



TRAVISIONS



LOCK-INSPECTOR:

'A Dedicated Subsurface Inspection Radar System for Increasing Inland Waterway Infrastructure Resilience'

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Idea Number: C2024-64
WATERBORNE | RA4



 **Newcastle University** / Centre for Mobility and Transport

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(0.0) Lock Wall Subsurface Inspection Radar

Presentation Outline:

❑ (1.0) Innovation Gaps in LWSSI

- (1.1) Dedicated SIR For LWSSI: LOCK-INSPECTOR*

(*) Work undertaken as part of the SIR development branch within EU-Horizon Europe Project 'Climate resilient and environmentally sustainable transport infrastructure, with a focus on inland waterways' (CRISTAL), grant no. 101069838.

❑ (2.0) Sub-Systems Evolution & Refinement

- (2.1) Capability Study: Toul Lock (Moselle River, France)
- (2.2) Rebar Characterisation

❑ (3.0) Future Developments?



This project has received funding from the European Union's Horizon Europe Research and Innovation Programme under grant agreement n° 101056931



(1.0) Innovation Gaps in Lock Wall Subsurface Inspection (LWSSI)

Improving EU Inland Waterway Resilience With Radar

- ❑ Locks allow large vessels to traverse otherwise impassable gradients... but are inherent network chokepoints.
- ❑ Resilience declines with structural fatigue → Void-washout begins behind lock walls...
 - **Danger!** | Defect growth undetected → Wall collapse → Major disruption.
 - **Challenge** | Europe's Inland Waterway Transport (IWT) bodies must achieve comprehensive LWSSI during scheduled maintenance drainage windows.
- ❑ **Key Innovation Gaps** | How can we...
 - Achieve maximal non-destructive LWSSI coverage & penetration? [G1]
 - Exploit automation to minimise data acquisition runtime? [G2]
 - Return more intuitive 3D visuals of void-washout defects? [G3]
- ❑ **Candidate LWSSI Technology** → Subsurface Inspection Radar (SIR) [1]
 - **Suitability** | Non-Destructive; Highly Penetrating; Compactable; Automatable; 3D Profiling Capability; etc.

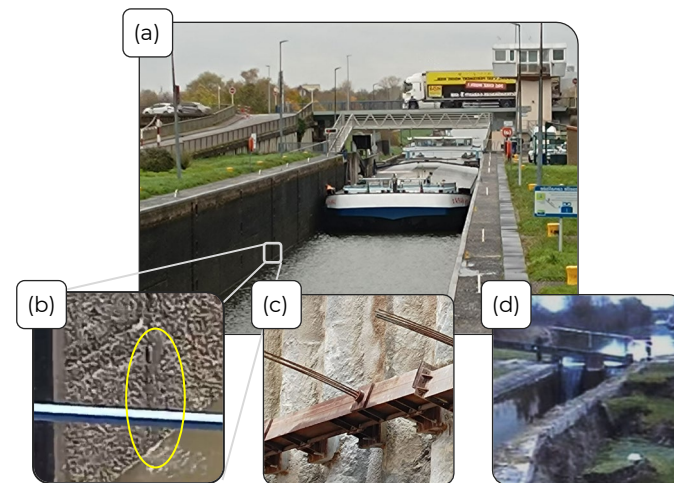


Fig. 1 – The sheer scale of European locks (a) makes them prone to void-washout defects (b). Defects grow over time, often concealed behind lock walls, which can degrade internal rebar (c) and undermine structural integrity.

An extreme example of catastrophic failure in a UK lock wall is shown in (d).
Image Credit [Ian Thompson, BBC 2013](#).



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[1] Seiffert, A., & Bödefeld, J. (2023). *Innovative methods for the inspection of hydraulic structures. In Life-Cycle of Structures and Infrastructure Systems* (pp. 548-554). CRC Press.



(1.1) Dedicated SIR for LWSSI: LOCK-INSPECTOR

Bridging The Innovation Gap

- ❑ EU-Horizons Research | Project: 'CRISTAL' [2] | SIR Branch.
- ❑ Technology Transfer: Euromobilita SRO (Czech) and SME Feasibility Study Phase 1 Project: Novel SIR to Inspect Tunnels and Tunnels Linings for improved maintenance. Tunnel (T) Vision; (grant no. 835567) (2019).
- ❑ **LOCK-INSPECTOR** is the first dedicated SIR system for LWSSI:

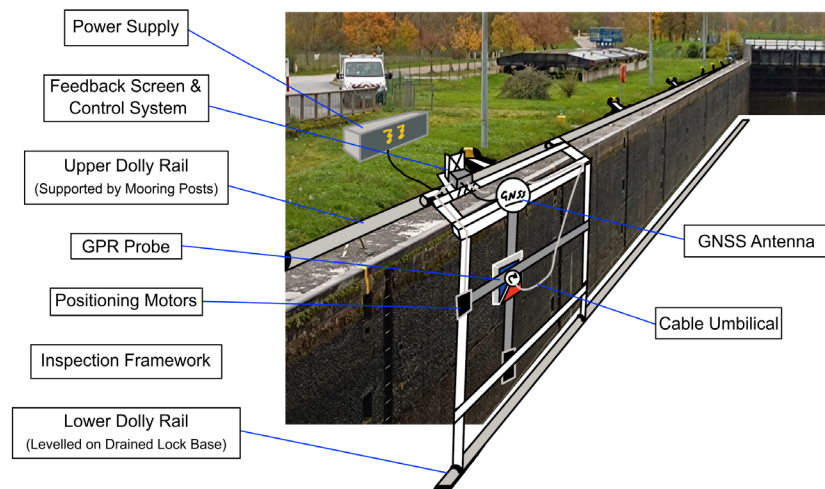
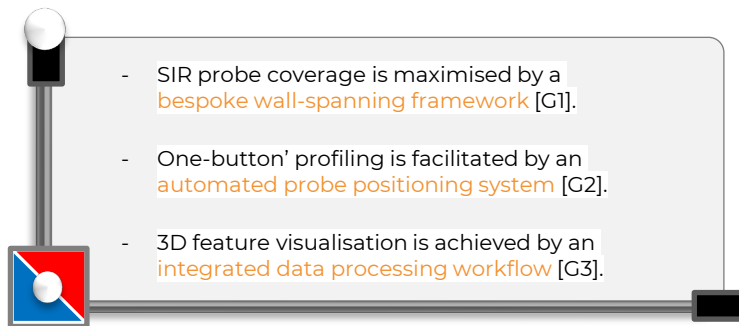


Fig. 2 – Concept diagram of a wall-mounted setup for LOCK-INSPECTOR. The system resembles a ladder on a library bookcase, tracking along a robust dolly track to profile the full lock wall.

When activated, positioning motors track the probe across the wall in a 2D grid 'Paneo' scanning pattern to gather SIR profiles of lock wall substructure. Motor encoders and a GNSS antenna facilitate data geolocation.

(2.0) Sub-Systems Evolution & Refinement

Overview: Electrical, Mechanical & Data Processing Elements

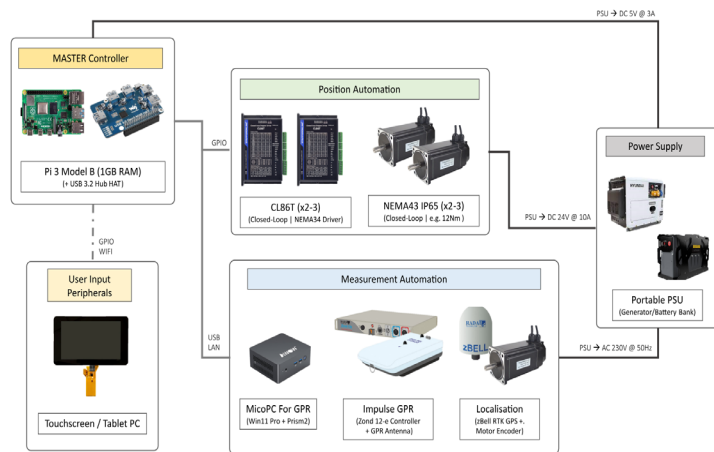


Fig. 3 – Subsystems for LOCK-INSPECTOR include: (i) Power Supply; (ii) Position Automation and (iii) Measurement Automation. The latter can be further subdivided into SIR (provisionally based on Impulse GPR hardware) and geolocation components.

Peripherals facilitate 'one-button' execution, setting adjustments and system debugging. A raspberry pi master controller regulates communication between each subsystem.

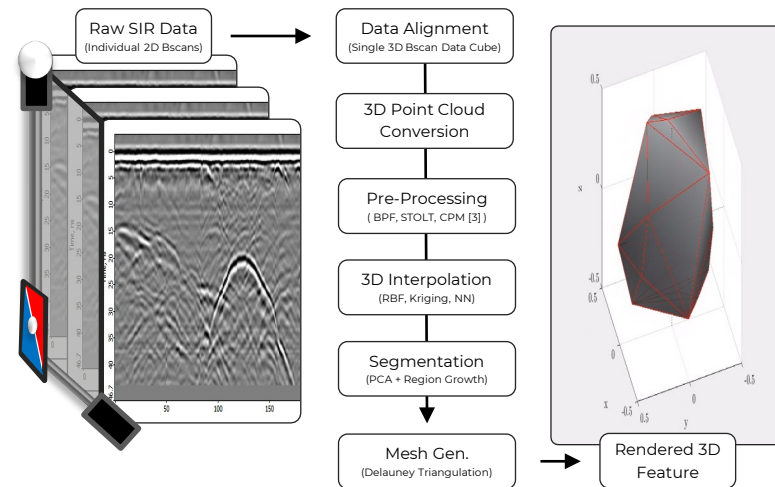


Fig. 4 – In development data processing workflow for 3D visualisation of features in SIR datasets.



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[3] McDonald, T., et al. (2021). *Spatial resolution enhancement of rotational-radar subsurface datasets using combined processing method*. In Journal of Physics: Conference Series (Vol. 2050, No. 1, p. 012001). IOP Publishing.

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SIR Performance Investigation on Reinforced Concrete Walls

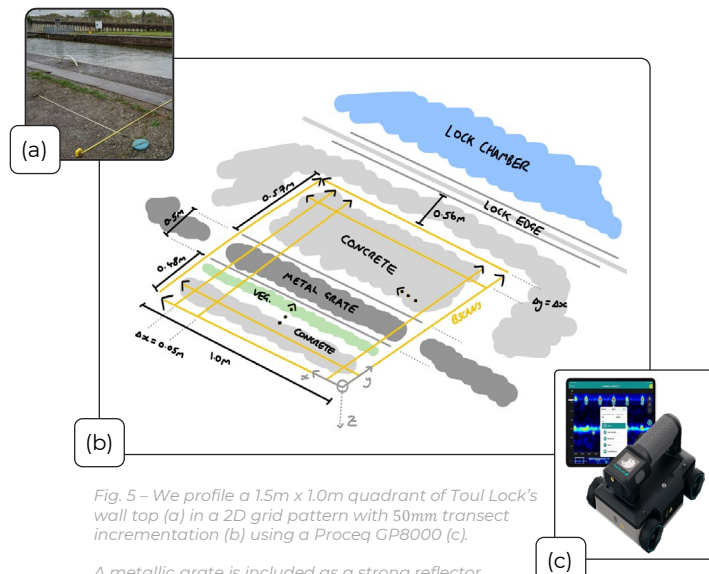


Fig. 5 – We profile a 1.5m x 1.0m quadrant of Toul Lock's wall top (a) in a 2D grid pattern with 50mm transect incrementation (b) using a Proceq GP8000 (c).

A metallic grate is included as a strong reflector, providing a reference target for orienting the dataset.

- ❑ Rebar **resonance** can limit SIR penetration → Approximation required for a 'typical' lock wall.
- ❑ **Challenge 1** - IWT bodies lack formal records of lock rebar geometry.
 - We **profile an in-service lock directly** using a Proceq GP8000 SIR rebar profiler.
 - Toul Lock | Constructed: 1969 | Reinforced Concrete | Chamber: $\approx 170 \times 15 \times 10 \text{m}$
- ❑ **Challenge 2** – The vertical lock wall is inaccessible whilst in-service.
 - We can scan the lock top and **infer geometry from above**.
 - This reasonably assumes rebar resembles a cubic lattice throughout.
- ❑ **Primary Objective:**
 - To determine **rebar diameter, pitch and first-layer recess** behind the vertical contact surface of a 'typical' European lock wall by direct measurement.
- ❑ **Secondary Objective:**
 - Establish how the rebar in the **authentic lock** compares to rebar in our research facility's **test-wall section** in Chesterfield (UK).
 - Is our wall-section a **reasonable analogue** for future lock wall experimentation?

(2.2) Rebar Characterisation:

SIR Performance Analysis

- ❑ **Test Wall** | Diameter $\approx 30\text{mm}$ | Pitch $\approx 100\text{mm}$ | Recess $\approx 20\text{mm}$
- ❑ **Toul Lock** | Diameter $\approx 10\text{mm}$ | Pitch $\approx 150\text{mm}$ | Recess $\approx 30\text{mm}$
- ❑ **Upshot** | Preliminary analysis $\rightarrow$ Test Wall is a viable Lock Wall analogue.

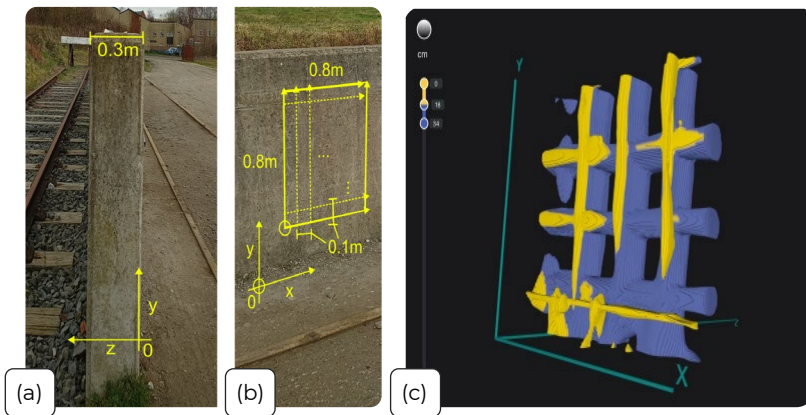


Fig. 6 – Test Wall quadrant (a, b) in Chesterfield (UK) is profiled by a Proceq GP8000. The returned 3D profile (c) we suspect is less distorted than Fig. 8b in part due to the homogeneity of Test Wall concrete, alongside the apparently thicker diameter rebar present.

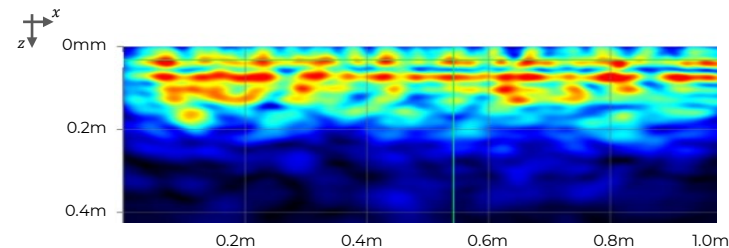


Fig. 7 – Rebar diameter & pitch is clearest viewed in an individual SIR transect aligned parallel to the lock edge. Red indicates metallic targets at $z \approx 27\text{mm}$, 73mm & 120mm .

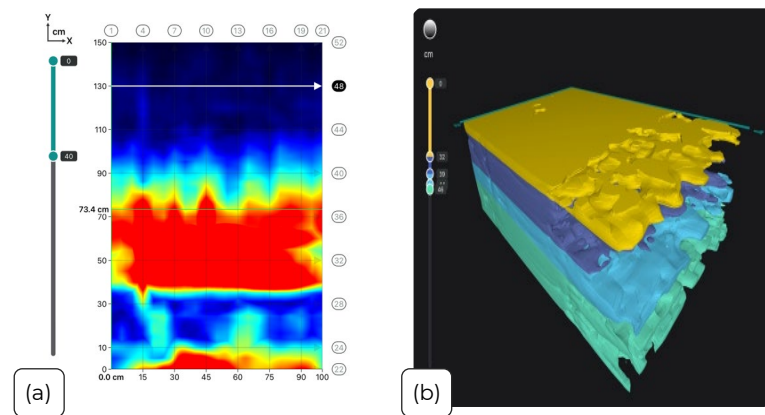


Fig. 8 – Lock top SIR profiles of Toul scan quadrant. Note in 2D (a) the prevalence of the metallic grate $0.35\text{m} < y < 0.9\text{m}$ is consistent with geometry expectations. The Proceq in-app 3D reconstructor (b) appears to blend rebar and resonance artifacts, increasing apparent diameter up to 30mm , albeit still comparable to Test Wall observations.



(3.0) Future Developments?

Scope For Resilient IWT Infrastructure

- ❑ **Short Term** | *Finalise data processing workflow for hardware design freeze:*
 - **Void-Washout Characterisation:** Assess SIR performance with (i) no rebar; (ii) 'typical' lock rebar; (iii) rebar suppression algorithms [4].
 - **Optimisation & System-Integration** of 3D visualisation algorithms.
 - **Full Workflow Validation** using (i) simulation & (ii) test-wall section (UK).
- ❑ **Long Term** | *Interfacing with new digital platforms for resilient infrastructure:*
 - **Target:** Develop SIR data exchange process to feed next-generation Digital Twin Locks (DTL), in development for EU-Project CRISTAL.
 - **Interest:** Subsurface condition data (i.e. SIR) hybridisation with surface condition data (e.g. LiDAR) → **Virtual Survey Environments**.
 - **Ambition:** Overlay SIR and DTL visualisations over working locks → An Onsite Augmented Reality LWSSI Survey Dashboard for surveyors.

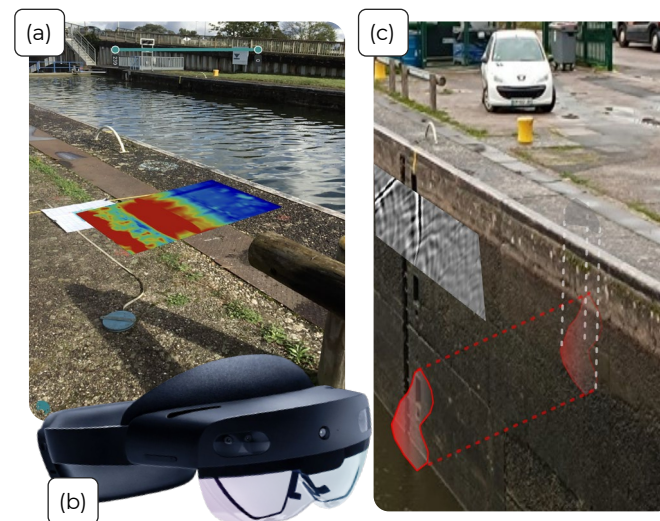


Fig. 9 – With continued refinement and optimisation, LOCK-INSPECTOR's datasets will be integrated into Project CRISTAL's multisensory Digital Twin Lock.

Interfacing with state of the art Augmented Reality systems like Proceq AR Viewer (a) or HoloLens 2 (b) presents a feasible basis for an interactive, **mixed reality survey platform for resilient IWT infrastructure management**.

In future planning for targeted maintenance, surveyors may one day use such a platform to directly see through walls (c).



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[4] Wang, Z., et al. (2023). *Unsupervised learning method for rebar signal suppression and defect signal reconstruction and detection in ground penetrating radar images*. Measurement, 211, 112652.



(4.0) Lock Wall Subsurface Inspection Radar

Presentation Summary:

- ❑ LWSSI **informs targeted maintenance** of high capacity locks on European Inland Waterways.
- ❑ Technology **innovation gaps** identified for **comprehensive & automated** profiling to **localise lock wall void-washouts** & **inspect rebar geometry**.
- ❑ **LOCK-INSPECTOR: Dedicated SIR System** under EU-Project CRISTAL development for effective LWSSI.
- ❑ Electromechanical **subsystem** design facilitates **automated positioning and measurement**.
- ❑ **Data processing workflow** to reconstruct **accessible 3D visualisations** of lock wall substructure.
- ❑ Preliminary **capability study at Toul Lock** characterises **rebar geometry** and **influence on SIR** profiles.
- ❑ LOCK-INSPECTOR development on target to feed upcoming **Digital Twin Locks**, with scope to **increase European IWT network resilience** by 2025.



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Questions Welcomed...



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