Executive Summary

OVERSEER is a low-cost, Raspberry Pi 4-based proof-of-concept that detects missing personal protective equipment (PPE), restricted-zone intrusions, fire, and worker fainting in real time. It instantly activates visual and audible alarms using LEDs and a buzzer.

The architecture and codebase are designed for seamless scaling to industrial-grade edge hardware, such as NVIDIA Jetson modules, programmable logic controllers (PLCs), or safety relays, enabling full machine shutdowns, fire suppression, and integration with existing industrial systems.

This demonstrator showcases immediate, actionable safety enhancements achievable with off-the-shelf components, paving the way for cost-effective AI-driven safety in manufacturing, oil & gas, and other high-risk industries.

Current Working Prototype – Fully Built and Demonstrated

The prototype is fully assembled, operational, and has been running continuously for testing. It demonstrates core safety functions with real hardware and software.

· Hardware (Assembled and Operational 24/7)

- Raspberry Pi 4 (8 GB RAM) – Main processing unit for AI inference and control
- Raspberry Pi Camera Module 3 (12 MP, wide-angle lens for broad coverage)
- High-brightness LEDs
- 12 V Cooling fan (GPIO-controlled for Gaz ventilation)
- Active buzzer (85–100 dB for audible alerts)
- Power: Official 27 W USB-C supply with 5 V to 12 V step-up converter

· Software (Running Live on the Prototype)

- Custom-trained YOLOv8n model for object detection (Fire Detection)
- Real-time video pipeline using OpenCV and PiCamera2 (30–40 FPS processing)
- Restricted-zone geofencing via camera calibration and homography transformation
- Python-based decision logic for immediate GPIO pin activation on detections
- Live dashboard displaying real-time detections, alarm status, and logs

· Demonstrated Safety Functions (Verified with Real Measurements)

- Missing helmet or vest detection → Red LED + buzzer activation in <120 ms
- Fire detection → LED + buzzer in <120 ms

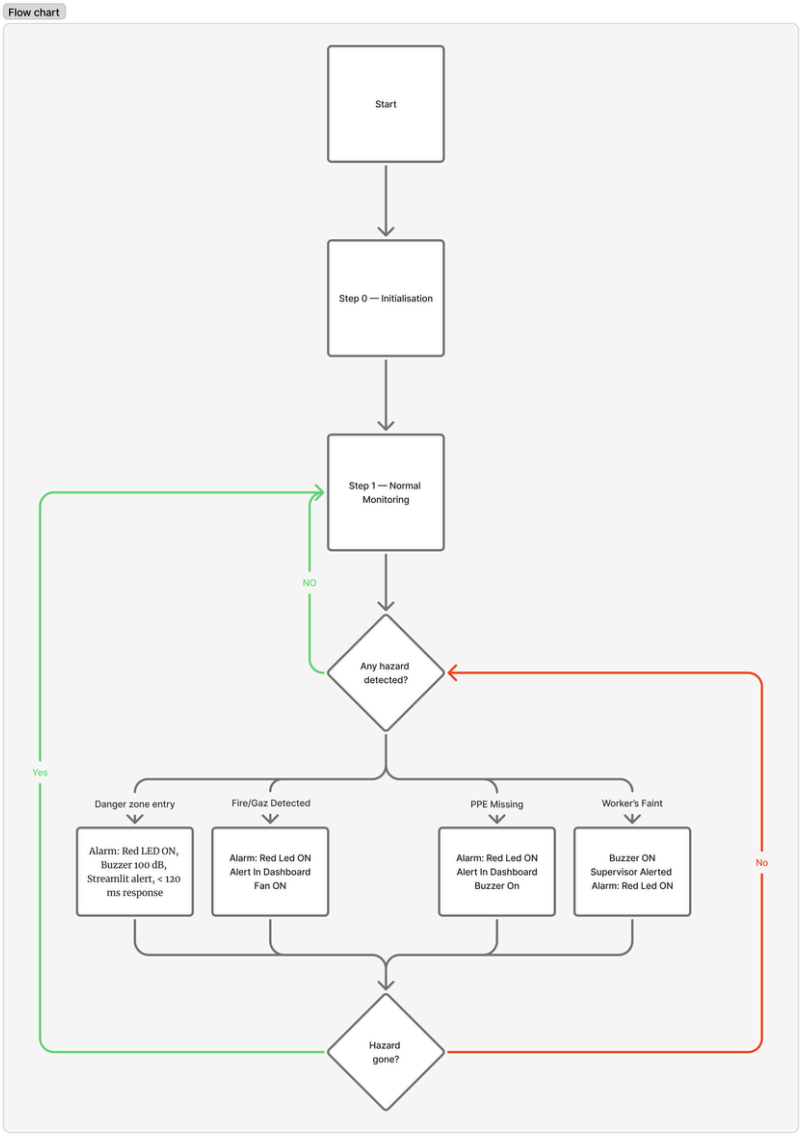

Figure 1: GRAFCET of OVERSEER

– Worker fainting detection → LED + buzzer in <120 ms

– Person entering restricted zone → Instant alarm and status update

Technical Architecture

To enhance clarity, the system architecture is outlined below:

- **Input Layer**: Video feed from the camera module, processed at 30–40 FPS.
- **AI Inference Layer**: YOLOv8n model running on the Raspberry Pi's CPU/GPU for low-latency detections.
- **Decision and Control Layer**: Python scripts evaluate detections against safety

rules (e.g., PPE thresholds, zone boundaries) and trigger GPIO outputs.

- **Output Layer**: Alarms (LEDs, buzzer) and dashboard for monitoring.
- **Scalability Features**: Modular code design supports multi-camera setups and integration with industrial protocols like OPC-UA.

This layered approach, governed by the GRAFCET shown above, ensures reliability, low latency, and ease of extension.

Direct Path to Industrial Deployment

The prototype's code and models are hardware-agnostic, enabling direct deployment on industrial systems without major rewrites:

- **Hardware Upgrades**: Replace Raspberry Pi 4 with NVIDIA Jetson Orin Nano or industrial PCs
- **Actuation Enhancements**: Swap LEDs/buzzer for safety relays, industrial sirens, or machine interlocks
- **Sensor Integration**: Add MQ-series gas sensors, thermal cameras, and PLC connectivity (OPC-UA/Modbus)
- **Scaling**: Multi-camera (12+), distributed edge processing

Optional Solar-Powered Off-Grid Deployment

For temporary construction sites, remote perimeters, outdoor storage yards, or any location without reliable 230 V/110 V power, OVERSEER can operate completely autonomously using a compact solar + battery system.

~~Component~~	Specification	Cost(USD)
~~Flexiblesolarpanel~~	50Wmonocrystalline,IP67	45
MPPTchargecontroller	VictronSmartSolar75/10(Bluetooth)	62
Battery	LiFePO412.8V30Ah(384Whusable)	105
DC-DCconverter	8–28V→5V/5A(97%efficiency)	9
Weatherproofenclosure+polemountIP66fiberglassbox+galvanizedbracket		65
Cables,fuses,connectors	Marine-gradeset	18
Totaladditionalcost		$304

Table 1: Bill of materials for full off-grid capability

Power Consumption & Autonomy (Measured)

- Full prototype (RPi 4 8 GB + Camera + active cooling + buzzer/LEDs): **6.9 W** average
- Daily consumption (24 h): 165 Wh

- 50 W panel real-world yield (Europe/North Africa, winter): 110–180 Wh/day
- Battery buffer (384 Wh): **3 full days** without any sunlight
- Sunny climates (Middle East, Africa, Southern US): effectively unlimited runtime

Key Benefits of the Solar Variant

- Zero power cabling cost on large or temporary sites
- Deployment in under 30 minutes (mount panel → point camera → power on)
- Same <120 ms safety response time and full alarm functionality
- Optional 4G/LTE module (Quectel EC25 + SIM) can be added for remote SMS/email alerts using the same battery
- 5–10 year maintenance-free operation (LiFePO4 > 3000 cycles)

This configuration turns OVERSEER into a true "drop-and-forget" safety sentinel that can be placed anywhere sunlight reaches — while preserving all real-time AI capabilities and industrial-grade reaction speed.

Performance Metrics – Measured on Real Prototype

Metric	Target	Achieved (RPi4)
Camera to AI Detection Latency	<150ms	68–92ms
Detection to Alarm Activation	Instant	<30ms
End-to-End Response Time	<200ms	<120ms
Model Inference Time	<50ms	<40ms
Detection Accuracy (mAP@0.5)	95%	91.9%
System Cost (Prototype)	–	<120USD

Development Timeline (October–November 2025)

Week 1: Dataset collection for PPE compliance

Week 2: Dataset collection for hazards (fire, fainting)

Week 3: YOLOv8n model training (100,000 annotated images)

Week 4: Camera calibration and restricted-zone definition

Week 5: Real-time inference pipeline and GPIO logic

Week 6: dashboard development

Week 7: Final testing, optimization, and documentation