University of Birmingham

School of Engineering

Integrated Design Project 3

FINAL INTEGRATED TEAM REPORT

Team Number	1

Abstract

This report presents the engineering solution developed by Team 1 for the 2028 Dakar Rally; the electrification and performance optimisation of a Toyota Hilux for high-speed, off-road endurance. The team responded to the global challenge of a vehicle that balances sustainability, speed, and safety by converting an existing internal combustion platform into a fully electric rally truck, which not only demonstrates technical innovation, but also aligns with long term sustainability goals through the use of zero emission powertrain and regenerative systems.

It outlines the global context surrounding the shift to sustainable motorsport and how the groups collaborated within the team, focusing on a specific subsystem. Team level decisions were managed through structured communication strategies and design validation milestones. It also explores wider implications of electrified off road racing in terms of commercial, ethical, legal opportunity and human factors. A detailed risk assessment was conducted to ensure the feasibility and safety of the concept, alongside a commercial business plan highlighting how manufacturers like Toyota could use this project to promote emerging battery technologies. The overall design strategy demonstrates how multidisciplinary collaboration can drive innovation, industry relevant outcomes in high performance vehicle engineering.

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Design of High Speed/High Efficiency Vehicle: Electric Rally Pick-up truck for the 2028 Dakar Rally

Global Challenge Context

The global challenge that the team decided to address was to develop a high-speed and high-efficiency off-road competition vehicle that is also sustainable. As the automotive industry undergoes a major transition from internal combustion engines (ICEs) to electrified powertrains, motor sport must follow suit to reduce carbon emissions and environmental impact.

Endurance events like the Dakar Rally have historically relied on diesel and petrol engines and now present an opportunity to showcase their commitment to a cleaner future through electric vehicles.

Toyota, a prominent manufacturer of off-road vehicles, plans to release a solid-state battery by 2028, and therefore has expressed interest in promoting a more sustainable vision for their renowned Hilux pick-up truck. Rather than developing an entirely new vehicle, they have tasked our own team with modifying an existing Hilux into a fully electric, high performance rally truck. This approach reflects a realistic and industry relevant challenge. Motorsport teams often work with manufacturers to develop competition vehicles such as in Formula 1. By electrifying the Hilux, we will not only address the technical challenges of EV racing but also demonstrate the capabilities of electric powertrains in extreme off-road conditions.

Key Performance Indicators (KPIs)

Table 1: Key Performance Indicators for this Project

Category	KPI	Target by group
Performance	0-100km/h Acceleration Top Speed	Vehicle Dynamics, Powertrain
	Handling Performance, Weight Distribution	Suspension, Tyres, Braking
Efficiency	Energy Consumption	Powertrain, Electrical Systems, Aerodynamics
Safety	Compliance with safety standards	Roll Cage, Crash Structure, Electrical Safety systems
Sustainability	Battery Technology, Energy Efficiency	Powertrain, Braking, Suspension
Durability	Component Endurance	Suspension, Steering, Tyres

Team Design Solution

Having been given the brief, our team is tasked with engineering a fully electric rally version of the Toyota Hilux using their proposed solid-state battery, which should be capable of competing in a Dakar Rally demonstrating sustainability, high performance, and efficiency.

The final design is shown in Figure 1.

Figure 1: Final Design

This begun with addressing the issues with the existing Hilux. Some key challenges included:

- Weight and packaging of battery systems
- Off-road durability of EV drivetrain
- Heat management in extreme environments
- Vehicle range and endurance
- Safety of battery in harsh conditions

To help tackle these challenges, the teams were divided into specialised subgroups.

Table 2: Groups and Focus Areas

Group	Areas of Focus	Why
BEng Mechanical 1	Roll Cage, Crash Structure, Cooling	The roll cage, chassis, and impact structure are critical components of a motorsport vehicle, designed to safeguard occupants while serving as integration points for other systems. Additionally, effective cooling is essential, particularly in harsh conditions, to maintain reliability throughout an event.
BEng Mechanical 2	Aerodynamics, Bodywork	The vehicle's aesthetics play a crucial role in promoting sponsors and attracting new clients. Additionally, the vehicle must maintain stability at high speeds over rugged terrain while minimising drag, ensuring adequate airflow to essential components such as the radiators

MEng Mechanical 1	Suspension, Vehicle Dynamics, Steering, Braking & Tyres	Effective vehicle handling in off-road terrain is essential for achieving both speed and predictability. Optimising kinematic points, tire size, and steering ratio enables the driver to maximise the car's performance
BEng Electrical 1	Sensors, Monitoring, Control Systems	Drivers need to be aware of different areas on the vehicle whether that is battery charge, current draw, or tyre pressure. Driver aids such as traction control and torque vectoring will facility fast driving.
Msc 1	Powertrain, Battery Thermal Management, Protection, Swapping	The vehicle's core relies on powerful motors to navigate tough terrain, while a durable high-voltage battery ensures endurance over long distances.
BEng Civil 1	Workshop and Vehicle Design Facility	To facilitate further business growth, there must be a facility to design new vehicles, within different markets, and additionally produce vehicles for the customer. To meet this criterion, Civil Engineering are producing a multi-purpose facility.

This structure was chosen and based off of what BMW do and base their divisions of different liens of products (BMW Group, n.d.), where there is a team leader (president in the Figure 2) and below that, there are divisions based off of each part of the car, which was what we have used.

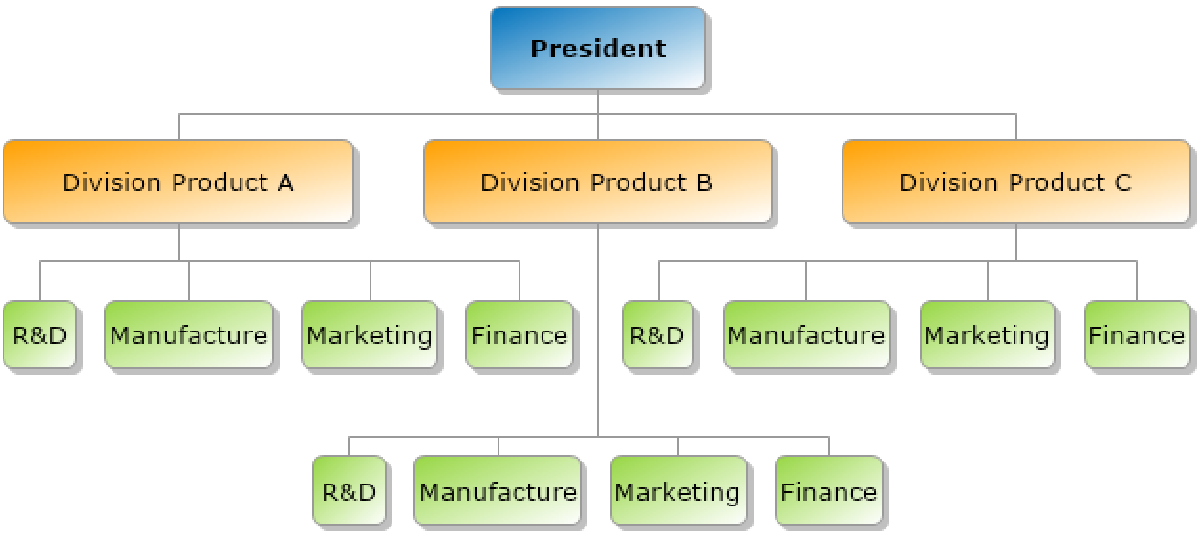

Figure 2: Division Organization Structure

Wider Implications

There are some wider implications that the development of this vehicle can extend to. It touches across critical themes across sustainability and innovation.

Sustainability

Electrifying a vehicle for the Dakar Rally introduces many sustainability benefits. This project aligns with Goal 9, Industry, Innovation, and Infrastructure through integration of the magneto piezoelectric damper, which as a regenerative feature, aims to reduce net energy demand, which also aligns with Goal 7, Affordable and Clean Energy. On the other hand, sustainable engineering also requires reflection material sourcing, particularly for batteries and specialist allow, as well as waste minimization through efficiency prototyping.

Commercial

This project highlights the growing commercial potential of electrified off road systems, which by demonstrating the viability of a fully electric rally vehicle in a high profile, high stress environment, offers OEMs an opportunity to develop and showcase advanced technologies that may translate into mainstream applications. Suspension components and regenerative shock absorbers have potential aftermarket value or as licensable IP. While costs are high due to prototyping and simulation needs, the long-term commercial outlook is strengthened by the potential to collaborate with manufacturers, secure sponsors, and promote IP based revenue models.

Ethical

From an ethical viewpoint, the project engaged with themes around safety, transparency, and social responsibility in engineering. The groups this in mind when designing systems that minimise harm, particularly in harsh environments like the Dakar Rally, and ensuring full driver responsibility by following safety guidelines. There are other ethical concerns associated with electrical vehicle development, including the extraction and processing of materials such as lithium, cobalt, and rare earth elements. Addressing these early builds awareness among students and reinforces the importance of responsible innovation in engineering.

Legal

The vehicles design was guided by a need to comply with legal and regulatory frameworks to both motorsport and engineering manufacturing. Compliance with FIA regulations for safety, construction, and powertrain classification was considered. These also adhered to safety policies and risk management protocols when prototyping and simulating results. Opportunities were also explored for protection and security for our systems, such as the design of the regenerative dampers, balancing creativity within the compliance of professional engineering practices.

Human Factors

Teams ensured that their design was suited around the driver as well the environment, aiming to ensure that the final vehicle would be ergonomic, serviceable, and safe. Consideration such as ride comfort, repair access and safety influences system level decisions in the suspension, bodywork, and powertrain. Modular components and race friendly layouts were prioritised to facilitate efficient maintenance during long rally stages. On a team level, communication, collaboration, and conflict resolution were also a big part of the project. The interdisciplinary teamwork displayed real world engineering environments.

Risk Assessment

Designing and manufacturing a fully electric rally pick-up track presents various risks. These risks arise from component failures, operator errors, and external factors. Table 3 below summarizes the major risks at a team level and the current control measures in place to mitigate them.

Table 3: Team Level Risk Assessment

Risk	Effect	Severity	Frequency	Risk Level	Current Risk Management
Component integration failure	Systems may not interface correctly, reducing performance and efficiency	Medium	Medium	Medium	Regular intergroup design, integration planning, interface specifications.
Collision	Injury, Vehicle Damage	High	Medium	High	Driver safety systems, robust roll cage
Battery Fire	Major safety hazard, injury	High	Low	High	Durable battery housing, fire suppression systems, thermal monitoring and cooling, compliance with safety protocols.
Electrical Faults	Loss of power/control	Medium	Medium	Medium	Backup systems, robust connections to handle rally.
Suspension Failure	Vehicle Instability	High	Low	Medium	Simulation testing
Software Malfunction	Inaccurate data, unintended behaviour in control systems	High	Medium	High	Redundant systems, fail-safe programming, real world testing.
Data Security Breach	Loss or theft of confidential CAD files, simulation data, or OEM agreements.	High	Medium	High	Use of secure cloud platforms, access control, regular backups and data encryption for sensitive files.
Exposure to Harmful Chemicals	Health risks from handling substances like coolants, adhesives, lubricants, or welding fumes.	Medium	Medium	Medium	Use of PPE, proper ventilation in workshop areas, COSHH assessments, and safe handling/storage protocols.

Business Plan

The project is designed with a business goal of providing a platform for automotive companies to promote sustainable off-road racing vehicles. As a motorsport engineering consultancy, we aim to deliver a customised, electrified Hilux Dakar prototype to promote their 2028 solid-state battery launch.

Target Market

- Primary Market – Automotive OEMs seeking high-profile platforms for promotional EV concepts
- Secondary Market – EV motorsport teams, including entrants in events such as Extreme E, Le Mans EV class (future), and other endurance-based EV series.

The initial showcase will be in 2028, and we will release a digital campaign allowing us to gain attention. Industry events could be held as well as participating in exhibitions to further put our brand out there.

Costs

Table 4 shows the costs of each individual area that was focused on. The costs for each division are shown in each report, and the overall costs for the company are shown in the Table below.

Table 4: Total Team Costs

Area	Cost (£)
Roll Cage, Crash Structure, Cooling	9,076.28
Aerodynamics, Bodywork	6,128
Suspension, Vehicle Dynamics, Steering, Braking & Tyres	46,135
Sensors, Monitoring, Control Systems	21,950
Powertrain, Battery Thermal Management, Protection, Swapping	66,460
Workshop and Vehicle Design Facility	388,544.43
Total	538,293.71

Funding Strategy

We are going to use Toyota as our anchor client to get things running. Then this will lead to getting other companies and supplier partnering and sponsoring us, in order to promote their companies, such as other vehicle companies or suppliers like battery or material providers. Revenue would be made through:

- Toyota
- Sponsorships
- Sustainability funding
- Partnerships

Additional investment opportunities include UK Motorsport development funds and private equity from automotive technology investors. The project's alignment with the UK government's Road to Zero strategy also opens eligibility for advanced propulsion research grants and low carbon innovation incentives.

Furthermore, there is also the opportunity to branch outside the Motorsport industry, into the public sector, facilitating the acquisition of government contracts.

Project Management

To keep track of time, weekly meetings were conducted by the group leaders to keep everyone up to date, and a Gantt chart was created to track progress and setbacks throughout the entire project. After the presentation, the weekly meetings with module and discipline leads helped to mitigate any issues within the team and clarify project briefings. A project management tree has been developed to help visualise the teams structure.

Table 5 shows the dependencies of the groups; the information they acquired from other groups.

Table 5: Group Dependencies

Group	Dependencies
BEng Mechanical 1	Dimensions form the Aero group that dictate the roll cage design, mounting points and where the roof scoop is. Mounting points for the suspension and the battery size to accommodate it into the chassis.
BEng Mechanical 2	Dimensions from the Chassis group helped dictate design parameters and dimensions. Feedback from Chassis group was used to figure out mounting points. Design specifications from Suspension group helped dictate wheel arch dimensions and ground clearance.
Meng Mechanical 1	Powertrain parameters to calculate suspension kinematics and vehicle dynamics. All groups for weight to adjust handing and damping parameters. Roll cage to figure out mounting points. Aerodynamics to find out projected vehicle area for braking.
MSc 1	External Cooling system helped powertrain cooling include battery and motors. Vehicle aerodynamics, suspension, braking system help our group in software simulation. Roll cage and impact structure protect out battery design. Manufacturing Facility and Testing Facility with Civil engineering group .
BEng Electrical 1	Detailed suspension parameters, including the specifications for twin-tube shock absorbers and springs. Critical safety data, such as maximum roll angles. Precise vehicle dimensions.
BEng Civil 1	The facility needs to accommodate all the needs of other groups. For this we needed to know generally what other groups needed to fabricate inhouse and what they needed to order in. This allowed us to dedicate adequate space for each operation, e.g. the welding corner.

Figure 3 shows a diagram of how the information was passed to other groups. The boxes show the information that was required, with the arrows indicating incoming information.

Figure 3: Group Integration Figure

In order to facilitate these meetings and communicate within the team, we used WhatsApp as our main messaging platform to communicate ideas and any scheduled meetings. To share files and store documents, Microsoft Teams was used as it is a secure platform and anyone who is in the team will be able to access them.

Gantt Chart

ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Meet Group and Rank Challenges	1	1	1	1	100%
Generate Ideas	1	1	1	1	100%
Discuss Internal Hurdles	2	1	2	1	100%
Produce Group and Team Level SoR	3	2	3	2	100%
Consider SDG	2	10	2	10	33%
Encorporate Team Integration	2	4	2	4	75%
Finalise Concept Design	4	1	4	1	100%
Develop Presentation	4	3	4	3	25%
Develop Concept Models	5	1	5	1	
Present Final Idea	6	1	6	1	
Write Final Report	7	5	7	5	
Iterate Concept Design Through	7	3	7	3	
Finalise Design	10	2	10	2	
Finalise Report and Submit	12	1	12	1	

Figure 4: Gantt Chart

References

BMW Group. (n.d.). *Company Portrait*. Retrieved from BMW Group: https://www.bmwgroup.com/en/company/company-portrait.html