

A decorative graphic on the left side of the slide, consisting of a dark blue circular area with a network of white and light blue lines and dots, resembling a molecular structure or a data network.

# Development of a Framework for Integrated Thermal and Visual Image Data Analysis to Support Targeted CUI Inspection Planning

# AGENDA

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1. Corrology Innovation Ltd. Introduction
2. The CUI Detection Challenge – Recap
3. The Framework – Integrating Multi-Spectral IR & RGB
4. Development Roadmap –
  - Phase 0 — Data & Labelling Strategy
  - Phase 1 — Automated RGB Detection & Diagnostics
  - Phase 2 — IR + RGB Fusion
  - Phase 3 — Hot-spots, Risk Ranking & Inspection Planning
  - Phase 4 — Continuous Learning / Model Improvement
5. Partnership Call – Invitation for Joint Data Cooperation
6. Summary



# CORROLOGY INNOVATIONS LTD.



Established in 2023 by a team of **Corrosion, Modelling, and IT Experts**



Developing a **SaaS** ecosystem that links and organizes the scattered corrosion information, transforming into a high-level, **structured corrosion platform**.



Designing and developing a suite of **corrosion models** for the petroleum industry, integrating research data, field experience, and industry standards into actionable corrosion intelligence



Optimizing **asset integrity** by reducing downtime and maintenance costs through **predictive analytics and real-time decision support**



## Key Variables

Alkaline sour water corrosion is primarily governed by three parameters, as mentioned earlier:

- $\text{NH}_4\text{HS}$  concentration,
- flow,
- $\text{H}_2\text{S}$  partial pressure.

Other important factors influencing sour water corrosivity include temperature,  $\text{NH}_3$  partial pressure, the presence of a liquid hydrocarbon phase, and the concentration of  $\text{CN}^-$ . It's worth noting that the discussed alkaline sour water corrosion refers to corrosion in the liquid phase. The influence of wetted deposit/under-deposit situations on corrosion is not fully understood in terms of impacting parameters. It's commonly acknowledged that corrosion under wetted  $\text{NH}_4\text{HS}$  deposits can be extremely severe, affecting not only carbon steel but also high-grade CRAs. Therefore, the primary and most effective mitigation measure is to eliminate such situations (wet deposits) from the operational environment by implementing adequate water washing.

## $\text{NH}_4\text{HS}$ concentration & $\text{H}_2\text{S}$ partial pressure

The concentration of  $\text{NH}_4\text{HS}$  alone should not be relied upon for determining sour water corrosivity. It should always be accompanied by **IG-Corrology®** been undoubt



# CORROLOGY INNOVATIONS LTD.

## Crude Corrosivity Risk Map | Knowledge Library

Choose File No file chosen

Download Excel template

Run Risk Assessment

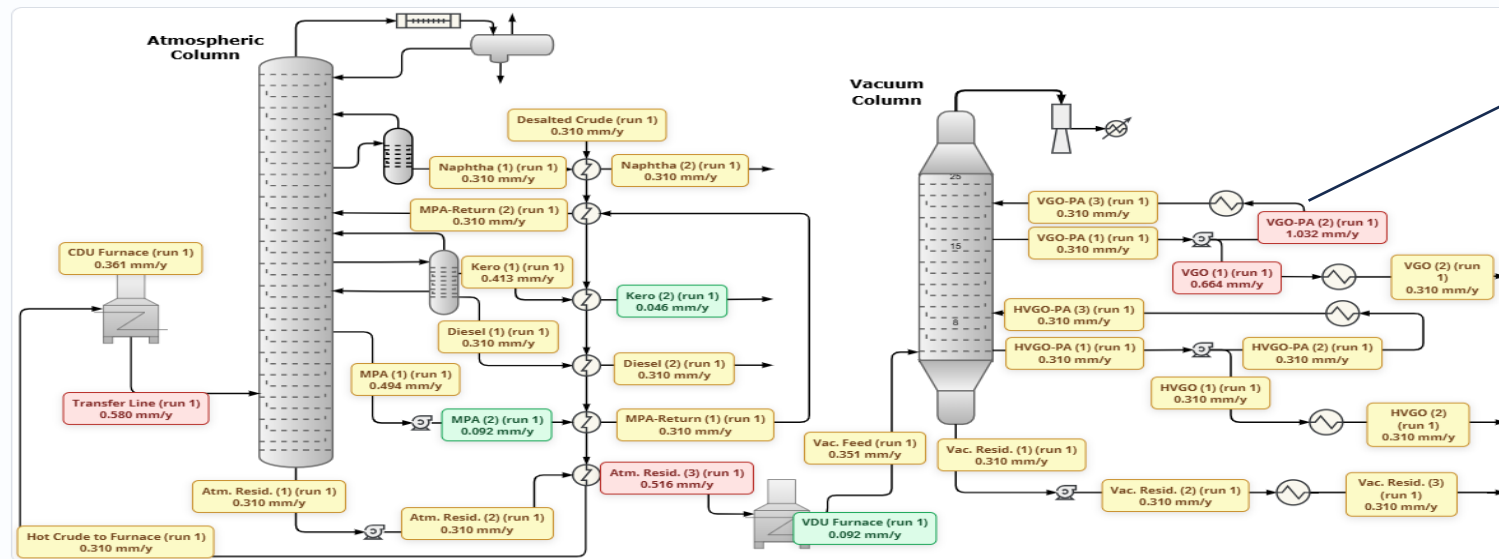
Clear Workspace

View by Risk Profile

Generate PDF Report

Generate Excel Report (CSV)

Low: < 0.2 mm/y Medium: 0.2 to < 0.5 mm/y High: ≥ 0.5 mm/y



Process Mapping  
(single or multi-point)

## CrudeOps – Smart Sensitivity Analysis

Unit	Circuit / Loop	Material	Parameter (sub-critical)	Corrosion Rate	Risk Rank	Remaining Service Life	Comments
CDU	Atm. Resid. (3)	Carbon Steel	TAN sub-critical: 0.4 mg/g	0.32 mm/y	Moderate	9.4 years	Moderate Risk: CR exceeds baseline. Requires S/TAN ratio verification and process parameter audit. Consider increased inspection frequency.
CDU	Atm. Resid. (3)	Low Cr (1-3 Cr)	TAN sub-critical: 0.3 mg/g	0.17 mm/y	Low	18.2 years	Acceptable CR, continue regular inspection and monitoring.
CDU	Atm. Resid. (3)	5Cr	TAN sub-critical: 1.2 mg/g	0.09 mm/y	Low	31.9 years	Acceptable CR, continue regular inspection and monitoring.

# CUI – DETECTION CHALLENGE

## Comprehensive CUI Assessment:

No single technique currently provides a complete solution.

## Pre-Assessment Workflow:

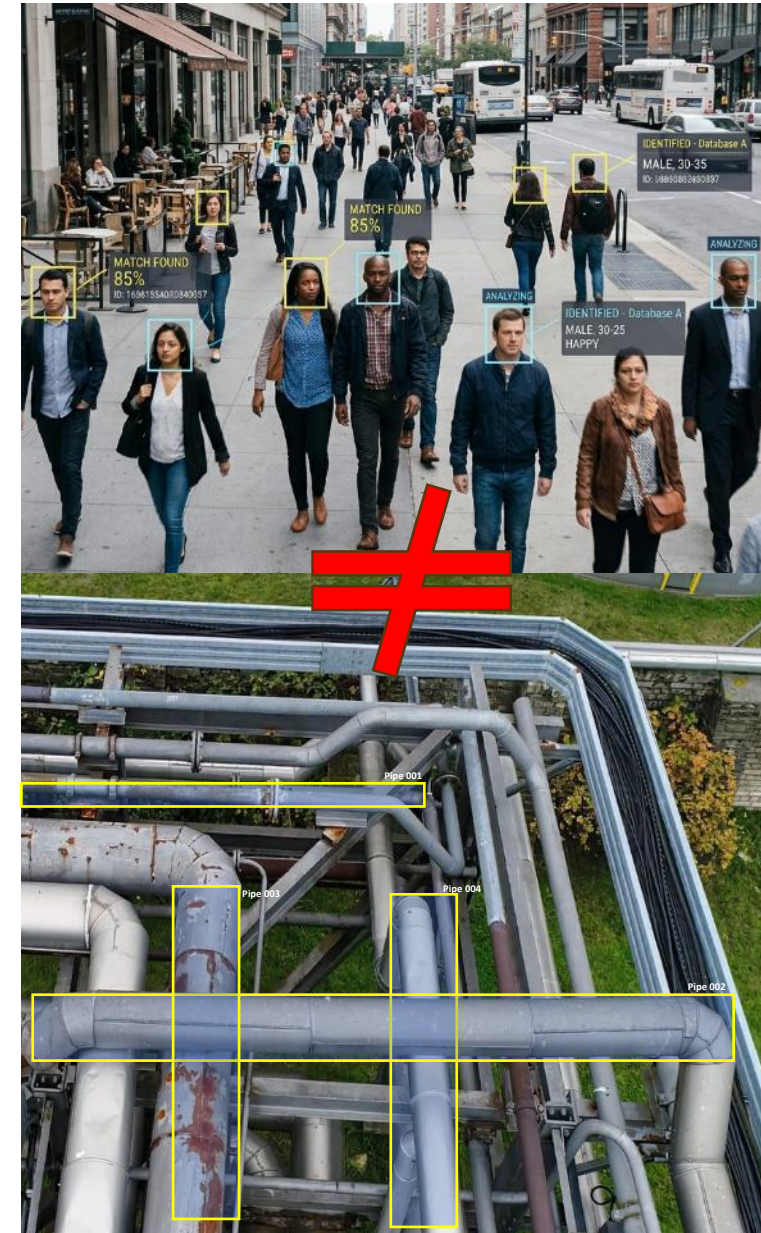
Utilizing Multi-Image analysis (RGB + IR) as a critical first step.

## Dual-Layer Analysis:

Rapid RGB screening followed by IR image for hot-spots detection.

## The Recognition Challenge:

Complex refinery environments (variable pipe sizes, colours, density, state of surface/cladding) complicate automated image recognition.



# THE VISION: WHAT WE ARE BUILDING

## A Framework for Automated CUI Assessment - Work in Progress

### ❑ The Problem:

- Manual photo reviews are slow, inconsistent, and hard to trend
- Findings rarely structured enough for CUI risk ranking

### ❑ What This Framework Delivers:

- Auto-identifies pipes, valves, tanks and flags risk zones from photos
- Learns from analyst corrections

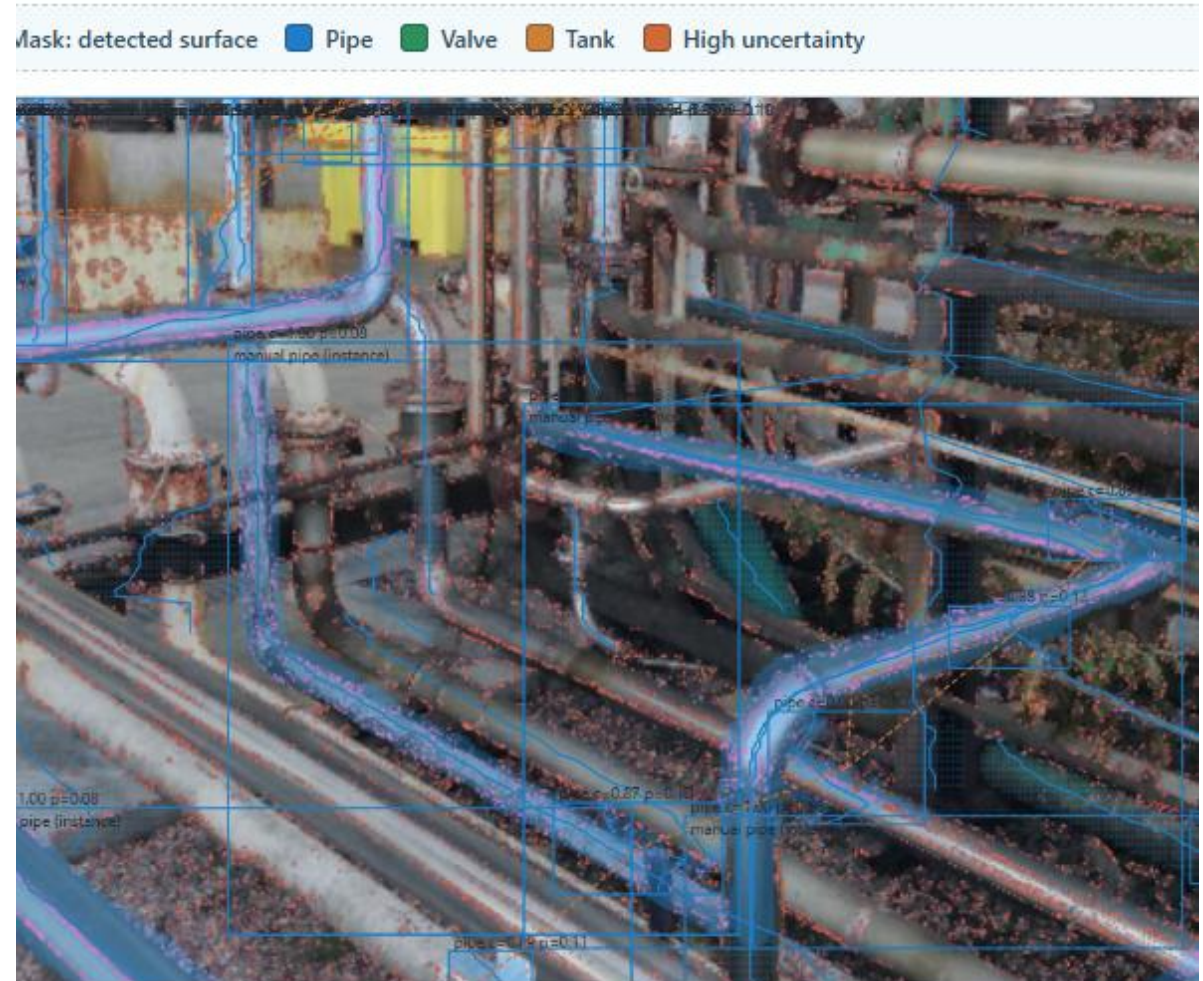
### ❑ Where We Are Now:

- Active prototype — core engine functional, being refined

Phase	Description	Status
Phase 0	Data & Labelling Strategy	✓ In development
Phase 1	Automated RGB Detection & Diagnostics	✓ In development
Phase 2	IR + RGB Fusion	☐ Planned
Phase 3	Hot-spots, Risk Ranking & Inspection Planning	☐ Planned
Phase 4	Continuous Learning / Model Improvement	☐ Planned

# SEGMENTATION AND ASSET MAPPING OVERVIEW

- Detects and maps corrosion-relevant equipment from standard RGB images.
- Performs **semantic segmentation**: labels each pixel by class, including pipe, valve, tank, column, exchanger, corrosion, and paint damage.
- Performs **object separation**: distinguishes individual assets within the same class.
- Uses a compact **multi-output segmentation** architecture designed for lightweight deployment.
- Supports practical field use with fast turnaround and low infrastructure overhead.



# HOW THE FRAMEWORK WORKS (PHASE 1: RGB)

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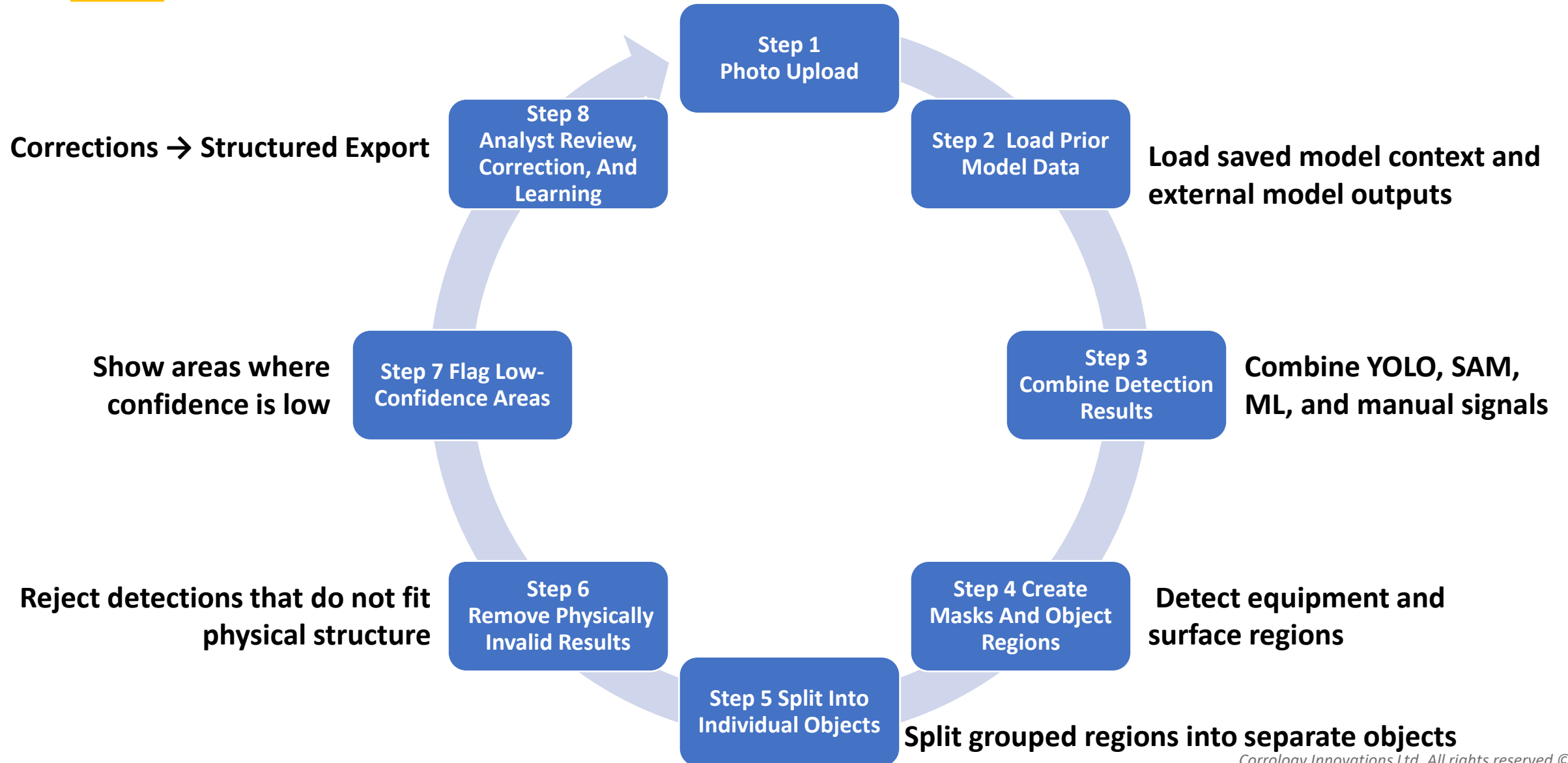
## □ Core principle:

- The system does not rely on color alone. It extracts multiple pixel-level signals before classifying image regions.

## □ The signals include:

- Raw color channels (red, green, blue)
- Edge strength
- Estimated surface depth from light and shadow
- Rust-sensitive features
- Shadow features
- Edge direction and local structure

# HOW THE FRAMEWORK WORKS - THE 8-STEP ANALYSIS PIPELINE



# ADVANCED REVIEW WORKSPACE AFTER IMAGE UPLOAD

1. Load And Queue Images

2. Tune Review Settings

The interface is divided into several functional areas:

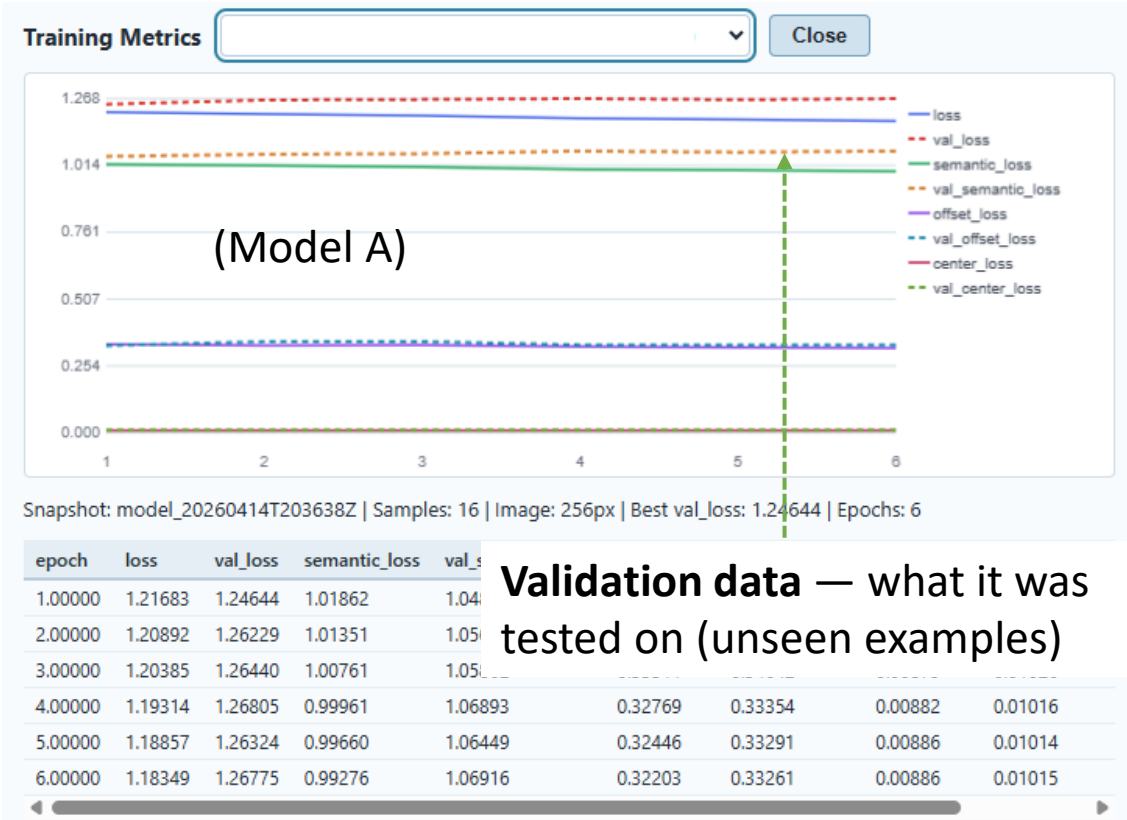
- IMAGE BATCH:** Includes an 'Upload image batch' section with a 'Choose Files' button and a file name 'pipe0013.png'.
- RUN AND NAVIGATE:** Contains primary commands: 'Run Analysis', 'Next Uncertain', 'Zoom In', 'Zoom Out', 'Reset View', and 'Zoom:100%'.
- System Status:** Shows 'Detector: ready | YOLO lazy-load | SAM vit\_b lazy-load | uptime 32s', 'Learning: markups staged - press Sync + Auto Learn', and 'GPU: TF GPU: 1 | PyTorch: CUDA'.
- Batch Images:** A panel for selecting the active frame, currently showing 'pipe0013.png'.
- Analysis Settings:** Includes 'RESPONSE' (Live), 'CONTROLS' (Grouped), and 'TUNING' (Focused) options. It also has sections for 'Core Fusion', 'Detector Thresholds', 'Surface Heuristics', and 'Review Modes' (Assessment: Detector-First, Hybrid, Conservative, Aggressive, balanced).
- Preview:** The central canvas area with 'Markup mode: Select / Edit | Markups: 19 | Selected: none'. It features 'ANNOTATE' (Pipe, Box, Freehand, Paint, Mark Uncertain, Add Markup as Instance, Clear Markups, Delete Selected Markup), 'DECIDE' (Reject Selected Detection, Exclude Corrosion Spot, Confirm as Pipe, Sync + Auto Learn), and 'INSPECT' (X-Ray: Off) controls.
- Canvas:** A large image of an industrial facility with blue pipes and tanks, overlaid with a grid of blue bounding boxes for detected objects.
- Insights:** A panel for 'Focused evidence, uncertainty, and fusion diagnostics'. It shows 'STATE: Live', 'EVIDENCE: Instances + Fusion', and 'PRIORITY: Uncertainty First'. It includes a 'SCENE SUMMARY' with steps 1-5, ML segmentation status, and a 'DETECTED INSTANCES' list with items like 'Pipe [448303] c=0.87'.

3. Run Analysis And Navigate

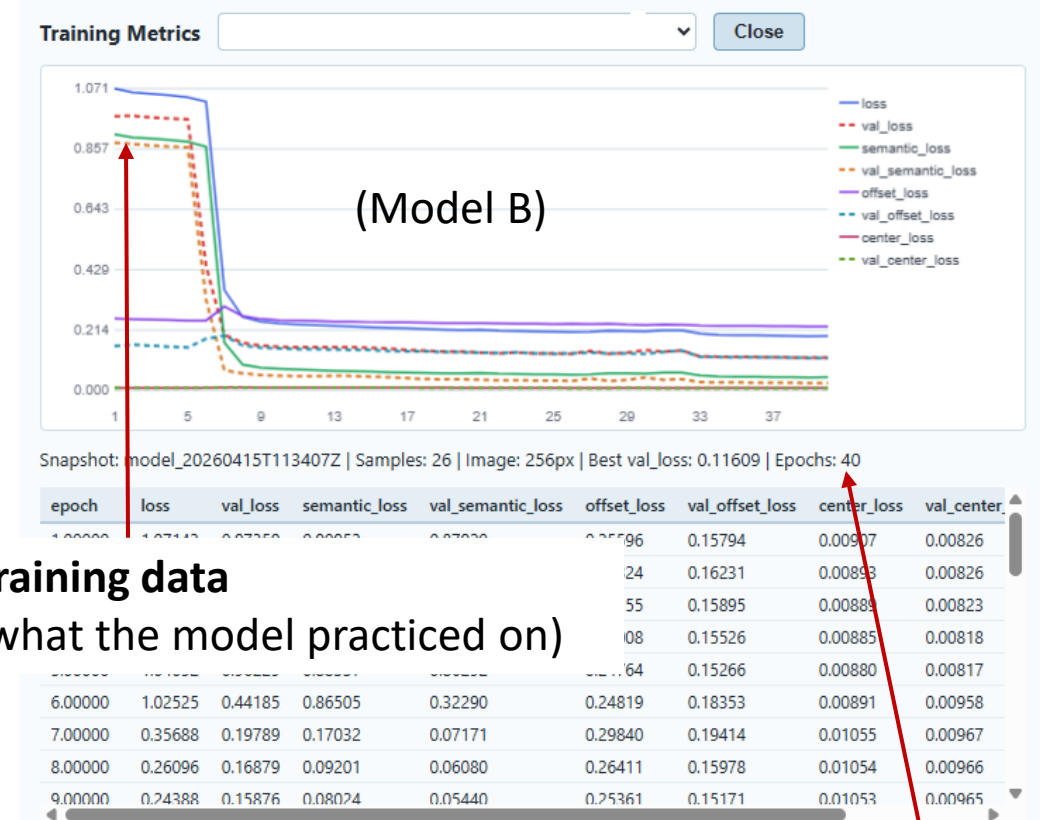
5. Inspect Evidence And Learning Runtime

4. Review And Annotate On Canvas

# MODEL ENHANCEMENT



**Validation data** — what it was tested on (unseen examples)



**Training data** (what the model practiced on)

Metric	(Model A)	(Model B)
Epochs	6 (Under-trained/Early exit)	40 (Full training cycle)
Sample Size	16 images	26 images
Best val_loss	1.24644 (High error)	0.11609 (Low error)
Trend	Stagnant / No learning	Successful convergence

**Number of epochs** (number of training rounds)

# IR + RGB FUSION (PHASE 2)

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## Combining Thermal And Visible Imaging For CUI Risk Assessment

### □ Phase 2:

- IR highlights temperature anomalies on insulated surfaces.
- RGB provides equipment structure and visual context.
- Combining IR and RGB can improve anomaly localization and review.
- Phase 2 extends the current analysis framework to thermal-assisted inspection.

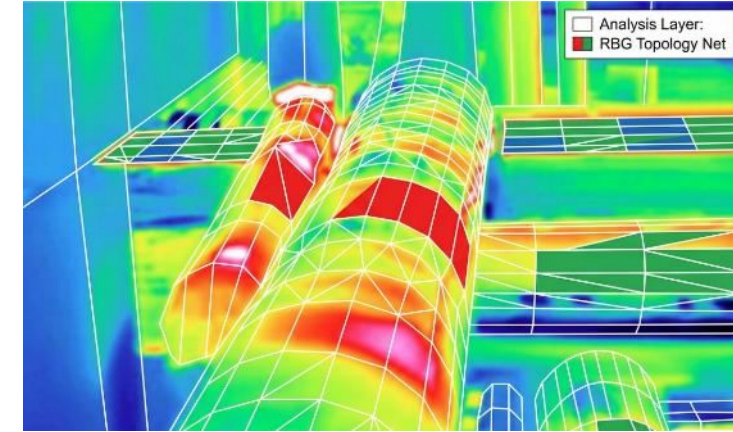
# HOT-SPOTS, RISK RANKING & INSPECTION PLANNING (PHASE 3)

## Phase 3:

- Per-equipment output:
  - Surface condition score from RGB
  - Thermal anomaly score from IR
  - Combined CUI risk score
  - Inspection priority level

## The Final Goal:

- User uploads a paired RGB + IR image set
- The system generates structured per-asset risk ranking
- Analysts review and correct results
- Feedback improves future model performance.

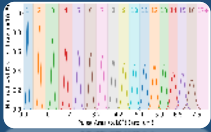


# PARTNERSHIP & DATA COOPERATION

## WHAT WE ARE LOOKING FOR



Synchronized RGB & IR images.



High-resolution dataset



Diversity: Variations in lighting, weather, and locations.



## VALUE



Access to Trained Segmentation Model



Collaborative Feature Engineering



Digital Twin Enhancement

# SUMMARY

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- RGB-based analysis platform for automated equipment detection and CUI-related review
- Designed to combine visual analysis, segmentation, and analyst feedback
- Built for staged expansion from RGB analysis to RGB + IR risk assessment
- Current roadmap:
  - Phase 0 — Data & Labelling Strategy
  - Phase 1 — Automated RGB Detection & Diagnostics
  - Phase 2 — IR + RGB Fusion
  - Phase 3 — Hot-spots, Risk Ranking & Inspection Planning
  - Phase 4 — Continuous Learning / Model Improvement
- Additional partner data will improve training quality, robustness, and deployment readiness

# THANK YOU!



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