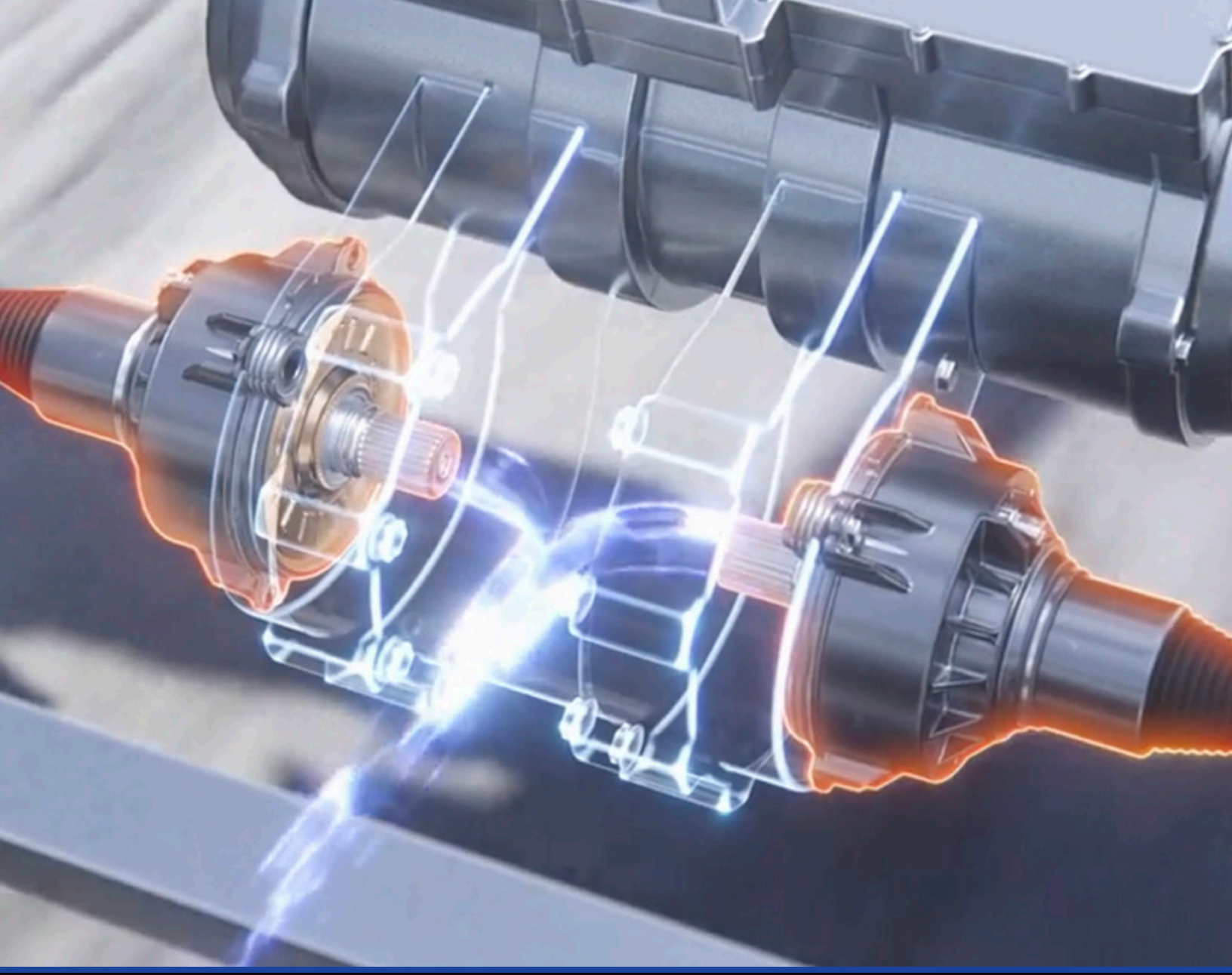

The Missing Link in Efficient and High-Performing AWD and 4WD Electrified Propulsion:

The Dynamic Controllable Clutch System – an Electro-Mechanical E-axle Disconnect Solution

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EV Propulsion is Evolving – Fast

Many countries have mandated electric propulsion as a requirement for all, or a high percentage of, new vehicle sales in the very near future. As a result, the transportation sector is experiencing a historically quick shift in product development, supply, and demand. Critical technologies high on this list include batteries and electric propulsion systems. However, to meet the high consumer demand for four-wheel-drive (4WD) and all-wheel-drive (AWD) SUVs and light-duty trucks, new torque-management solutions are needed that are designed specifically for electric drivetrain systems. Means Industries has a successful track record of bringing first-to-market technology into the vehicle space, including the selectable one-way clutch and advanced aluminum flowforming processes. Therefore, the company was primed to address this key issue when it developed its Dynamic Controllable Clutch, an Electro-Mechanical E-axle Disconnect system that is currently launching in production on a suite of 4WD electric vehicles (EV). This innovative disconnect system seamlessly engages and disengages front and rear electric drivetrains, enabling near instantaneous torque vectoring while also conserving energy and extending vehicle range by up to 10%.

The global shift to EVs over internal combustion engines (ICE) has launched an abundance of technological startup companies, much like in the early days of Silicon Valley. Many of these startups have forward-thinking products and solutions that require the help of agile Tier 1s with a successful track record of helping their customers engineer and launch commercially successful products. They may also need the manufacturing expertise and techniques developed by established global suppliers to scale up production volume while meeting stringent quality requirements.

Means Industries, an Amsted Automotive Group company, stands out in the field of propulsion-solutions providers. For nearly 100 years, Means has established itself as a high-quality supplier of the year for many of its OEM customers. Its agile structure and relentless focus on leading-edge innovations give customers the driving pace of a startup and the stable support and continuity of an established, knowledgeable, and experienced global supplier, capable of volume production manufacturing and meeting or exceeding all quality certifications for the automotive industry. Means offers customers a partnership that specializes in the development of first-to-market advanced mechanical and electro-mechanical clutch systems for performance and light to heavy commercial vehicles.

Amsted Automotive is also an industry leader in integrated complex metal-forming assemblies, powered metallurgy, net-shaped cold forming, and soft magnetic composites. Each of Amsted Automotive's technologies enables its customers to design lighter, more efficient e-drive and driveline systems. As a full-service supplier, Amsted Automotive has the capabilities to design and scale-up high-performing, cost-effective solutions in-house, and those savings are passed on to its partners.

> Means Industries stands out with the culture and innovation of a high-tech startup company combined with the financial resources and experience necessary to execute volume production manufacturing that meets or exceeds all quality certifications for the automotive industry.

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Clutch Innovation for the EV Market

Clutches designed for traditional ICE powertrains were not engineered for the unique parameters and characteristics found in electric propulsion systems. This created a demand for new solutions in EV clutch and disconnect technology. It required discrete and modular solutions that could be integrated into the electro-mechanical systems that work with onboard power sources yet would not compete for space and power from the electric drive system. The result had to be smooth performance and energy efficiency in the torque transfer system, combined with a reduction in energy loss and mass in transmissions and drivelines. The system also had to meet the automotive industry's regulatory requirements, including emissions standards.

This led Means to develop the Dynamic Disconnect Clutch. It allows the components to couple and decouple smoothly, with on-demand functionality imperceptible to the driver. Developing efficient, seamless, on-demand AWD and 4WD systems for EVs is of particular importance for sport-utility vehicles (SUV) and crossover-utility vehicles (CUV), as they are the fastest-growing segments globally. In addition to light-duty pickup trucks, which have maintained their significant market share for decades. These vehicles appeal to consumers for a variety of reasons, including the additional mobility and safety benefits that come with having AWD and 4WD.

Dynamic Controllable Clutch & Electro-Mechanical E-Axle Disconnect Benefits

- Discrete and simplified technology packaging
- Imperceptible engagement and disengagement
- Easy to apply, calibrate, and use
- Torque dense and robust design ideal for delivering quality components and managing the extreme torque and impact demands of electric vehicle propulsion

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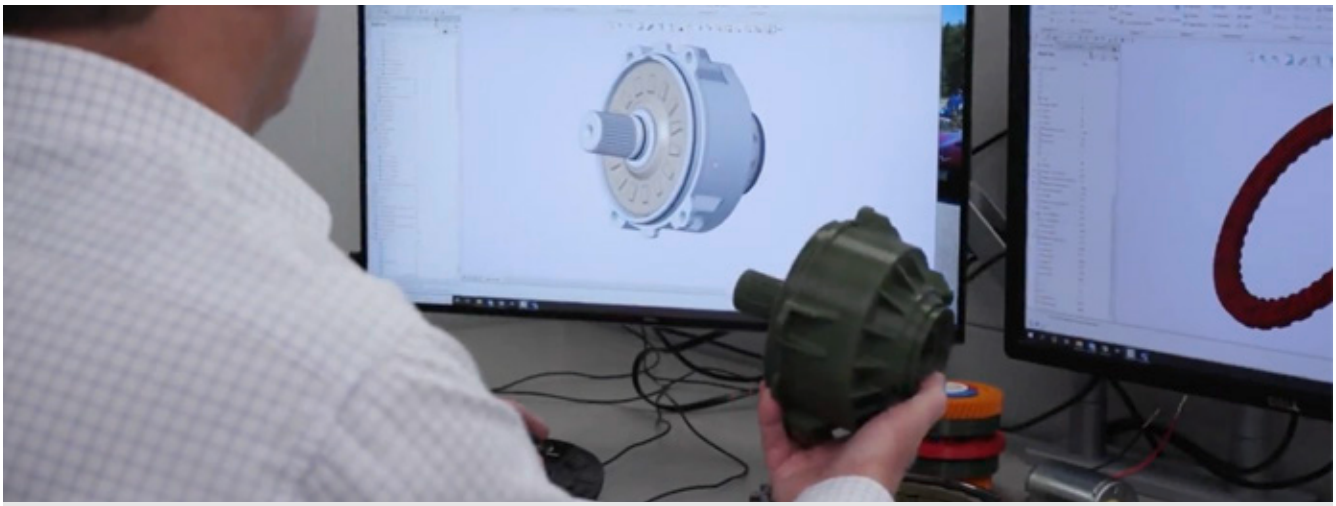
Problems with Using Traditional Clutches in EVs

Simply put, traditional automotive clutches had not been designed for use in electric propulsion. Traditional clutches, such as hydraulic or even electrically actuated dog clutches, dramatically increase power losses and system mass. They also prove to be difficult to calibrate and are not the best solution for the instantaneous actuation desired by AWD and 4WD consumers.

OEMs have typically used dog clutches or wet clutch packs in these systems to disconnect the front and rear drive axles. Dog clutches, or other typical mechanical locking devices, often require a significant amount of actuation and holding energy, can be hard to use, are often slow to engage, and lack smoothness – this “clunky” engagement can be disruptive to the driver. Wet clutch packs, on the other hand, are easy to use and perform well, but they are remarkably inefficient and heavy. They rely solely on hydraulics, which is incompatible with the idea of efficient and cost-effective electric propulsion designs. Additionally, wet clutch setups by themselves are not a “locking” mechanical device. And they would require the driveline engineer to develop an entire adjacent hydraulic system to function the clutch, which adds mass, costs, and complexity to the system.

While these two types of clutches can be integrated well into appropriate ICE-based powertrain systems, their shortcomings are compounded when used in an electric propulsion system – where hydraulics have been all but eliminated. EV powertrains favor mechatronic solutions that are easily calibrated and draw very little power for engagement and holding state.



Addressing a key issue in electric propulsion led to the development of the Dynamic Controllable Clutch, an Electro-Mechanical E-axle Disconnect driveline system that efficiently engages and disengages rear electric drivetrains from their drive axles while conserving energy and extending vehicle range.

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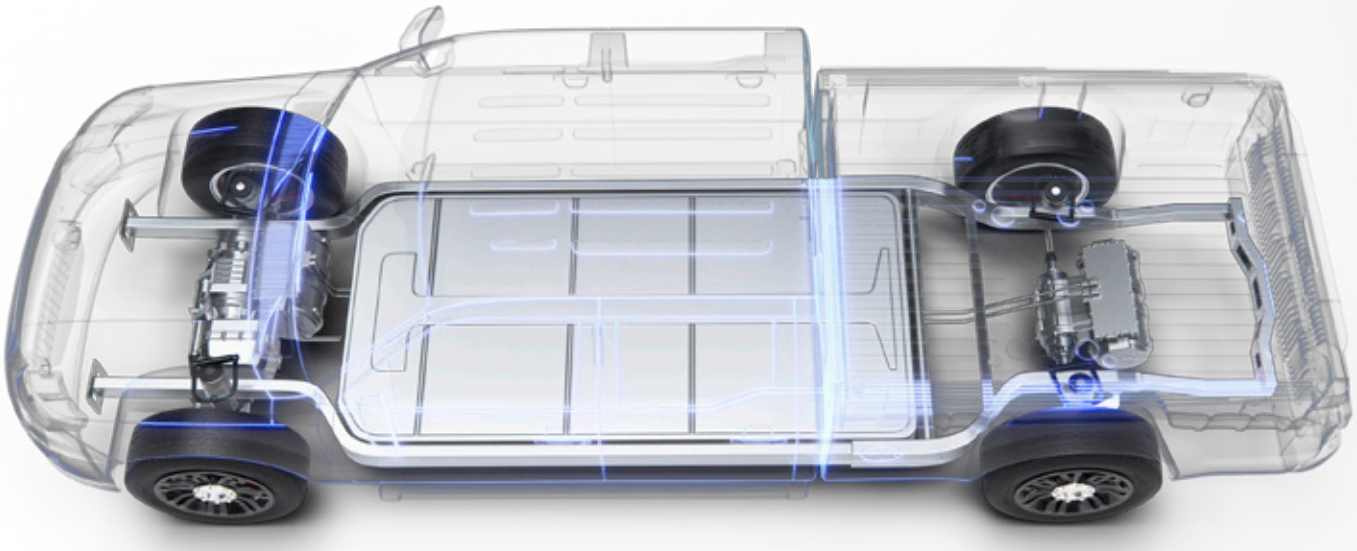

Pushing the Boundaries of New EV Clutch Technology

With its Dynamic Controllable Clutch (DCC), Means developed a novel way of disconnecting the e-motor from the wheels in electric-drive units, one that would also conserve energy and extend vehicle range by up to 10%.

DCC provides the benefits of latching in state without a constant power supply. Hydraulic control is eliminated, as are the associated costs and complexities. Even electrical requirements are reduced, as power is only consumed during state transition. DCC uses electric actuation to create substantial packaging and system efficiencies by eliminating complex hydraulic systems.

DCC leverages an electro-magnetic, 12-volt actuation system that utilizes a linear actuator to shift the DCC between states. DCC magnetically latches in each state, which significantly reduces energy requirements to keep an AWD or 4WD system engaged. This application of mechatronics enables shift times of less than 20 milliseconds.

The robust design, which is discrete and in a simplified package, also reduces the risks associated with performance applications and high-torque impact from electrified propulsion systems.

Electro-Mechanical E-axle Disconnect application of the DCC provides efficient and unnoticeable engagement and disengagement of the front and rear electric drivetrain from the drive axles, while maintaining full on-road and off-road capability.

And here's another first that was accomplished: Electrodynamic E-axle Disconnect is the first production disconnect solution to be located at the EV transmission output.

This application of mechatronics enables shift times of less than 20 milliseconds.

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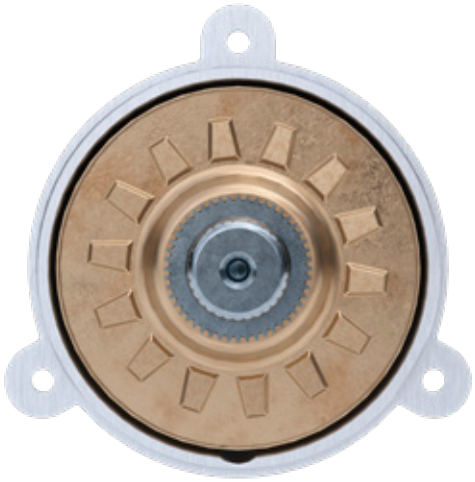
Early Challenges of Implementing Disconnect Technology

There are certainly challenges – but not roadblocks – with being first to market with any new technology or product. To adapt DCC as an Electro-Mechanical E-axle Disconnect to meet the needs of an OEM partner with a 4WD EV in development for deployment in 2021, accomplishments included:

- Working within a condensed development time of 2 years, from project start to launch.
- Specifications robust enough for a 4WD performance vehicle reaching 0-60 mph in 3 seconds, off-roading, and towing capability of up to 11,000 pounds.
- Ability to transfer 6,200 lb-ft (8,500 Nm) of ultimate torque.
- Imperceptible engagement and disengagement of the clutches.
- Sealed-for-life environment outside of the transmission.
- Being located outside of the transmission, the clutch assembly would be exposed to harsh elements and varied terrain that a performance 4WD vehicle may see both on and off road, such as mud, dust, water, and sand. There would also be exposure to weather and environmental changes, including desert and tundra.



Dynamic Controllable Clutch and Electro-Mechanical E-axle Disconnect Solutions provide a novel way to disconnect the e-motor from the wheels in electric-drive units, one that would also conserve energy and extend vehicle range by up to 10%.

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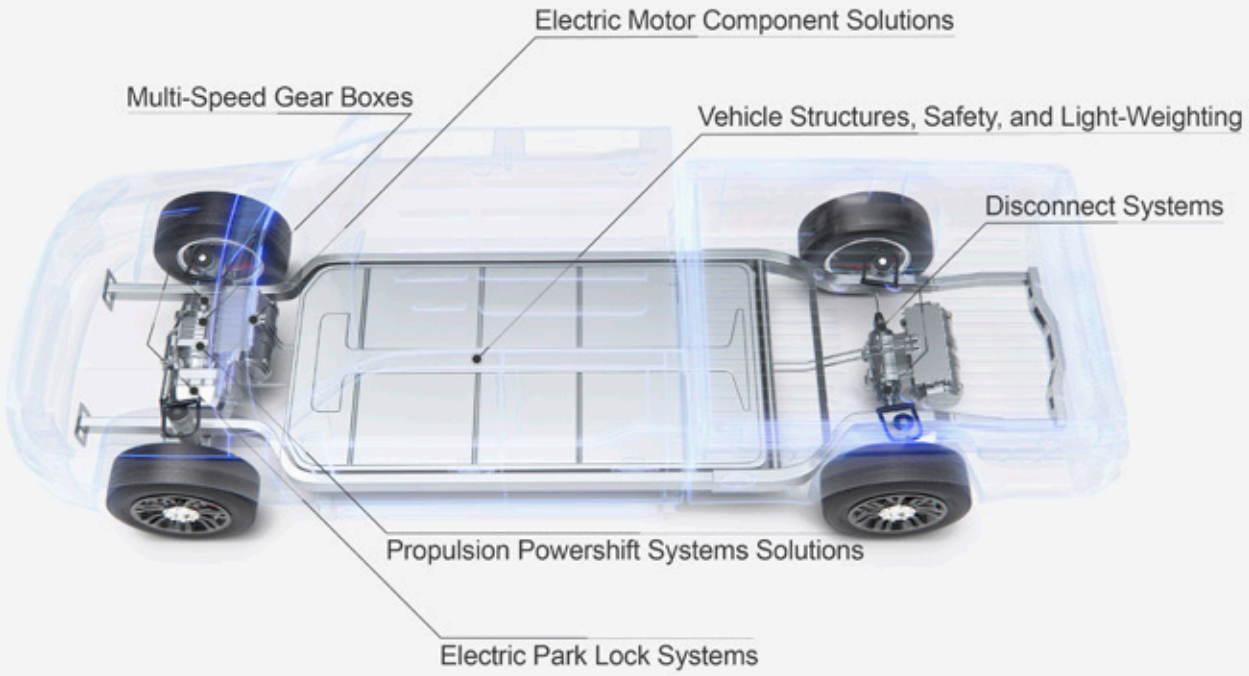
Patented Technology that Facilitated Means EV Clutch Innovation



Among the forward-thinking mechanical solutions to engineering an efficient disconnect system were these patented and patent-pending Means technologies:

- Overrunning coupling and control assembly, coupling assembly and locking member for use therein.
- Device and apparatus for controlling the operating mode of a coupling assembly, coupling and control assembly and electric motor disconnect and pass-through assemblies.
- Electro-Dynamic Coupling and Control Assembly and Switchable Linear Actuator Device for use therein.

Dynamic Controllable Clutch & Electro-Mechanical E-Axle Disconnect Performance

- Significant battery and structural mass reduction opportunity
- Sub 20 millisecond engagement time
- Transfer 6,200 lb-ft (8,500 Nm) of ultimate torque
- 10% increased battery range due to improved energy efficiency

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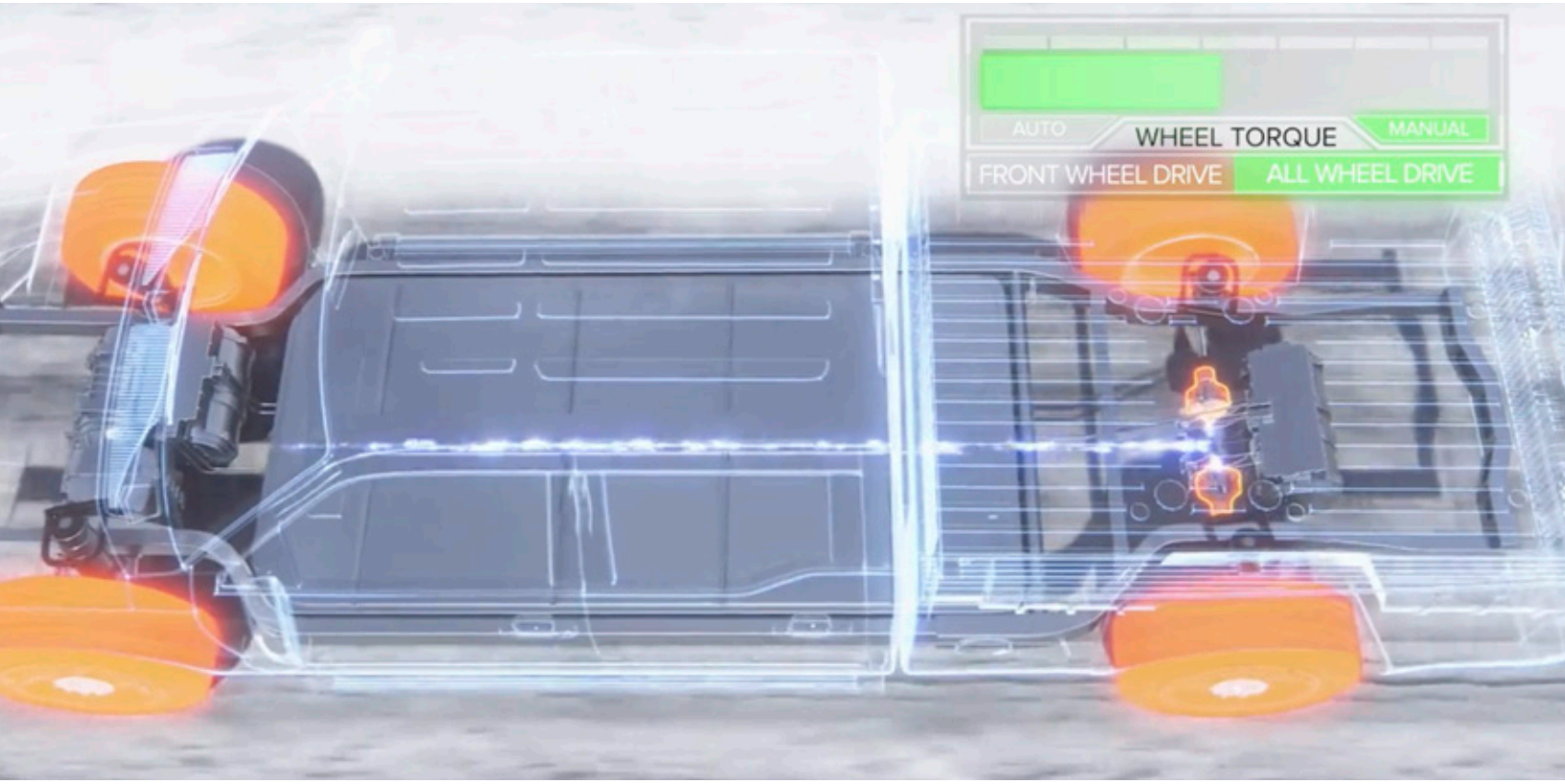

The Future of EV Propulsion is Now

Trailblazing new propulsion technology is what drives Amsted Automotive Group. Electro-Mechanical Drivetrain Disconnects, Mechatronic Clutches, Electric-Motor Housings with Thermal-Management, and Integrated Electric Park-Lock systems are but a few of the leading-edge technologies that have allowed Amsted Automotive Group and its partners to lead the narrative of what defines propulsion system design – then and now.

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