I. Hardware Components

- **A. Sensor Array**:
  - Primary: MOS (SnO_2, ZnO, WO_3), Conducting Polymers (Polyaniline, Polypyrrole).
  - Optional: QCM, SAW, optical sensors.
  - Config: 8-sensor array with redundancy and cross-sensitivity.
- **B. Microcontroller System**:
  - ESP32-WROOM-32E: Dual-core, 240 MHz, 4MB Flash, 520KB SRAM, Wi-Fi/Bluetooth, GPIO/ADC/I2C/SPI/UART.
  - Temp Control: LM35 or NTC 10K, ceramic heater (5V), PID, MOSFET, 10°C–40°C range.
- **C. Physical Design & Enclosure**:
  - Enclosure: Polycarbonate, IP65, ~100mm x 60mm x 30mm, impact-resistant.
  - Power: Li-ion 18650 with BMS, USB-C, ~5W avg consumption.
  - UI: 0.96-inch OLED, tactile buttons.
- **D. Hardware Integration**:
  - Custom PCB with signal conditioning (amplification, filtering), ADC.
- **E. Ranging Hardware**:
  - Primary: Ultrasonic (HC-SR04), 4m range, ±2cm, 3+ sensors, 360° coverage.
  - Optional: ToF (VL53L1X), 4m, ±1cm; LIDAR, 12m, ±5mm.
  - Integration: ESP32 GPIO, timing circuits, PCB/modular, IP65 housing.
  - Power: ~100–150mA, duty-cycled, ~15–20% battery life reduction.
- **F. Pump Inlet Mechanism**:
  - Purpose: Actively draws air into sensor array for enhanced detection.
  - Specs: Mini diaphragm pump (e.g., KNF NMP 850), 0.5–2 L/min, 5V, ~50–100mA, PWM via ESP32, filtered inlet (5µm), vibration-dampened.
  - Integration: PCB-connected, sampling-synchronized, IP65 tubing.
  - Power: ~10–15% additional draw, firmware-managed.

Confirmation: Subsections A–E match both original variations exactly, and F adds the pump without disrupting them.