Defining semantics for digital twins of façade component testing facilities

LUXEMBOURG INSTITUTE OF SCIENCE AND TECHNOLOGY | LIST

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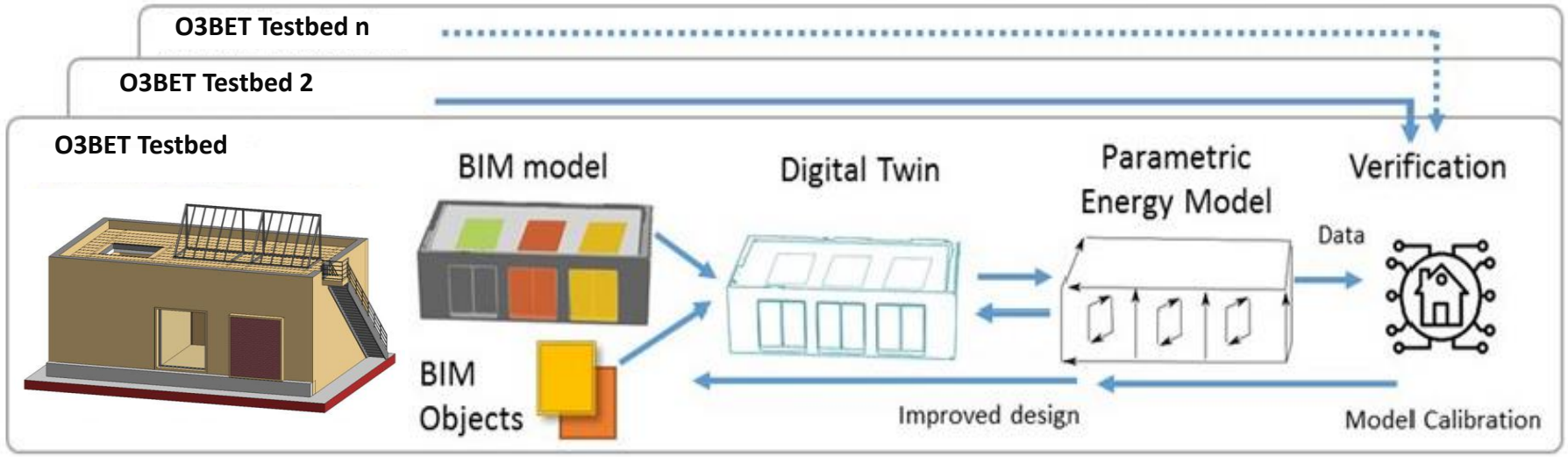
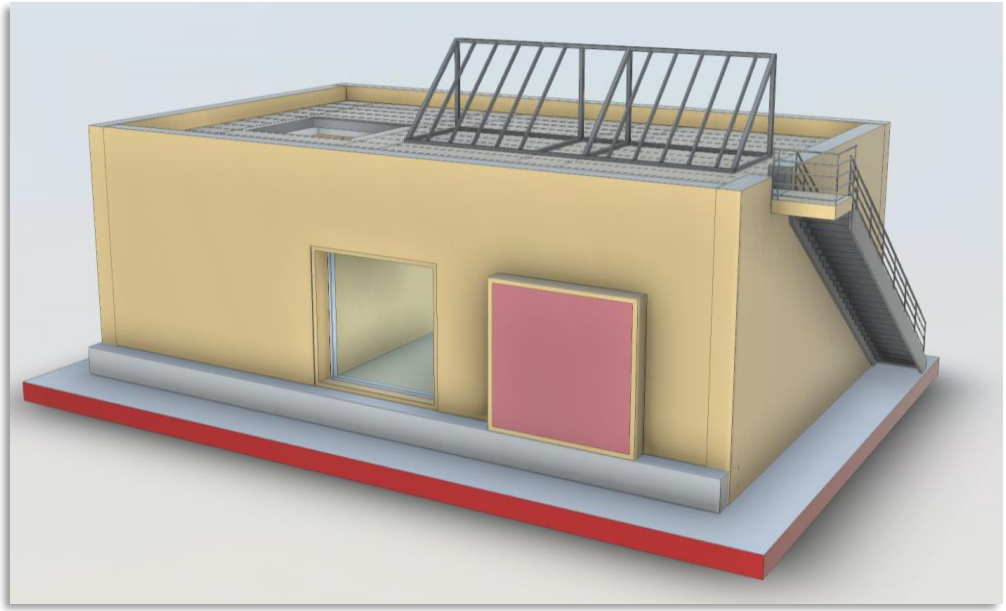
metabuilding labs

What is an O3BET-DT?

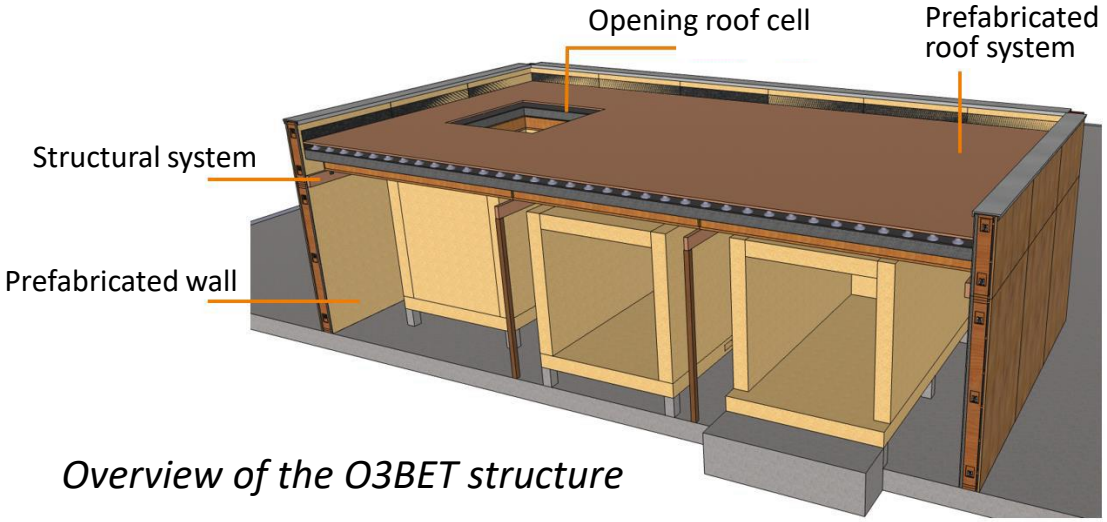
O3BET | Open Source
Open Data
Open Access | **Building Envelope Testbench**



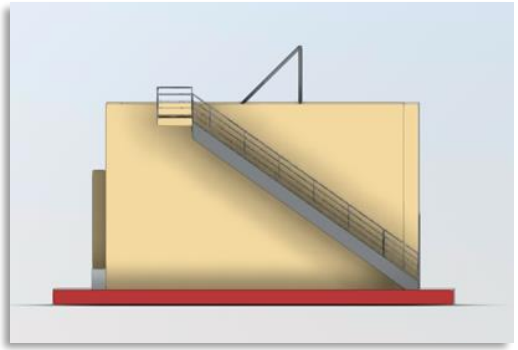
Design of the O3BET dismountable and movable modules

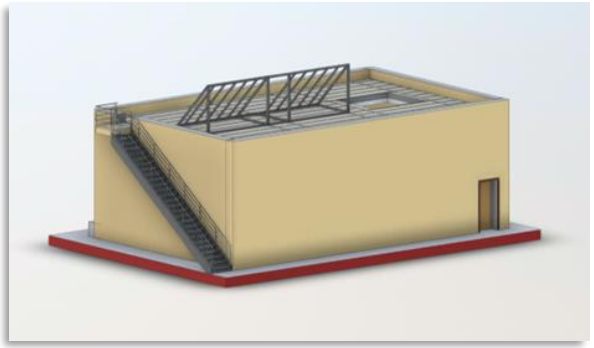


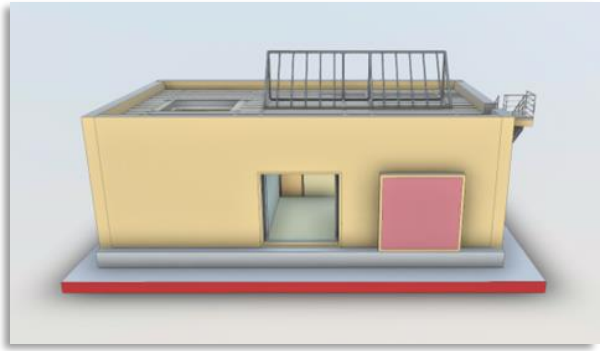
Alternative with two façade cells and one roof cell

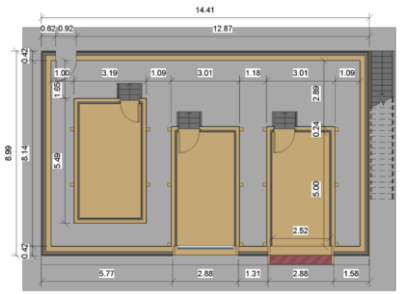


Overview of the O3BET structure







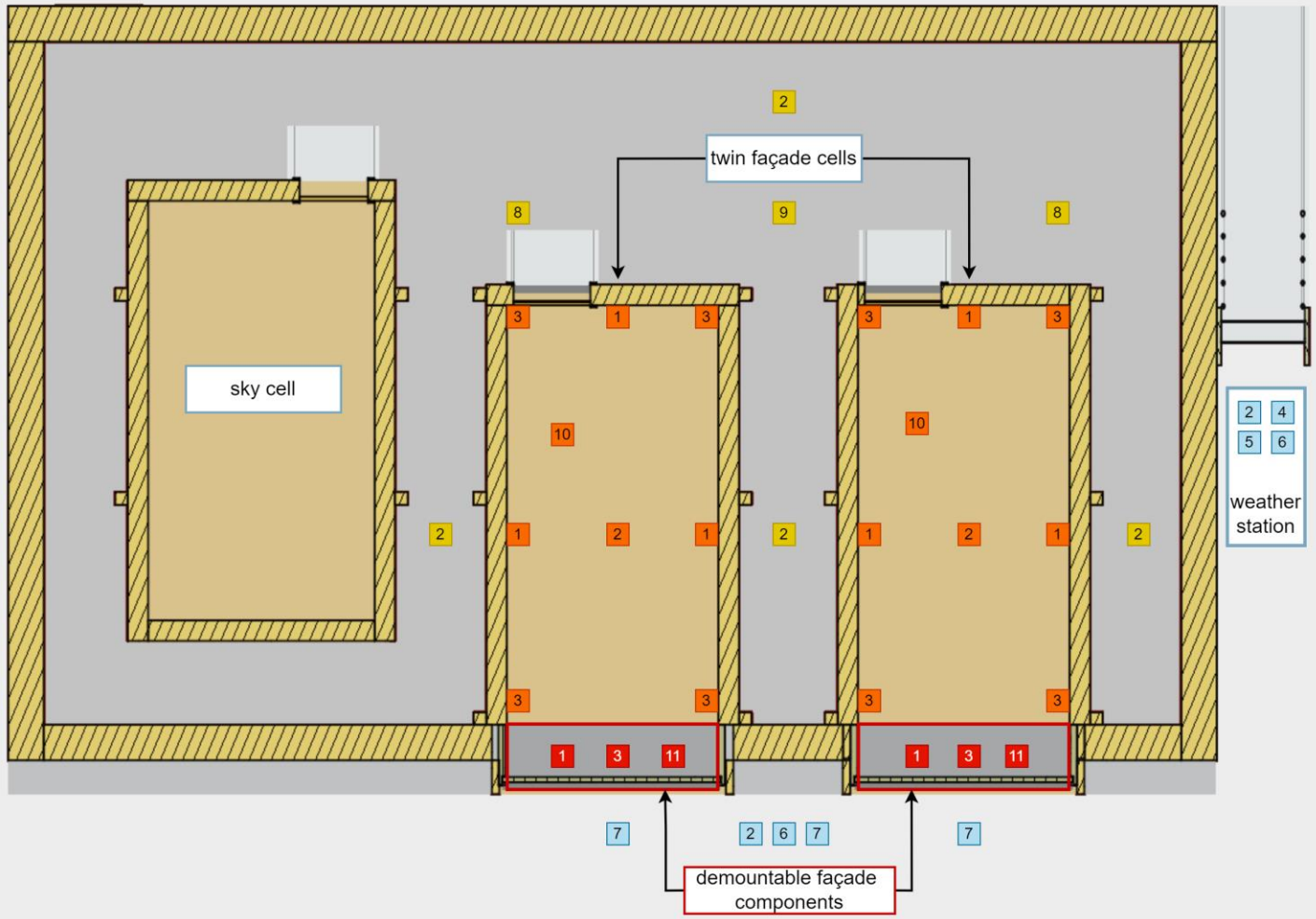


Cartif’s O3BET in Valladolid, Spain – October 2023

O3BET network in:

- France
- Spain
- Italy
- Sweden
- Poland
- Hungary
- Ireland

What does an O3BET look like on the inside?



SCOPES

- Facade element
- Internal (cell)
- Internal (guard zone)
- External

MEASUREMENTS & DEVICES

1. Temperature (suface)
2. Temperature (air)
3. Heat flux (tiles)
4. Humidity
5. Rainfall
6. Wind speed & direction
7. Pyranometer (+diffusometer)
8. Power meter
9. Tightness test equipment (blower door)
10. Actuator for Heater & blower
11. Fluxometer

(Boje et al., 2023)

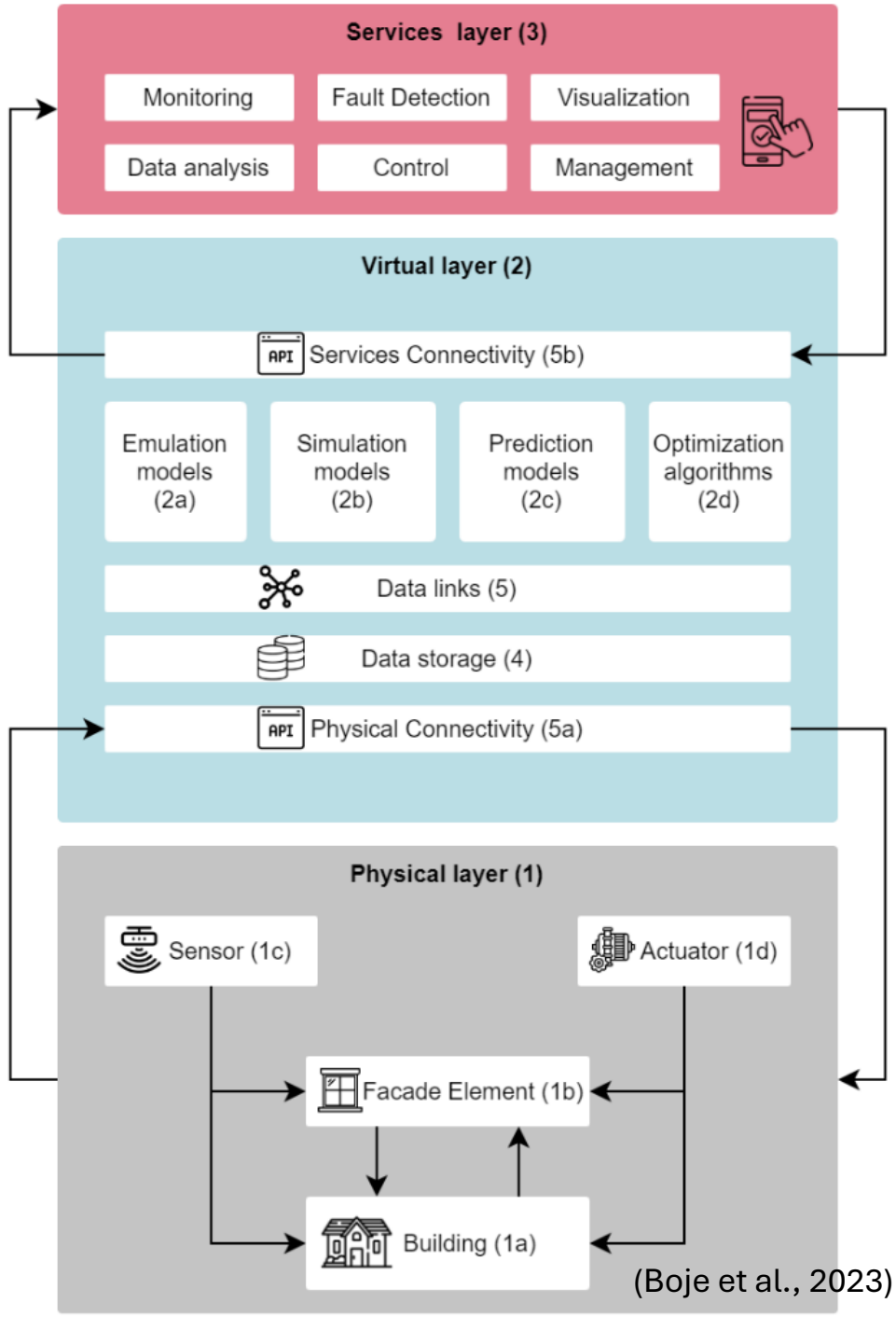
Why do we need a digital twin paradigm?

Digitalise and streamline the modular testing process.

Monitor the testing environment in different contexts.

Simulate different scenarios for novel technologies.

Explore design options, models and different applications.



(Boje et al., 2023)

What are the constraints of the O3BET testing process?

Procedural – things which are part of the process: the testing campaign, the different actors and users of the digital twin, etc.

Spatial – things which represent the facility spatially, delimitating the motoring, testing and modelling boundaries.

Equipment and sensing – facility sensors and actuators, their locations, properties and related components.

Measurements – sensor observations, units, properties etc.

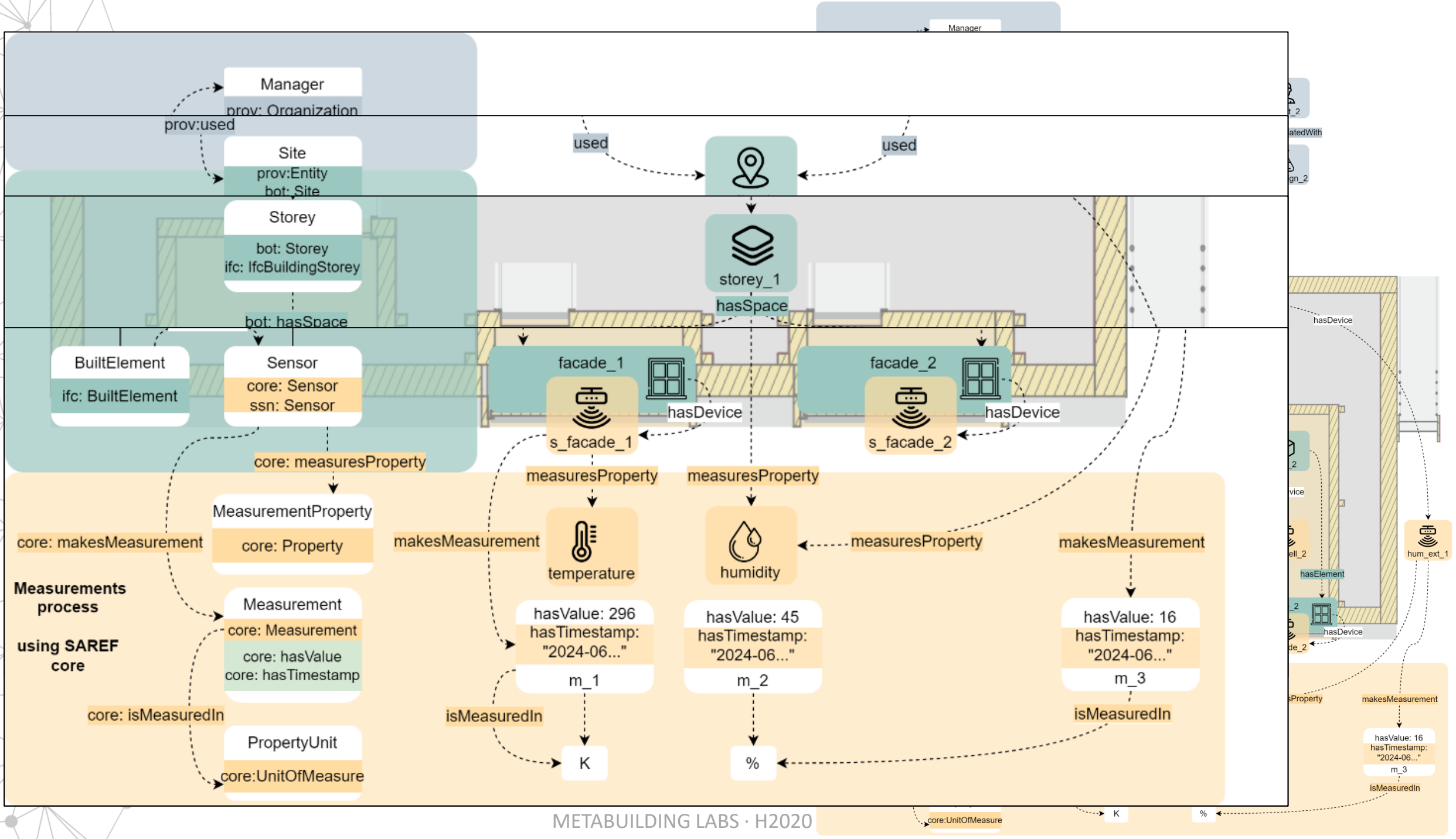
Virtual system boundaries – modularity of testing, the connections between the different contexts and digital twin instances (e.g. façade DT, cell DT, facility DT contexts).

What ontologies can define the O3BET-DT?

Table 1

List of selected ontologies for the O3BET-DT and their requirements coverage

Prefix	Namespace	Coverage
bot	https://w3c-lbd-cg.github.io/bot/	Spatial, Element
core	https://saref.etsi.org/core/	Sensing, Equipment, Measurements
ifc	http://standards.buildingsmart.org/IFC/DEV/IFC4_3/OWL#	Element, Components, Properties,
prov	https://www.w3.org/TR/prov-o/	Process, Actors
noria	https://w3id.org/noria/ontology/	Diagnosis, Fault Detection
props	http://www.w3id.org/opm#	Properties


Manager
prov: Organization
prov:used
Site
prov:Entity
bot: Site
Storey
bot: Storey
ifc: IfcBuildingStorey
bot: hasSpace
BuiltElement
ifc: BuiltElement
Sensor
core: Sensor
ssn: Sensor
used
used
storey_1
hasSpace
facade_1
facade_2
hasDevice
hasDevice
s_facade_1
s_facade_2
core: measuresProperty
measuresProperty
measuresProperty
MeasurementProperty
core: Property
core: makesMeasurement
makesMeasurement
temperature
humidity
measuresProperty
makesMeasurement
Measurements process
using SAREF core
Measurement
core: Measurement
core: hasValue
core: hasTimestamp
hasValue: 296
hasTimestamp: "2024-06..."
m_1
hasValue: 45
hasTimestamp: "2024-06..."
m_2
hasValue: 16
hasTimestamp: "2024-06..."
m_3
core: isMeasuredIn
isMeasuredIn
isMeasuredIn
PropertyUnit
core:UnitOfMeasure
K
%
hasDevice
hasElement
hasDevice
hum_ext_1
makesMeasurement
hasValue: 16
hasTimestamp: "2024-06..."
m_3
isMeasuredIn

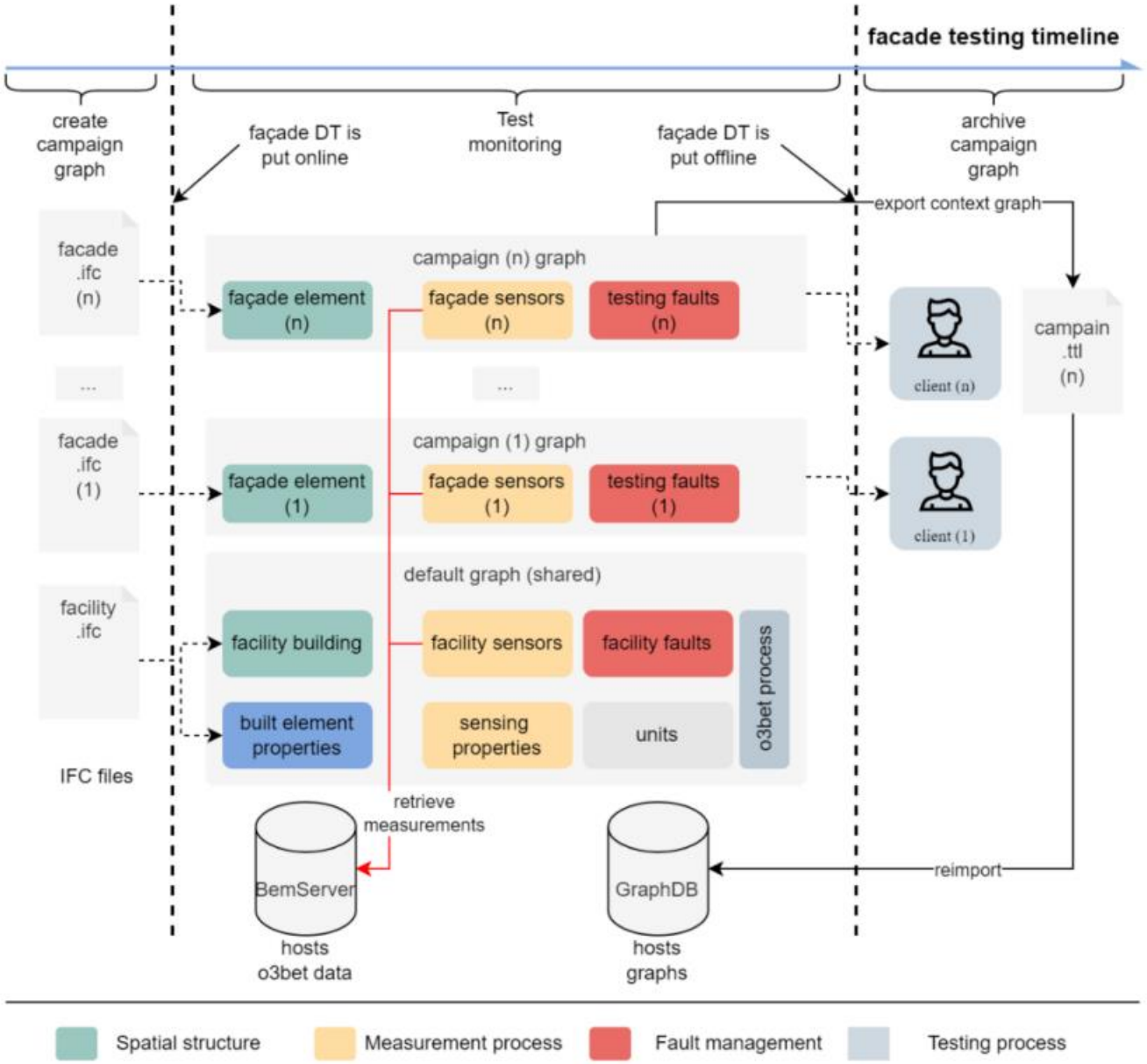


Figure 2: Data flows within the test environment, with federation, import and export per testing campaign.

```
@base <http://example.org/res/> .

<Default/Manager/1> a prov:Organization;
  foaf:name "Nobatek/Inef4" .

<Default/Site/1> a bot:Site;
  rdfs:label "site_1";
  ifc:IfcGloballyUniqueId "3mlLlL$$L9TAvl1XnR6S2O";
  bot:hasBuilting <Default/Building/1> .

<Default/Building/1> a bot:Building;
  rdfs:comment "O3BET testing facility";
  rdfs:label "building_1";
  ifc:IfcGloballyUniqueId "3mlLlL$$L9TAvl1XnR6S2R";
  bot:hasStorey <Default/Storey/1> ;
  schema:hasDevice <Default/Sensor/4> .

<Default/Sensor/4> a core:Sensor;
  rdfs:label "hum_ext_1" .

<Default/Storey/1> a bot:Storey;
  rdfs:label "storey_1";
  bot:hasSpace <Default/Space/1>, <Default/Space/2>,

<Default/Space/1> a bot:Space;
  rdfs:label "cell_1";
  ifc:IfcGloballyUniqueId "28q5ptbDv7ZQBbWtsNBbvG";
  schema:hasDevice <Default/Sensor/1> .

<Default/Sensor/1> a core:Sensor;
  rdfs:label "hum_cell_1" .

<Default/MeasurementPropertyType/Temperature> a core:Property;
  rdfs:label "temperature";
  core:isMeasuredIn <Default/PropertyUnit/Kelvin> .

<Default/PropertyUnit/Kelvin> a core:Property;
  rdfs:label "Kelvin";
  schema:symbol "K" .
```

```
@base <http://example.org/res/> .

<Campaign/1> a prov:Activity;
  rdfs:label "campaign_1";
  prov:startedAtTime "2024-06-13T08:30:00.000Z";
  prov:endedAtTime "2024-06-14T18:19:59.000Z";
  prov:wasStartedBy <Default/Manager/1>;
  prov:wasAssociatedWith <Campaign/1/Client/1>;
  prov:used <Default/Site/1> .

<Default/Space/1> bot:hasElement <Campaign/1/BuiltElement/1> .

<Campaign/1/BuiltElement/1> a ifc:IfcBuildingElement;
  rdfs:label "facade_1";
  ifc:IfcGloballyUniqueId "1gzL_9brz3BvRXw4rGT1iR";
  schema:hasDevice <Campaign/1/Sensor/5> .

<Campaign/1/Sensor/5> a core:Sensor;
  rdfs:label "s facade 1";
  core:measuresProperty <Default/MeasurementPropertyType/Temperature>;
  core:makesMeasurement <Campaign/1/Measurement/m_1> .

<Campaign/1/Measurement/m_1> a core:Measurement;
  core:hasValue "23";
  core:hasTimestamp "2024-06-14T14:10:10.000Z";
  core:isMeasuredIn <Default/PropertyUnit/Kelvin> .

<Campaign/1/Fault/1> a noria:EventRecord;
  noria:loggingTime "2024-06-14T14:15:11.000Z";
  noria:logText "sensor reading failure";
  noria:logOriginatingManagedObject <Campaign/1/Sensor/5> .

<Campaign/1/Client/1> a prov:Organization ;
  foaf:name "LDAC 2024" .
```

Figure 3: Sample TTL statements of the default graph (left) which is shared, and linked statements in the testing campaign graph (right) outlined in green.

a)

```
PREFIX bot: <https://w3id.org/bot#>
PREFIX core: <https://saref.etsi.org/core/>
PREFIX prov: <http://www.w3.org/ns/prov#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
select ?campaign ?site ?building
# select everything in the triple store
where {
    ?campaign rdf:type prov:Activity . # from campaign graph
    ?campaign prov:used ?site . # from campaign graph
    ?site bot:hasBuilding ?building . # from default graph
}
```

	campaign	site	
1	http://example.org/res/Campaign/1/	http://example.org/res/Default/Site/1	http://example.org/res/Default/Building/1
2	http://example.org/res/Campaign/2/	http://example.org/res/Default/Site/1	http://example.org/res/Default/Building/1

b)

```
PREFIX bot: <https://w3id.org/bot#>
PREFIX core: <https://saref.etsi.org/core/>
PREFIX prov: <http://www.w3.org/ns/prov#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
select ?campaign ?site ?building
from default # default(shared) graph
from <http://example.org/res/Campaign/1/> # the context of only 1 campaign graph
where {
    ?campaign rdf:type prov:Activity . # from campaign graph
    ?campaign prov:used ?site . # from campaign graph
    ?site bot:hasBuilding ?building . # from default graph
}
```

	campaign	site	
1	http://example.org/res/Campaign/1/	http://example.org/res/Default/Site/1	http://example.org/res/Default/Building/1

Figure 4: Sample SPARQL on retrieving campaigns (a) unspecified, (b) named graphs.

GraphQL sample

```
query SampleQuery($graph: [String!]) {
  sensor(from: $graph) {
    rdfs_label
    makesMeasurement {
      isMeasuredIn {
        id
      }
      hasValue
      hasTimeStamp
    }
  }
}
```

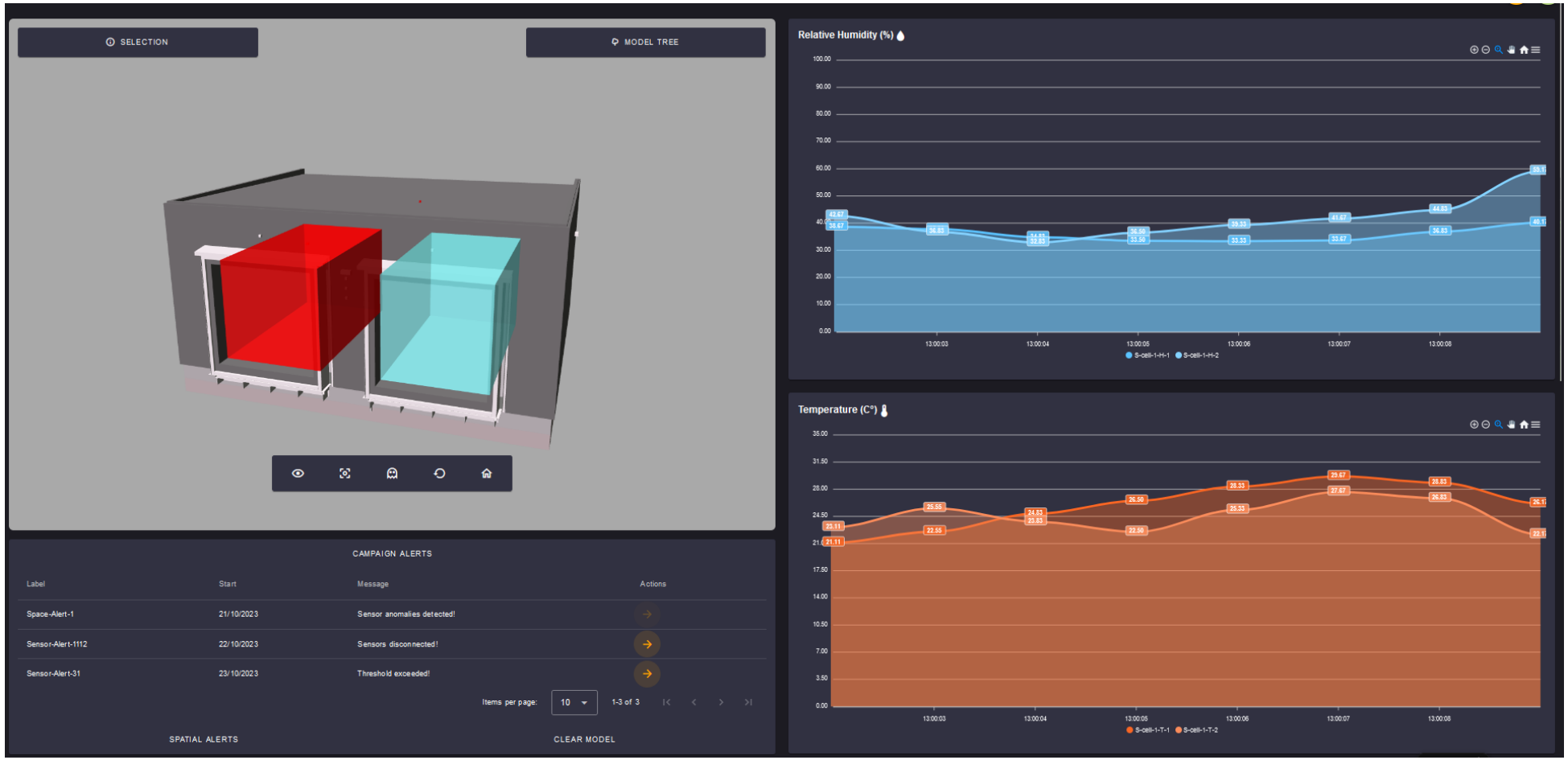
QUERY VARIABLES

```
{
  "graph": "http://example.org/res/Campaign/2/"
}
```


```
{
  "data": {
    "sensor": [
      {
        "rdfs_label": "s_facade_2",
        "makesMeasurement": [
          {
            "isMeasuredIn": {
              "id": "http://example.org/res/Default
/PropertyUnit/Kelvin"
            },
            "hasValue": "26",
            "hasTimeStamp": "2024-06-14T14:10:10Z"
          }
        ]
      }
    ]
  }
}
```


Figure 5: GraphQL on finding a sensor and its measurements within the context scope of a single campaign.

Prototype – User Interface development ongoing



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GraphDB

Import

Explore

Graphs overview

Class hierarchy

Class relationships

Visual graph

Similarity

SPARQL

Monitor

Setup

Lab

Help

Graphs overview

Search Graphs

Showing 1 - 5 of 5 results Graphs per page: All

Clear repository Export repository

Graphs
The default graph
http://www.list.lu/buildsemantix/campaign/buildingModule/
http://www.list.lu/buildsemantix/campaign/iotModule/
http://example.org/res/Campaign/1/
http://example.org/res/Campaign/2/

Conclusions and future work

O3BET-DT – has very specific needs for context creation which is achieved relatively well using semantic web approaches, but not without effort. Modularity of testing is facilitated quite well by adopting a modular connected graph approach.

Alignment and links – the O3BET-DT use cases need certain particularities which reuse existing ontologies and extend them with ad-hoc properties or other “abstract” classes to group things

GraphQL – very flexible and transparent for the front-end application, but certain functionalities are not usable, such as querying more than one graph in one query.

Future work – alert implementation, real-time data tests, production deployment and testing on real use cases

The Project : www.metabuilding-labs.eu

The Platform : www.metabuilding.com

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References

Boje, C., Mack, N., Kubicki, S., López Vidal, A., Casado Sánchez, C., Dugué, A., & Brassier, P. (2023, July 10). *Digital Twin systems for building façade elements testing*. https://doi.org/10.35490/EC3.2023.240

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