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ASSESSING THE UNDERWORLD – A THREE-INFRASTRUCTURE APPROACH TO REMOTE SENSING

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Assessing the Underworld's Core Proposition

Our city streets consist of three interdependent infrastructures:

the road structure, *the buried infrastructure (pipes, cables)* and *the ground*

We contend that what is buried in, and on, the ground is to some degree controlled by the ground

... if the ground properties change, or the ground moves, the adjacent / overlying utility and road infrastructures respond accordingly

We have created a Decision Support System to inform streetworks engineers of *the options* for addressing the challenges of maintenance, repair and upgrade of buried infrastructure systems and/or the roads, *and their consequences*

... we need to be informed by the ground conditions and how the ground might react to any new activity or intervention

The information in this and subsequent slides is drawn from Rogers et al. (2017)

Assessing the Underworld's Core Proposition

ATU developed novel surface-deployed sensor technologies, and robotic in-pipe pigs, to

assess the condition of buried pipelines and cables

assess the condition of the surface infrastructure that overlies it

assess the condition of the ground

…which supports the road, and both supports and loads the buried infrastructure

We thereby sought to realise our vision:

that any civil engineering intervention in this system is undertaken with a full knowledge of the consequences

... being informed by information heretofore unavailable

The Problem

Owner/operators of buried infrastructure tend to focus on short-term impacts to their assets whilst undertaking streetworks and fail to consider the potential deterioration their interventions may have on surrounding assets – *True of False?* Is this because:

- The cost models they use only consider short-term, direct construction costs, whilst ignoring whole life costs of the integrated system?
- There are pressures from the regulatory authorities?
- The need to rapidly react to failures fails to allow the time to plan … and make the business case for trenchless technologies?
- There is a belief that alternative construction processes (such as trenchless technologies) are not reliable or cost effective?
- There is a conservative approach to construction process selection by the companies undertaking the work?

The Problem

The argument is usually cost, yet …

Cost analyses that claim to show trenching, rather than trenchless, construction is cheaper consider only direct short-term construction costs and ignore the wider/long-term costs of:

- damage inflicted on third party assets
- damage to the surrounding road pavement
- deterioration of the ground beneath the road, *which supports both the road pavement layers and the buried utilities*
  - … thus changing the loading conditions
  - … and causing deterioration of both the buried and surface infrastructures
- disruption to society's functions, including congestion and lost working hours
- damage to the environment, such as exacerbating poor air quality

The Solution

Trenchless technologies also potentially cause damage and disruption

… but this is primarily associated with uncertainty

These uncertainties could be minimized, and in many cases fully mitigated, if we could

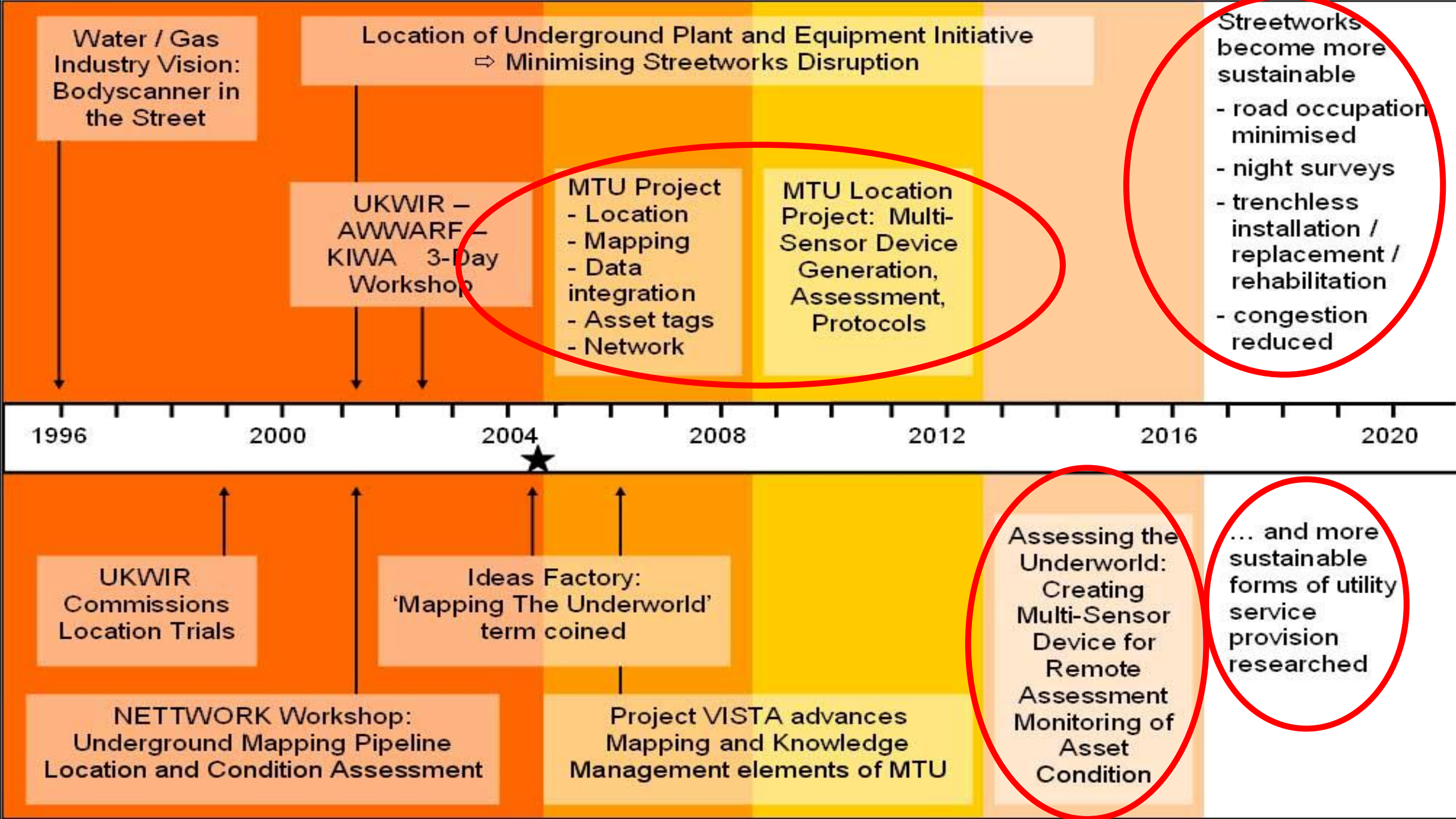
- *map accurately the existing utilities* and
- *understand the condition of the three interdependent infrastructures*

… considering road, ground and existing utilities as an interconnected system of systems

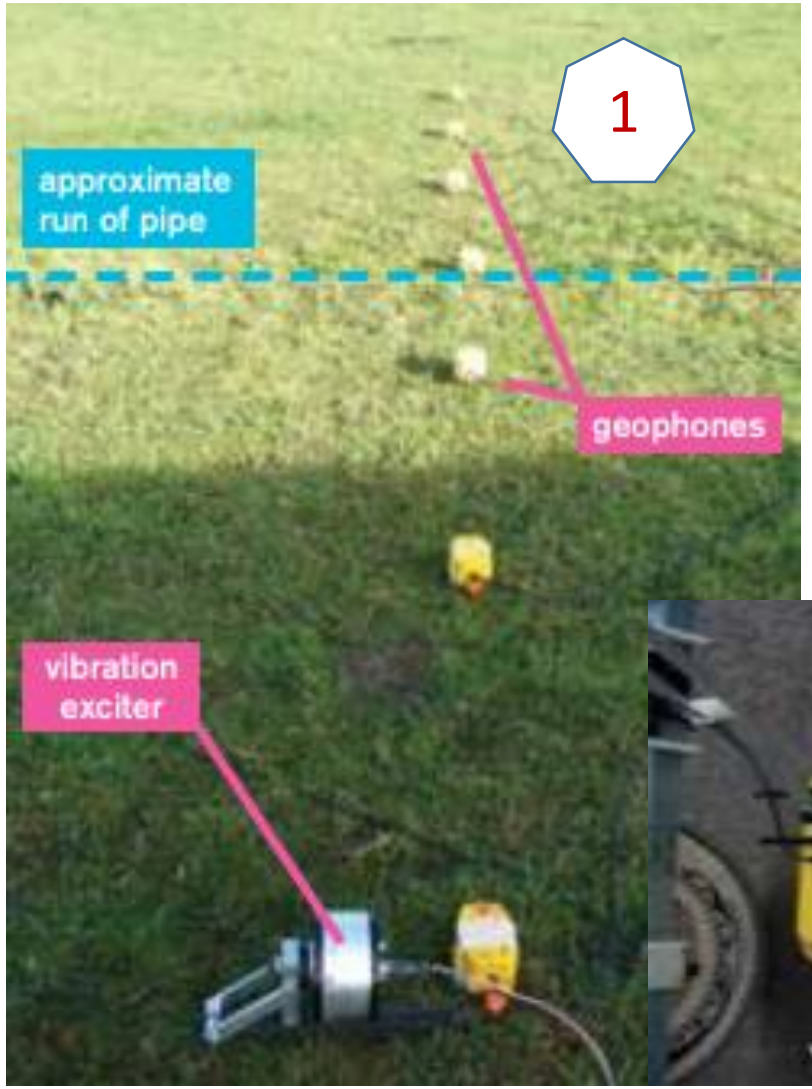
- inform our trenchless designs by factoring in the condition of these three interconnected infrastructure systems

Geophysical techniques have been utilized in managing buried infrastructure for decades, but with a focus on locating and mapping buried utilities rather than assessing their condition

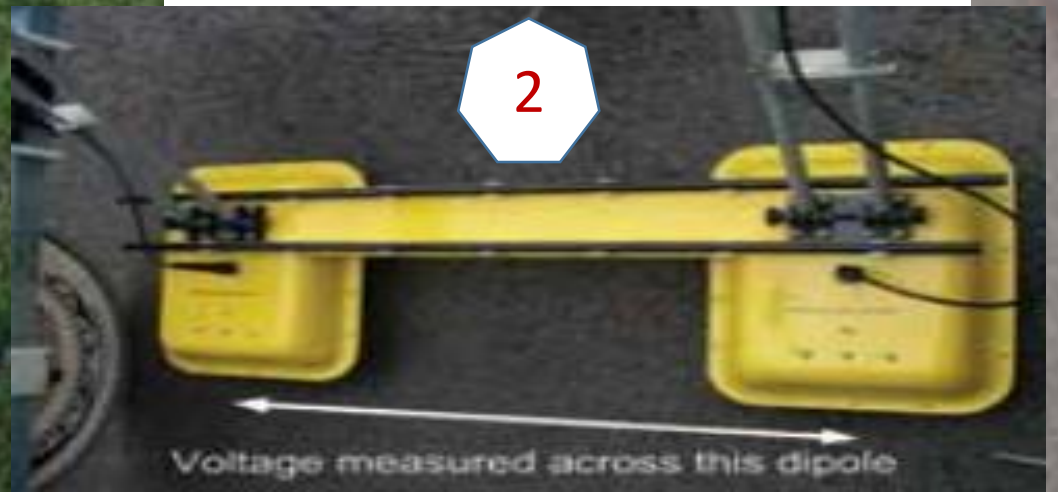
What is their potential for condition assessment?

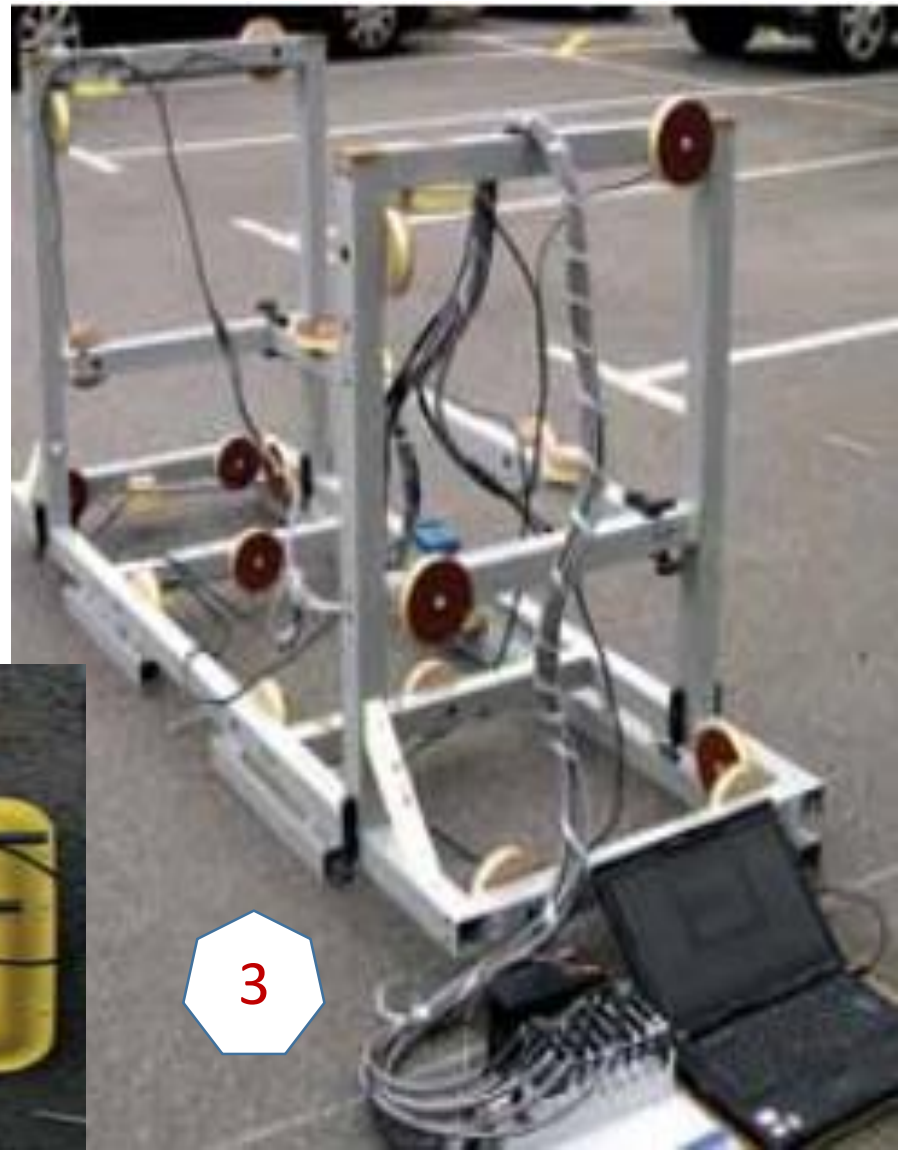

Water / Gas Industry Vision: Bodyscanner in the Street
Location of Underground Plant and Equipment Initiative
⇨ Minimising Streetworks Disruption
Streetworks become more sustainable
- road occupation minimised
- night surveys
- trenchless installation / replacement / rehabilitation
- congestion reduced
UKWIR – AWWARF – KIWA 3-Day Workshop
MTU Project
- Location
- Mapping
- Data integration
- Asset tags
- Network
MTU Location Project: Multi-Sensor Device Generation, Assessment, Protocols
1996
2000
2004
2008
2012
2016
2020
UKWIR Commissions Location Trials
Ideas Factory: 'Mapping The Underworld' term coined
NETTWORK Workshop: Underground Mapping Pipeline Location and Condition Assessment
Project VISTA advances Mapping and Knowledge Management elements of MTU
Assessing the Underworld: Creating Multi-Sensor Device for Remote Assessment Monitoring of Asset Condition
… and more sustainable forms of utility service provision researched

The Geophysical Sensors



1. Vibro-acoustics
2. Low-frequency electromagnetic fields non-contact electrodes
3. Passive magnetic fields





Matrix of Opertional Capability

	Road Furniture Cable	Single phase cable	Three phase cable	Pot-ended cable	Plastic gas service pipe	Plastic water service pipe	Metal gas service pipe	Metal water service pipe
V-A	1	1	1	1	2	2	2	2
PMF	2	2	2	1	0	0	1	1
LFEM	2	1	1	2	2	2	2	2
GPR	1	1	2	2	2	2	2	2

	Plastic Gas mains pipe	Plastic Water mains pipe	Metal Gas mains pipe	Metal Water mains pipe	Asbestos cement water pipe	Drains	Telecoms duct shallow	Large Telecoms duct deep
V-A	2	2	2	2	1	2	1	1
PMF	0	0	1	1	0	0	1	0
LFEM	1	1	1	1	1	2	2	1
GPR	2	2	2	2	2	2	1	2

The Good Intentions

A road pavement structure should spread the traffic load such that

… the maximum bearing stress of the ground is not approached and

… only relatively small strains accumulate under the dynamic load with time

A road pavement is constructed such that the substructure remains unsaturated and surface water is drained away before it can permeate through the pavement and negatively impact upon the load bearing capabilities of the ground

Utilities are buried at sufficient depths such that they are protected from high or concentrated traffic loads, hence preventing damage or failure

… which in turn assumes sufficiently-good ground properties (or condition) to provide support to both the surface and buried infrastructures

The Reality

However, deterioration, or failure, of one component in this interconnected system will inevitably result in negative impacts upon the others. For example:

- damage to the surface layers of the pavement may result in pathways for water to seep into the ground and soften it
- softened ground results in changes in load transmission and may result in surface settlements

  … which undermines the support for the road pavement
- softened ground causes differential loading to be transmitted to buried pipes / cables
- overstressed water / sewer pipes can crack and leak, causing ground softening

  … which undermines support for the road pavement

Trenching softens / weakens the ground, provides a pathway for water ingress, causes lateral pipe displacements in parallel pipes (if the ground moves, so do the pipes) and differential pipe settlements of crossing pipes, and …

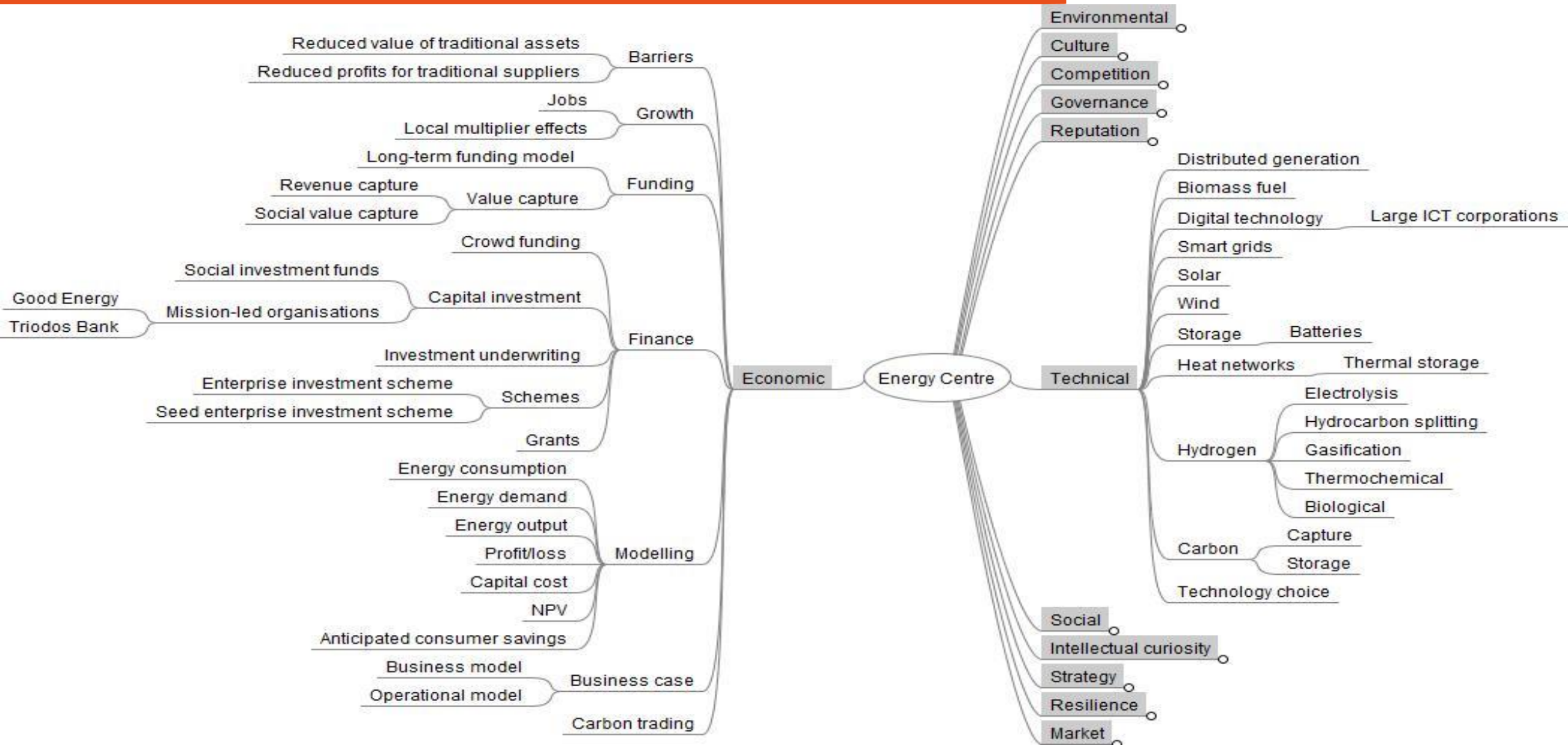
The Reality

Trenchless technologies likewise have potential impacts:

- *Launch and reception pits act like small-scale trenching operations*
- *Outward ground displacements (moling, pipe splitting, over-pressurized HDD bores) can occur*
- *Inward ground displacements (microtunnelling, under-pressurized HDD bores) can occur*
- *Drilling fluids to stabilize a HDD bore can disrupt the soil fabric*
- *Consolidation of drilling fluids post-construction can result in ground settlement*

All of these potential consequences need to be identified and considered in any analysis of the consequences of the streetworks operations, of course.

System Mapping



Pipebots

In collaboration with

The University Of Sheffield.

UNIVERSITY OF BIRMINGHAM

University of BRISTOL

UNIVERSITY OF LEEDS

Supported by

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Engineering and Physical Sciences Research Council

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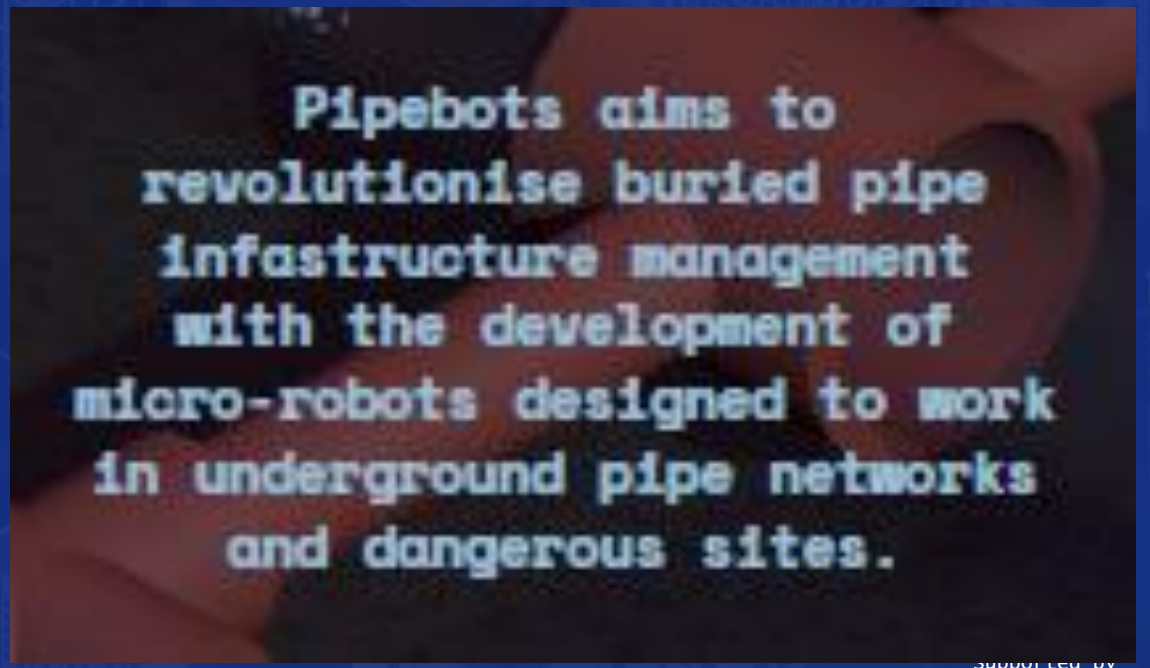

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TWENTY65

EPSRC Grand Challenge: Balancing the impact of City Infrastructure Engineering on Natural systems using Robots:

Conclusions

It is often said that everything in life is interdependent in some way

… all actions have consequences

The fundamental premise of the construction industry is that actions are carried out to provide some beneficial facility or service

… and utility services are a public good – they deliver societal benefits

It is only right and proper to identify and allow for all of these consequences

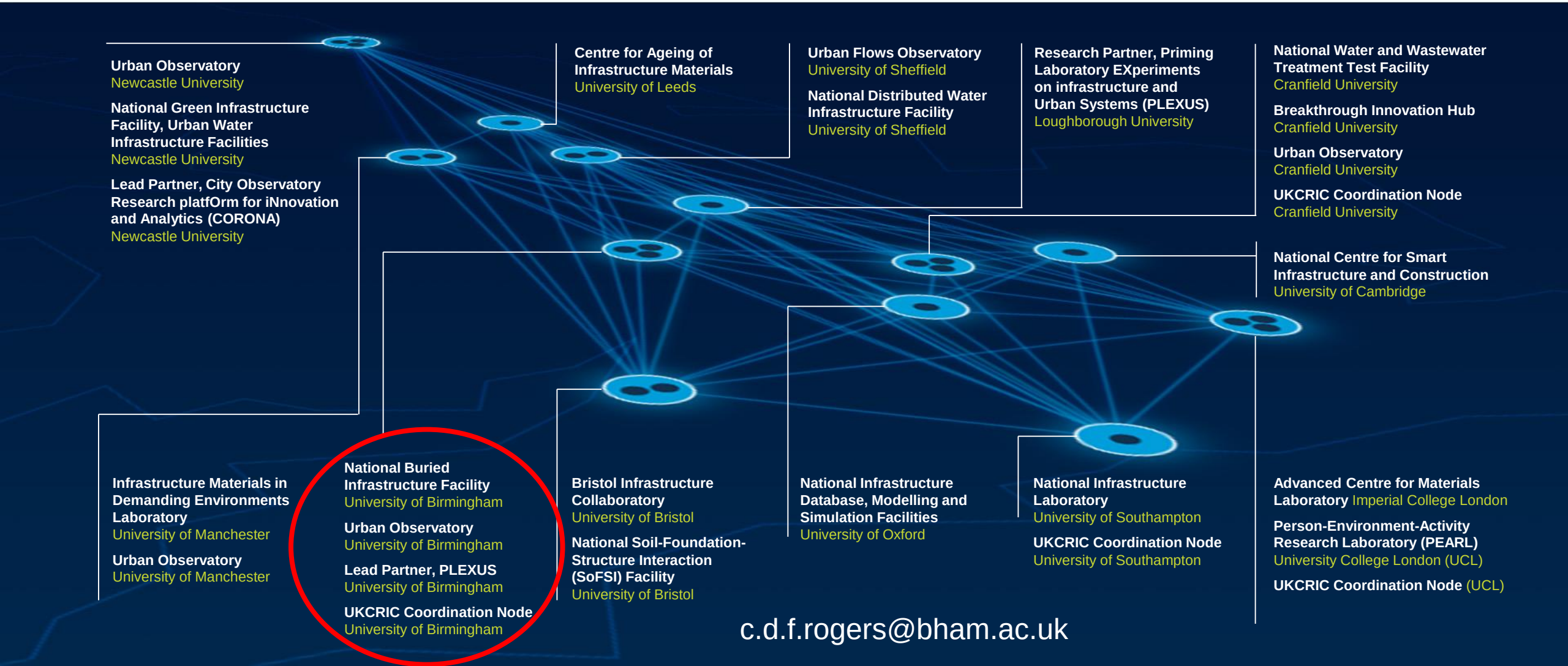
It is imperative that we appreciate the interdependencies between the three infrastructures in the street:

the road structure, *the buried infrastructure (pipes, cables)* and *the ground*

All have performance expectations, can deteriorate with time (for which we need deterioration models), need maintenance, and hence need monitoring

… and engineering interventions must be carried out sensitively

UK Research Facilities and Programmes



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