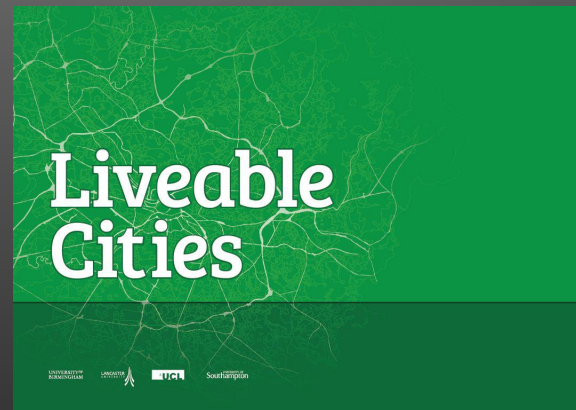


Engineering the Underworld towards Future Liveable Cities

Professor Chris Rogers
University of Birmingham
21st May 2015



What Can The Subsurface Do For Us?

We expect a lot of the ground ... especially that beneath our cities.

The ground serves cities by providing multiple potential functions
... and we duly exploit them in different ways, at different times

We design our exploitation very specifically

... (as engineers) we seek to optimise our designs

... we start by defining the function(s) we need

... we carry out ground investigations – can our needs be met?

... we design according to what the ground can offer

OR we treat the ground to improve its (specific) functionality

How does this sit with sustainability?

... allowing future generations to meet their own needs

How does this sit with resilience?

... continuing to deliver functions in the face of change

Resilience Through Innovation

Critical Local Transport and Utility Infrastructure

What Do We Want Of Our Cities?

A place to trade (especially food)

A place of safety

... with a source of clean water

An agglomeration of people

... a place to live, work and play

... an amalgam of residential, commercial, retail, industry, leisure, transport and open spaces, green spaces

... a place of business, busyness and peaceful solitude

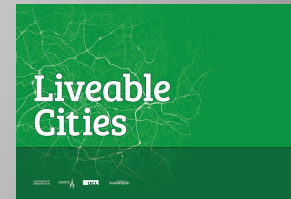
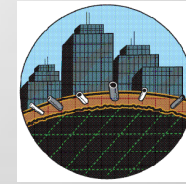
... dynamic 24 hour city living

... a place for biodiversity to flourish – trees, birds, bats

Civil engineers need to support all this by *supply* (water, electricity, gas, telecommunications , etc.), *removal* (wastewater, drainage, solid waste) *and facilitation of movement* (people, goods)

... we create, and add to, (interdependent) infrastructure systems

... supporting the UK's city systems and the UK's system of cities



Resilience Through Innovation

Critical Local Transport and Utility Infrastructure

What Can The Subsurface Do For Us?

The ground is part of the dynamic natural environmental system that interfaces with cities and citizens ... *through the interaction of heat, water, chemical and biological phenomena and physical stresses*

This interaction is modified by what goes on in cities and the changing context in which cities exist

... *population growth*

... *increasing urbanisation*

... *changing demography (e.g. an ageing population)*

... *climate change (e.g. flooding, droughts)*

... *resource scarcity (water security, food security, energy security)*

... *infectious diseases*

... *(international) migration*

... *CO₂ emissions, and GHG emissions more generally*

Yet when dealing with these changing contexts, the need for sustainability and resilience persists

What Can The Subsurface Do For Us?

Humans first encountered the ground in its natural state

... but in making provision for urban living the ground has been (anthropogenically) altered in several ways at different times

This alteration has been driven by the multitude of functions for which the ground has been and is being used :

... a source of resources (water, construction materials, heat, fuel)

... a place of storage (water, waste of many types)

... physical structural support (buildings, infrastructure, utilities, embankments, slopes, basements)

... a moderator of flows (canal liners, drainage media, earth dams)

... a growing medium for green infrastructure (trees)

When exploiting the ground to deliver these functions, we typically do so with a specific purpose in mind

... our 'engineering solutions' typically create a long-term legacy

... this locks in societal behaviours and locks out other solutions

What Can The Subsurface Do For Us?

What if we treat the ground in terms of Ecosystem Service Provision?

Cities derive ecosystem services from what nature provides:

... the flora and fauna, water, the atmosphere – ***the ground?***

Considerable attention is paid to air quality, water quality, environmental health and biodiversity in cities

... ‘ground quality’ is universally overlooked

“A nation that destroys its soil, destroys itself” – President Roosevelt

It might be out of sight and out of contact

... but it is nevertheless a vital resource in need of recognition, protection and enhancement

By describing the multiple functions of the ground in terms of ‘ecosystem services’, we can explore how to assess, enhance, monitor and manage the balance between a city’s requirements of its sub-surface soils and the engineered and natural systems in cities

How Might We Rethink Ground Exploitation?

Urban engineering is becoming ever more aware of the importance of the ground as an enabler of healthy future urban living – healthy for individuals, society collectively and the planet.

This has led to the ambition, emerging from the research consortia focussing on future cities and infrastructure systems, for:

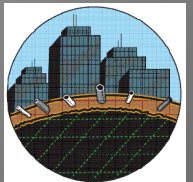
... the need for the ground to be multi-functional

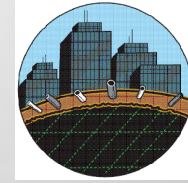
... and for engineers to employ their ingenuity to maintain, and enhance, this functionality for future exploitation / generations.

This is the thinking that underpins Birmingham's contribution to the recently-announced £138m investment in UKCRIC's capital facilities

... UKCRIC being the UK Collaboratorium for Research in Infrastructure and Cities, led by Brian Collins

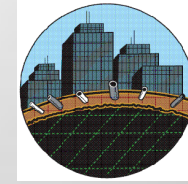
... We are to build a buried infrastructure centre





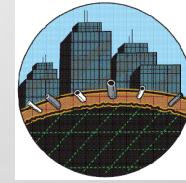
We want our utility services to be invisible
... so we bury them where we can

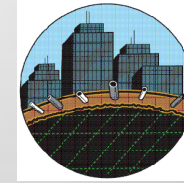
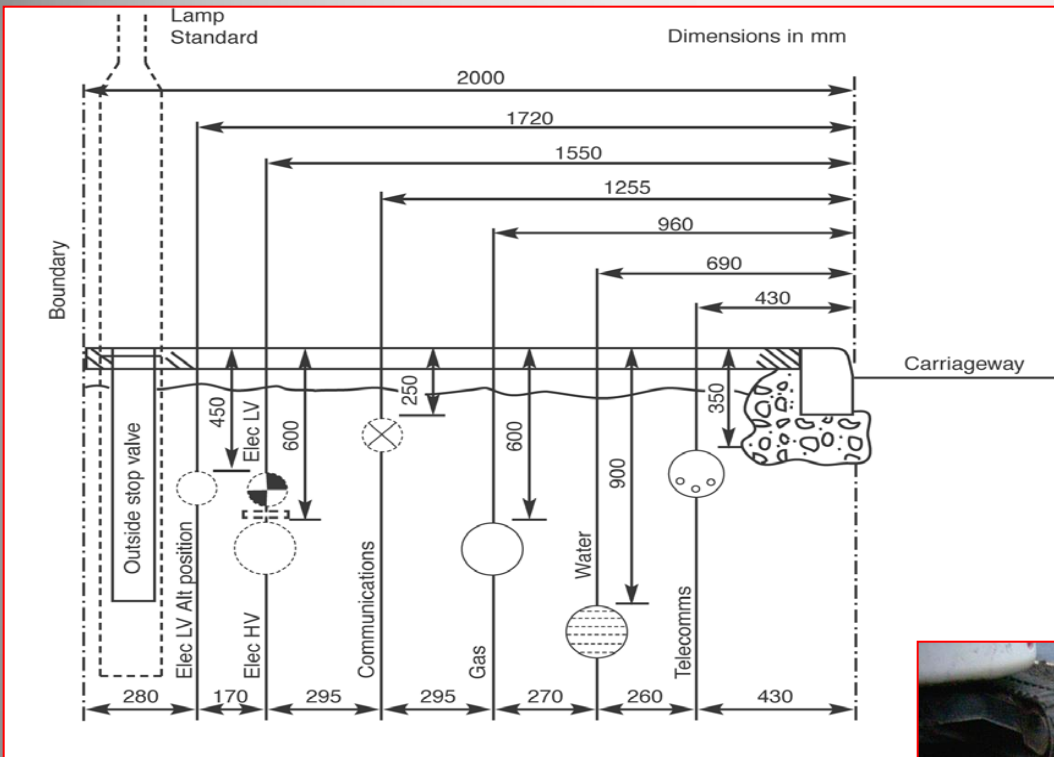
We bury them along our common ground in cities
... beneath the transport corridors, specifically roads
... and our roads are congested



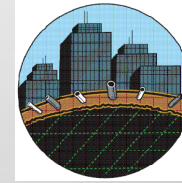
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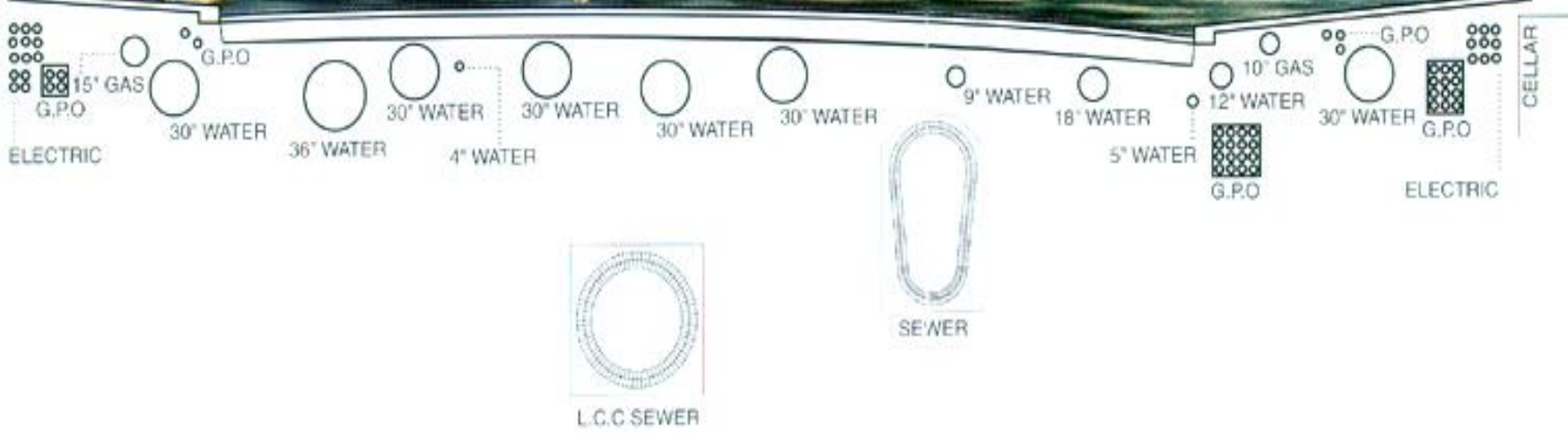




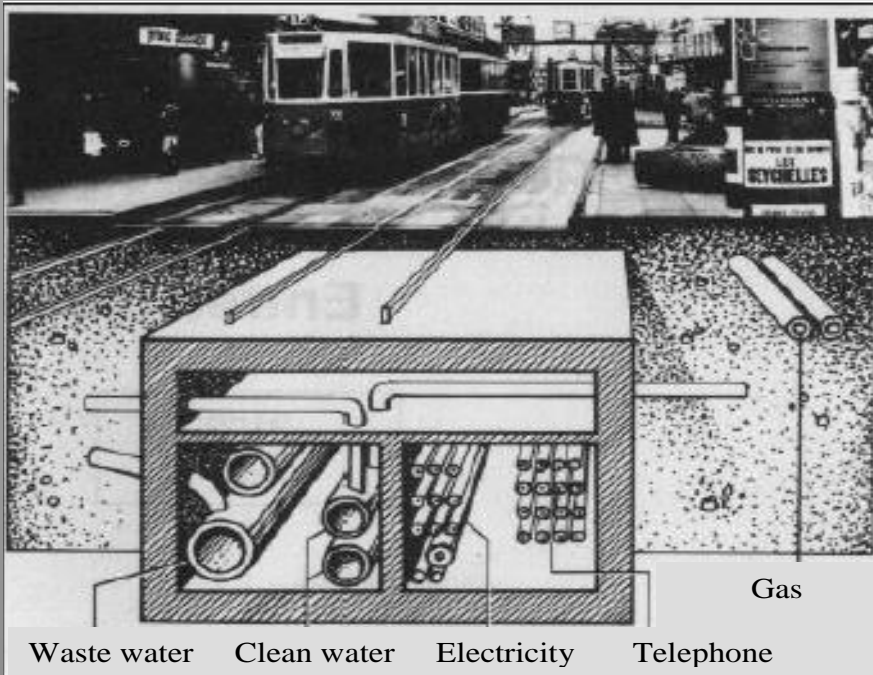
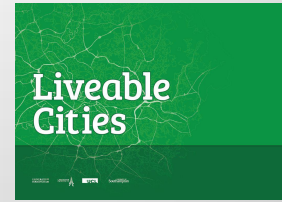
Current Exploitation of the Subsurface



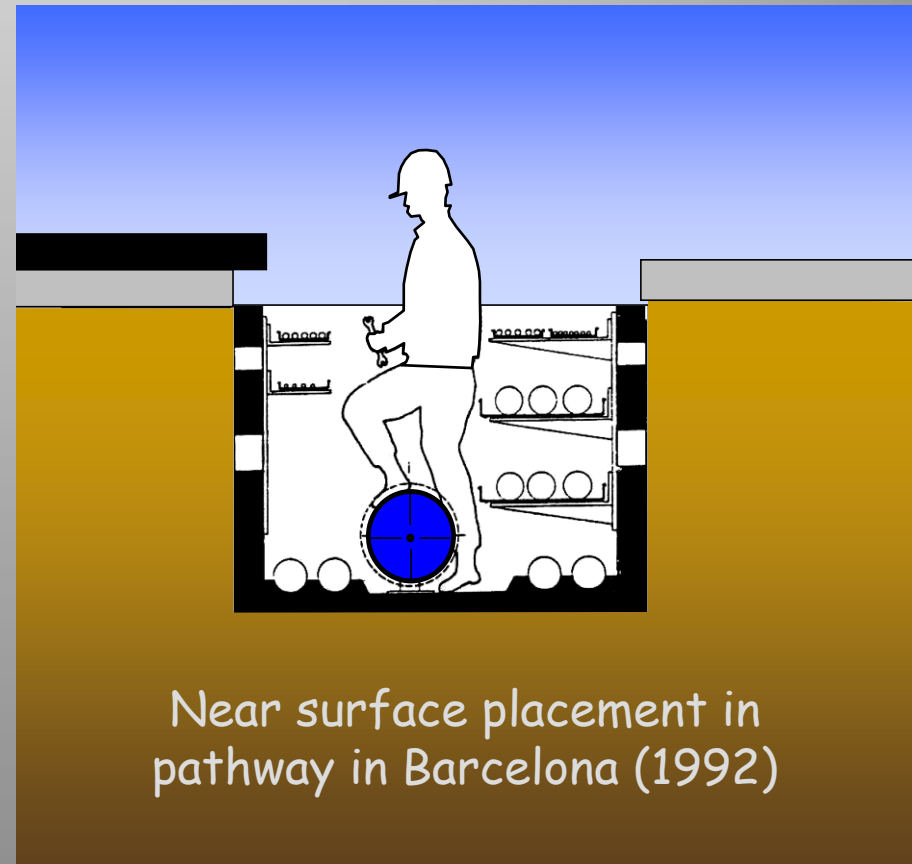
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Alternative Means of Exploitation

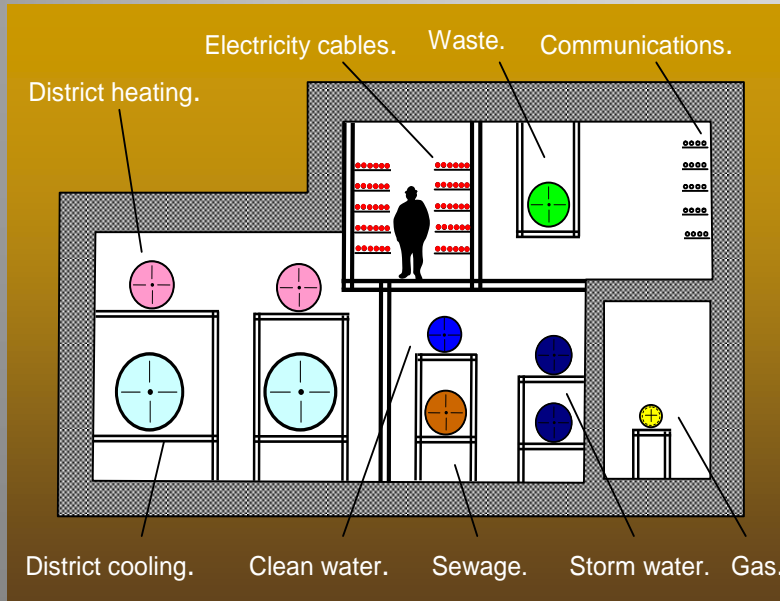
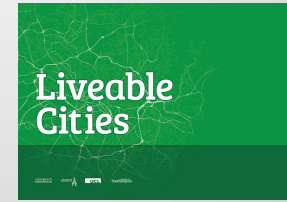


Near surface placement under tramway in Geneva (1972)

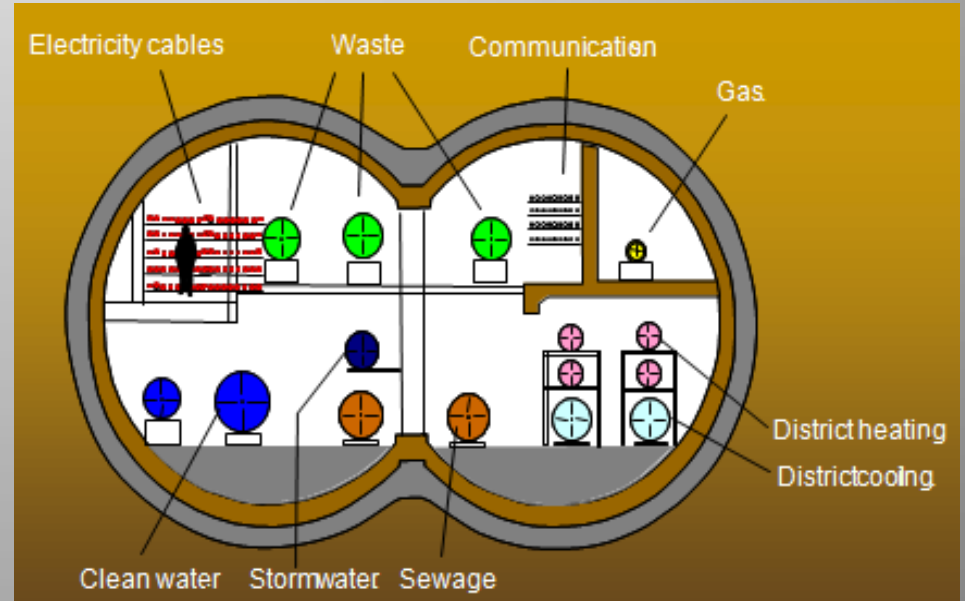


Near surface placement in pathway in Barcelona (1992)

Alternative Means of Exploitation

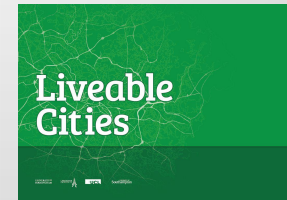


'cut and cover' in Japan (2002)

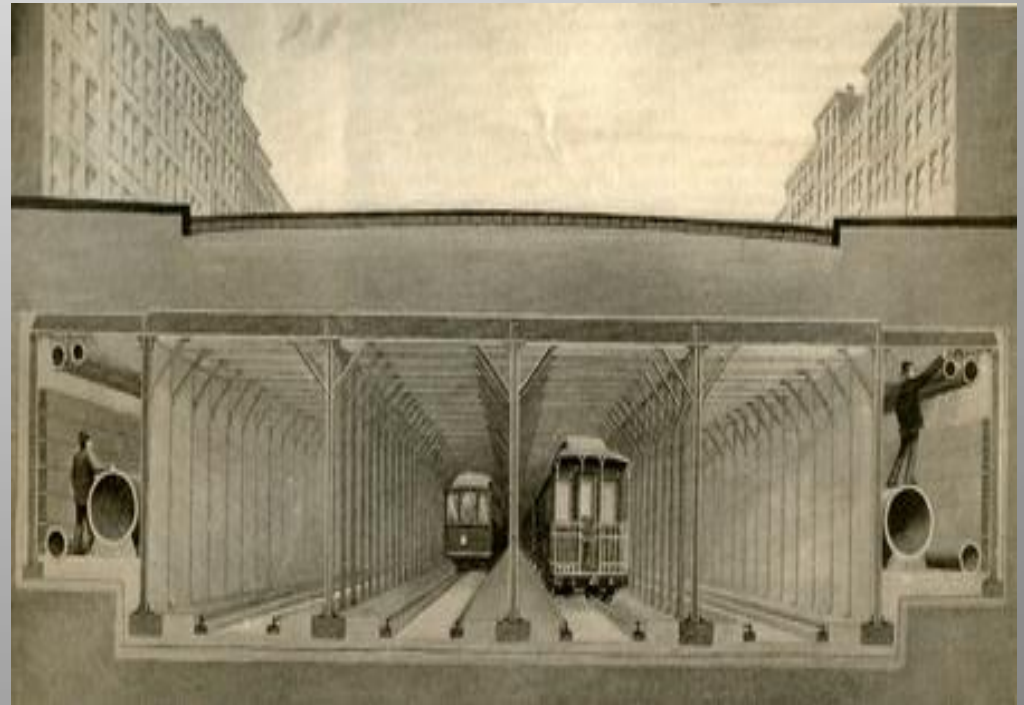


'DOT tunnelling' in Japan (2002)

Alternative Means of Exploitation



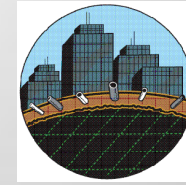
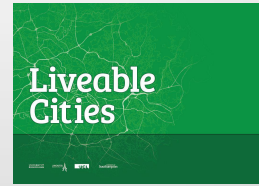
Traditional placement method in 1880s



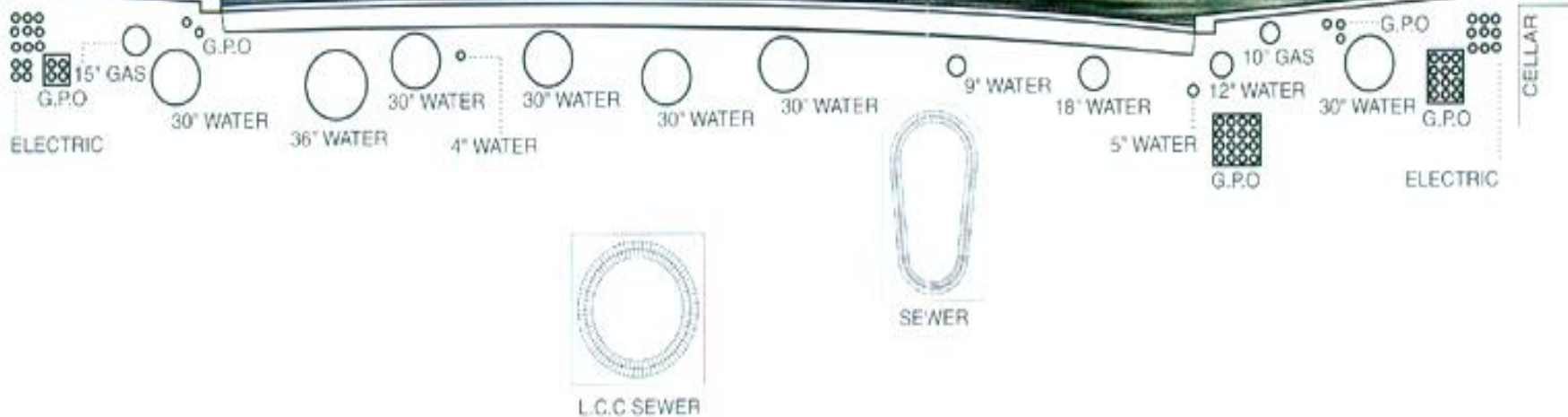
Concept design for a multi-utility tunnel in 1901 (Scientific America)

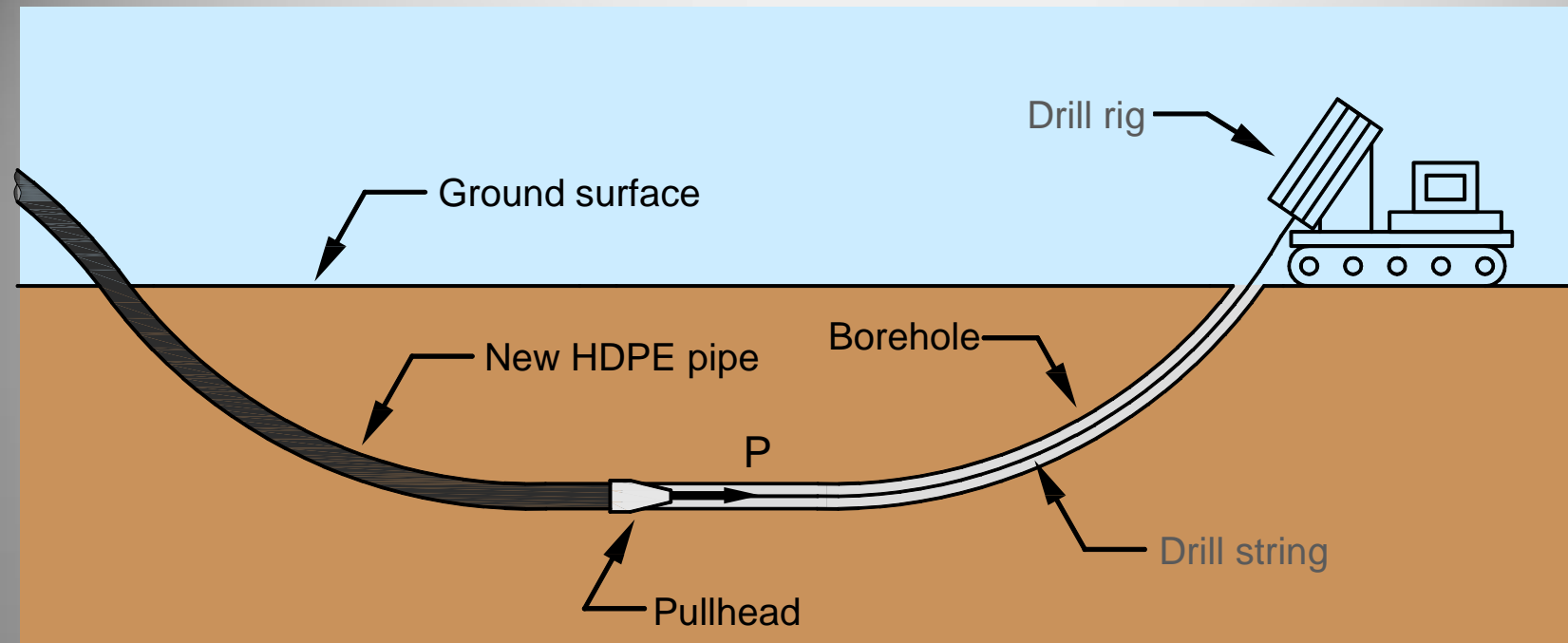
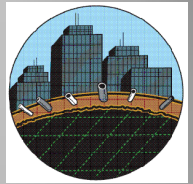
The concept for alternative approaches existed over 100 years ago...

Competition for Space



Tree
Roots ?



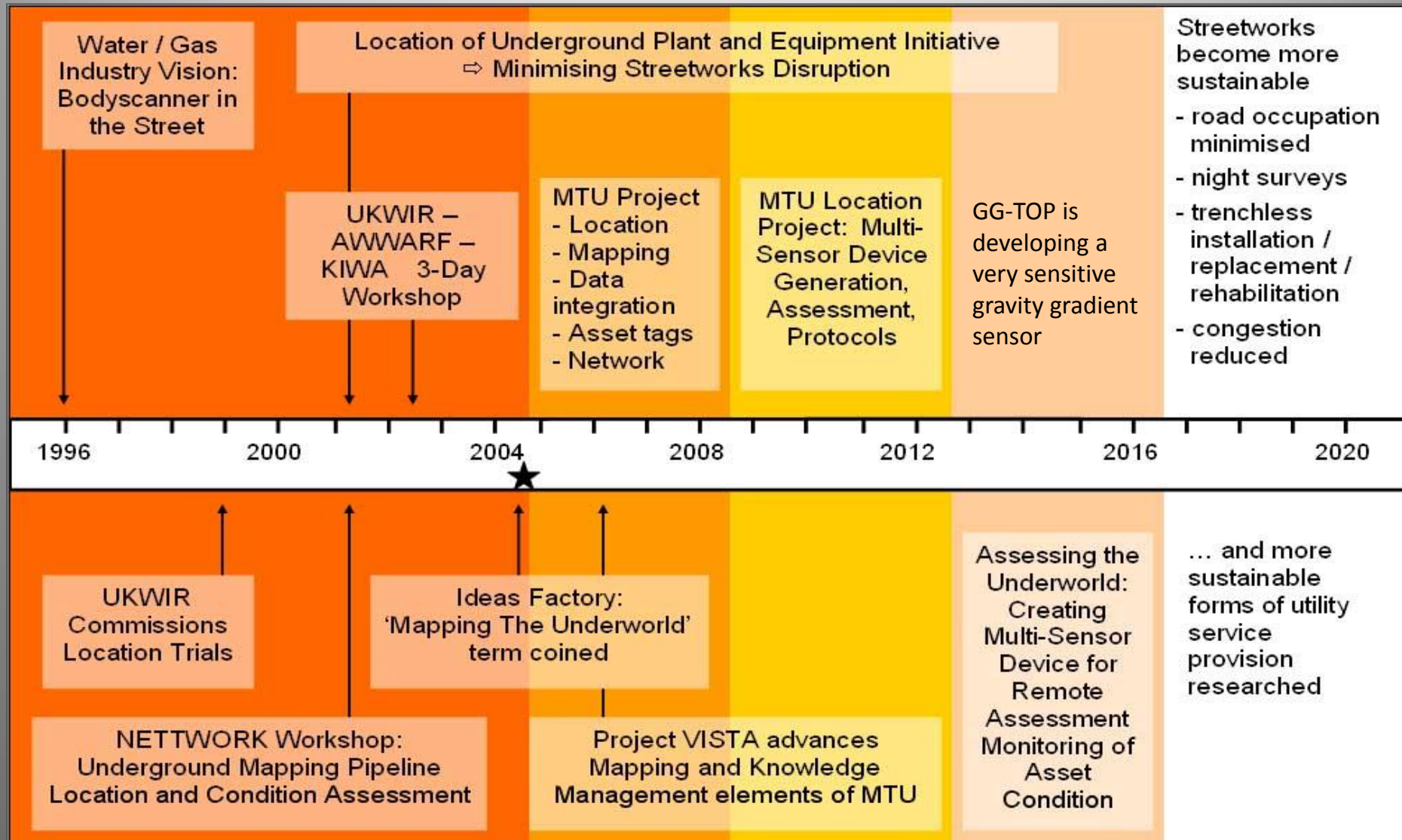
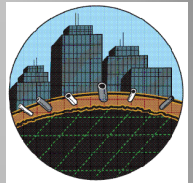


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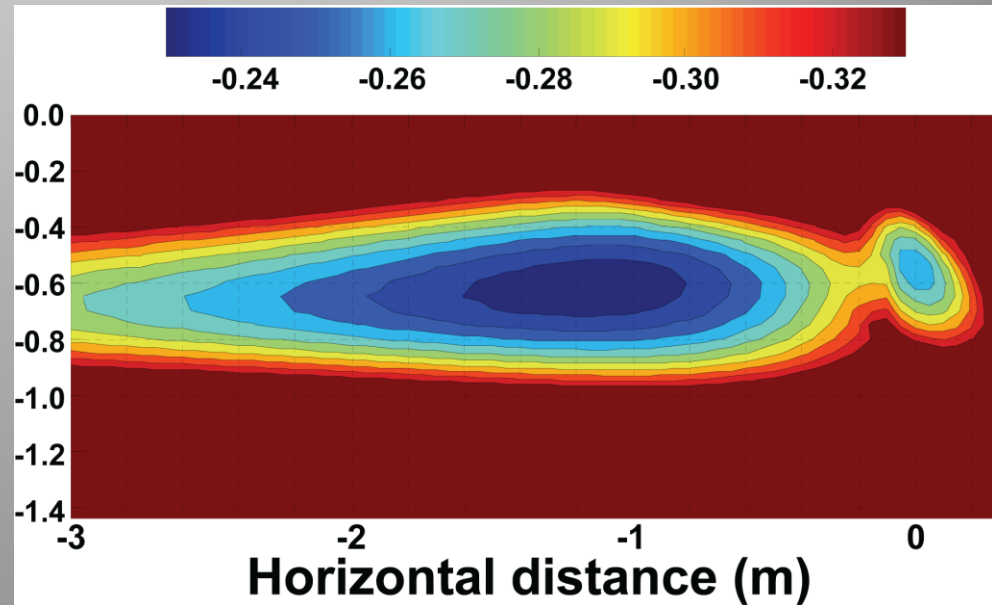
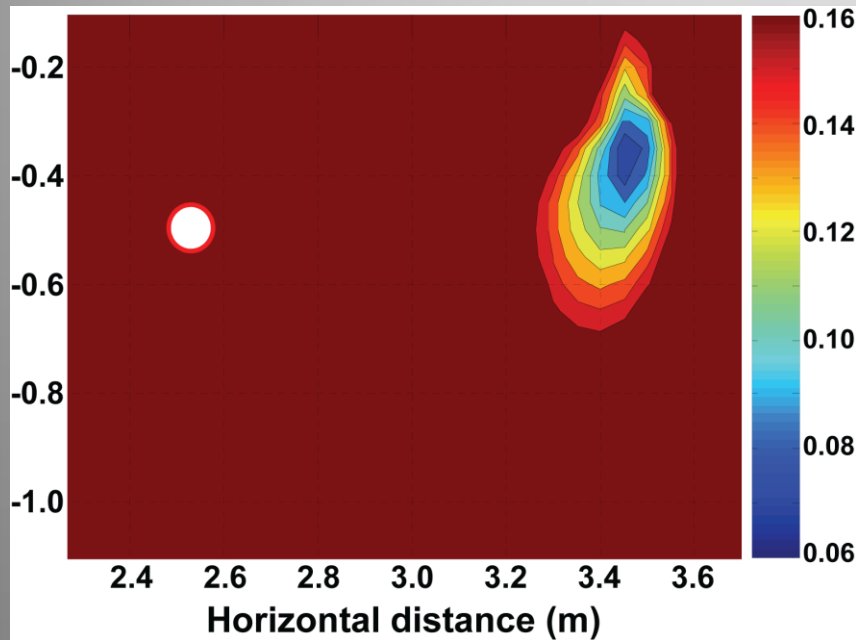
We could go trenchless – directional drilling could install them deeper
... but then we are blighting the underground space

Visualising the Subsurface – Mapping the Underworld



MTU's Development of a Multi-Sensor Device

Passive Magnetic Fields



Health of the Underworld



Assessing the Underworld is using MTU's multi-sensor platform, with amendments and additions, and robotic in-pipe pigs to

... assess the condition of buried pipelines and cables

... and of the ground in which they are buried

... and of the road infrastructure that overlies it

For example, a deteriorated water pipeline gives a different response than a pristine pipeline



Our next phase is Valuing the Underworld



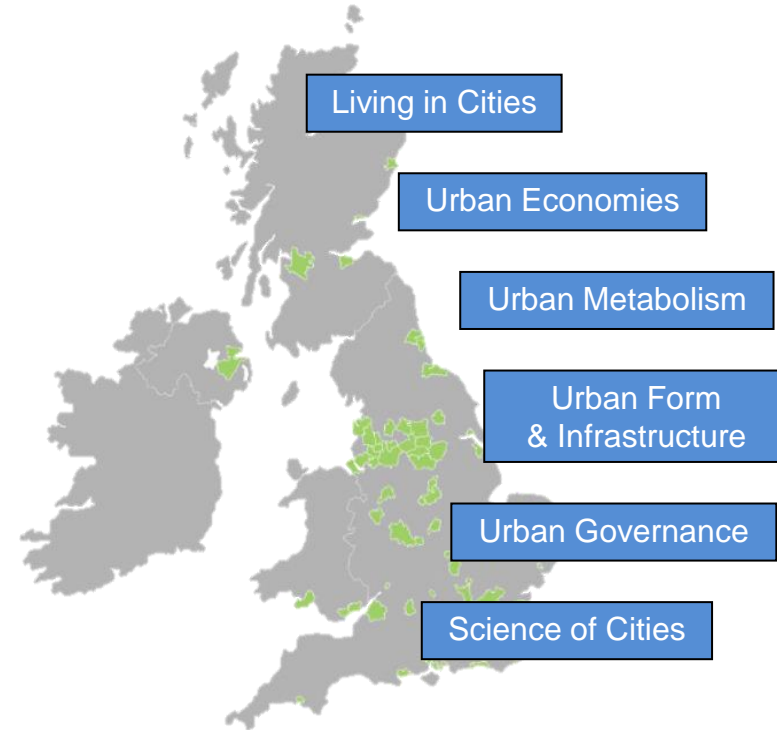
Foresight Future of Cities: The role of the subsurface

Project aim:

Provide central and local government with an evidence base to support decisions in the short term which will lead to positive outcomes for cities in the long term

There are many core questions, including:

- What is a successful city?
- What can the subsurface do for us?
- How do cities grow and develop?
- Can we make cities more sustainable?
- What are the options for city governance?
- How will city ambitions relate to national frameworks?



6 KEY THEMES



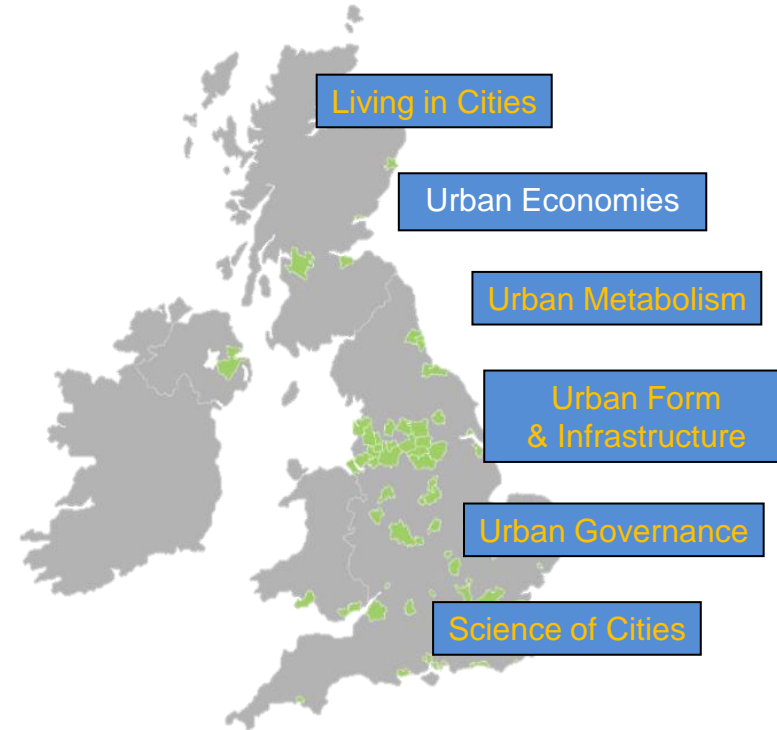
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6 KEY THEMES

Liveable Cities

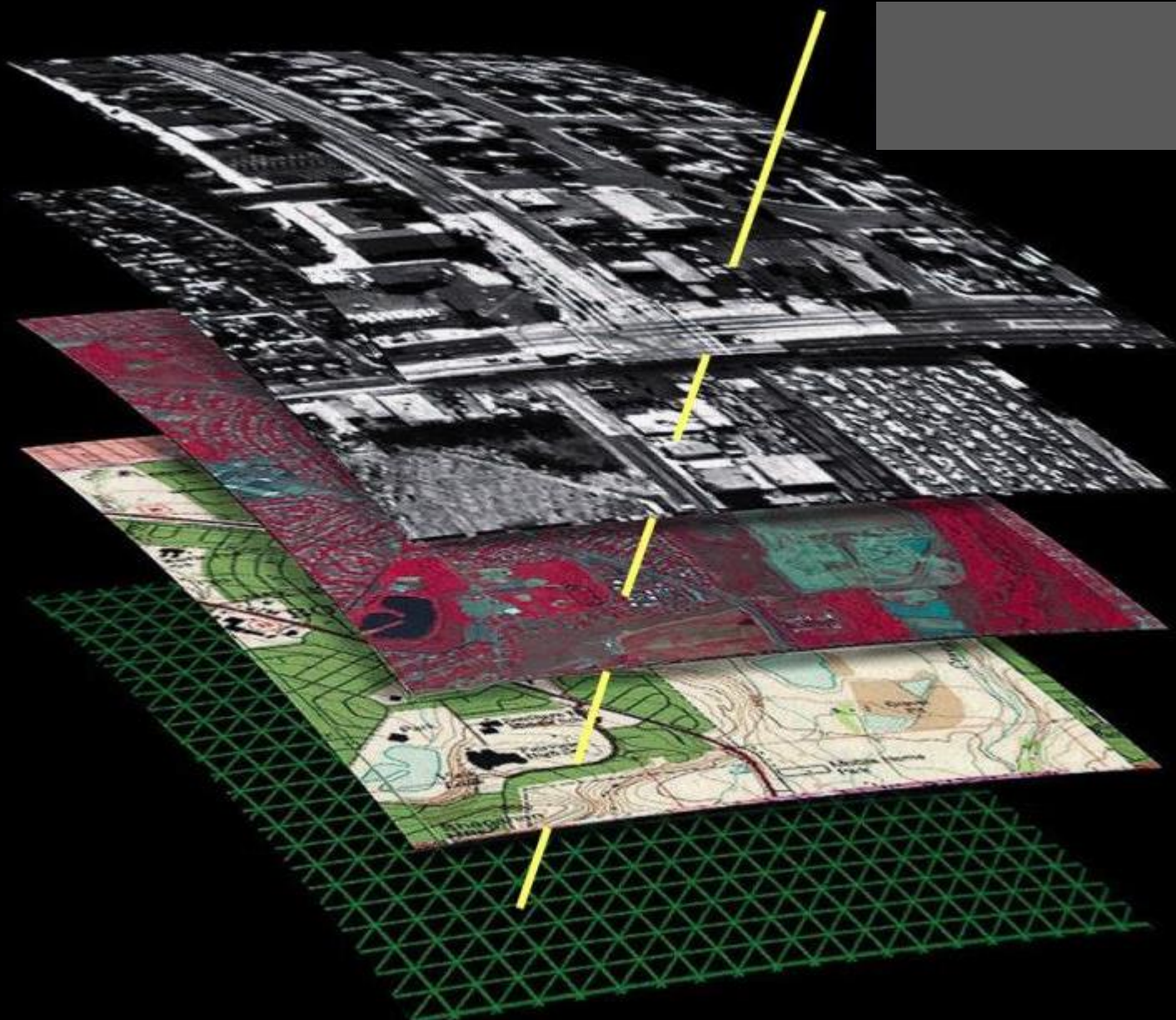
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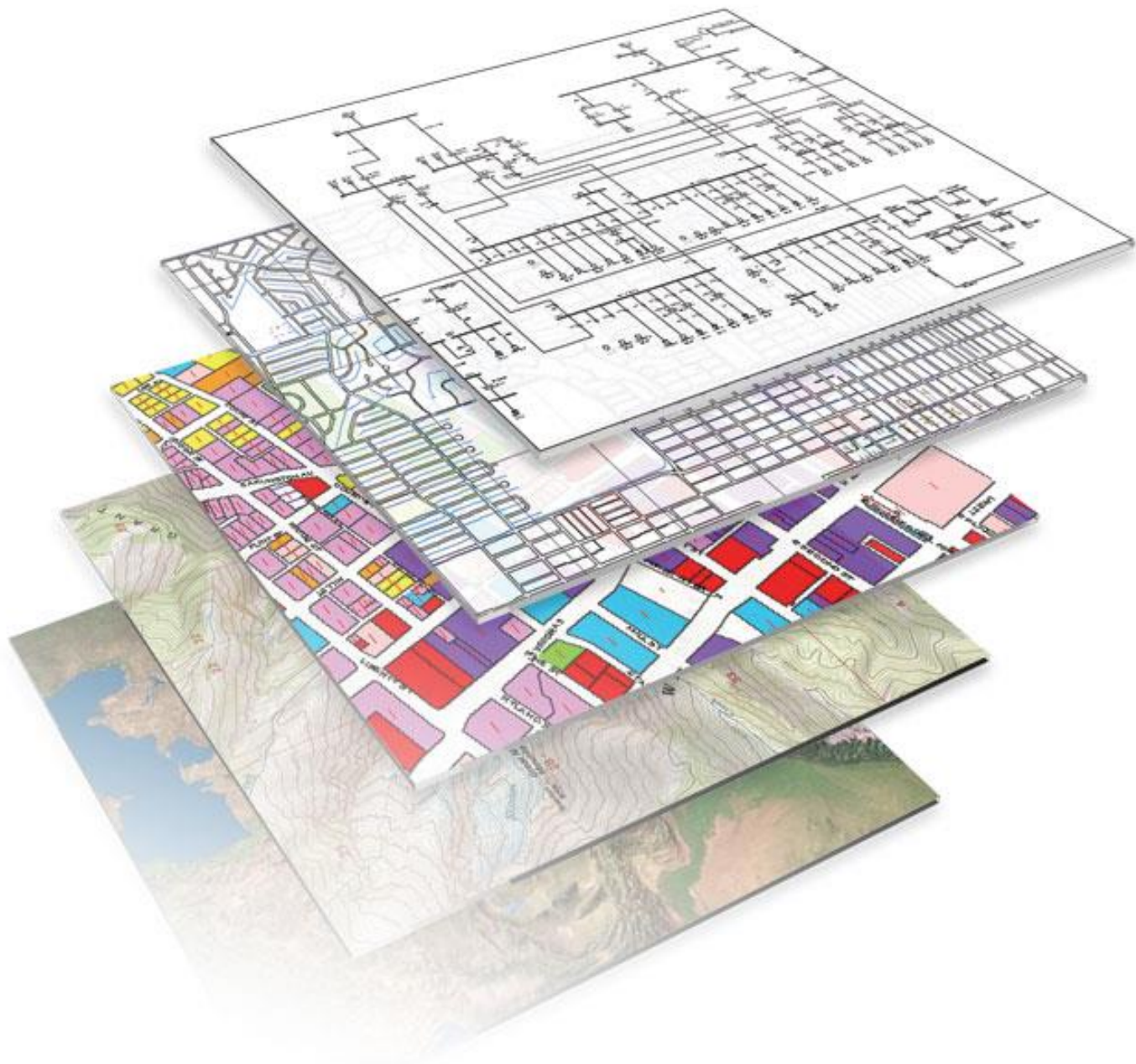


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Foresight – Aspirational Scenarios



We're defining a set of principles that combine to describe the characteristics, or functions, of future cities we aspire to

- *surveys of the aspirations of individuals from across society*
- *sector-focussed workshops (e.g. retail, environmental scientists, transport, heritage organisations, utility service providers, healthcare professionals, creative artists, etc.)*
- *literature study (five city typologies model)*

Every city is unique, having developed as a result of its current and historical context, so for our case study cities

- *we are applying the 'aspirational principles' to explore how cities might be re-engineered*
- *And hence what future infrastructures should provide*

Research Challenges

Phase 1 - Research Challenges

Future Scenarios *Urban metabolism*

Performance of Cities *Energy*

Wellbeing and Mobilities

Policy and Governance

Phase 2 – Intensive cross-consortium thought experiments

- *The Sharing City*
- *Radical Mobilities City (a 'no cars' Birmingham)*
- *The Ecosystem Serviced City*
- *The Rezoned City*
- *The City of Synthesised Flows*
- *The Investing City* – founded on the alternative business models work of ICIF and iBUILD
- *Principles into Practice*



Exploitation of the Subsurface with Foresight



Vision:

- To test the resilience of actions being taken today (today's 'interventions' in the infrastructure web)

Method:

- Identifies intended benefit(s) of our subsurface exploitation
- Identifies the necessary conditions for each benefit to be delivered and established whether they are in place today
- Assesses the necessary conditions in the four futures
 - ... will the necessary conditions remain in place?

Provides analyses to determine the robustness of 'solutions' to future changes and facilitate their modification (if necessary)

Fortress World

- In this scenario, powerful actors organise themselves into alliances in an effort to safeguard their own interests
- The UK divides into two groups: an authoritarian elite who live in interconnected, protected enclaves ('gated communities') controlling access to resources, and an impoverished majority outside



Market Forces

- In this scenario, current demographic, economic, environmental, and technological trends unfold without major surprise, with convergence toward today's structures
- Competitive, open markets drive UK development. The self-correcting logic of the market is expected to cope with problems as they arise
- Sustainability issues are addressed more through rhetoric than action
- Materialism and individualism spread as core human values, whereas social and environmental concerns are secondary



Policy Reform

- In this scenario, co-ordinated government action is initiated to reduce poverty and social conflict while enhancing environmental sustainability
- Strong government policies and some changes in consumer behaviour emerge to support environmental and social consciousness. Such policies help to negate trends toward high distributional inequity.
- Tensions still exist between the continued dominance of conventional ideologies and values and key sustainability goals



New Sustainability Paradigm

- In this scenario, new socio-economic arrangements and fundamental alterations in societal values result in changes to the character of UK urban civilisation
- The notion of progress evolves and a deeper basis for human happiness and fulfilment is sought
- An ethos of 'one planet living' pervades, facilitating a shared vision for a more sustained quality of life, now and in the future



The Urban Futures Method



Solution, intended benefit

Fortress
World

Market
Forces

Policy
Reform

New
Sustainability
Paradigm

The Urban Futures Method



Solution, intended benefit

Necessary Conditions

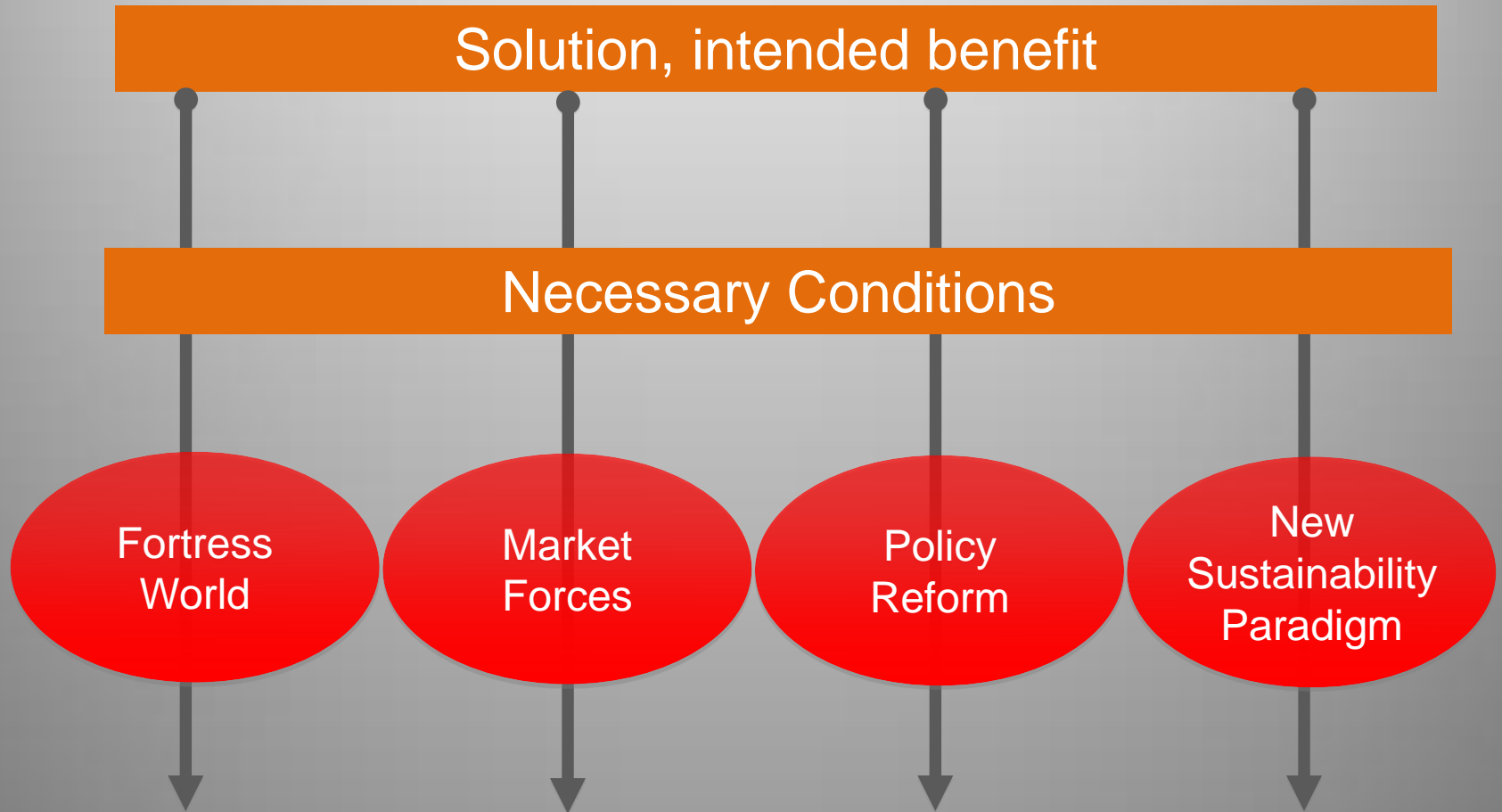
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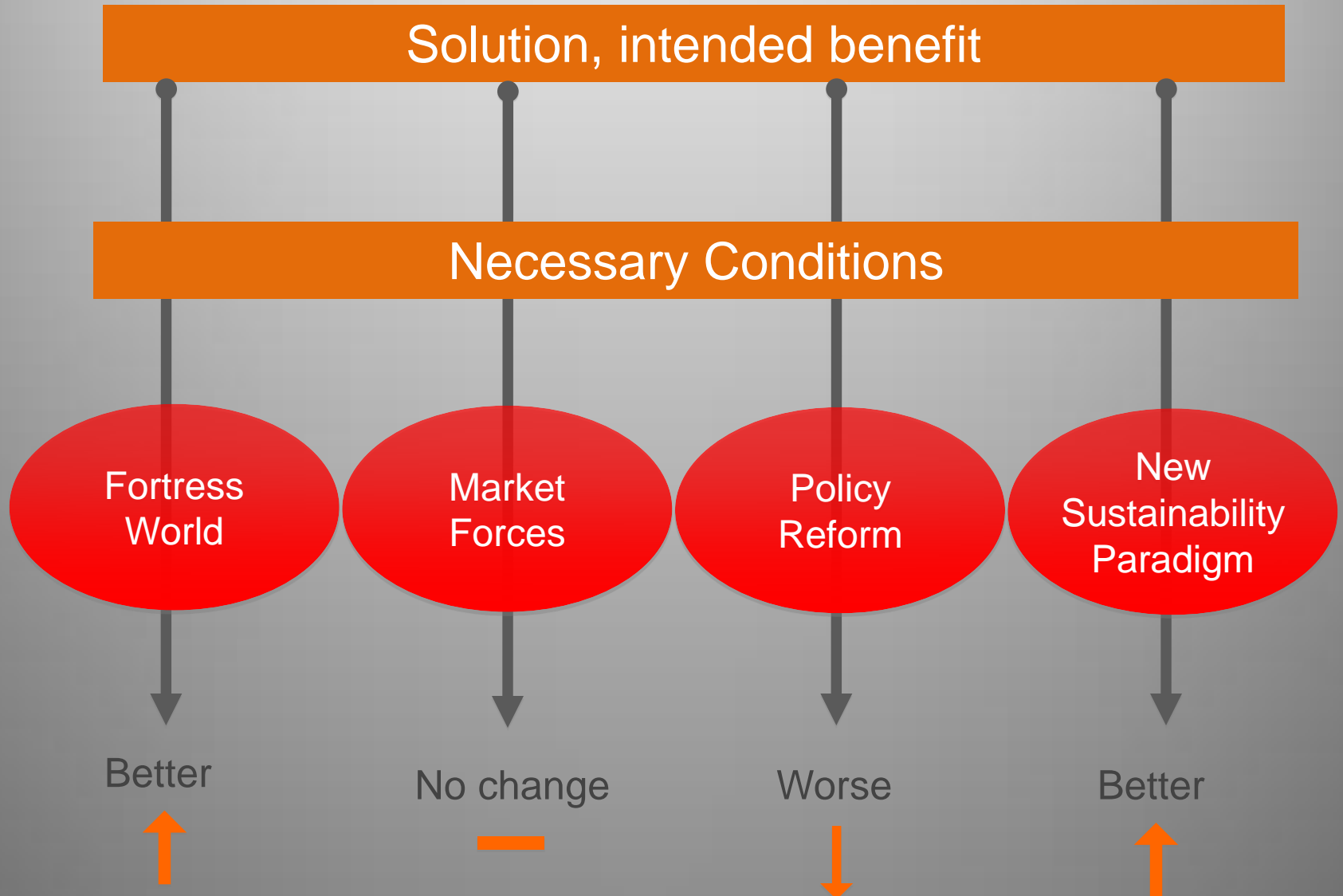
Policy
Reform

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Paradigm

The Urban Futures Method



The Urban Futures Method



Analysis Methodology



Solutions
and Intended
Benefits

Necessary
Conditions

Analysis in
Four
Scenarios

Implement
Robust
Solutions

Implement
Vulnerable
Solutions

Adapt
Solutions

Conclusions

We need to know the location and condition of buried infrastructure

- *Mapping the Underworld*
- *Assessing the Underworld*

Aspirational futures will inform us of future infrastructure needs

- *Liveable Cities*

There are ways to test whether today's infrastructure interventions are likely to continue to deliver their functions in the far future

- *Urban Futures*

And there are new opportunities to inform the infrastructure debate

... parallel programmes are studying infrastructure interdependencies and novel business models, looking at how value is created and captured, and how investment propositions can be improved

- *iBUILD* (locally) and *ICIF* (nationally)

Science-based policy options for the UK's City Systems and the UK's System of Cities, looking forward to 2040 and 2065, are emerging

- *Foresight Future of Cities*

