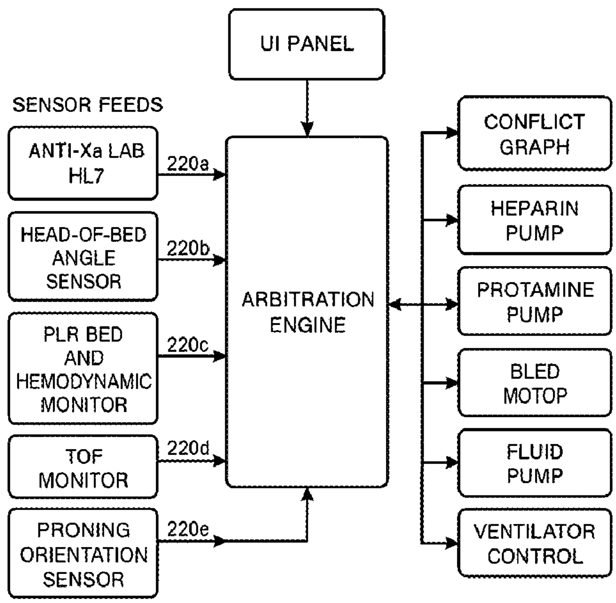
Figures:

FIG. 1


UI PANEL
SENSOR FEEDS
ANTI-Xa LAB HL7
HEAD-OF-BED ANGLE SENSOR
PLR BED AND HEMODYNAMIC MONITOR
TOF MONITOR
PRONING ORIENTATION SENSOR
220a
220b
220c
220d
220e
ARBITRATION ENGINE
CONFLICT GRAPH
HEPARIN PUMP
PROTAMINE PUMP
BLED MOTOP
FLUID PUMP
VENTILATOR CONTROL

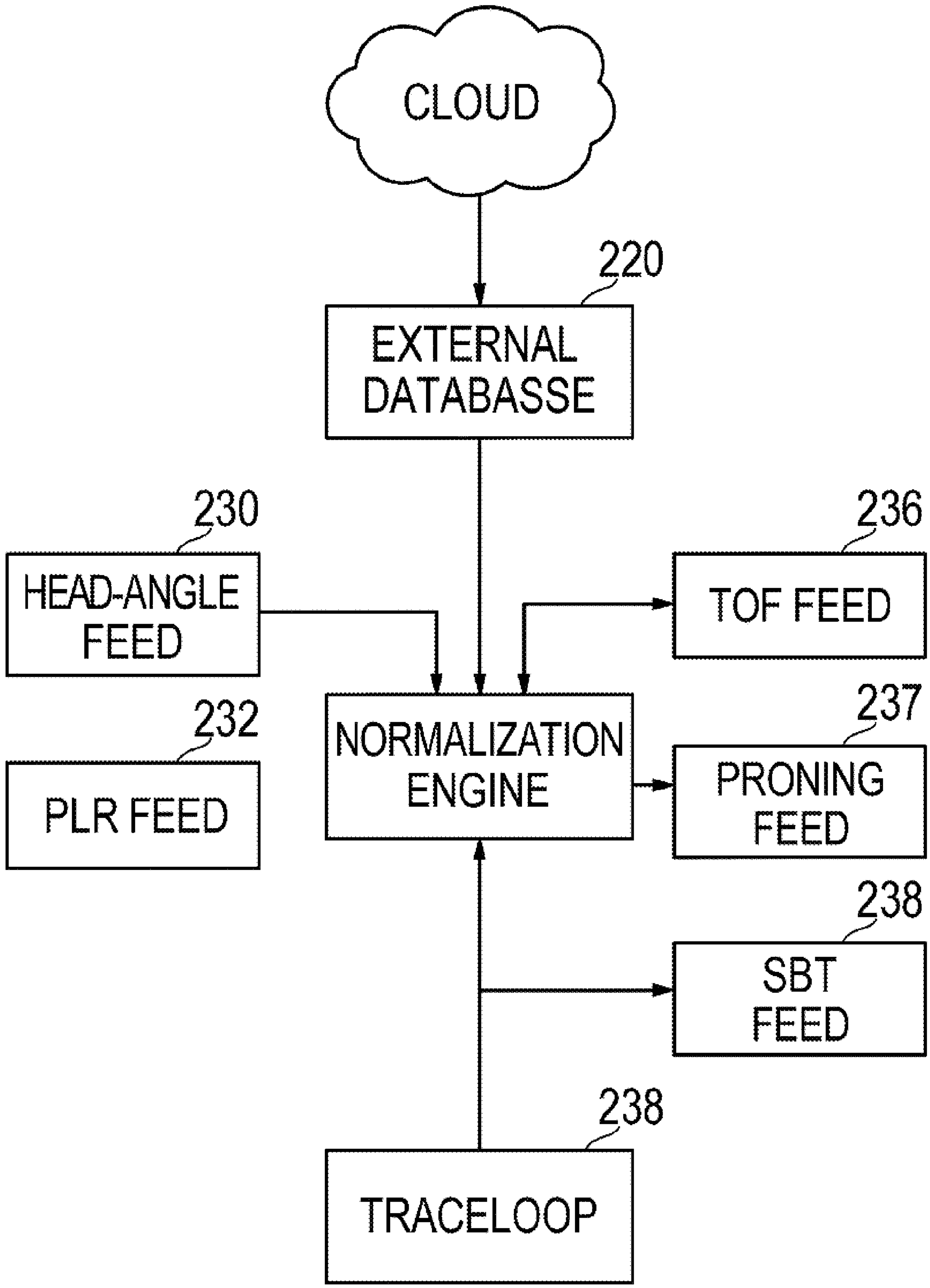

CLOUD
220
EXTERNAL DATABASSE
230
HEAD-ANGLE FEED
236
TOF FEED
232
PLR FEED
NORMALIZATION ENGINE
237
PRONING FEED
238
SBT FEED
238
TRACELOOP

FIG. 2

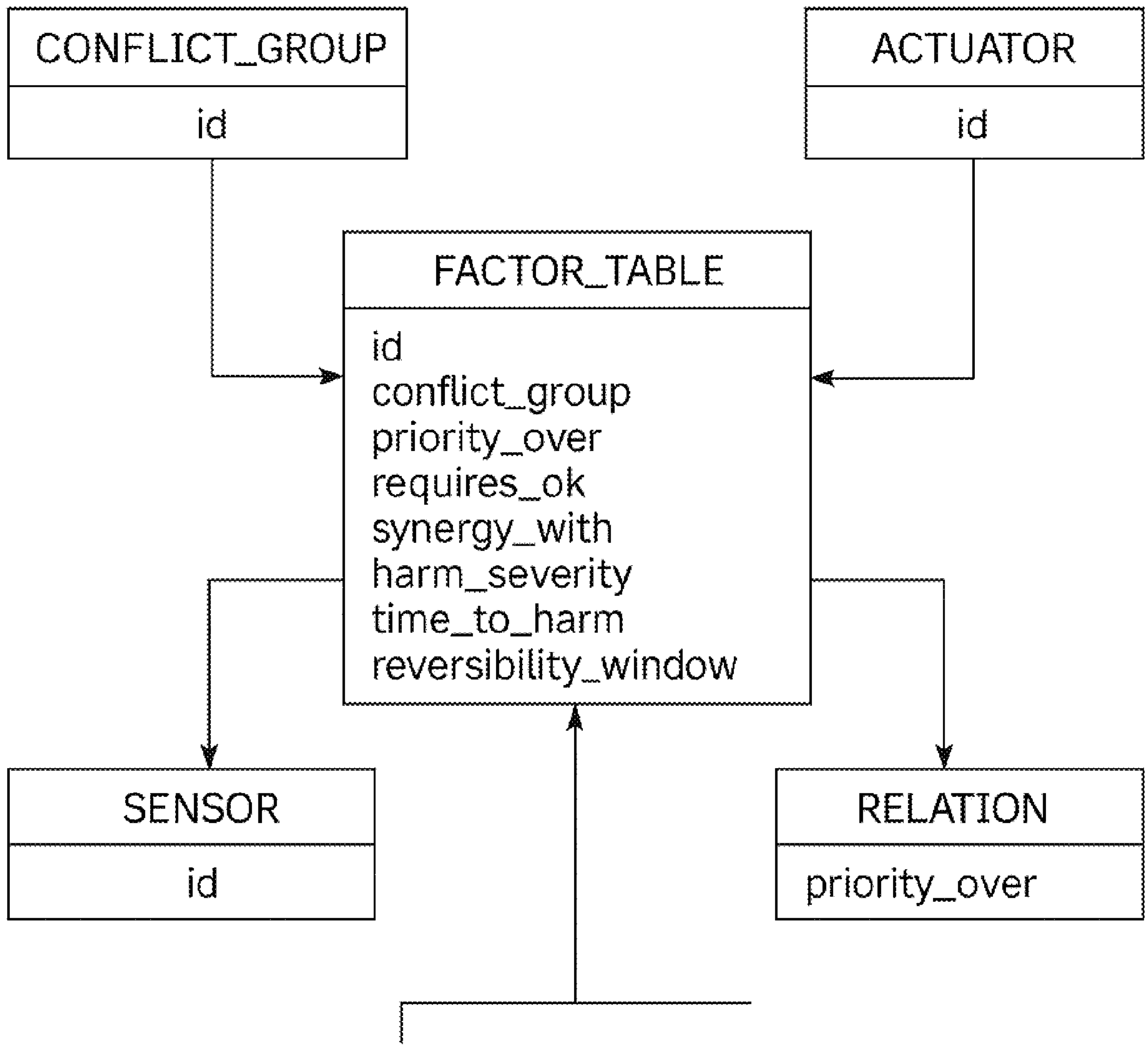

CONFLICT_GROUP
id
ACTUATOR
id
FACTOR_TABLE
id
conflict_group
priority_over
requires_ok
synergy_with
harm_severity
time_to_harm
reversibility_window
SENSOR
id
RELATION
priority_over

FIG. 3

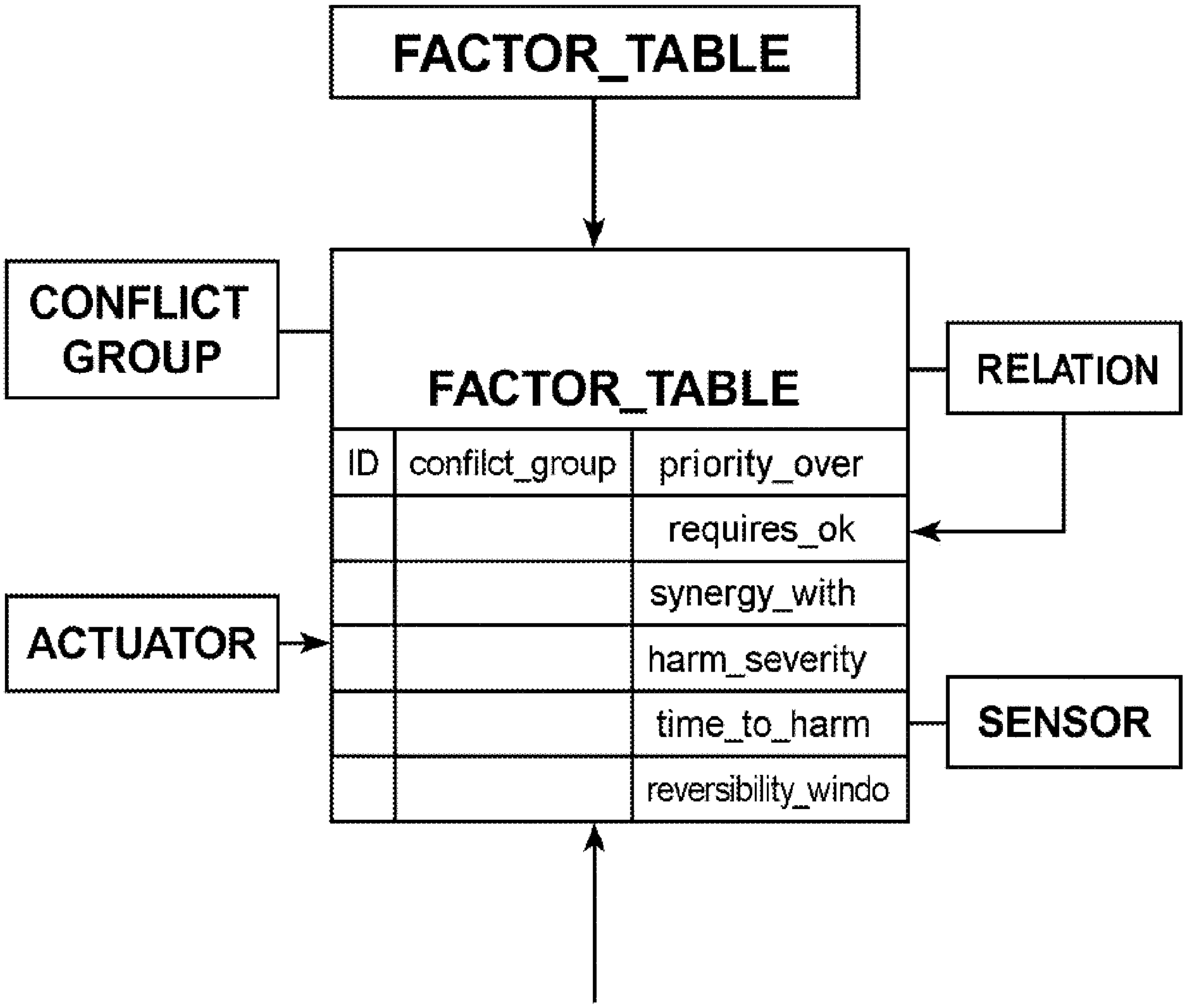
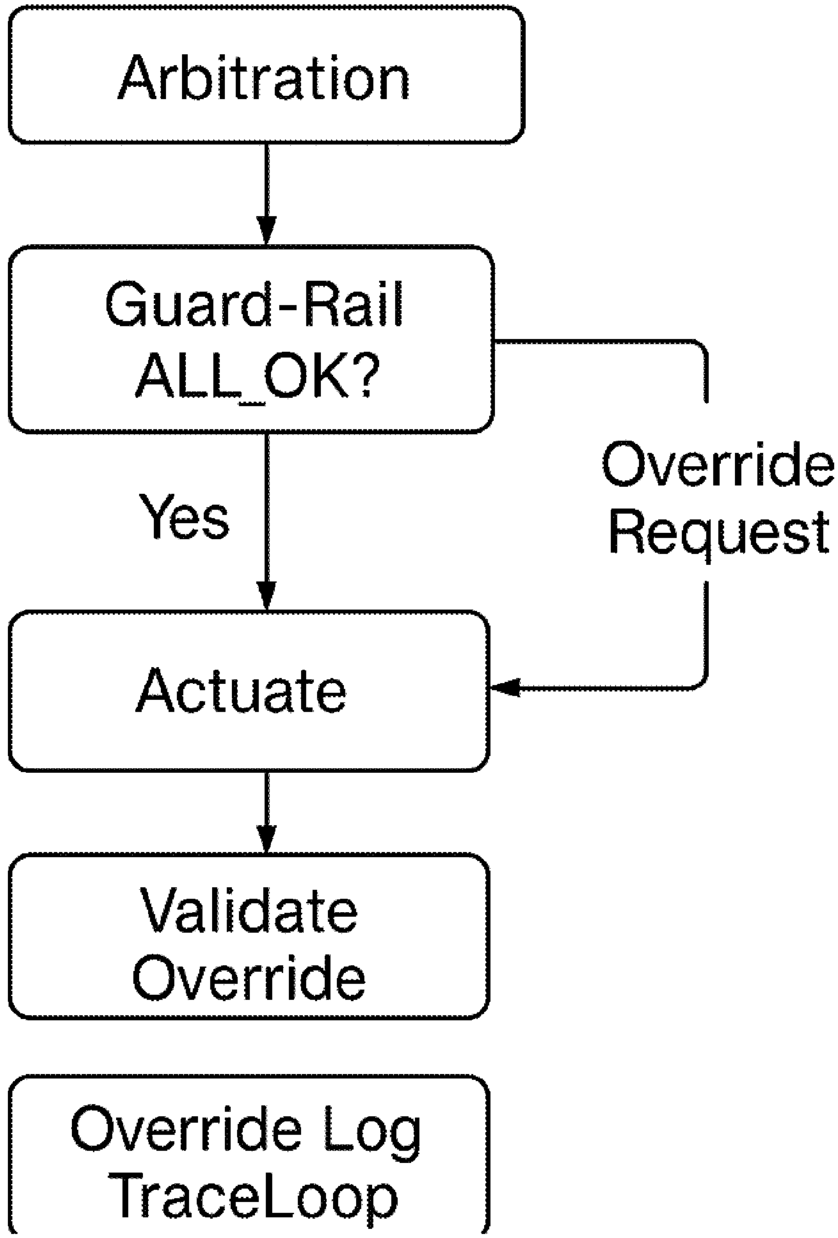

FACTOR_TABLE
CONFLICT GROUP
FACTOR_TABLE
RELATION
ID
confilct_group
priority_over
requires_ok
synergy_with
ACTUATOR
harm_severity
time_to_harm
SENSOR
reversibility_windo

FIG. 3


Arbitration
Guard-Rail
ALL_OK?
Yes
Override
Request
Actuate
Validate
Override
Override Log
TraceLoop

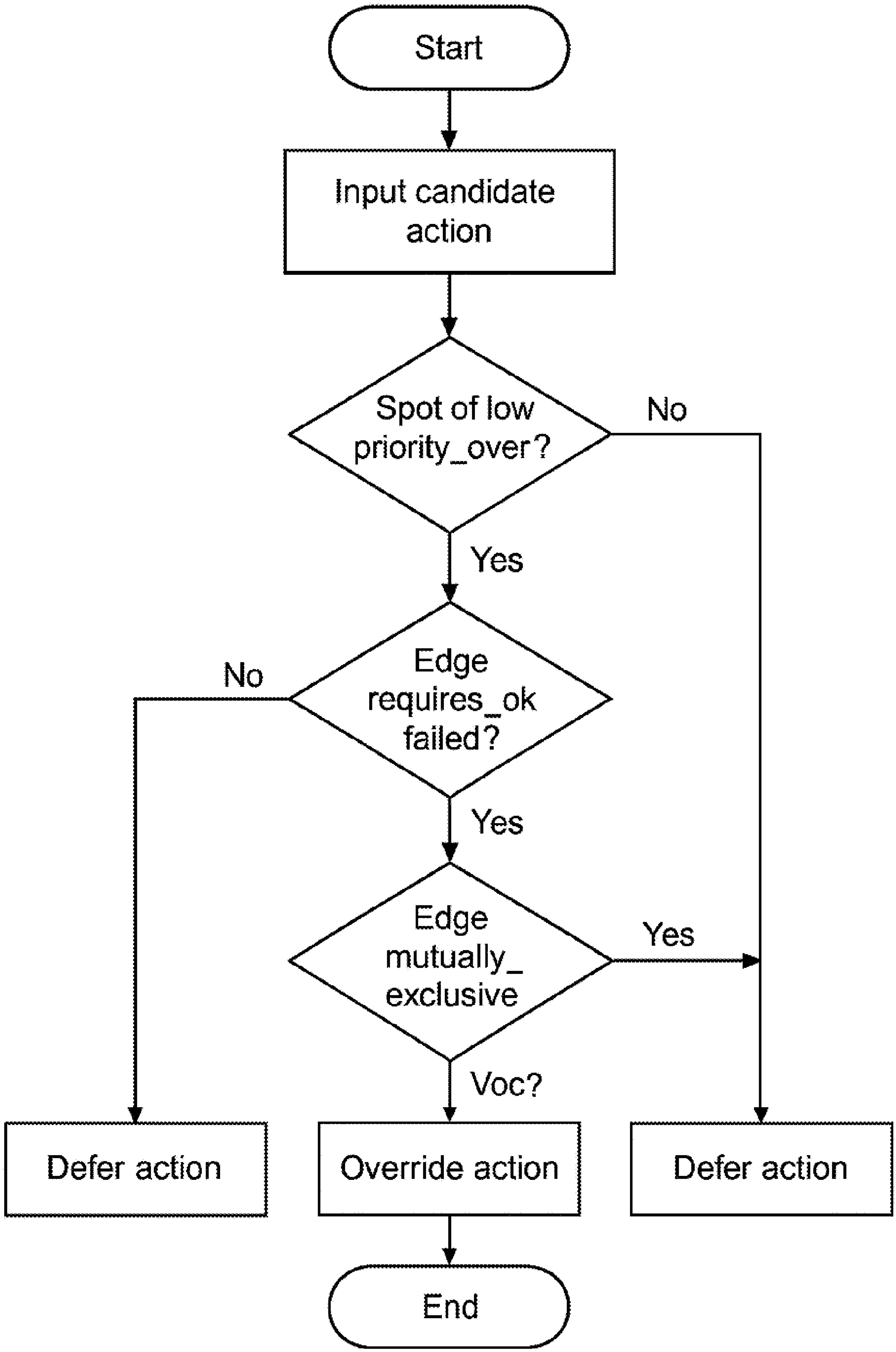


Fig. 4 Arbitration and overdide flow for TraceLoop

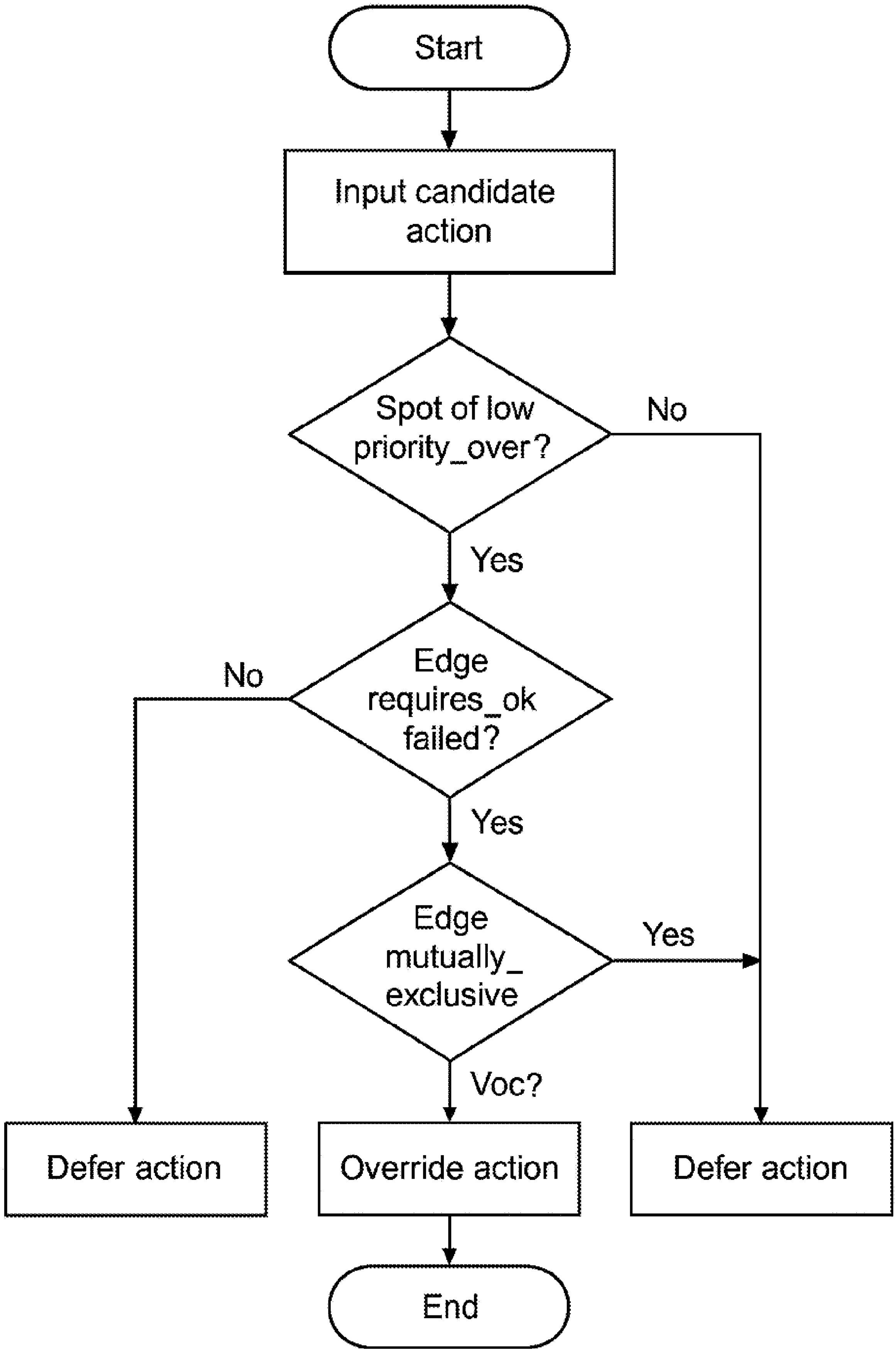


Fig. 4 Arbitration and overdide flow for TraceLoop

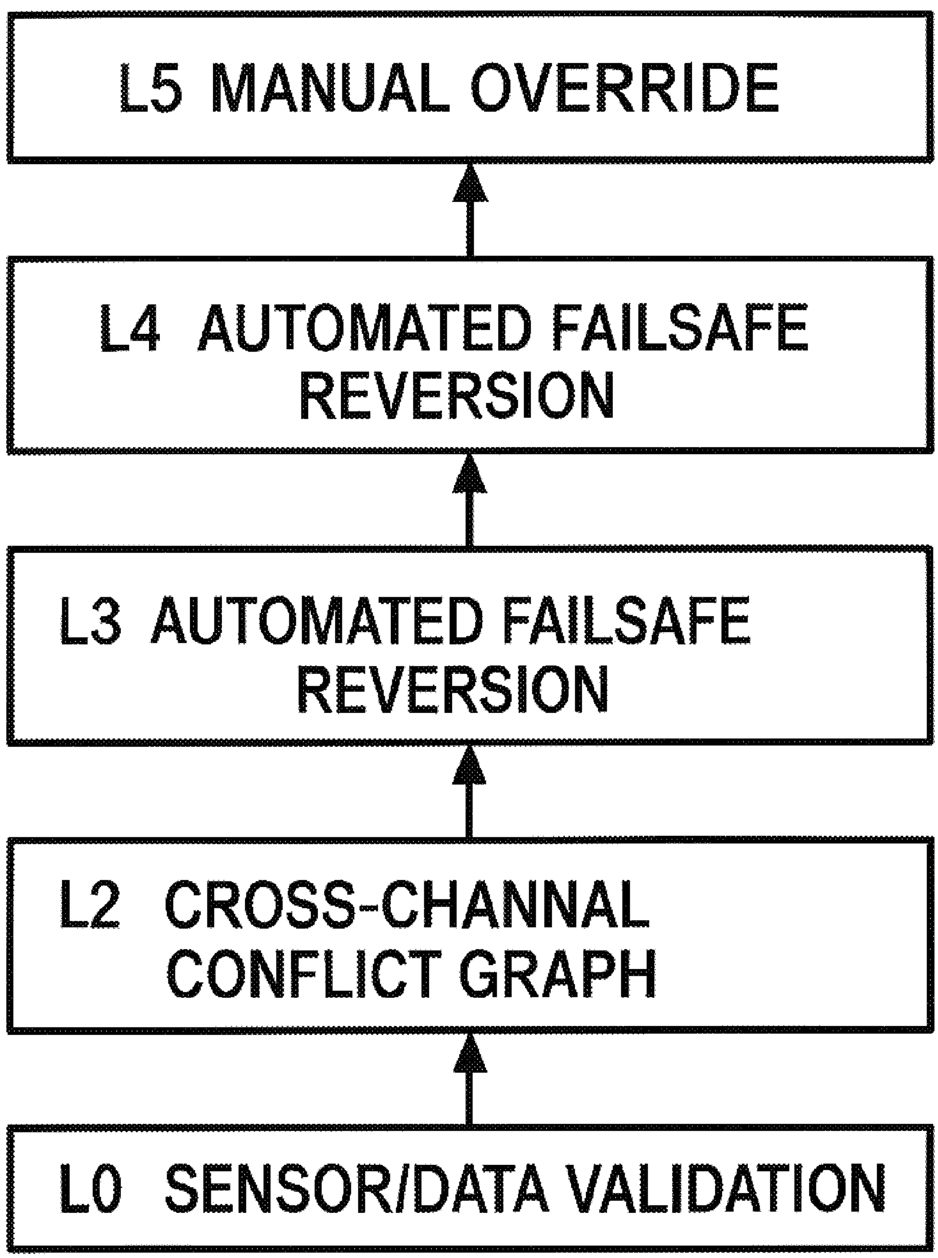

L5 MANUAL OVERRIDE
L4 AUTOMATED FAILSAFE REVERSION
L3 AUTOMATED FAILSAFE REVERSION
L2 CROSS-CHANNAL CONFLICT GRAPH
L0 SENSOR/DATA VALIDATION

FIG. 5

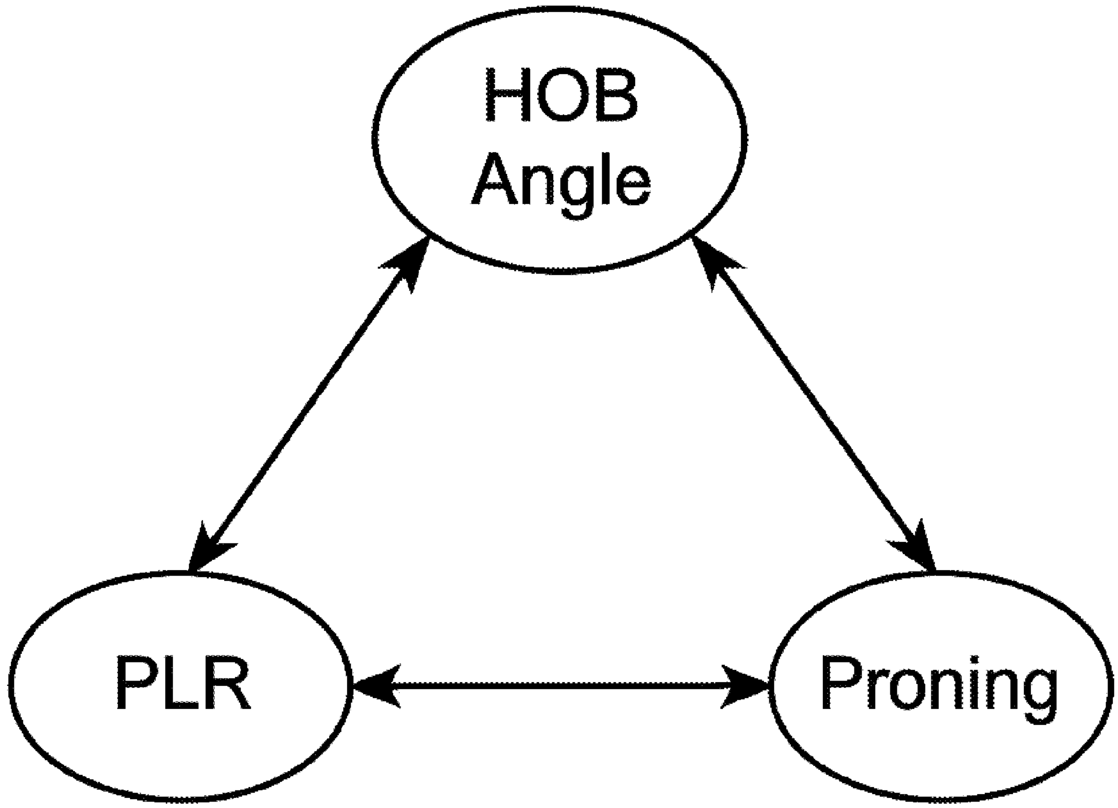


FIG. 6

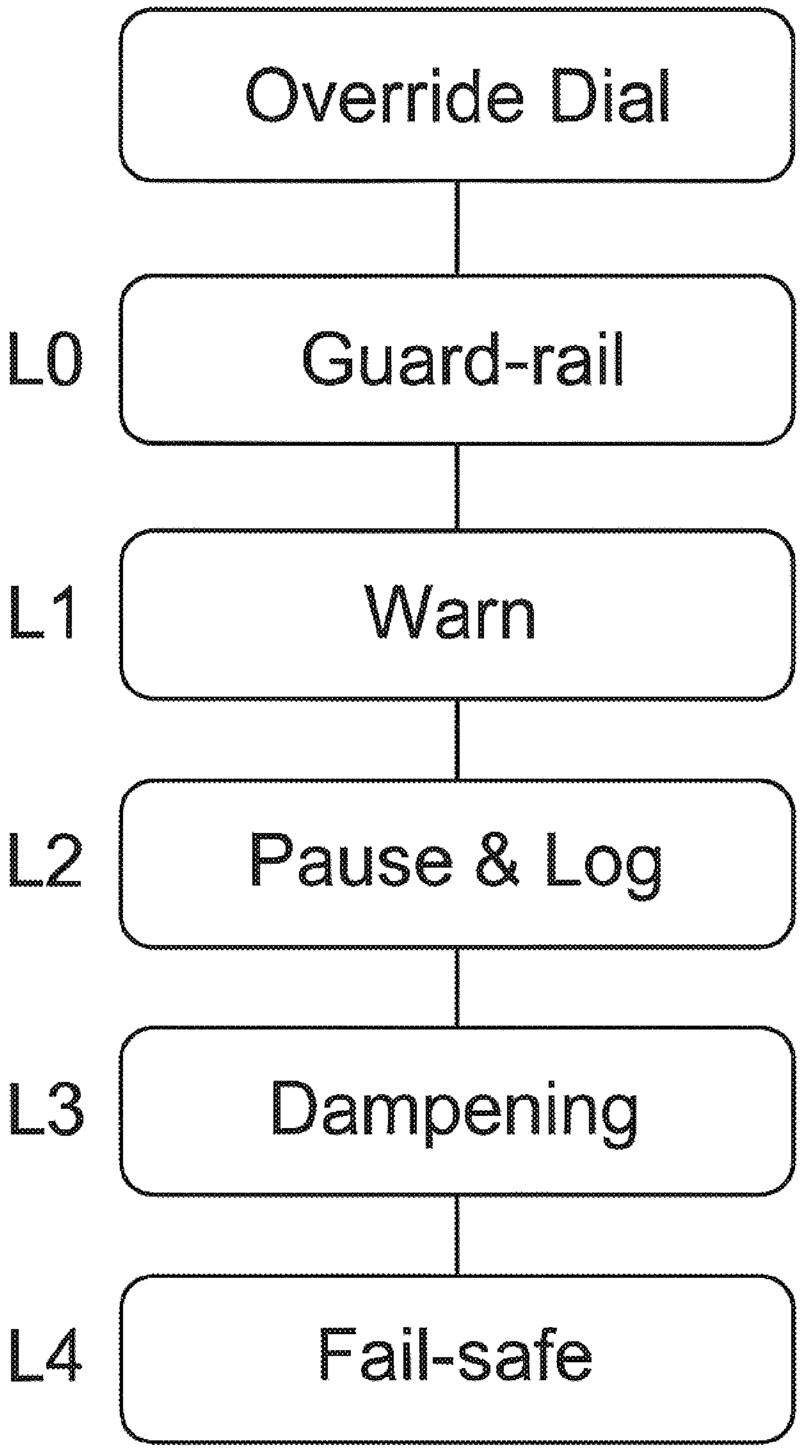

Override Dial
L0
Guard-rail
L1
Warn
L2
Pause & Log
L3
Dampening
L4
Fail-safe

FIG. 7

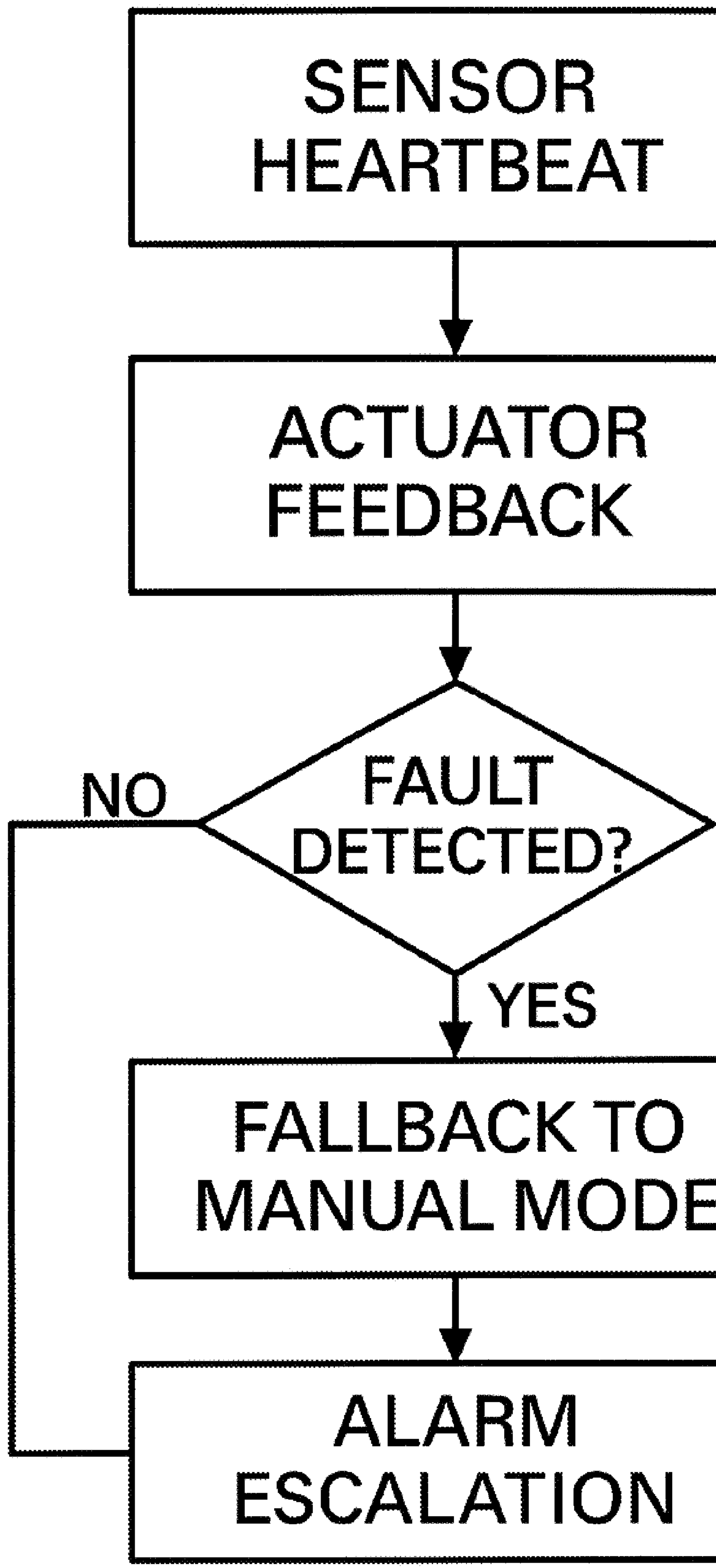

SENSOR HEARTBEAT
ACTUATOR FEEDBACK
FAULT DETECTED?
NO
YES
FALLBACK TO MANUAL MODE
ALARM ESCALATION

FIG. 8

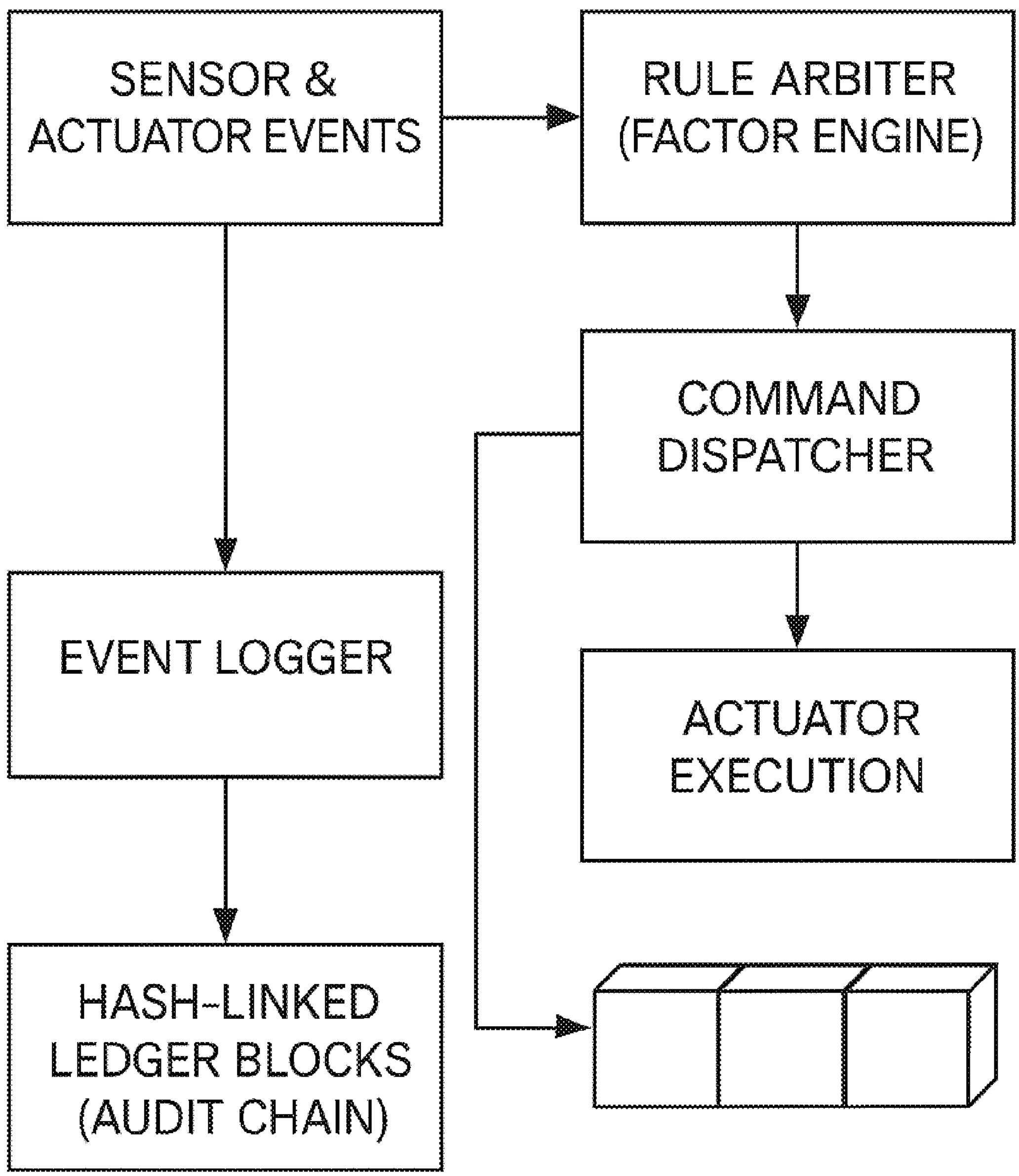
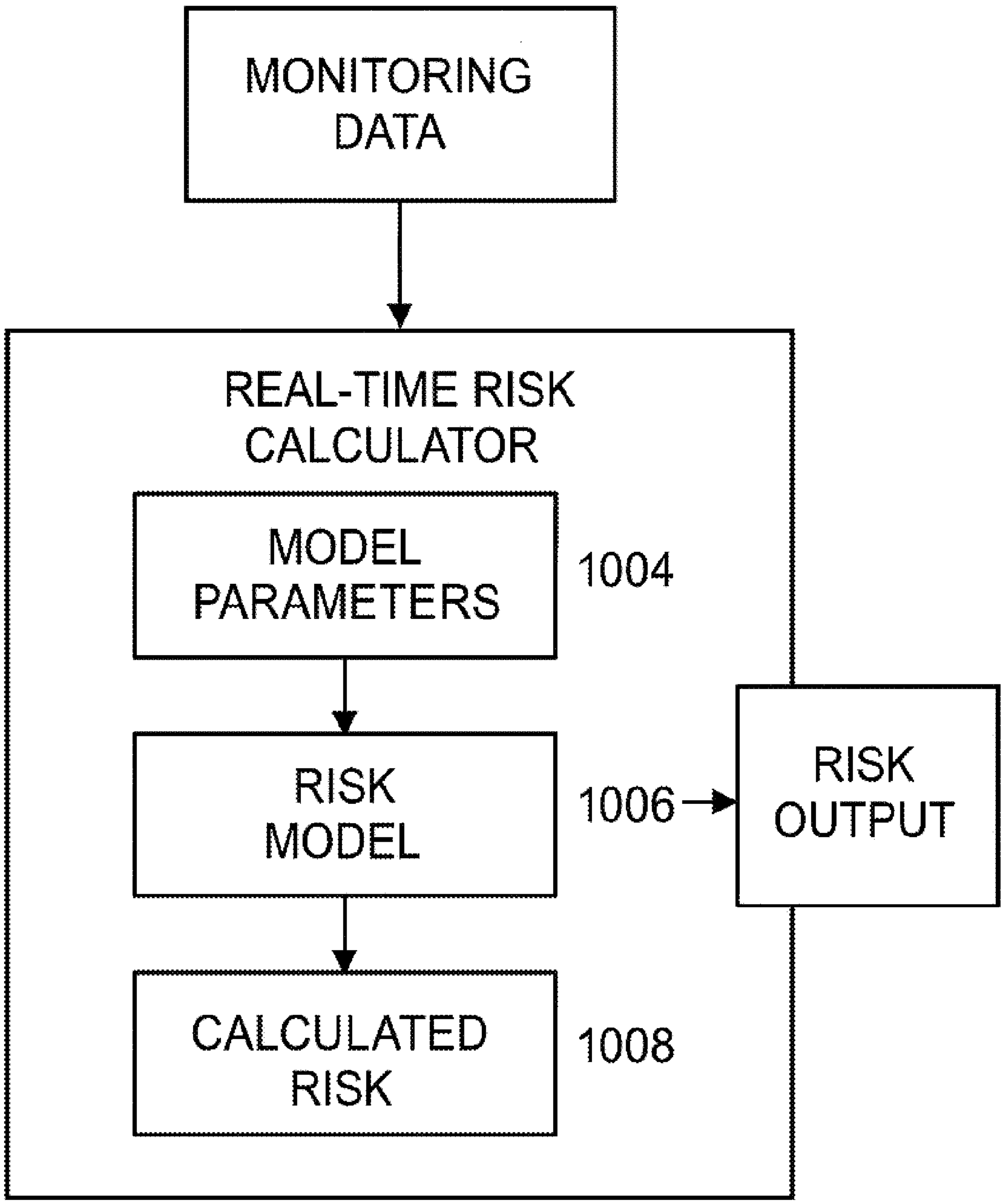

SENSOR &
ACTUATOR EVENTS
RULE ARBITER
(FACTOR ENGINE)
COMMAND
DISPATCHER
EVENT LOGGER
ACTUATOR
EXECUTION
HASH-LINKED
LEDGER BLOCKS
(AUDIT CHAIN)

FIG. 9



MONITORING DATA
REAL-TIME RISK CALCULATOR
MODEL PARAMETERS
1004
RISK MODEL
1006
RISK OUTPUT
CALCULATED RISK
1008

FIG. 10

FACTOR TABLE (Simplified)

ID	layer	conflict_ _group	mutually exclusive	synergy with	low threshold	harm severity	time - to_harm	default_ dose	auto execute

FIG. 11

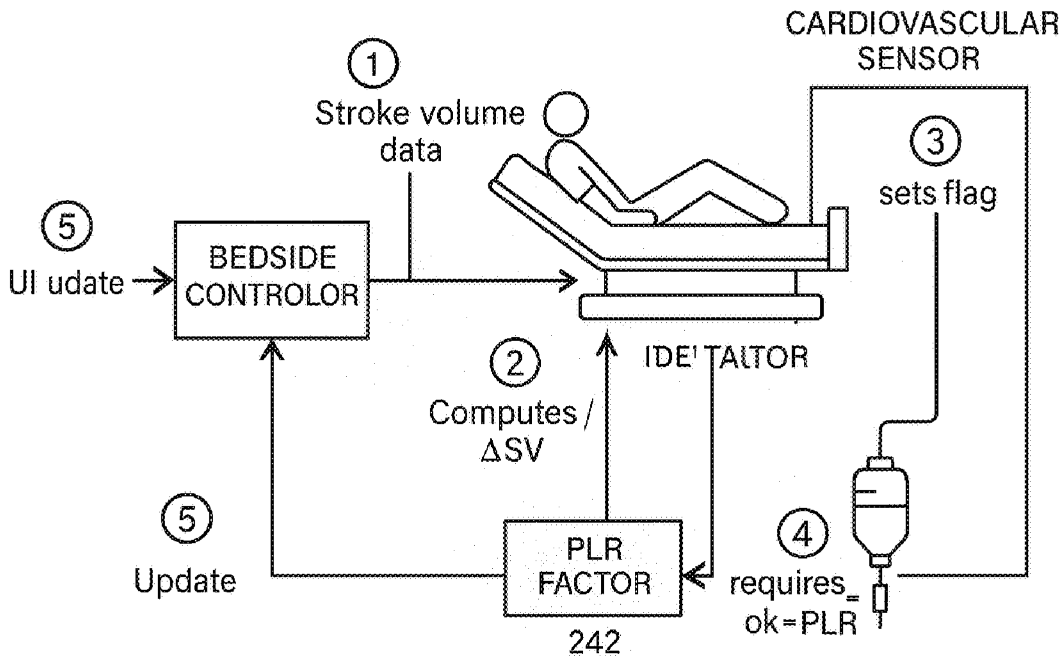


FIG. 12 – Passive Leg Raise Response Integration

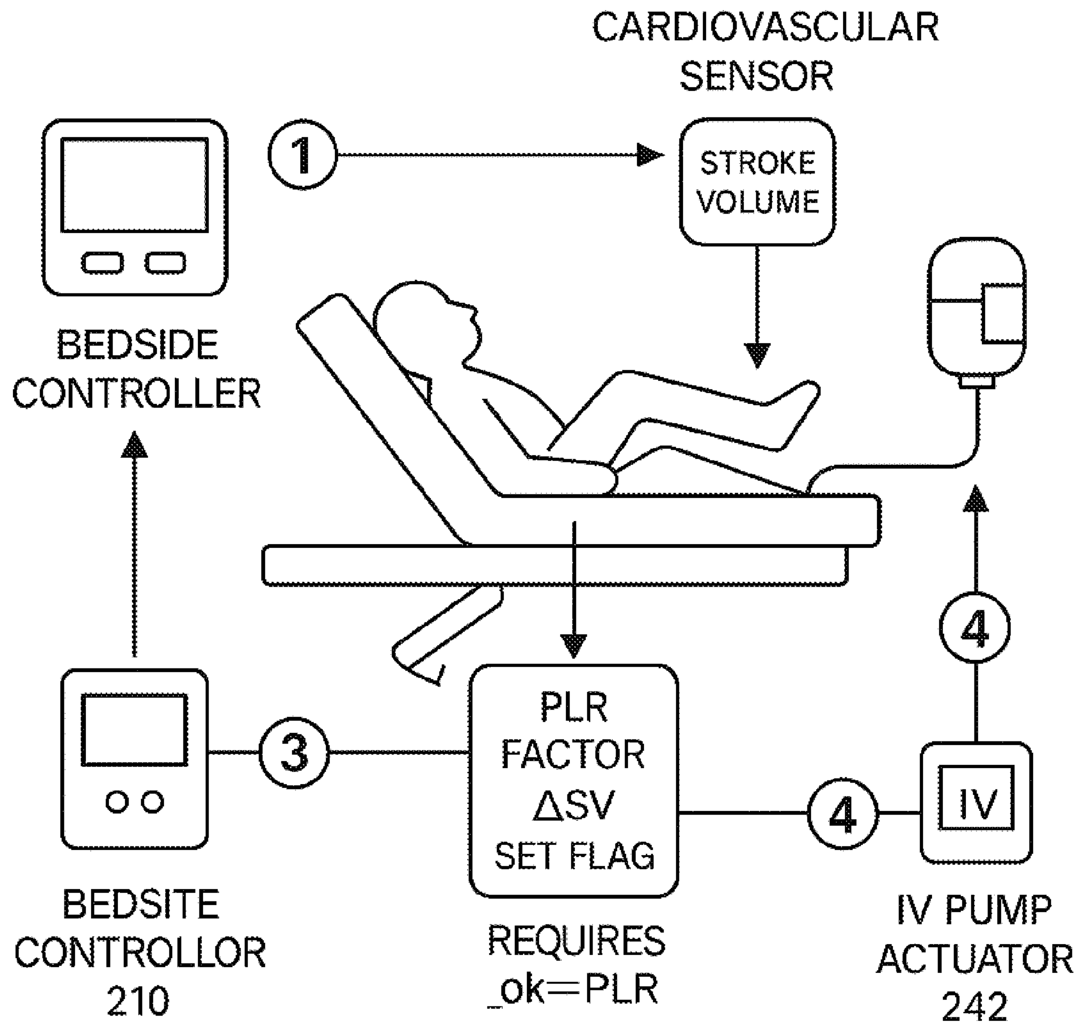


FIG. 12 – PASSIVE LEG RAISE RESPONSE INTEG-INTEGRATION

FIG. 12 – Passive Leg Raise (PLR) Response Integration

The schematic shows five numbered stages:

1. Stroke-volume sensor feed → bedside controller 210
2. Controller computes ΔSV and routes to the PLR Factor block

3. Factor sets “responsive” flag ($\geq 10\ \%\ \Delta SV$)

4. Flag un-gates the Fluid-Bolus loop, driving IV-Pump 242

5. UI chip 220 receives a real-time status update

Bed actuator and cardiovascular sensor share conflict-group BED; IV pump resides in IV_PUMP. Arrows trace the closed-loop flow from leg-raise command through hemodynamic feedback to automated fluid therapy.

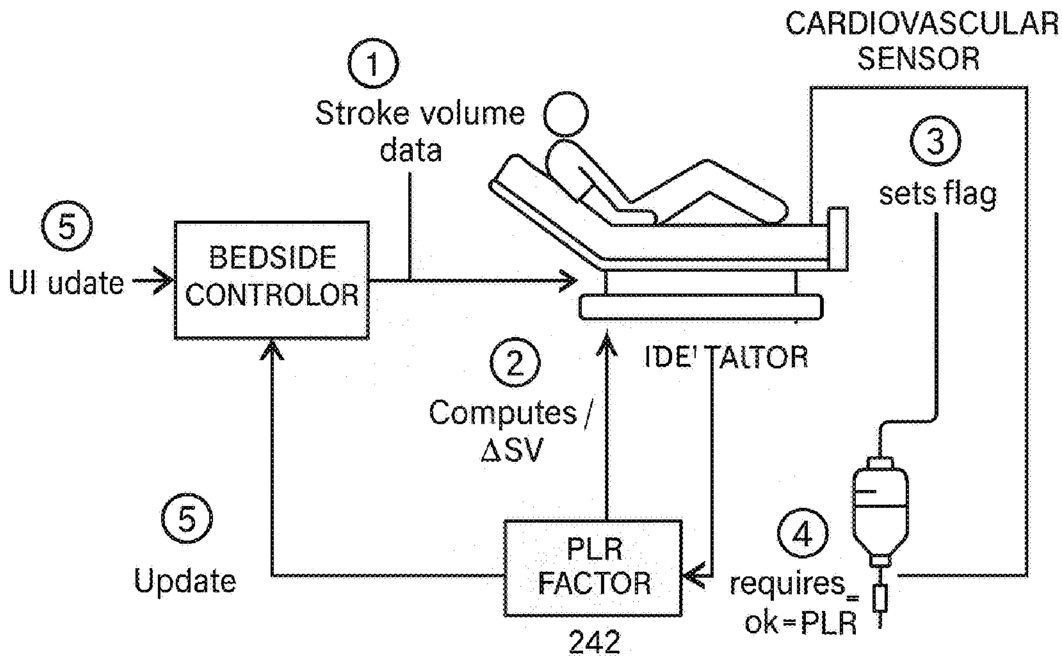


FIG. 12 – Passive Leg Raise Response Integration

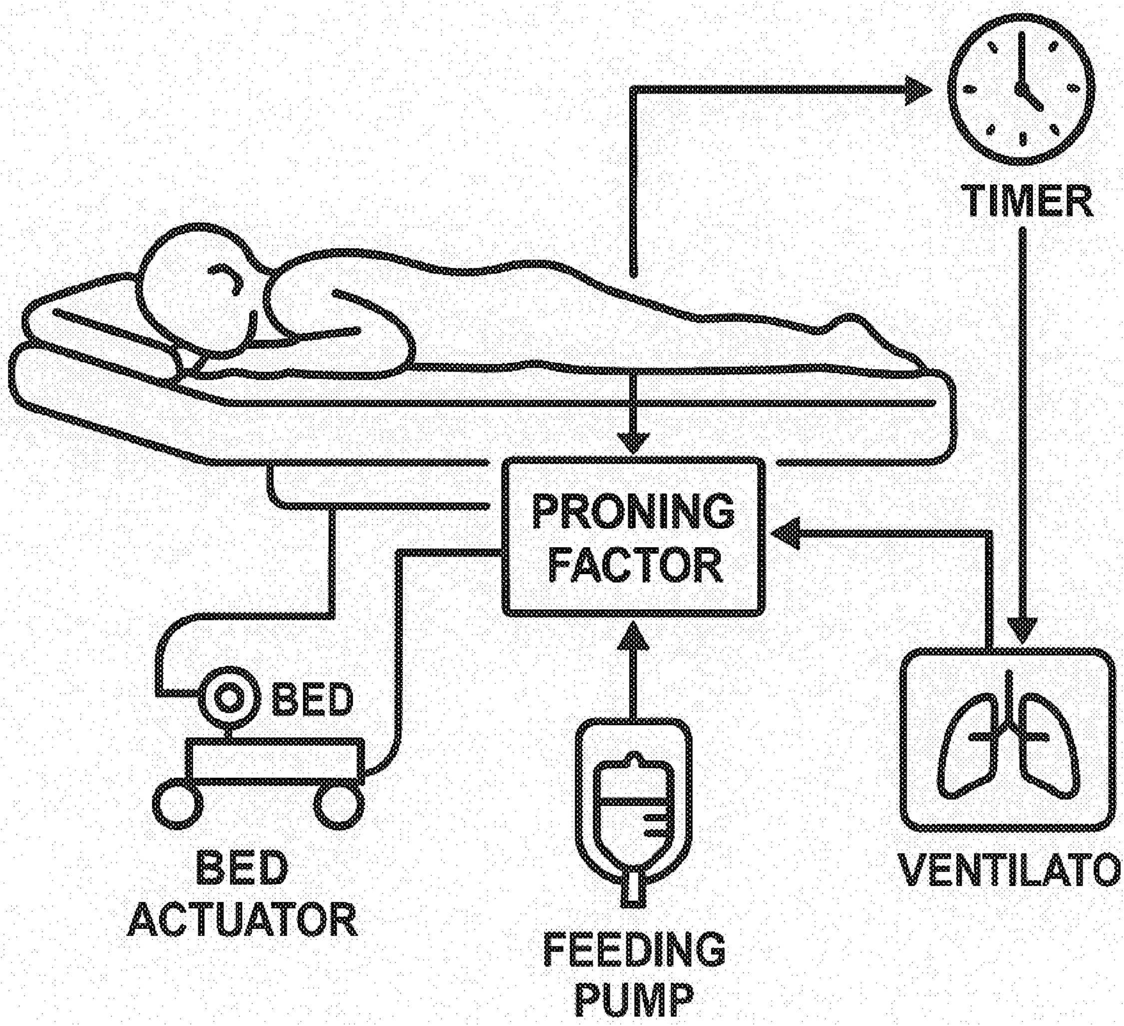


FIG. 13 – PRONING POSITION MODULE INTEGRATION

FIG. 13 – Proning Position Module Integration

The line-art schematic captures the prone-care workflow:

- A Proning Factor block commands the Bed Actuator to keep the patient face-down for the target duration (timer icon beneath).
- When the Proning Factor is true, the diagram shows feed pump auto-paused (left arrow) and ventilator loop active (right arrow), reflecting the cross-channel rules (feeding requires_ok = NOT PRONING; ventilation synergy_with = PRONING).

- All items share the BED conflict group, preventing simultaneous bed maneuvers.

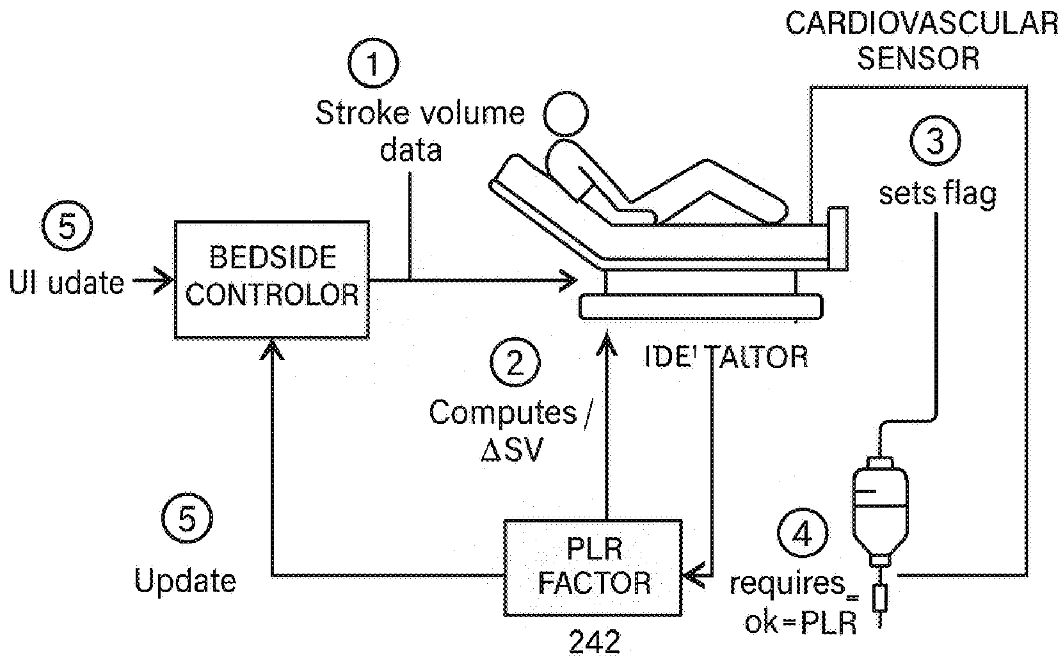


FIG. 12 – Passive Leg Raise Response Integration

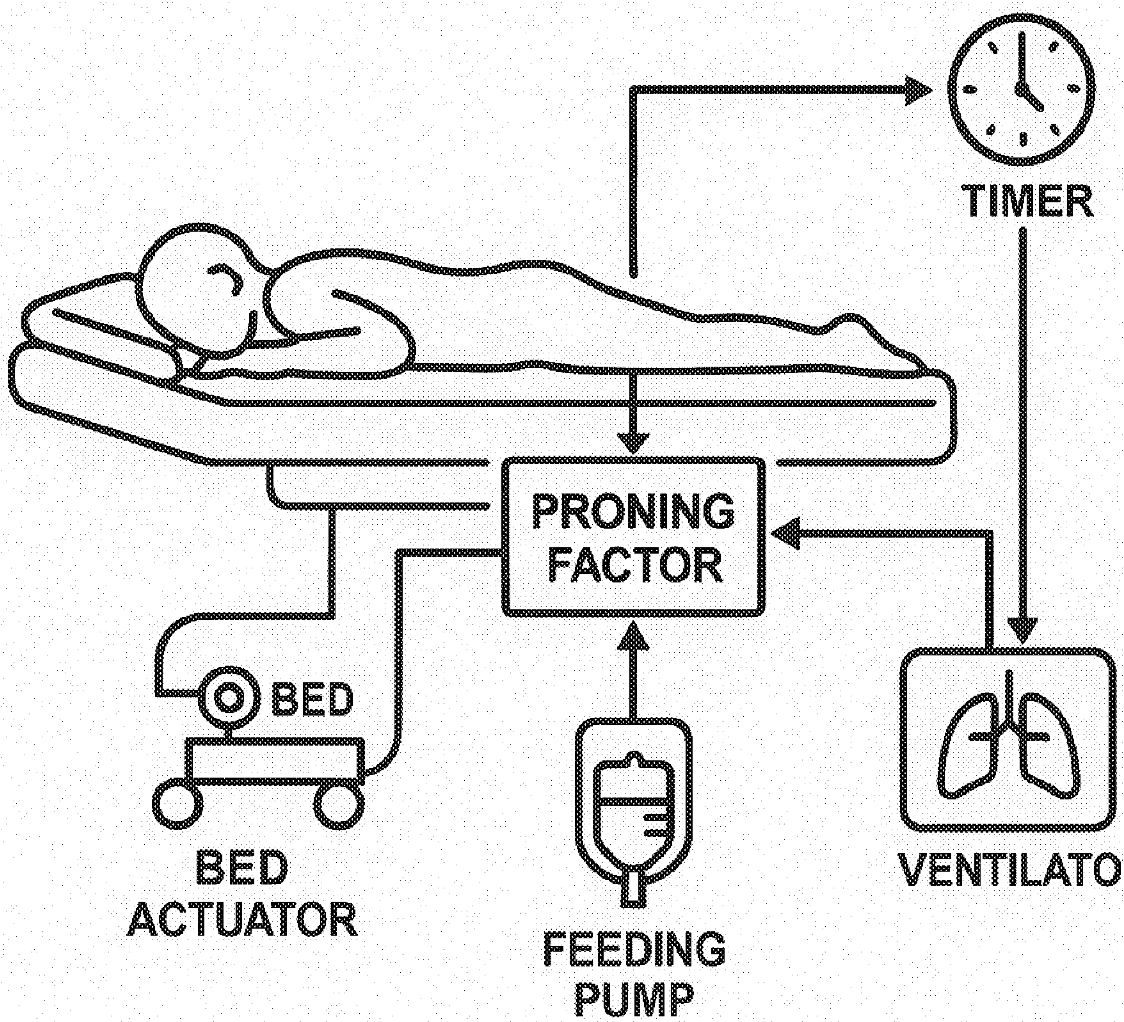


FIG. 13 – PRONING POSITION MODULE INTEGRATION

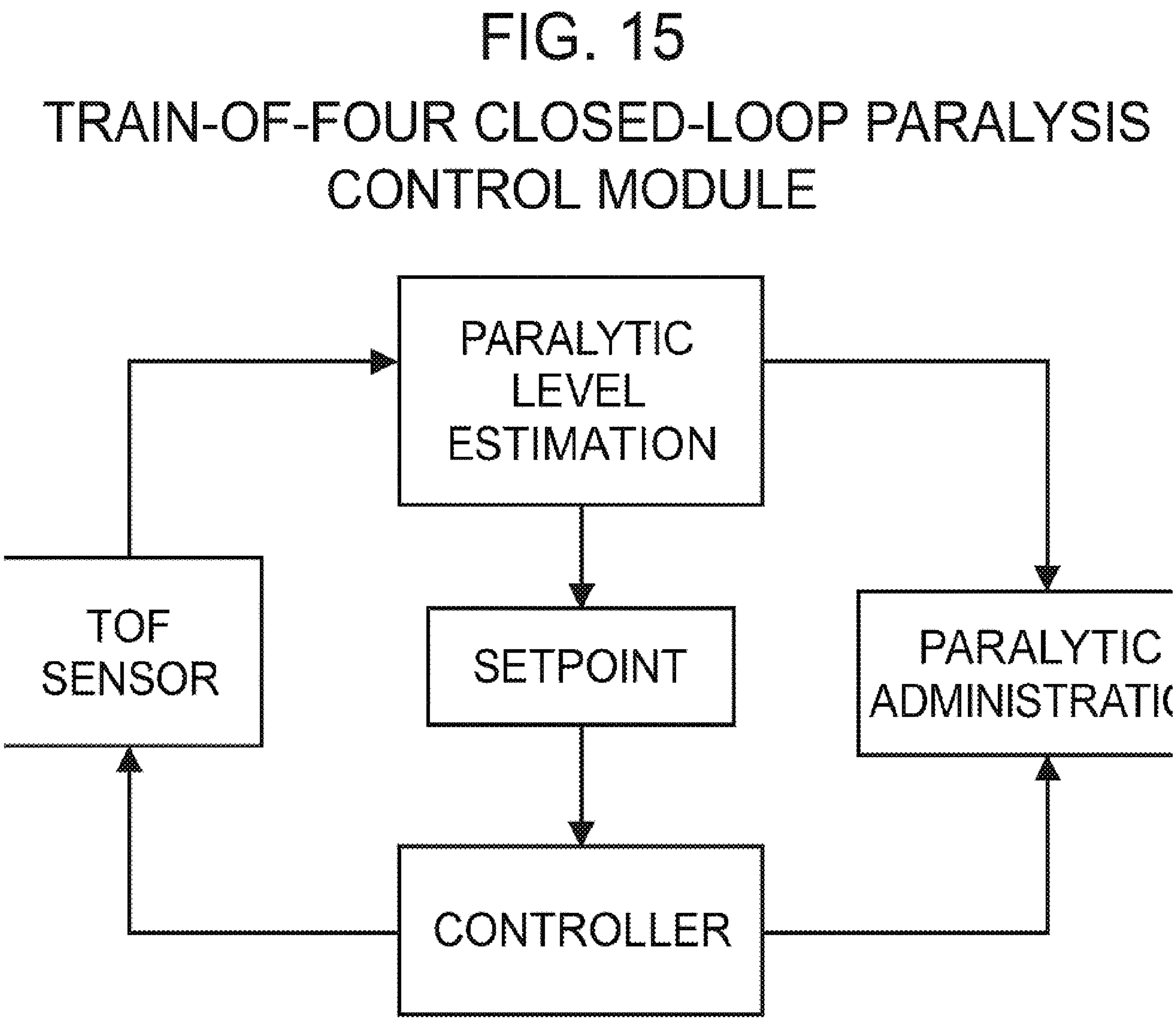


FIG. 15 — Train-of-Four (TOF) Closed-Loop Paralysis-Control Module

Sub-part	Description	Novel purpose

1000 TOF Sensor	Low-profile thumb accelomyograph patch that feeds twitch-amplitude samples (4 × 2 Hz) to the controller.	Converts conventional qualitative TOF into quantitative, streamable telemetry.
1010 Paralytic-Level Estimator	DSP block that filters artefacts, normalises twitch-4 ÷ twitch-1 and derives real-time TOF ratio.	Enables sub-minute trending for ultra-tight blockade titration.
1020 Set-point Generator	Dynamically picks target ratio (e.g. 0.2 for ARDS, 0.9 for recovery) based on higher-order protocol inputs.	Embeds protocol logic so targets shift automatically as sedation/wake cycles change.
1030 PID Controller	Calculates infusion-rate delta every cycle, weighted by reversibility_window to avoid overshoot.	First adaptive NMBA dosing loop that factors drug offset kinetics into gain scheduling.
1040 Paralytic-Administration Pump	Smart syringe-pump channel; accepts micro-dose commands (±5 %/step, max q2 min).	Micro-dosing minimises cumulative exposure and ICU-awakened weakness.
1050 Feedback Arrow	Closes loop every 30 s; if telemetry loss > 90 s watchdog drops infusion to a safe hold rate.	Built-in fail-safe unique to this cartridge-based controller.

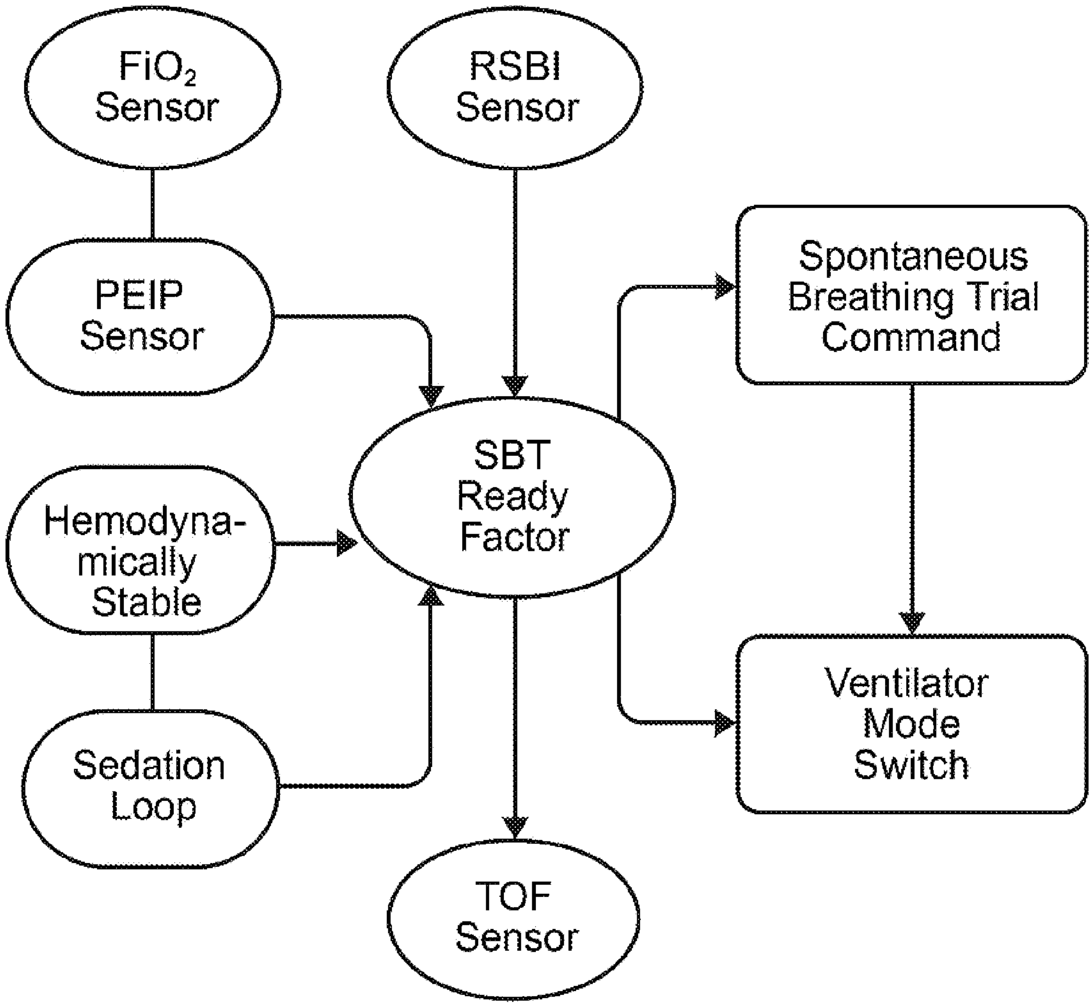


FIG. 16

COMPOSITE SBT READINESS DECISION GRAPH

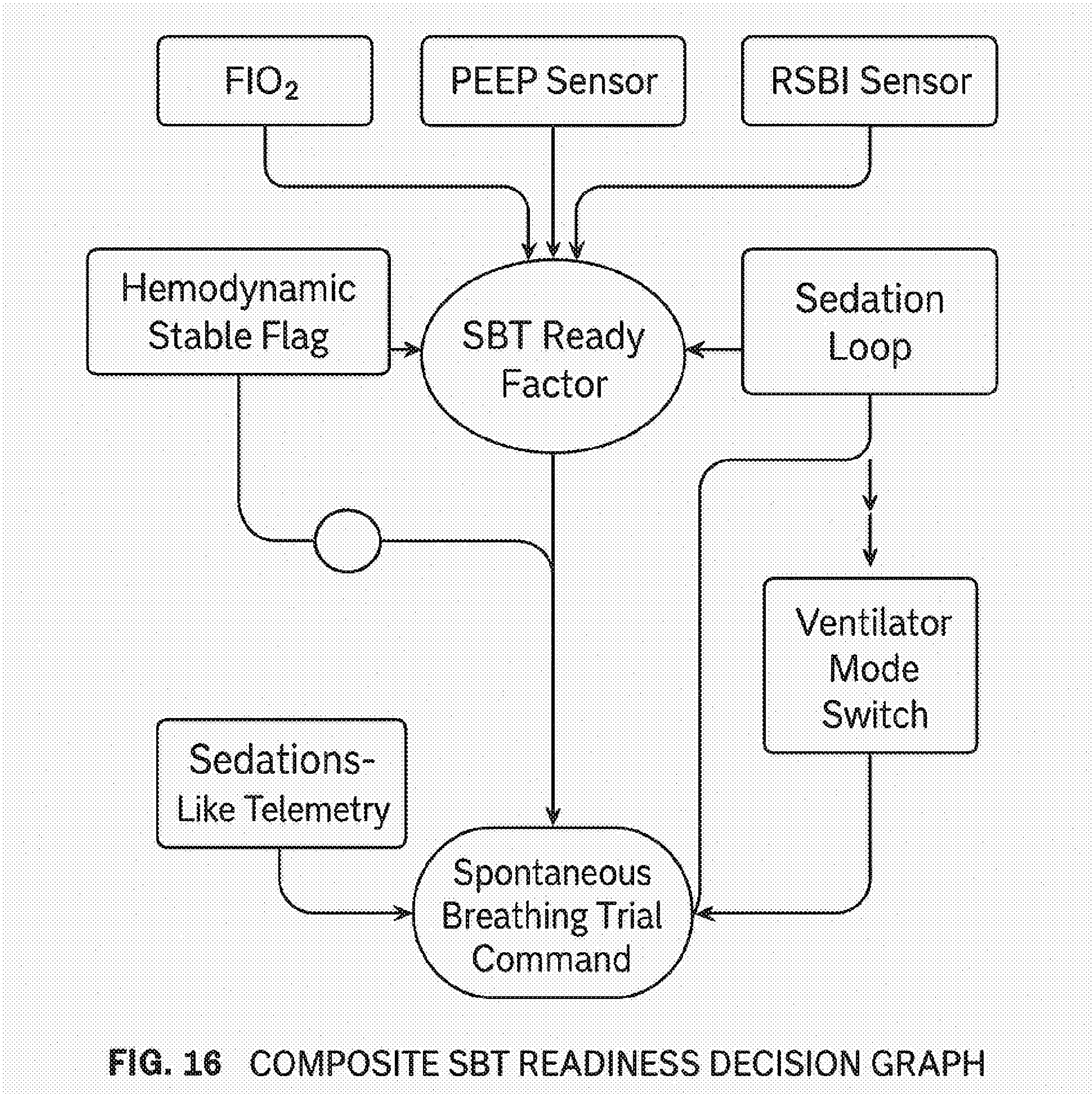


FIG. 16 — Composite SBT Readiness Decision Graph

Sub-part	Function	Novelty in TraceLoop-MX

4.1 FiO_2 Sensor	Streams fractional inspired-oxygen setting from ventilator.	Continuous ingestion allows real-time threshold (< 0.5) enforcement—not just charted once per shift.
4.2 PEEP Sensor	Captures positive-end expiratory pressure.	Decimated 1 Hz feed feeds rule engine; enables minute-by-minute readiness gating.
4.3 RSBI Sensor	Computes Rapid-Shallow-Breathing Index from RR ÷ VT.	Auto-derived every 5 s—eliminates manual calcs, yields earlier extubation.
4.4 Hemodynamic-Stable Flag	Boolean lifted from vasopressor infusion risk score (< 5 µg norad).	Cross-loop synthesis—ties infusor data into respiratory decision path.
4.5 Sedation Loop	Provides current RASS target & infusion state.	Dynamic synergy: controller can lighten sedation only when SBT flag true.
4.6 TOF Sensor	Ensures no residual paralysis (ratio ≥ 0.9) before trial.	Bridges neuromuscular and ventilator domains—unique multi-system gate.
4.7 SBT-Ready Factor (core)	AND-gate that flips true when all upstream nodes green ≥ 10 min.	Encodes protocol logic in machine-readable DAG—novel composite sensor.

4.8 Spontaneous Breathing Trial Command	Issues CPAP/PS 5 command to ventilator plus overrides feeding & sedation.	One-shot actuator packet bundles multi-device coordination.
4.9 Ventilator Mode Switch	Low-latency write to ventilator API; reverts on fail.	Adds closed-loop ventilator control absent from baseline TraceLoop IP.

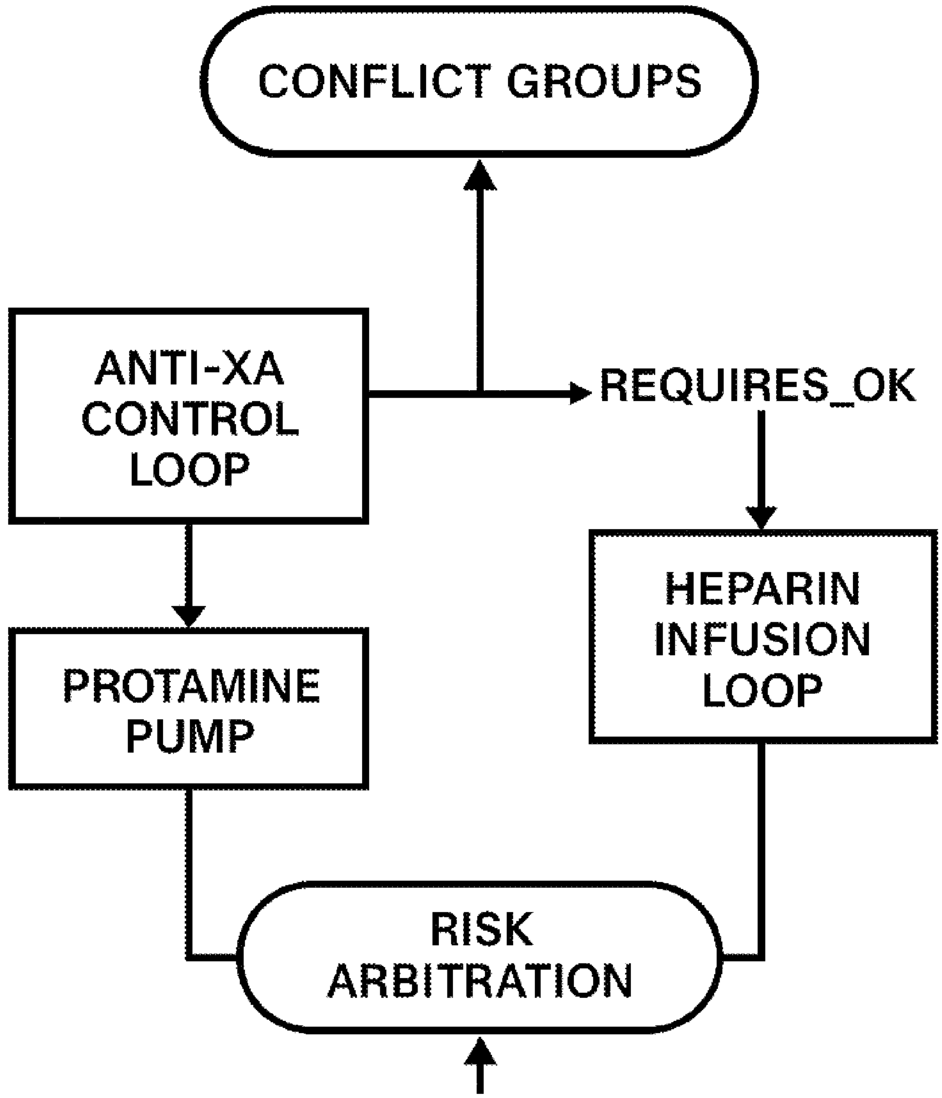

CONFLICT GROUPS
ANTI-XA
CONTROL
LOOP
REQUIRES_OK
PROTAMINE
PUMP
HEPARIN
INFUSION
LOOP
RISK
ARBITRATION

FIG. 17

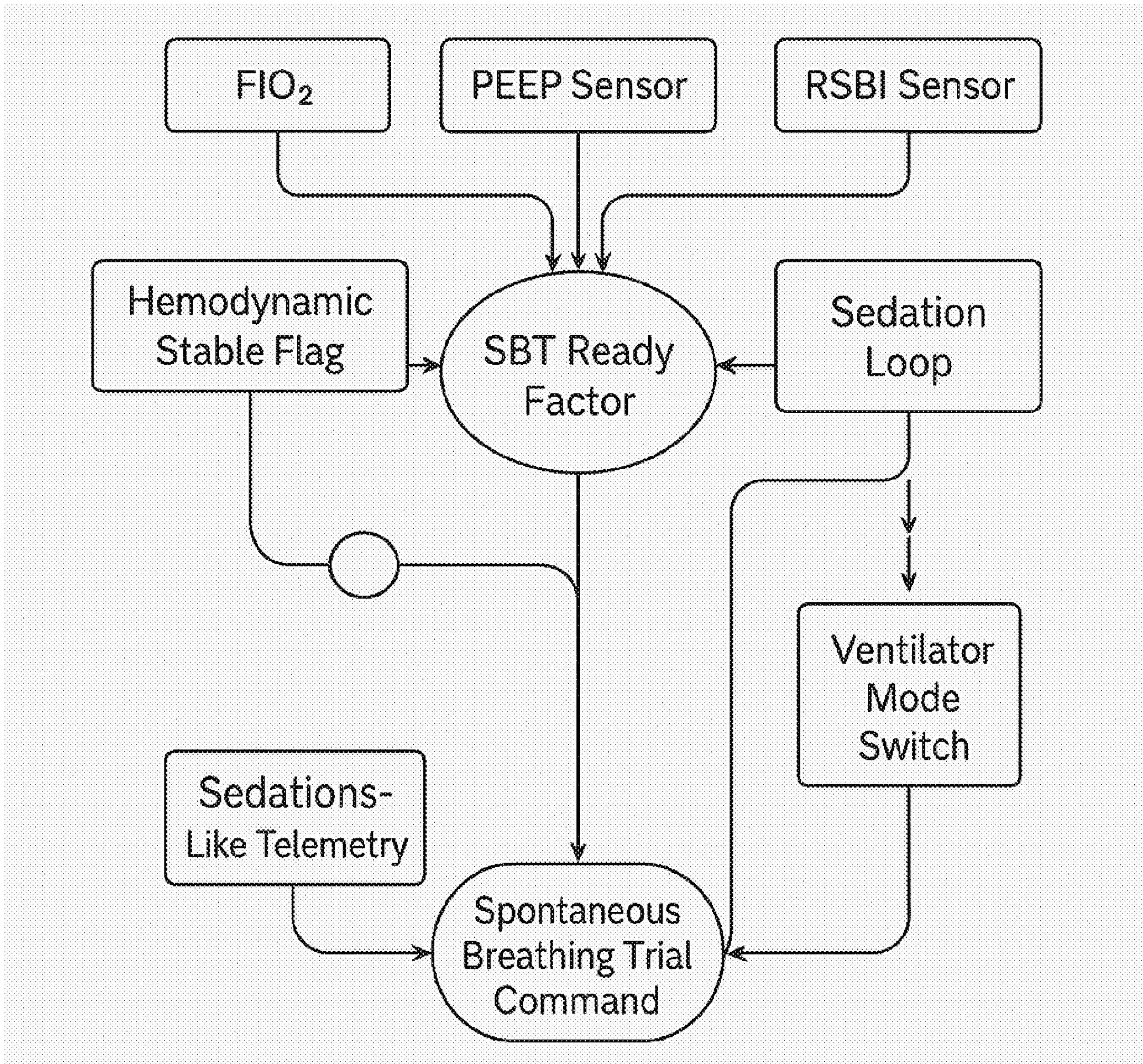


FIG. 16 COMPOSITE SBT READINESS DECISION GRAPH

FIG. 17 — Anti-Xa & Heparin Dual-Loop Interaction

Sub-part	Description	Novel control insight

5.1 Anti-Xa Control Loop	Reads sensor value, drives protamine pump when Anti-Xa > 0.7 IU/mL.	Assigns risk 17.5 giving it natural pre-emption over heparin infusion.
5.2 Protamine Pump	Micro-doses neutraliser (≤ 1 mg / min) under loop authority.	Guard-rail: rate‑limited via reversible-window-aware PID.
5.3 Heparin Infusion Loop	Maintains baseline anticoagulation when Anti-Xa < 0.3 IU/mL.	Carries lower risk (15) and has requires_ok = Anti-Xa Loop gate.
5.4 Conflict-Groups Node	Shows both loops use distinct pumps; thus physical conflict is zero—only logical gating applies.	Demonstrates novel separation of hardware vs logic conflict.
5.5 Risk-Arbitration Node	Engine selects winner each 10 ms cycle; if Anti-Xa high, protamine wins and heparin is blocked.	Encapsulates deterministic safety behaviour unique to this dual-loop design

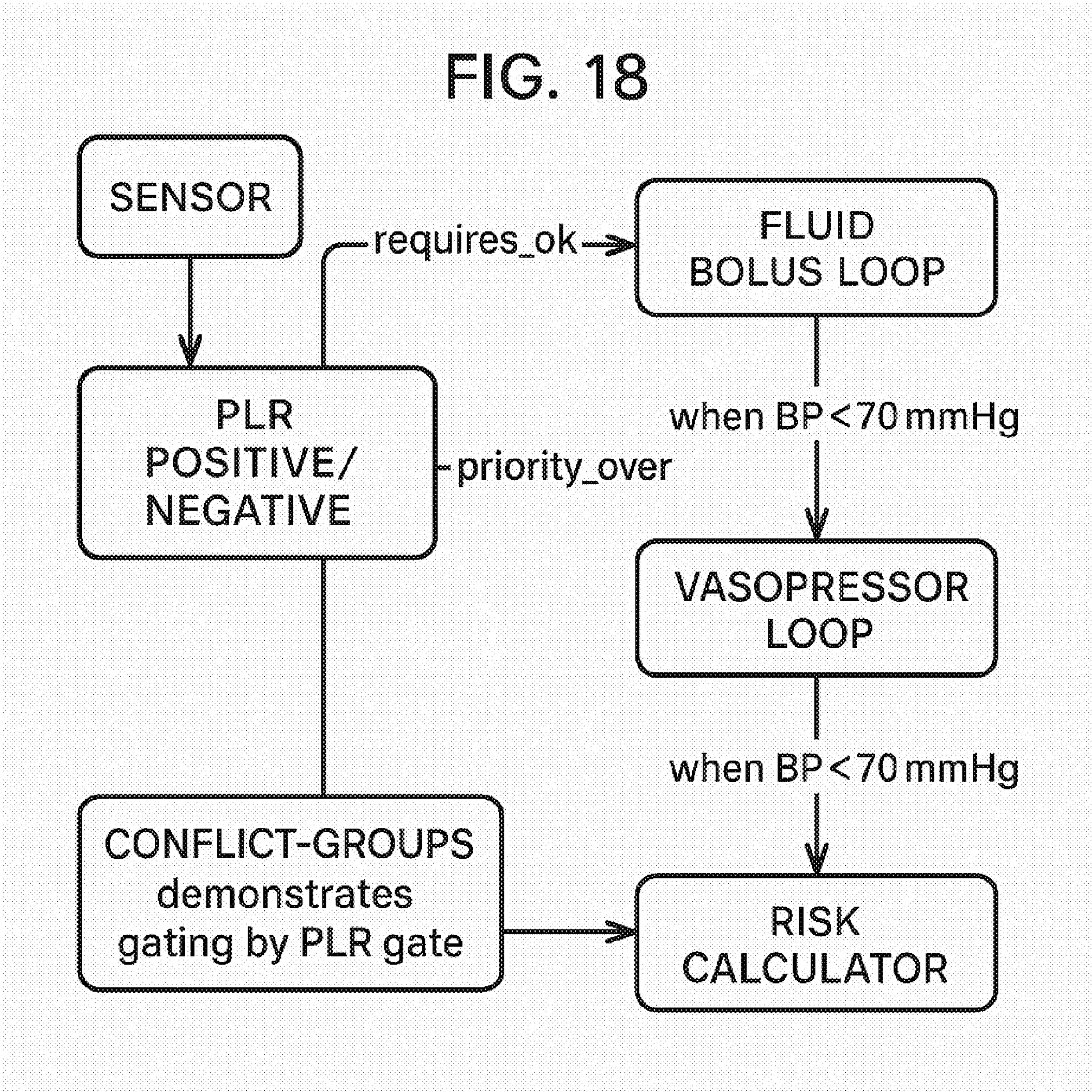


FIG. 18 — PLR-Gated Fluid-vs-Vasopressor Arbitration

Sub-part	Function	Novel aspect

6.1 PLR Sensor	Delivers Positive/Negative flag after leg-raise.	Continuous telemetry—no manual data entry.
6.2 PLR-Gate Node	Boolean factor; TRUE only when $\Delta SV \geq 10$ %.	Acts as machine-readable “fluid responsiveness” credential.
6.3 Fluid-Bolus Loop	Gives 4 mL kg IV bolus when MAP < 65 mmHg and PLR-Gate TRUE.	requires_ok = PLR-Gate prevents futile fluid loading.
6.4 Vasopressor Loop	Starts norepinephrine if MAP < 65 mmHg and PLR-Gate FALSE.	priority_over arrow flips if gate false; pressor wins.
6.5 Risk-Calculator Node	Computes dynamic risk so whichever loop is active gets higher harm score, feeding scheduler.	Numeric arbitration replaces ad-hoc clinician choice.
6.6 Conflict-Groups (IV_PUMP vs PRESSOR_PUMP)	Shows loops run on separate pumps, so logic—not hardware—drives exclusivity.	Illustrates TraceLoop’s novel ability to gate cross-actuator therapies by diagnostic