



*“Demonstrating the Benefits that Hybridisation can Deliver to the British Forces Today”*



- Millbrook Proving Ground – Orientation
- Scope of TD6
- Benefits
- Challenges
- Industrial capacity

# UTAC FIVE ACTIVITIES PILLARS



- **New energies & Carbon free mobility**
  - **Simulation**
- **Software defined vehicles**
  - **Cybersecurity**
- **Automated & Connected vehicle**
- **Vehicle engineering**



- **Electromobility (battery/e-motor/vehicle)**
- **ElectroMagnetic Compatibility & Acoustics**
- **Safety & Autonomous Driving**
  - **Powertrain**
    - Tyres
    - Components
- **Durability & measurement**
  - **On-site testing**
- **Bespoke test systems**
- **Tracks & venues rental**



- **Regulatory expertise**
  - **Type approval**
    - **Certification**
  - **Qualified operators**
  - **Market surveillance**
    - **Standardization**
- **National Individual Vehicle**
  - **Vehicles inspection**
    - **NCAP**



- **Corporate Events**
- **Products launches**
  - **Filming**
- **Tracks & venues rental**
- **Technological park rental**
- **Classic & sportscars festivals**



- **Expertise**
- **Internal audit**
- **Driving training**
- **Regulatory & testing training**
- **Management System training**

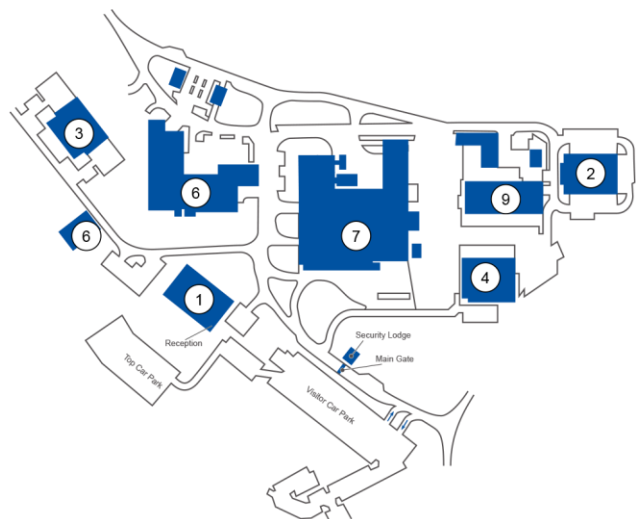
# Millbrook Proving Ground



10/07/2023

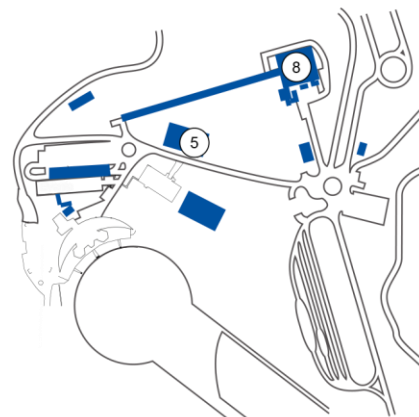
**Commercial in Confidence**

# LABORATORY TESTING - UK



Bedford Site Map

- **Offices and Customer Workshops**
  1. Main Reception Building
  2. Workshops
  3. Workshops
  4. Innovation Centre
  5. Commercial Vehicle Workshops
- **Propulsion Testing**
  6. Dynamometer, PEMS and Engine Testing
  9. Battery Testing
- **Safety Testing**
  7. ServoSled
  8. Full-scale Crash and Safety Systems Testing
- **Vehicle and Interior Systems Testing**
  7. Main Workshop Building and Instrumentation
  9. Environmental Chambers and Component Testing



Leyland Site Map

- **Propulsion Testing**
  1. Engine Testing
  2. Driveline Testing
  3. Electric Machine Testing
- **Vehicle Testing**
  4. Semi-Anechoic Chamber
  5. Structural Testing
- **Interior Systems Testing**
  6. Vehicle Interior Environment Quality
- 7. Environmental Chambers
- 8. Seat Testing
- 9. Materials Testing
- **Other**
  10. Offices
  11. Stores
  12. Fuel Stores
  13. Vibration Testing
  14. Instrumentation and Calibration





- Multiple MoD studies but limited experimentation
- Most views on EVs are based on passenger cars
- The MoD drive towards Net Zero by 2050 (NZ50)
- The need for an Army Electrification Strategy
- The significant increase in electrical and electronic systems used by soldiers and vehicles


# TD6 Scope



## TD6: Hybrid Electric Drives (HED)(Wheeled)

*"Demonstrating the benefits that platform hybridisation can deliver to the battlefield today"*

**Hybridisation Benefits to be Investigated**




<p><b>Lethality:</b> "The capacity to engage, damage, neutralise or eliminate the threat"</p> <p>Future Systems Enable Energy Weapons Enable Future Targeting Systems</p>  <p>Future Armour</p>	<p><b>Sustainability:</b> "The ability to endure and maintain during a mission"</p> <p>Maintainability Modular Components</p> <p>Reliability Component Reliability</p> <p>Supportability Increased Fuel Efficiency / Reduced Consumption</p> <p>Off-board Power Supply</p>	<p><b>Survivability:</b> "The ability to remain mission-capable after a single engagement"</p> <p>Vulnerability Enable Future Electric Armour</p> <p>Detectability Improved Signature Management &gt; Thermal &gt; Electrical &gt; Acoustic</p> <p>Susceptibility Redundancy of Powertrain &amp; Components</p>	<p><b>Mobility:</b> "The ability to keep moving while retaining the ability to fulfil the primary mission"</p> <p>Reach Increased Range Improved Cross-country Performance Improved Wading</p> <p>Tractability -Increased Gradients -Better Soft Terrain -Larger Obstacle Surmounting</p> <p>Manoeuvrability -Skid Steering -Torque Vectoring</p>
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What could this deliver?

### Legacy Platform Powertrain:

### HED Converted Platform Powertrain: (Series Hybrid)

### TD6 Demonstrator Vehicles & Driveline Configurations (per Fr/Rr axle):

<p><b>FOXHOUND</b></p>  <p>In-Wheel Hub Drive (IWHD):</p> <p>Mobility &amp; Sustainability</p>
<p><b>JACKAL</b></p>  <p>In-Body Hub Drive (IBHD):</p> <p>Mobility &amp; Survivability</p>
<p><b>SV 6-Tonne</b></p>  <p>Differential Drive (DD):</p> <p>Sustainability &amp; Lethality</p>

**Key:** Battery Power: kWh, Electric Motor: M, Mechanical Differential: D, Vehicle Hull: ▽

### Battlefield Electrification:

*"The process of powering by electricity, and the introduction of such power by changing over from an earlier power source"*

**Mobile Electrical Power Supply**

- Integrated Mobile Supply
- Open Architecture
- Instantaneous Availability
- High Voltage Source

**Future LOSA (Land Open Systems Architecture)**

- GVA/GBA/GSA Compliance
- Automation
- Autonomy
- Dismounted Soldier Systems

**Who uses Power on the Battlefield?**


**NOW**

- Forward Operating Bases
- Field Hospitals
- C4ISR Systems
- Electronic Warfare
- Repair and Recovery

**FUTURE?**

- Marsupial Operations (Unmanned Systems)
- Direct Energy Weapons (DEWS)
- Active Protection Systems
- Smart Sensors
- Dismounted Soldiers
- Open Power Architecture
- 3D Printing

**Replaced by:**



**HED**

For further information on TD6 HED contact Clifford Holden; Clifford.Holden255@mod.gov.uk

# Benefits Map



Initial research into the application of hybrid technology to existing military vehicles has captured the following potential benefits, challenges, and areas of enquiry.

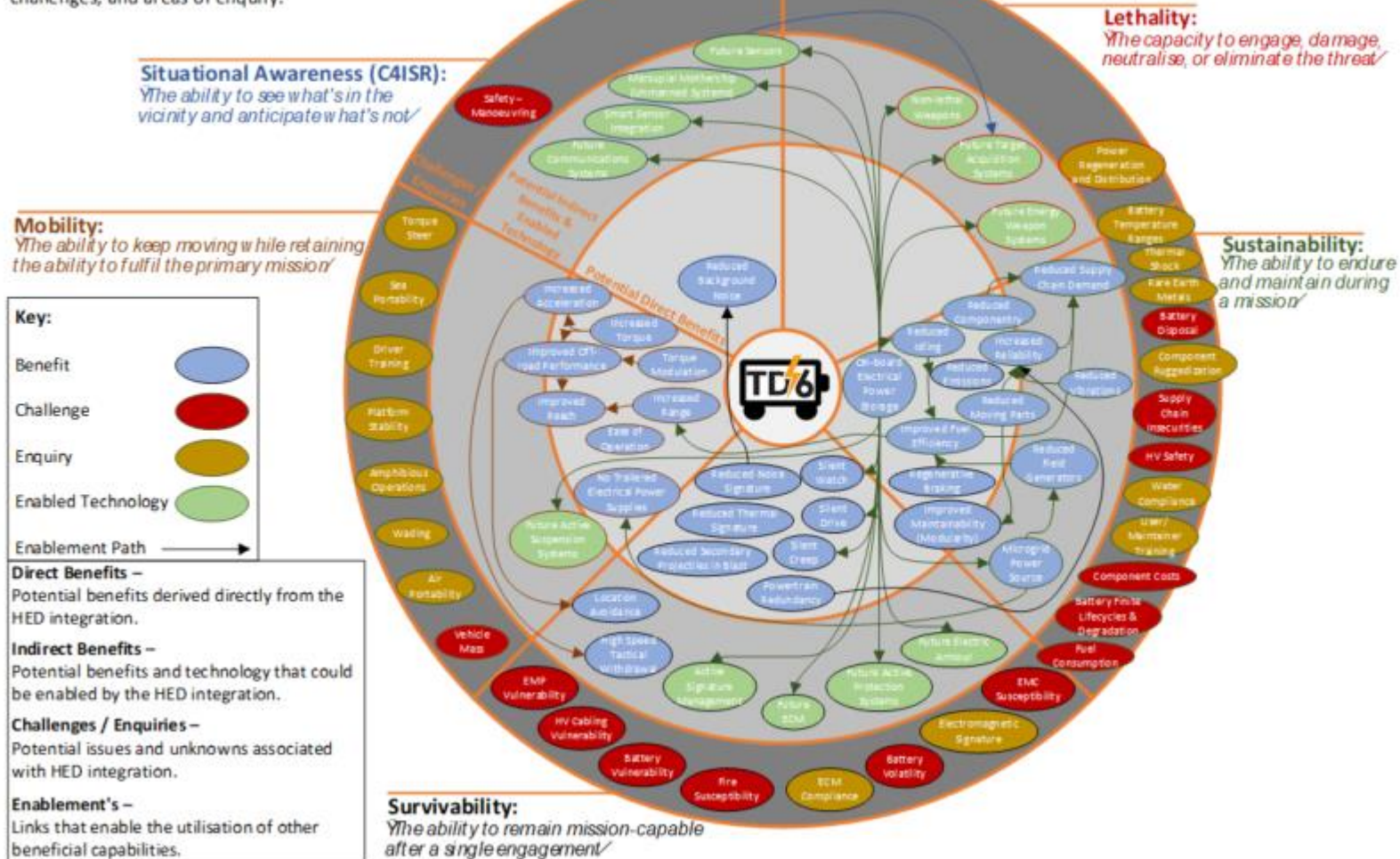


Figure 1: TD6 HED Benefits Map



# Benefits



- Benefits of individual wheel control
  - Powertrain redundancy
  - Torque modulation
- Speed and acceleration

Base vehicle with automated gearbox  
Demonstrates why manual has to be used for X Country!



Hybrid vehicle  
Just press the pedal!



- Ease of control
- Situational awareness
- Stealth
  
- ULEZ Compliance
- Reliability
- Adaptability



# Off-Board Power



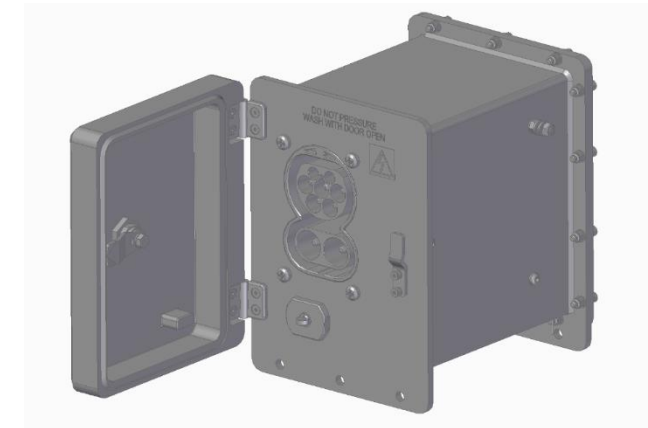
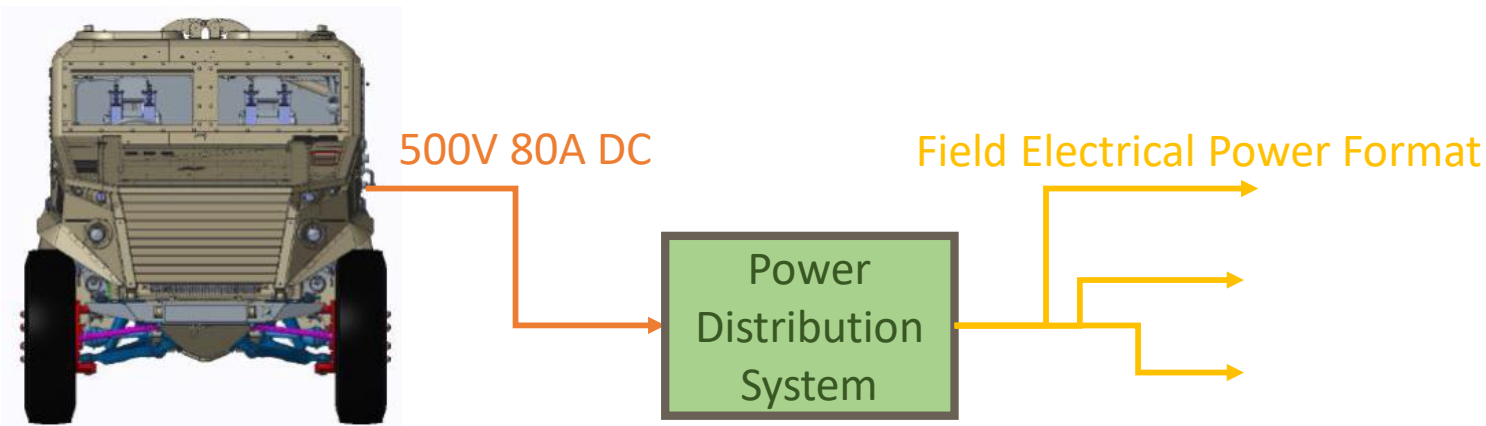
Each TD6 vehicle has an integrated Combined Charging Socket (CCS) that it can deploy up to 40kW of DC power from.

This DC power can then be converted by a Power Distribution System into a format useable by deployed infrastructure.

The power can be delivered silently for a finite time by the vehicles batteries, or continuously by the integrated vehicle generator, replacing the requirement for a field generator.



Comparative 40kW Generator

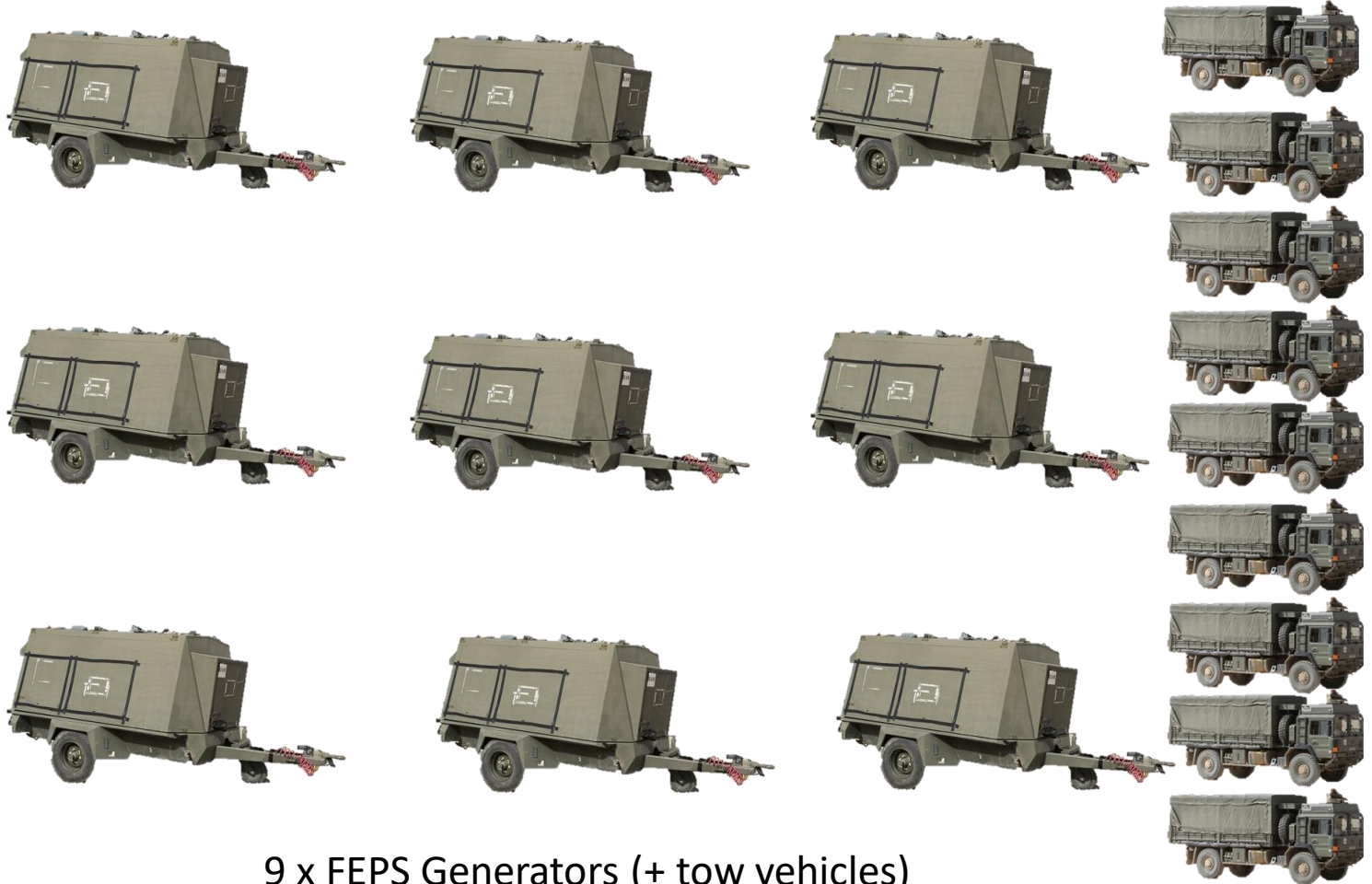


Vehicle CCS Power Port

# How much of a Potential Game Changer is This?



1 x 500kW HED SV



9 x FEPS Generators (+ tow vehicles)

Availability of on-board power assists integration of other technologies:

- Directed Energy Weapons
- Electric Armour and Defensive Aid Suites
- Sensors
- Marsupial operations for electric vehicles
- Autonomy
- Microgrid/Vehicle to Grid power



# Challenges





## TD6 Vehicles were prototypes using COTS components:

- Physical loading
  - Instantaneous and continuous shock loading
- Thermal loading
  - The inability to specify an exact temperature range in order to optimise cooling/heating systems and components
  - Can cause them to become physically larger and bulkier so that performance can be maintained under more extreme conditions.

Time period:	No. of buses	Consumption difference:	Consumption difference:
01/06/19 - 31/03/20		Cold vs normal temps	Hot vs normal temps
12m buses	79	14% ▲ in cold temps	9% ▲ in high temps
18m buses	27	21% ▲ in cold temps	12% ▲ in high temps

- Environmental effects
  - As above – extreme hot and cold, high temp and humidity
- EMC
  - Significantly higher requirement than commercial standards





- Important to consider the predicted in-service lifetimes when developing future HED platforms to ensure designs are upgradeable as the technology develops.
- Difficult to determine the direction of travel for vehicles - likely be heavily influenced by the direction of the commercial market
- NATO single fuel policy



- Lithium Ion batteries are considered dangerous cargo by sea and air. This becomes even more complex once the vehicle has been subject to damage or combat conditions
- Military vehicles spend considerable periods of time laid up or covering only very low mileage. In the same way as consideration is given to the effects of high usage on system components, consideration needs to be given to the effects upon batteries and power electronics of low usage and storage.



- New skills
- Infrastructure
- Battery Management
- Configuration Control
- Security

# Benefits of individual wheel control....

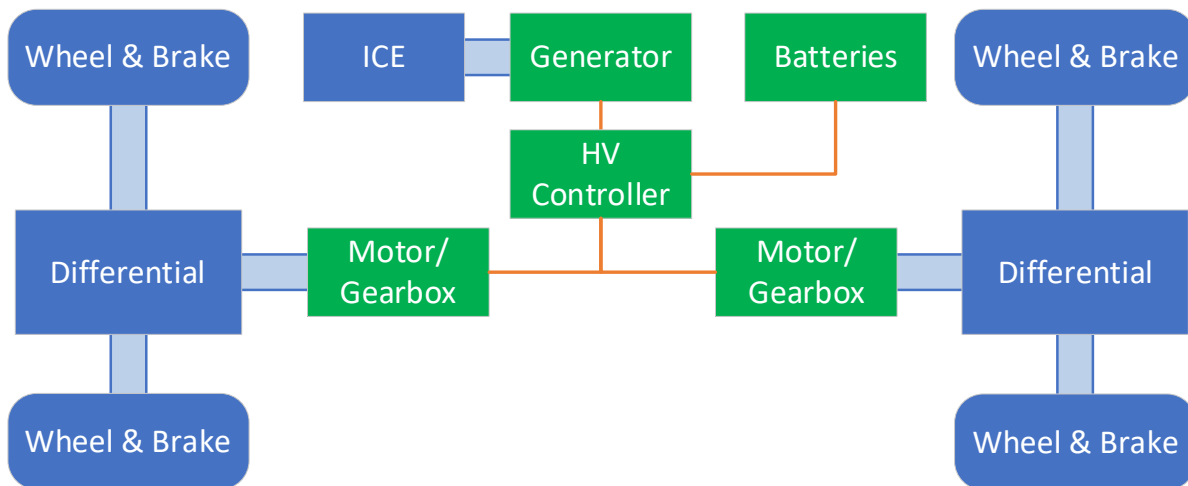


# Questions



# TD6 SV 6-Tonne HED:

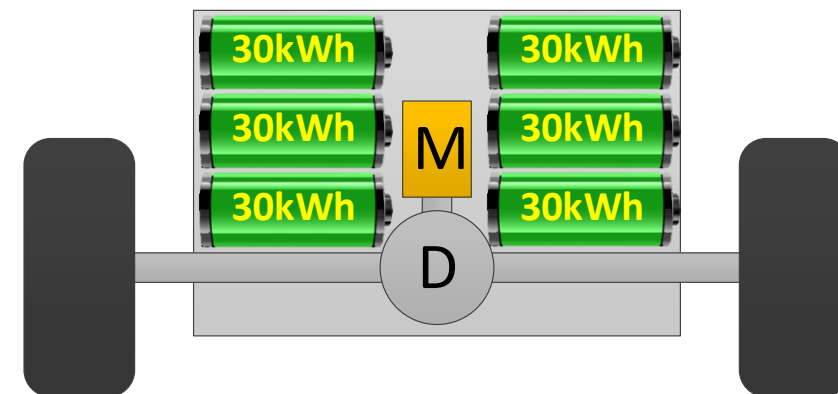
Platform Engineering;  
Powertrain Design, Manufacture, Integration and Commissioning;



Components Added	Components Removed
6 x 30kWh Battery	Gearbox
1 x 230kW Generator	Transfer Box
2 x 150kW Traction Motor	
HV Controller	

Estimated Performance	
Potential Peak Off-Vehicle Export Power	510kW
Stored Energy	180kWh
Silent Drive Time (Off-road)	80 mins
Maximum Torque per Wheel	10,700Nm

Differential Drive (DD):

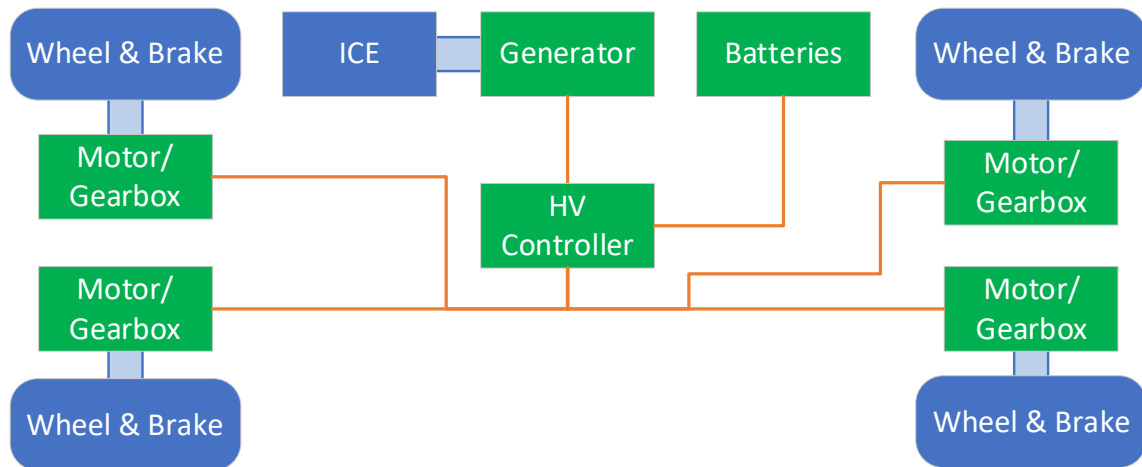


Key: Battery Power: kW    Electric Motor:    Mechanical Differential:    Vehicle Hull:

# TD6 JACKAL HED:

Platform Engineering;

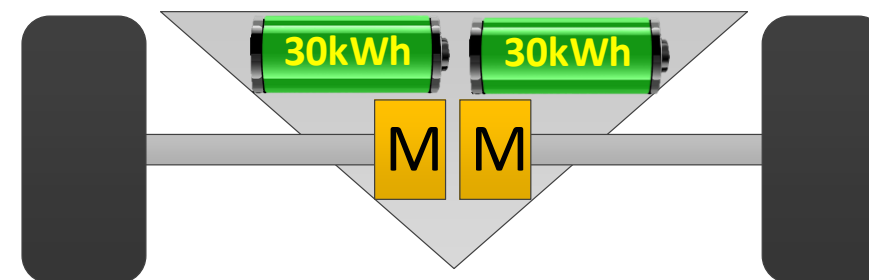
Powertrain Design, Manufacture, Integration and Commissioning;



Components Added	Components Removed
2 x 30kWh Battery	Gearbox
1 x 150kW Generator	Differentials
4 x 60kW Traction Motor	Drive Shafts
4-Cyl Engine	6-Cyl Engine
HV Controller	Transfer Box

Estimated Performance	
Potential Peak Off-Vehicle Export Power	190kW
Stored Energy	60kWh
Silent Drive Time (Off-road)	120 mins
Maximum Torque per Wheel	8,800Nm

In-Body Hub Drive (IBHD):



**Key:** Battery Power: kW    Electric Motor: M    Mechanical Differential: D    Vehicle Hull:

OFFICIAL

# TD6 FOXHOUND HED:

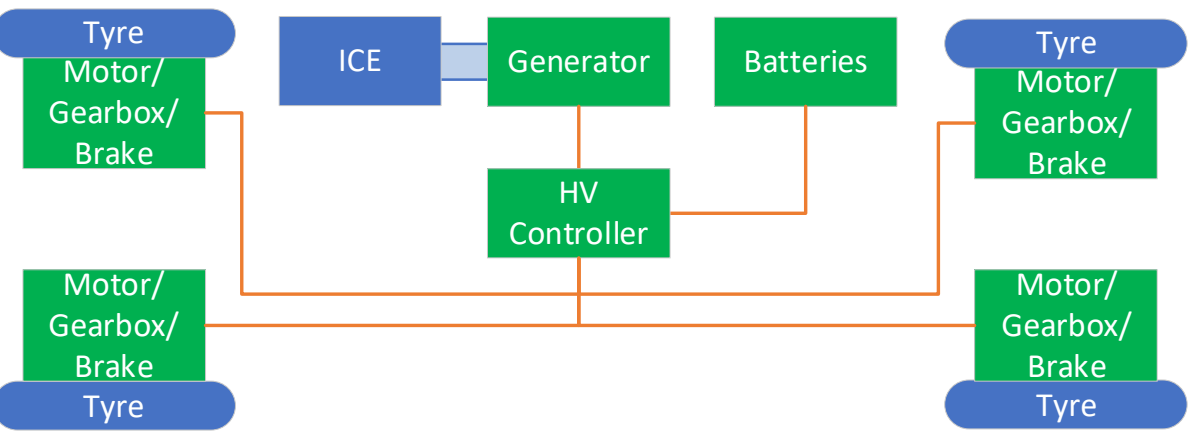
Platform Engineering;

Powertrain Design, Manufacture, Integration and Commissioning;

GENERAL DYNAMICS

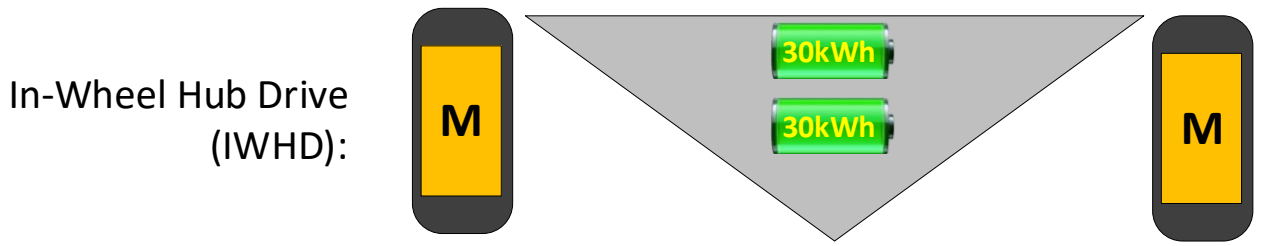
Land Systems-United Kingdom

MAGTEC  
ELECTRIC VEHICLE DRIVE SYSTEMS



Components Added	Components Removed
1 x 60kWh Battery	Gearbox
1 x 135kW Generator	Differentials
4 x 60kW In-wheel Traction Motor	Drive & Prop Shafts
HV Controller	Full Hydraulic System
	Wheels and Brakes

Estimated Performance	
Potential Peak Off-Vehicle Export Power	195kW
Stored Energy	60kWh
Silent Drive Time (off-road)	~120 mins
Maximum Torque per Wheel	11,000Nm



Key: Battery Power: kW Electric Motor: Mechanical Differential: Vehicle Hull:

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