SPHERE Project

A BIM Digital Twin Environment

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This project has received funding from the H2020 programme under Grant Agreement No. 820773

What is SPHERE?

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What is SPHERE?

> **SPHERE is the first european project about Digital Twins applied to the construction sector.**

SPHERE is a research and innovation project co-financed by the European Commission's H2020 program.

The project aims to develop **a BIM-based Digital Twin Environment (DTE)** to optimise the building lifecycle, reduce costs and improve energy efficiency in residential buildings.

SPHERE
BIM DIGITAL TWIN PLATFORM

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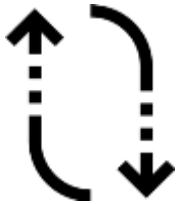
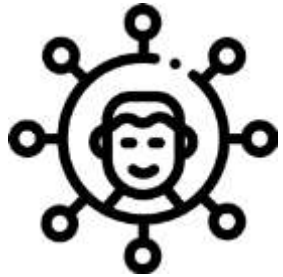
What is SPHERE?

PLATFORM AS A SERVICE (PaaS)

BUILDING SPECS & REAL TIME DATA

VERTICAL INTEGRATED PROCESSES





USER CENTERED DESIGN (UCD)

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Objetives

25% **Reduction** in construction time

15% **Less energy demand** during the operational phase

25% **Less CO2 and GHG emissions** in buildings

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BIM Digital Twin Instance

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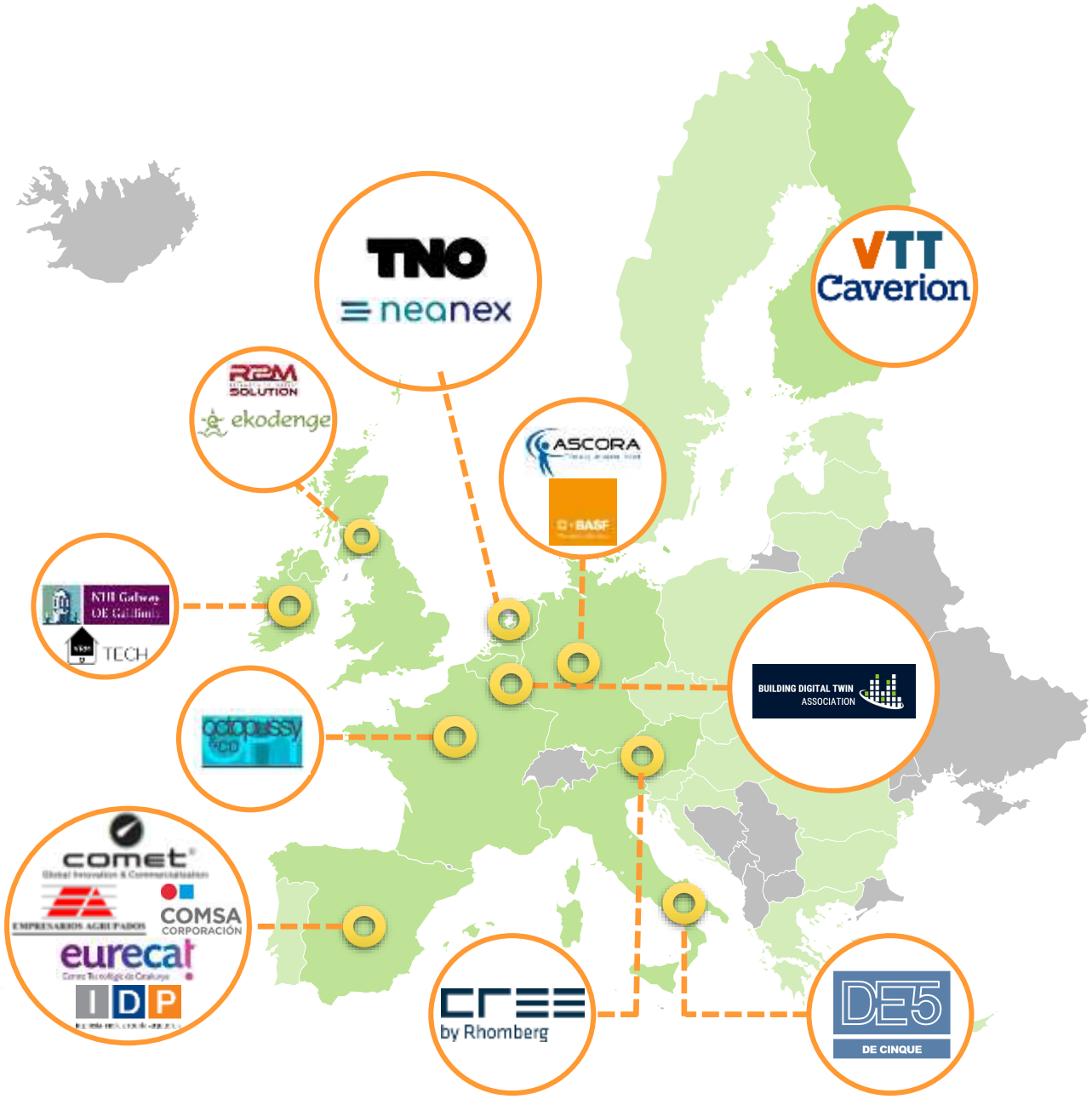


Consortium

Composed of 18 partners from 10 different EU countries, consisting of muti-purpose SME technology leaders as well as software tool providers and expert reasearchers. The combination and integration of their knowledge and experience is the key to SPHERE's success.

Duration: 4 years

Budget: 12 M€

Coordinators:

IDP VTT

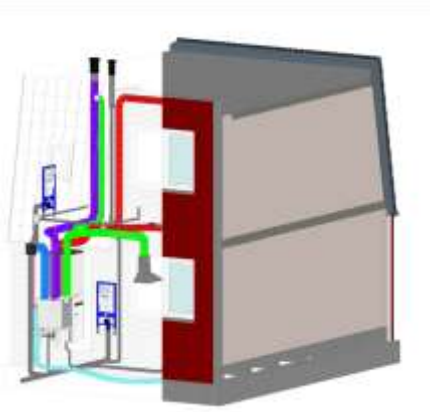
4 Pilot Sites

New Construction

- Italy
- Austria

Retrofitting

- Neatherlands
- Finland



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L1 An integrated framework enabling novel design, construction and operation & maintenance methods

IDDS integrates the tools necessary to improve and reduce the time and costs needed to assess, design and manage the construction process, such as: Time planning (4D), CAPex and OPex (5D), energy efficiency and environmental impact (6D) and Facility Management (7D).

L2 SPHERE ICT Platform as a Service for Residential Buildings

A cloud-based collaborative, Platform as a Service (PaaS) will be developed to connect the buildings assets to the digital world and achieve end-to-end integration and synchronization of the buildings data. Datasets will use an extended Graph Database Ontology, compliant with ISO standards and synchronized by Block Chain.

L3 SPHERE integrated life cycle design approach in Digital Twins

Vertical Integrated Life Cycle Design (ILCD) is necessary to fulfill the performance requirements on building materials and structures from the early design stages. By introducing ILCD-based tools & methods, the Digital Twin can integrate a more sustainable and environmental-friendly process that links product design decisions to actual manufacturing/assembly operations.

L4 SPHERE ICT Building and Construction APPs

Through a dashboard, users will be able to predict the future behaviour and performance of the physical building, to interrogate its current situation or to help establish building benchmarks based on past history. BIM Bots and Intelligent Energy System Designer (IESD) will help attain this knowledge. The level of access to these tools will depend on the user rights and their role in the real-life building.

L5 SPHERE ICT Operation and Maintenance APPs

To manage the ICT operation and apps maintenance, four different tools will be used: Cloud BEMS based on VRM Tech's ISO50001 compliant tool to addresses the Energy Action Plan, Human Thermal Model Building Automation (HTM) control provided by VTT to improve both the thermal satisfaction of occupants and energy efficiency of buildings, TNO's self learning BIMbots to develop user behaviour models and libraries and Eurecat's iPredict, a predictive maintenance module based on AI and machine learning to minimize downtimes and reduce energy waste.

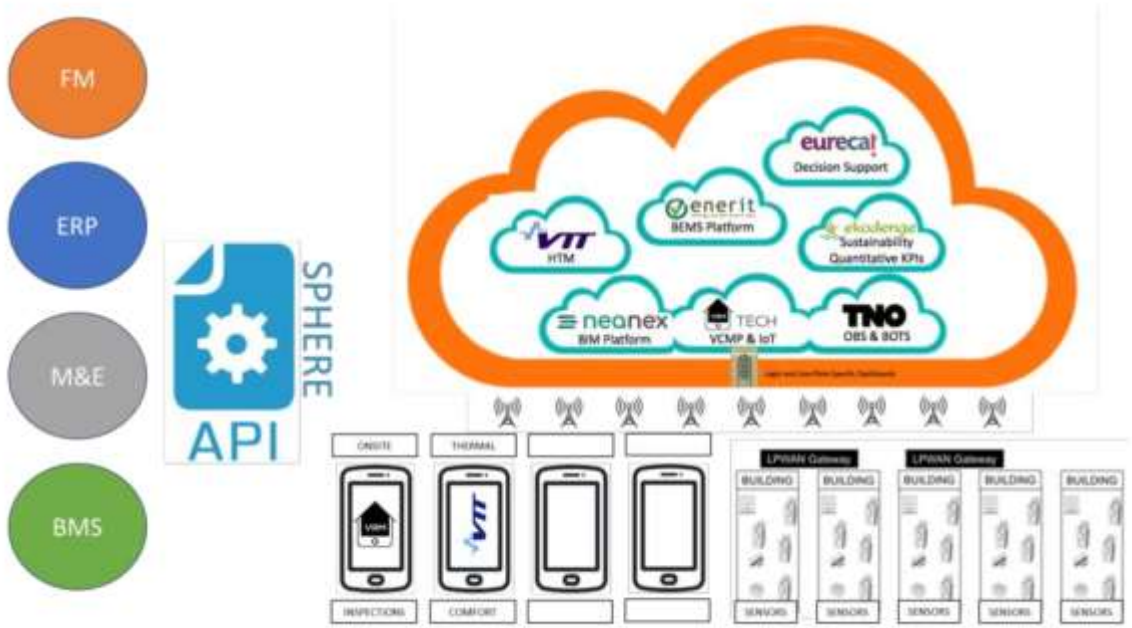
L6 Demonstration

SPHERE's demonstration activities will allow partners to monitor, centralise and implement innovative tools and hybrid systems in real building projects. From the early stages, we associate the project team with local stakeholders who will be actively integrated in the design and assessment of the solution.

BDTE ICT Architecture

ICT PaaS for Building Digital Twin Environments

- Decentralized data storages
- Services and APPs
- Agreed APIs
- Open data formats
- Life-cycle approach



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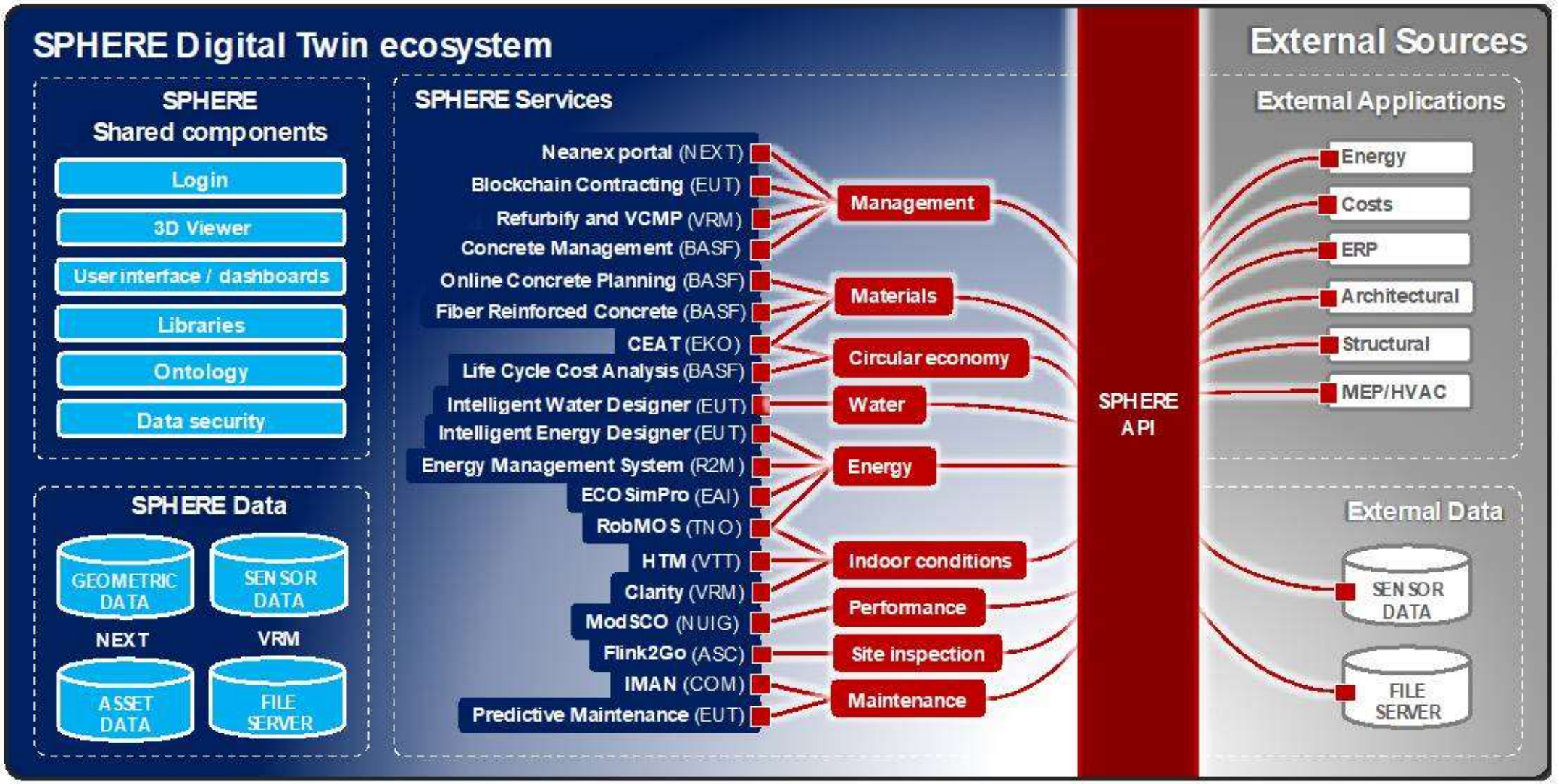
BDTE ICT Architecture



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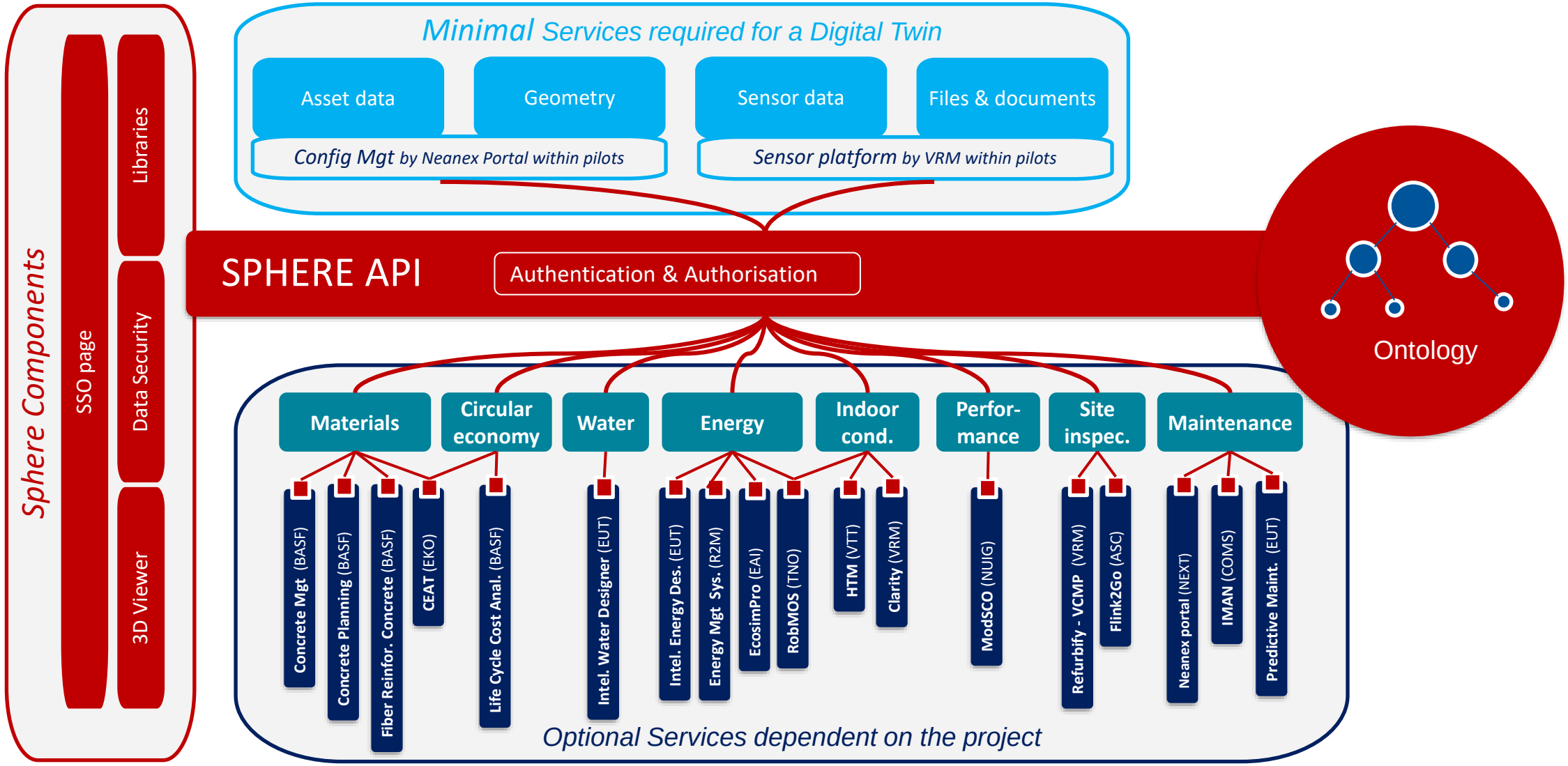
BDTE ICT Architecture



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SPHERE - **Building Digital Twin Ontology**

Approach to develop the desired **Top model Ontology**:

1. Literature
2. Criteria
3. Selection

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SPHERE and the **Open Building Digital Twin API** for sensor data.

- SPHERE's ultimate goal is the improvement and optimisation of buildings' design, construction & performance and management, reducing construction costs and their environmental impact while increasing overall energy performance.

- A Building Digital Twin's success is based on its ability to maintain an accurate representation of the physical entity, to update and adapt to actual changes effectively. To this end SPHERE focus a Building Digital Twin API, to enable IoT sensor data to be captured, communicated and validated by SPHERE tools within the eco-system.

API cooperation with bSi

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SPHERE and the **Open Building Digital Twin API** for sensor data.

- SPHERE achieve identification, location and transmission of data sets within the eco-system (and H2020 sister projects), and a true, dynamic Building Digital Twin delivering dynamic data hosted and communicated efficiently.

- The **BuildingSmart** roadmap and OpenCDE workstreams represent a complimentary avenue through which to collaborate over the next 12-24 months, with further opportunities likely via the newly formed Building Digital Twin Association.

API cooperation with bSi

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SPHERE – Tools providing Services

Services will be implemented in pilots based on Use Case analysis ->

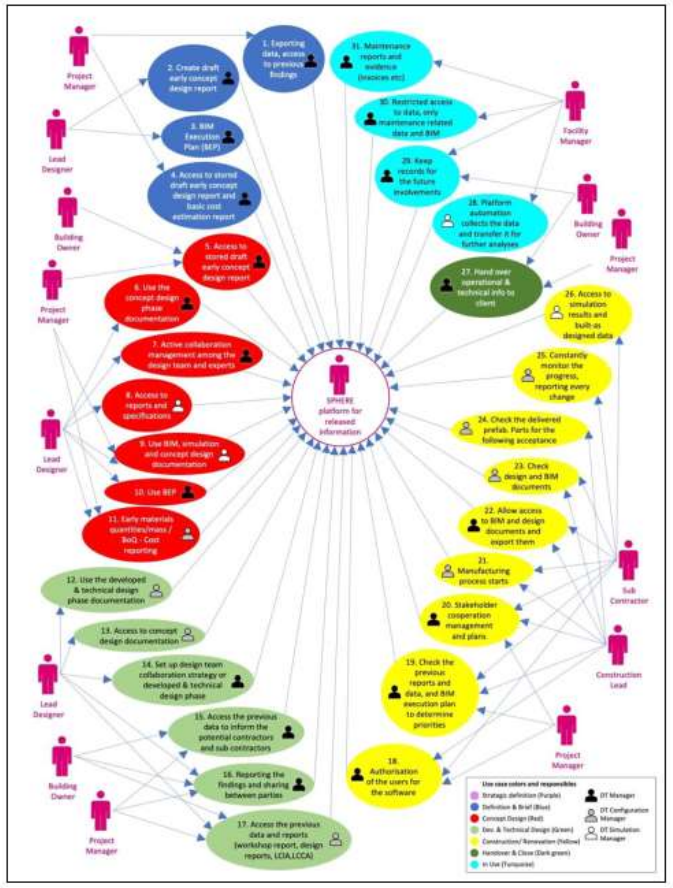

Figure 4. Use Case diagram for Austria pilot.

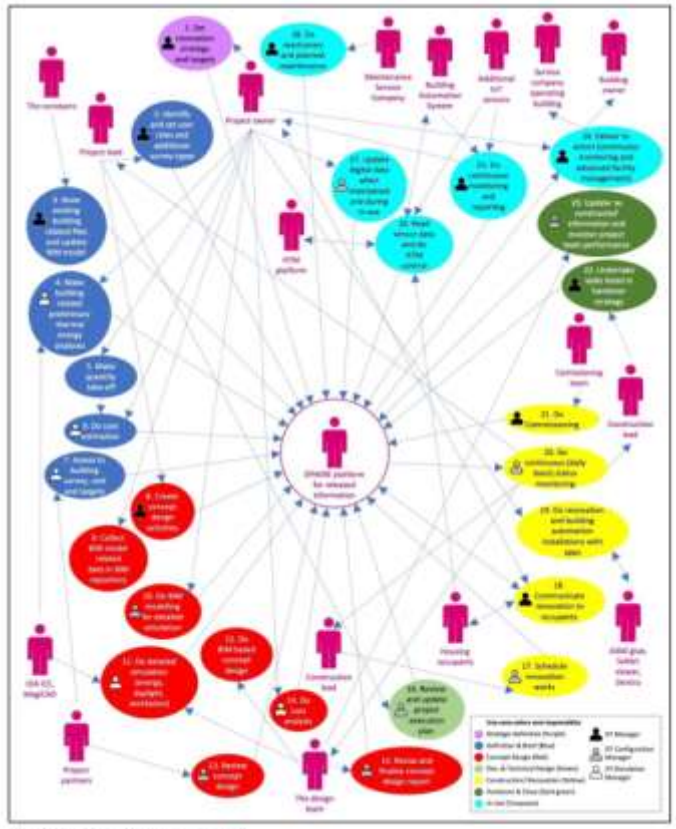

Figure 5. Use Case diagram for Finland pilot.

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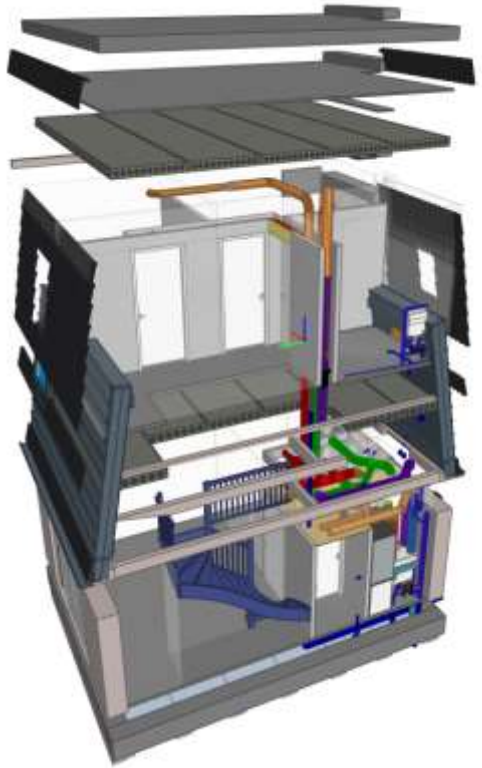
SPHERE – **Tools providing Services**

Currently implementing -> Real Time Simulation in TNO's pilot



- PASSIVE BUILDING: WALLS, FLOORS, FACADES, COVER, DOORS, WINDOWS
- VENTILATION SYSTEM: SPACES, HOME VENTILATION MACHINE, NETWORKS
- HOME VENTILATION MACHINE, PART OF VENTILATION SYSTEM

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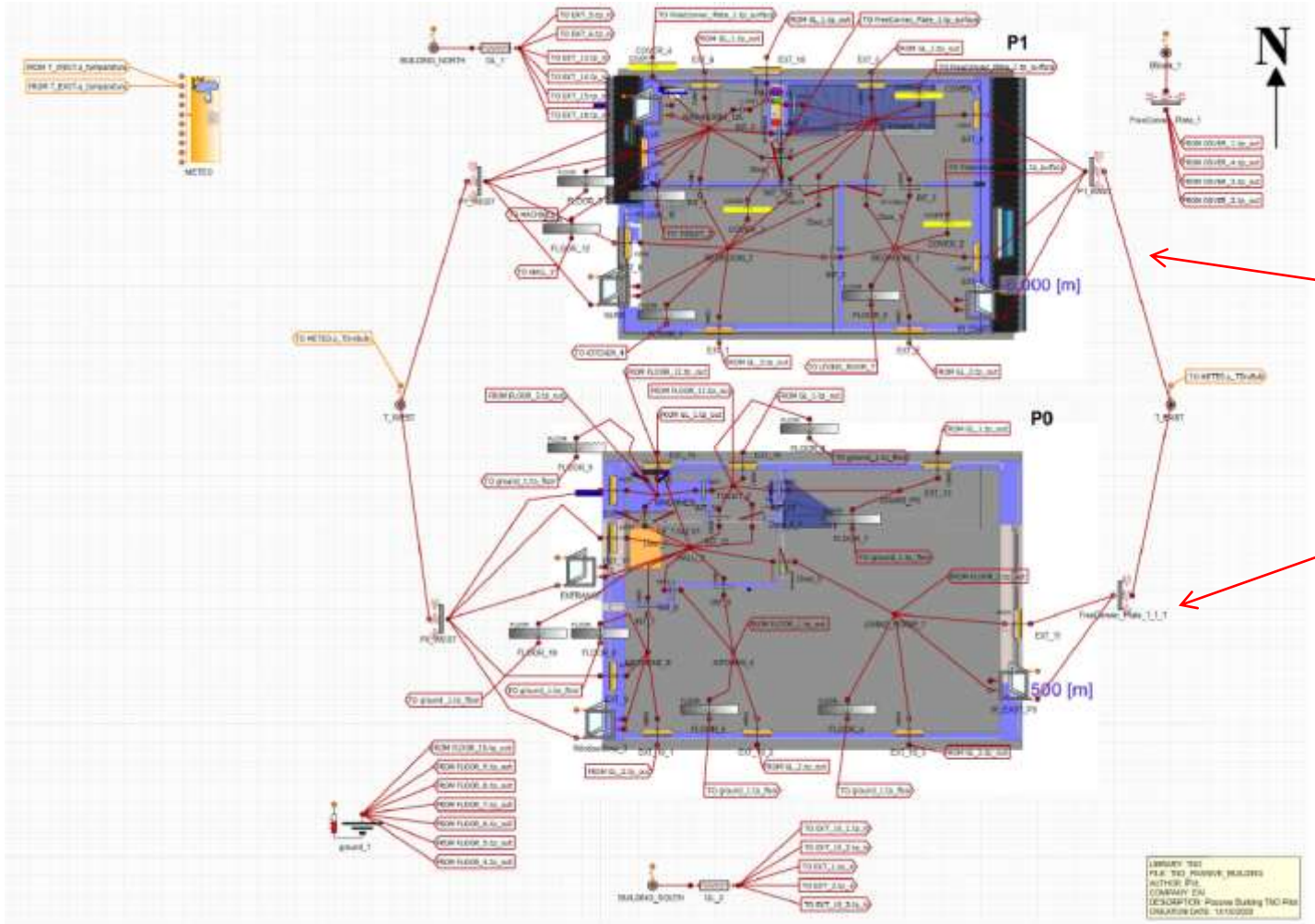
SPHERE – Tools providing Services



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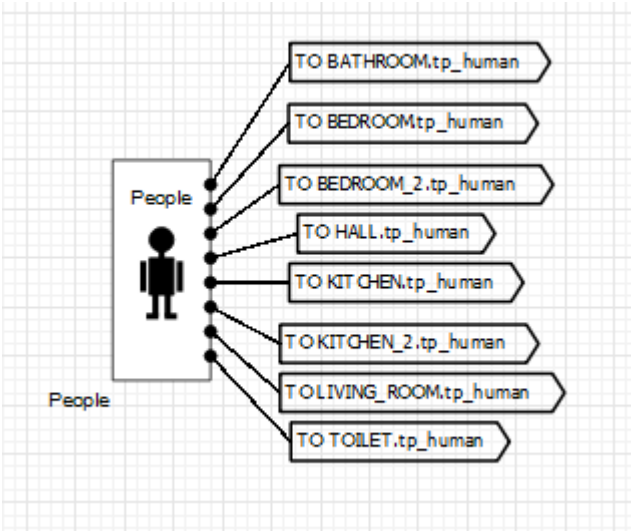
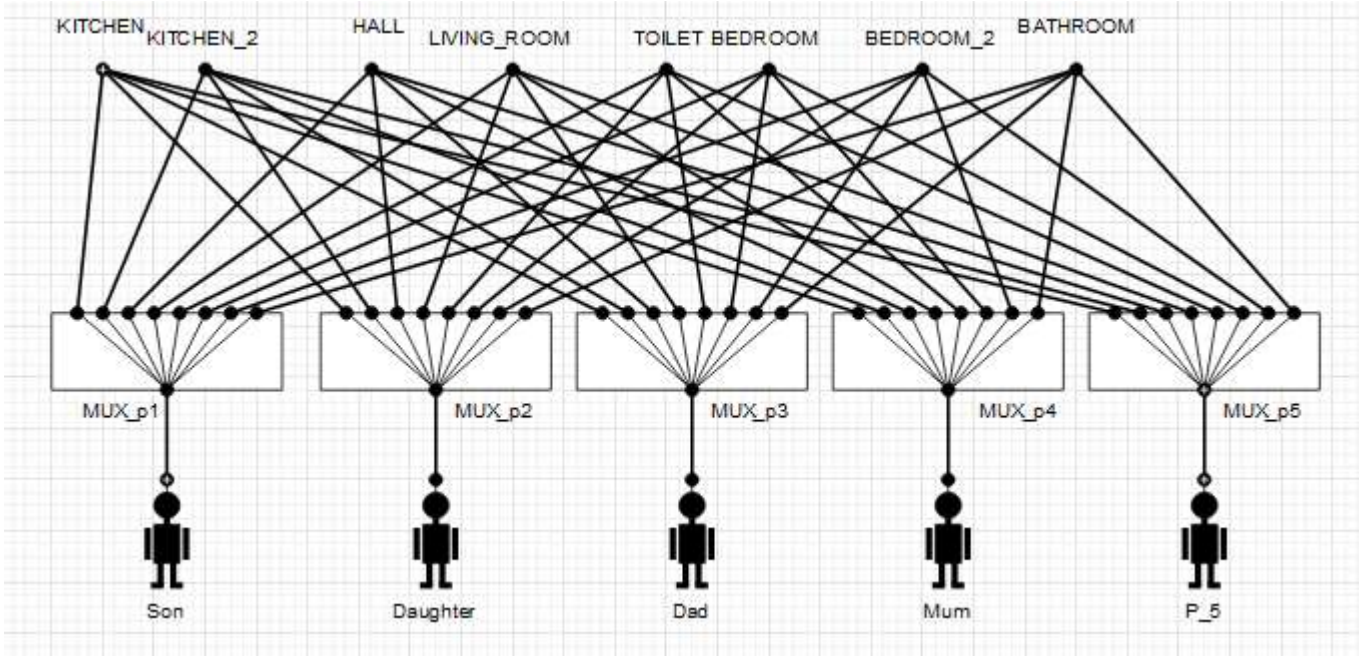
SPHERE – Tools providing Services

- Occupancy model based on HVMs dummies



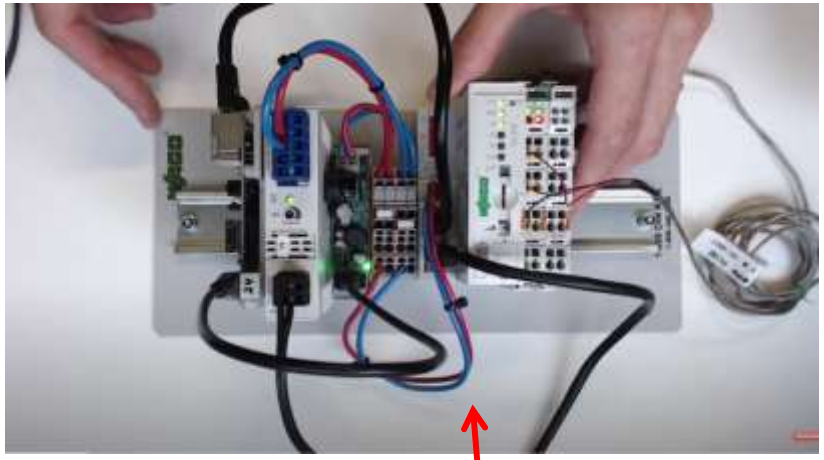


SUSTAINABLE PLACES

SPHERE – Tools providing Services

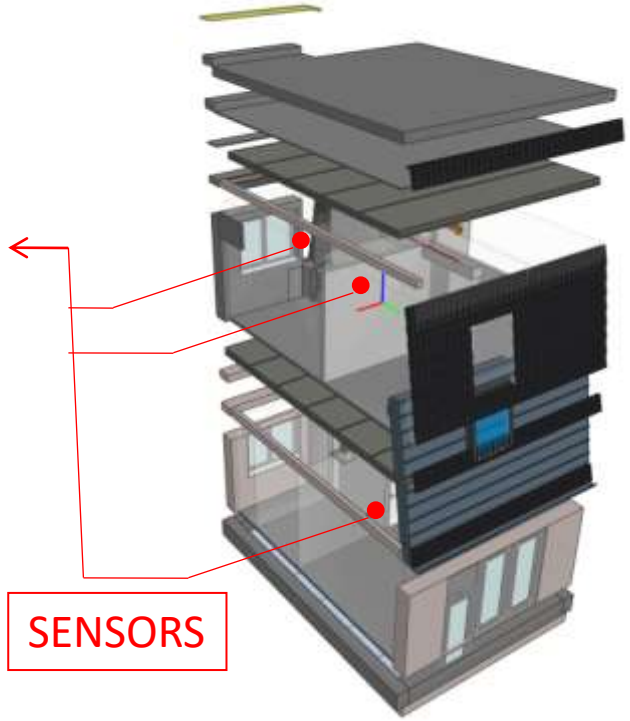
Smart machine/smart building: simulation integrated with real time **(SIMBOTS)**

SCADA REAL OR MOCKUP



Raspberry Pi

MOCKUP OR REAL BUILDING



SENSORS

CLASICAL CONFIGURATION USING A BMS

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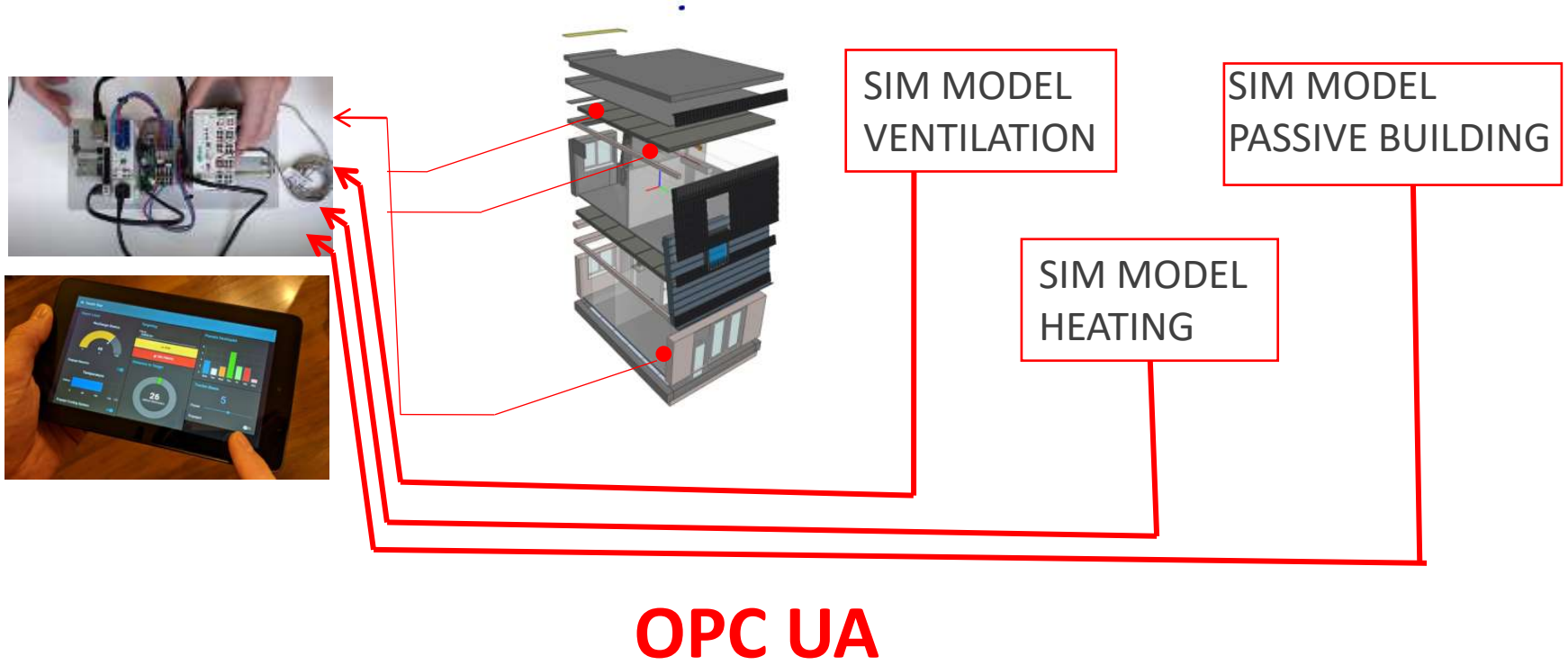
SPHERE – Tools providing Services

Smart machine/smart building: simulation integrated with real time **(SIMBOTS)** 2



PROPOSED CONFIGURATION USING A BMS, SIMULATED MODELS AND HMs

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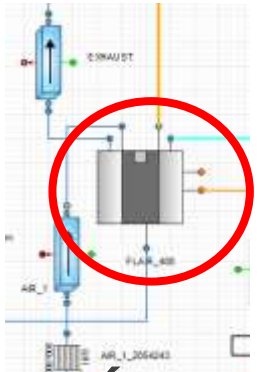
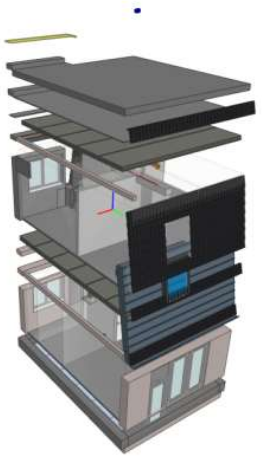
SPHERE – Tools providing Services

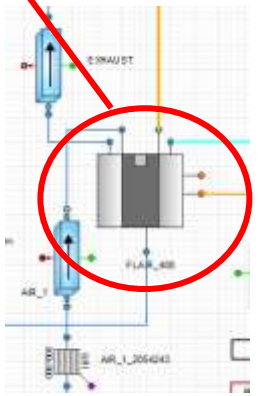


PROJECT

BRINK´S FLAIR 400 SIMBOT

The same MACHINE model but packed as DECK/OPC,
Working INSITE, with many potential uses





REAL TIME

BRINK´S FLAIR 400 SIMBOT

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BIM4Ren

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BIM DIGITAL TWIN PLATFORM

SPHERE Project

BUILDING DIGITAL TWIN ASSOCIATION

http://buildingdigitaltwin.org/

SPHERE Developments and the BDTA

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Building Digital Twin Association

Created in May 2020 in Antwerp (Belgium), under the umbrella of the SPHERE project to promote the adoption of Digital Twins in the construction sector.

BUILDING DIGITAL TWIN ASSOCIATION

SUSTAINABLE PLACES

BDTA: Mission

Objectives:

- Support the **Open Knowledge** generated in the SPHERE project
- Generate an **ecosystem for the mass implementation** of Digital Twins in the European Union

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BDTA: Principles

GP 1. OPEN

Develop an Open Technology Framework ready to evolve as a community along the lifespan of AECOO assets and cities

GP 2. ETHICAL

Provide a Citizen Centered Vision to guarantee Privacy and Ethical usage of the generated data

GP 3. RELIABLE

Synchronize updated information of smart and connected buildings towards an un-siloed complete information

GP 4. CIRCULARITY

Allow seamless environmental assessment across lifecycles for a circular management of building environment

GP 5. CLIMATE GOALS

Optimize Energy Performance in buildings by reducing gap projections between lifecycles

GP 6. ECONOMIC VALUE

Generate trustworthy baselines to generate economical guarantees to current and new business in AECOO sector

SUSTAINABLE PLACES

BDTA: Working Areas

- **METHODOLOGY: Definitions**
- TRAINING: New Roles
- DATA GOVERNANCE TOOLS: SPHERE PaaS, BDTE OPEN ONOTLOGY, Open BDT API
- BDT Community

http://buildingdigitaltwin.org/

SUSTAINABLE PLACES

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BUILDING DIGITAL TWIN ASSOCIATION

SPHERE: Definitions White Paper

> A document that will be an essential reference in the scientific literature on this new discipline

It presents a series of **clear and precise definitions** that allow to lay the foundations for the development of the software that will act as a standardized physical-digital framework for Digital Twins.

The first version was published on the project website on **December 2019**.

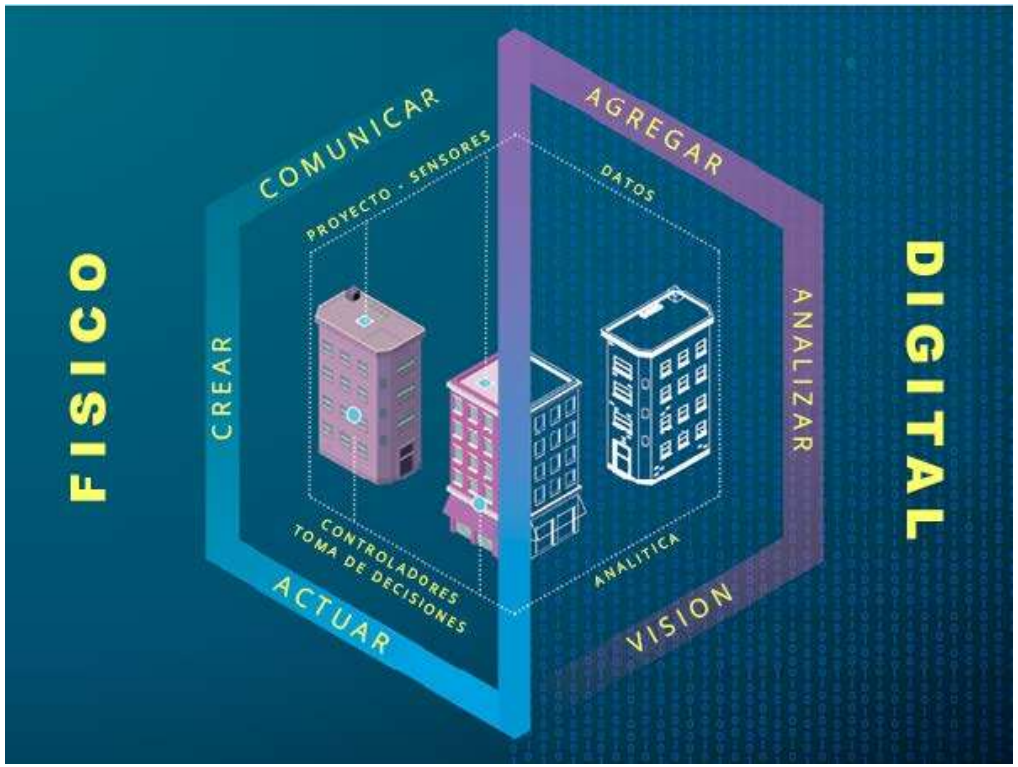
DOWNLOAD

English

Spanish

SUSTAINABLE PLACES

New definitions of building Digital Twins from the SPHERE Project



Building Digital Twin Prototype

(Design & Construction)

Building Digital Twin Instances

(Operation & Maintenance)

Building Digital Twin Aggregates

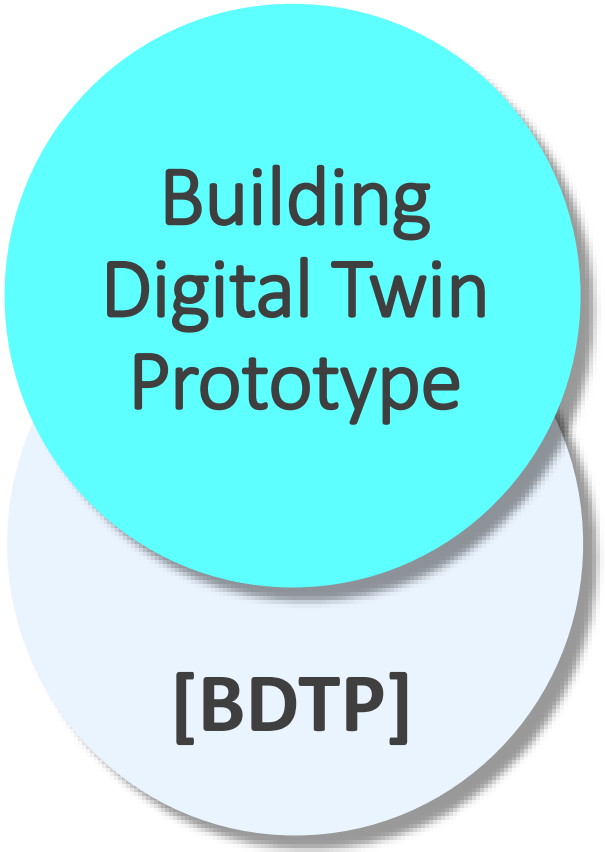
(Horizontal & Vertical)

Building Digital Twin Environment

(Interrogative & Predictive)

SUSTAINABLE PLACES

New definitions of building Digital Twins from the SPHERE Project



A Building Digital Twin describing the AECOO asset during its design and construction. It contains the informational sets necessary to describe and produce a physical version that duplicates or twins the virtual version.

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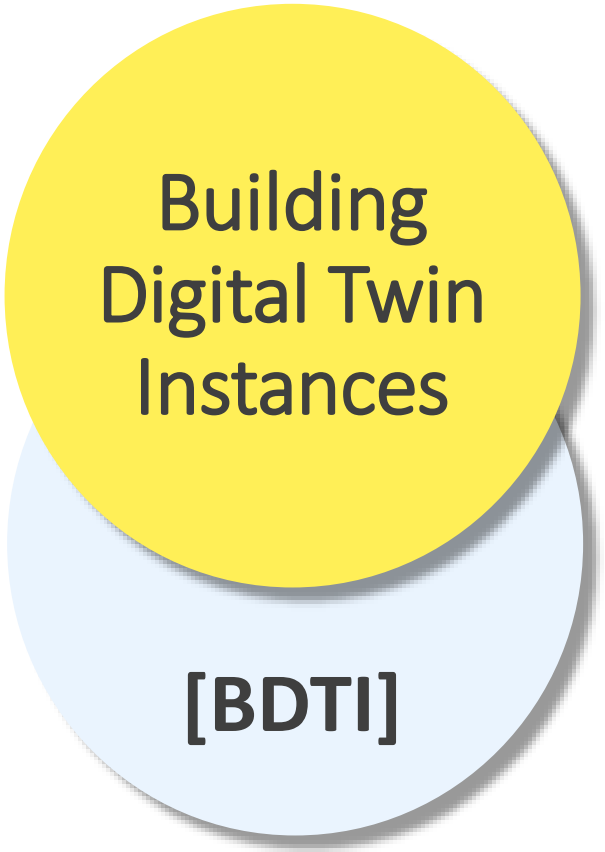
New definitions of building Digital Twins from the SPHERE Project



A Building Digital Twin that is linked to throughout the life of a specific corresponding physical product, including pairing when the asset starts its operation. In the AECOO sector, this milestone corresponds to the legally binding As Built Documentation.

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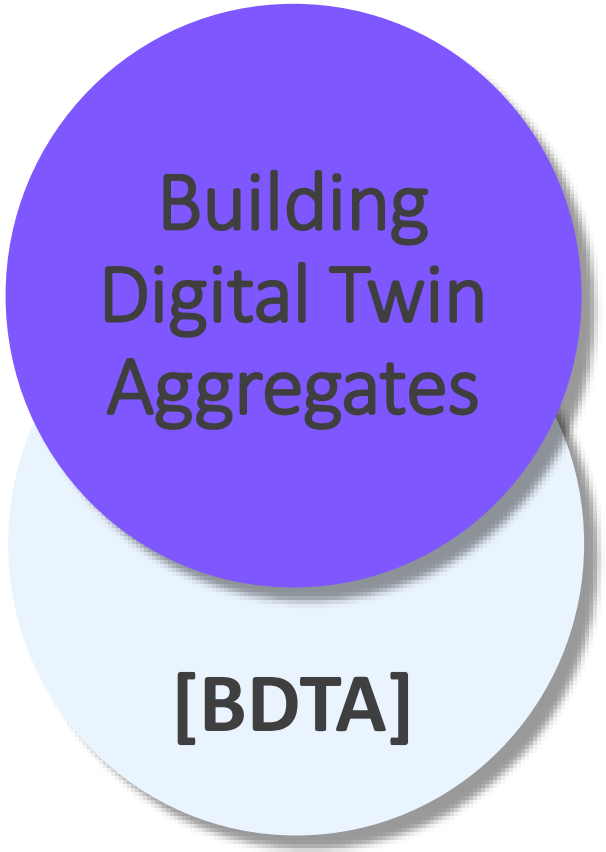
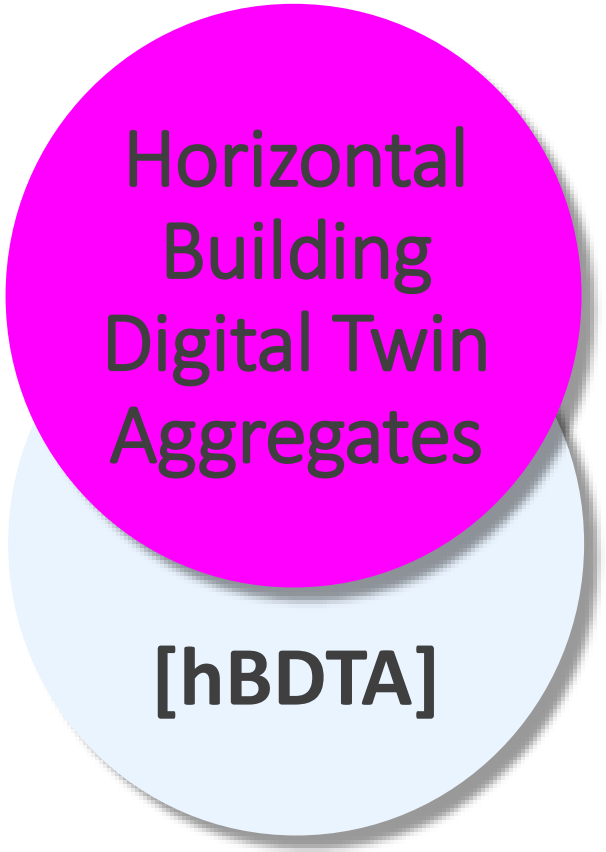
New definitions of building Digital Twins from the SPHERE Project



In AECOO, similar to manufacturing, this type of Building Digital Twin is the aggregation of multiple DTIs. Instead of having an independent data structure, DTAs are a computing construct which provide direct access to all DTIs, hence allowing ad-hoc or proactively queries for benchmarking and comparisons.

SUSTAINABLE PLACES

New definitions of building Digital Twins from the SPHERE Project



This type of DT is following the same principle than in manufacturing use case, by linking similar DTIs. However, in general AECOO products presents a smaller number of assets and much more heterogeneity than manufacturing products. In addition, the legal persons involved in their production are many more than in manufacturing supply chains (e.g. OEMs and TIER1, TIER2) providing a much more distributed data ownership. These two inherent characteristics of AECOO use cases may hinder both the representativeness of the aggregated data as well as the potential of queries scopes.

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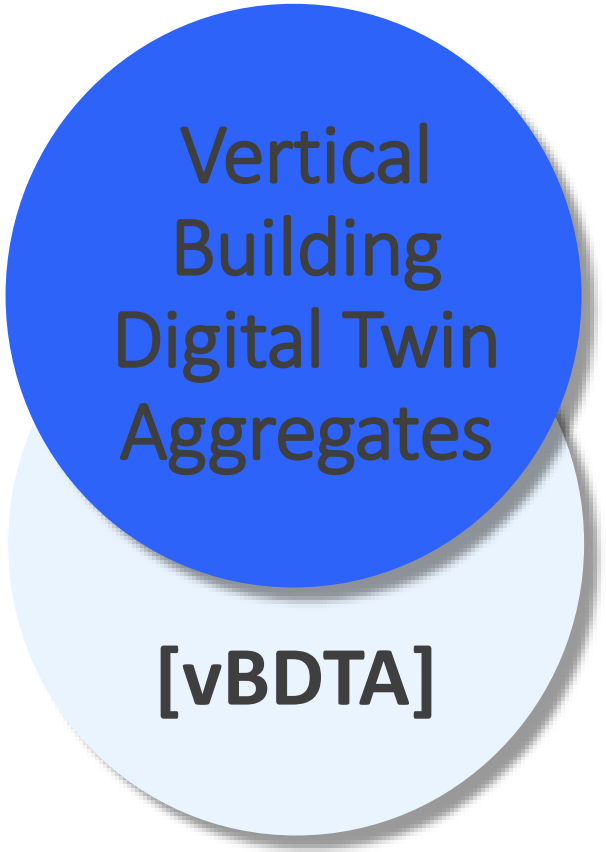
New definitions of building Digital Twins from the SPHERE Project



Building scale is the hinge in between cities and its contents, and the synchronization of Building Digital twins across the Digital Twin scales will allow the vertical aggregation from appliances to districts. In there, vBDTA will put the focus on the AECOO stakeholders needs of relevant information and optimized queries.

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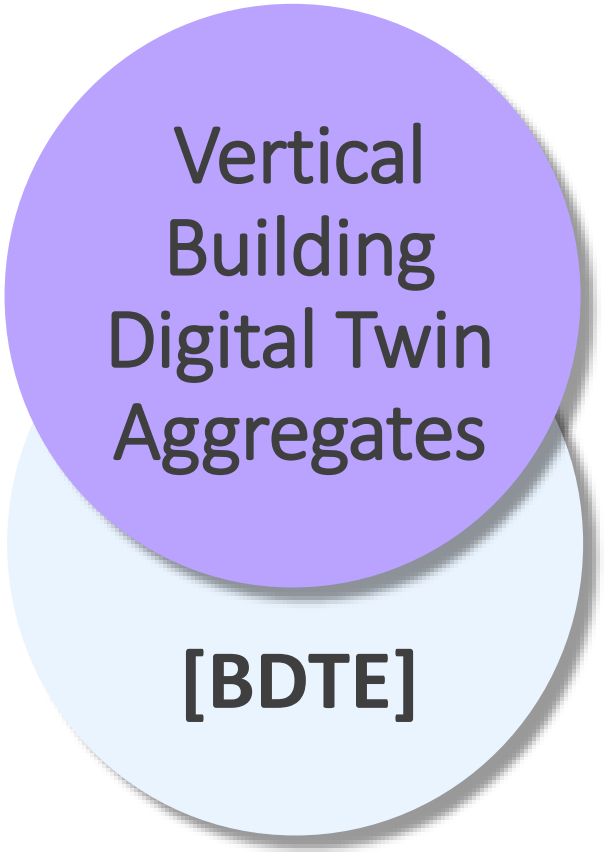
New definitions of building Digital Twins from the SPHERE Project



Beyond this, by the creation of any DTE, two main purposes are sought: Predictive (intimately linked with simulation tools of DTPs and DTIs) and Interrogative (applying to DTIs as well as to DTAs in-depth analysis). As it happens to be in any DTE, these two basic drivers may include completely different requests depending on which is the role of the stakeholder interacting and the typology of the Digital Twin.

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BDTA: Working Areas

- METHODOLOGY: Definitions
- **TRAINING: New Roles**
- DATA GOVERNANCE TOOLS: SPHERE PaaS, BDTE OPEN ONOTLOGY, Open BDT API
- BDT Community

http://buildingdigitaltwin.org/

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BUILDING DIGITAL TWIN ASSOCIATION

New roles and processes for implementing building Digital Twins

Building Digital Twin Manager (BDTM)

Building Digital Twin Configuration Manager (BDTCM)

Building Digital Twin Simulation Manager (BDTSM)

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New roles and processes for implementing building Digital Twins

Building Digital Twin Manager (BDTM)

- Coordinator. In charge of the authenticity and quality of the data
- Construction Process Expert, Data Governance, Legal.

The BDTM will be responsible for developing and adapting the correct procedures to create and manage the DT of the asset along its lifecycle. The Digital Twin Manager assures that the model and the external database works correctly, and all the users have access to the DT platform. All changes (Ex: new users, substitution of a equipment, etc.) suffered by the DT are controlled by the DT Manager. This new figure will be liable to certify, audit and record the evolution of any kind of Building Digital Twin across its lifespan, including two main aspects, the *Configuration Management*, focused on the management and control of the DT system elements and configuration and *Simulation Manager*.

New roles and processes for implementing building Digital Twins

Building Digital Twin Configuration Manager (BDTCM)

- Simulation, BAC, IoT

As a broad and transversal concept, configuration management (CM) refers to the process of systematically handling changes to a system in a way that it maintains integrity over time, here defined as life cycle. Because the different data sources and formats, information storage and access require the interaction of several servers, and the Configuration Management evolves into an Orchestration process conducted by the figure of the Configuration Manager. It is required that the environment created under the DT concept be provided of a controller brain to synchronise the different functions, from the user queries to the internal data processes along time. As example, the architecture proposed in SPHERE platform is a PaaS which acts as a system of systems. It hence comprises a multilayer ecosystem able to communicate with external environments.

New roles and processes for implementing building Digital Twins

Building Digital Twin Simulation Manager (BDTSM)

DTsManager acts as the general coordinator for the definition of simulation-based services of any Digital Twin Environment, for example SPHERE PaaS capabilities and the main functions.

- System engineering. Admin and Configuration. .

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BUILDING DIGITAL TWIN ASSOCIATION

Based on SPHERE BDTE Tech Developments:

PaaS Architecture
Open BDT API
BDT Ontology

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SPHERE - **Building Digital Twin Ontology**

- Different information and different information needs call for different models, types, descriptions.
- However, when these different options do not align, there is little point in using an ontology.
- Hence, **we need a top model**. Some sort of universal basic truth that matches our information. An ontology about our ontologies, or a model about our models.
- A generic and accurate top-model ensures a wider compatibility with other ontologies.
- However, this general top-model is not specific enough for our needs.
    - Specify this ontology when starting the use cases
    - By adding an OTL (object-type library) that describes specificities

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SPHERE - Building Digital Twin Ontology

	A	C	D	E	F	G	H	I	J	L	M	N	O
1					MUST HAVE								
2	**Ontology**	**Last update**	**Estimated installed base**	**Proven compatibility**	**Domain independence**	**Extensible**	**Semantic richness**	**Sensor resources**	**Sensor data**	**Compatibility IFC**	**Detailed description**	**No datatype limitation**	**Availability/License**
3	SSN	2017	large	DogOnt, IoT-O, BACS,	OK	OK	OK	OK	OK	OK	OK	OK	OK
4	Xue et al	2015			NOK	OK	?	OK	OK				NOK
5	M3	2020	small	IFC, SSN	OK	OK	OK	OK	OK	OK			NOK
6	OntoSensor	2008			OK	NOK		OK	OK				
7	MyOntoSens	2015	very small	SSN	OK		?	OK			?		NOK
8	Proposed by Hirmer et al. (based on SensorML)							OK	OK				
9	Sensor Core Ontology (Shi et al)	2012	very small		OK	OK		OK	OK		NOK		
10	SAREF	2018	?	IFC	NOK	OK	OK	OK	NOK	OK	OK		
11	SAREF4EE			IFC	NOK	OK		OK	OK	OK			
12	SAREF4BLDG			IFC, SSN	NOK	OK		OK	OK	OK			
13	Ontology by Dey et al. for smart energy meters	2014	low		NOK								
14	BRICK			IFC, RealEstateCore (v	NOK		NOK	OK		OK	NOK		OK
15	IoT-O	2018		SSN		NOK		OK	OK		NOK		
16	BACS Ontology	2017	small	SSN	NOK		OK	OK	OK	OK	depends on part	OK	OK
17	DogOnt	2019		SSN	NOK	OK		OK	OK				
18	ifcOWL			SSN	OK	OK	OK	NOK	NOK	OK	OK	NOK	
19	BONSAI		large	IFC	NOK	OK	NOK	NOK	NOK	OK	NOK		
20	COSE ontology: Casas Ontology for Smart Environments	2011	very small										NOK
21	SBOnto	2017			NOK		NOK				NOK		NOK
22	oneM2M		large in industry										docx
23	Haystack tagging ontology				NOK		NOK				OK		
24	OEMA (ontology for energy management applications)				NOK								
25	BASOnt			IFC	NOK				limited	OK	NOK		paper
26	ASHRAE (BACNet)				OK			NOK	NOK				OK
27	RealEstateCore	2019		IFC (v4), SSN (v4), BR	NOK	OK	OK	OK	OK	v4 OK	OK	OK	OK
28	gbXML	2017			NOK			OK	OK		NOK		
29	IMDF				NOK								
30													

SUSTAINABLE PLACES

SPHERE - **Building Digital Twin Ontology**

Criteria sensor ontology

- Domain independence: otherwise it is not a top-model and not re-usable for other applications
- Extensibility: in case we want to connect it to other aspects of our system
- Semantic richness: meaning and interrelationships need to be clearly defined
- Sensor resources: we want it to say something about sensors
- Sensor data: we also want to know something about results
- Compatibility IFC: A very important standard, so this deserves some special attention
- Detailed description: interpretation leads to disagreement and errors
- No datatype limitation: leads to technically limited applicability
- Availability: we need this as a starting point, anyone should be able to re-use our core model

SUSTAINABLE PLACES

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SPHERE - **Building Digital Twin Ontology**

SSN:

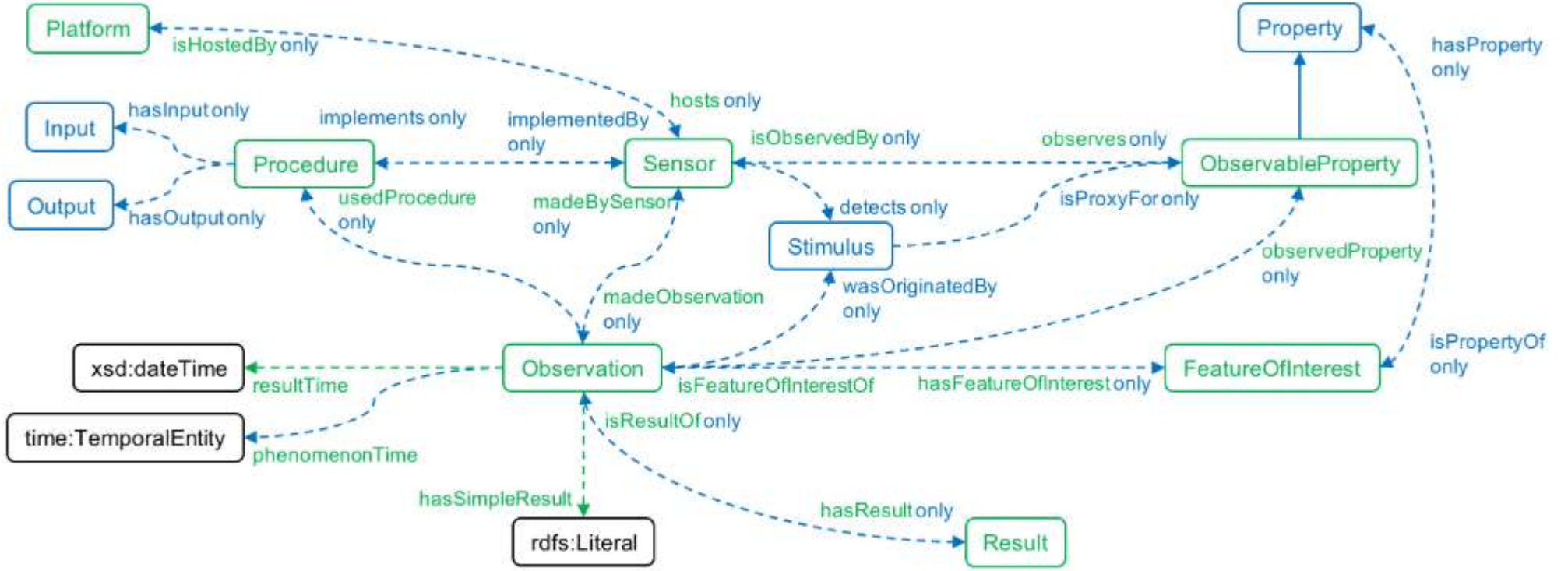
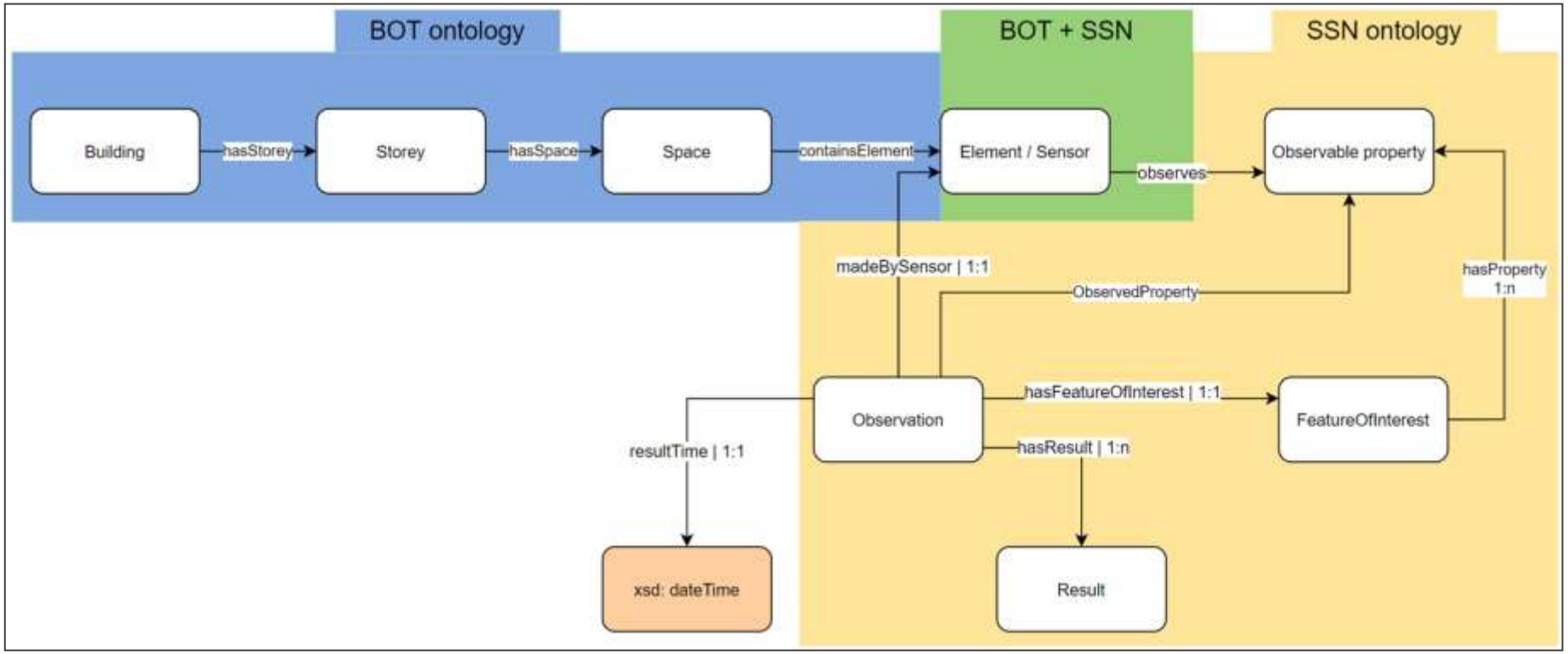


Figure 10 Classes and relationships involved in Observation (SOSA/SSN)

SUSTAINABLE PLACES

SPHERE - **Building Digital Twin Ontology**

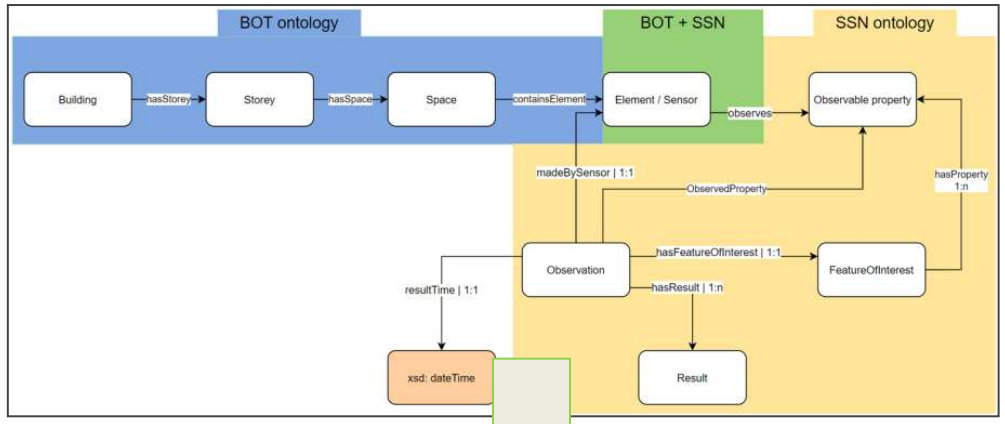
Combination of Ontologies

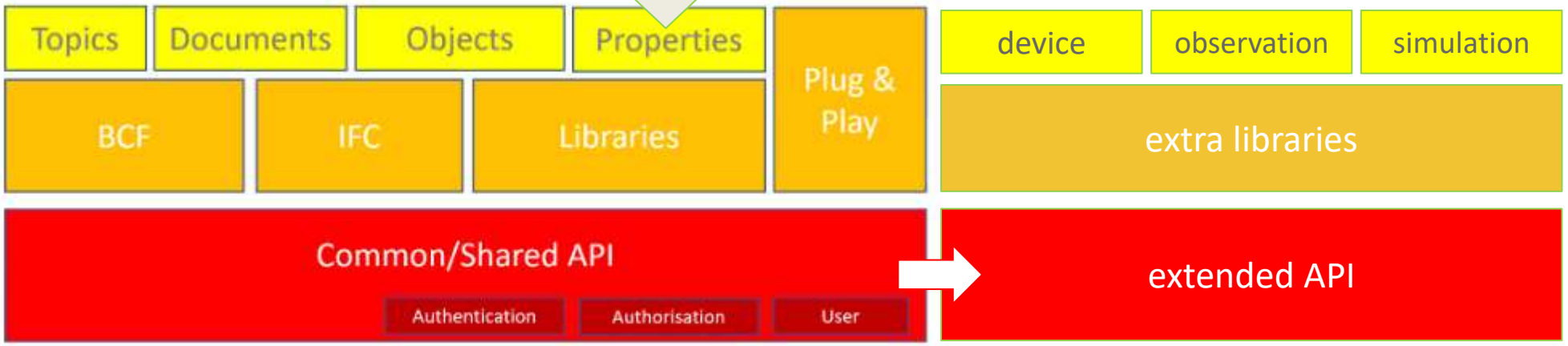


SUSTAINABLE PLACES

SPHERE - **Building Digital Twin Ontology**

Link to bS Open CDE initiative





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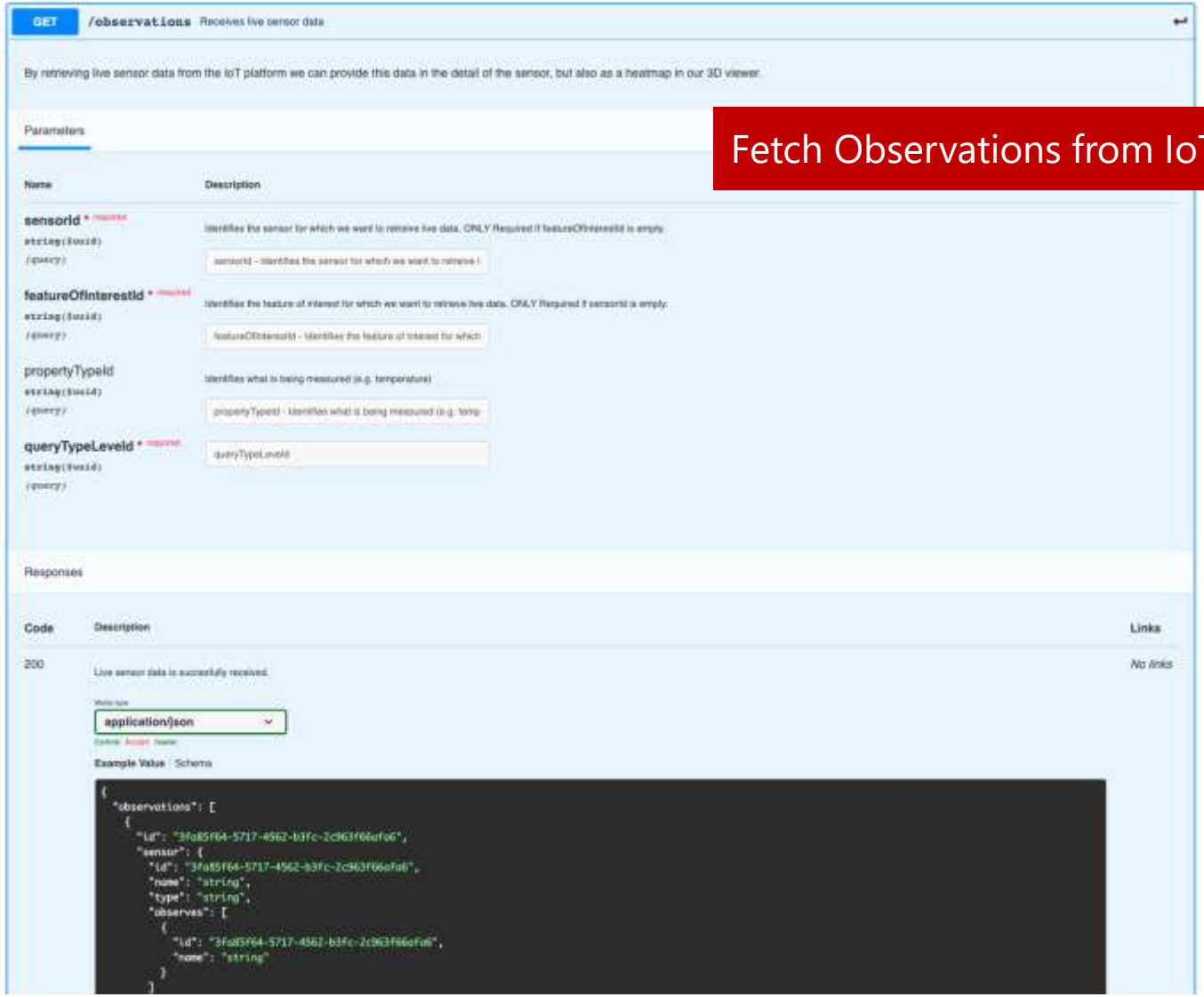
API development



Fetch Observations from IoT platform

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Results – Neanex Portal linked to IoT platform

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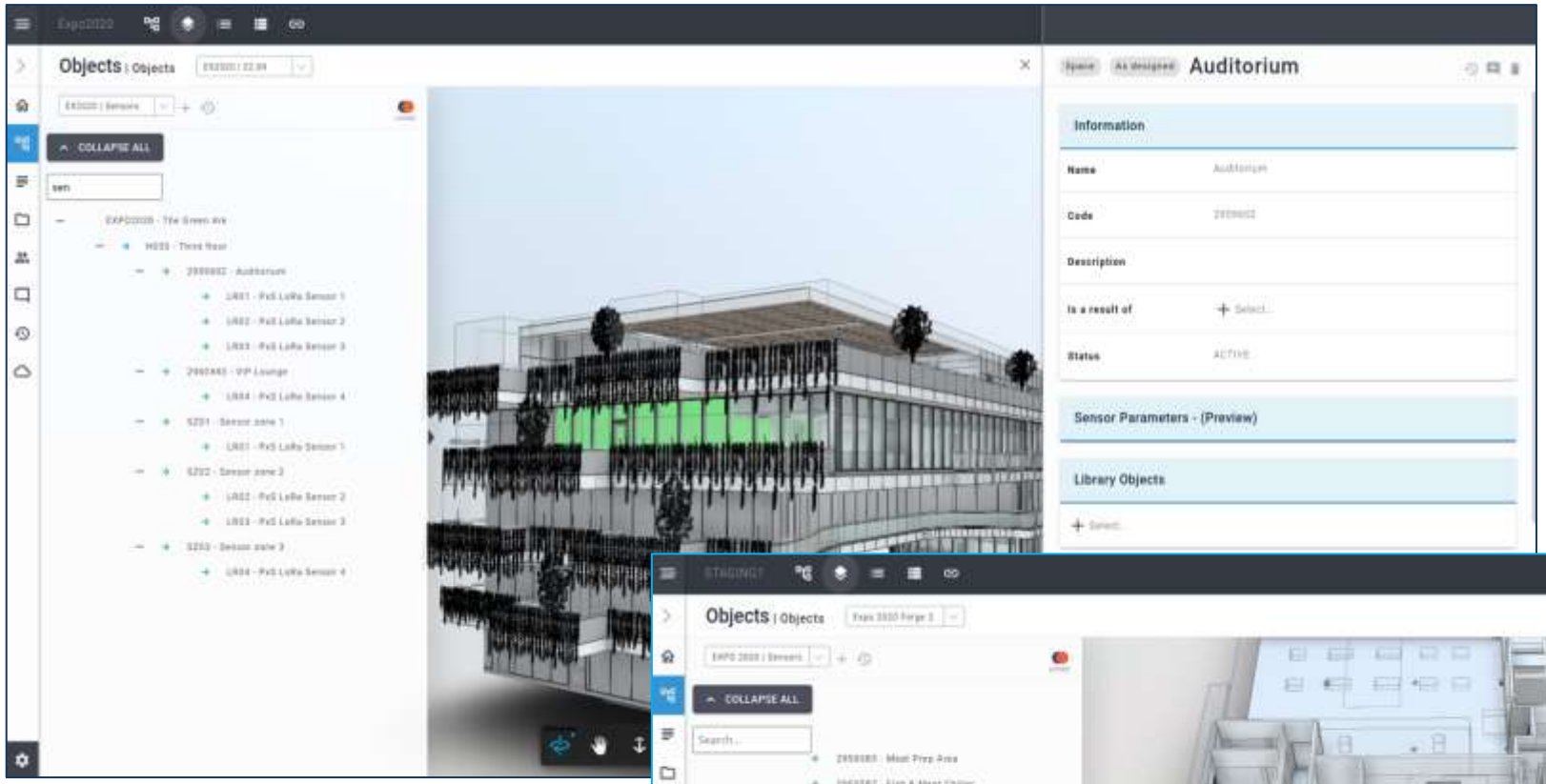

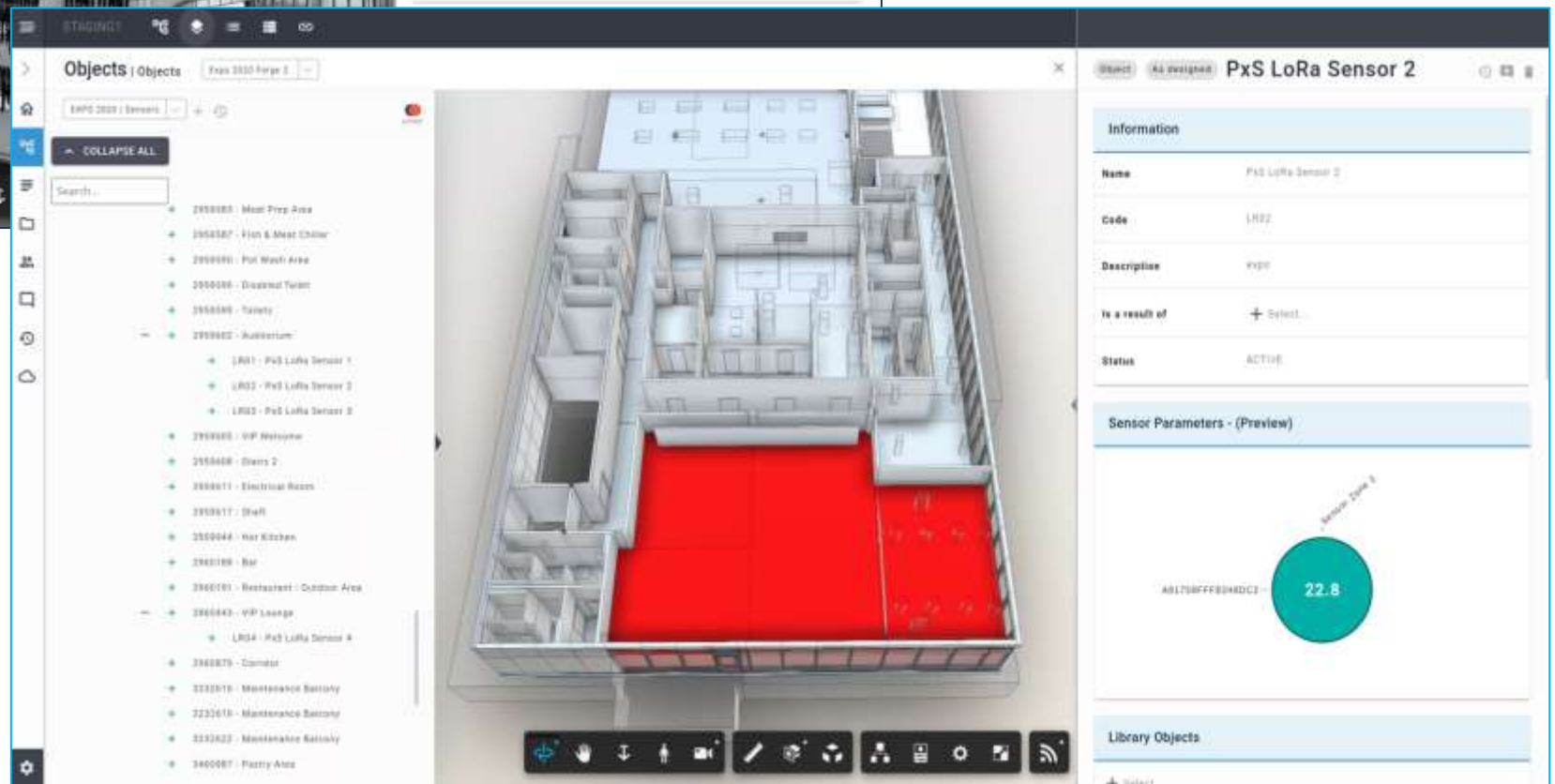

VRM TECH

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BDTA: Working Areas

- METHODOLOGY: Definitions
- TRAINING: New Roles
- DATA GOVERNANCE TOOLS: SPHERE PaaS, BDTE OPEN ONTOLOGY, Open BDT API
- **BDT Community**

http://buildingdigitaltwin.org/

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BUILDING DIGITAL TWIN ASSOCIATION

BDTA: BDT Community

- **Working in the First BDT Congress to be celebrated in Barcelona in April 2021**

http://buildingdigitaltwin.org/

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Learn more about BDTA and SPHERE!

www.sphere-project.eu

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White Paper

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This project has received funding from the H2020 programme under Grant Agreement No. 820773

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