

Baja Ducati — Engineering Feasibility Read & System Architecture

The credibility spine. Powertrain and vehicle-systems engineering assessment of a Ducati-register motorcycle re-engineered for Baja / open-desert terrain, on the client-locked series-hybrid (electric-primary + small ICE range-extender), ride-by-wire architecture.

Prepared for: a strategic / insider audience (manufacturer, race outfit, moto engineers) who know bikes cold. **Truth standard:** every load-bearing spec, supplier, and lead time below traces to a source fetched for this brief (cited inline) or is written as an honest range with the basis named. Where an off-the-shelf part does not exist, it is said plainly. **Date:** 24 September 2026.

0. Verdict in one line

Buildable — with caveats, as a running prototype, not a production machine. Every subsystem here exists as real hardware from a real supplier today. The engineering is not in inventing components; it is in *packaging two energy systems into one motorcycle* without wrecking the mass centralization that makes it read Ducati, and in *sealing and cooling* that machine against fine sand and desert heat. Those are the two hard problems, and they are hard, not hand-wavable. The critical path is the frame + packaging integration and the range-extender genset (no off-the-shelf motorcycle-scale unit exists — it is an integration job). Full verdict and critical path in §7.

1. The thesis, stated as an engineer would defend it

"Ducati-style" is road-race DNA: a rigid trellis (or monocoque) frame, a low and forward mass centroid, the engine as a stressed member, wheels tucked tight under a compact wheelbase. Baja is the physical opposite: 300 mm of wheel travel, a tall stance, a long wheelbase for high-speed stability over whoops, wide flotation over soft sand, and *everything sealed* against dust that behaves like a fine abrasive slurry.

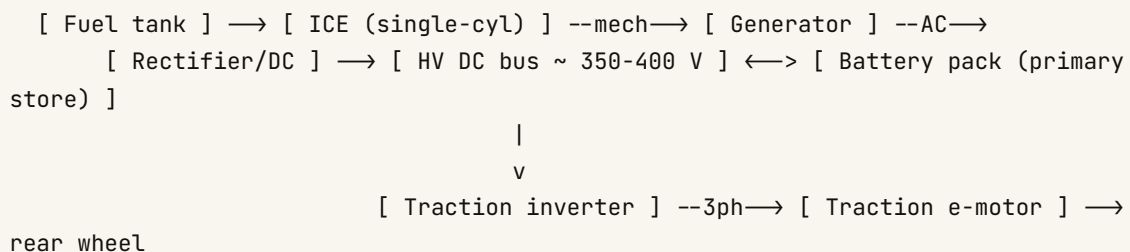
The resolution is not a compromise between the two — it is a deliberate re-mapping of which Ducati cues are **visual/architectural** (keep them) and which are **dynamic** (discard them for desert physics):

- **Keep (reads Ducati):** the trellis-frame visual language, the tank-to-tail line, mass *visually* centralized around the mid-frame, the naked-mechanical aesthetic, the single-sided-swingarm cue if the rear packaging allows it.
- **Discard (would kill it in the desert):** the low stance, the short travel, the tight tuck of unsprung and sprung mass low and forward, the sealed-for-tarmac-not-dust philosophy.

The series-hybrid architecture is what makes this *resolvable* rather than merely *stylable*: because the wheels are driven by an e-motor and the ICE never touches the driveline (§2.1), the designer is freed to place the ICE genset **wherever the mass budget wants it** rather than where a chain run demands it. That decoupling is the single most important enabling fact of the whole machine, and it is the honest "why series-hybrid" answer for an insider who asks why not a parallel hybrid or a simpler pure-EV.

2. System architecture — the powertrain

2.1 Topology (series-hybrid, client-locked)



The wheels are **only ever driven by the traction e-motor**. The ICE has no mechanical path to the ground — it spins a generator at its efficient RPM to feed the DC bus and top up the battery. This is the defining property of a series hybrid (range-extended EV / REEV), and it is confirmed as the standard series-REEV description on MAHLE's own range-extender page: "an auxiliary power unit consisting of a small internal combustion engine coupled with an electric generator which is used to re-charge" the battery (mahle-powertrain.com, fetched 2026-09-24).

Why this topology for this machine (the insider answer):

1. **Torque control in sand.** E-motor torque is commanded electronically at millisecond resolution — the traction/slip control loop can meter torque to a slipping rear wheel far faster

and finer than any cable-and-butterfly ICE can. In soft sand, where the difference between drive and dig-in is a few percent of wheelspin, this is a genuine, defensible functional advantage, not a marketing line.

2. **Range without chargers.** The 200-mile-no-charger desert reality is met by carrying fuel, not by carrying an impractically large battery. The battery is sized for the *dynamic* demand (peak power, regen, thermal buffer); the fuel carries the *energy* for range. This is the correct division of labor and is the honest "why not pure EV" answer.
3. **Genset runs at one point.** Because the ICE is decoupled from road speed, it runs at or near its single best-efficiency point (BSFC island), which is why a small engine can do the work of a much larger road engine and why the emissions/efficiency story is defensible.

2.2 Traction e-motor – selection

Design target: a Baja-capable performance single needs roughly **80–110 kW peak** and **~110–130 kW is the class ceiling** you would ever want on two wheels in sand (more is untractable). Continuous power in the desert matters more than peak: sustained high-speed sand running is a continuous-power duty cycle, not a drag race, so the **continuous rating and its thermal derate are the numbers an insider will actually interrogate.**

Grounded candidate — EMRAX 268 (axial-flux PMSM). From EMRAX's own datasheet v1.5 (emrax.com, PDF fetched 2026-09-24):

Spec	Value (owner's sheet)
Peak power	210 kW
Continuous power (S1)	94–117 kW depending on cooling/voltage
Peak torque	500 Nm
Continuous torque	200–250 Nm
Weight	21.4–22.3 kg
Cooling	air / water / combined; IP66 in liquid-cooled form
Operating voltage	100–830 V
Max speed	4500 rpm
Peak efficiency	up to 96%

Engineering note: the EMRAX 268 is *over-spec* on peak for a motorcycle (210 kW peak is car/aircraft territory), which is exactly why it is a safe choice — it will run a bike's duty cycle deep inside its continuous envelope, where the **IP66 liquid-cooled variant** gives real sealed-against-dust ingress protection (§4.2). The honest read is: we do not need all its peak; we buy it for its continuous headroom, its sealing, and its axial-flux packaging (a 94 mm-long "pancake" that tucks against the swingarm pivot, aiding mass centralization — the Ducati cue). A lighter, cheaper alternative is the **EMRAX 228** (12.2 kg, 100 kW peak, 30–50 kW continuous, air/liquid/combined, IP21/IP65 — from the specs circulated in the EMRAX builder community, to be confirmed against EMRAX's own 228 datasheet before BOM lock). The 228 is arguably the *right* motor for a lightweight prototype; the 268 is the safe-headroom choice. Either is a real, orderable EMRAX part.

Alternative for higher continuous torque: YASA 750R (axial-flux, 700–790 Nm peak, 200 kW peak, ~37 kg, 0–3250 rpm, >95% eff — yasa.com and Stealth EV's package sheet, fetched 2026-09-24). Heavier and higher-torque than a motorcycle needs; noted as a real option but not the recommendation.

Recommendation: EMRAX 228 (liquid-cooled, IP65) for a lightweight prototype; EMRAX 268 (liquid-cooled, IP66) if the mass budget and peak-power ambition run higher. Both are grounded, orderable, and sealed. **Lead time: see §3.**

2.3 Traction inverter / motor controller

The inverter is the piece that actually delivers the sand-torque-control advantage, so it is spec'd to the motor's current, not guessed. **Grounded candidate — Cascadia Motion PM250DZ** (the Rinehart Motion Systems RMS lineage, explicitly "designed for on and off road Electric (EV) or Hybrid Electric (HEV) applications" — EV West / Cascadia data, fetched 2026-09-24):

Spec	Value
Continuous current	450 A
Peak current	600 A (some sheets cite up to 700 Arms peak)
DC operating voltage	300–800 VDC (100–820 on the DZ variant)
Peak electrical output	~300 kW

The PM250DZ comfortably drives an EMRAX 228/268 (whose continuous motor current is ~220 A liquid-cooled, peak ~500 A) with margin. **Honesty flag:** the specific PM250DZ unit surfaced in stock is end-of-life at one distributor; Cascadia Motion's current-production PM/HD inverter

family (or an equivalent from a peer supplier) is what a real build would spec — the *class* of part is proven and off-road-rated; the exact model is a purchasing detail to confirm at BOM lock, not an engineering risk.

2.4 Ride-by-wire and vehicle control

Ride-by-wire on this machine is **simpler than on a comparable ICE bike**, because there is no throttle butterfly to actuate — the "throttle" is a torque request to the inverter. The rider's twist-grip is a position sensor; the vehicle control unit (VCU) maps that to a torque command with a rider-mode / traction-control layer on top.

- **Twist-grip / throttle-by-wire sensor + VCU logic:** standard, low-risk. On the ICE genset side, if the range-extender engine is throttle-by-wire (most modern singles are), that is a Bosch/Magneti-Marelli-class electronic throttle body — proven, off-the-shelf motorcycle technology (the ride-by-wire market has been standard on premium bikes — Ducati, KTM, Yamaha YCC-T, Aprilia — for over a decade; PRNewswire / Research & Markets, fetched 2026-09-24).
- **IMU-based stability & traction control:** the honest note is that motorcycle stability control (e.g. the Bosch MSC class) is a mature, homologated system on road bikes but is **tuned for tarmac**; a desert-specific slip target (you *want* controlled wheelspin in sand, not zero) is a **calibration and software problem**, not a hardware one. This is a named piece of real engineering work (§6.5) but it is development, not invention.

Bottom line on the powertrain: every block in the §2.1 diagram is a real, sourced part or a proven part *class*. The powertrain is not where the risk lives. The risk lives in packaging it (§6.2) and sealing/cooling it (§6.1, §6.3).

2.5 Battery pack — sizing thinking

The pack is the **primary energy store for dynamics** and the **thermal/power buffer**; the fuel carries the range energy (§2.1). So the pack is sized by *power and thermal need plus a useful all-electric range*, not by the 200-mile figure.

Sizing logic (shown, not asserted):

- **All-electric range target:** a useful "silent/clean" range of ~40–60 mi (65–95 km) before the genset needs to run. Desert energy consumption for an aggressive ~180–220 kg machine in sand is high — call it ****~90–130 Wh/km**** (a defensible off-road range; road e-motos run 50–80 Wh/km, sand is materially worse, and this is stated as an estimate, not a measured figure). That puts a 50 mi (80 km) electric range at roughly **7–10.5 kWh usable**.

- **Power/thermal buffer:** to deliver 80–110 kW peak and absorb regen without the genset, and to survive sustained high-C draw in desert heat, the pack wants headroom above the pure-energy number.
- **Recommended pack:** ~14–18 kWh nominal, high-power cell chemistry, ~350–400 V nominal to match the inverter/motor bus.

Cell selection (grounded, from About:Energy's manufacturer-sourced library, fetched 2026-09-24):

Cell	Capacity	Energy density	Max continuous discharge	Best for
Molicel INR-21700-P42A	4.2 Ah	216 Wh/kg	45 A (10.7C)	high-power, motorsport/aviation
Molicel P45B	4.5 Ah	231 Wh/kg	45 A	high-power, slightly higher energy
LG M50LT (21700)	4.8 Ah	270 Wh/kg	14.4 A	high-energy, range

The high-energy vs high-power tradeoff, decided honestly: an 80–110 kW pull from a ~15 kWh pack is a high-C event; the LG M50LT's 14.4 A limit means it would need a large parallel count to survive the current, at which point you are carrying a bigger, heavier pack than the energy requires. The **Molicel P42A / P45B (45 A continuous each)** is the correct chemistry for this machine — it takes the power draw and the regen without a thermal panic, at the cost of ~15% lower energy density than the M50LT. This is the standard motorsport-EV choice and is the defensible answer to an insider who asks "why not the high-energy cell." A pragmatic build could blend — but for a prototype, a single high-power chemistry keeps the BMS and thermal model simple.

Pack construction: cylindrical 21700 in a welded module with a proper BMS, liquid or forced-air cooling plate, and — critically for this machine — a **sealed enclosure** (§4.2, §6.3). Pack integration (cell-to-module-to-pack, BMS, contactors, cooling) is a real engineering deliverable and a long-lead item (§3), because a bespoke pack is bespoke; there is no off-the-shelf 15 kWh motorcycle pack in this power class you simply bolt in.

2.6 Range-extender genset — sizing

Sizing logic: in a series hybrid, the genset only needs to supply the **average (cruise) power**, not the peak — the battery covers the peaks. Sustained desert cruise for this machine is on the order of ~12–20 kW at the wheel; accounting for genset and conversion efficiency, an ICE

producing ~15–25 kW mechanical, driving a generator for ~12–20 kW electrical, keeps the battery topped over a long day. That is the honest sizing: small engine, run near its efficiency island, sized to *average* not *peak*.

The honest gap (an insider will look for this): there is **no off-the-shelf ~15–20 kW motorcycle-scale series-hybrid genset you can order as a unit**. The market's compact range-extendors are either car-scale (Brogen's smallest listed system is 65/80 kW at 270 kg — brogenevsolution.com, fetched 2026-09-24; Horse Powertrain's B15+EG50 is a car REEV product) or bespoke/prototype (MAHLE's compact range-extender engine, AVL, the Lotus Range Extender demonstrator). So this is an **integration job, not a purchase**:

- **Engine:** a modern single-cylinder ~450–690 cc EFI four-stroke (the KTM/Husqvarna LC4-class single, or a purpose small engine) run at a fixed efficient RPM. These engines exist as proven, homologated hardware; adapting one to constant-speed genset duty is well-understood.
- **Generator:** a compact PMSM run as a generator — the very same axial-flux machines (EMRAX, YASA) are explicitly rated by their makers for **generation** duty (YASA lists "generation" as a primary application; EMRAX markets the 268 as "a lightweight high power output generator"). A small EMRAX (188/207-class) or a purpose PM generator is the honest part here.
- **Integration:** coupling, rectifier, genset controller that starts/stops and holds the BSFC point, plus NVH isolation.

This genset integration is a named critical-path item (§3, §7), and it is the single most bespoke subsystem on the machine. Calling it off-the-shelf would be the naive move an insider would catch instantly.

3. Chassis, frame & suspension — reading Ducati, surviving Baja

3.1 Frame concept

The move: a steel trellis frame — the literal Ducati signature — re-proportioned for desert geometry. The trellis is not just an aesthetic borrow; it is genuinely the right structure here:

- It gives the **visual Ducati read** the brief's thesis demands (naked tubework, mechanical honesty).
- It is **repairable in the field** — a welded steel trellis can be fixed in a Baja pit with a welder; a cast-alloy beam or carbon monocoque cannot. For a desert race machine this is a real functional argument, not a rationalization.

- It packages the **series-hybrid mass** well: the battery (the densest single mass) sits in the main triangle where a Ducati's engine would be — preserving the *visual and actual* mass centralization — while the genset tucks lower/rearward (§6.2).

Geometry re-map for the desert (the honest numbers):

- **Wheelbase:** stretched from sportbike ~1,440–1,470 mm toward **~1,550–1,600 mm** for high-speed straight-line stability over whoops. (Rally raid machines run long; a KTM 450 Rally is materially longer than a supermoto.)
- **Rake/trail:** relaxed from a sportbike's ~24° toward a rally **~26–28°** for stability and to carry the long-travel front end.
- **Ground clearance:** ~**300–350 mm** (rally-raid territory; the Kove 800 X Rally advertises >270 mm / 27+ cm — dirtandtrail.co.za, fetched 2026-09-24), versus a sportbike's ~130 mm.
- **Seat height:** the honest consequence — desert travel and clearance push seat height to ~**910–960 mm** (the KTM 790 Adventure R Rally jumps to 910 mm precisely because of the long-travel Rally suspension — enduro21.com, fetched 2026-09-24). This is a real ergonomic tradeoff to state, not hide.

Swingarm: a long aluminium swingarm; a **single-sided swingarm** is available as a Ducati styling cue *if* the rear packaging (motor + genset) allows the extra width — flagged as a design-vs-mass decision for the industrial designer (§7), not an engineering blocker.

3.2 Suspension — real travel numbers

This is where the machine is honestly a **rally-raid bike underneath the Ducati skin**, and the travel numbers are non-negotiable desert physics. Grounded reference points (all fetched 2026-09-24):

Reference machine	Front travel	Rear travel	Components
KTM 450 Rally Replica	304 mm	280 mm	WP XACT PRO 7548 fork / XACT PRO 7750 shock
KTM 890 Adventure R Rally	270 mm	270 mm	WP XPLOR PRO (Cone Valve)
Kove 800 X Rally	270 mm	~250 mm	YU-AN 49 mm USD fork / piggyback shock

Recommendation: target ~**300 mm front** / ~**290 mm rear** wheel travel — full rally-raid spec — on a **48 mm closed-cartridge USD fork** and a **piggyback/remote-reservoir rear shock**. Named suppliers, all real and orderable:

- **WP Suspension** (XACT PRO / XPLORE PRO) — the KTM/Husqvarna rally choice, factory-racing-derived. This is the credibility pick.
- **KYB** — supplies the Kove 800 X Pro (48 mm USD, 240 mm) and much of the factory MX/enduro world.
- **Showa** — the other tier-one off-road fork/shock house.
- **Öhlins** — premium, off-road range, the natural pairing for a Ducati-register premium machine.

The remote/piggyback reservoir is not optional in the desert: sustained high-speed damping in heat dumps enormous energy into the oil; a remote reservoir is required to keep the damping fluid from fading (§4.3). This is a stated desert requirement, and it is why the reference bikes all run piggyback shocks.

3.3 Wheels, tyres & flotation

- **Wheels:** spoked **21" front** / **18" rear** (rally-raid standard; the KTM 890 Adv R Rally runs exactly this) — spoked rims flex and survive impacts that would crack a cast wheel, and are field-serviceable.
- **Tyres / flotation:** soft-sand flotation is a **tyre-pressure and footprint** strategy more than a wheel one. The desert answer is a knobby rally tyre run at low pressure with heavy-duty tubes or a mousse, and a **wider rear** than a sportbike for float. Paddle-style rear options exist for pure dune work but are a use-case choice. This is a tuning/spec item, not an engineering risk — flagged so the designer draws the correct wide-rear stance rather than a sportbike's tight rear.

Frame + suspension bottom line: the chassis is a rally-raid chassis wearing trellis clothing. Every suspension component is a real, orderable WP/KYB/Showa/Öhlins part at proven rally travel numbers. The engineering work is the **frame design and packaging** (§6.2), which is bespoke fabrication — the critical-path item alongside the genset.

4. Desert-specific engineering

This section is the difference between a concept and a machine that survives a real Baja day: 40–50°C ambient, direct sun on black components, and airborne dust that behaves like a fine cutting compound. Three systems carry the risk: **sealing, thermal, and cooling**. Each is treated as its own problem below and again, as a named risk, in §6.

4.1 The dust problem, stated precisely

Desert dust is not "dirt." It is sub-100-micron silica that finds every gap, and it is abrasive. Left unmanaged it destroys three things: **rotating seals** (motor shaft, wheel bearings, swingarm/linkage bearings), **electrical connectors** (HV and signal), and **air paths** (radiators, genset intake, any cooling fan). Every one of these has a proven mitigation — the discipline is that *all of them must be applied at once*, because dust exploits the single weakest gap.

4.2 Sealing strategy (ingress protection)

- **Motor:** spec the **IP66 liquid-cooled EMRAX variant** (owner's datasheet confirms IP66 for the liquid-cooled 268; IP65 for the liquid-cooled 228). IP6x is the *dust-tight* class — this is exactly why the sealed motor variant, not the cheaper air-cooled IP21 one, is specified. Stated as a hard requirement, not a nice-to-have.
- **Battery pack & electronics:** a **sealed IP67 enclosure** for the pack, VCU, and inverter, with pressure-equalization vents (Gore-type membrane) so the sealed box breathes temperature changes without breathing dust. Standard, proven EV practice.
- **HV & signal connectors:** sealed automotive/motorsport connectors (Amphenol/TE Deutsch-class), IP67+, on every mate. No open spade terminals anywhere.
- **Bearings & seals:** labyrinth + lip seals on the swingarm pivot, linkage, and wheel bearings; this is standard rally-raid practice and the reason rally bikes survive Dakar dust. A named maintenance item, not a novel one.
- **Air intake (genset only):** the genset ICE breathes air, so it needs a **heavy-duty multi-stage air filter** (foam pre-filter + paper element, the desert-race standard). This is the one unavoidable open air path on the machine, and it is a solved problem in rally raid — but it is a real, named maintenance and packaging item (§6.1).

4.3 Thermal management in desert heat + sand

The honest thermal picture, stated as an insider would want it: **the machine has three heat sources and one hostile environment.**

1. **Battery** — sustained high-C draw in 45°C ambient is the hardest thermal case on the vehicle. High-power cells (Molicel P42A/P45B, §2.5) help because they run cooler at a given power, but the pack still needs **active liquid cooling with a dedicated cold-plate and radiator**, and a BMS that will derate power before the pack cooks. Stated plainly: **thermal derate in the desert is real** — the machine's *continuous* performance in extreme heat is set by cooling capacity, not by the motor's peak. This is the number an insider will push on, and the honest answer is "we design the cooling to the desert continuous case, and we accept a derate at the extreme."

2. **Motor** — the EMRAX liquid-cooled variant needs min 6 l/min coolant flow (owner's sheet); manageable with a proper pump and radiator.
3. **Inverter** — liquid-cooled, shares or parallels the motor loop.
4. **Genset ICE** — its own liquid cooling loop plus exhaust heat to route away from the rider, tank, and pack.

Cooling architecture: likely **two liquid loops** — a low-temperature loop for battery + power electronics (needs cooler coolant) and a high-temperature loop for the ICE genset. Radiators sized for **still-air, high-ambient worst case** (a stationary bike in the sun is the worst cooling case, not the moving one), with forced-air fans that are themselves dust-protected. Radiator placement and airflow is a **packaging + industrial-design constraint** (§7): the radiators need clean, front-facing air and must not be blanked by bodywork — a real tension with the tight Ducati bodywork aesthetic, and a named design decision.

4.4 Flotation (cross-reference)

Covered in §3.3: wide rear, low-pressure knobby/mousse, spoked 21/18. Flotation is a tyre/geometry strategy, low engineering risk, but it drives the machine's *stance* — flag to the designer so the renders show desert proportions, not sportbike proportions.

Desert-engineering bottom line: every mitigation here is proven rally-raid or proven EV practice. Nothing is invented. The risk is that **all of it must be done at once and done well** — a single unsealed connector or an under-sized radiator fails the whole machine in the desert. That is why §6 names thermal-in-heat and sand-sealing as *hard*, even though each individual fix is known.

5. Components, suppliers & lead times

Honesty note on lead times: exact lead times are not published on supplier spec pages — they are quoted per-order and swing with demand. The bands below are **engineering-planning estimates** based on the nature of each part (COTS vs bespoke vs racing-program-derived), flagged as estimates, not vendor-quoted dates. Every one should be confirmed with a written quote at BOM lock; the analyst should treat the *bespoke* rows as the schedule drivers.

Subsystem	Named supplier(s)	Part / class	Sourcing nature	Lead-time estimate (basis)
Traction motor	EMRAX (Slovenia); alt.	EMRAX 228 or 268, liquid-cooled	COTS but low-volume, made-	~ 10–20 wk (specialist motor, not a stock item;

Subsystem	Named supplier(s)	Part / class	Sourcing nature	Lead-time estimate (basis)
	YASA (UK)	IP65/66	to-order	confirm with EMRAX)
Inverter	Cascadia Motion (US) / RMS lineage; peers	PM/HD-class, HEV/off-road rated	COTS, automotive/motorsport	~ 8–16 wk (some variants EOL — confirm current model)
Battery cells	Molicel (Taiwan)	INR-21700-P42A / P45B	COTS commodity cells	~ 4–12 wk for volume; sample qty faster
Battery pack	bespoke integrator	14–18 kWh, ~350–400 V, sealed IP67, liquid-cooled	BESPOKE — designed & built	~ 16–28 wk (design + build + BMS + test)
Suspension	WP (Austria); alt. KYB, Showa, Öhlins	~300 mm rally fork + piggyback shock	COTS racing components	~ 8–16 wk (racing-spec, made-to-order)
Frame	bespoke fabricator	steel trellis, rally geometry	BESPOKE — designed & fabricated	~ 12–24 wk (design, jig, weld, test)
Range-extender genset	bespoke integration (engine + PM generator)	~15–25 kW ICE + PM generator + controller	BESPOKE — the hardest integration	~ 20–36 wk (no off-the-shelf unit; §2.6)
Ride-by-wire / throttle	Bosch / Magneti Marelli class	ETB + twist-grip sensor + VCU	COTS motorcycle tech	~ 6–12 wk
Stability/traction ECU	Bosch MSC class + custom calibration	IMU + control + desert calibration	COTS hardware, bespoke software	HW ~6–12 wk; calibration = development effort, not a lead time
Wheels/tyres	spoked 21/18; rally tyre + mousse	COTS rally-raid	~ 4–8 wk	
Connectors/seals	Amphenol / TE Deutsch class	IP67 HV + signal	COTS	~ 4–8 wk

The three schedule drivers (longest-lead / bespoke): the **frame**, the **battery pack**, and the **range-extender genset**. These gate the prototype timeline; everything else can be bought in parallel. The analyst should build the timeline backward from the genset (~20–36 wk) as the long pole.

6. The hard parts — named as hard, with mitigations

An insider reads a feasibility document to find the glossed risk. There isn't one here; these are the real ones, each with its honest mitigation. "Here is the risk and here is the mitigation" is the credibility posture.

6.1 Sand ingress (HARD)

Risk: sub-100- μ m abrasive dust destroys seals, connectors, bearings, and clogs air paths. The genset's air intake is the one unavoidable open breathing path. **Mitigation:** IP66/67 sealed motor, pack, and connectors throughout (§4.2); labyrinth+lip seals on all rotating joints; multi-stage desert air filter on the genset intake; pressure-equalization membranes on sealed boxes. **Residual risk:** maintenance interval — filters and seals are consumables in the desert, and the machine must be *designed for fast field service* of them. Named, not solved-and-forgotten.

6.2 Hybrid packaging vs. Ducati mass centralization (HARD — the defining problem)

Risk: a Ducati reads as Ducati because its mass is tucked tight and central. This machine carries **two** energy systems — a ~15–18 kWh battery *and* an ICE + generator + fuel tank + two cooling loops. Naively packaged, that mass sprawls, the polar moment of inertia balloons, and the machine handles like a loaded mule, not a Ducati. **Mitigation (and why series-hybrid earns its keep):** because the ICE is mechanically decoupled (§2.1), the packaging is a **free optimization** rather than a chain-constrained one:

- **Battery** = the densest mass → sits **central, in the main frame triangle** where a Ducati's engine lives. This single choice preserves the mass centroid and the visual Ducati read at once.
- **Genset (ICE+generator)** = second-densest → mounted **low and as central as the frame allows**, below/behind the battery, keeping mass low.
- **Fuel tank** = variable mass → kept **close to the mass centroid** so the bike's balance barely shifts between full and empty (a real handling concern over a 200-mi day).
- **Axial-flux motor** (94 mm long, EMRAX) → tucks at the swingarm pivot, minimizing rear overhang. **Residual risk:** this is a genuine 3D packaging puzzle and the prototype's hardest

design task. It is *solvable* — the decoupling makes it solvable — but it is real work and it drives the whole industrial-design brief (§7). Named as the defining engineering challenge, honestly.

6.3 Thermal in desert heat (HARD)

Risk: sustained high-power draw at 45–50°C ambient is the worst thermal case; the worst *cooling* case is a stationary machine in the sun. Under-cool it and the pack derates or the machine limps.

Mitigation: dual liquid loops (LT for pack/electronics, HT for ICE), radiators sized to the still-air high-ambient worst case, high-power cells that run cooler, BMS derate as the safety net (§4.3).

Residual risk: honest performance derate at the thermal extreme — we design to hold continuous desert performance and accept that peak-on-peak-on-heat is bounded by cooling. Stated as a spec, not hidden.

6.4 Weight budget with both systems aboard (HARD)

Risk: rally-raid bikes target ~150–165 kg dry (Kove 800 X Rally claims 165 kg). This machine carries a battery **and** a genset **and** a fuel tank. A rough honest bill: motor ~12–22 kg + inverter ~10 kg + ~15 kWh high-power pack ~90–110 kg + genset (engine+generator) ~35–55 kg + fuel + frame + rally suspension + wheels. **A realistic all-up prototype is on the order of ~200–240 kg wet** — heavier than a pure rally bike, in the range of a big adventure bike. This must be stated, not buried. **Mitigation:** the pack is the dominant mass, so **size it honestly to the dynamic need, not oversized for range** (the fuel carries range — that is the whole point of the hybrid); high-power cells let a smaller pack deliver the power; the trellis frame and axial-flux motor are mass-efficient choices. **Residual risk:** this will not be a 160 kg feather. The honest positioning is "a fast, long-range desert machine in the ~200–240 kg class," and the pitch should own that number rather than imply a rally-bike weight it cannot hit. An insider who does the mass math will respect the honesty and distrust a claimed 170 kg.

6.5 Desert traction-control calibration (MODERATE, named)

Risk: off-the-shelf motorcycle stability/traction control is tuned to *prevent* wheelspin on tarmac; sand *needs* controlled wheelspin. Wrong calibration makes the bike worse than a cable throttle.

Mitigation: the hardware (IMU, VCU, e-motor torque control) is proven; the **desert slip-target calibration is bespoke software/development work** (§2.4). It is development, not invention, and the e-motor's fine torque control is what makes a good desert calibration *possible* — which is one of the strongest "why electric" arguments in the whole pitch.

7. Prototype feasibility verdict

7.1 Verdict

BUILDABLE — WITH CAVEATS, as a running prototype.

Every subsystem is real hardware from a real supplier or a proven part-class today. Nothing on this machine requires an invention. The machine is buildable by a competent small engineering team with a good fabricator, a battery integrator, and a genset integration partner. The caveats are honest and specific, not deal-breakers:

1. **The range-extender genset is a bespoke integration** — no off-the-shelf motorcycle-scale unit exists; it is engine + PM generator + controller, integrated (§2.6). Longest lead pole.
2. **The packaging of two energy systems** into one Ducati-proportioned machine is the defining design task (§6.2) — solvable *because* series-hybrid decouples the ICE, but real work.
3. **The weight will land ~200–240 kg wet** (§6.4), heavier than a pure rally bike. Own the number.
4. **Desert sealing + thermal must all be done at once** (§6.1, §6.3) — known fixes, unforgiving of any single miss.
5. **Desert TC calibration** is development work (§6.5).

This is exactly the profile a strategic investor should *want*: a machine whose risk is in **integration and engineering execution**, not in unproven physics or unobtainium parts. That is a fundable risk profile.

7.2 Critical path (longest-lead items, in order)

1. **Range-extender genset integration** (~20–36 wk) — start first; it is the long pole and the most bespoke.
2. **Frame design + fabrication** (~12–24 wk) — gates the whole rolling chassis and every packaging decision.
3. **Battery pack design + build** (~16–28 wk) — bespoke, and it defines the mass centroid the frame is built around.

These three run in parallel but interlock (the frame is designed *around* the pack and genset), so the honest prototype timeline is driven by **frame → pack → genset co-design**, not by any single part's ship date. Motor, inverter, suspension, wheels, and electronics are all shorter-lead and bought in parallel.

8. PACKAGING INPUTS — for the industrial designer

(Flagged for the render brief so the machine depicts the *ACTUAL* architecture, not a generic e-moto. Every render must be conditioned on these physical facts.)

- **Battery (densest mass, ~90–110 kg):** sits **central, in the main frame triangle** — exactly where a Ducati's engine visually sits. This is the mass anchor and the Ducati read. A sealed, liquid-cooled box; visually it can read as the "engine" block of the trellis.
 - **Traction motor (axial-flux, ~94 mm long, compact disc):** at the **swingarm pivot / low-rear**, driving the rear wheel. Short axial length means minimal rear overhang — draw it tucked, not slung out back.
 - **Range-extender genset (ICE + generator, ~35–55 kg):** mounted **low and central-rear, below/behind the battery**. It is a compact single-cylinder + generator, not a big engine. Keep it low for mass; it needs an exhaust routed away from rider/tank/pack, and an air intake with a visible heavy-duty desert air filter.
 - **Fuel tank:** positioned **near the mass centroid** (not high and forward like a road tank) so balance barely changes full-to-empty. Can wear the Ducati tank-line silhouette while sitting lower/more central than it looks.
 - **Cooling (two radiators + fans):** need **clean front-facing airflow** — this is a real tension with tight Ducati bodywork; radiators must not be blanked. Design bodywork with genuine air paths (this is a design feature to celebrate, not hide — "wind-tunnel" credibility).
 - **By-wire electronics (VCU, inverter, BMS):** in a **sealed IP67 box**, packaged in dead space around the pack; small, no styling constraint beyond being sealed and cooled.
 - **Stance to draw:** **~300–350 mm ground clearance, ~1,550–1,600 mm wheelbase, ~910–960 mm seat height, spoked 21" front / 18" rear, wide desert rear tyre, ~300/290 mm suspension travel, remote-reservoir piggyback rear shock, 48 mm USD fork.** This is a *tall, long, wide-footed rally machine with a trellis frame and Ducati bodywork language* — NOT a low sportbike. The single most important instruction: **do not draw a low-slung sportbike stance**. The magic is Ducati *language* on rally-raid proportions.
 - **Ducati cues to keep:** steel trellis tubework (visible, mechanical), tank-to-tail line, central mass, naked-mechanical aesthetic, optional single-sided swingarm (if rear width allows).
-

9. COST INPUTS — for the cost / prototype analyst

(Component list with the expensive and long-lead items called out. These are the cost drivers to build the honest prototype cost band around. Dollar figures are deliberately NOT asserted here — the analyst grounds them; this flags WHAT drives the cost.)

High-cost / bespoke (the cost drivers):

- **Battery pack** — the single largest component cost; ~15 kWh of high-power cells + BMS + sealed liquid-cooled enclosure, bespoke-built. Cost scales with kWh and cell choice (Molicel high-power cells cost more per kWh than commodity high-energy cells).
- **Range-extender genset** — bespoke integration cost (engineering + engine + PM generator + controller); high NRE (non-recurring engineering) because nothing off-the-shelf exists.
- **Frame** — bespoke design + jig + fabrication; NRE-heavy for a prototype (one-off tooling).
- **Traction motor (EMRAX/YASA)** — specialist axial-flux motor; several thousand €/unit class, low-volume pricing.
- **Inverter (Cascadia-class)** — motorsport/HEV inverter; four-figure component.
- **Suspension (WP/Öhlins rally)** — racing-spec fork + shock; premium four-figure set.

Moderate:

- Wheels (spoked rally set), tyres + mousse, brakes, by-wire throttle + VCU, IMU/stability ECU hardware, sealed connectors & harness, cooling hardware (radiators, pumps, fans).

Effort/NRE line items (not a part, but real prototype cost):

- Battery pack engineering & test.
- Genset integration engineering.
- Frame design & fabrication.
- Desert TC / control software calibration.
- Assembly, instrumentation, and desert test program.

Analyst flags: the prototype cost is **NRE-dominated** (bespoke frame, pack, genset engineering), not part-cost-dominated. Build the band as *components + NRE + test*, and call out that a first prototype is far more expensive per-unit than any production estimate — an insider expects to see that distinction, and expects the frame/pack/genset engineering to be the biggest lines.

10. Source ledger

Every load-bearing spec above traces to one of these, fetched 24 Sep 2026:

- **EMRAX 268 motor** — owner's datasheet v1.5 (emrax.com PDF): 210 kW peak / 117 kW cont, 500/250 Nm, 21.4–22.3 kg, IP66 liquid-cooled, 100–830 V. *Read on EMRAX's own page.*
- **EMRAX 228** — 12.2 kg, 100 kW peak, 30–50 kW cont, IP21/IP65 (builder-community spec; **to confirm on EMRAX's own 228 datasheet before BOM lock**).
- **YASA 750R** — yasa.com + Stealth EV package sheet: 700–790 Nm peak, 200 kW peak, ~37 kg, >95% eff.
- **Cascadia Motion PM250DZ inverter** — EV West / Cascadia data: 450 A cont / 600 A peak, 300–800 VDC, ~300 kW, explicitly HEV/off-road rated.
- **Molicel P42A / P45B cells** — About:Energy (manufacturer-sourced): 216 / 231 Wh/kg, 4.2 / 4.5 Ah, 45 A continuous.
- **LG M50LT cell** — About:Energy: 270 Wh/kg, 4.8 Ah, 14.4 A (the high-energy contrast).
- **Suspension travel** — KTM 450 Rally Replica: 304 mm front / 280 mm rear WP XACT PRO (bikes4sale, KTM-derived spec); KTM 890 Adv R Rally 270 mm WP XPLORE PRO (carbike360); Kove 800 X Rally 270/250 mm (dirtandtrail); KTM 790 Adv R Rally seat height 910 mm consequence (enduro21).
- **Range-extender context** — MAHLE compact range-extender page (series-REEV definition); Brogen range-extender systems (smallest listed 65/80 kW, 270 kg — confirms no moto-scale off-the-shelf unit); Horse Powertrain B15+EG50 (car REEV).
- **Ride-by-wire** — standard on premium motorcycles for 10+ years (Ducati/KTM/Yamaha YCC-T/Aprilia; PRNewswire/Research & Markets).

Estimates (range consumption, pack sizing, genset sizing, weight, lead times) are flagged in-line as engineering estimates with their basis; they are not vendor-quoted numbers and are marked as such so no false precision reaches an insider's hands.