Newcastle University

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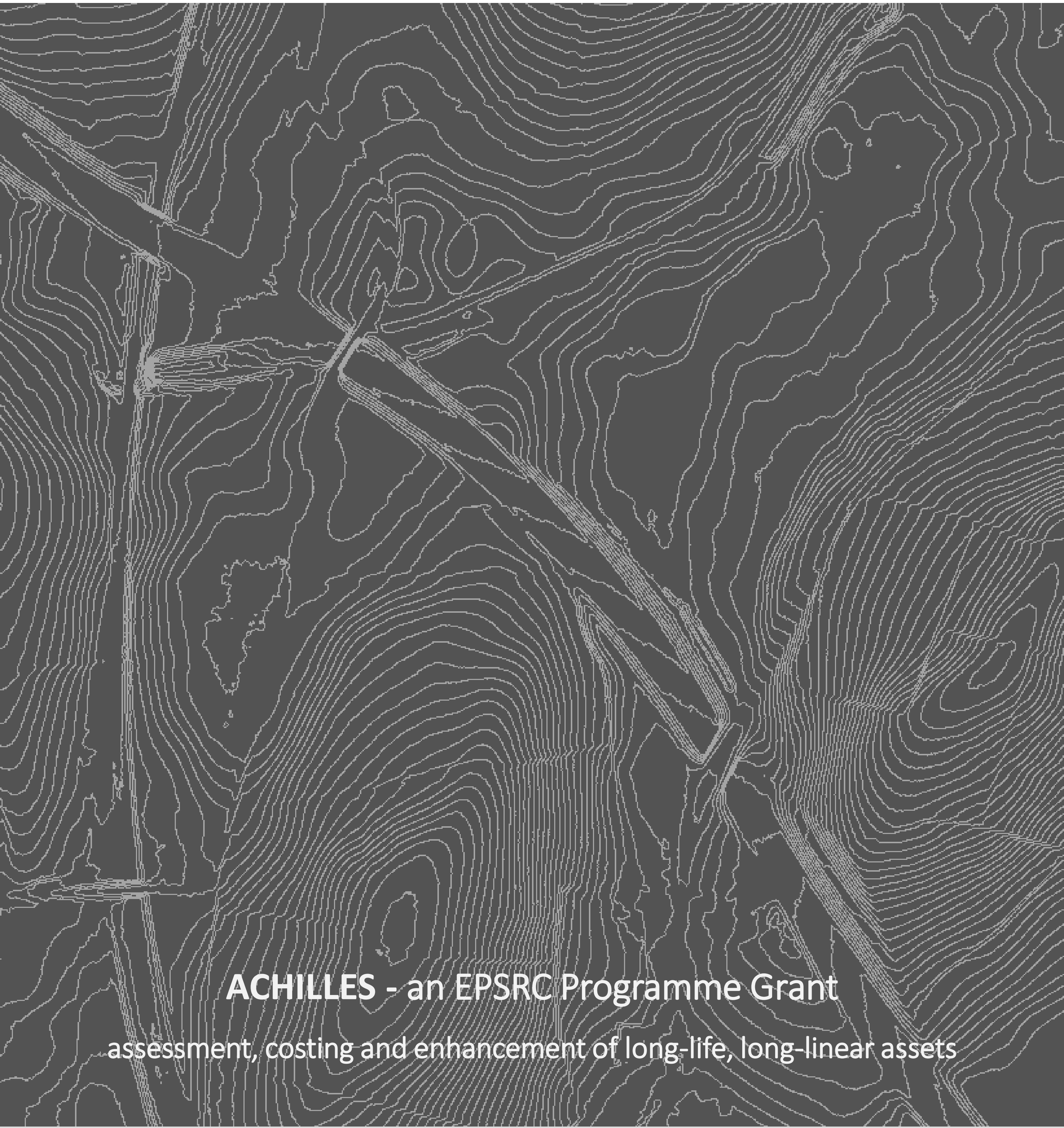
ADDRESSING INFRASTRUCTURE'S ACHILLES HEEL



ACHILLES - an EPSRC Programme Grant

assessment, costing and enhancement of long-life, long-linear assets

Healing Achilles

addressing deterioration of long-linear infrastructure assets for a more reliable future

developing knowledge and tools for predictable and improved long-term asset performance at an affordable cost

What are long-linear infrastructure assets? Long Linear Assets (LLAs) are fundamental to the delivery of critical services over long distances (e.g. road & railway embankments and cuttings, pipeline bedding, flood protection structures). The focus of ACHILLES is on the geotechnical aspects of these assets.

Why is there a problem?
Infrastructure is fundamental to our economy and society. It is one of the ten pillars of the UK Industrial Strategy. Geotechnical LLAs are a major infrastructure component (e.g. earthworks) and fundamental to the delivery of critical services over long distances. Earthwork failures break links in these vital chains.
There are some 10,200 km of flood defences in the UK; 80,000 km of highways; 15,800 km of railways. Failure of these assets is common. For example, in 2015 there were 143 earthworks failures on the national rail network.
The resulting cost of failure is high. For example, for Network Rail, emergency repairs cost 10 times more than planned works, which cost 10 times more than regular maintenance. And vulnerability to these failures is significant; there are some 748,000 houses with at least a 1:100 annual chance of flooding and derailment from slope failure is the greatest infrastructure-related risk faced by our railways.

What are the main challenges?
At present the exact reasons for and timing of failure are poorly understood. Unanticipated failures cause severe disruption with associated high costs, and damage to reputation.
Asset owners have access to large quantities of failure and condition data from their networks (recently enabled by technological advances in data capture and storage).
Current approaches to address future failure based are largely based on past experience and this limits realistic extrapolation to future performance.

s the infrastructure becomes older its condition deteriorates. In addition, it is ever more intensively used and subject to increasingly extreme weather patterns. These factors combine to significantly increase the likelihood of future failures. Climate change has been identified as one of the dominant factors driving this change.

The challenge is to bring together new advances in research and technology with industry-led advances in design and asset management practice from different LLAs to reduce the risks posed to infrastructure systems from deterioration and future change. The research outcomes will inform timely commitment of resources to address these risks.

Who is ACHILLES working with?
The ACHILLES consortium has a strong core network of people and organisations through previous Research Council funded projects and national networks which investigated sustainable management and resilience of transport infrastructure. Examples of previous research of the consortium includes projects such as BIONICS, 2004-2009, CLIFFS, 2005-present, FUTURENET 2009-13 and iSMART 2013-17.

It is an essential component of the Programme Grant to regularly engage with stakeholders. ACHILLES also benefits from intensive industrial collaborations.

The Programme Grant is supported by International External Advisory Board and Industry-led Impact Advisory Group members, all of whom bring different and invaluable contributions to the research through their experience.

The ACHILLES Programme Grant brings these contributions together and couples these with statistical advances to enable rigorous use of network data, and economics to assess the value of design, monitoring and mitigation options.

Why now?
Current techniques can estimate future rates of deterioration that might lead to failure in transport infrastructure slopes, but are difficult to scale up, do not capture all drivers of deterioration relevant to all LLAs, are poor at dealing with uncertainty and heterogeneity, and lack rigorous validation against representative field data.

ACHILLES will build on and enhance the core consortium's complementary skills, deep understanding of the problem, reputation and the momentum of industry interactions.

As deterioration is currently an industry top priority concern we will link into ongoing industry-driven projects. The timing of the development of the National Infrastructure Commission assessment method provides a further opportunity to maximise impact.

Our long-term vision is for the UK's infrastructure to deliver consistent, affordable and safe services, underpinned by intelligent design, management and maintenance.

THE LONG-TERM VISION

The ACHILLES programme grant will deliver research outcomes that will contribute to the UK's infrastructure ability to deliver consistent, affordable and safe services, underpinned by intelligent design, management and maintenance

PHASE 1
performance, simulation, measurement, uncertainty

KEY STAGE GATE
priorities, focus, scope, impact

PHASE 2
solutions, tools, strategies, decisions

Research Challenge RC1
Deterioration processes

Research Challenge RC2
Asset performance - long linear assets

Research Challenge RC3
Forecasting and decision support - network analyses

DETECT
MITIGATE
FORECAST

Integration along cross-cutting themes
performance, data, simulation/modelling, monitoring/measurement, uncertainty & heterogeneity, design & decisions

What is ACHILLES going to do? Government investment in infra-structure (digital, energy, transport, water, flood defence) must deliver safe, resilient and affordable services that meet societal need. The functioning of infrastructure systems is dependent upon the ground beneath or around its assets (e.g. pylon, pipe or rail track). Tools to assess, monitor, design and repair the ground are fundamental. ACHILLES will deliver these tools.

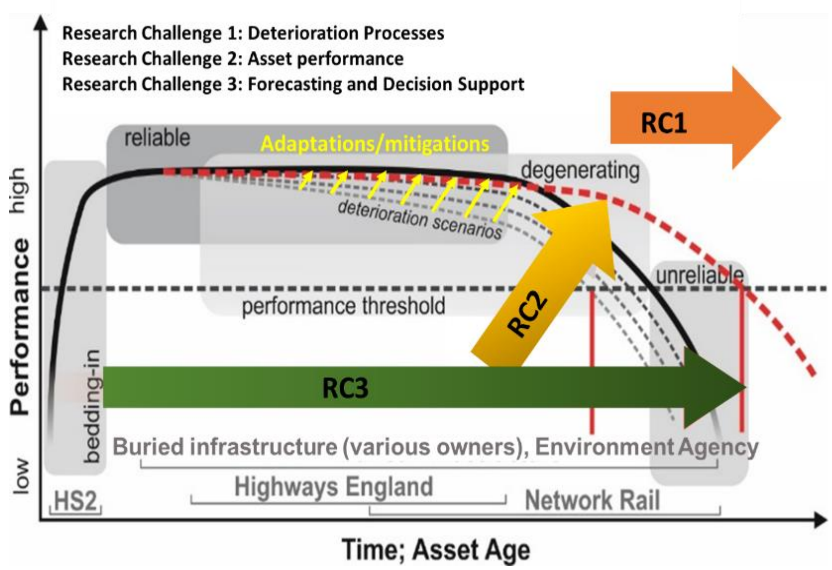
The team have central roles in UKCRIC (the integrated infrastructure labs (Newcastle), the linear infrastructure lab (Southampton), modelling & simulation facilities and the UKCRIC Observatories) and are well positioned to align ACHILLES with these activities.

ACHILLES will combining new scientific understanding of the deterioration of engineered soils with statistical approaches to uncertainty and hetero-geneity. This will enable a fundamentally new approach to efficient and effective management of Long Linear Asset (LLA) performance by addressing three main research challenges illustrated in the diagram.

The Research Challenges
RC1 Deterioration Processes will provide understanding of material scale deterioration – from nano (surface chemistry of clays) through to macro (lysimeter) scale. The current state-of-the-art does not consider cross scale conceptual models of deterioration; existing constitutive models are severely limited in their ability to capture deterioration. Earth assets suffer deterioration resulting from fissuring, loss of suction, chemical changes (weathering), and cyclic development of shear strain. The new insights into deterioration processes will be used to develop performance curves for a range of engineering geo materials, performance indicators (such as strength, stiffness and permeability) and (novel) material-scale mitigation measures.

RC2 Asset Performance will challenge current understanding of deterioration mechanisms at the asset scale, building on long-term monitoring of full-scale assets, stakeholder performance data and coupled numerical modelling (developed in previous research and enhanced by RC1). New asset systems (e.g. buried pipe, flood embankment) will be considered, and new sensors / sensor networks will be added. Evidence-based performance curves for a range of exemplar single assets, strategies for asset-scale deterioration detection, assessments of engineering performance, and design mitigation measures will be produced.

RC3 Forecasting and Decision Support will utilise hierarchical Bayesian modelling to synthesise multiple available data sources with physical models to properly quantify uncertainty for predictions at the network scale. When combined with a deeper understanding of asset-owner decisions, RC3 will develop appropriately calibrated forecast models and probabilistic ranking of potential network-scale interventions to enable optimisation of investment strategies. The cost of (obtaining) different forms and quantities of data, and the reliability of the information it can provide, will be placed in the context of the cost and risk of different decisions



The three research challenges superimposed on a generalised deterioration model for transport earthworks (adapted from Thurlby, 2013)

ACHILLES - Transformative Contributions

1. Understand deterioration of engineered soils
2. Link deterioration to performance over a range of spatial scales
3. Systematically upscale process modelling from material to asset to network
4. Enable sensor technologies for deterioration characterisation and monitoring
5. Understand scientific worth of data
6. Understand status of uncertainty and heterogeneity across all scales
7. Integrate outputs within a decision-making framework

The ACHILLES Team

Newcastle University **Prof Stephanie Glendinning, Prof Darren Wilkinson, Prof Chris Kilsby, Prof Stefano Utili, Dr Ross Stirling, Dr Peter Helm, Dr Mo Rouainia**

Durham University **Prof David Toll, Dr Paul Hughes, Dr Kate Dobson**

Loughborough University **Prof Neil Dixon, Dr Tom Dijkstra, Dr Harry Postill, Dr Alister Smith, Dr Ashraf El-Hamalawi**

University of Southampton **Prof William Powrie, Prof John Preston, Dr Joel Smethurst**

University of Bath **Dr Kevin Briggs**

University of Leeds **Dr Fleur Loveridge**

British Geological Survey **Dr Jon Chambers, Dr David Gunn**

ACHILLES CONTACT

Stephanie Glendinning FICE, Principal Investigator, Professor of Civil Engineering, Dean of Strategic Projects – SAgE Faculty
Newcastle University
Newcastle upon Tyne
NE1 7RU, UK

e stephanie.Glendinning@Newcastle.ac.uk
t +44 191 208 5508

Tom Dijkstra FGS, Academic Programme Manager, School of Architecture, Building and Civil Engineering
Loughborough University
LE11 3TU, UK

e t.a.dijkstra@lboro.ac.uk
t +44 1509 226192

The ACHILLES Expert Advisory Board

Chair **Prof Michael Davies**, University of Sussex

The ACHILLES Impact Advisory Group

Chair **Simon Abbott**, Network Rail