Simulation as a Service

Resilience by design

by SIM-CI

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CONTENT

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Critical Infrastructure systems are the lifelines of our safety and prosperity, nerve systems that facilitate communication, transportation, trade and financial transactions.

We aim to build strong alliances which turn global challenges into opportunities for international business.

PROTECTING SOCIETIES' CORE ASSETS

The world is hyper connected thanks to Critical Infrastructures (CI) above and below street level. The CI systems are more and more effected by:

Smart Grids - Distributed Energy - Urbanization - Climate Change - Cyber Attacks

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PAIRING HARD SCIENCE & DISRUPTIVE TECHNOLOGY TO MEET GLOBAL CHALLENGES

- Severe weather patterns
- Energy transition
- Food & safety
- Urbanization
- Cyber secure society
- Global defense & security

DIGITAL TWIN CITIES

MIMICKING ALL VITAL URBAN PROCESSES & INFRASTRUCTURES

to predict and foresee future events & scenarios

DIGITAL TWIN CITIES

- Accurate representation of infrastructures
- Validated real-time and historic data
- Scientific models to create, validate and assess mitigation & contingency scenarios

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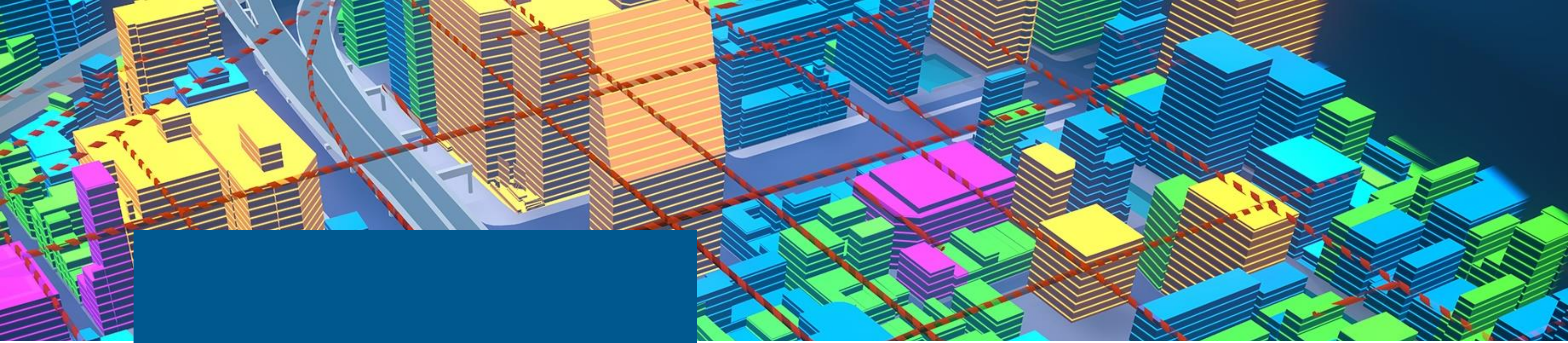

Input many data sets enabling subscribers to run their own Simulations

We started in the Netherlands

- Massive amounts of data!
- All the buildings and roads combined with soil structure
- High resolution point clouds
- Traffic data
- Weather data
- Energy data (power gas)
- Sewage data
- Water usage

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DIGITAL TWIN CITIES

PAIRING HARD SCIENCE AND DISRUPTIVE TECHNOLOGY

Network models:

- Gas model
- Water model
- Sewage model
- Electricity: LV & MV model
- Condition-based risk assessment
- Electricity state estimation

Interdependencies:

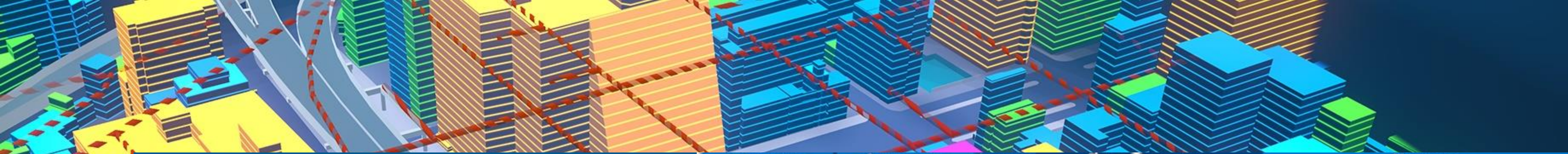
- E-G (decomposing PVC)
- W-G (scour hole)
- Flooding model
- Flooding electricity analysis
- Weather influence on electricity usage
- HG interdependecies
- Stray-current corrosion

Deterioration models:

- Electricity deterioration
- Gas deterioration
- Water deterioration
- Forces in the water network
- Electricity component failure

Other:

- Science as a service
- Simulation as a service



OUTPUT: YOUR PERSONAL SIMULATION COCKPIT

Output data available in:

- Multi User Virtual Reality
- Mixed Reality
- Augmented Reality

- Voice commands
- Custom reporting possible
- Live data feeds on economic impact and business continuity

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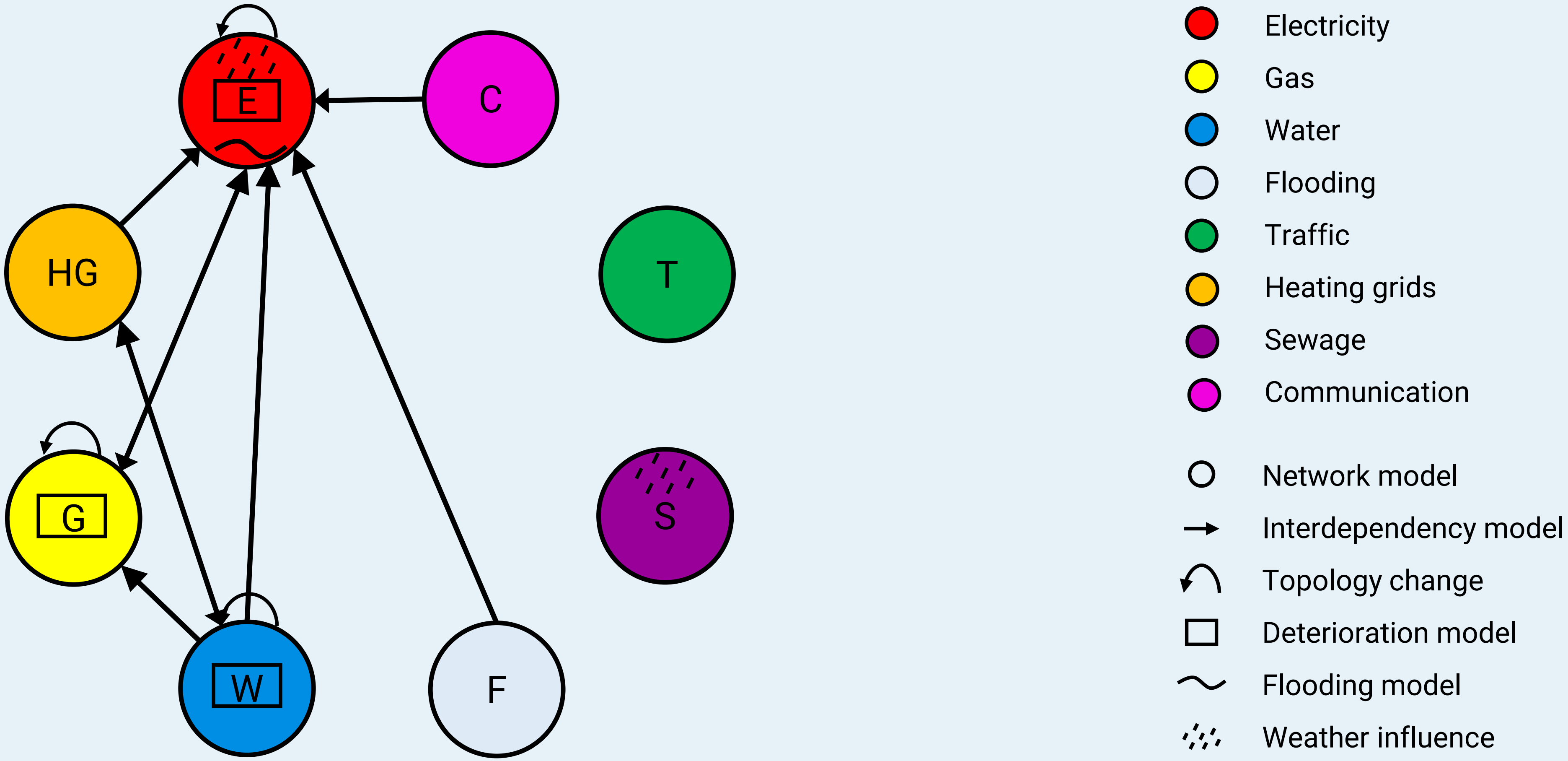
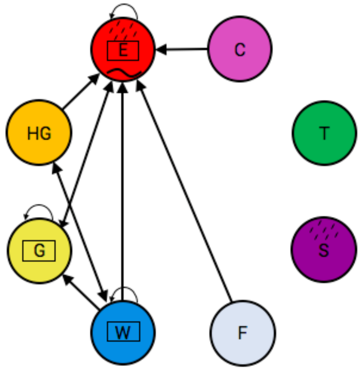
DIGITAL ACTIONABLE INFORMATION

WHAT DO WE DO?


E
C
HG
T
G
S
W
F
Electricity
Gas
Water
Flooding
Traffic
Heating grids
Sewage
Communication
Network model
Interdependency model
Topology change
Deterioration model
Flooding model
Weather influence

NETWORK MODEL



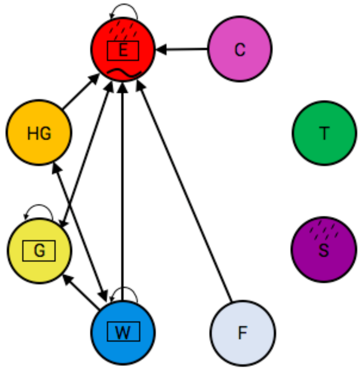
Ohm's law:

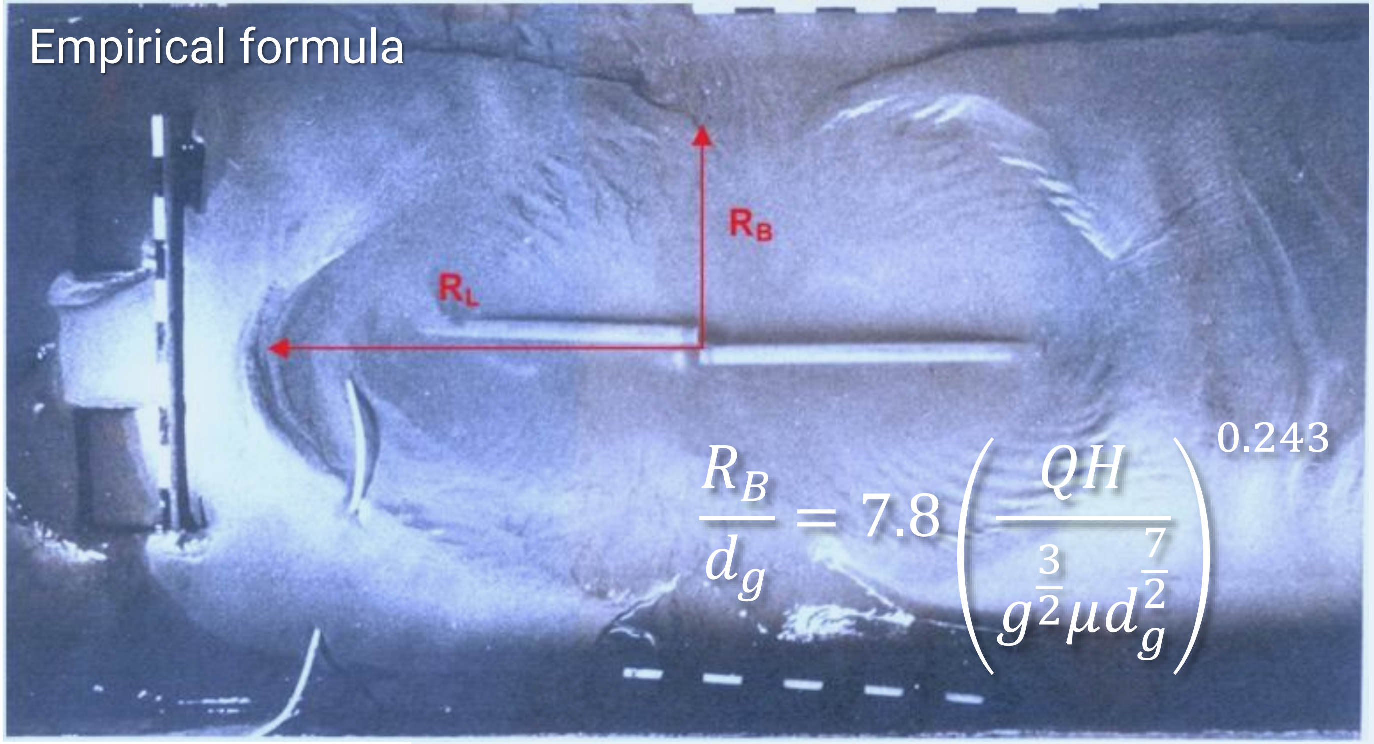
$$I = \frac{V}{R}$$

Kirchhoff's circuit laws:

$$\sum_{k=1}^{n} I_k = 0 \qquad \sum_{k=1}^{n} V_k = 0$$

INTERDEPENDENCY MODEL





$$\frac{R_B}{d_g} = 7.8\left(\frac{QH}{g^{\frac{3}{2}}\mu d_g^{\frac{7}{2}}}\right)^{0.243}$$

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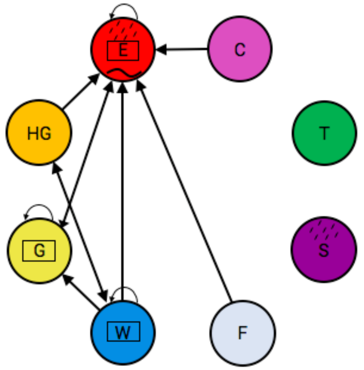
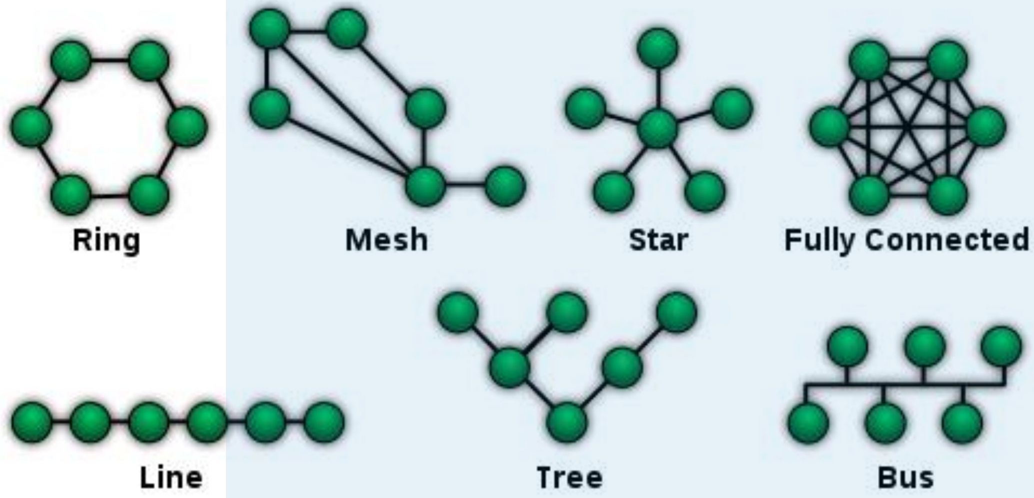
TOPOLOGY CHANGE





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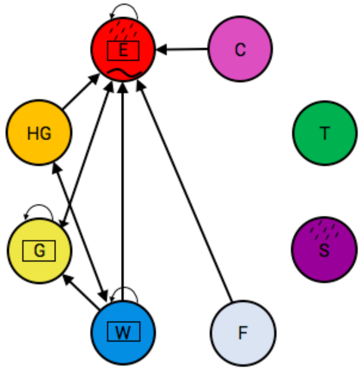
AGEING AND DETERIORATION MODELS



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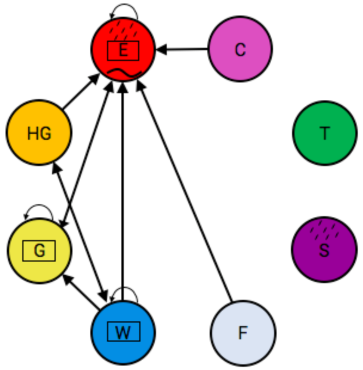
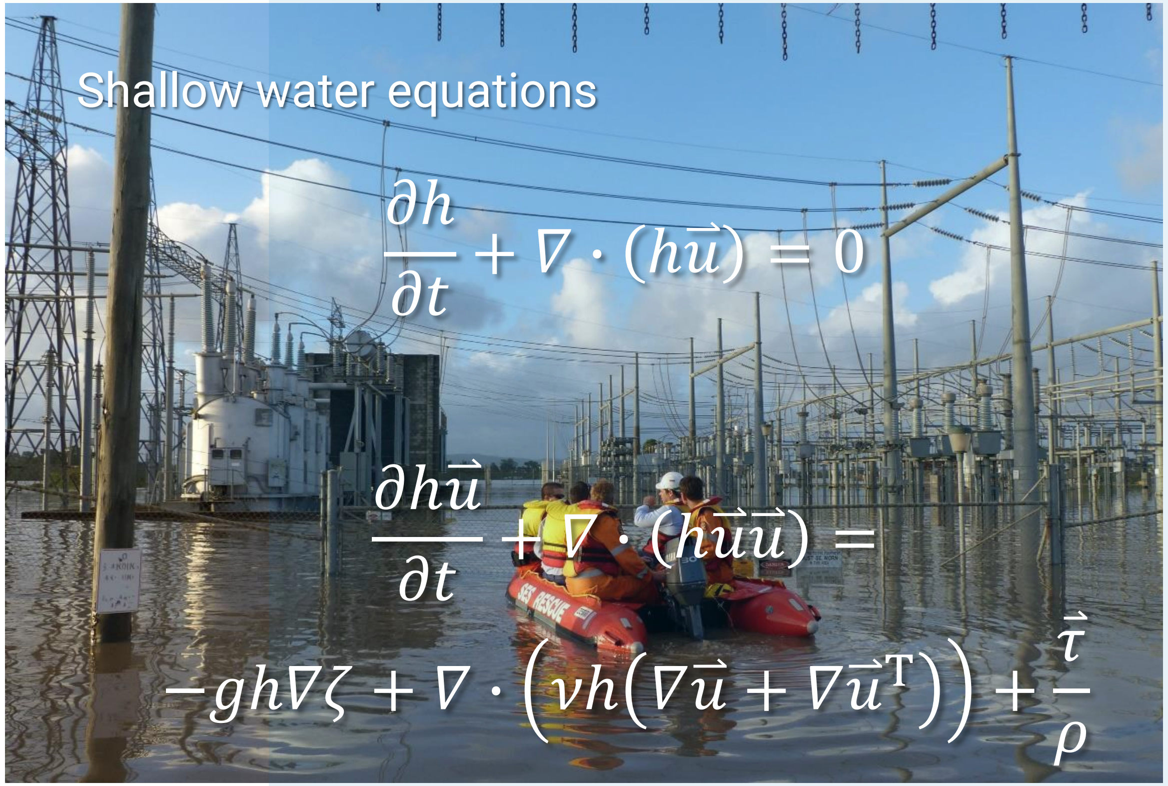
FLOODING MODEL





$$\frac{\partial h}{\partial t} + \nabla \cdot (h\vec{u}) = 0$$

$$\frac{\partial h\vec{u}}{\partial t} + \nabla \cdot (h\vec{u}\vec{u}) = -gh\nabla\zeta + \nabla \cdot \left(\nu h\left(\nabla\vec{u} + \nabla\vec{u}^{\mathrm{T}}\right)\right) + \frac{\vec{\tau}}{\rho}$$

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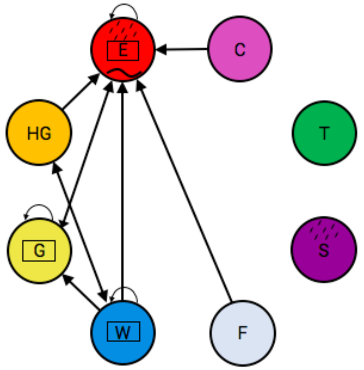
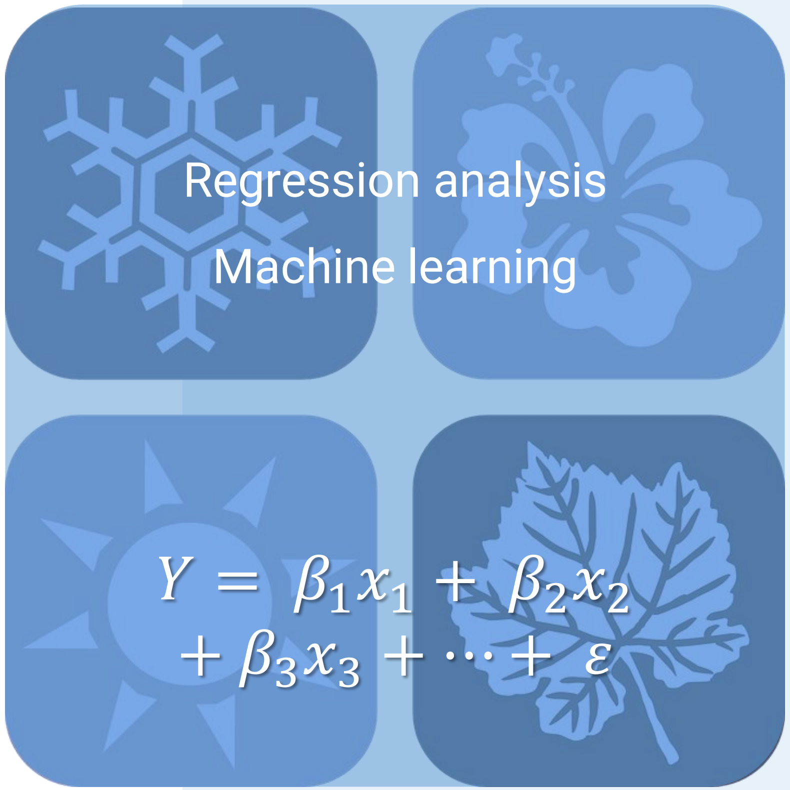
WEATHER INFLUENCE





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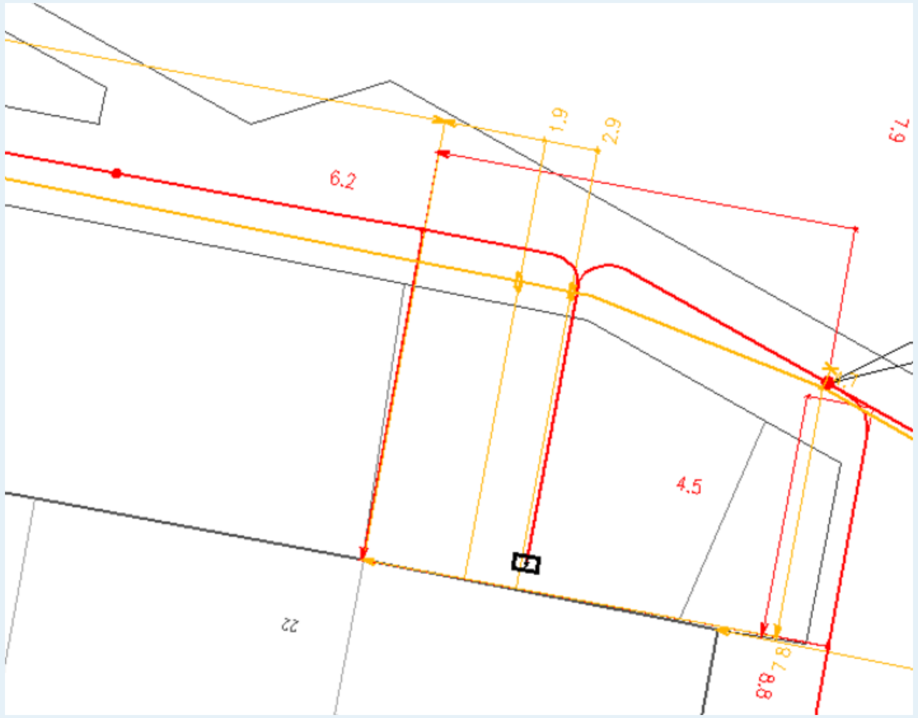
INTERDEPENDENCY ELECTRICITY-GAS

Heat produced by a failing electricity joint is causing decomposition of PVC gas pipes



The model can be used to decide which steps to take when this interdependency has happened

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INTERDEPENDENCY ELECTRICITY-GAS

Failing electricity cable/joint

Decomposition

HCl gas pollution

Component deterioration

$> 200°C$

< 0.30 m

$PVC \rightarrow 0.59HCl + 0.41Rest$

Soot

Model outcome: amount produced HCl gas

INTERDEPENDENCY ELECTRICITY-GAS

Failing electricity cable/joint　　Decomposition　　HCl gas pollution　　Component deterioration

HCl is carried along natural gas flow

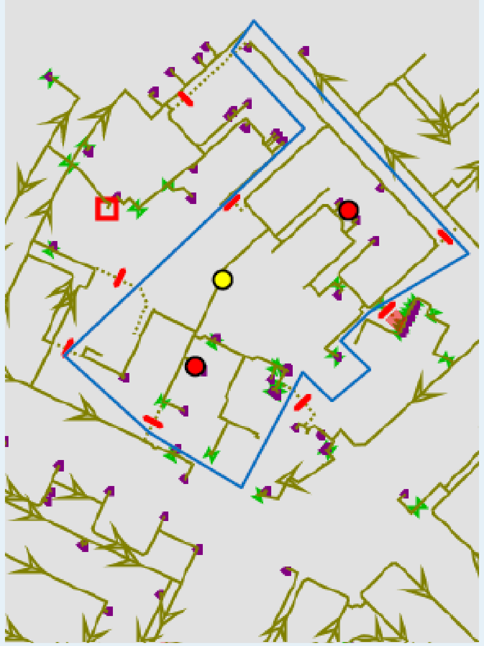
$$\frac{\partial c}{\partial t} + u \cdot \nabla c = \varepsilon \nabla^2 c$$

Model outcome:
HCl concentration in time and space

POM degradation: Acidolysis

pH < 4

Model outcome:
pH value in time and space



WATER – GAS INTERDEPENDENCY

A water main broke causing a nearby gas pipe to break as well
Water and mud entered the gas pipe causing 6 km of contaminated gas pipe
Cleaning took 1 week
1300 affected households couldn't heat their houses, take warm showers or cook food

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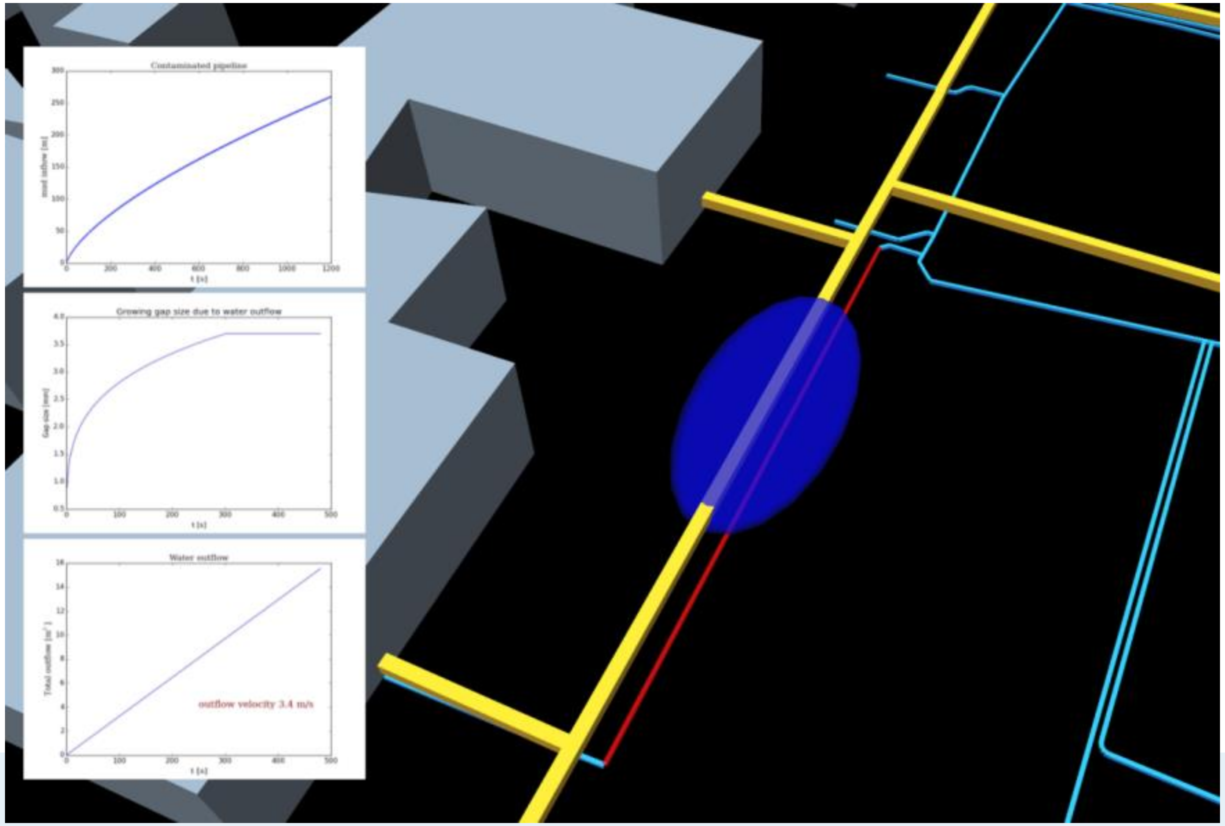
WATER – GAS INTERDEPENDENCY

Model purpose:

- Deteriorating water mains
- More occurrences of this interdependency



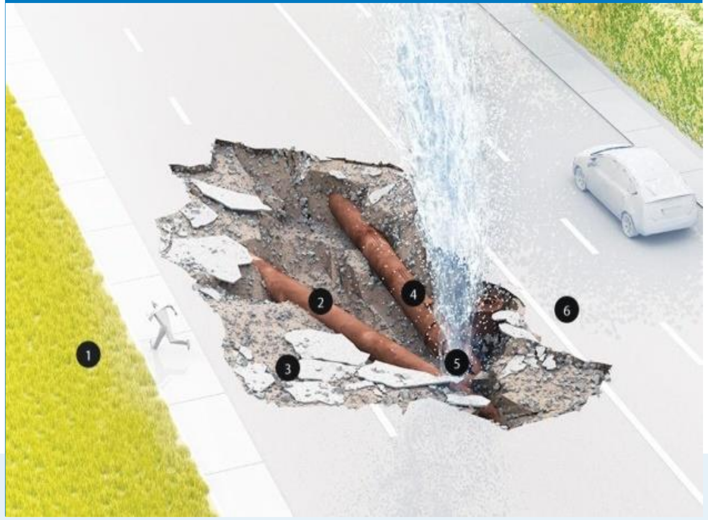
The model will:

- Find high-risk locations
- Determine spread of contamination in the gas grid

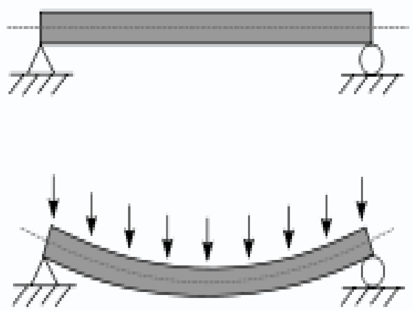
WATER – GAS INTERDEPENDENCY

THREE SUBMODELS

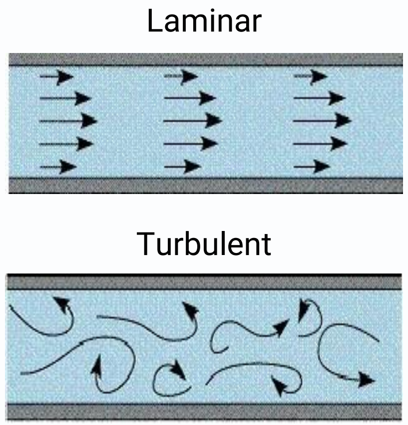
1 WATER OUTFLOW AND SCOUR HOLE FORMATION



2 BENDING AND BREAKING OF GAS PIPE



3 WATER AND SOIL INFLOW



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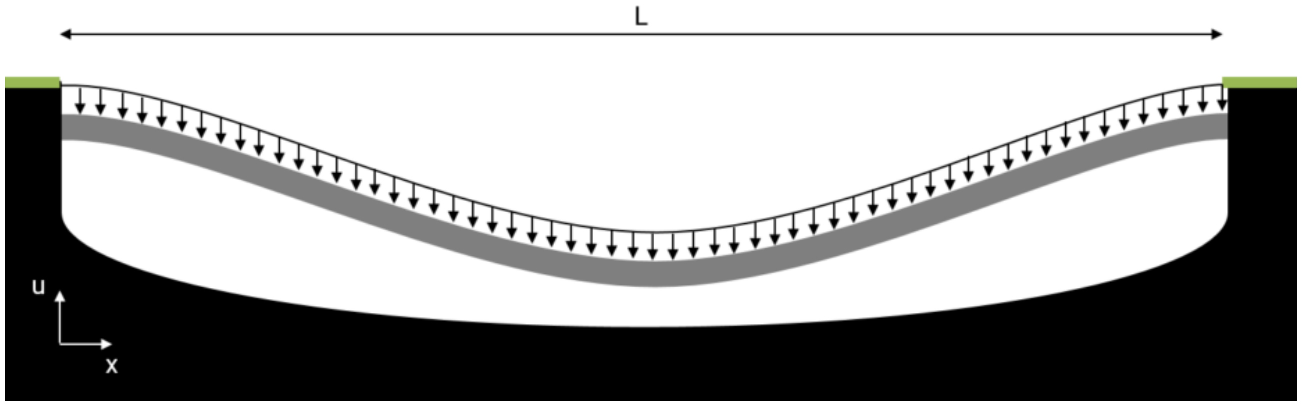
BENDING OF GAS PIPE

W-G INTERDEPENDENCY



The pipe bending *u* depends on pipe weight, material elasticity and the pipe's area moment of inertia, as

$$u''''(x) = \frac{\rho A g}{EI}$$

$$\frac{12EI}{p(x)}u(x) = -\frac{1}{2}x^4 + Lx^3 - \frac{1}{2}L^2x^2$$

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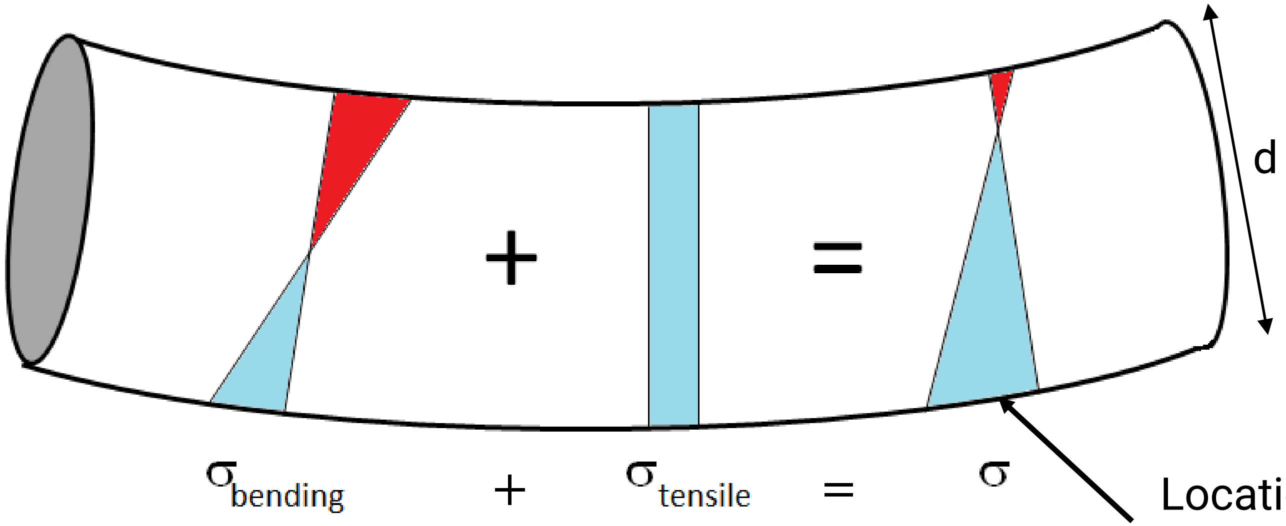
BREAKING OF GAS PIPE

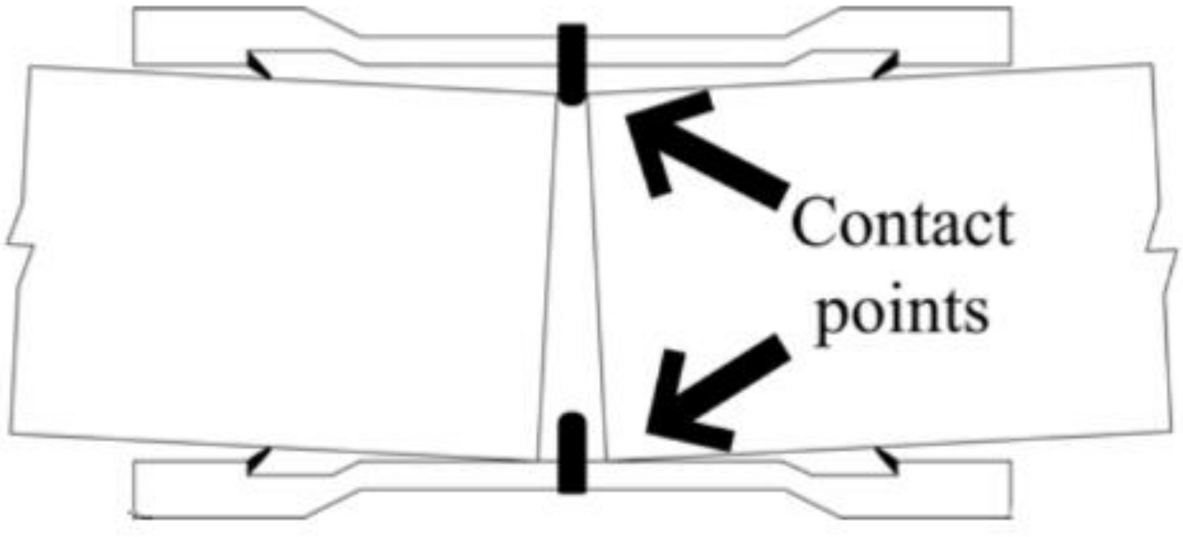
W-G INTERDEPENDENCY



The pipe will break when the total stress exceeds the material's ultimate strength

ADDING JOINTS

WATER – GAS INTERDEPENDENCY

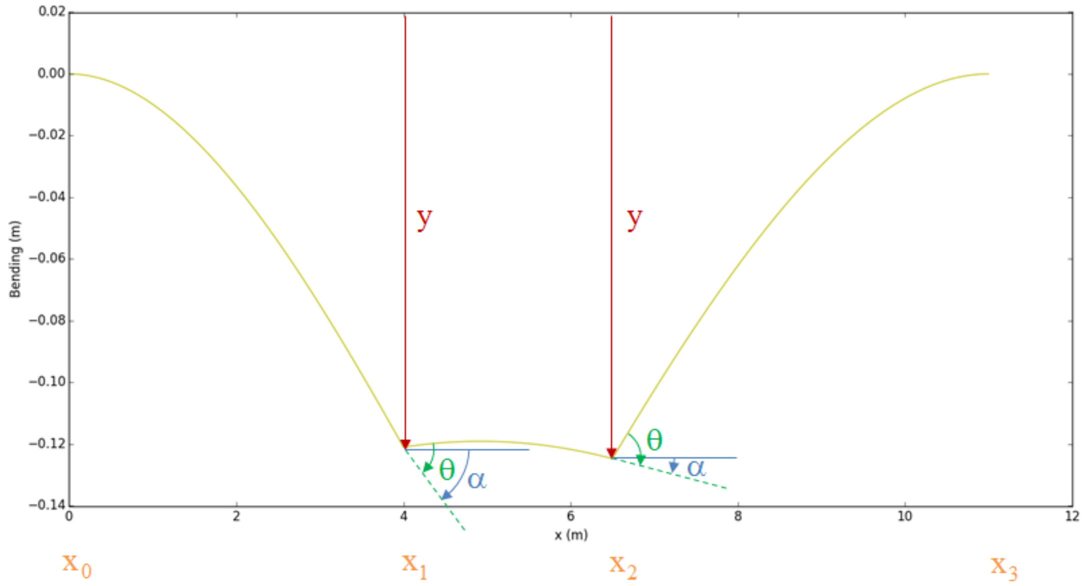


Joints connect pipe segments. They add additional bending.

The y-positions and angles of the joints are unknown. This is found by stress minimization.

ADDING JOINTS

WATER – GAS INTERDEPENDENCY



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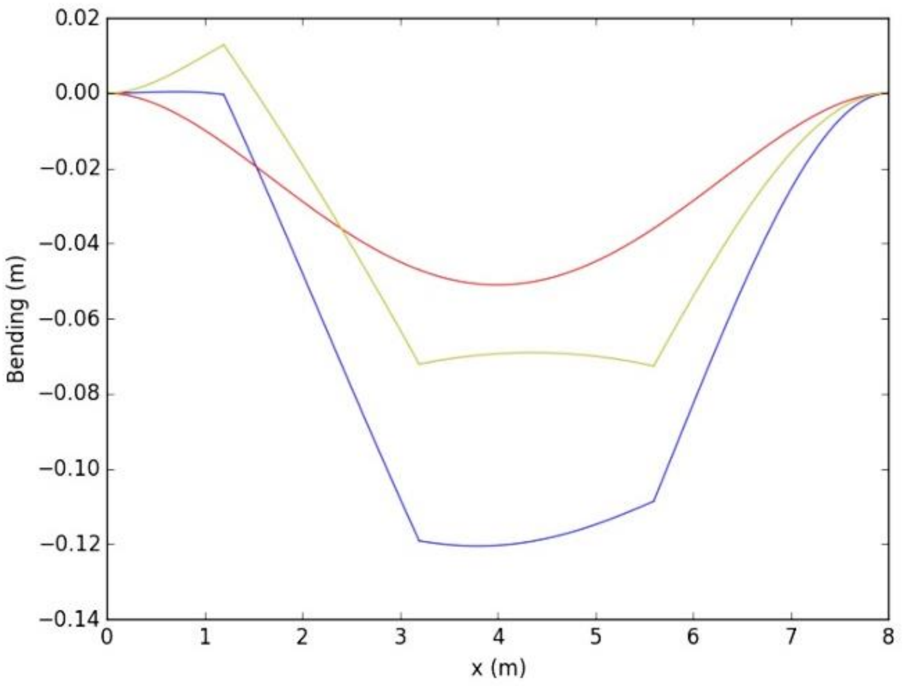
SIMULATION RESULTS

WATER - GAS INTERDEPENDENCY



The total bending of the pipe is the superposition of bending with and without joints.

Asbestos cement spanning 8 m

Inner diameter 100 mm

Outer diameter 124 mm

FLOODING ELECTRICITY MODEL

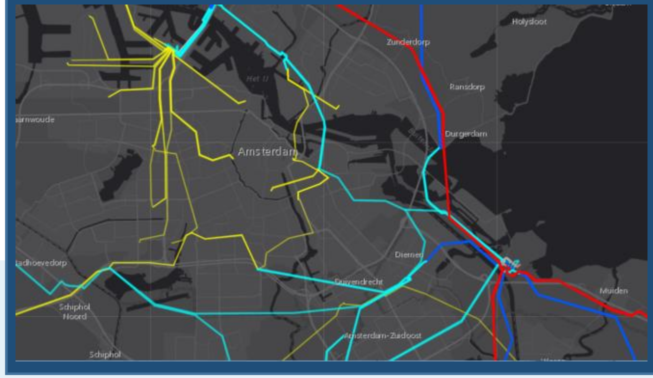
- Calculates the effects of a flooding on the high and medium voltage grid
- Will help to design resilient grids
- Will help to act during a flooding

FLOODING ELECTRICITY MODEL

Flooding data*

Water depth

Electricity data



Station coordinates

Connectivity and load

Failure analysis

Failed stations

Connectivity and load analysis

Blacked-out areas

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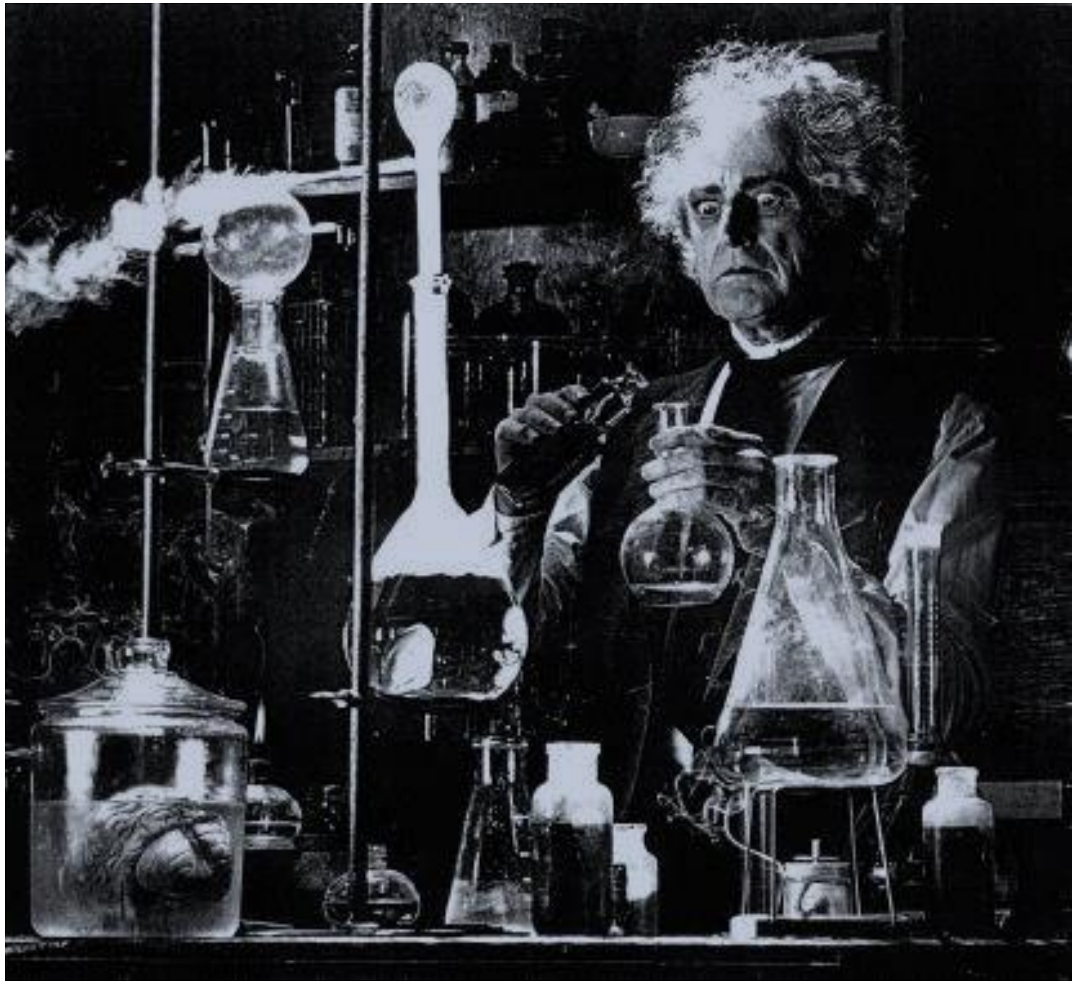
* This image shows no actual flooding data

CHALLENGES IN MODELLING

- Data for running the models (access)
- Quality of the data
- Cost of data transport/storage and security
- Measurements for validation
- Uncharted scientific territory
- Cooperation is crucial to succeed

CHALLENGES IN SOCIETY

- (Re)use from scientific models, increase quality scientific research
- Limit redundancy and lower costs…
- What scientific areas are really relevant for society and how can we maximize impact (as researchers).



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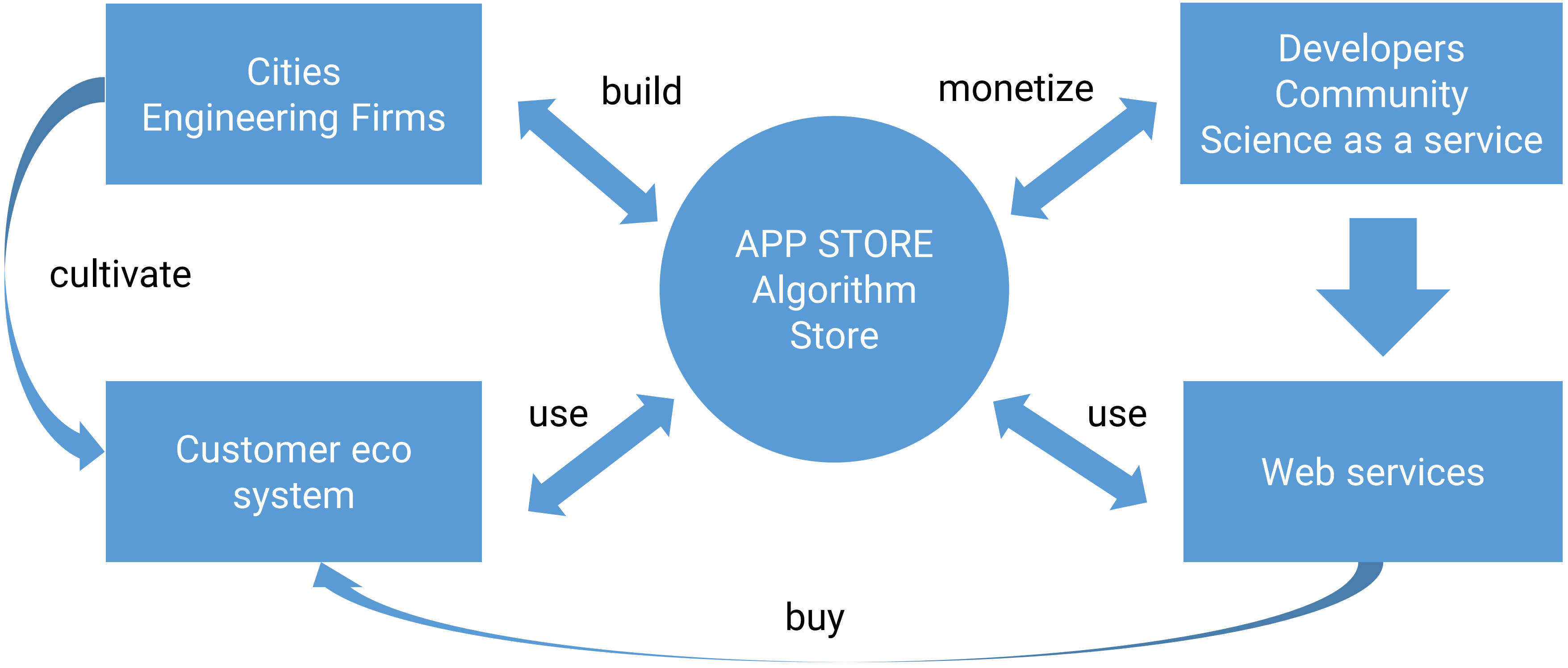
φ(x) = 1/√2πσ e
2σ²
p(x₁ ≤ x ≤ x₂)
φ(x)
0
x₁
x₂

SCIENCE AS A (WEB)SERVICE / PAY PER PLAY



- Automated Publication Process
- Automated Royalty Process (Crypto or real)
- Balancing Society and Commercial Ratios.


ECONOMIC SYSTEM
GLOBAL MARKET
EXCHANGE
CALCULATOR
FINANCIAL INFORMATION
Economic system
Capital and labor
Market Economy

PARTNERS

WE ARE PROUD TO WORK WITH:

THANK YOU

ANY MORE QUESTIONS?

Zuid Hollandlaan 7, 2596 AL Den Haag, Zuid Holland, The Netherlands