in some deeper anchors that the operator had to apply a vertical force that could not be measured by the proposed tool. In addition, the instrumentation proposed on the AFT caused additional issues with repeatability and additional adjustments. Commenters did not like the potentiometer due to it oscillating and causing adverse noise, which lead to non-repeatable measurements.

The IIHS force/depth tool was evaluated as two separate tools for this initial assessment. Figure 7 shows the IIHS tool being used as an AFT. Following the IIHS test method, the guide rod was placed on the lower anchor, and the load was applied at the lowest possible angle that allowed the top and bottom surfaces of the slider body of the tool to touch the seat cushion. This angle was maintained while the tool was loaded and until the anchor was engaged. This differs from the procedure proposed in the NPRM, in which a specific approach angle is specified.

The overall concept was very useable, and the guide rod and overall length of the tool seemed to improve the ease of use of the tool. However, it was difficult to read the angle on the digital inclinometer and the load on the digital read-out force gauge while loading the tool through the fabric onto the anchor.

Figure 7. IIHS AFT Test Mode

Based on the evaluation of the IIHS force/depth tool and to address the NPRM comments, a modified AFT/ADT was developed which incorporated the guide rod and force gauge slider body into one tool, like the IIHS tool. The slide pin, slide tab, and spring assembly in the NPRM AFT were replaced with a 6.4-mm square cross-section guide rod with a concave notch that pre-positions the tool to align it with the lower anchor before the force is applied. The instrumentation was also modified: an analog position sensor (Model G-NSDOG2-003[2]) and an Interface S-Type load cell (Model SSM-AJ-100[3]) were added. In addition, the tool was lengthened by 116 mm, and handles were added for hand placement, allowing additional stability and space for instrumentation. The modified AFT/ADT is shown in Figure 8, and it is a total new design for the AFT from the NPRM AFT. Also, the previously discussed test methods specified by IIHS for aligning the jaw of the tool on the fabric and determining the approach angle were adopted.

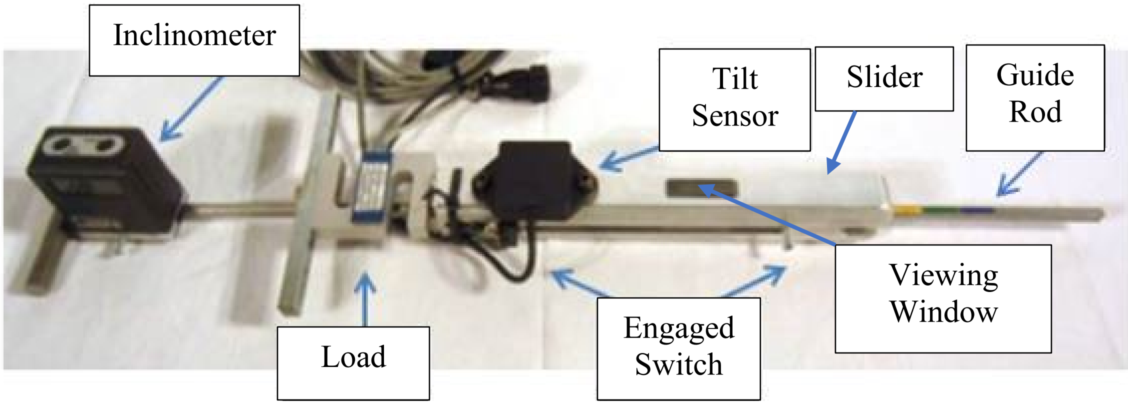

Figure 8. Modified AFT/ADT

NHTSA decided that the modified AFT/ADT used with the IIHS test methods for measuring the force would result in more consistent results than the NPRM AFT test procedure, by resolving the issue of aligning the tool with hidden anchors and reducing the inconsistencies from off-axis loading.

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[2] TE Connectivity Measurement Specialties, Schaffhausen, Switzerland.
[3] Interface Inc., Scottsdale, AZ.

Anchor Depth Tool

The ADT proposed in the NPRM was found to be subjective due to the difficulty in controlling the required view angle of 30° from the vertical plane and holding the tool approximately parallel to the seat cushion surface. The commenters suggested that it was hard to maintain the angles in a controlled fashion due to only using an inclinometer and that the absence of a consistent viewing angle led to variations in how technicians viewed the tool's pass/fail line.

The IIHS force/depth tool used the force gauge slider and incorporated the depth tool into the guide rod that is used to align the tool with the lower anchor. That tool was re-designed into the modified AFT/ADT shown in Figure 8. The new design was also thought to be easier to use for depth measurement and would result in less subjectivity based on operator viewing angle. The modified AFT/ADT included both the depth tool rod and additional instrumentation to digitally record the angle at which the test is conducted.

The procedure used to make depth measurements with the modified AFT/ADT followed the same approach as that specified for the IIHS force/depth tool. The procedure places the tool on the seat cushion and has the user place the notched end of the guide rod in the center of the lower anchor bar when the slider of the tool is retracted, as seen in Figure 9.

Figure 9. Aligning the Modified AFT/ADT for Depth Measurement

The slider of the tool is pushed forward until the end of the tool contacts the cushions and then is slightly lifted so that the top and bottom surfaces of the slider body of the tool touch the seat cushion (Figure 10) at the lowest possible angle. In some cushion designs, the top and/or bottom surfaces of the tool may not contact the seat cushion before the modified AFT/ADT slider is engaged; if this is the case, the tool should be held at the lowest angle achievable.

Figure 10. Modified AFT/ADT Depth Measurement Orientation

At this angle, the depth is viewed through the viewing window shown in Figure 11. The angle of the tool is recorded in addition to the depth reading color. The guide rod was colored so that 20-

mm increments could be distinguished by different colors. The color pattern for the modified AFT/ADT used in this evaluation is shown in Figure 12. The colors represent the following depth measurements: -20 to 0 mm is blue; 0 to 20 mm is green; 20 to 40 mm is yellow; 40 to 60 mm is white; 60 to 80 mm is red; 80 to 100 mm is gold; 100 to 120 mm is black.

Figure 11. Modified AFT/ADT Viewing Window for Depth Measurement

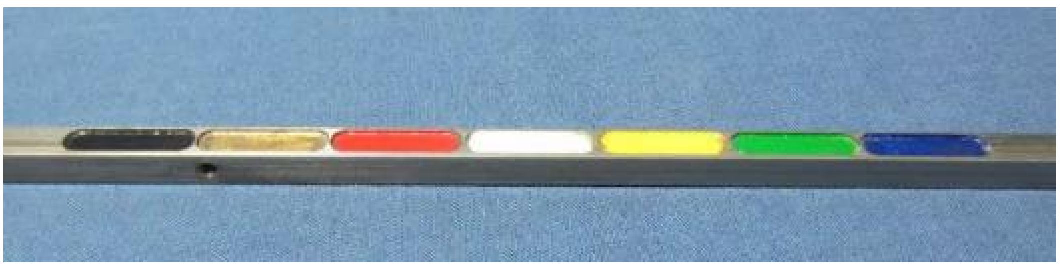

Figure 12. Modified AFT/ADT Guide Rod Color Pattern for Depth Measurement

In the cases where the tool slider body did not touch the seat cushion because of a tunnel or other open access, a tunnel adaptor (provided by IIHS) was placed against the opening. From there, the guide rod was placed at the angle that allows the top and bottom front surface of the force tool slider to rest touching the tunnel adaptor (Figure 13).

Figure 13. Modified AFT/ADT With Tunnel Adaptor for Depth Measurement

Preliminary test results comparing this modified AFT/ADT to the NPRM ADT led to additional observations and further modifications. Depending on the size and design of the upper cushion to the bottom cushion, the modified AFT/ADT depth tool measurement was found to be just as subjective as the NPRM ADT, due to the variability of how the approach angle of the tool was determined. This was particularly the case for lower anchors that were deeper than 20 mm. It was also observed that the modified AFT/ADT approach angle varied depending on the vehicle seat cushions, whereas the NPRM ADT proposed approach angle was parallel to the seat and the viewing angle was 30° from vertical. Also, when the guide rod end was fully engaged with the lower anchor, the guide rod color seen through the view window was not always positioned between the blue and green colors. This suggested that the tool was not always starting at zero, leading to additional subjectivity.

The results of this preliminary analysis led to a new, simpler tool design that was similar to the NPRM ADT. The new tool was a metal bar with an attached CRS anchor hook and a scribed line that represents the zero-line marked on top of the hook. The zero-line represents the back side of the lower anchor as it was attached. To make it more visual, yellow tape was wrapped around the tool from 0 to 20 mm and white tape was wrapped around from 20 to 40 mm. The tool is then used as a simple meet/not meet indicator, by visual inspection (Figure 14). Also, instead of taking the reading at a viewing angle of 30° from vertical, as proposed in the NPRM, this angle was changed to a range of 20 to 40° from horizontal. Based on testing, it was determined that allowing a range of view angles from 20 to 40° provided consistent results between testers.

Figure 14. Meet/Not Meet ADT

The procedure for this additional analysis with the meet/not meet ADT was as follows:

1. Attach the ADT at the center of the lower anchor,
2. Pull the tool taut and parallel to the seat pan cushion,
3. Record the measurement from a viewing angle of 20 to 40°.
    a. If any yellow is visible, the anchor is considered to have met the criterion.

Clearance Angle Tool

Unlike the NPRM CAT, the IIHS CAT (Figure 5) did not include recordable instrumentation but used a digital read-out force gauge and inclinometer. Otherwise, the IIHS CAT was the same as the NPRM CAT; however, there were differences in the test methods. In the IIHS method, the user applies a 67-newton (15-lb) force perpendicular to the tool. If seat back interaction prevents the 67-newton force from being achieved, the user applies the force following the seat back contour, as shown in Figure 15, until the 67-newton force is met. The maximum angle is then recorded. While using the IIHS CAT, technicians found that it was difficult to apply and hold a vertical load of 67 newtons while trying to read the angle of the tool from the inclinometer. This method was slightly different than the NPRM-proposed method of applying the 67-newton force vertically, and it added variability while applying the load along the seat back.

Figure 15. IIHS CAT Testing

NHTSA performed several modifications to the NPRM CAT to create the CAT Version 1 (CAT V1). The NPRM CAT had digital instrumentation that allowed time-history data to be recorded, but after reviewing the comments received on the NPRM, it was determined to add new instrumentation that is more repeatable and more easily acquired (Figure 16). The rotary potentiometer was replaced by an analog position sensor (Model G-NSDOG2-003), as the new sensor more reliably collects the angle data. Also, an Interface S-Type load cell (Model SSM-AJ-100) replaced the latch load cell.

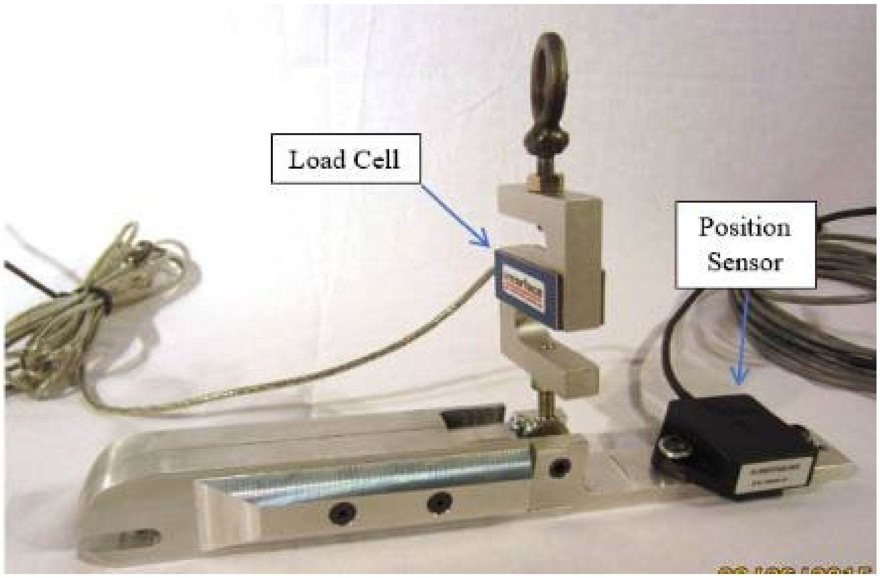

Figure 16. CAT V1 Instrumentation

A CAT pulley bridge was designed and added to improve the ease of use and reduce operator variability (Figure 17). The pulley bridge was set-up to span the space between the front and rear seats. Once in place and directly above the CAT, the pulley bridge is leveled by adjusting the front seat height and/or using shims. Once leveled, the attachment cable and the 67-newton weight are attached to the CAT. The cable is checked and adjusted so that the force is applied vertically to the tool. The data acquisition system is not triggered until the CAT is loaded with the weight hanging motionless. The pulley bridge does add time to the test setup, but it helps in applying a more vertical load on the tool.

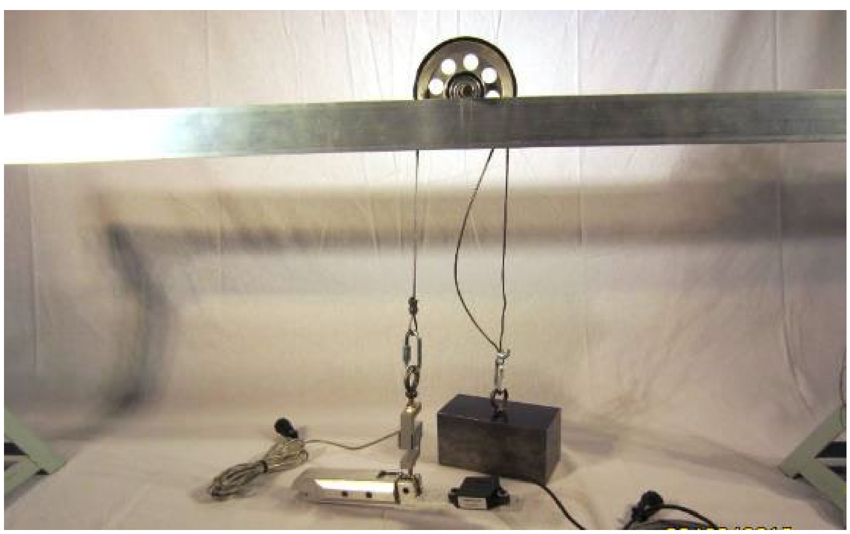

Figure 17. CAT V1

In addition, the tool face was modified to improve its durability. The head of the NPRM CAT was originally made from aluminum, but with use, the edges started to wear down which could allow for inconsistent results. For CAT V1, the jaw of the tool was reinforced with steel plates, and the latch tooth was refabricated to be made completely out of steel. These changes did not affect the tool's shape or functionality. The steel reinforcements are shown in Figure 18.

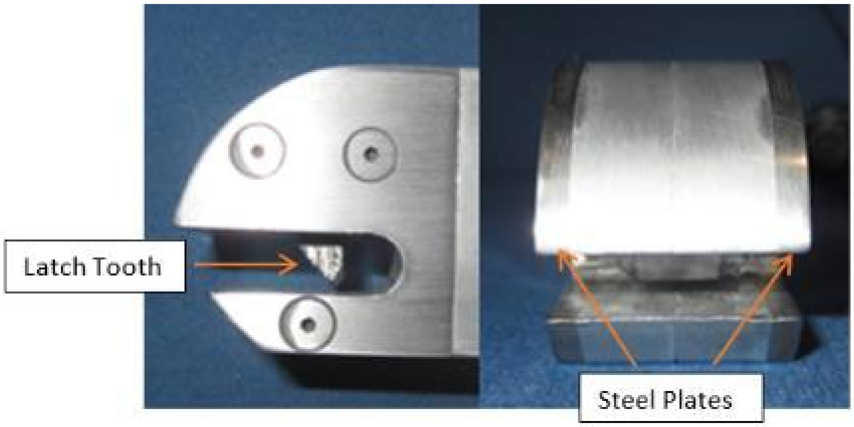

Figure 18. Steel Reinforcements of CAT V1

NHTSA Post-NPRM Testing Phase 1 - Methodology

NHTSA conducted a study to assess tool reproducibility and repeatability (R&R) with different tools and users. The new modified tools described earlier (modified AFT/ADT, meet/no meet ADT, and CAT V1) were used and compared to additional newly fabricated tools with the following exceptions. Only one meet/not meet (m/nm) ADT was fabricated (Figure 14) and the CAT V1 had one tool with an aluminum latching tooth instead of steel tooth. The tools will be named the following for clarification: modified AFT/ADT-1 and -2 depth, modified AFT/ADT-1 and -2 force, CAT V1-1 (steel tooth) and -2 (aluminum tooth) and one m/nm ADT.

Nine vehicles with a variety of different lower anchors were selected for this study, and three technicians were utilized. The anchor assessment criteria used were those proposed in the NPRM, which are as follows: an ADT measurement of 20 mm or less, an AFT measurement of 178 newtons or less, and a CAT measurement of 54° or greater.

The operators were selected to have various skill levels. Technician 1 had experience with previous LATCH usability tool work. Technician 2 had test experience but no specific experience with the usability tools. Technician 3 had minimal test experience and no knowledge of the usability tools. Each technician completed three tests in each vehicle at a minimum of two lower anchor locations. However, due to limited time, not all vehicles were tested by every technician and with each toolset. However, technician 1 tested using all the tools on all the anchors in each of the vehicles. Technicians 2 and 3 tested on a subset of anchors in all the vehicles but with only one each of the toolsets. Technician 1 used the modified AFT/ADT-1 depth, the modified AFT/ADT-1 force, and CAT V1-1 (steel tooth), and technician 2 used the modified AFT/ADT-2 depth, the modified AFT/ADT-2 force, and CAT V1-2 (aluminum tooth). All three technicians evaluated the m/nm ADT. A draft procedure was written and given to the technicians to follow and is included in Appendix A.

Test Matrix

Testing was completed on nine vehicles of different makes and models; model years ranged from 2012 to 2015. The vehicles were selected to include anchors that were suspected of being both difficult and easy to use. The vehicle selection included vehicles that had hidden anchors, visible anchors, and anchors with access tunnels. Ideally, the order of testing would be ADT, AFT, and CAT at each test location and repeated three times with each toolset, except for the meet/not meet ADT which did not have repeats. To increase efficiency, the three repeat measurements with each tool were conducted consecutively, rather than alternating tools.

A sample test matrix demonstrating the order of testing that was completed for each vehicle is shown in Table 1. The data was collected using a DTS data acquisition system with a sample rate of 250 samples per second for 10 seconds of pre-event and 1 second of post-event. The total time needed to complete all the necessary testing in one vehicle, using both sets of tools, at three locations was approximately five hours.

Table 1. Phase 1 Test Matrix for R&R Evaluation

Vehicle		Technician 1																								
		m/nm ADT		**Modified AFT/ADT 1 - Depth**				**Modified AFT/ADT 1 - Force**				**CAT V1 1**				**Modified AFT/ADT 2 - Depth**				**Modified AFT/ADT 2 - Force**				**CAT V1 2**		
	Outboard Anchor	m/nm ADT-1		ADT1-1	ADT1-4	ADT1-7		AFT1-1	AFT1-4	AFT1-7		CAT1-1	CAT1-4	CAT1-7		ADT2-1	ADT2-4	ADT2-7		AFT2-1	AFT2-4	AFT2-7		CAT2-1	CAT2-4	CAT2-7
	Inboard Anchor	m/nm ADT-2		ADT1-2	ADT1-5	ADT1-8		AFT1-2	AFT1-5	AFT1-8		CAT1-2	CAT1-5	CAT1-8		ADT2-2	ADT2-5	ADT2-8		AFT2-2	AFT2-5	AFT2-8		CAT2-2	CAT2-5	CAT2-8
	Center Anchor	m/nm ADT-3		ADT1-3	ADT1-6	ADT1-9		AFT1-3	AFT1-6	AFT1-9		CAT1-3	CAT1-6	CAT1-9		ADT2-3	ADT2-6	ADT2-9		AFT2-3	AFT2-6	AFT2-9		CAT2-3	CAT2-6	CAT2-9
		Technician 2																								
		m/nm ADT		**Modified AFT/ADT 1 - Depth**				**Modified AFT/ADT 1 - Force**				**CAT V1 1**														
	Outboard Anchor	m/nm ADT-1		ADT1-1	ADT1-4	ADT1-7		AFT1-1	AFT1-4	AFT1-7		CAT1-1	CAT1-4	CAT1-7												
	Inboard Anchor	m/nm ADT-2		ADT1-2	ADT1-5	ADT1-8		AFT1-2	AFT1-5	AFT1-8		CAT1-2	CAT1-5	CAT1-8												
	Center Anchor	m/nm ADT-3		ADT1-3	ADT1-6	ADT1-9		AFT1-3	AFT1-6	AFT1-9		CAT1-3	CAT1-6	CAT1-9												
		Technician 3																								
		m/nm ADT														**Modified AFT/ADT 2 - Depth**				**Modified AFT/ADT 2 - Force**				**CAT V1 2**		
	Outboard Anchor	m/nm ADT-1														ADT2-1	ADT2-4	ADT2-7		AFT2-1	AFT2-4	AFT2-7		CAT2-1	CAT2-4	CAT2-7
	Inboard Anchor	m/nm ADT-2														ADT2-2	ADT2-5	ADT2-8		AFT2-2	AFT2-5	AFT2-8		CAT2-2	CAT2-5	CAT2-8
	Center Anchor	m/nm ADT-3														ADT2-3	ADT2-6	ADT2-9		AFT2-3	AFT2-6	AFT2-9		CAT2-3	CAT2-6	CAT2-9

NHTSA Post-NPRM Testing Phase 1 - Results

The test results for each vehicle tested are in Appendix B, which includes tables of all the measurements and AFT data plots. Each table is broken down into four sections (modified AFT/ADT depth-1 and -2, modified AFT/ADT force-1 and -2, CAT V1-1 and -2, and meet/not meet ADT). Each section includes data from each test location (outboard, inboard, center, etc.), technicians, and the three repeat measurements.

A summary of the results for every vehicle tested can be found in Table 2. A position was considered as not meeting the criterion if at least one of the three repeat measurements did not meet the criterion and is labeled with an "N." If there is nothing in the block, it met the criterion.

Table 2. Meet/Not Meet Results of R&R Study

		Tool Set 1				Tool Set 2				Tool Set 1				Tool Set 2			
		Meet/Not Meet ADT	**Modified AFT/ADT - Depth**	**Modified AFT/ADT - Force**	**CAT V1**	**Meet/Not Meet ADT**	**Modified AFT/ADT - Depth**	**Modified AFT/ADT - Force**	**CAT V1**	**Meet/Not Meet ADT**	**Modified AFT/ADT - Depth**	**Modified AFT/ADT - Force**	**CAT V1**	**Meet/Not Meet ADT**	**Modified AFT/ADT - Depth**	**Modified AFT/ADT - Force**	**CAT V1**
2012 Mercedes C300	Driver Outboard			N				N			N	N				N	
	Driver Inboard																
2012 Honda Odyssey	Driver Outboard				N				N		N		N				N
	Driver Inboard				N				N		N		N				N
2012 Jeep Grand Cherokee	Driver Outboard	N	N		N	N	N			N	N		N	N	N		
	Driver Inboard	N	N			N	N			N	N			N	N		
2014 Jeep Grand Cherokee	Driver Outboard	N	N		N	N	N		N	N	N		N	N	N		N
	Driver Inboard	N	N			N	N			N	N			N	N		
	Passenger Outboard	N	N		N	N	N		N	N	N		N	n/a	n/a	n/a	n/a
	Passenger Inboard	N	N		N	N	N		N	N	N		N	n/a	n/a	n/a	n/a
2014 Honda Odyssey	Driver Outboard																
	Driver Inboard								N								
	Center Driver				N				N				N				N
2015 Chevy Silverado	Driver Outboard		N	N			N	N			N				N		
	Driver Inboard		N				N				N				N		
2015 Chrysler 200	Driver Outboard		N				N			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Driver Inboard		N				N			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

		Tool Set 1				Tool Set 2				Tool Set 1				Tool Set 2			
		Meet/Not Meet ADT	**Modified AFT/ADT - Depth**	**Modified AFT/ADT - Force**	**CAT V1**	**Meet/Not Meet ADT**	**Modified AFT/ADT - Depth**	**Modified AFT/ADT - Force**	**CAT V1**	**Meet/Not Meet ADT**	**Modified AFT/ADT - Depth**	**Modified AFT/ADT - Force**	**CAT V1**	**Meet/Not Meet ADT**	**Modified AFT/ADT - Depth**	**Modified AFT/ADT - Force**	**CAT V1**
2014 Cadillac ATS (Tunnel access)	Driver Outboard	N	N			N	N			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Driver Inboard	N	N			N	N			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2014 Subaru Legacy (Tunnel access)	Driver Outboard		N		N		N		N	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	Driver Inboard		N				N			n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

NHTSA Post-NPRM Testing Phase 1 - Discussion

Overall, the modified tools used in this R&R study were found to be easier to use than the tools proposed in the NPRM. The new tilt sensors were the biggest improvement. The oscillation in the tool angle data caused by the lever arm attached to the potentiometer in the NPRM tools was removed, resulting in a more accurate angle reading. The other major improvement was the addition of the pulley bridge to the CAT, which reduced variability caused by the technician not loading the tool vertically or struggling to maintain the 67-newton load while recording the angle.

Throughout the testing, the technicians provided feedback on the usability of the toolsets. Each technician struggled using the modified AFT/ADT force tool. The biggest issue regarding the modified AFT/ADT force tool was the difficulty in applying the force while holding the angle of the tool as determined by the procedure. After every vehicle, this same comment was noted. They noted that the method of touching the top and bottom surfaces of the tool should be more defined or perhaps changed to a set angle. They also commented that the angle was variable depending on how much they allowed the tool to touch the seat cushions. In addition, when the force was being applied, the seat cover could interfere with the lower anchor making it very difficult to engage the tool and collect an accurate reading. Another observation noted with the different technicians was the physical body positioning while using the modified AFT/ADT for force measurements during the testing. Technician 1 was small in stature, so he was able to position himself directly behind the tools to allow for more control and a more even loading rate of the tool. Technicians 2 and 3 were larger in stature and not able to get behind the tool; rather they attempted to load the tool from the side (they also were less experienced with the tools). The data shows difficulty in maintaining the tool angle and applied loading rate and the variability between the technicians.

Like the modified AFT/ADT force comment, it was noted that the modified AFT/ADT depth measurement could have a variable approach angle depending on how much the tool touched the seat cushions. The technicians liked the simplicity of the m/nm ADT; the measurement was able to be collected quickly and with minimal difficulty.

The modified AFT/ADT depth results were compared to the m/nm ADT depth results. The method of measuring depth with the modified AFT/ADT was now different than the original survey that led to the development of the NPRM usability tools. The primary difference being that the results of the modified AFT/ADT depth differed from that of ADT in the NPRM and the m/nm ADT due to the method of interaction with the lower anchor, as depicted in Figure 19. The NPRM ADT and m/nm ADT used a hook style attachment, while the modified AFT/ADT used a guide rod. This difference causes the zero point to be different depending on the approach angle and attachment point. The modified AFT/ADT tool design caused a difference of approximately 3 mm from the result collected with the m/nm ADT. The Mercedes C300, Chevrolet Silverado, and Chrysler 200 had different depth measurements between the modified AFT/ADT and m/nm ADT.

Figure 19. Modified AFT/ADT Depth and M/NM ADT Depth Measurement Difference

There were very few comments on the CAT V1 usability, primarily just that additional time was needed to set-up the pully bridge and get the tool in place.

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Post-NPRM Modification Discussion: UMTRI Modifications

The efforts described previously resulted in more robust tools and procedures than those proposed in the NPRM, however it was recognized that additional improvements could be made. Therefore, NHTSA contracted UMTRI to re-evaluate the tools and complete an assessment of tool variability. In its pilot study, UMTRI conducted limited testing to suggest modifications to improve the tools and procedures. In the (Klinich et al. in press) gauge repeatability and reproducibility (GRR) study a statistical analysis was conducted using three people installing the tools in twenty vehicles with two toolsets each, measuring the depth, attachment force, and clearance angle of the lower anchors.

Tool Assessment by UMTRI

In the pilot study, the tools were tested at UMTRI in certain vehicles to determine if additional modifications were needed prior to starting the GRR evaluation. After discussions with NHTSA, additional modifications were made to each of the usability tools to address potential repeatability and ease of use issues.

UMTRI ADT Modifications

After discussions with NHTSA about the study presented in Section 2, UMTRI modified the meet/not meet ADT. A sliding view bar and additional depth gauge measurement device were added to create a more consistent view angle and collect a numerical value for the depth, instead of just a meet/not meet reading. Based on its experience during pilot testing, additional modifications of adding a zeroing strip and making the gauge movable were completed. The final version of the tool from UMTRI is shown in Figure 20. This tool will be called ADT V2 in this report. A second tool was fabricated to be used during the GRR study to evaluate tool variability.

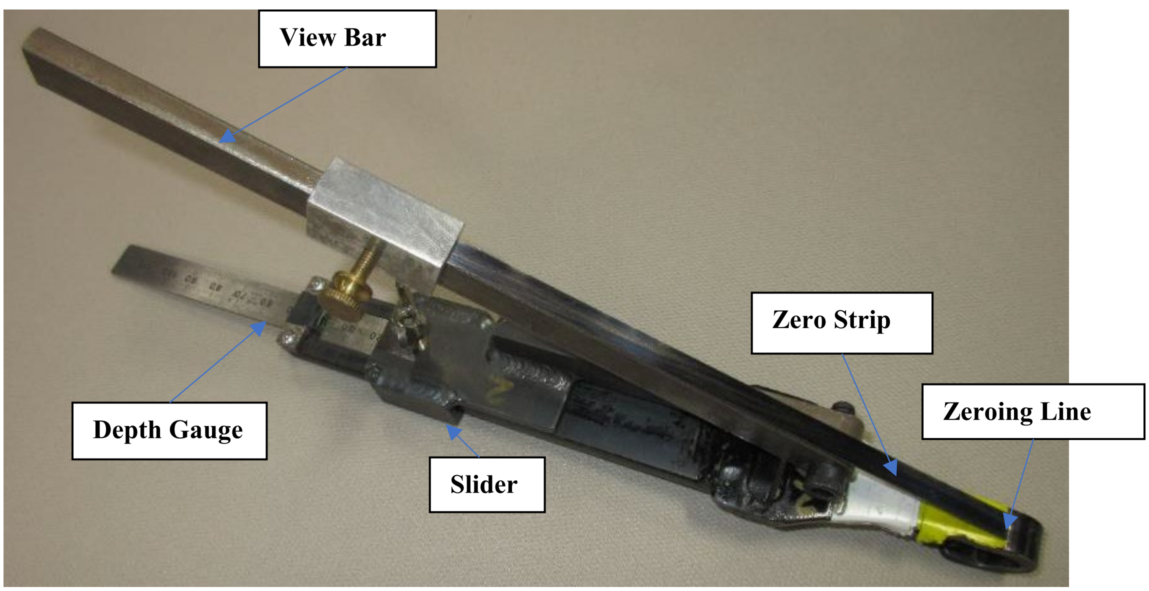

Figure 20. UMTRI Attachment Depth Tool (ADT V2)

To use the tool, the operator attaches the tool to the lower anchor, places the tool on the seat cushion in line with the center of the lower anchor, and adjusts the view bar to 30° from horizontal using a digital inclinometer. The tool is removed from the vehicle to adjust the zero strip (thin metal material) downward so that it touches the zeroing line on the tool base (this line is etched on to tool at the rear of the anchor bar and is in line with the front edge of the yellow tape on the tool hook). The depth gauge is adjusted to zero when the zero strip is touching the zeroing line and locked into place by tightening the screws on the rear of the tool or taping the gauge down. Without moving the depth gauge, the slider is moved to the rear of the tool, the tool is placed back in the vehicle, the hook is attached to the lower anchor, and the tool is laid on the seat in line with the center of the lower anchor. The view bar and zero strip are moved forward until the zero strip touches the seatback. The depth measurement is read from the depth gauge at rear of the ADT V2.

UMTRI AFT Modifications

After discussions with NHTSA about the force tool (Section 2), UMTRI re-modified the modified AFT/ADT force tool to add stability to the tool and to resolve the variability of the approach angle. The first modification was to add a motorized actuator to allow for a steady rate of force application (two different actuators were used during the UMTRI study, which had similar specifications). In addition, a support leg was added to the rear of the tool to stabilize the tool and maintain the approach angle. An additional modification was made to the guide rod to remove the colored rod and replace it with a solid rod for simplicity, since this tool will not be used for depth measurements. This new tool will be referred to as AFT V2 for this report (Figure 21). The second identical tool from Section 2 was modified in the same way to evaluate tool variability during the GRR study.

Figure 21. UMTRI Attachment Force Tool in Vehicle (AFT V2)

During the pilot study, UMTRI determined the approach angle of the tool as 20 ± 2° relative to horizontal and developed a procedure for use with the updated tool (AFT V2). The procedure calls for the operator to place the guide rod, while the slider body is retracted, onto the center of the lower anchor and set the tool at 20° to horizontal. The operator then applies a reaction force to the rear of the AFT V2 by holding the rear of the tool and bracing their elbow on the B-pillar or front seatback. The operator then turns on the switch that drives the actuator forward until it engages with the lower anchor and triggers the data collection software. Data is collected for approximately ten seconds prior to the trigger event and one second post event. The maximum force prior to the event is recorded as the attachment force.

UMTRI also explored the use of the force tool with a different type of actuator model. The same data processing was used with this second type actuator. One issue that arose from the different model was that the dimensions were slightly longer so that the tool had to be adjusted in order to not bottom out at the fully engaged position. However, the second actuator did not allow for the tool to be adjusted properly. One suggestion proposed by UMTRI to fix the issue was to put a through hole and nut at the load cell for other actuators to be used.

UMTRI CAT Modifications

UMTRI did not have any modifications to the CAT V1 itself but did some minor modifications to the pulley bridge. They modified it by adding an adjuster leg to the front of the tool as well as a bubble level indicator to aid in placing the bridge as horizontal as possible (Figure 22). This tool will be referred to as CAT V2 for this report. The second identical tool from Section 2 was modified in the same way to evaluate tool variability during the GRR study.

Figure 22. UMTRI Clearance Angle Tool in Vehicle (CAT V2)

UMTRI made additional clarifications to the test procedure for this tool, including adding tolerances to the positioning of the pulley bar (0 ± 5° relative to horizontal) and to the vertical cables (90 ± 5° relative to horizontal).

UMTRI Results and Discussion

The GRR study was a repeatability and reproducibility evaluation of the effects of different operators, tools, and vehicles and consisted of two phases. Each phase tested 10 vehicles, for a total of 20 vehicles tested. The test matrix consisted of 20 vehicles with three installers with varying levels of experience. The vehicles chosen were model years 2013 to 2017 and had a variety of types of lower anchors in different seating configurations. For the testing, a subset of 10 of the 20 vehicles were measured depending on the tool being tested.

Of the 10 vehicles tested, 3 did not meet the criterion for the ADT V2. The largest difference in results between operators occurred in vehicles with deeper anchors. For the AFT V2, all the vehicles met the proposed criterion. However, disengagement of the AFT V2 from the anchor occurred during testing. If the tool disengaged more than four times during testing, the anchor was marked as not meeting the criterion. Disengagement was more prevalent at higher loads. For the CAT V2, three did not meet the proposed criterion, while the other 7 did.

UMTRI found that vehicle variation accounts for 93 percent of the variation for the ADT V2, 67 percent of the variation for the AFT V2, and 92 percent of the variation for the CAT V2. For the ADT V2 and the CAT V2, almost all the variation between results was due to differences in the vehicles. However, the AFT V2 had less variability due to the vehicle differences, and therefore other factors influenced the results. The overall results suggested that the tools were repeatable, but a lot of variability was seen with the AFT V2 tool (Klinich et al., 2018).

NHTSA Post-NPRM Modifications Phase 2 – NHTSA Usability Study

In fall 2018, after the UMTRI study, the modified tools of each type were sent back to VRTC for further evaluation. This section discusses an additional usability study looking at the modifications developed and analyzed by UMTRI during the GRR study and NHTSA's last version of the toolsets. Any additional modifications to the tools done by NHTSA were given a subsequent version number.

Tool Modifications

Depth Tool

Based on observations from the UMTRI study, a new depth tool was created by VRTC for an additional comparison (Figure 23). This tool was called ADT V3 in the VRTC usability study discussed in earlier section. The new tool added more stability to the slider by increasing the sheath size, or the amount of material that encases the base, circled in Figure 23. This reduced the amount of wobbling in the slider as it is manipulated during the test. The length of the tool was also increased to give the tool base a length of an additional 305 mm. This length change provided more stability with the tool when placed on the seat and allowed the user to have more area for holding the tool. Last, the front end of the tool was bent to the same radius as the hook from the UMTRI tool (ADT V2) and the aluminum hanger was removed. The zeroing line was etched on top of the tool to represent the edge of the LATCH anchor bar; this is the zero point on this tool and the yellow tape was not used with this tool.

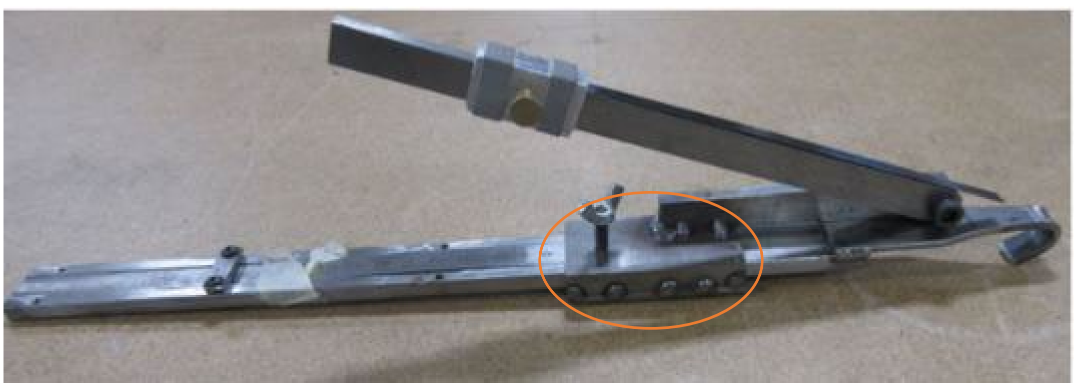

Figure 23. VRTC Lengthened Attachment Depth Tool (ADT V3)

Both ADT V2 and ADT V3 were tested following the UMTRI procedure of setting the view bar to 30° from the horizontal plane as the tool is zeroed based on the contact area. The tool was then placed on the seat pan and the view bar was moved forward until the strip or bar touched the seatback. At this point the depth was measured from the rear of the tool.

Applied Force Tool

Based on observations from the UMTRI study, small adjustments were made on both tools. It was observed that the guide rod was not flush inside the front of the tool, which could cause the trigger to be off when engaging with the lower anchor. The trigger and bolt were adjusted so that when the tool is triggered, the guide rod was flush with the face of the tool instead of sticking out slightly as shown in Figure 24. This was done by changing the length of the bolt so that the shaft of the bolt contacted the switch instead of the bolt head (Figure 25). Both tools used the same actuator (Firgelli Automations, FA-150-S-12-4) used by UMTRI.

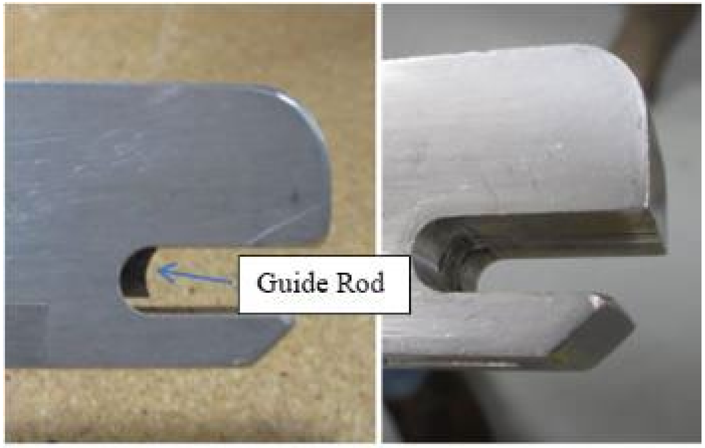

Figure 24. Guide Rod Adjusted From Sticking Out (left) to Flush With Face (right)

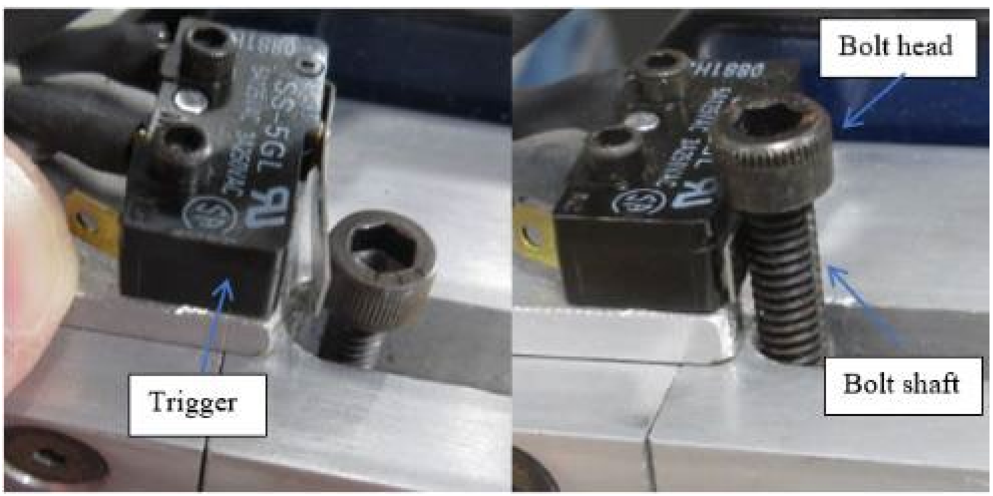

Figure 25. Bolt Head (left) Versus Shaft Contacting Switch (right)

One of the AFT V2 tools had two modifications made to create AFT V3. The first modification was adding a handle to the rear of the tool to assist the operator in applying the necessary reaction force when using the tool with the actuator. UMTRI had observed that when conducting the study with two different actuators, there was some difference in the length of the tool depending on which actuator was used. For consistency, it was suggested to either add a slot at the mounting location of the actuator or a through hole and nut to the S-Type loadcell to give some flexibility for installing different models of actuators. Therefore, the second modification made was a through hole and nut (Figure 26) to monitor how this change affected the overall results and if it improved the tool usability. The AFT V3 fully assembled is shown in Figure 27.

Figure 26. Through Hole and Nut Modification

Figure 27. Attachment Force Tool (AFT V3)

The VRTC usability study used the UMTRI test procedure for both AFT V2 and AFT V3. With the tool head fully retracted, the guide rod of the tool was placed on the center of the anchor. The tool and support leg were adjusted so the tool was held 20 ± 2° to horizontal. The operator then braced their elbow against the front seatback or B-pillar and pressed the switch to activate the actuator. The switch was held until the tool head was fully engaged with the anchor.

Clearance Angle Tool

No changes were made to the actual tool body on the CAT V1, but there was modification in the pulley bridge, therefore the tool used is referred to as CAT V2. The UMTRI test procedure was used with the two identical CATs for this analysis. The pulley bridge was placed in the vehicle and leveled using the adjuster legs. The pulley wheel was placed in the bridge. The CAT was then attached to the anchor and the cable routed over the pulley wheel. The 67-newton weight was attached to the cable and adjusted so the cable ran vertical from the tool. Once the weight was hanging steady, the clearance angle measurement was recorded.

Usability Study – Vehicle Selection and Methodology

The vehicles for this usability study were chosen in order to compare test data from previous research conducted at VRTC and UMTRI. Vehicles selected were based on previous test results and had a variety of anchor types (visible, hidden, tunnels). The vehicles were inspected prior to testing for any damage or wear to the LATCH anchors. The following vehicles were selected for testing. Vehicles marked with an asterisk were previously tested by UMTRI and were used for reproducibility analysis.

- 2016 Chevrolet Tahoe*
- 2016 Nissan Rogue*
- 2016 Subaru Outback*
- 2014 Jeep Grand Cherokee
- 2014 Cadillac ATS
- 2018 Ford Fiesta*
- 2015 Toyota Sienna*

This usability study was conducted to compare the results using the newly modified tools to previous testing results and to evaluate the proposed test procedures provided by UMTRI for completeness and robustness.

The operators for this evaluation were two different technicians with limited knowledge of the tools. Operator 1 conducted the tests in five of the seven vehicles, whereas operator 2 conducted the tests with the remaining two vehicles, the Ford Fiesta and the Toyota Sienna. The UMTRI procedure, with additional small clarifications by VRTC, was provided to both technicians (Klinich et al., 2018).

The procedure determines the seatback angle for vehicles with adjustable seatbacks per the SAE J826 method (SAE International, 2015), which sets the seatback to 25°. This was followed for all the vehicles used for this series of testing. The Toyota Sienna was tested using both this method (seatback at 25°) and the method suggested in the owner's manual for use with the CRS with LATCH configuration (Figure 28). No other vehicles used in this testing had alternate instructions in the vehicle's owner's manual.

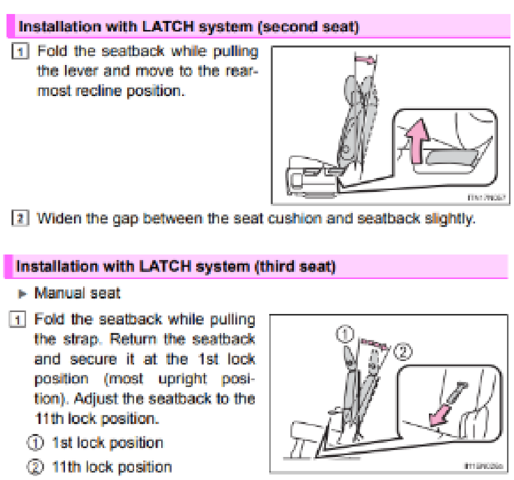

Figure 28. LATCH Installation Instructions from Toyota Sienna Manual

Each lower anchor was tested one time with each of the tools. Tools were tested on each anchor using the order of ADT, AFT, then CAT. For timeliness, each tool was tested on all anchors per row before moving to the next tool. A wait time of five minutes was applied between any tests on the same lower anchor. If the result fell within a set of repeat criteria, the tool was repeated two more times for a total of three tests. The repeat criterion for the ADT: a depth of anchor in the seat bight of 20 ± 2 mm; AFT: an attachment force of 178 ± 9 newtons; CAT: a clearance angle of 54 ± 2°. A minimum of 20 minutes wait time was used between any repeat tests. If a result fell outside of the repeat criteria, the test on the anchor was not repeated.

Table 3 provides a sample of the test matrix. The column labeled "Tool" indicates the tool type followed by the version. The anchors are labeled per location in the vehicle, 2R IB represents the second row right inboard anchor, 2R OB represents the second row right outboard anchor, 2CR is the second row center right anchor, 2CL is the second row center left anchor, 2L IB is the second row left inboard anchor, and 2L OB is the second row left outboard anchor.

Table 3. Example Test Matrix

Vehicle	Tool	Anchors					
YR Make Model	ADT V2	2R IB	2R OB	2CR	2CL	2L IB	2L OB
	AFT V2	2R IB	2R OB	2CR	2CL	2L IB	2L OB
	CAT V2	2R IB	2R OB	2CR	2CL	2L IB	2L OB
	ADT V3	2R IB	2R OB	2CR	2CL	2L IB	2L OB
	AFT V3	2R IB	2R OB	2CR	2CL	2L IB	2L OB
	CAT V2	2R IB	2R OB	2CR	2CL	2L IB	2L OB

Data was collected using a DTS data acquisition system with a sample rate of 250 samples per second for 10 seconds of pre-event and 1 second of post-event for the AFT (the event is lower anchor engagement of the AFT). The test results recorded for the AFT were determined in post processing of the data. The average force between 3 and 6 seconds prior to the event was used to calculate the zero-offset of the data. The results reported were the maximum force recorded prior to time zero with this offset applied. Values reported for the CAT were at the event trigger, which was after the weight was applied and was hanging stationary.

Usability Study – Results

Results from testing are shown in Table 4, based on the criteria proposed in the NPRM. A position is indicated with an "N" if it did not meet the criterion or if at least one of the repeat measurements did not meet the criterion. For the AFT, an anchor was also considered to have not met the criterion if the tool disengaged from the anchor. The Toyota Sienna was tested at both seatback angle settings, which produced the same results regarding meeting the criteria or not.

Table 5 shows the numerical values that correspond to the results in Table 4 for all vehicles. An asterisk means repeat testing was done, and the value shown is the average. The values with light orange highlights indicate the anchor did not meet the proposed criterion. The values with dark orange highlights indicate that even though the average result was within the proposed criterion, the anchor did not meet the criterion for at least one of the three repeats. Appendix E contains all results by vehicle from each tool and toolset. Plots for the AFT for each vehicle are also displayed in Appendix E.

Table 4. Meet/Not Meet Results From Usability Testing

Toolset	Anchor	16 Chevrolet Tahoe			16 Nissan Rogue			16 Subaru Outback			14 Jeep Grand Cherokee			14 Cadillac ATS			18 Ford Fiesta			15 Toyota Sienna		
		ADT	**AFT**	**CAT**	**ADT**	**AFT**	**CAT**	**ADT**	**AFT**	**CAT**	**ADT**	**AFT**	**CAT**	**ADT**	**AFT**	**CAT**	**ADT**	**AFT**	**CAT**	**ADT**	**AFT**	**CAT**
1 ADTV3 AFTV3 CATV2	2L OB									N			N		ND		N	N	N			
	2L IB						N				N				ND		N	N	N			
	2CL				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
	2CR				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
	2R IB												N		ND		N		N			
	2R OB									N			N		ND		N		N			
2 ADTV2 AFTV2 CATV2	2L OB									N			N		ND		N	N	N			
	2L IB						N				N				ND		N	ND	N			
	2CL				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
	2CR				-	-	-	-	-	-	-	-	-	-	-	-	-	-	-			
	2R IB						N				N		N		ND		N		N			
	2R OB									N	N		N		ND		N		N			
1 ADTV3 AFTV3 CATV2	3CL																					
	3CR																					
	3R IB																					N
	3R OB																					
2 ADTV3 AFTV3 CATV2	3CL																					
	3CR																					
	3R IB																					N
	3R OB																					

pass	ND-no data/unable to get data	fail	pass but had failed repeats

* repeats

Table 5. Results From Usability Testing

Vehicle	Toolset	Anchor	ADT depth (mm) <20	AFT force (N) ≤177.9	CAT angle (deg) >54
2014 Cadillac ATS	ADTV3 AFTV3 CATV2	2L OB	-29	ND	66.5
		2L IB	-42	ND	67.1
		2R IB	-36	ND	67.2
		2R OB	-17	ND	68.7
	ADTV2 AFTV2 CATV2	2L OB	-15	ND	63.7
		2L IB	-29	ND	67.3
		2R IB	-23	ND	67.9
		2R OB	-5	ND	65.6
2016 Nissan Rogue	ADTV3 AFTV3 CATV2	2L OB	1	114.3	56.3
		2L IB	10	101.0	49.3
		2R IB	4	84.5	54.7*
		2R OB	2	106.7	58.4
	ADTV2 AFTV2 CATV2	2L OB	14	101.5	56.2*
		2L IB	12	72.8	49.4
		2R IB	13	54.0	52.4*
		2R OB	14	78.2	58.2
2014 Jeep Grand Cherokee	ADTV3 AFTV3 CATV2	2L OB	10	47.4	53.0*
		2L IB	19.7*	56.6	56.1*
		2R IB	13	105.2	49.4
		2R OB	13	51.0	49.9
	ADTV2 AFTV2 CATV2	2L OB	14	48.6	53.2*
		2L IB	21.3*	60.5*	56.1
		2R IB	20.3*	48.3	49.3

Vehicle	Toolset	Anchor	ADT	AFT	CAT
			depth (mm)	force (N)	angle (deg)
			<20	≤177.9	>54
		2R OB	20.7*	40.4*	50.1
2016 Chevy Tahoe	ADTV3 AFTV3 CATV2	2L OB	-4	54.6	73.2
		2L IB	-5	66.3	73.4
		2CL	-3	76.7	70.5
		2CR	-4	51.6	71.6
		2R IB	-6	52.0	77.6
		2R OB	-7	59.4	72.8
	ADTV2 AFTV2 CATV2	2L OB	-1	54.0	74.6
		2L IB	-3	64.5	74.4
		2CL	-1	62.9	71.4
		2CR	-5	50.6	71.4
		2R IB	-6	54.7	74.8
		2R OB	-9	58.6	73.0
2016 Subaru Outback	ADTV3 AFTV3 CATV2	2L OB	-15	79.2	52.8*
		2L IB	-21	25.4*	56.6*
		2R IB	-17	51.2	57.3
		2R OB	-11	85.9	53.3*
	ADTV2 AFTV2 CATV2	2L OB	-15	67.7	53.9*
		2L IB	-24	41.4	56.5
		2R IB	-17	43.7	58.3
		2R OB	-13	77.0	54.4*
2018 Ford Fiesta	ADTV3 AFTV3 CATV2	2L OB	38	140.1*	47.1
		2L IB	37	304.1	35.6
		2R IB	26	126.2	39.9
		2R OB	31	72.1	51.6

Vehicle	Toolset	Anchor	ADT	AFT	CAT
			depth (mm)	force (N)	angle (deg)
			<20	≤177.9	>54
	ADTV2 AFTV2 CATV2	2L OB	39	137.5*	46.6
		2L IB	30	ND	36.0
		2R IB	24	87.5	39.8
		2R OB	36	88.2	51.6
2015 Toyota Sienna (seatback angles at mfg setting - 2R: 38/39 deg, 3R: 33.8/34 deg)	ADTV3 AFTV3 CATV2	2L OB	0	134.6	67.0
		2L IB	8	159.2*	66.4
		2R IB	9	78.6	63.8
		2R OB	8	73.2	63.4
		3R OB	4	57.8	67.1
		3R IB	-4	38.9	51.1
		3CR	-10	42.4	65.9
		3CL	-10	41.0	64.5
	ADTV2 AFTV2 CATV2	2L OB	3	139.2	66.7
		2L IB	8	117.6	64.9
		2R IB	9	95.5	62.1
		2R OB	8	69.2	61.8
		3R OB	0	55.2	66.9
		3R IB	-15	47.9	50.9
		3CR	-10	28.6	70.3
		3CL	-11	17.9	66.3
2015 Toyota Sienna (seatback angles OSCAR 25 deg)	ADTV3 AFTV3 CATV2	2L OB	13	83.6	56.3
		2L IB	15	101.9	56.9
		2R IB	11	93.0	60.7
		2R OB	5	98.3*	60.3
		3R OB	0	40.5	67.0

Vehicle	Toolset	Anchor	ADT	AFT	CAT
			depth (mm)	**force (N)**	**angle (deg)**
			<20	**≤177.9**	**>54**
		3R IB	0	32.9	49.7
		3CR	-13	31.6	70.6
		3CL	-5	32.5	67.6
	ADTV2 AFTV2 CATV2	2L OB	9	76.5	58.1
		2L IB	17	98.8	56.0
		2R IB	12	98.3	59.9
		2R OB	5	79.6	58.7
		3R OB	0	54.3	67.1
		3R IB	-2	44.9	51.5
		3CR	-18	39.1	70.8
		3CL	-17	16.0	65.7

pass	ND-no data/unable to get data	fail	pass but had failed repeats

* repeats

The results show that there were no major differences between tool versions in the meet/not meet results. Two noted differences were with the depth tool in the Jeep Grand Cherokee and the clearance tool in the Nissan Rogue. In the Grand Cherokee with ADT V3, the responses showed a majority of results met the criterion, whereas with ADT V2, the majority did not meet the criterion. All the Jeep results that did not meet the criterion were near the threshold and had to be repeated. The Jeep Grand Cherokee had hidden anchors as shown in Figure 29.

Figure 29. Jeep Grand Cherokee Hidden Anchors

There were also differences shown in the CAT results of the Nissan Rogue. However, all the values were near the 54° criterion, and this lower anchor was located deeper than in some of the other vehicles.

In addition to the meet/not meet comparison of the tools, results from the ADT V2, AFT V2, and CAT V2 were compared to the results from the UMTRI GRR study to evaluate the reproducibility of the tools. Comparisons of the results are shown in Table 6. The UMTRI results presented in the table are the average of the three repeats conducted at UMTRI (Klinich et al., 2018). The VRTC results are those ADT V2, AFT V2, and CAT V2 (same as the UMTRI tool). The VRTC result is from a single test unless repeats were conducted, then the result is the average of the repeats (these are marked with an asterisk). The model years and some seat cushion fabric types differed between the UMTRI and VRTC test vehicles.

Overall the results were very similar, and more differences were seen with the ADT and the AFT than with the CAT. For the ADT, the biggest difference was in the Nissan Rouge which had deeper anchors. However, since UMTRI recorded any measurement with the ADT that was less than zero as zero and VRTC recorded them as negative values, direct comparisons could not be made for some of the vehicles. The AFT also showed some difference in certain locations. Overall, the AFT had greater variability across all vehicles regardless of the depth of the anchors

Table 6. Comparisons Between VRTC and UMTRI Data (ADT V2, AFT V2, CAT V2)

Nissan Rogue						
Location	ADT (mm)		AFT (N)		CAT (deg)	
	UMTRI	**VRTC**	**UMTRI**	**VRTC**	**UMTRI**	**VRTC**
2L OB	4.6	14.0	109.4	101.5	57.4	56.2*
2L IB	9.6	12.0	90.9	72.8	51.7	49.4
2R IB	7.5	13.0	83.8	54.0	51.3	52.4*
2R OB	6.7	14.0	86.1	78.2	56.6	58.2
Subaru Outback						
Location	ADT (mm)		AFT (N)		CAT (deg)	
	UMTRI	**VRTC**	**UMTRI**	**VRTC**	**UMTRI**	**VRTC**
2L OB	-	-15.0	-	67.7	-	53.9*
2L IB	-	-24.0	-	41.4	-	56.5
2R IB	-	-17.0	-	43.7	-	58.3
2R OB	0.0	-13.0	108.7	77.0	49.4	54.4*
Chevy Tahoe						
Location	ADT (mm)		AFT (N)		CAT (deg)	
	UMTRI	**VRTC**	**UMTRI**	**VRTC**	**UMTRI**	**VRTC**
2L OB	-	-1.0	-	54.0	-	74.6
2L IB	-	-3.0	-	64.5	-	74.4
2CL	0.0	-1.0	-	62.9	68.2	71.4
2CR	0.0	-5.0	80.4	50.6	69.0	71.4
2R IB	0.0	-6.0	91.0	54.7	70.0	74.8
2R OB	0.0	-9.0	69.9	58.6	70.1	73.0

Ford Fiesta						
Location	ADT (mm)		AFT (N)		CAT (deg)	
	UMTRI	**VRTC**	**UMTRI**	**VRTC**	**UMTRI**	**VRTC**
2L OB	-	39.0	-	137.5*	-	46.6
2L IB	-	30.0	-	ND	-	36.0
2R IB	-	24.0	-	87.5	-	39.8
2R OB	32.0	36.0	102.0	88.2	49.1	51.6

Toyota Sienna									
Location	ADT (cm)			AFT (N)			CAT (deg)		
	UMTRI	**VRTC**	**VRTC (25°)**	**UMTRI**	**VRTC**	**VRTC (25°)**	**UMTRI**	**VRTC**	**VRTC (25°)**
2L OB	-	0.3	0.9	-	139.2	76.5	-	66.7	58.1
2L IB	-	0.8	1.7	-	117.6	98.8	-	64.9	56.0
2R IB	1.3	0.9	1.2	-	95.5	98.3	60.8	62.1	59.9
2R OB	1.2	0.8	0.5	118.9	69.2	79.6	62.1	61.8	58.7
3L OB	-	-1.1	-1.7	-	17.9	16.0	-	66.3	65.7
3L IB	-	-1.0	-1.8	-	28.6	39.1	-	70.3	70.5
3R IB	0.0	-1.5	-0.2	62.5	47.9	44.9	56.1	50.9	51.5
3R OB	0.0	0.0	0.0	64.3	55.2	54.3	67.5	66.9	67.1

Values for UMTRI are averages, VRTC values are single points unless a * then average of 3 repeats

Comparisons are only with toolset 2

Only Toolset 2 results shown

NHTSA Post-NPRM Phase 2 - Usability Study – Discussion

AFT

It was easier to apply the reaction force and to adjust the approach angle for the AFT V3, which was modified with the handle, the actuator, and the support leg. However, even with the actuator there were still issues with disengagement of the tool and interaction with the seat cover or tunnel flaps, such as with the Cadillac ATS. The deep anchors also proved difficult for the AFT to engage and led to disengagement of the guide rod from the anchor prior to reaching the end stroke of the actuator. Additionally, in some cases the operator could not provide enough reaction force onto the tool to get it to engage with the anchor, and the tool would disengage or not trigger when trying to attach to the anchor (Fiesta).

Also, the shape of the guide rod was offset to the anchor as shown in Figure 30. While this shape aligns with the tool profile, it allowed for the tool to slip off some of the lower anchors, causing disengagement of the tool. It was noted that for the lower anchors where the AFT criterion was not met, it was due to disengagement of the tool during the test rather than the tool exceeding the force threshold.

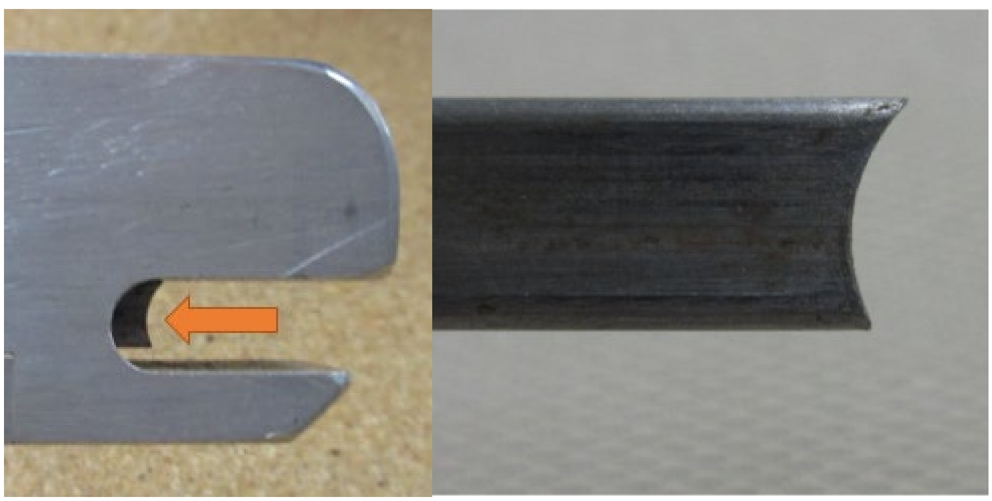

Figure 30. Curvature of Guide Rod

As discussed in earlier in the report, a through hole was added to the AFT V3 to accommodate different actuators. After assessing the tool in this usability study, it was found this modification caused some additional flexing at the bolt, which led to questionable data spikes at impact or soon thereafter. Figure 31 shows this phenomenon.

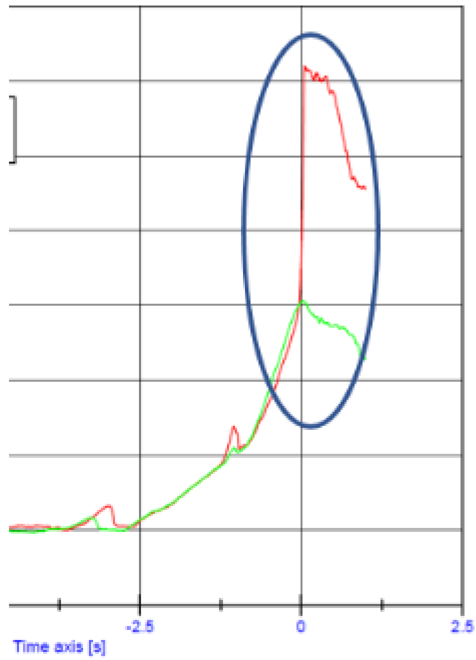

Figure 31. AFT Force Plot Showing Spike in Data From Through Hole in AFT V3

Generally, in the vehicles where the anchors did not meet the proposed criterion with the force tool, the lower anchor also did not meet the proposed criterion with another tool. An exception to this was the Cadillac ATS. This vehicle had tunnels, or flaps of material, in front of the lower anchors. The AFT was not able to fit into this opening because the tool was too wide (Figure 32). This anchor met the proposed criteria when tested with the ADT and CAT.

Figure 32. Interaction of AFT With ATS Tunnel Flaps

ADT

It was observed that determining when the ADT V2 contacted the seatback still subjective. The zero strip on the ADT was thin and flimsy and sometimes would catch on the white and yellow tape (shown in Figure 20) or on the seat during the procedure. This made it challenging to determine what the correct zero-position should be to complete the test. It was especially difficult to determine when the tool was touching the seatback for seats with dark fabric. Additionally, there were differences in positioning the ADTs from the two tool versions when the seat had any contours along where the lower anchors were located. When placed on the seat in line with the center of the anchor, the shorter tool (ADT V2) typically tilted toward the center of the seat due to the bolster on the side. This did not occur with the longer tool (ADT V3). The longer tool was also more stable and easier to grasp during testing and alignment.

Additional minor modifications to ADT V3 were made after this usability study was completed to make the tool more stable and easier to use, and they were not expected to affect the resulting measurements. This tool was named ADT V4. The tool was modified with a set screw that could be loosened or tightened by hand quickly to easily move the measurement ruler to the zero setting. Also, at the front of the tool a lock nut replaced the traditional nut to keep the view bar from loosening during the view angle adjustment. A piece of tape was added to the front of the view bar to hold the zeroing strip along the view bar and decrease its flexing. These modifications are shown in Figure 33 and are reflected in the final drawing package in Appendix C. In addition, the test procedure was revised to reflect changes to the zeroing method due to the tool modifications described above.

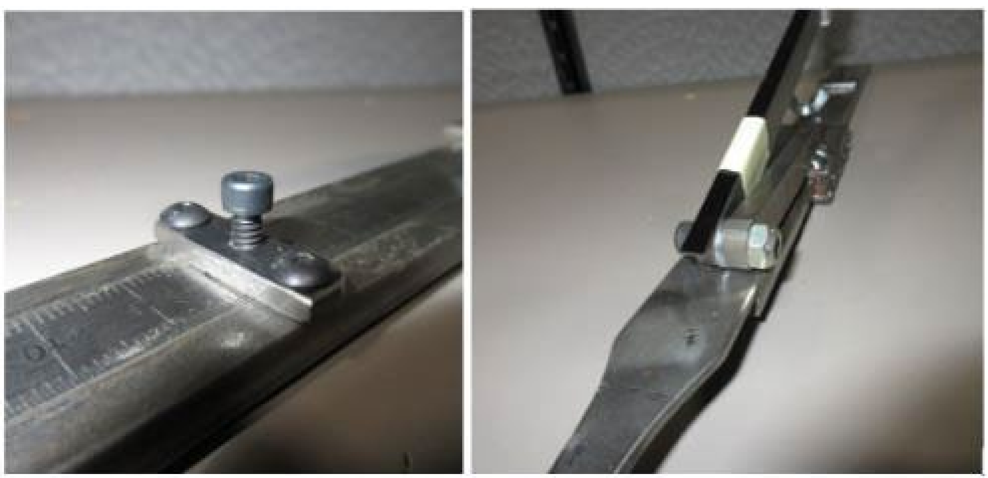

Figure 33. Additional Modifications to ADT (ADT V4)

The base angles of the two tools were slightly different due to the longer base causing the tool to interact with a different part of the seat, thus changing the point of contact for the initial angle to be determined. Since the 30° view angle is based on the initial angle of the tool, the depth measurement was slightly different for some of the seats.

Further analysis was conducted to compare the longer tools, ADT V3/V4, to ADT V2 in the initial vehicle seat setup and in some hard to position vehicles (e.g. waterfall bolsters). In the setup of the depth tool, the seat pan angle is used for the initial position to determine the 30° view bar. The procedure proposed in the NPRM for the ADT has the user hold the tool parallel to the seat, while the UMTRI procedure has the user lay the tool on the seat. Seat pan angles from the vehicles used in the usability testing study are tabulated in Table 7. Also included are the seat pan angles from two vehicles with large waterfall boosters, a 2011 Cadillac CTS and a 2010 Kia Forte. Table 7 also lists the resulting ADT base angles obtained while following the UMTRI procedure. Note that while the longer tools (ADT V3/V4) consistently produced larger base angles than the shorter tool, the angles were similar for the two tools for most vehicles. However, they were quite different in the vehicles with the large waterfall boosters, since the shorter tool allowed for negative base angles (see Figure 34).

Table 7. Seat Pan Angle and Base Angle Comparison

Vehicle	Anchor	Seat Pan Angle	Toolset	Base Angle
2014 Jeep Cherokee	2LIB	16	V3	12.6
			V2	9.6
2016 Nissan Rogue	2LIB	8	V3	6.8
			V2	5.0
2016 Chevrolet Tahoe	2LIB	10	V3	7.2
			V2	5.1
2013 Subaru Outback	2LIB	13	V3	10.5
			V2	7.3
2015 Toyota Sienna	2LIB	17	V3	17.6
			V2	16.1
	3RIB	13	V3	15.3
			V2	11.8
	3CR	15	V3	14.7
			V2	12.7
2011 Cadillac CTS	2RIB	17	V4	0.1
			V2	-6.8
2010 Kia Forte	2RIB	15	V4	1.6
			V2	-4.1

Figure 34. 2011 Cadillac CTS Lower Anchor With ADT V2 and ADT V4

To reduce potential variability of laying the tool on the seat, it was determined to modify the procedure so that the tool is held parallel to the seat pan, as was proposed in the NPRM. The additional steps to the procedure are as follows. First, measure the seat pan angle using a two-foot level that is placed on the longitudinal centerline of the seat pan such that it just contacts the seat back. Place an inclinometer on the level and record the angle (Figure 35). Place the tool at the desired base angle using shims or blocks to hold the tool stable, if needed (Figure 36).

Figure 35. Measuring Seat Pan Angle Using 2-Foot Level and Inclinometer

Figure 36. ADT Measurement Using Shims to Hold Base Angle

Although this was limited testing, the additional methods and tool modifications provide less subjectivity due to measuring the seat pan, and the longer length of ADT V4 allows the tool to be more stable in vehicles during the testing. Waterfall bolsters do provide more of a challenge with the depth tool, but if the lower anchors are 20 mm or less in the seat bite, it will be less of an issue for the testing. The test results using ADT V4 in the Cadillac CTS and Kia Forte can be found in Appendix F.

Summary

The lower anchor usability tools and procedures proposed in the NPRM for FMVSS No. 225, dated January 2015, were evaluated, and updated. These updates were based on comments and overall test observations by both UMTRI (work sponsored by NHTSA) and NHTSA. The usability tools were also compared to the testing tools used by the IIHS group, who currently rates vehicles based on the anchorage locations. The updates to the final tool designs are summarized below.

ADT

The tool was redesigned. The longer tool provides stability, and the 30° viewing angle combined with the zero-strip and depth gage allow for actual depth measurements rather than just indicating whether the anchor met or did not meet the criterion. Figure 38 shows the proposed tool and the final tool design as detailed in this report.

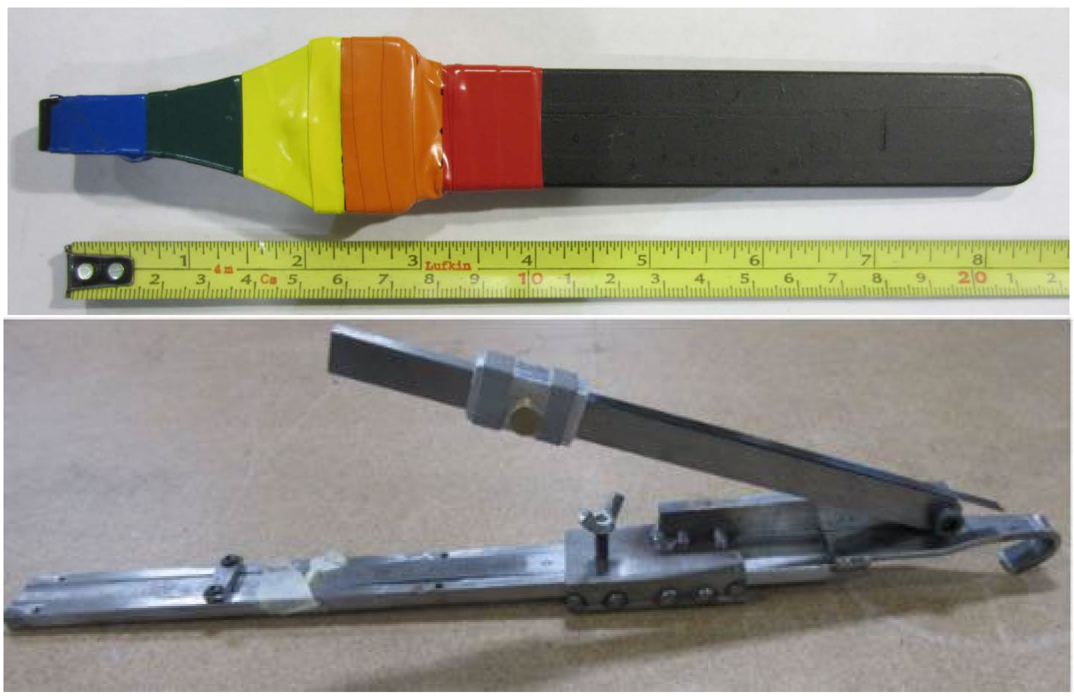

Figure 37. NPRM ADT (Top) Versus ADT V4 (Bottom)

AFT

The AFT overall shape did not change, but the instrumentation was updated, the anchor attachment was updated, and the overall length of the tool was increased. To help the operator apply the load consistently, an actuator was added along with a handle and support leg (Figure 39). Overall the improvements increased the usability and repeatability of the tool, but force measurement issues with the tool still exist, such as disengagement of the tool from the anchor and interaction with the seat cover or tunnel flaps.

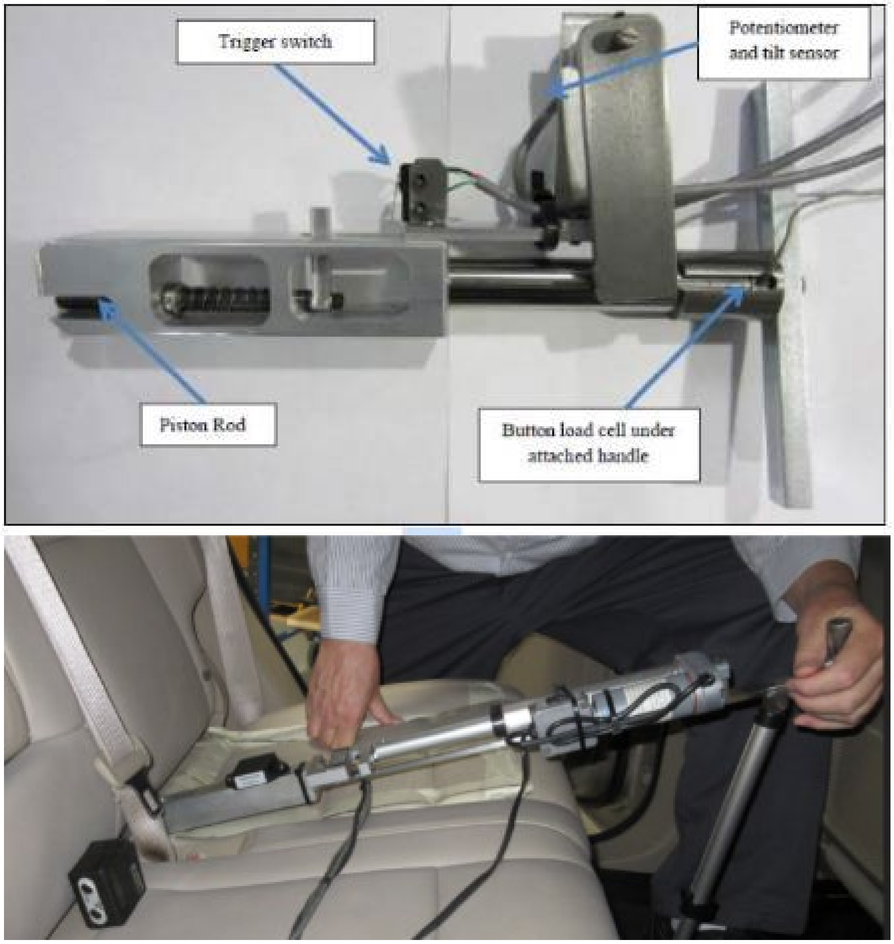

Figure 38. NPRM AFT (Top) Versus AFT V3 (Bottom)

CAT

The CAT overall shape did not change, but the instrumentation was updated, and a pulley bridge was added with a 67-newton weight to apply a consistent, vertical force to the tool (Figure 40). This tool was the most repeatable of the three usability tools.

Figure 39. NPRM CAT (Top) Versus CAT V2 (Bottom)

The variety of studies detailed in this report support the final design and test procedures for the LATCH usability tools. The final drawing package is in Appendix C and the final VRTC test procedure is in Appendix D.

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Appendix A: NHTSA Post-NPRM Phase 1 Procedure

1. Lower Anchor Data Setup
    1.1. Before collecting lower anchor data, adjust the seatback to a standard position. If the seatback is not fixed, set the seatback as specified by the vehicle manufacturer for the final seatback position for child restraint installations.
        1.1.1. If the seatback is not fixed and no seatback angle is recommended, then set the seat back to 25° using a 2-ft level and digital inclinometer along the front of the seat back cushion. Record the angle.
        1.1.2. If possible, measure and record the angle of the head restraint post as a quick reference angle.
    1.2. For each seat position with lower anchor hardware, lower anchors are designated as Driver Outboard, Driver Inboard, Center Driver, Center Pass, Passenger Outboard, and Passenger Inboard.
    1.3. Using the appropriate LATCH tool, document the anchor depth within the seat bight, anchor attachment force, and clearance angle around the anchors following the procedures described in sections 25 below. Measurements should be documented for inboard, outboard, and center anchors.

2. Attachment Force Tool
    2.1. The lower anchor depth within the seat bight and lower anchor attachment force are measured using the attachment force tool (Figure A-1). The attachment force tool consists of a square cross-section guide rod, force tool slider, and force gauge. Additionally, an angle gauge is mounted to the guide rod.

Figure A-1. AFT Used to Measure Depth of Lower Anchor Within Seat Bight and Attachment Force

    2.2. With the force tool slider retracted, place the notched end of the guide rod in the center of the lower anchor bar and apply gentle pressure to seat it.
    2.3. Position the guide rod at the angle that allows the top and bottom front surface of the force tool slider to rest touching the seat cushion (Figure A-2). Record the approach angle using an angle gauge on the guide rod. If the force tool slider does not touch the seat cushion because of a tunnel or other open access, follow the guidelines in step 2.4.

Figure A-2. Initial Position of Force Tool Slider With Seat Cushion Touching Top and Bottom Surfaces

2.4 Place the tunnel adapter against the opening. Then position the guide rod at the angle that allows the top and bottom front surface of the force tool slider to rest touching the tunnel adaptor (Figure A-3). If contact of the guide rod with the seat pan occurs before the top and bottom front surface are in contact with the tunnel adaptor, then use the resulting angle. Record the approach angle using an angle gauge on the guide rod.

Figure A-3. Initial Position of Force Tool Slider With Tunnel Adaptor Touching Top and Bottom Surfaces

3. Record the Depth of Lower Anchor within Seat Bight

The guide rod is color-coded to measure the depth in 20-mm increments, based on the following color scale: blue = -20 to 0 mm, green = 0 to 20 mm, yellow = 20 to 40 mm, white = 40 to 60 mm, red = 60 to 80 mm, gold = 80 to 100 mm, black = 100 to 120 mm.

Record the color visible at the front edge of the reference window (Figure A-4). This indicates the depth of the anchor within the seat bight. Remove the tunnel adaptor, if applicable.

Figure A-4. Depth Within Bight is Estimated From Color Visible at Front Edge of Viewing Window (white in this example)

4. Attachment Force

   Once the guide rod is in place and the depth within the bight has been recorded, the force tool slider must slide into the seat bight (if applicable) and onto the lower anchor bar with a longitudinal force applied to the force gauge with no other assistance, including application of vertical or lateral forces on the force tool slider or manipulation of seat cushions. If covers are provided over the lower anchor, then testing is done with the covers moved out of the way or stored per the vehicle owner's manual. If anchors can be stowed, anchor testing is done with anchors positioned in the manufacturer's recommended position. If funnel guides are provided as standard equipment with the vehicle, place the funnel guide on the anchor before evaluating the anchor.

   4.2 While maintaining the angle recorded in step 2.3, move the force tool slider along the guide rod (Figure A-5) until the force tool slider bottoms out, which occurs when the engaged switch is activated.

Figure A-5. Measuring Lower Anchor Attachment Force

Record the attachment force using the AFT. The attachment force recorded should be the peak value that occurs during the entire motion, from initial cushion contact (if applicable) until the force tool has bottomed out.

5. Clearance Angle Tool

   5.1. Seatback cushion stiffness and the vehicle anchor structure must be designed to allow a child restraint connector to rotate upward about the anchor bar, a measure called clearance angle.

   5.2. The clearance angle is measured with the CAT, force gauge, and angle gauge (Figure A-6).

Figure A-6. CAT

5.3. Attach the CAT to the lower anchor.
5.4 Place the pulley bridge directly above the CAT. For example, the front of the pulley bridge may rest on the front seatback and the rear of the pulley bridge may rest on the rear seat back (Figure A-7).
5.5 The pulley bridge should be leveled using any means necessary (e.g., raising or lowering the front seat, using shims).
5.6 Extend the attachment cable over the pulley and attach a load of 67 N (15 lb) to the attachment cable. Pulley should self-locate so that the loading cable is vertically loading the CAT (Figure A-7). Verify the loading cable is vertical using an inclinometer.
5.7 Record the clearance angle.

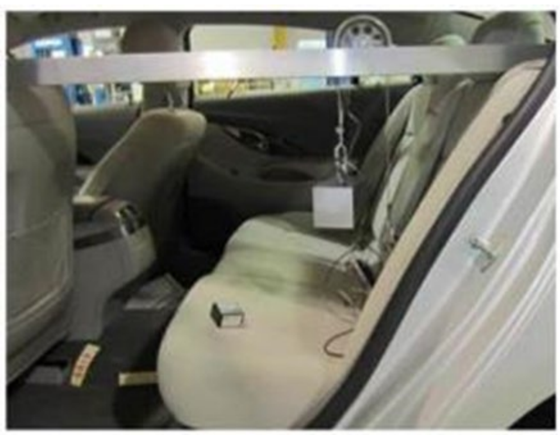


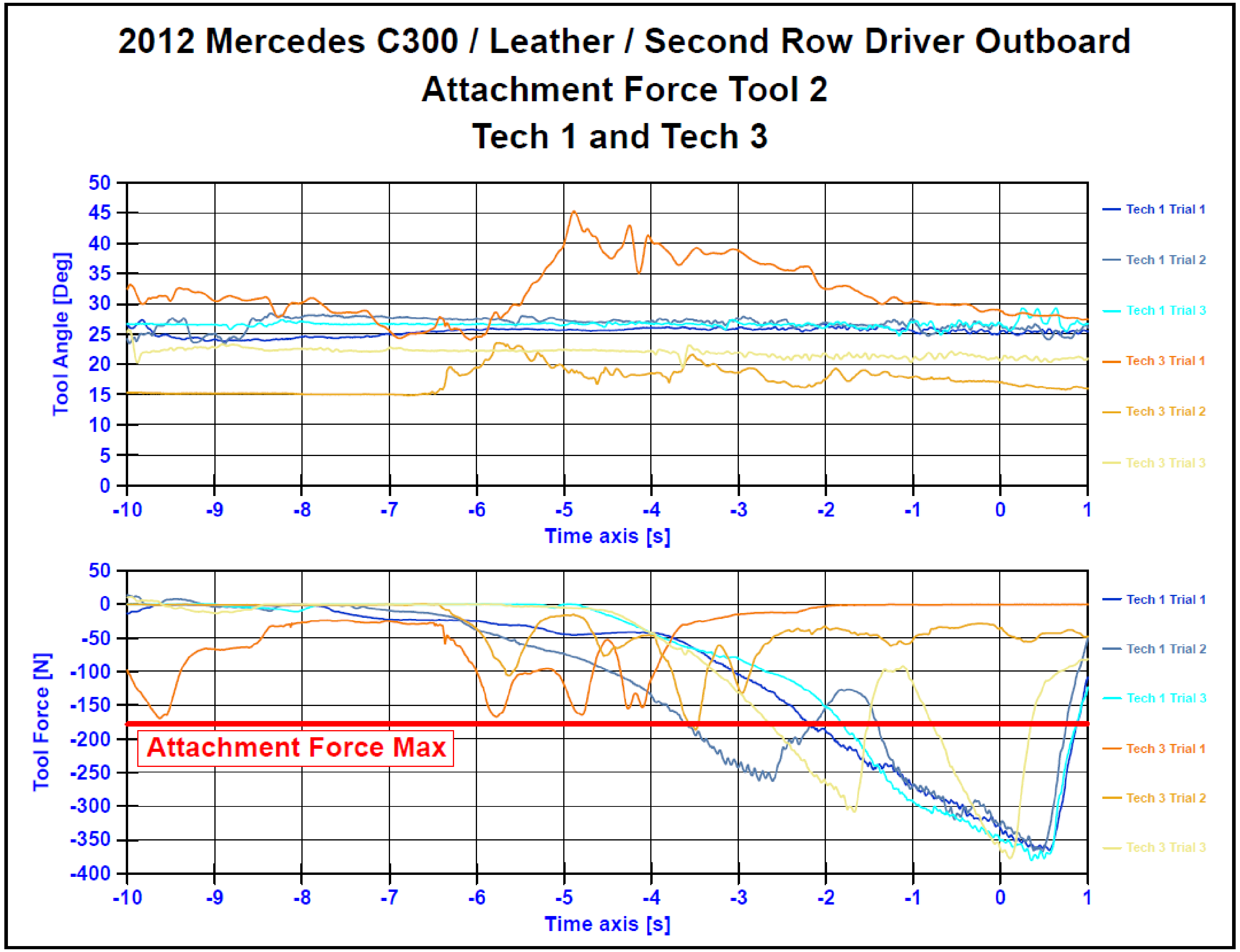
Figure A-7. Measuring Lower Anchor Clearance Angle

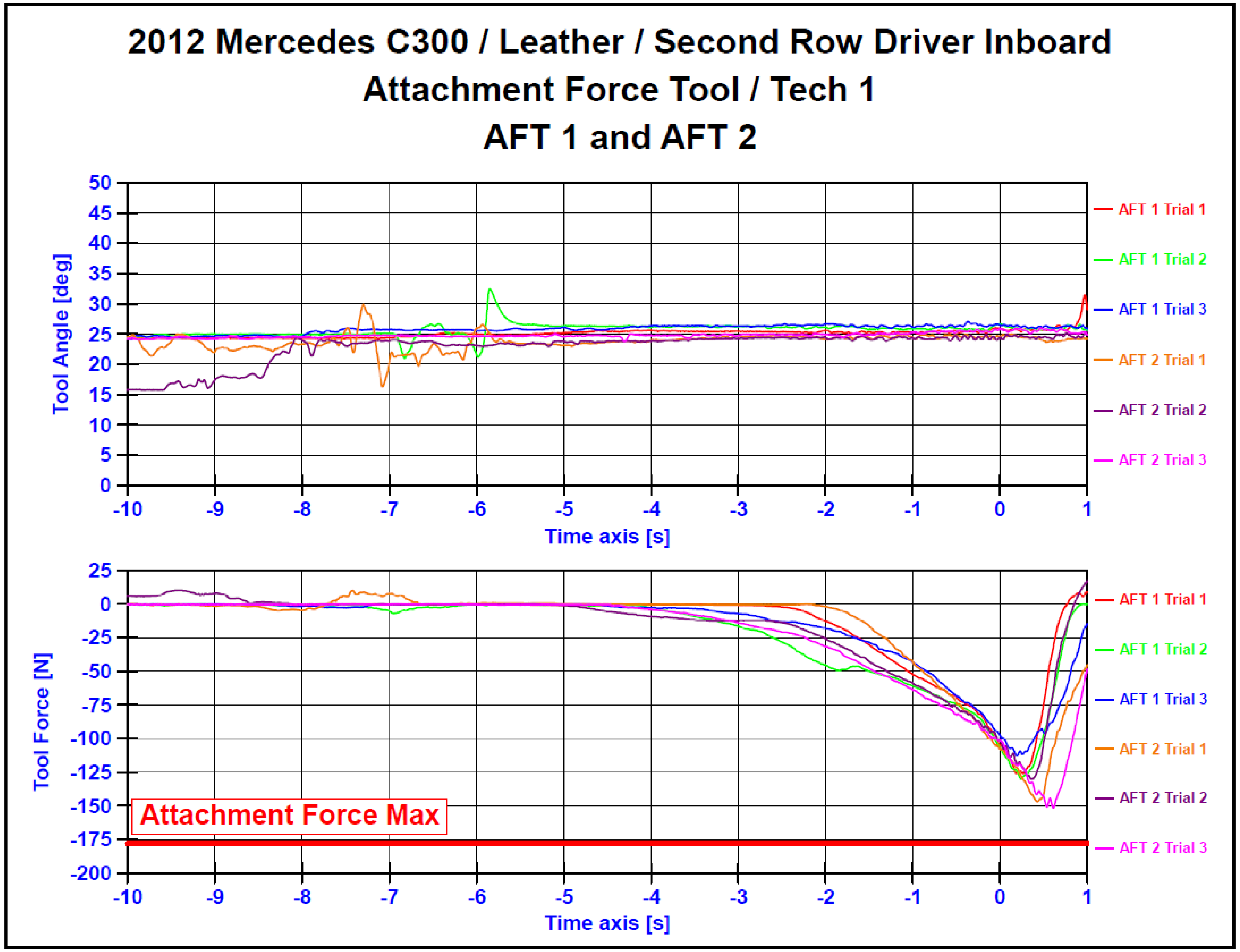
Appendix B: Post-NPRM Results Tables

In the results tables presented in this appendix, cells that are highlighted red did not meet the following criteria: an anchor depth of 20 mm or less, an attachment force of 178 newtons (40 lb) or less, and a clearance angle of 54° or greater. In the first section for the IIHS ADT, the tool color (depth) and approach angle were recorded for each test. The second section with the AFT results shows calculations of the peak force that was recorded along with the approach angle while attaching the AFT to the anchor. The third section for the CAT data illustrates the angle that was measured once the tool was loaded and the weight was motionless from the pulley bridge. The fourth section includes the results from the ADT that tabulates the results as a Y (met criterion) or W (did not meet criterion).

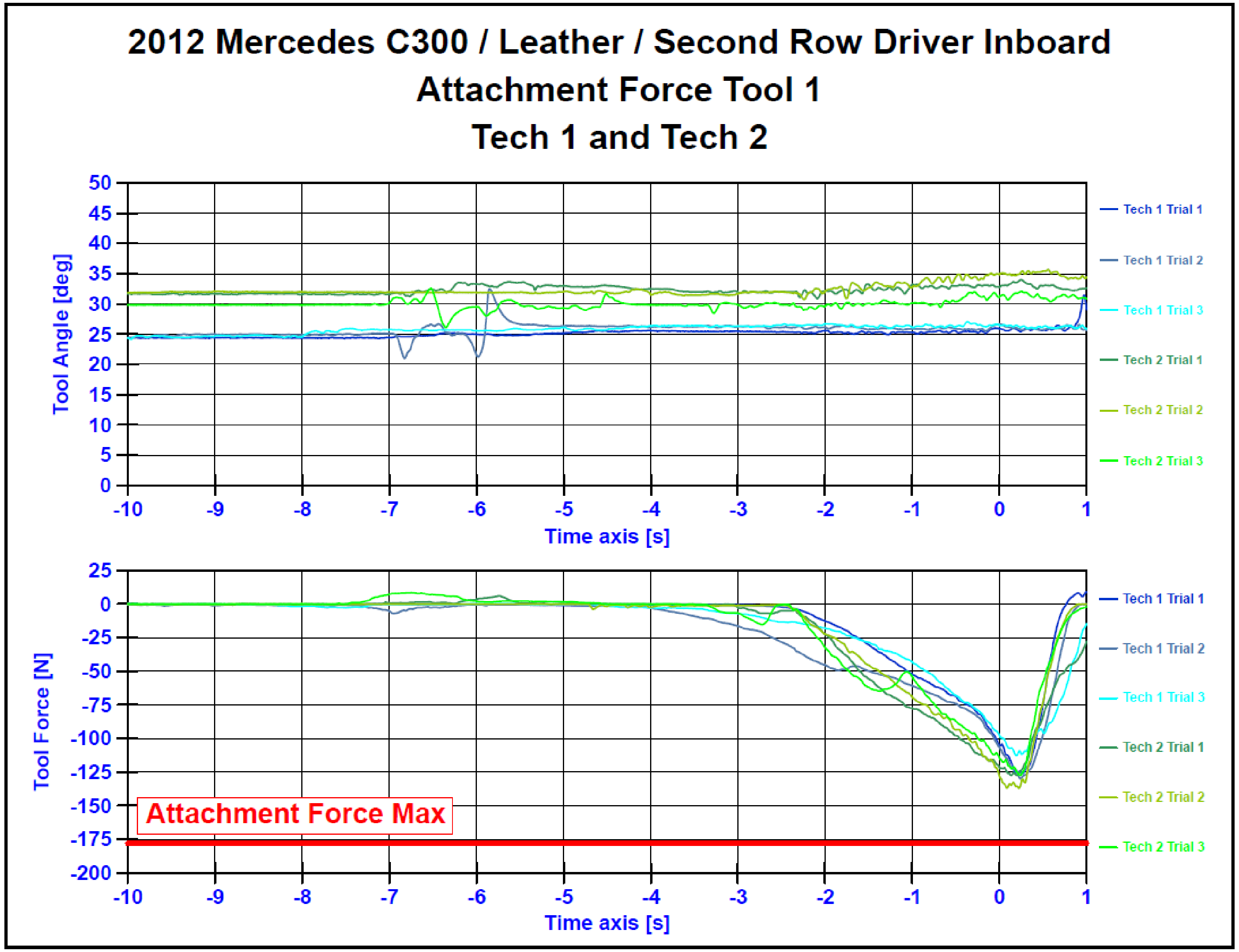
2012 Mercedes C300 – Leather

	Tech 1												Tech 2						Tech 3					
	Tool Set I						Tool Set II						Tool Set I						Tool Set II					
	Meas. 1		Meas. 2		Meas. 3		Meas. 1		Meas. 2		Meas. 3		Meas. 1		Meas. 2		Meas. 3		Meas. 1		Meas. 2		Meas. 3	
	Modified AFT/ADT Depth - Blue (B) / Green (G) / Yellow (Y) White (W) Red (R) / Gold (GLD) / Black (BLK)																							
Driver Outboard	G /28°		G /28°		G /28°		G /28°		G /28°		G /28°		Y / 36°		Y / 36°		Y / 36°		G / 23°		G / 24°		G / 21°	
Driver Inboard	G /26°		G /26°		G /26°		G /26°		G /26°		G /26°		G / 32°		G / 32°		G / 30°		G / 25°		G / 23°		G / 24°	
	Modified AFT/ADT Force - LBF (N) / Degrees																							
	Lbf (N)	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**
Driver Outboard	69 (307)	28	63 (280)	28	63 (280)	28	75 (334)	28	74 (329)	28	78 (347)	28	57 (254)	36	73 (325)	36	69 (307)	36	38 (169)	23	41 (182)	24	82 (365)	21
Driver Inboard	24 (107)	26	24 (107)	26	22 (98)	26	24 (107)	26	22 (98)	26	22 (98)	26	27 (120)	32	29 (129)	32	26 (116)	30	32 (142)	25	29 (129)	23	26 (116)	24
	CAT V1 - Degrees @ 15 lbf (67 N) vertical																							
Driver Outboard	64		65		65		65		66		66		65		65		66		67		65		68	
Driver Inboard	68		69		70		71		72		72		70		69		71		71		72		72	
	Meet/Not Meet ADT - Yellow (Y) = Met Criterion / White (W) = Did Not Meet Criterion																							
Driver Outboard	Y												Y						Y					
Driver Inboard	Y												Y						Y					


2012 Mercedes C300 / Leather / Second Row Driver Outboard
Attachment Force Tool 2
Tech 1 and Tech 3
Tool Angle [Deg]
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3
Tool Force [N]
Attachment Force Max
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3



2012 Mercedes C300 / Leather / Second Row Driver Inboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3


2012 Mercedes C300 / Leather / Second Row Driver Inboard
Attachment Force Tool 1
Tech 1 and Tech 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
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-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
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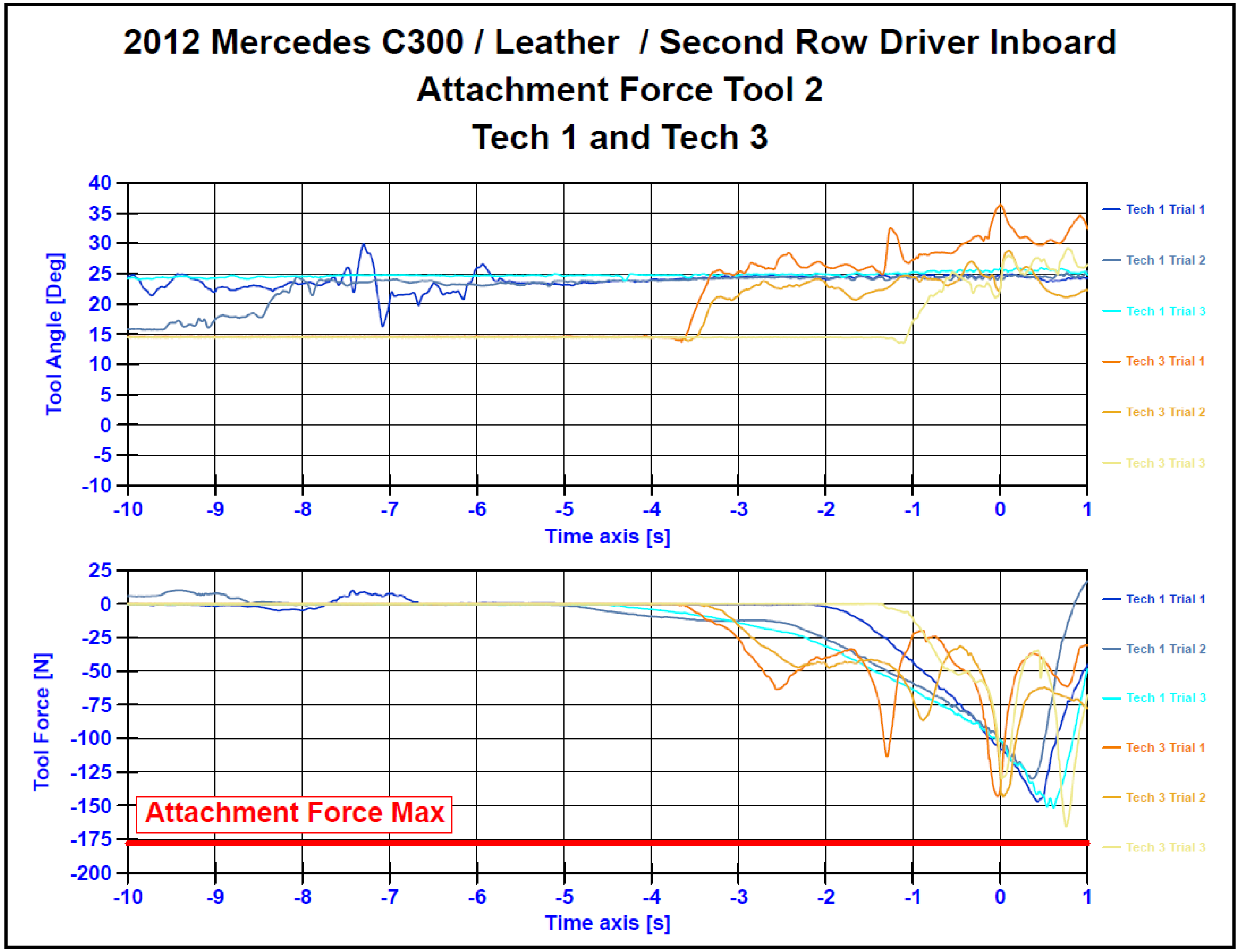
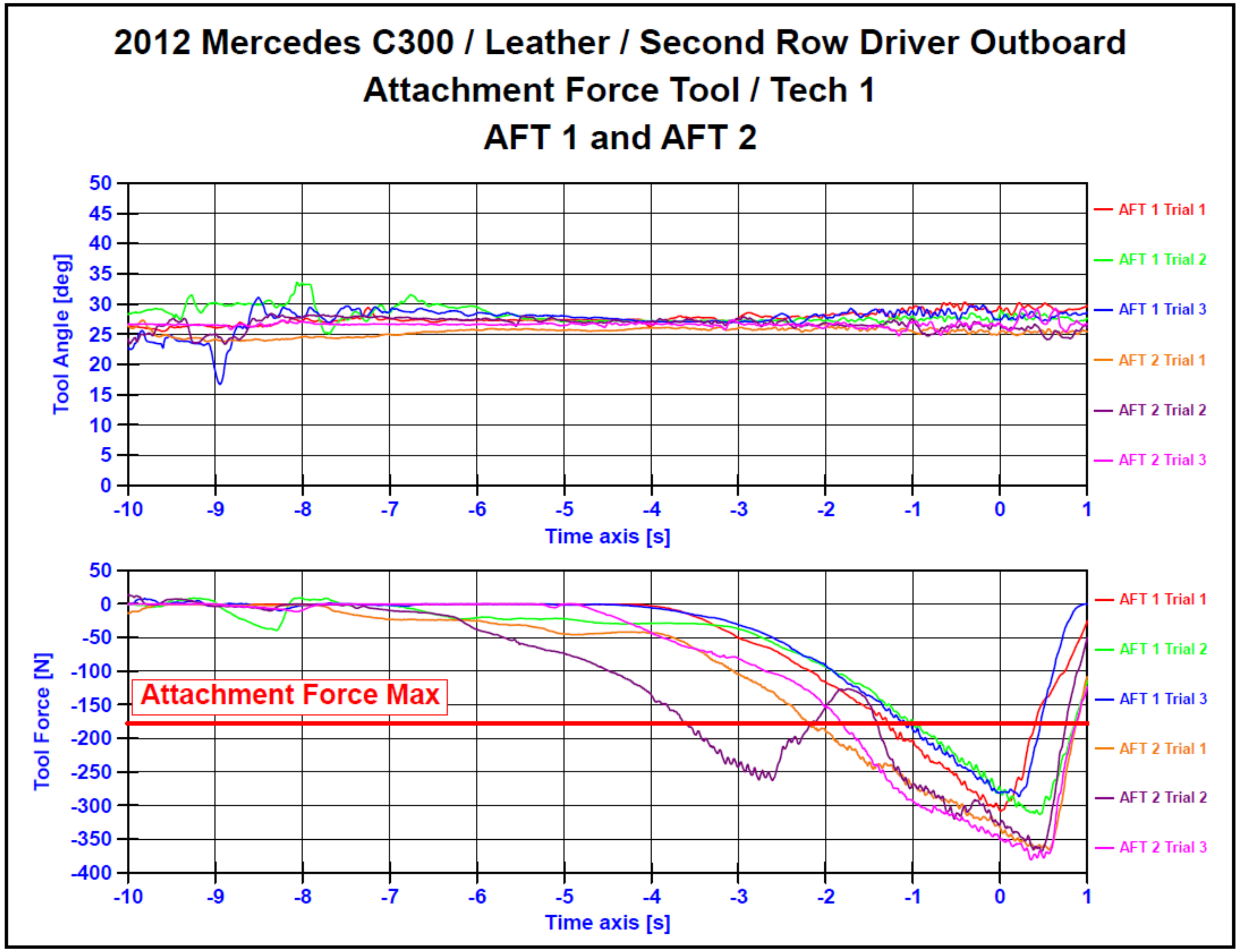
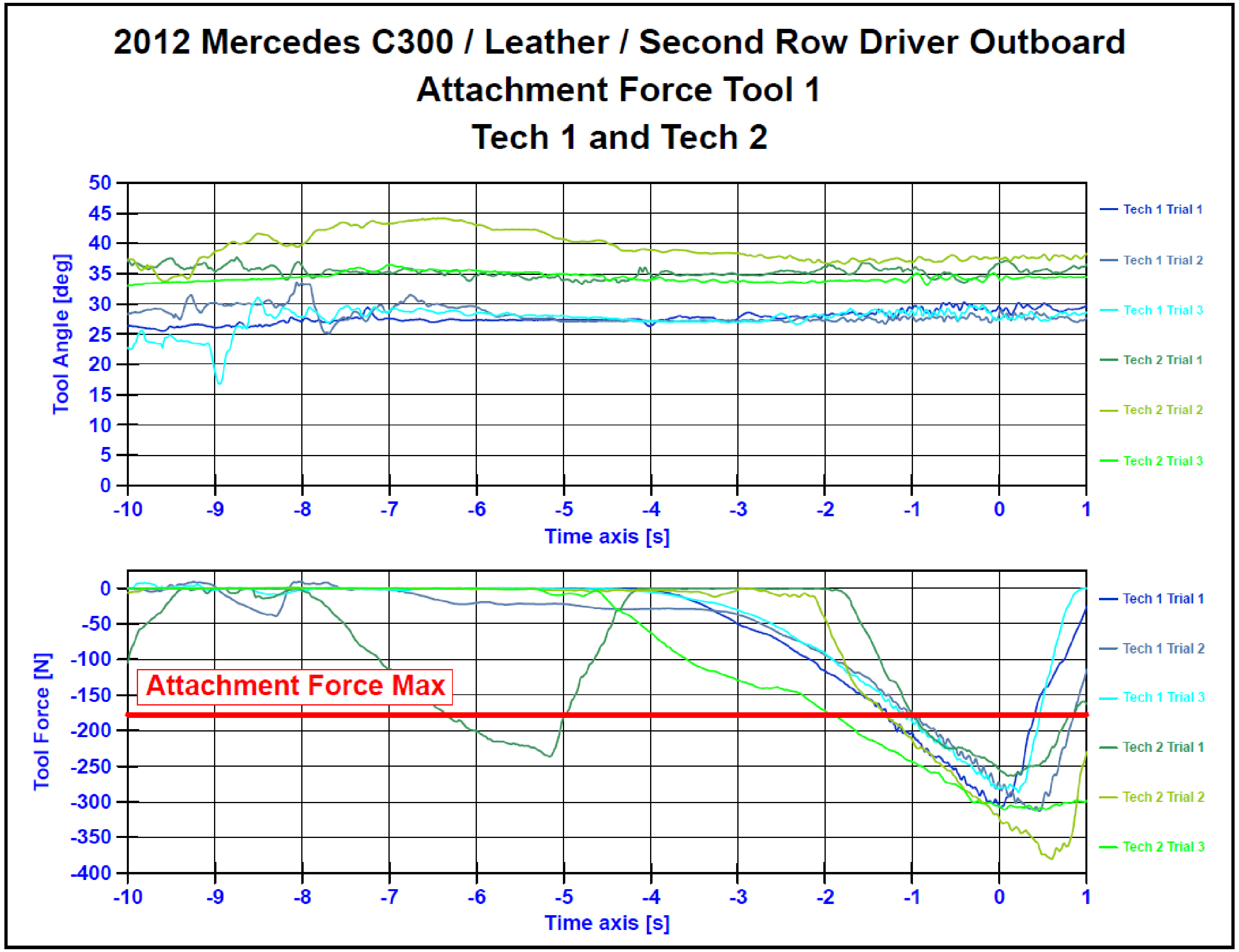
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3


2012 Mercedes C300 / Leather / Second Row Driver Inboard
Attachment Force Tool 2
Tech 1 and Tech 3
Tool Angle [Deg]
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3
Tool Force [N]
Attachment Force Max



2012 Mercedes C300 / Leather / Second Row Driver Outboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
50
0
-50
-100
-150
-200
-250
-300
-350
-400
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3



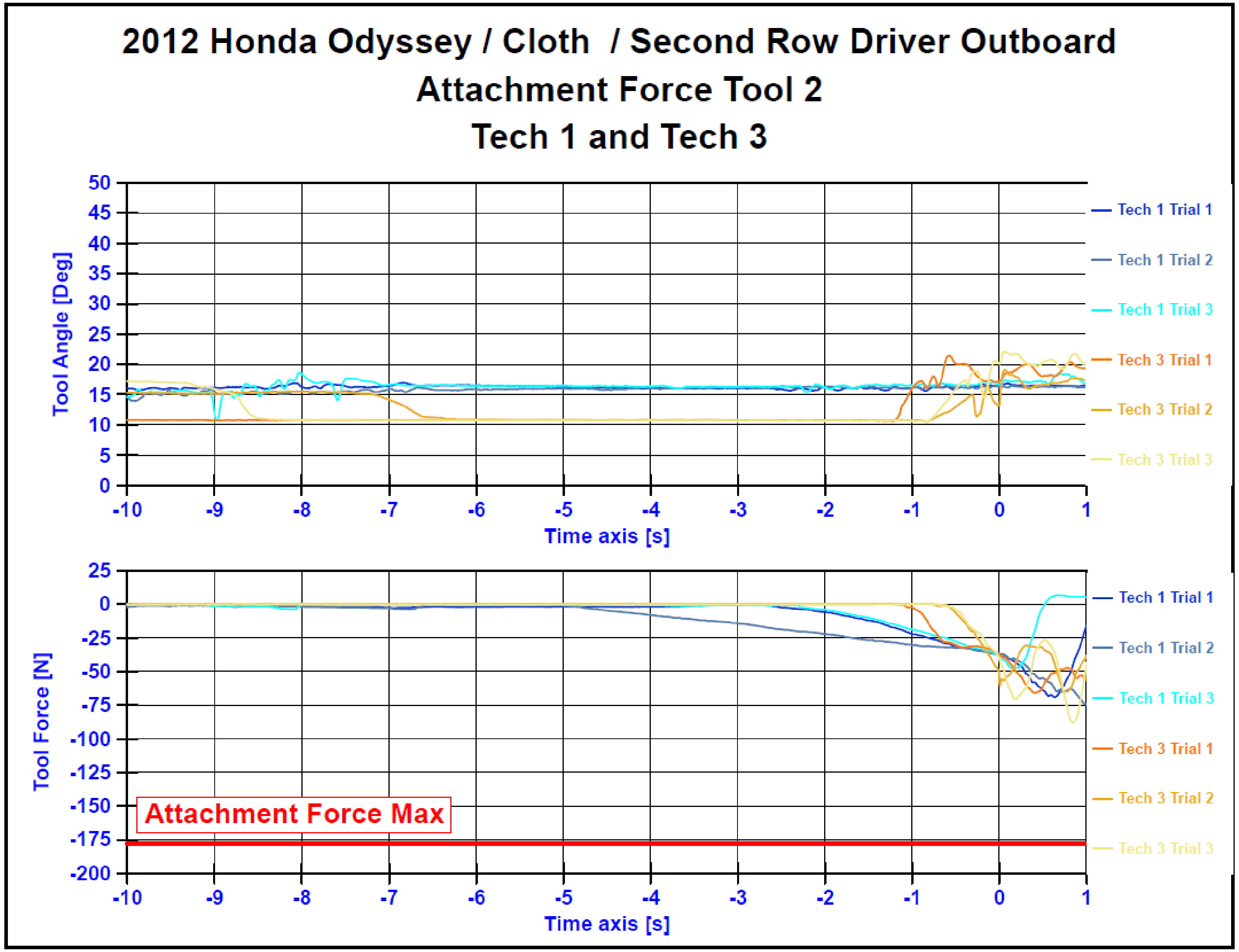
2012 Mercedes C300 / Leather / Second Row Driver Outboard
Attachment Force Tool 1
Tech 1 and Tech 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3
Tool Force [N]
0
-50
-100
-150
-200
-250
-300
-350
-400
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3

2012 Honda Odyssey – Cloth

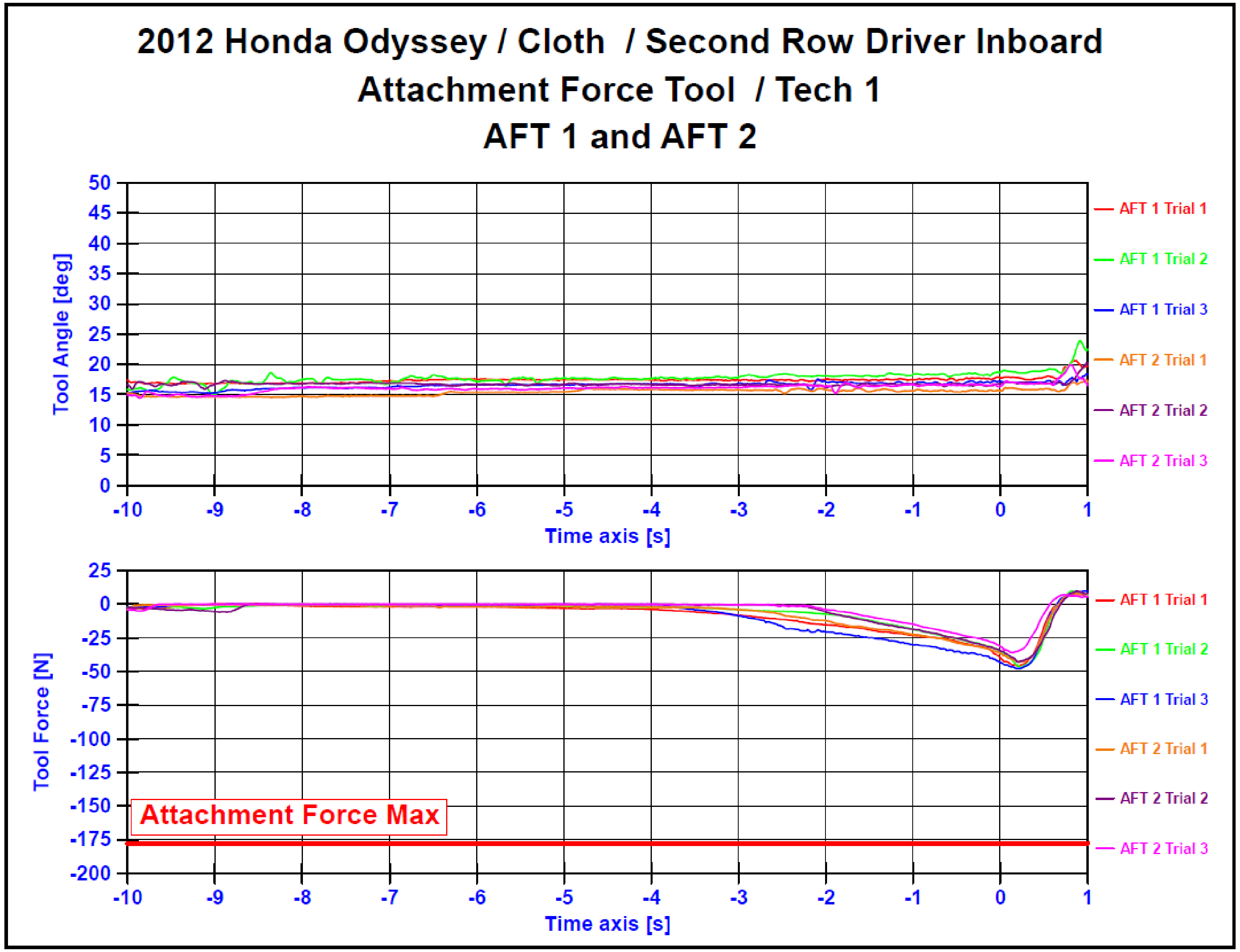
	Tech 1						Tech 2			Tech 3		
	Tool Set I			Tool Set II			Tool Set I			Tool Set II		
	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3
	Modified AFT/ADT Depth - Blue (B) / Green (G) / Yellow (Y) White (W) Red (R) / Gold (GLD) / Black (BLK)											
Driver Outboard	G /18°	G /18°	G /18°	G /17°	G /17°	G /17°	Y /23°	Y /24°	Y /13°	G /20°	G /17°	G /18°
Driver. Inboard	G /18°	G /18°	G /18°	G /17°	G /17°	G /17°	Y /30°	Y /29°	Y /28°	G /18°	G /19°	G /19°

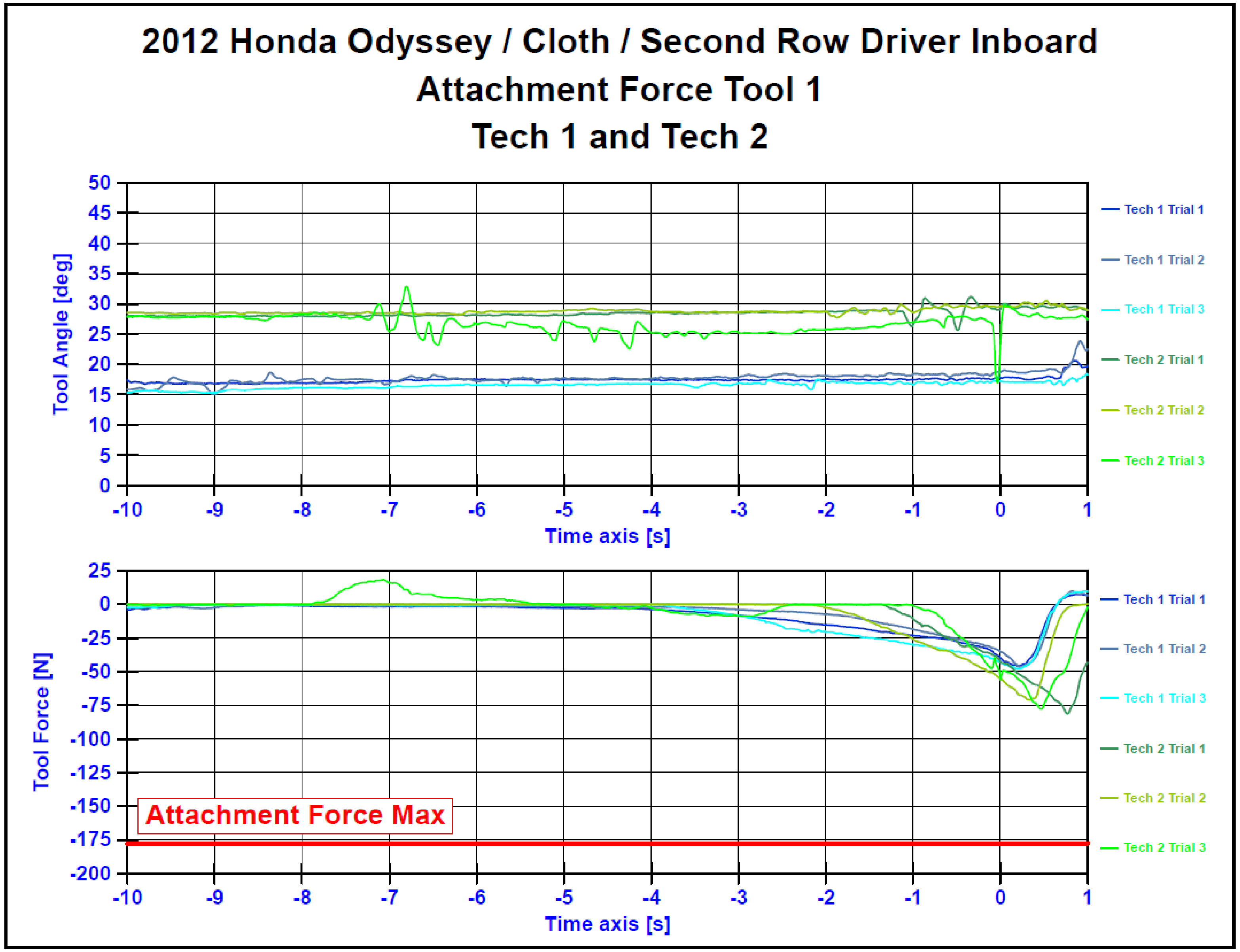
	Modified AFT/ADT Force - LBF (N) / Degrees																							
	Lbf (N)	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**
Driver Outboard	10 (44)	18	11 (49)	18	10 (44)	18	9 (40)	17	8 (36)	17	9 (40)	17	13 (58)	23	13 (58)	24	14 (62)	23	8 (36)	20	13 (58)	17	9 (40)	18
Driver. Inboard	9 (40)	18	8 (36)	18	10 (44)	18	8 (36)	17	8 (36)	17	7 (31)	17	10 (44)	30	12 (53)	29	11 (49)	28	12 (53)	18	11 (49)	19	17 (76)	19

	CAT V1 - Degrees @ 15 lbf (67 N) vertical											
Driver Outboard	43	43	43	43	43	43	43	43	43	43	43	43
Driver. Inboard	42	42	42	43	43	43	42	42	42	42	42	42
	Meet/Not Meet ADT - Yellow (Y) = Met Criterion / White (W) = Did Not Meet Criterion											
Driver Outboard	Y						Y			Y		
Driver Inboard	Y						Y			Y		

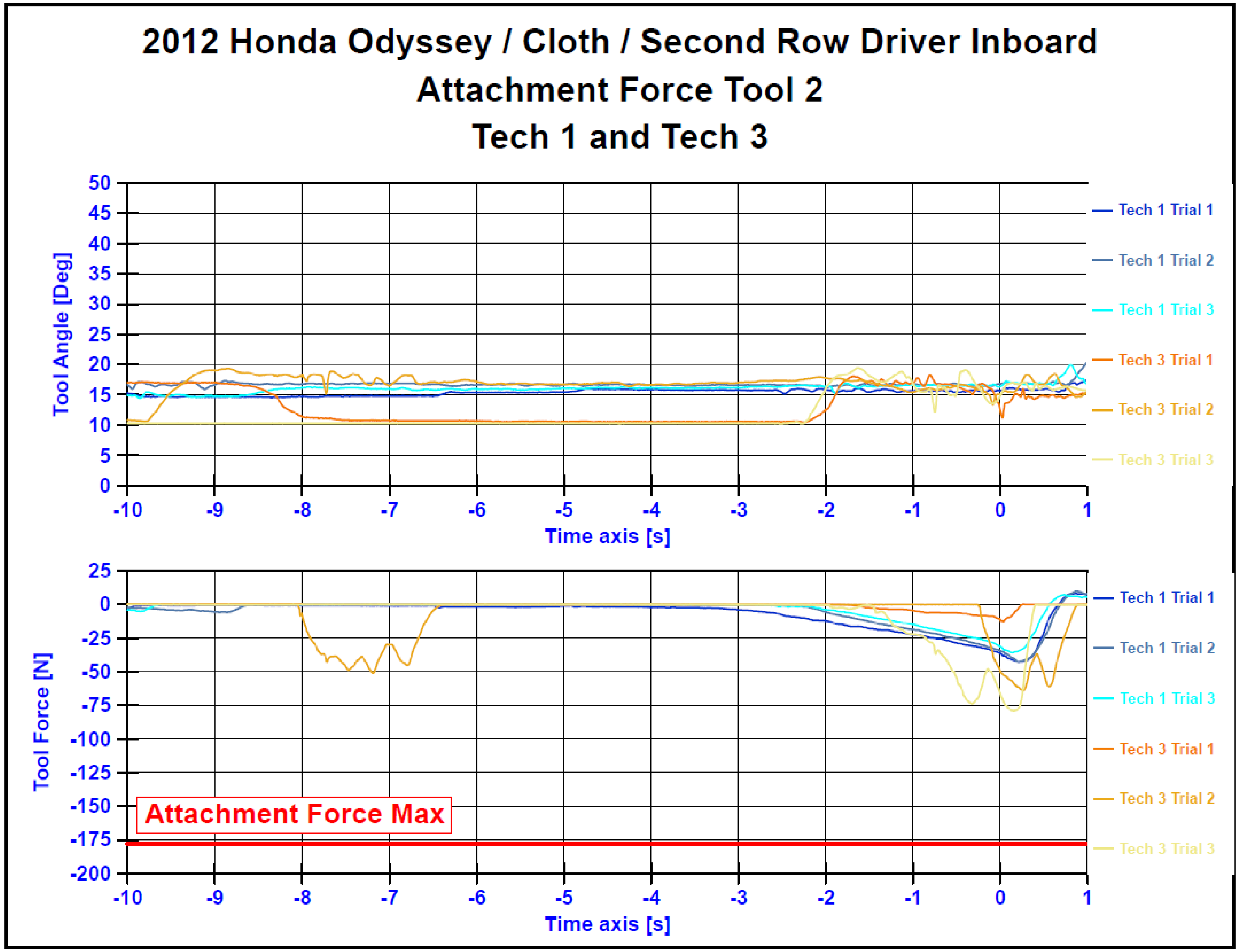


2012 Honda Odyssey / Cloth / Second Row Driver Outboard
Attachment Force Tool 2
Tech 1 and Tech 3
Tool Angle [Deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max

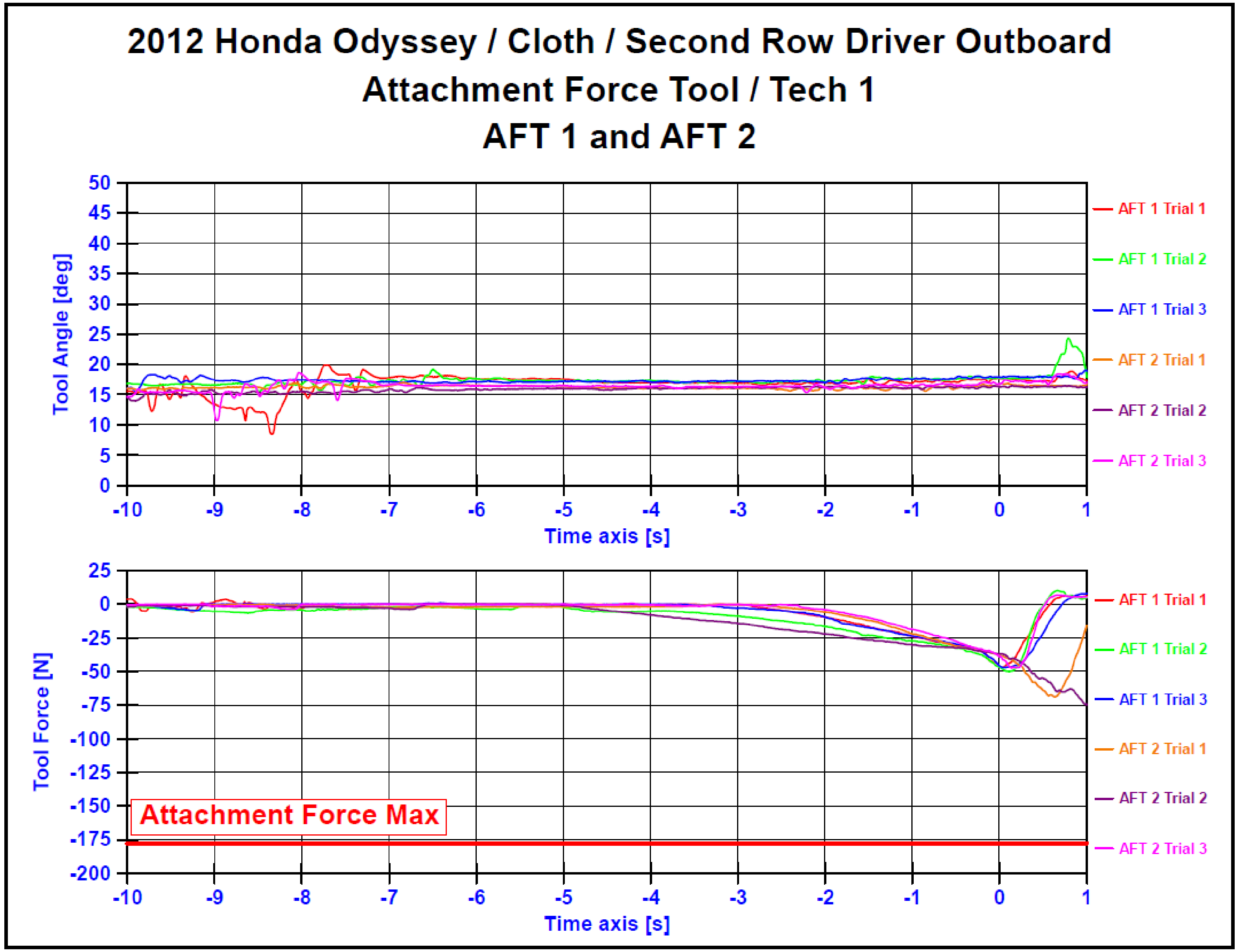

2012 Honda Odyssey / Cloth / Second Row Driver Inboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3

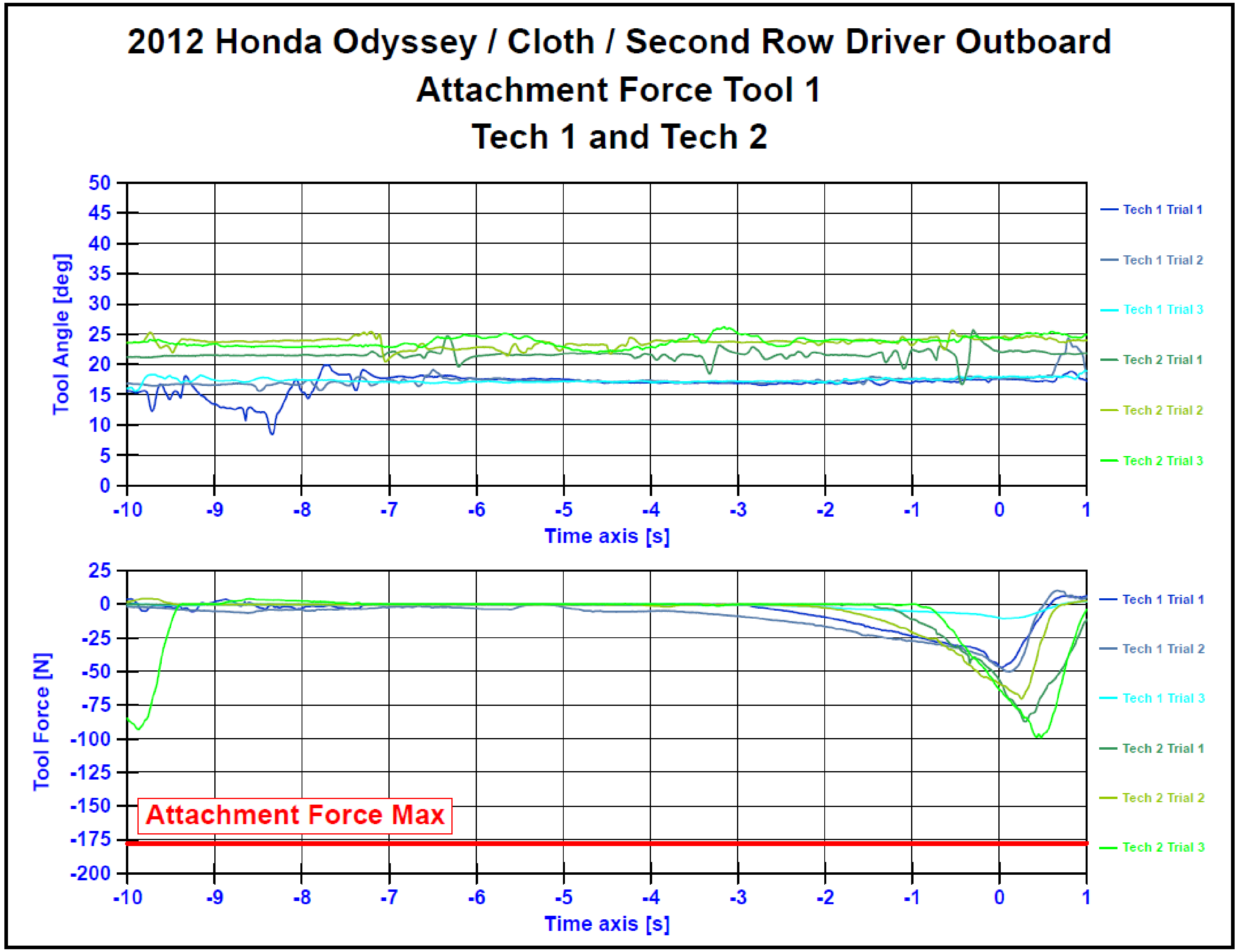


2012 Honda Odyssey / Cloth / Second Row Driver Inboard
Attachment Force Tool 1
Tech 1 and Tech 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
Time axis [s]



2012 Honda Odyssey / Cloth / Second Row Driver Inboard
Attachment Force Tool 2
Tech 1 and Tech 3
Tool Angle [Deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3


2012 Honda Odyssey / Cloth / Second Row Driver Outboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3



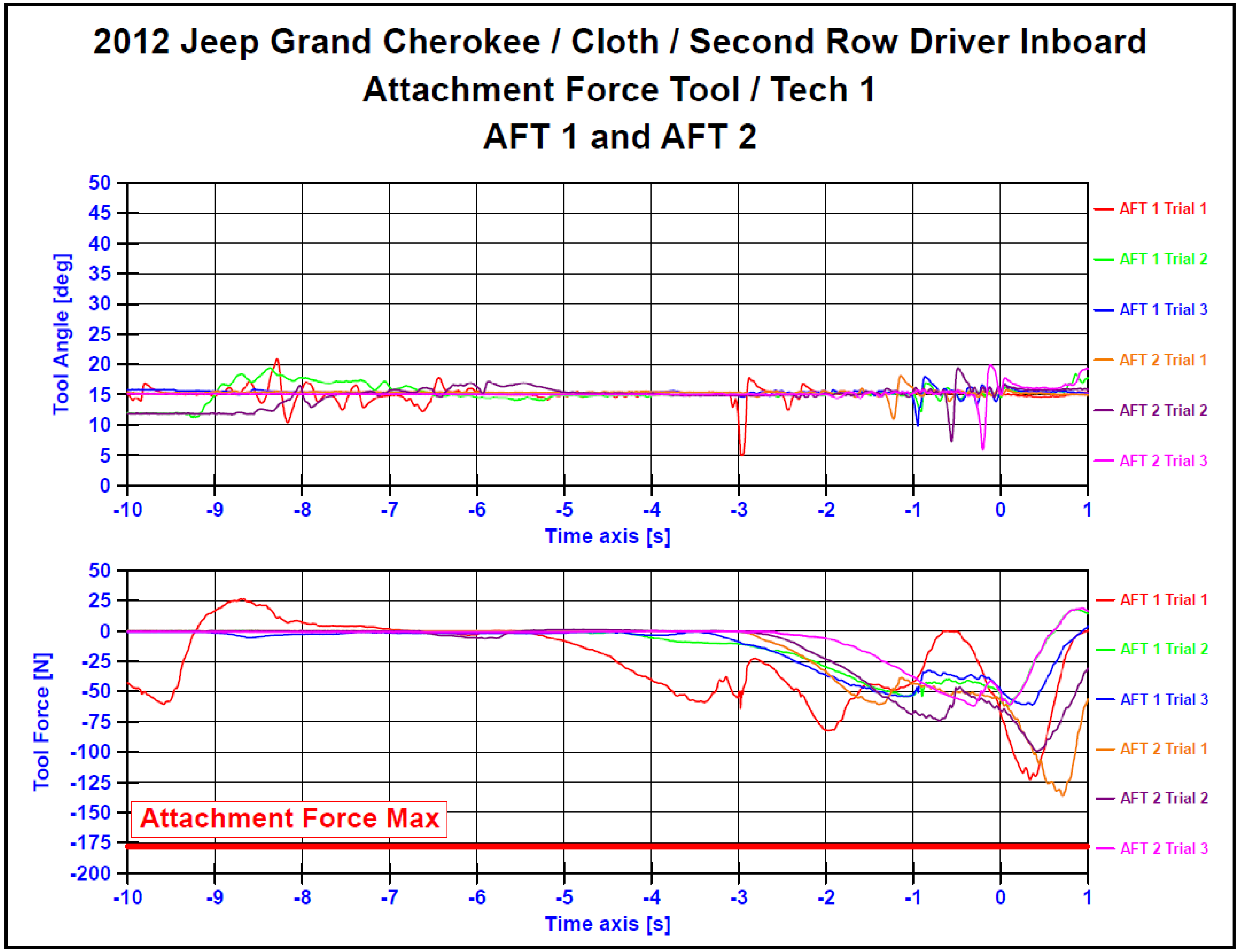
2012 Honda Odyssey / Cloth / Second Row Driver Outboard
Attachment Force Tool 1
Tech 1 and Tech 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max

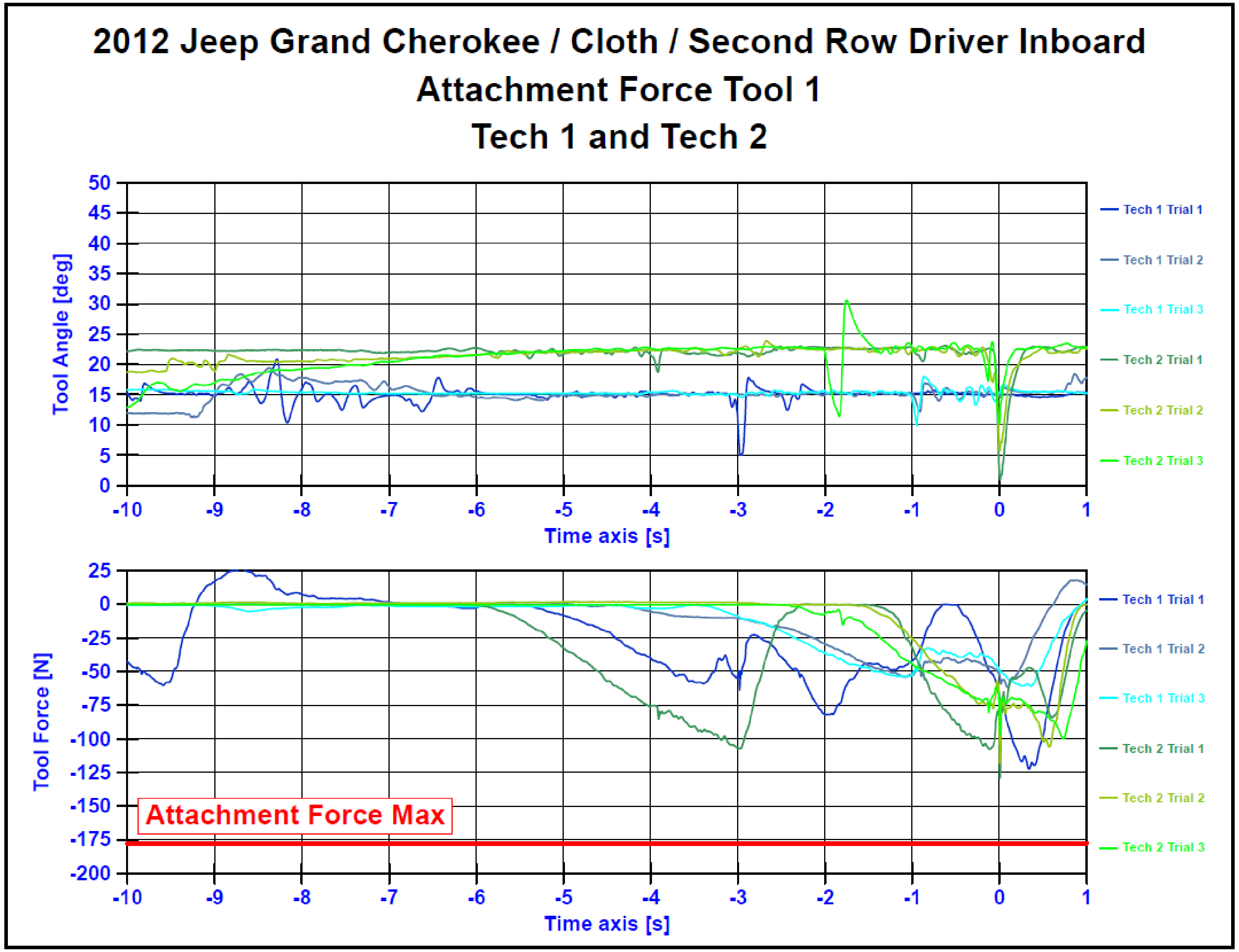
2012 Jeep Grand Cherokee – Cloth

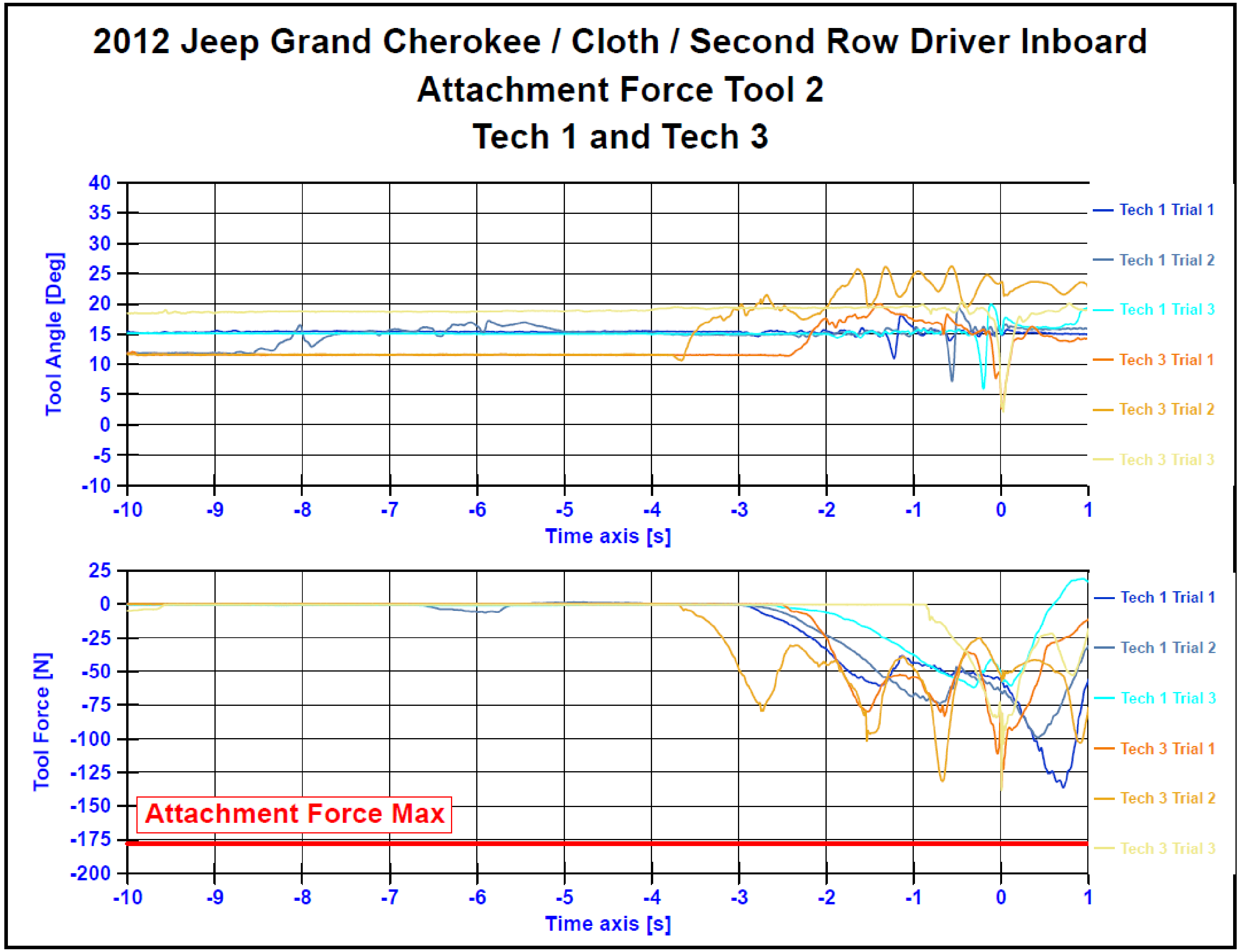
	Tech 1						Tech 2			Tech 3		
	Tool Set I			Tool Set II			Tool Set I			Tool Set II		
	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3
	Modified AFT/ADT Depth - Blue (B) / Green (G) / Yellow (Y) White (W) Red (R) / Gold (GLD) / Black (BLK)											
Driver Outboard	Y/18°	Y/18°	Y/18°	Y/18°	Y/18°	Y/18°	W/26°	W/25°	W/25°	Y/20°	Y/20°	Y/17°
Driver Inboard	Y/15°	Y/15°	Y/15°	Y/16°	Y/16°	Y/16°	W/24°	W/24°	W/24°	Y/17°	Y/20°	Y/20°
	CAT V1 - Degrees @ 15 lbf (67 N) vertical											
Driver Outboard	53	54	54	55	55	55	53	54	54	54	54	54
Driver Inboard	57	58	58	59	58	59	57	58	58	58	58	58
	Meet/Not Meet ADT - Yellow (Y) = Met Criterion / White (W) = Did Not Meet Criterion											
Driver Outboard	W						W			W		
Driver Inboard	W						W			W		

Modified AFT/ADT Force - LBF (N) / Degrees

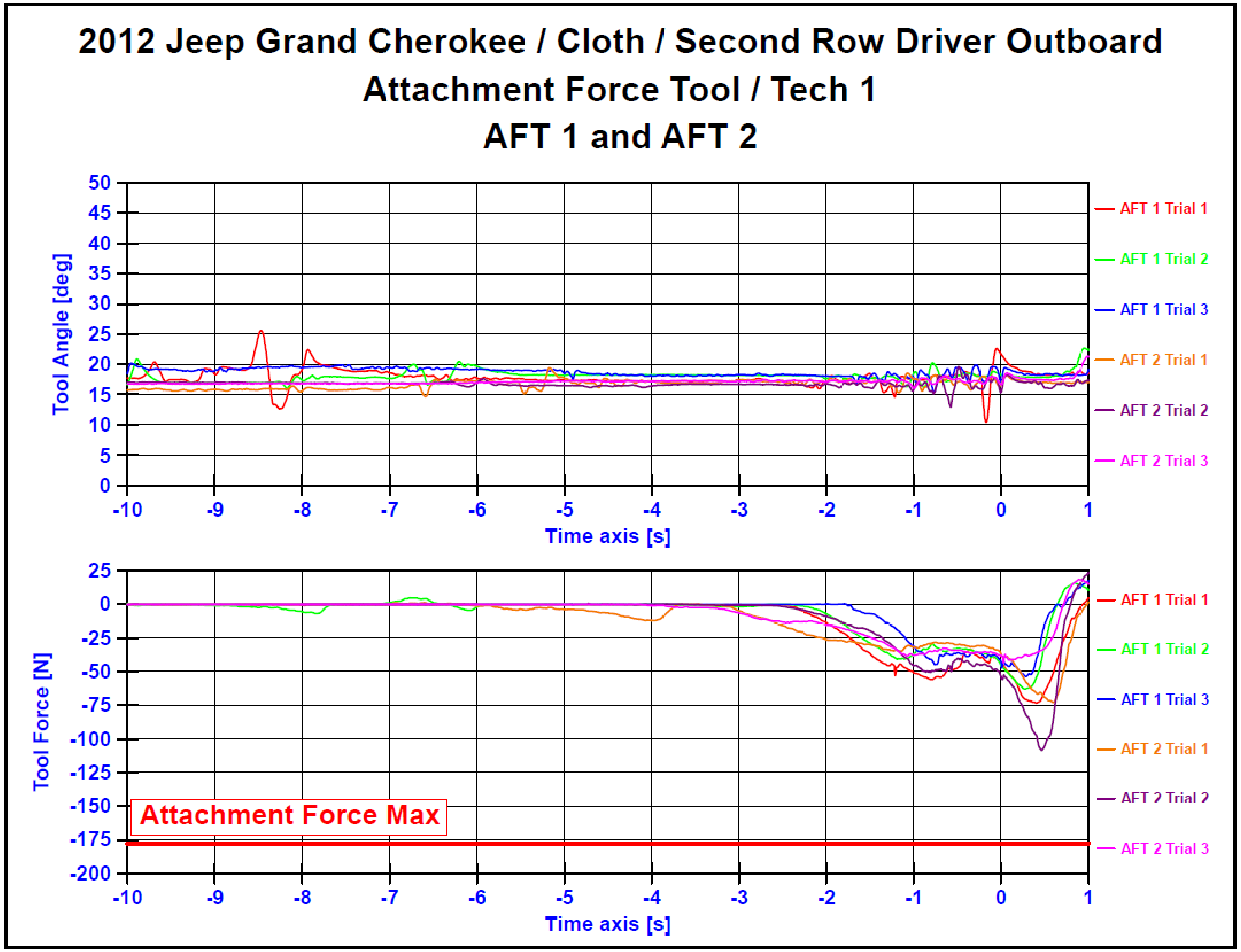
	Tech 1 Tool Set I Meas. 1		Meas. 2		Meas. 3		Tech 1 Tool Set II Meas. 1		Meas. 2		Meas. 3		Tech 2 Tool Set I Meas. 1		Meas. 2		Meas. 3		Tech 3 Tool Set II Meas. 1		Meas. 2		Meas. 3	
	Lbf (N)	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**
Driver Outboard	13 (58)	18	10 (44)	18	10 (44)	18	8 (36)	18	11 (49)	18	9 (40)	18	15 (67)	26	20 (89)	25	17 (76)	25	27 (120)	20	14 (62)	20	13 (58)	17
Driver Inboard	18 (80)	15	12 (53)	15	12 (53)	15	14 (62)	16	17 (76)	16	14 (62)	16	24 (107)	24	18 (80)	24	16 (71)	24	25 (111)	17	30 (133)	20	19 (85)	20


2012 Jeep Grand Cherokee / Cloth / Second Row Driver Inboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
50
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3

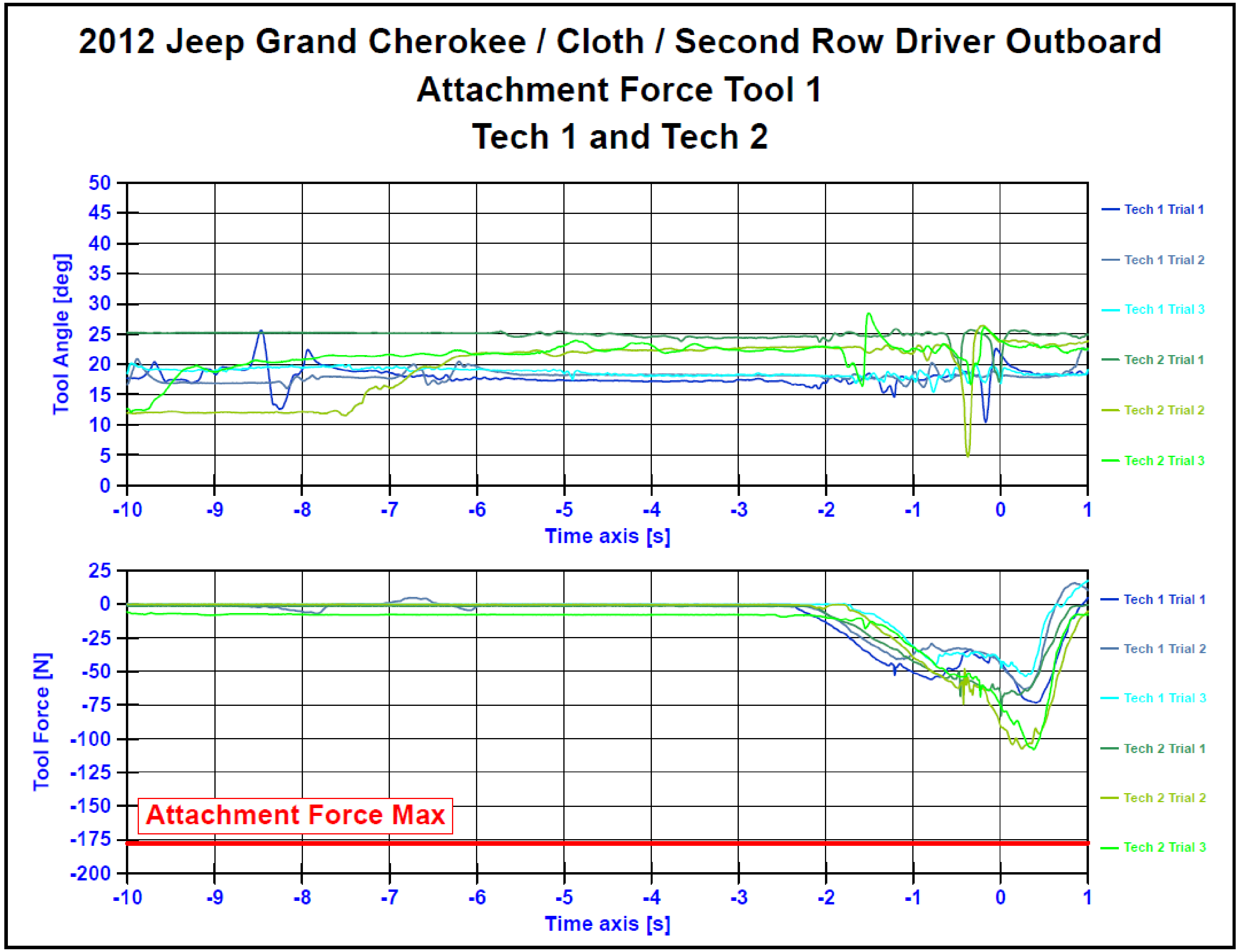

2012 Jeep Grand Cherokee / Cloth / Second Row Driver Inboard
Attachment Force Tool 1
Tech 1 and Tech 2
Tool Angle [deg]
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3
Tool Force [N]
Attachment Force Max
Time axis [s]



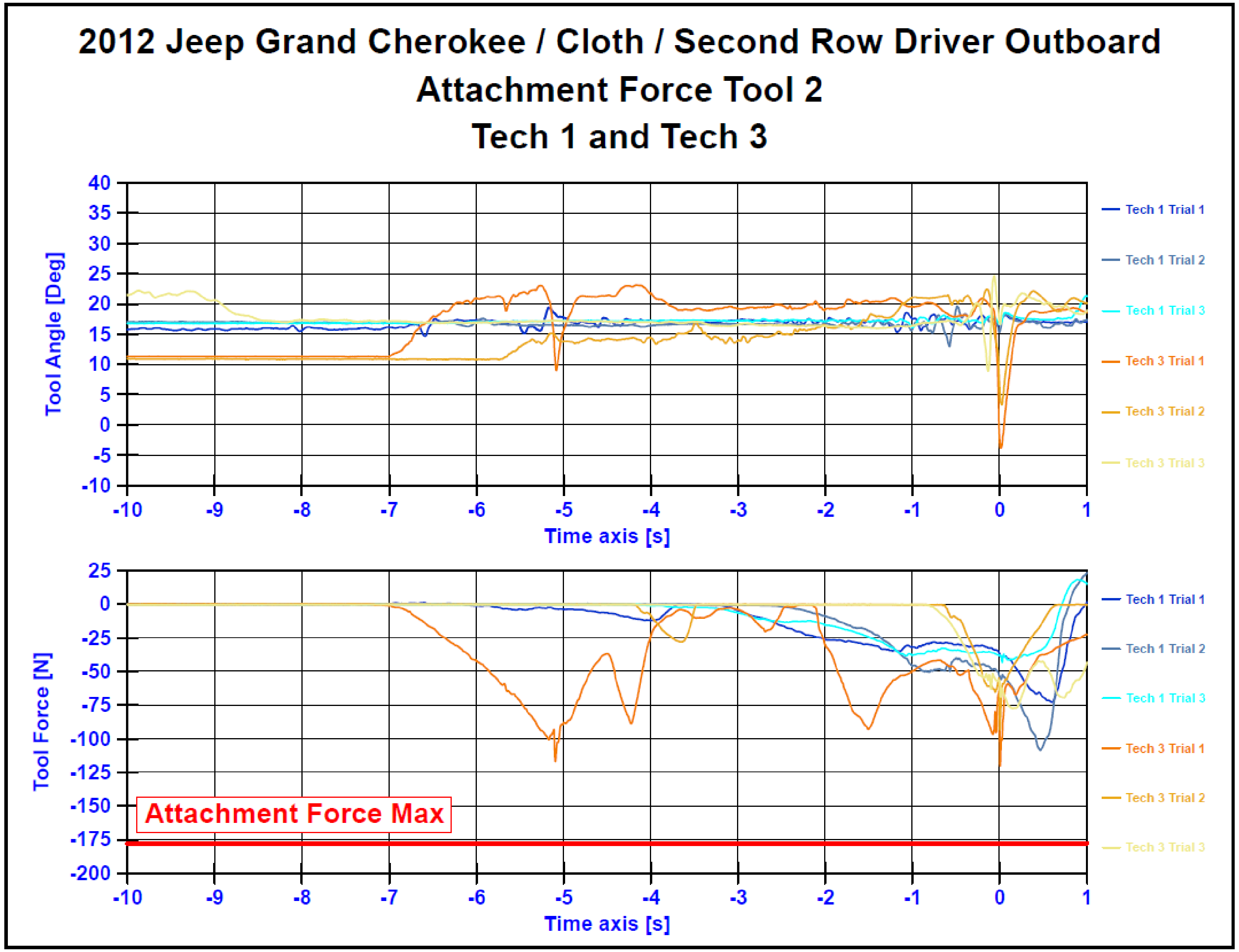
2012 Jeep Grand Cherokee / Cloth / Second Row Driver Inboard
Attachment Force Tool 2
Tech 1 and Tech 3
Tool Angle [Deg]
40
35
30
25
20
15
10
5
0
-5
-10
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
Time axis [s]



2012 Jeep Grand Cherokee / Cloth / Second Row Driver Outboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3



2012 Jeep Grand Cherokee / Cloth / Second Row Driver Outboard
Attachment Force Tool 1
Tech 1 and Tech 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3



2012 Jeep Grand Cherokee / Cloth / Second Row Driver Outboard
Attachment Force Tool 2
Tech 1 and Tech 3
Tool Angle [Deg]
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3
Tool Force [N]
Attachment Force Max

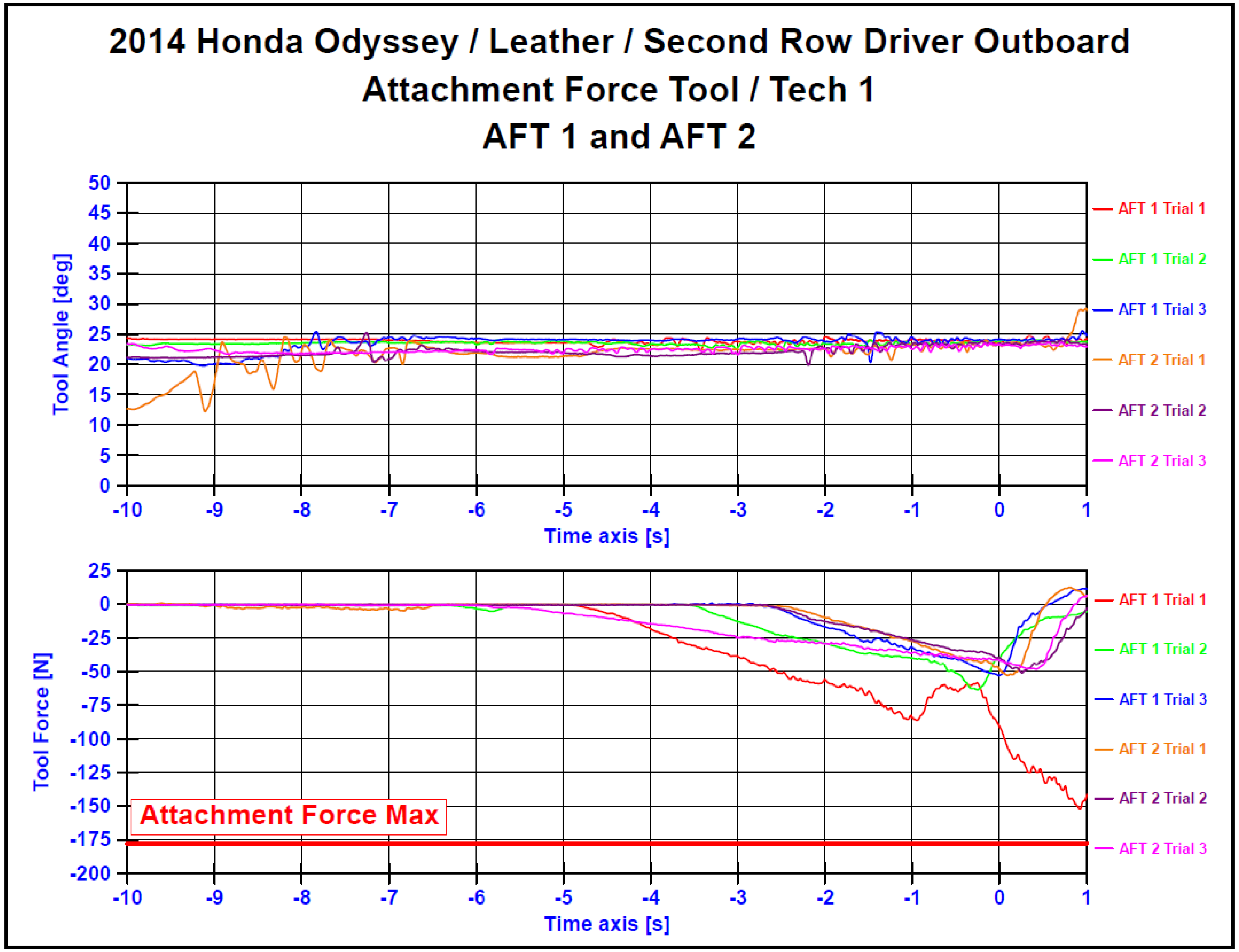
2014 Honda Odyssey – Leather

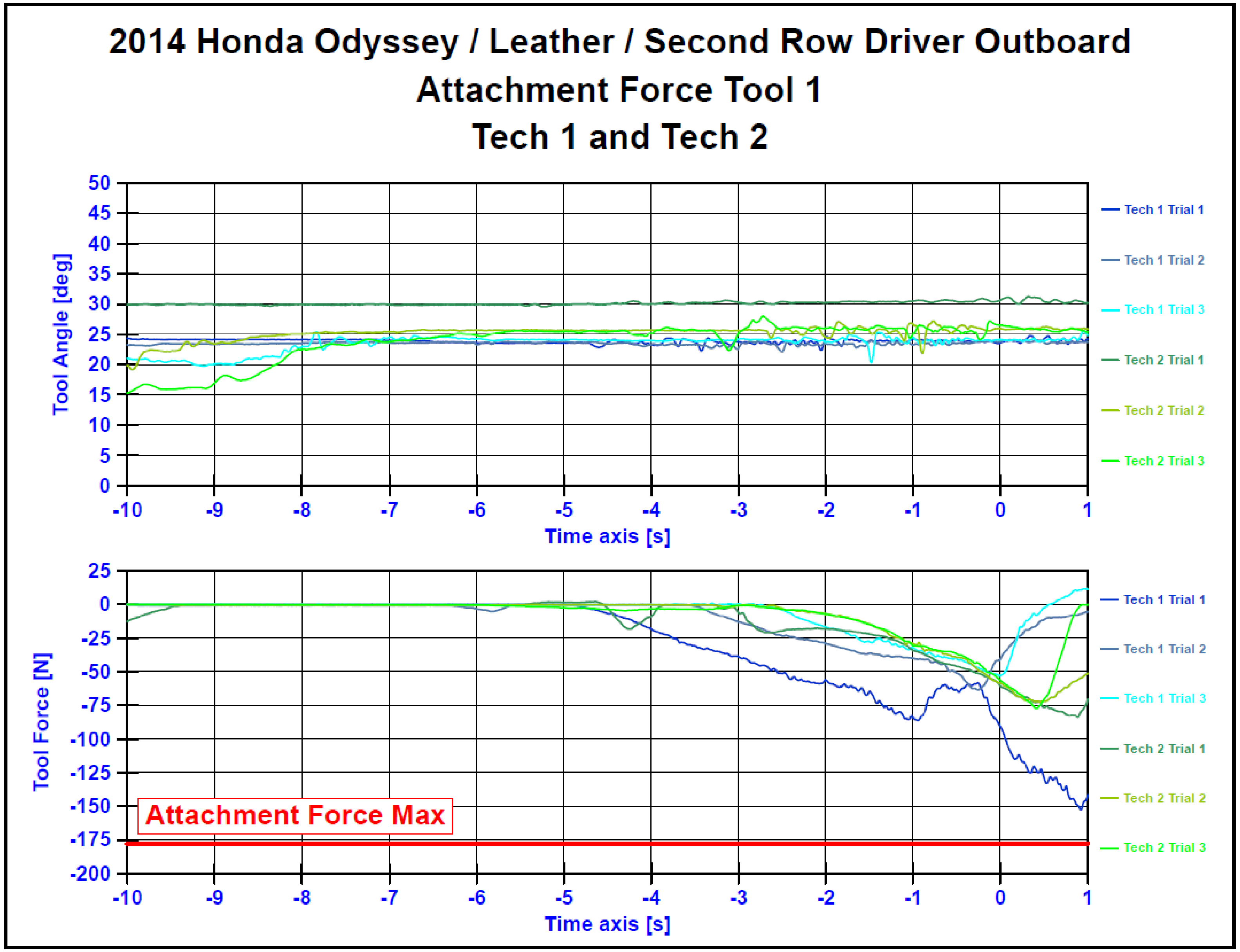
	Tech 1						Tech 2			Tech 3		
	Tool Set I			Tool Set II			Tool Set I			Tool Set II		
	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3
	Modified AFT/ADT Depth - Blue (B) / Green (G) / Yellow (Y) White (W) Red (R) / Gold (GLD) / Black (BLK)											
Driver Outboard	G / 25°	G / 24°	G / 24°	G / 24°	G / 24°	G / 24°	Y / 29°	G / 26°	G / 26°	G / 13°	G / 13°	G / 13°
Driver Inboard	G / 25°	G / 24°	G / 24°	G / 25°	G / 24°	G / 23°	G / 29°	G / 28°	G / 29°	G / 14°	G / 12°	G / 13°
Center Driver	B / 12°	B / 12°	B / 12°	B / 12°	B / 12°	B / 13°	B / 12°	B / 12°	B / 12°	B / 14°	B / 12°	B / 11°

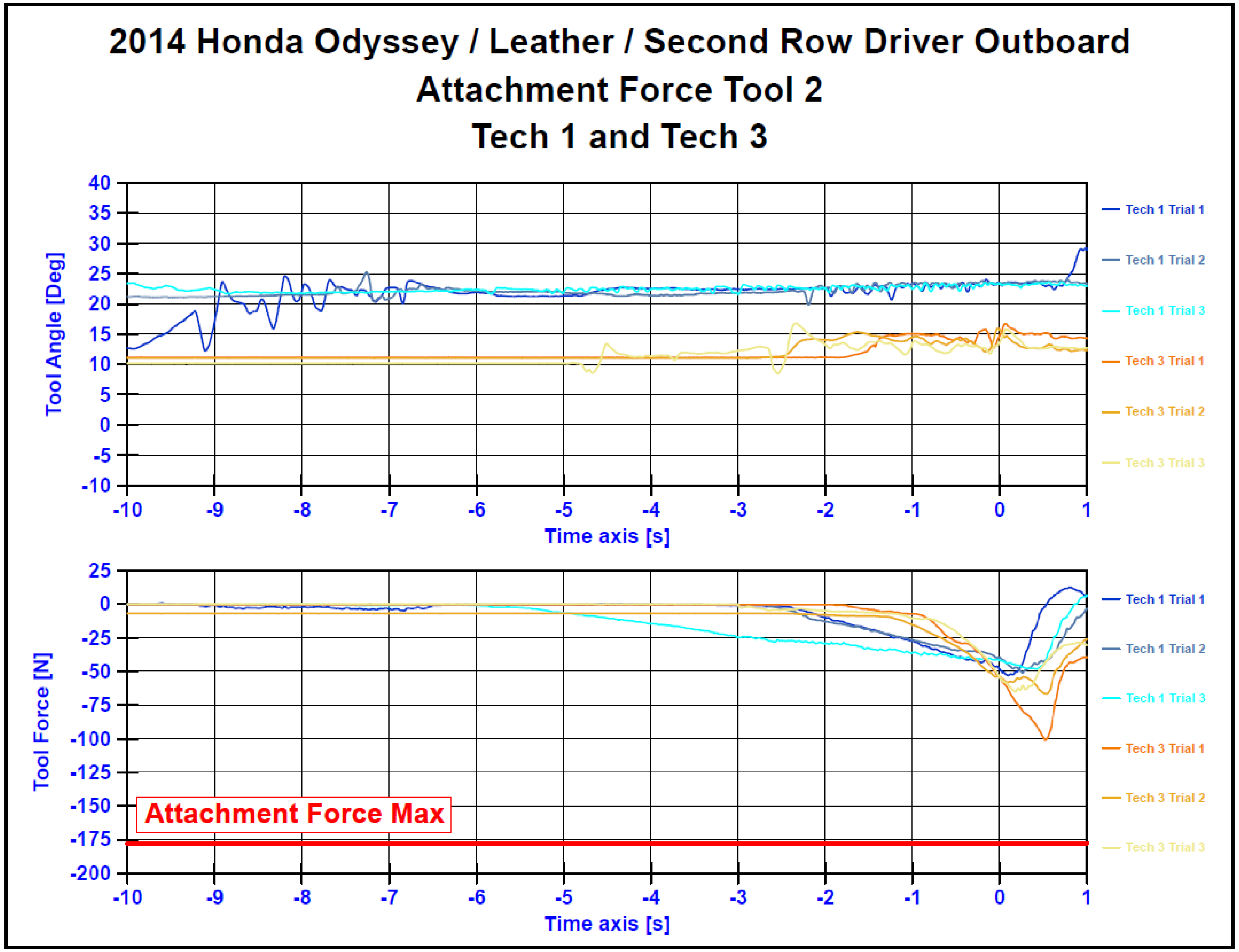
	Modified AFT/ADT Force - LBF (N) / Degrees																							
	Lbf (N)	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**
Driver Outboard	20 (89)	25	14 (62)	24	12 (53)	24	11 (49)	24	9 (40)	24	9 (40)	24	14 (62)	29	13 (58)	26	13 (58)	26	12 (53)	13	12 (53)	13	12 (53)	13
Driver Inboard	17 (76)	25	11 (49)	24	11 (49)	24	9 (40)	25	8 (36)	24	9 (40)	23	23 (102)	29	19 (85)	28	11 (49)	29	10 (44)	14	13 (58)	12	8 (36)	13
Center Driver	4 (18)	12	4 (18)	12	4 (18)	12	1 (4)	12	2 (9)	12	2 (9)	13	4 (18)	12	9 (40)	12	3 (13)	12	2 (9)	14	6 (27)	12	3 (13)	11

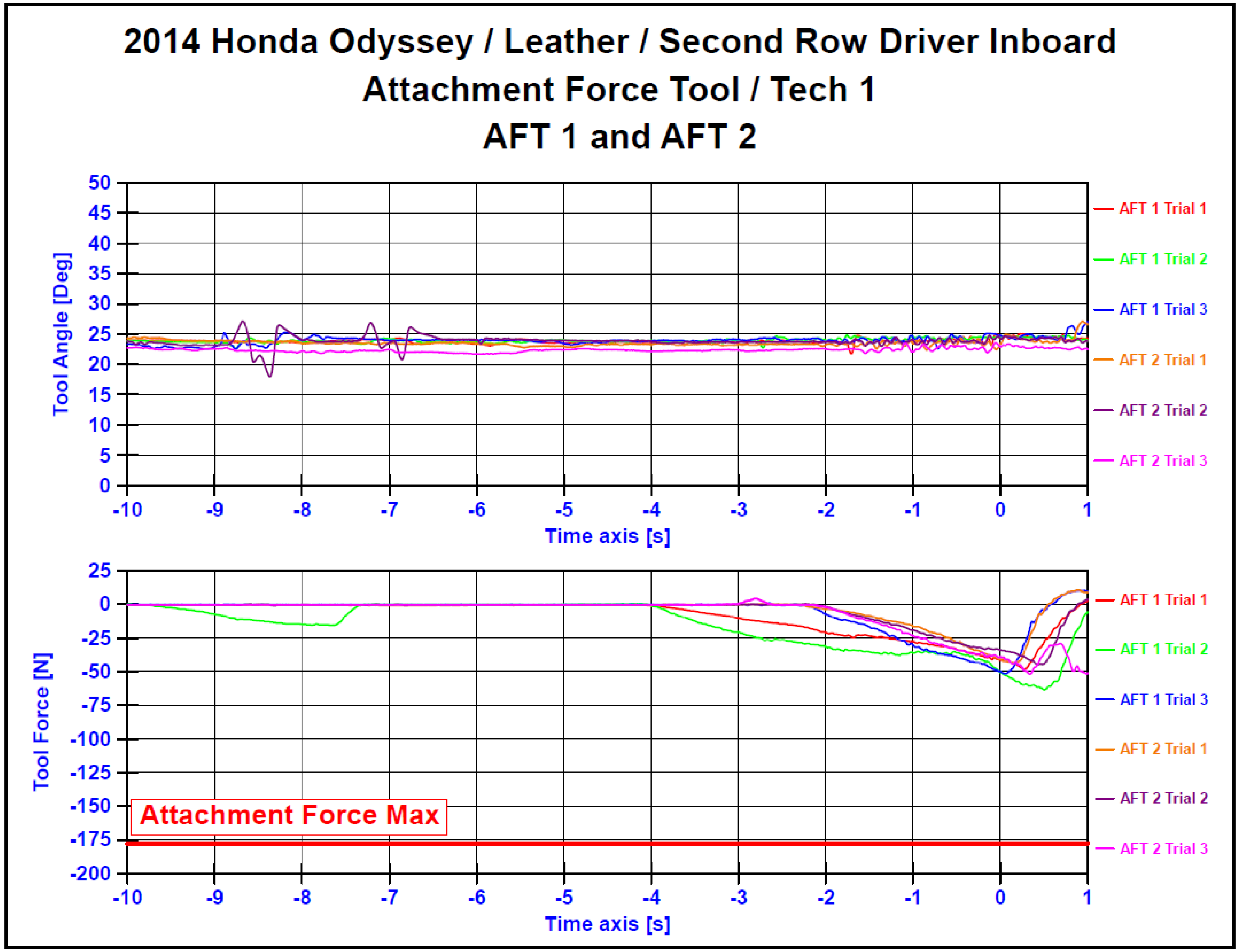
	CAT V1 - Degrees @ 15 lbf (67 N) vertical											
Driver Outboard	64	65	65	69	69	69	69	70	69	66	68	69
Driver Inboard	67	68	67	48	50	50	69	69	70	69	71	71
Center Driver	52	53	53	54	54	54	53	53	53	54	54	54

	Tech 1						Tech 2			Tech 3		
	Tool Set I			Tool Set II			Tool Set I			Tool Set II		
	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3
	Meet/Not Meet ADT - Yellow (Y) = Met Criterion / White (W) = Did Not Meet Criterion											
Driver Outboard	Y						Y			Y		
Driver Inboard	Y						Y			Y		

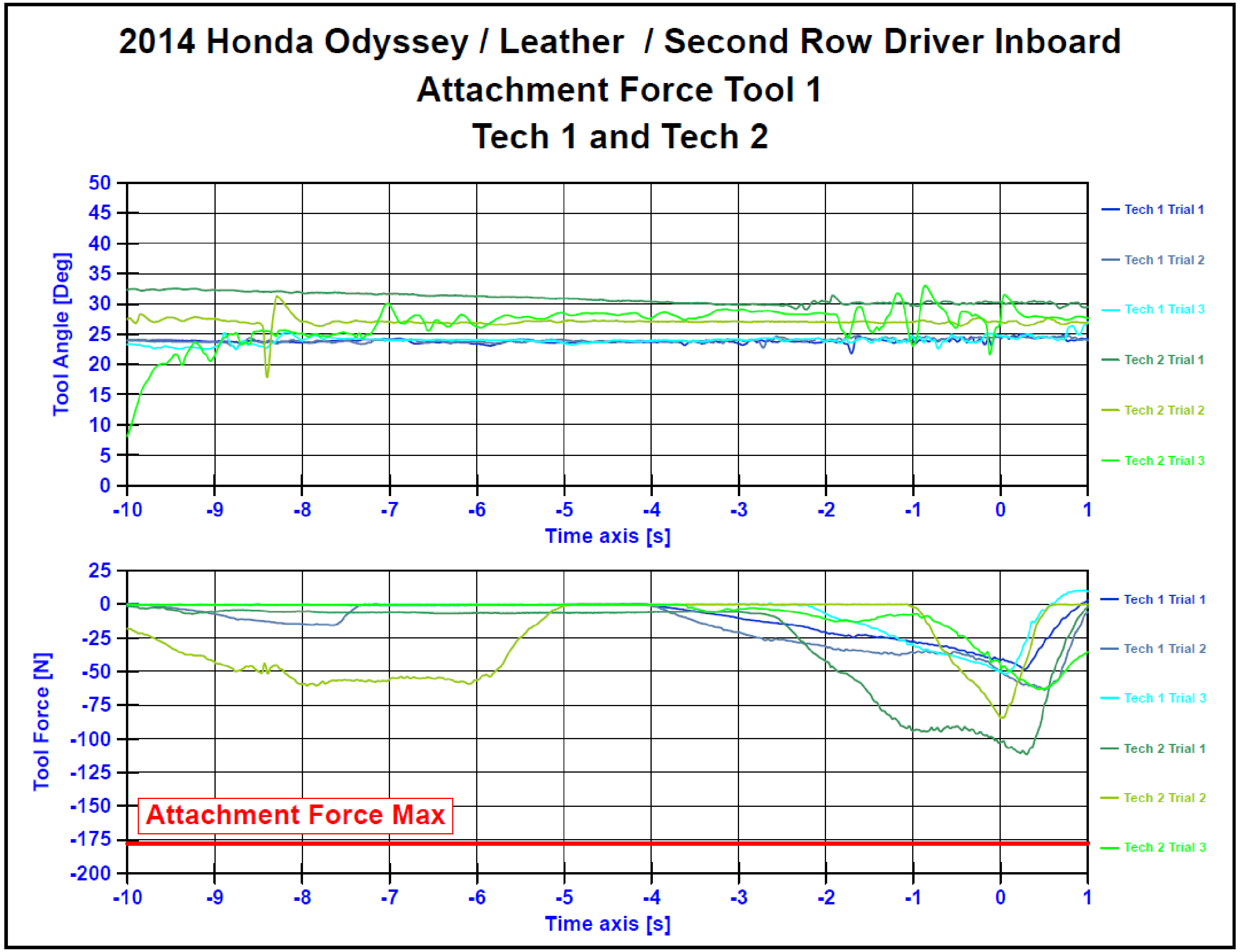

2014 Honda Odyssey / Leather / Second Row Driver Outboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
Time axis [s]

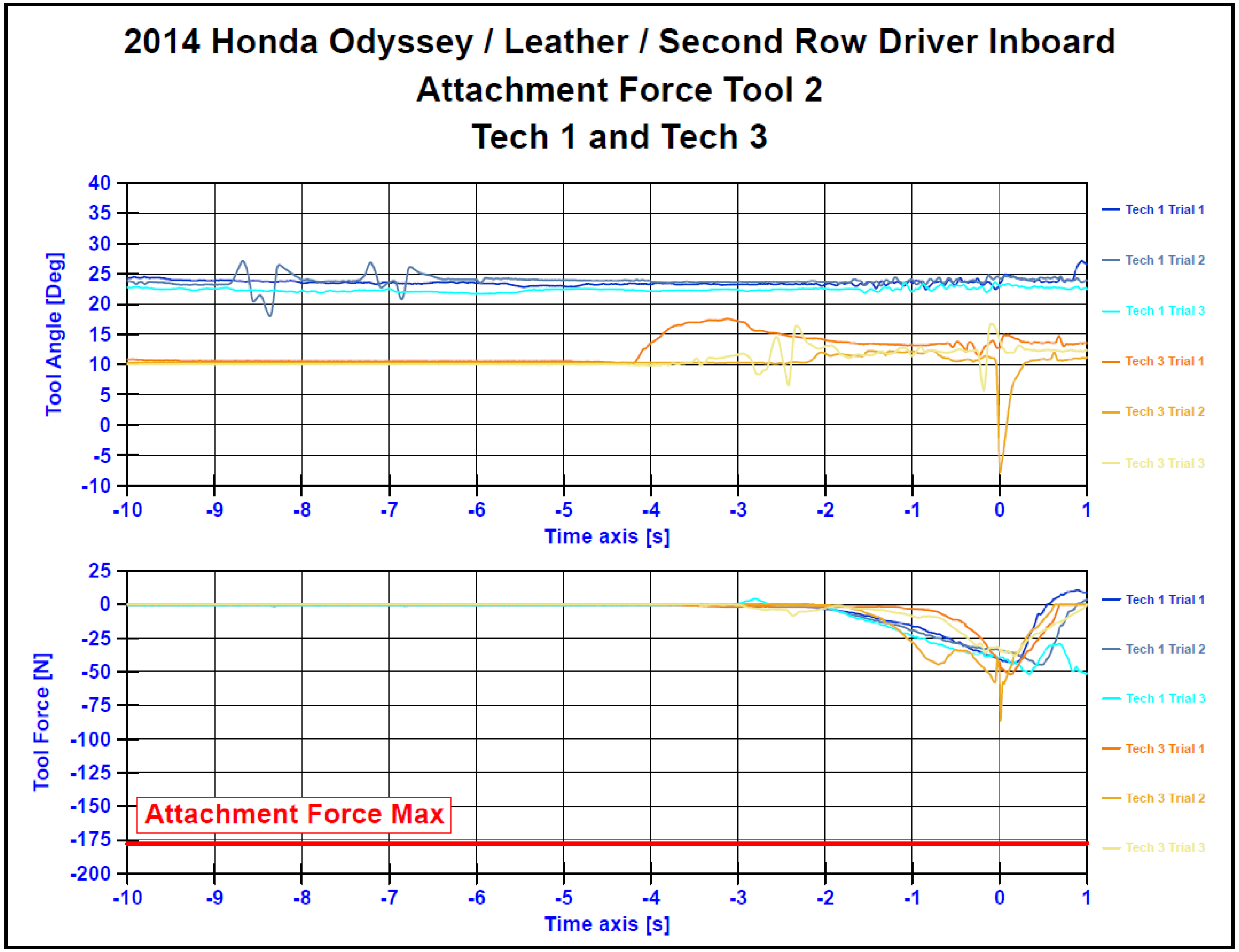

2014 Honda Odyssey / Leather / Second Row Driver Outboard
Attachment Force Tool 1
Tech 1 and Tech 2
Tool Angle [deg]
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3
Tool Force [N]
Attachment Force Max
Time axis [s]

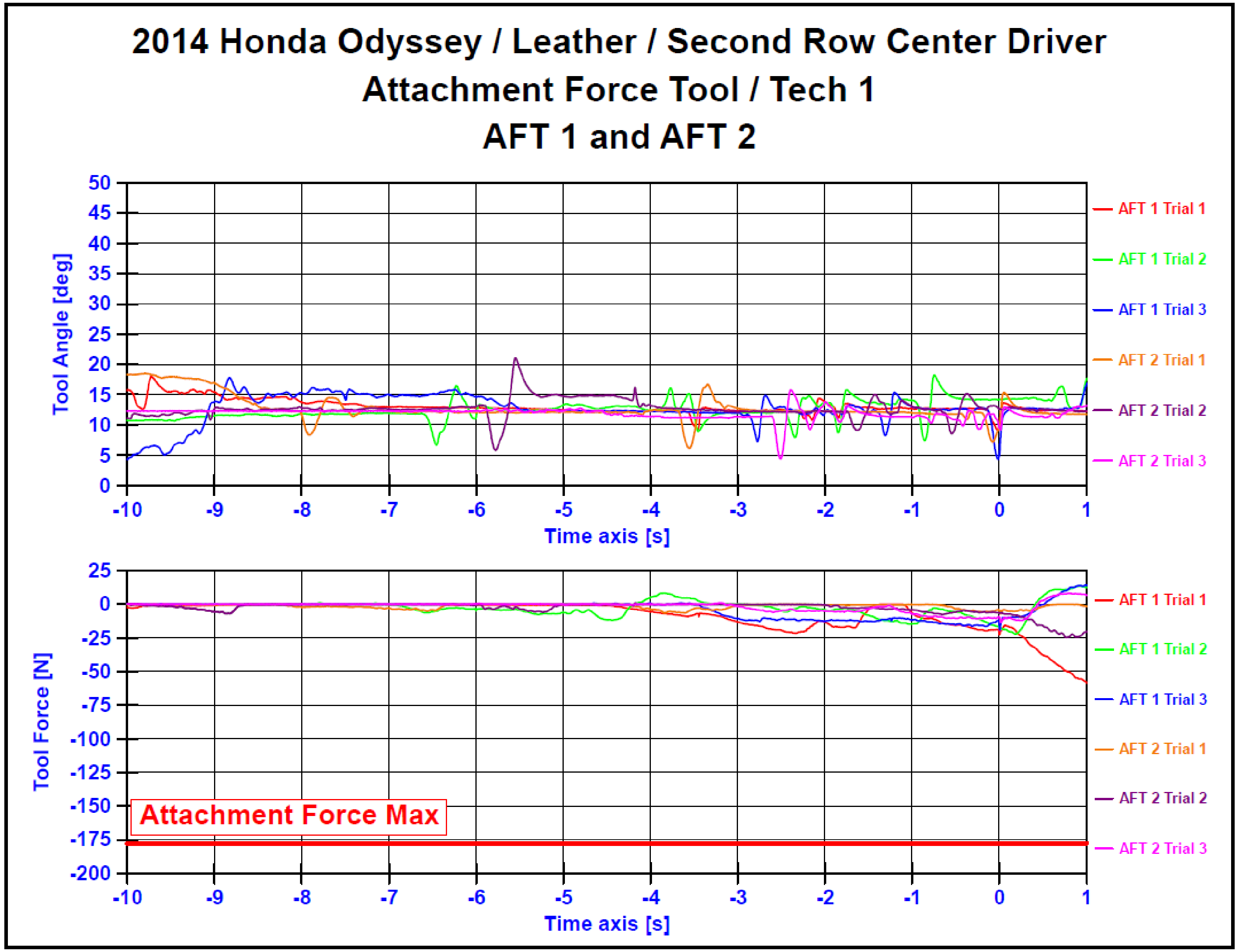

2014 Honda Odyssey / Leather / Second Row Driver Outboard
Attachment Force Tool 2
Tech 1 and Tech 3
Tool Angle [Deg]
Time axis [s]
Tool Force [N]
Attachment Force Max
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3

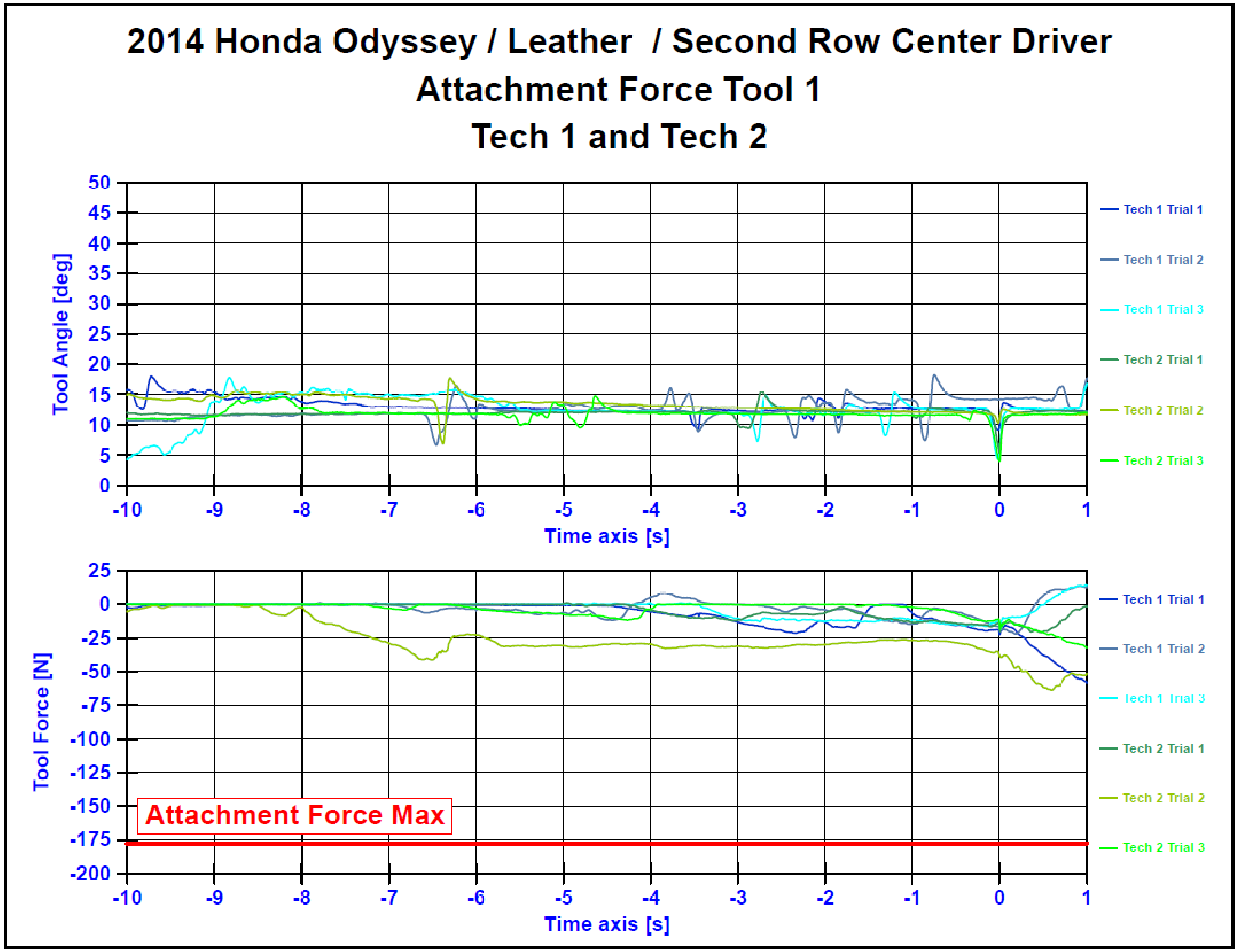


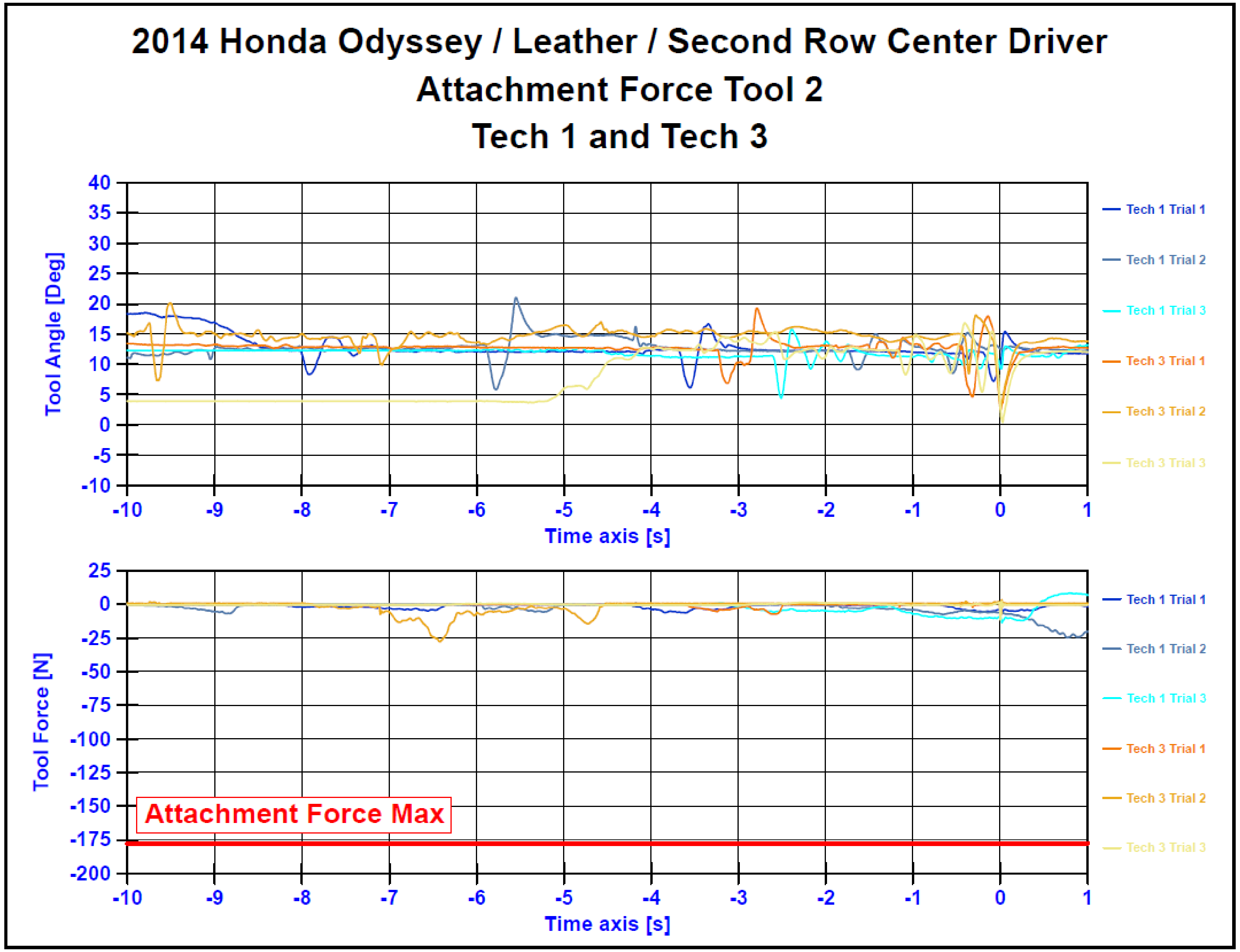
2014 Honda Odyssey / Leather / Second Row Driver Inboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [Deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max


2014 Honda Odyssey / Leather / Second Row Driver Inboard
Attachment Force Tool 1
Tech 1 and Tech 2
Tool Angle [Deg]
Time axis [s]
Tool Force [N]
Attachment Force Max
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3


2014 Honda Odyssey / Leather / Second Row Driver Inboard
Attachment Force Tool 2
Tech 1 and Tech 3
Tool Angle [Deg]
Time axis [s]
Tool Force [N]
Attachment Force Max
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3


2014 Honda Odyssey / Leather / Second Row Center Driver
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3


2014 Honda Odyssey / Leather / Second Row Center Driver
Attachment Force Tool 1
Tech 1 and Tech 2
Tool Angle [deg]
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3
Tool Force [N]
Attachment Force Max



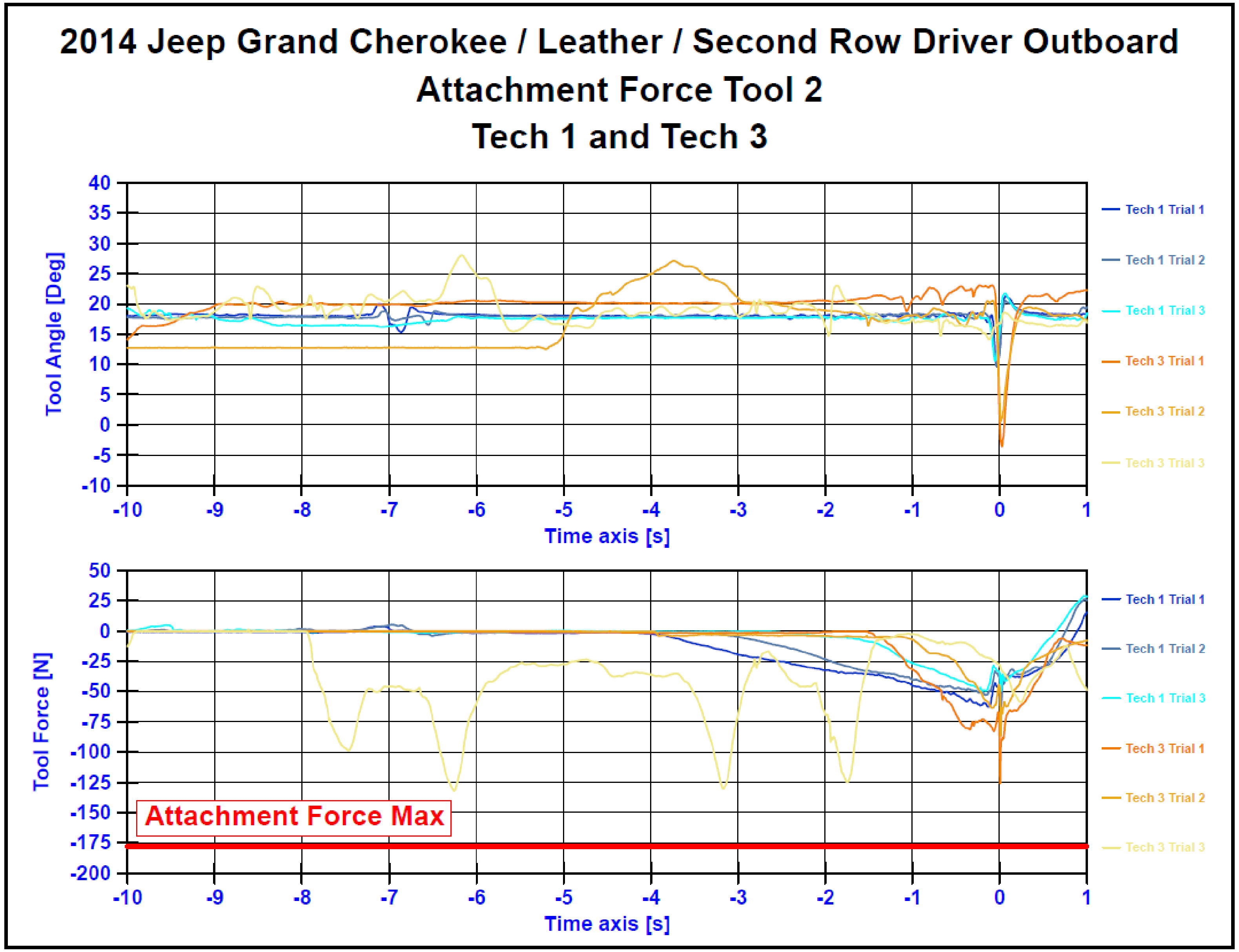
2014 Honda Odyssey / Leather / Second Row Center Driver
Attachment Force Tool 2
Tech 1 and Tech 3
Tool Angle [Deg]
40
35
30
25
20
15
10
5
0
-5
-10
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
Time axis [s]

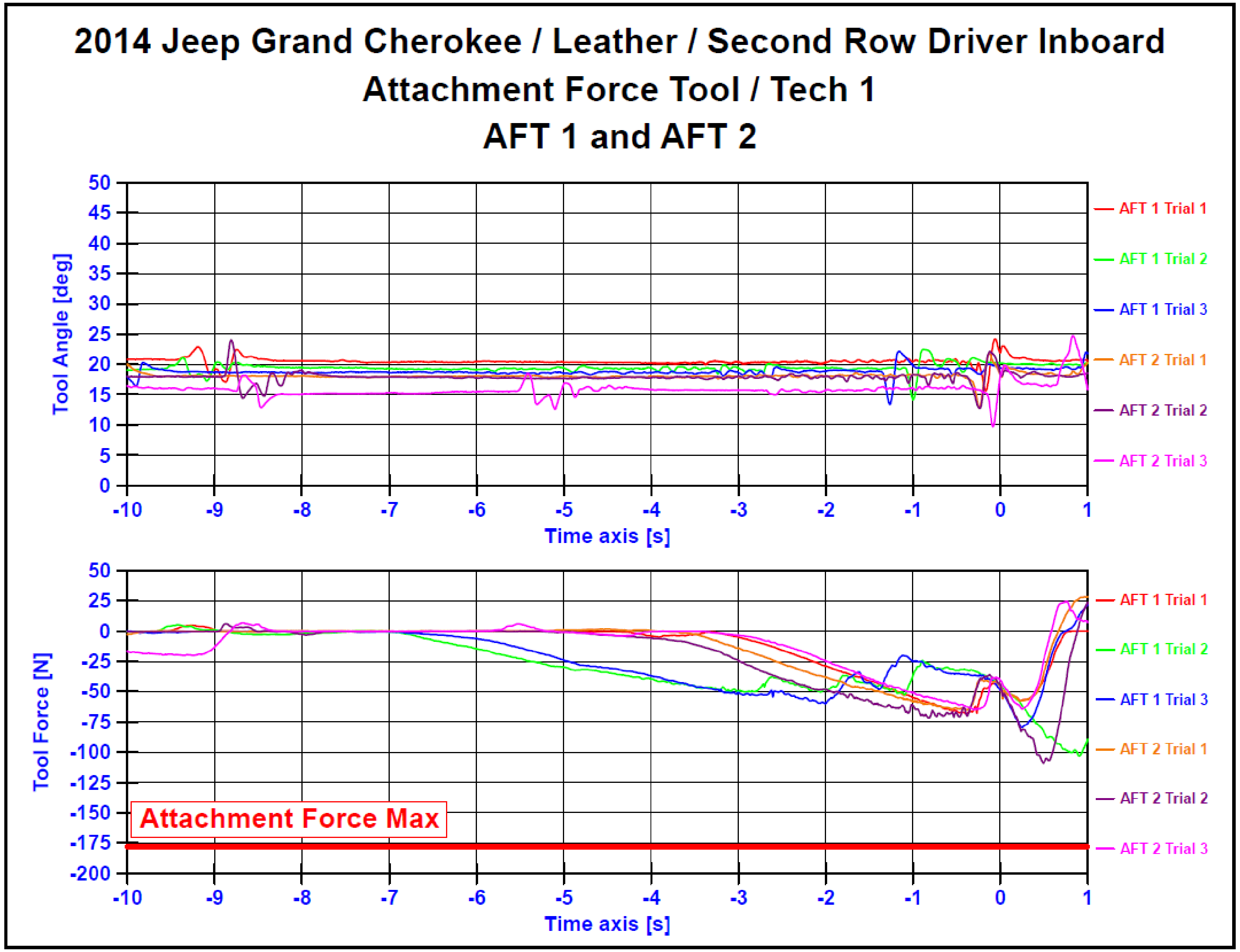
2014 Jeep Grand Cherokee – Leather

	Tech 1						Tech 2			Tech 3		
	Tool Set I			Tool Set II			Tool Set I			Tool Set II		
	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3
	Modified AFT/ADT Depth - Blue (B) / Green (G) / Yellow (Y) White (W) Red (R) / Gold (GLD) / Black (BLK)											
Driver Outboard	Y/20°	Y/20°	Y/20°	Y/19°	Y/18°	Y/19°	Y/20°	Y/20°	Y/21°	Y/22°	Y/18°	Y/21°
Driver Inboard	Y/21°	Y/20°	Y/20°	Y/18°	Y/16°	Y/17°	W/23°	W/22°	W/21°	Y/23°	Y/18°	Y/19°
Passenger Outboard	Y/19°	Y/16°	Y16°	Y/17°	Y/17°	Y/18°	W/20°	W/21°	W/20°			
Passenger Inboard	W/18°	Y/17°	Y/17°	Y/17°	Y/17°	Y/17°	W/20°	W/20°	W/20°			

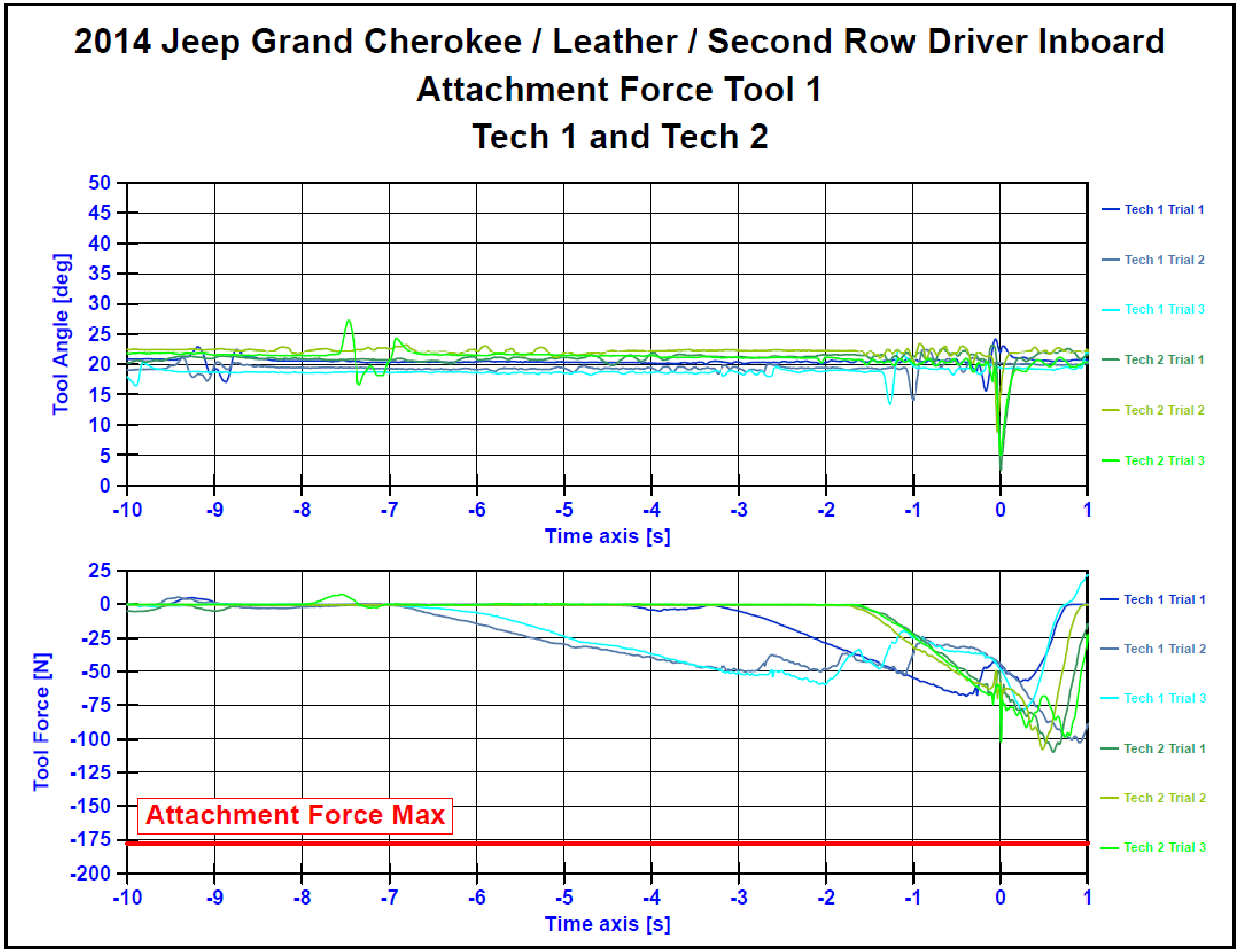
	Modified AFT/ADT Force - LBF (N) / Degrees																							
	Lbf (N)	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**
Driver Outboard	24 (107)	20	12 (54)	20	12 (54)	20	14 (62)	19	12 (54)	18	11 (49)	19	15 (67)	20	14 (62)	20	13 (58)	21	18 (80)	22	14 (62)	18	30 (133)	21
Driver Inboard	15 (67)	21	12 (54)	20	13 (58)	20	14 (62)	18	19 (85)	16	15 (67)	17	15 (67)	23	14 (62)	22	17 (76)	21	20 (89)	23	16 (71)	18	21 (93)	19
Passenger Outboard	16 (71)	19	18 (80)	16	21 (93)	16	14 (62)	17	12 (54)	17	12 (54)	18	32 (142)	20	17 (76)	21	18 (80)	20						
Passenger Inboard	14 (62)	18	11 (49)	17	11 (49)	17	14 (62)	17	16 (71)	17	16 (71)	17	15 (67)	20	18 (80)	20	16 (71)	20						

	Tech 1						Tech 2			Tech 3		
	Tool Set I			Tool Set II			Tool Set I			Tool Set II		
	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3
	CAT V1 - Degrees @ 15 lbf (67 N) vertical											
Driver Outboard	52	52	52	52	53	53	52	52	52	53	52	53
Driver Inboard	55	55	55	56	56	56	55	55	55	55	55	56
Passenger Outboard	51	50	50	52	52	51	47	45	49			
Passenger Inboard	49	49	49	50	51	52	49	49	50			
	Meet/Not Meet ADT - Yellow (Y) = Met Criterion / White (W) = Did Not Meet Criterion											
Driver Outboard	W						W			W		
Driver Inboard	W						W			W		
Passenger Outboard	W						W					
Passenger Inboard	W						W					

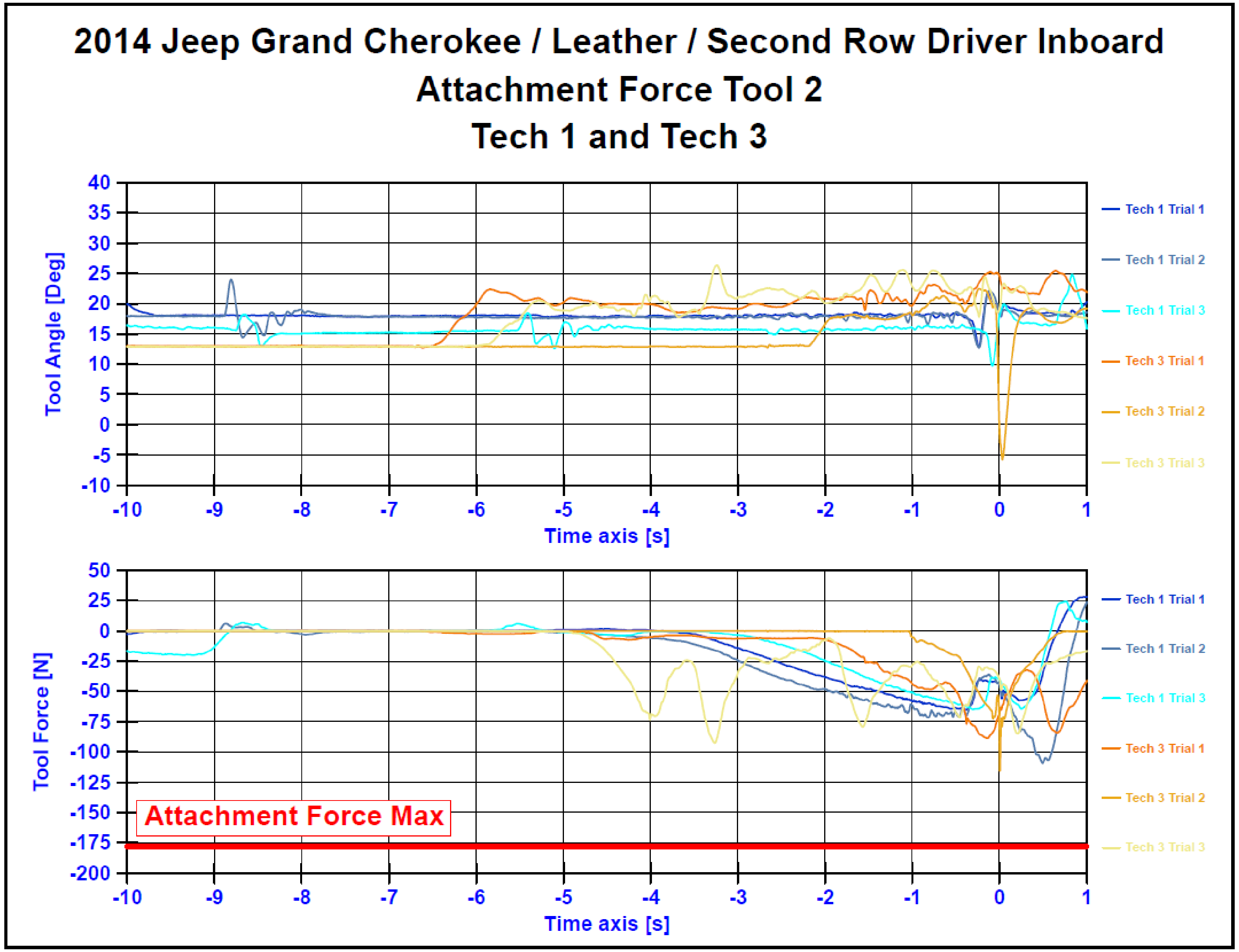

2014 Jeep Grand Cherokee / Leather / Second Row Driver Outboard
Attachment Force Tool 2
Tech 1 and Tech 3
Tool Angle [Deg]
40
35
30
25
20
15
10
5
0
-5
-10
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3
Tool Force [N]
50
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3



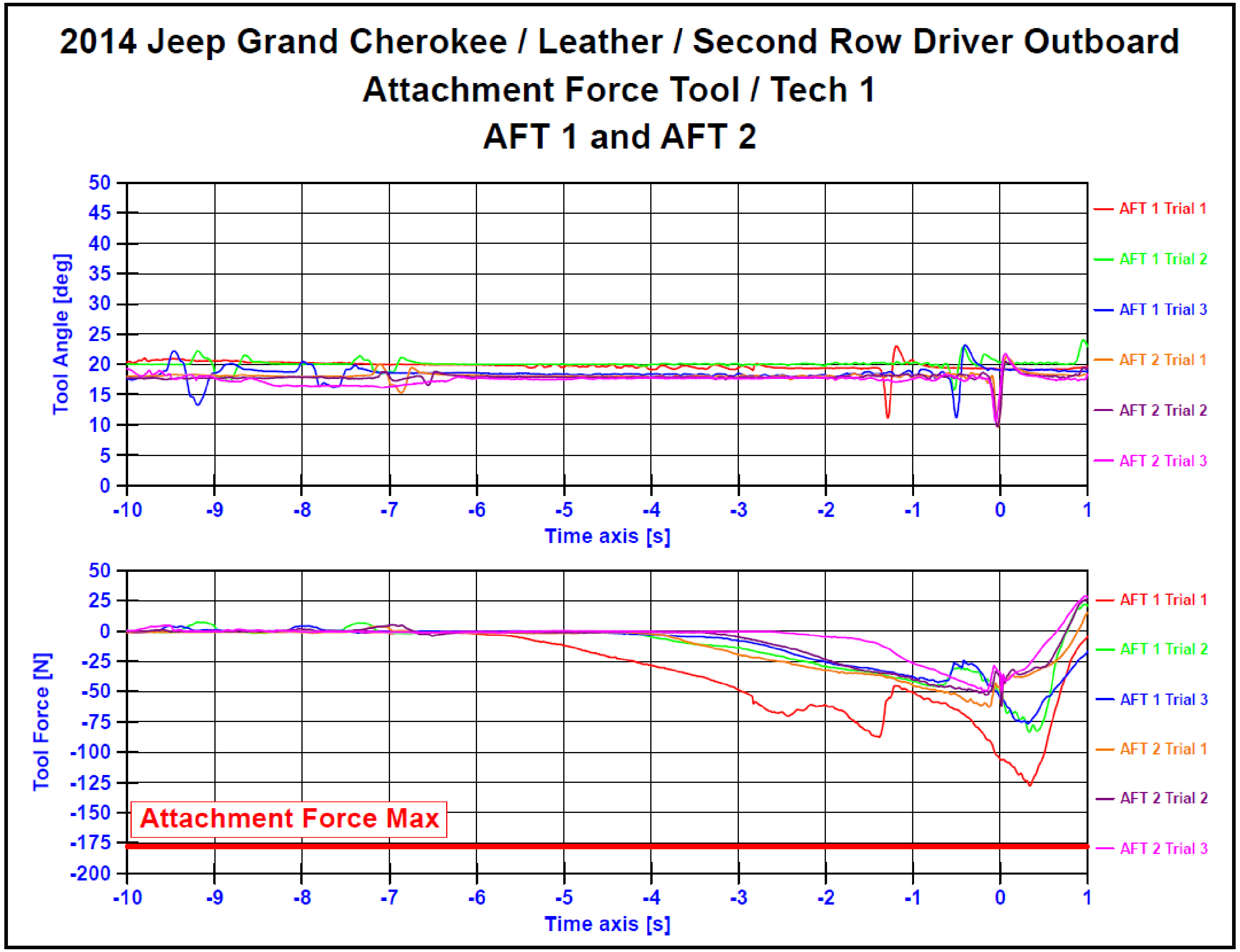
2014 Jeep Grand Cherokee / Leather / Second Row Driver Inboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
50
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3

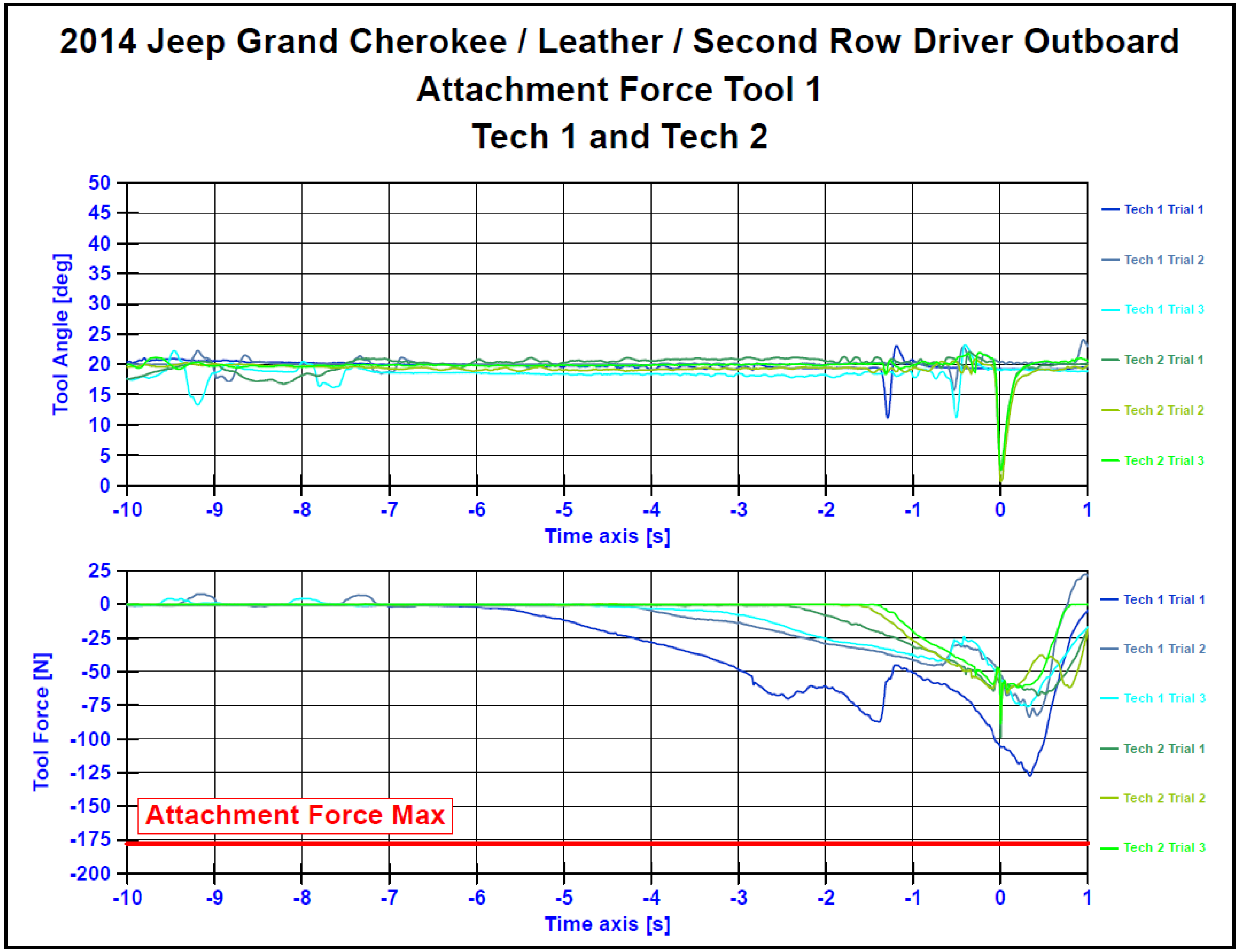


2014 Jeep Grand Cherokee / Leather / Second Row Driver Inboard
Attachment Force Tool 1
Tech 1 and Tech 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3

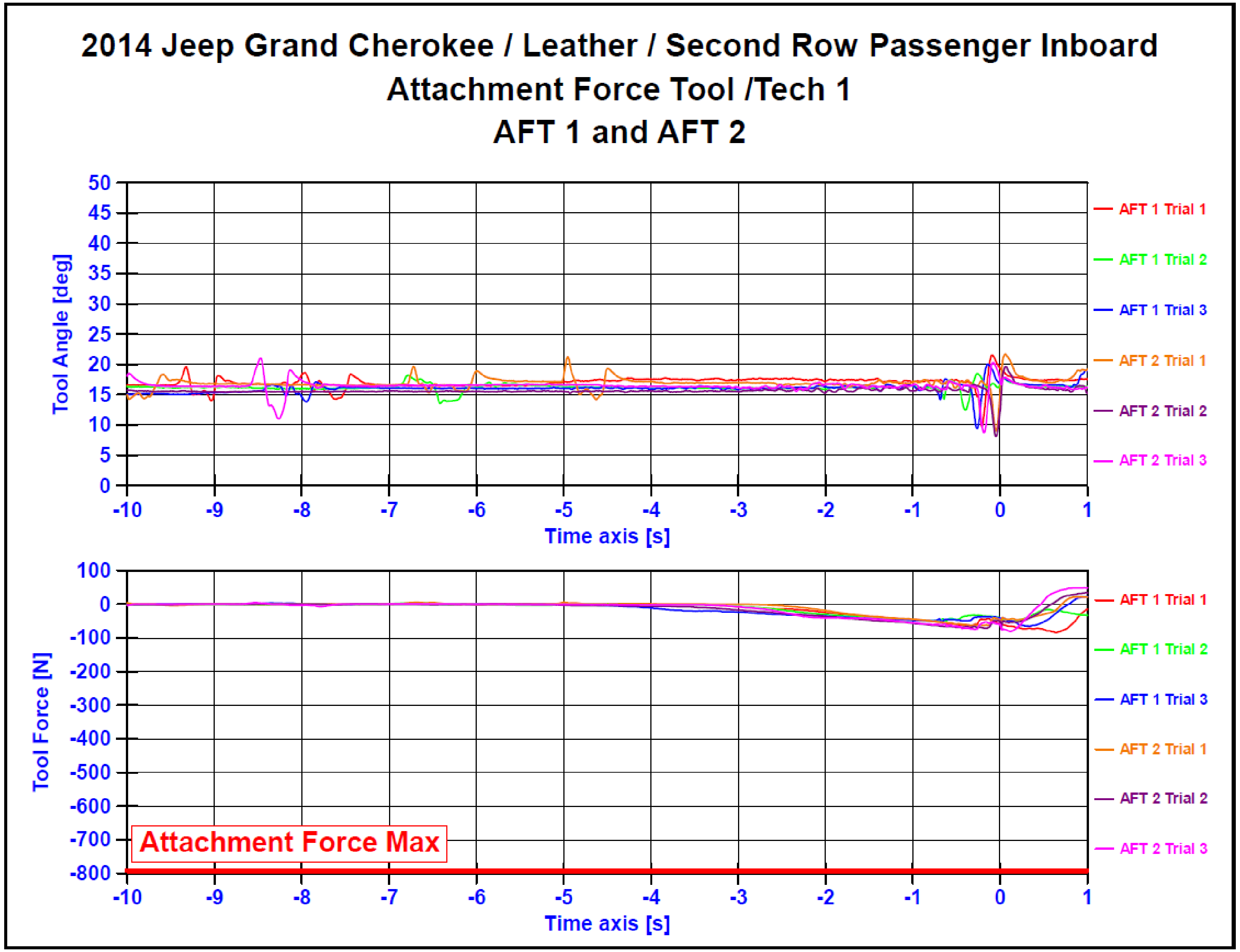


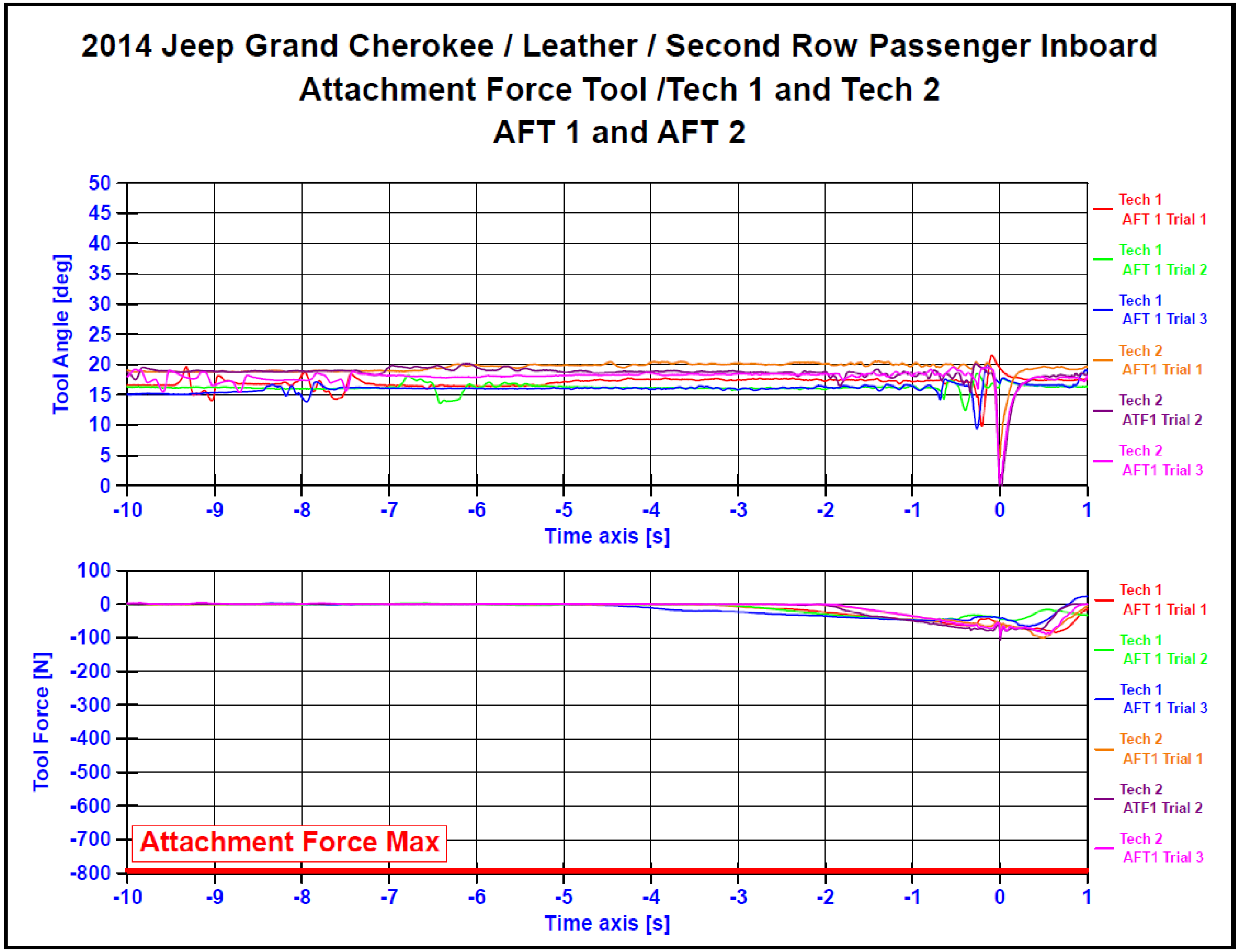
2014 Jeep Grand Cherokee / Leather / Second Row Driver Inboard
Attachment Force Tool 2
Tech 1 and Tech 3
Tool Angle [Deg]
Time axis [s]
Tool Force [N]
Attachment Force Max
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3


2014 Jeep Grand Cherokee / Leather / Second Row Driver Outboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
50
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3

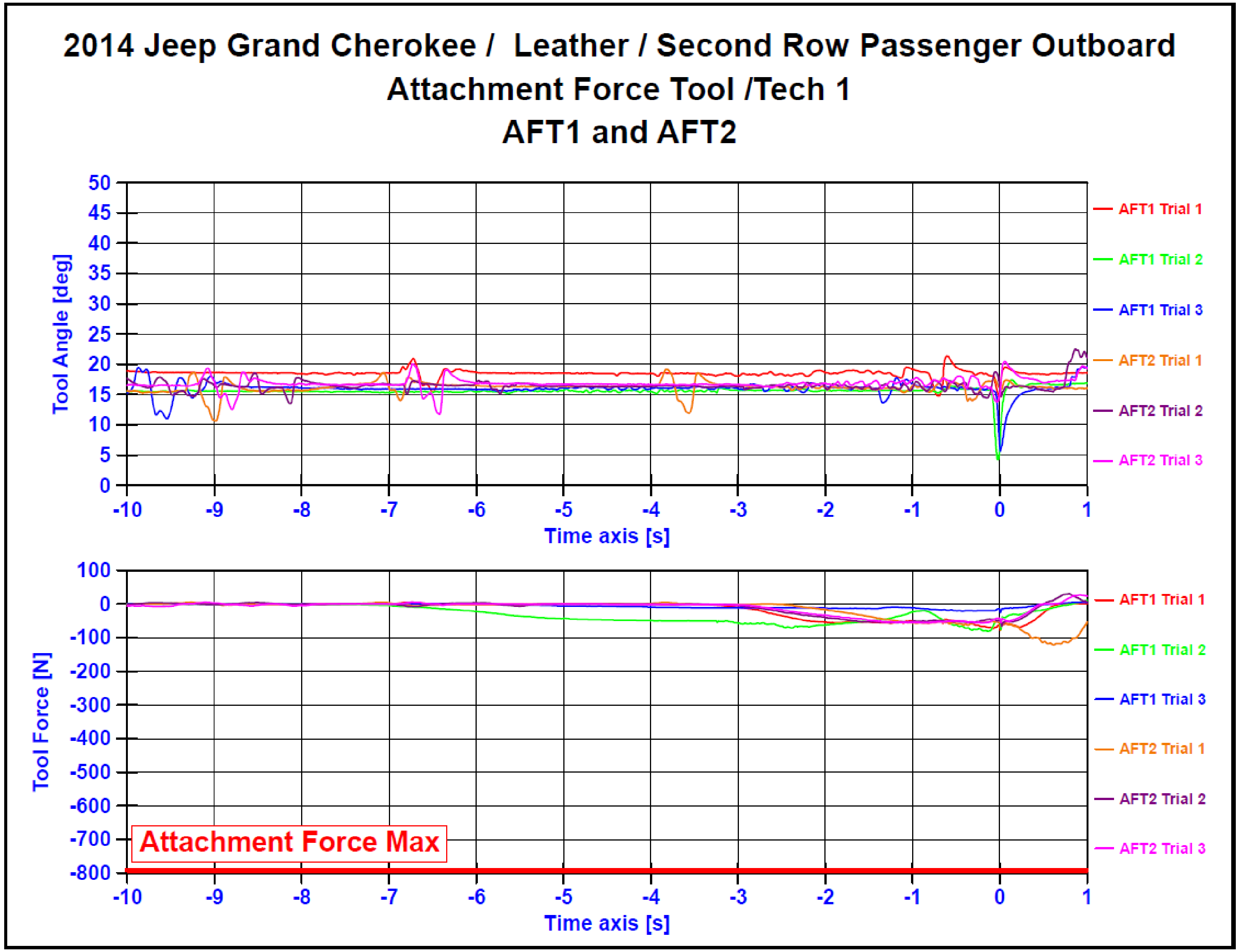


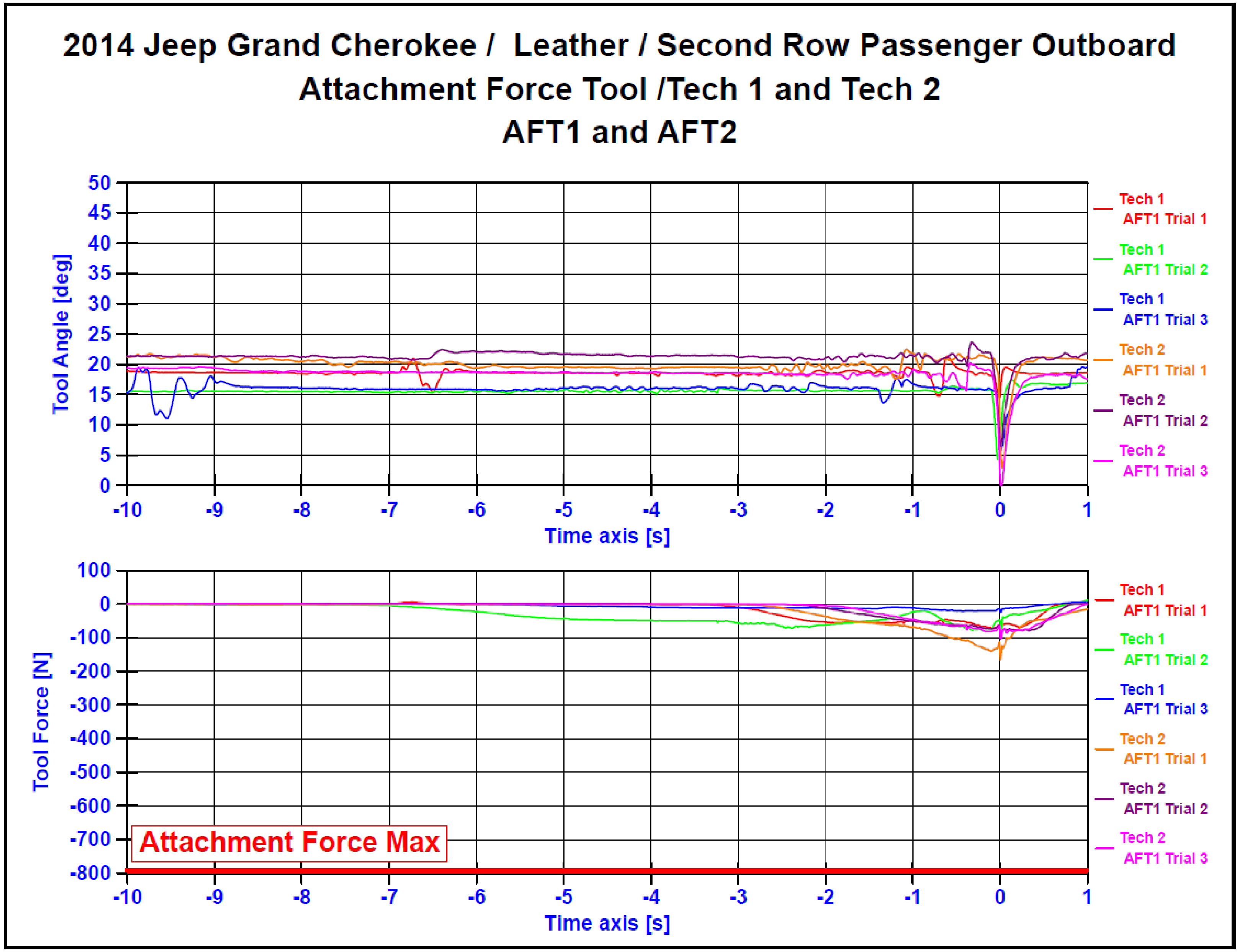
2014 Jeep Grand Cherokee / Leather / Second Row Driver Outboard
Attachment Force Tool 1
Tech 1 and Tech 2
Tool Angle [deg]
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3
Tool Force [N]
Attachment Force Max
Time axis [s]


2014 Jeep Grand Cherokee / Leather / Second Row Passenger Inboard
Attachment Force Tool /Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
Attachment Force Max
Time axis [s]



2014 Jeep Grand Cherokee / Leather / Second Row Passenger Inboard
Attachment Force Tool /Tech 1 and Tech 2
AFT 1 and AFT 2
Tool Angle [deg]
Time axis [s]
Tech 1 AFT 1 Trial 1
Tech 1 AFT 1 Trial 2
Tech 1 AFT 1 Trial 3
Tech 2 AFT1 Trial 1
Tech 2 ATF1 Trial 2
Tech 2 AFT1 Trial 3
Tool Force [N]
Attachment Force Max
Time axis [s]


2014 Jeep Grand Cherokee / Leather / Second Row Passenger Outboard
Attachment Force Tool /Tech 1
AFT1 and AFT2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT1 Trial 1
AFT1 Trial 2
AFT1 Trial 3
AFT2 Trial 1
AFT2 Trial 2
AFT2 Trial 3
Tool Force [N]
100
0
-100
-200
-300
-400
-500
-600
-700
-800
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT1 Trial 1
AFT1 Trial 2
AFT1 Trial 3
AFT2 Trial 1
AFT2 Trial 2
AFT2 Trial 3



2014 Jeep Grand Cherokee / Leather / Second Row Passenger Outboard
Attachment Force Tool /Tech 1 and Tech 2
AFT1 and AFT2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
Tech 1 AFT1 Trial 1
Tech 1 AFT1 Trial 2
Tech 1 AFT1 Trial 3
Tech 2 AFT1 Trial 1
Tech 2 AFT1 Trial 2
Tech 2 AFT1 Trial 3
Tool Force [N]
100
0
-100
-200
-300
-400
-500
-600
-700
-800
Attachment Force Max
Time axis [s]

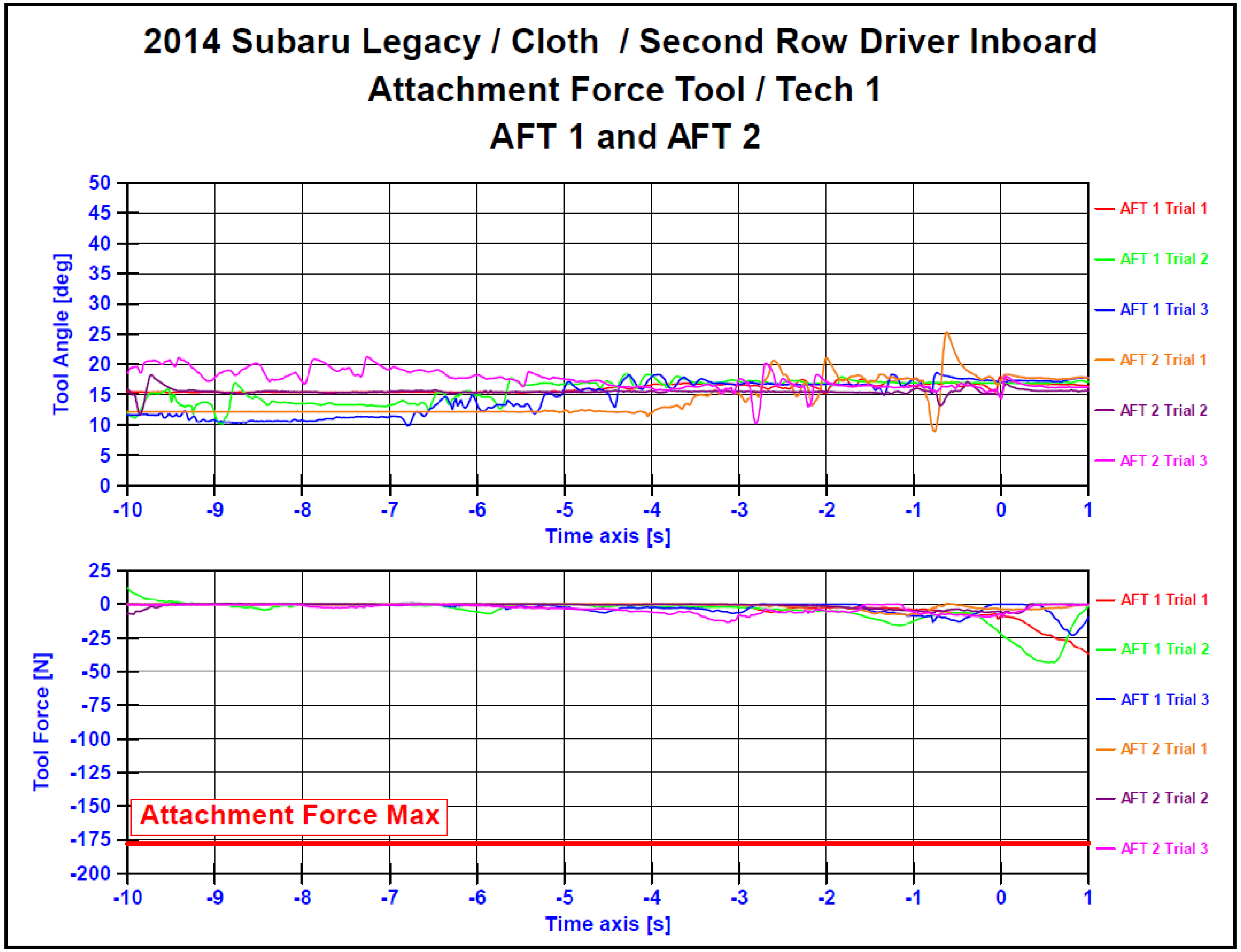
2014 Cadillac ATS – Leather

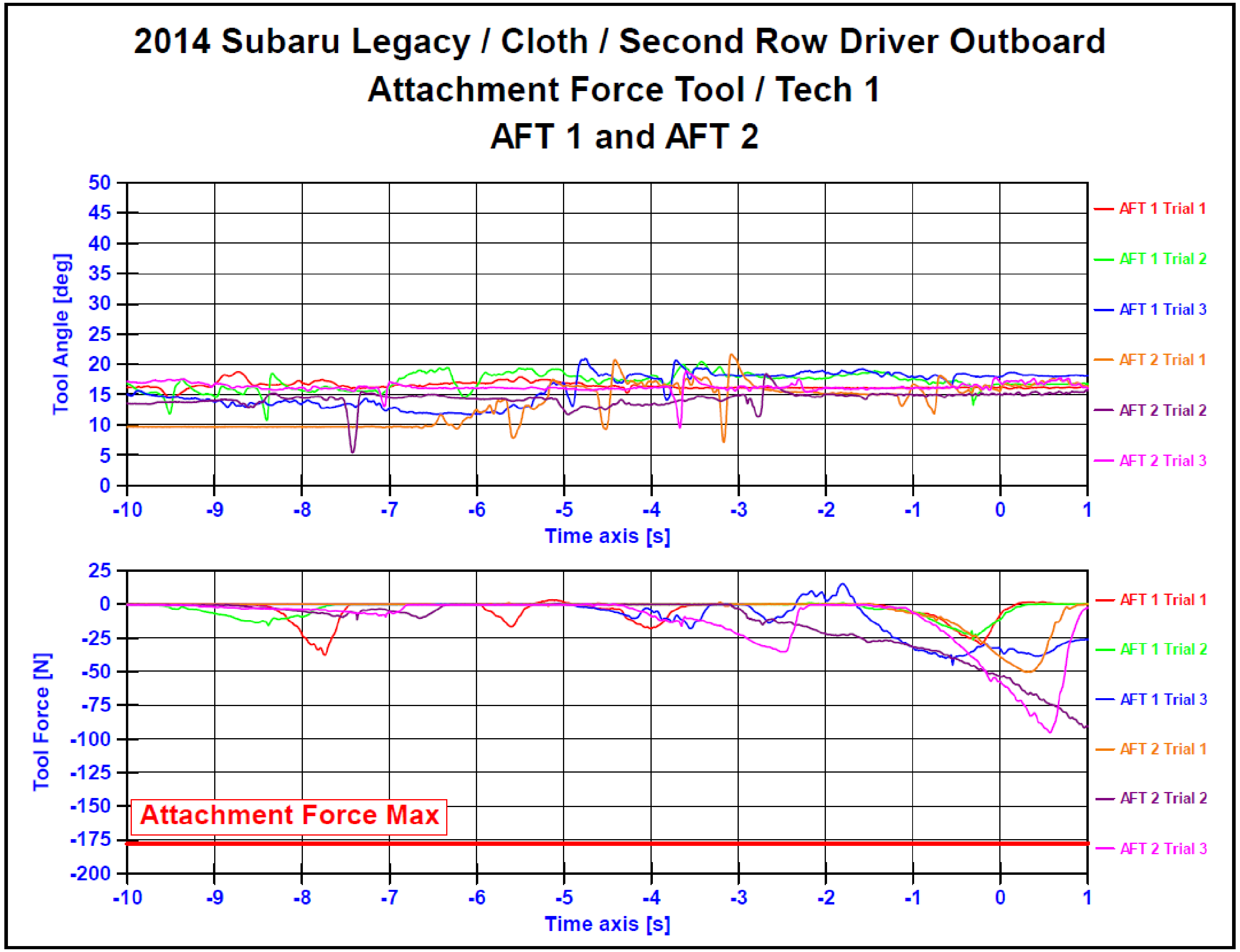
	Tech 1											
	Tool Set I						Tool Set II					
	Meas. 1		Meas. 2		Meas. 3		Meas. 1		Meas. 2		Meas. 3	
	Modified AFT/ADT Depth - Blue (B) / Green (G) / Yellow (Y) White (W) Red (R) / Gold (GLD) / Black (BLK)											
Driver Outboard	W/18°		W/18°		W/18°		W/18°		W/18°		W/18°	
Driver Inboard	W/18°		W/18°		W/18°		W/18°		W/18°		W/18°	
	Modified AFT/ADT Force - LBF (N) / Degrees											
	Lbf (N)	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**
Driver Outboard												
Driver Inboard												
	CAT V1 - Degrees @ 15 lbf (67 N) vertical											
Driver Outboard	66		64		65		64		63		64	
Driver Inboard	63		63		63		64		64		64	
	Meet/Not Meet ADT - Yellow (Y) = Met Criterion / White (W) = Did Not Meet Criterion											
Driver Outboard	W											
Driver Inboard	W											

The AFT could not be used correctly. For it to engage, it had to be wiggled side to side to work its way through the seat cover, or the seat cover had to be held out of the way.

2014 Subaru Legacy – Cloth

	Tech 1											
	Tool Set I						Tool Set II					
	Meas. 1		Meas. 2		Meas. 3		Meas. 1		Meas. 2		Meas. 3	
	Modified AFT/ADT Depth - Blue (B) / Green (G) / Yellow (Y) White (W) Red (R) / Gold (GLD) / Black (BLK)											
Driver Outboard	W/17°		W/17°		W/17°		W/17°		W/17°		W/17°	
Driver Inboard	W/17°		W/17°		W/17°		W/17°		W/17°		W/17°	
	Modified AFT/ADT Force - LBF (N) / Degrees											
	Lbf (N)	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**
Driver Outboard	9 (40)	15	6 (27)	16	10 (44)	17	9 (40)	17	12 (53)	17	13 (58)	17
Driver Inboard	3 (13)	17	5 (22)	17	3 (13)	17	2 (9)	17	1 (4)	17	2 (9)	17
	CAT V1 - Degrees @ 15 lbf (67 N) vertical											
Driver Outboard	50		50		50		51		51		51	
Driver Inboard	55		55		55		56		56		56	
	Meet/Not Meet ADT - Yellow (Y) = Met Criterion / White (W) = Did Not Meet Criterion											
Driver Outboard	W											
Driver Inboard	W											


2014 Subaru Legacy / Cloth / Second Row Driver Inboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
Attachment Force Max
Time axis [s]


2014 Subaru Legacy / Cloth / Second Row Driver Outboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3

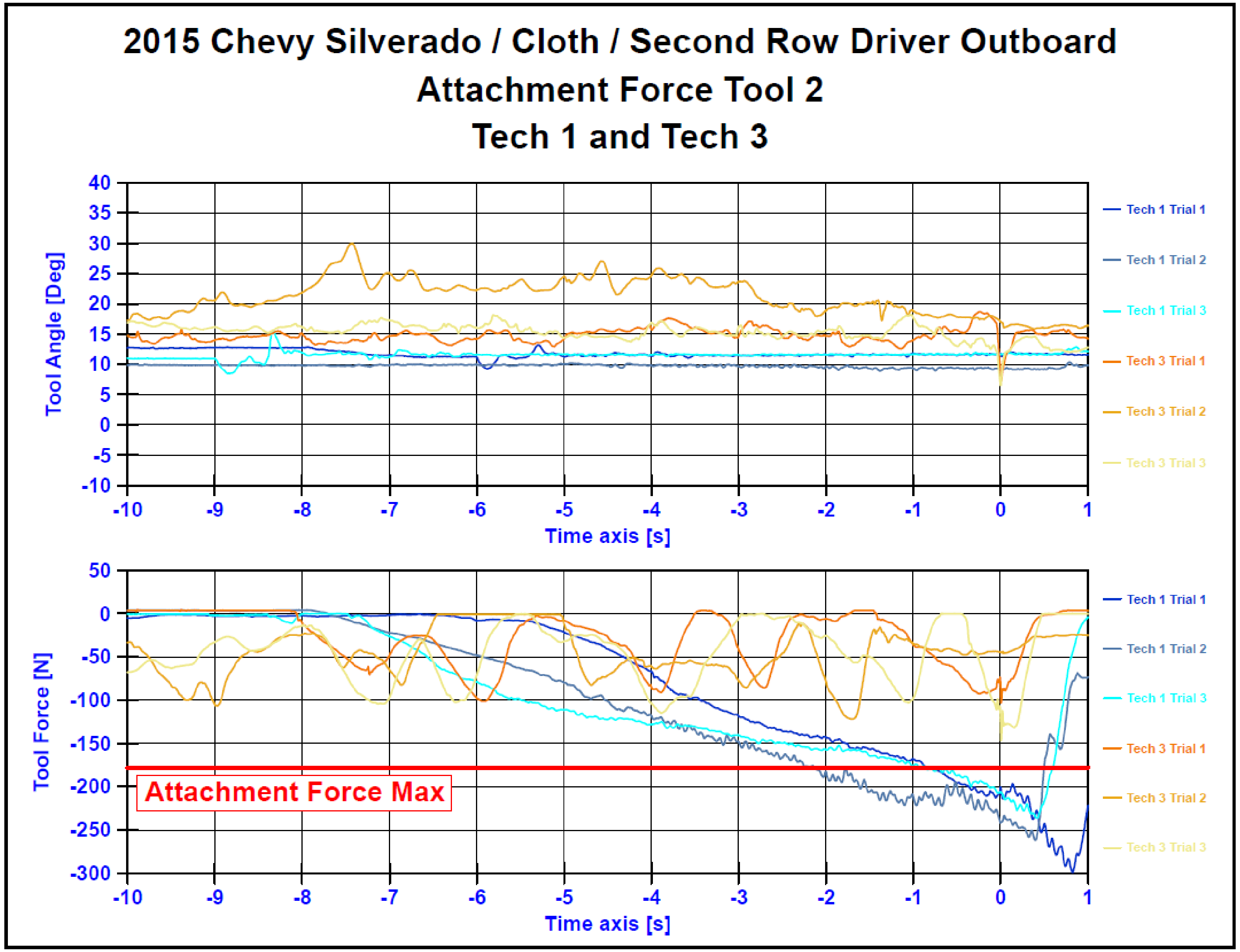
2015 Chevrolet Silverado – Cloth

	Tech 1						Tech 2			Tech 3		
	Tool Set I			Tool Set II			Tool Set I			Tool Set II		
	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3
	Modified AFT/ADT Depth - Blue (B) / Green (G) / Yellow (Y) White (W) Red (R) / Gold (GLD) / Black (BLK)											
Driver Outboard	Y / 11°	Y / 12°	Y / 10°	Y / 11°	Y / 10°	Y / 10°	Y / 18°	Y / 18°	Y / 18°	Y / 13°	Y / 13°	Y / 13°
Driver Inboard	Y / 10°	Y / 10°	Y / 10°	Y / 9°	Y / 10°	Y / 10°	Y / 12°	Y / 13°	Y / 12°	Y / 13°	Y / 12°	Y / 12°

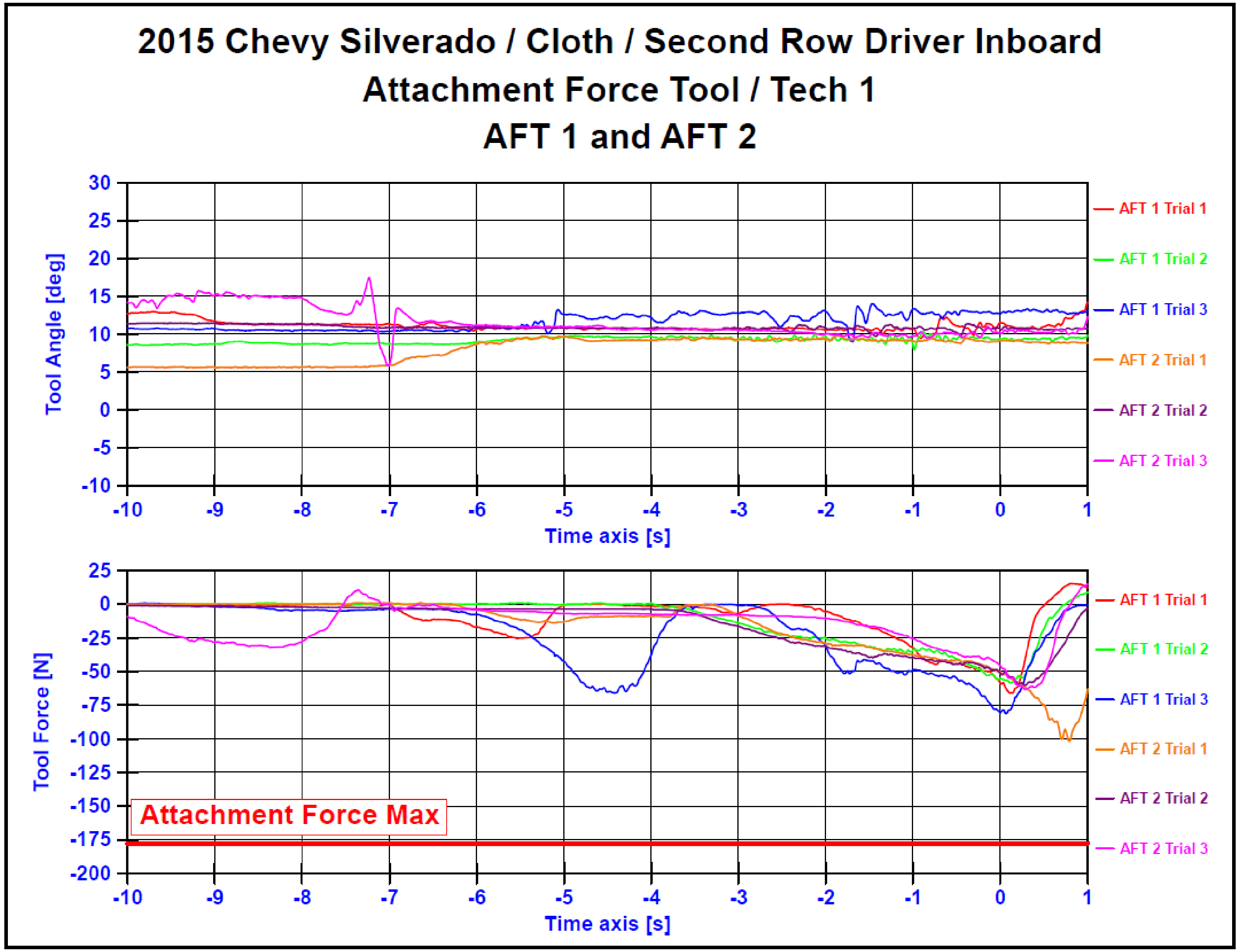
Modified AFT/ADT Force - LBF (N) / Degrees

	Lbf (N)	Deg	Lbf (N)	Deg	Lbf (N)	Deg	Lbf (N)	Deg	Lbf (N)	Deg	Lbf (N)	Deg	Lbf (N)	Deg	Lbf (N)	Deg	Lbf (N)	Deg	Lbf (N)	Deg	Lbf (N)	Deg	Lbf (N)	Deg
Driver Outboard	39 (173)	11	40 (178)	12	48 (214)	10	48 (214)	11	54 (240)	10	46 (205)	10	25 (111)	18	22 (98)	18	21 (93)	18	23 (102)	13	27 (120)	13	27 (120)	13
Driver Inboard	13 (58)	10	12 (53)	10	18 (80)	10	11 (49)	9	11 (49)	10	10 (44)	10	13 (58)	12	17 (76)	13	15 (67)	12	12 (53)	13	16 (71)	12	19 (85)	12

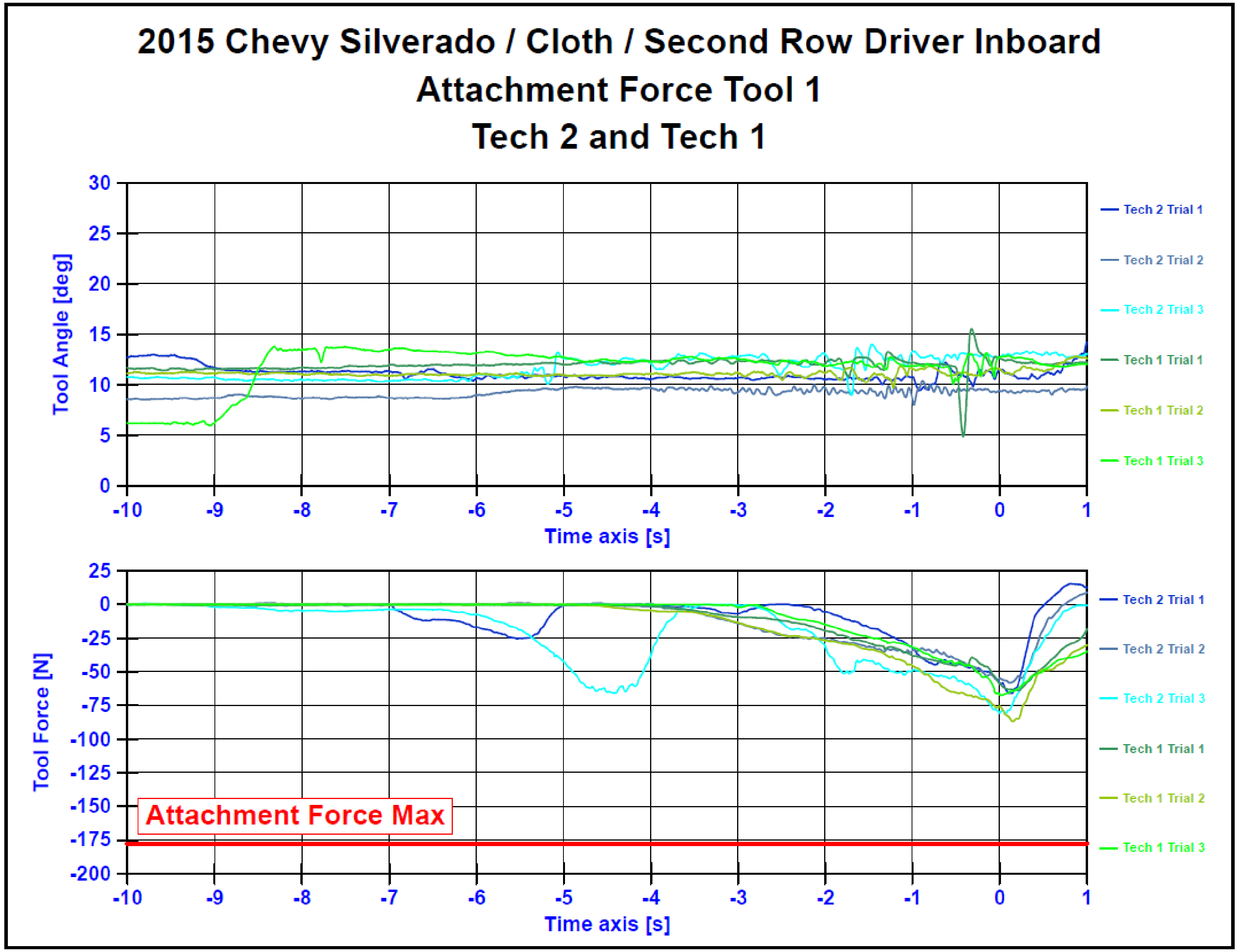
	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3	Meas. 1	Meas. 2	Meas. 3
	CAT V1 - Degrees @ 15 lbf (67 N) vertical											
Driver Outboard	61	60	60	61	61	61	61	63	65	62	62	63
Driver Inboard	62	62	63	61	62	62	62	64	65	63	64	64
	Meet/Not Meet ADT - Yellow (Y) = Met Criterion / White (W) = Did Not Meet Criterion											
Driver Outboard	Y						Y			Y		
Driver Inboard	Y						Y			Y		

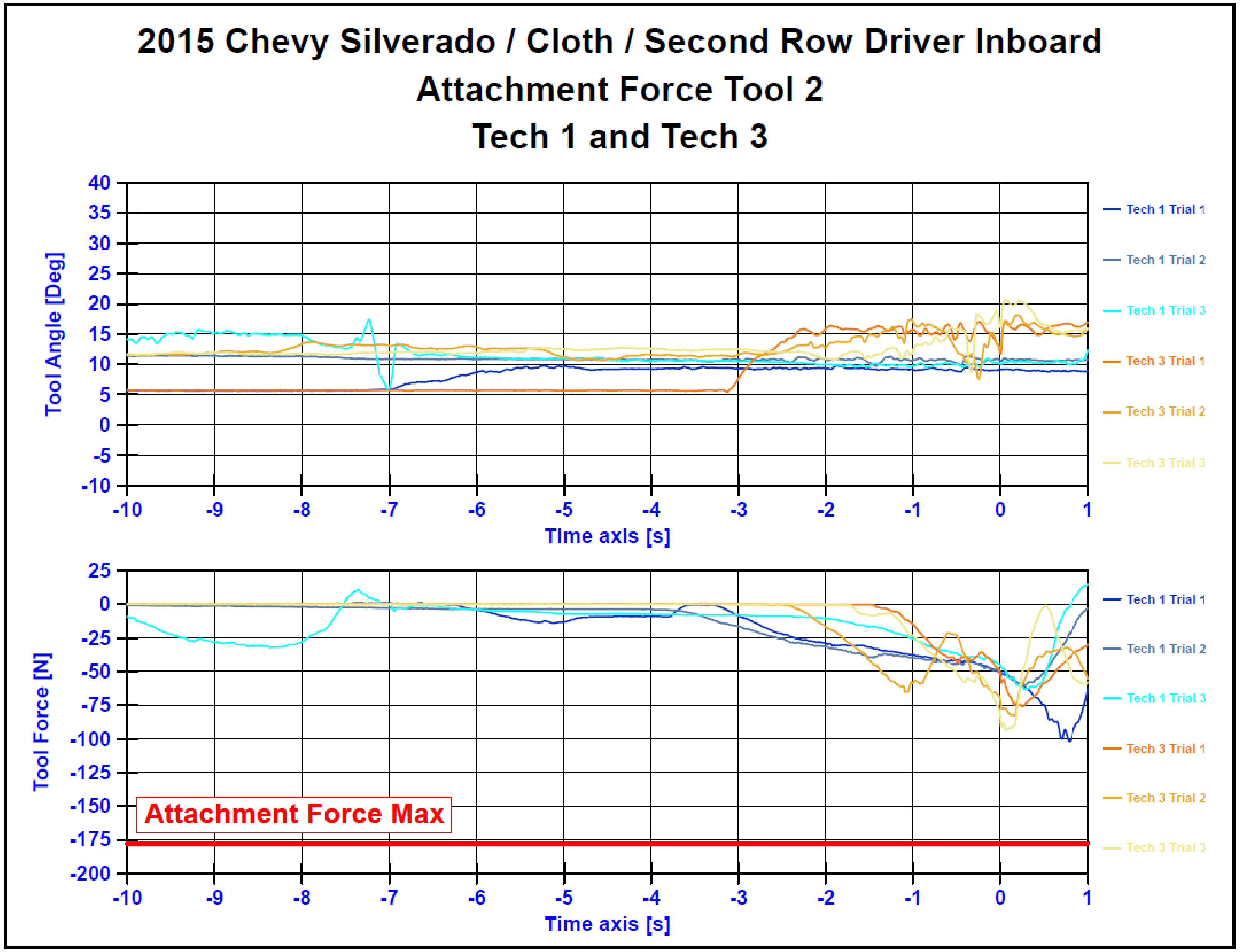


2015 Chevy Silverado / Cloth / Second Row Driver Outboard
Attachment Force Tool 2
Tech 1 and Tech 3
Tool Angle [Deg]
Time axis [s]
Tool Force [N]
Time axis [s]
Attachment Force Max
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3

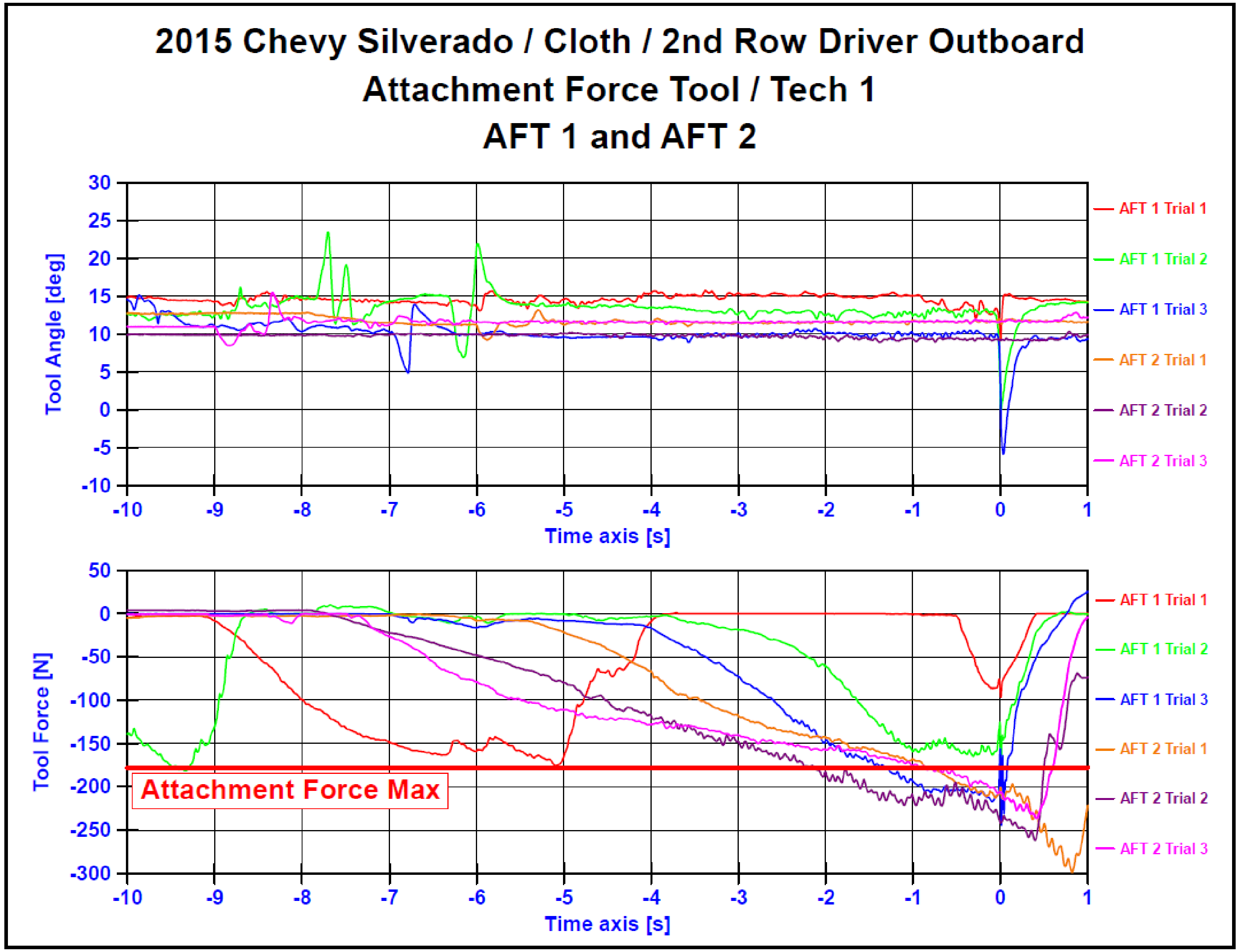


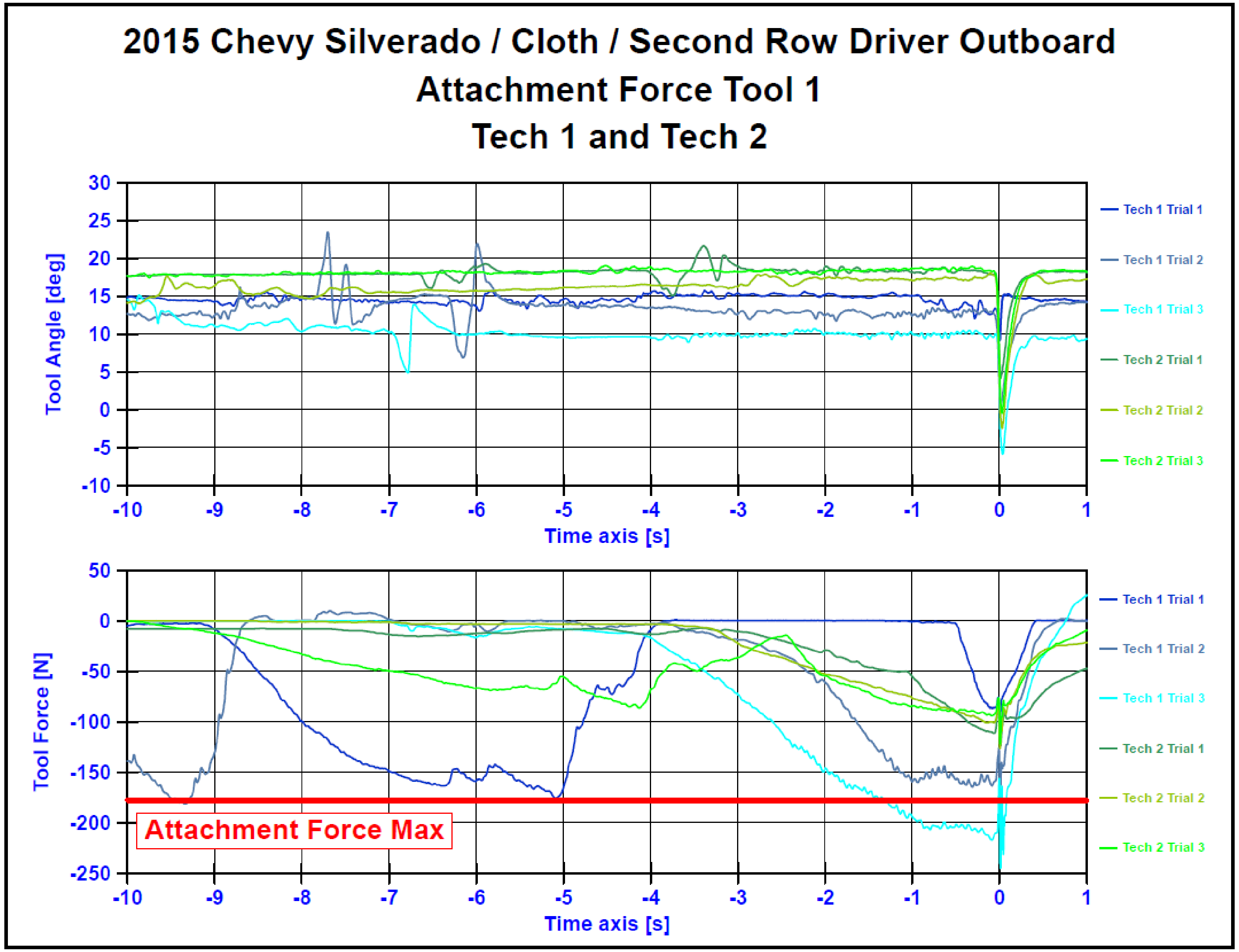
2015 Chevy Silverado / Cloth / Second Row Driver Inboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
30
25
20
15
10
5
0
-5
-10
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3


2015 Chevy Silverado / Cloth / Second Row Driver Inboard
Attachment Force Tool 1
Tech 2 and Tech 1
Tool Angle [deg]
Time axis [s]
Tool Force [N]
Attachment Force Max
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3



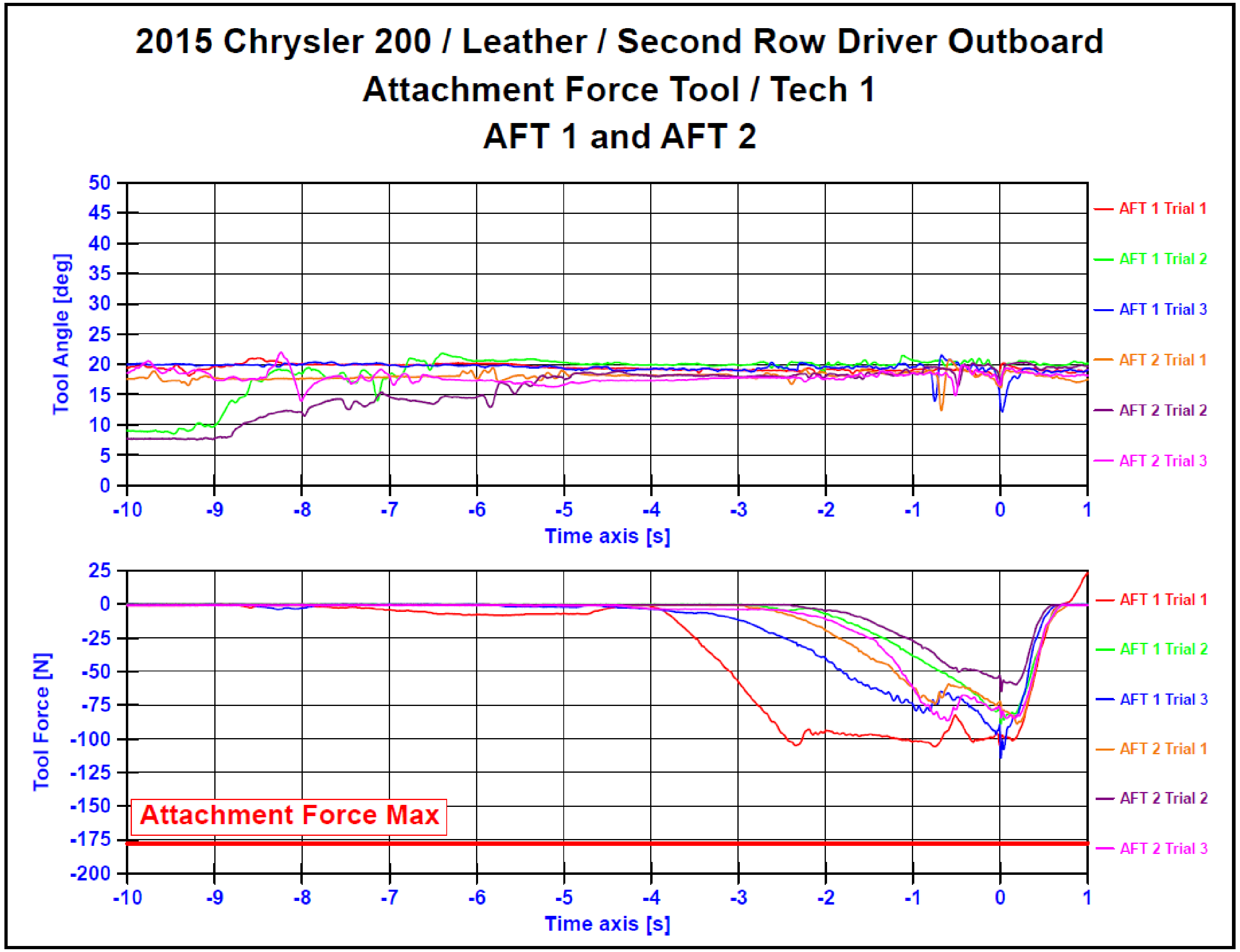
2015 Chevy Silverado / Cloth / Second Row Driver Inboard
Attachment Force Tool 2
Tech 1 and Tech 3
Tool Angle [Deg]
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3
Tool Force [N]
Attachment Force Max
Time axis [s]
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 3 Trial 1
Tech 3 Trial 2
Tech 3 Trial 3


2015 Chevy Silverado / Cloth / 2nd Row Driver Outboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
30
25
20
15
10
5
0
-5
-10
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
50
0
-50
-100
-150
-200
-250
-300
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3

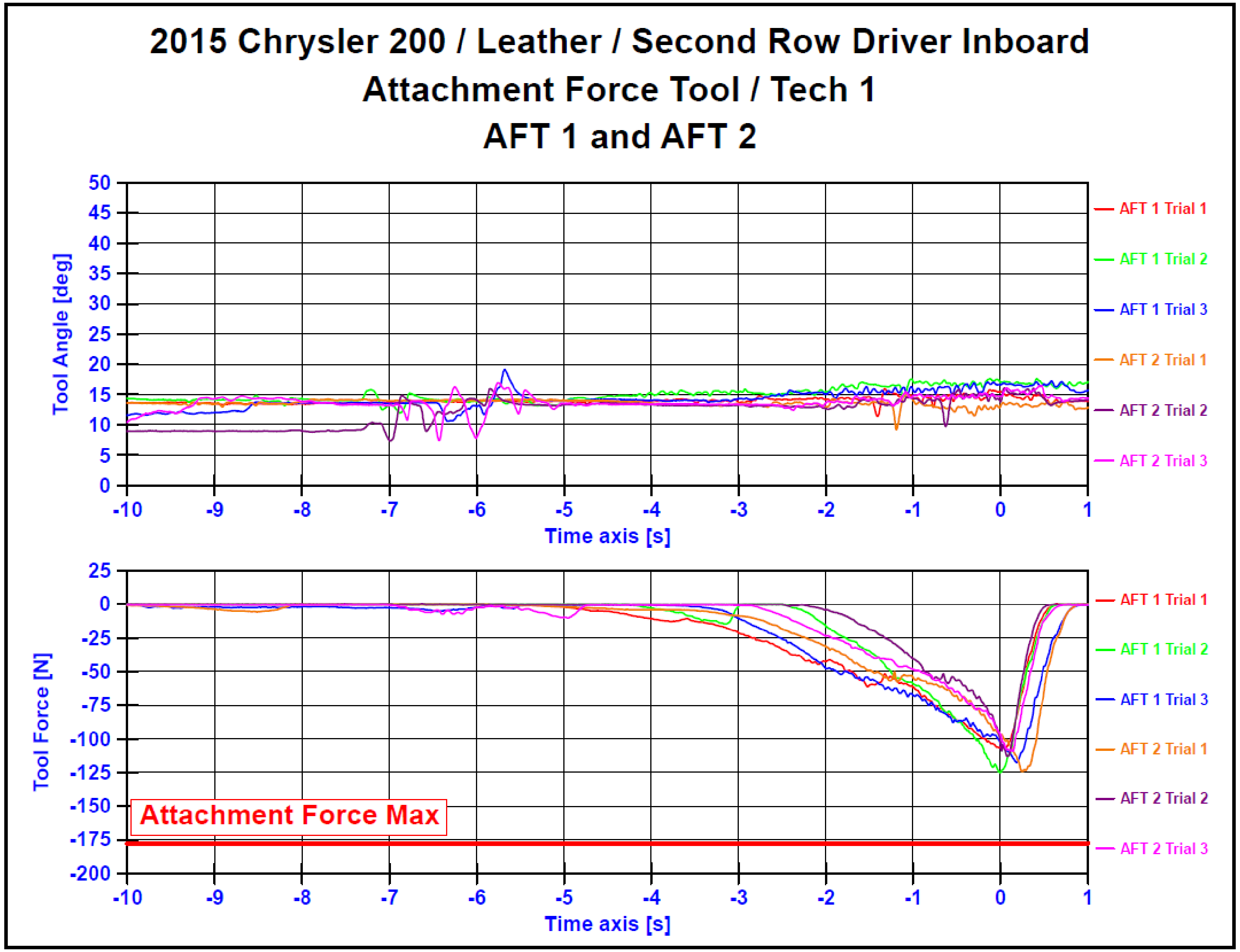

2015 Chevy Silverado / Cloth / Second Row Driver Outboard
Attachment Force Tool 1
Tech 1 and Tech 2
Tool Angle [deg]
Time axis [s]
Tool Force [N]
Attachment Force Max
Tech 1 Trial 1
Tech 1 Trial 2
Tech 1 Trial 3
Tech 2 Trial 1
Tech 2 Trial 2
Tech 2 Trial 3

2015 Chrysler 200 – Leather

	Tech 1											
	Tool Set I						Tool Set II					
	Meas. 1		Meas. 2		Meas. 3		Meas. 1		Meas. 2		Meas. 3	
	Modified AFT/ADT Depth - Blue (B) / Green (G) / Yellow (Y) White (W) Red (R) / Gold (GLD) / Black (BLK)											
Driver Outboard	Y/20°		Y/20°		Y/20°		Y/20°		Y/20°		Y/20°	
Driver Inboard	Y/14°		Y/14°		Y/14°		Y/14°		Y/14°		Y/14°	
	Modified AFT/ADT Force - LBF (N) / Degrees											
	Lbf (N)	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**
Driver Outboard	24 (107)	20	18 (80)	20	22 (98)	20	17 (76)	20	12 (53)	20	19 (85)	20
Driver Inboard	24 (107)	14	28 (125)	14	23 (102)	14	22 (98)	14	23 (102)	14	22 (98)	14
	CAT V1 - Degrees @ 15 lbf (67 N) vertical											
Driver Outboard	63		63		63		65		65		65	
Driver Inboard	66		64		66		66		66		66	
	Meet/Not Meet ADT - Yellow (Y) = Met Criterion / White (W) = Did Not Meet Criterion											
Driver Outboard	Y											
Driver Inboard	Y											



2015 Chrysler 200 / Leather / Second Row Driver Outboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3



2015 Chrysler 200 / Leather / Second Row Driver Inboard
Attachment Force Tool / Tech 1
AFT 1 and AFT 2
Tool Angle [deg]
50
45
40
35
30
25
20
15
10
5
0
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
Time axis [s]
AFT 1 Trial 1
AFT 1 Trial 2
AFT 1 Trial 3
AFT 2 Trial 1
AFT 2 Trial 2
AFT 2 Trial 3
Tool Force [N]
25
0
-25
-50
-75
-100
-125
-150
-175
-200
Attachment Force Max

Appendix C: Final Drawing Package

Appendix D: Final VRTC LATCH Tools Usability Test Procedure

Test Conditions/Test Setup

Testing should be performed in a controlled environment with a temperature of 18.9 to 25.6° C (66 to 78° F) and a relative humidity from 10 to 70 percent. The test vehicle should be in the controlled environment for at least 4 hours prior to a test. The temperature and humidity of the test environment should be recorded for each test.

Set cold tire pressures according to the vehicle manufacturer's recommendations. The vehicle should be tested on a level horizontal surface such that the angle measured at the rear sill is 0 ± 2°.

If the rear seat has fore-aft adjustability, set the seat to the midtrack position of available travel.

For vehicles with adjustable seatbacks, set the rear seatback angle to the design seatback angle using the tools and procedures described in SAE J826. If the design seatback angle is unknown, set the angle to be 25 ± 1°. To facilitate future positioning, record the angle of a component on the seatback (such as head restraint post).

Lower anchors are designated as:

Left outboard, left inboard, center left, center right, right inboard, right outboard.

Remove any covers from the lower anchors. If necessary, flaps can be secured in the open position using masking tape (Scotch brand masking tape type 232, ~25 mm [1 in] wide, 12 in or less per component, or equivalent). Seatbelt components can be shifted away from the lower anchors and secured with masking tape. If stowable, place the lower anchors in the use configuration specified by the vehicle manufacturer.

Testing on each anchor should be performed in the following order: depth, force, clearance. A minimum of 5 minutes should pass before consecutive tests with different tools on the same anchor. A minimum of 30 minutes should pass between repeat tests using the same tool on the same anchor. A minimum of 4 hours should pass between testing with different toolsets.

Place a strip of masking tape on the seat cushion that is centered on the lower anchor and parallel to the seat cushion centerline. This will serve as a visual guide for aligning the tools during testing. Draw centerlines on tape to reference.

Take pictures of each seat (full view) and each anchor (zoomed in) and take notes on description of anchors, if anchor is hard to find, any barriers around anchor, etc. during testing.

Lower Anchor Data

1. Anchor Depth Tool (ADT)

The anchor depth is recorded using the depth tool (Figure D-1). The tool consists of a depth gauge, slider, and view bar with zeroing strip. The depth tool hook has a zero-scribe line to represent the back edge of the lower anchor when the tool is attached to it.

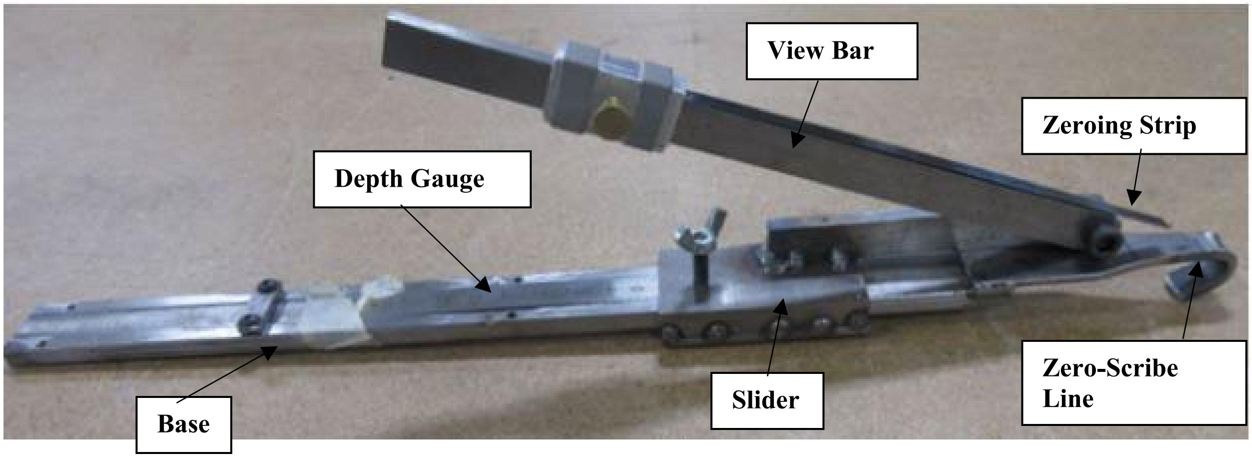


Figure D-1. Anchor Depth Tool (ADT)

1.1 Place a 2-foot level along the centerline of the seat. Place an inclinometer on the level and record the angle of the seat pan (Figure D-2).

Figure D-2. Measure the Seat Pan Angle Using a 2-Foot Level and Inclinometer

1.2 Subtract the angle measured in step 1.1 from 30°. With the tool on a flat surface, adjust the view bar to read this calculated angle. This will set the view bar to read 30° to horizontal when the tool is placed in the vehicle.

1.3 Slide the zeroing strip along the view bar so that it is barely touching the top of the depth tool hook. Move the view bar forward on the depth tool, so the end of the zeroing strip is aligned with the zero-scribe line. Make sure the zeroing strip is not raised from the surface of the view bar or bound up.

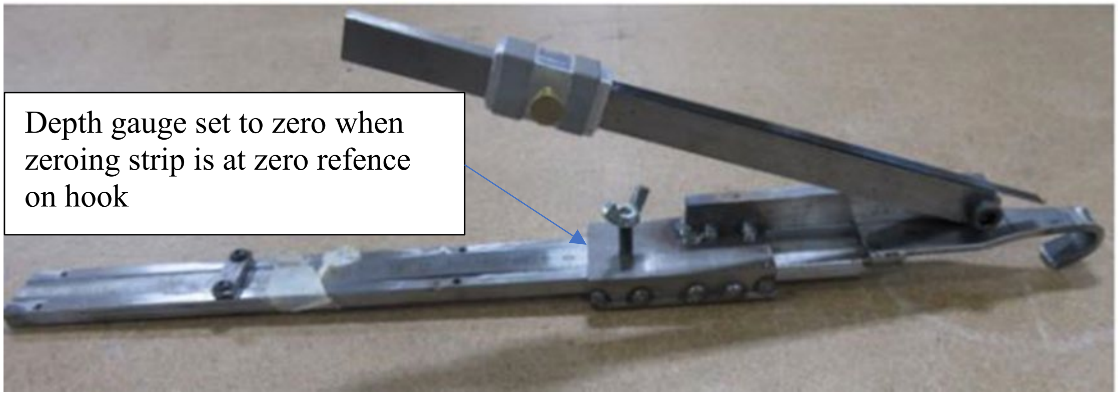


Figure D-3. Setting Zero on Depth Gauge at Back of Slider when Zeroing Strip is at its Zero Reference on Hook.

1.4 Slide the Depth Gauge so that it reads 0 mm at the rear edge of the slider when the zeroing strip is touching the zero-scribe line (See Figure D-3). Tighten the thumb screw at the back to keep the depth gauge in place.
NOTE: for visible anchors, align the depth gauge to 20 mm (20 mm=0 mm) so that negative values can be read

1.5 Move the slider to the rear most position and re-attach the depth tool to the center of the lower anchor; pull it towards the front of the vehicle to engage with the lower anchor. The tool should be centered on the anchor; the lower anchor button indicator may or may not correspond with the center of the anchor. The tool should be aligned with the masking tape and should be as parallel to the vehicle centerline as possible.

1.6 Place an inclinometer on the base of the tool. Adjust the base angle of the tool to be within ± 2° of the seat pan angle recorded in step 1.1. If needed, use shims to adjust the base angle (Figure D-4). This sets the tool to be parallel to the seat pan angle.

Figure D-4. Setting Tool Parallel to Seat Pan Angle Using Shims

1.7 Move the entire slider bar forward until the zeroing strip contacts the vehicle seatback or tunnel. Record the depth gauge measurement to the nearest millimeter. Record time measurement was taken. Take pictures of tool on anchor with gauge visible (side view).

1.8 Test each anchor once unless the value recorded is **<u>20 ± 2 mm</u>**. If so, repeat the test 2 more times with a wait time of at least 30 minutes between repeats.

2. Attachment Force Tool

The lower anchor attachment force is measured using the attachment force tool (Figure D-5). The AFT consists of a square cross-section guide rod, force tool slider, load cell, actuator, digital angle gauge, and support leg.

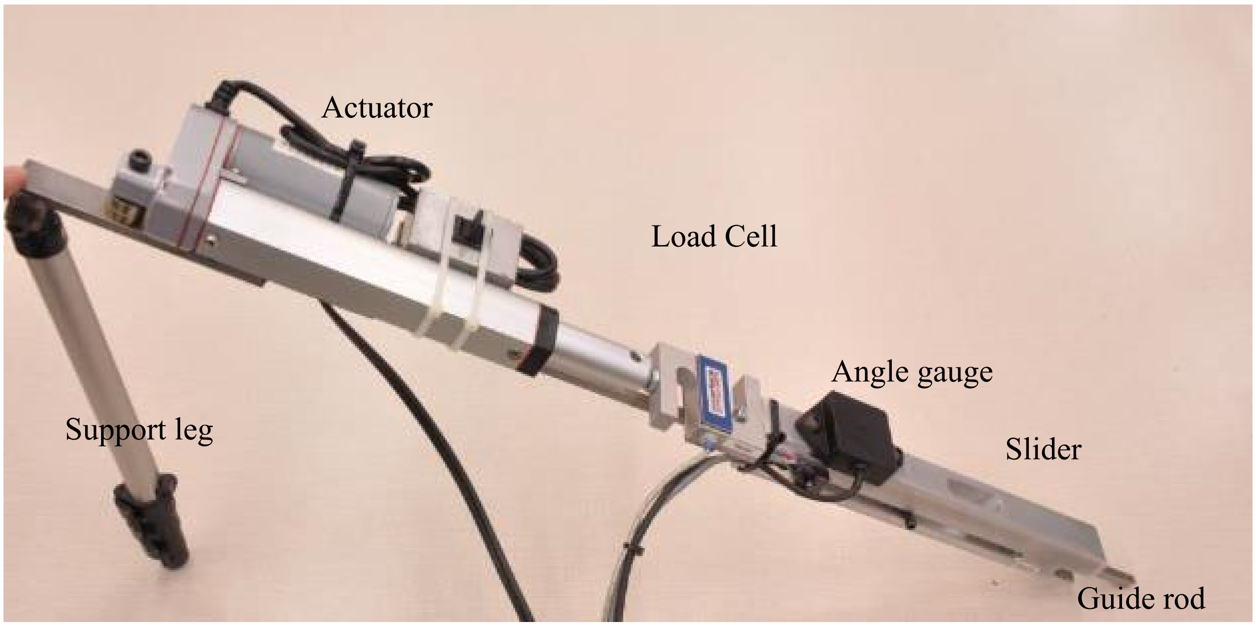


Figure D-5. AFT Used to Measure Lower Anchor Attachment Force

2.1. With the force tool slider fully retracted (guide rod should be extended beyond the front surface of slider), place the notched end of the guide rod in the center of the lower anchor bar and apply gentle pressure to seat it.

2.2. As shown in Figure D-6, position the force tool so the approach angle is 20 ± 2° relative to horizontal. Adjust the force tool leg support so it rests on the rear floor of the vehicle and keeps the tool at the 20-degree approach angle. If the force cannot be measured at this angle, measure the force at the closest angle to this corridor and document this angle.

Figure D-6. Initial Position of Force Tool Slider with Approach Angle of 20°

2.3 The operator should position one hand at the end of the force tool and brace an elbow against the front seat or B-pillar to provide a path for a reaction force. The tool should be as parallel with the vehicle centerline as possible. The data system should be set to record as soon as the load is applied to the tool and to automatically collect data for 10 seconds prior to the tool fully engaging with the lower anchor and for 1 second post engagement.

2.4 Engage the actuator until it stops. The event switch on the tool should be set to trigger when the tool is fully engaged.

2.5 If the fabric or other material around the anchor causes the tool to disengage from the anchor, the test is not valid. If the tool disengages, repeat up to three times to have a successful test. If the force cannot be measured after four attempts, the lower anchor does not meet the criterion. If the 20° approach angle varies more than ± 2° over the loading phase, it is not a valid test and should be repeated. Wait time between failed trials should be at least 5 minutes.

2.6 The maximum force recorded should be the highest force observed during the movement of the slider onto the lower anchor prior to the event (time zero). Record the maximum force seen prior to time zero, the angle at this force measurement, and the time the measurement was taken.

2.7 Test each anchor once unless the recorded value is **178 ± 9 N**. If so, repeat the test 2 more times with a wait time of at least 30 minutes between repeats.

3. Clearance Angle Tool (CAT)

The clearance angle is measured using the clearance angle tool, which consists of a CRS attachment gauge, a load cell, and a digital angle gauge (Figure D-7). A pulley bridge and weight are used to apply load to the CAT.

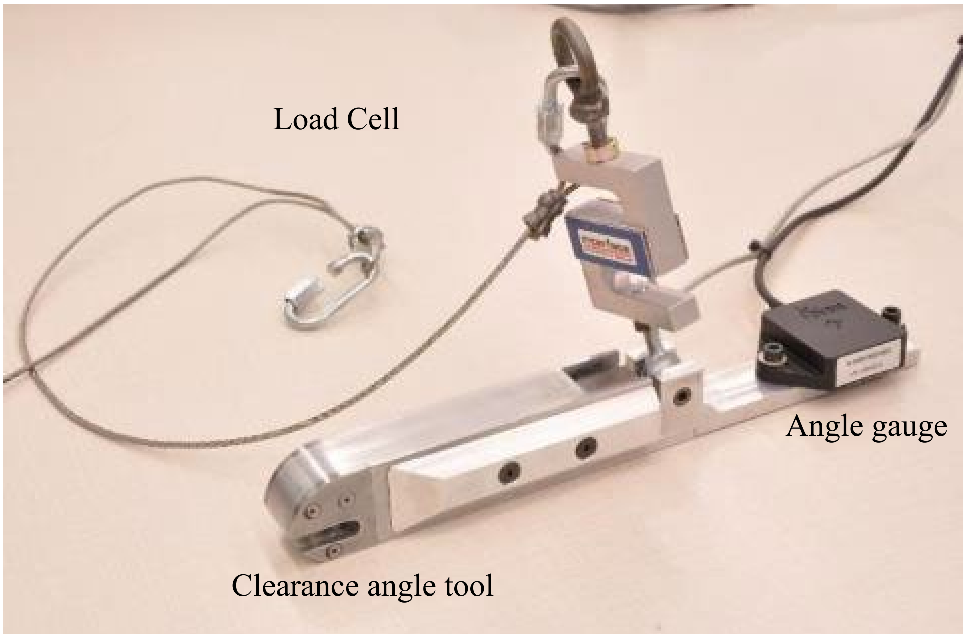


Figure D-7. CAT

3.1 Prepare the lower anchor test position by either removing the head restraints from the seat in front and behind the lower anchor or lift them to their highest position.
3.2 Place the pulley bridge so it rests on the tops of the rear and front seatbacks above the lower anchor. Use the leveling feet to position the bridge so it is horizontal within ± 5° about its longitudinal axis. If necessary, change the front seatback angle to help level the pulley bridge.
3.3 Attach the CAT to the center of the lower anchor hardware and the pulley cable. Insert the pulley wheel onto the bridge and route the cable over it.
3.4 Gently attach a weight of 67 ± 0.4 N (15 ± 0.1 lb) to the attachment cable. The weight should be hanging freely without any swinging. The attachment cable should be vertical within ±5° from both the front and the side, as shown in Figure D-8.

Figure D-8. Pulley Wire Should be Vertical From Both the Side and Front of Vehicle

3.5 Trigger the data system to record the angle and load. To count as a valid test, the load should be 67 ± 0.4 N. Record angle and load at time zero on the data system and record the time the measurement was taken.

3.6 Test each anchor once unless the recorded value is **<u>54 ± 2°</u>**. If so, repeat the test 2 more times with a wait time of at least 30 minutes between repeats.

Appendix E: VRTC Usability Study Results Tables

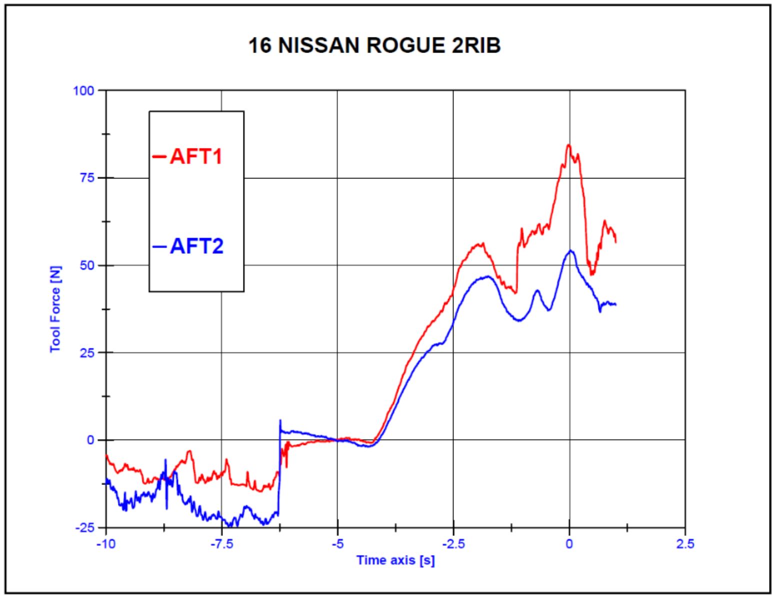
2014 Cadillac ATS

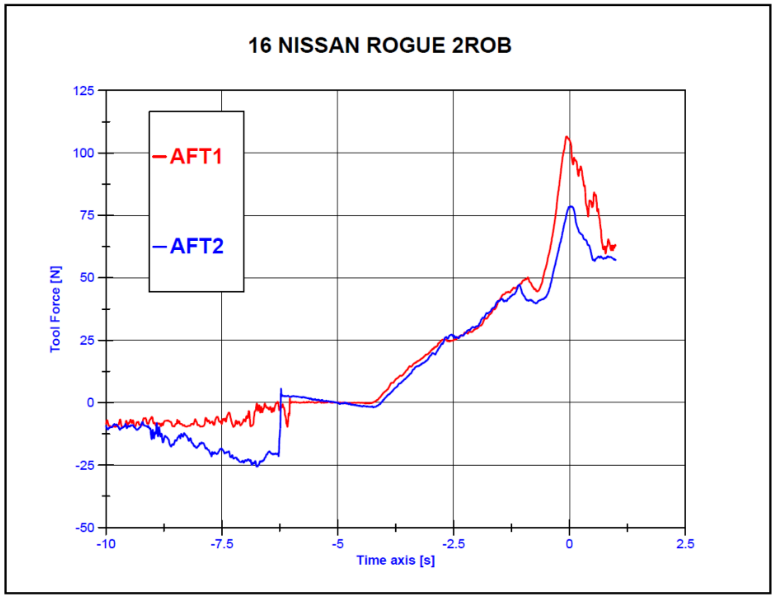
	Tech 1											
	Tool Set I						Tool Set II					
	Meas. 1		Meas. 2		Meas. 3		Meas. 1		Meas. 2		Meas. 3	
	Modified AFT/ADT Depth - Blue (B) / Green (G) / Yellow (Y) White (W) Red (R) / Gold (GLD) / Black (BLK)											
Driver Outboard	W/18°		W/18°		W/18°		W/18°		W/18°		W/18°	
Driver Inboard	W/18°		W/18°		W/18°		W/18°		W/18°		W/18°	
	Modified AFT/ADT Force - LBF (N) / Degrees											
	Lbf (N)	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**	**Lbf (N)**	**Deg**
Driver Outboard	The AFT could not be used correctly. For it to engage, it had to be wiggled side to side to work its way through the seat cover, or the seat cover had to be held out of the way.											
Driver Inboard												
	CAT V1 - Degrees @ 15 lbf (67 N) vertical											
Driver Outboard	66		64		65		64		63		64	
Driver Inboard	63		63		63		64		64		64	
	Meet/Not Meet ADT - Yellow (Y) = Met Criterion / White (W) = Did Not Meet Criterion											
Driver Outboard	W											
Driver Inboard	W											

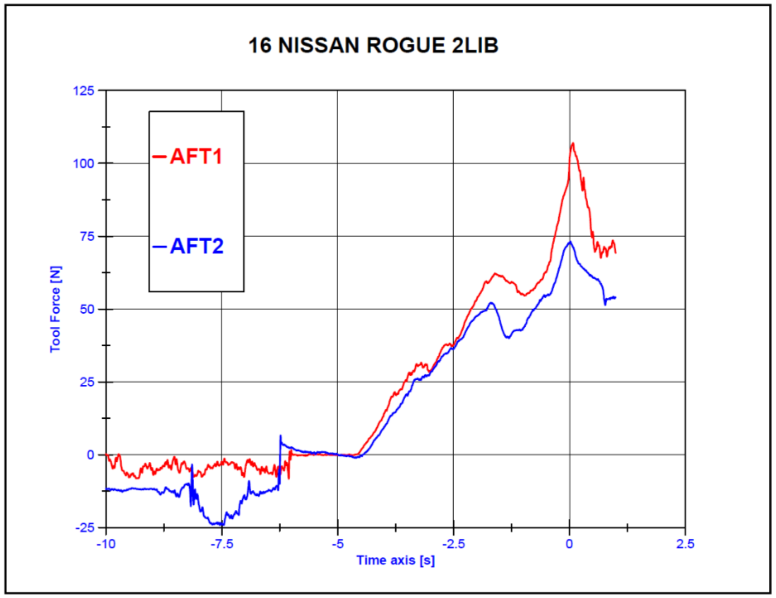
No AFT Plots – unable to engage anchor due to flaps on tunnels

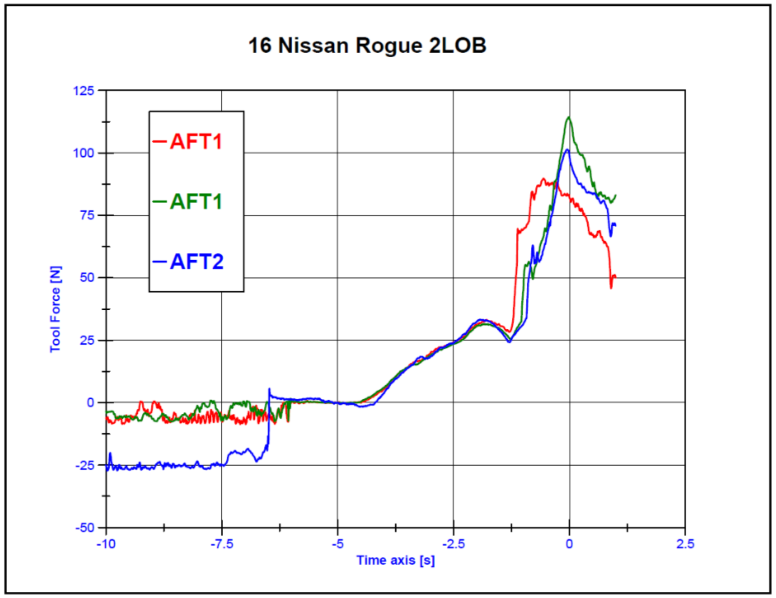
2016 Nissan Rogue

VRTC 2018 results									
ADT			AFT				CAT		
mm	toolset	Seat/Anchor	deg	lb (N)	toolset	Seat/Anchor	deg	toolset	Seat/Anchor
10.0	V3	2L IB	20.3	22.7 (100.9)	V3	2L IB	49.3	V3	2L IB
12	V2	2L IB	21.3	16.4 (72.8)	V2	2L IB	49.4	V2	2L IB
1	V3	2L OB	20.6	25.7 (114.4)	V3	2L OB	56.3	V3	2L OB
14	V2	2L OB	21.2	22.8 (22.8)	V2	2L OB	55.9	V2	2L OB
4	V3	2R IB	21.5	19 (84.5)	V3	2R IB	56.4	V2	2L OB
13	V2	2R IB	21.9	12.1 (54)	V2	2R IB	56.1	V2	2L OB
2	V3	2R OB	21.6	24.0 (106.7)	V3	2R OB	54.2	V3	2R IB
1.4	V2	2R OB	22.1	17.6 (78.2)	V2	2R OB	55.0	V3	2R IB
							54.8	V3	2R IB
							54.4	V2	2R IB
							53.0	V2	2R IB
							49.7	V2	2R IB
							58.4	V3	2R OB
							58.2	V2	2R OB
							Averages		
							54.7	V3	2R IB
							56.2	V2	2L OB
							52.4	V2	2R IB
Notes: 2016 Nissan Rogue, cloth									


16 NISSAN ROGUE 2RIB
AFT1
AFT2
Tool Force [N]
Time axis [s]
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

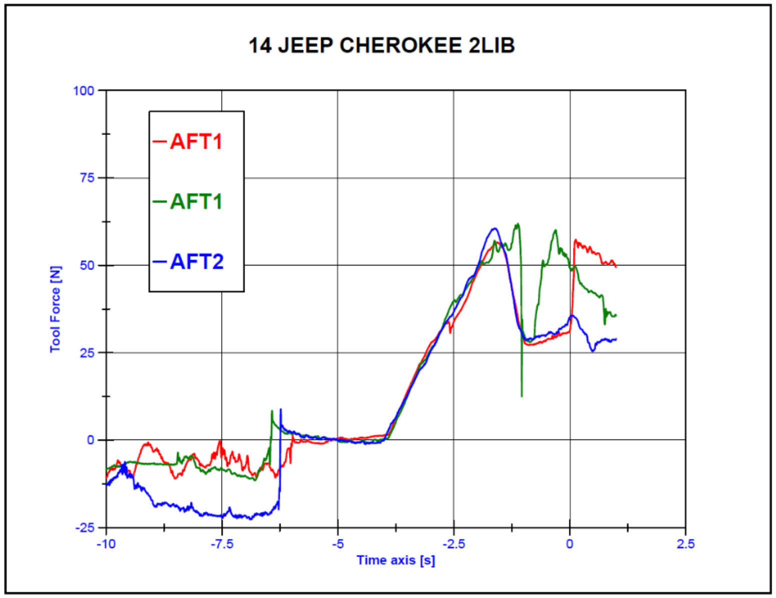

16 NISSAN ROGUE 2ROB
AFT1
AFT2
Tool Force [N]
Time axis [s]
125
100
75
50
25
0
-25
-50
-10
-7.5
-5
-2.5
0
2.5

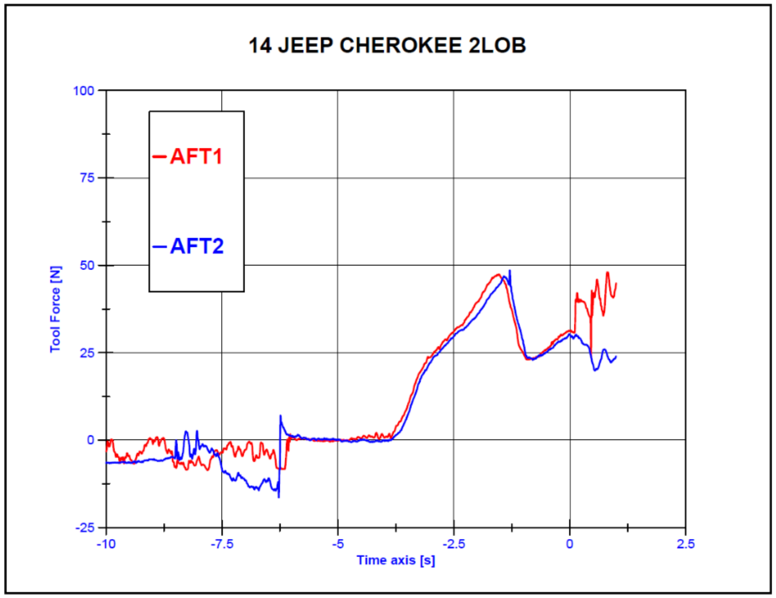

16 NISSAN ROGUE 2LIB
AFT1
AFT2
Tool Force [N]
Time axis [s]
125
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

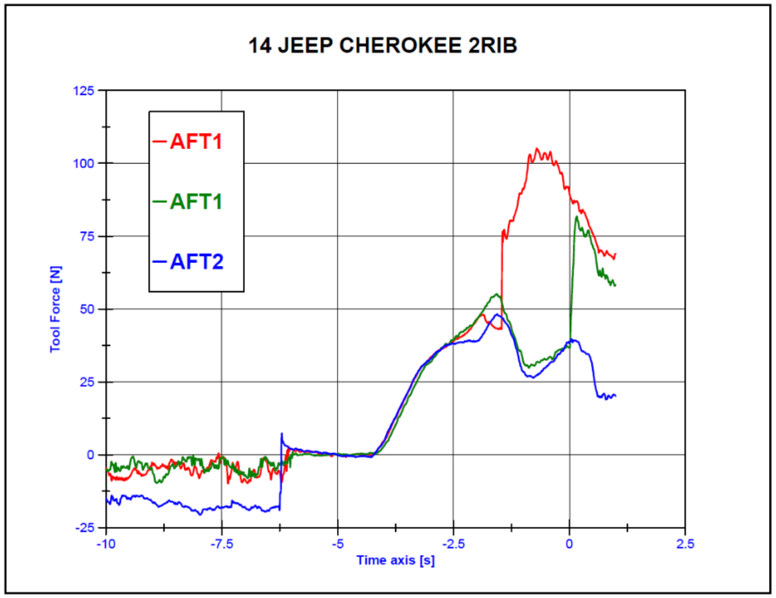

16 Nissan Rogue 2LOB
AFT1
AFT1
AFT2
Tool Force [N]
Time axis [s]
125
100
75
50
25
0
-25
-50
-10
-7.5
-5
-2.5
0
2.5

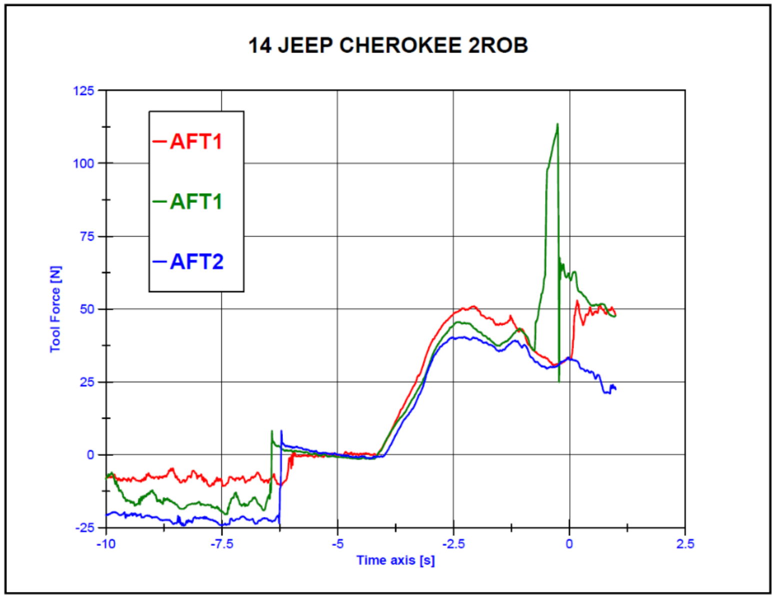
2014 Jeep Grand Cherokee

VRTC 2018 results										
ADT			AFT				CAT			
mm	toolset	Seat/Anchor	deg	lb (N)	toolset	Seat/Anchor	deg	toolset	Seat/Anchor
22	V3	2L IB	20.8	12.7 (56.6)	V3	2L IB	56.0	V3	2L IB
20	V3	2L IB	21.5	13.6 (60.5)	V2	2L IB	56.1	V3	2L IB
17	V3	2L IB	21.0	10.7 (47.4)	V3	2L OB	56.3	V3	2L IB
20	V2	2L IB	20.6	10.9 (48.6)	V2	2L OB	56.1	V2	2L IB
23	V2	2L IB	21.2	23.6 (105.2)	V3	2R IB	52.8	V3	2L OB
21	V2	2L IB	21.6	10.9 (48.3)	V2	2R IB	52.9	V3	2L OB
10	V3	2L OB	21.2	11.5 (51.0)	V3	2R OB	53.3	V3	2L OB
14	V2	2L OB	20.4	9.1 (40.4)	V2	2R OB	53.4	V2	2L OB
13	V3	2R IB					53.1	V2	2L OB
20	V2	2R IB					53.1	V2	2L OB
21	V2	2R IB					49.4	V3	2R IB
20	V2	2R IB					49.3	V2	2R IB
13	V3	2R OB					49.9	V3	2R OB
19	V2	2R OB					50.1	V2	2R OB
23	V2	2R OB					Averages		
20	V2	2R OB					53.0	V3	2L OB
Averages							56.1	V3	2L IB
20	V3	2L IB					53.2	V2	2L OB
21	V2	2L IB							
20	V2	2R IB							
21	V2	2R OB							
Notes: 2014 Jeep Grand Cherokee, cloth kickback/disengagement on V2, 2LIB and 2ROB									


14 JEEP CHEROKEE 2LIB
AFT1
AFT1
AFT2
Tool Force [N]
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5
Time axis [s]

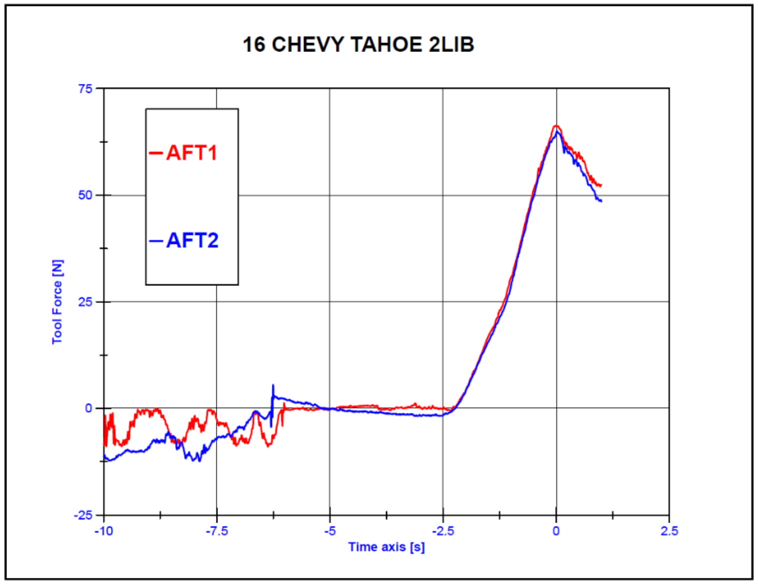

14 JEEP CHEROKEE 2LOB
AFT1
AFT2
Tool Force [N]
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5
Time axis [s]

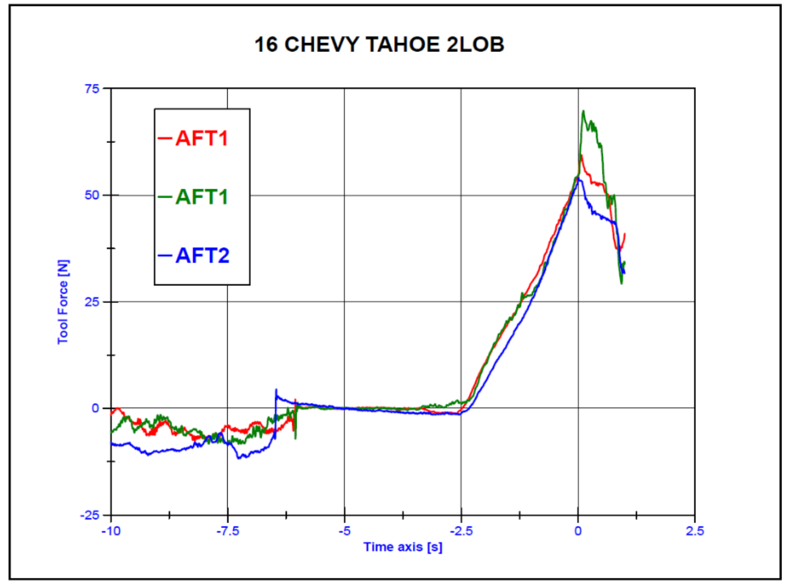

14 JEEP CHEROKEE 2RIB
AFT1
AFT1
AFT2
Tool Force [N]
125
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5
Time axis [s]

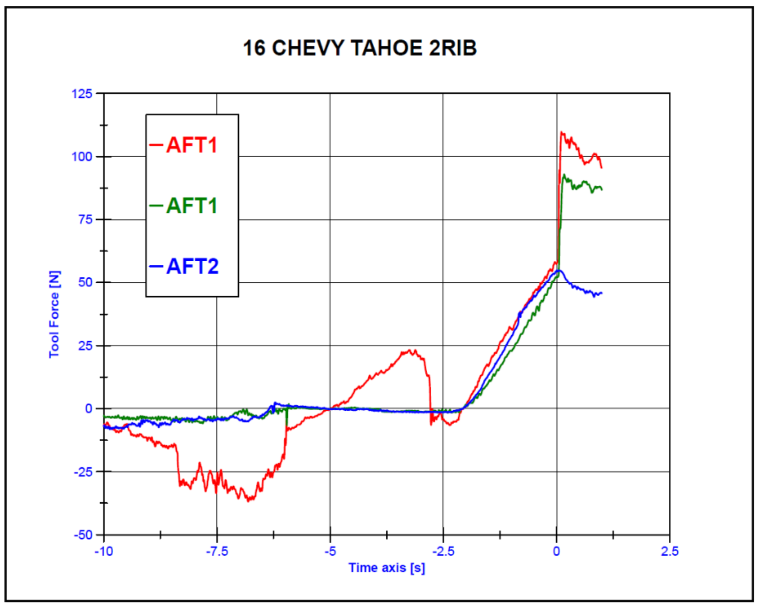

14 JEEP CHEROKEE 2ROB
AFT1
AFT1
AFT2
Tool Force [N]
125
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5
Time axis [s]

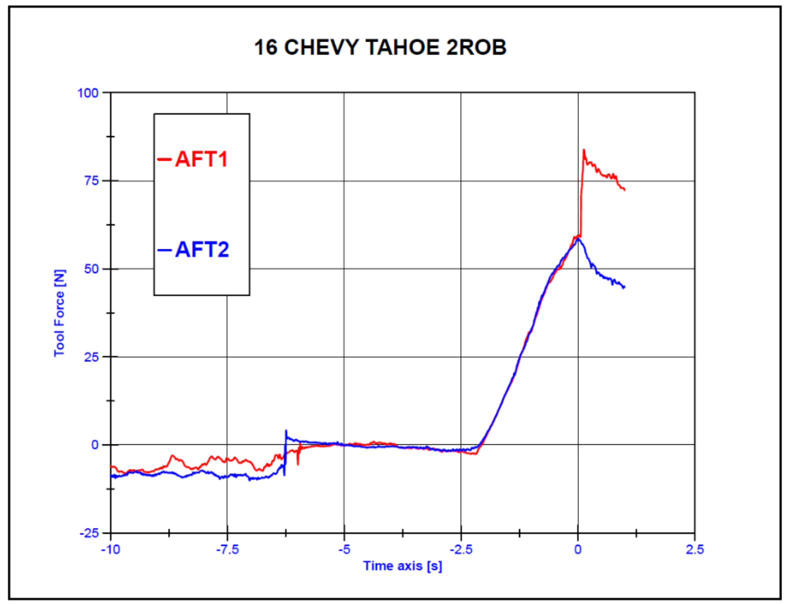
2016 Chevrolet Tahoe

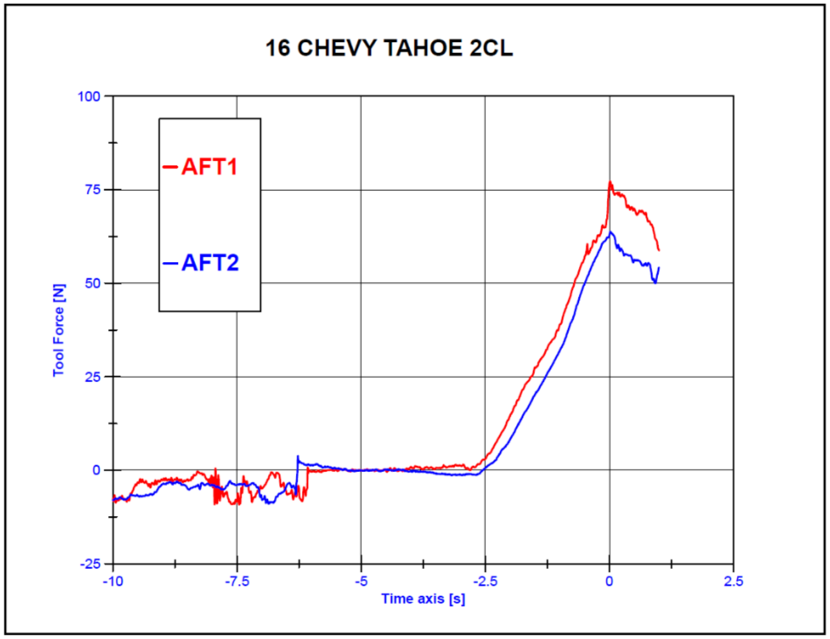
VRTC 2018 results (repeats if within criteria)									
ADT			AFT				CAT		
mm	toolset	Seat/Anchor	deg	lb (N)	toolset	Seat/Anchor	deg	toolset	Seat/Anchor
-3	V3	2CL	21.7	17.3 (76.7)	V3	2CL	70.5	V3	2CL
-1	V2	2CL	20.1	14.1 (62.9)	V2	2CL	71.4	V2	2CL
-4	V3	2CR	22.2	11.6 (51.6)	V3	2CR	71.6	V3	2CR
-5	V2	2CR	21.1	11.4 (50.6)	V2	2CR	71.4	V2	2CR
-5	V3	2L IB	18.9	14.9 (66.3)	V3	2L IB	73.4	V3	2L IB
-3	V2	2L IB	21.0	14.5 (64.5)	V2	2L IB	74.4	V2	2L IB
-4	V3	2LOB	21.1	12.3 (54.6)	V3	2LOB	73.2	V3	2LOB
-1	V2	2LOB	21.2	12.1 (54)	V2	2LOB	74.6	V2	2LOB
-6	V3	2R IB	20.4	11.7 (52.0)	V3	2R IB	77.6	V3	2R IB
-6	V2	2R IB	21.0	12.3 (54.7)	V2	2R IB	74.8	V2	2R IB
-7	V3	2R OB	21.1	13.4 (59.4)	V3	2R OB	72.8	V3	2R OB
-9	V2	2R OB	20.9	13.2 (58.6)	V2	2R OB	73.0	V2	2R OB
Notes: 2016 Chevy Tahoe, cloth									

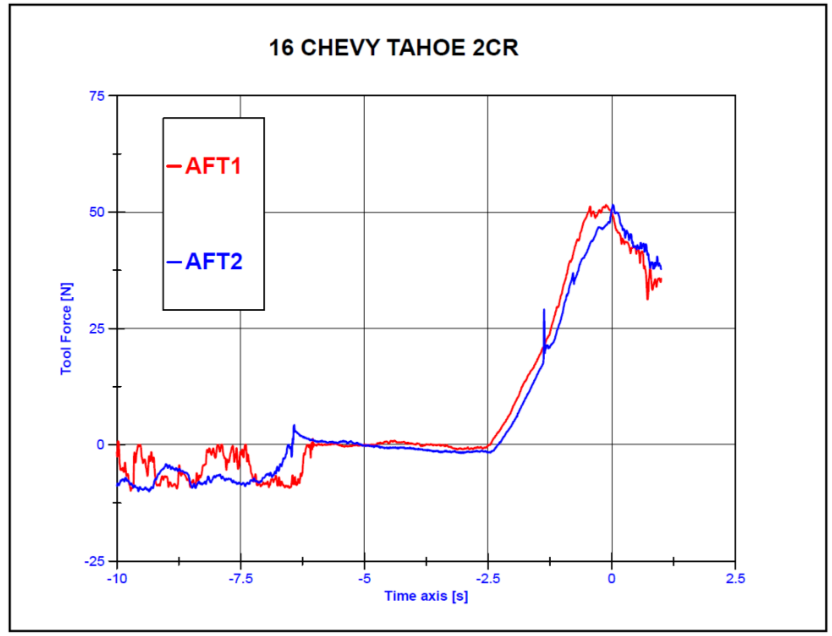

16 CHEVY TAHOE 2LIB
AFT1
AFT2
Tool Force [N]
Time axis [s]
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5


16 CHEVY TAHOE 2LOB
AFT1
AFT1
AFT2
Tool Force [N]
Time axis [s]
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5


16 CHEVY TAHOE 2RIB
AFT1
AFT1
AFT2
Tool Force [N]
Time axis [s]
125
100
75
50
25
0
-25
-50
-10
-7.5
-5
-2.5
0
2.5

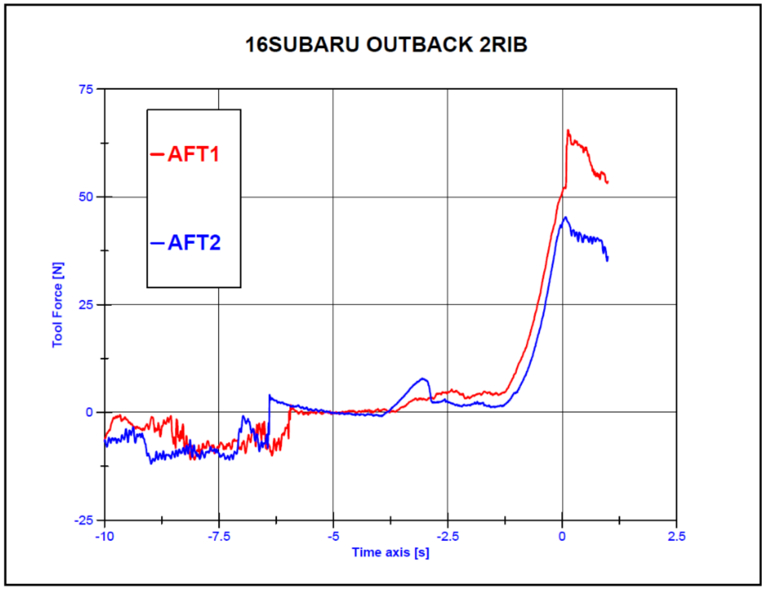

16 CHEVY TAHOE 2ROB
AFT1
AFT2
Tool Force [N]
Time axis [s]
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

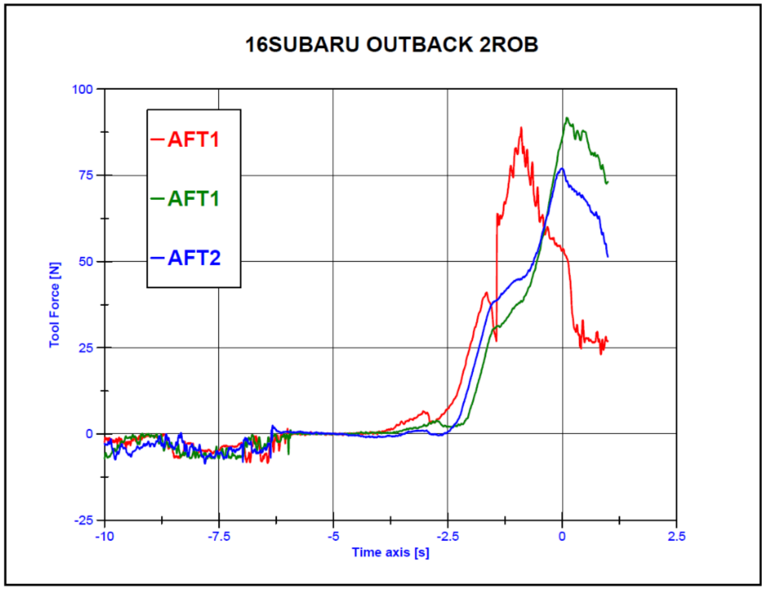

16 CHEVY TAHOE 2CL
AFT1
AFT2
Tool Force [N]
Time axis [s]
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

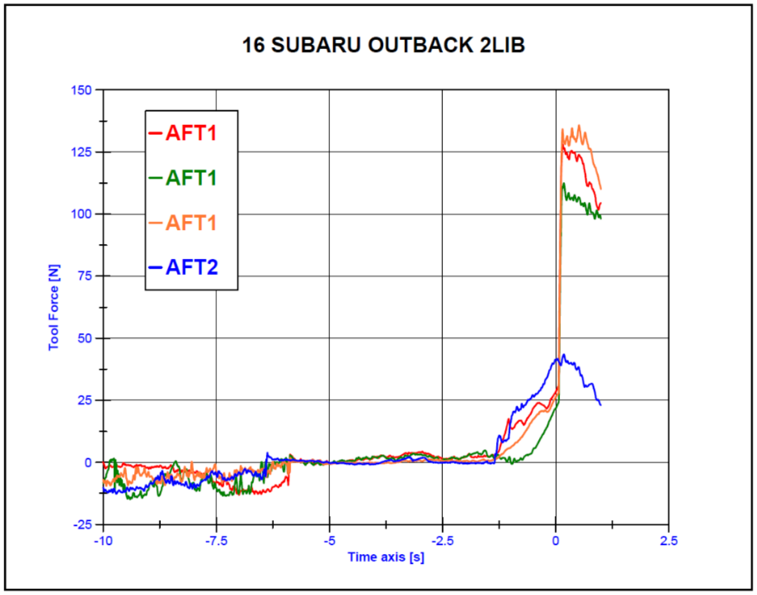

16 CHEVY TAHOE 2CR
AFT1
AFT2
Tool Force [N]
Time axis [s]
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

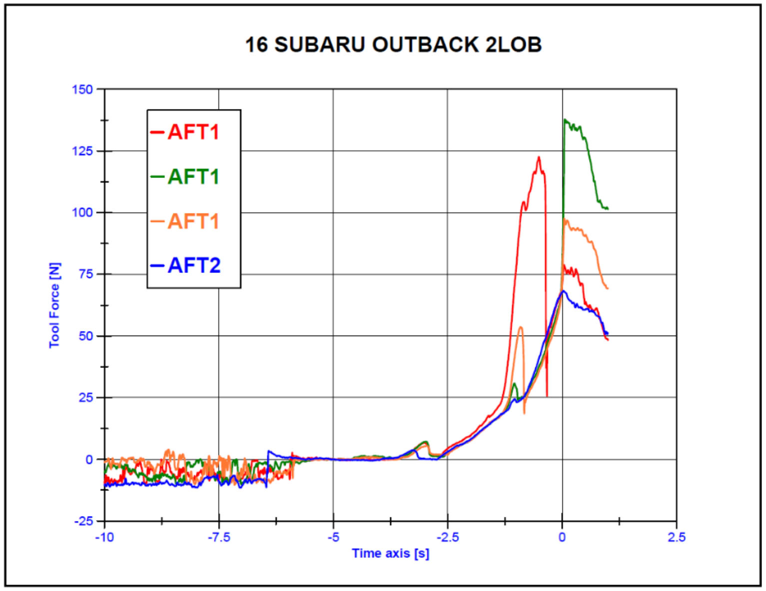
2016 Subaru Outback

VRTC 2018 results									
ADT			AFT				CAT		
mm	toolset	Seat/Anchor	deg	lb (N)	toolset	Seat/Anchor	deg	toolset	Seat/Anchor
-21	V3	2L IB	21.7	6.4 (28.4)	V3	2L IB	55.8	V3	2L IB
-24	V2	2L IB	21.8	4.9 (21.8)	V3	2L IB	57.1	V3	2L IB
-15	V3	2L OB	22.0	5.9 (26.4)	V3	2L IB	57.0	V3	2L IB
-15	V2	2L OB	20.2	9.3 (41.4)	V2	2L IB	56.5	V2	2L IB
-17	V3	2R IB	21.0	17.8 (79.2)	V3	2L OB	52.3	V3	2L OB
-17	V2	2R IB	20.3	15.2 (67.8)	V2	2L OB	53.3	V3	2L OB
-11	V3	2R OB	19.7	11.5 (51.2)	V3	2R IB	52.9	V3	2L OB
-13	V2	2R OB	21.0	9.8 (43.7)	V2	2R IB	53.9	V2	2L OB
			19.5	19.3 (85.9)	V3	2R OB	53.6	V2	2L OB
			20.9	17.3 (76.9)	V2	2R OB	54.2	V2	2L OB
							57.3	V3	2R IB
							58.3	V2	2R IB
							52.8	V3	2R OB
							53.6	V3	2R OB
							53.5	V3	2R OB
							53.3	V2	2R OB
							54.9	V2	2R OB
							55.0	V2	2R OB
			Averages				Averages		
			21.8	5.7 (25.5)	V3	2L IB	52.8	V3	2L OB
							56.6	V3	2L IB
							53.3	V3	2R OB
							53.9	V2	2L OB
							54.4	V2	2R OB
Notes: 2016 Subaru Outback, cloth									


16SUBARU OUTBACK 2RIB
AFT1
AFT2
Tool Force [N]
Time axis [s]
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

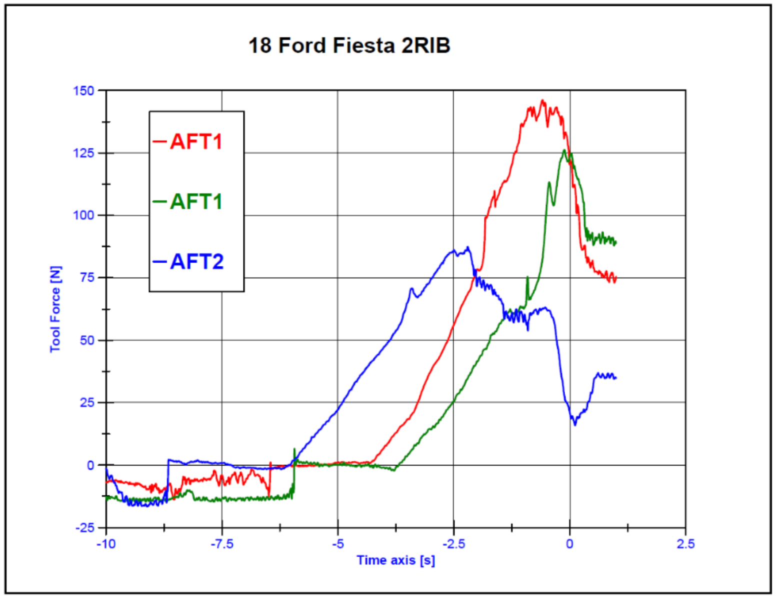

16SUBARU OUTBACK 2ROB
AFT1
AFT1
AFT2
Tool Force [N]
Time axis [s]
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

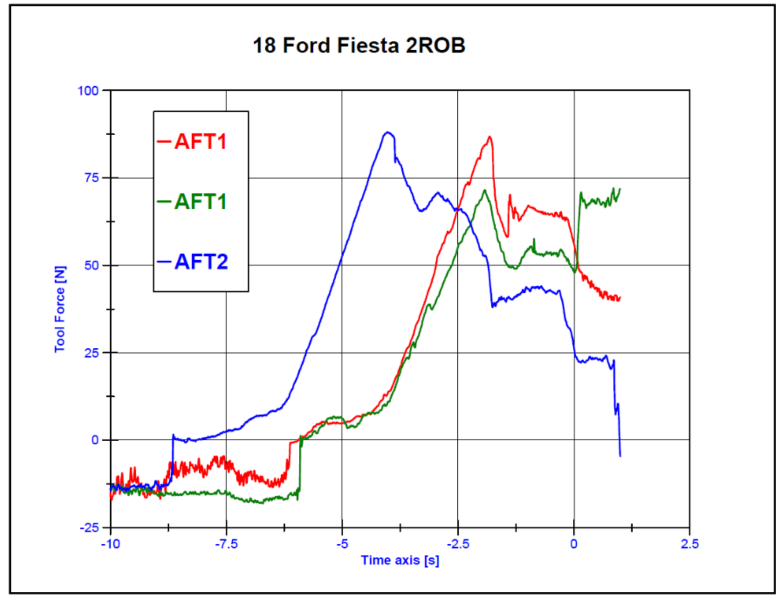

16 SUBARU OUTBACK 2LIB
AFT1
AFT1
AFT1
AFT2
Tool Force [N]
Time axis [s]
150
125
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

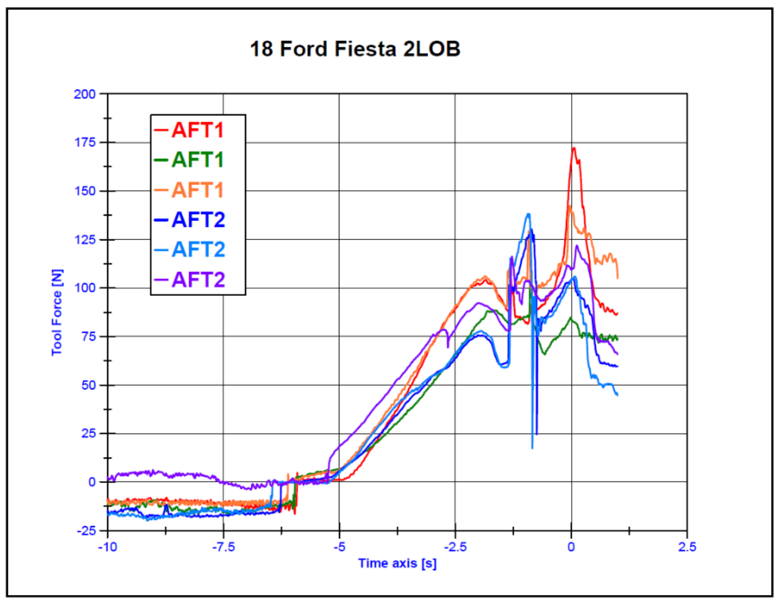

16 SUBARU OUTBACK 2LOB
AFT1
AFT1
AFT1
AFT2
Tool Force [N]
Time axis [s]
150
125
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

2018 Ford Fiesta

VRTC 2018/19 results										
ADT			AFT				CAT			
mm	toolset	Seat/Anchor	deg	lb (N)	toolset	Seat/Anchor	deg	toolset	Seat/Anchor	
37	V3	2L IB	20.9	68.4 (304.1)	V3	2L IB	35.6	V3	2L IB	
30	V2	2L IB	-	-	V2	2L IB	36.0	V2	2L IB	
38	V3	2L OB	20.7	38.8 (172.4)	V3	2L OB	47.1	V3	2L OB	
39	V2	2L OB	20.4	23.6 (104.9)	V3	2L OB	46.6	V2	2L OB	
26	V3	2R IB	20.4	32.0 (142.4)	V3	2L OB	39.9	V3	2R IB	
24	V2	2R IB	20.2	36.2 (160.9)	V2	2L OB	39.8	V2	2R IB	
31	V3	2R OB	20.3	29.3 (130.3)	V2	2L OB	51.6	V3	2R OB	
36	V2	2R OB	20.6	31.1 (138.3)	V2	2L OB	51.6	V2	2R OB	
			20.2	26.9 (119.7)	V2	2L OB				
			20.7	28.4 (126.2)	V3	2R IB				
			20.3	19.7 (87.45)	V2	2R IB				
			19.9	16.2 (72.1)	V3	2R OB				
			20	19.8 (88.2)	V2	2R OB				
			Averages							
			20.5	31.5 (139.9)	V3	2L OB				
			20.3	30.9 (137.3)	V2	2L OB				
Notes: 2018 Ford Fiesta, cloth AFT had difficulty attaching to anchor, tool either pushed back on user or slipped off anchor during test - only valid tests displayed here										

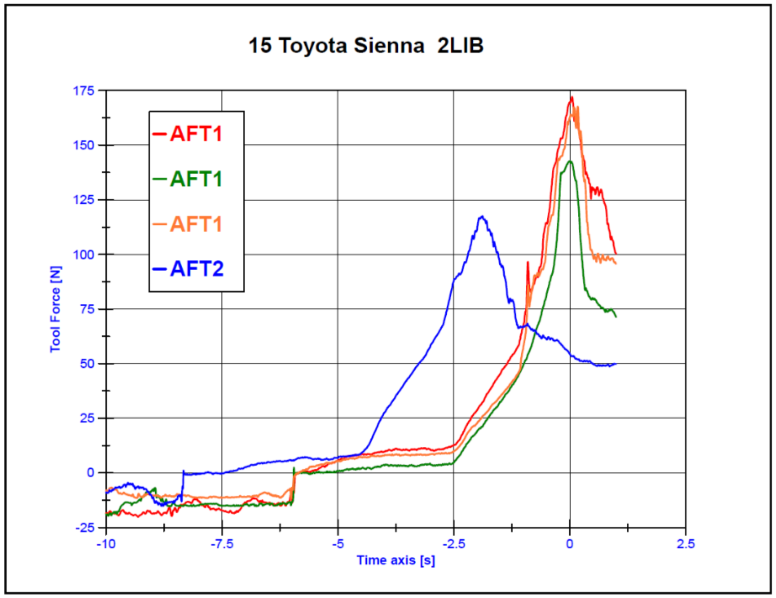

18 Ford Fiesta 2RIB
AFT1
AFT1
AFT2
Tool Force [N]
Time axis [s]
150
125
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

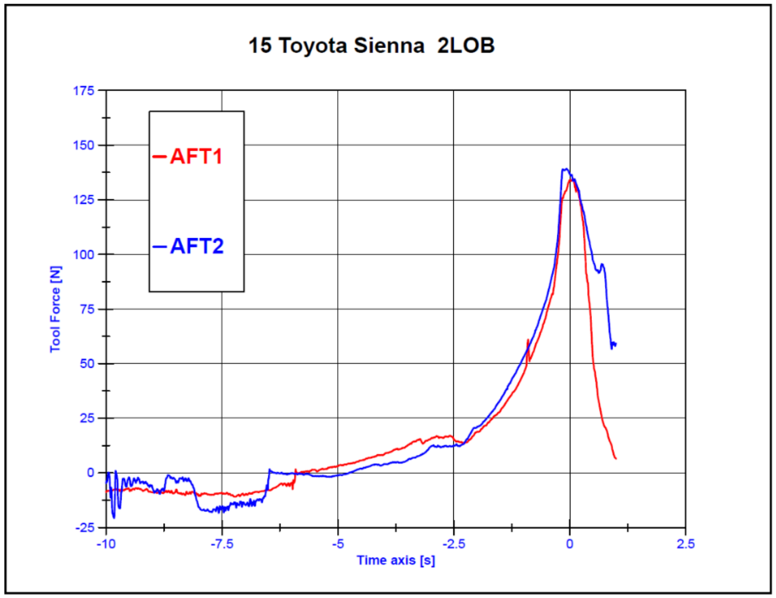

18 Ford Fiesta 2ROB
AFT1
AFT1
AFT2
Tool Force [N]
Time axis [s]
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

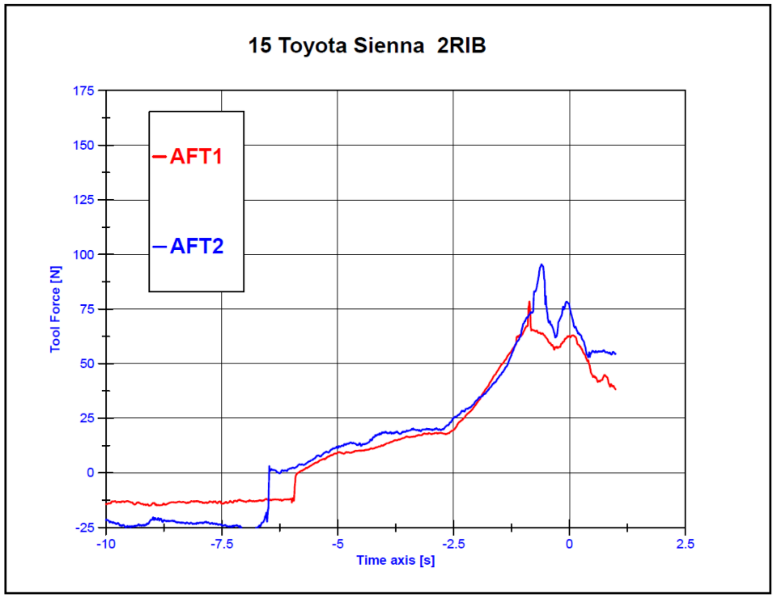

18 Ford Fiesta 2LOB
AFT1
AFT1
AFT1
AFT2
AFT2
AFT2
Tool Force [N]
Time axis [s]
200
175
150
125
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

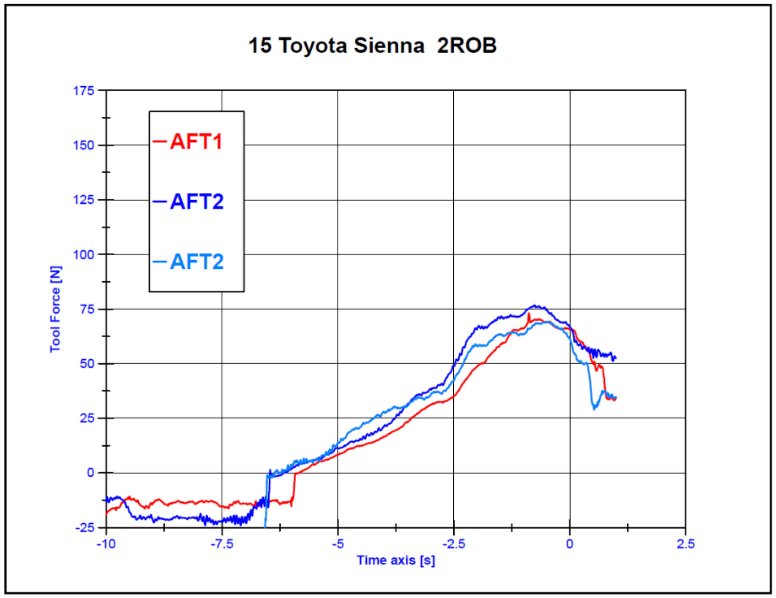
2015 Toyota Sienna

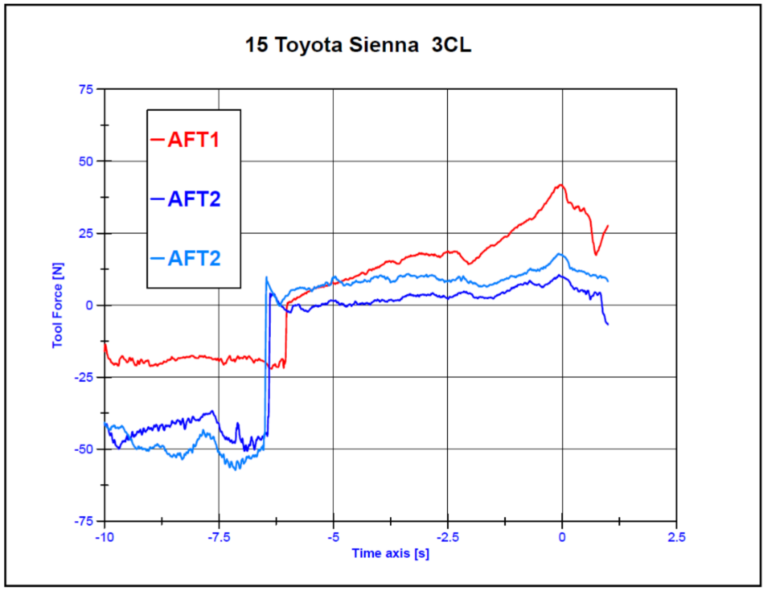
VRTC 2018/19 results									
ADT			AFT				CAT		
mm	toolset	Seat/Anchor	deg	lb (N)	toolset	Seat/Anchor	deg	toolset	Seat/Anchor
8	V3	2L IB	19.7	38.7 (172.2)	V3	2L IB	66.4	V3	2L IB
8	V2	2L IB	20.6	32.1 (142.7)	V3	2L IB	64.9	V2	2L IB
0	V3	2L OB	19.5	36.6 (162.7)	V3	2L IB	67.0	V3	2L OB
3	V2	2L OB	20.6	26.4 (117.6)	V2	2L IB	66.7	V2	2L OB
8	V3	2R 0B	20.3	30.3 (134.6)	V3	2L OB	63.4	V3	2R 0B
8	V2	2R 0B	20.4	31.3 (139.2)	V2	2L OB	61.8	V2	2R 0B
9	V3	2R IB	20.4	16.5 (73.2)	V3	2R OB	63.8	V3	2R IB
9	V2	2R IB	20.8	15.6 (69.2)	V2	2R OB	62.1	V2	2R IB
-10	V3	3CL	20.3	17.7 (78.6)	V3	2R IB	64.5	V3	3CL
-11	V2	3CL	20.7	21.5 (95.5)	V2	2R IB	66.3	V2	3CL
-10	V3	3CR	21.2	9.22 (41.0)	V3	3CL	65.9	V3	3CR
-10	V2	3CR	20.4	4.0 (17.9)	V2	3CL	70.3	V2	3CR
-4	V3	3R IB	21.1	9.7 (43.3)	V3	3CR	51.1	V3	3R IB
-15	V2	3R IB	20.4	6.4 (28.6)	V2	3CR	50.9	V2	3R IB
4	V3	3R OB	19.5	8.9 (39.4)	V3	3R IB	67.1	V3	3R OB
0	V2	3R OB	19.6	10.8 (47.9)	V2	3R IB	66.9	V2	3R OB
			19.9	13.1 (58.1)	V3	3R OB			
			20.1	12.4 (55.2)	V2	3R OB			
			Averages						
			19.9	35.8 (159.2)	V3	2L IB			
Notes: 2015 Toyota Sienna, cloth - seatback at mfg specified angle									

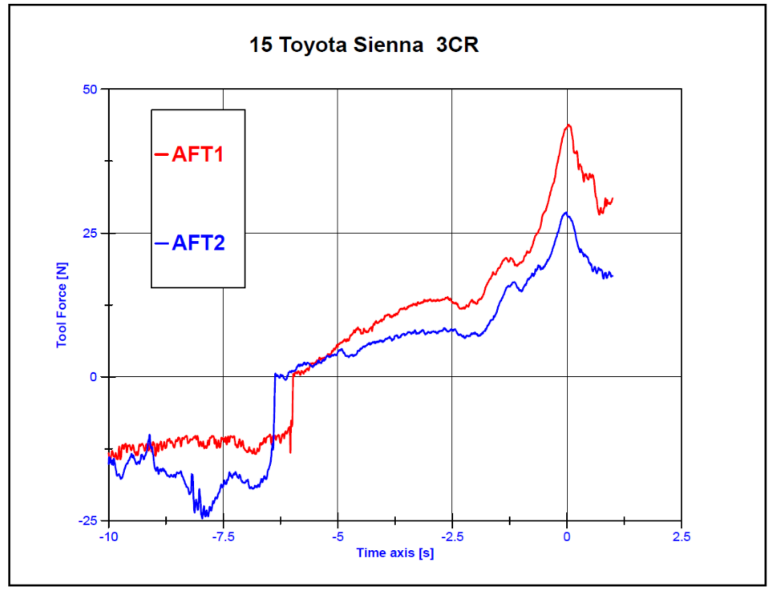

15 Toyota Sienna 2LIB
AFT1
AFT1
AFT1
AFT2
Tool Force [N]
Time axis [s]
175
150
125
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

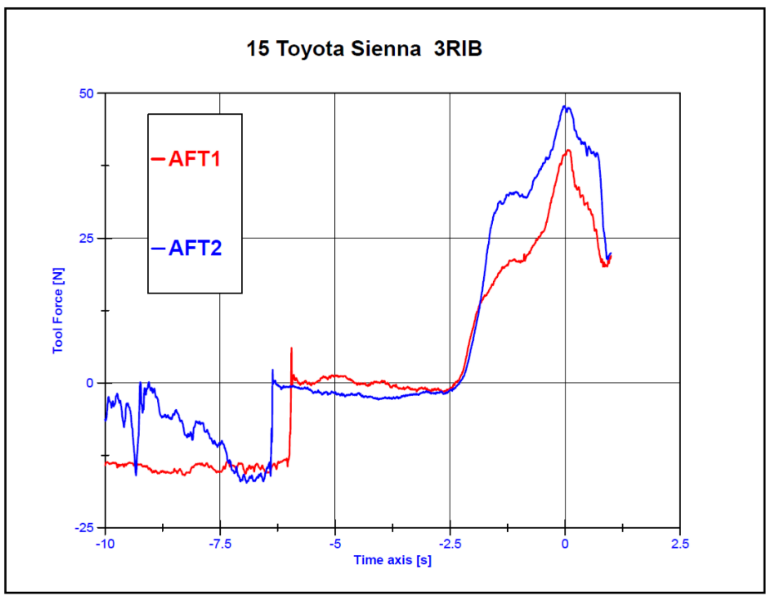

15 Toyota Sienna 2LOB
AFT1
AFT2
Tool Force [N]
Time axis [s]
175
150
125
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

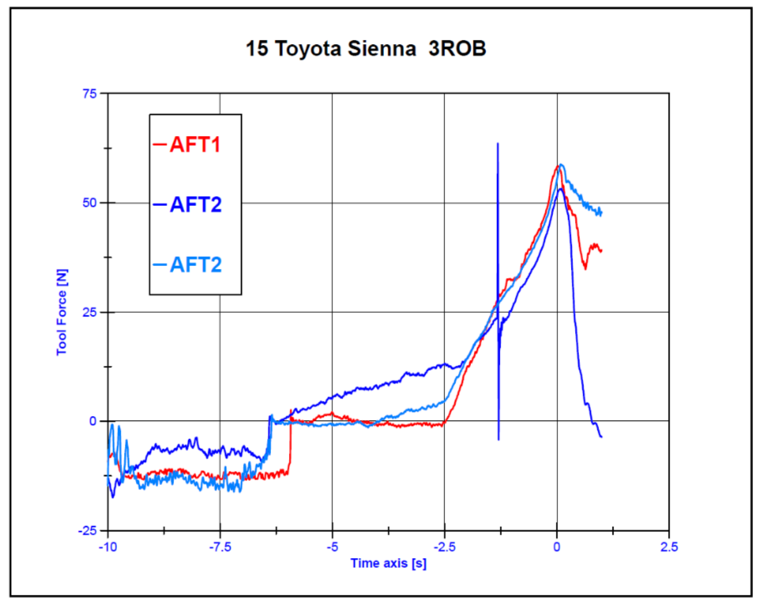

15 Toyota Sienna 2RIB
AFT1
AFT2
Tool Force [N]
Time axis [s]
175
150
125
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5


15 Toyota Sienna 2ROB
AFT1
AFT2
AFT2
Tool Force [N]
Time axis [s]
175
150
125
100
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5


15 Toyota Sienna 3CL
AFT1
AFT2
AFT2
Tool Force [N]
Time axis [s]
75
50
25
0
-25
-50
-75
-10
-7.5
-5
-2.5
0
2.5

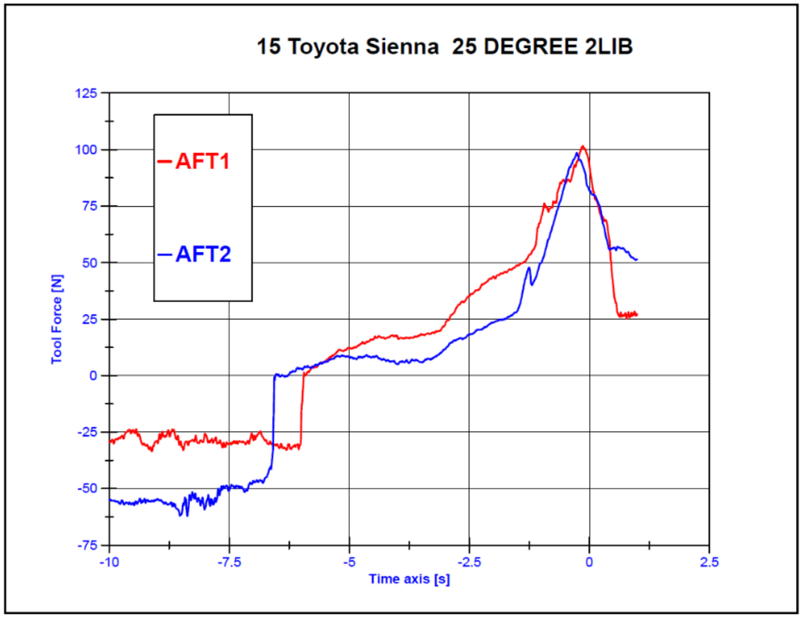

15 Toyota Sienna 3CR
AFT1
AFT2
Tool Force [N]
Time axis [s]
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

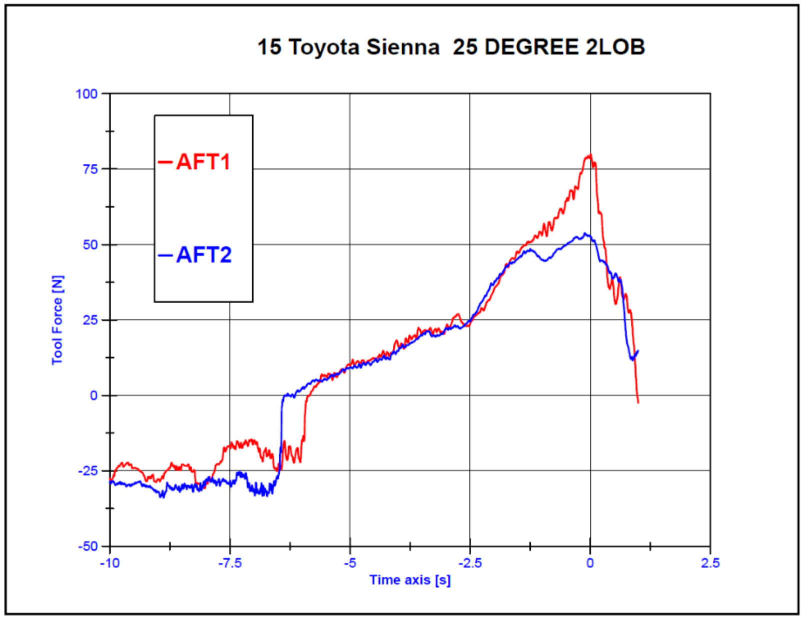

15 Toyota Sienna 3RIB
AFT1
AFT2
Tool Force [N]
Time axis [s]
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

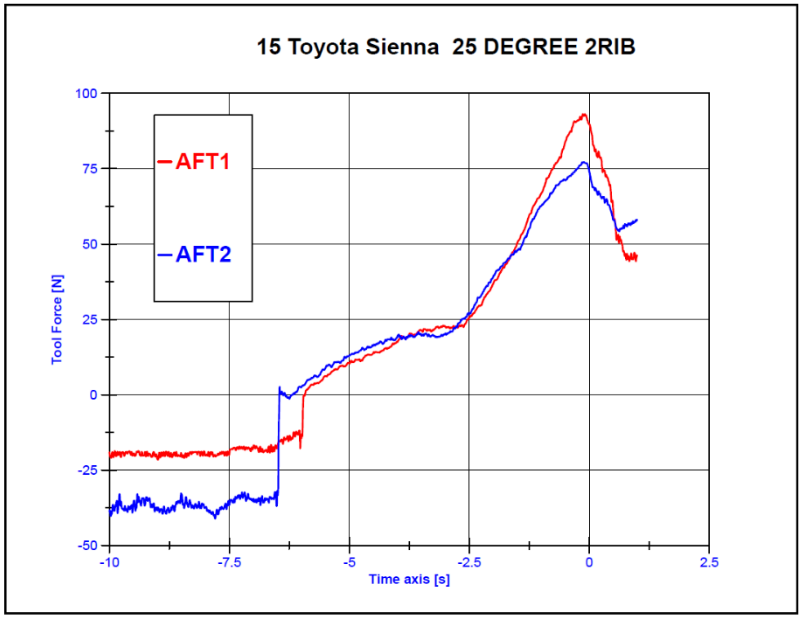

15 Toyota Sienna 3ROB
AFT1
AFT2
AFT2
Tool Force [N]
Time axis [s]
75
50
25
0
-25
-10
-7.5
-5
-2.5
0
2.5

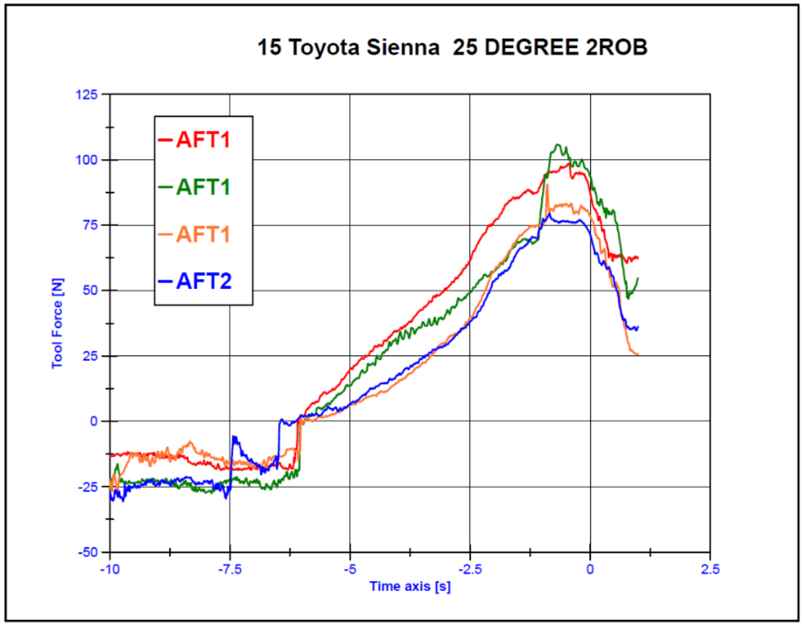
2015 Toyota Sienna – 25 Degree Seatback

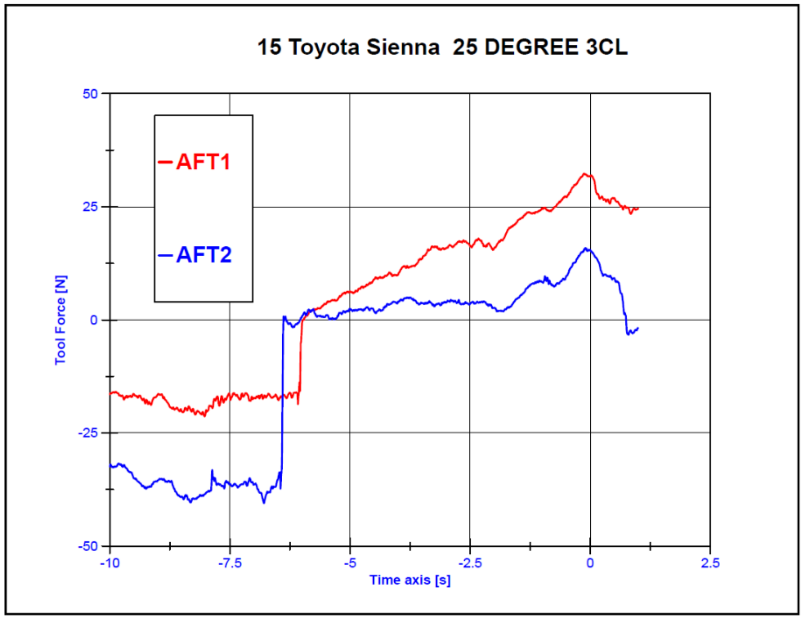
VRTC 2018/19 results									
ADT			AFT				CAT		
mm	toolset	Seat/Anchor	deg	lb (N)	toolset	Seat/Anchor	deg	toolset	Seat/Anchor
15	V3	2L IB	21.4	22.9 (101.9)	V3	2L IB	56.9	V3	2L IB
17	V2	2L IB	20.8	22.2 (98.8)	V2	2L IB	56.0	V2	2L IB
13	V3	2L OB	20.4	18.8 (83.6)	V3	2L OB	56.3	V3	2L OB
9	V2	2L OB	20.6	17.2 (76.5)	V2	2L OB	58.1	V2	2L OB
5	V3	2R 0B	22.0	22.2 (98.8)	V3	2R OB	60.3	V3	2R 0B
5	V2	2R 0B	21.6	23.8 (105.9)	V3	2R OB	58.7	V2	2R 0B
11	V3	2R IB	21.1	20.4 (90.7)	V3	2R OB	60.7	V3	2R IB
12	V2	2R IB	21.1	17.9 (79.6)	V2	2R OB	59.9	V2	2R IB
-5	V3	3CL	21.6	20.9 (93.0)	V3	2R IB	67.6	V3	3CL
-17	V2	3CL	21.2	22.1 (98.3)	V2	2R IB	65.7	V2	3CL
-13	V3	3CR	21.2	7.3 (32.5)	V3	3CL	70.6	V3	3CR
-18	V2	3CR	20.3	3.6 (16.0)	V2	3CL	70.5	V2	3CR
0	V3	3R IB	19.7	7.1 (31.6)	V3	3CR	49.7	V3	3R IB
-2	V2	3R IB	20.4	8.8 (39.1)	V2	3CR	51.5	V2	3R IB
0	V3	3R OB	19.5	7.4 (32.9)	V3	3R IB	67.0	V3	3R OB
0	V2	3R OB	19.9	10.1 (44.9)	V2	3R IB	67.1	V2	3R OB
			20.0	9.1 (40.5)	V3	3R OB			
			20.2	12.2 (54.3)	V2	3R OB			
			Averages						
			21.6	22.1 (98.4)	V3	2R OB			
Notes: 2015 Toyota Sienna, cloth - seatback at 25 degree OSCAR									

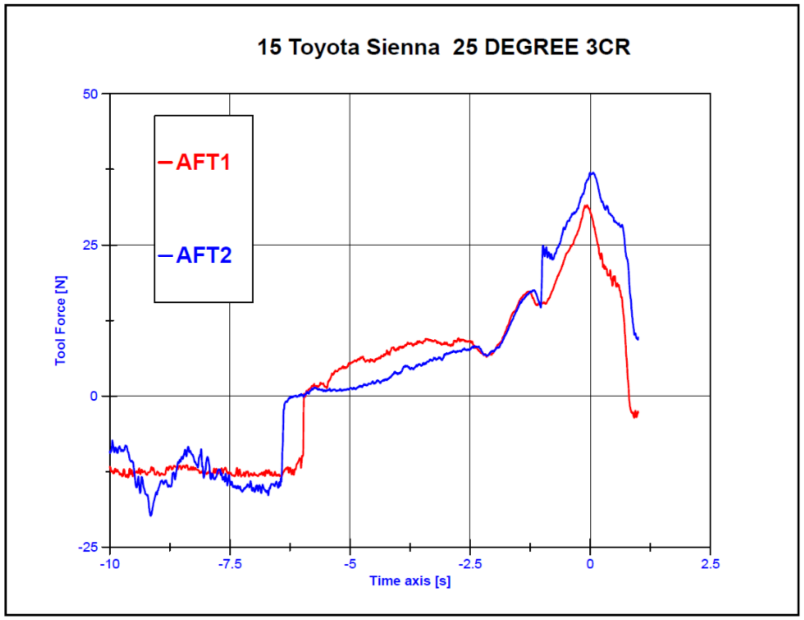

15 Toyota Sienna 25 DEGREE 2LIB
AFT1
AFT2
Tool Force [N]
Time axis [s]
125
100
75
50
25
0
-25
-50
-75
-10
-7.5
-5
-2.5
0
2.5

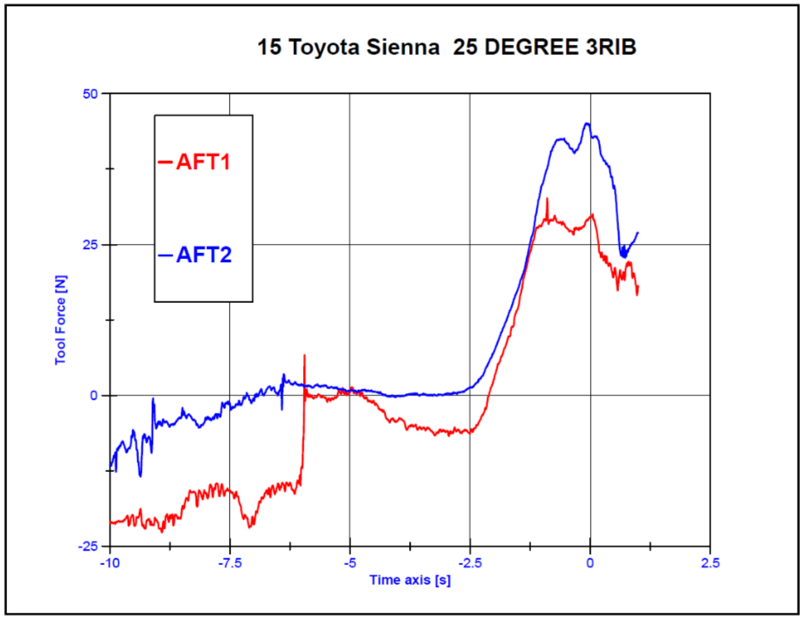

15 Toyota Sienna 25 DEGREE 2LOB
AFT1
AFT2
Tool Force [N]
Time axis [s]
100
75
50
25
0
-25
-50
-10
-7.5
-5
-2.5
0
2.5

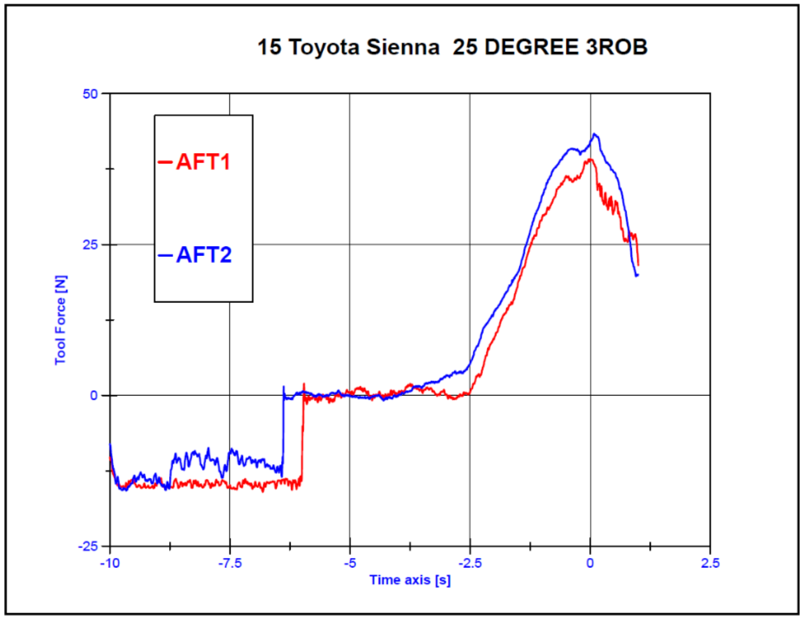

15 Toyota Sienna 25 DEGREE 2RIB
AFT1
AFT2
Tool Force [N]
Time axis [s]
100
75
50
25
0
-25
-50
-10
-7.5
-5
-2.5
0
2.5


15 Toyota Sienna 25 DEGREE 2ROB
AFT1
AFT1
AFT1
AFT2
Tool Force [N]
Time axis [s]
125
100
75
50
25
0
-25
-50
-10
-7.5
-5
-2.5
0
2.5


15 Toyota Sienna 25 DEGREE 3CL
AFT1
AFT2
Tool Force [N]
Time axis [s]


15 Toyota Sienna 25 DEGREE 3CR
AFT1
AFT2
Tool Force [N]
Time axis [s]


15 Toyota Sienna 25 DEGREE 3RIB
AFT1
AFT2
Tool Force [N]
Time axis [s]


15 Toyota Sienna 25 DEGREE 3ROB
AFT1
AFT2
Tool Force [N]
Time axis [s]

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Appendix F: ADT Comparison Data

The table below shows comparisons between the seat pan angles, seat base angles, and the depth measurements in seven vehicles tested with ADT V2 and ADT V3/V4.

The last two vehicles listed in the table, the Cadillac CTS and the Kia Forte, were both selected because of unique waterfall lower anchor attachment locations. Additional tables and plots included in this appendix show the repeat tests conducted on these two vehicles with ADT V2 and ADT V4 in both outboard and inboard locations.

Vehicle	Anchor	Seat Pan Angle	Toolset	Depth (mm)	Base Angle
2014 Jeep Grand Cherokee	2LIB	16	V3	20	12.6
			V2	21	9.6
2016 Nissan Rogue	2LIB	8	V3	10	6.8
			V2	12	5.0
2016 Chevrolet Tahoe	2LIB	10	V3	-5	7.2
			V2	-3	5.1
2013 Subaru Outback	2LIB	13	V3	-21	10.5
			V2	-24	7.3
2015 Toyota Sienna	2LIB	17	V3	15	17.6
			V2	17	16.1
	3RIB	13	V3	0	15.3
			V2	-2	11.8
	3CR	15	V3	-13	14.7
			V2	-18	12.7
2011 Cadillac CTS	2RIB	17	V4	-9	5.0
			V4	-7	17.0
			V2	4	-5.0
2010 Kia Forte	2RIB	15	V4	0	5.0
			V4	-	15.0
			V2	1	-4.1

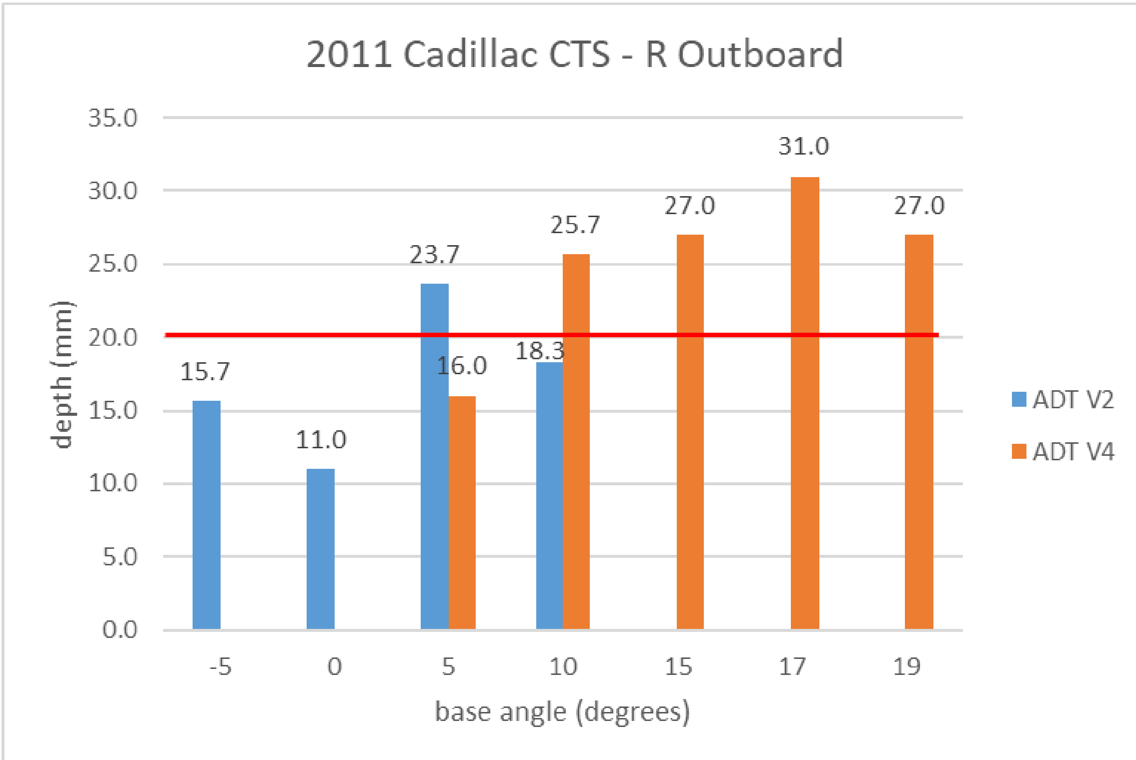
2011 Cadillac CTS

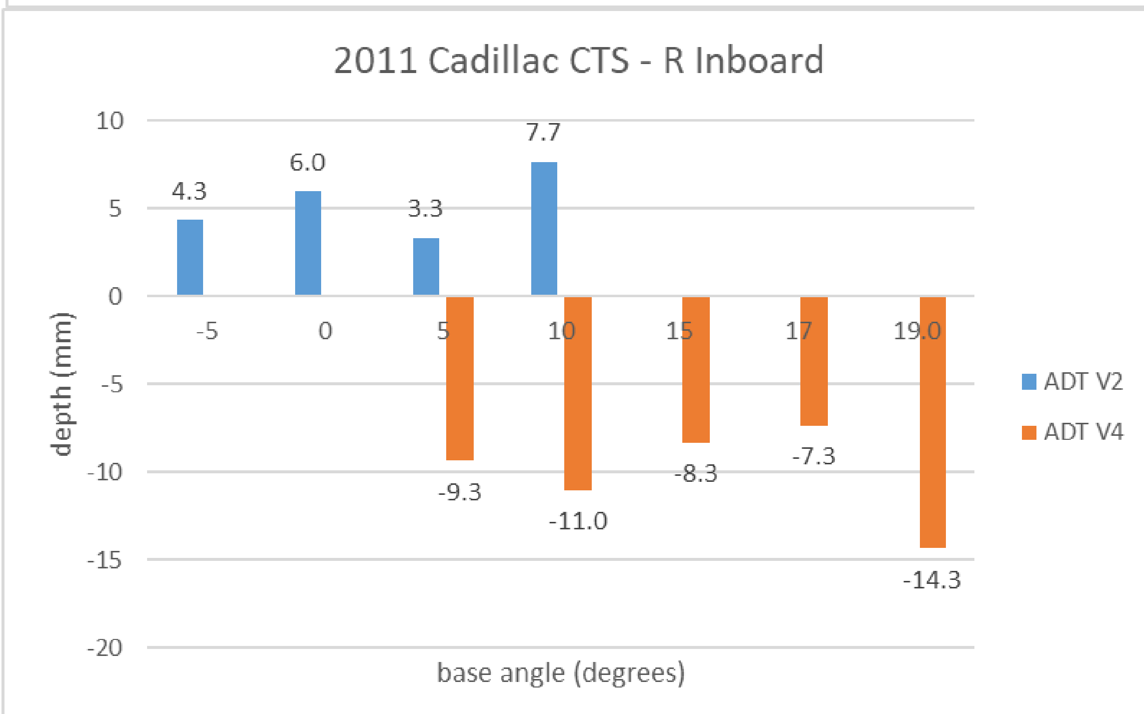
ADT V2

-5 deg	R Outboard		R Inboard	
repeat	mm	deg	mm	deg
1	15	-5	3	-5
2	16	-5	5	-5
3	16	-5	5	-5
avg	**15.7**	**-5**	**4.3**	**-5**
0 deg	R Outboard		R Inboard	
repeat	mm	deg	mm	deg
1	11	0	7	0
2	11	0	6	0
3	11	0	5	0
avg	**11.0**	**0**	**6.0**	**0**
5 deg	R Outboard		R Inboard	
repeat	mm	deg	mm	deg
1	24	5	1	5
2	24	5	4	5
3	23	5	5	5
avg	**23.7**	**5**	**3.3**	**5**
10 deg	R Outboard		R Inboard	
repeat	mm	deg	mm	deg
1	18	10	11	10
2	17	10	8	10
3	20	10	4	10
avg	**18.3**	**10**	**7.7**	**10**

ADT V4

-5 deg	R Outboard		R Inboard	
repeat	mm	deg	mm	deg
1				
2				
3				
avg				
0 deg	R Outboard		R Inboard	
repeat	mm	deg	mm	deg
1				
2				
3				
avg				
5 deg	R Outboard		R Inboard	
repeat	mm	deg	mm	deg
1	15	5	-9	5
2	17	5	-8	5
3	16	5	-11	5
avg	**16.0**	**5**	**-9.3**	**5**
10 deg	R Outboard		R Inboard	
repeat	mm	deg	mm	deg
1	26	10	-10	10
2	26	10	-11	10
3	25	10	-12	10
avg	**25.7**	**10**	**-11.0**	**10**
15 deg	R Outboard		R Inboard	
repeat	mm	deg	mm	deg
1	23	15	-11	15
2	30	15	-6	15
3	28	15	-8	15
avg	**27.0**	**15**	**-8.3**	**15**
17 deg	R Outboard		R Inboard	
repeat	mm	deg	mm	deg
1	28	17	-7	17
2	34	17	-7	17
3	31	17	-8	17
avg	**31.0**	**17**	**-7.3**	**17**
19 deg	R Outboard		R Inboard	
repeat	mm	deg	mm	deg
1	26	19	-17	19
2	29	19	-15	19
3	26	19	-11	19
avg	**27.0**	**19**	**-14.3**	**19.0**


2011 Cadillac CTS - R Outboard
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
depth (mm)
15.7
11.0
23.7
16.0
18.3
25.7
27.0
31.0
27.0
-5
0
5
10
15
17
19
base angle (degrees)
ADT V2
ADT V4


2011 Cadillac CTS - R Inboard
10
5
0
-5
-10
-15
-20
depth (mm)
4.3
6.0
3.3
7.7
-9.3
-11.0
-8.3
-7.3
-14.3
-5
0
5
10
15
17
19.0
base angle (degrees)
ADT V2
ADT V4

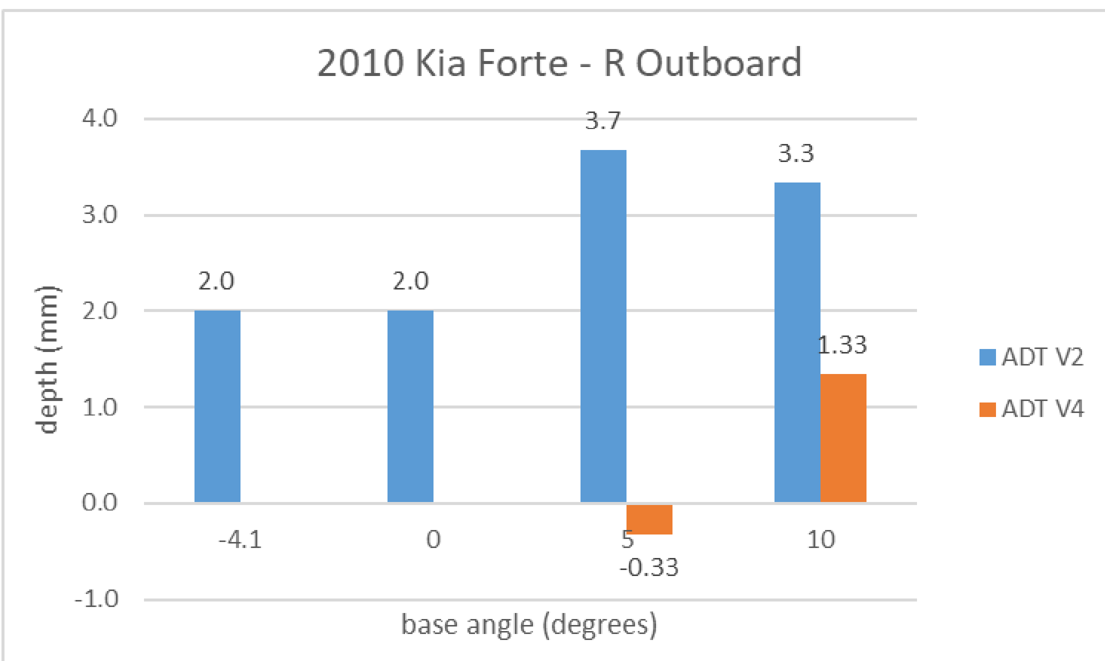
2010 Kia Forte

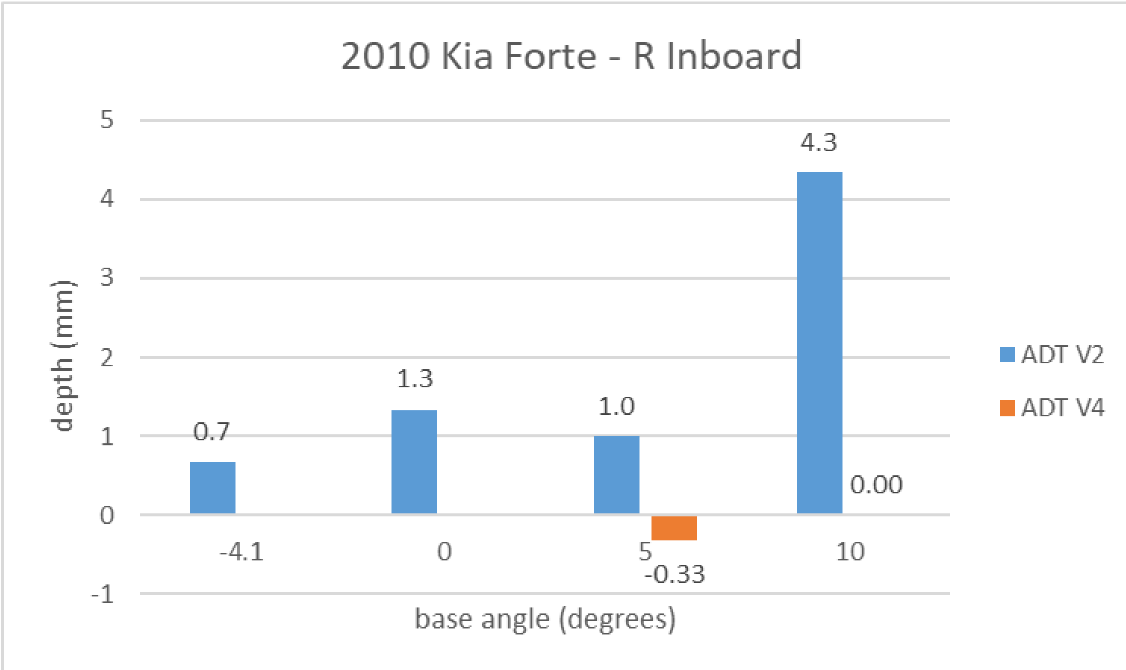
ADT V2

-4.1 deg repeat	R Outboard mm	R Outboard deg	R Inboard mm	R Inboard deg
1	2	-4.1	1	-4.1
2	2	-4.1	1	-4.1
3	2	-4.1	0	-4.1
avg	**2.0**	**-4.1**	**0.7**	**-4.1**
0 deg repeat	R Outboard mm	R Outboard deg	R Inboard mm	R Inboard deg
1	-4	0	1	0
2	5	0	2	0
3	5	0	1	0
avg	**2.0**	**0**	**1.3**	**0**
5 deg repeat	R Outboard mm	R Outboard deg	R Inboard mm	R Inboard deg
1	5	5	0	5
2	3	5	2	5
3	3	5	1	5
avg	**3.7**	**5**	**1.0**	**5**
10 deg repeat	R Outboard mm	R Outboard deg	R Inboard mm	R Inboard deg
1	4	10	2	10
2	3	10	5	10
3	3	10	6	10
avg	**3.3**	**10**	**4.3**	**10**

ADT V4

-4.1 deg repeat	R Outboard mm	R Outboard deg	R Inboard mm	R Inboard deg
1				
2				
3				
avg				
0 deg repeat	R Outboard mm	R Outboard deg	R Inboard mm	R Inboard deg
1				
2				
3				
avg				
5 deg repeat	R Outboard mm	R Outboard deg	R Inboard mm	R Inboard deg
1	-1	5	0	5
2	0	5	0	5
3	0	5	-1	5
avg	**-0.33**	**5**	**-0.33**	**5**
10 deg repeat	R Outboard mm	R Outboard deg	R Inboard mm	R Inboard deg
1	2	10	1	10
2	1	10	-1	10
3	1	10	0	10
avg	**1.33**	**10**	**0.00**	**10**




2010 Kia Forte - R Inboard
depth (mm)
5
4
3
2
1
0
-1
0.7
1.3
1.0
4.3
0.00
-0.33
-4.1
0
5
10
base angle (degrees)
ADT V2
ADT V4

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