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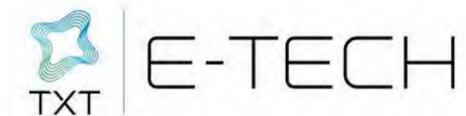
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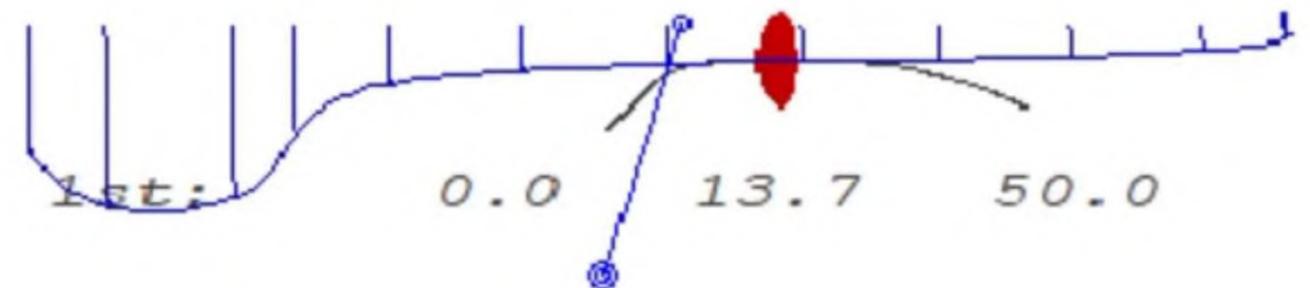
Technical Overview



5 February 2026

Introduction: Turnout Deterioration Mechanisms

- Changes in crossing geometry affecting train dynamics
- Mechanical wear due to repeated wheel impacts
- Material fatigue from maintenance process (grinding & welding)
- Surface damage from environmental exposure



Introduction: Turnout Deterioration Mechanisms

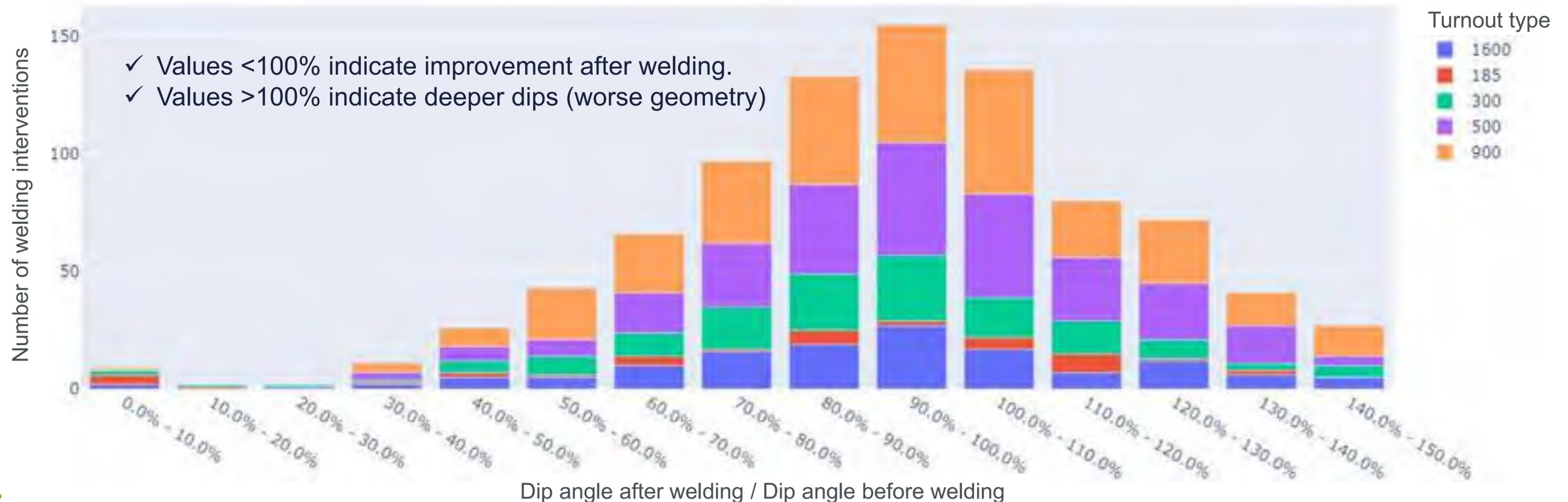
- Turnout components experience multiple surface and structural defect modes
- Defects worsen rapidly under repeated wheel impacts
- Poor weld/grind quality can trigger or accelerate these mechanisms



Inconsistent Repair Quality: Evidence From Field Welding Data

- Railway crossings are high-wear assets requiring frequent intervention.
- **~50% of welds improve dip angle (<100%), but ~50% actually worsen it (>100%).**
- Repair outcomes vary significantly between teams and sites.
- Highlights the need for objective measurement and guided maintenance workflows.

Effect of turnout welding work on the average dip angle (6 months before vs. 6 months after welding)



Introduction: Welding & Grinding at Railway Crossings

- Repair quality is highly variable, as shown by field data.
- Inspection & repair rely heavily on expert judgement, straightedges, and manual tools.
- Defects are marked, welded, and ground on-site under time pressure.
- Geometry checks use straightedges, gauges, and visual inspection.
- Acceptance criteria are inconsistent across sites and teams.
- Documentation depends on photos and manual measurements.



Current Crossing Repair Workflows

Inspection

Visual checks to identify target areas



Grinding

Smoothing irregular surfaces, restoring rail geometry



Welding

Rebuilding worn sections, repairing cracks



Re-measurement

Manual checks to verify repaired geometry



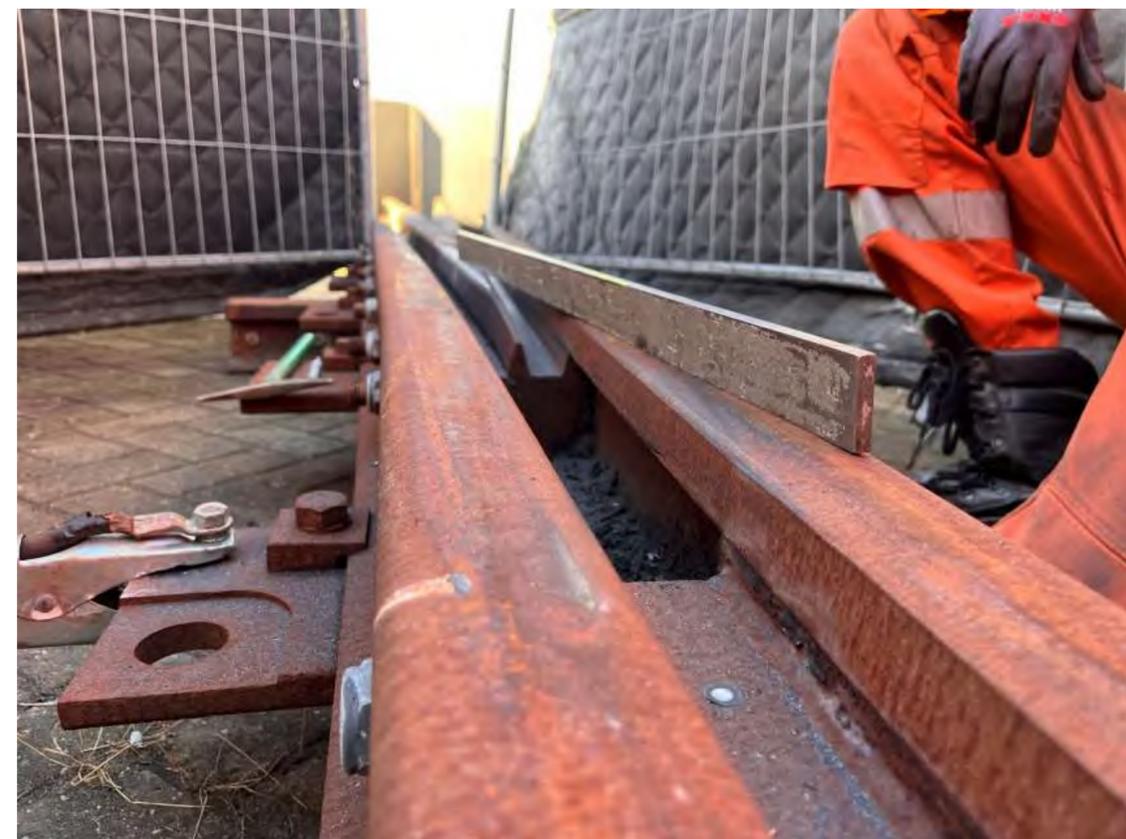
Limitations of current inspection and repair workflows

Current Challenges:

- Results depend strongly on individual experience and skill
- Limited ability to visualise where and how much to weld or grind
- Manual measurements provide sparse, localised checks
- Quality control often happens after work is completed
- Documentation is fragmented and difficult to trace or compare over time

Need:

- ✓ Faster, more efficient inspections
- ✓ Accurate, data-driven decision support
- ✓ Reliable, embedded quality control
- ✓ Traceable records over time

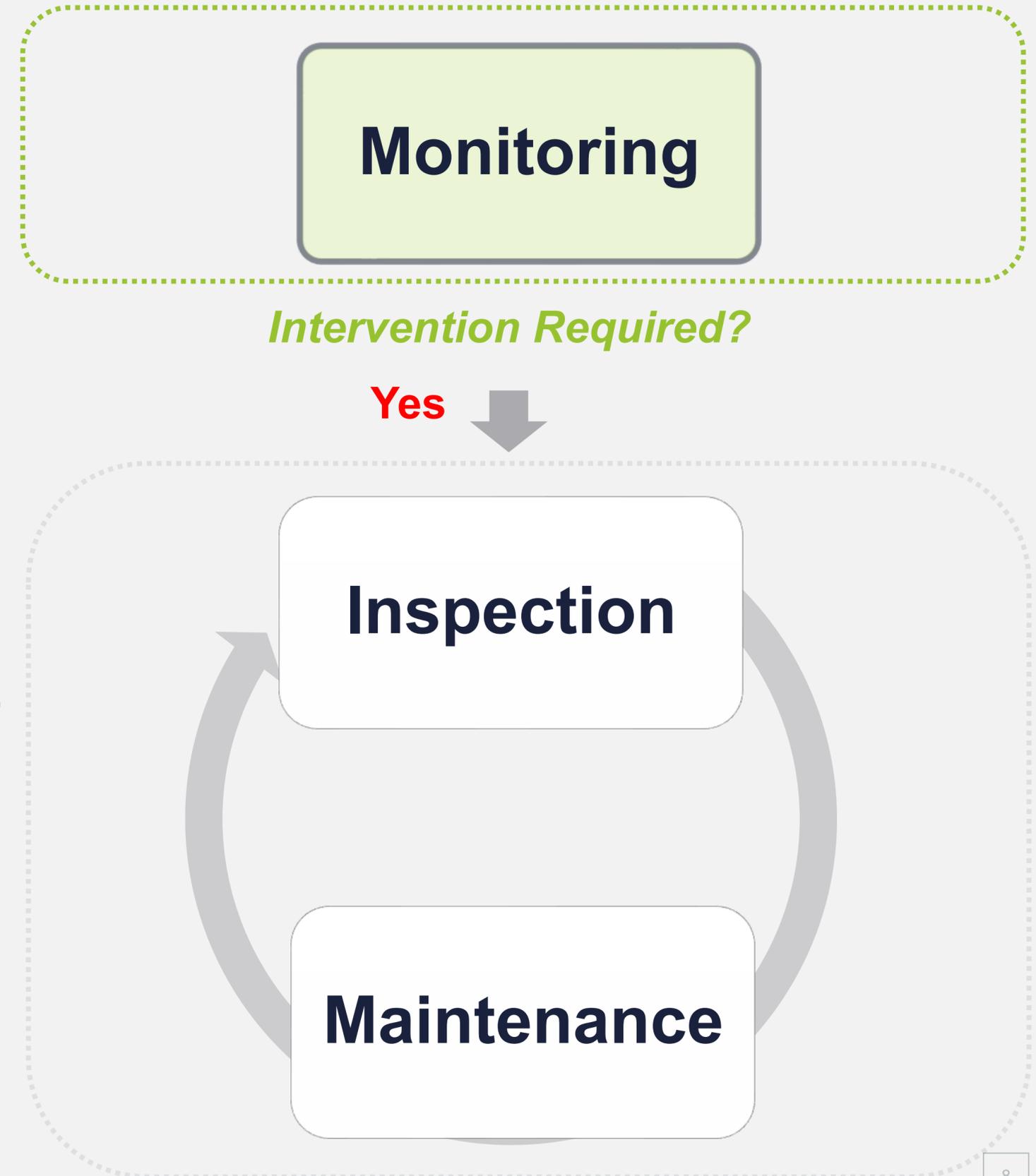


Workflow

A. MONITORING

Sensor Integration

- Track stress and performance monitoring.
- Provides data that indicates where intervention is likely needed and why.
- Change detected?
 - ✓ **Yes: Inspection is required**
 - ✓ No: Keep monitoring



Workflow

B. INSPECTION

1. Scanning

1.1. Preparation

- QR codes installed on the rail.
- Stable reference frame for all AR and measurement tasks.



Architecture Mapping

Monitoring

Intervention Required?

Yes

Inspection

Maintenance

Intervention Loop

Workflow

B. INSPECTION

1. Scanning

1.1. Preparation

- QR codes installed on the rail.
- Stable reference frame for all AR and measurement tasks.

New QR Code attachment being developed

- ✓ QR code material upgraded: sturdy and weather-resistant
- ✓ Clamps replaced with a rail-foot bracket for secure, stable mounting
- ✓ Designed for long-term field use in real railway environments



QR codes mounted on clamp



Architecture Mapping

Monitoring

Intervention Required?

Yes

Inspection

Maintenance

Intervention Loop

Workflow

Loop 1

B. INSPECTION

1. Scanning

1.2. 3D Scanning

- Capture the physical geometry of the crossing surface.
- Handheld 3D scanner to capture:
 - ✓ wear patterns
 - ✓ surface geometry
 - ✓ damage features



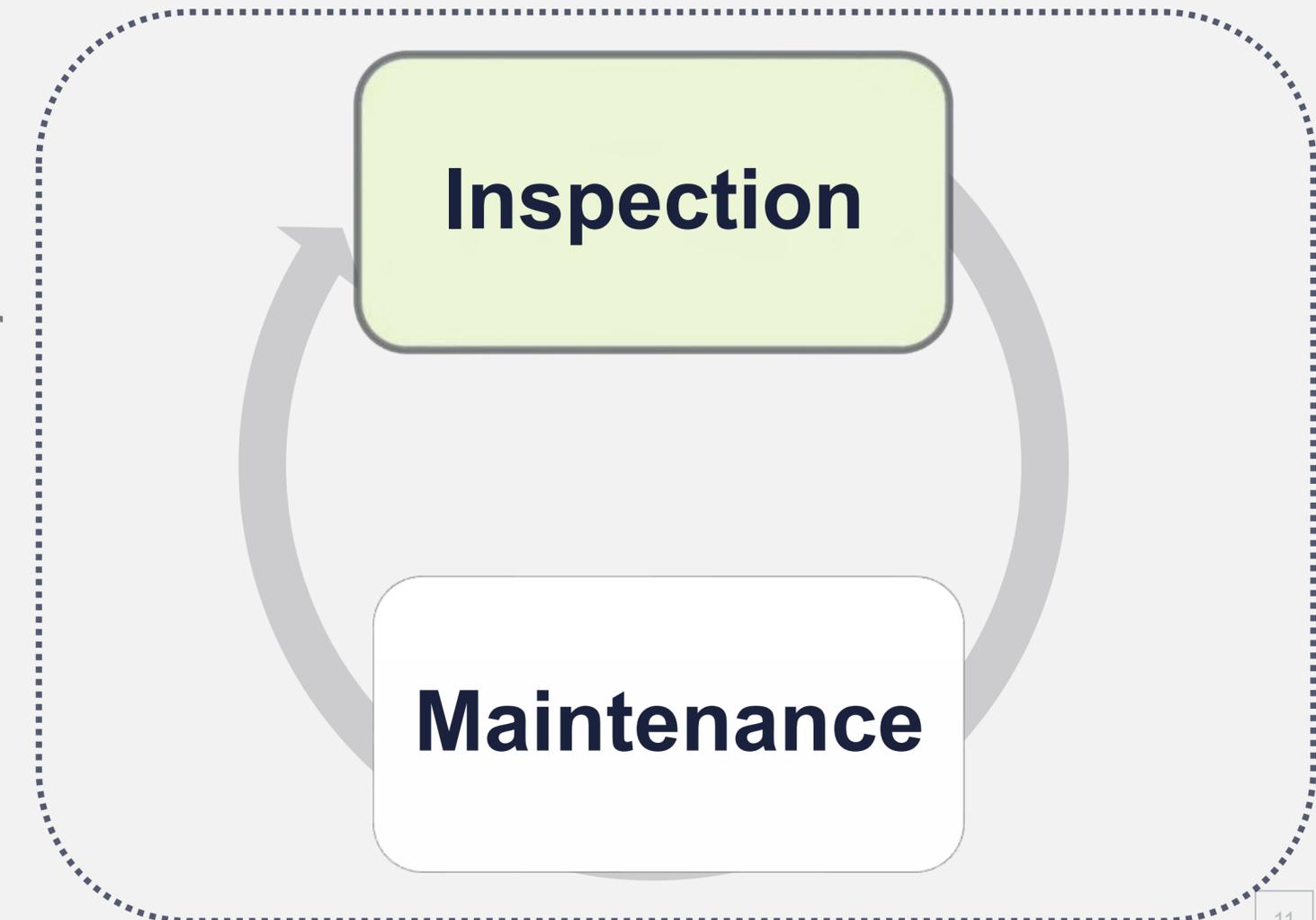
Architecture Mapping



Intervention Required?

Yes ↓

Intervention Loop



Workflow

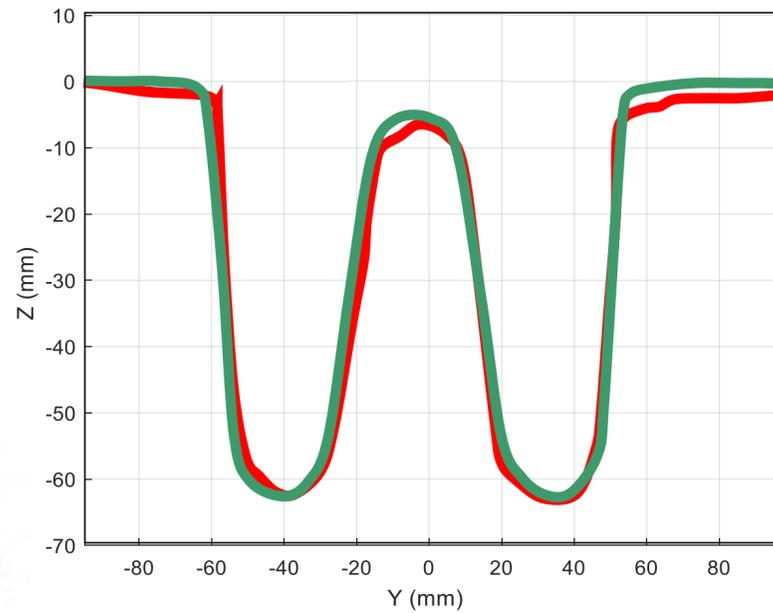
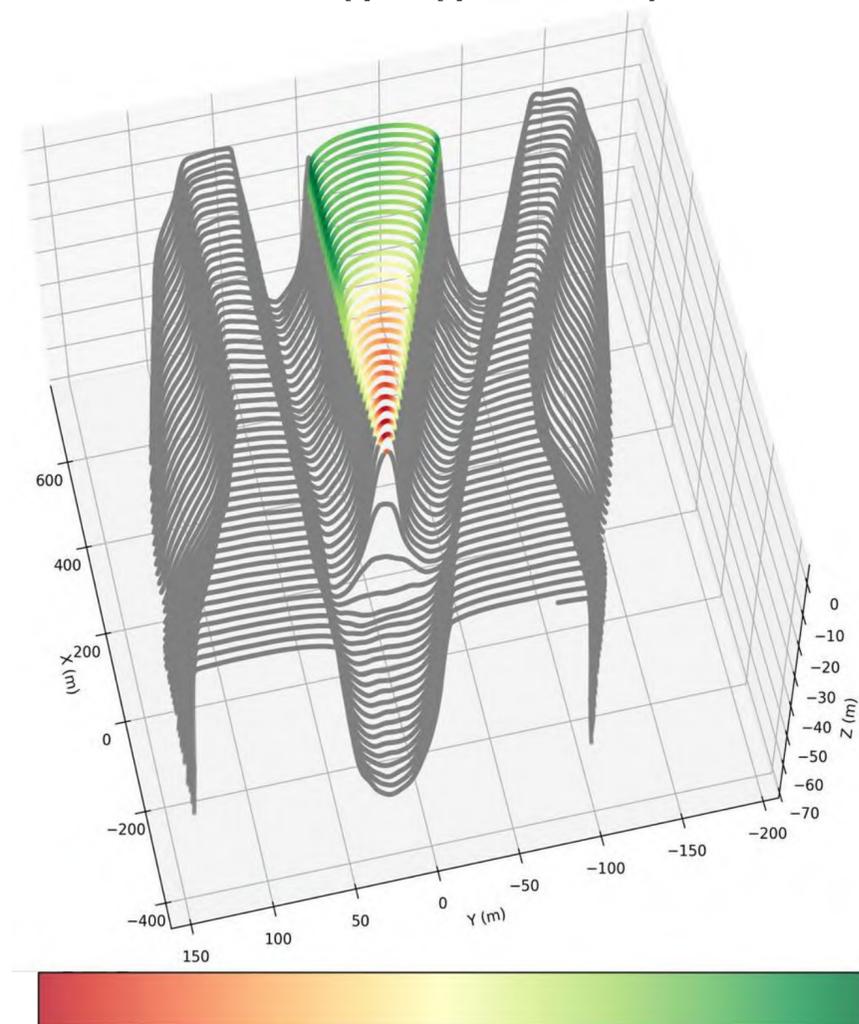
B. INSPECTION

2. Data Processing & Analysis

2.1. Digital Twin

- Transform raw scans into:
 - ✓ Surrogate models.
 - ✓ Crossing geometry optimisation.
 - ✓ Target geometry.

Loop 1



— Current Geometry
— Target Geometry

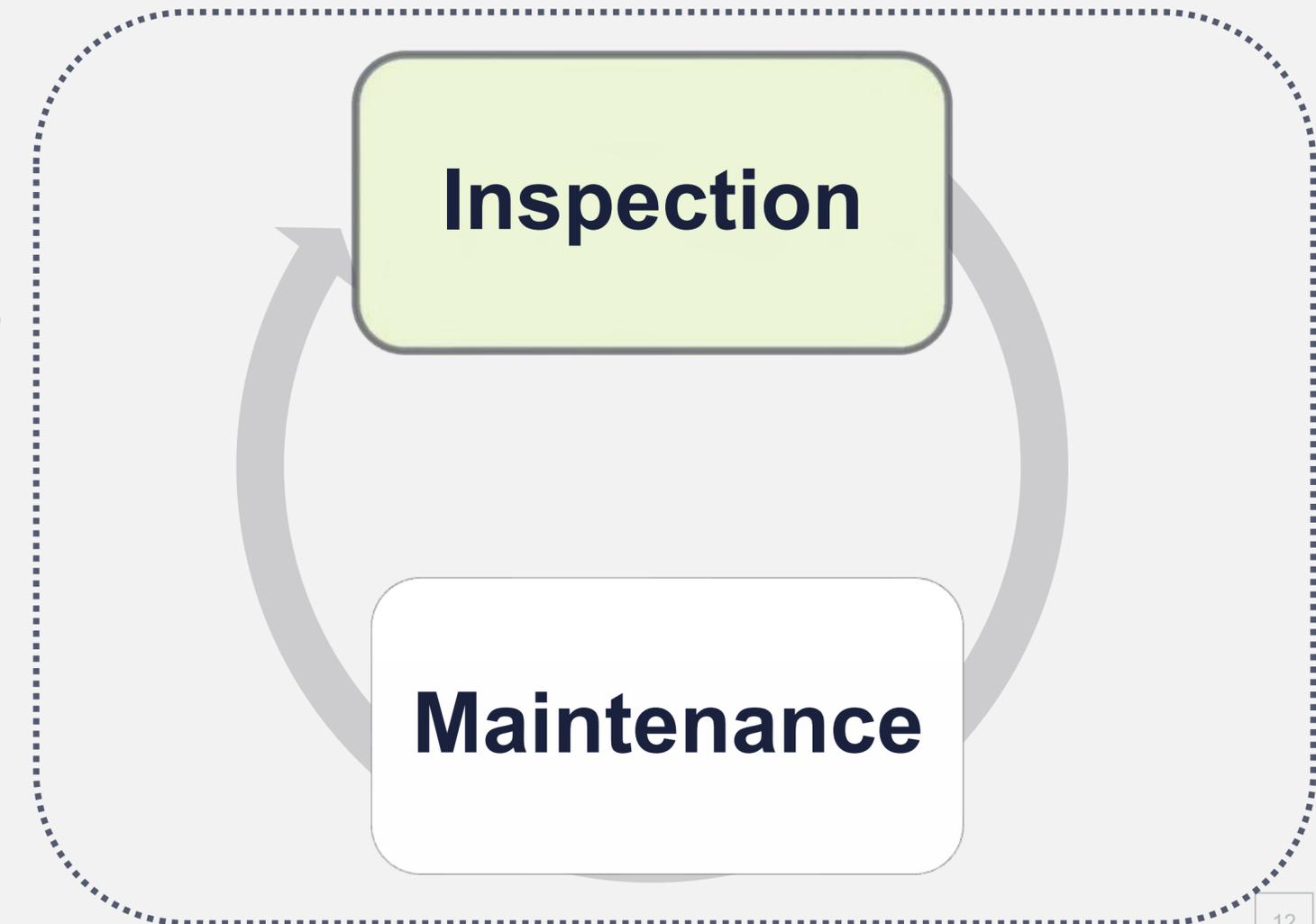
Architecture Mapping



Intervention Required?

Yes ↓

Intervention Loop



Workflow

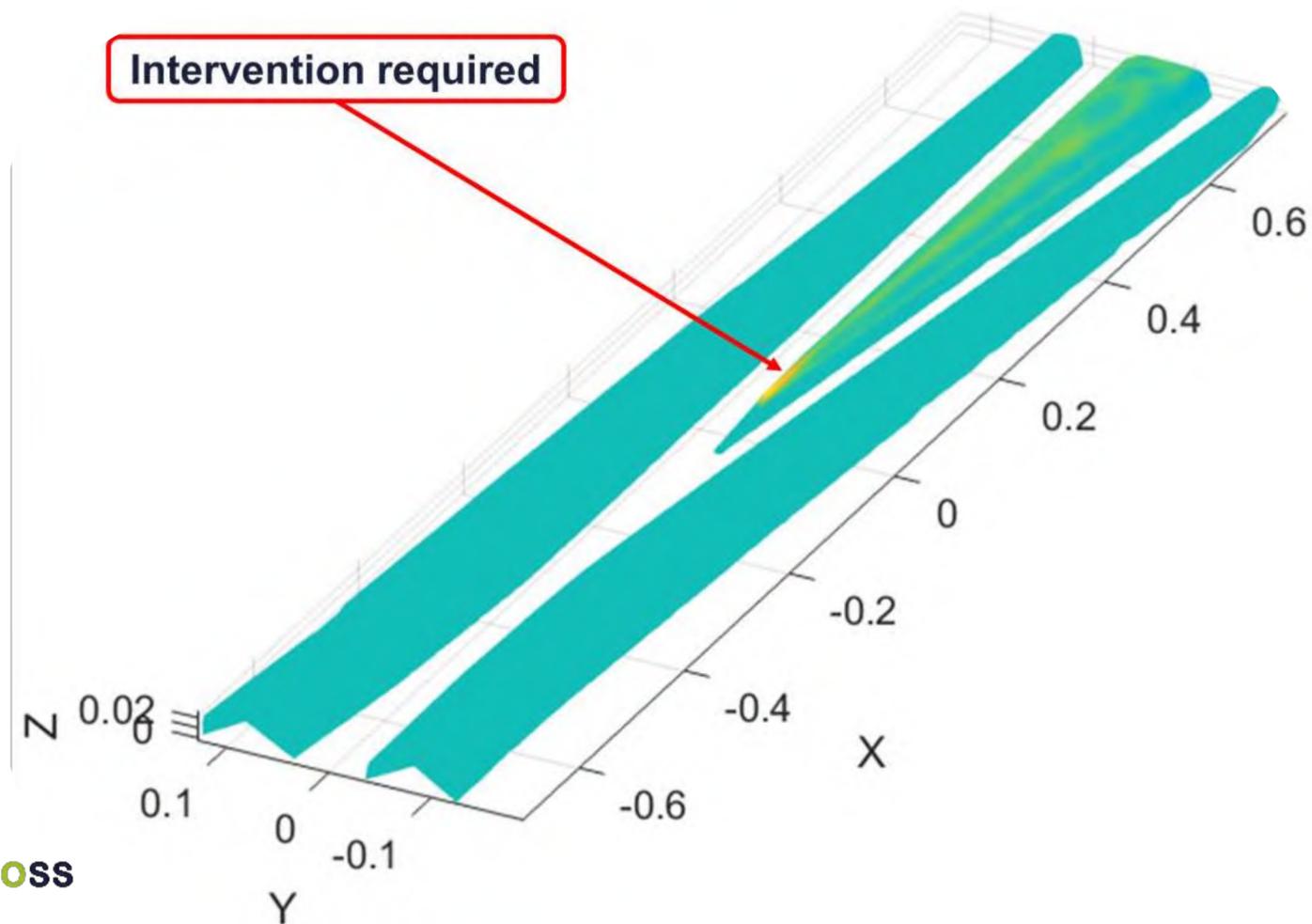
Loop 1

B. INSPECTION

2. Data Processing & Analysis

2.2. Overlay Generation

- Transform data into actionable information.
 - ✓ Decision layer: Expert scenarios identify repair actions.
 - ✓ Overlay generation: heat-maps



Architecture Mapping

Monitoring

Intervention Required?

Yes

Inspection

Maintenance

Intervention Loop

Workflow

Loop 1

C. MAINTENANCE & QUALITY CONTROL

1. AR Visualisation

- AR overlays corrective actions onto the real turnout.
- Modes used: Welding (W), Grinding (G), Combined (C)



Architecture Mapping

Monitoring

Intervention Required?

Yes

Inspection

Maintenance

Intervention Loop

Workflow

Loop 1

C. MAINTENANCE & QUALITY CONTROL

2. 3D Templates

- Physical profile guides
- Allows engineers to quickly check whether the rail has reached the target profile



Architecture Mapping

Monitoring

Intervention Required?

Yes

Inspection

Maintenance

Intervention Loop

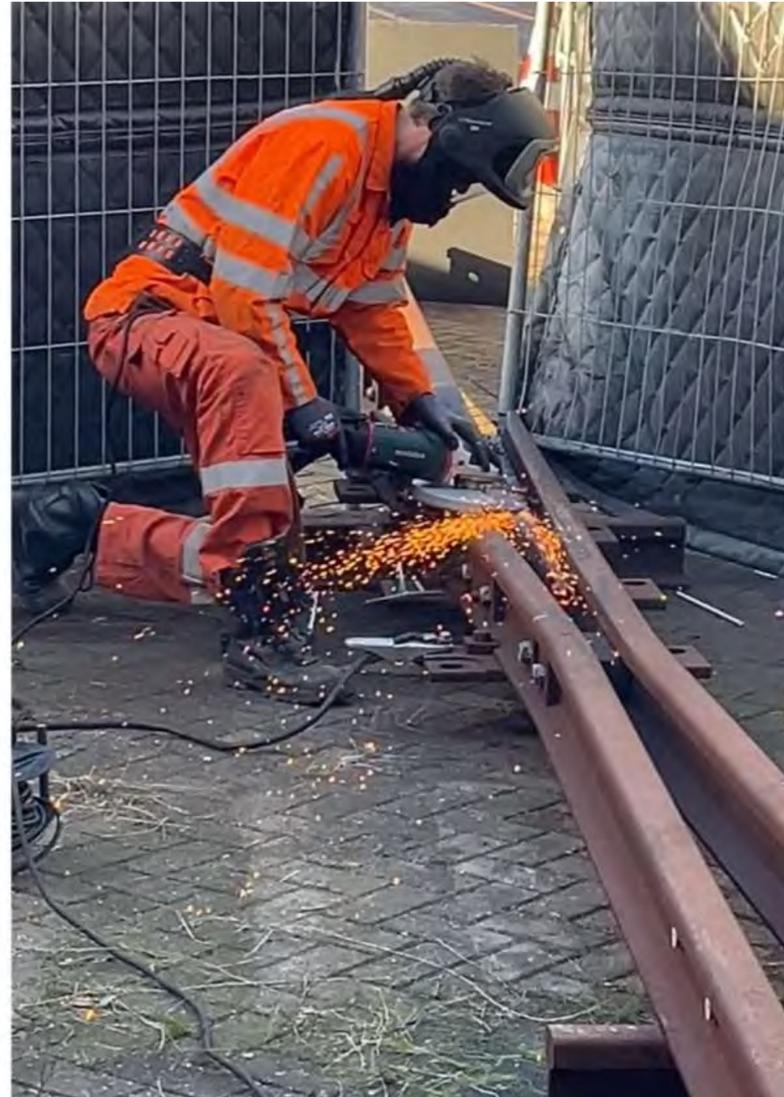
Workflow

Loop 1

C. MAINTENANCE & QUALITY CONTROL

3. Maintenance Actions

- Welding (add material): AR tool
- Grinding (remove material): 3D Templates



Architecture Mapping

Monitoring

Intervention Required?

Yes

Inspection

Maintenance

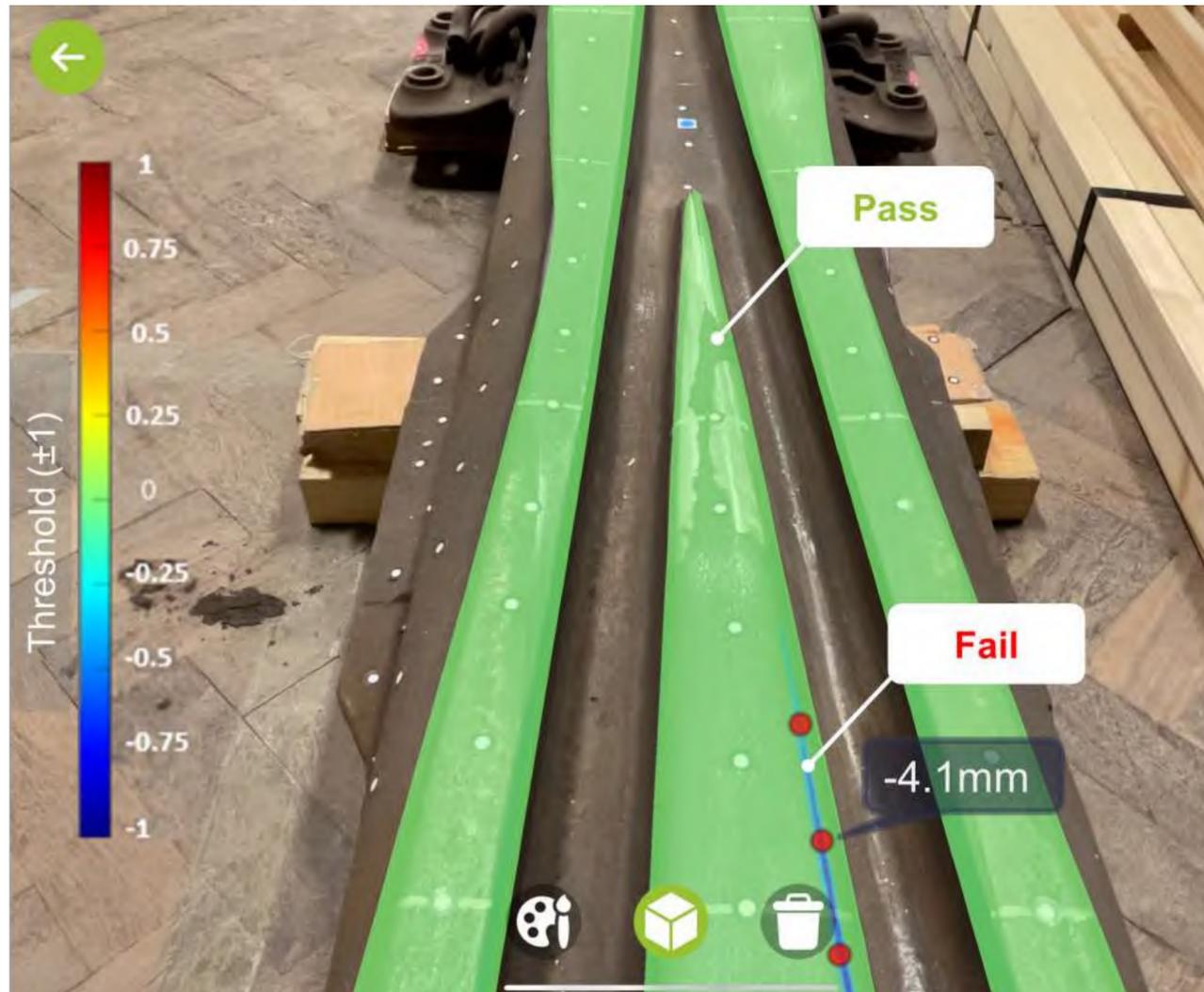
Intervention Loop

Workflow

Loop 2

C. INSPECTION + MAINTENANCE (update)

1. Re-scan after maintenance
 - Database Update
2. Data Processing & Analysis
 - Repair decision layer Update
3. AR verification with threshold mode:
 - Welding (W) + Grinding (G) + Combined (C) + Threshold (T)



Architecture Mapping

Monitoring

Intervention Required?

Yes

Inspection

Maintenance

Intervention Loop

Workflow

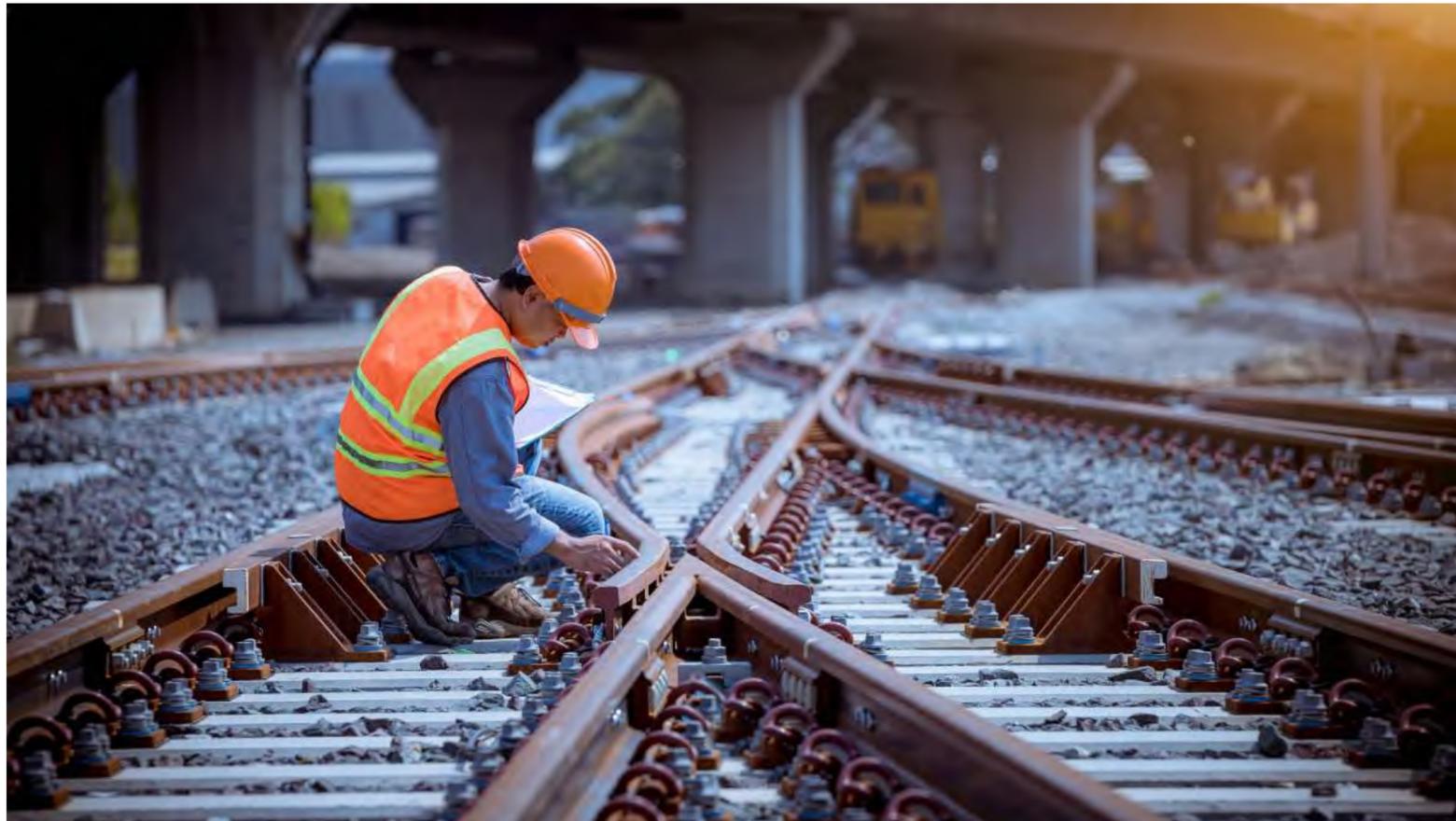
Loop 2

C. INSPECTION + MAINTENANCE (update)

Validation & Logging

After repair, AR can be used to:

- ✓ Validate geometry against design tolerances
- ✓ Capture a final inspection report
- ✓ Log time and steps for audit purposes



Architecture Mapping

Monitoring

Intervention Required?

Yes

Inspection

Maintenance

Intervention Loop

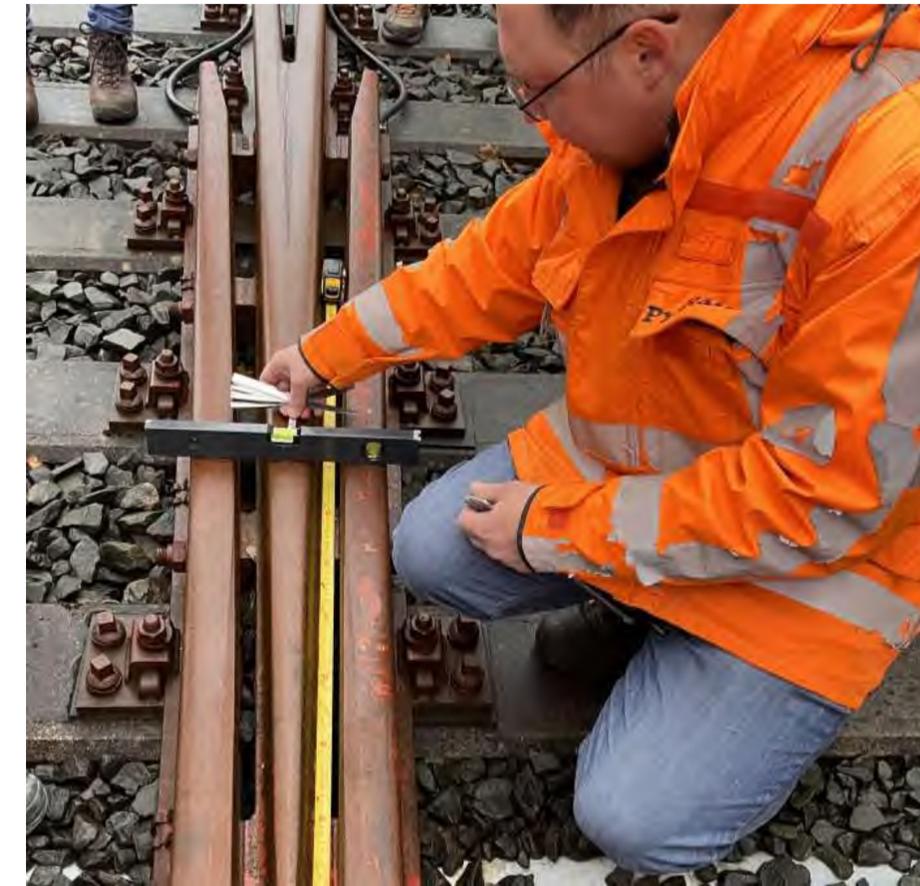
INSPECTION

Current strategy

- Manual marking and measurement
- Straightedges, gauges, spot checks
- Limited spatial coverage
- No record of full geometry

XCROSS approach: High-resolution 3D scanning

- Full crossing surface captured in minutes
- Digital model enables:
 - ✓ defect depth and extent analysis
 - ✓ comparison against target / optimal profiles
- Data prepared for downstream maintenance guidance



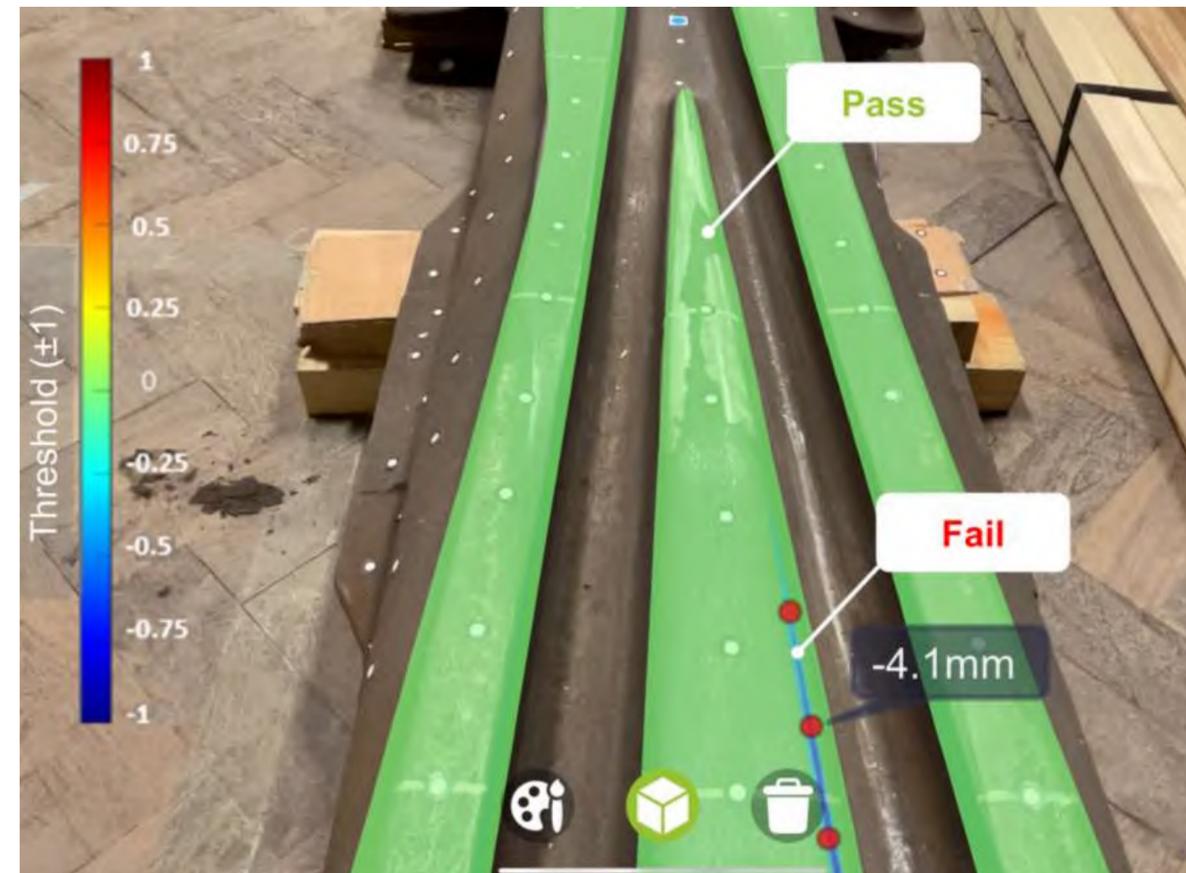
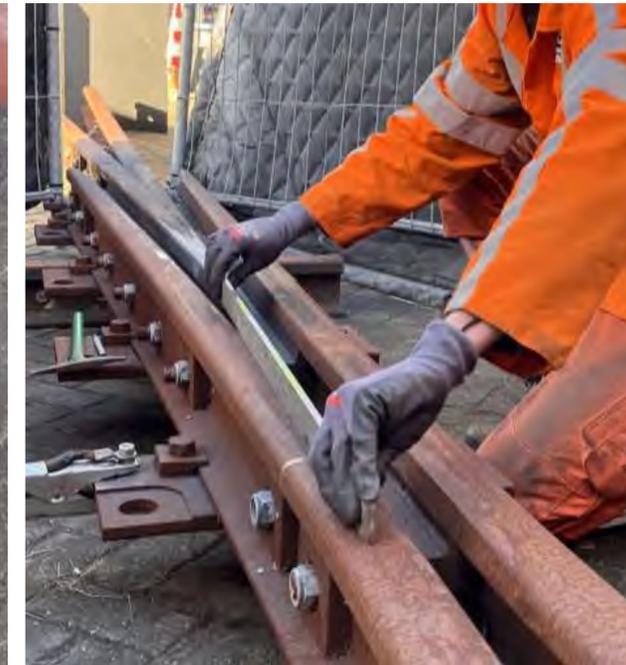
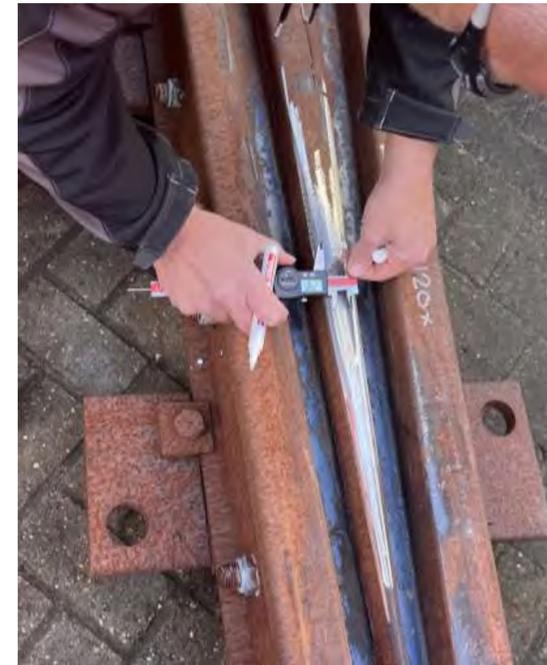
MAINTENANCE & QUALITY CONTROL

Current strategy

- Defects marked manually
- Welding and grinding guided by experience
- Geometry checked intermittently
- Quality Control:
 - ✓ often verified by a different person, later
 - ✓ Visual inspection with Manual gauges
- Limited traceability

XCROSS approach: AR and 3D printed profiles - guided corrective actions

- ✓ Welding mode
- ✓ Grinding mode
- ✓ Combined mode
- ✓ Threshold mode: Clear “pass/fail” regions
- Overlays show where and how much material to add or remove
- Real-time visual guidance
- 3D-printed physical profile aids for direct checking
- Digital records stored for traceability and future comparison



Key Innovations

1. Sensor-Based Condition Monitoring

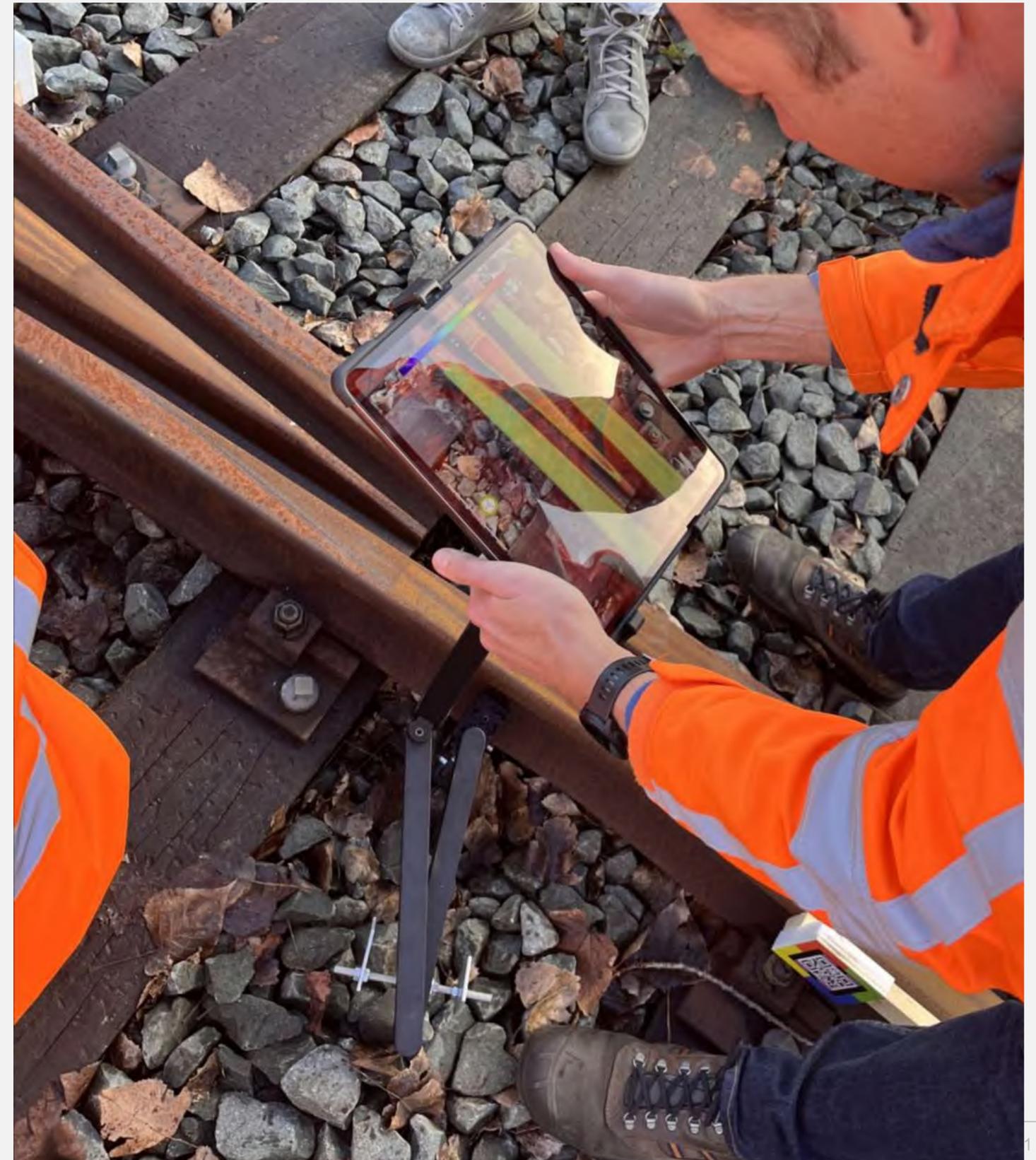
- Early detection of wear patterns
- Supports predictive maintenance

2. Integrated 3D Scanning and Spatial Referencing

- High-accuracy 3D scanning with onboard processing
- Stable QR marker-based referencing enables repeatable alignment across inspection and maintenance

3. Data-to-Action AR Guidance

- Processed scan data translated into AR guidance for welding and grinding
- Mode-based visualisation supports targeted, informed decision-making



Key Innovations

4. 3D Printing Applications

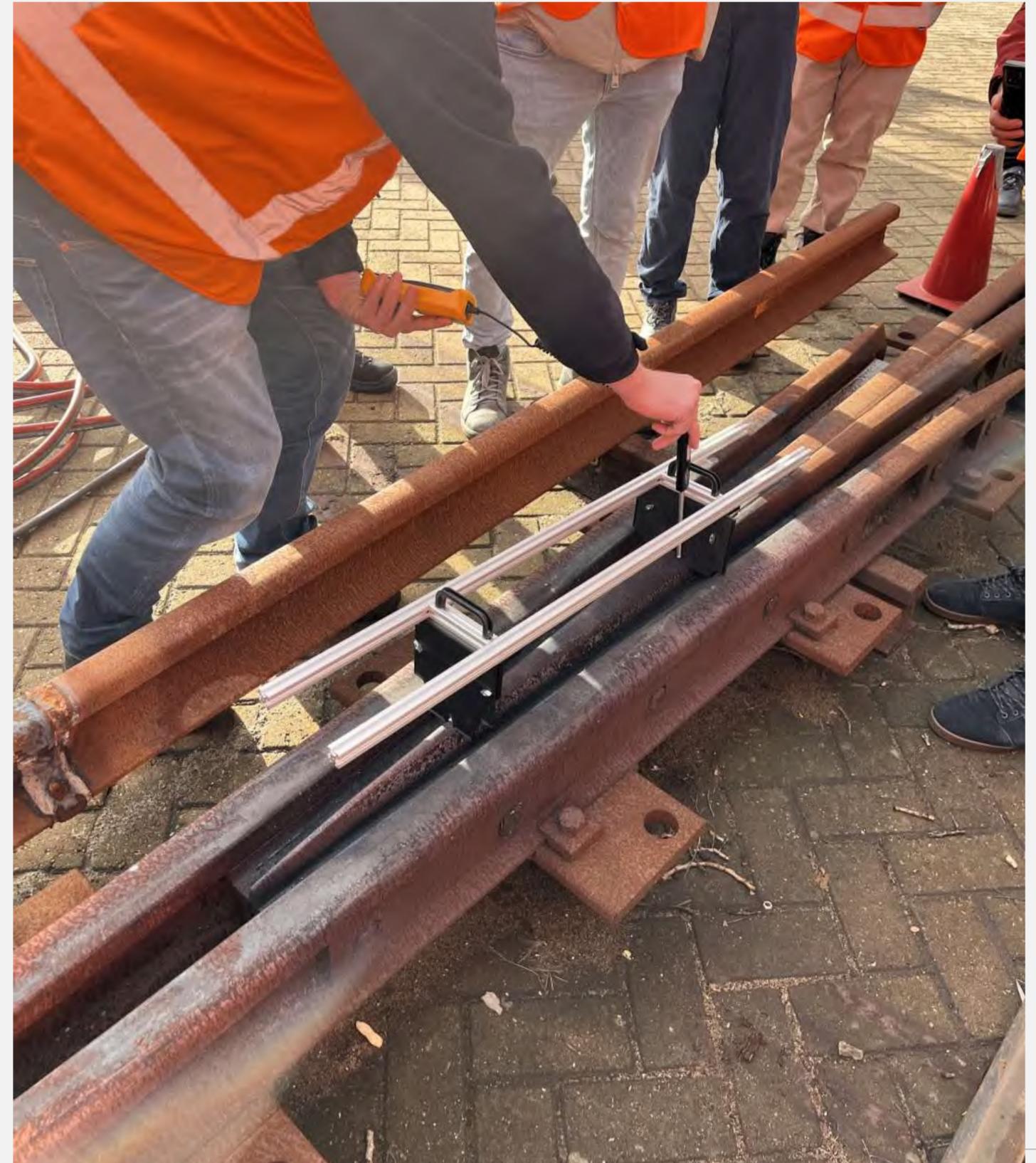
- Printing of maintenance templates
- Supports practical field testing and validation
- Materials and designs capable of withstanding high temperatures

5. Workflow-Embedded Quality Control

- Re-scanning and AR verification
- Threshold-based feedback supports objective quality assessment

6. Field-Ready, Scalable System Design

- Designed for real railway environments



Questions





Thank you
for your attention

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