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Europe's Rail

CROSS

AR Tool

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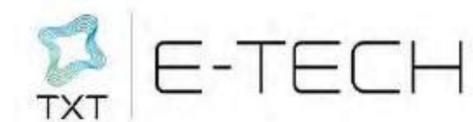
05 February 2026

Workflow Overview

1st Loop

1. **Inspection**
   - Scanning
   - Data processing
     (Digital Twin + decision layer)
2. **Maintenance**
   - AR Visualisation of corrective actions
     (Modes: Welding + Grinding + Combined)
   - 3D Printed Profile Guides (Modes: Welding)

2nd Loop

1. Re-scan and Update data
2. AR verification & threshold mode
   (Modes: Welding + Grinding + Combined + Threshold)

Goal:
   - ✓ Reduce inspection time,
   - ✓ Improve inspection records,
   - ✓ Support W/G decision-making,
   - ✓ Improve repair QC

MONITORING

Intervention Loop

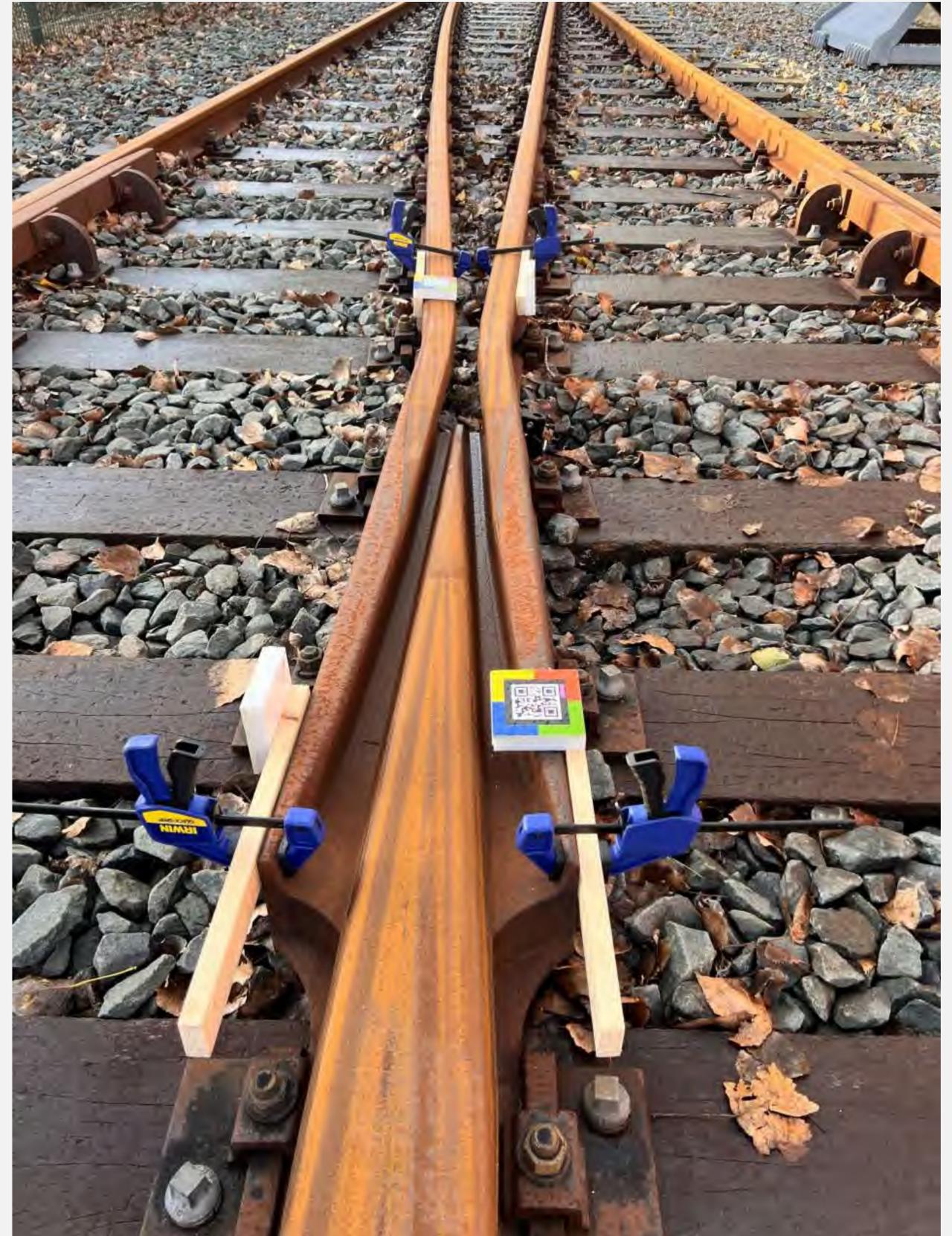**INSPECTION**
- 3D scanning
- Data Processing

MAINTENANCE
- AR Visualisation
- 3D templates

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1. INSPECTION: AR alignment

- QR codes placed on the railway crossing during inspection
- QR codes remain in place for maintenance and quality control
- iPad uses QR codes to spatially align AR content

- ✓ AR aligns pre-processed inspection results

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1. Inspection: 3D Scanning

- High-Fidelity 3D Data Capture
- Fast operation
- Works in day and night
- Captures full crossing geometry with sub-mm accuracy
- Real-time 3D reconstruction in the device
- Portable & field-ready (battery powered)
- Create highly detailed inspection reports/database

  Used for either:
  - ✓ Inspection
  - ✓ To inform welding/grinding
  - ✓ Quality control after welding/grinding

1. INSPECTION: Data Processing
What is Digital Twin?

Digital representation of a real railway crossing, continuously updated using 3D scan data, to support prediction, decision-making, and maintenance guidance.

In XCROSS, the Digital Twin enables:

✓ Understanding wear and degradation

✓ Computing an achievable target profile

✓ Generating actionable repair guidance
(AR + 3D templates)

1. INSPECTION: Data Processing
Why do we need Digital Twin?

- 3D scanning captures the current worn geometry (what the crossing looks like today)

- Maintenance requires a target repair profile (what the crossing should look like after intervention).

- Geometry alone does not indicate:

  - where material should be added (welding)

  - where material should be removed (grinding)

  - whether the repair improves long-term performance

- **A Digital Twin links inspection data to engineering outcomes**, enabling: consistent, traceable, and optimised intervention planning
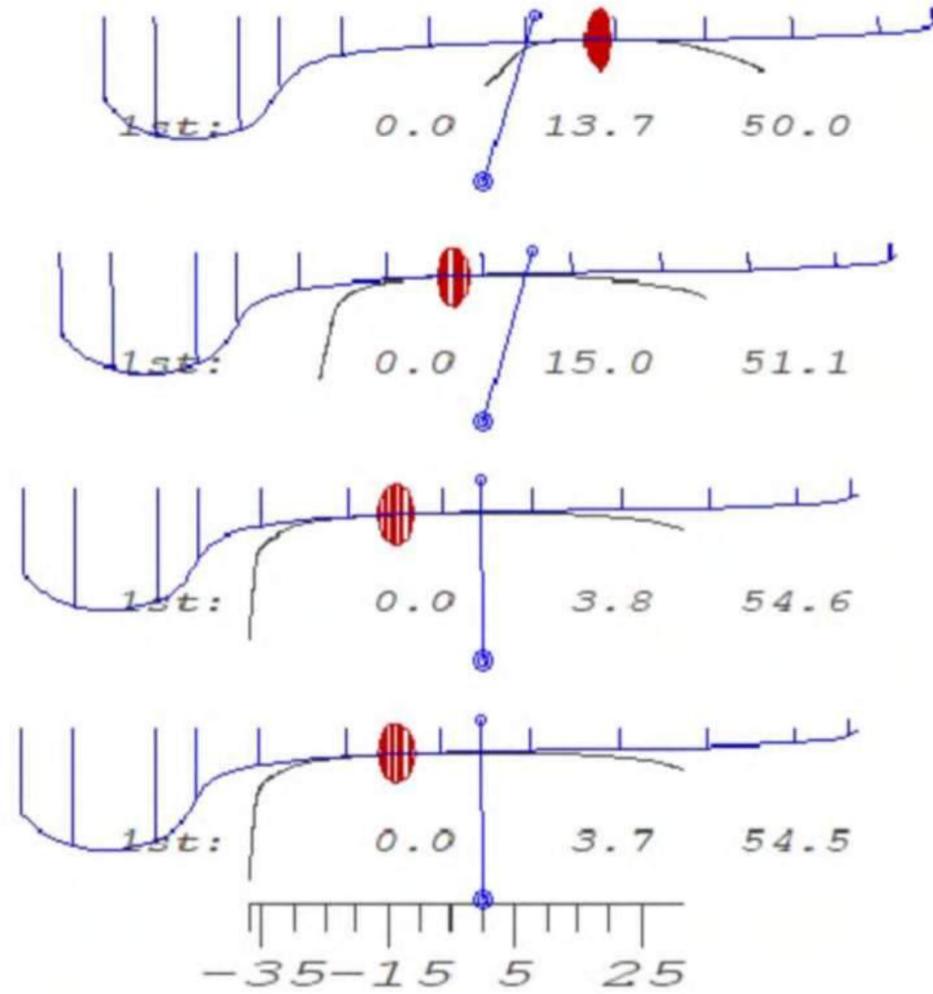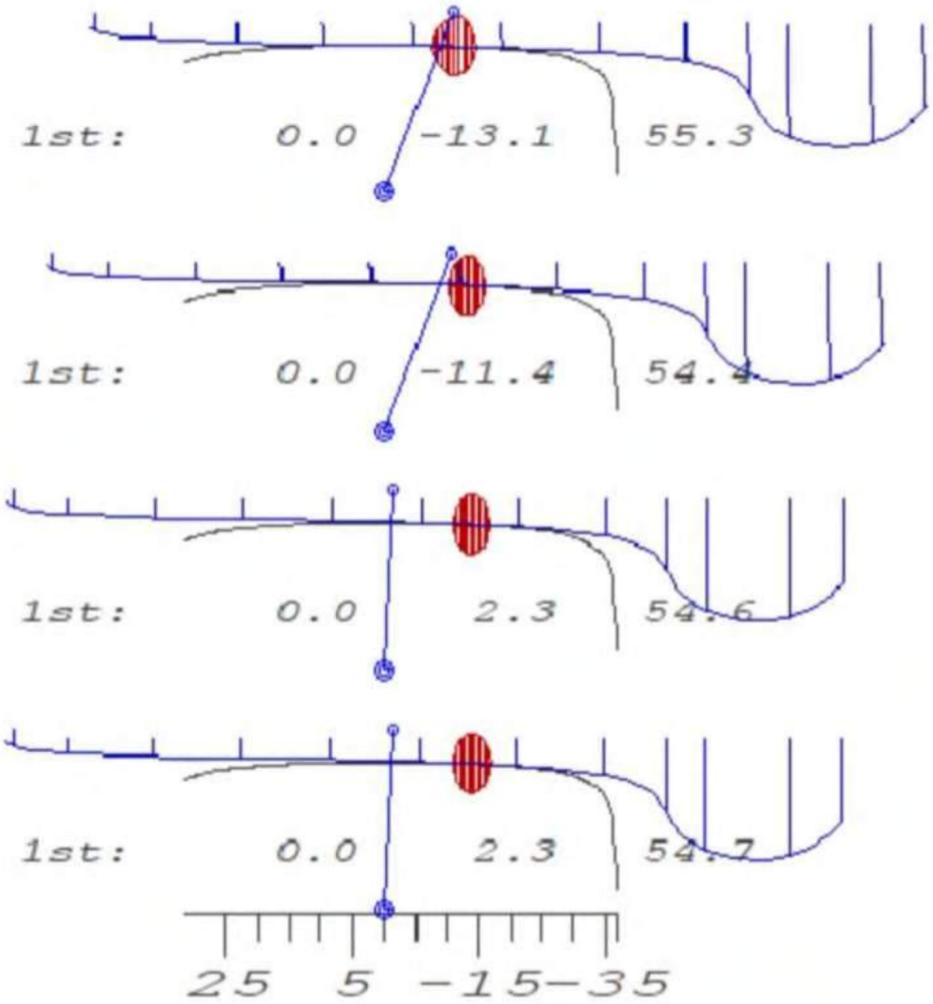

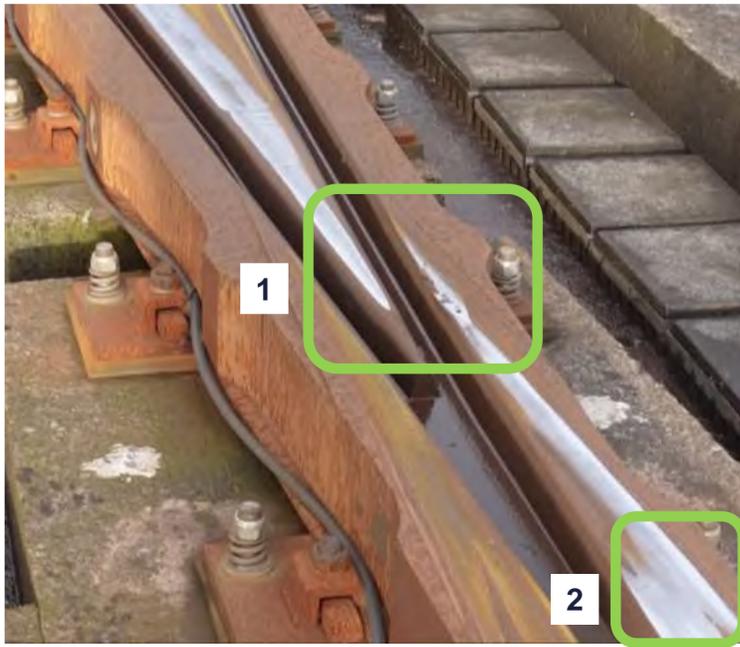3D Profile Point Cloud with Differences
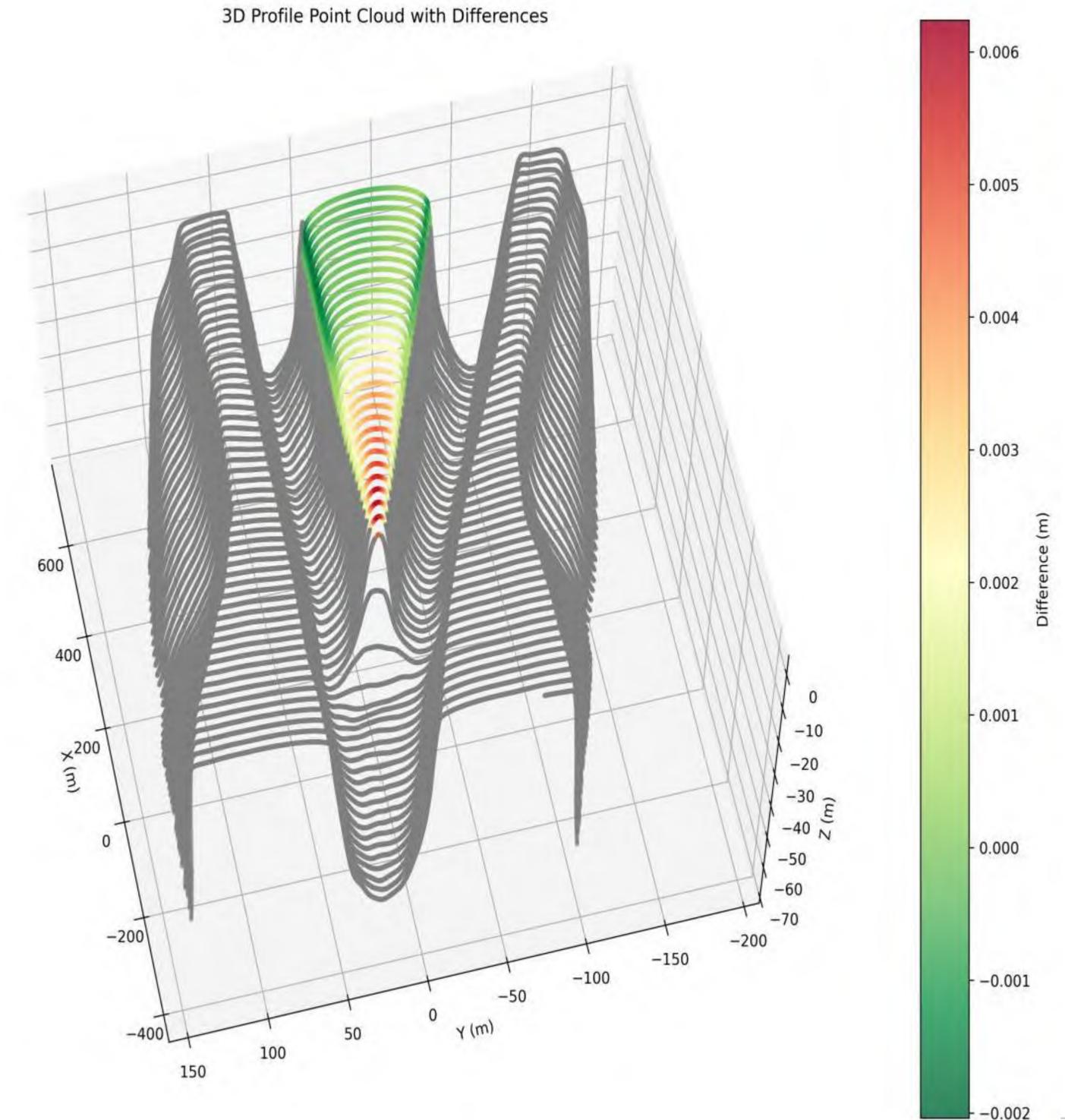
1. INSPECTION: Data Processing
Why do crossings degrade?

- Crossings experience high-impact forces
- Wear evolves over time
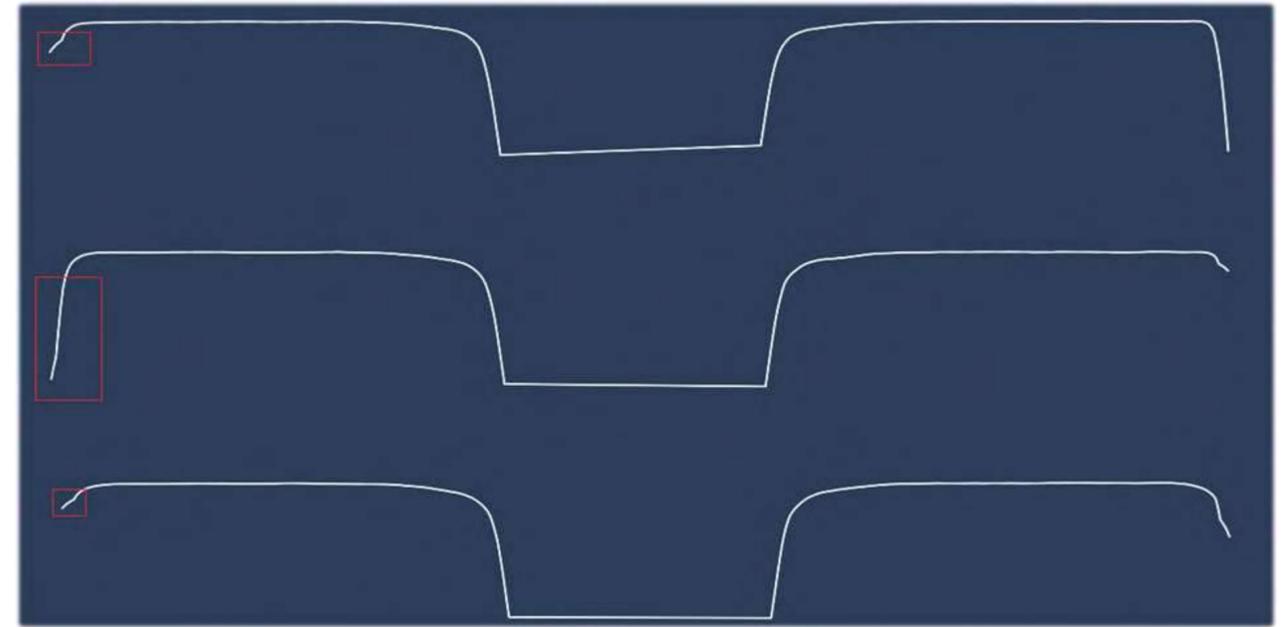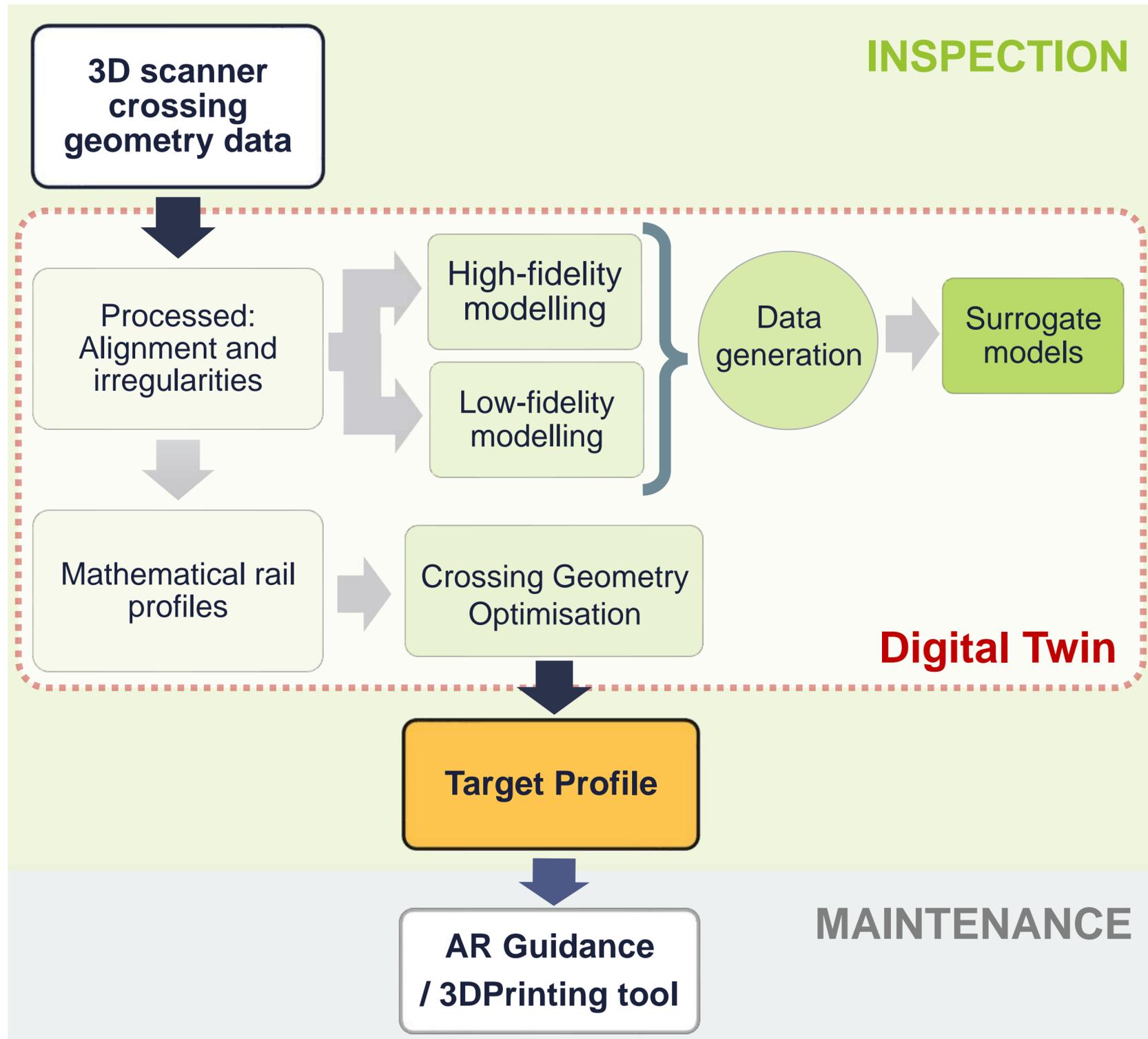- Geometry changes affect safety and ride quality

2. INSPECTION: Examples of Turnout Defects Observed on Field

No.	Defect type	Required action
1	Gauge corner wear	Grinding
2	Running band deformation /plastic flow	Grinding + monitoring
3	Surface spalling/flaking	Light grinding + monitor for crack propagation
4	Head wear/abrasion	Grinding or weld restoration (depending on depth)
5	Crossing nose material loss	Weld or component replacement

1. INSPECTION:
Data Processing

INSPECTION

- **3D scanner crossing geometry data**
- Processed: Alignment and irregularities
- High-fidelity modelling
- Low-fidelity modelling
- Data generation
- Surrogate models
- Mathematical rail profiles
- Crossing Geometry Optimisation

Digital Twin

- **Target Profile**

MAINTENANCE

- **AR Guidance / 3DPrinting tool**
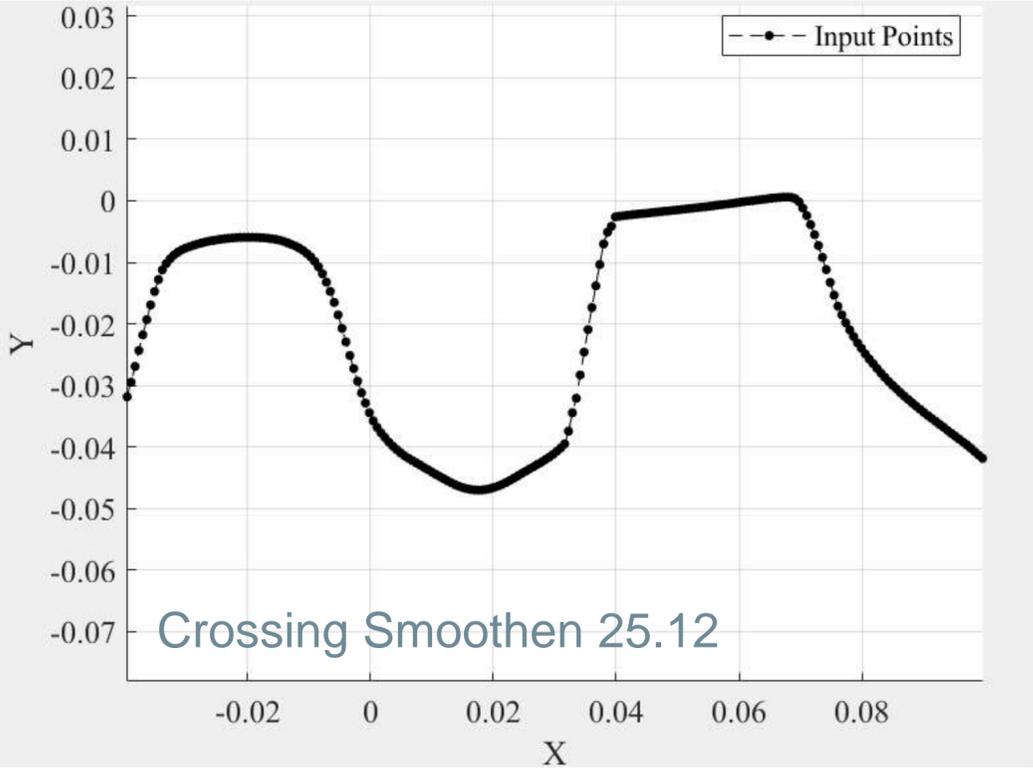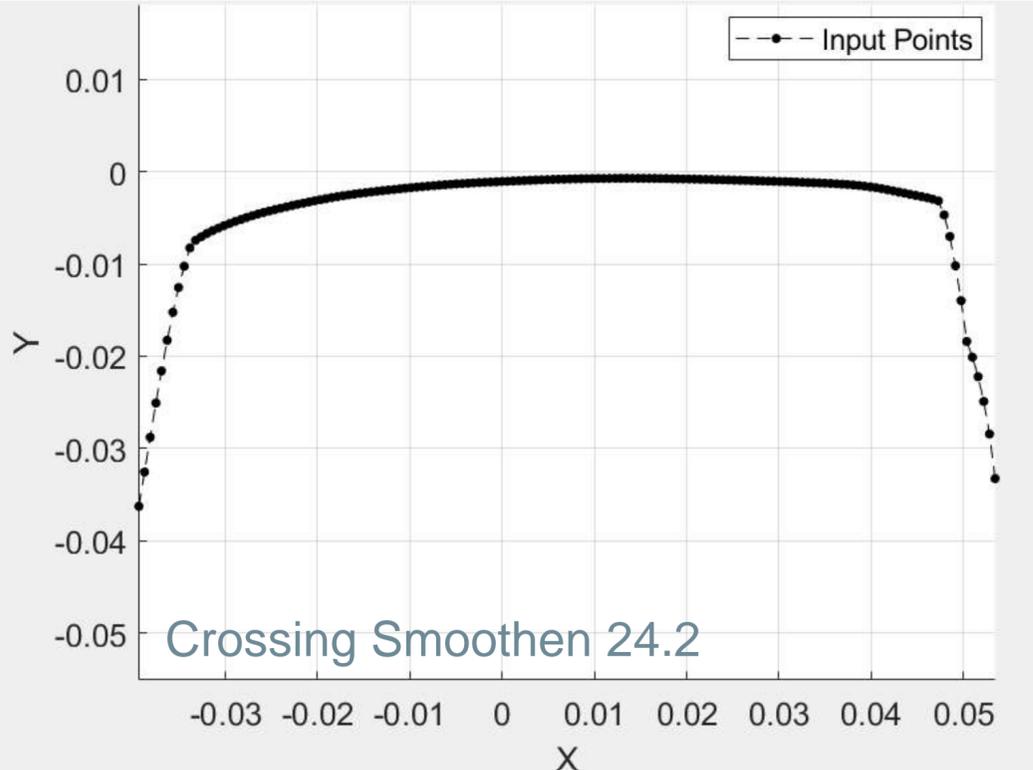
Corrections for alignment and irregularities
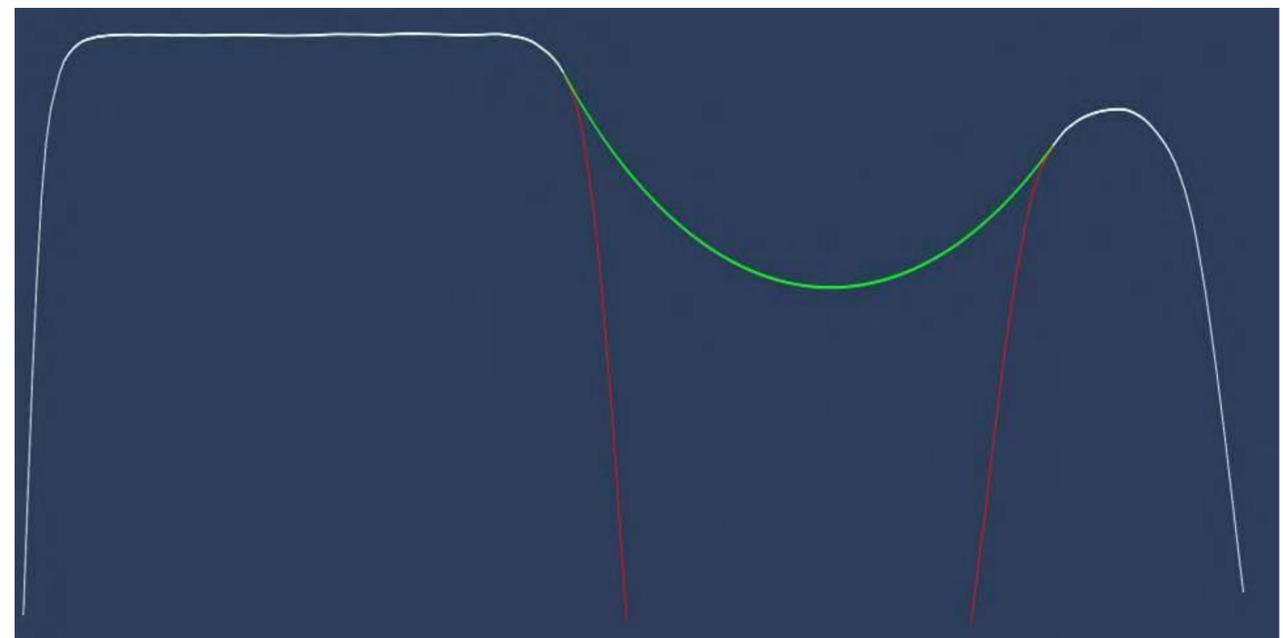
Circular interpolation for high-fidelity modeling

1. INSPECTION: Data Processing
Scanned Crossing Geometry

UoL Crossing @ University of Leeds

Crossing Smoothen 24.2

Crossing Smoothen 25.12

Crossing Smoothen 25.46
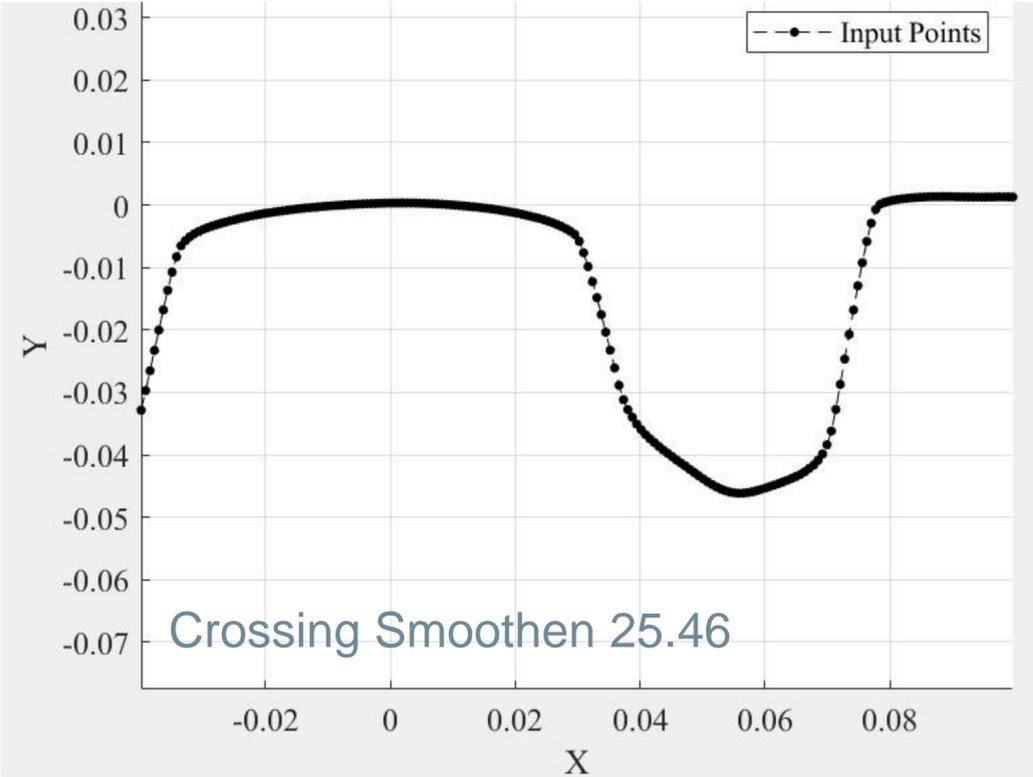
1. INSPECTION: Data Processing
High– VS Low–Fidelity Modelling

Balancing speed and accuracy:

Model type	Purpose in XCROSS	Characteristics
Low-fidelity	Rapid approximation of scanned geometry	Fast, smooth, suitable for optimisation
High-fidelity	Accurate representation for wheel–rail dynamics	Captures critical contact zones and impact behaviour

Together, they ensure the target geometry is both achievable and safe

1. INSPECTION: Data Processing
   High–Fidelity Modelling of Railway Crossings

Scanned Versus Approximated B-Spline Crossing Profiles
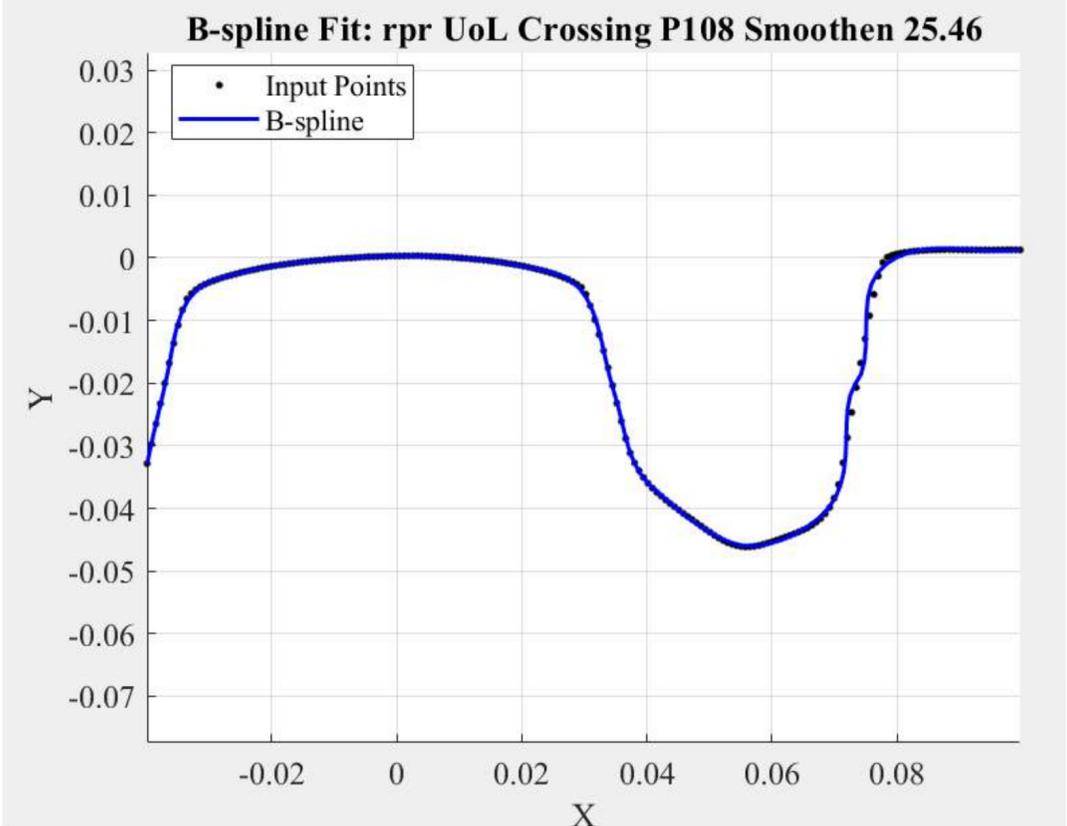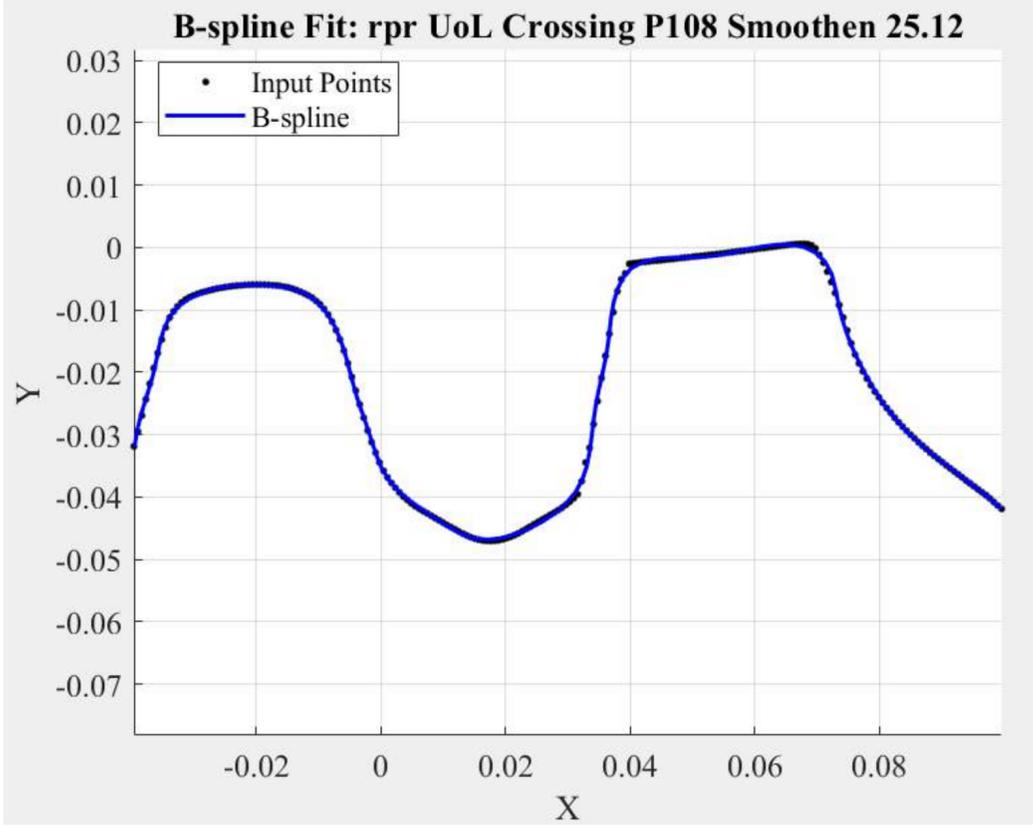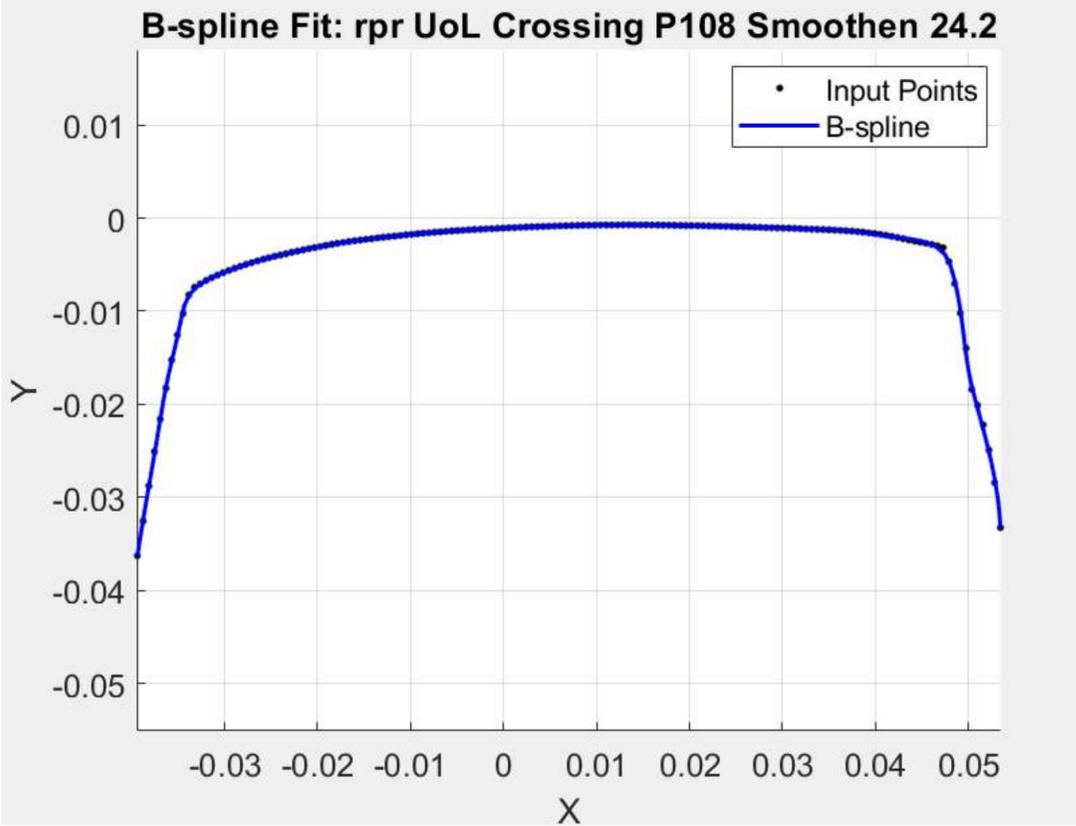
Weighted B-Spline Approximation:

Close to the actual scanned geometry obtained from 3D scanner (Particular emphasis on top of nose and wing rail)
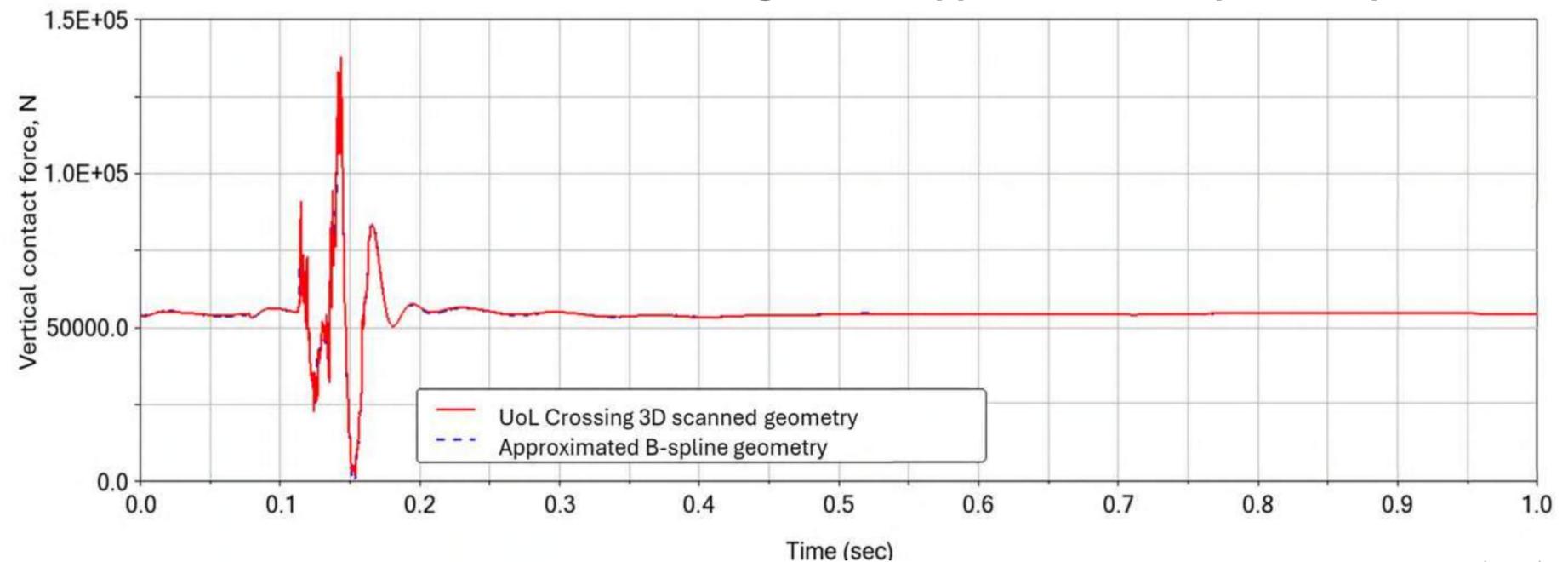
1. INSPECTION: Data Processing
High–Fidelity Modelling of Railway Crossings in VI-Rail

- Full **3D multibody vehicle–track interaction** modelling with wheel-rail contact mechanics.

- Explicit modelling of **crossing geometry** (frog and wing rails)

- Accurate simulation of **impact forces and transient dynamics** at crossings

Validation: Measured UoL crossing versus Approximated B-spline rail profiles
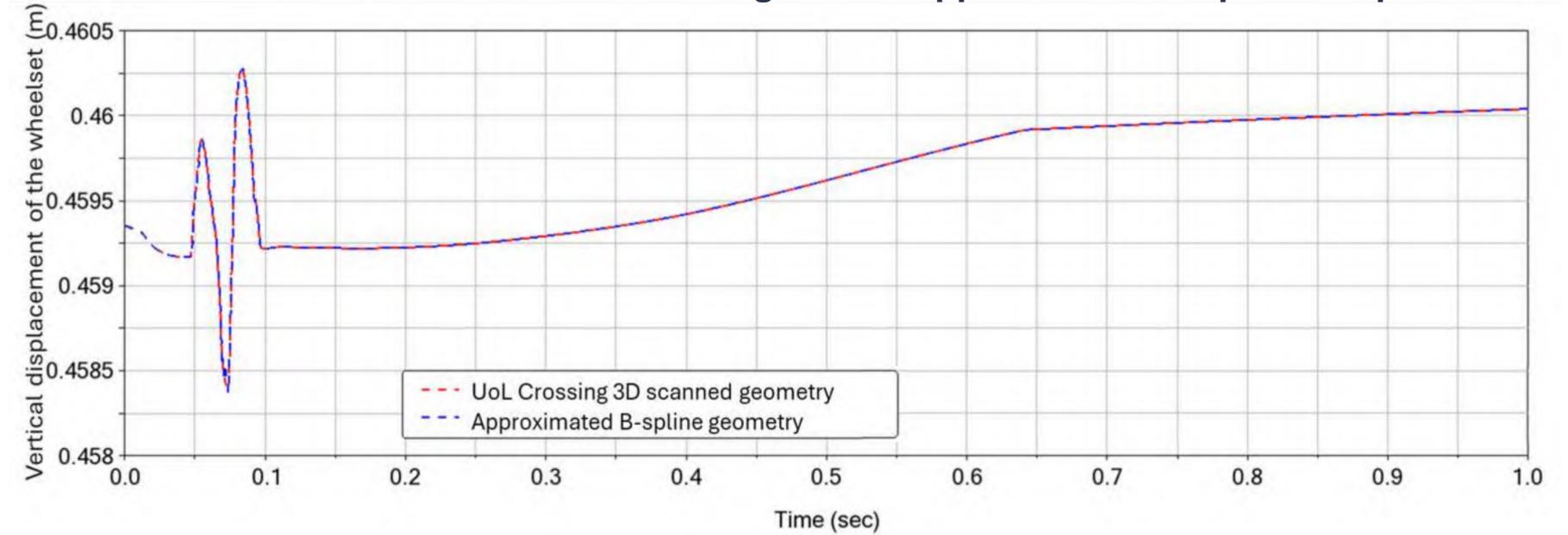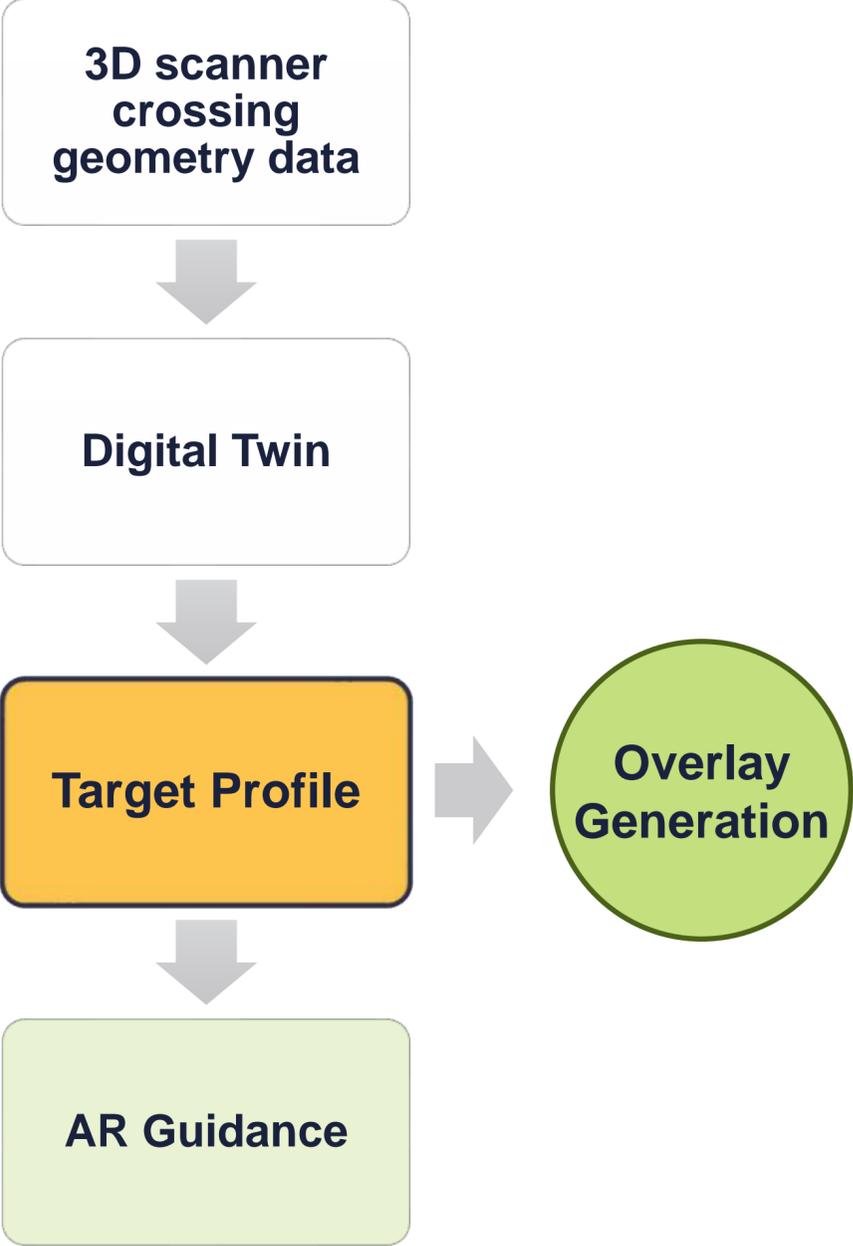

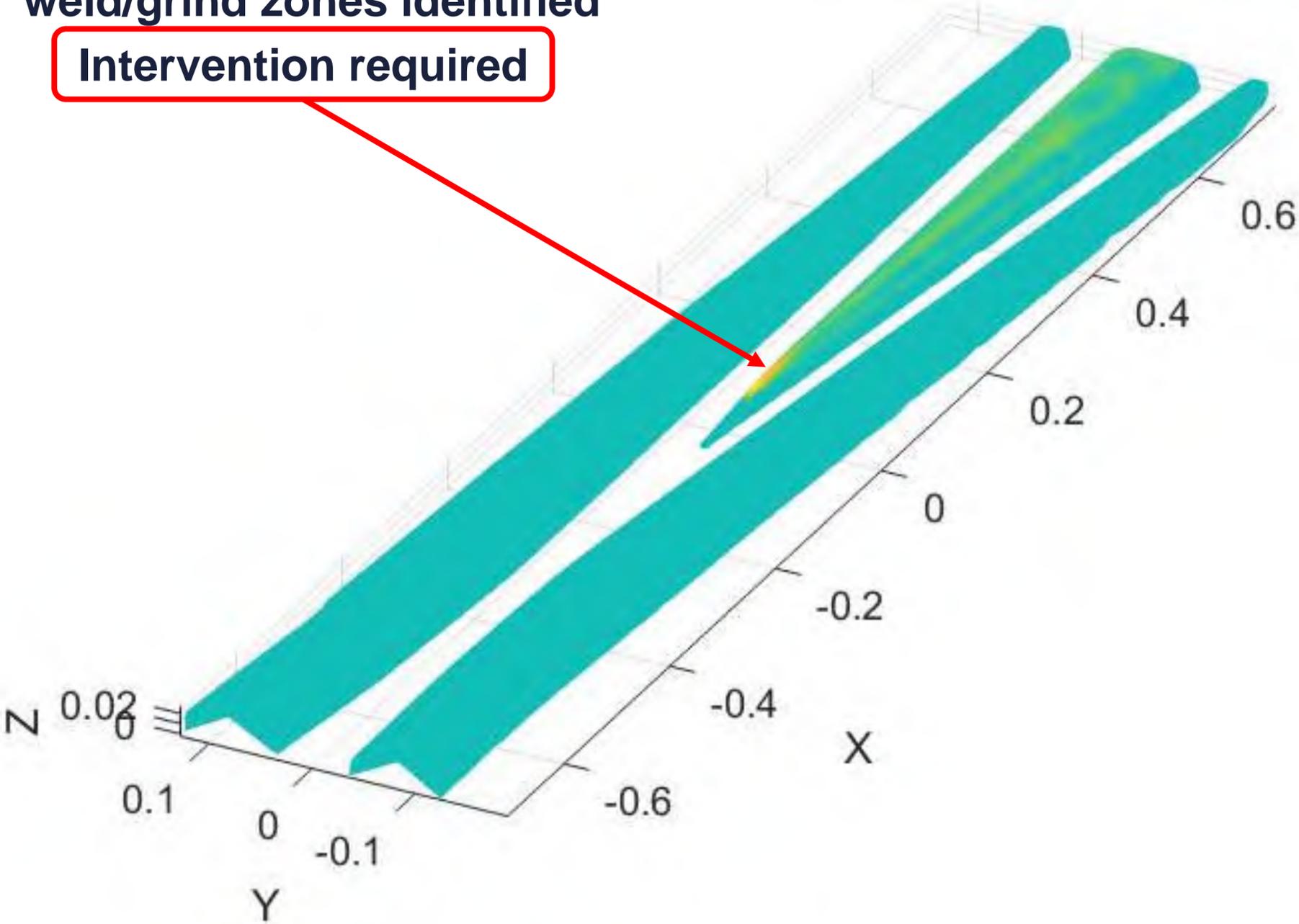**Validation: Measured UoL crossing versus Approximated B-spline rail profiles**

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1. INSPECTION: Data Processing
Output: Overlay generation

3D scanner crossing geometry data

Digital Twin

Target Profile → Overlay Generation

AR Guidance

**weld/grind zones identified**

Intervention required

DT converts scanned crossing geometry into an achievable target profile, which is then used to generate the intervention zones visualised in AR.

2. MAINTENANCE:
What is Augmented Reality?

- Technology that overlays digital information onto the real world

- Enhances what users see and interact with

- Can display images, measurements, instructions, or visual cues

- Provides guidance, context, and actionable insights in real time

- Supports faster, more accurate decision-making
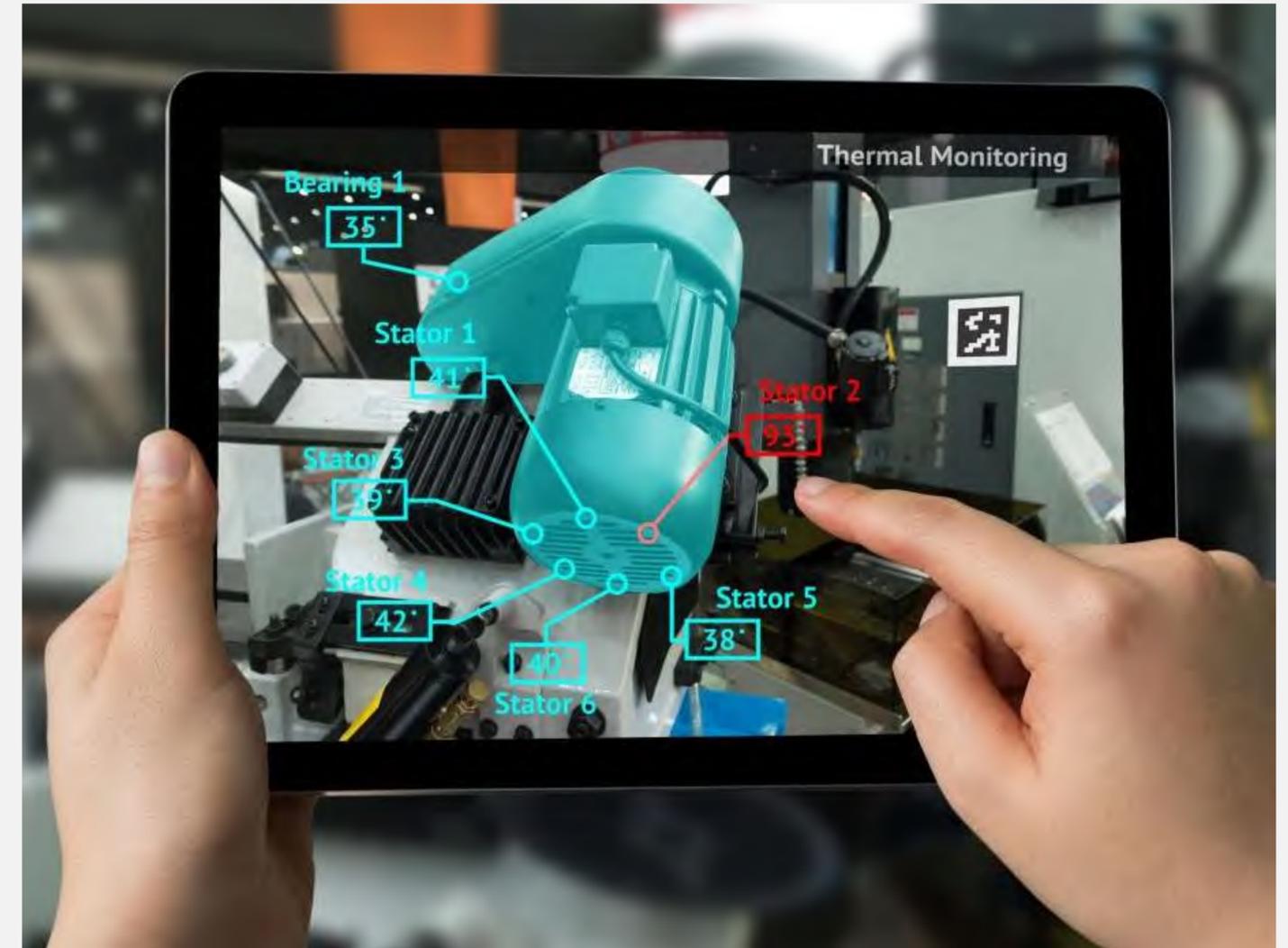
2. MAINTENANCE: On-Site Visual Guidance Augmented Reality App

- Displays the target profile superimposed onto the real crossing
- Colour-coded overlays. E.g.
  - Blue → grinding required
  - Yellow → welding required
- Anchors to the real geometry using scan alignment QRs

- ✓ Engineers see exactly **where** and **how much** to grind or weld
- ✓ Repeat scanning + AR in a loop for quality control
- ✓ Record work quality

2. MAINTENANCE:

1. Vertical wear/material loss → weld build-up required
2. Minor Material excess → grinding required
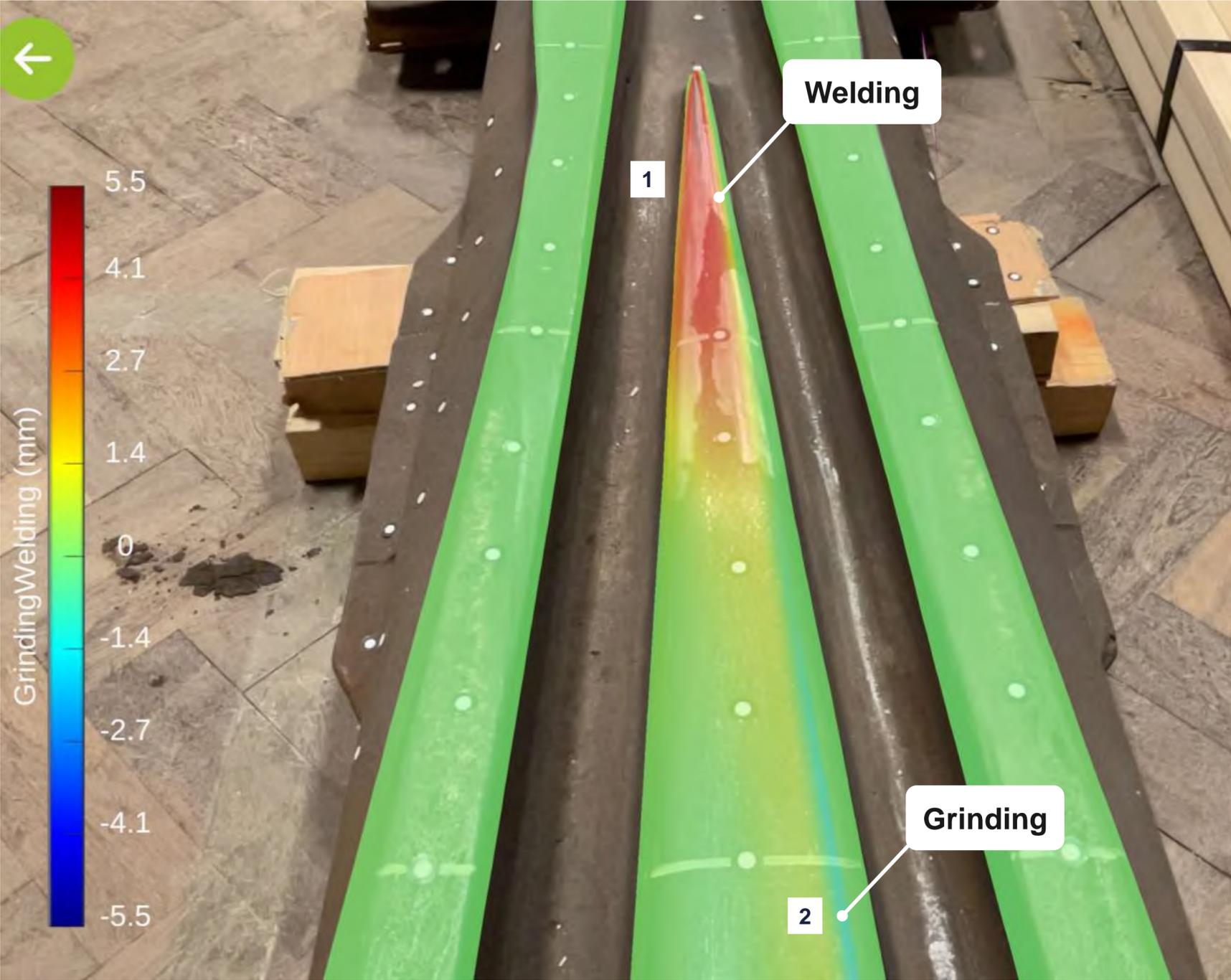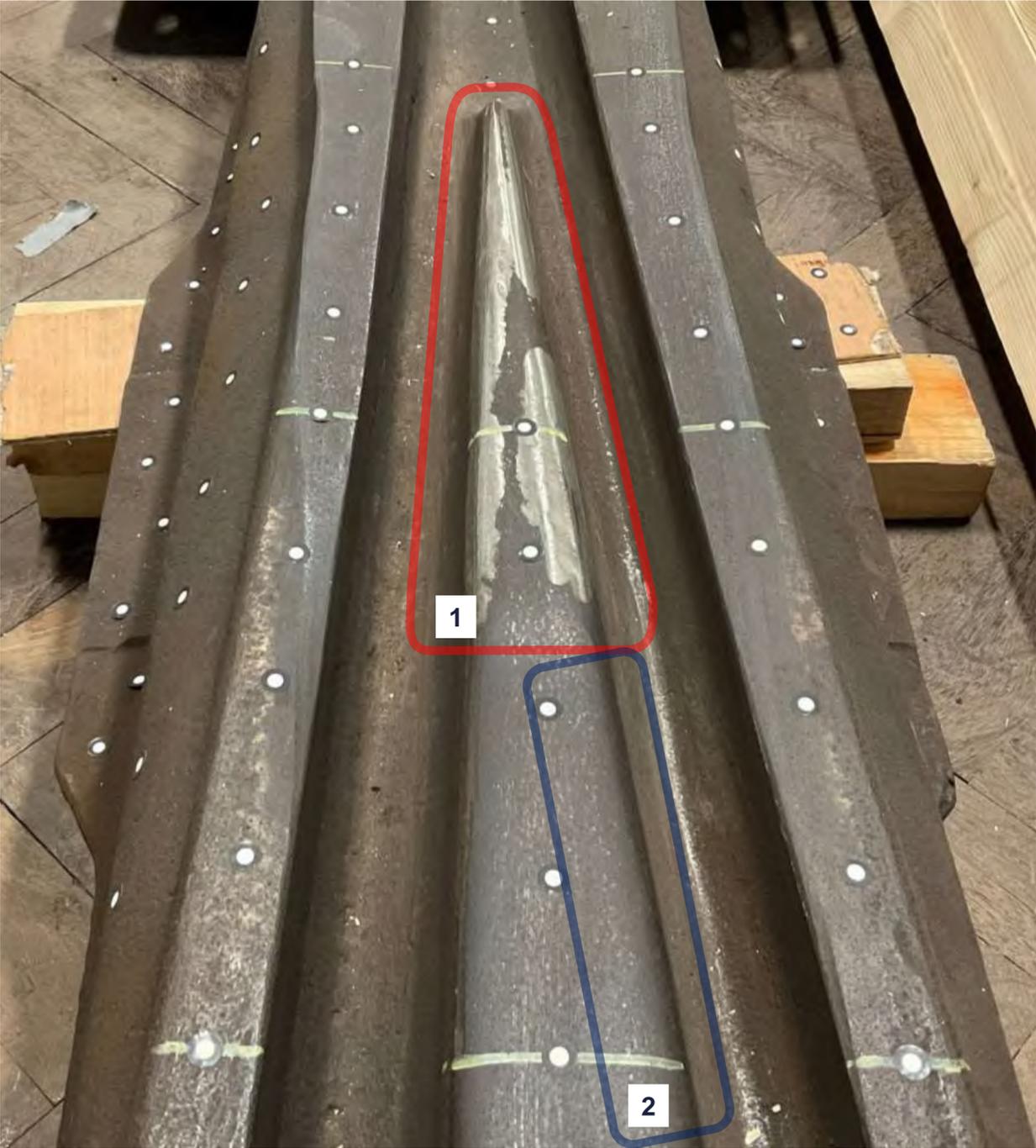
2. MAINTENANCE: AR Maintenance Modes
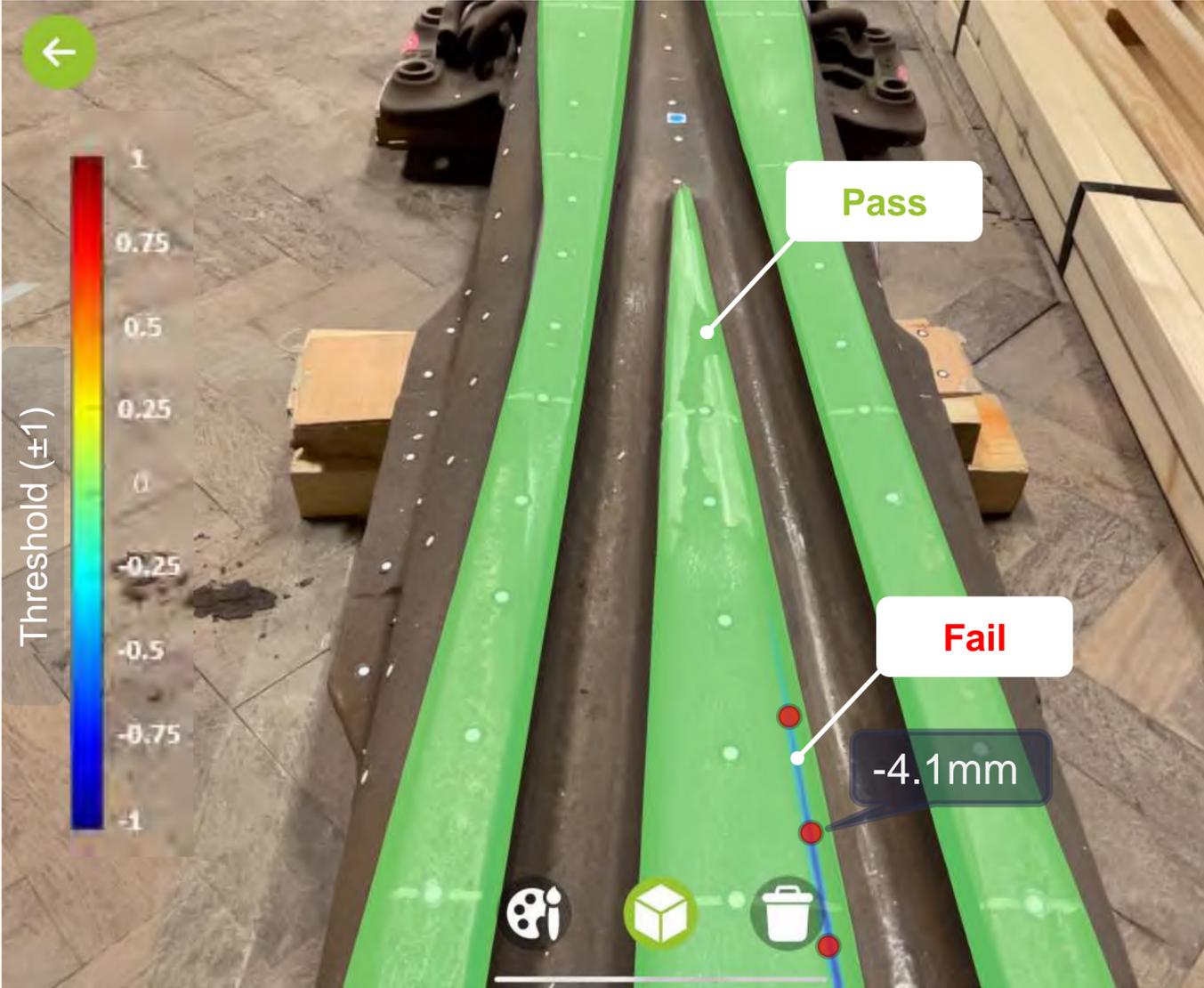
Mode	Purpose	Stage
Welding	Material addition	Maintenance/Quality Control
Grinding	Material removal	Maintenance/Quality Control
Combined	Mixed defects	Maintenance/Quality Control
Threshold/QC	Pass–fail verification	Quality control
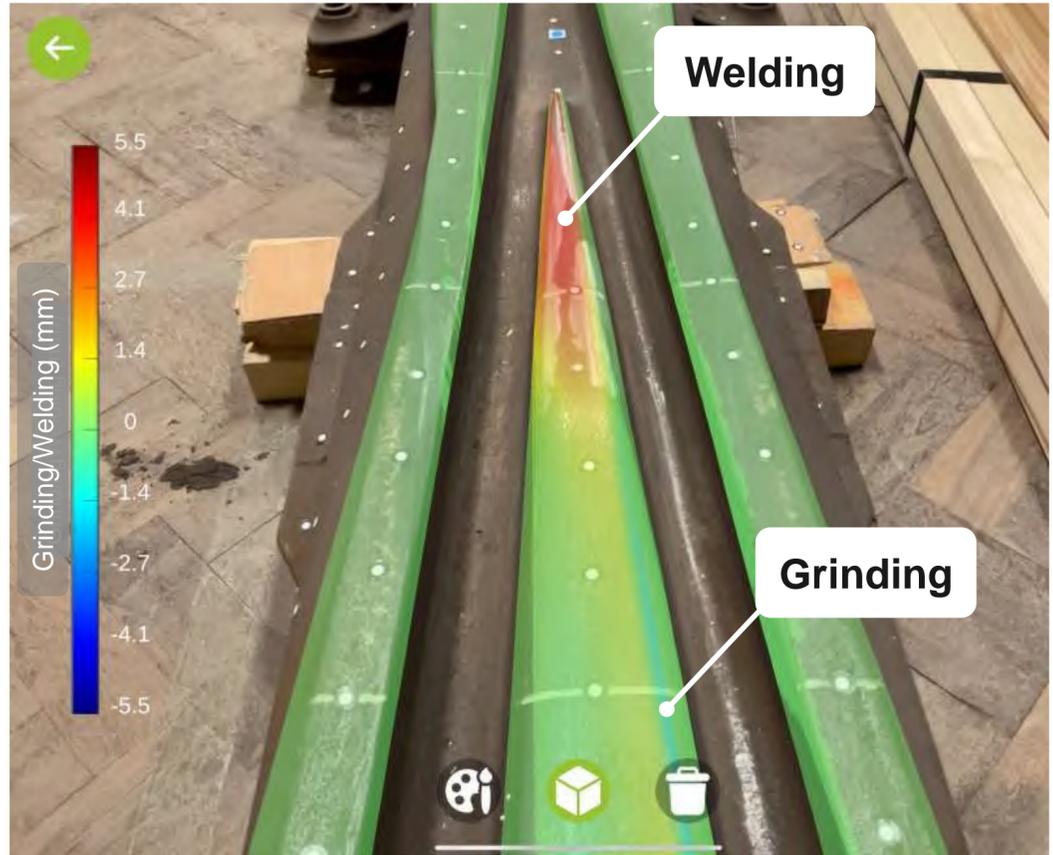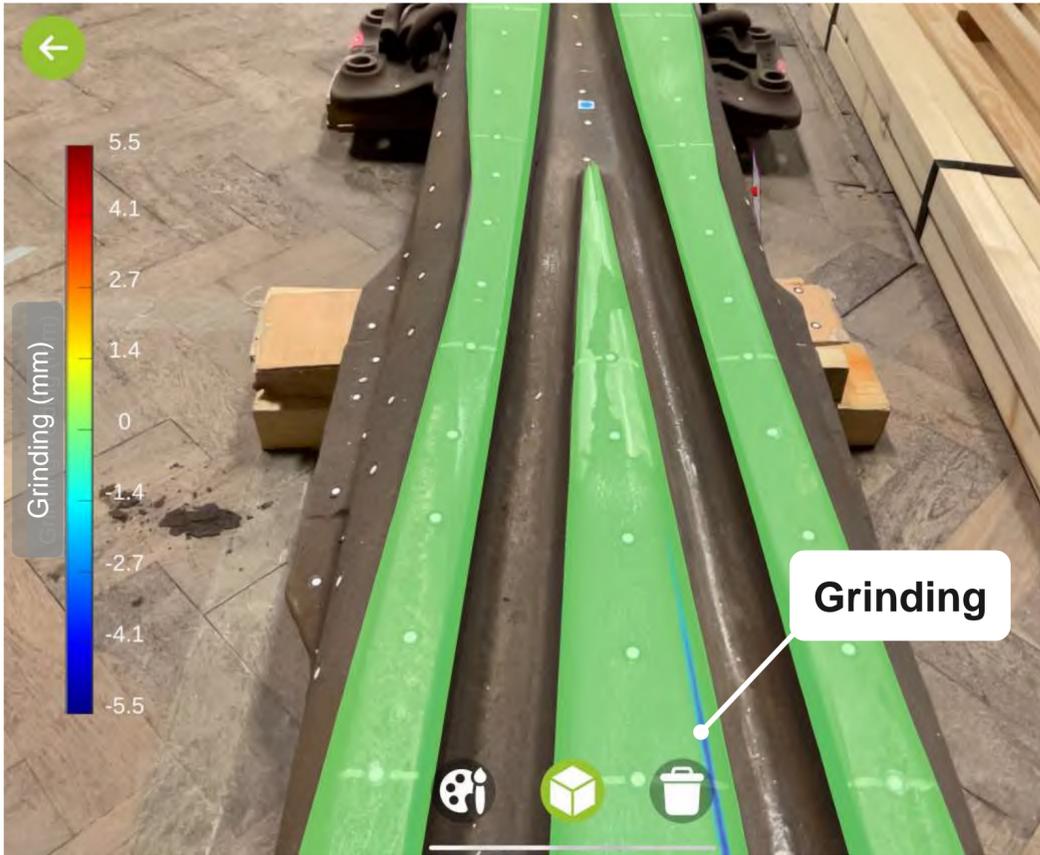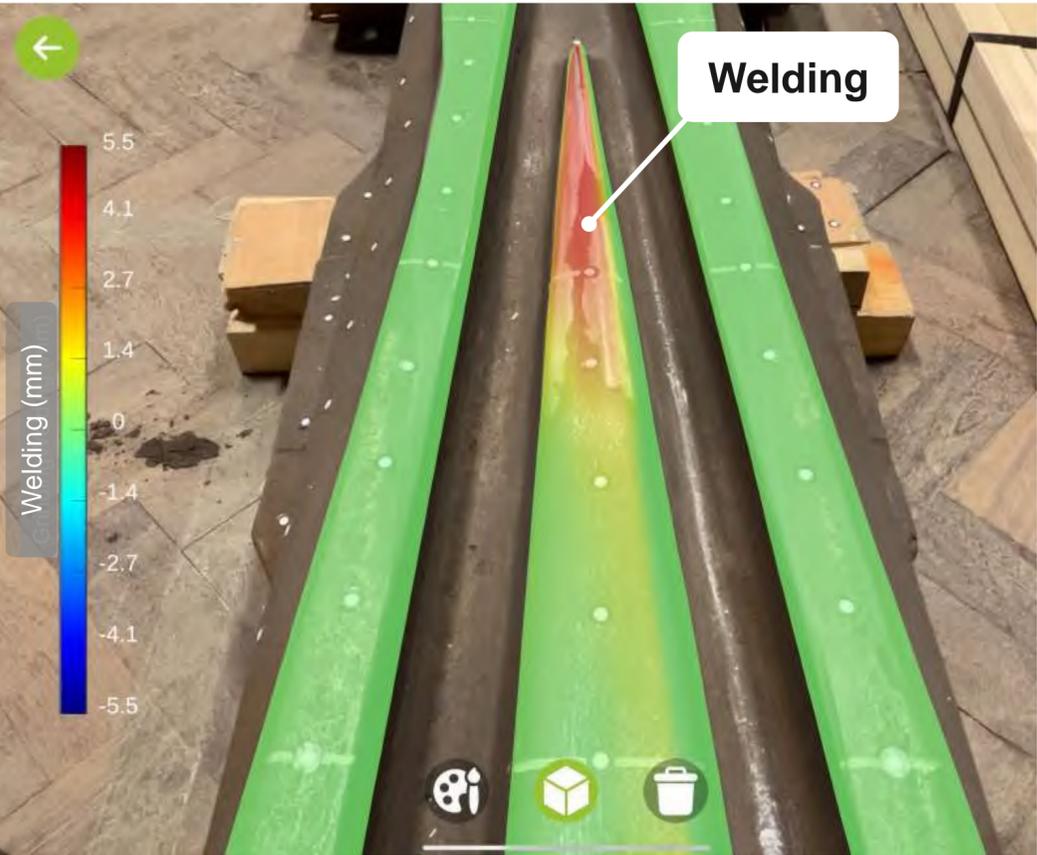
Mode-based visualisation reduces cognitive load for engineers

2. MAINTENANCE: AR Quality Control (QC) / Threshold Mode

| Mode	Purpose	Stage
Welding	Material addition	Maintenance/Quality Control
Grinding	Material removal	Maintenance/Quality Control
Combined	Mixed defects	Maintenance/Quality Control
Threshold/QC	Pass–fail verification	Quality control

✓ Areas requiring further cutting or material addition

✓ "OK" zones within tolerance

✓ Pass/fail visualisation directly on the crossing

✓ Visual Aids included

2. MAINTENANCE: Colour Mapping and Accessibility

- AR overlay visualised using colour-coded heat maps

- Multiple colour maps are supported

- Colour scales can be selected to suit user preference and viewing conditions

- Designed to support users with **different colour vision abilities**
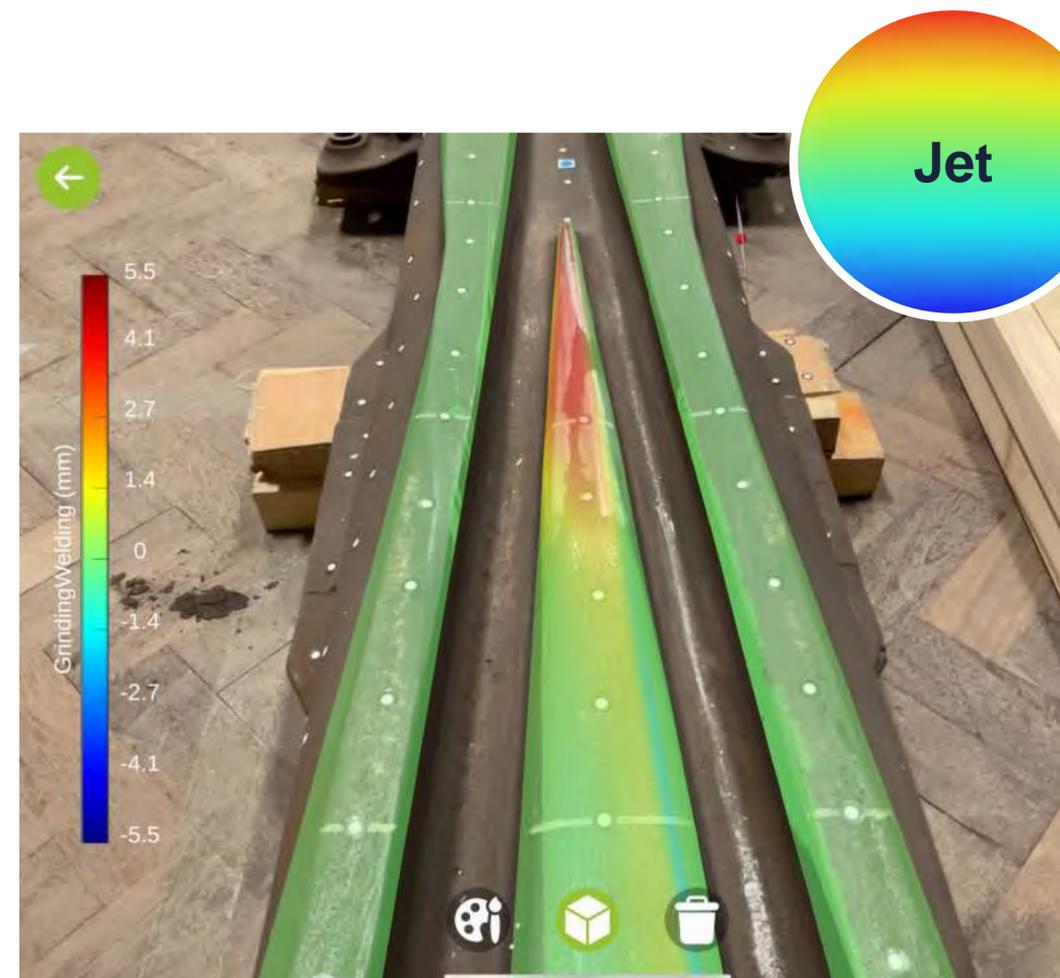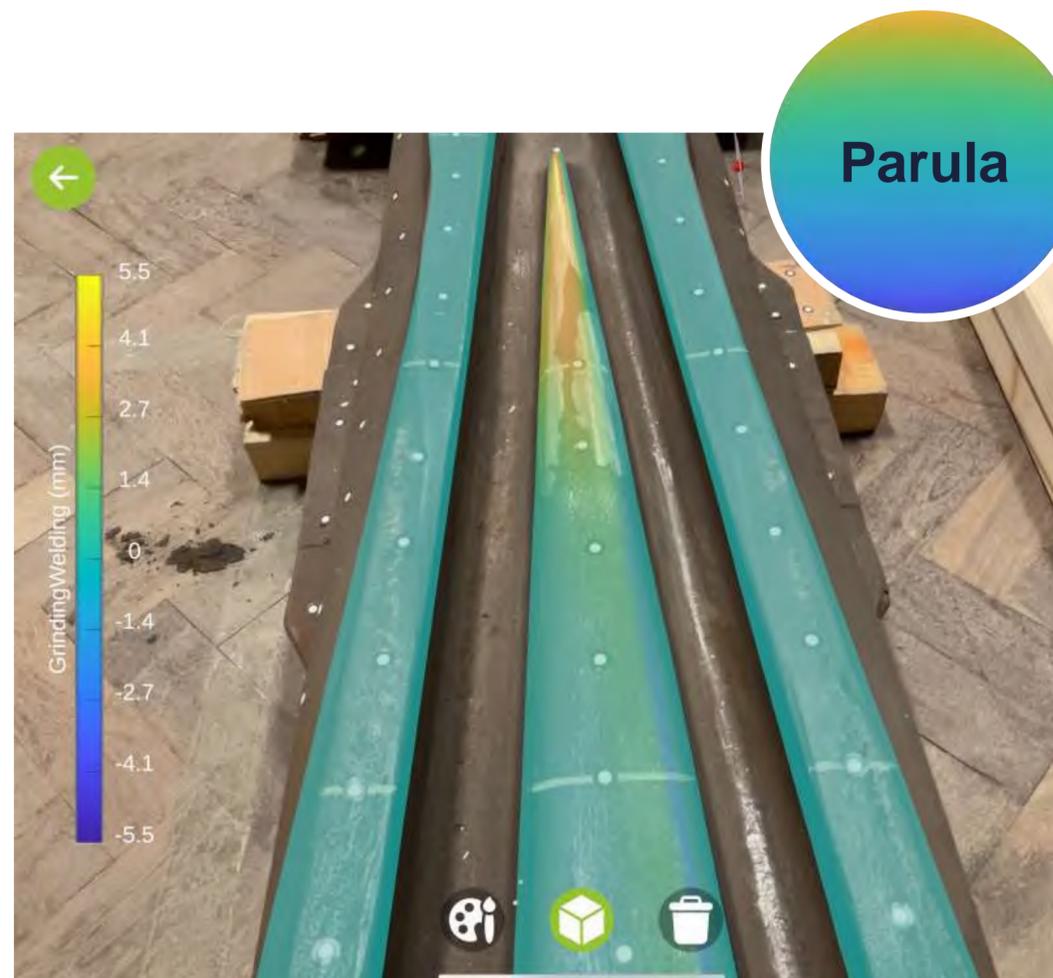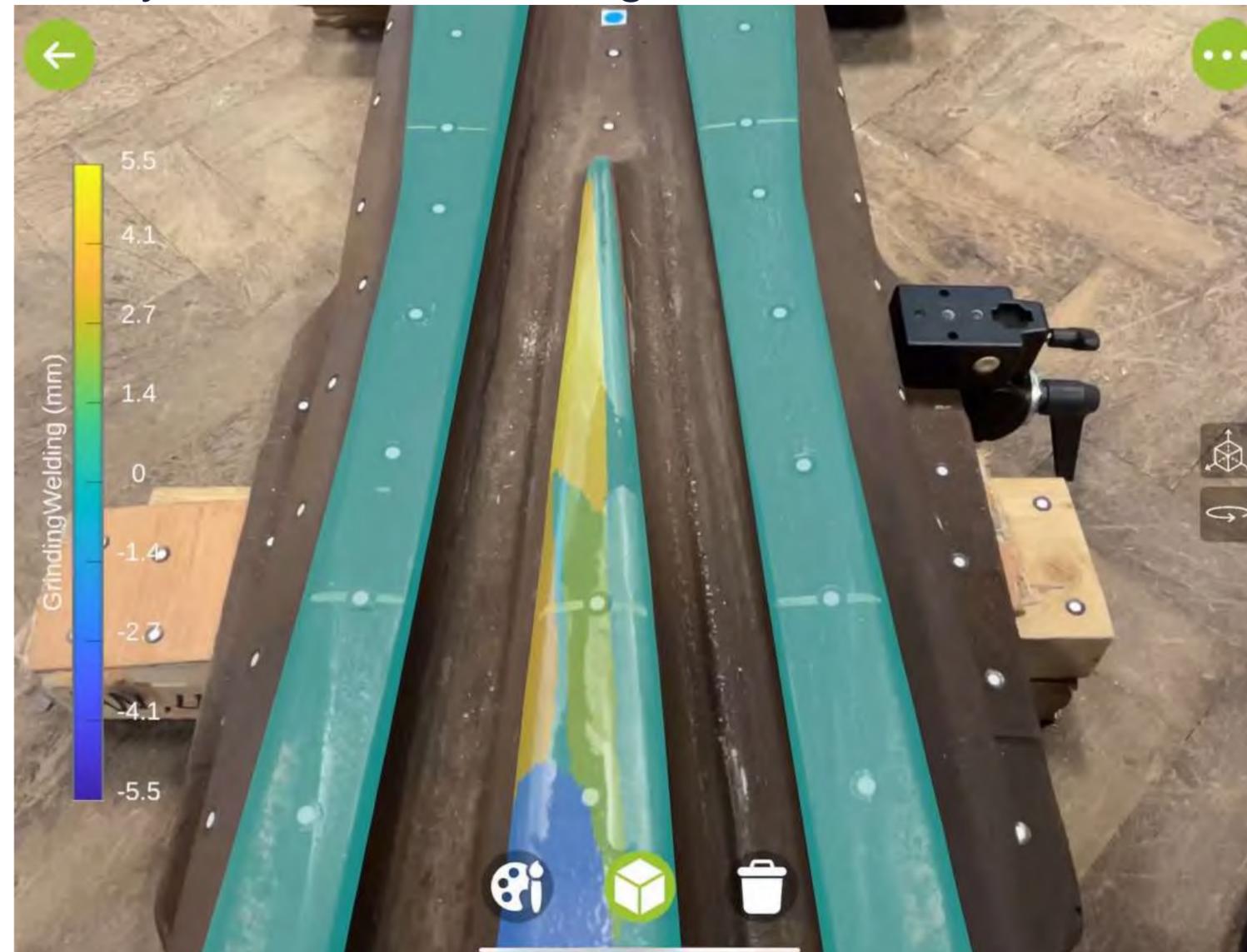
2. MAINTENANCE: Additional Colour Options
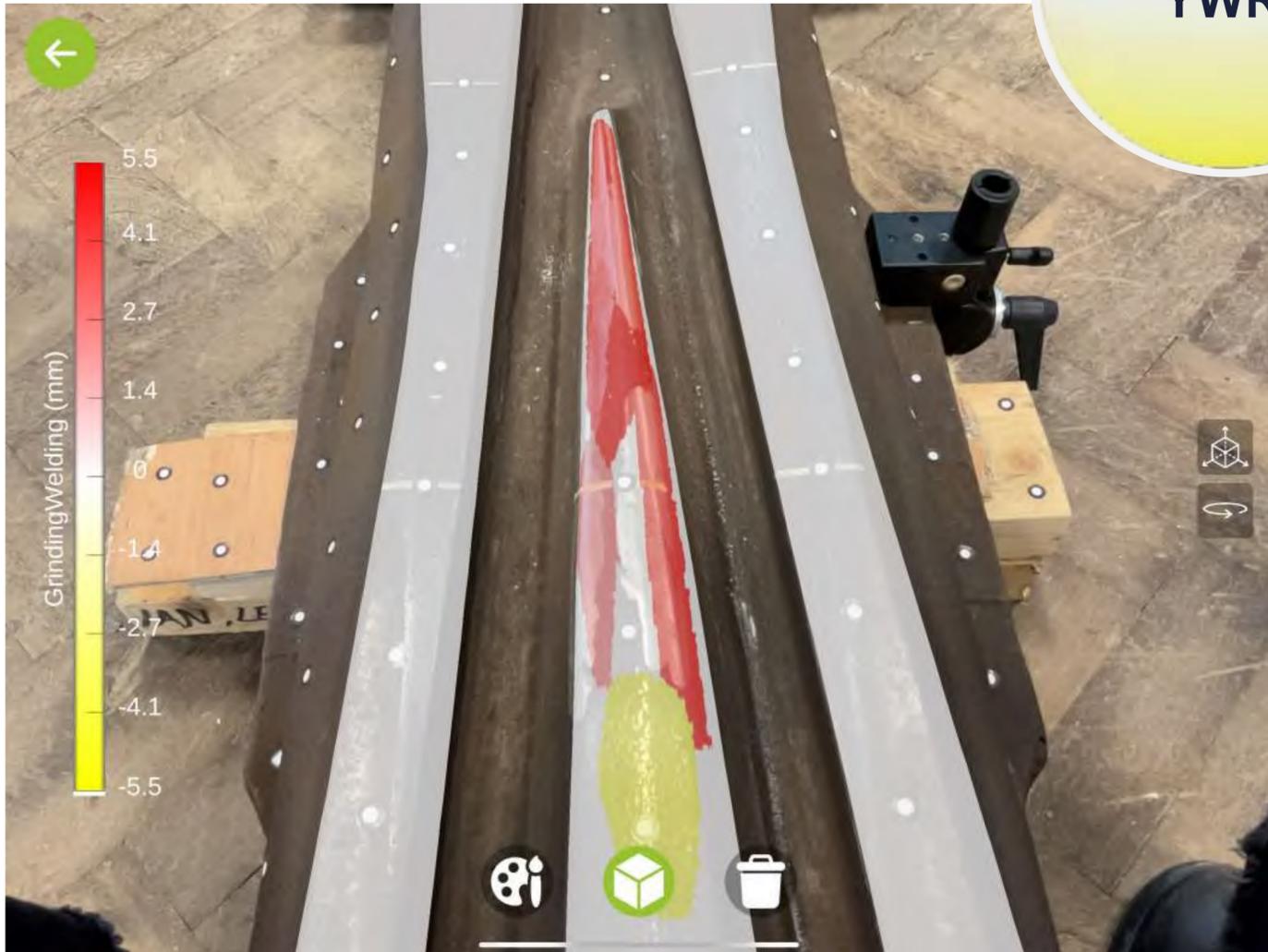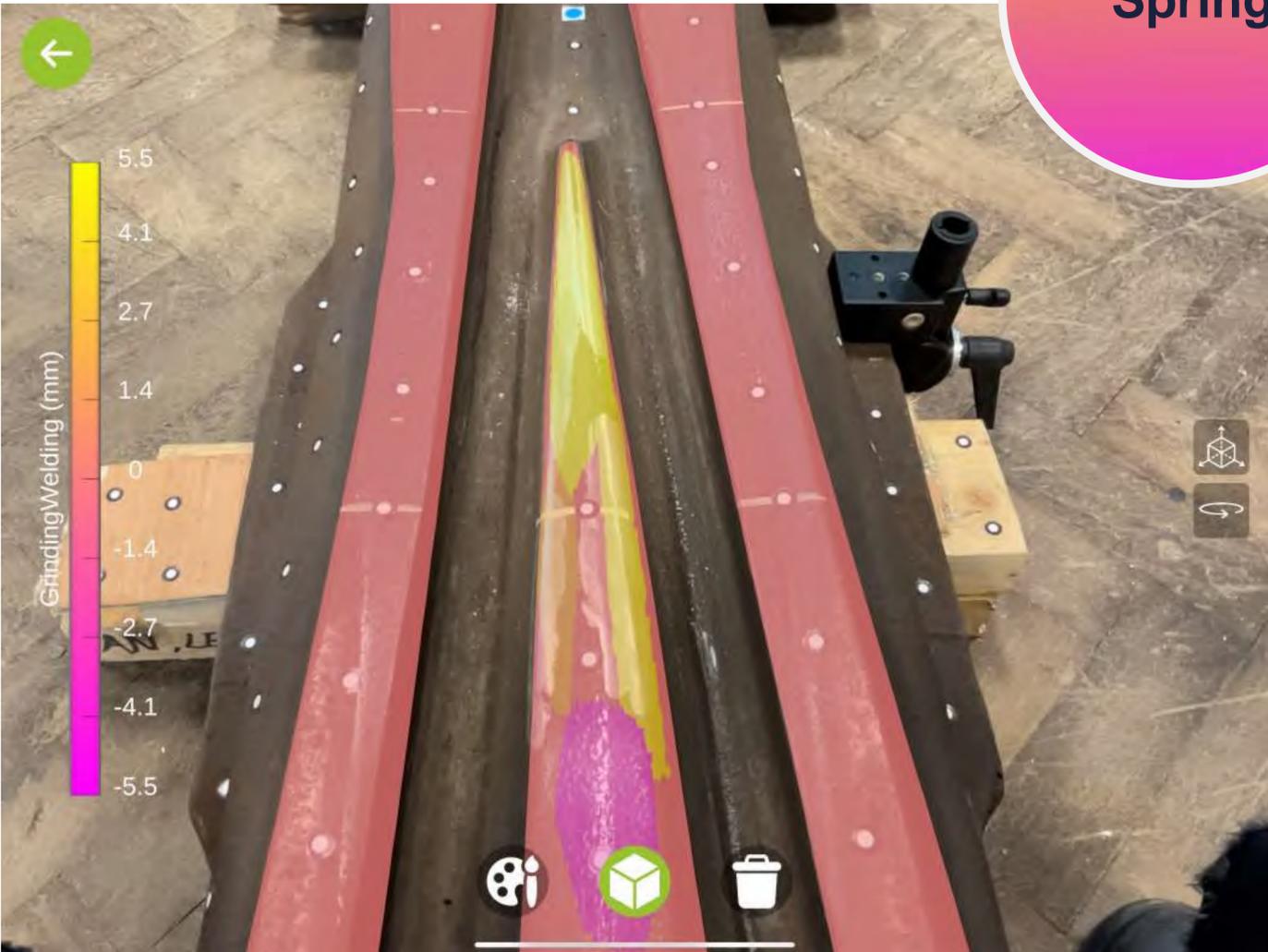
Note: Synthetic heatmap for demonstration only

2. MAINTENANCE: AR Visualisation Control & Transparency

Transparency control

- Transparency is adjusted using a **user-controlled slider bar**
- Allows real-time adaptation to lighting and surface conditions
- Supports safe and clear visibility of the real crossing

Note: Synthetic heatmap for demonstration only

2. MAINTENANCE:
AR Visualisation Control & Transparency Modes

1. **Uniform transparency**

   • Homogeneous transparency across the entire overlay

   • Used to maintain visibility of the real rail surface

   • Transparency level adjustable by the user

2. **Discrete (priority-based) transparency**

   • Higher colour intensity in areas requiring maintenance

   • Reduced visibility in non-critical regions

   • Transparency remains adjustable but applied selectively
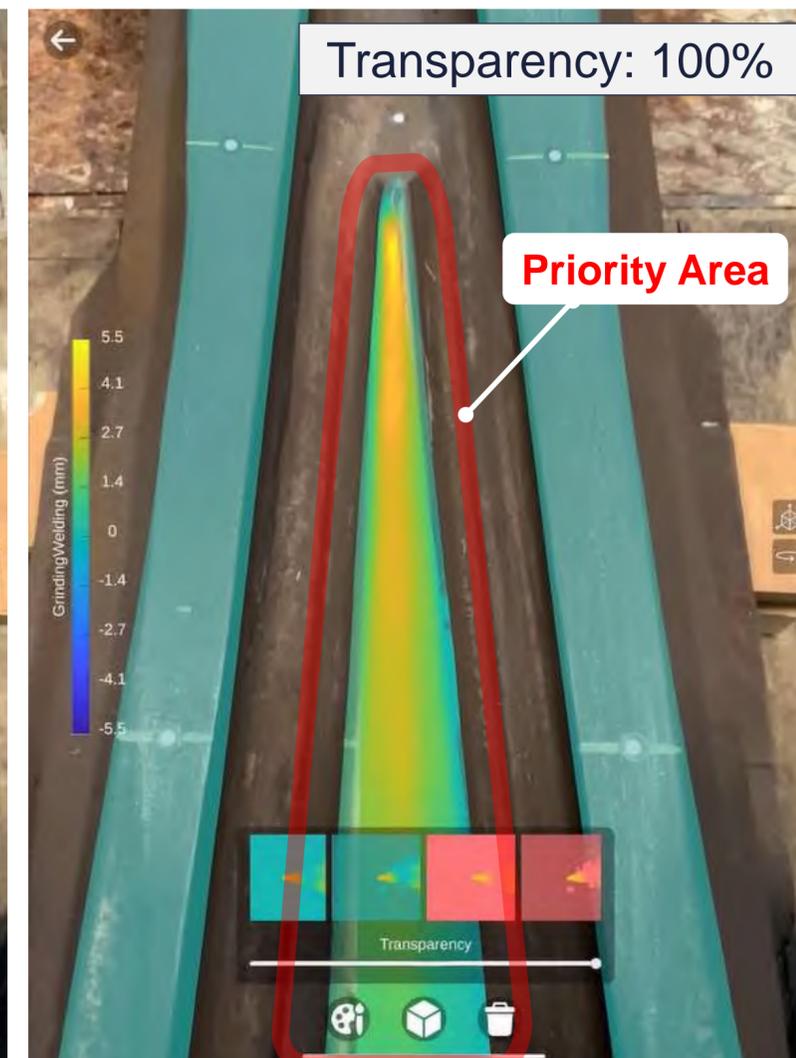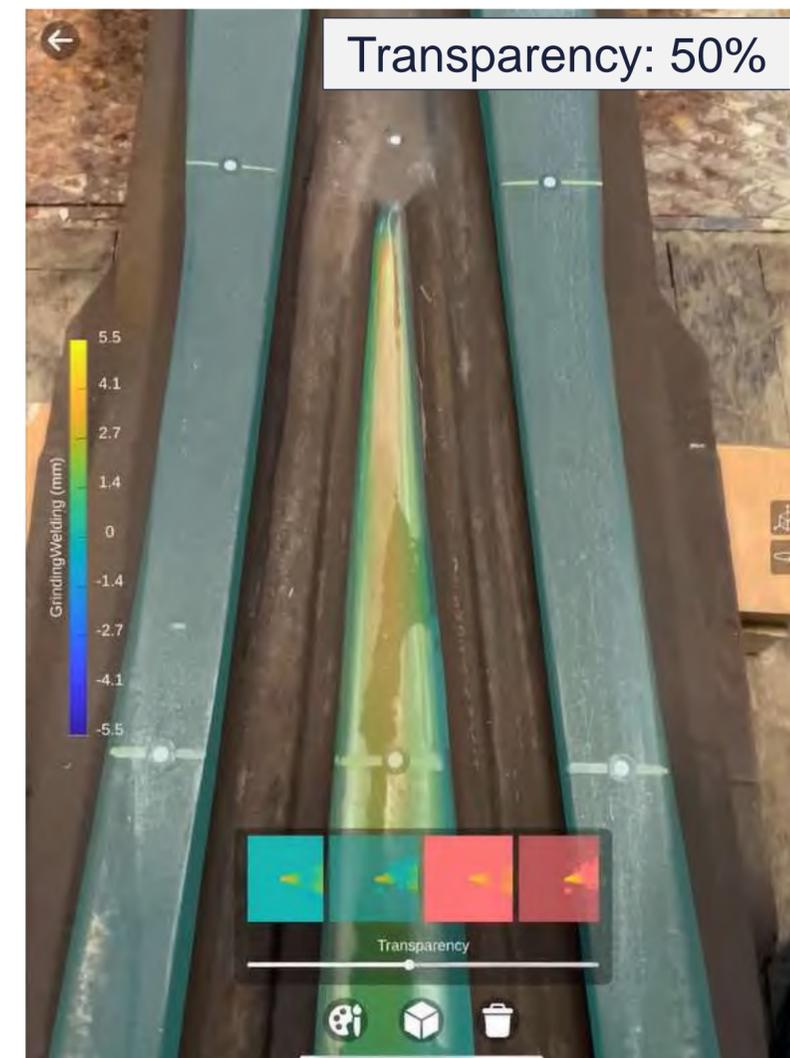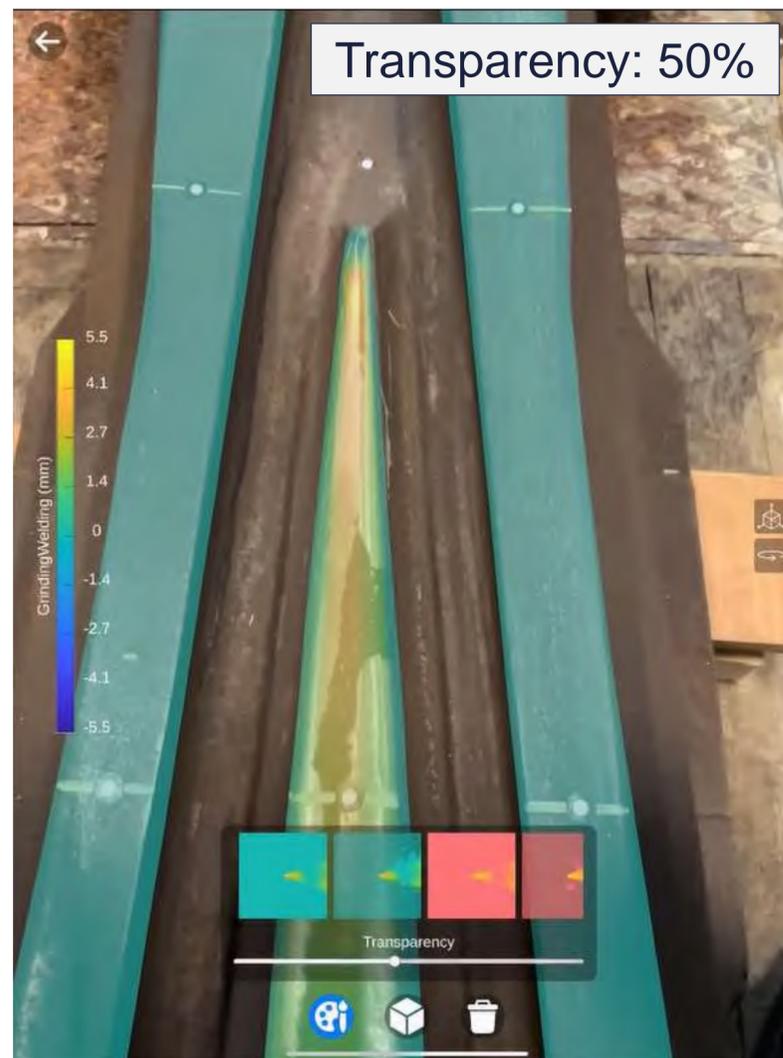
2. MAINTENANCE:
Field usability for railway maintenance

- Tablet-based AR system

- Hands-free operation using an adjustable mounting arm

- Fast QR-based setup on-site

- Designed for outdoor railway environments

- Clear visual filtering via AR modes

STAKEHOLDER ENGAGEMENT:
Feedback → Improvements → Impact

1. **QR codes**
   - Stay in place from inspection through maintenance, keeping AR accurately aligned.
   - Must be durable (weather-, heat-, and dust-resistant) to survive on-site grinding and welding.

2. **AR App**
   - Simplified overlays with clear grind vs weld regions (colour-blind-safe).
   - Expert-reviewed scenarios (grind/weld/combined/ thresholds).
   - On-device prompts highlight intervention areas and tolerance/pass–fail limits.

3. **Integrated Workflow**
   - ✓ Scan → AR → re-scan loop ensures accurate, consistent, and repeatable repairs.

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