Robotics for the inspection of underground pipes

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www.pipebots.ac.uk

Presentation structure

- Problem
- Challenges
- State-of-the-art pipe inspection technologies
- Pipebots Grant and its vision
- Pipebots Grant structure and Research Themes
- What has been achieved so far and lessons learnt
- Beyond Pipebots

Background

- >343,000km of clean water pipes in the UK.
- ~1161 million m^3/year of drinking water are lost in the UK
- > 600,000km of sewer pipes
- 1.5 million roadworks/year related to buried infrastructure in the UK
- Associated traffic disruption causes a loss to the economy of ~£5.5 billion year
- Pipeline leak / blockage management is reactive
- Only ~50% of buried assets are recorded with accurate position on statutory records

Background

Issue	Impact
~ £7 billion per annum: cost of utility streetworks to the UK economy	**… 78%** of which is **indirect costs including social and environmental impacts**
Road occupation due to utility streetworks causing traffic delays	Accounted for equivalent of ~ **6.16 million days** of work in the UK in 2014-2015
An estimated 1.37 million streetworks undertaken by utility companies alone	This equates to **2.4 million road openings** in the UK in 2014-2015

Adapted from Bob Gallian, former CEO NJUG (Streetworks UK)

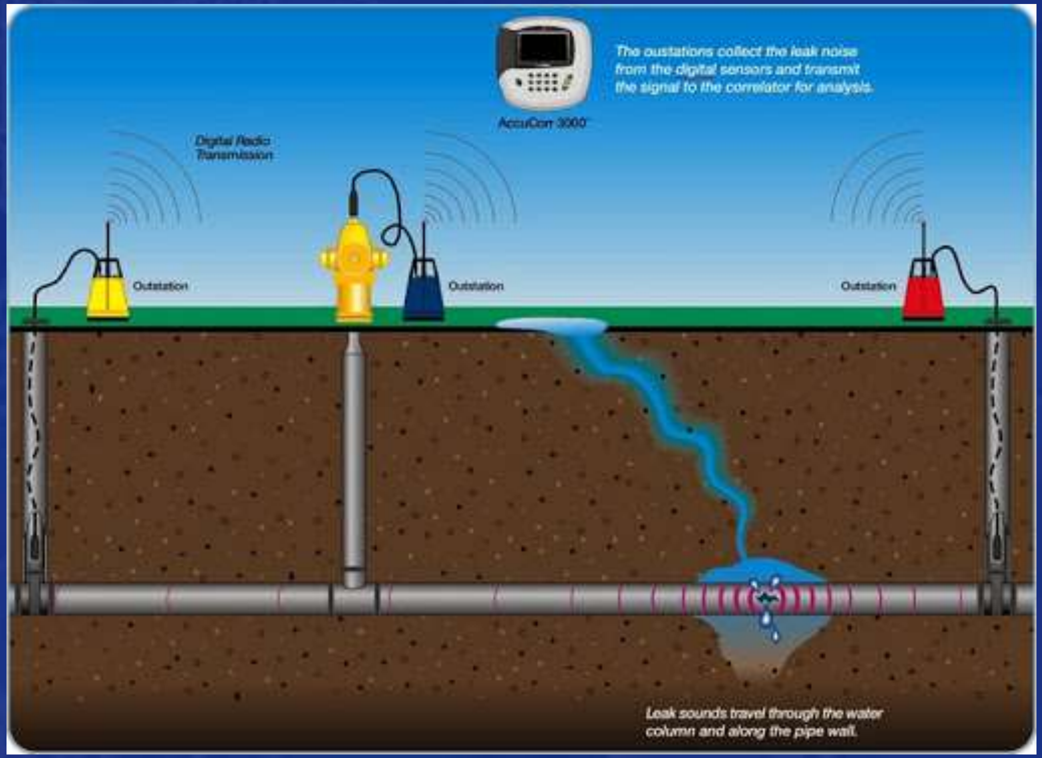
- In 2014-2015, utility streetworks in England and Wales have incurred costs of more than £1.5 billion
- The projected cumulative total cost of utility streetworks in the UK from 2013 to 2030 is £319 billion
- We dig some 4 million holes in UK's roads each year trying to locate services…

This incurs unnecessary costs, causes disruption, safety issues …

Current state-of-the-art: human-controlled CCTV

Current state-of-the-art: guided waves or correlators

www.guided-ultrasonics.com

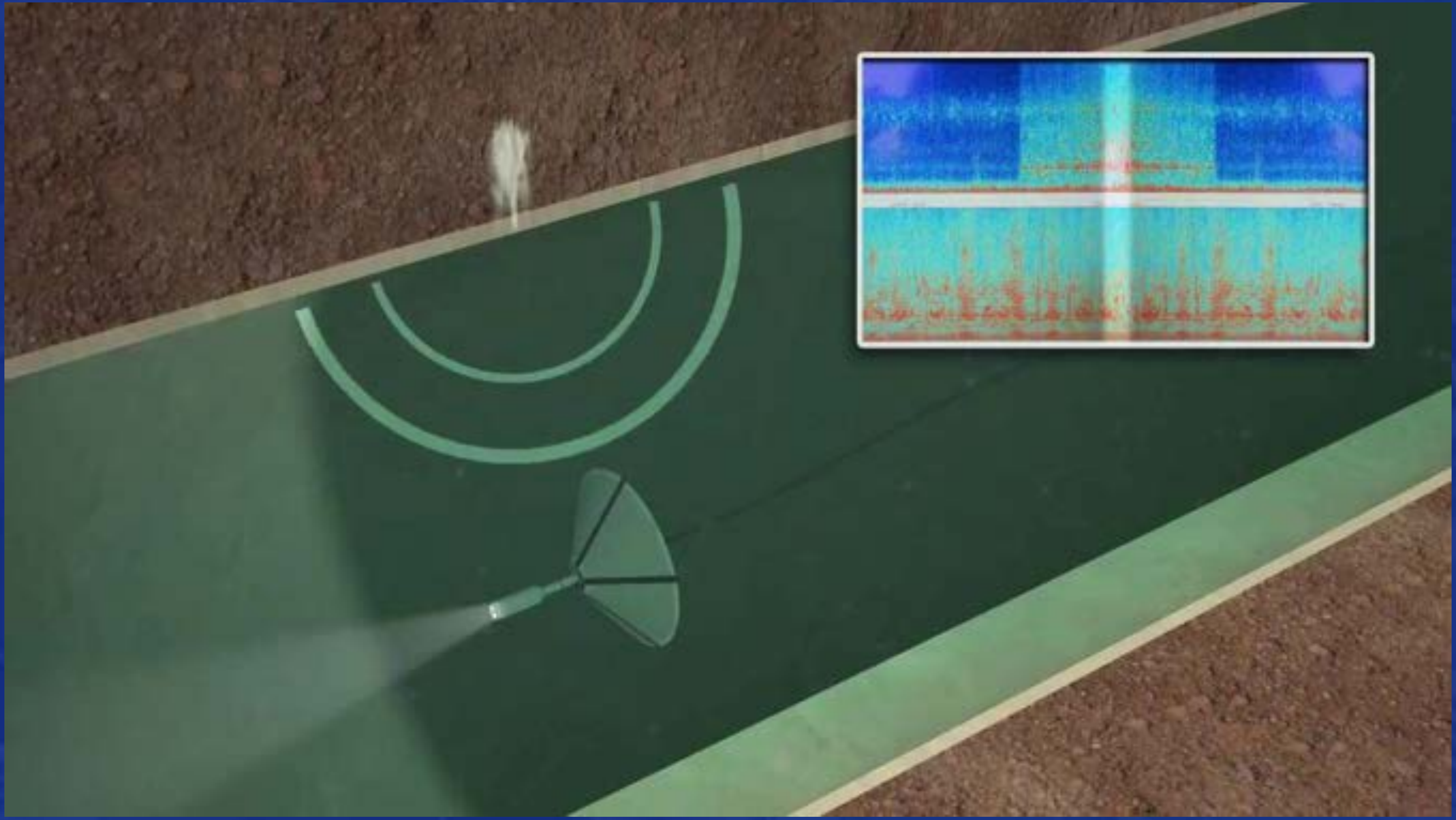


http://www.fscleakdetection.com/leak-detection

Current state-of-the-art: Smart Ball

www.puretechltd.com

Current state-of-the-art: Sahara



https://www.wrcplc.co.uk/leak-detection-location

Summary of existing inspection methods:

- they all require human intervention
- they all cause disruption at the surface
- they all are difficult to operate in complex networks

What is Pipebots?

Aim:

Development of micro-robots designed to work in underground pipe networks

- 5 year, EPSRC Programme grant
- March 2019 – February 2024
- 4 Academic institutions
- Over 40 researchers
- Over 30 industry partners
- Links to other groups overseas

www.pipebots.ac.uk

In partnership with:

The University Of Sheffield. University of Birmingham. University of Bristol. University of Leeds

Supported by:

EPSRC Engineering and Physical Sciences Research Council. TWENTY65. UKCRIC. Self Repairing Cities

What is our vision?

In partnership with: www.pipebots.ac.uk Supported by:

The University Of Sheffield. UNIVERSITY OF BIRMINGHAM University of BRISTOL UNIVERSITY OF LEEDS EPSRC Engineering and Physical Sciences Research Council TWENTY65 UKCRIC SELF REPAIRING CITIES

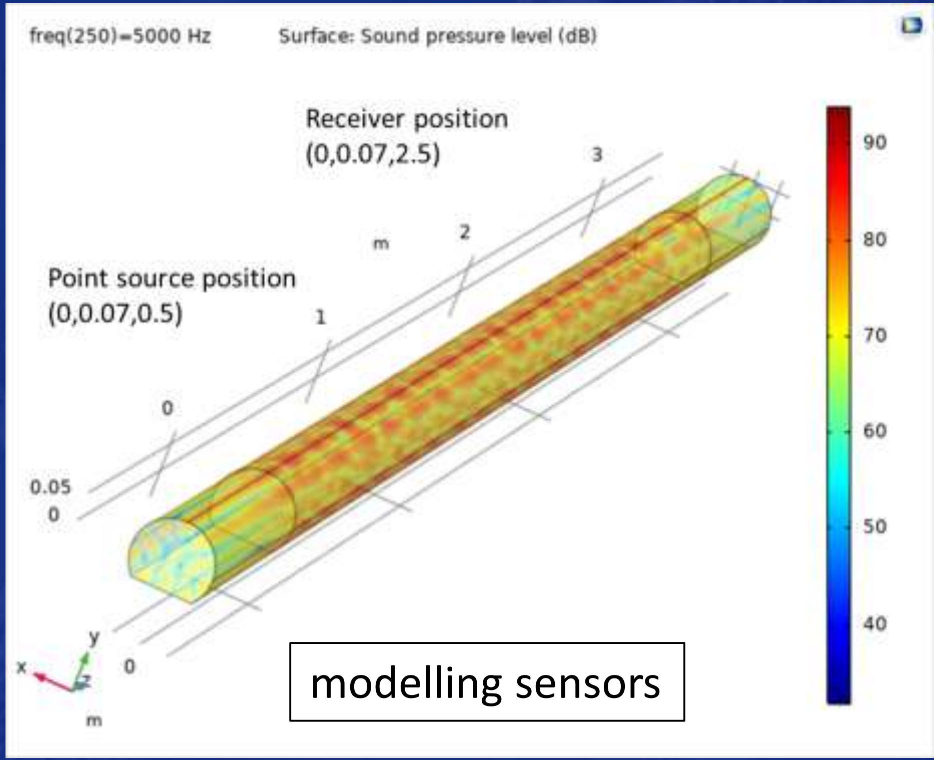
What we will do to realise the vision?

- Develop a new science of sensing for high fidelity in-pipe inspection
- Integrate this new science with robotic, navigation and communication solutions to work autonomously in buried pipe networks
- Advance this science from a laboratory prototype to field scales
- Actively engage with the end user community throughout the research programme
- Establish a world leading research Centre of Autonomous Sensing for Buried Infrastructure

Theme Contributions

- **T2** – Sound-based sensing system capable of measuring relevant properties of the environment.
- **T3** – A mobile platform capable of fitting in the sewer and carrying all payloads. Development of a low-level electronic hardware and control system.
- **T4** – A simple autonomous control strategy to guide initial exploration by the robot.
- **T5** – A vision system (relying on a suitable sensor suite) capable of being mounted on the mobile platform.
- **T6** – Evaluation of candidate wireless communication systems. Working with T3 to implement some form of wireless communication on platform.
- **T7** – Define system requirements. This provides the foundation for alternative business models for wider use of autonomous robots in buried pipes.
- **T8** – Design the experiments and implement the trials at the UKCRIC facilities.

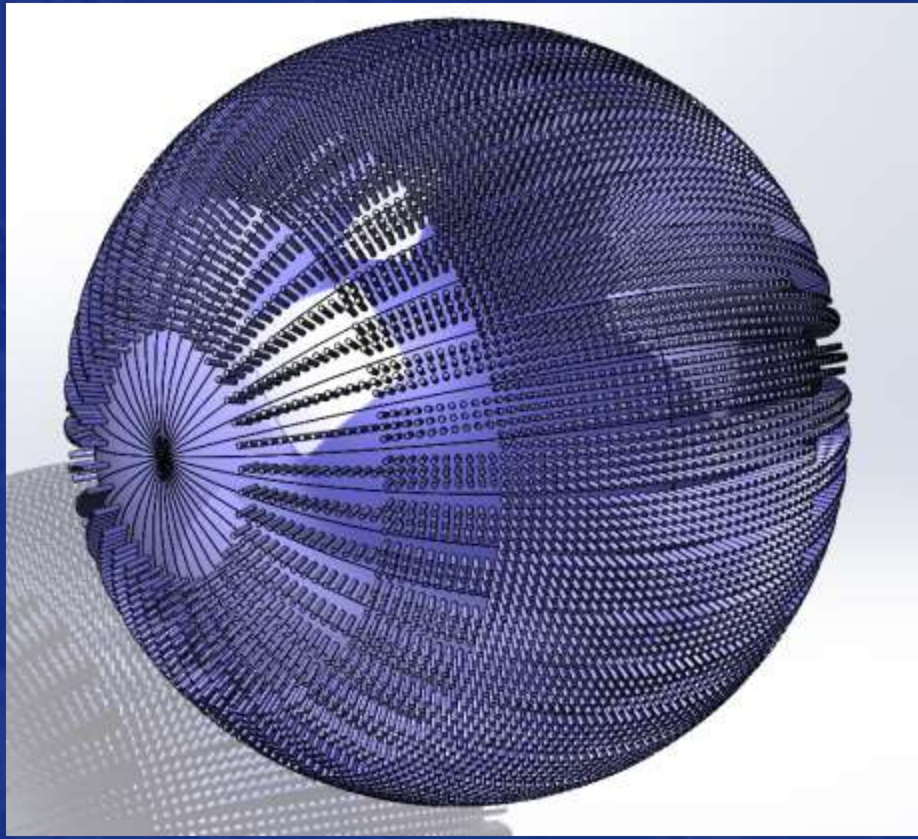
Theme 2: Sensors



Developed models for medium/long range audible sound propagation in clean and wastewater pipes

Developed and tested short range ultrasonic defect detection system

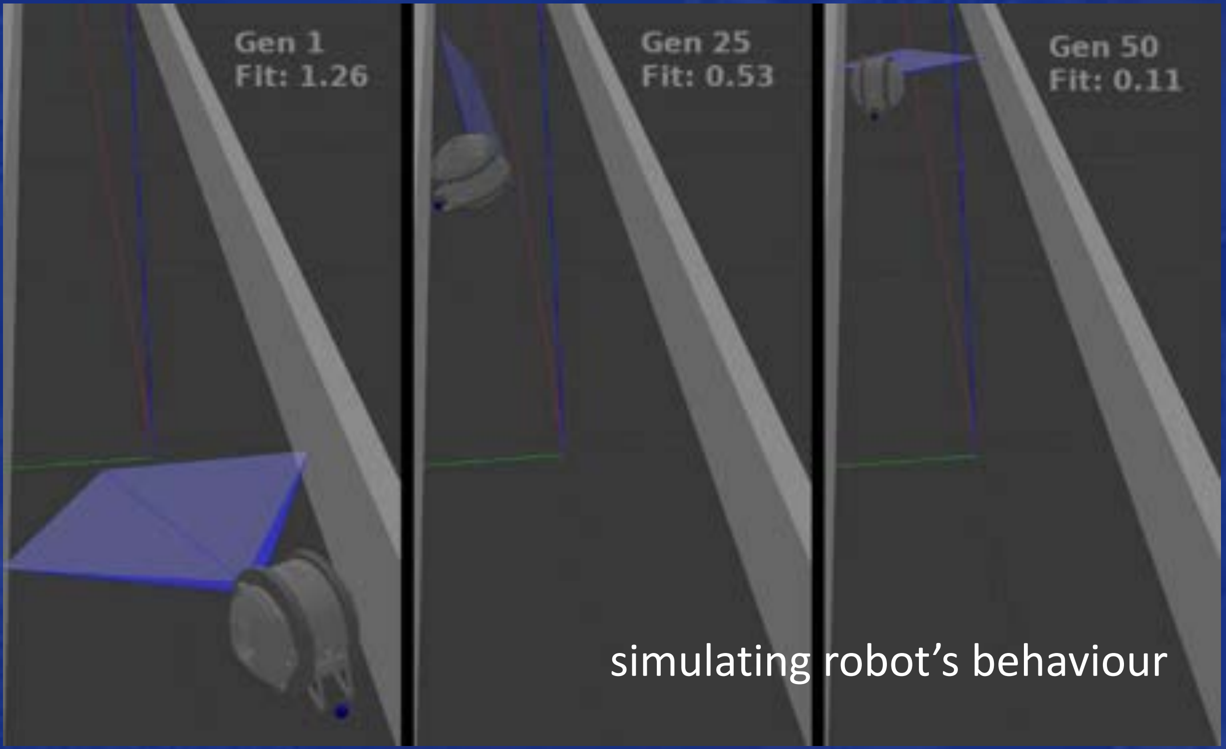
Theme 3: Robotic Systems



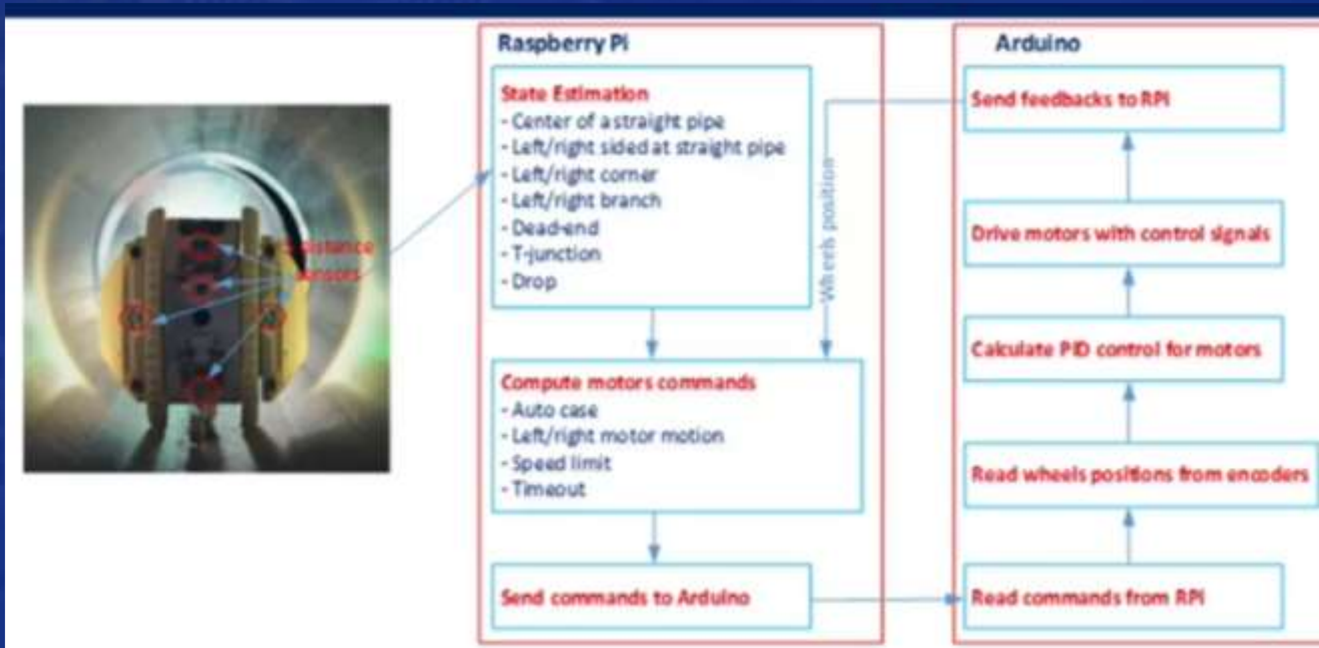
Developed a number of small robotic platforms including Sprintbot (above) & new robot concepts.

Studied interconnecting robots which can work together to cope with pipe artefacts.

Theme 4: Control



simulating robot's behaviour

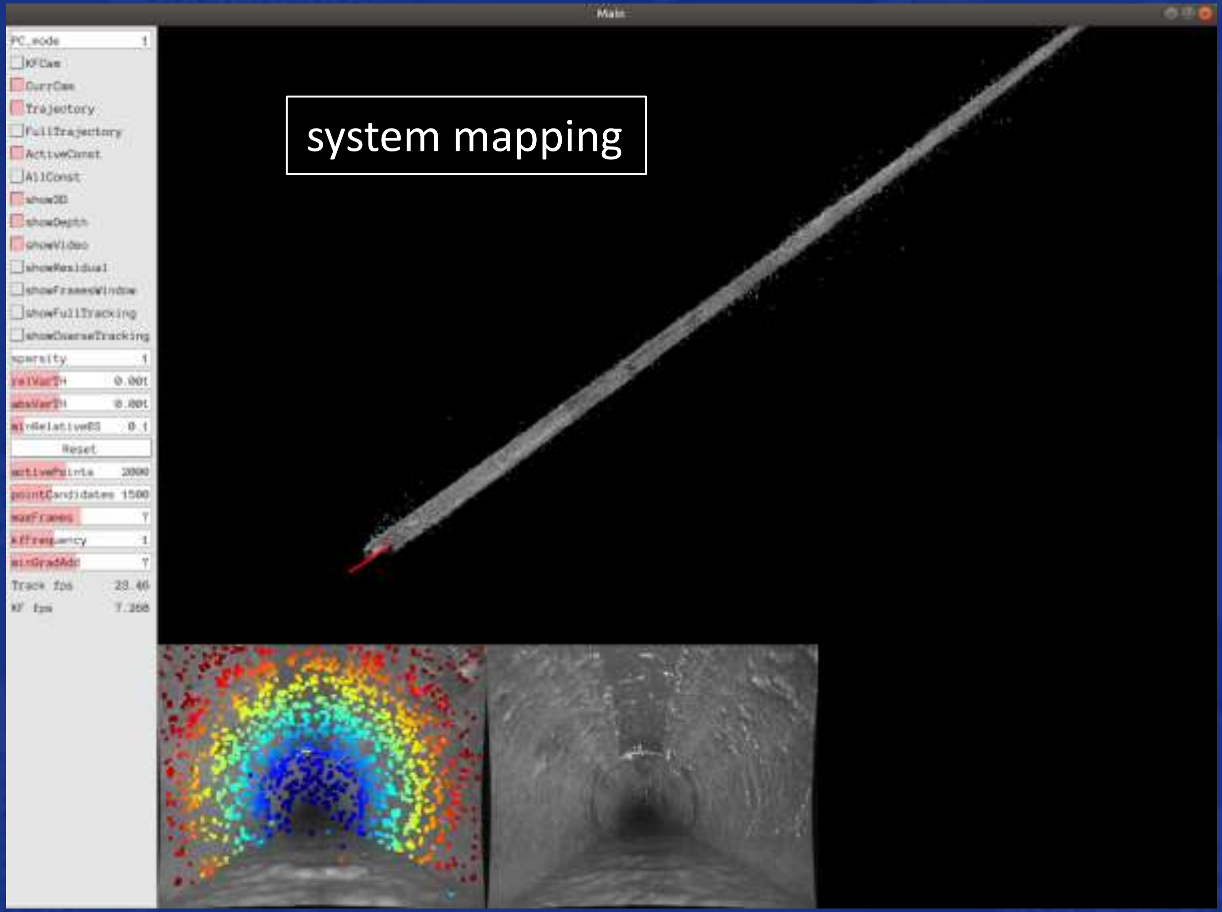


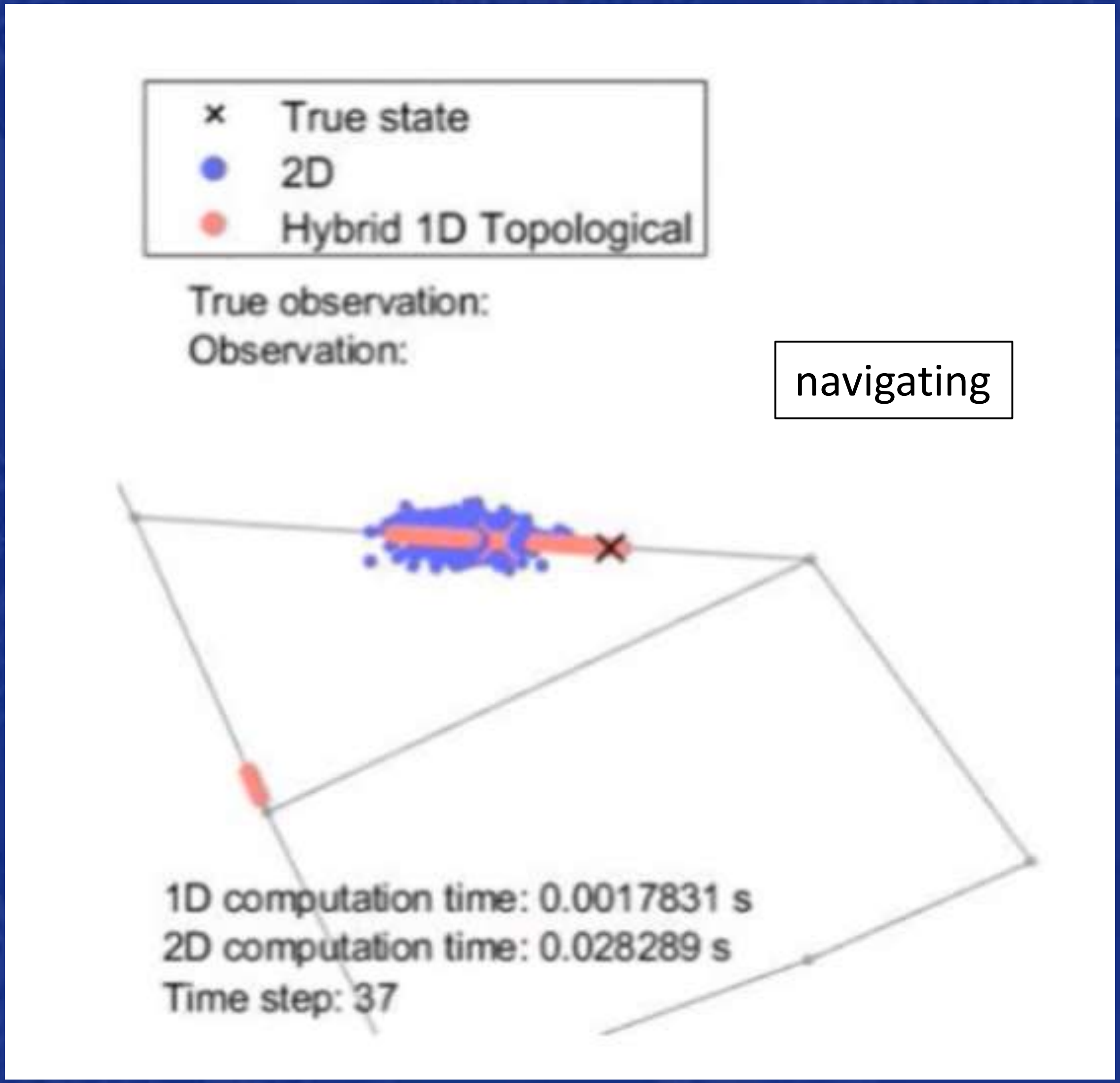
developing software for robot's control

Developed low-level robot control to cope with noise and sensor inaccuracies.

Studied through simulation cooperative robot assembly to overcome blockages & level changes.

Theme 5: Navigation

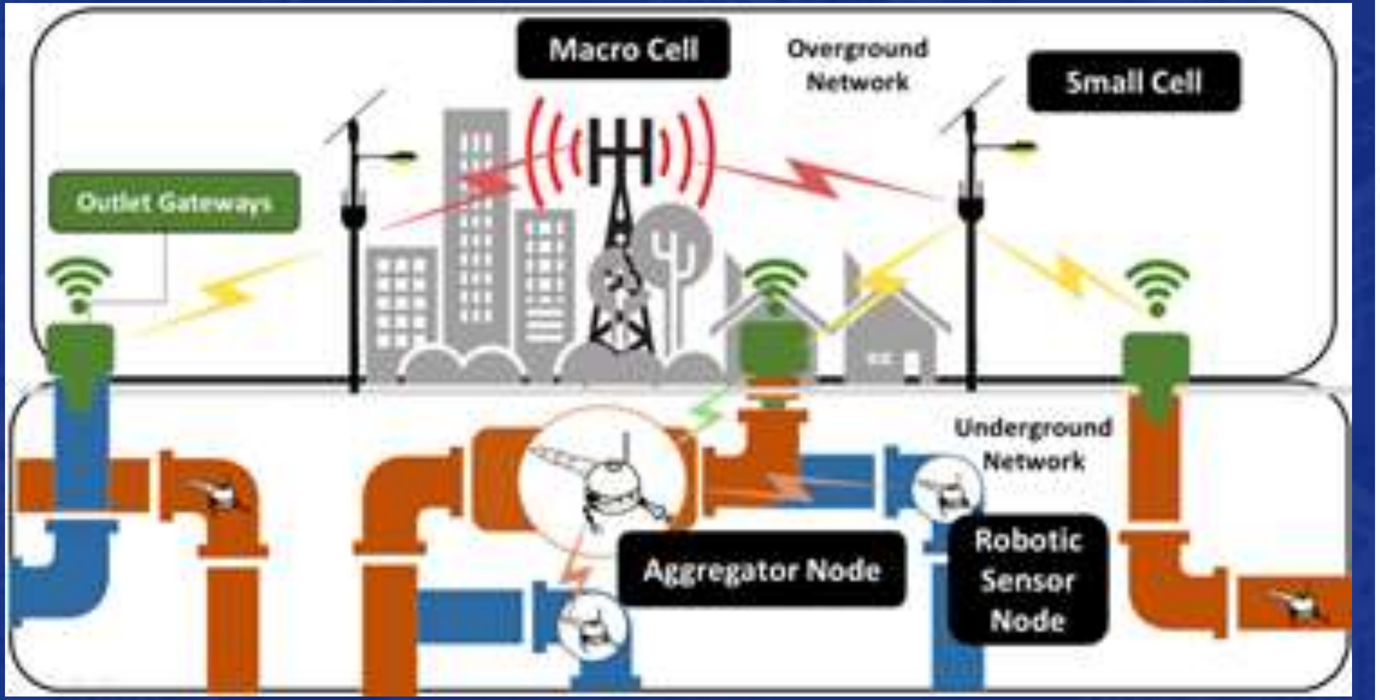




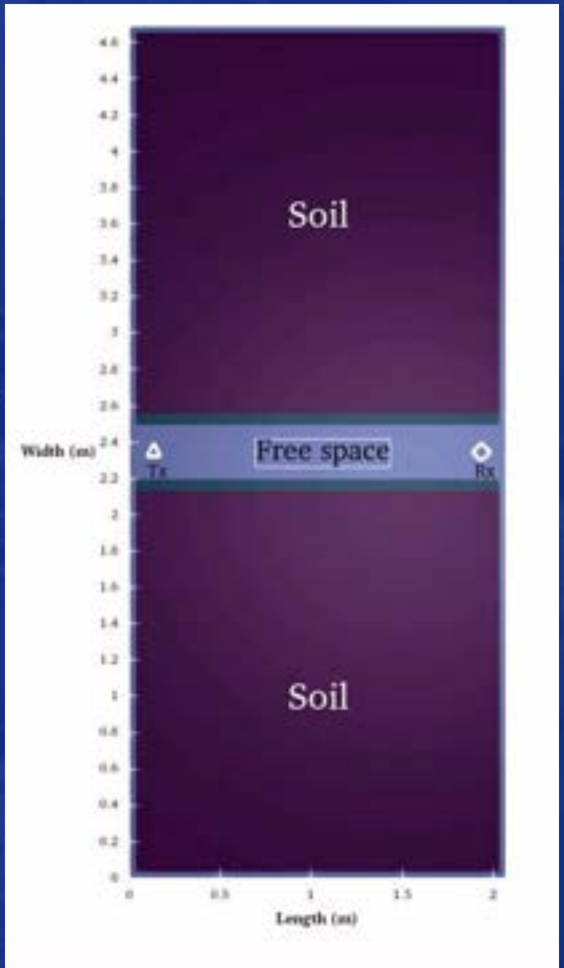
Developed algorithms for mapping & robot localisation in pipes using visual & acoustical data.

Tested these algorithms through simulation and in the iCAIR laboratory.

Theme 6: Communication



simulating comms

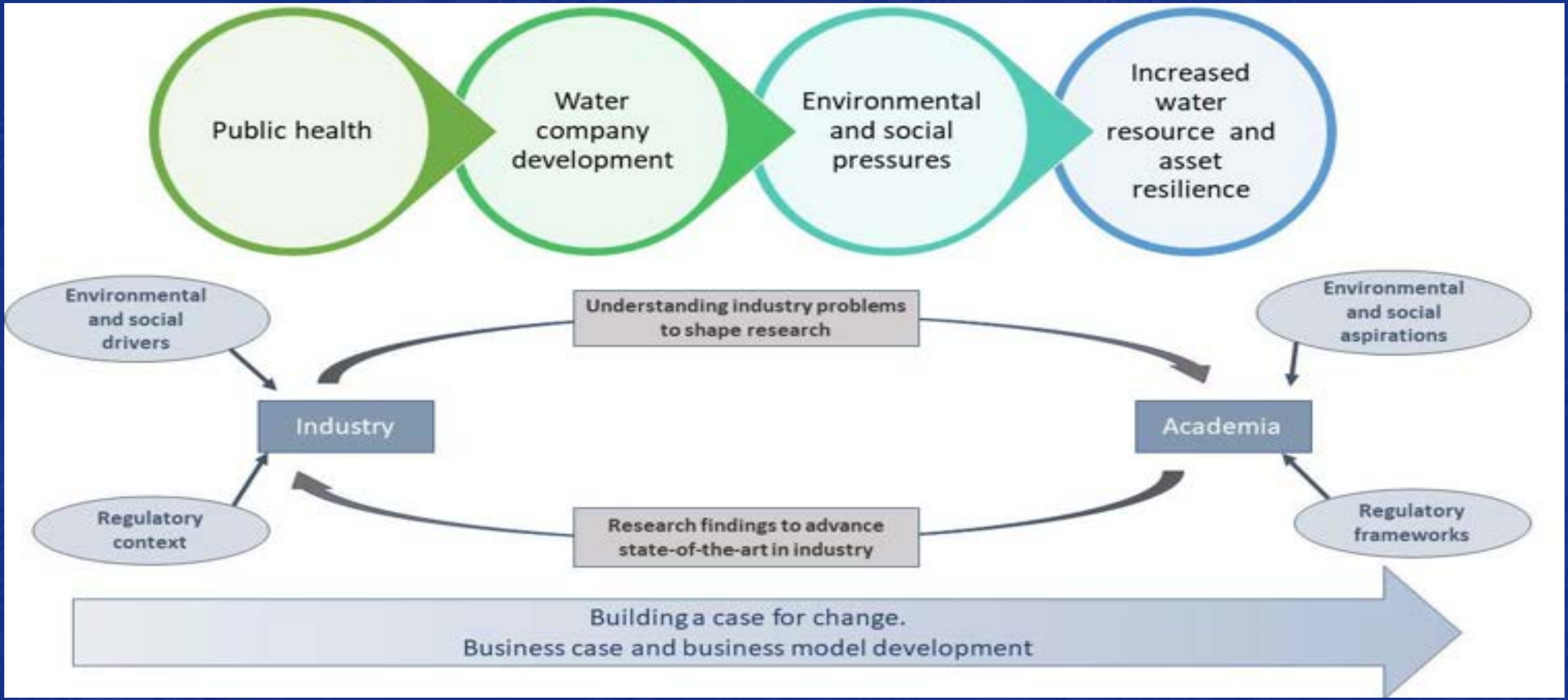


testing comms

Developed a model for RF propagation in buried pipes and carried out simulations.

Carried out laboratory experiments in iCAIR to validate the model.

Themes 7: Emerging Science, Business Models, System Knowledge & End-User Engagement



Creating the business case, alternative business models and governance frameworks.

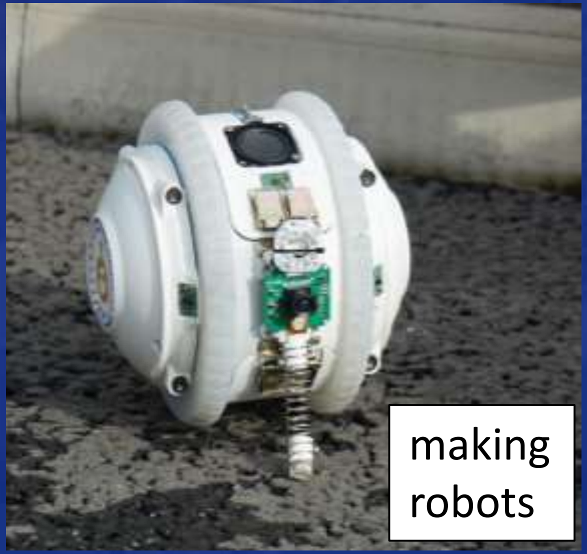
Preparing the way for industry transformation via robotic sensing scenarios.

Theme 8: Development of a testing facilities for robots

www.icair.ac.uk

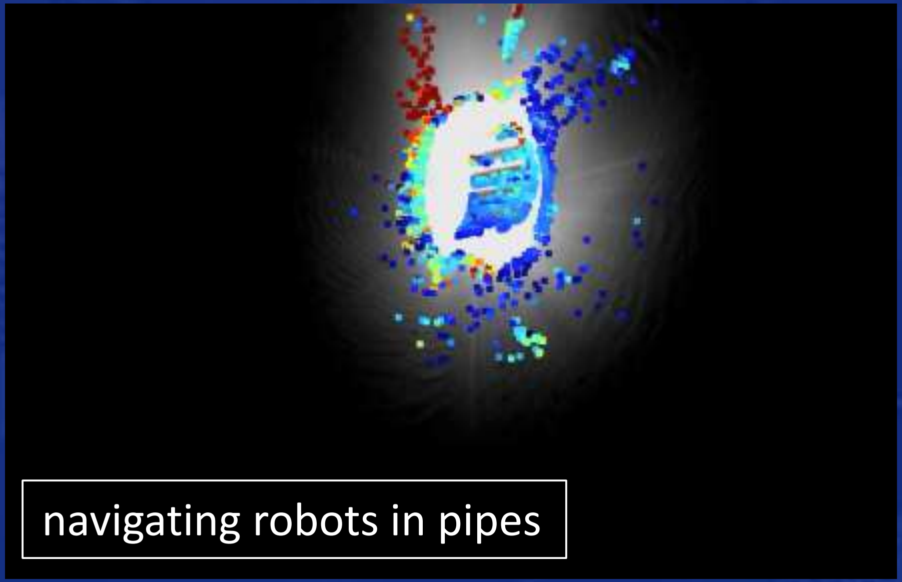
Where are we now?

working collaboratively



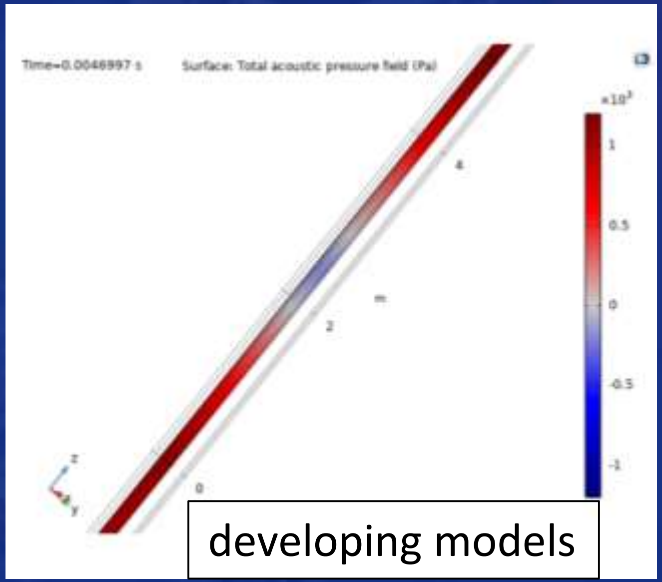
making robots

software integration



navigating robots in pipes

testing robots



developing models

High-Level Outcomes: Research Challenges

Hardware Miniaturisation:

Our robots need to be much smaller. There are technical challenges to be addressed.

Locomotion:

More robust locomotion methods will be required. Options are to be explored.

In-Pipe Computer Vision and Navigation:

The in-pipe conditions are challenging for vision and navigation. Hardware improvements and algorithm adaptations are to be explored.

Low-Level Behaviour and Control:

More robust behavioural algorithms are required. We will explore different architectures.

Sound-Based Sensing:

Richer feature extraction from sound-based sensing is desirable. We will explore the possibility of using sound in lieu of vision for mapping algorithms.

How do we Enable Change to Happen?

- First – Compile a rigorous Evidence Base
- Second – Make the Case for Change

  Comprehensive, accessible, transparent
- Third – Create the Business Models to implement change

  Balance the (multiple) forms of value against the cost
- Fourth – Engineer all of the Forms of Governance

  To enable the business models to work

  The 'formal' systems of governance
  - *Legislation, Regulation, Taxation*
  - *Codes and Standards*

  … and the 'informal' systems of governance
  - *Citizen and societal attitudes and behaviours*
  - *Societal norms, social acceptability, practice norms*

… and reflect
… and iterate

Pipebots Beneficiaries

- **Utility companies and their sub-contractors will be able**

  … to autonomously monitor on an unprecedented scale

  … to proactively rehabilitate buried pipes at reduced cost

- **Instrument/equipment manufacturers will be able**

  … to produce new sensing and rehabilitation solutions

- **General public will benefit from**

  … greatly reduced failures and interruption to services

  … a more sustainable supply

  … fewer road closures and less traffic disruption

What is beyond Pipebots?

- Taking technology to a higher TRL via follow-on projects
- Working with, and making sure it is adopted by, water utilities
- Developing a new governance framework
- Delivering the transformative vision to minimise streetworks

  … that avoid the disruption of traffic in streets

  … enabled by trenchless technologies

This Programme Grant is open for collaboration with external academic and non-academic partners

If you would like to collaborate, please contact:

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