1. Project Summary

Motivation & Specs

Oil spills on runways are invisible hazards causing loss of friction. Our goal is to build a **Real-time Computer Vision System (30 FPS)** to detect and localize these spills using semantic segmentation on edge hardware.

Changes from Proposal

We pivoted from generic FOD (screws, trash) to exclusively **Oil Spills**. This shifts the challenge to identifying amorphous, transparent liquid textures.

Novelty & Contributions

Due to extreme data scarcity, we developed a **Generative AI Pipeline** (Stable Diffusion + ControlNet) to synthesize realistic oil spill datasets.

2. Related Work

Study / Year	Tools & Methods	Data Used	Results & Relevance
Airport-FOD3S (2025)	Generative AI: Stable Diffusion, CycleGAN Detector: YOLOv11	Real: 4,800 Syn: 19,200	**mAP: 86.95%** Validates our choice of Stable Diffusion for augmenting runway datasets.
Open-World FOD (2024)	Detection: YOLOv11, YOLOv8 GenAI: DCGAN	15 Classes Mobile camera data	Improved detection of unknown objects ("Out-of-Distribution").
FOD-S2R (Dec 2024)	Pipeline: 3-phase augmentation Sim2Real: Unreal Engine 5	Real: 3,114 Syn: 3,137 (3D)	Proved **Synthetic + Real** training outperforms Real alone. Supports our hypothesis.

3. Dataset Generation & EDA

Generation Pipeline Flow

Input Image
Source runway background

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Segmentation Model (SegFormer)
Propose spill area

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Masking
Create binary mask for inpainting

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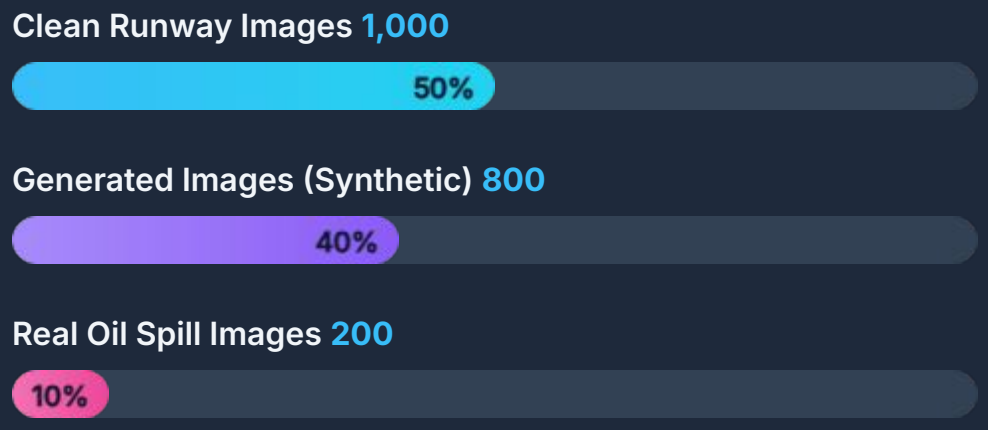
Inpaint (Stable Diffusion)
Synthesize oil texture in masked area

↓

Final synthetic dataset
The dataset we use to train the model

Dataset Composition



TOTAL IMAGES

2,000

Synthesis Architecture

0. Raw Assets: Source backgrounds from high-res drone/satellite imagery.

1. Mask Extraction: Derived binary masks from latent noise for auto-labeling.

2. Inpainting: Stable Diffusion 1.5 + ControlNet for realistic liquid physics.

4. Preliminary Results (Epoch 14)

Metric Snapshot

Comparison against COCO Baseline

mAP @ 0.50 **40%**

Recall **14.8%**

Error Analysis

- **Low Precision (High False Positives):**
  Model currently predicts "oil" on most dark shadows and wet patches. Threshold refinement needed.
- **Low Recall (Underfitting):**
  Model misses >85% of spills. Likely due to early training stage (Epoch 14) and difficult synthetic-to-real domain transfer.

The model failed to train properly

5. Project Timeline & Scope

We are currently iterating on the dataset generation process to improve model generalization before the final defense.

Current Focus

Improve Synthetic Data

Optimizing the generation pipeline for better realism. Focusing on lighting consistency and texture blending to reduce false positives.

Next Step

Retrain & Validate

Fine-tune the YOLO model on the improved hybrid dataset. Validate performance metrics on real-world holdout set.

Final Step

Final Presentation

Compile results, error analysis, and demo video into the final defense deck. Showcase the finalized edge-ready model.