The University Of Sheffield.

RISE Resources, Infrastructure Systems and built-Environments

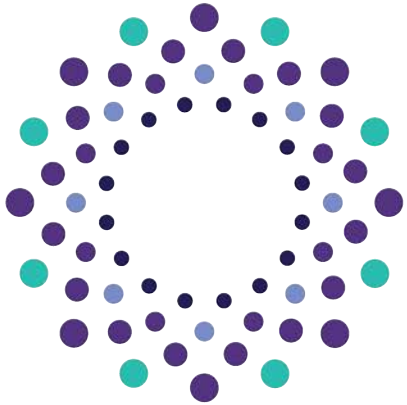
Engineering and Physical Sciences Research Council

Active Building Centre

UKCRIC UK Collaboratorium for Research in Infrastructure and Cities

MOTT MACDONALD | SMART INFRASTRUCTURE

INDUSTRIAL STRATEGY | UK Research and Innovation



URBAN FLOWS OBSERVATORY

Urban Digital Twin.

Professor Martin Mayfield, Infrastructure Lead, Faculty of Engineering

Dr Danielle Densley Tingley, Lecturer in Architectural Engineering, Civil and Structural Engineering

Professor Daniel Coca, Head of Department, Automatic Control and Systems Engineering

@urbanflowsObs

urbanflows.ac.uk

January 2021

URBAN FLOWS OBSERVATORY

We aspire to help cities to thrive within the carrying capacity of the planet by developing a globally leading understanding of the flows of energy and resources.

Our Objectives

1. Quantify how our consumption of energy/resources impacts on the environment – **GHG emissions** & **air quality** & to identify **levers for change**
2. Understand the **Urban Metabolism** required to deliver a **Circular Economy**
3. Provide an **evidence base** that facilitates local & national decision making

Status:

- £2.4m capital funding, 29 months through a 36 month *build* programme.
- £2.1m supporting research funding secured over this period.

....to help create healthy, happy cities.

Scalable hardware and software platform for Urban Analytics

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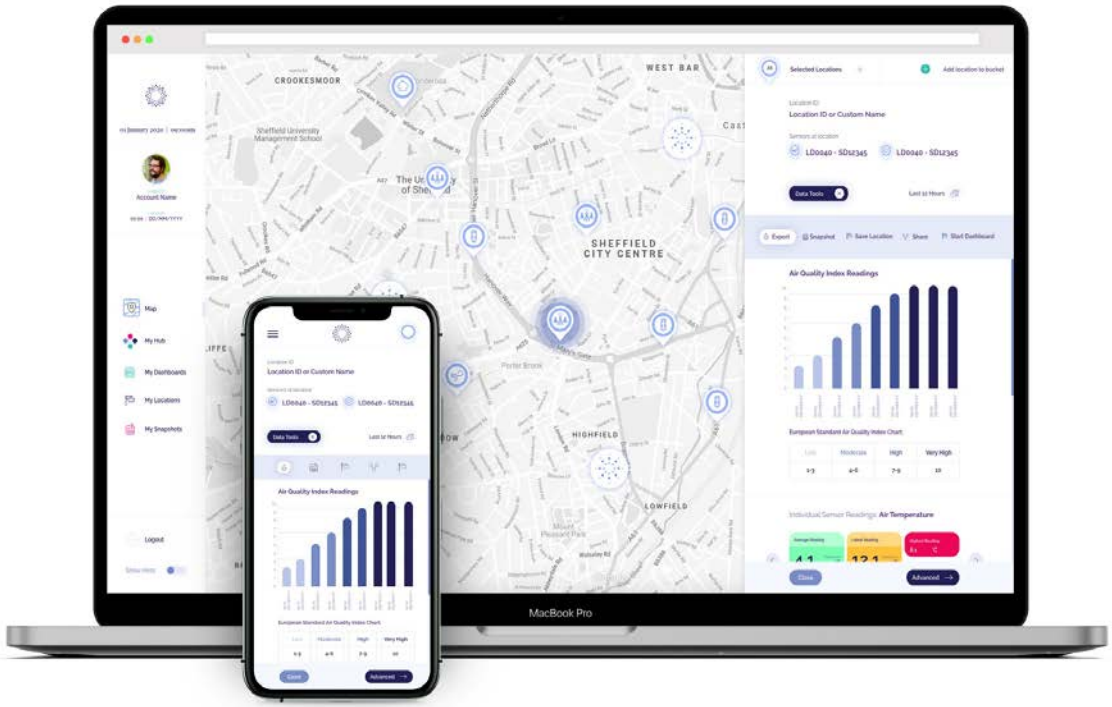
£2.4m capital investment

A platform for urban research and innovation through hosting, analysing and visualisation any geo-located data (transport, health, education, societal, economic)



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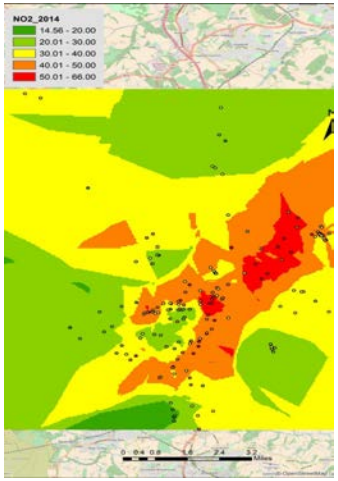
Platform



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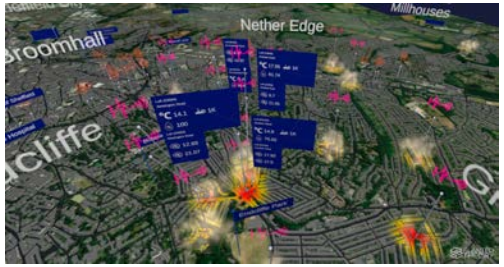

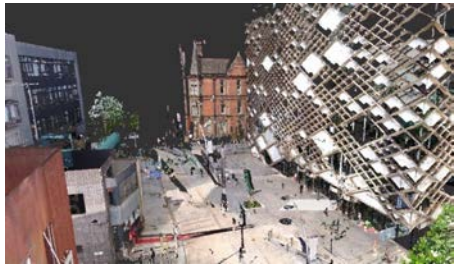

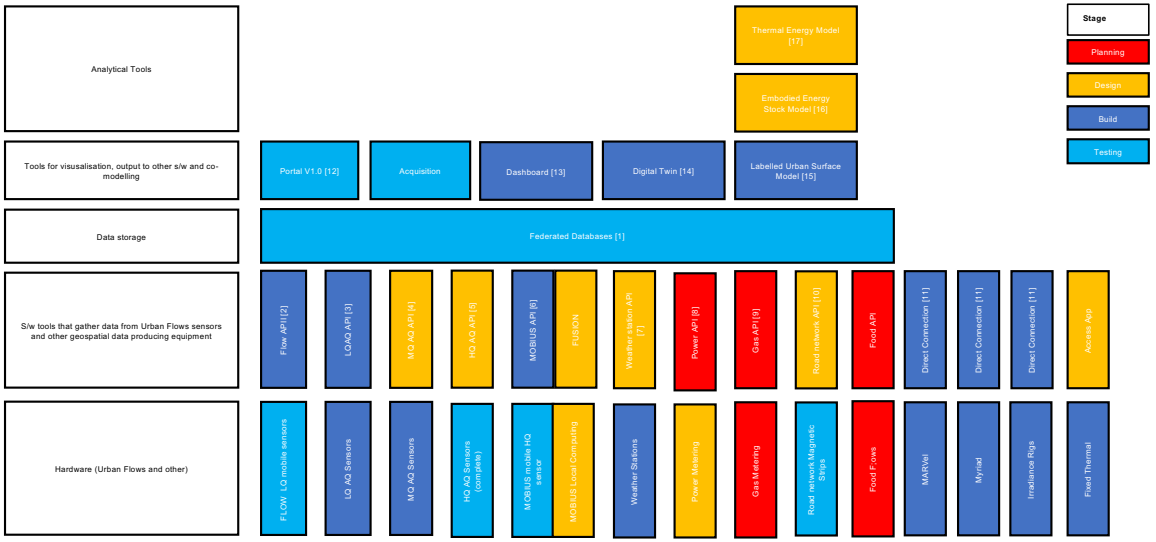

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Data Ingestion

MARVel
Multispectral Advanced Research VehicLe

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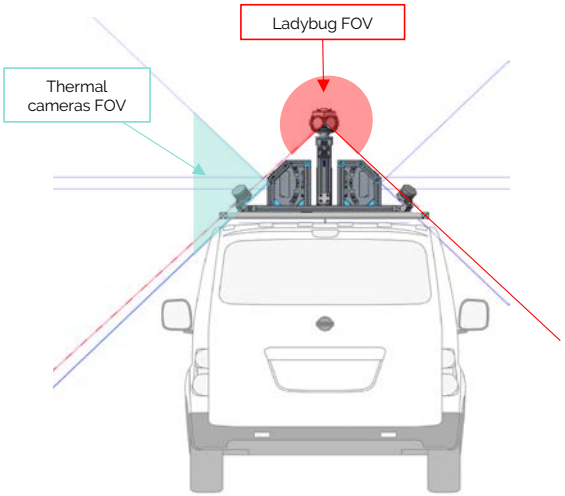
AMRC ADVANCED MANUFACTURING RESEARCH CENTRE

LiDAR Unit x 4
Velodyne Puck
16 channels @ 100m Range
Up to 600,000 Points per Second per Unit

Visual Camera Unit
Ladybug5+ 360° spherical camera, 90% full sphere FOV.
30 MP (5 MP x 6 CMOS sensors)

Thermal Camera x 4
FLIR A615
Resolution of 640 × 480 each @ 50 FPS
Temp. Range -20 to +150°C with an accuracy of ±2°C or ±2%

Hyperspectral Camera x 2
Specim FX10 VNIR
400nm – 1000nm with 224 Spectral Bands @ 330 FPS



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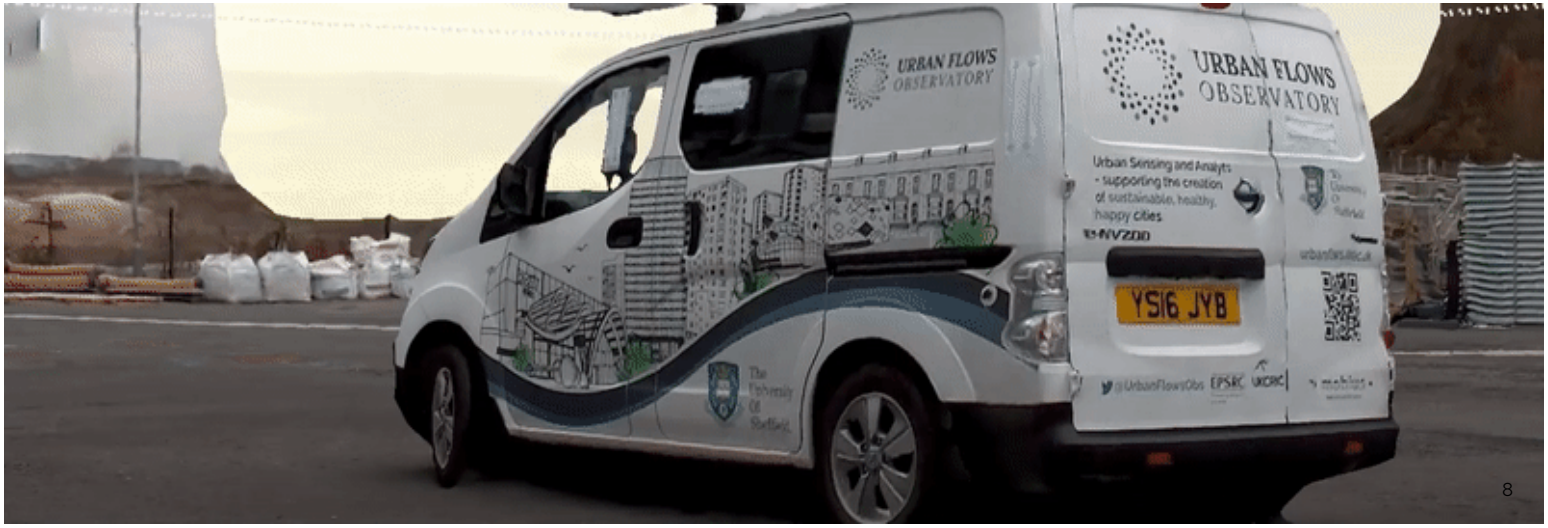
3D Photogrammetry



Early work focused on building location and data capture

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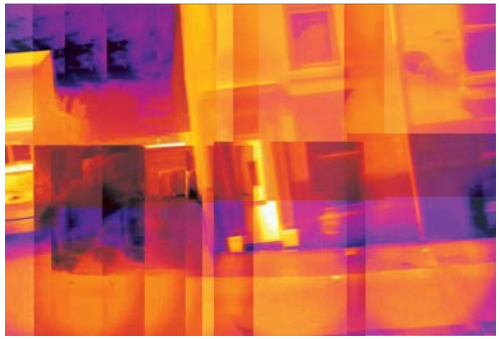
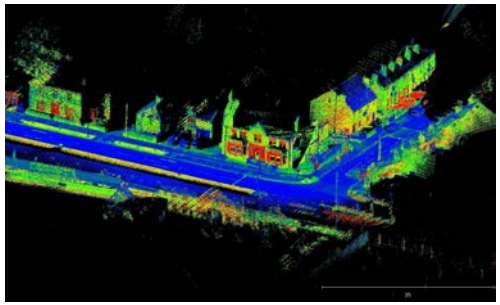
Data Capture and Building Co-Location

Visual Data Capture & Non-Normalised Thermal Data



3D Scene

LiDAR Data Capture

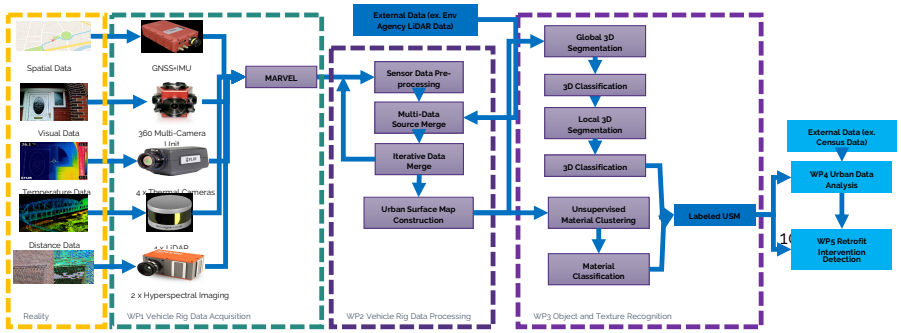


Turning data in to information

URBAN FLOWS OBSERVATORY

2D Façade Semantic Segmentation nearly complete

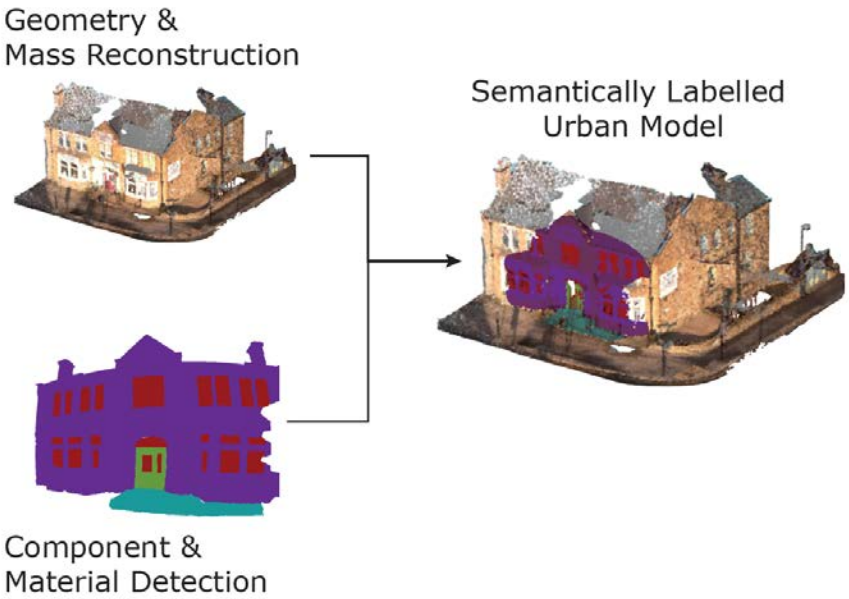
Building Façade Image Semantic Segmentation Using an Ensemble of Deep Neural Networks



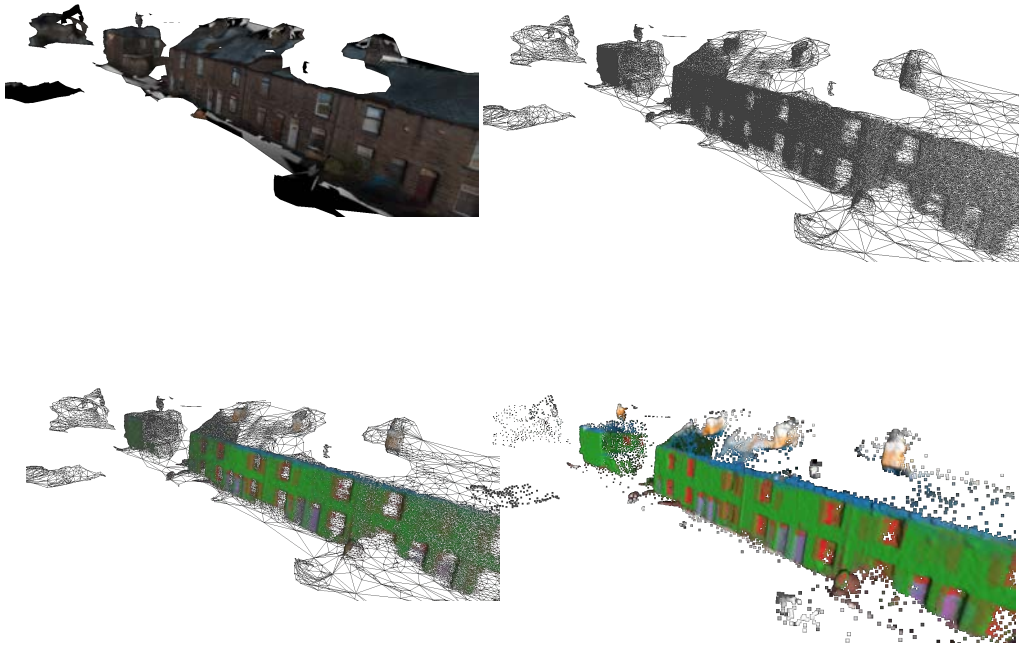
Turning data in to information

URBAN FLOWS OBSERVATORY

3D Façade Semantic Segmentation nearly complete.



3D Labelled Urban Surface Map to support automation of retrofit process being progressed with the Active Building Centre.



Third party data

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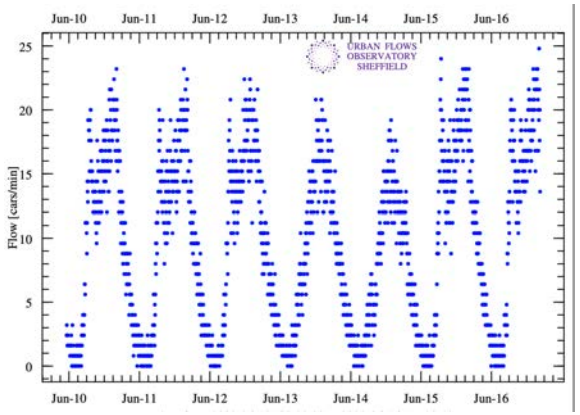
Near-Real-Time harvesting of

- Sheffield City Council traffic data from 600+ sensors including
  - Flow
  - Occupancy
  - Speed (to come)
  - ANPR (anonymised) (to come)
- Strategic Road Network Traffic data 4000+ sensors including
  - Speed
  - Vehicle category
  - Lane occupancy
  - Headroom
- Environment Agency river level data



RESEARCH OBJECTIVE*: model system across scales to understand how national issues affect Sheffield and visa versa*

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Visualisation

Urban Scale VR Platform

Proof of Concept with Hackathon winner

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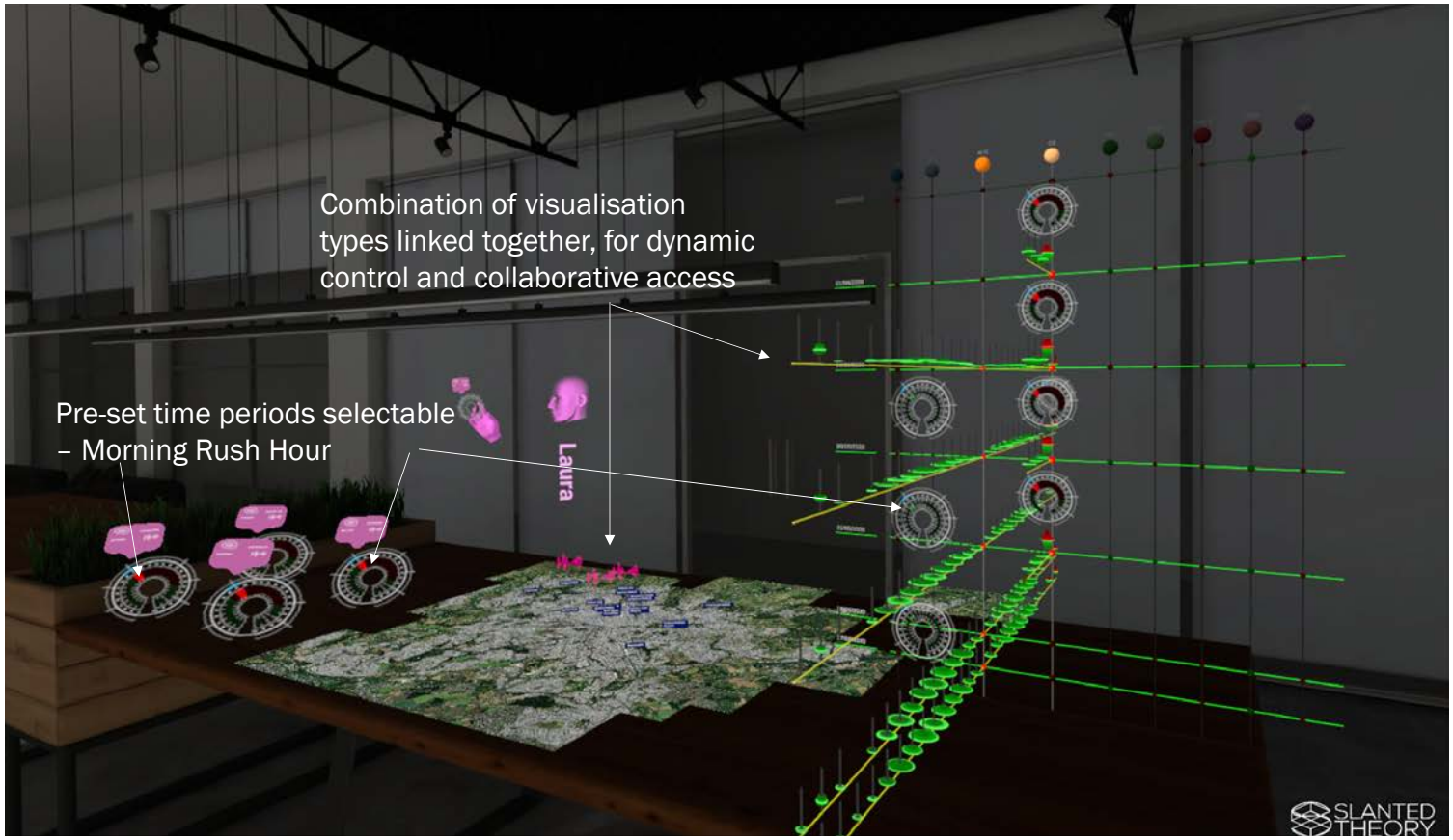

Urban Scale VR Platform

Project briefed with Sheffield City Council

Trail with Sheffield City Council and City Region planned.

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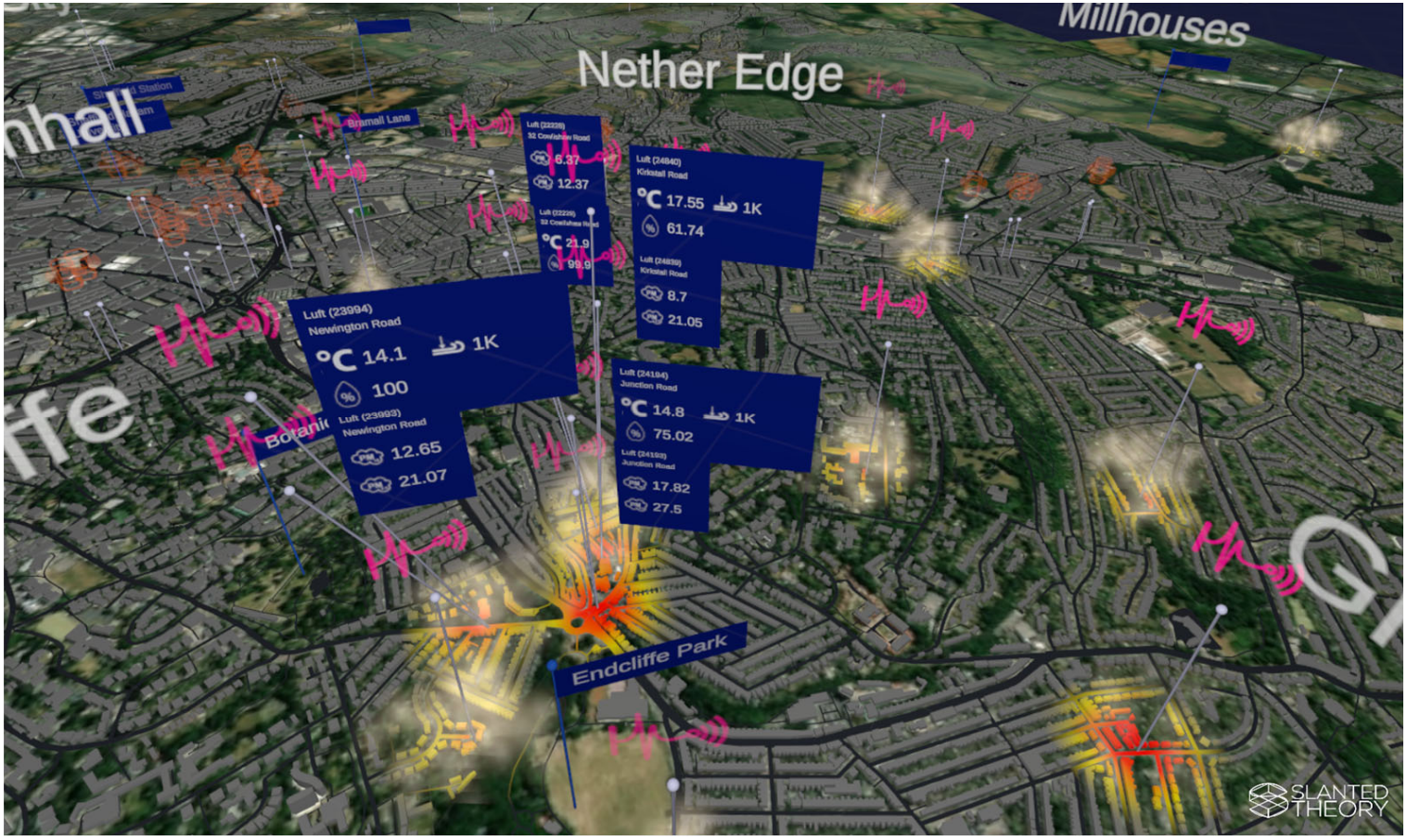

Urban Scale VR Platform

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”Digital Twin” work

Urban Scale Digital Twins

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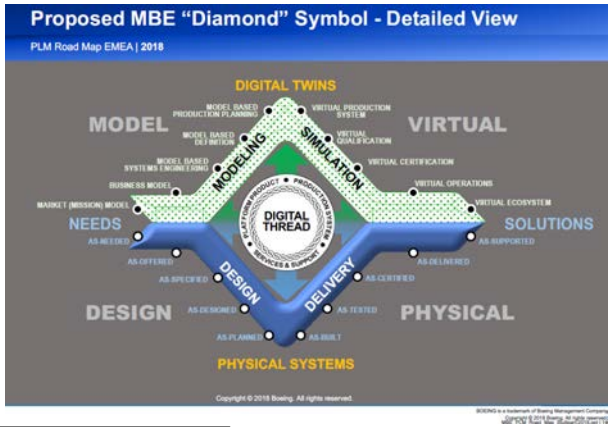
Challenges:

1. Unlike jet engines and other discrete engineering systems, Cities are messy open systems;
2. Model based Systems Engineering is a good way to think about DT's but runs in to trouble in cities as they are existing systems of systems within very little understanding of their structure and systemic interactions.
3. The lack of data on the structure and dynamics of key elements of the city makes it currently impossible to consider a whole system model for a city;
4. Currently, when combining three or more systems, the degree of uncertainty generated renders output useless;
5. The role of humans in the system can be modelled across one system but when considering dynamics across two or more systems (for instance, energy/transport) the degree of uncertainty in future scenarios begins to compromise results (particularly when considered across scales);
6. Modelling across scales (important for urban modelling) has not yet been effectively cracked in any field of science.



Some good work in here and its clear the modelling community are up for the challenge but urban system challenges are significant.

Urban Scale Digital Twin Development

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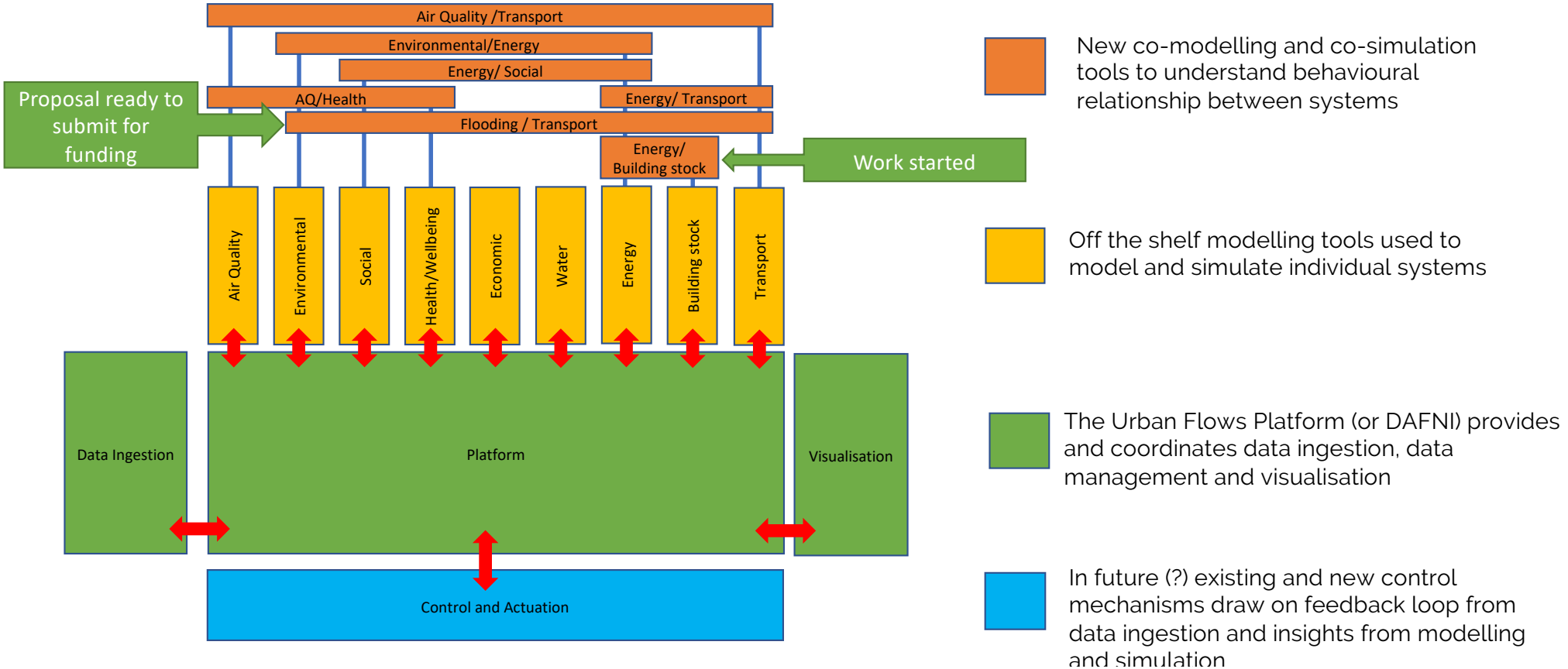
Urban Scale Digital Twins should provide a common approach for data ingestion, platform management and visualization while allowing the use of current single system models to be used, adapted and connected to other models.



Urban Digital Twin – PoC Brief

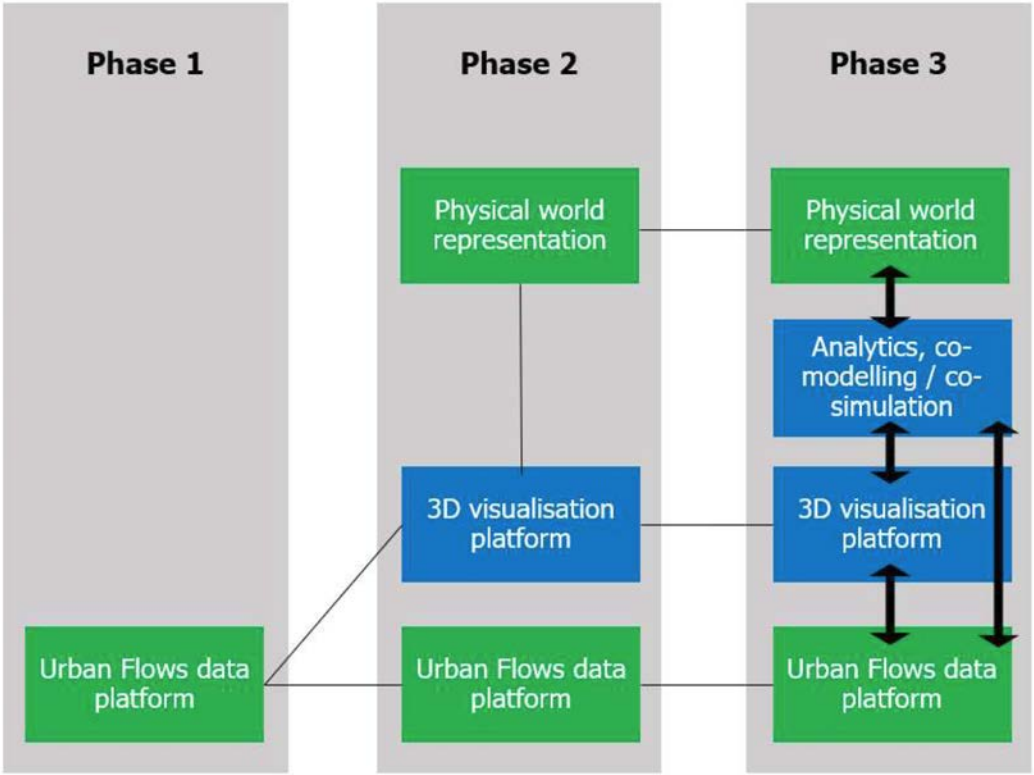
URBAN FLOWS OBSERVATORY

Proof of Concept Brief

Explore how to connect real time data with modelling tools (air quality and transport first).

Develop a single tool to visualise (via Unity) inputs from sensors, LiDAR/Photogrammetry, BIM. This acts as an allegory from co-modelling later.

1. Provide a visualisation to display the Observatory platform data in a 3D context
2. Connect off-the-shelf tools to achieve PoC and remain software-agnostic
3. Leave the way open for loading of future Observatory data



Urban Digital Twin – PoC Spatial Scope

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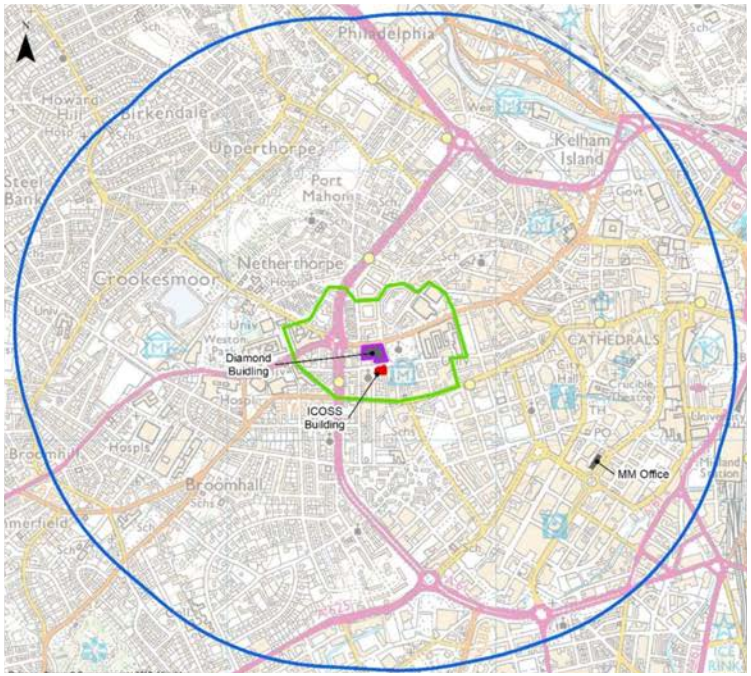

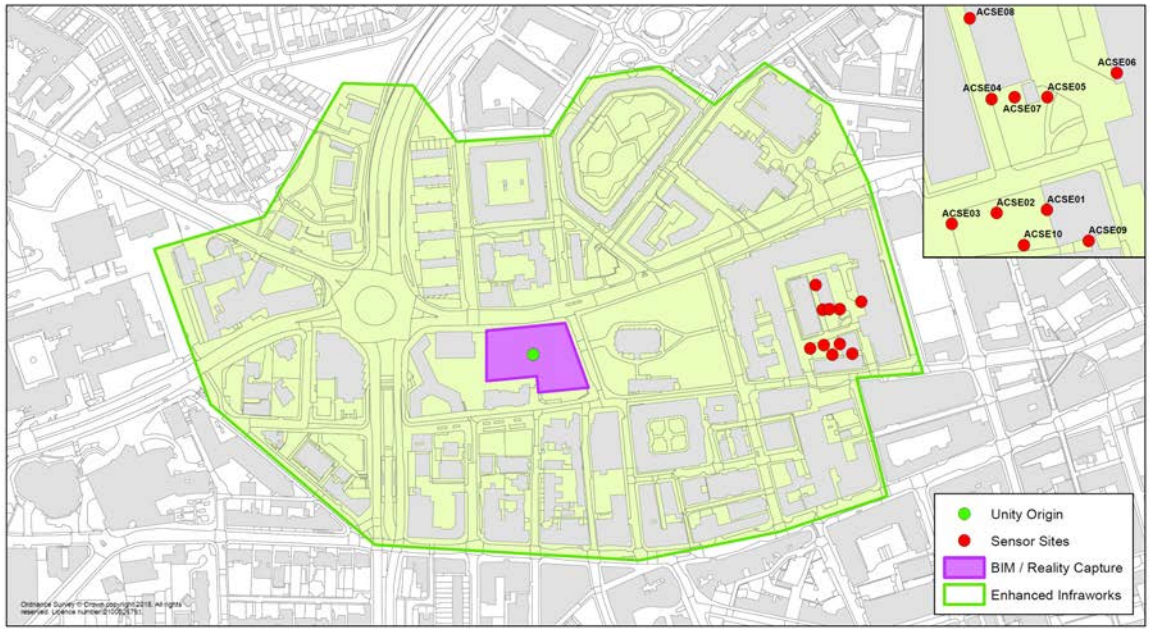

Urban Digital Twin – PoC High Fidelity 3D Data Types

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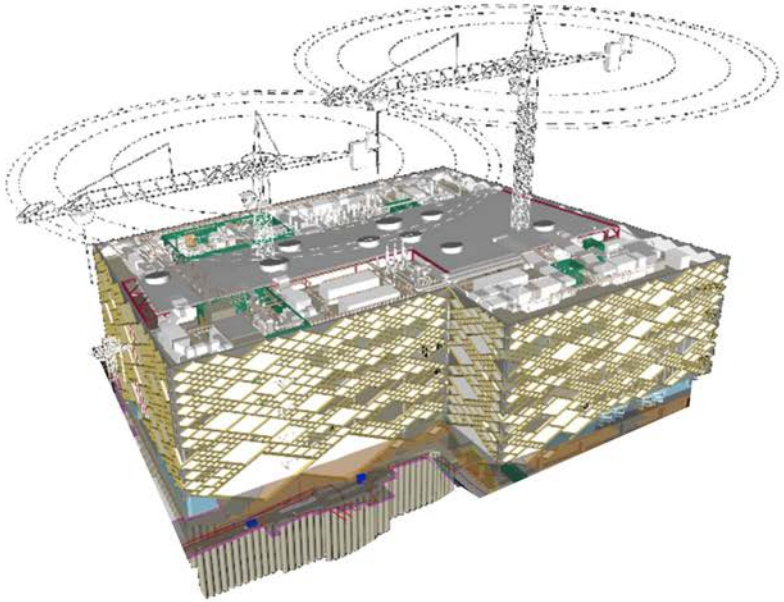
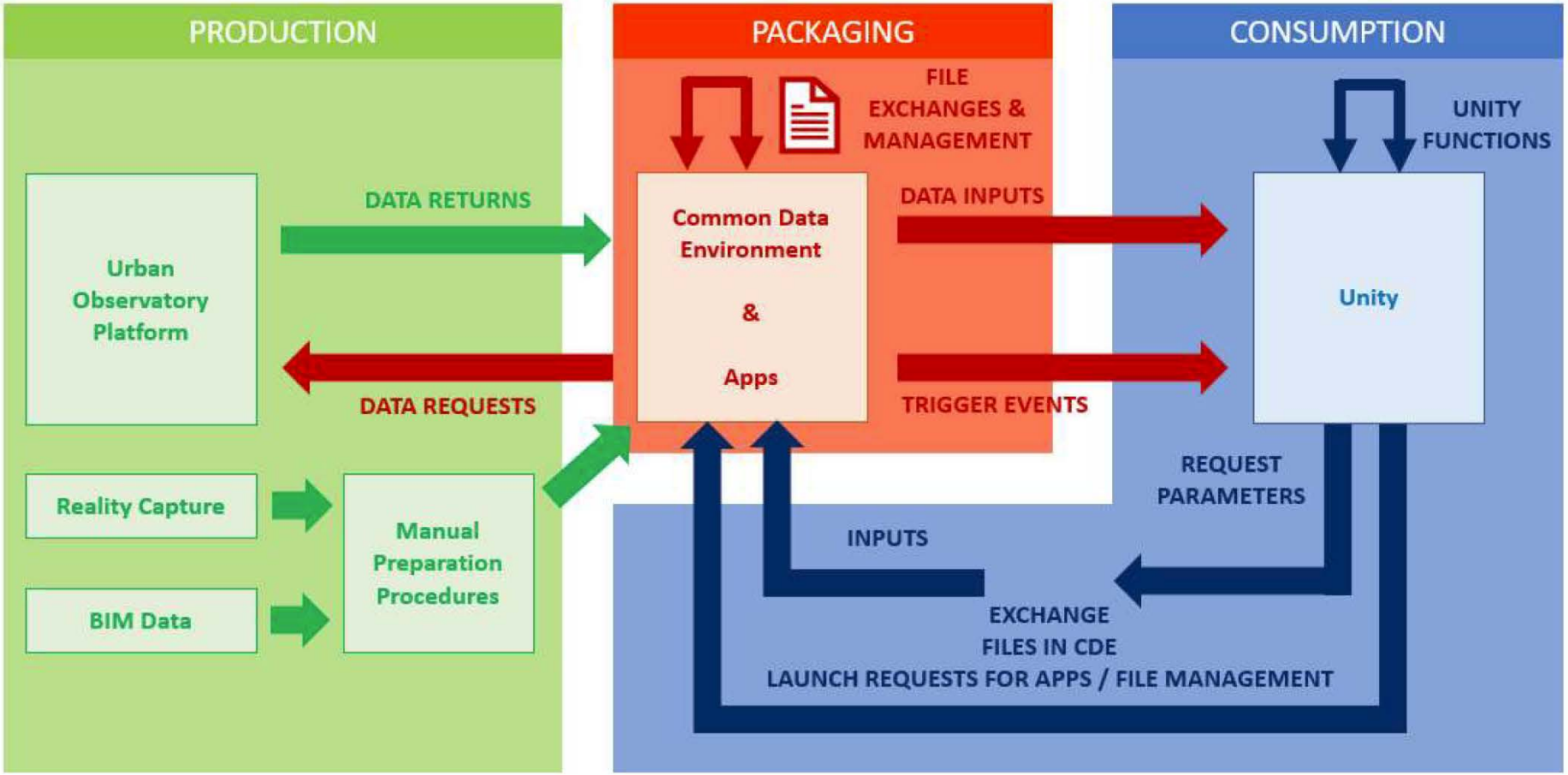
BIM



Reality Capture Data

Urban Digital Twin PoC – Simplified Architecture



Urban Digital Twin PoC – Full Architecture

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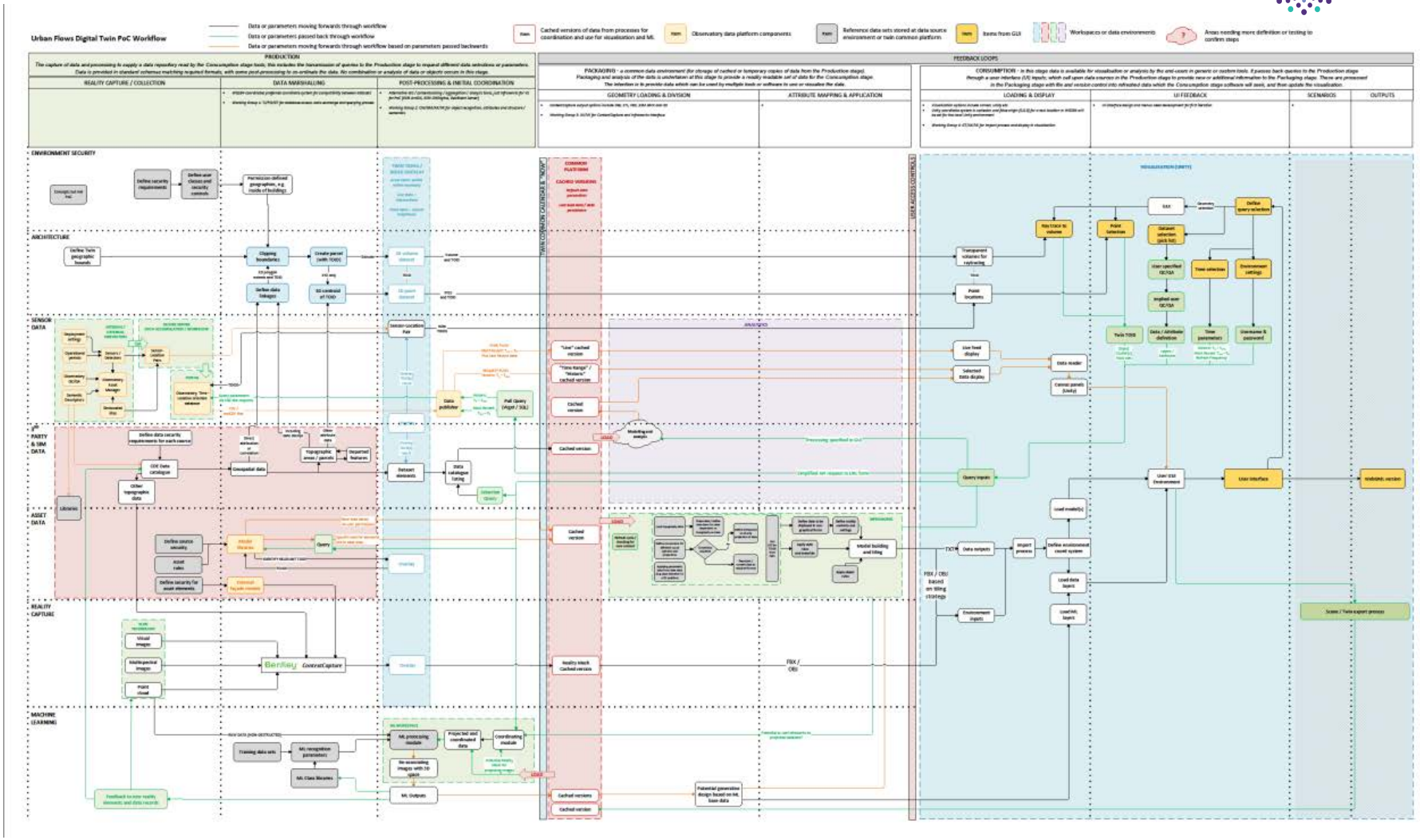

Urban Digital Twin PoC – Visulisation

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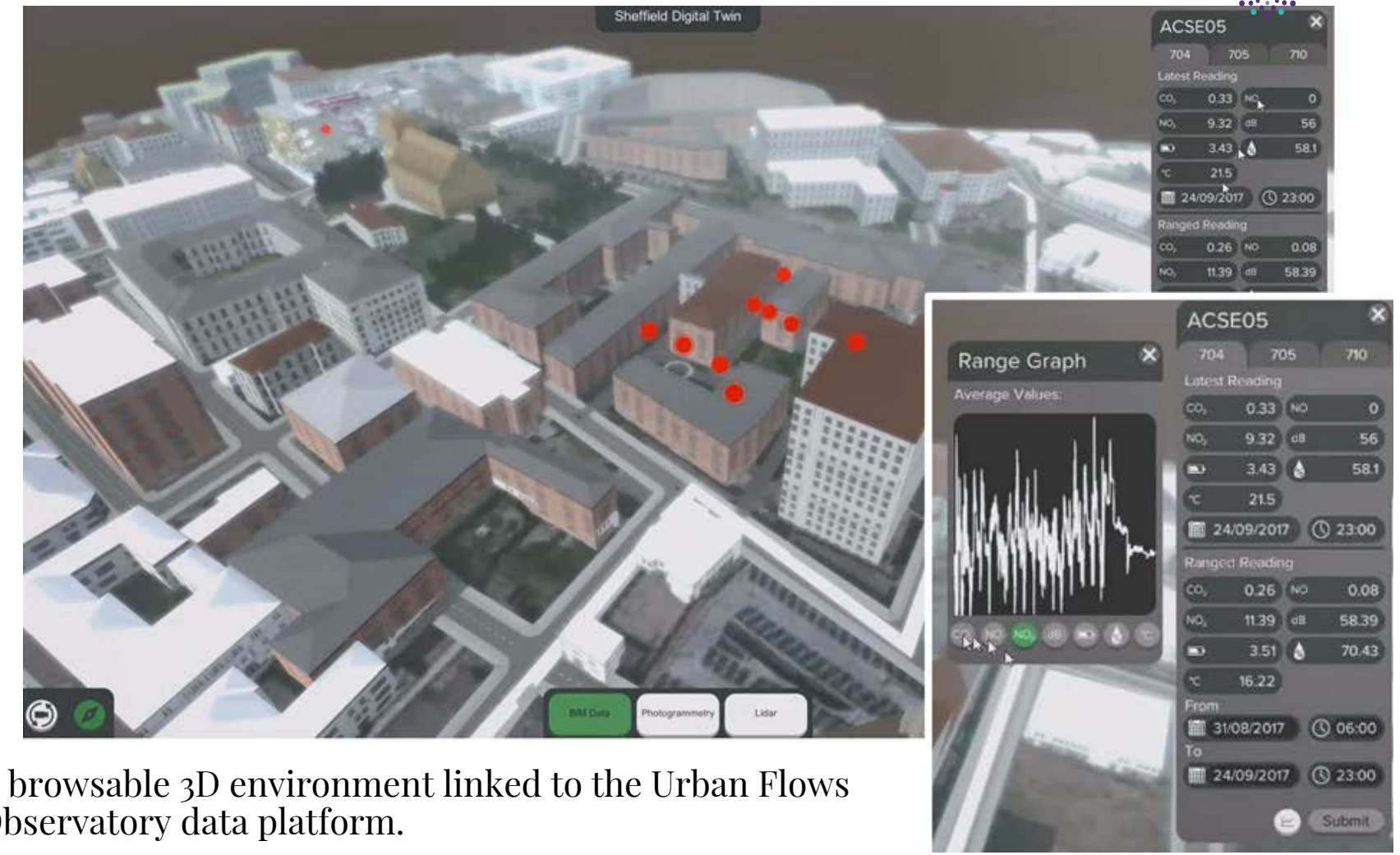

A browsable 3D environment linked to the Urban Flows Observatory data platform.

Urban Digital Twin v2

URBAN FLOWS OBSERVATORY

Visualisation split into a high-resolution desktop version and low-resolution online version interactable through online web browser.

Version 2 is primarily focusing on:

- Increasing the PoC's spatial scope.
- Improving 3D data fidelity while retaining visulisation performance.
- Simplifying complex multi-source data fusion processes.

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Closing thoughts – Urban Scale Digital Twins

1. Exploration of how to harvest data from current processes should be accelerated.
2. Exploration of how to gather data from sensors deployed for other reasons (Smart Phones, Autonomous Vehicles) should be accelerated.
3. Much more work is needed to define and demonstrate the value of urban scale DT's;
4. Methods need to be scalable (easy for software, hard for hardware).

The University Of Sheffield.

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Thank you