# Industrial-University Collaboration:

# A Long-Term, High-Value Example

10th June 2013

Phil Atkins* + many others

*University of Birmingham

Mapping the Underworld

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# Mapping the Underworld

Structure:

- Audience Participation ….
- Starting Point – Why?
- A Time-Line – Stage 1 – Mapping the Underworld
- Feasibility Study
- A Time-Line – Stage 2
- Geophysical Electrical Resistivity Surveys
- A Time-Line – The Unexpected …
- Crazy Science – Gravity Measurements
- A Time-Line – Stage 3
- Assessing the Underworld
- Summary

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# A Question: What is the difference between the following?

M31, in the Andromeda Galaxy captured by NA… (USA…

(UMCP)

Civic Drive (Ipswich Star)

We can see to the end of the Universe more easily than we can see one metre under ground!

A good telescope only costs a few €1000s, congestion alone costs Europe €80bn per year.

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# A Question: What is the difference between the following?

M31 in the Andromeda Galaxy captured by NAS… …n/Stefan Immler (GSFC) and Erin Grand (UMCP)

The Universe evolves more rapidly than an academic!

Phil Atkins (Academic)

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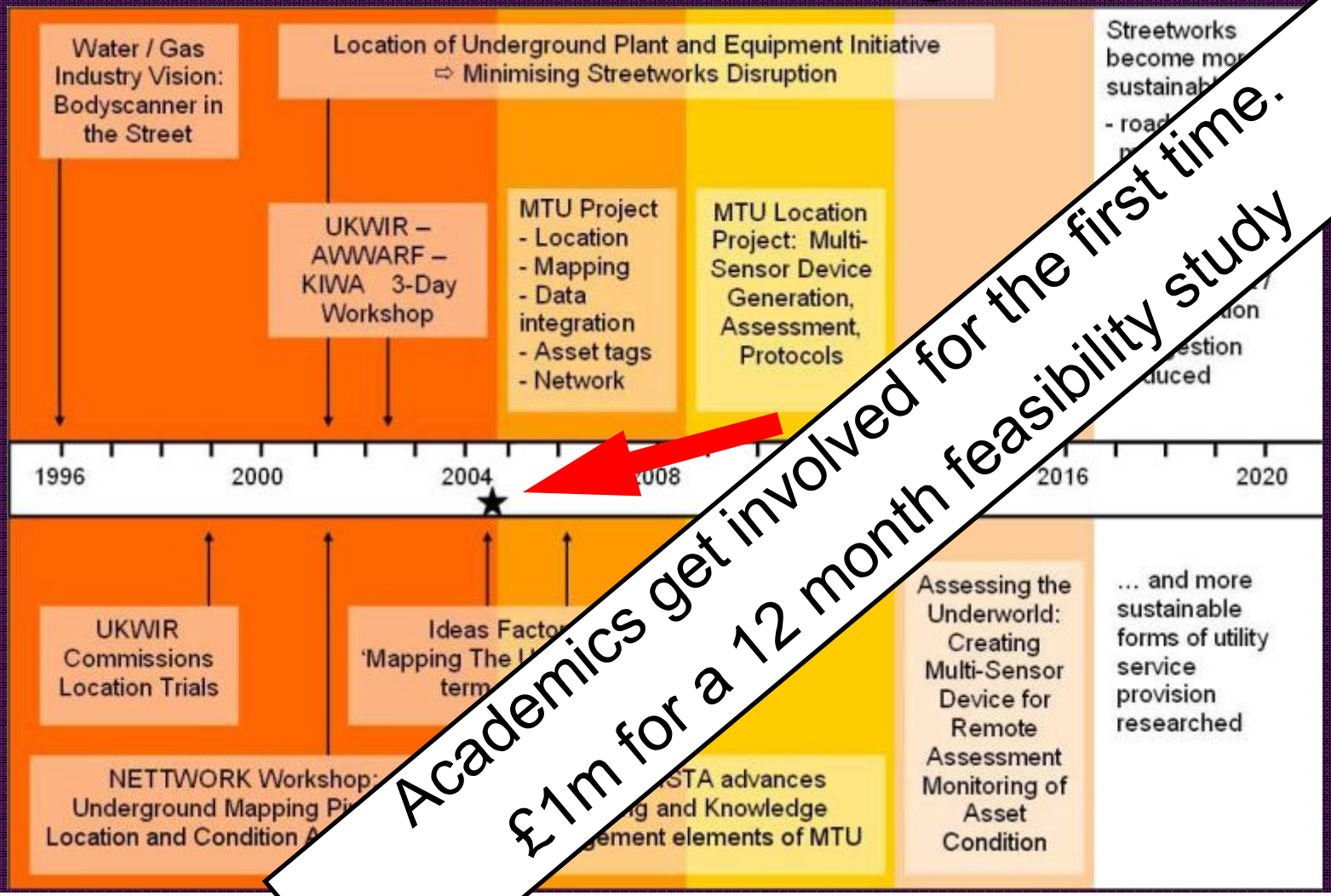
# How would you do it?

Image: The British Society of Dowsers


# A Time-Line – Stage 1




Academics get involved for the first time.
£1m for a 12 month feasibility study

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# A Time-Line – Stage 1 - Success

Water / Gas Industry Vision: Bodyscanner in the Street

Location of Underground Plant and Equipment Initiative
⇨ Minimising Streetworks Disruption

UKWIR – AWWARF – KIWA 3-Day Workshop

MTU Project
- Location
- Mapping
- Data integration
- Asset tags
- Network

MTU Location Project: Multi-Sensor Device Generation, Assessment, Protocols

Streetworks become more sustainable
- road occupation minimised
- night surveys
- trenchless installation / replacement / rehabilitation
- congestion reduced

1996 2000 2004 2008

UKWIR Commissions Location Trials

Ideas Factory: 'Mapping The Underworld' term coined

NETTWORK Workshop: Underground Mapping Pipeline Location and Condition Assessment

Project VISTA ac
Mapping and Kno
Management eleme


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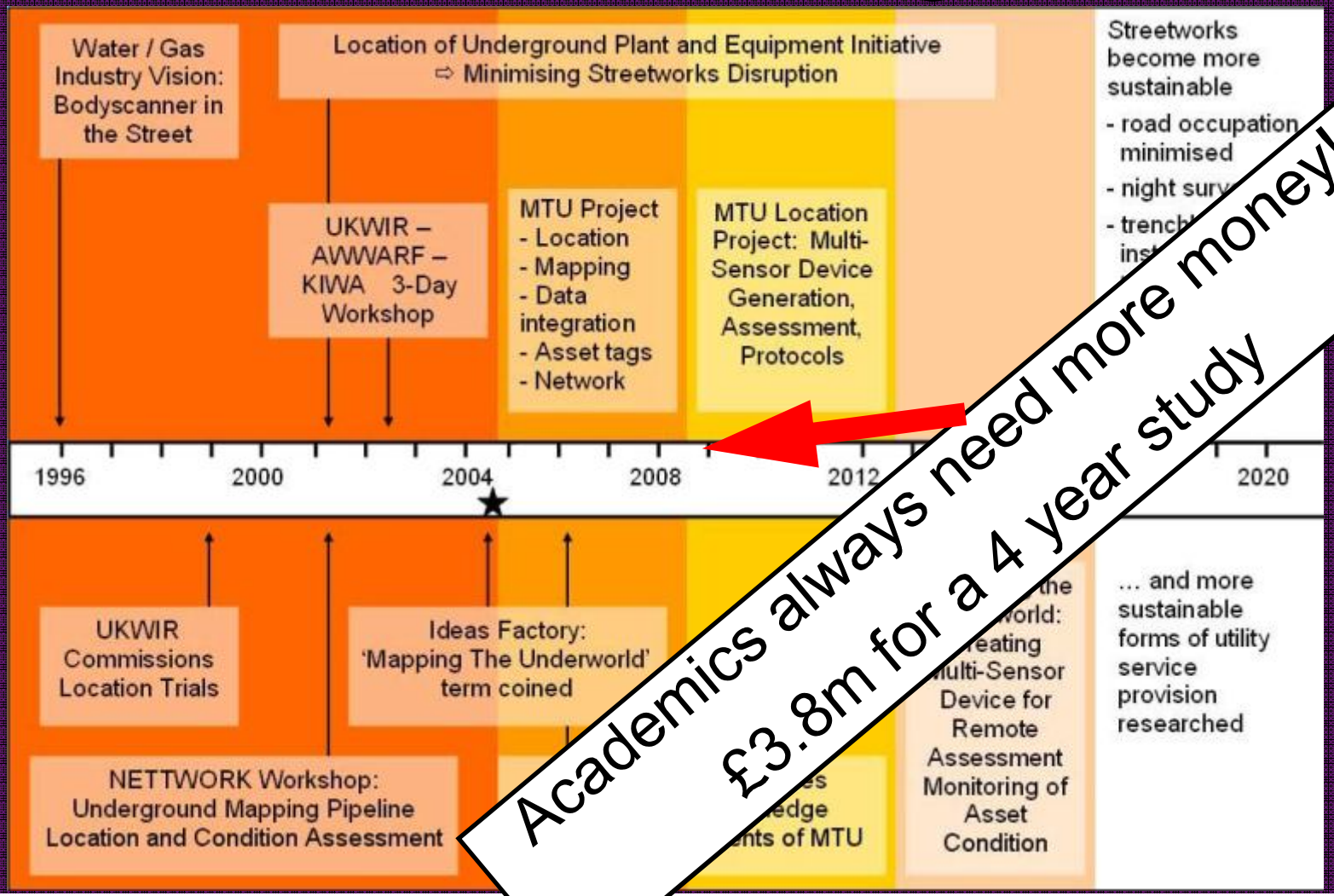
# A Time-Line – Stage 2

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# Just One Bit of a Large Project

# Low Frequency Electromagnetic Methods

This is my bit!

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# Geophysical Electrical Resistivity Surveys

Advantages:

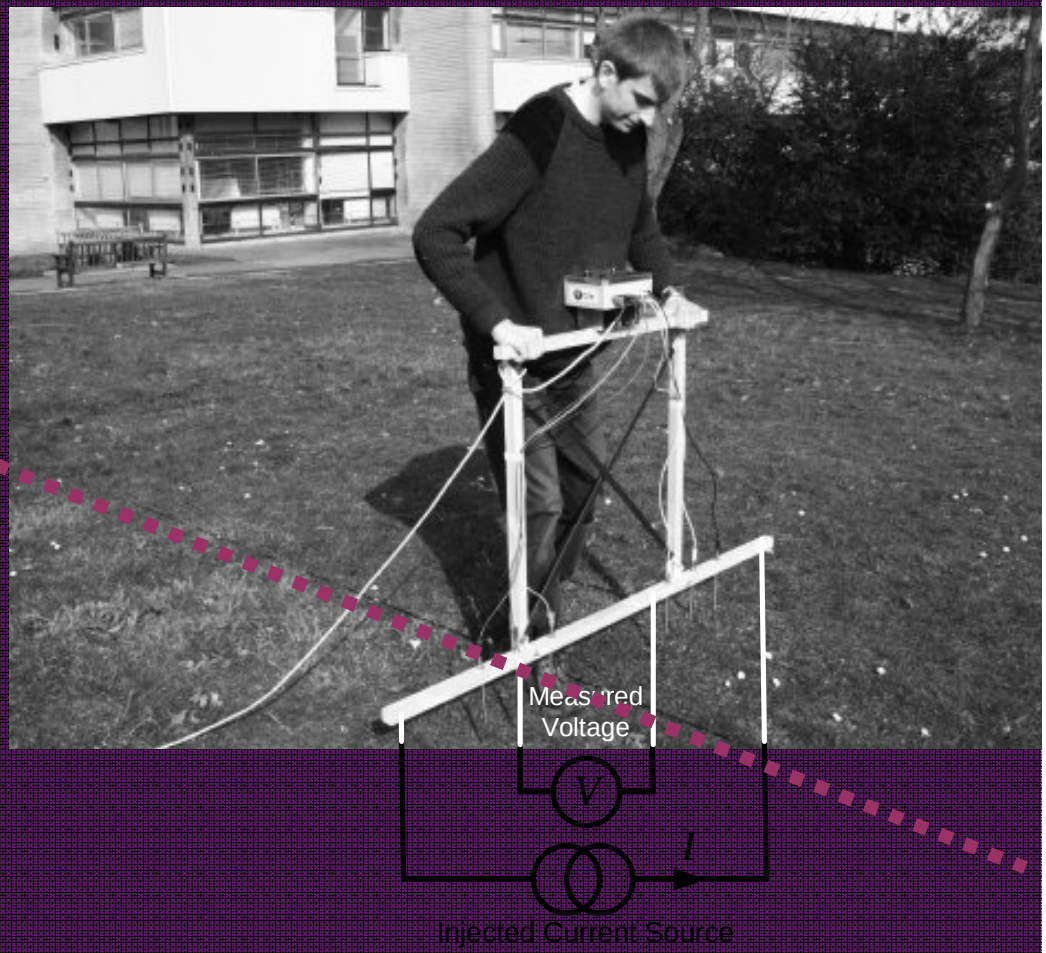
- Detects objects at range of depths
- Detects many materials

Disadvantages:

- Slow, man-power expensive.
- Unknown performance on paved surfaces

Method:

- Inject a current $I$
- Measure a voltage $V$
- Calculate the ratio, $R = V/I$
- Repeat for each spatial position

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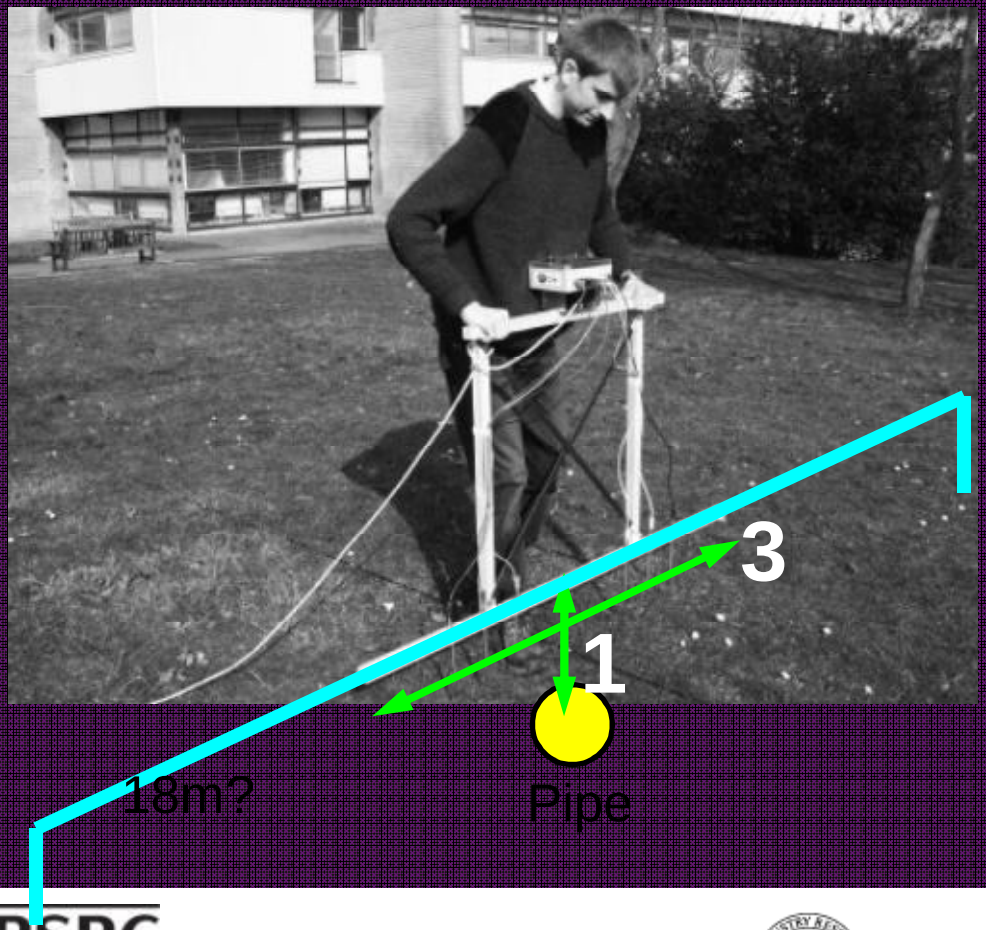
# Geophysical Electrical Resistivity Surveys

Depth Capability:

- Typically one-third of the current injection separation

Design Aim:

- Make unit as large as possible (18m?)

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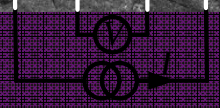
# Depth Capability Improvement

Transfer mobile current injection electrodes to fixed, well-separated locations.

This is known as a ‘Bipole’,





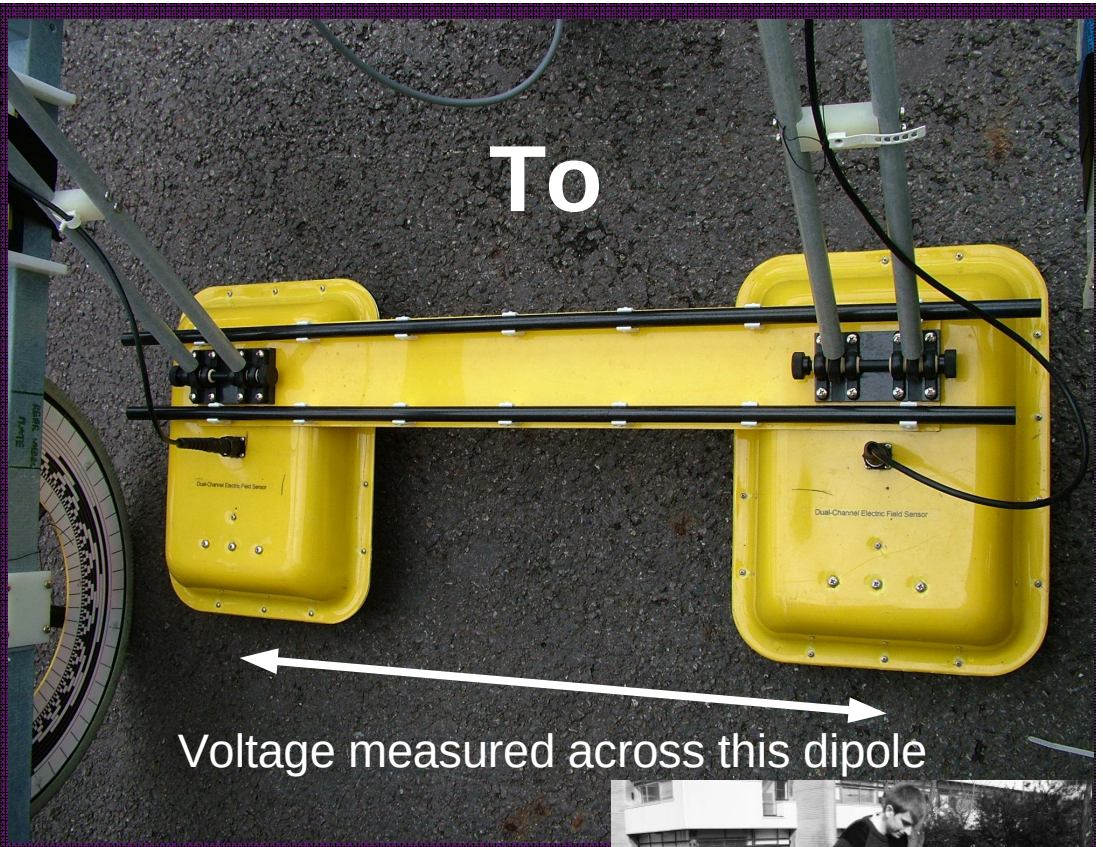


# Survey Speed Improvement

Transfer mobile voltage measurement electrodes to non-contact slider-plates.

This is known as a 'Dipole'.

But, the bad news is that we need to know position and heading of the dipole very accurately. Signal level decays rapidly with distance from source electrodes ($r^3$).





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# Complete Vision

Including:

Transmit Bipole

Receive Dipole

Urban navigation system based on laser scanners, as GNSS is not sufficient.



LIDAR detector - Range: 20m (1mm resolution), 270 degrees coverage

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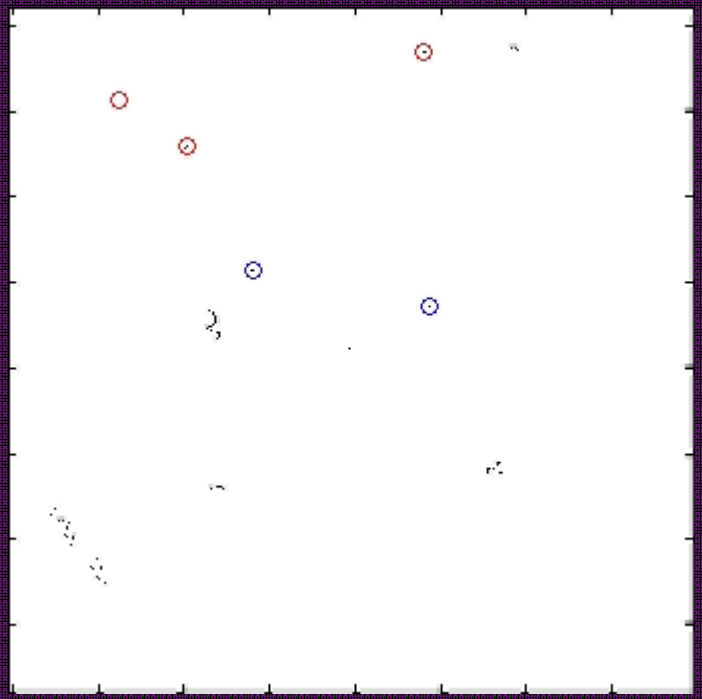
# Lamp Post Navigation

The most 'effort-consuming' activity has been that of obtaining position and heading information to the desired accuracy (10 cm and 0.5 degree). This has to be obtained using on-board sensors (LIDARs)



Estimating both rotation and translation parameters is 'interesting'.

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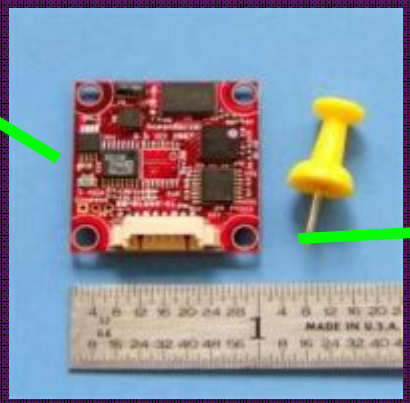
We need to seed the approximate position and heading of the cart to aid the tracking algorithm.

Position is obtained using a robot total station – Leica TS15

Heading is obtained using a magnetic compass from an underwater autonomous vehicle.

Magnetic compasses introduce significant deviation due to local iron work

Leica TS15 Robot Total Station



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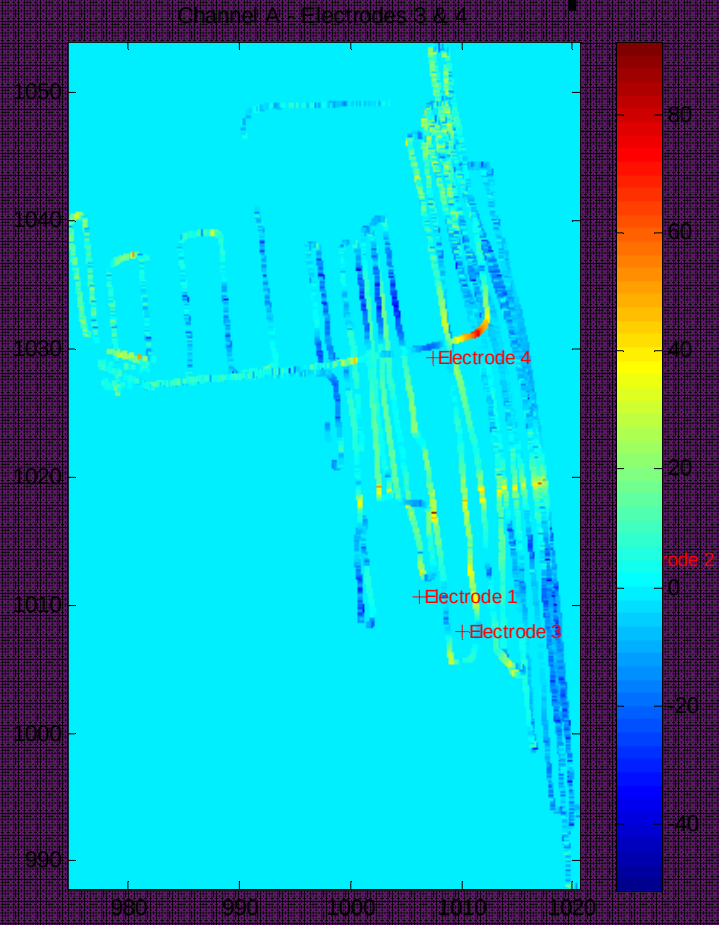
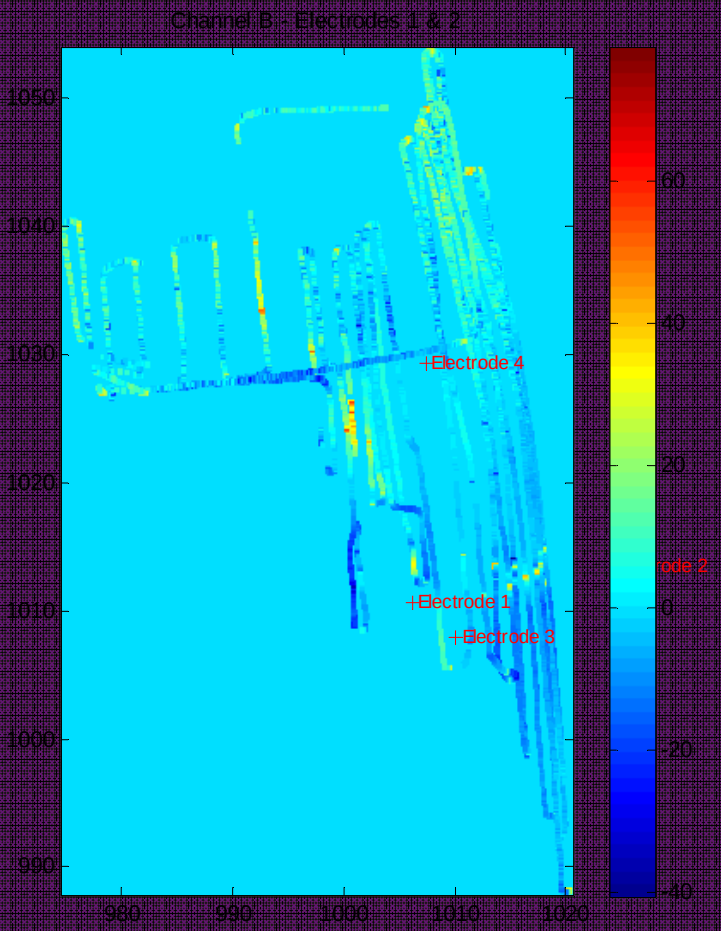
# Do We See Pipes and Cables on Raw Data?




We actually inject currents in two different directions (x&y) to look for pipes running in different directions




Are we fooling ourselves – software bugs? How much is hidden in the noise?

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Step 1: Take data sampled at random points in s… patial data) and transform to a regularly spaced grid.

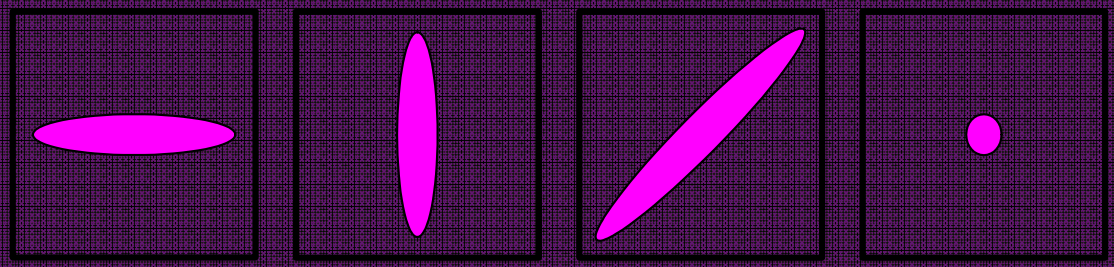
Step 2: Filter data so we 'tune' for utility s… straight runs)

Step 3: Perform a 'detection' (yes/no)


Hard Science

Spatial Frequ…

Wiggl…



Filter Coefficients Tuned to Different Directions of Pipes

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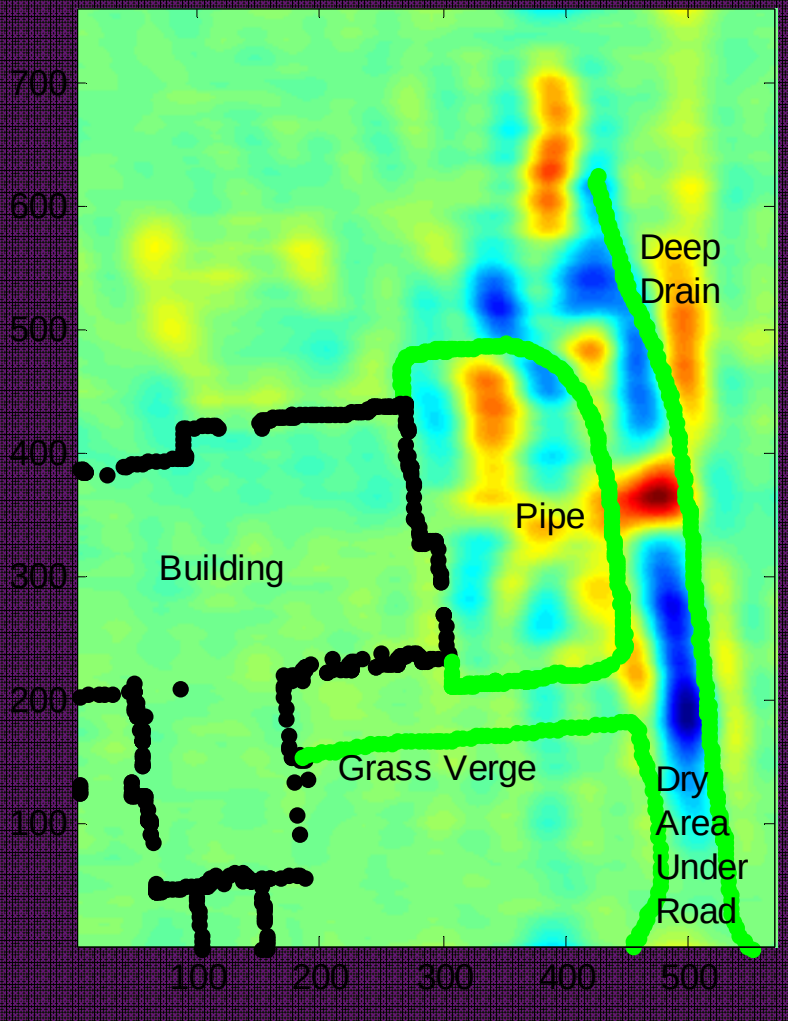
# Typical Results

Processed for one direction of pipe only.

The aim of Mapping the Underworld was to generate maps – here we see a map!

Perhaps not what you expected?

The 'coloured anomalies' indicate areas worthy of further consideration.

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# Problem

Everything we have seen so far results in deep assets being shielded by near-surface assets.

What should we use?

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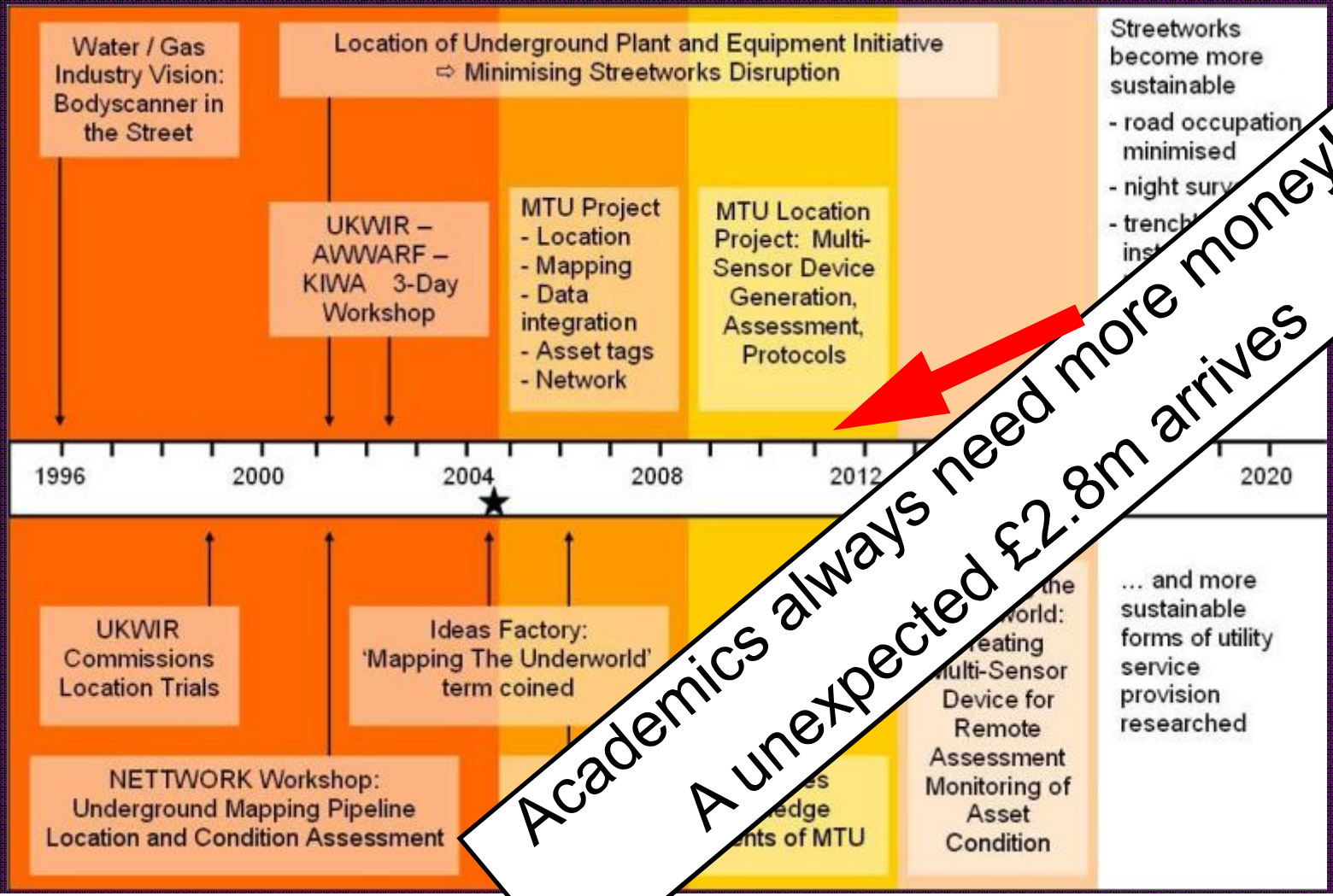
# A Time-Line – Stage 2b (Unexpected)

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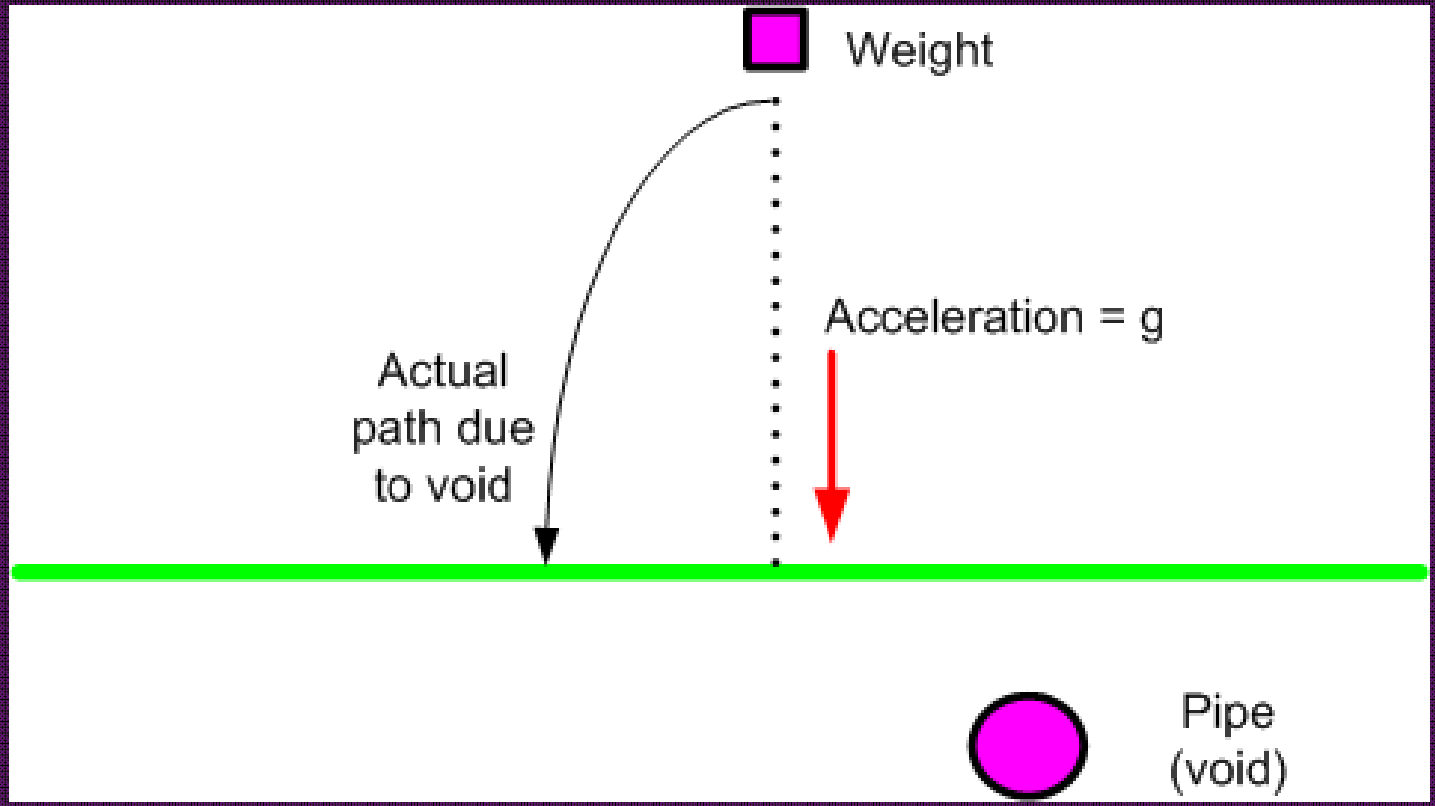
# Other Techniques

# Crazy Science

# Gravity Measurements

University of Birmingham

# Gravity Measurements




The path of a falling object will depend on what is under the ground – gravity can never be shielded.

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# Gravity Measurements

- We need a very large number of identical masses.
- Use individual atoms.
- But these must have no thermal motion = zero temperature.
- They must be dropped in a very hard vacuum.
- So use laser cooling of atoms.

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# Gravity Measurements
## The fun bits ….


+

= autonomous, all-terrain, self-powered, survey vehicle.

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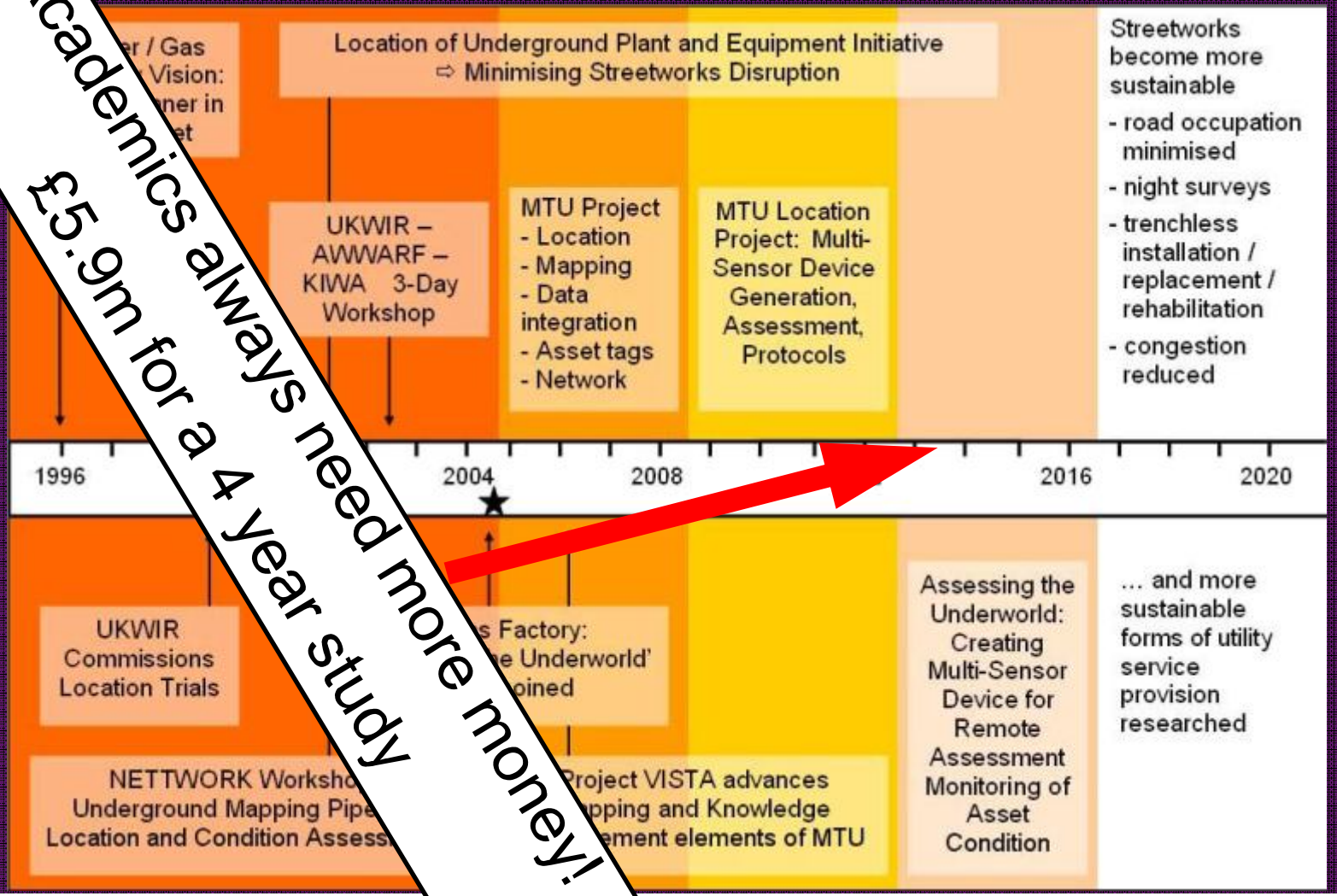
# A Time-Line – Stage 3




Academics always need more money!

£5.9m for a 4 year study

# Stage 3
# Assessing the Underworld

The group has just been awarded £5.9m to look at all aspects of assessing the condition of the underworld. A very small number of the topics include:

1. **Tree Root Damage Under Paved Areas.**
2. **Determination of Deep Cracks Within Road Slabs.**
3. **Partial discharge faults in underground cables.**
4. **Measurement of internal degradation of live water pipes.**
5. **Geotechnical implications on underground condition.**

# Conclusions

- That's a multi-million pound industrial-university collaboration.
- The science and technology developed has not been the important bit.
- It has been the standards, codes-of-practice, influence-on-government, bringing people together, Radio 4 programme, etc. that has been the real success.
- We also have great difficulty recruiting good engineers……

## Any Questions?

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