Cambridge Judge Business School
Cambridge Centre for Risk Studies 2017 Risk Summit

BENEFITS OF IMPROVING INFRASTRUCTURE RESILIENCE

Dr Edward Oughton, Research Associate
Cambridge Centre for Risk Studies

Centre for
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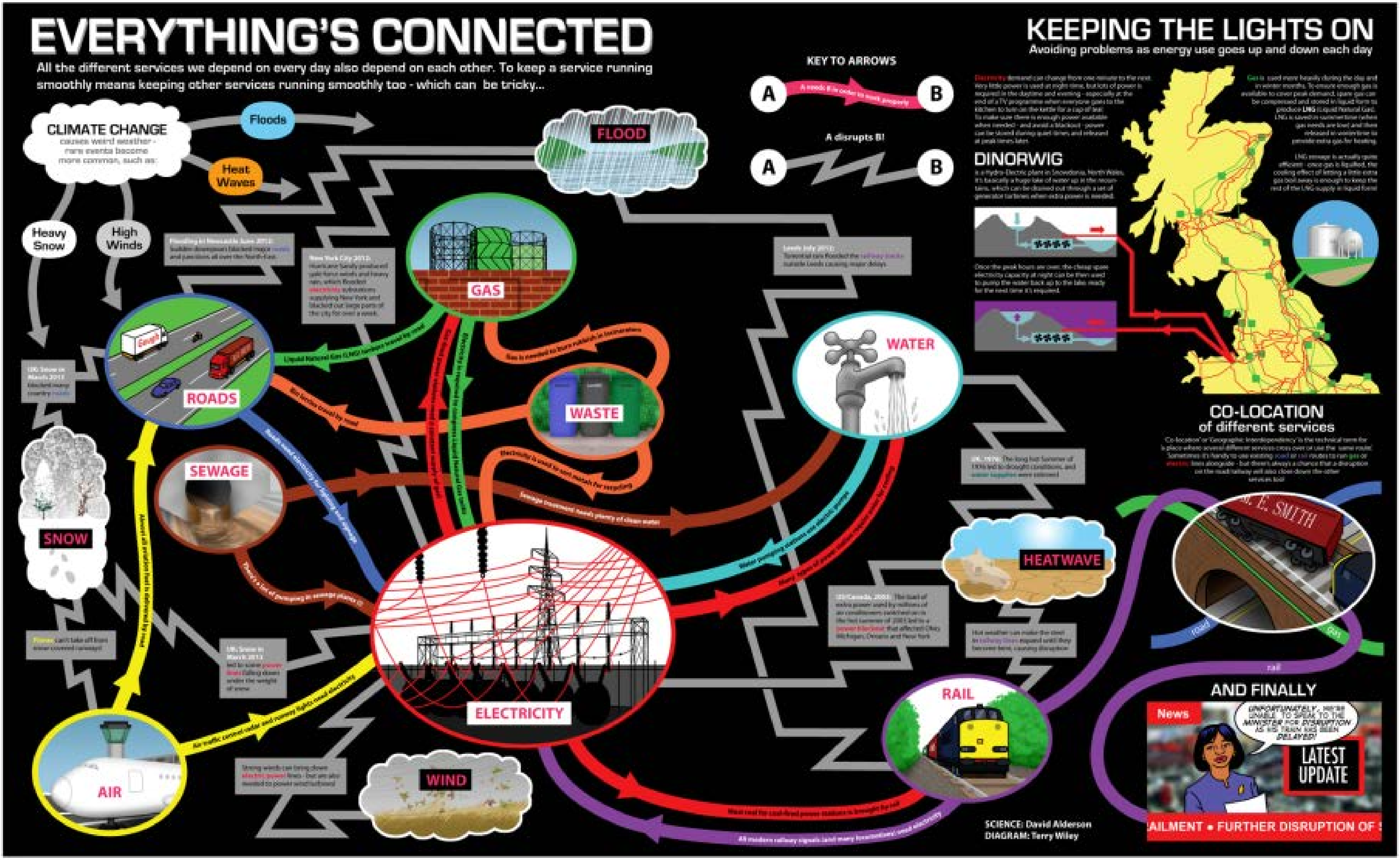
Presentation Overview

1. Current context

2. Infrastructure in Pandora

3. The benefits of infrastructure resilience

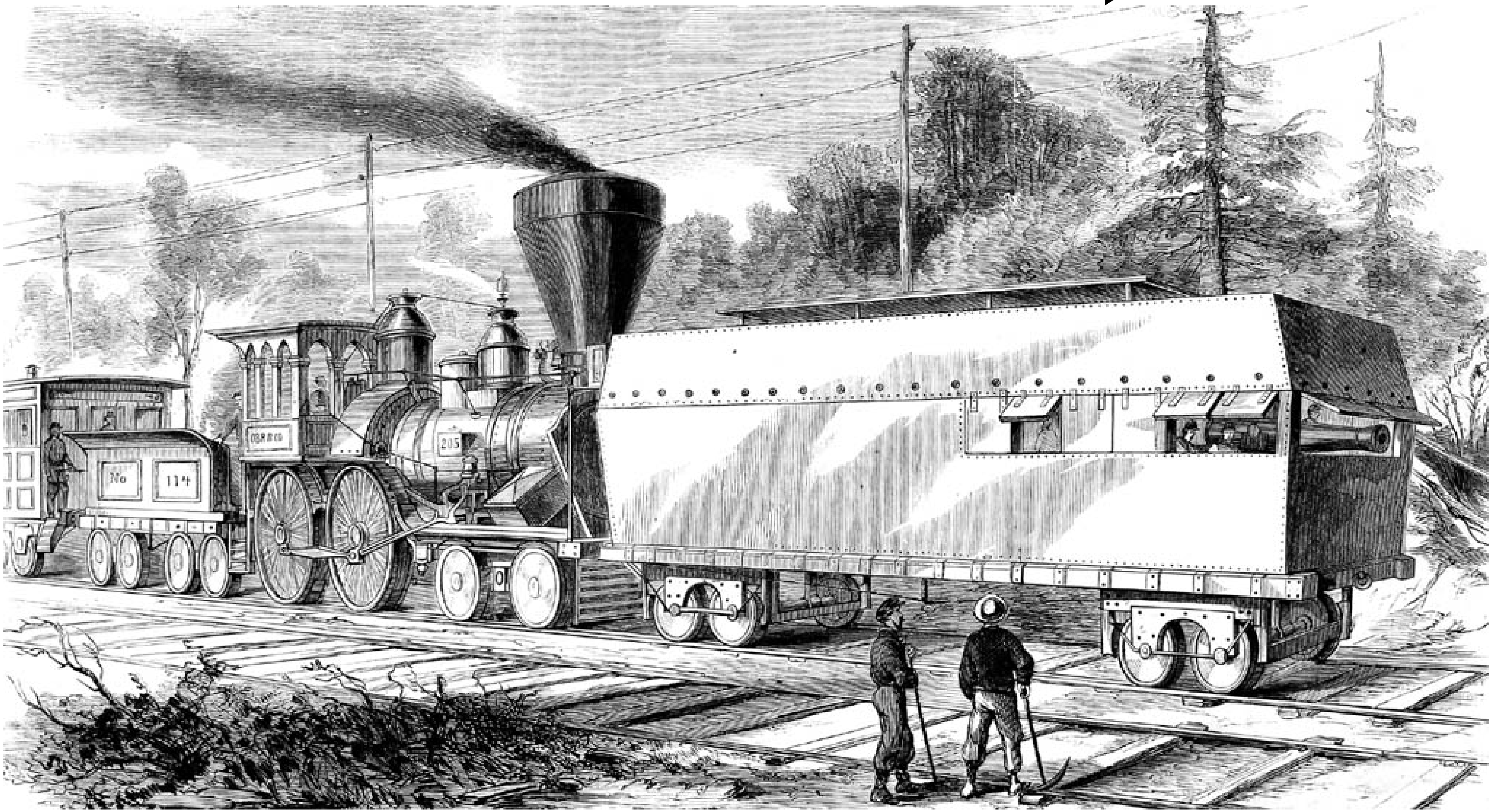
What Are Infrastructure Interdependencies?



Infrastructure Interdependencies

The Telegraph

Not a new development...



…but they are becoming much more pervasive!

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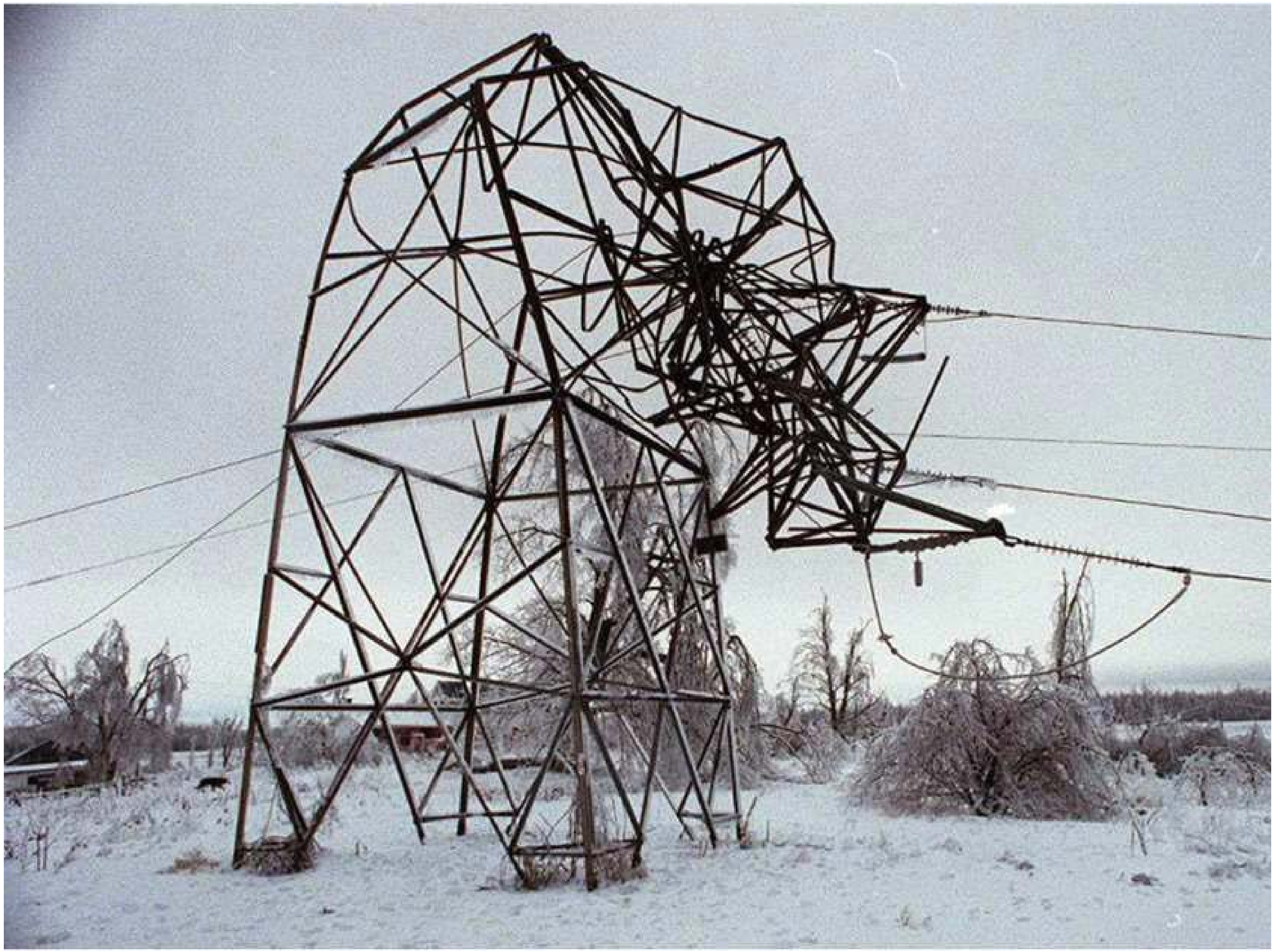
Canada (1998) Ice Storm



USA (2001) – Terrorist Attack

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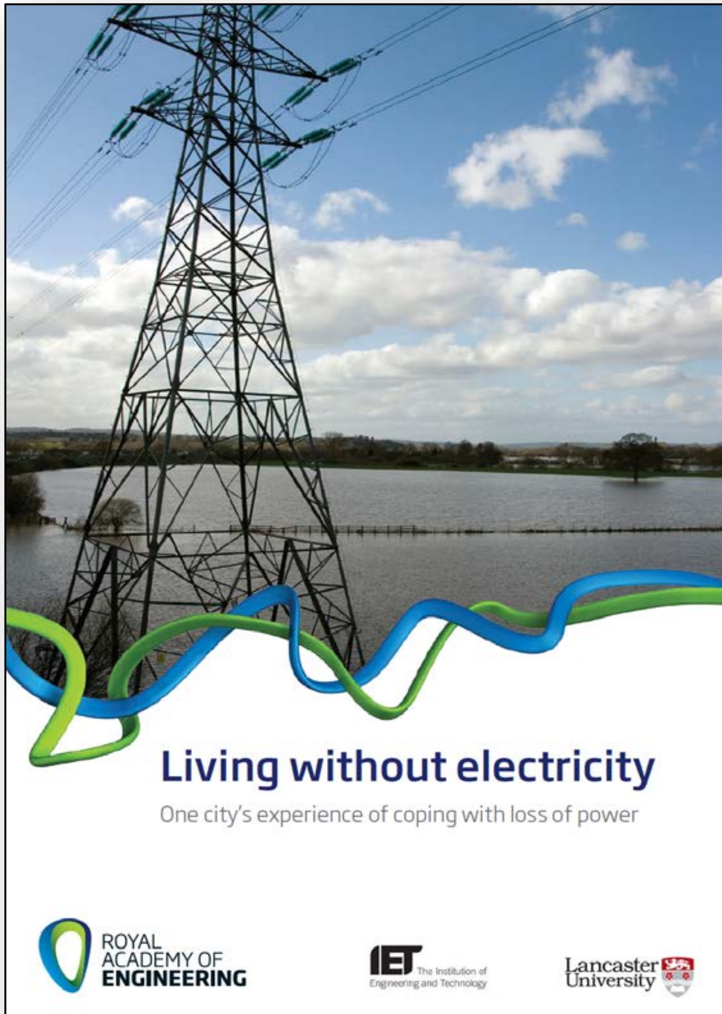
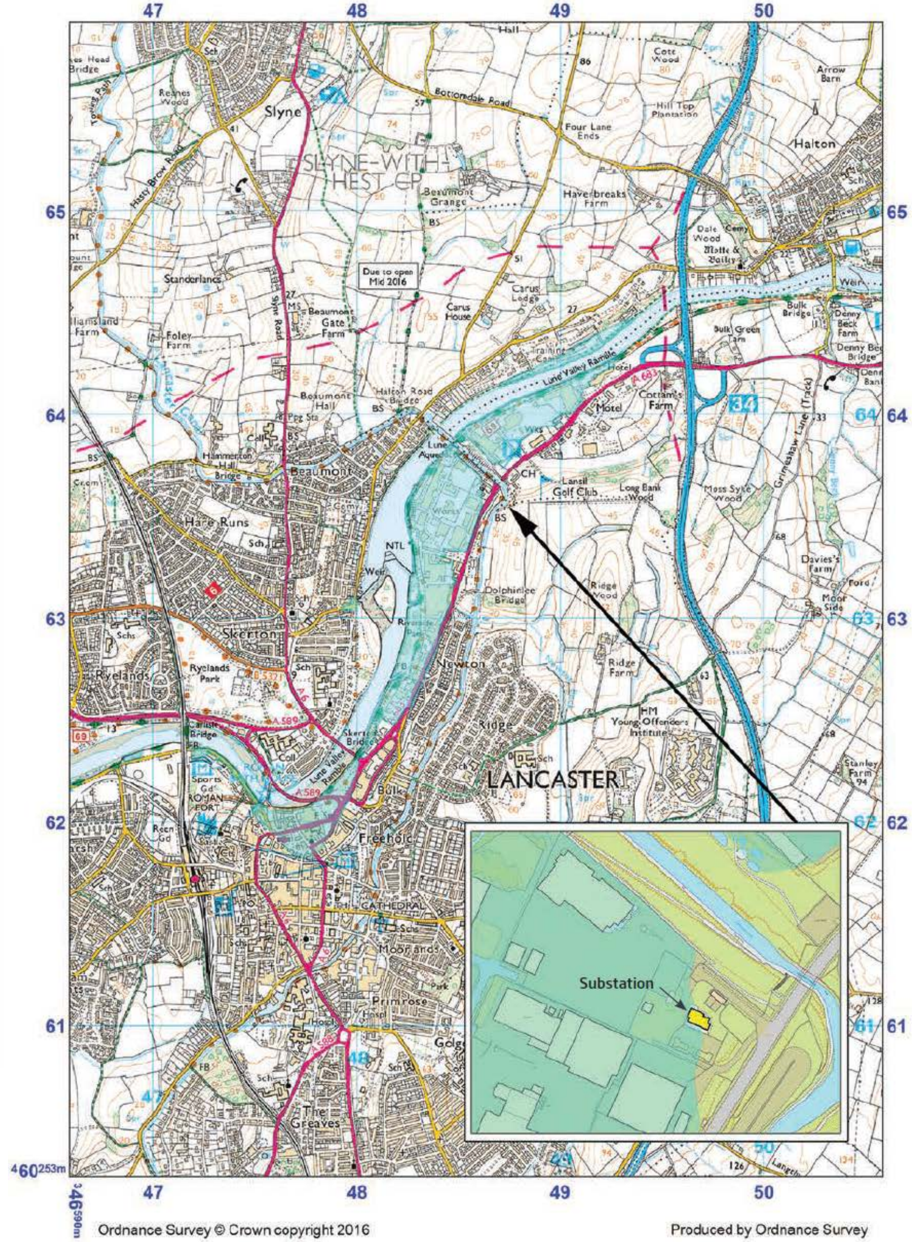
Lancaster (2015)





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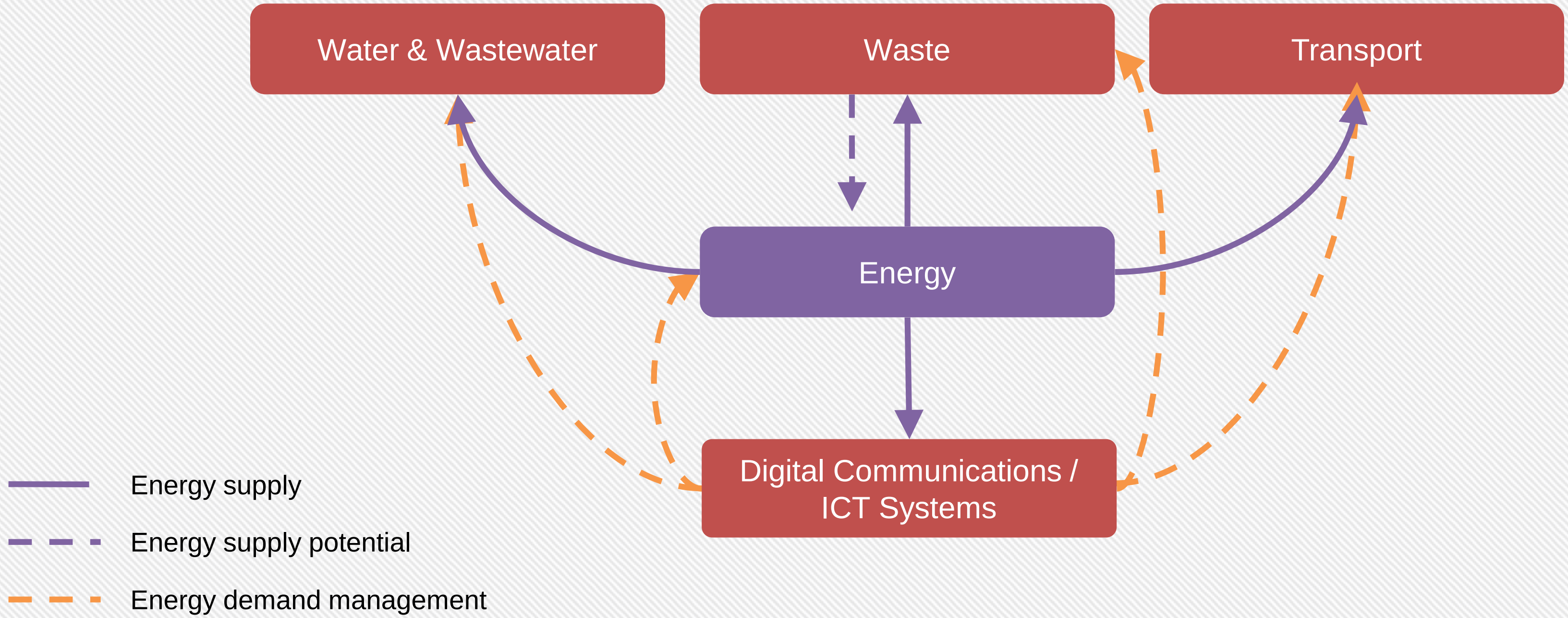
A Smarter Future: Growing Interdependency



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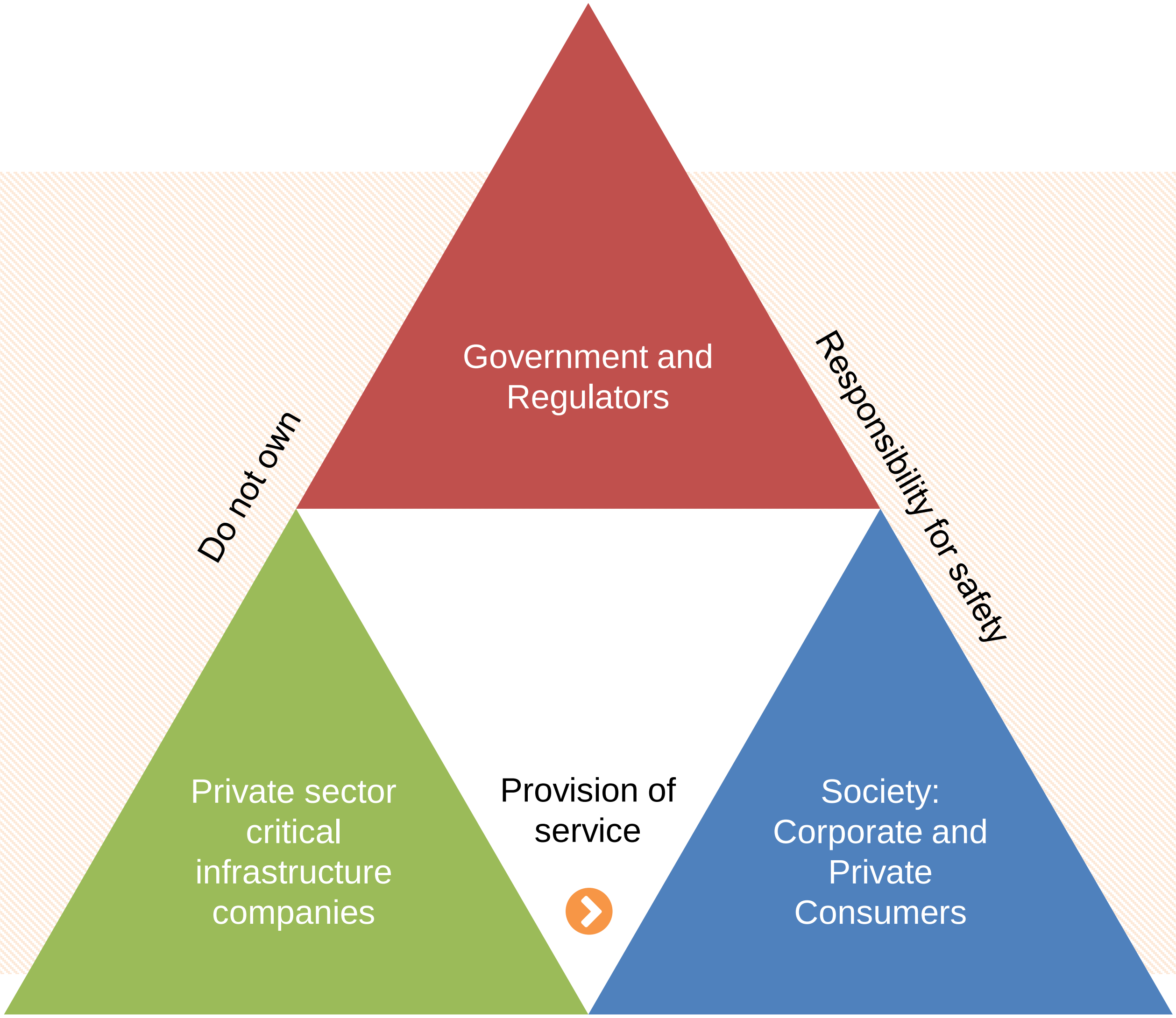
Optimising the Risk Equation

Who Bears the Risk?
Who Benefits from Resilience?



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The Benefits of Critical National Infrastructure (CNI) Resilience

New analytics

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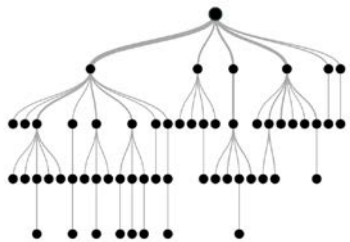
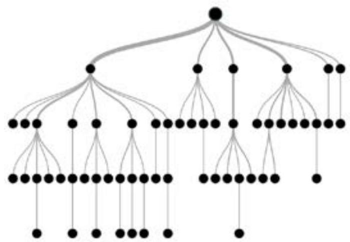
New analytics



Better decision-making

The Benefits of Critical National Infrastructure (CNI) Resilience

New analytics



Better decision-making

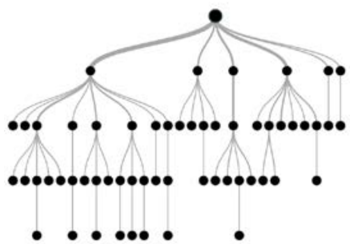
Improved Management

Of CNI assets and systems

Of *indirect corporate exposure* to CNI

The Benefits of Critical National Infrastructure (CNI) Resilience

New analytics



Better decision-making

Improved Management

- Of CNI assets and systems
- Of *indirect corporate exposure* to CNI

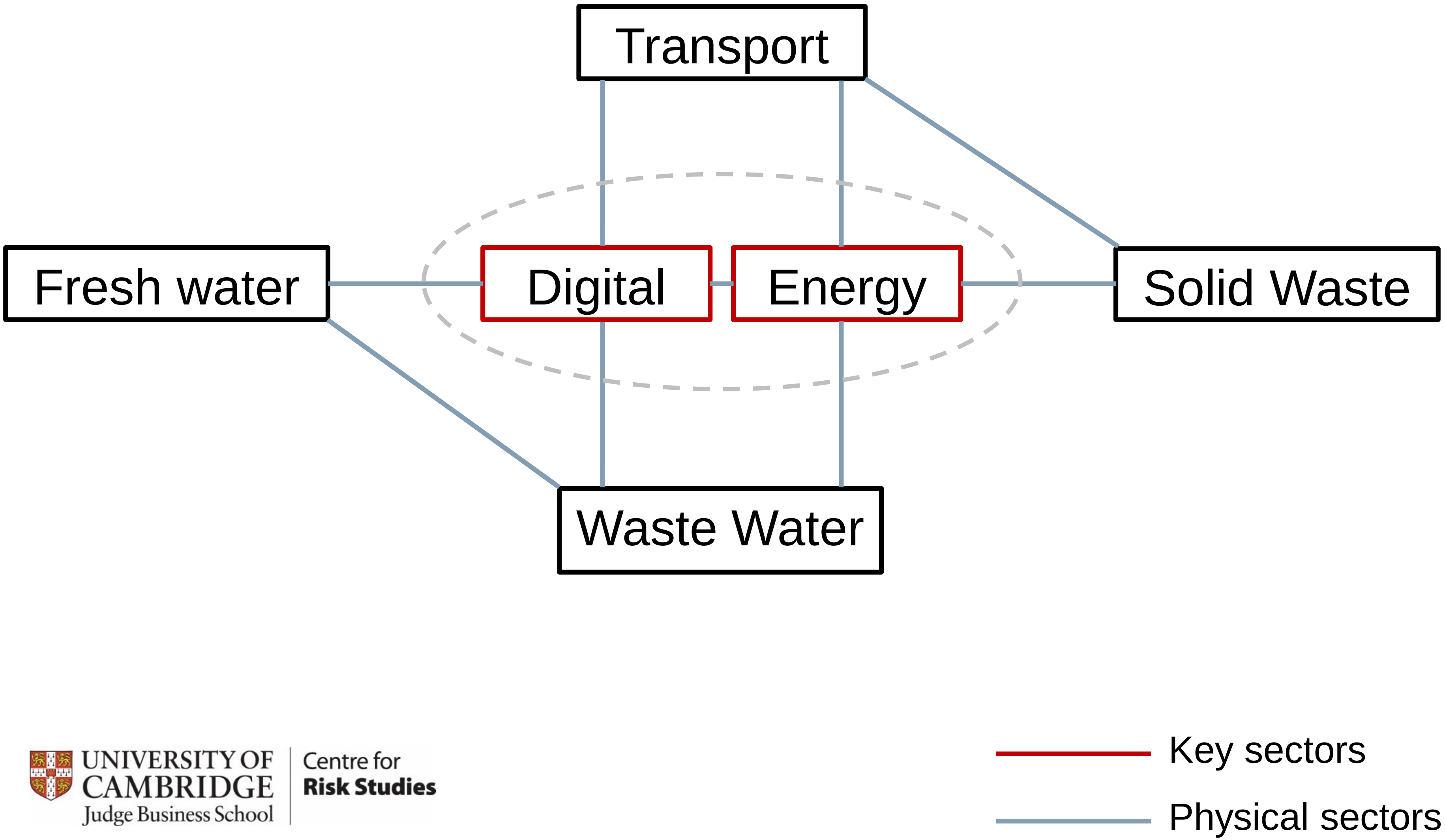
Proactive

- Preventing failure or exposure

Reactive

- Managing and mitigating service interruption

A System-of-Systems Approach to Infrastructure



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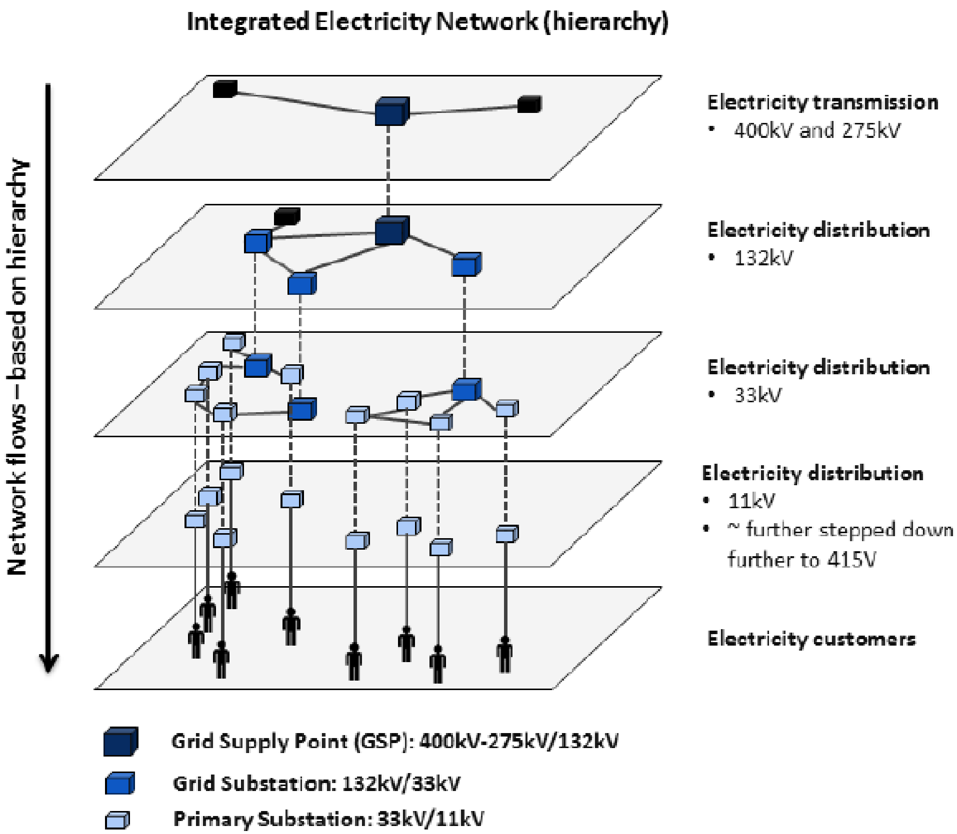
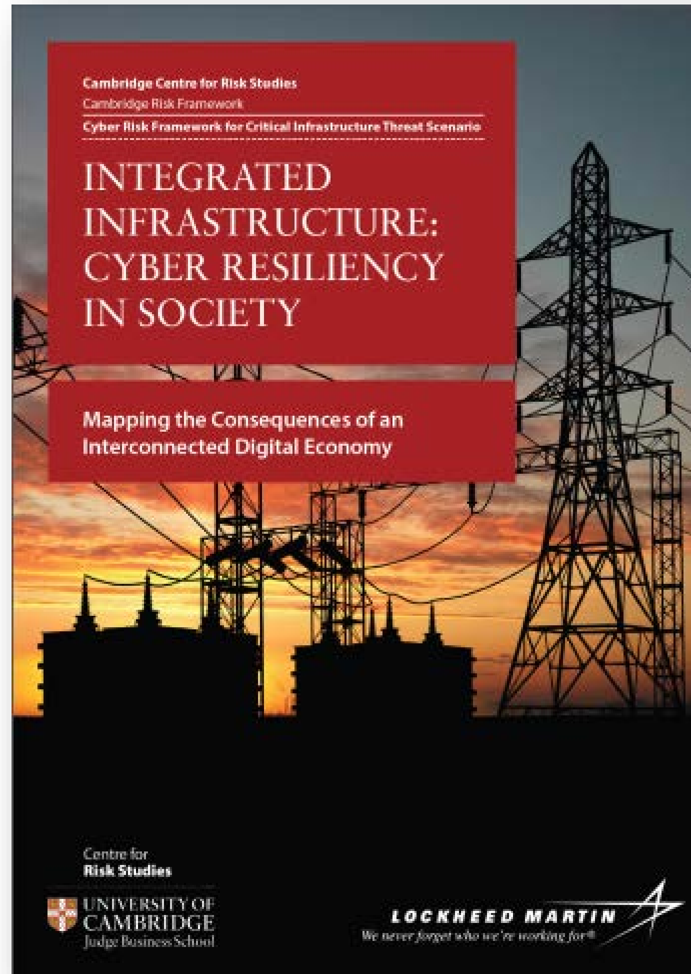
Integrated Infrastructure Scenario – *Modelling Assets*





Slide credit: Scott Thacker of ITRC

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ITRC

Critical Infrastructure Failure Due to Space Weather – *Modelling Value Flows*

AGU PUBLICATIONS

Space Weather

RESEARCH ARTICLE

10.1002/2016SW001491

Key Points:
- Under the scenarios explored potential daily lost GDP ranges from $6.2 to 42 billion for the U.S.
- The direct economic cost incurred within the blackout zone only represents approximately 49% of the total potential macroeconomic cost
- Cost-benefit analysis of investment in space weather forecasting and mitigation must take account of indirect supply chain loss

Supporting Information:
- Supporting Information S1

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Citation:
Oughton, E. J., A. Skelton, R. B. Horne, A. W. P. Thomson, and C. T. Gaunt (2017), Quantifying the daily economic impact of extreme space weather due to failure in electricity transmission infrastructure, *Space Weather*, 15, doi:10.1002/2016SW001491.

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Quantifying the daily economic impact of extreme space weather due to failure in electricity transmission infrastructure

Edward J. Oughton[1], Andrew Skelton[1], Richard B. Horne[2], Alan W. P. Thomson[3], and Charles T. Gaunt[4]

[1]Centre for Risk Studies, Judge Business School, University of Cambridge, Cambridge, UK, [2]British Antarctic Survey, Natural Environment Research Council, Cambridge, UK, [3]British Geological Survey, Natural Environment Research Council, Edinburgh, UK, [4]Department of Electrical Engineering, University of Cape Town, Cape Town, South Africa

Abstract Extreme space weather due to coronal mass ejections has the potential to cause considerable disruption to the global economy by damaging the transformers required to operate electricity transmission infrastructure. However, expert opinion is split between the potential outcome being one of a temporary regional blackout and of a more prolonged event. The temporary blackout scenario proposed by some is expected to last the length of the disturbance, with normal operations resuming after a couple of days. On the other hand, others have predicted widespread equipment damage with blackout scenarios lasting months. In this paper we explore the potential costs associated with failure in the electricity transmission infrastructure in the U.S. due to extreme space weather, focusing on *daily economic loss*. This provides insight into the direct and indirect economic consequences of how an extreme space weather event may affect domestic production, as well as other nations, via supply chain linkages. By exploring the sensitivity of the blackout zone, we show that on average the direct economic cost incurred from disruption to electricity represents only 49% of the total potential macroeconomic cost. Therefore, if indirect supply chain costs are not considered when undertaking cost-benefit analysis of space weather forecasting and mitigation investment, the total potential macroeconomic cost is not correctly represented. The paper contributes to our understanding of the economic impact of space weather, as well as making a number of key methodological contributions relevant for future work. Further economic impact assessment of this threat must consider multiday, multiregional events.

1. Introduction

Space weather disturbances of the upper atmosphere and near-Earth space can disrupt a wide range of technological systems [*Hapgood et al.*, 2012]. Over the past decade many reports have analyzed the potential effects of extreme space weather on electricity transmission infrastructure [*Space Studies Board*, 2008; *OECD*, 2011; *JASON*, 2011; *North American Electric Reliability Corporation*, 2012; *Cannon et al.*, 2013]. The economic costs associated with these extreme events have been heralded as being as high as $1–2 trillion in the first year, equivalent to a so-called "global Hurricane Katrina." To date, however, there has been a lack of *transparent* research around how these direct and indirect economic costs actually stack up, which is surprising given the level of debate and uncertainty surrounding the vulnerability of electricity transmission infrastructure to extreme space weather.

Research in this paper has been produced by a similar team that originally developed the Helios Solar Storm Scenario [*Oughton et al.*, 2016]—the first space weather stress test for the global insurance industry. Ultimately, these are different pieces of work. Helios purposefully explored the sensitivity of economic loss due to different temporal restoration periods, in order to provide a tool for stressing the portfolio exposure of global insurance companies. Helios is not a prediction but a hypothetical range of scenarios to enable mitigation of space weather risks in the insurance industry. On the other hand, this paper focuses purely on the daily direct and indirect economic consequences of how an extreme space weather event may affect U.S. domestic production, as well as other nations via supply chain linkages, based on different blackout zones.

Two opposing views have emerged. On the one hand, some believe that the potential damage would not be that large and that we are relatively well prepared to deal with an extreme geomagnetic disturbance (GMD). The worst case scenario is seen to be an electrical collapse of the transmission grid, probably initiated by loss

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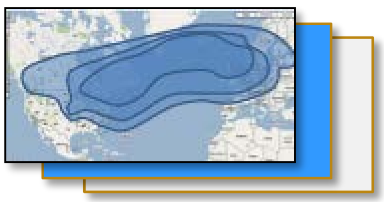
Infrastructure in Pandora

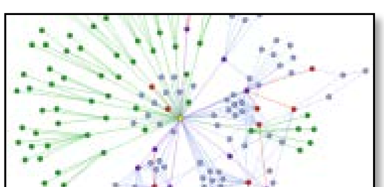
Threat Maps

Scenarios



Exposure Data

Network Models



Infrastructure in Pandora

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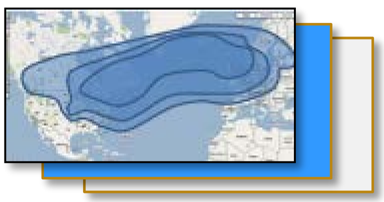

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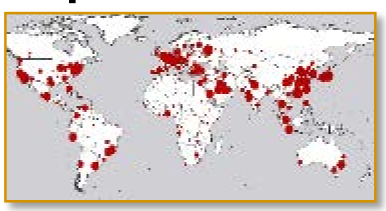

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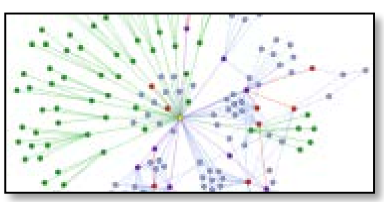

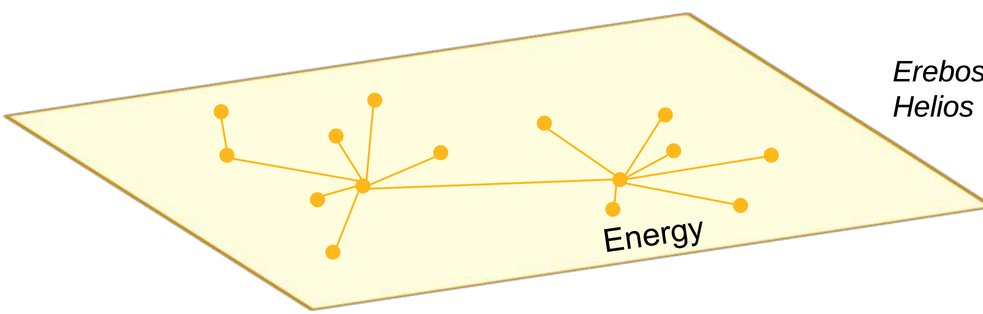

Erebos Scenario
Helios Scenario

Infrastructure in Pandora

Threat Maps

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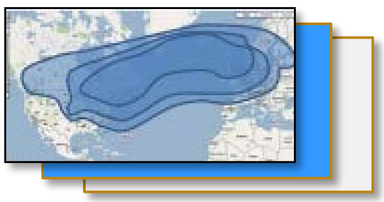

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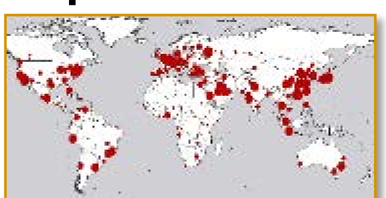

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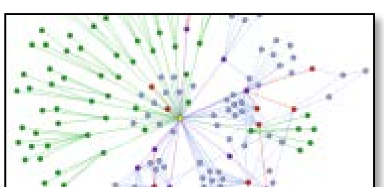

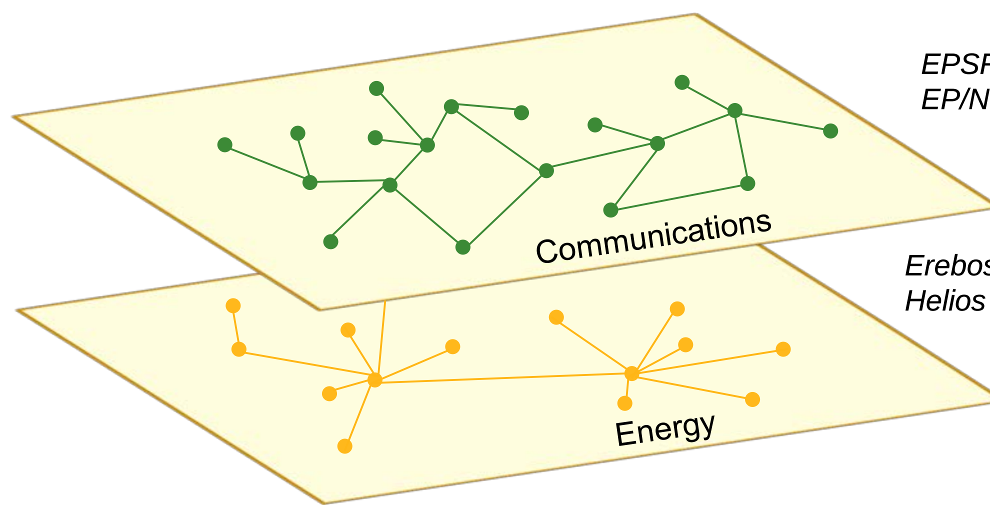

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EP/N017064/1

Erebos Scenario
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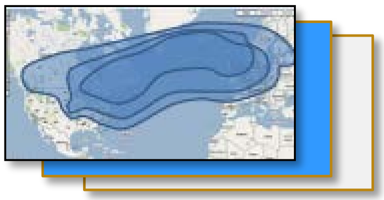

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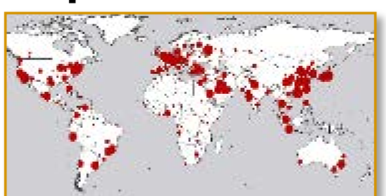

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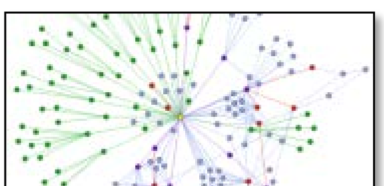

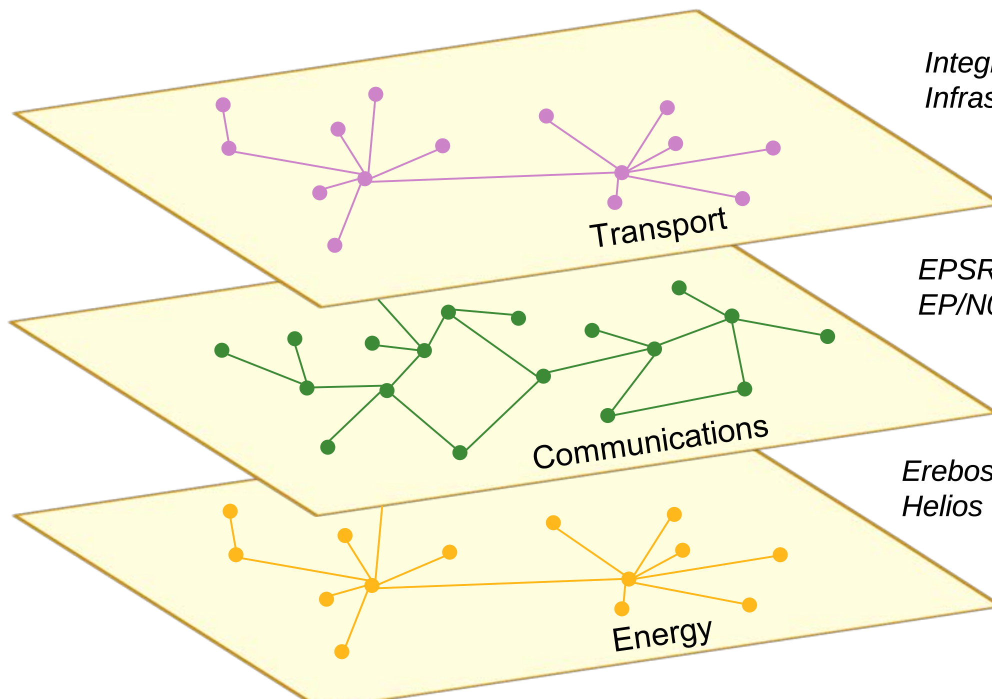

Integrated Infrastructure

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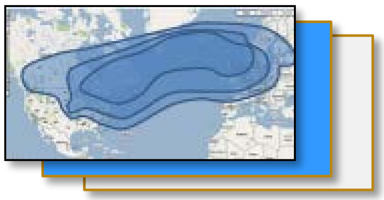

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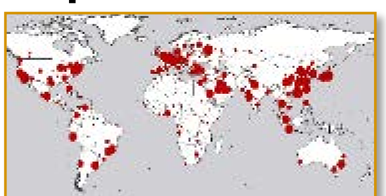

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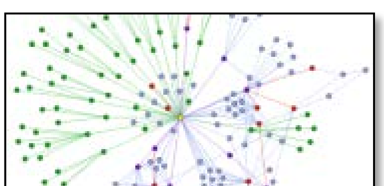

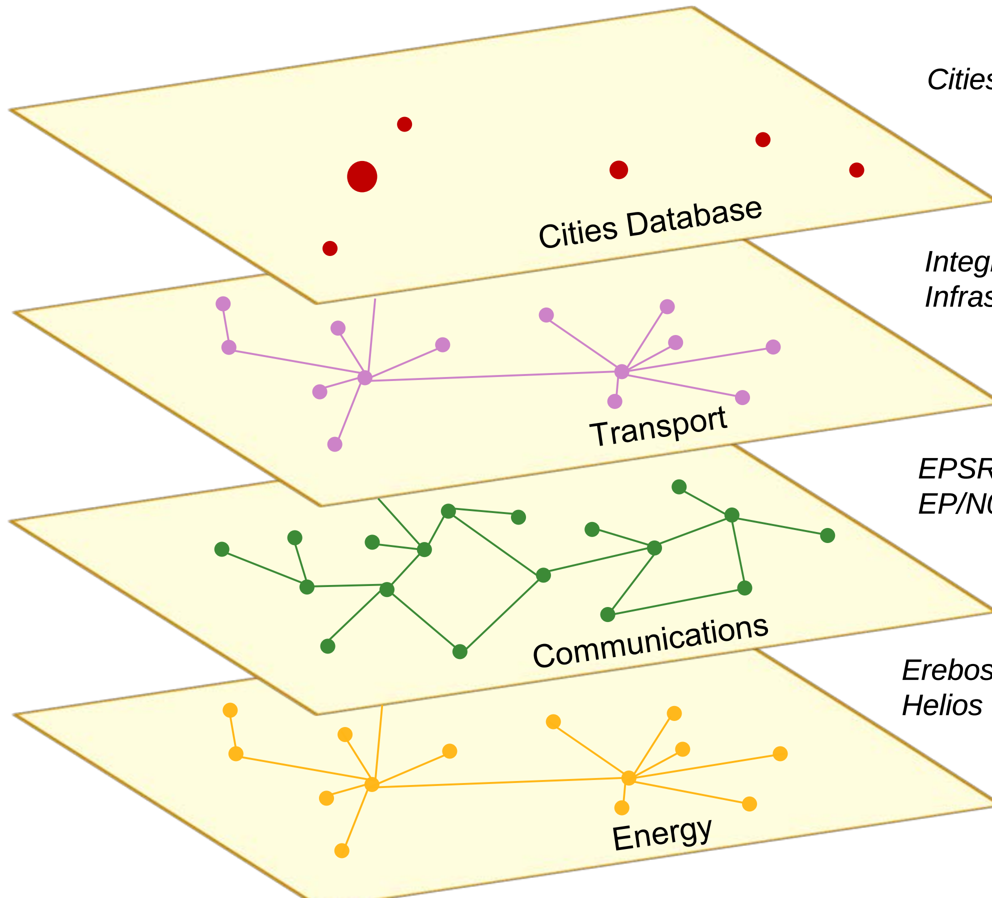

Cities at Risk

Integrated Infrastructure

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Erebos Scenario
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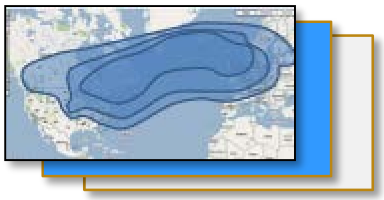

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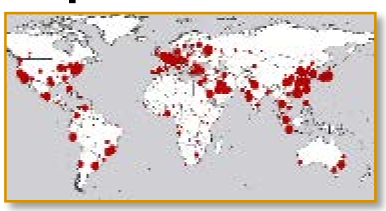

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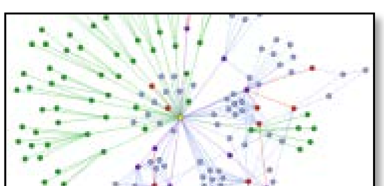

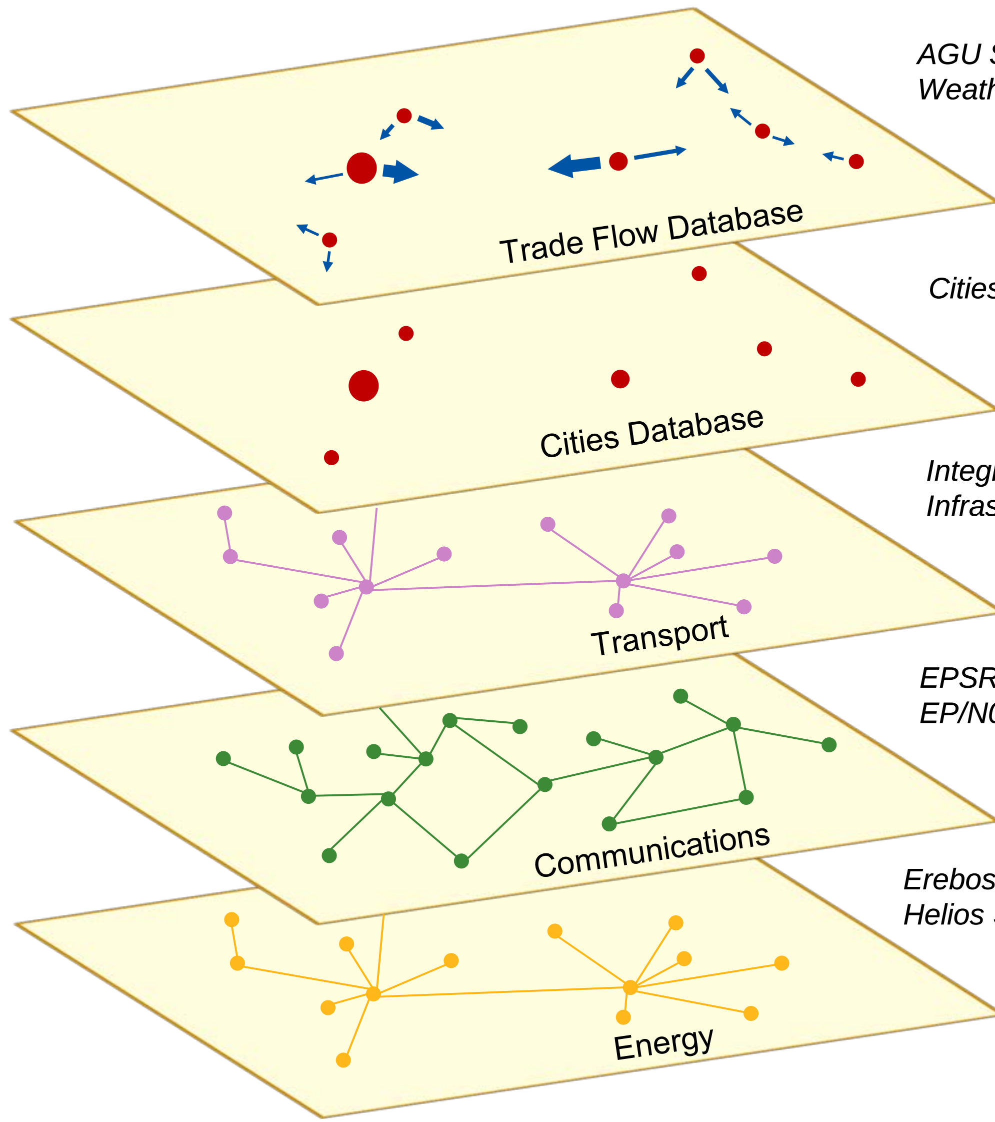

AGU Space Weather Paper

Cities at Risk

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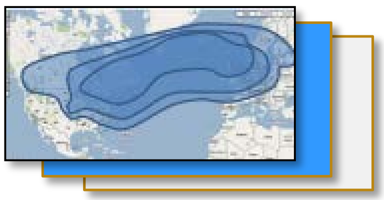

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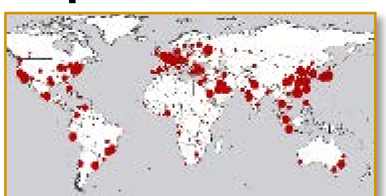

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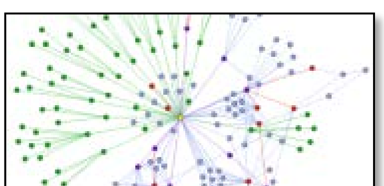

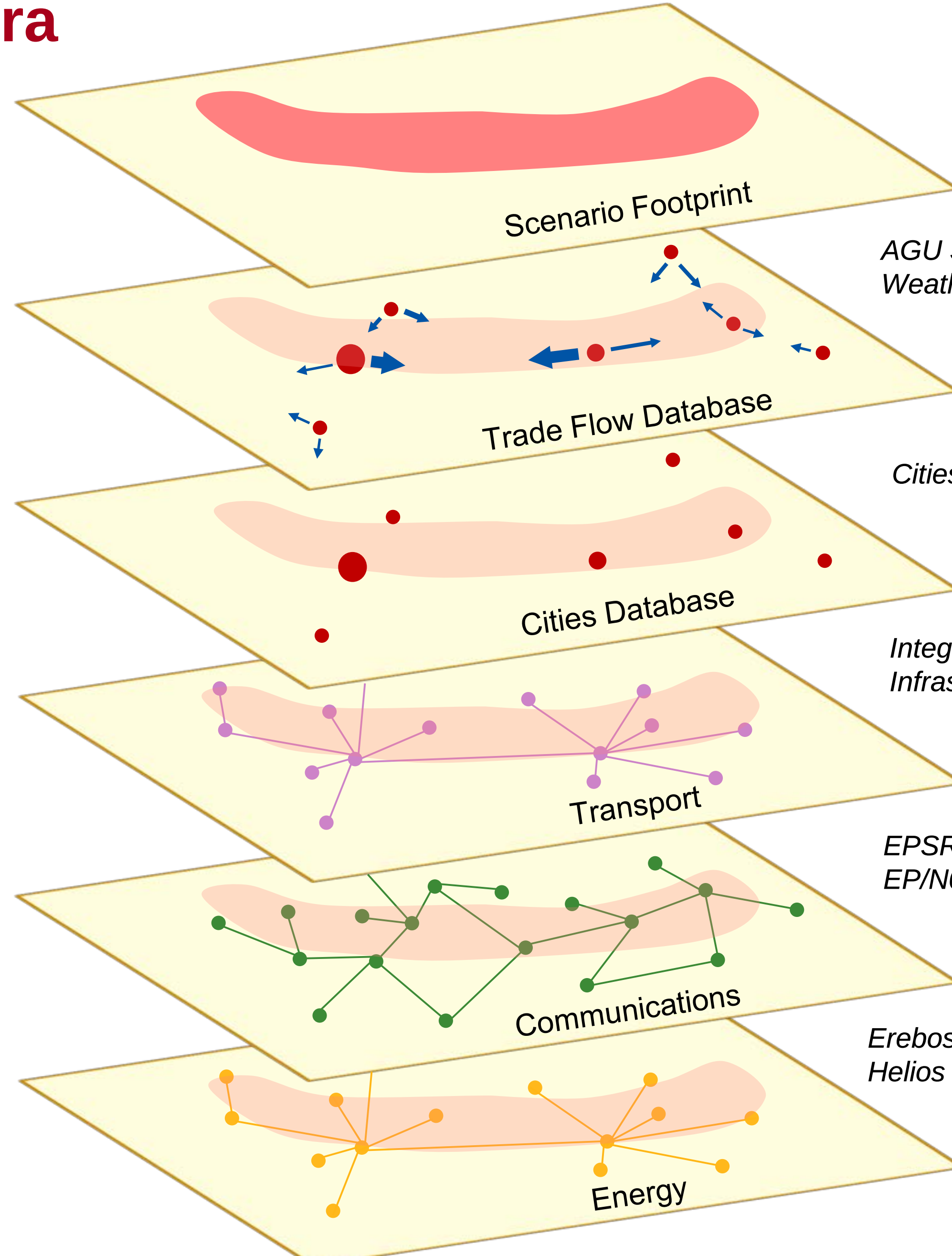

AGU Space Weather Paper

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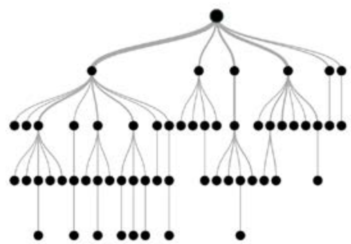
The Benefits of Critical National Infrastructure (CNI) Resilience

New analytics



Better decision-making

Improved Management

Of CNI assets and systems

Of *indirect corporate exposure* to CNI

Proactive

Preventing failure or exposure

Reactive

Managing and mitigating service interruption

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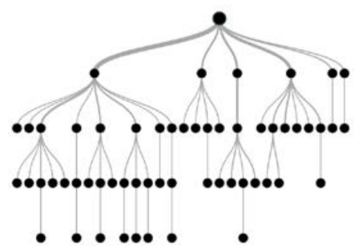

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Private Benefits

Operational continuity	Brand protection	Balance Sheet Protection

Benefits gained by infrastructure operators and users

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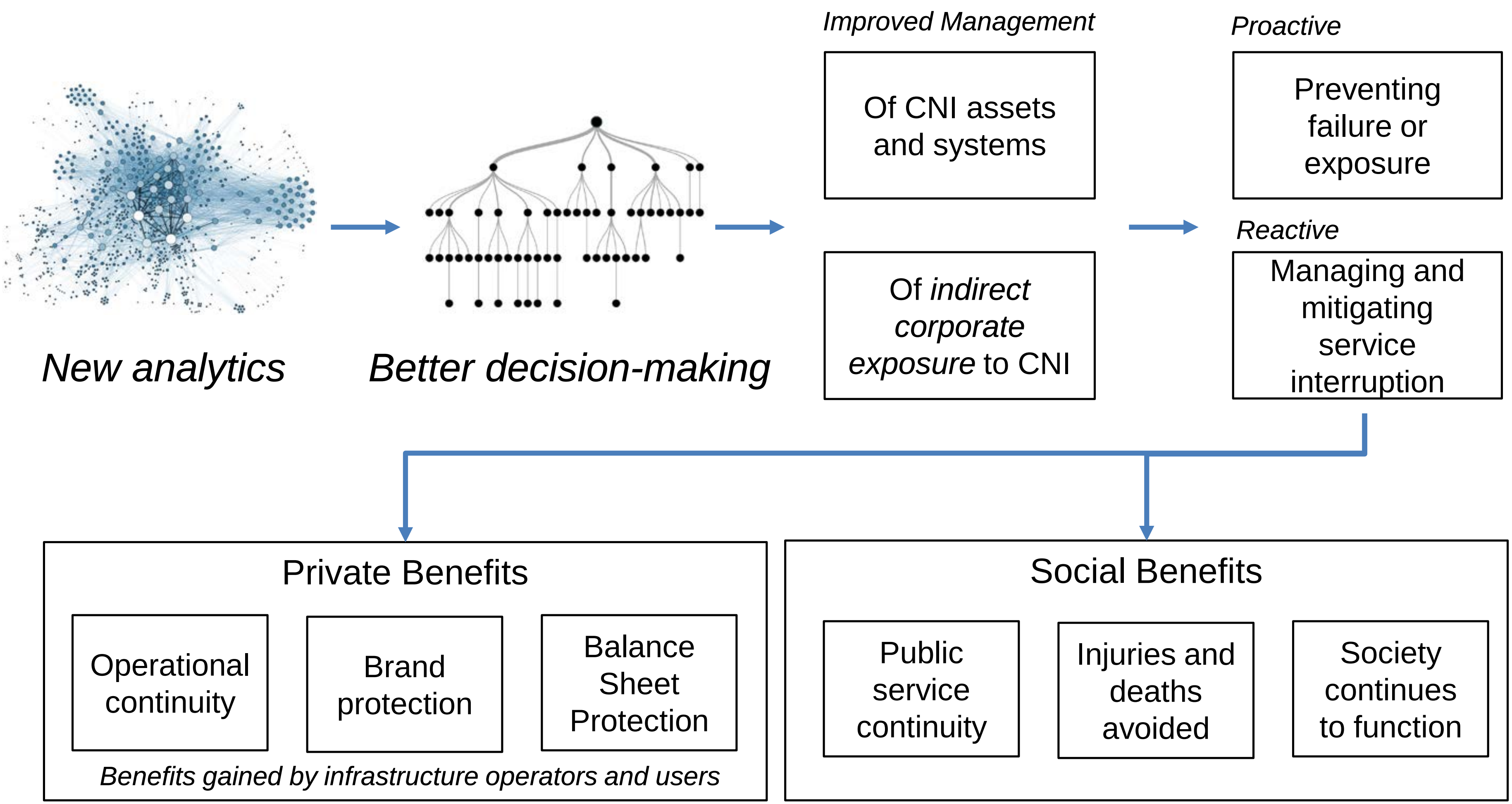
The Benefits of Critical National Infrastructure (CNI) Resilience



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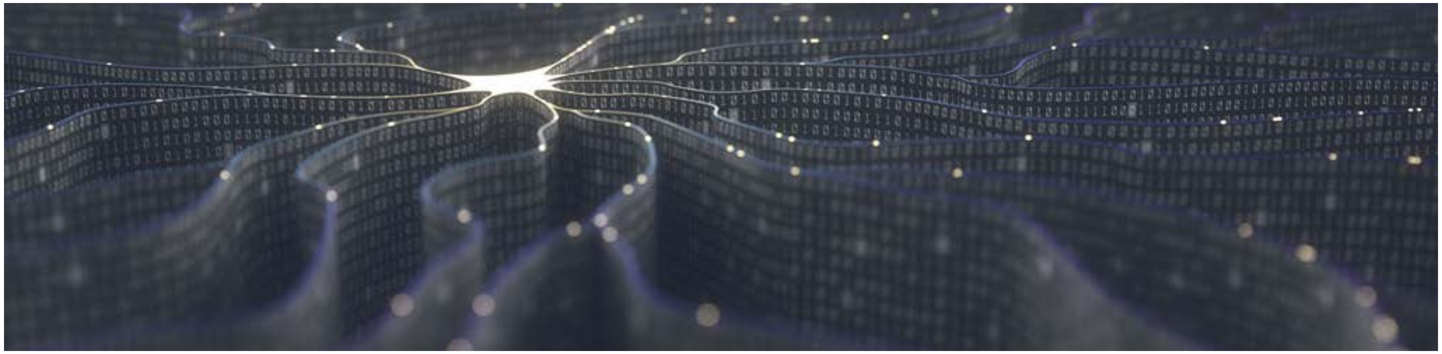
DAFNI – Data and Analytics For National Infrastructure

The UK's National infrastructure modelling, simulation and visualisation facilities



£8 million awarded from UKCRIC's £138 million

Innovate UK
Technology Strategy Board

National Infrastructure Commission

Catapult Future Cities

Science & Technology Facilities Council

University of Oxford

University of Cambridge

Imperial College London

Ordnance Survey

Newcastle University

University of Birmingham

The University Of Sheffield.

University of Southampton

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UCL

University of Leeds

Cranfield University

DAFNI – Data and Analytics For National Infrastructure

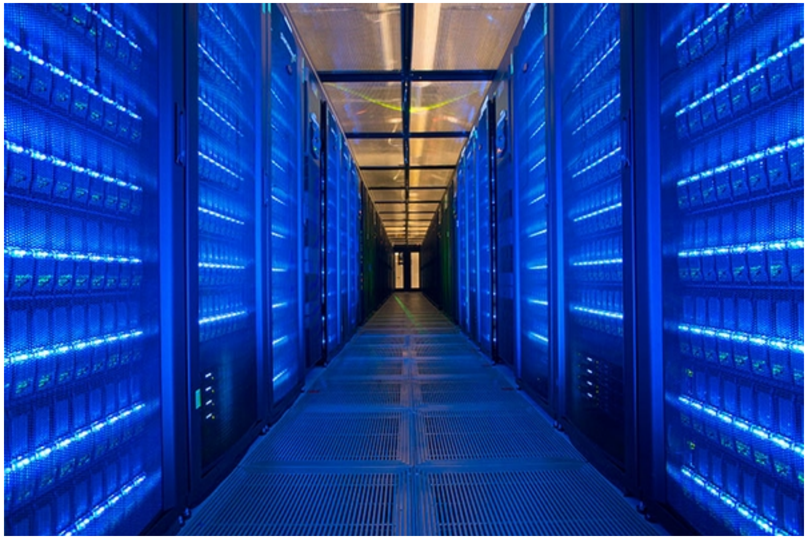
The UK's National infrastructure modelling, simulation and visualisation facilities

Theme 1: Complex systems modelling and simulation

Theme 2: Data assimilation and model calibration

Theme 3: System optimisation and uncertainty analysis

Theme 4: Visual analytics and decision support



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To Conclude

1. Infrastructure interdependencies are *pervasive*
2. Corporate operations suffer indirect exposure
3. Balance sheet and brand protection are the key private benefits of infrastructure resilience

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