DUALITY AI SPACE STATION SAFETY: OBJECT DETECTION FOR ASTRONAUT SAFETY

HackWithHyderabad Hackathon 2025 – Project Submission Report

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EXECUTIVE SUMMARY

Space stations pose unique safety challenges due to their zero-gravity environments and complex equipment layouts. Our project leverages state-of-the-art AI—specifically YOLOv8—to create a digital safety officer that can detect seven critical safety equipment types in real-time. With high accuracy and rapid inference, our solution supports astronaut safety monitoring, fast incident response, and streamlined maintenance. Successfully deployed as a web and API-based system, it demonstrates scalability and practical readiness for future space missions.

PROBLEM CONTEXT

Astronauts operate in high-risk, zero-gravity environments where misplaced or inaccessible safety equipment can be life-threatening. Manual tracking of safety tools is error-prone and distracts from mission-critical tasks. Emergencies such as fire, decompression, or medical needs demand instant access to equipment. The lack of automated inventory and monitoring increases risk and cognitive burden for crew members. There is a pressing need for real-time digital solutions to monitor equipment and alert astronauts proactively.

PROPOSED SOLUTION

We present an AI-powered digital safety officer using YOLOv8 for object detection:

- Detects and classifies 7 key equipment classes: OxygenTank, NitrogenTank, FirstAidBox, FireAlarm, SafetySwitchPanel, EmergencyPhone, FireExtinguisher.
- Provides real-time visual overlays (bounding boxes) and alerts for missing/misplaced equipment.
- Seamlessly integrates into space station video feeds, supporting both automated monitoring and manual review.
- Accessible via web app and API for astronauts and ground control.

USE CASE SCENARIOS

1. **Safety Monitoring:** Continuous AI surveillance to ensure all critical equipment is present and accessible.
2. **Maintenance Tracking:** Alerts when equipment is moved or missing, supporting scheduled checks and repairs.
3. **Inventory Management:** Automated log of equipment status and location, reducing manual inventory efforts.
4. **Emergency Response:** Instant detection and highlighting of nearest safety equipment during incidents.
5. **Astronaut Training:** Visual feedback for trainees to learn equipment locations and station layout.

BENEFITS & IMPACT

- **Enhanced Astronaut Safety:** AI reduces human error and helps crew locate equipment instantly.
- **Faster Incident Response:** Real-time alerts facilitate immediate action in emergencies.
- **Reduced Cognitive Load:** Crew can focus on mission without worrying about equipment tracking.
- **Scalable & Adaptable:** Can be extended across stations, missions, and future planetary bases.

TECHNICAL ALIGNMENT

- **Core Technology:** YOLOv8 (Ultralytics)
- **Dataset:** Duality Falcon 7-class dataset (custom annotated for space station safety gear)
- **Performance Metrics:**
  - mAP@50: **0.7321**
  - mAP@50-95: **0.6361**
  - Precision: **0.8835241502442965**
  - Recall: **0.6648288815906493**
  - Inference Speed: **2.4ms** preprocessing, **420.5ms** inference per frame
- **Training Visuals:**

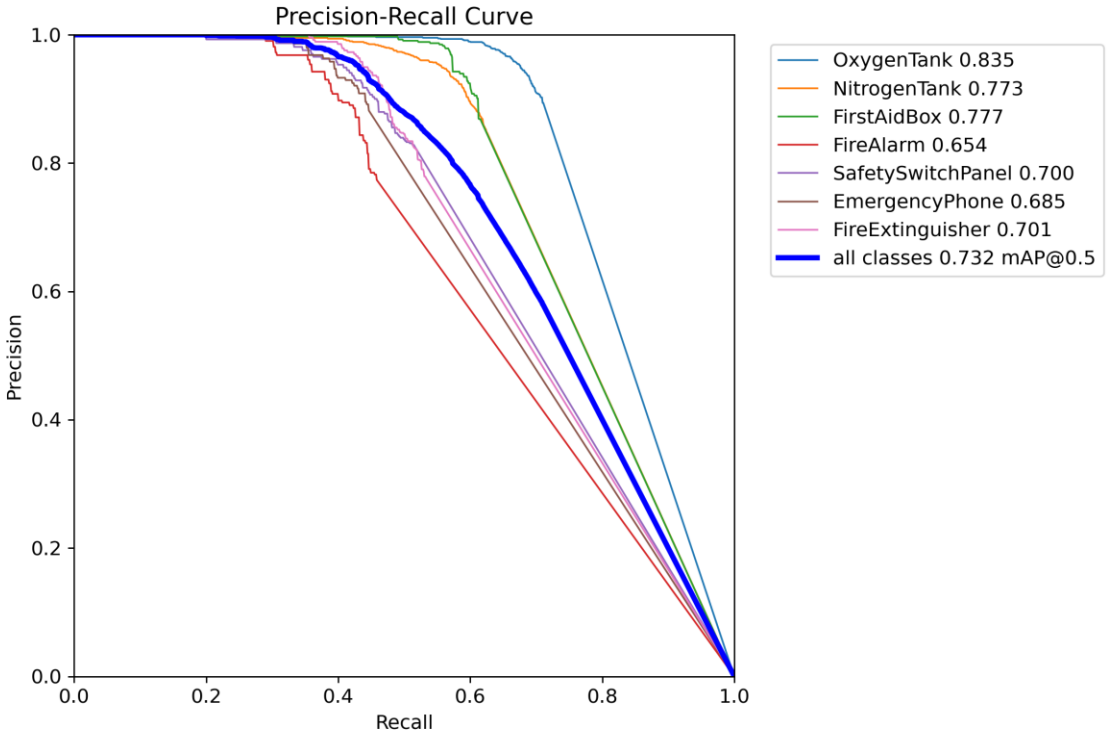


FIGURE 1: PRECISION-RECALL CURVE

MODEL DEVELOPMENT & EVALUATION

- **Preprocessing & Annotation:** Used Duality Falcon platform for accurate bounding box annotations and class labels.
- **Training Pipeline:** Data split [to be specified], ensuring balanced class representation.
- **Hyperparameter Tuning:** Optimized for both speed (real-time inference) and accuracy.
- **Evaluation:** Benchmarked against hackathon judging criteria.
- **Results:**

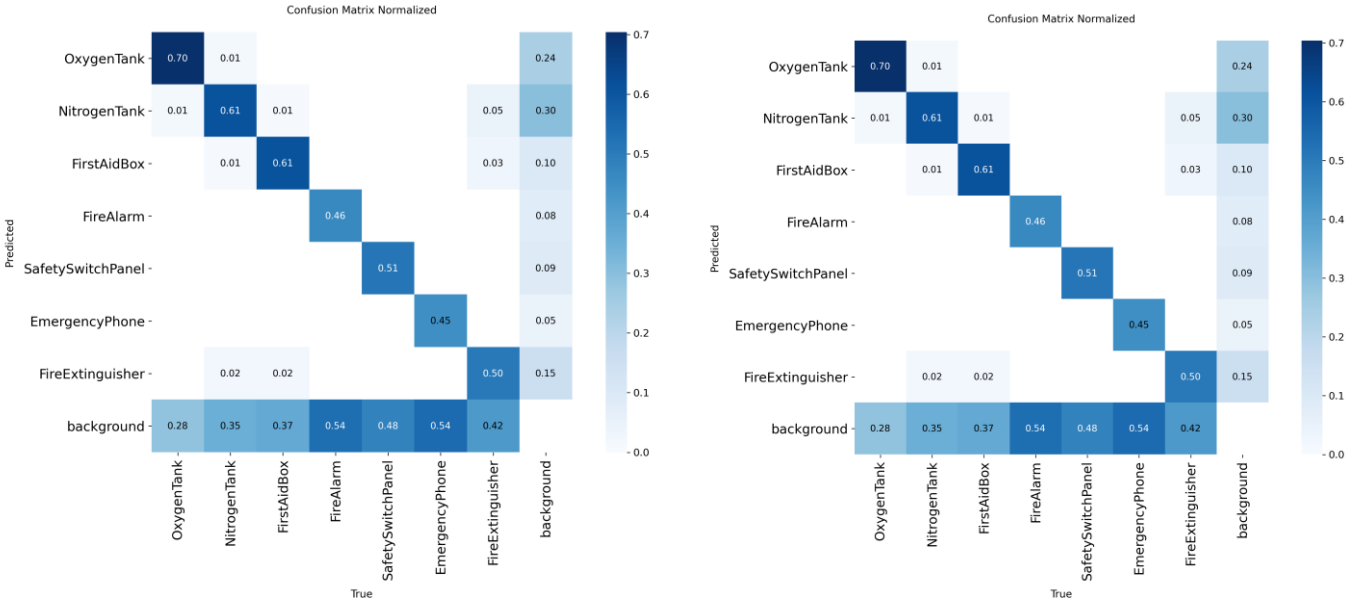
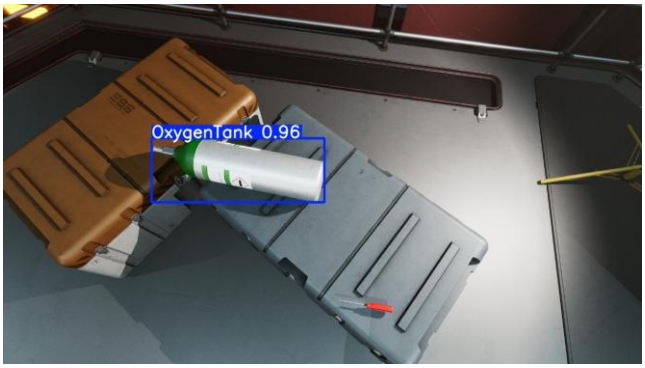
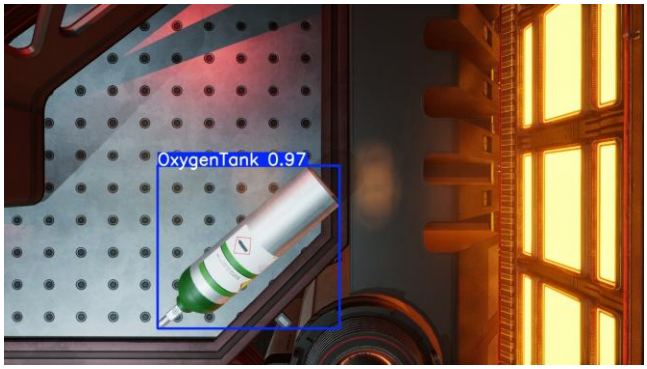


FIGURE 2: CONFUSION MATRIX

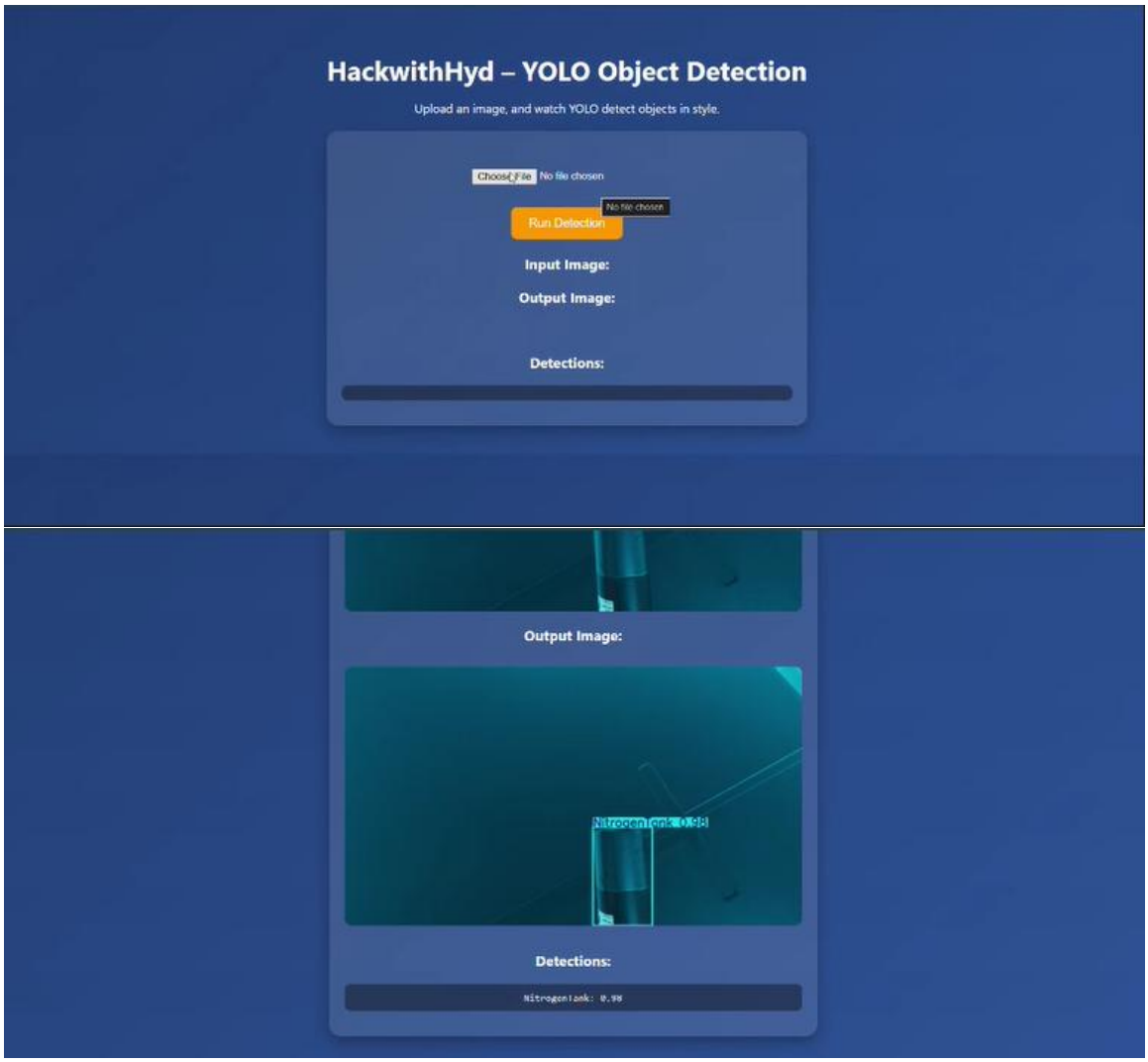
Sample Detection Images (Test Set):





Deployment Details

- **Frontend:** Hugging Face Gradio app provides an intuitive interface for testing and demo.
- **Backend/API:** Model wrapped as an API endpoint for integration with other systems.
- **Web Integration:** Accessible via GitHub Pages for easy sharing and public visibility.
- **Deployment Screenshots:**



FUTURE SCOPE & BONUS USE CASE PROPOSAL

- **Robotic Integration:** Enable robotic arms to retrieve tools detected by the model.
- **Anomaly Detection:** Extend model to identify micrometeoroid impacts or thermal blanket tears.
- **Ground-Control Dashboards:** Real-time monitoring and alerts for mission support teams on Earth.
- **Extended Applications:** Adapt model for planetary habitats and autonomous exploration vehicles.

CONCLUSION

Our prototype validates the practical role of AI in astronaut safety—combining robust detection accuracy with real-time deployment. The system is ready for integration, scalable, and adaptable to evolving space missions. It lays the foundation for future smart space station environments.

REFERENCES

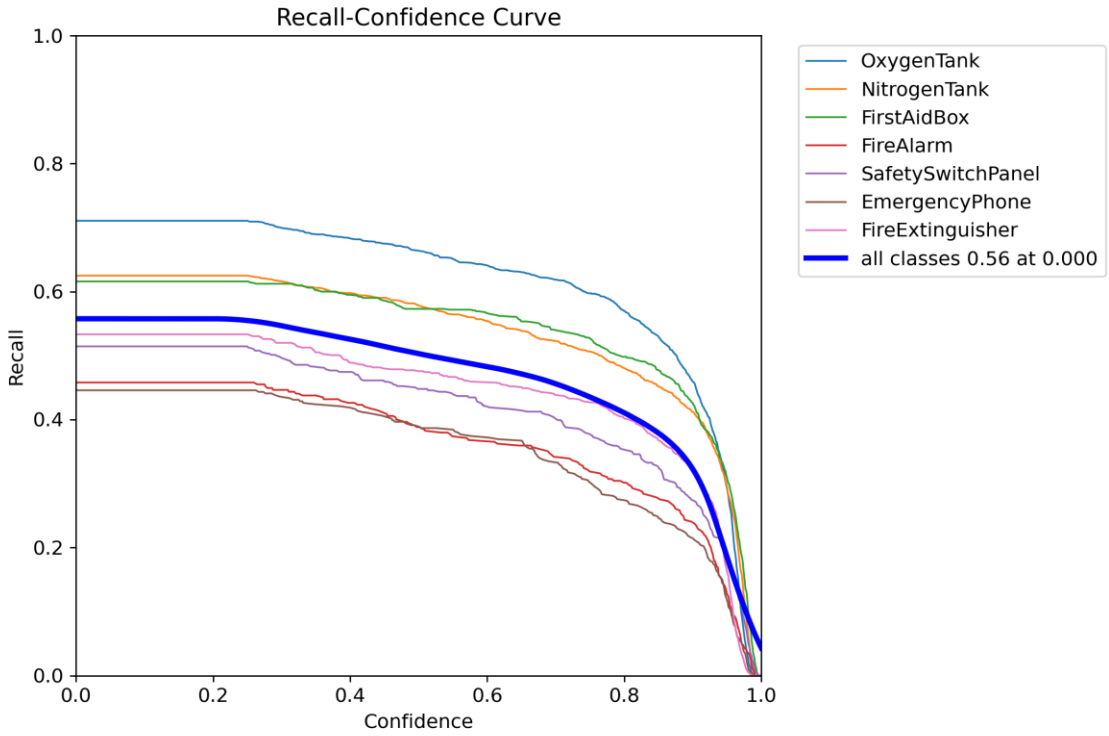
1. YOLOv8 Documentation: https://docs.ultralytics.com/
2. Duality AI Falcon Platform: https://www.duality.ai/product
3. Hackathon Guidelines: HackWithHyderabad Hackathon Duality Problem Statement

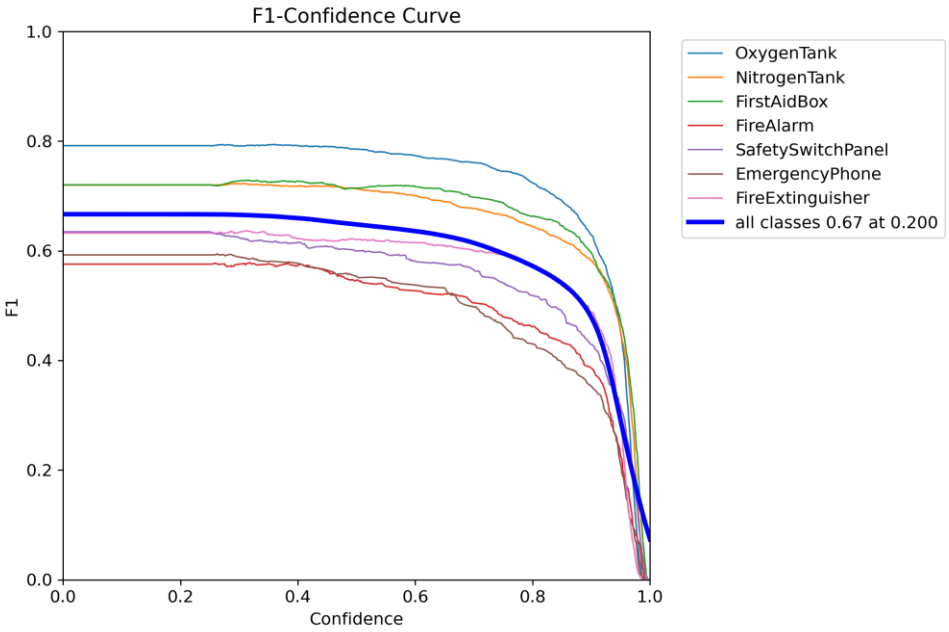
APPENDIX

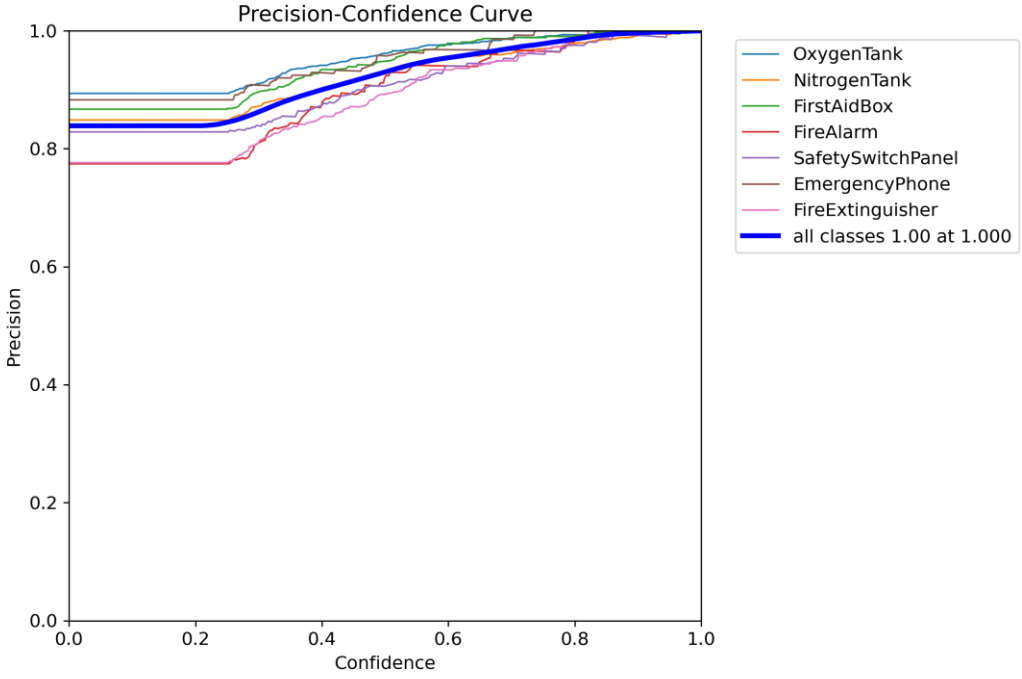
Training screenshots

```
    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    16/20      4.46G      0.491     0.4402     0.8528         16        640: 100% ──────────── 111/111 1.0it/s 1:55
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% ──────────── 11/11 1.1it/s 10.5s
                 all        336       1005      0.876      0.669      0.747      0.604

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    17/20       4.5G     0.4801     0.4269     0.8506         14        640: 100% ──────────── 111/111 0.9it/s 1:59
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% ──────────── 11/11 1.0it/s 10.5s
                 all        336       1005      0.884      0.654      0.744       0.61

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    18/20      4.53G     0.4815      0.423     0.8458         26        640: 100% ──────────── 111/111 0.9it/s 1:57
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% ──────────── 11/11 1.0it/s 10.6s
                 all        336       1005      0.891      0.665      0.747      0.611

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    19/20      4.72G     0.4699     0.4089     0.8433         28        640: 100% ──────────── 111/111 0.9it/s 1:58
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% ──────────── 11/11 1.1it/s 10.4s
                 all        336       1005      0.886       0.66      0.745      0.612

    Epoch    GPU_mem   box_loss   cls_loss   dfl_loss  Instances       Size
    20/20      4.76G     0.4592     0.3994     0.8416         10        640: 100% ──────────── 111/111 0.9it/s 2:01
               Class     Images  Instances      Box(P          R      mAP50  mAP50-95): 100% ──────────── 11/11 1.0it/s 10.8s
```

Performance benchmarks




F1-Confidence Curve
F1
Confidence
0.0
0.2
0.4
0.6
0.8
1.0
OxygenTank
NitrogenTank
FirstAidBox
FireAlarm
SafetySwitchPanel
EmergencyPhone
FireExtinguisher
all classes 0.67 at 0.200


Precision-Confidence Curve
Precision
Confidence
0.0
0.2
0.4
0.6
0.8
1.0
OxygenTank
NitrogenTank
FirstAidBox
FireAlarm
SafetySwitchPanel
EmergencyPhone
FireExtinguisher
all classes 1.00 at 1.000