

Open Wheel Assist

OWA-W

A low-cost, open, removable dual-motor assist kit for ordinary manual wheelchairs
— help on slopes without taking away manual control.

RESEARCH PROTOTYPE — NOT A CERTIFIED PRODUCT

Stage
TC-WA-00 Concept / Feasibility

Risk class
TC-R3 High

Evidence
E0-E1 (calculation only)

Document
OWA-W-PKG-001 rev A · 12 Oct 2026

Slopes, not flat ground, are where manual wheelchair users lose independence

Keep the simplicity and independence of a manual wheelchair — add low-cost assistance only when the user needs it.

- Commercial power-assist costs several thousand euros (SmartDrive MX2+: £6,395 incl. VAT, UK retail).
- Products are proprietary, dealer-serviced and often not reimbursed.
- OWA-W targets **≈ €450 in parts**, built and repaired by a bicycle or electronics workshop.

Who it is for

Adults (≤ 100 kg) who self-propel a rigid or folding manual chair and struggle with ramps or fatigue.

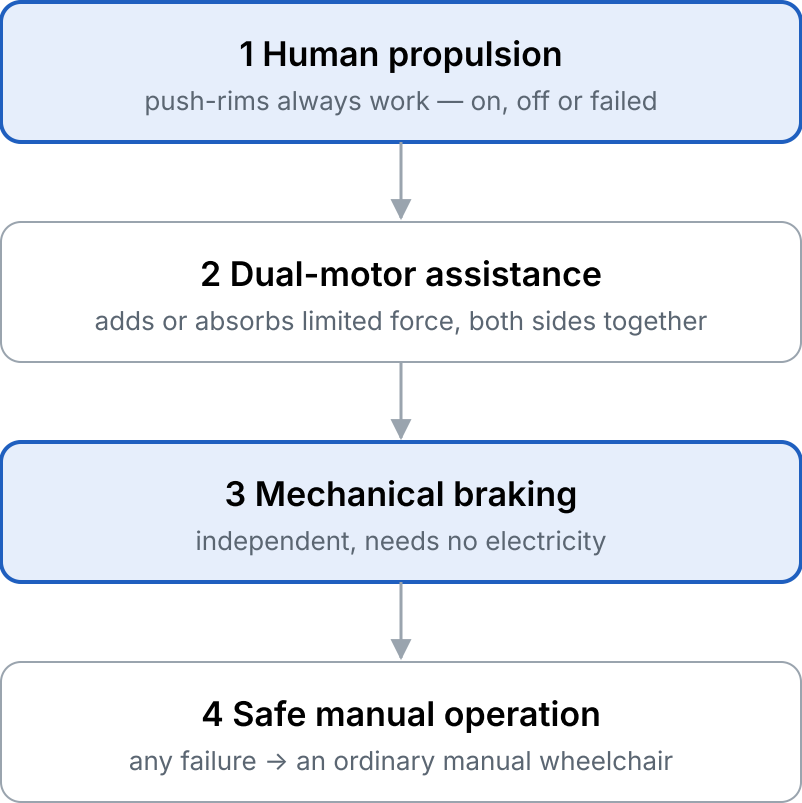
Not for — initially

Users who cannot self-propel or operate push-rim brakes, children, tilt/recline or bariatric chairs.

Who carries the risk

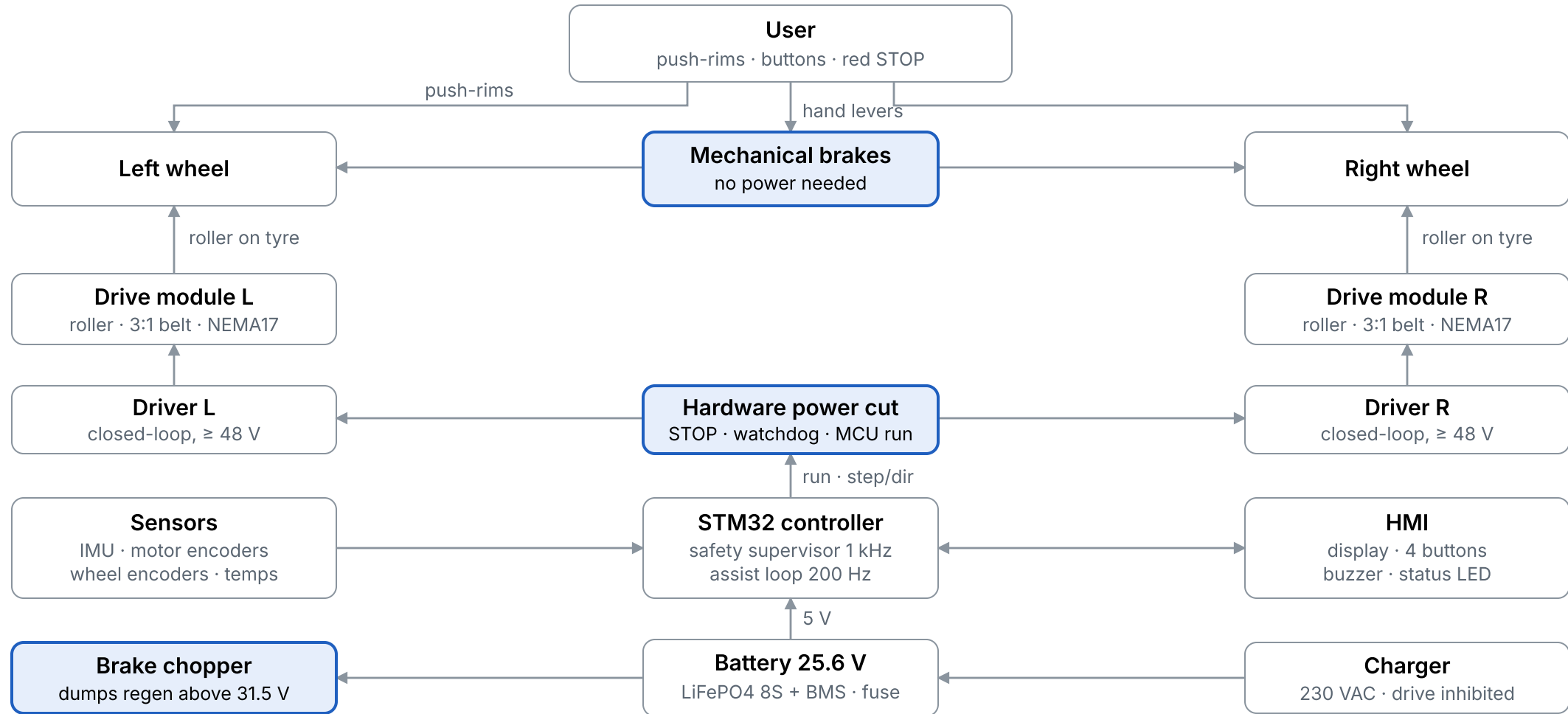
The user (runaway, tip, sudden loss of assist), bystanders, and anyone building a community copy.

The motors are assistants; the person and the mechanical brakes stay in charge

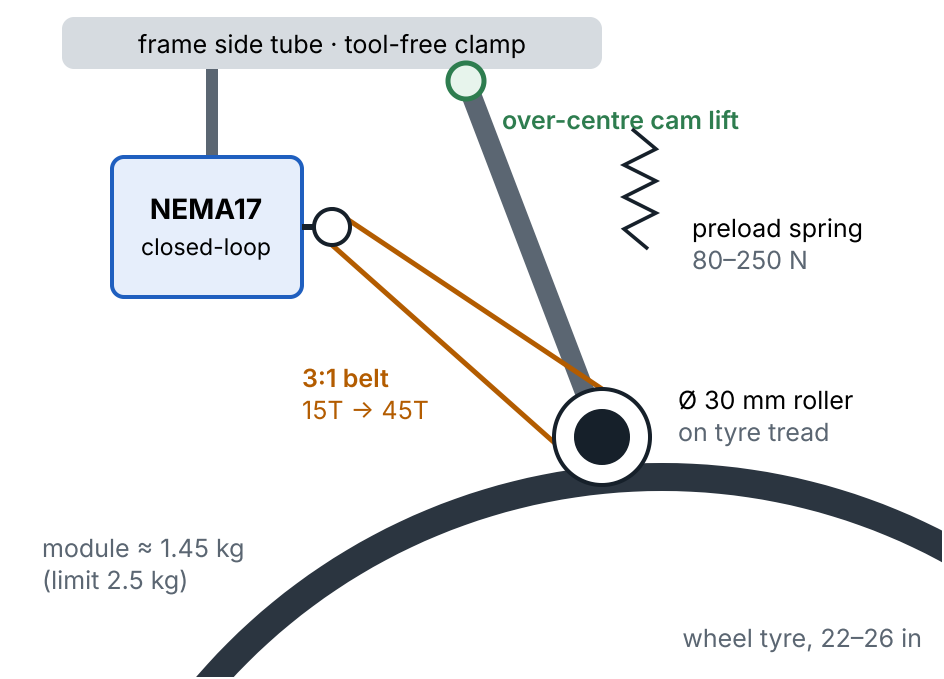


MODE	WHAT HAPPENS
MANUAL	No assist; rollers lifted off the tyres, zero drag. Default at power-up.
ASSIST	User moves the chair; motors add limited, ramped force. Never starts on its own.
UPHILL	IMU detects grade; both motors add more force, smoothly limited.
DOWNHILL	Motors provide damping only — labelled and treated as <i>not</i> a brake.
HILL HOLD	Short electronic hold when stopped; mechanical brake still required.
PARK	Conventional mechanical parking brakes.
STOP	Red button cuts motor power in hardware, ≤ 100 ms.

Two layers: assist can fail completely and the chair is still a manual wheelchair



Each side: a clamp-on swing-arm roller drive that a cam lifts fully off the tyre



Disengagement options compared

CONCEPT	DRAW IN MANUAL	FAILURE DIRECTION	SCORE
Swing arm + cam lift	Zero	Spring fails → disengaged	5
Electromagnetic clutch	Low	Open on power loss, may stick	3
Servo-actuated cam	Zero	Fault may leave it engaged	3
One-way freewheel	Low fwd, high back	No descent damping, blocks reverse	2
Belt de-tension lever	Roller still drags	Belt may jam	2

Checks still open: self-energising contact angle must not jam in reverse (DF-03); the module must not obstruct the parking brakes (H-03); anti-tippers are mandatory whenever assist is fitted.

A typical 1:16 ramp needs about 89 N at the tyres for a 121 kg chair and user

GRADE	TYPICAL PLACE	GRAVITY N	ROLLING N	TOTAL N	POWER AT 2 KM/H
0 %	Flat pavement	0	17.8	17.8	10 W
4 %	Gentle street	47.5	17.8	65.3	36 W
6 % (1:16)	Typical ramp	71.1	17.8	88.9	49 W
8.3 % (1:12)	Max public ramp	98.5	17.7	116.2	65 W
12 %	Steep driveway	141.4	17.7	159.1	88 W

Load case

User 100 kg + chair 15 kg + kit 6 kg = **121 kg**

Rear wheel 24 in, $r \approx 0.30$ m

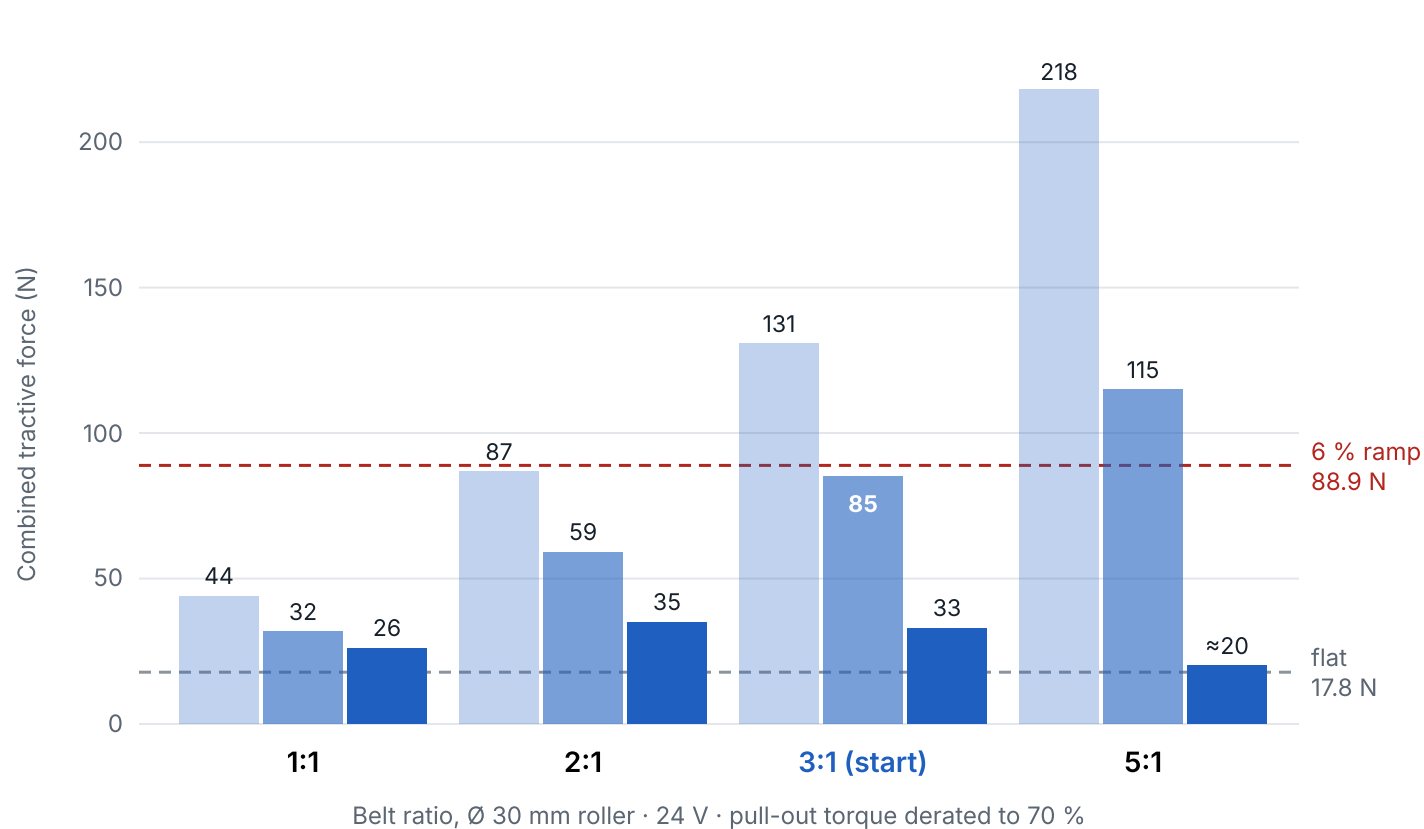
$C_{rr} = 0.015$ smooth (0.03 rough: +18 N)

$$F = m \cdot g \cdot \sin \theta + C_{rr} \cdot m \cdot g \cdot \cos \theta$$

All values are combined for **both** wheels. The user's own push supplies the remainder — OWA-W assists, it does not replace the user.

Evidence E1

At 3:1 the two motors nearly cover a 6 % ramp at creep speed — but not at walking speed



- Hold at standstill
- 0.5 km/h (creep)
- 2 km/h (slow walk)

Roller size and belt ratio act only as one combined gearing $G = i / r$; force depends on G alone.

The steppers are **power-limited**: $\approx 15\text{--}20\text{ W}$ mechanical each at 24 V. Higher gearing buys hold force, not speed.

Assumed 48 mm-stack NEMA17, $\approx 0.55\text{ Nm}$ holding. To be replaced by measured curves in TC-WA-01.

Evidence E1

OWA-W is realistic as slope creep-assist, hill hold and descent damping — not as 6 km/h drive

1 · Ship with a 4 km/h cut-off

6 km/h stays a hypothesis; $2 \times 15\text{--}20\text{ W}$ cannot assist at that speed on any slope.

3 · Wet roller grip is the limit

$\mu \approx 0.6$ dry vs 0.3 wet $\rightarrow 110\text{ N}$ vs 225 N preload for 45 N per side. One-sided slip is a yaw hazard.

5 · Hill hold is not a brake

$\approx 130\text{ N}$ hold exceeds 6% demand, but vanishes with power loss, faults or slip.

7 · Cut standstill current

$\approx 9\text{ W}$ per idle motor; firmware drops to hold current or disables the drivers.

2 · Test 24 V and 36 V

Stepper torque at speed rises with bus voltage; 36 V could roughly double force at 2 km/h (E0).

4 · Closed-loop steppers are mandatory

Open-loop steppers stall silently and force collapses to zero. Encoders detect it in time.

6 · Descent energy needs a dump

Up to $35\text{--}40\text{ W}$ on an 8% descent; if the BMS refuses charge, a hardware brake chopper absorbs it.

Battery is not the constraint

$\approx 55\text{ W}$ during assist; $240\text{ Wh} \rightarrow \approx 4\text{ h}$ continuous, a full day at $15\text{--}20\%$ duty. **Force is.**

STM32 controller, hardware safety chain and a LiFePO4 pack

Controller: STM32

- Hardware quadrature encoders, deterministic safety loop
- No radio → Radio Equipment Directive does not apply
- ESP32 only as an optional helper, never in the safety path
- Starts in MANUAL, assist level 0

Safety chain (no firmware)

- STOP (NC) · watchdog · MCU run → hardware AND → motor power
- Both drivers cut together, ≤ 50 ms on asymmetry
- Brake chopper above 31.5 V, TVS backup
- Charging inhibits drive

Battery: LiFePO4 8S

- 25.6 V, ≈ 8–10 Ah, 205–256 Wh
- Lower fire severity, ≈ 2,000+ cycles
- ≈ 0.5 kg heavier than Li-ion — accepted
- Certified 29.2 V charger (IEC 60335-2-29), stays on chair

SENSOR	PURPOSE	SAFETY USE
Motor encoders ×2	Stall detection, closed loop	Yes — asymmetry cut
Wheel encoders ×2	True speed; compare with roller speed to detect slip	Yes — slip and yaw
IMU (6-axis)	Grade, pitch rate, yaw rate	Yes — tip-back cut-off
Bus V/I, motor NTC ×2	Load, regen, thermal derating	Yes

Once given to anyone — even free — OWA-W is an MDR Class I medical device

- **EN 12184:2022** explicitly covers manual wheelchairs with an add-on electrically powered drive and push-assist wheelchairs.
- Comparable add-ons (Alber/AAT, munevo) declare **Class I, Annex VIII Rules 1 + 13**, citing EN 12184 and ISO 7176-14/-21.
- Publishing designs ≠ placing on the market — to be confirmed with **JAZMP**.
- A workshop building a kit for someone else becomes the **manufacturer**.
- Decision: design to the Class I file from day one.

No claims of: preventing shoulder injury, reducing falls, improving health outcomes, or being safe for daily use.

STANDARD / LAW	COVERS
MDR 2017/745	Technical file, QMS, PRRC, UDI, PMS
ISO 7176-1/-2	Static and dynamic stability
ISO 7176-3	Brakes
ISO 7176-14	Power and control systems
ISO 7176-21	EMC
ISO 7176-8/-9/-25	Strength, climate, batteries
ISO 14971 · IEC 62304 · IEC 62366-1	Risk, firmware, usability
Battery Reg. 2023/1542 · RoHS · WEEE	Battery and electronics
ZPrCP (Slovenia)	Road status — open question

Six catastrophic hazards — each one that design can reach has a hardware control

ID	HAZARD	KEY CONTROL	VERIFIED BY
H-01	Runaway on descent; motors stall or slip	Independent mechanical brakes; motors only damp	V-02, V-11
H-02	Excess assist → rearward tip	Force ramp ≤ 40 N/s, pitch-rate cut-off, anti-tippers	V-06
H-05	One side loses drive → swerve	Both sides off ≤ 50 ms, closed loop, slip compare	V-05
H-07	Battery thermal runaway	LiFePO4, BMS, V-0 enclosure, certified charger	V-13
H-10	Clamp loosens → module in spokes	Captive pin, positive stop, fatigue test	V-21
H-14	Faulty community build	Build checklist, self-test, "reference ≠ validated" labelling	Documented residual risk

15

hazards identified (ISO 14971 style)

8 / 14

DFMEA lines at High action priority (AIAG-VDA)

12 / 21

verifications that test failure or misuse, not normal use

Four weeks on the bench replace every calculated number with measured data

STEP	TEST	OUTPUT
T1–T2	Holding and pull-out torque, 50–1,500 rpm, 24 V and 36 V	Torque vs RPM
T3–T4	Current and efficiency across load	Current vs Torque, Efficiency vs Load
T5–T6	30 min endurance; standstill heating	Temperature vs Time
T7	Both motors into one load shaft	$F_{\text{TOTAL}} = F_L + F_R$ measured
T8	Back-drive with BMS charge open	Bus voltage, chopper duty
T9–T10	Fault injection, stall detection	Time to zero torque
T11	Display in sunlight, gloved buttons	HMI observations

Gate G2 decision rule

GO — ≥ 40 N combined at 2 km/h, thermal limits met

RE-SCOPE — 25–40 N: creep-assist ≤ 1.5 km/h with panel agreement, or BLDC fallback

STOP stepper path — < 25 N or thermal fail; publish as an open negative result

No wheelchair, no person. Budget $\approx$ €500 test equipment + €200 motors.

About €460 in parts — roughly a tenth of the leading commercial power-assist

OWA-W kit (parts)



SmartDrive MX2+ (UK retail, incl. VAT)



Bar lengths to scale (£6,395 ≈ €7,400 at an assumed £1 = €1.16).
Different products: SmartDrive is a validated, certified device.

LARGEST COST ITEMS	€
Battery pack (LiFePO4 8S, BMS, enclosure)	100
2 × closed-loop NEMA17 + driver	80
2 × swing arm, clamp, spring, cam	50
Charger (certified)	30
Everything else (14 lines)	200

7

LOCAL

10

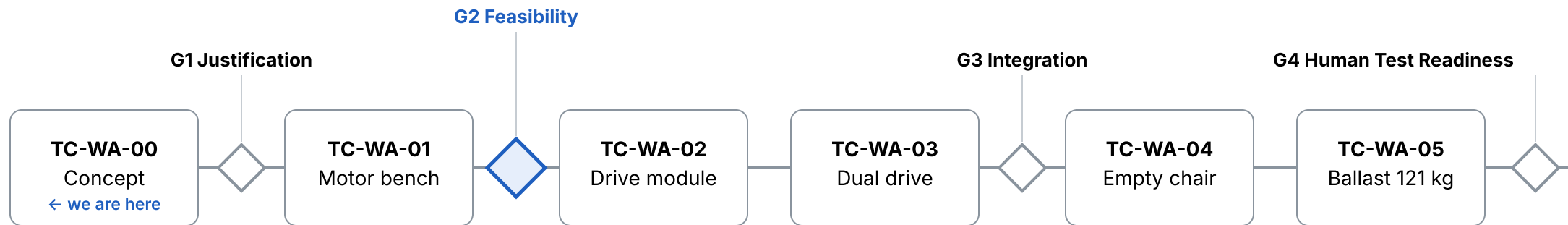
REGIONAL

1

SPECIAL

Metric hex fasteners only · no drilling of the chair · one-off retail estimates (E0).

Six stages and four gates before any human contact



G1: panel confirms VoC · JAZMP query sent · independent reviewer named

G2: ≥ 40 N at 2 km/h → go · 25–40 N → re-scope · < 25 N → stop stepper path

G3: V-01, V-05, V-07 and V-08 pass on the dual fixture

G4: all safety-critical tests pass · ISO 7176-21 EMC · independent review · ethics and informed consent

After G4 only: open custom PCB, then a controlled field pilot. No final CAD or PCB routing before G2.

What OWA-W needs now to reach Gate G1

Actions

- Recruit an advisory panel: ≥ 3 self-propelling users, a caregiver, a wheelchair technician, an OT
- Interview the panel and survey 3 real daily routes (slopes, kerb ramps, surfaces)
- Send a written status query to JAZMP on open-source publication
- Name an independent safety reviewer (not the designer)
- Buy two candidate motor pairs and build the TC-WA-01 rig

How to contribute

Wheelchair users and therapists

Join the advisory panel — every user need is still an assumption (E0).

Engineers

Review the feasibility calculations, safety chain and bench test plan.

Workshops

Help define what a local bicycle or electronics shop can build and repair.

Affordable. Open. Repairable. Modular. Human-controlled.

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