Urban Modeling using OGC Standards

GISMO Membership Meeting, 15 June 2017

George Percivall
CTO, Chief Engineer
Open Geospatial Consortium

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Making location count.

Urban Modeling using OGC Standards

- What is OGC and what standards have been approved recently
- 3D Data Integration
- Future City Pilot
- Underground Infrastructure Study

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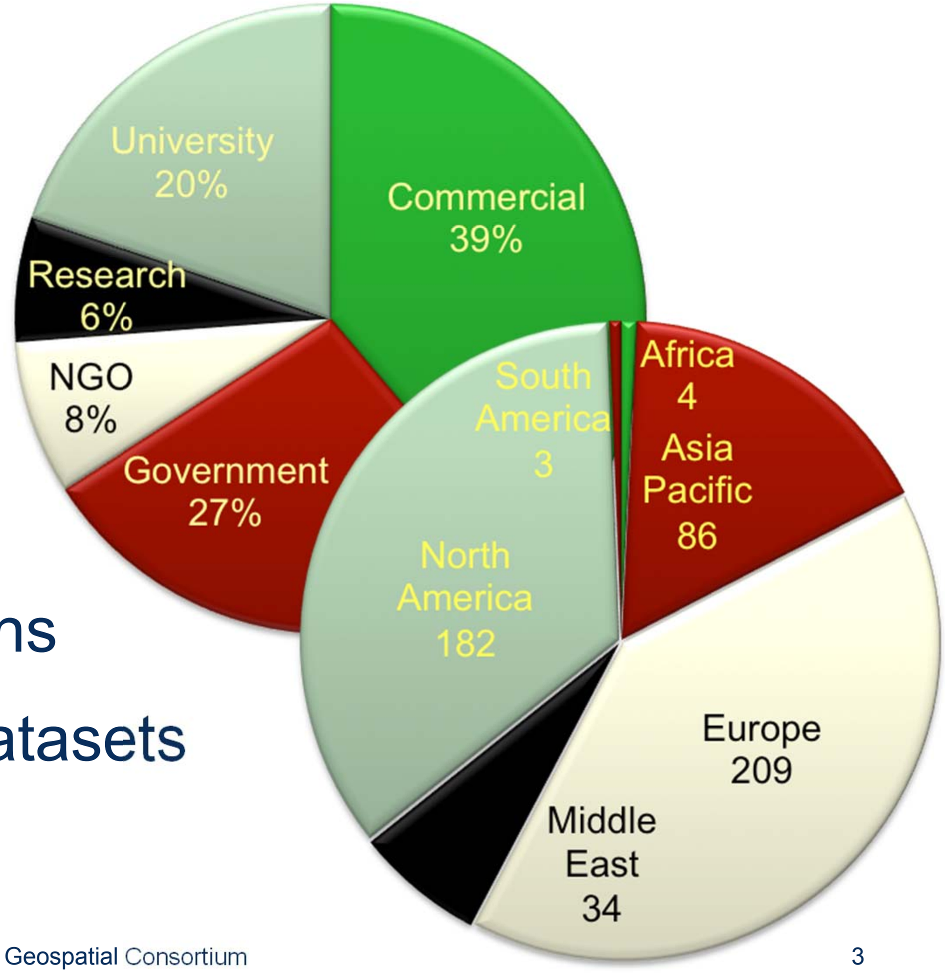
The Open Geospatial Consortium

Not-for-profit, international voluntary consensus standards organization; leading open innovation for geospatial data

- Founded in 1994
- 525+ member organizations
- 100 innovation initiatives
- 48 Open Standards
- 230 OGC certified products
- Thousands of implementations
- Enabling access to 100K+ datasets



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Example OGC Commercial Members

Ordnance Survey
DigitalGlobe
Google™
ESRI
pitney bowes
ORACLE
INTERGRAPH
BENTLEY
AIRBUS DEFENCE & SPACE
Trimble
HARRIS
AUTODESK
NAVTEQ
agi Analysis software for land, sea, air, & space
Boundless
LOCKHEED MARTIN
LUCIAD
PCI Geomatics
CAE
THALES
ENVITIA World Class Spatial Information Technologies
Spacemetric
Microsoft
1Spatial
VENCORE
Raytheon
Snowflake software
ROLTA
Leica Geosystems
galdos systems inc
Skyline
CubeWerx Interoperable Services for the Geo-Spatial Web
Insurance Evolved FM Global
LIZARDTECH a celartem Company
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exactEarth
BAE SYSTEMS

What is a Standard?

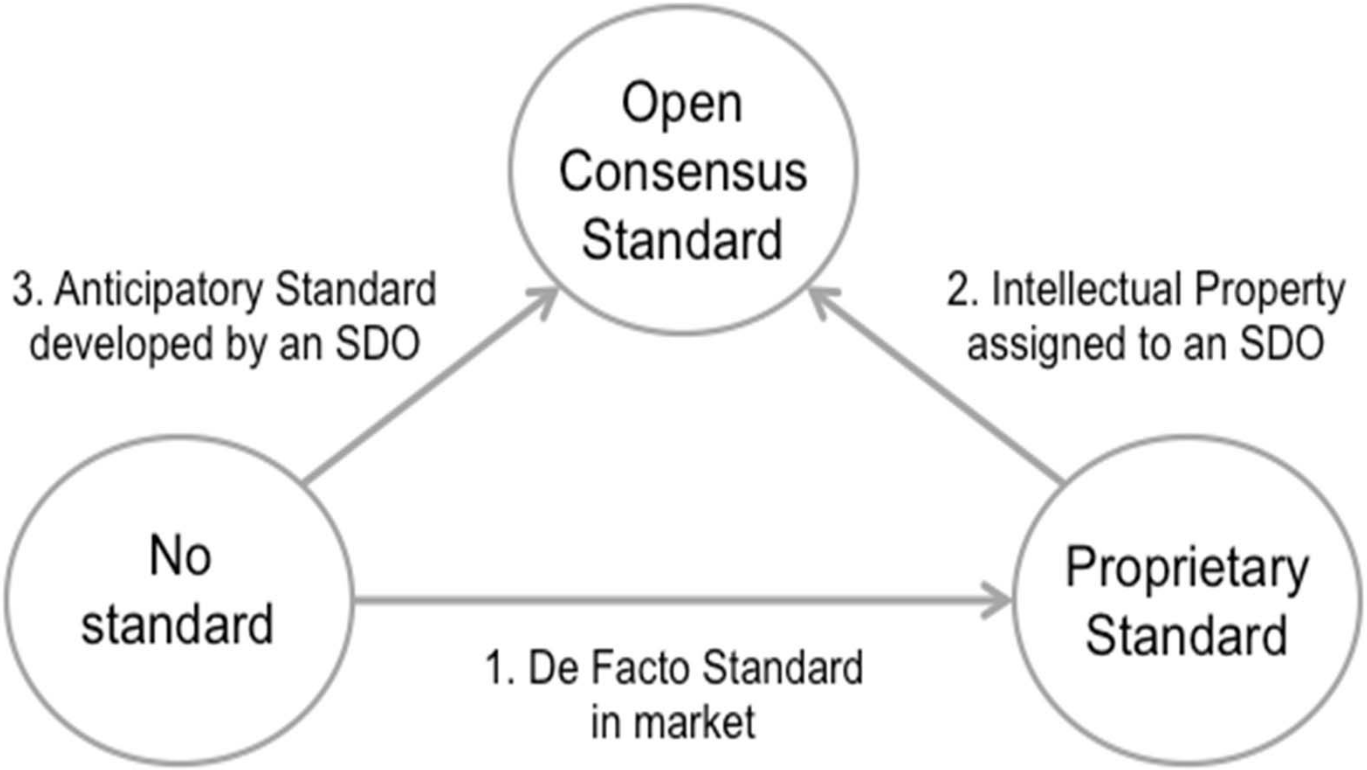
- “*An agreed way of doing something*”

What is a Standard?

- "*An agreed way of doing something*"
- **Standards are distilled wisdom** of people with expertise in their subject matter and who know the needs of the organizations they represent – people such as manufacturers, sellers, buyers, customers, trade associations, users or regulators.
- **Standards are knowledge**. They are powerful tools that can help drive innovation and increase productivity. They can make organizations more successful and people's everyday lives easier, safer and healthier.

EC: Practical standards guide for researchers - en

Innovation in Standards



Recent examples with research connections

2. 3D Tiles Community Standard (in process)
3. Discrete Global Grid Systems (DGGS) Standard

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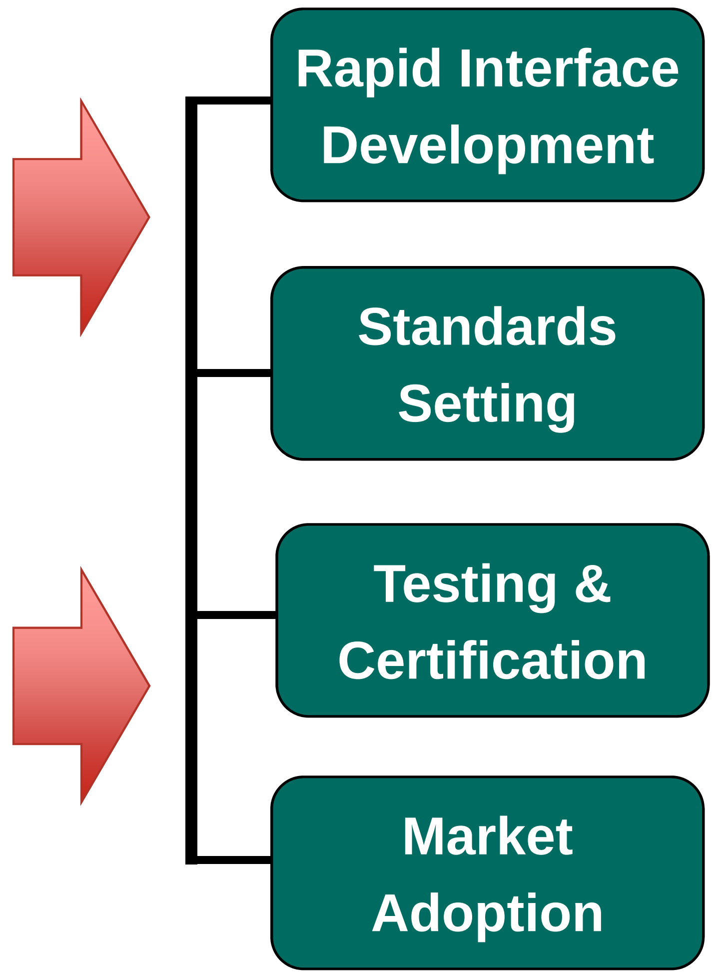
OGC's Approach for Advancing Interoperability

- ***Innovation Program*** – a global, innovative, hands-on rapid prototyping and testing program designed to unite users and industry in accelerating interface development and validation, and the delivery of interoperability to the market
- ***Standards Program*** – Consensus standards process similar to other Industry consortia (World Wide Web Consortium, OMA etc.).
- ***Compliance Program*** – allows organizations that implement an OGC standard to test their implementations with the mandatory elements of that standard
- ***Communications and Outreach Program*** – education and training, encourage take up of OGC specifications, business development, communications programs



Standards Program - 2017 first half in one slide

1	Abstract Specification Topic approved
11	Standards approved
2	new Community standard work items started
1	Best Practice approved
30+	Engineering Reports approved
2	Discussion or White Papers approved
2	new Standards Working Groups (SWG)
2	new Domain Working Groups (DWGs)
1	new Subcommittee

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OGC Standards approved in the past 6 months

- Discrete Global Grid Systems (DGGS) Core Standard
- InfraGML 1.0 Parts 0 through 6
- Coverage Implementation Schema (CIS) 1.1
  - CIS – ReferenceableGridCoverage Extension
- GeoAPI 3.0.1 Implementation Standard
- Moving Features Access

3D DATA INTEGRATION

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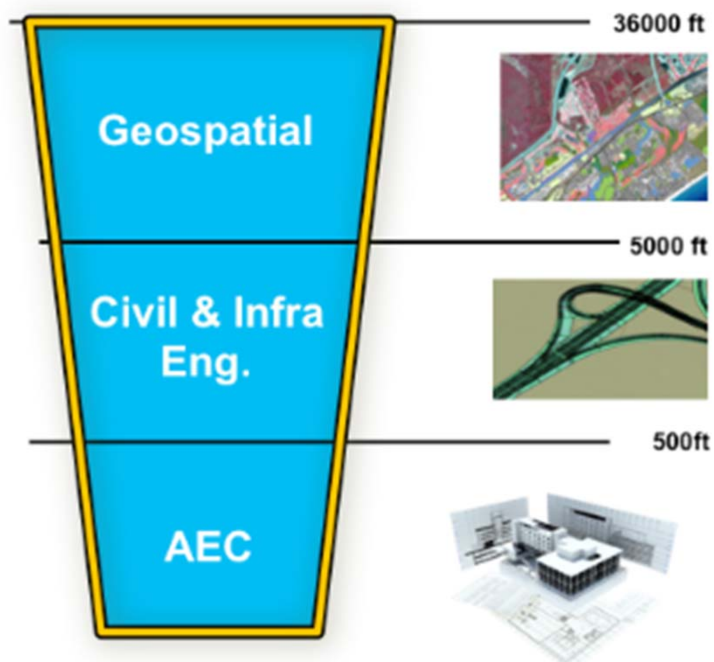
Merging of spatial domains

- Geospatial, Civil Engineering & BIM come together in the Urban environment and are destined to work together



Graphics: OGC

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3D Data Integration

"3D integration may be the biggest challenge in 3D domain"

- how to integrate 3D data with different semantics
- how to integrate data above and below surface;
- how to integrate vector and voxel data;
- how to integrate bathymetry data with digital terrain data;
- how to integrate sensor data (temperature, wind air quality) with a 3D city model and
- how to integrate these with simulation software etc.

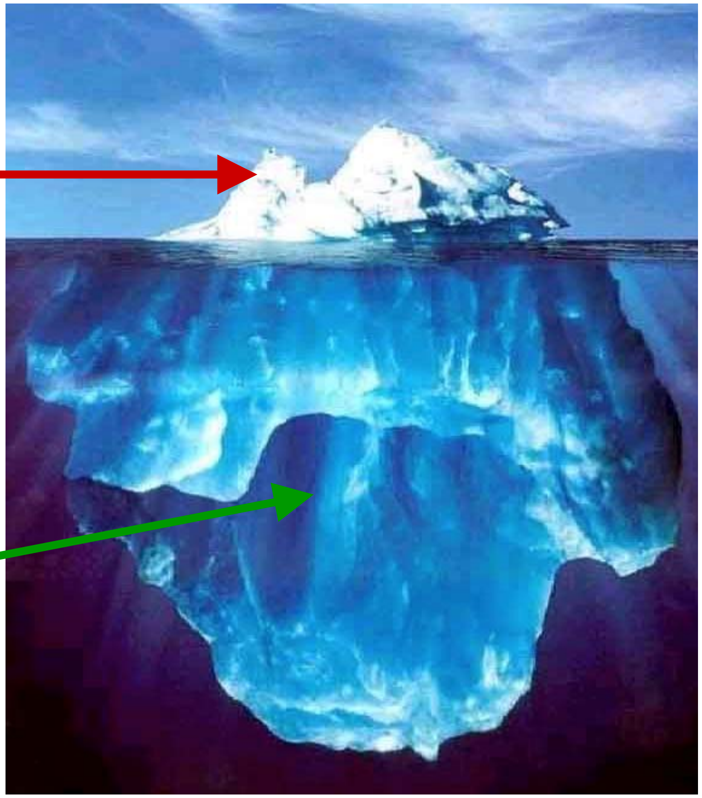
Towards sustainable and clean 3D Geoinformation
Jantien STOTER, Hugo LEDOUX, Sisi ZLATANOVA, Filip BILJECKI 3D GeoInformation, Department of Urbanism, Delft University of Technology

3D City Modeling

Far more than the **3D visualization** of reality

- **geometry** and its **appearance** are **only one aspect** of an entity (not SMART)
- Key issue (to make things SMART): **Semantic modeling**

  meaning / structure / relationships



- **Enabling geospatial smart city services**
- **Need for standards to integrate data**

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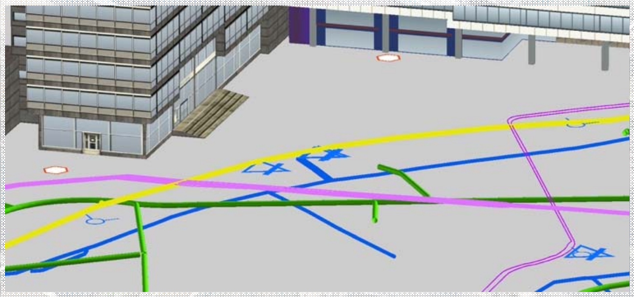
Semantic 3D City Models - Berlin

>500,000 buildings;

- **fully-automatically generated from 2D cadastre footprints & airborne laserscanning data.**
- **textures (automatically extracted from aerial images)**
- **semantic information (includes data from cadastre)**
- **3D utility networks from the energy providers**



- **modeled according to CityGML**

Source: Nagel, Kolbe, 2010

Global use of CityGML City Models

- European-wide INSPIRE (Infrastructure for Spatial Information in Europe)
- Netherlands National 3D standard
- Germany: Berlin, Dresden, Stuttgart, Bonn, Cologne, Frankfurt/Main
- Austria: Vienna, Salzburg
- France: Paris
- Switzerland: Geneva
- Finland
- U.A.E. – Abu Dhabi
- Kingdom of Bahrain
- Malaysia
- China,
- Singapore

Putrajaya, Malaysia
Source: UTM.MY

Wuhan, China
Source: Nagel, Kolbe, 2010

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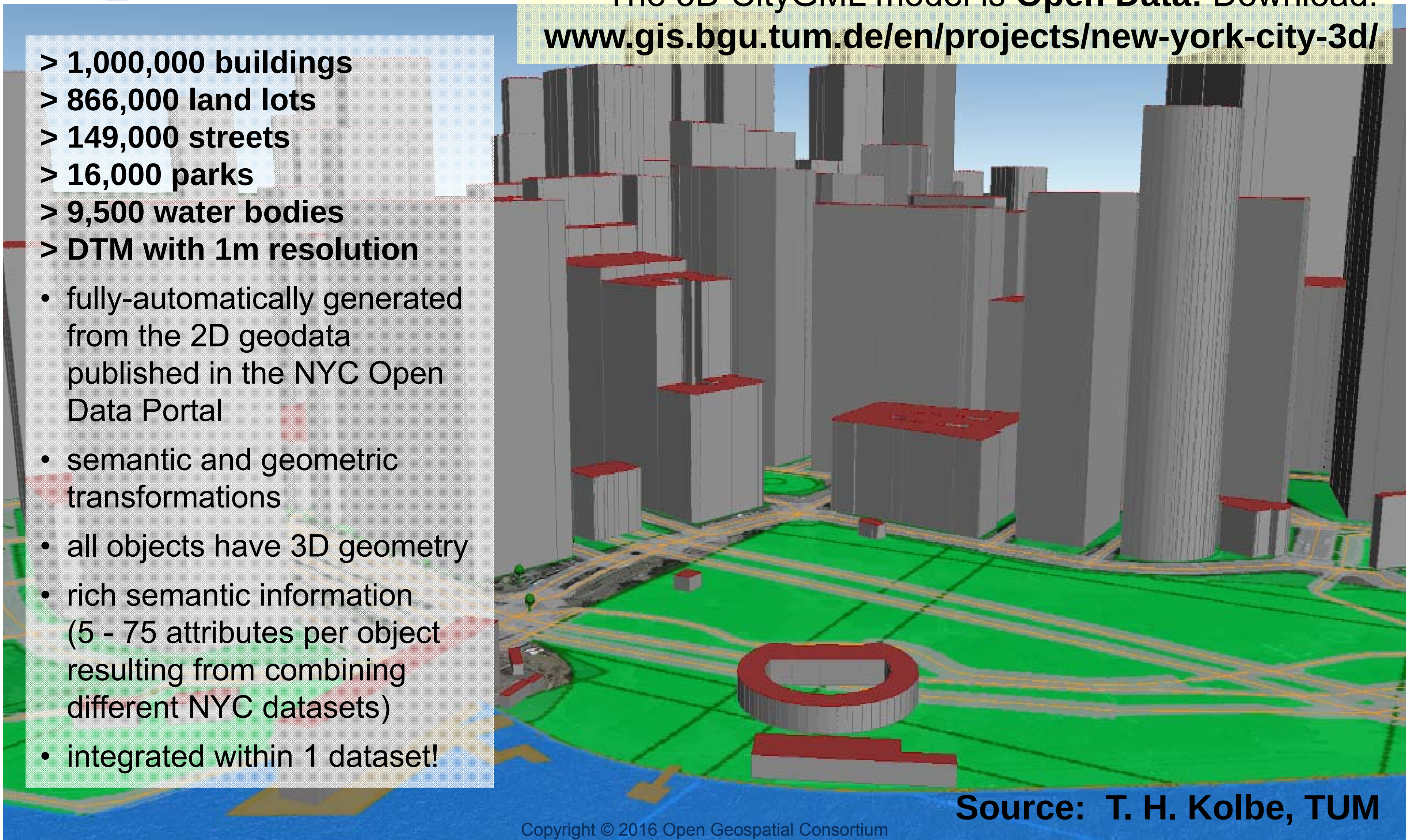
New York City open data in CityGML

The 3D CityGML model is **Open Data!** Download:
www.gis.bgu.tum.de/en/projects/new-york-city-3d/



> 1,000,000 buildings
> 866,000 land lots
> 149,000 streets
> 16,000 parks
> 9,500 water bodies
> DTM with 1m resolution

- fully-automatically generated from the 2D geodata published in the NYC Open Data Portal
- semantic and geometric transformations
- all objects have 3D geometry
- rich semantic information (5 - 75 attributes per object resulting from combining different NYC datasets)
- integrated within 1 dataset!

Source: T. H. Kolbe, TUM

Challenges in Generating NYC 3D City Model

- only 2D and 2.5D data given → generation of 3D geometries
  - volumetric building and tree models
  - all other feature types mapped onto the terrain
  - special treatment of road geometries to include different height levels
- data heterogeneity
  - different coordinate reference systems
  - different exchange formats (Shapefiles, ESRI GeoDB, Excel etc.)
  - no standardized semantic data model / ontology (each department defines their own data structures)
  - 1:1, 1:n, and n:m mappings required
- huge data volume
  - large area with > 1 million buildings; big DTM; in total about 4 million objects

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Multiple NYC CityGML Datasets

NYC 3-D Building Model

http://www1.nyc.gov/site/doitt/initiatives/3d-building.page

3D CityGML model from NYC Open Data

> 1,000,000 buildings
> 866,000 land lots
> 149,000 streets
> 16,000 parks
> 9,500 water bodies
> DTM with 1m resolution

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www.gis.bgu.tum.de/en/projects/new-york-city-3d/

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Software supporting CityGML (as of Nov 2015)

- Oracle 11g / Tech. University of Berlin: Oracle schema/loader/updater citygml4j, open-source Java class library and API for the processing of 3D city models (free), *can handle any ADE*
- VirtualCitySystems
- Bentley: Bentley Map
- Autodesk: LandXplorer CityGML Viewer (free) + studio (authoring/management)
- Safe Software FME (reader & writer)
- ESRI: ArcGIS10 (import)
- University of Bonn: Aristoteles Viewer (free)
- Snowflake software: Go Publisher WFS
- Interactive Instruments: WFS
- HST Stuttgart: QS-City 3D, a free online service for checking CityGML Data
- CPA: SupportGIS3D
- GTA: Tridicon CityDiscoverer
- MetGeoInfo: CityGRID
- Bitmanagement: BS Contact Geo 3D
- Ptolemy3D: virtual globe CityGML plugin
- RhinoTerrain: CityGML support in development
- FH GK: CityGML-Toolchain , different tools incl. Sketch-Up plugin (free)
- FZ Karlsruhe: FZKViewer, viewer for IFC and CityGML data (free)
- Revisitor: WI-MAP
- LibCitgyGML: C++ Library (http://code.google.com/p/libcitygml), OpenSceneGraph

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CityGML Quality Validation Domains

Level	Domain	Specification
6	Application-specific	Mostly project-specific, natural language specification, sometimes CityGML profiles (ISO 19109) or CityGML ADEs
5	Semantics	Natural language specification (if at all!)
4	Conformance Requirements	Natural language specification
3	Geometrie / Topologie	ISO 19107, Algebraic topology, computational geometry
2	Referential Integrity	Natural language specification, partly mapped to Schematron
1	Schema conformity	Formal grammar (XML Schema)

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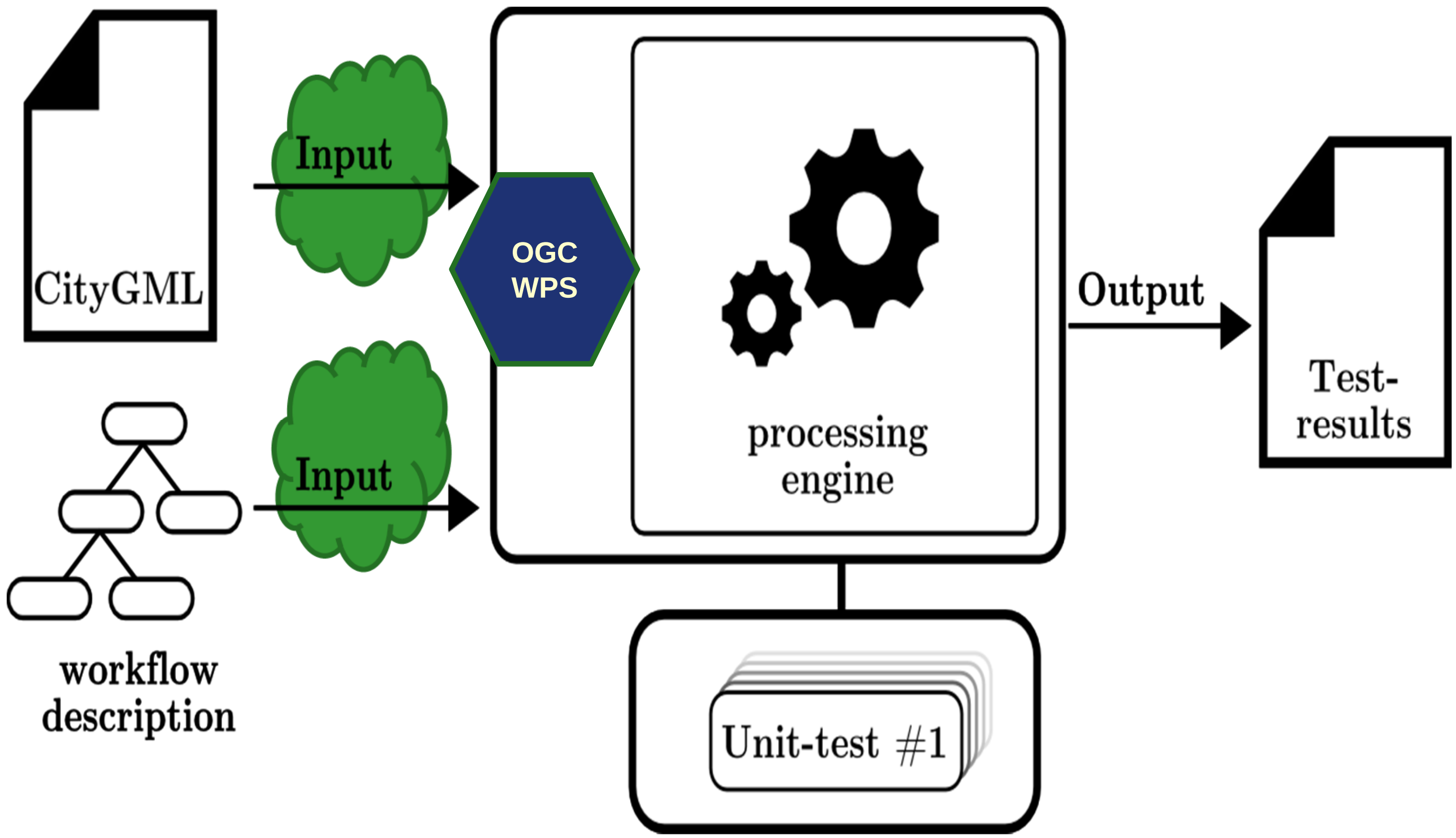
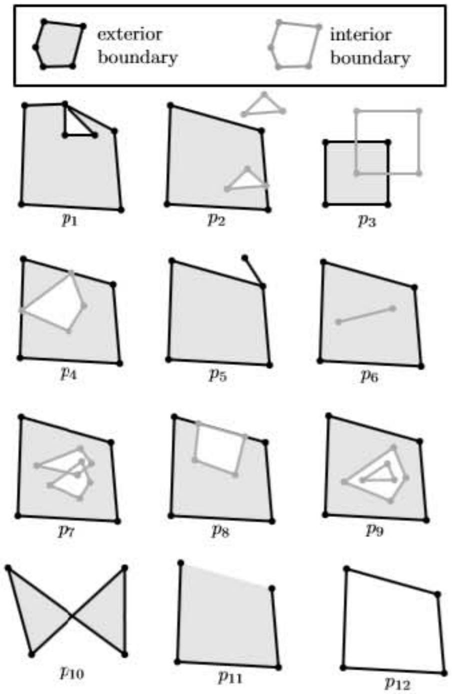
CityGML QIE Validation Framework

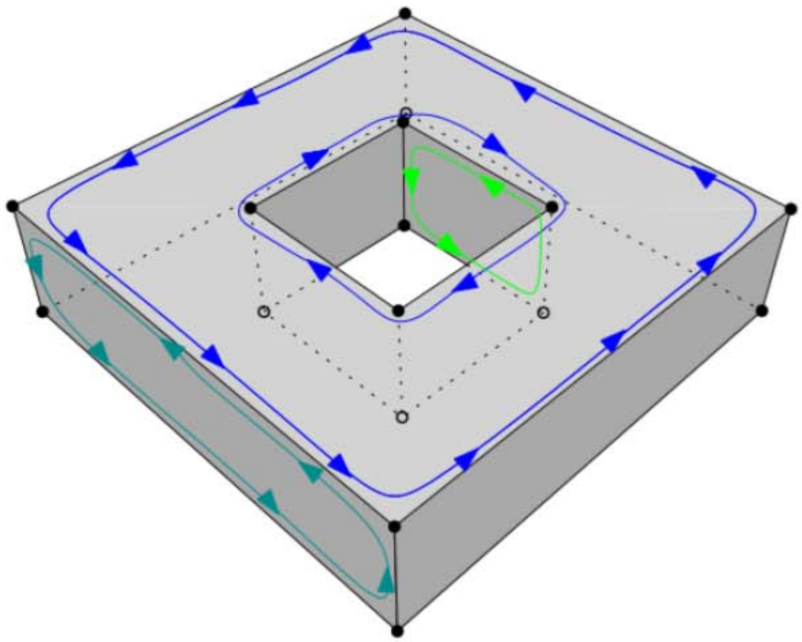


Quality Check Example: Geometry

Ledoux: Three-dimensional primitives in the context of the CityGML QIE



Invalid Polygons



Valid Solid

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FUTURE CITY PILOT, PHASE 1 FCP1

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Future City Pilot

- OGC Future City Pilot, Phase 1
  - Completed December 2016
  - Urban Planning, Urban Flooding, Health Alert, Dynamic Modeling
  - Cities: Greenwich, Rennes, Munich
- The Visionary Sponsors
  - Ordnance Survey Great Britain,
  - Sant Cugat del Vallès (Barcelona), Spain,
  - Institut National de l'Information Géographique et Forestière (IGN)
  - virtualcitySYSTEMS GmbH Berlin

virtualcitySYSTEMS

IGN INSTITUT NATIONAL DE L'INFORMATION GÉOGRAPHIQUE ET FORESTIÈRE

Ordnance Survey

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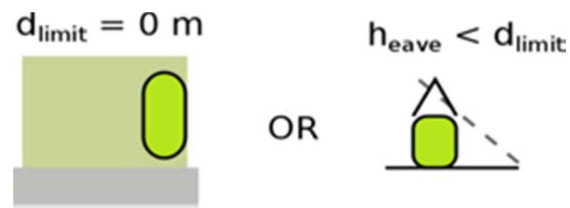
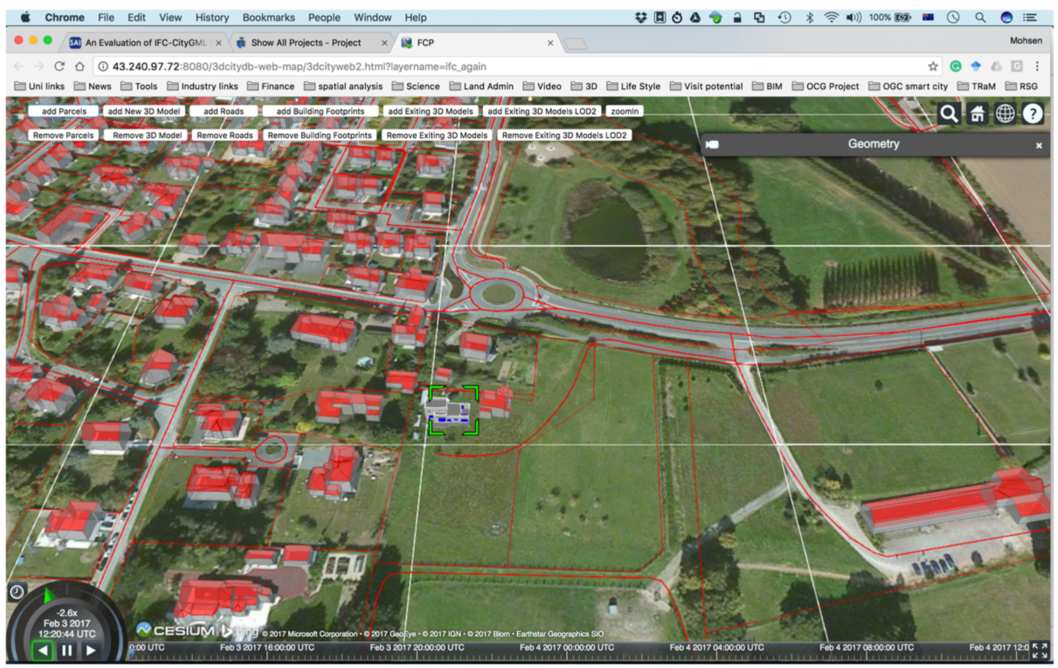
FCP1 Scenario: Urban Planning

- Scenario: Model Update Validation
  - Static 3D models *'easy'* to make
  - Maintaining a city model is harder
  - **Validation of new components**
  - Parts of a city planning tools



Graphics: IGN France



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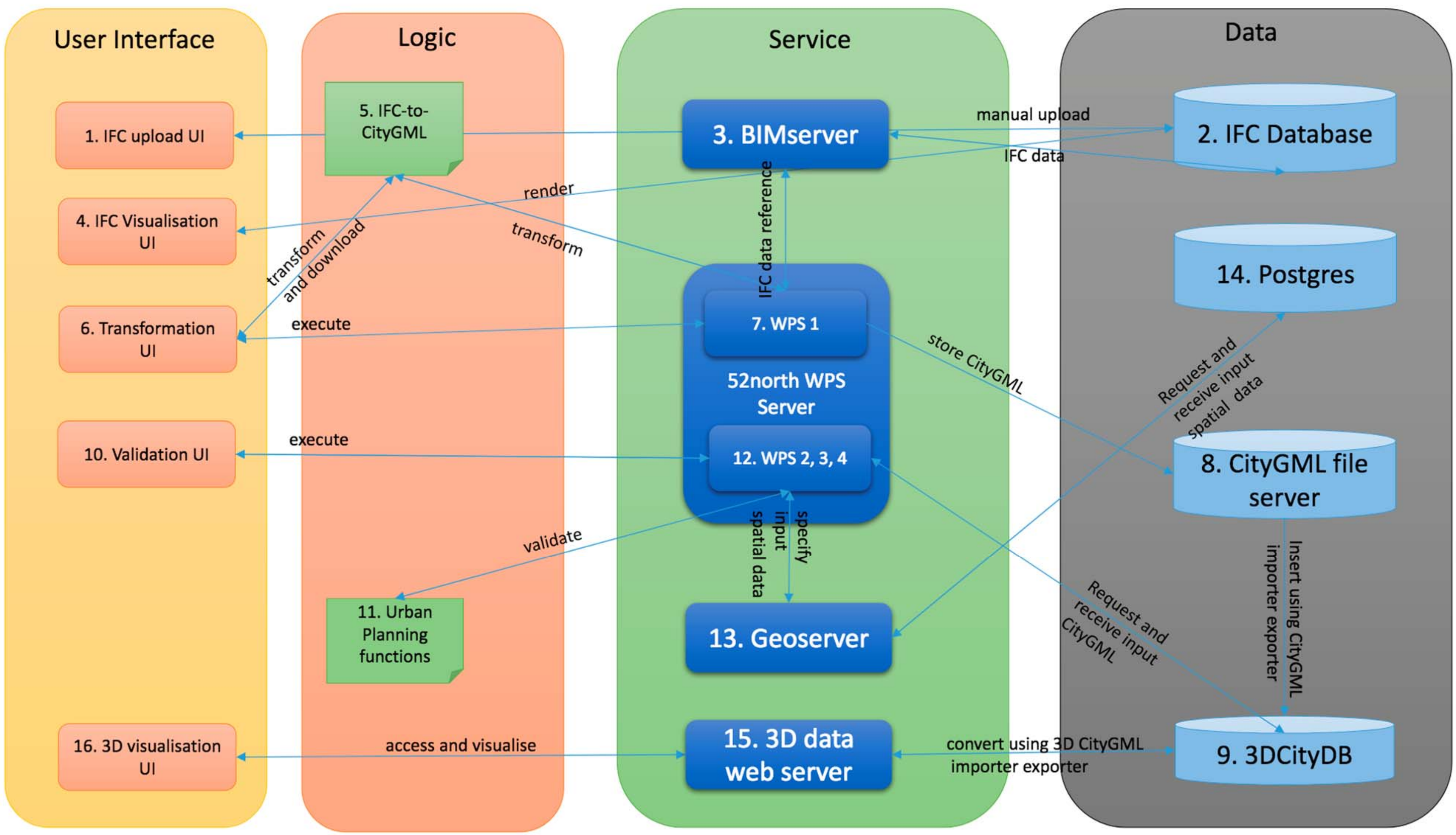
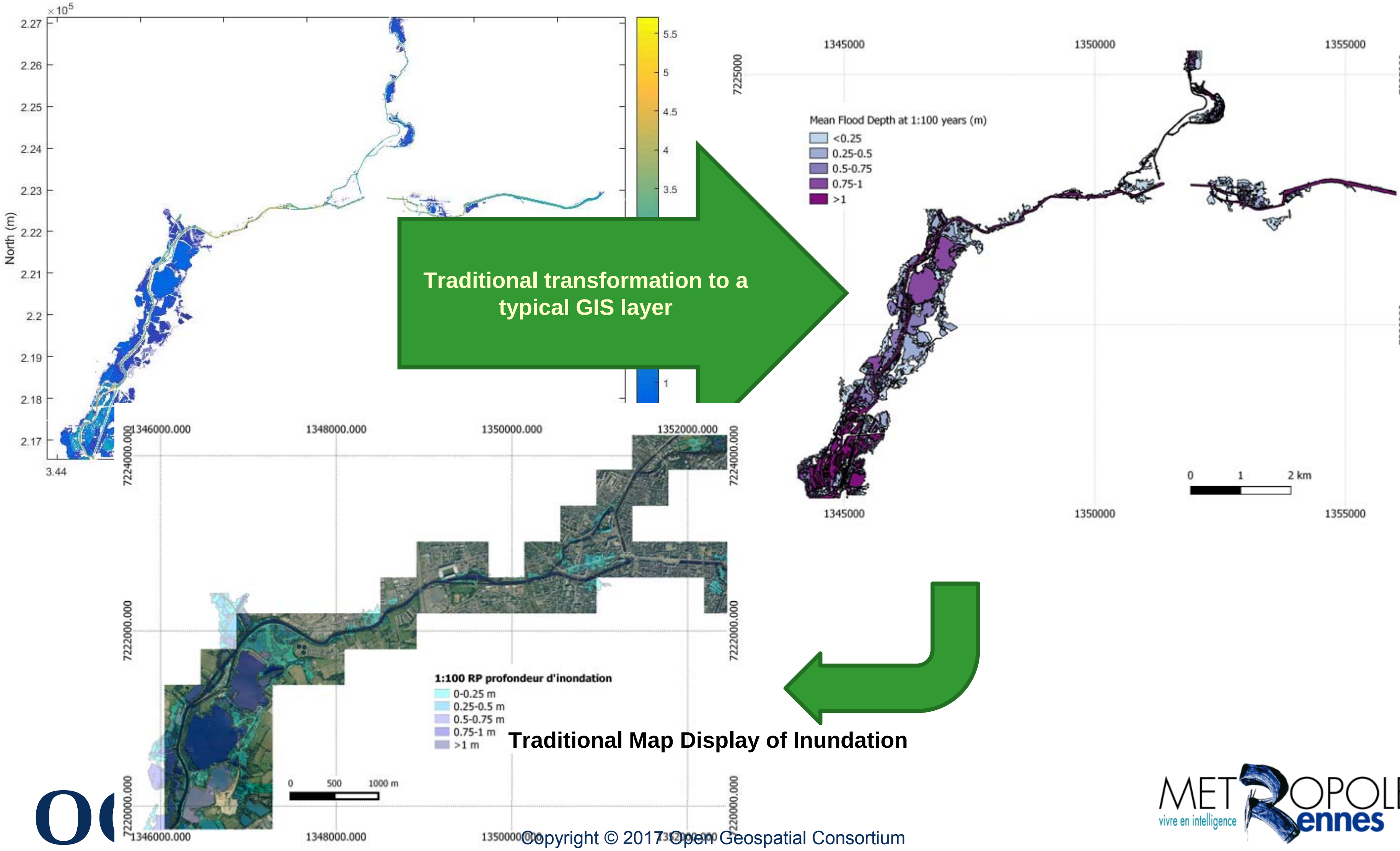
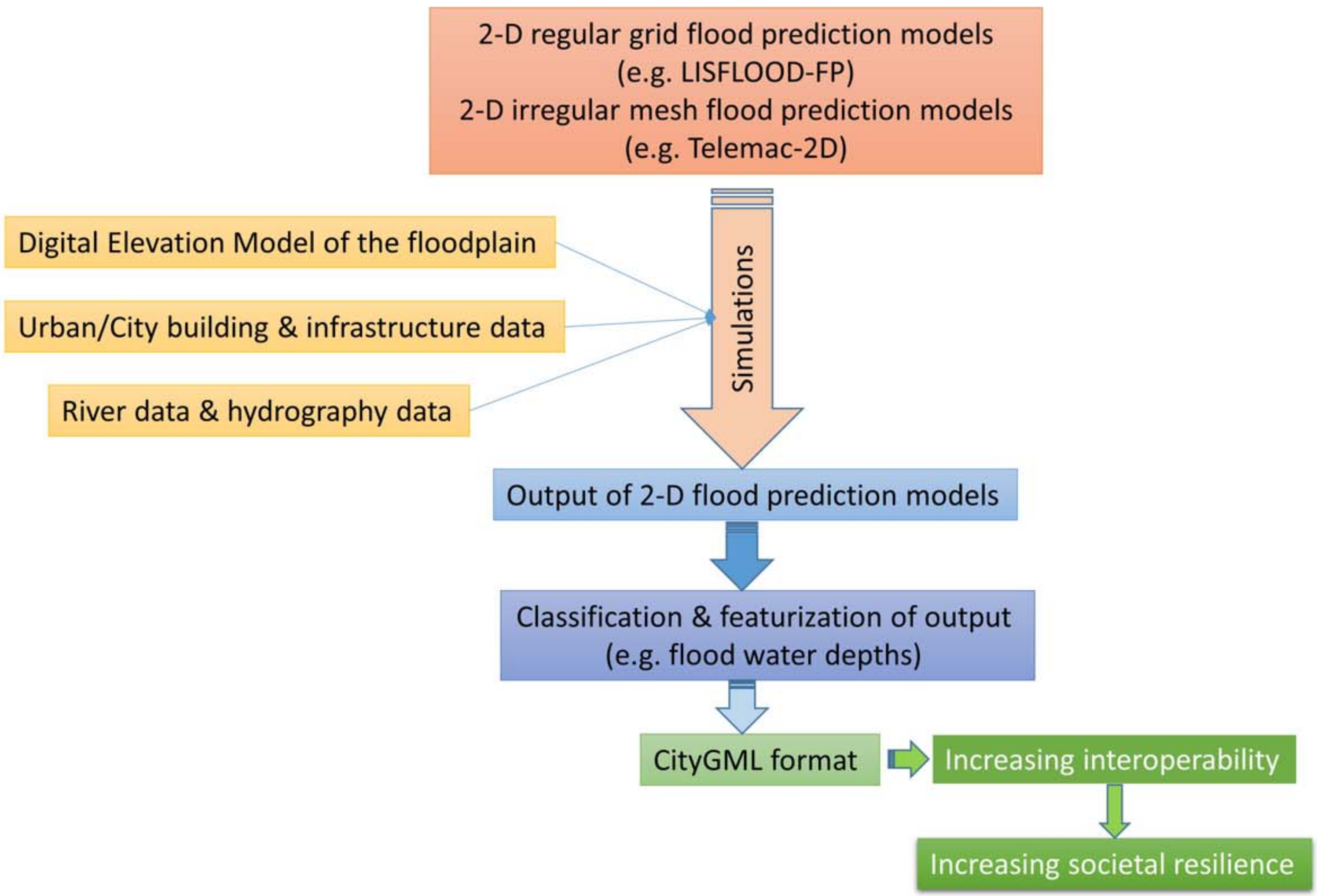
FCP1 – Urban Planning



Transforming Traditional Approaches:
Example of Rennes, France: 1:100 year (mean depth)



FCP1 Workflow of Inundation Modeling



CityGML Encoding

```
CityGML_Rennes_Flood.gml
<?xml version="1.0" encoding="UTF-8"?>
<core:CityModel xmlns:app="http://www.opengis.net/citygml/appearance/2.0" xmlns:luse="http://www.opengis.net/citygml/landuse/2.0" xmlns:wtr="http:/
    <gml:boundedBy>
        <gml:Envelope srsDimension="3" srsName="urn:ogc:def:crs,crs:EPSG:6.12:3948,crs:EPSG:6.12:5720">
            <gml:lowerCorner>1344064.2188 7216529.4531 0.125</gml:lowerCorner>
            <gml:upperCorner>1357029.2188 7227149.4531 1.125</gml:upperCorner>
        </gml:Envelope>
    </gml:boundedBy>
    <core:cityObjectMember>
        <wtr:WaterGroundSurface/>
    </core:cityObjectMember>
    <core:cityObjectMember>
        <wtr:WaterBody gml:id="DN_1">
            <gen:stringAttribute name="Height">
                <gen:value>0.125</gen:value>
            </gen:stringAttribute>
            <wtr:lod1MultiSurface>
                <gml:MultiSurface srsDimension="3">
                    <gml:surfaceMember>
                        <gml:Polygon>
                            <gml:exterior>
                                <gml:LinearRing>
                                    <gml:posList>1350664.2188 7223059.4531 0.125 1350699.2188 7223059.4531 0.125 1350699.2188 7223054.4531 0.125 13
                                </gml:LinearRing>
                            </gml:exterior>
                            <gml:interior>
                                <gml:LinearRing>
                                    <gml:posList>1350639.2188 7223029.4531 0.125 1350639.2188 7223024.4531 0.125 1350654.2188 7223024.4531 0.125 13
                                </gml:LinearRing>
                            </gml:interior>
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                    </gml:surfaceMember>
                    <gml:surfaceMember>
                        <gml:Polygon>
                            <gml:exterior>
```

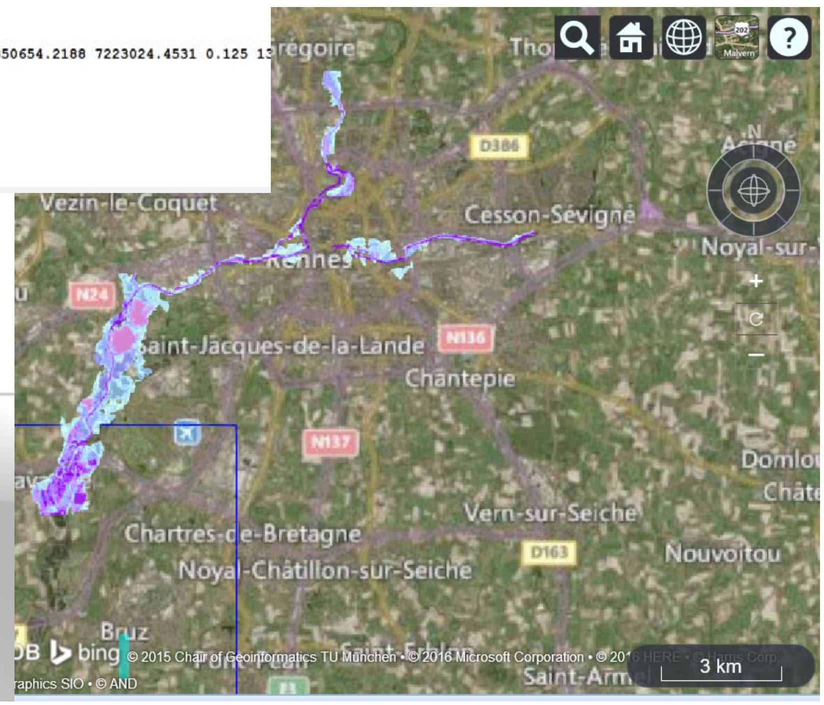

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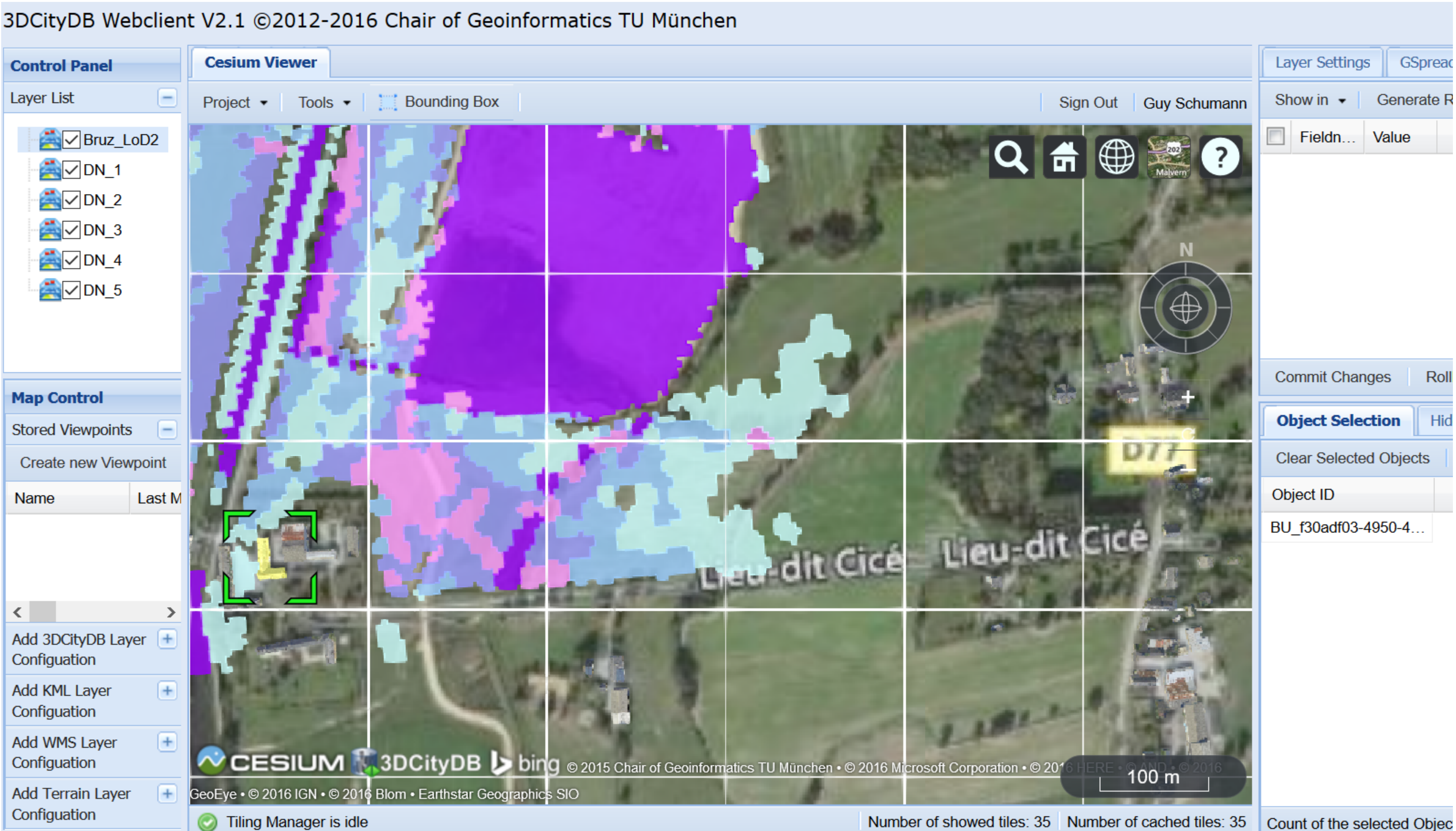
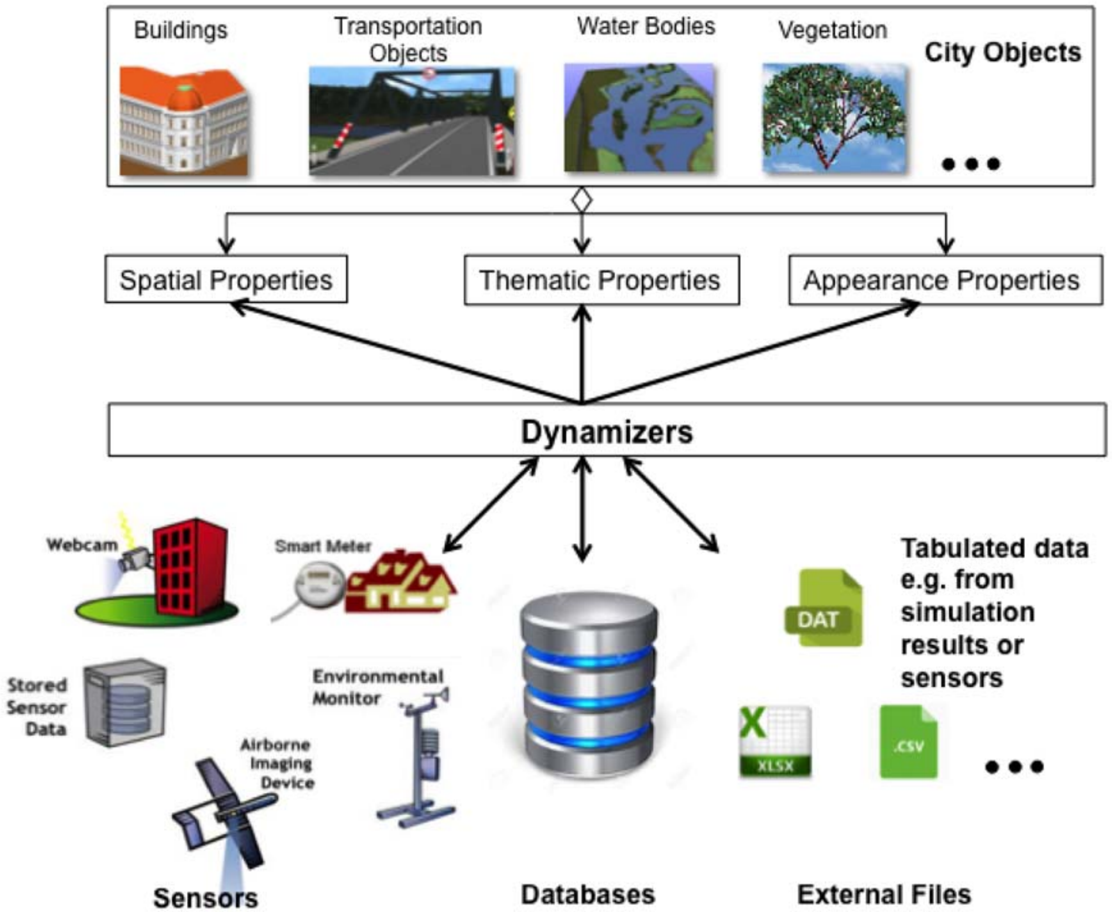
FCP1 – Flood inundation model with other city infrastructure layers



Adding Dynamic Processes to Urban Models



Dynamizers

- Enhance properties of city objects by overriding static values
- Time-variant values from sensors, simulations, and external files

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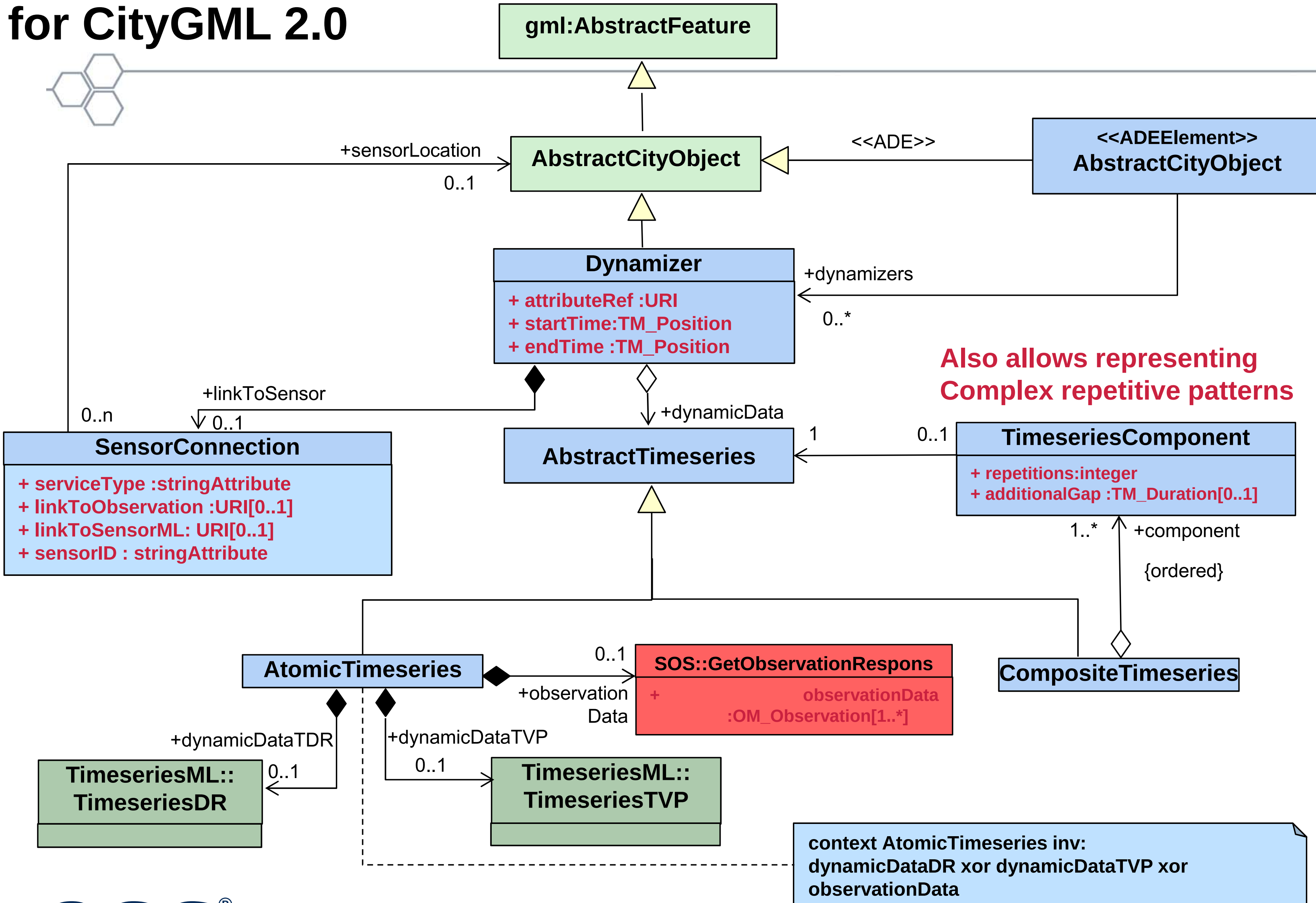
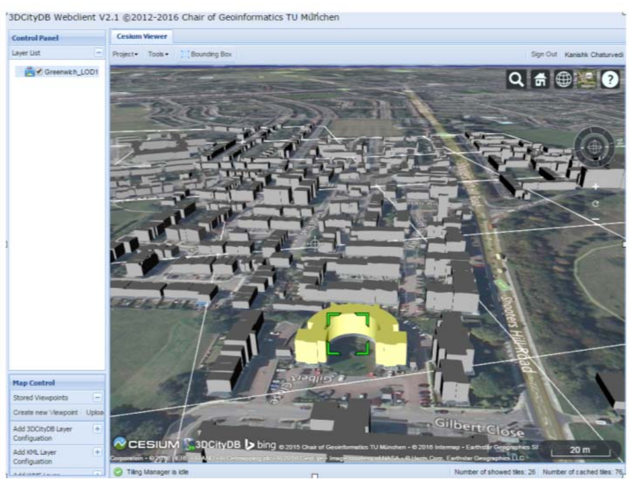
Dynamizer ADE for CityGML 2.0



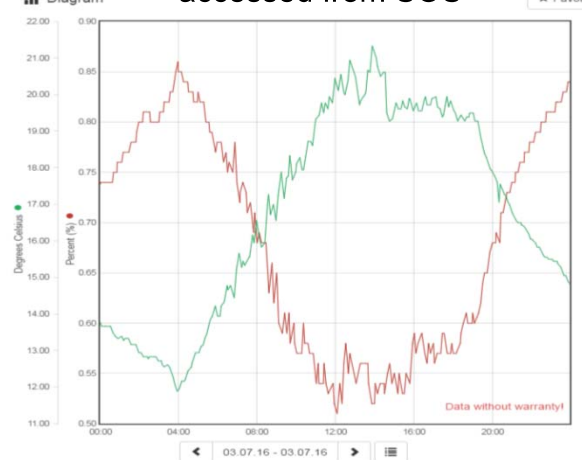
FCP1 Scenario: Health Alerts

- Building Humidity and Heat during weather extremes
  - Dynamize: Override static CityGML properties with dynamic observations from SOS
  - Identify residents of senior living facility at risk

Visualization of and interaction with 3D building geometries

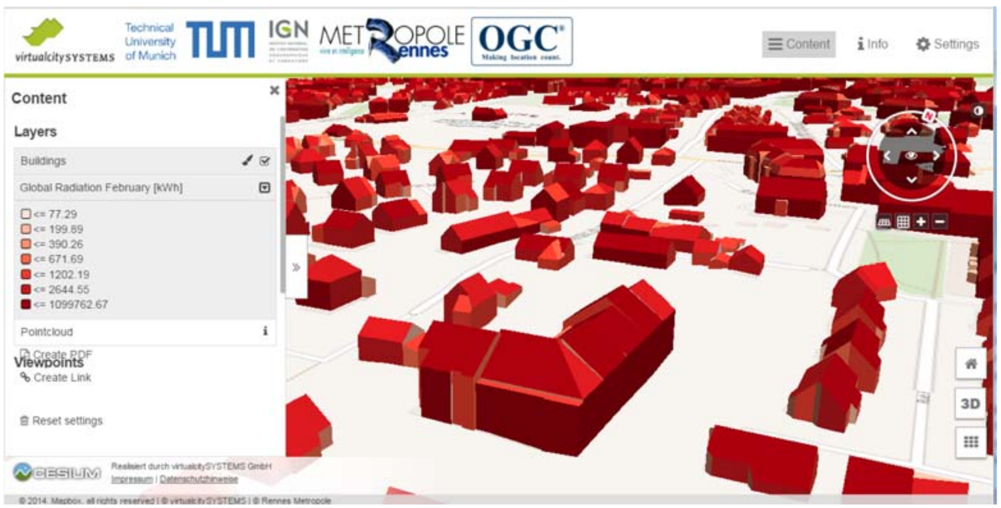


Real-time temperature, humidity accessed from SOS



FCP1 Scenario: Energy

- Provide better services to the citizens and the energy planners by making sophisticated solar potential analysis.
- Visualization of solar energy production for roofs and facades of building



Plans for Future City Pilot, Phase 2

- Run in 2017
- Also in the Geospatial, Civil Engineering & BIM
- Requirements are coming in
- Worldwide scope
- Include Indoor & Facility Management
  - VR, AR?

- Interested to sponsor or participate?
  - Let me know!

UNDERGROUND MAPPING AND MODELING

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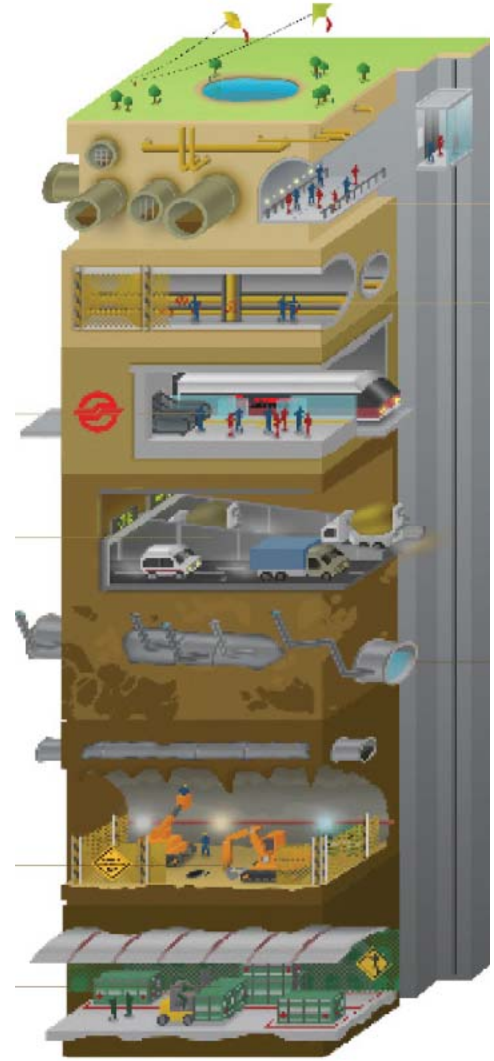
Underground Infrastructure

3D semantic modeling of utility networks, underground environment

- ROI for improving accuracy of geolocation of underground utilities
  - USDOT - ROI of $4.62 for $1.00 invested (Source: Between the Poles)
- Underground Infrastructure Mapping and Modeling Study
  - Sponsors: FCNY, SLA, OS
  - Workshop April 2017
  - Pilot to begin in 2017



Source: Singapore Land Authority

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http://www.opengeospatial.org/projects/initiatives/undergroundcds

OGC Concept Development Study (CDS)

- To assess emerging technologies & architectures in support of interoperability initiatives and open standards
- Process
  - 1. Request for Information (RFI)
    - Wide request for input on relevant technologies and open standards
    - RFI frames the questions to be addressed
  - 2. Workshop
    - Workshop to discuss and advance the concepts in the RFI
    - Presentations based on RFI Responses
  - 3. Report
    - Engineering Report of open standards and architecture views
    - Describe approach indicating feasibility and maturity

Responses to Underground RFI

Accenture	Bentley	BGS
Boston City	BRGM	Cesar Quiroga
CityGML Chair	Dassault Systemes	Delft University
Dubai Elec/Water	EPRI	Erik Stubkjaer
Geoweb 3D	HERE	HL Consulting
Informatie Vlaanderen	LandInfra SWG	Les Guest Assoc.
Luciad	Robin Danton	Rotterdam City
Sewer Network	Spacetime Technology	St Paul Minnesota
Swiss Water SJIB	Technics Group	Tech. Univ München
	UMS Bernice	

Underground CDS Workshop, April 2017

April 24th

1 – Opening, Introductions, Overview

2 – Cities with underground projects

3 – Underground information systems practices

4 – Data models for integration and data sharing

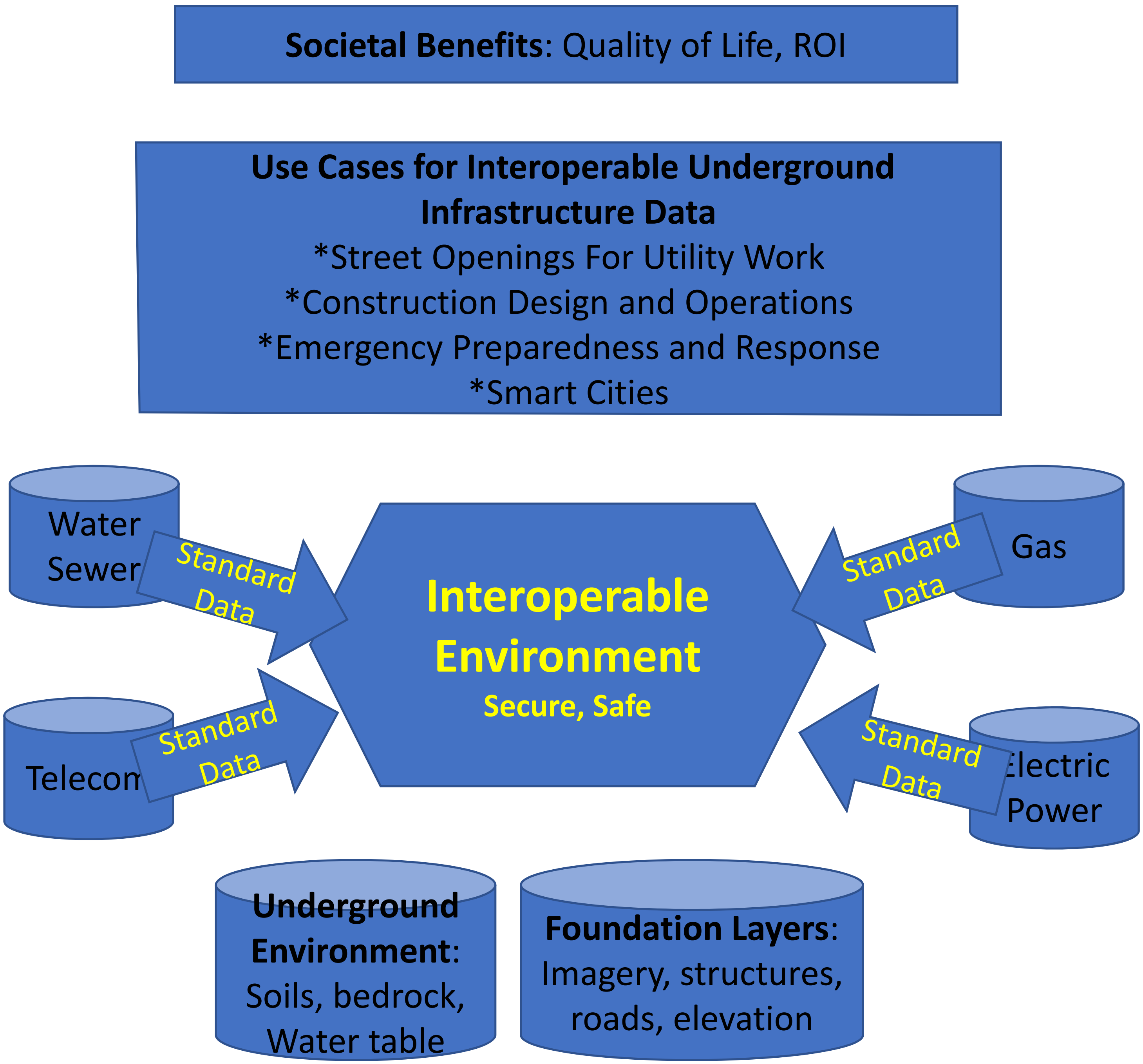
April 25th

5 – Underground Environment data model

6 – Data collection, curation, integration, analysis

7 – Breakout sessions

8 – Workshop summary; Planning Pilot phase



Source: Alan Leidner, NCNY

Underground challenges

1 Data Governance

UGI ownership not clearly defined

2 Data Completeness Accuracy

Existing UGI:
1. Incomplete/hard to retrieve
2. Unreliable or inaccurate
3. Not georeferenced
4. Not digitised

3 Data Sharing

No systematic sharing and some legal and confidentiality concerns

4 Data Standards

No common UGI standards

5 Data Platform

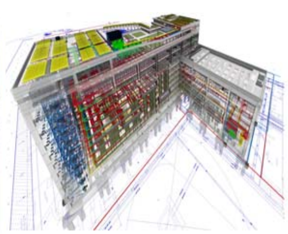
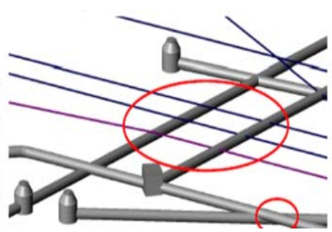
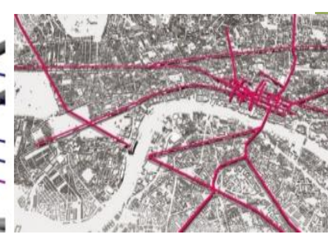
Yet to identify government-wide platform to support UGI use and sharing

6 Technology

Cost-effective and sustainable methods for UGI collection and management needs to be studied

7 Funding

Funding required by UGI owners in collection and management

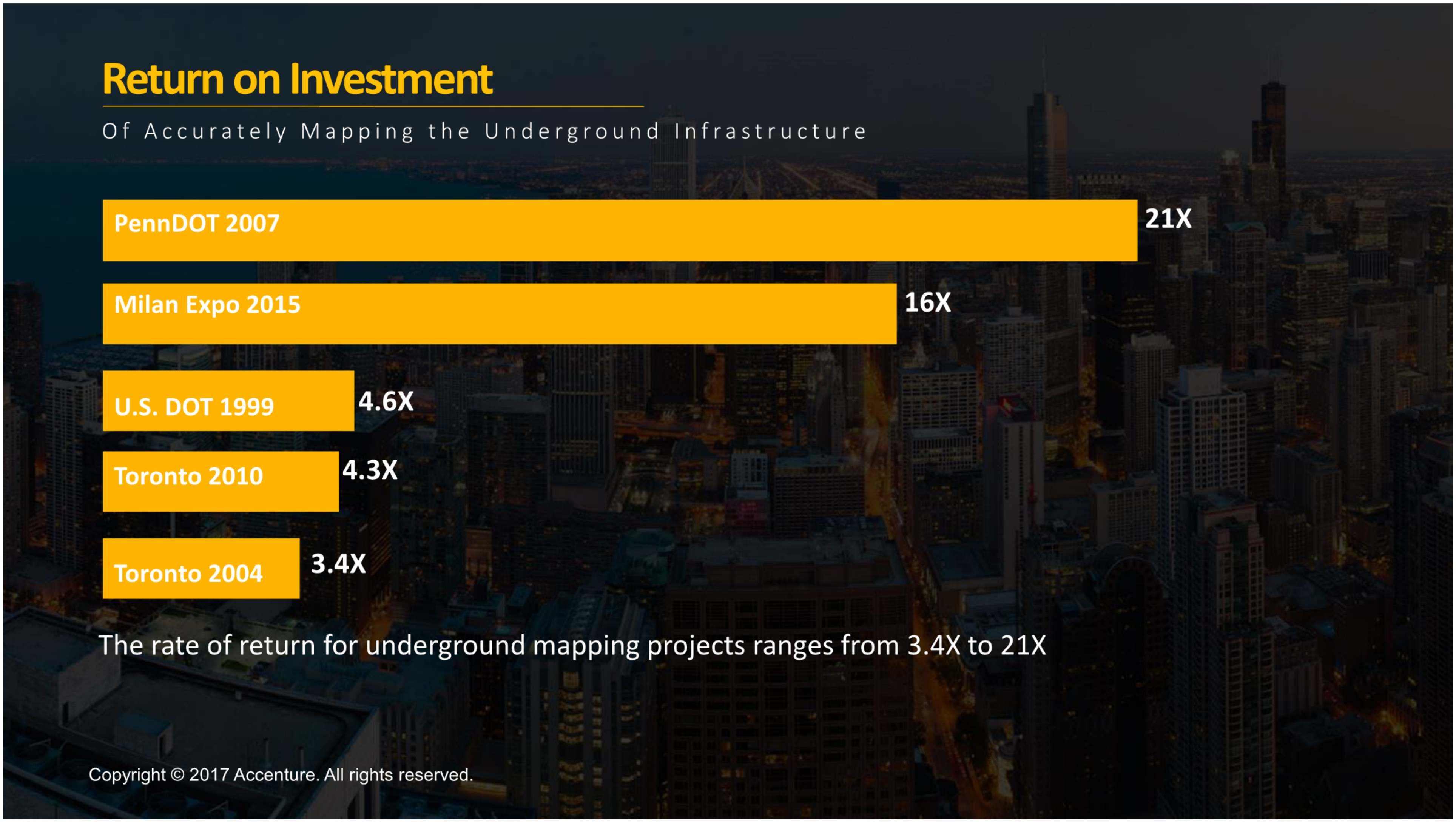
Source: Ng Siau Yong, Singapore Land Authority

A common problem that costs:

- **Roadworks and congestion:** road works account for 38% of the most serious and severe traffic disruptions in London: total cost of £752M[1].
- **Cable strikes:** Est 60,000 incidents per year (Cognisco 2015)
- **Excessive surveying and digging prior to new development**: Including abortive digging (unfound asset), or extended digging (crossing the whole road rather than a portion).
- **Physical ground constraints:** Late stage awareness of ground properties and physical constraints to planned development is costly.
    - Ground risks are one of main causes of project delay (50%), and of Insurance claims on completed projects.
    - Alignment of Crossrail was influenced by need to avoid over 200 existing obstructions
    - Crossrail2 re-routed via Balham due to geological concerns.
    - Access to a robust geological model estimated to deliver +£160M[3] cost-savings to London construction projects.
- **Infiltration from the water supply network:** Infiltration of groundwater into underground assets is believed to costs the water industry £M annually.
    - In 2013/14, three water companies in the UK spent an additional £80 million responding to impacts of groundwater infiltration.
    - Leakage from the water supply network is significant due to aging infrastructure: for Thames Water's = 641ML/d (about ~25% of daily supply).

Source: Andy Ryan, Ordnance Survey Great Britain

Ordnance Survey



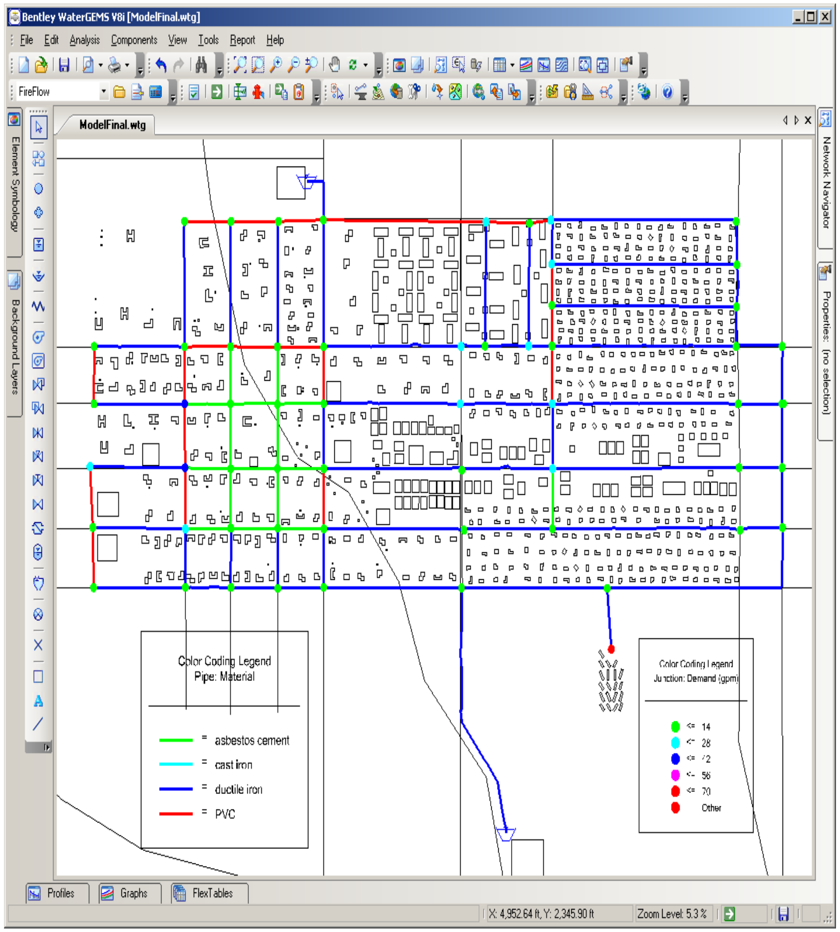
Source: Eric Bergstrom, Accenture

Use Case: Subsurface Utility Engineering (SUE)

- High potential for utility conflicts and relocations on projects
- Limited, narrow, and congested right-of-ways
- Increasingly tight project schedules
- Deeper utility installation using less detectible materials
- Multiple owner entities with inaccurate documentation

Use Case: Analytical Modeling

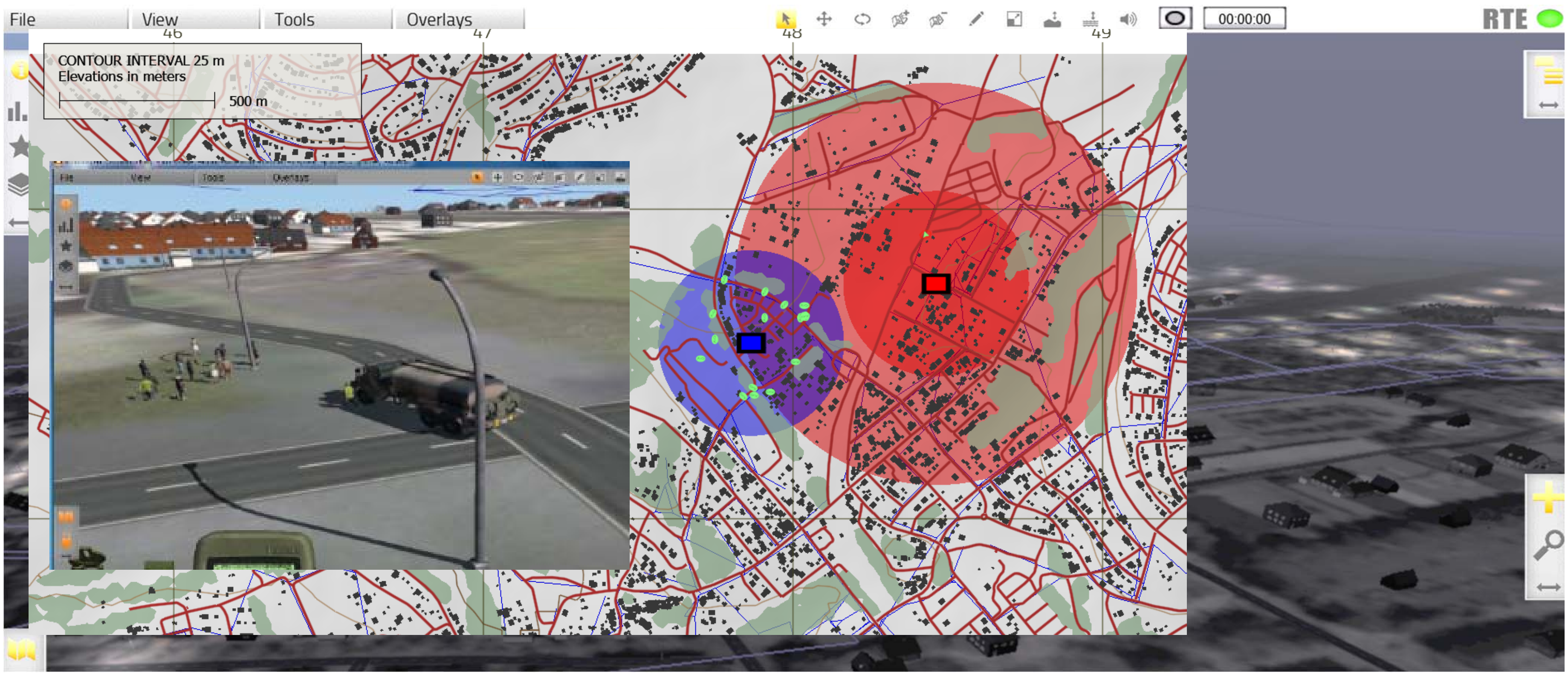
- GIS is typically the primary source of data for analytical models
  - Spatial Data
  - Physical Data
  - Geometric Network
- GIS is typically not built with analytical modeling as a primary use
  - Not all required data is in GIS
  - Data is not necessarily high-enough quality
  - Features are not necessarily at the right granularity
- GIS and Analytical Model diverge over time
  - Data changes in each need to be reconciled
  - Update / extend without overwriting corrected data



Bentley

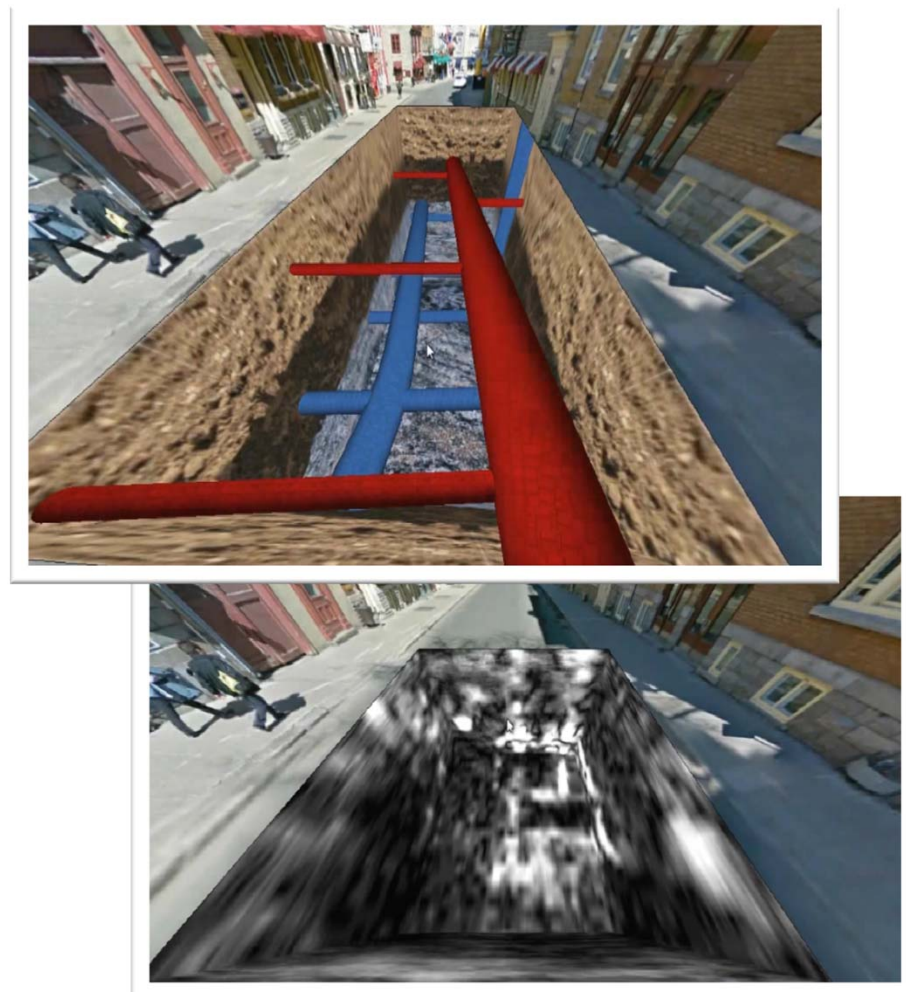
Use case – Simulation of cascading effects (II)

- Explosion in distribution station → Power failure in a district of the city
- Cascading effects caused by power failure → Failure of water works and of water supply



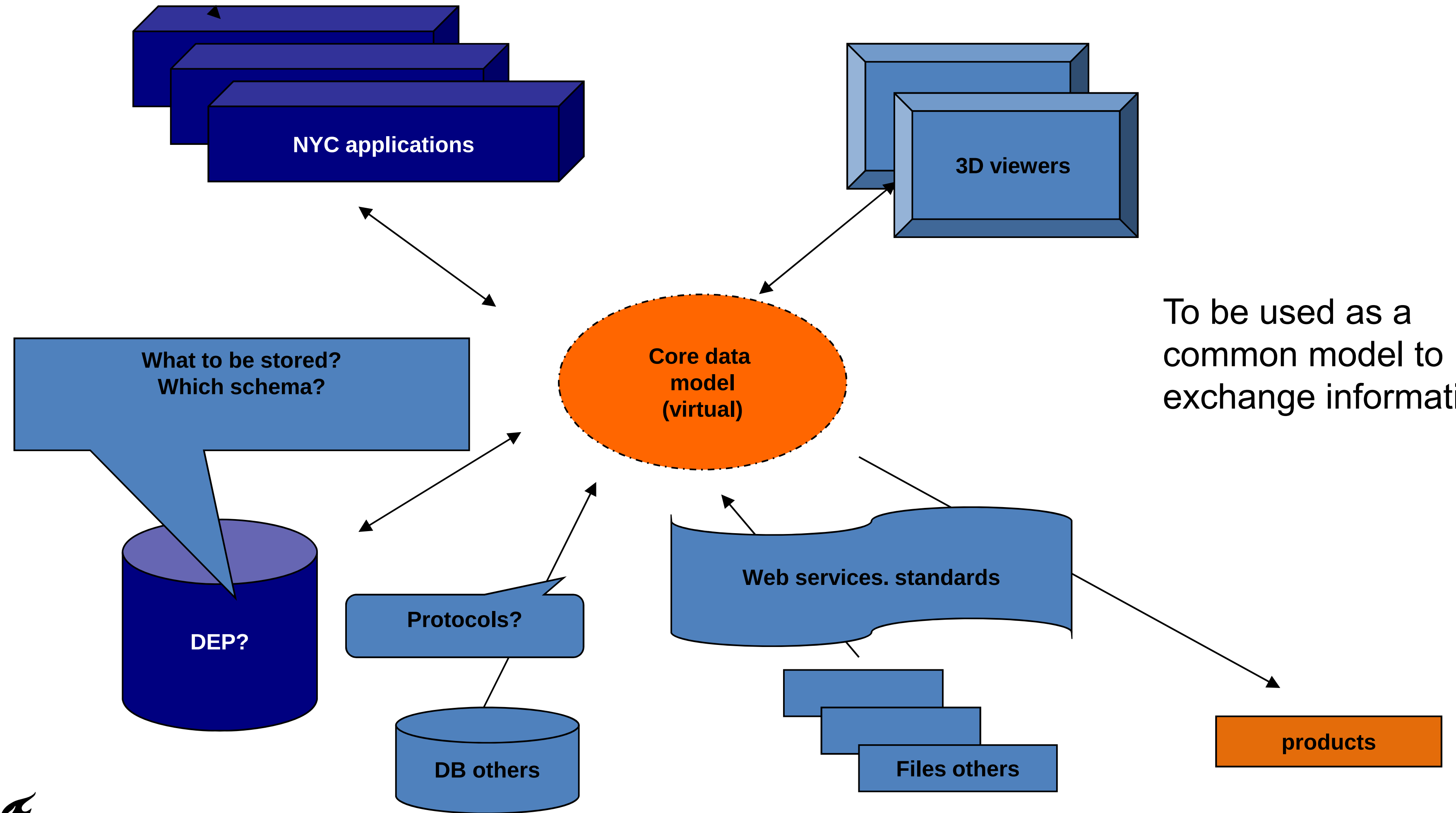
Use Case: Augmented Reality

- The potential of the virtual excavation for visualizing subsurface utility models, in an augmented reality context, for excavation work planning
- The appropriateness of the virtual excavation and of vertical pipe model projections to augment a changing terrain surface with subsurface utility models, to facilitate live excavation work
- The capacity of our augmentation techniques to facilitate planning on an actual excavation site
- The potential of using robotic total stations for providing high accuracy augmentations



Bentley

City of New York: Core data model



To be used as a common model to exchange information

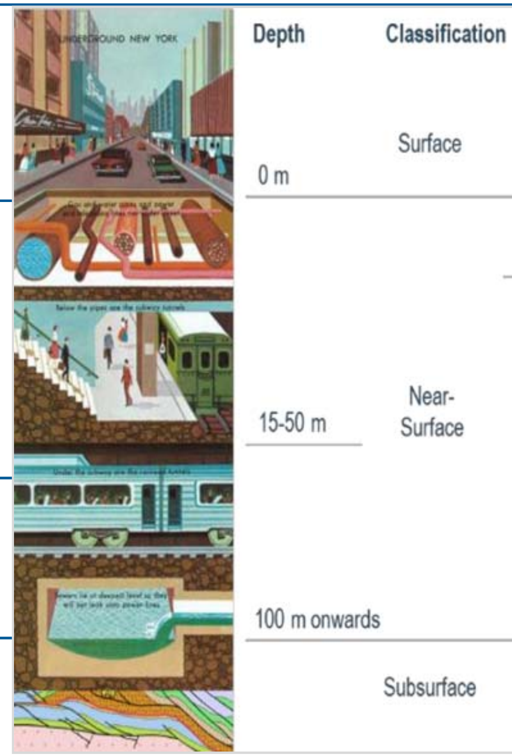
The problem

- Different data models
- Maintained by different organizations with a different purpose
- Stored in different ways (systems, formats and schemas)
- Different representations of geometry and semantics
- Lack of analytical capabilities (no network structure)
- Lack of relationships (e. g. with above ground features of interest)
- Interoperability issues



City Infrastructure Lifecycle Management

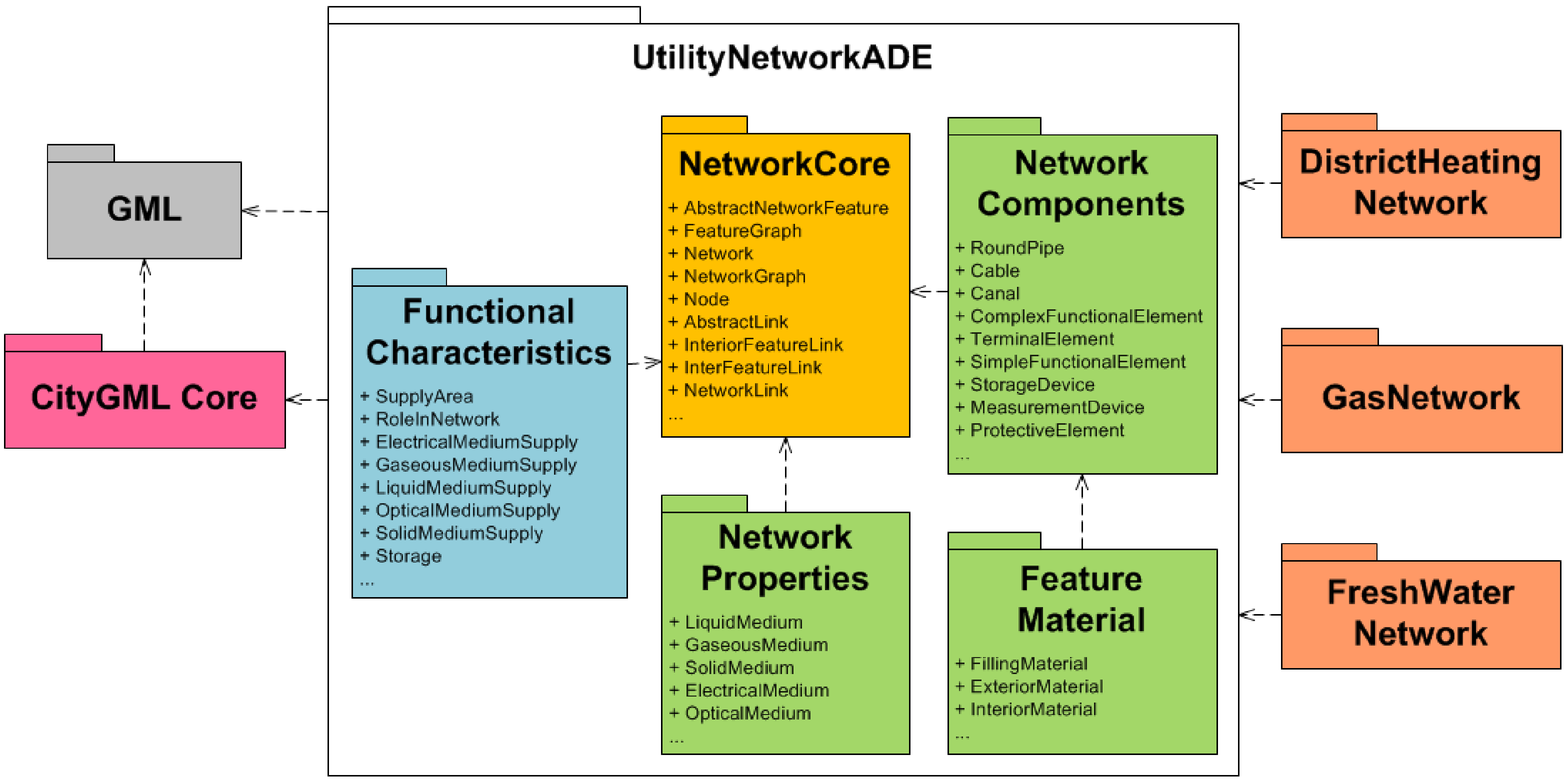
Interoperability: The Integration of Standards via the Platform



How its governed and represented		Information represented	
BOM KML OGC *ISO 10303 (STEP)*	*ISO/IEC 15288* *ISO 55000* *ISO 16739* *ISA 95*	Buildings Road & Traffic Rail	Terrain & Land use
CityGML ISO TCS211 *CityGML 3.0* *CI/ASCE 38-02* *ANSI/ASCE/EWRI 12-13, 1313, 14-13* *ANSI/ASCE/EWRI 56-10, 57-10* *ISO 15926 (Xmplant)*		Basements, Cellars Cable network Utilities Telecommunications Water	
ASCE/EWRI 45-05, 46-05 & 47-05 *ASCE/EWRI 12-05, 13-05 & 14-05*		Road Tunnels Subways Sewage	
GML; GeoSciML EarthResourceML INSPIRE		Geology Geotech, RQD etc	

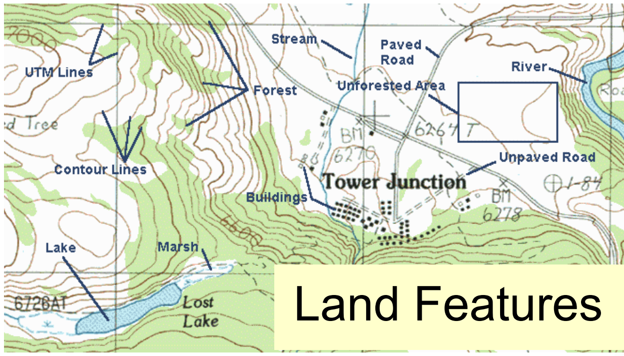
CityGML Utility Network ADE

The **CityGML Utility Network ADE** extends CityGML by the possibility to **represent supply and disposal networks in 3D city models**



LandInfra / InfraGML

http://www.opengeospatial.org/standards/landinfra



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American Society of Civil Engineers (ASCE) Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data

CI/ASCE 38-02

"Quality Levels" for Depicted Utility Infrastructure:

QL D - Verbal Account or Record

QL C - Records and Surface Features

QL B - Records and GP Detection (identify and work through discrepancies)

QL A - Exposed and Verified – Discrete

P.E. Affixes Seal to Product

DRAFT

UESI/ASCE XX-16

ASCE / ANSI STANDARD

American Society of Civil Engineers

Standard for Recording and Exchanging Utility Infrastructure Data

This document uses both Système International (SI) units and customary units.

Table 2. Positional Accuracy Requirements

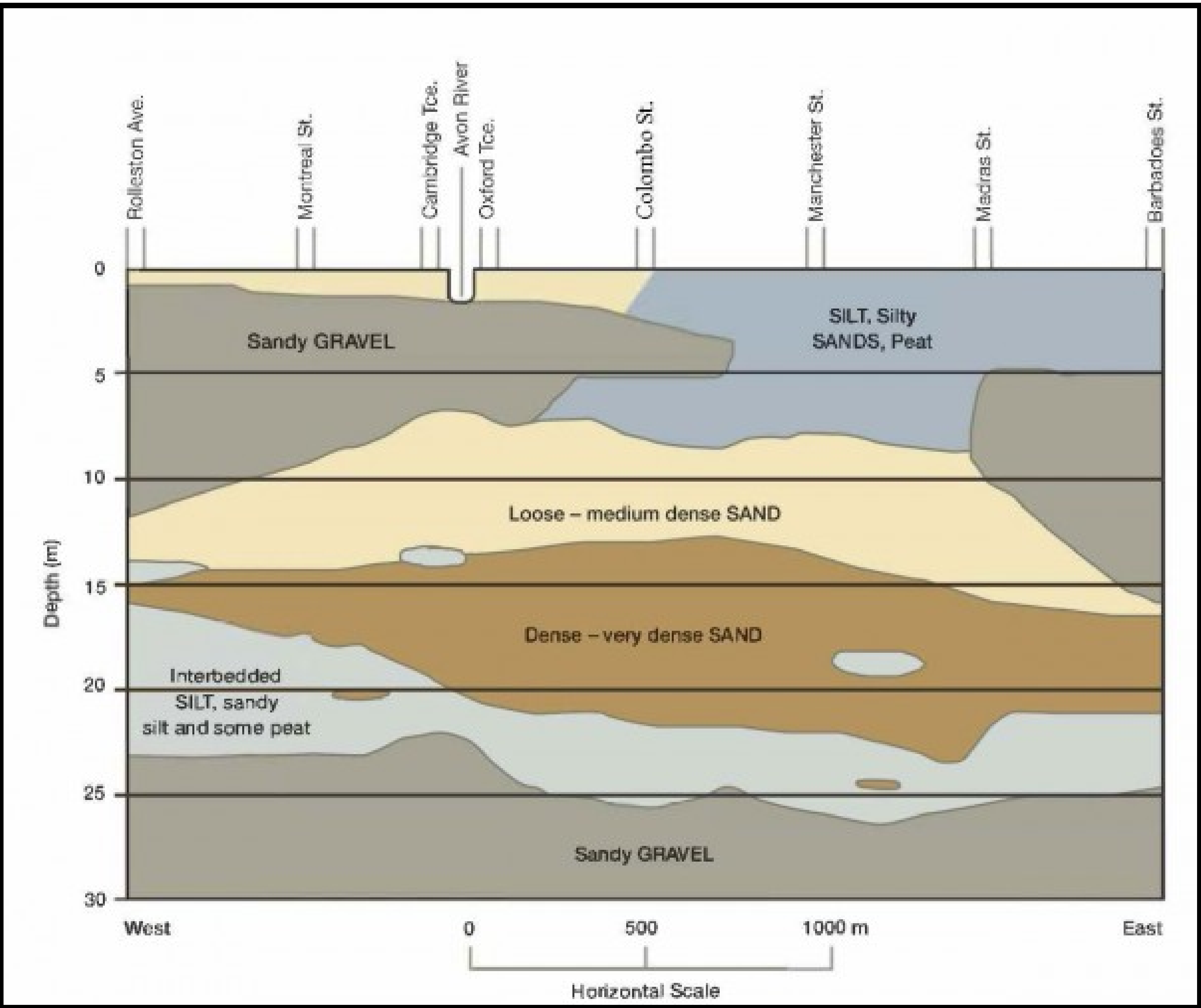
Level	Positional Accuracy[1]	Applies to	Comment
1	±15 mm (±0.1 feet) Vertical	Z data	Coincides with requirements in ASCE 38-17 quality level A (QLA)
	±50 mm (±0.2 feet) Horizontal	X and Y data	
2	±50 mm (±0.2 feet)	X, Y, and Z data	
3	±150 mm (±0.5 feet)	X, Y, and Z data	
4	±300 mm (±1 foot)	X, Y, and Z data	
5	±1000 mm (±3+ feet)	X, Y, and Z data	
6	±1000 mm (±3+ feet)	X and Y data	Positional accuracy of the Z data is unreliable or not available
9	Indeterminate		Positional accuracy of the X, Y, and Z data is indeterminate.

[1] At the 95% confidence level, using the root-mean-square error (RMSE) in accordance with FGDC-STD-007.3-1998.

The positional accuracy levels defined in Table 2 match up loosely with the following concepts:

- Level 1 is designed specifically to match up with QLA as defined in ASCE 38-17.
- Level 2 is substantially identical to Level 1, but removes the close tolerance on vertical methods and thus can be generally achieved without the need for survey bench leveling.
- Level 3 is generally possible using GPS equipment and RTK methods.
- Level 4 is provided as an additional breakpoint between levels 3 and 5.
- Level 5 is generally achievable by post-processed mapping grade GPS equipment.

There is soil in between the various utilities, tunnels, foundations, etc.



Soil Heterogeneity in 2D.

Voxels for Underground Infrastructure - a vector-to-raster perspective

Ben Gorte, Sisi Zlatanova, Delft University of Technology

Integration of Underground Infrastructure Data

- pipes: water, sewer, gas, steam
- cable & fibre: electricity, telephone, cableTV, internet
- subway: tunnels, stations
- buildings: basements, foundations
- manholes, conduits, ducts

Not so much about what happens *inside* the pipes (etc.) ...

… but about what happens *between* the elements of different systems

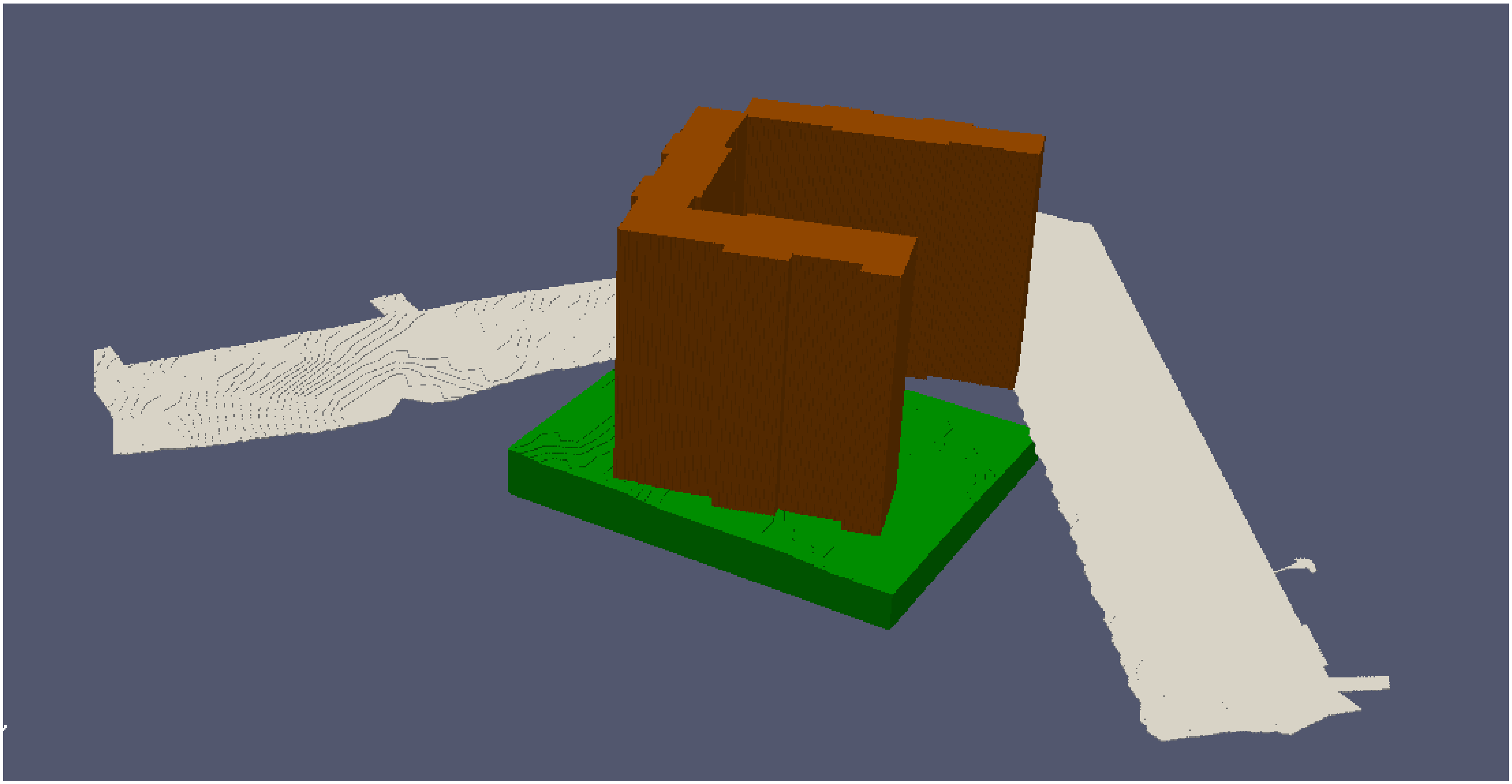
- in relation to their surrounding: soil, salinity, water table
- in case of *events*

A technical or a political problem?

Certainly an organizational problem!

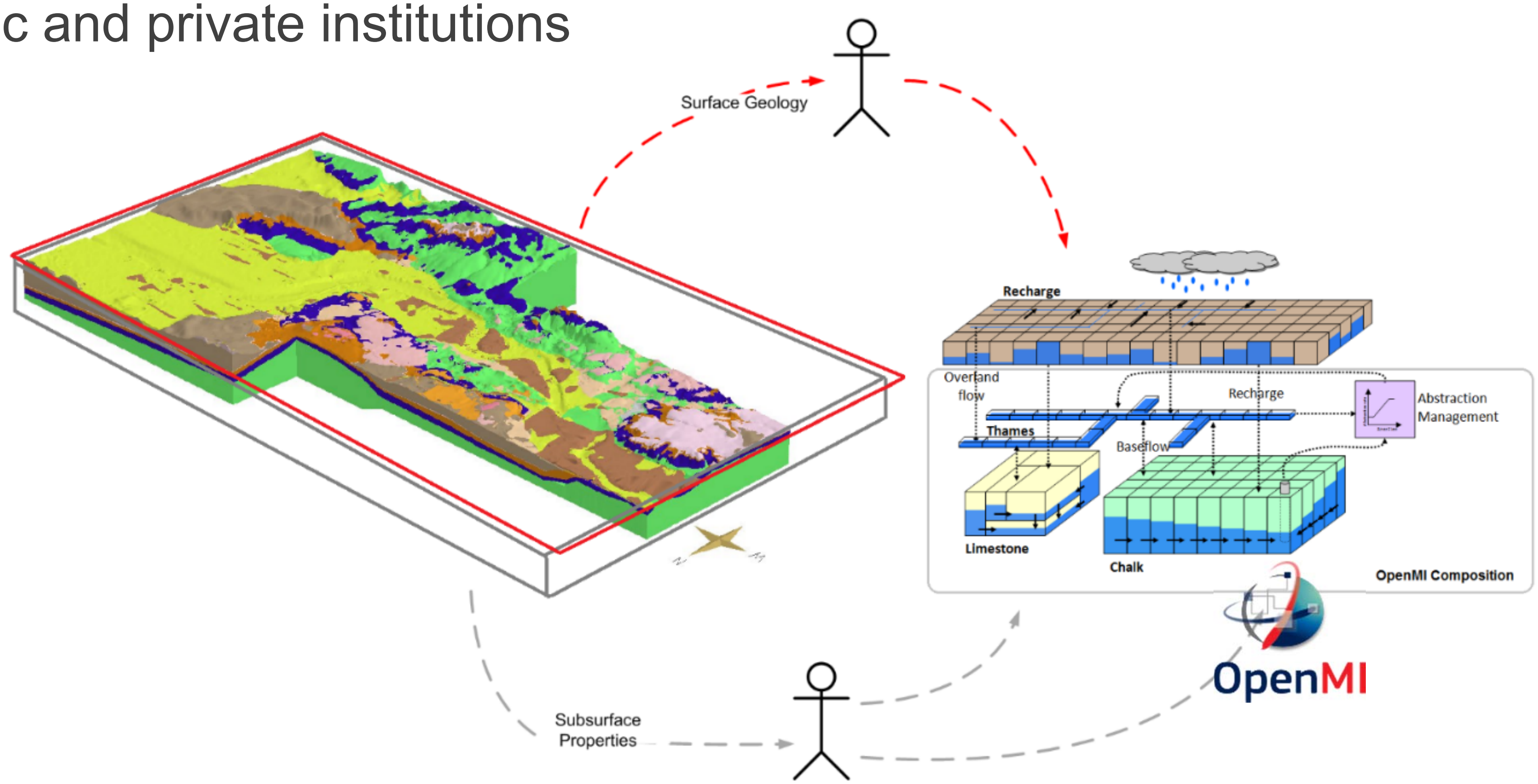
Multi-resolution Object Database

full res = 0.25m



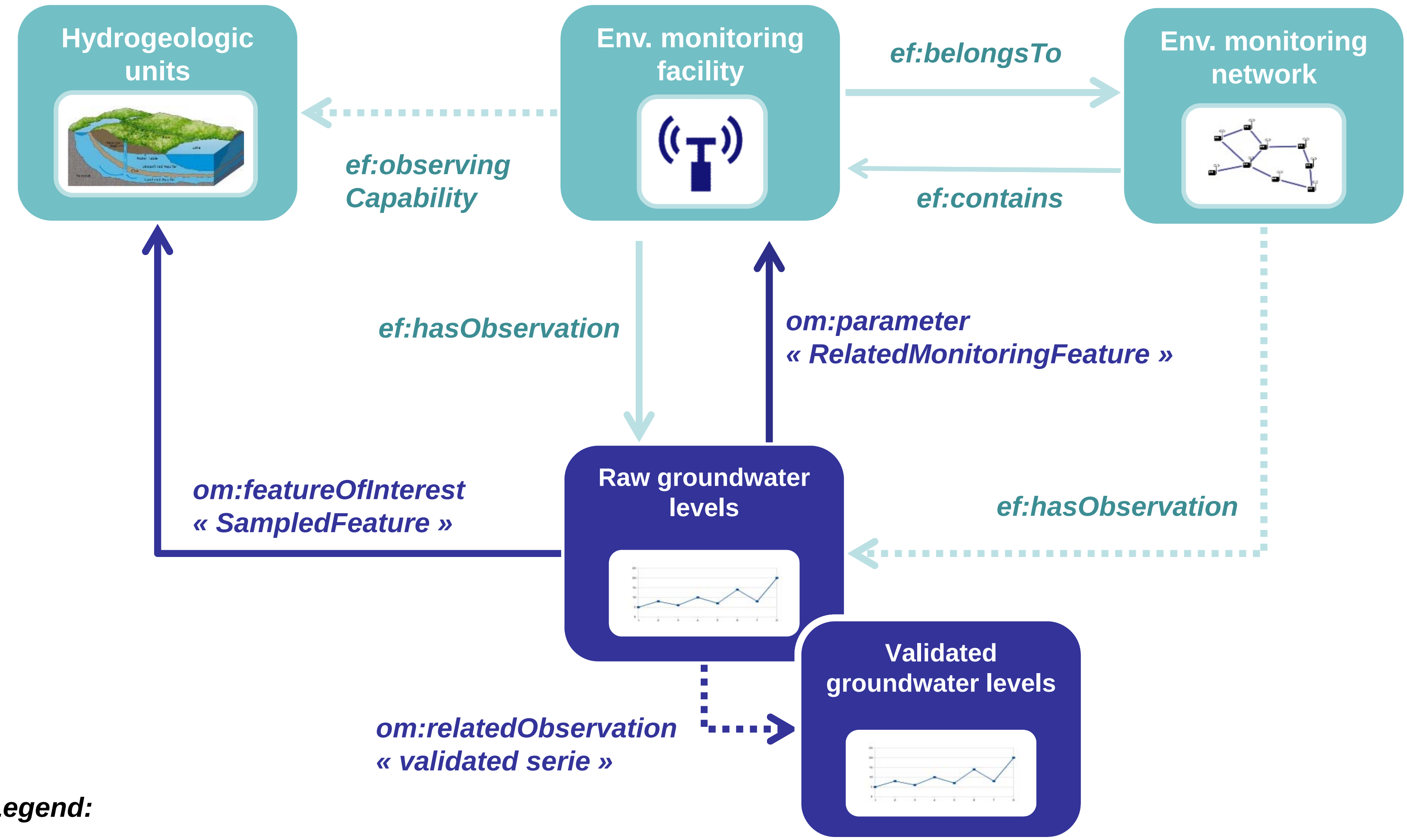
Integrated modelling

- Underground water cycles are more complex in urban environments
- To understand these processes requires integration of data and process models from a range of scientific disciplines as well as public and private institutions



Manual transfer of surface and subsurface properties between 3D geological models (left) and coupled, grid based, process models (right). From Thames basin scale (kms) to abstraction borehole scale (cm) *Watson et al., 2015.*

Linked data: applied to groundwater monitoring



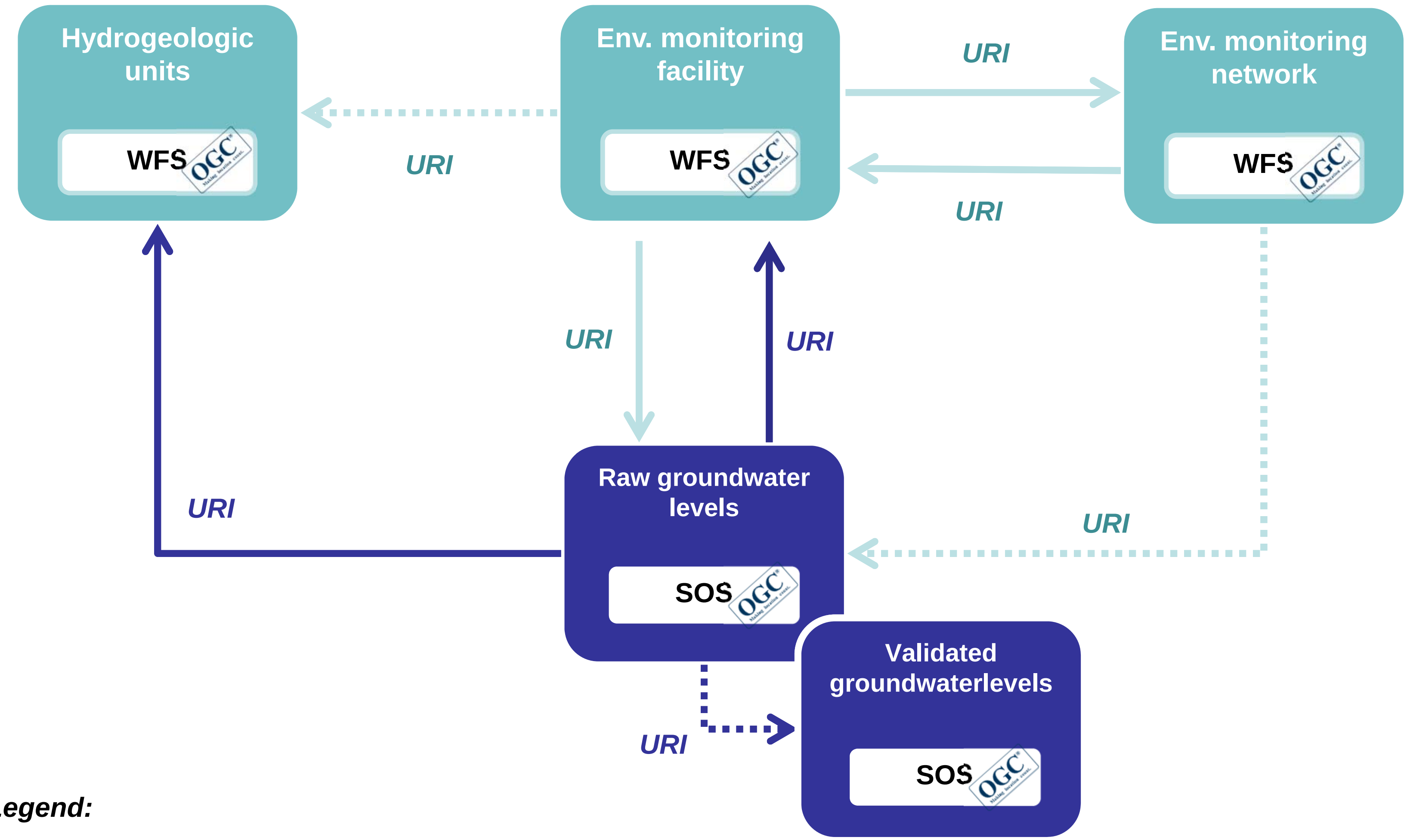
Legend:

Features provided according to INSPIRE directive

Observation(s) provided according to WaterML 2.0

brgm Geoscience for a sustainable Earth

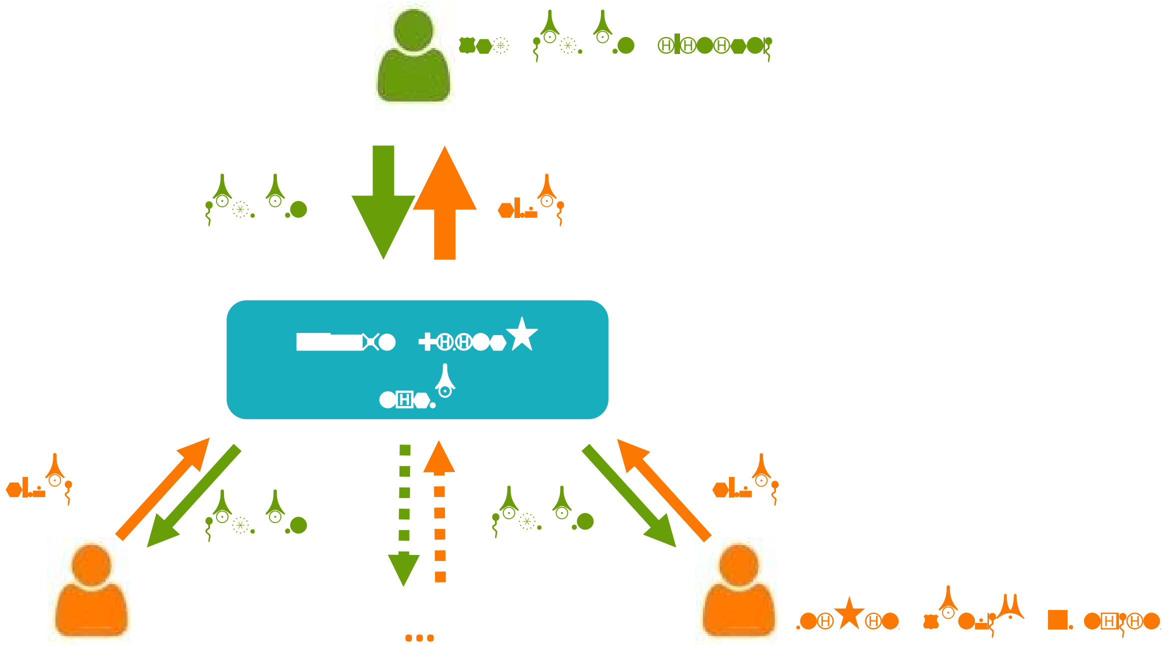
Linked data: applied to groundwater monitoring



Legend:

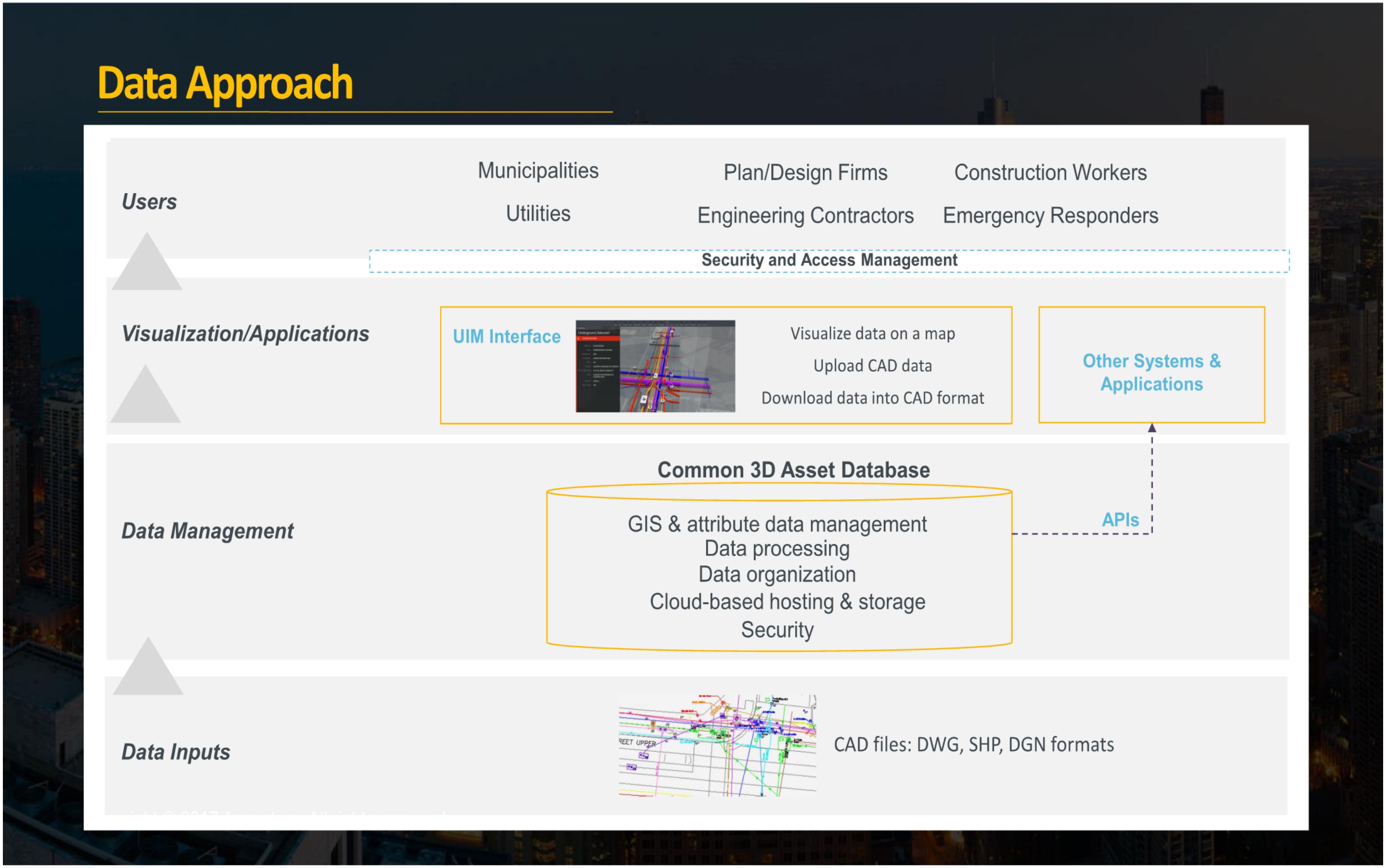
Features provided according to INSPIRE directive

Observation(s) provided according to WaterML 2.0

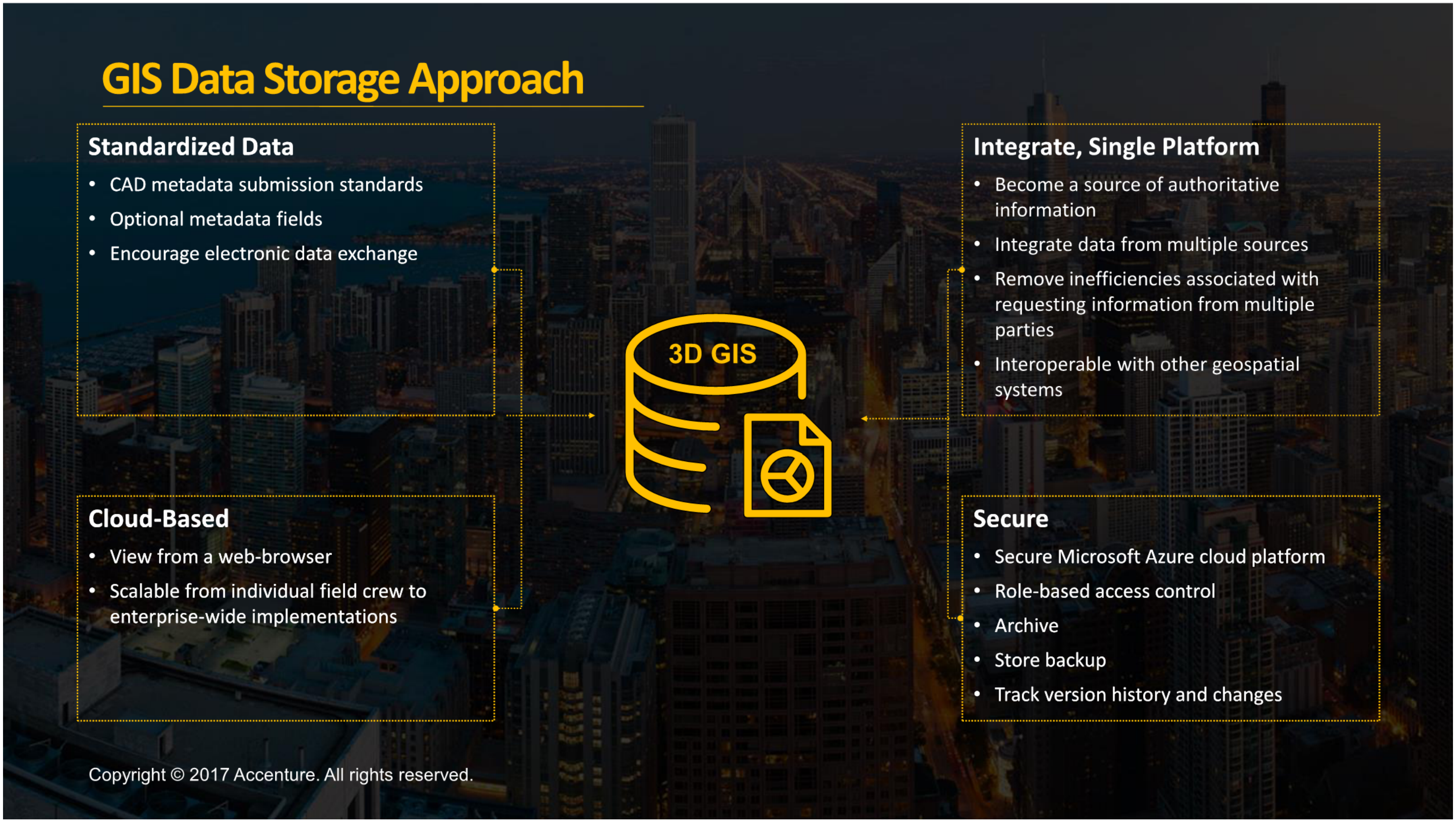


Use of KLIP is enforced by law in Flanders

Source: Jef Daems, KLIP product owner



Source: Eric Bergstrom, Accenture

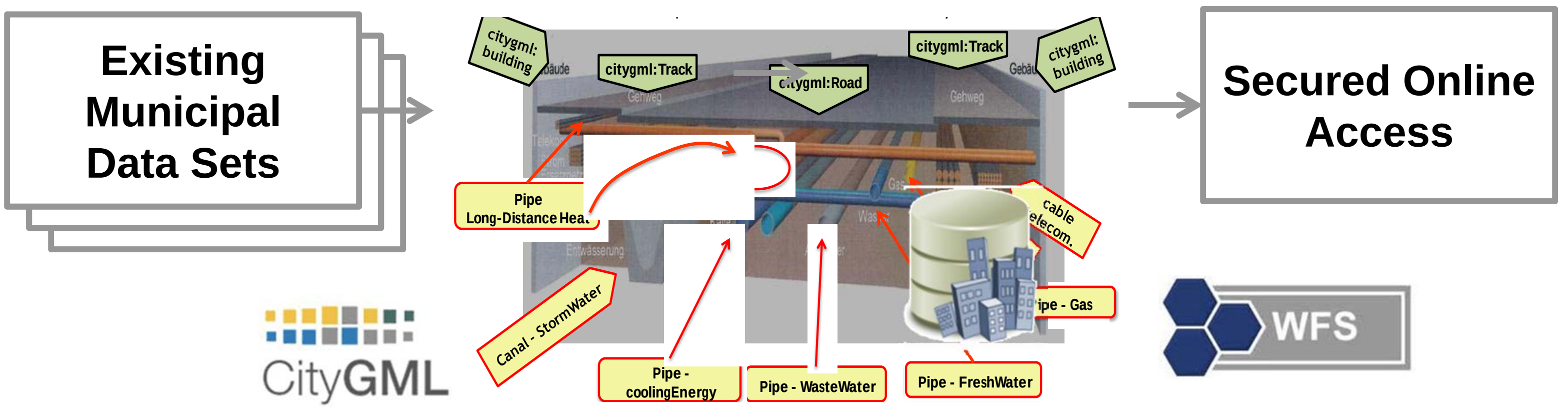


Source: Eric Bergstrom, Accenture

Underground Pilot

- 3D integration of underground critical infrastructure with secure online services for multiple applications
  - Routine SUE operations; Analytics, e.g. cascading failures
  - Foster coordination of data providers and consumers in secure message exchanges based on standards

Underground Infrastructure Data Model



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Benefits of an Open Standards Approach

- **Reduce risk** by aligning projects on open standards, program development is based on proven practices
- **Improve choice in marketplace** by broaden choice of IT solutions through plug-and-play based on standards
- **Enable legacy systems to interoperate with new technologies** by adapting these systems to leverage standard interfaces and encodings.
- **Reduce overall system lifecycle costs** by reducing or eliminating custom integration through the use of open standards

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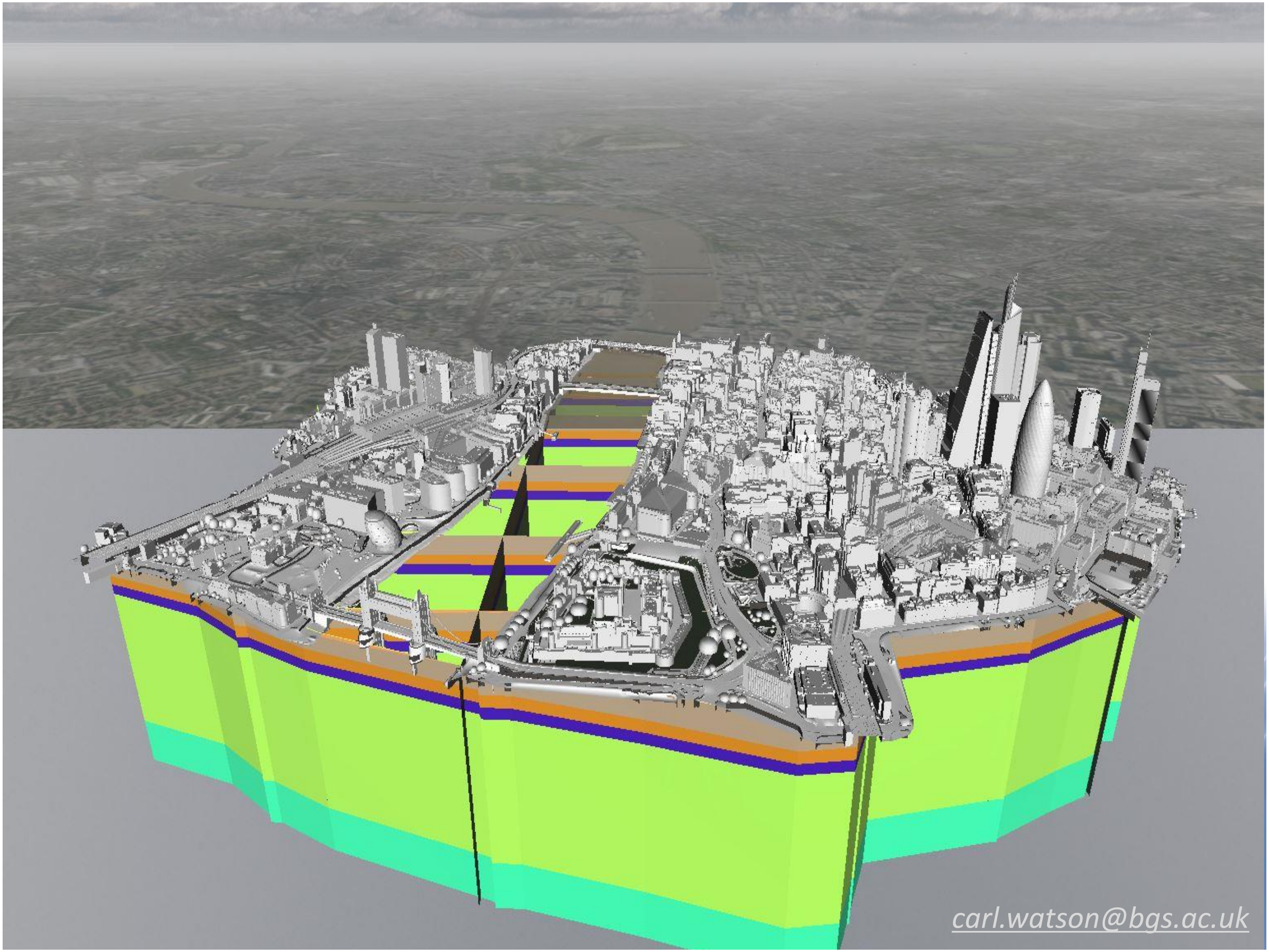
carl.watson@bgs.ac.uk

For Details on OGC …

OGC Standards

– Freely available
– www.opengeospatial.org/standards

OGC Innovation

– http://www.opengeospatial.org/ogc/programs/ip

George Percivall

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