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Evaluation of Allison Transmission FuelSense®2.0 with DynActive® Shifting for Improved Fuel Economy

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ABSTRACT

Most military wheeled vehicles operate with a simplistic table-based transmission shift strategy. However, Allison Transmission Inc has created an innovative algorithm-based transmission shift strategy known as FuelSense®2.0 with DynActive® Shifting which optimizes gear selection by accounting for driver demand and vehicle load. This method of shifting has the potential to significantly improve fuel economy while only minimally degrading vehicle performance. In this study, FuelSense®2.0 with DynActive® Shifting was evaluated across three platforms which included the Family of Medium Tactical Vehicles (FMTV), and the Heavy Tactical Vehicles (HTV) Heavy Expanded Mobility Tactical Truck (HEMTT) and Palletized Loading System (PLS). The trucks were drive-cycle tested using both an environmentally controlled dynamometer laboratory and a real-world proving ground user trial.

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1. INTRODUCTION

Setting a major priority for the Army, Congress approved significant funding for research programs to deliver on Demand Reduction (DR) across a wide range of military systems and logistics. A specific area of keen interest regarding DR efforts is reducing the Army's demand for fuel consumption. This single aspect provides multiple benefits such as increased mission range, lower greenhouse gas (GHG) emissions, and alleviates battlefield supply chains.

While military vehicles are known for their extreme automotive requirements in areas such as mobility, performance, and durability, they usually don't accomplish their mission very efficiently. For decades, vehicle performance specifications (PSPECs) have been written to ensure compliance against the outer boundaries of operation such as vehicle top speed, acceleration, maximum sustained hill climb,

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DISTRIBUTION STATEMENT A. Approved for public release; distribution Is unlimited. OPSEC#8400 and peak tractive effort over a range of ambient temperatures of up to 120°F and down to -60°F[1]. However, time spent operating at these boundary conditions is often only a fraction of the vehicle's Operational Mode Summary / Mission Profile (OMS/MP) throughout its lifecycle.

While operating at these severe requirements is critical, focus on these areas have often neglected optimization of part load conditions. Because of this, valid trade space exists to employ improved control strategies for better management of the vehicle's engine, transmission, cooling system, and other powertrain components. Allison Transmission Inc has a portfolio of control functions, wholistically called FuelSense®2.0, available to optimize different load conditions. One such control strategy is DynActive® Shifting which utilizes an algorithmic-based logic to select the most desirable transmission gear to keep the engine at peak efficiency based on driver demand and vehicle load.

As part of a Cooperative Research and Development Agreement (CRADA)[2] with Allison, FuelSense®2.0 with DynActive® Shifting was evaluated to determine improvements to fuel economy on three different platforms which included FMTV, HEMTT, and PLS over various mission weights such as vehicle curb weight (VCW), gross vehicle weight (GVW), and gross combined weight (GCW). The evaluation started with a user trial at the Keweenaw Research Center (KRC) in Houghton, MI with the primary focus of capturing driver feedback on vehicle response and performance. During this testing period, estimated improvement in fuel economy was also measured through data collected from the vehicle controller area network (CAN) bus. After completion of the user trial, further testing was conducted in environmentally controlled dynamometer laboratories at both Allison's Vehicle Electrification + Environmental Test center and the Army's Power Energy Vehicle Environmental Laboratory (PEVEL) to judge the fuel economy improvements during drive cycle testing and the impact to vehicle acceleration.

Due to the extensive data collected throughout this study over FMTV, HEMTT, and PLS, this paper introduces the test methodology for all three vehicles, but focuses on HEMTT test results. Fuel economy testing on a chassis dynamometer conducted on the PLS showed very similar trends and improvements as seen on HEMTT. However, this was not the case for FMTV. Ultimately, the fuel economy chassis dynamometer testing for FMTV was inconclusive and further evaluation is warranted to definitively characterize the impact of DynActive® Shifting on FMTV.

2. THEORY OF OPERATION

Initially released about 10 years ago, DynActive® Shifting has been deployed by Allison in thousands of commercial vehicles such as line haul trucks, transit buses, refuse haulers, gravel trains, and other heavy-duty applications. In these vocational scenarios, this Commercial Off The Shelf (COTS) software advertises savings up to 6%[3] in fuel economy.

The fuel savings from DynActive® Shifting comes from the fact that it is an algorithmic-based control logic. Presently, military vehicles are shifting according to tables programmed into the transmission control module (TCM) of accelerator pedal and transmission output speed. DynActive® Shifting takes several additional factors into account such as driver demand, engine load, and available engine torque, which is established via a defined engine curve saved on the TCM. DynActive® Shifting is constantly calculating if the engine has enough available torque to upshift the transmission gear while still meeting the driver's demanded torque. A transmission upshift would result in the engine operating at a lower speed and thus a more efficient operating point, which normally results in a more efficient use of fuel. Depending on the vehicle's accessory control strategy (cooling fan, environmental systems, battery charging systems), operating the engine at a lower speed may also decrease accessory loads which can be another avenue for fuel savings.

A specific scenario where DynActive® Shifting can really offer significant benefit is in convoy resupply missions. Often, these involve driving at low speeds (20-40 MPH) for several hours at a time. In this condition, DynActive® Shifting usually selects a higher transmission gear than table-based shifting which lowers the engine speed by 200-300 RPM, allowing the engine to operate at a more efficient point. Since this type of driving is typically at a constant speed, the driver realizes virtually no change in vehicle performance while saving fuel.

During periods of heavy acceleration or dynamic changes in vehicle speed or road grade, DynActive® Shifting may cause some drivers to sense lagging in the vehicle's responsiveness. This is because DynActive® Shifting attempts to maintain the most efficient engine speed-to-transmission gear configuration possible and a transition from efficiency to performance focus often requires a gear shift or engine spool up period.

To achieve a balance between vehicle performance and fuel savings, DynActive® Shifting is adjustable by setting what is known as the "bias levels". These programmable features with a range of 0-100% where higher bias levels offer more fuel savings and lower bias levels improve vehicle performance. DynActive® Shifting can also be balanced with other TCM features to maximize vehicle performance in specific operating maneuvers.

Since DynActive® Shifting is a COTS software, it can easily be enabled through a TCM reflash. One limitation is the feature is only available on Gen V TCMs and newer. Currently, the Army does operate vehicles with Gen IV TCMs and older. Only FMTVs, HEMTTs, and PLSs with Gen V TCMs would be potential candidates for this update.

Testing of DynActive® Shifting on multiple platforms, highlighted the advantages of combining DynActive® Shifting with other fuel saving endeavors such as optimizing the cooling fan control strategy. During testing of the PLS with DynActive® Shifting, the increased frequency of the system upshifting into a higher gear, also reduced the parasitic losses from the cooling fan to a greater degree than was seen with the HEMTT platform. This was due to the PLS hydraulic cooling fan system being designed to increase fan speed as engine speed increased, whereas the HEMTT's hydraulic cooling fan operates at 3 standard speeds regardless of engine RPM.

3. DRIVER PERSPECTIVE FROM USER TRIAL

Evaluation of DynActive® Shifting began with a user trial on FMTV, HEMTT, and PLS at KRC in Houghton, MI. The primary purpose of this testing was to expose drivers of various levels of experience to DynActive® Shifting in back-to-back comparisons against table-based shifting. Each of these vehicles were driven at VCW, GVW, and GCW over a range of bias levels. Multiple drivers experienced the change in transmission shifting by repeating three laps on two different road courses. Using "on-road" courses at KRC, the vehicles were able to reach speeds of 60 MPH, though usage of this course was limited. Mileage was also accumulated on "off-road" courses roads at KRC, however speeds on these courses were limited to around 40 MPH. Both courses had average speeds of about 25 MPH.

At the end of each comparison test, drivers were given a survey to capture their feedback between the performance of table-based shifting versus DynActive® Shifting. They answered multiple questions describing their experience and rated the categories from “No Change” to “Unacceptable Change”. As a general trend, all the drivers noticed a decrease in responsiveness of the vehicle as bias level severity increased. This was an anticipated outcome as most methods of improving fuel economy often degrade vehicle performance. Below, the aggregated survey results from the HEMTT are shown in *Figure 1.*

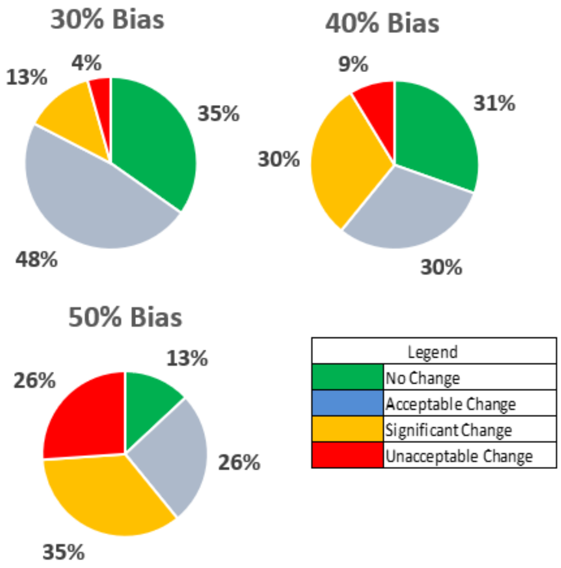

Figure 1: Survey Results from HEMTT

Although the surveys were a qualitative evaluation, it did give an important perspective as to the sensation felt by the driver. In addition to the survey, response of the vehicle was also judged quantitatively with metrics such as course average speed, course max speed, and lap time. From reviewing these parameters, it was difficult to judge any significant change in the vehicle’s performance from table-base shifting to DynActive® Shifting. Better correlations between the qualitative and quantitative evaluations were expected.

To investigate the correlation results further, maps of the driver’s accelerator pedal position were built. Each map separated the range of pedal position in 10% bins. This revealed a general trend that drivers were spending more time in the range 90-100% pedal position when operating with a DynActive® Shifting enabled vehicle. *Figure 2* displays a map for one of the HEMTT drivers during testing on the KRC road course. Even though the drivers were obtaining similar course speed and lap time, they were using a higher pedal position to get there.

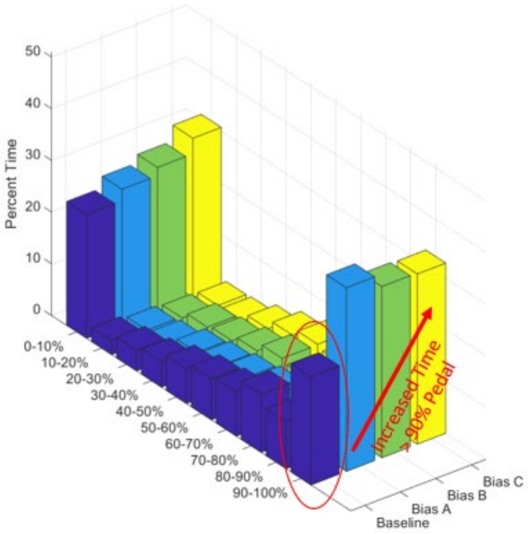

Figure 2: Map of Accelerator Pedal Position

One interpretation of this data could indicate that the negative feedback from the driver surveys resides in the extended time at higher pedal positions. This was the driver’s way to compensate for the decreased responsiveness of the vehicle. Ultimately, this seemed effective as there was no major penalty measured in vehicle speed and lap time. However, the sensation and perception were still identifiable to the driver.

While conducting the user trial, data was also recorded from the vehicle’s CAN bus. One of the available parameters was the engine’s fueling rate. This channel is calculated by the engine control module (ECM) based on the engine speed and load. Although this is a calculated quantity, it is valid for relative comparisons against itself. Since the nature of this test is an evaluation of table-base shifting versus DynActive® Shifting, this CAN channel provided a reliable estimation to judge a change in fuel economy. As seen in *Table 1*, all three test vehicles indicated an improvement in fuel economy with HEMTT showing the largest gains.

	Bias A	Bias B	Bias C
FMTV	3.0%	2.0%	2.2%
HEMTT	7.9%	9.9%	11.2%
PLS	6.9%	5.1%	5.8%

Table 1: Fuel Economy Improvement at GVW

4. FUEL ECONOMY AND ACCELERATION ON CHASSIS DYNAMOMETER

While the user trial at KRC provided valuable insight to the driver's experience of DynActive® Shifting, additional testing was needed in a repeatable, controlled environment to properly characterize potential fuel economy improvement. Also, results were needed to determine the impact of DynActive® Shifting on vehicle acceleration. To satisfy these goals, the HEMTT was tested on a chassis dynamometer (*Figure 3*) in an environmentally controlled chamber at the US Army's Power Energy Vehicle Environmental Laboratory (PEVEL).

Figure 3: US Army PEVEL

For relevance to the HEMTT's OMS/MP, drive cycles were developed using data from courses at Aberdeen Proving Ground. Specifically, the Munson Test Area (MTA) Fuel Economy Loop (4.8 miles) and Churchville C (2.3 miles) were selected. Aside from one steep hill, Munson Fuel Economy Course is a relatively flat gravel road course. In contrast, Churchville C has grade varying ±10%. Both of these courses were operated as grade vs distance when applied by the dynamometer.

Testing for the HEMTT at PEVEL included all three vehicle weights (VCW, GVW, GCW). To judge the impact of ambient temperature on DynActive® Shifting, testing was completed at an ambient temperature of 80°F and repeated at 120°F. Speed control of the vehicle was handled by a proportional integral derivative (PID) control loop by the dynamometer.

The HEMTT and PLS vehicles currently use the same calibrated TCM but have different peak engine power ratings (500 hp in the HEMTT vs 600 hp in the PLS). The intent was to maintain this strategy with the implementation of DynActive® Shifting. Although a TCM can store two shift strategies, the TCM can only store one defined engine curve, which is required for the implementation of DynActive® Shifting. Testing initially utilized different defined torque curves (500 hp and 600 hp) specific to each vehicle. This was accomplished by using a vehicle specific TCM, which is the Allison recommended strategy. To test the results of using a single defined engine curve, and return to a shared single TCM, two of the HEMTT biases (0% & 50%) were programmed according to the 600 hp engine torque curve (PLS powerpack configuration) instead of the 500 hp engine curve which matched the HEMTT's engine performance. This vehicle configuration was then tested in the same manner as the vehicle specific TCM's. It should be noted, the defined engine curve in the TCM had no bearing on the engine calibration in the ECM.

Much of the content in this section are excerpts from the *GPMH23025 – HEMTT Mobility Performance and FuelSense®2.0*[4] test report. This report provides an in-depth view of all aspects of the chassis dynamometer test. A similar report[5] for the PLS also exists which details the chassis dynamometer test. Due to the Controlled Unclassified Information (CUI) nature of these test reports, they are only available through special approval.

4.1. ACCELERATION

Based on the theory of operation, DynActive® Shifting improves fuel economy with increased bias levels, but the fuel economy or performance effects of changing the engine torque curve were not fully defined.

To better understand the effect of changing the bias level and the engine torque curve, performance testing was conducted using a configuration matrix. This matrix would vary one of the following parameters, while maintaining the other two: DynActive® Shifting bias level; TCM defined engine torque curve; and test cell ambient temperature (80°F or 120°F).

The results from the testing give a clearer picture of the individual performance impact of the DynActive bias severity level and defined engine torque curve on vehicle acceleration. Throughout the testing, table-based shifting maintained the best acceleration performance. However, the 0% bias with the 600 hp (PLS specific) defined engine torque curve was very close in matching the table-based performance. In general, the biases with a lower severity level had better acceleration while the calibrations with the 600 hp (PLS specific) defined engine torque curve performed better than the HEMTT specific (500 hp) engine torque curve. Both were expected trends based on the theory of operation for DynActive® Shifting. *Figure 4* (80°F) and *Figure 5* (120°F) give the percentage time increase for vehicle acceleration to 60 MPH for each bias calibration. Each bar in *Figure 4* and *Figure 5* represents the average results of all three weight configuration (VCW, GVW, and GCW).

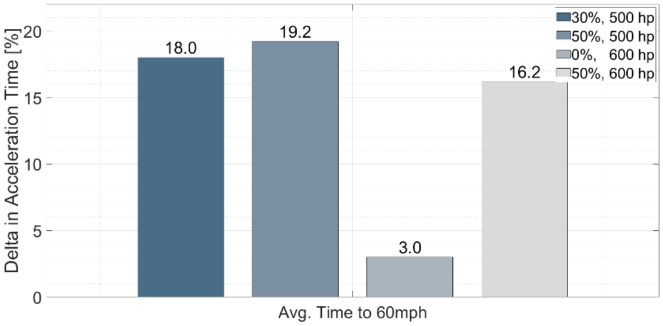

Figure 4: % Change in Acceleration Time at 80°F

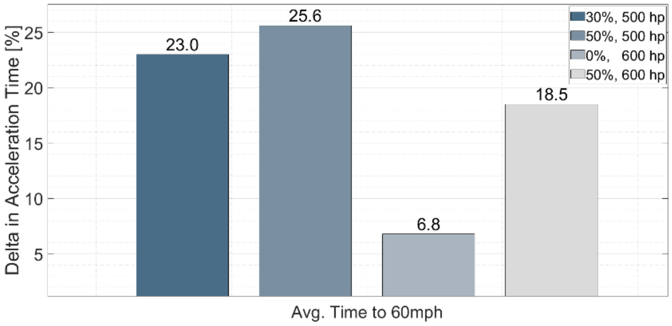

Figure 5: % Change in Acceleration Time at 120°F

4.2. DRIVE CYCLE FUEL ECONOMY

According to the theory of operation for DynActive® Shifting, the calibration expected to improve fuel economy the most was the 50% bias with the 500 hp (HEMTT specific) defined engine torque curve. Conversely, the 0% bias with the 600 hp (PLS specific) defined engine torque curve was expected to provide the lowest fuel savings. As a general trend, this was observed throughout all the road course testing.

4.2.1 Munson Fuel Economy Loop

The Munson Test Area (MTA) Fuel Economy Loop used for this test was 4.85 miles long. While most of the course does not change grade significantly, it did contain a steep grade of almost 30%. At the request of the customer, the hill grade was reduced to 10% to ensure that even at the heaviest vehicle configuration, the HEMTT would be able to complete the course without use of low gear in the transfer case. As a representative vehicle velocity trace was not available, the HEMTT was driven at a constant speed using three different speed limits, 20 MPH, 40 MPH, and 50 MPH. While this provided a consistent method to evaluate the performance of DynActive® Shifting, it didn't replicate the natural speed variation due to coasting, braking, and steering when negotiating the course's curves. When categorizing this type of driving, this most closely represents a line haul mission in convoy where vehicle speed is relatively constant, but with variations in the terrain grade.

When testing the MTA Fuel Economy course at 80°F, the supermajority of the fuel savings came from runs made at the 20 MPH speed limit which posted almost a 25% reduction in fuel. For all four of the DynActive® Shifting biases, the transmission was able to achieve a higher gear and maintain that gear throughout the course. This provides an example where DynActive® Shifting can save fuel consumption in a steady-state driving scenario in addition to transient variation in vehicle speed and load. Fuel savings at 40 MPH and 50 MPH were usually between 0.5% to 3%. However, the 0% bias with 600 hp defined engine torque curve did register an increase in fuel consumption at -1.3% and -0.2% for 40 MPH and 50 MPH respectively. All the test results for 20 MPH, 40 MPH, and 50 MPH are averaged together and presented in *Table 2* for each of the biases. Fuel savings for 30% 500 hp defined engine torque curve, 50% 500 hp defined engine torque curve, and 50% 600 hp defined engine torque curve were almost identical. Although not far behind, 0% 600 hp defined engine torque curve posted the lowest fuel savings.

	500 hp		**600 hp**	
	30%	**50%**	**0%**	**50%**
VCW	8.4%	8.2%	6.8%	8.9%
GVW	11.4%	11.5%	9.9%	11.6%
GCW	11.3%	11.5%	9.5%	10.9%
Average	**10.4%**	**10.4%**	**8.7%**	**10.5%**

Table 2: Combined Fuel Savings on Munson

4.2.2 Churchville C

In comparison to the MTA Fuel Economy loop, the grade profile of Churchville C varies much more significantly in the severity of positive and negatives slopes. A representative vehicle velocity trace was available based on Heavy Equipment Transporter (HET) Churchville C data and adapted to the vehicle being tested. This provided a dynamic change in vehicle speed due to negotiation of course curves and stopping at intersections. Each lap of Churchville C was 2.3 miles with grades of -10% to +10%. To provide evaluation of DynActive® Shifting over a range of driving conditions, the vehicle velocity trace was scaled to a "moderate pace" with a maximum speed of about 35 MPH and an "aggressive pace" with a maximum speed of about 45 MPH. This course provides a picture of potential fuel savings where both speed and grade variation are present.

Testing of Churchville C was performed at both 80°F and 120°F for VCW, GVW, and GCW. Across both ambient temperatures, two different driving styles (e.g. moderate, aggressive), and all three vehicle weight configurations, the fuel savings was relatively consistent. VCW benefited the most (5.9% to 8.9%) from all the DynActive® Shifting biases and GCW benefited the least (2.8% to 5.8%). In general, fuel savings at 80°F tended to be slightly higher than those measured at 120°F. All the test results at 80°F and 120°F for both moderate and aggressive driving styles are averaged together and presented in *Table 3* for each of the bias calibrations. Fuel savings was best for 50% 500 hp defined engine torque curve (7.1%) and the least for 0% 600 hp defined engine torque curve (4.3%).

	500 hp		**600 hp**	
	30%	**50%**	**0%**	**50%**
VCW	8.0%	8.9%	5.9%	6.1%
GVW	6.4%	6.6%	4.0%	5.9%
GCW	4.6%	5.8%	2.8%	4.5%
Average	**6.3%**	**7.1%**	**4.3%**	**5.5%**

Table 3: Combined Fuel Savings for Churchville C for 80°F and 120°F

4.2.3 Mission Profile

According to the OMS/MP for the HEMTT, the vehicle is expected to spend approximately 85% time on secondary roads, trails, and cross country, while spending approximately 15% on primary roads. Using the MTA Fuel Economy Loop as a surrogate for primary roads and Churchville C for secondary roads, trails, and cross country, an approximation of fuel savings across the OMS/MP can be made. This is provided in *Table 4* for each of the bias levels at each vehicle weight configuration. Overall, the 50% 500 hp defined engine torque curve calibration posted the best fuel savings at 7.6% and the 0% 600 hp defined engine torque curve posted the least fuel savings at 4.9%. *Figure 6* compares the averaged fuel savings across ambient temperatures, vehicle speed limits, and vehicle weights for each bias calibration for MTA Fuel Economy, Churchville C, and the approximated OMS/MP.

	500 hp		**600 hp**	
	30%	**50%**	**0%**	**50%**
VCW	8.1%	8.8%	6.0%	6.5%
GVW	7.2%	7.3%	4.9%	6.7%
GCW	5.6%	6.7%	3.8%	5.5%
Average	**6.9%**	**7.6%**	**4.9%**	**6.2%**

Table 4: Fuel Savings for Approximation of OMS/MP

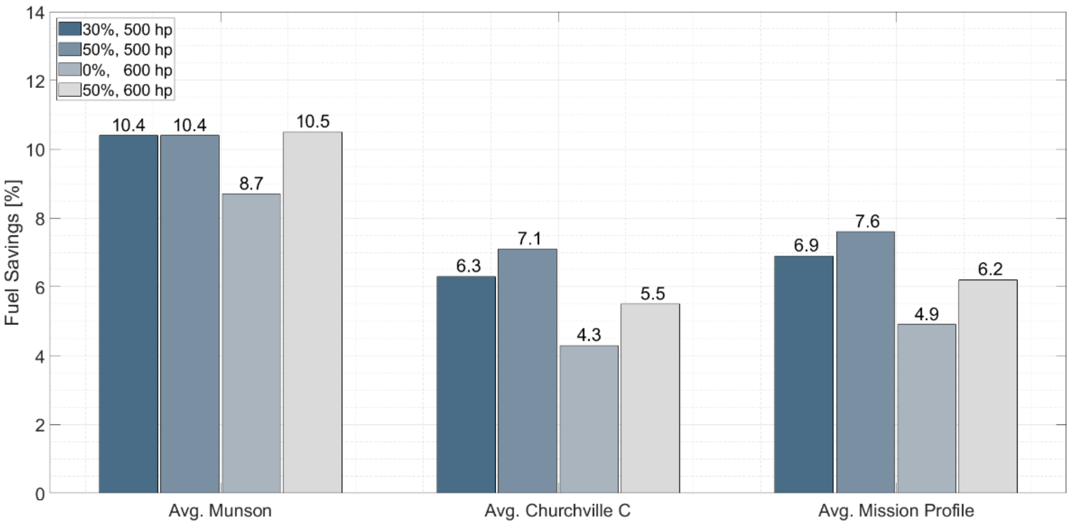

Figure 6: Fuel Savings over OMS/MP

5. CONCLUSION

Over the course of this test program, DynActive® Shifting was evaluated for degradation of vehicle acceleration and improvement in fuel economy. In comparison to the Baseline, acceleration decreased by 3% or less when the 0% bias with PLS specific (600 hp) defined engine torque curve was selected. When judging improvements to fuel economy, DynActive® Shifting demonstrated potential to reduce fuel consumption in both steady-state and transient driving conditions. Aggregating results from road course replication using PEVEL's dynamometer over MTA Fuel Economy Loop and Churchville C, an approximation of the OMS/MP showed savings of up to 7.6% when using the 50% bias with 500 hp defined engine torque curve (See *Figure 6*). Based on the priority for fuel economy versus performance, DynActive® Shifting can be programmed to the mission requirements of the vehicle.

Although these results are specific to the HEMTT, DynActive® Shifting did demonstrate the ability to save fuel. Depending on the degree of fuel savings desired, the impact to the vehicle's acceleration and responsiveness can be minimized. While this study only investigated the impact of DynActive® Shifting on FMTV, HEMTT, and PLS, the Army does have other tactical and combat vehicles which may also benefit from DynActive® Shifting and could be a valid path to fuel economy improvement.

6. REFERENCES

[1] Department of the Army. (26 June 2020). *AR 70-38: Research, Development, Test and Evaluation of Material for Worldwide Use.*

[2] Department of the Army. *FuelSense®2.0 Software Update for the Medium & Heavy Truck Fleet.* CRADA # 23-03.

[3] Allison Transmission Inc, "FuelSense®2.0," AllisonTransmission.com. 10140-02-highway-fs-flyer-sa8814en_final-lr_web.pdf (allisontransmission.com) (accessed Feb. 26, 2024).

[4] S. Beiter, S. Zielinski, "HEMTT Mobility Performance and FuelSense®2.0 Testing," Test Report, GPMH23025, 10 Jan 2024. DTIC AD1229466.

[5] S. Beiter, S. Zielinski, "PLS Mobility Performance and FuelSense®2.0 Testing," Test Report, GPMH23026, 01 April 2024. DTIC AD1229405.