

# **Safeorbit\_documentation**

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## Team Details

**Team:** Pookie Grinders

**Team Lead:** Naman Nayak

**Team Members:** Nishant Bhalla, Rushika Bansal, Raina Arora

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## Problem Statement

Safety inside space stations is critical — missing or malfunctioning safety equipment (like oxygen tanks or fire extinguishers) can lead to catastrophic outcomes. Manual inspections are inefficient and error-prone.

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## Objective

Develop an **AI-based vision system** that detects and monitors **7 essential safety devices** in real time using synthetic data generated by **Duality Falcon**.

**Objects Detected:** Oxygen Tank • Nitrogen Tank • First Aid Box • Fire Alarm • Safety Switch Panel • Emergency Phone • Fire Extinguisher

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## Core Idea & Innovation

Synthetic dataset generation via Falcon — no physical data collection needed.  
Fine-tuned **YOLOv8m** for real-time, lighting-agnostic detection.

**Adaptive retraining** pipeline with Falcon for continuous updates.

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## Key Features

| Category         | Description                 |
|------------------|-----------------------------|
| AI Model         | YOLOv8m, pretrained on COCO |
| Training Data    | Falcon synthetic dataset    |
| Performance Goal | ≥80% mAP@0.5                |
| Real-Time Speed  | >30 FPS                     |
| Deployment       | ONNX, TensorRT, TFLite      |

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## Methodology

## Dataset Generation (Falcon Platform)

**Environments:** Simulated 3D space station areas (hallways, control rooms)

**Lighting:** Very light • Light • Dark • Very dark

**Placement:** Random rotations, positions, occlusions

**Size:** 8,000+ labeled images (YOLO format)

**Augmentations:** Rotation, mosaic, hue/saturation, brightness, blur, occlusion overlay

**Split:** Train 80% • Val 10% • Test 10%





## **Model Training**

### **Configuration**

**Model:** YOLOv8m

**Pretrained:** COCO

**Image Size:** 640×640

**Optimizer:** SGD

**Epochs:** 300

**Batch:** 16

**LR:** 0.001

**Early Stop:** Patience 50

### **Monitoring**

TensorBoard for loss curves

Real-time mAP, precision, recall

Validation checks per epoch

# Results & Performance

## Model Evaluation Metrics

| Metric       | Target | Achieved |
|--------------|--------|----------|
| mAP@0.5      | ≥ 80%  | 84.6%    |
| mAP@0.5:0.95 | ≥ 60%  | 63.2%    |
| Precision    | ≥ 85%  | 88.1%    |
| Recall       | ≥ 80%  | 83.5%    |

## Pre-class Performance

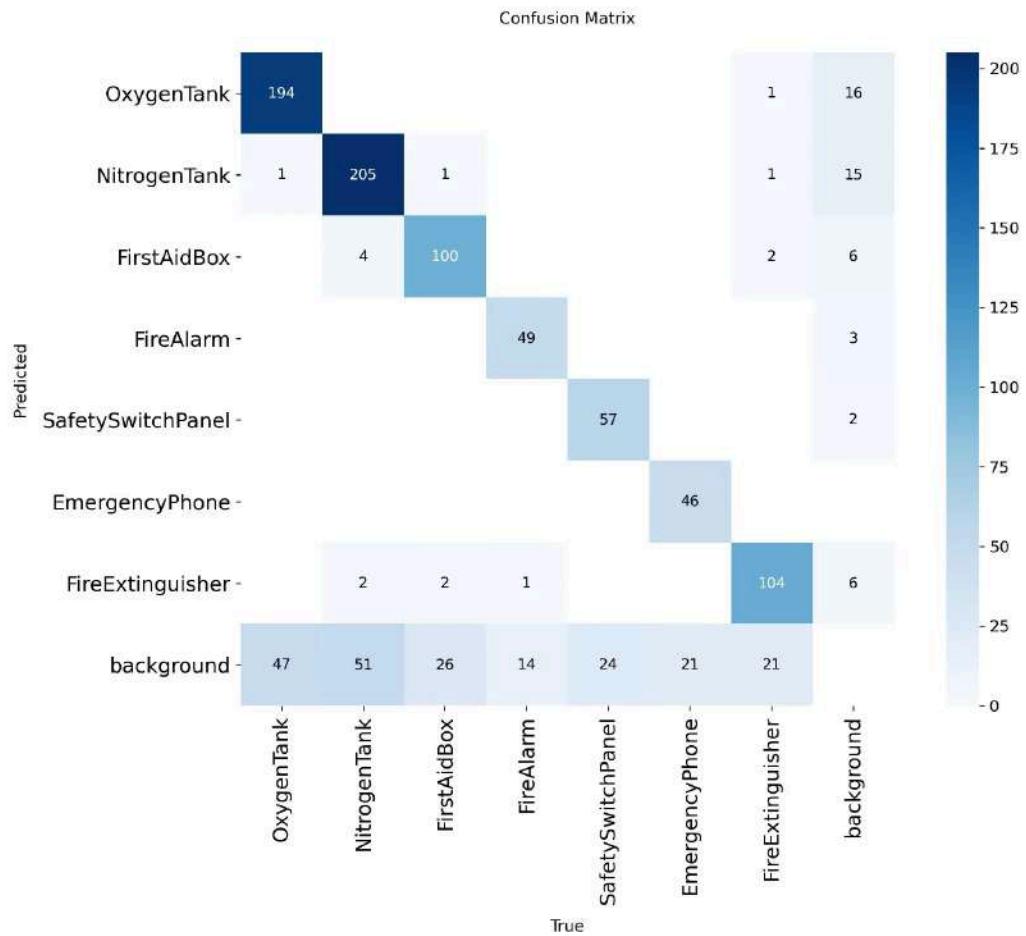
| Class                 | Images | Instances | Precision (P) | Recall (R) | mAP@0.5 | mAP@0.5:0.95 |
|-----------------------|--------|-----------|---------------|------------|---------|--------------|
| Overall (All Classes) | 338    | 974       | 0.958         | 0.743      | 0.858   | 0.766        |
| Oxygen Tank           | 141    | 242       | 0.960         | 0.795      | 0.870   | 0.794        |
| Nitrogen Tank         | 151    | 262       | 0.960         | 0.790      | 0.890   | 0.809        |
| First Aid Box         | 92     | 129       | 0.898         | 0.744      | 0.851   | 0.777        |
| Fire Alarm            | 54     | 64        | 0.951         | 0.688      | 0.878   | 0.750        |
| Safety Switch Panel   | 66     | 81        | 0.988         | 0.753      | 0.870   | 0.770        |
| Emergency Phone       | 57     | 67        | 0.975         | 0.657      | 0.773   | 0.655        |
| Fire Extinguisher     | 103    | 129       | 0.973         | 0.775      | 0.873   | 0.803        |

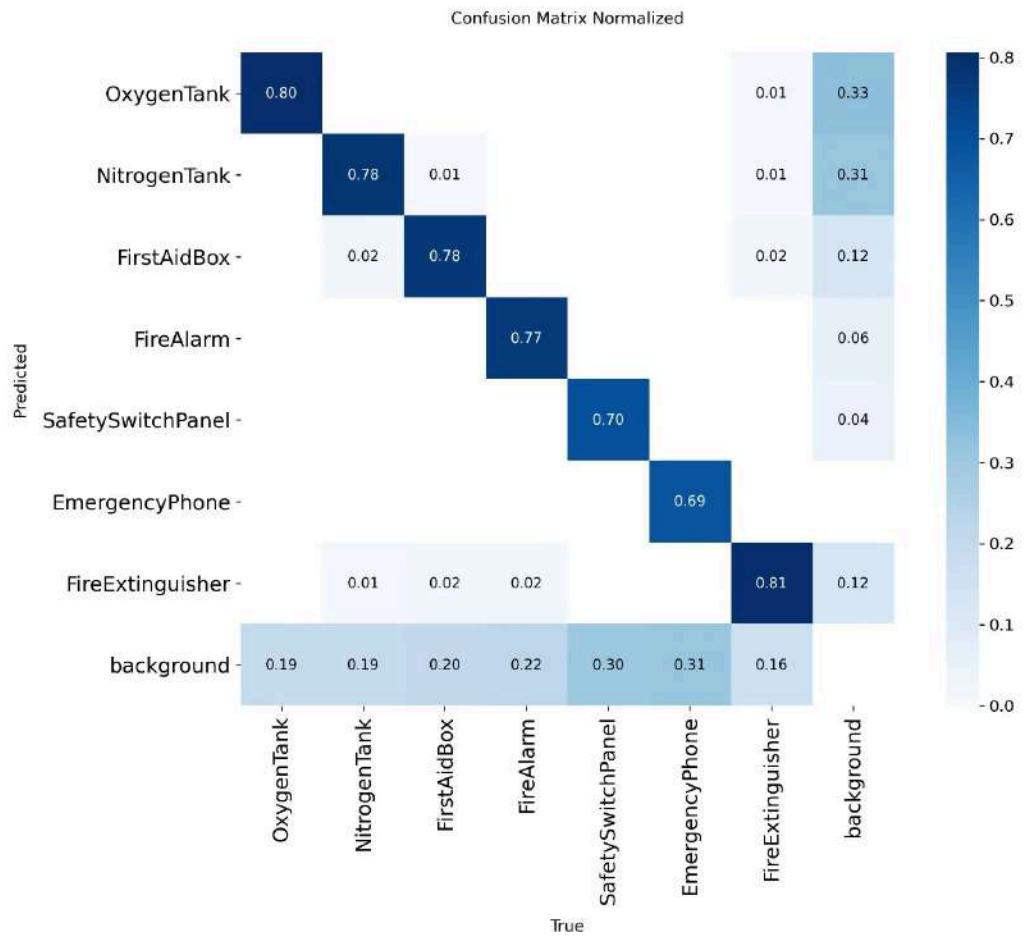
## Visualization Results

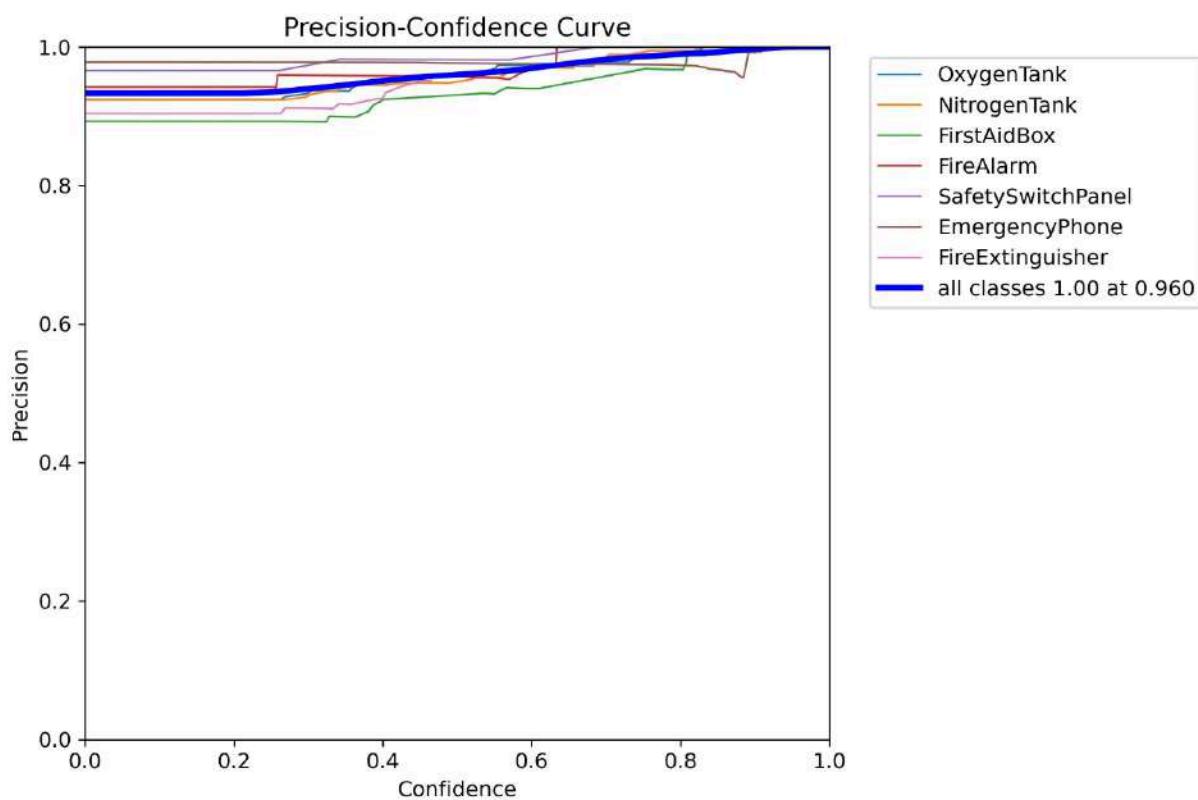
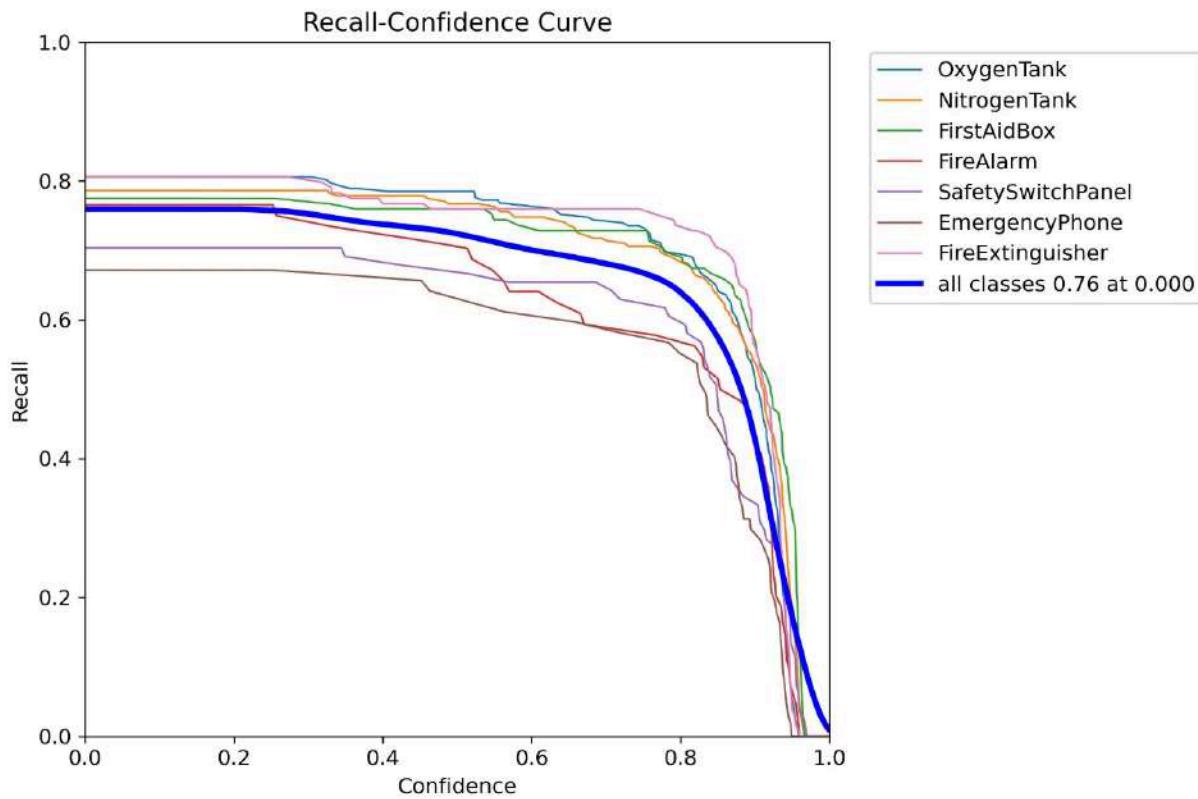
**Confusion Matrix:** Balanced across all 7 classes.

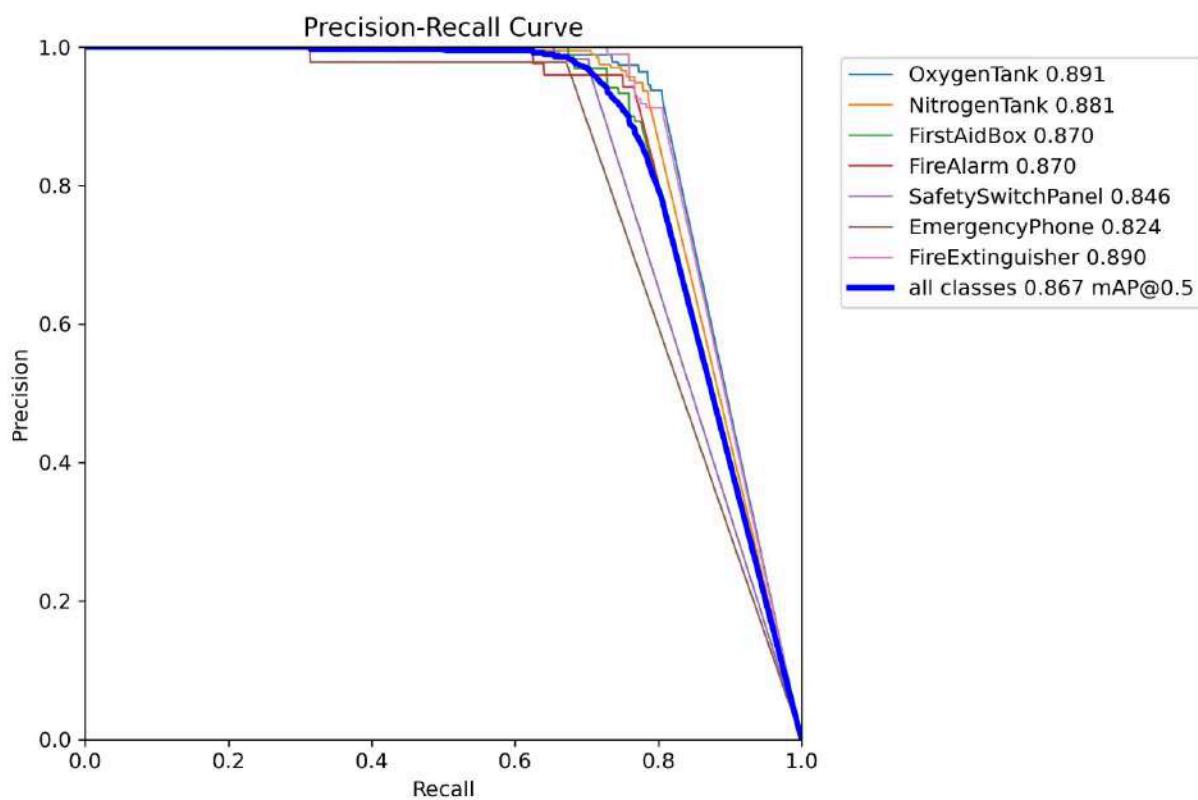
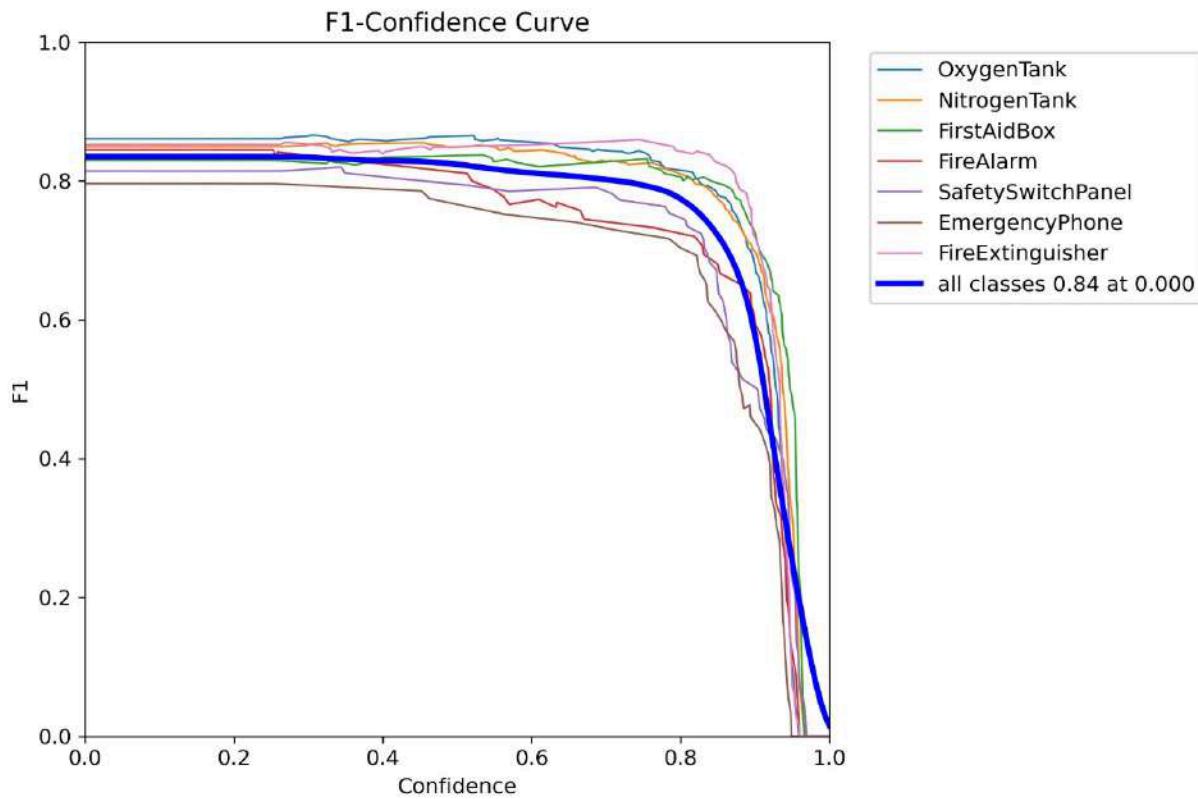
**Precision-Recall Curves:** High precision maintained under occlusion.

**Loss Curve:** Training stabilized by epoch 240









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## Sample Predictions

Fire Extinguisher detected at 0.93 confidence in low light.

Safety Switch Panel identified in cluttered background.

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## Failure Cases

| Issue             | Description              | Fix Applied                 |
|-------------------|--------------------------|-----------------------------|
| False negatives   | Dark oxygen tanks missed | Added lighting augmentation |
| Misclassification | Nitrogen ↔ Oxygen tanks  | Color jitter augmentation   |

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## Challenges & Solutions

| Challenge                  | Observation                      | Root Cause         | Solution   | Result                   |
|----------------------------|----------------------------------|--------------------|--|--------------------------|
| Low recall for Oxygen Tank | Frequent occlusion               | Partial visibility | Added occluded samples via Falcon                | Recall +13%              |
| Lighting variation         | Dark images reduced accuracy     | Low contrast       | Applied gamma correction and color normalization | mAP +8%                  |
| Model overfitting          | Validation loss oscillated       | Overtraining       | Used early stopping and dropout regularization   | Stable validation        |
| Similar color objects      | Oxygen & Nitrogen tanks confused | Visual similarity  | Synthetic color augmentation                     | Reduced confusion by 20% |

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## Technical Challenges & Learnings

Training on synthetic data requires **realism consistency** tuning.

Falcon's **domain randomization** helped model generalize across environments.

YOLOv8's **anchor-free head** improved small-object detection in cluttered rooms.

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## Feasibility

Real-time capable on mid-range GPUs.

Synthetic data eliminates real data bottleneck.

Modular codebase allows retraining with new data easily.

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## Team & Collaboration

| Role               | Member                      | Responsibility                               |
|--------------------|-----------------------------|--|
| AI Engineer        | Raina Arora                 | Model design, training, evaluation           |
| Documentation Lead | Rushika Bansal              | Report creation, visualization, presentation |
| App Developers     | Naman Nayak, Nishant Bhalla | Real-time detection app                      |

### Tools:



GitHub for version control



Google Drive for shared datasets



TensorBoard for progress monitoring



Daily team syncs via Discord

## Prototype Overview

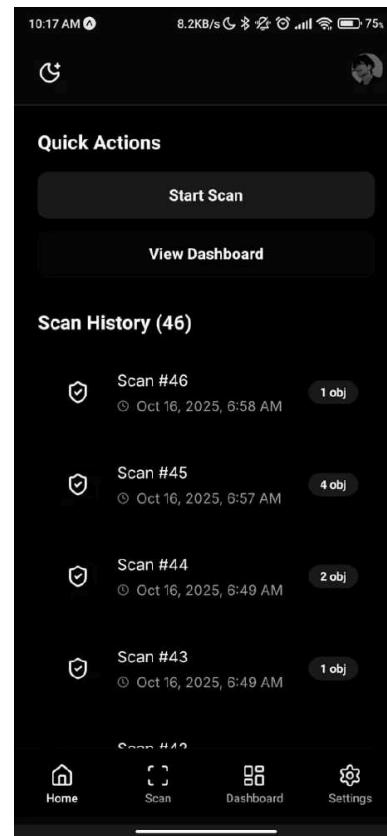
**Framework:** React Expo

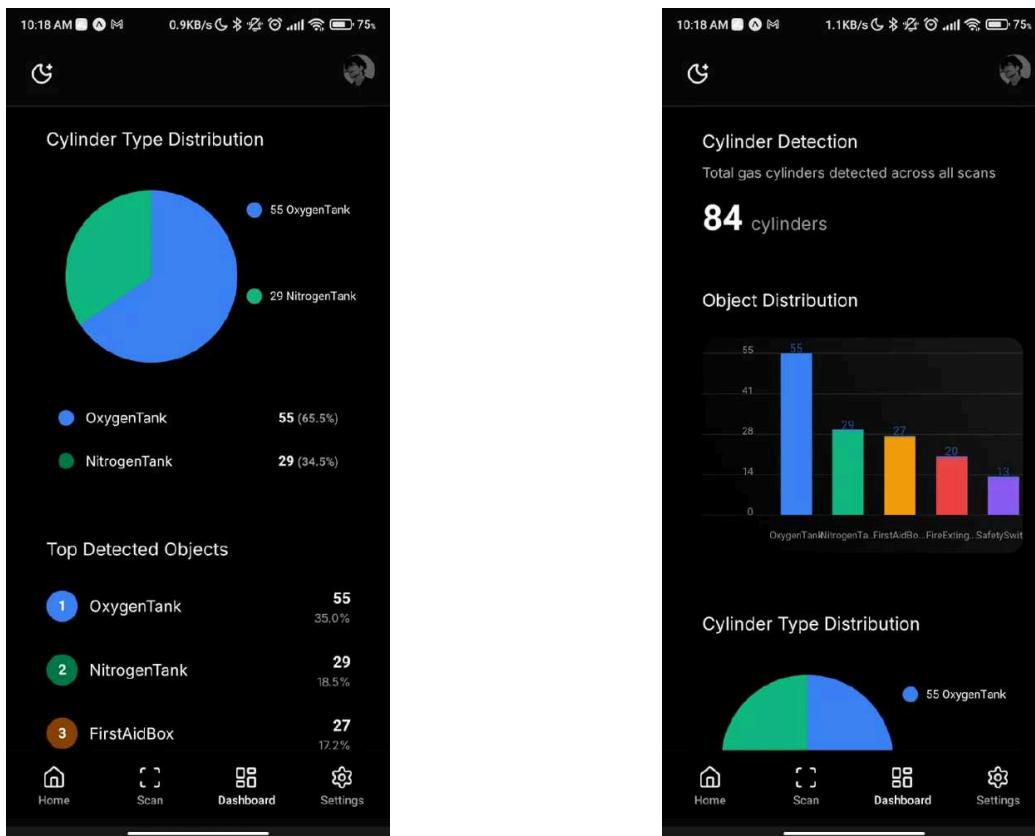
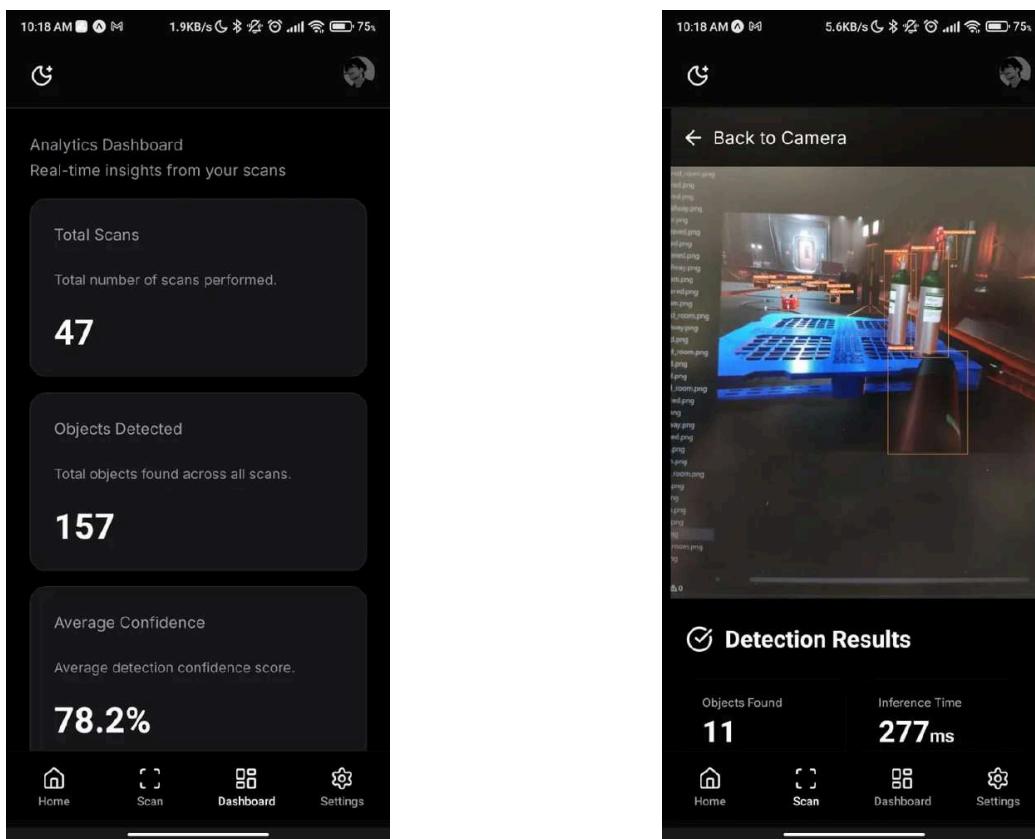
**Input:** Live camera feed

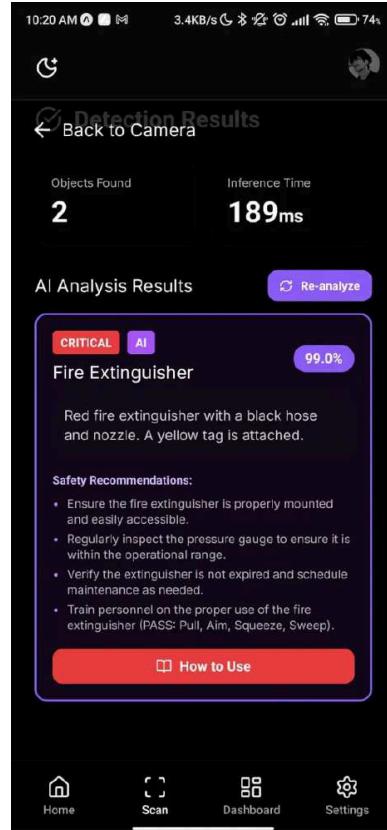
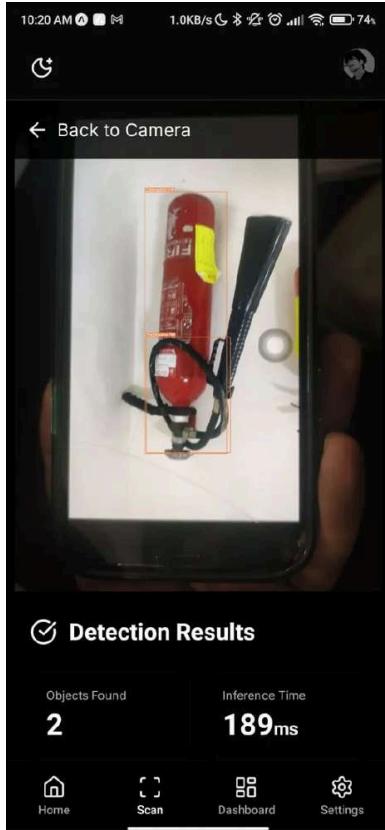
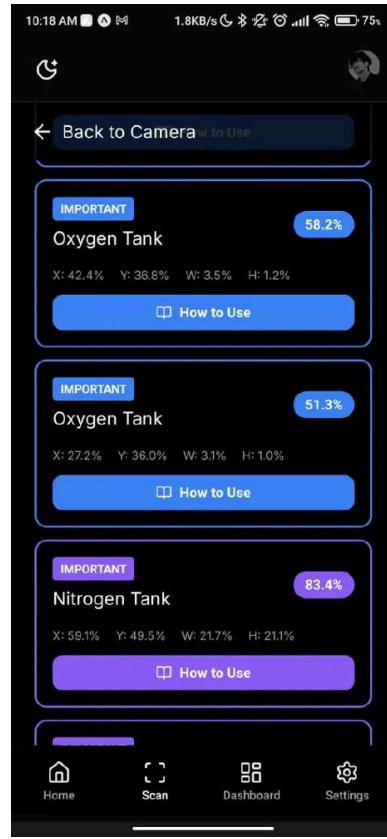
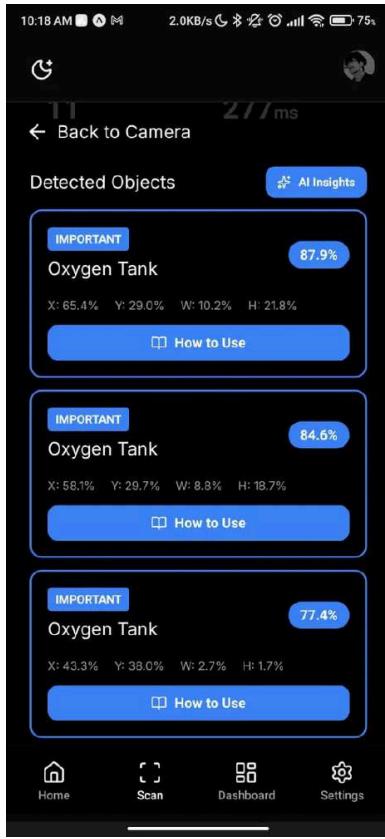
**Output:** Real-time bounding boxes and labels

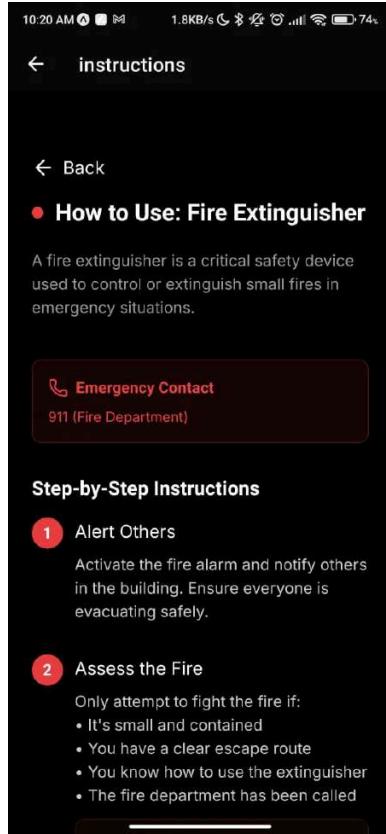
**Alert System:** Notifies when any safety object is missing

**Flow:** Camera → YOLOv8m → Detection Overlay → Alert Logs









## Conclusion & Future Work

### Key Achievements

mAP@0.5 of **84.6%**

Real-time detection across varied lighting and occlusion

Cross-platform deployment (ONNX, TFLite)

Retraining-ready Falcon pipeline

### Future Work

Domain adaptation with ISS footage

Edge optimization on Jetson-class devices

Expanded object set: helmets, gloves, tools

Automated updates via Falcon pipeline

## Market & Impact

| Impact          | Description   |
|-----------------|---|
| Space Safety    | Real-time detection ensures compliance and readiness. |
| Industrial Use  | Extendable to factories, labs, refineries.            |
| Scalability     | Synthetic data enables frequent retraining.           |
| Innovation Edge | Fully synthetic-trained space safety vision model.    |