



WEARABLE COMMUNICATION / SEPT-OCT 2026

Fermata

A quiet signal.
A chosen reply.

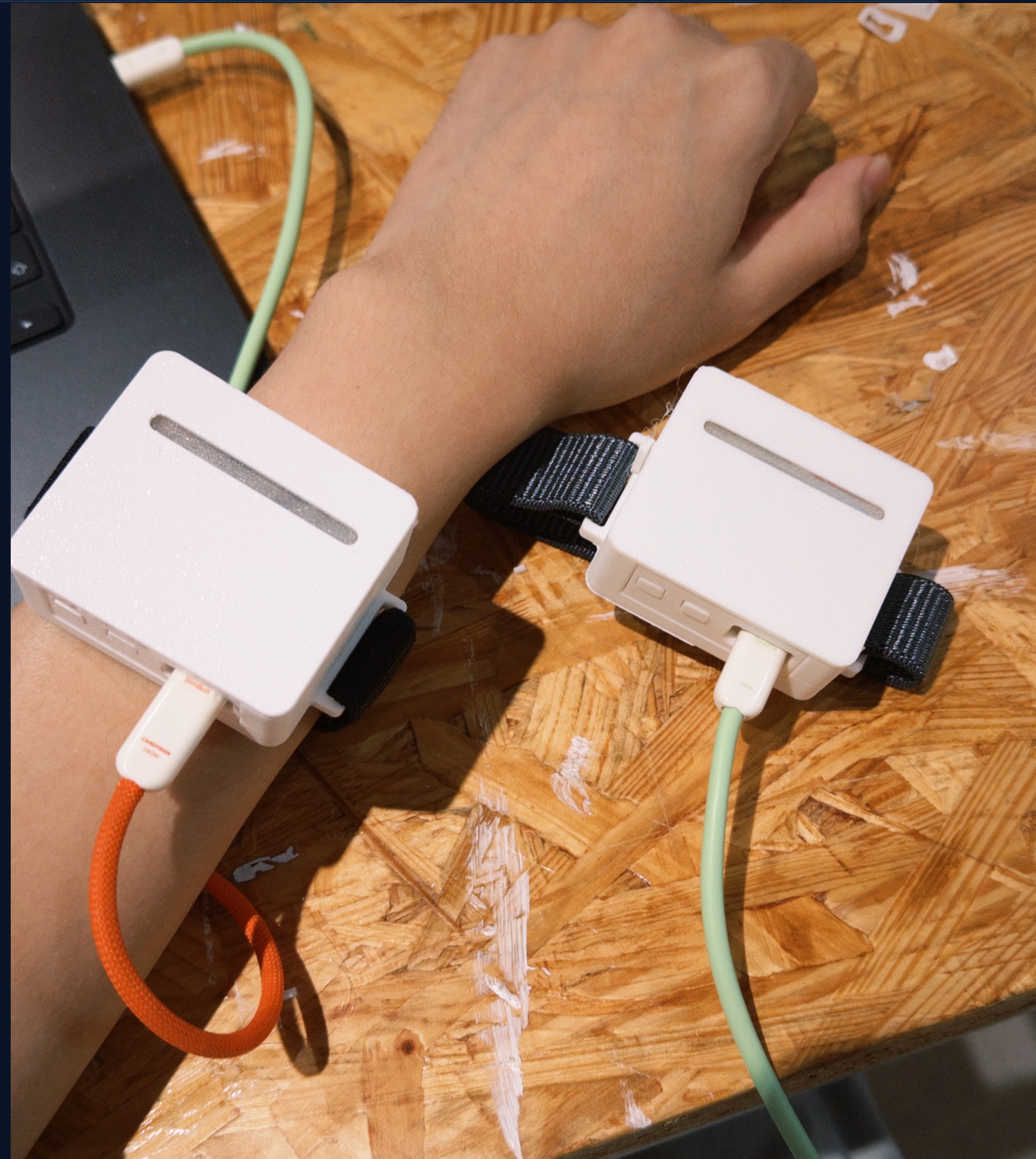
A pair of local, haptic wristbands for moments when eyes and hands are already occupied.

在两个人之间，留一个回应的余地。

RESEARCH PROTOTYPE / EDITION 24 OCT 2026

Interaction / electronics / firmware / physical integration

Actual photograph: author-supplied worn prototype, 19 October 2026.
Technical edition. Development tests and proposed user research are distinguished.





Three cues. One deliberate conversation.

A small vocabulary keeps the sender's intention and the recipient's choice visible.

设备收到，不等于人已理解。



Attention

I want to reach you.



haptic cue + optional light



Got it

I choose to respond.



haptic cue + optional light



Wait

I need a moment.



haptic cue + optional light

Left: generated product visualization based on the author's real photograph; not a new physical test. Cue mapping: Pair v326-v328 firmware. The pulse marks are semantic illustrations, not measured actuator waveforms.

The research becomes a testable choice.

A musical starting point narrowed into a two-person question.

研究不是装饰：每条依据，都要落到一个设计决定。

RESEARCH BASIS

R1 / TACTONS

Rhythm, duration and other tactile parameters can form structured messages.

DESIGN CHOICE

Keep the vocabulary small.

WHAT TO CHECK

Can a wearer distinguish the cues and remember their meaning?

R2 / MUSICAL HAPTICS

Co-design connects body placement, shared activity and performance constraints.

Test the whole wearable.

Does placement or musical activity change noticeability and comfort?

R3 / HAPTIC ICONS

Noticing a cue and identifying it are separate measures.

Separate delivery, noticing and reply.

Which stage failed when no response arrives?

COMMON GROUND

audience observation + room-scale light

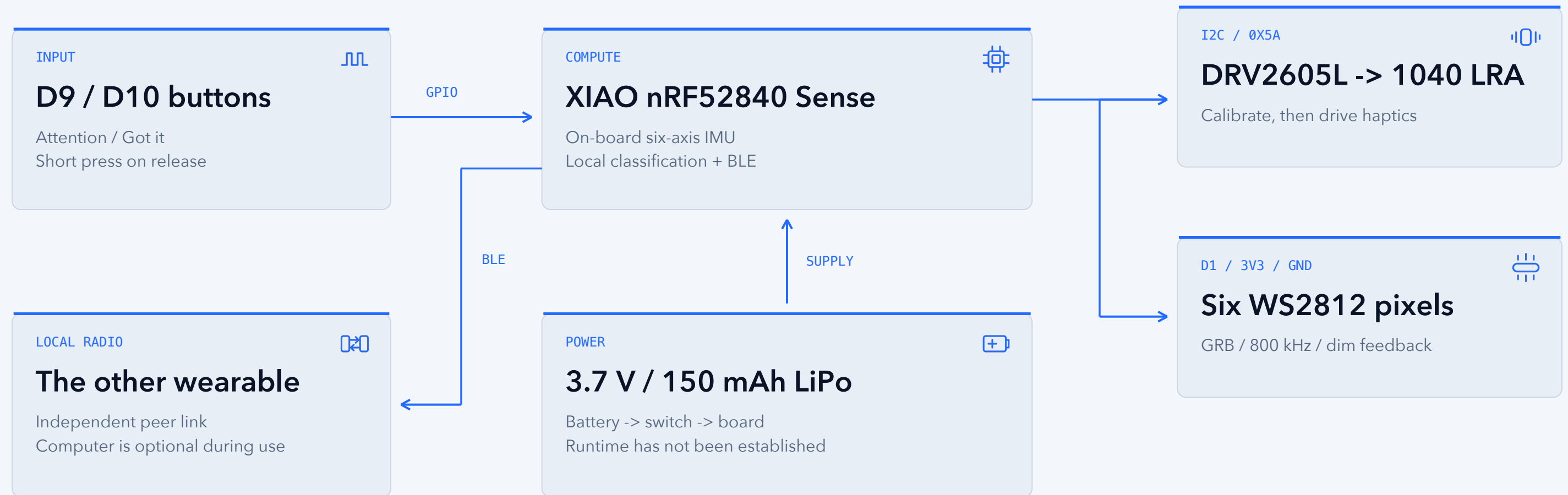
FERMATA

two people / intentional cue / explicit reply

R1: Brewster & Brown (2004). R2: Turchet & Barthet (2019). R3: Chan, MacLean & McGrenere (2005). References on page 20. Common Ground contributes the origin story; its audience camera and uncompleted interview/persona sections are not current results.

One controller. Two channels of feedback.

October prototype topology, redrawn from the firmware and collaborator PCB review.

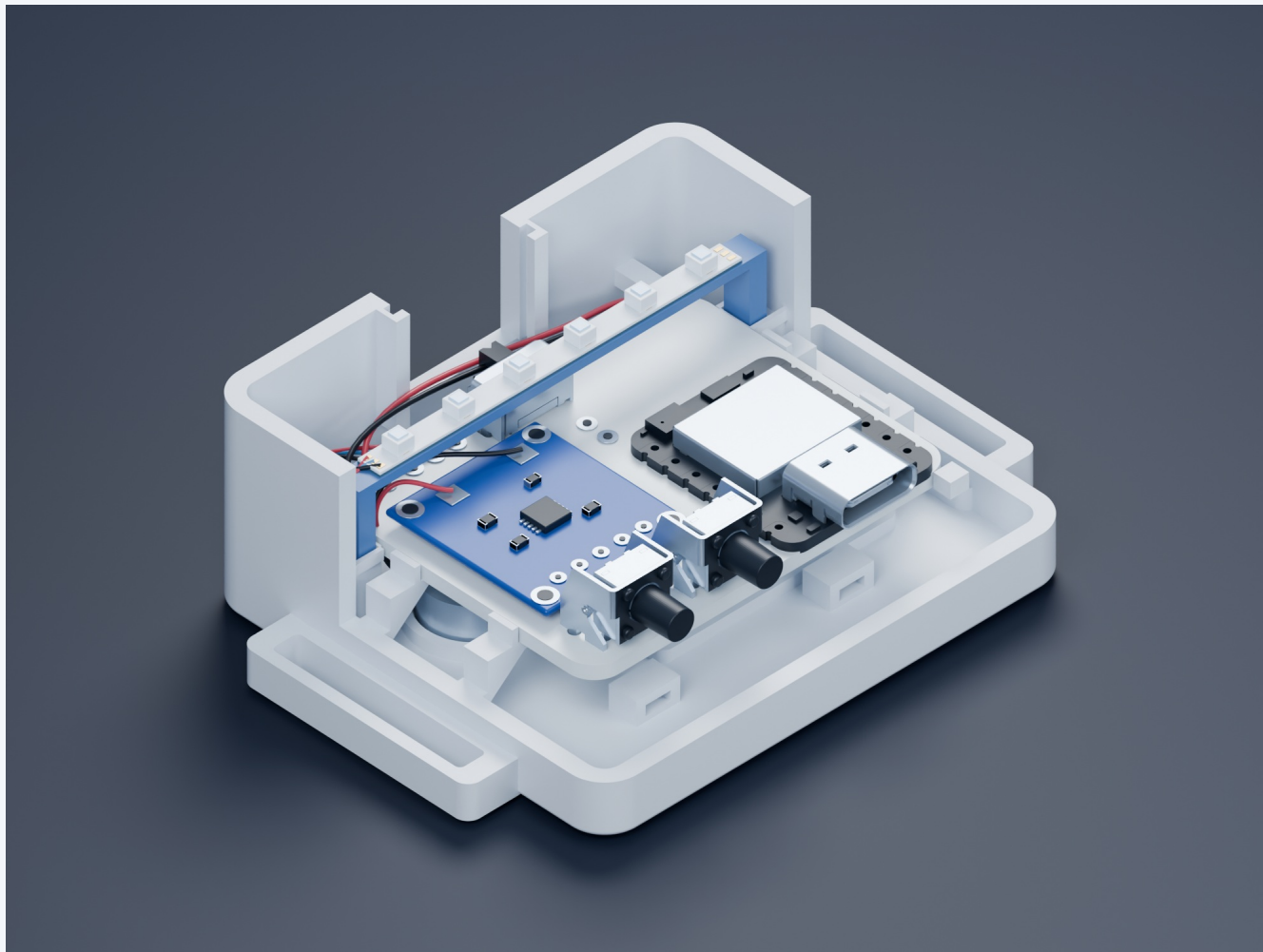


Sources: Pair v328 Hardware/Config/Protocol; October 9 hardware record; September 27 PCB review. Logical topology, not a fabrication schematic. Actual 3V3 LED setup is documented; exact LED subtype and long-term supply suitability remain open.

The carrier is only part of the electronics.

Source geometry and an organized assembly study are shown as separate evidence layers.

01 / ASSEMBLY RECONSTRUCTION



02 / SOURCE CARRIER GEOMETRY



42.97 x
32.98 mm

1.60 mm board body.
Collaborator-supplied CAD.



ADDED TO THE CARRIER

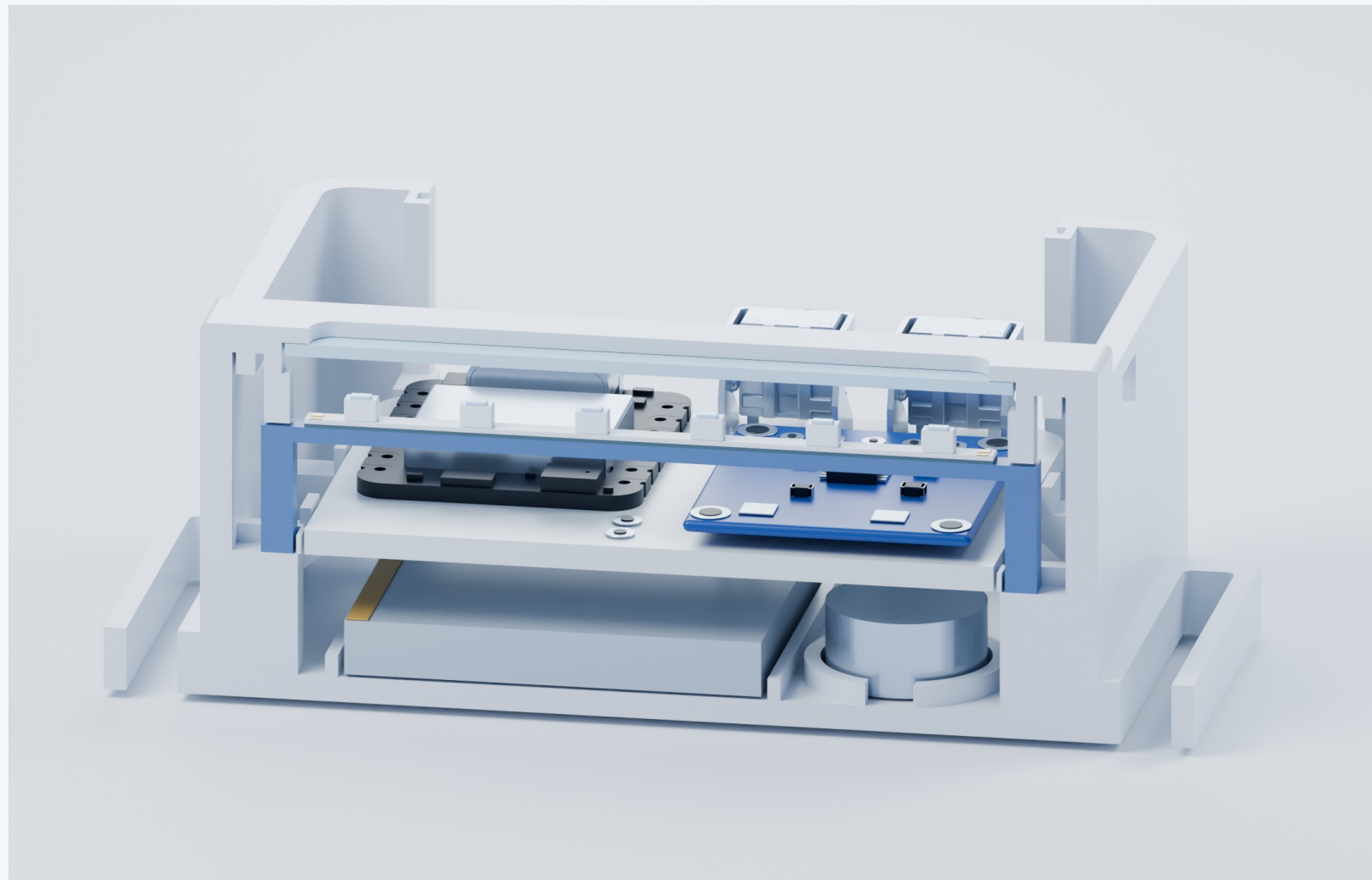
Driver / six LEDs / leads / battery / LRA
Archived light bridge and shell supports

Cutaway study: the straight strip rests on the archived bridge.

Organized assembly study: source carrier and shell/bridge CAD, photo-guided modules, user-reported battery/LRA dimensions and schematic leads. Driver size and LED spacing remain approximate; six LEDs follow configuration and user confirmation. PCB: collaborator. Final placement, wiring and fit remain unverified.

The light strip needs a place to rest.

The bridge, shell supports, diffuser and light window form one mechanical path.



01 / SUPPORTED STRIP

Archived bridge and two feet seat on the shell. A 0.2 mm adhesive layer is an assumption.

02 / LIGHT PATH

A 0.8 mm diffuser sits above the LED envelope, with a nominal 2.35 mm clearance.

03 / RESTRAINT & SERVICE

v1.3.1 lid: four flat PCB stops and two quarter-turn keys. Controls and wire exits remain accessible.

04 / BODY CONTACT

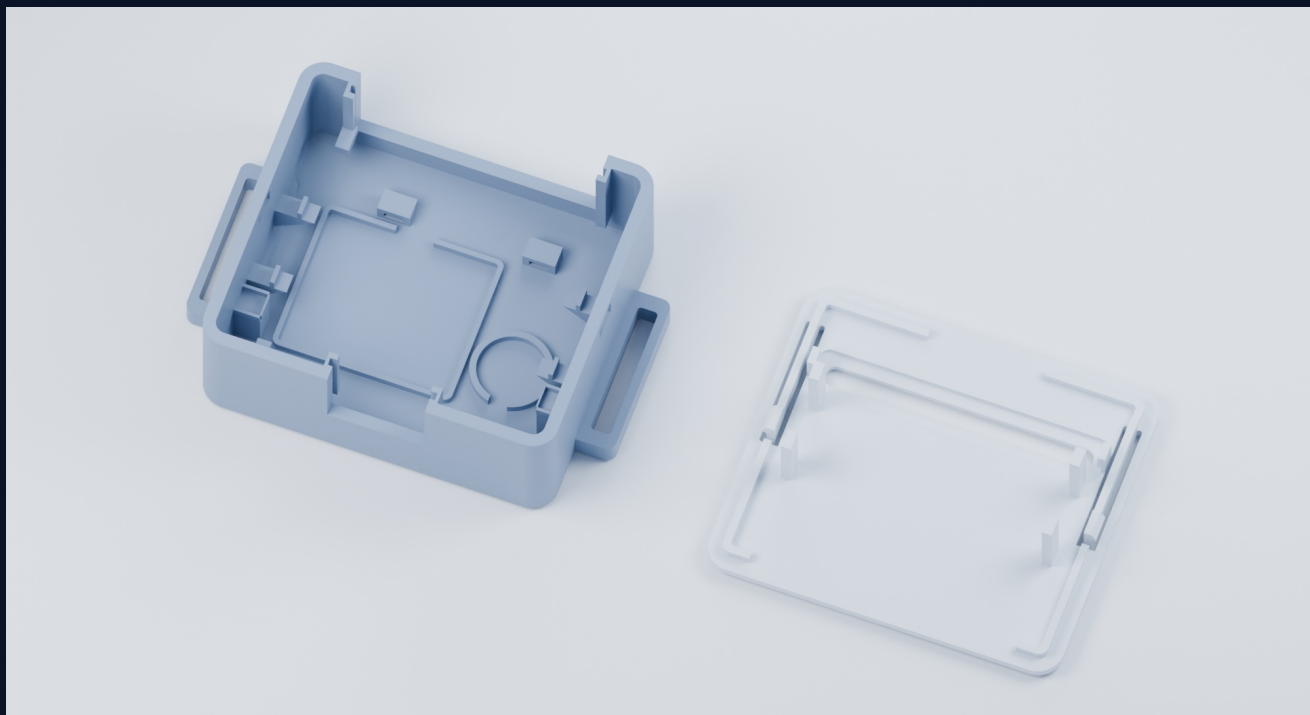
Battery and LRA sit below the board; the base and strap carry the body-facing assembly.

Nominal CAD section, not an assembly measurement: bridge top Z17.6; LED base Z17.8; LED thickness 2 mm is the archived CAD assumption. Battery 26 x 22 x 3.5 mm and LRA diameter 10 x 4.8 mm are user-reported envelopes. Driver/LED details and schematic leads remain approximate; fit and tactile coupling need physical checks.

Fit is something the parts have to prove.

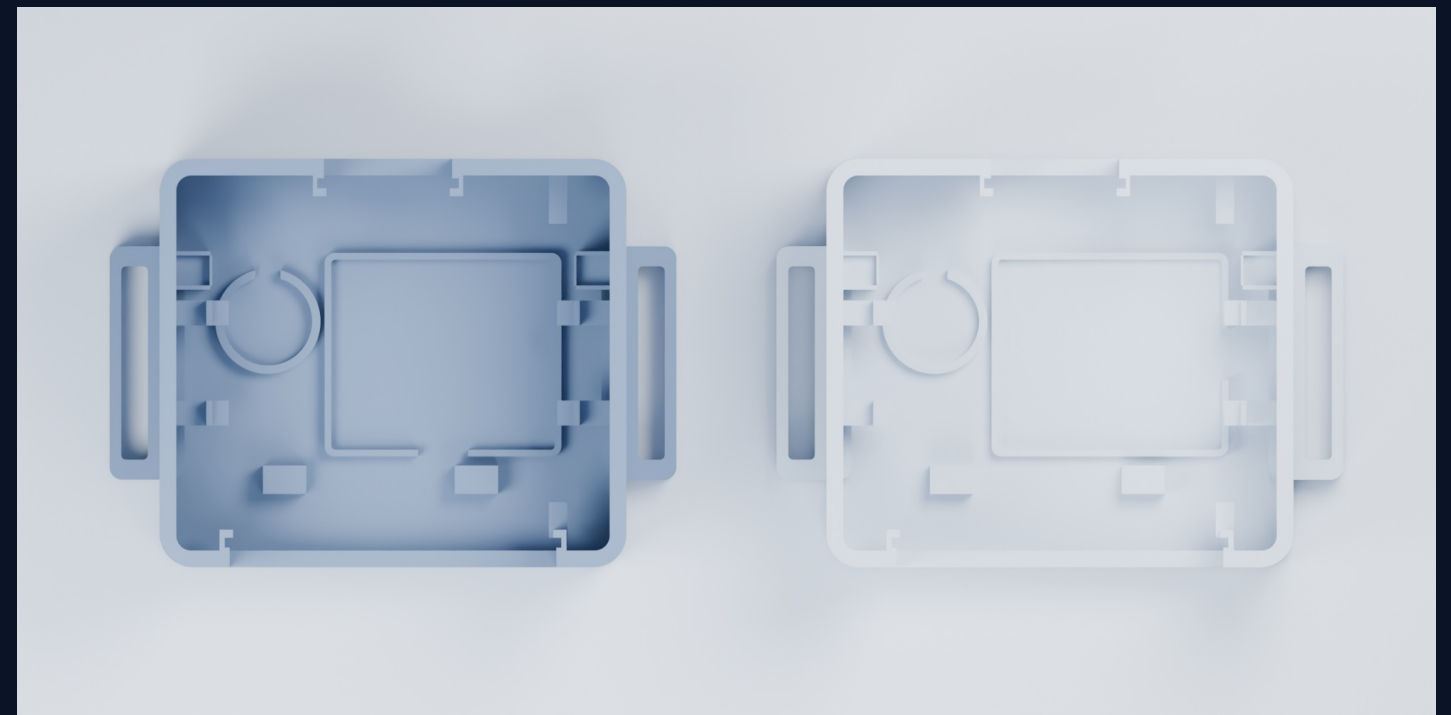
A plausible CAD explanation can be corrected by the real assembly.

装配反馈改变设计，也会推翻先前的判断。



V1.0 / HISTORICAL SNAP STUDY

Nut-fit failure -> a fastener-free study.



V1.1 TO V1.3.2 / WIRE ROUTE

A short-edge outlet creates a deliberate lead path.

Archived meshes with illustrative colors. Snap latches, retained/sliding lids and the battery opening are distinct revision studies. A suspected short button actuator was later traced to reversed installation; that diagnosis was withdrawn rather than preserved as a design success.

A readable interface for an ambiguous signal.

Observe the raw motion, mark the intended action, then inspect the event trail separately.

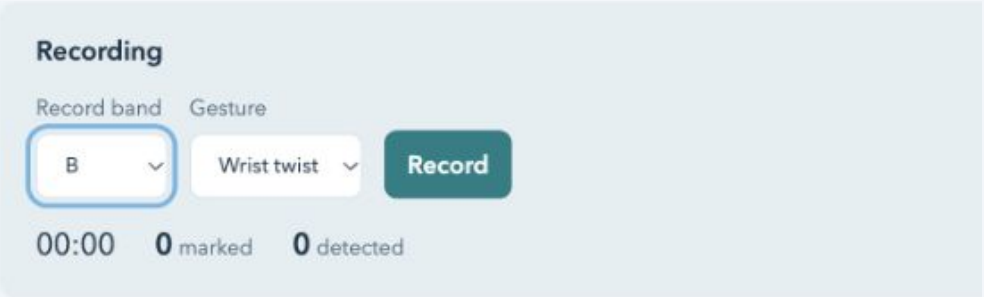
01 / OBSERVE THE LIVE SIGNAL



Actual historical A/B interface capture. Each band keeps its own waveform, power state and latest event.

Original screenshot: Pair v328 results/dual_ble_battery.png, 906 x 817 px. All closeups clip those original pixels. This historical UI capture is not the selected USB recording shown on the following pages. Exact event tracing is reconstructed from source logs, not invented as a UI screenshot.

02 / SELECT & MARK



The screenshot displays the 'Recording' section of the interface. It features a 'Record band' dropdown menu set to 'B', a 'Gesture' dropdown menu set to 'Wrist twist', and a 'Record' button. The status bar shows '00:00', '0 marked', and '0 detected'.

Choose a band and gesture. Recording locks the panel role and feedback controls; physical buttons remain active.

SYSTEM OUTPUT IS A SEPARATE OBSERVATION



The screenshot displays the 'Last: wrist twist' event output. It shows 'B received' and '2m ago'.

A mark records the action attempt. The firmware may still reject it; its output must not rewrite the label.

Record what happened, not what should happen.

The panel is a research instrument: role, transport, clocks, labels and output events stay explicit.

按真实动作标记；设备漏识别，也不能改写标签。

03 / TRACE A REAL SESSION

20261019_142008_test_cc691f

Band A / v326 / recognizer v322 / USB / Test

2.347656 s	Cycle 1 marked
3.938476 s	Cycle 2 marked
4.612000 s	Wrist turn recognized
4.613000 s	Attention request
4.615000 s	Local motor starts
4.616000 s	Transmit attempt 1
4.661000 s	Device ACK on A
4.926000 s	Local motor finishes

A-device excerpt clock. Human marks use the latest received sample; no explicit group-onset mark exists here.

Source: Recognition Panel capture code and recorded-event-story-v4.json, with original log lines and hashes. Packet session 1957751726 / sequence 8 / Attention. One band is recorded at a time. This record does not establish B playback, felt sensation or a human reply. Device, host and browser clocks are not interchangeable.



THREE TIME REFERENCES

Device

unwrapped device_us

Host

monotonic receipt time

Human

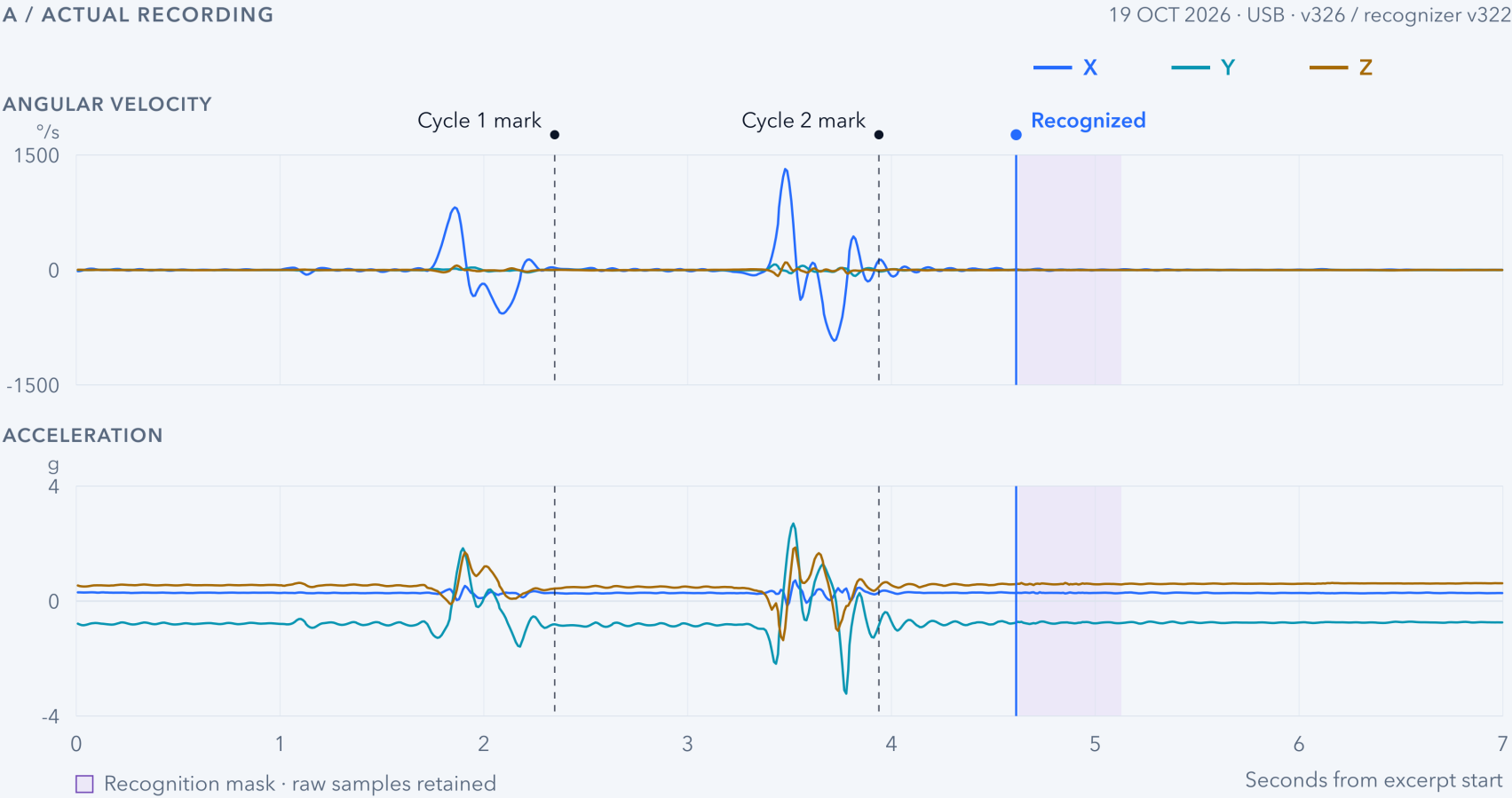
browser / cycle marker

SAVE A SESSION, NOT JUST A GRAPH

imu.csv + markers.jsonl + sample_timing.jsonl
session.json + SHA-256 manifest
pair_events.jsonl (later captures / where available)

The waveform, the mark and the event differ.

A real six-axis recording connects physical movement to the system's interpretation.



4.612 s

local recognition

4.615 s

local haptic start

4.661 s

device receipt

One selected example. Cycle markers include human reaction delay; device receipt does not establish human perception.

Actual recorded data. Cycle markers are human annotations; accepted events are firmware outputs; haptic masking excludes samples from recognition while raw logging continues. Source session and timing caveats are embedded in the chart/provenance record.

729 RAW SAMPLES

A seven-second excerpt from band A, v326 / recognizer v322, over USB.

4.612 S / RECOGNITION

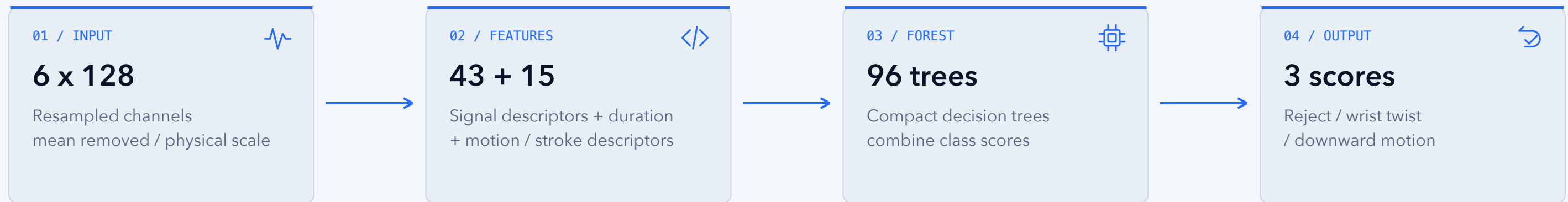
Local motor start follows at 4.615 s. Device delivery ACK is logged at 4.661 s.

53 MASKED ROWS

Motor activity cancels recognition candidates. All raw samples remain in the capture.

58 descriptors turn a motion window into evidence.

Six channels are resampled to 128 frames; the model receives both signal shape and motion structure.



RFCORE.H / FEATURE EXTRACTION

```
features[12+d] = float(min);
features[18+d] = float(max);
features[24+d] = float(absSum/FRAMES);
features[30+d] = float(crossings);
features[36+d] = float(diff/(FRAMES-1));
```

43 / SIGNAL DESCRIPTORS + DURATION

Seven statistics x six channels = 42
plus window duration = 43

15 / MOTION STRUCTURE

stroke counts / angle ratios / axis energy
quiet fractions / gyro norm / longest quiet interval

Sources: current Pair v328 RfCore.h and RfModel.h; aligned training feature pipeline. Current A326/B328 retains recognition lineage v322. A classifier score is one gate in a streaming system, not evidence of a successfully communicated human message.

Train offline. Decide causally on the wrist.

Windows and feature extraction must mean the same thing in Python and C++.

训练与运行，必须看到同一种动作窗口。

[TRAIN_ALIGNED.PY](#) / [FORMATTED SOURCE](#)

```
def model():
    return RandomForestClassifier(**params)
rf = model()
rf.fit(x, y, sample_weight=weights)
probabilities = rf.predict_proba(x)
```

[RFCORE.H](#) / [STAGED INFERENCE](#)

```
unsigned until = tree+32 < RfModel::TREES
    ? tree+32 : RfModel::TREES;
for (; tree<until; tree++)
    RfModel::tree(tree, features, probability);
if (tree<RfModel::TREES) return;
```

WHOLE-SESSION SPLITS

Neighboring windows and augmentations stay in the same train/validation/test partition.

SELECT, THEN FREEZE

Train/validation choose settings. A new candidate does not silently overwrite the device.

EMIT WITH TIMING

0.65 acceptance gate; 230 ms staging budget; 800 ms event cooldown.

Source excerpts only reformatted. The 230 ms setting is a computation/scheduling budget, not measured end-to-end latency. Development replay parity checks consistency; it does not measure perception, battery life or new-user generalization.

A good cropped score failed in continuous use.

0.929 macro F1 on 45 isolated fragments did not survive automatic runtime window boundaries.

CONTINUOUS REPLAY / SAME 8 HISTORICAL TARGET GROUPS

COUNTS, NOT A GENERAL ACCURACY ESTIMATE

Manual-window RF

Trained on manually cropped clips



0 / 8

matched groups

Aligned-window RF

Training + runtime share boundaries



7 / 8

matched groups

3 unassigned outputs remain

Detected events without a confirmed annotated group; not automatically called false triggers.

Previously inspected recordings. Windowing, segmentation and fitting changed together; no isolated classifier-cause claim.

[PROBLEM](#) / [DIFFERENT BOUNDARIES](#)

Manual: 3.810 s / score 0.866.

Automatic: 2.010 s / 0.438; rejected. Three other twists had no valid candidate.

[CHANGE](#) / [SHARED REPRESENTATION](#)

Use the same causal WindowStream and 58 features in training and replay. Add partial / cross-group negatives and whole-recording splits.

[RESULT](#) / [STILL IMPERFECT](#)

Aligned replay: 7/8 target groups; three unassigned outputs remain. Segmentation, labels and fitting changed together.

Source: ML Training README; continuous/aligned replay artifacts; technical-cases-v4.md. Correlated windows were weighted with one training-only hard-negative pass. Previously inspected historical data, not blind generalization. Original motor masks remain fixed; the change does not isolate a single classifier cause.

Keep the regression beside the improvement.

Historical development replay compares a v322 lineage with an unflashed v325 candidate.

v322 BASELINE → v325 CANDIDATE

18 OCT 2026 / DEVELOPMENT REPLAY / NOT DEPLOYED

WHY A CANDIDATE?

Explore completed prefixes without waiting for a third cycle to stop.

WHY NOT DEPLOY?

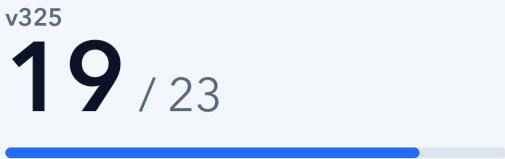
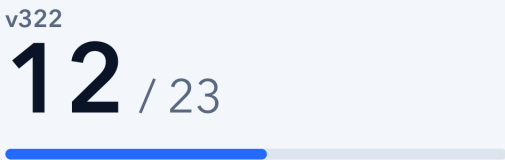
A test-set improvement coexists with a validation regression.

WHAT REPLAY CANNOT DO

Original motor masks remain fixed.
New hypothetical haptic feedback is not simulated.

Test recordings

Matched annotated groups



+7 matched

Validation recordings

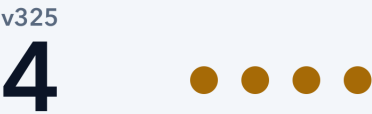
Matched annotated groups



-1 matched

Unassigned outputs

In positive test recordings



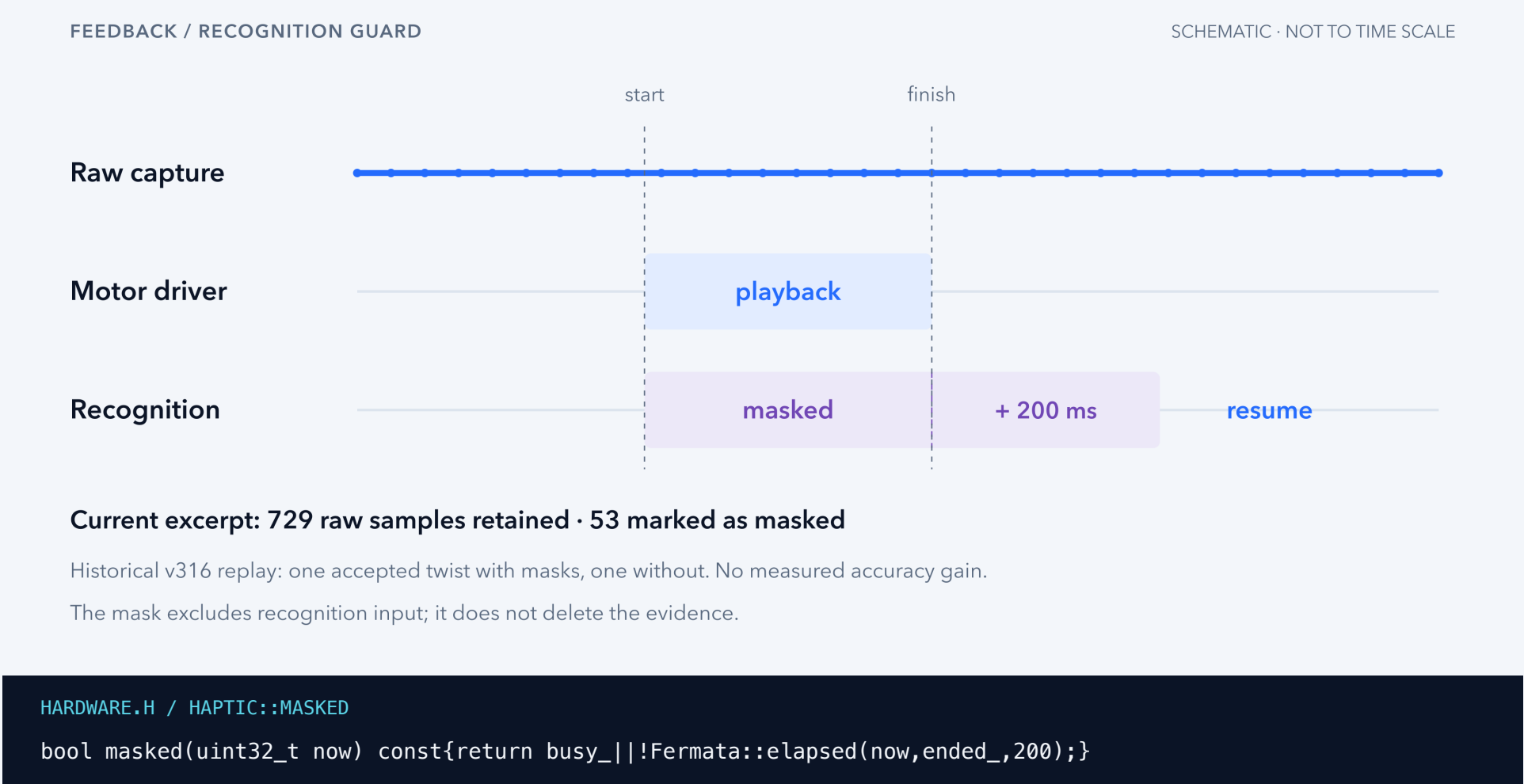
-1 unassigned

More test matches, one fewer validation match. Previously inspected recordings; no blind performance claim.
Deployed pair remains A v326 / B v328 with the v322 recognizer. Unassigned output ≠ confirmed false trigger.

Source: Gesture v0.3.25/results/comparison.json. Test matches: 12/23 -> 19/23; validation: 10/11 -> 9/11; unassigned test outputs: 5 -> 4. Previously inspected recordings are not a fresh blind test. Latest deployed pair remains A326/B328 with v322 recognition.

Keep recording when feedback moves the sensor.

A preventive guard separates actuation from recognition without hiding the raw signal.



PROBLEM / FEEDBACK ENTERS INPUT

v316 accepted one live twist; later attempts failed after the mask ended. Motor vibration was a risk, not an established cause of those misses.

CHANGE / GUARD, BUT RETAIN

Exclude playback and its 200 ms recovery from recognition; reset contaminated windows. Retain the raw samples and flags in the capture.

RESULT / NO ACCURACY GAIN SHOWN

The 120 s record contains 12,513 raw / 54 masked samples. Clearing masks in replay produced the same one accepted twist; the logs are identical.

Sources: v316 gesture_haptic_imu.csv, masked/unmasked replay logs and validation record; current Hardware.h/RfCore.h. v316 was a DTW-era experiment with incomplete action labels. Current v322 retains the recording/masking separation; the v326 excerpt preserves 729 raw samples, including 53 masked rows.

A delivery receipt is not a felt cue or a reply.

Radio acceptance, actuator output, sensation and intentional response need separate checks.

送达、振动、感受到、主动回复，是不同的证据。

EVIDENCE CHAIN / DISTINCT CLAIMS

SCHEMATIC · NOT ONE RECORDED CONVERSATION



PROBLEM / ACK WITHOUT HAPTICS

v309 logged three Attention ACKs. B showed blue light for two formal actions, but flags=2 reported NO_HAPTIC: the motor was not ready.

CHANGE / SEPARATE THE STATES

Update both bands, retain calibration, add B-side Wait, and key receive / haptic / light events. Keep a physical Received press distinct from automatic ACK.

RESULT / SEVEN BUTTON CHECKS

v326: A pressed three times, B four. Each matched peer output evidence; the author confirmed vibration and green light both ways. These are separate tests.

Separate v326 button test: 7 physical Received presses + peer output logs + human confirmation.

The button test is not a reply to the selected waveform. Host receipt order is not physical latency.

ACK = peer acceptance. Received = deliberate message. Neither implies agreement.

```
FERMATABAND.INO / TWO SEPARATE SOURCE LOCATIONS
sendAck(f, flags);
if (b == Button::SHORT) { logEvent("BUTTON_RECEIVED",RECEIVED); requestSignal(RECEIVED); }
```

Sources: v309 test record; v326 all_physical_presses.json and human_confirmation.json; current v328 source. Different dates/versions, not a controlled gesture comparison or user study. Unkeyed HAPTIC_FINISHED is paired to a matched start within one second. The selected A gesture on pages 9-10 does not establish a human reply.

Four failures that changed the system.

Observe -> isolate -> change -> check. Keep the limit of each check visible.

OBSERVED FAILURE	TECHNICAL CHANGE	CHECK / LIMIT
IMU did not respond	→ Use the high-drive IMU power-pin mode OUTPUT_H0H1	→ Sensor ID and ~104 Hz acquisition returned. A short bring-up result, not long-duration reliability.
Gyroscope clipping	→ Expand +/-1000 to +/-2000 deg/s. Keep each recording's original scale.	→ Old clipped peaks cannot be recovered. Range change alone did not improve recognition.
BLE reconnect loop	→ Clear invalid RX / TX / CCCD state after discovery failure and disconnect.	→ 41 disconnects / ~55 s -> 0 / 60.25 s. Power and placement also changed.
Debug link broke the pair	→ Separate subscribed connection handles; peer channel and computer service isolated.	→ v328 computer reconnect preserved peer/boot state. Five battery observations cover only 20 seconds.

Sources: October 9 hardware bring-up; Gesture v322 range review; October 11 reconnect investigation; Pair v328 disconnect isolation and STATUS.json. USB power-transition resets remain unresolved. These checks do not establish long-duration reliability.

Delivery, sensation and choice need separate evidence.

The archive contains wearer checks and development replays; an external user study is still proposed.

开发回放、实物联调与用户验证分别记录。

7

BUTTON REPLIES

A: 3 / B: 4. Wearer confirmed vibration and green light both ways.

5 / 10

A WRIST-TWIST MATCHES

New-enclosure check. Downward motion matched 3/7. Disconnects also occurred.

6

DELIVERED B TWISTS

All arrived in one batch while A haptics were skipped. Later Wait was seen and felt.

PROPOSED / 3-4 PAIRS / ONE SHARED ACTIVITY

01



Learn

Cue distinctions
and agreed meanings

02



Use

Buttons first; then
gestures during a task

03



Separate

Delivery / notice /
interpretation / reply

04



Reflect

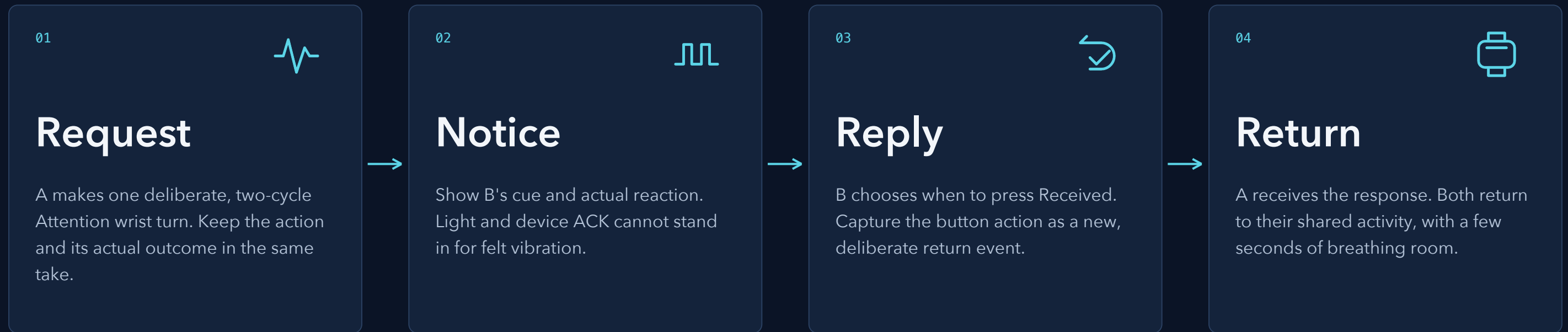
Comfort / interruption /
later meaning recall

Sources: Pair v326 human_confirmation and enclosure records; Pair v327 twist/dip reviews. Counts are events/groups in development checks, not participant counts or independent sessions. The study protocol is proposed, not completed.

One cue. One chosen reply.

Planned demonstration / filming has not taken place. Target edit: 25-35 seconds.

待拍摄分镜；保留真实过程，不拼接成虚假的一次成功。



CONTINUOUS MASTER

Film 45-60 seconds showing both wearers. Add closeups after a continuous, verifiable take.

RECORD THE TAKE

Log firmware, model, power state and take ID. Keep device, host and camera clocks distinct.

KEEP THE OUTCOME HONEST

Retain failed takes. A button-triggered fallback must be labelled; do not edit it into a gesture success.

Production plan: output/production/Fermata-filming-script.md. Establishing shot precedes these four stages; the website reserves #demonstration for the future film. The sequence is planned, not a recorded gesture trial or completed user study. Edit durations are not device-latency measurements.



The work lives between the parts.

Physical form, sensing, computation and communication have to agree.

从一个动作，到另一位佩戴者的回应。

RESEARCH

R1 **Brewster & Brown (2004). Tactons.**

Structured tactile messages for non-visual information display. AUIC 2004.

R2 **Turchet & Barthet (2019).**

Co-design of Musical Haptic Wearables for Electronic Music Performer's Communication. THMS 49(2), 183-193.

R3 **Chan, MacLean & McGrenere (2005).**

Learning and identifying haptic icons under workload. World Haptics, 432-439.

R4 **NYU ITP. Journals & Documentation.**

Interaction, circuit, code and process as a connected account.

PROJECT ARTIFACTS

HARDWARE / MECHANICS

Collaborator PCB review; enclosure v1.0 / v1.3.1 / v1.3.2; archived bridge and diffuser; October actual photographs.

DATA / MODEL

Recognition Panel sessions; aligned ML replay; v325 candidate comparison; v316 mask and v326 button logs.

DEPLOYED SYSTEM

Pair v328 Hardware, Config, Protocol, RfCore and DebugLink; STATUS and disconnect-isolation evidence.

VISUAL PROVENANCE

Photos and UI identified; product image generated. Assembly CAD and reconstructions distinguished. Filming storyboard remains a plan.

CREDITS

Raphael (Boyan) Peng: concept, interaction, firmware and integration. Later PCB: collaborator. Gottfried: project feedback.

Detailed local provenance accompanies the website assets, technical research notes and PDF build manifest. Fermata visual identity: paired arches, technical sans, cobalt/cyan signals and a cool engineering palette. No fabricated participant quotes, interviews or final success rate are used.