ENLIVEN AI

PHASE I – PERSONALIZED BIOMECHANICS VISION SYSTEM

TECHNICAL ANNEX & STATEMENT OF WORK (NO INTERPRETATION)

Applies to: iOS (on-device) + AWS (cloud)

Primary Pose Model: OpenPose (MANDATORY)

Scope: Personalized body calibration + 10 exercises

Purpose: Lock technical scope, KPIs, deliverables, cues, and tempo requirements for commercial negotiation

1. NON-NEGOTIABLE ENGINEERING PRINCIPLES

1. OpenPose BODY_25 keypoint schema is mandatory
2. Personalized anthropometric calibration is mandatory
3. Rule-based biomechanics corrections are mandatory
4. ML scoring is supplementary only
5. All corrections and tempo rules must be numerically defined
6. All performance targets must be measurable
7. No “heuristic”, “high-level”, or “estimated” logic is acceptable

2. REQUIRED MODEL STACK

2.1 Pose Estimation

SIA Enliven
Auguliena, Gulbene LV-4410
+371 25749643
www.enliven.ai
info@enliven.ai

Cloud (AWS – High Precision)

- OpenPose (CMU OpenPose family)
- BODY_25 or BODY_25B keypoints
- Deterministic single-person selection
- Outputs: (x, y, confidence) per keypoint

iOS (Real-Time)

- Lightweight OpenPose-derived model
- Must output identical BODY_25 keypoints (same indices)
- CoreML + Metal Performance Shaders
- Quantized (8-bit or mixed precision)

If a student model is used on device, it must be distilled from OpenPose and preserve BODY_25 schema exactly.

3. COORDINATE SYSTEM & ANGLE DEFINITIONS (GLOBAL)

3.1 Coordinate System

- Image space origin top-left
- +x right, +y down
- Vectors normalized before angle computation

3.2 Joint Angle Formula (MANDATORY)

For any joint B with points A–B–C:

angle(B) = arccos((BA · BC) / (|BA| · |BC|))

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+371 25749643
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info@enliven.ai

Output in degrees, range 0°–180°.

3.3 Trunk Angle

- Vector: midHip → neck
- Reference: vertical (0, −1)
- Trunk angle = arccos(dot(trunk, vertical))

4. TEMPORAL PROCESSING RULES (GLOBAL)

- All biomechanics computed on smoothed signals only
- Filters:
  - One-Euro filter (real-time)
  - Savitzky–Golay (window ≥9 frames, poly order 2) post-set
- Violations must persist ≥120 ms (~4 frames @30fps) to trigger
- Single-frame spikes ignored

5. PERSONALIZED BODY SCAN & CALIBRATION (MANDATORY)

5.1 Calibration Capture Protocol

1. Front standing neutral
2. Side standing neutral
3. T-pose (~90° shoulder abduction)
4. Hip hinge ~45°
5. Single-leg stance left
6. Single-leg stance right

5.2 Outputs (User Calibration Profile – UCP)

- Normalized segment ratios: torso, femur, tibia, upper arm, forearm, shoulder width, hip width

- Joint-center offsets: hip, shoulder approximations
- Optional ROM baseline

5.3 Calibration KPIs

- Segment repeatability ≤ ±3%
- Jitter reduction ≥15%
- Angle stability improvement ≥15%

6. PHASE I EXERCISE SCOPE (MANDATORY)

1. Squat
2. Deadlift
3. Push-Up
4. Bent-Over Barbell Row
5. Overhead Barbell Press
6. Pull-Up
7. Lunge
8. Sit-Up
9. Russian Twist
10. Barbell Bench Press

Each must include: rep detection, phase segmentation, angles/velocities, corrections, scoring, overlays, and audio triggers.

7. EXACT BIOMECHANICS + TEMPO TRACKING (NO INTERPRETATION)

7.0 Tempo Standard (Applies to ALL 10 Exercises)

The system must track and score tempo per rep as 3–1–1–1:

- Eccentric: 3.0 seconds (target)
- Bottom/End-range pause: 1.0 second (target)
- Concentric: 1.0 second (target)
- Top/Between-rep pause: 1.0 second (target)

Tempo Measurement Requirements

For each rep, compute:

- t_eccentric, t_bottom_pause, t_concentric, t_top_pause
- Total rep time
- Deviation (%) from target for each phase

Phase Timing Tolerances (Acceptance)

A rep is “tempo-correct” if each phase is within:

- Eccentric: 3.0s ± 0.4s
- Bottom pause: 1.0s ± 0.25s
- Concentric: 1.0s ± 0.25s
- Top pause: 1.0s ± 0.25s

Tempo Failure Classification

- “Too fast eccentric”: t_eccentric < 2.6s
- “Too slow eccentric”: t_eccentric > 3.4s
- “No bottom pause”: t_bottom_pause < 0.6s
- “No top pause”: t_top_pause < 0.6s
- “Too slow concentric”: t_concentric > 1.4s

Tempo KPI (Per Set)

- At least 85% of reps must be correctly classified for phase timing on labeled evaluation sets.

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Auguliena, Gulbene LV-4410
+371 25749643
www.enliven.ai
info@enliven.ai

7.1 SQUAT (3–1–1–1 required)

Depth (Knee Flexion)

- Valid: knee angle ≤100°
- ATG: ≤85°
- Insufficient: >110°

Forward Torso Lean

- Excessive: trunk angle >50°

Knee Valgus

- Medial knee deviation ≥8% femur length (≥120 ms)

Heel Lift / Ankle

- Bottom dorsiflexion ≥15°
- Heel rise ≥3% tibia length

Tempo

- Eccentric: time from standing start to bottom position
- Bottom pause: bottom position stability (knee angle within ±3° band)
- Concentric: bottom to standing completion
- Top pause: standing stable before next eccentric

7.2 DEADLIFT (3–1–1–1 required)

Lumbar Rounding Proxy

- Trunk angle change ≥15° during pull (setup vs mid-pull)

Bar Drift

- Wrist forward displacement ≥7% femur length

Squatty Setup

- Knee angle at setup <115°

Tempo

- Eccentric: top to bar-at-floor/end-range
- Bottom pause: bar motion near-zero + joint stability
- Concentric: floor to lockout
- Top pause: lockout stable (hip+shoulder vertical stability)

7.3 PUSH-UP (3–1–1–1 required)

Elbow Flare

- Shoulder–elbow–wrist angle >75°

Hip Sag / Pike

- Hip deviation ≥5% torso length

Depth

- Chest proxy within 8 cm of floor plane

Tempo

- Eccentric: top plank to bottom
- Bottom pause: bottom stable (elbow angle within ±4° band)
- Concentric: bottom to top plank
- Top pause: plank stable (hip line stability)

7.4 BENT-OVER BARBELL ROW (3–1–1–1 required)

Torso Hinge Maintenance

- Torso angle drift >10° across rep = momentum/poor control

Row ROM

- Elbow flexion change (top to bottom) must exceed 35°
- If <35°: partial ROM

Asymmetry

- Left/right wrist vertical displacement difference ≥10% = asymmetry

Tempo

- Eccentric: bar lowering/top to bottom hang
- Bottom pause: bar stable at hang
- Concentric: pull to top contraction
- Top pause: stable at top (wrist/hand near-constant)

7.5 OVERHEAD PRESS (3–1–1–1 required)

SIA Enliven
Auguliena, Gulbene LV-4410
+371 25749643
www.enliven.ai
info@enliven.ai

Lumbar Overextension

- Backward trunk lean >12°

Lockout

- Elbow flexion >10° at top = incomplete

Bar Path Drift

- Wrist horizontal deviation >6% torso length = drifting forward

Tempo

- Eccentric: from lockout to bottom rack position
- Bottom pause: stable at rack (wrist vertical velocity ~0)
- Concentric: rack to lockout
- Top pause: lockout stable

7.6 PULL-UP (3–1–1–1 required)

ROM

- Top: chin proxy ≥4 cm above wrist line
- Bottom: elbow angle ≥165°

Kipping

- Hip horizontal oscillation ≥10% femur length

Tempo

- Eccentric: top to bottom hang
- Bottom pause: dead hang stability (velocity near 0)
- Concentric: pull to top
- Top pause: hold at top stable

7.7 LUNGE (3–1–1–1 required)

Front Knee Tracking

- Medial deviation ≥7% tibia length

Torso Lean

- Forward lean >35°

Step Length Consistency

- Front ankle-to-hip horizontal distance changes >15% across reps = inconsistent stride

Tempo

- Eccentric: standing to bottom
- Bottom pause: bottom stability
- Concentric: bottom to standing
- Top pause: stable before next rep/side transition

7.8 SIT-UP (3–1–1–1 required)

SIA Enliven
Auguliena, Gulbene LV-4410
+371 25749643
www.enliven.ai
info@enliven.ai

Momentum

- Angular velocity spike >2× average concentric velocity

ROM

- Trunk flexion amplitude below minimum threshold (to be defined by labeled examples) is partial rep; vendor must implement based on trunk angle change per rep.

Tempo

- Eccentric: down phase
- Bottom pause: stable on floor
- Concentric: up phase
- Top pause: stable upright

7.9 RUSSIAN TWIST (3–1–1–1 required)

Rotation Symmetry

- Left/right amplitude difference >15%

Excess Flexion

- Trunk flexion beyond baseline +15° during twists indicates collapsing rather than rotating

Tempo

Because Russian twist is alternating, define one “rep” as: center → left → center (or center → right → center).

- Eccentric: center to end-range
- Bottom pause: end-range hold
- Concentric: end-range back to center
- Top pause: center stabilization before next side

7.10 BARBELL BENCH PRESS (3–1–1–1 required)

Elbow Angle at Bottom

- Valid: 75°–95°
- Excess flare: >100°

Bar Path Asymmetry

- Left/right wrist vertical difference ≥10%

Depth / Touch

- Bar-to-chest proxy achieved: wrist y-position reaches defined bottom band (must be calibrated from first correct rep per user)

Tempo

- Eccentric: lockout to bottom
- Bottom pause: bottom hold
- Concentric: bottom to lockout
- Top pause: lockout stable

8. PERFORMANCE KPIs (NUMERIC)

SIA Enliven
Auguliena, Gulbene LV-4410
+371 25749643
www.enliven.ai
info@enliven.ai

Pose Tracking

- OKS ≥92% (target 95%)
- Critical joint dropout ≤1%
- Jitter ≤5 px RMS

Rep Detection

- Controlled ≥99%
- Real-world ≥95%
- False reps ≤2%

Phase Segmentation

- ≥95% boundary accuracy (±5 frames)

Corrections

- Precision ≥90%
- Recall ≥85%
- F1 ≥0.87 per fault type

Tempo Tracking KPI

- Phase timing classification accuracy ≥85% on labeled evaluation sets

9. DATA REQUIREMENTS (CONCRETE)

Per exercise:

- ≥120 correct videos
- ≥120 incorrect videos

- 6–12 reps/video
- Angles: 40% side, 30% front, 30% 45°
- Female ≥40%, male ≥40%

Labels per rep:

- start_frame, bottom_frame, end_frame
- valid_rep
- fault_types[]
- fault_severity (0–3)
- tempo_phase_timestamps (eccentric start/end, bottom pause start/end, concentric start/end, top pause start/end)

10. SDK & API

iOS SDK

```
startSession(exerciseId, userCalibrationProfile)
processFrame(pixelBuffer, timestamp)
endSession()
```

Outputs must include:

- repCount
- currentPhase
- angles
- velocities
- tempo phase timers
- warnings[]
- confidence

Cloud API

- POST /analyzeSet
- Returns: full JSON + overlay instructions (or rendered overlay video)

11. AUDIO CUE LIBRARY (MANDATORY)

Cue IDs, Trigger Logic, and Required Phrasing Categories

The system must emit cue events in real time. Cue texts must be editable by Enliven, but cue IDs and trigger logic must be implemented by vendor.

11.1 Global Tempo Cues (All Exercises)

These cues are driven by tempo thresholds (Section 7.0).

- CUE_SLOWER_ECCENTRIC

  Trigger: t_eccentric < 2.6s (current rep predicted fast or live estimate indicates under-target)

- CUE_MAINTAIN_ECCENTRIC_3S

  Trigger: eccentric ongoing and predicted finish <3.0s by >0.3s

- CUE_HOLD_BOTTOM_1S

  Trigger: bottom reached; bottom pause <0.6s or user starts concentric early

- CUE_FAST_CONCENTRIC_1S

  Trigger: t_concentric > 1.4s (too slow concentric)

- CUE_HOLD_TOP_1S

  Trigger: top reached; top pause <0.6s before next rep

- CUE_TOO_FAST_OVERALL

  Trigger: total rep time <5.0s (target is 6.0s total)

- CUE_TOO_SLOW_OVERALL

  Trigger: total rep time >7.5s

11.2 Global ROM / Control Cues (All Exercises)

- CUE_DEEPER_LOWER

  Trigger: end-range threshold not met (e.g., squat depth, push-up depth, bench depth)

- CUE_CONTROL_RANGE

  Trigger: velocity spikes exceeding 2× rep median velocity (momentum)

- CUE_STABILIZE

  Trigger: excessive joint/path jitter (beyond stability bands) during pauses

11.3 Limb Angle / Path Cues (Upper Body)

These apply to push-up, bench, row, overhead press, pull-up.

- CUE_ELBOWS_IN

  Trigger: elbow flare exceeds threshold (push-up >75°, bench >100°)

- CUE_ELBOWS_OUT_SLIGHT

  Trigger: elbows too tucked (if elbow angle below acceptable band; vendor must calibrate “too tucked” from labeled correct data)

- CUE_WRISTS_STACKED

  Trigger: wrist path deviates laterally beyond 8% forearm length

- CUE_BAR_PATH_STRAIGHT

SIA Enliven
Auguliena, Gulbene LV-4410
+371 25749643
www.enliven.ai
info@enliven.ai

Trigger: bar path drift proxy >6% torso length (OHP) or asymmetry >10% (bench)

- CUE_FULL_LOCKOUT

  Trigger: top elbow flexion >10° (OHP, bench), pull-up top not reached

- CUE_FULL_RANGE

  Trigger: ROM deficiency (row elbow ROM <35°, pull-up bottom <165° elbow)

11.4 Lower Body Alignment Cues

- CUE_KNEES_OUT

  Trigger: squat/lunge valgus thresholds exceeded

- CUE_CHEST_UP

  Trigger: squat forward lean >50° or deadlift trunk deviation ≥15°

- CUE_HIPS_BACK

  Trigger: deadlift squatty setup (knee <115°), hinge pattern incorrect

- CUE_FEET_FLAT

  Trigger: heel lift proxy triggers

- CUE_EQUAL_WEIGHT

  Trigger: hip shift / asymmetry exceeds acceptable band (defined by pelvis shift vs femur length; vendor must compute and report)

11.5 Exercise-Specific Cue Mapping (Minimum Required)

Squat

- CUE_SLOWER_ECCENTRIC

- CUE_HOLD_BOTTOM_1S
- CUE_FAST_CONCENTRIC_1S
- CUE_HOLD_TOP_1S
- CUE_DEEPER_LOWER
- CUE_KNEES_OUT
- CUE_CHEST_UP
- CUE_FEET_FLAT

Deadlift

- Tempo cues (same)
- CUE_CHEST_UP
- CUE_HIPS_BACK
- CUE_BAR_PATH_STRAIGHT
- CUE_CONTROL_RANGE

Push-Up

- Tempo cues (same)
- CUE_DEEPER_LOWER
- CUE_ELBOWS_IN
- CUE_STABILIZE (plank line)
- CUE_CONTROL_RANGE

Bent-Over Row

- Tempo cues (same)
- CUE_CONTROL_RANGE (no torso swinging)
- CUE_BAR_PATH_STRAIGHT (wrist path)
- CUE_FULL_RANGE

Overhead Press

- Tempo cues (same)
- CUE_FULL_LOCKOUT
- CUE_BAR_PATH_STRAIGHT
- CUE_STABILIZE (avoid leaning)

SIA Enliven
Auguliena, Gulbene LV-4410
+371 25749643
www.enliven.ai
info@enliven.ai

Pull-Up

- Tempo cues (same)
- CUE_FULL_RANGE (bottom)
- CUE_FULL_LOCKOUT (top completion concept)
- CUE_CONTROL_RANGE (no kipping)

Lunge

- Tempo cues (same)
- CUE_DEEPER_LOWER (if depth standard not met)
- CUE_KNEES_OUT
- CUE_CHEST_UP
- CUE_STABILIZE (balance)

Sit-Up

- Tempo cues (same)
- CUE_CONTROL_RANGE (no momentum)
- CUE_FULL_RANGE

Russian Twist

- Tempo cues (same, per rep definition)
- CUE_CONTROL_RANGE
- CUE_STABILIZE
- CUE_EQUAL_WEIGHT (symmetry)

Bench Press

- Tempo cues (same)
- CUE_DEEPER_LOWER
- CUE_ELBOWS_IN
- CUE_BAR_PATH_STRAIGHT
- CUE_FULL_LOCKOUT

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Auguliena, Gulbene LV-4410
+371 25749643
www.enliven.ai
info@enliven.ai

11.6 Audio System Constraints

- Cue latency <200 ms from detection to emitted event
- Confidence gating:
  - Rule-based cues require confidence ≥0.85 (vendor must define confidence computation)
- Cooldown:
  - No repeating same cue more often than once every 2.5 seconds
- Cue priority:

1. Safety/alignment (lumbar rounding, valgus)
2. ROM (depth/full range)
3. Tempo
4. Fine technique (bar path, elbows)

12. REMOVAL OF ALL ESTIMATION LANGUAGE

The following phrases are not acceptable:

“robust”, “high precision”, “advanced”, “AI judgement”, “poor form” without numeric definition.

All logic must map to numeric thresholds in Sections 7 and 11.

13. MILESTONE-BASED ACCEPTANCE (FOR COMMERCIAL TERMS)

M1 – OpenPose BODY_25 pipeline validated

M2 – Calibration implemented with ≥15% improvement

M3 – All 10 exercises tracked with ≥95% real-world rep accuracy

M4 – Corrections meet precision/recall targets; tempo tracking functional; cue library implemented

M5 – Production-ready iOS + AWS delivery with full SDKs and documentation

Failure at any milestone allows rejection or renegotiation.