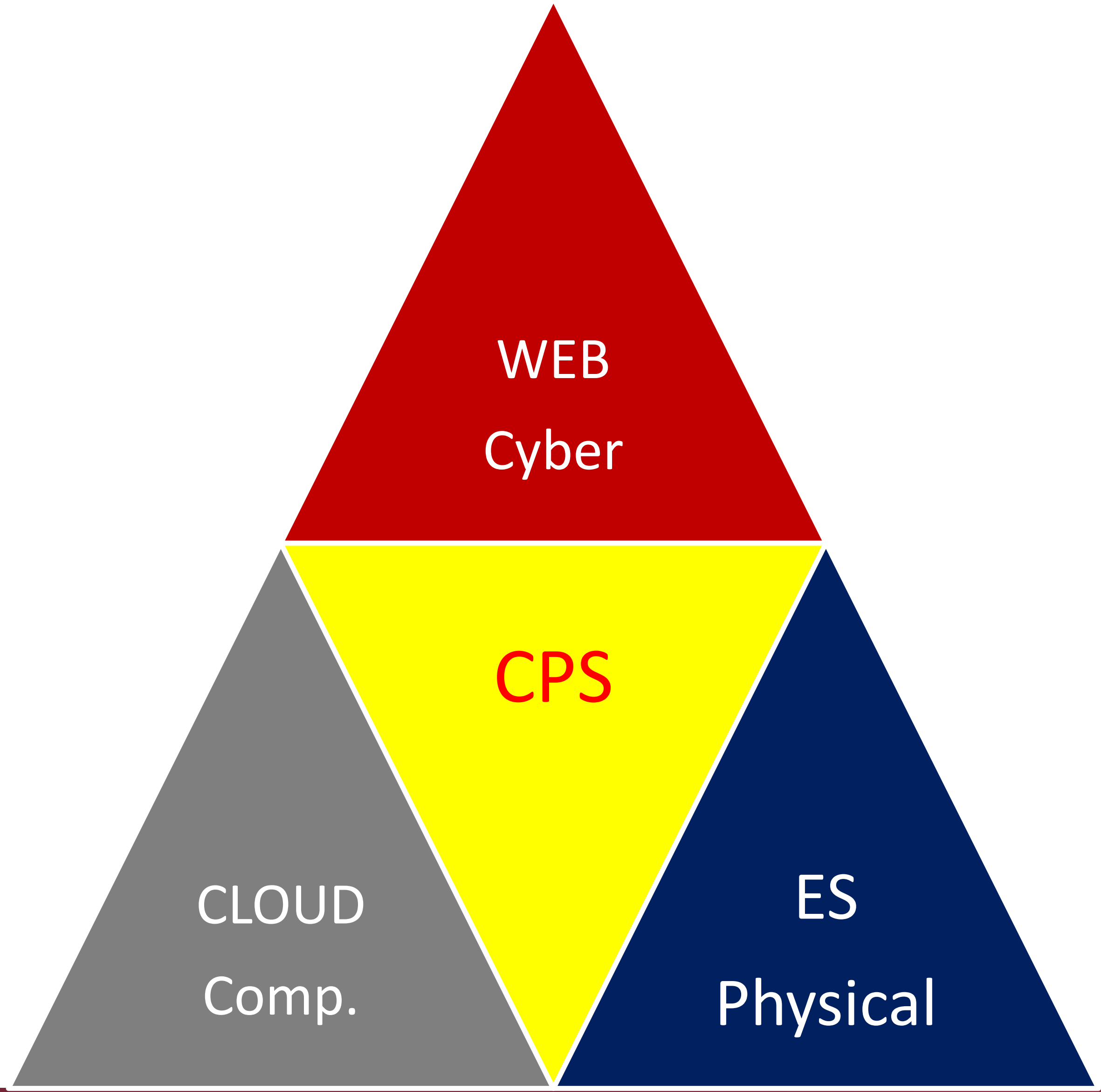
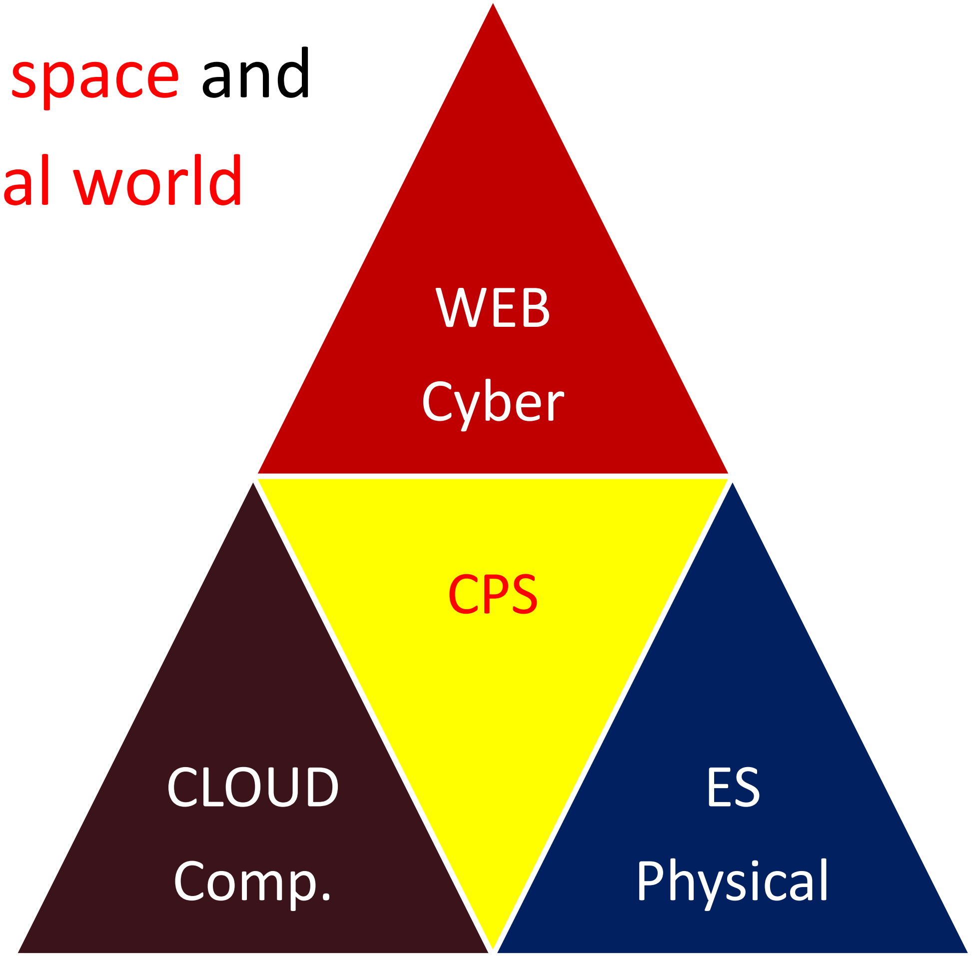
The design triangle



The new era: dynamic CPS (?)

- Unlimited intelligence
  by the synergy of
  - intelligence in the cyber space and
  - ES interfacing the physical world



Reusable sensors
Multiple, on-demand algorithms

Intention

Reality: record flood

- A lot of e-mails:
  - Is it safe to come to Budapest?
- Fortunately: no request for "Life west under your *conference* seat"

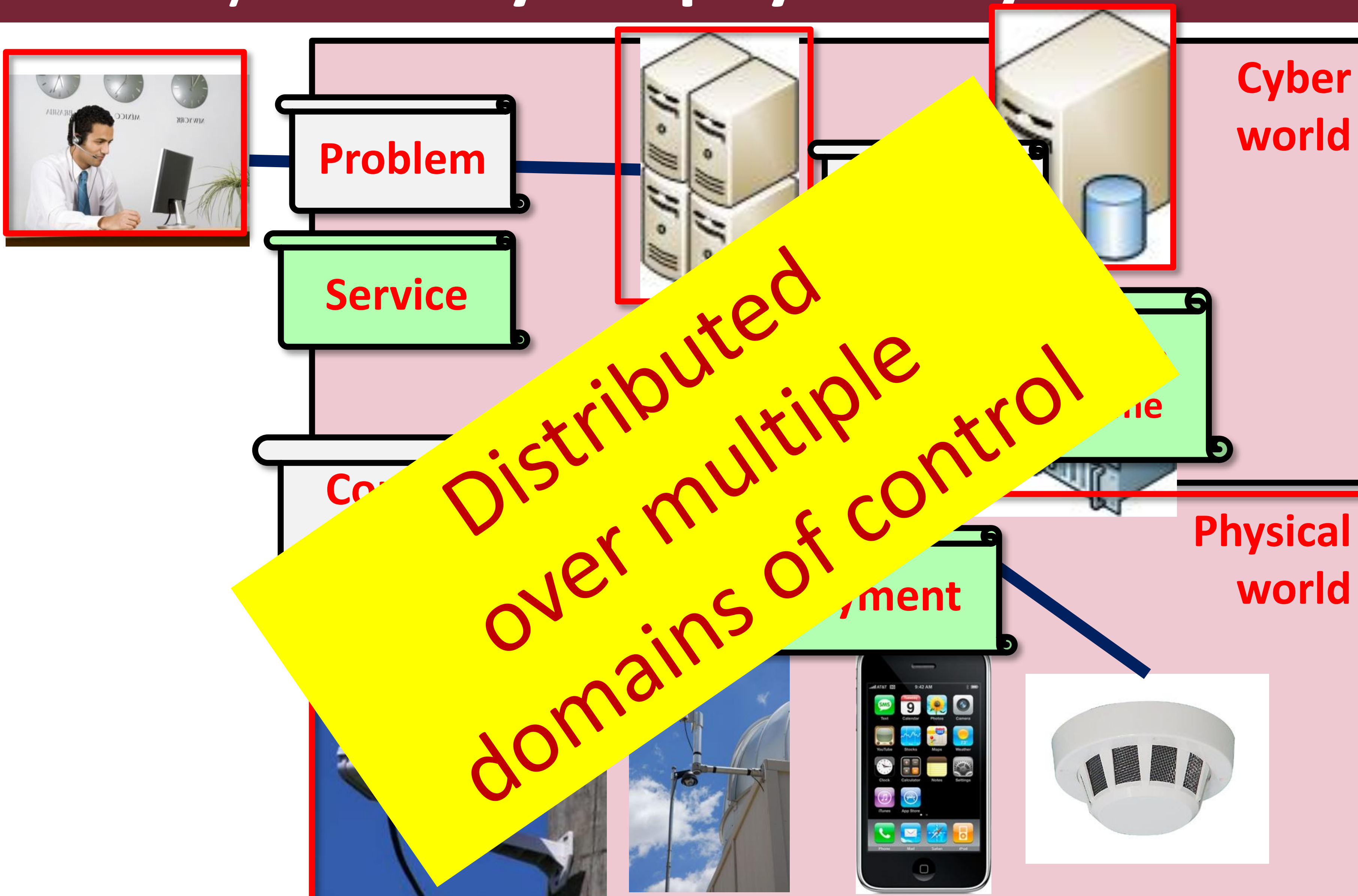
[Solution]

Example

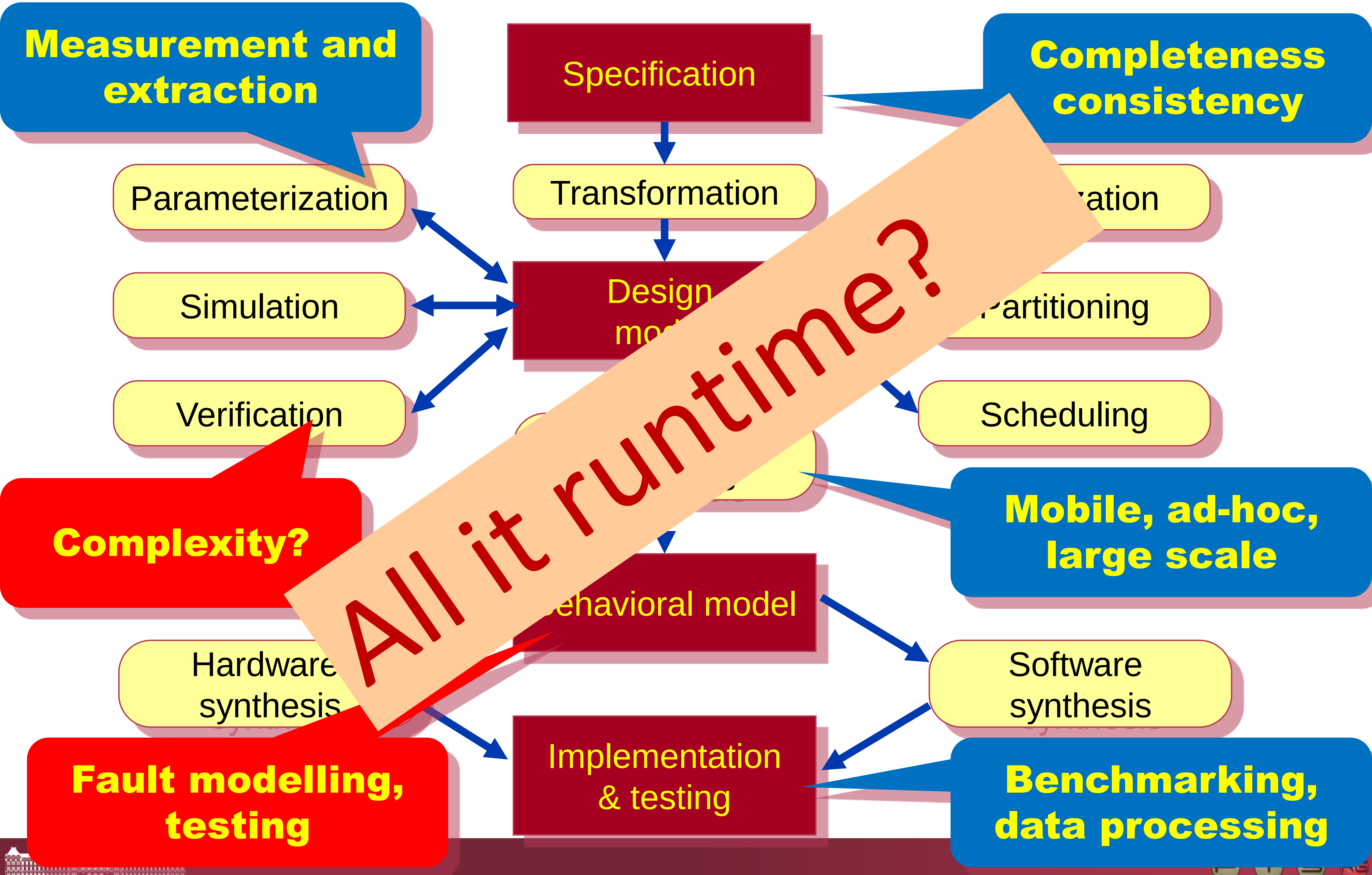
Cameras on riverside

- Different applications concurrently using the same primary information
- Tasks can change according to time/season/requirements
  - Identification of ships
  - Monitoring the break-up of ice
  - Monitoring the water level
  - Monitoring the speed of flood
  - Pollution check
  - Supervision of hostile entrance to the ship

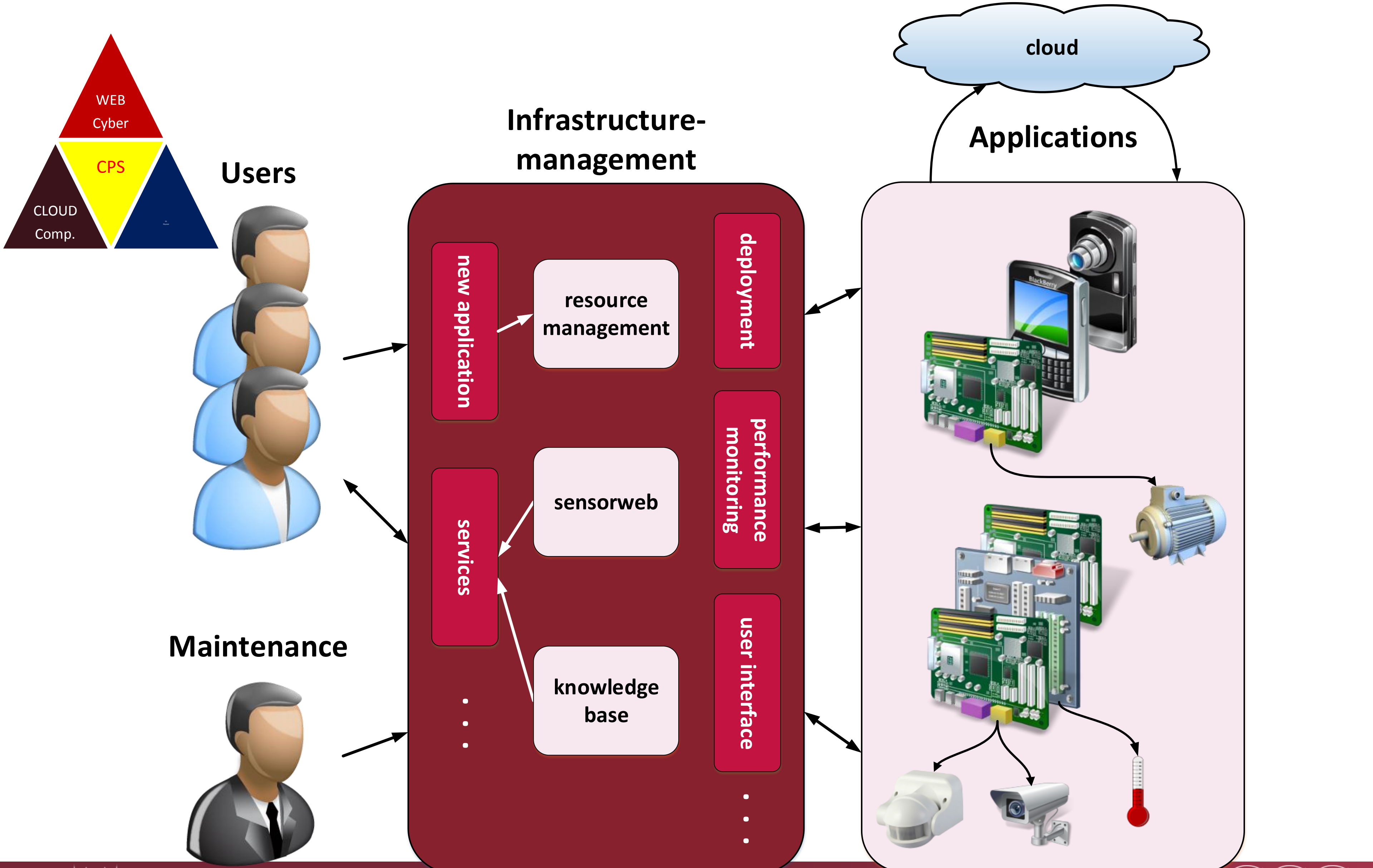
Dynamic cyber-physical systems



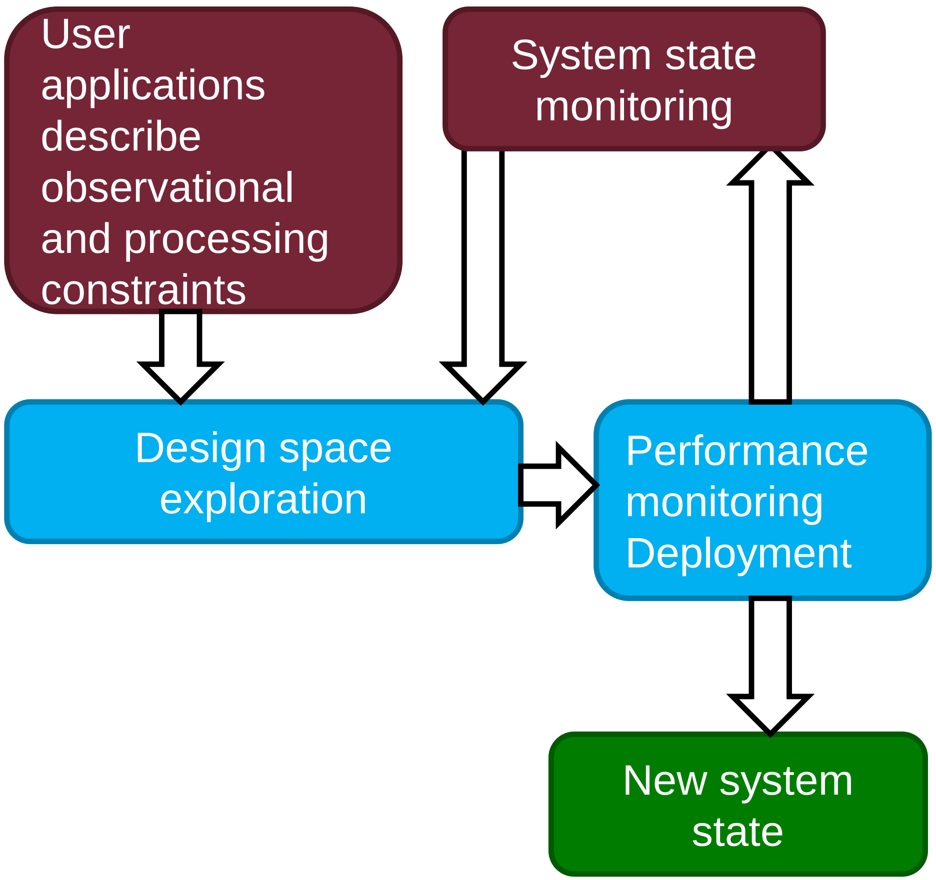
Critical CPS design and challenges

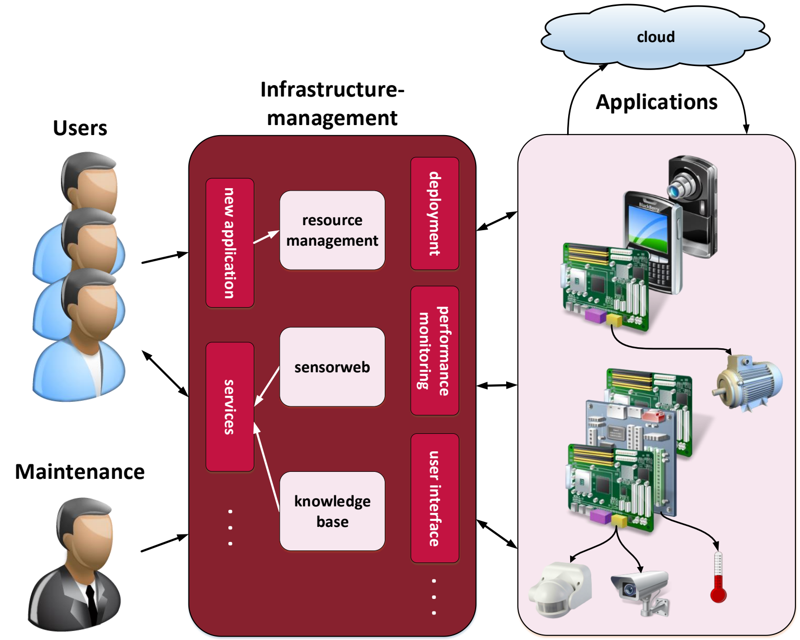


Dynamic composition of cyber-physical systems

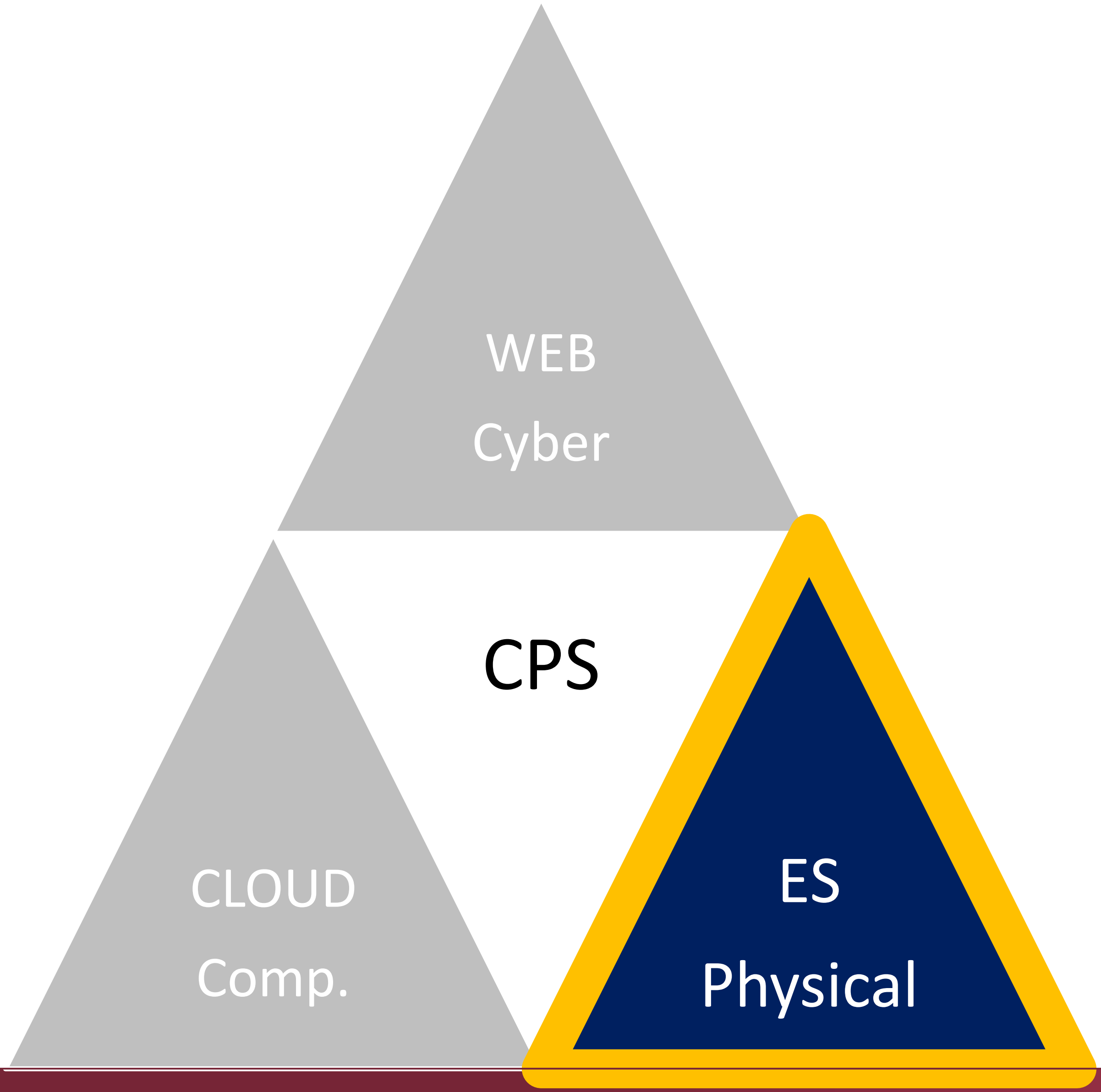


Dynamic reconfiguration of resources





The change in ES design



Service Oriented Approach

SOA

Embedded systems provide services

- Information of
  - sensors
  - Internet
- High level information derived
- Actuation possibility (limited)

Services in a database

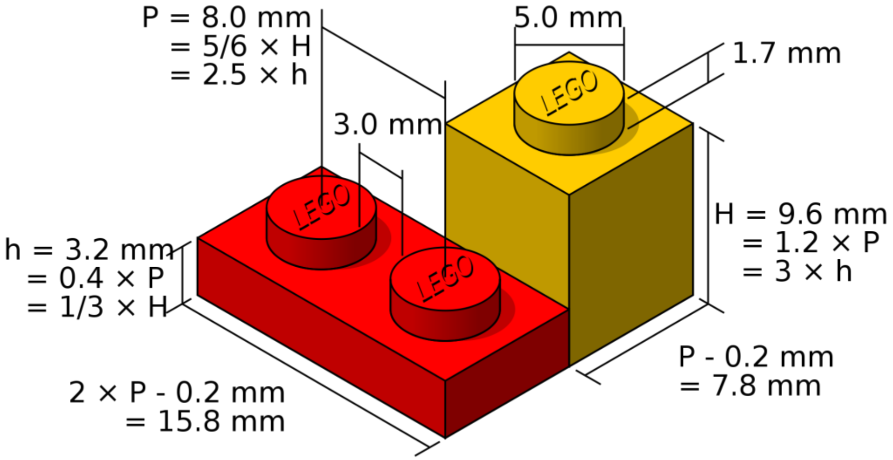
MDD

Upon a new task:

- solution based on
  - design patterns and
  - available resources

New solution deployed

- no interference with the already running ones



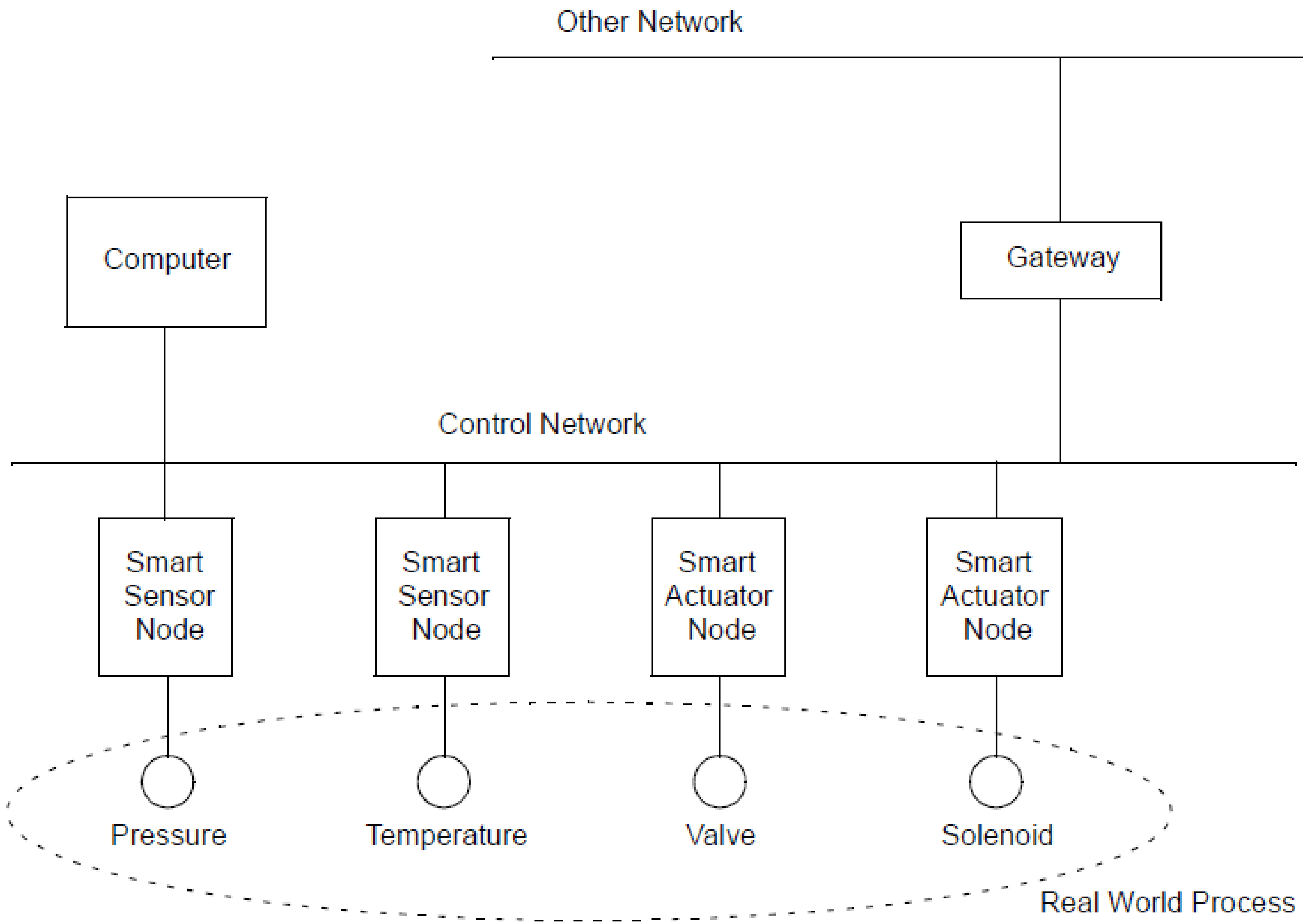
UNIFICATION IS THE KEY

Ontologies and Semantic Technologies

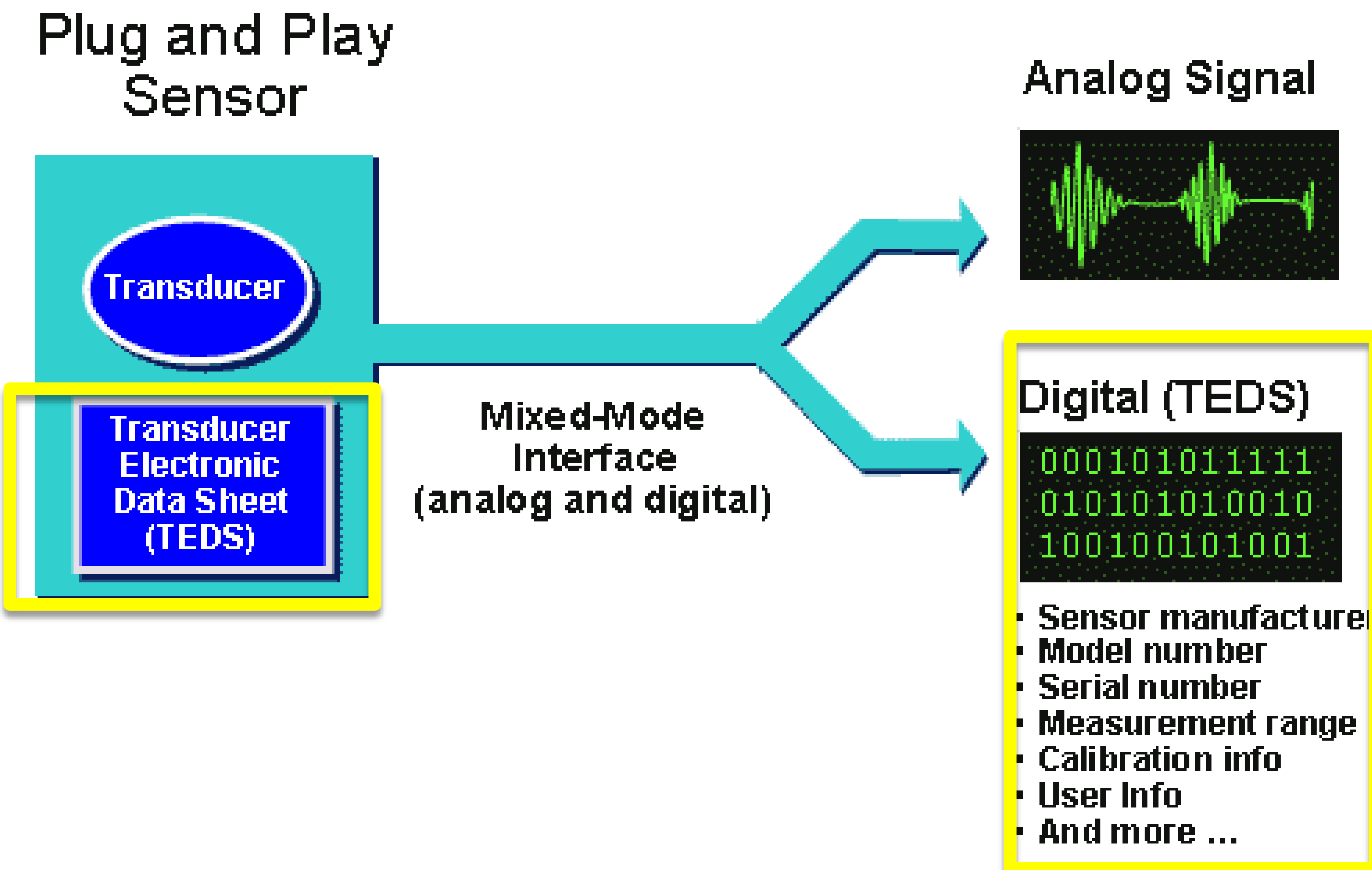

DCV
ACV
DCA
DT-830B
COM


www.radiomuseum.hu

Smart transducers



Plug and play (vs. SOA ?)

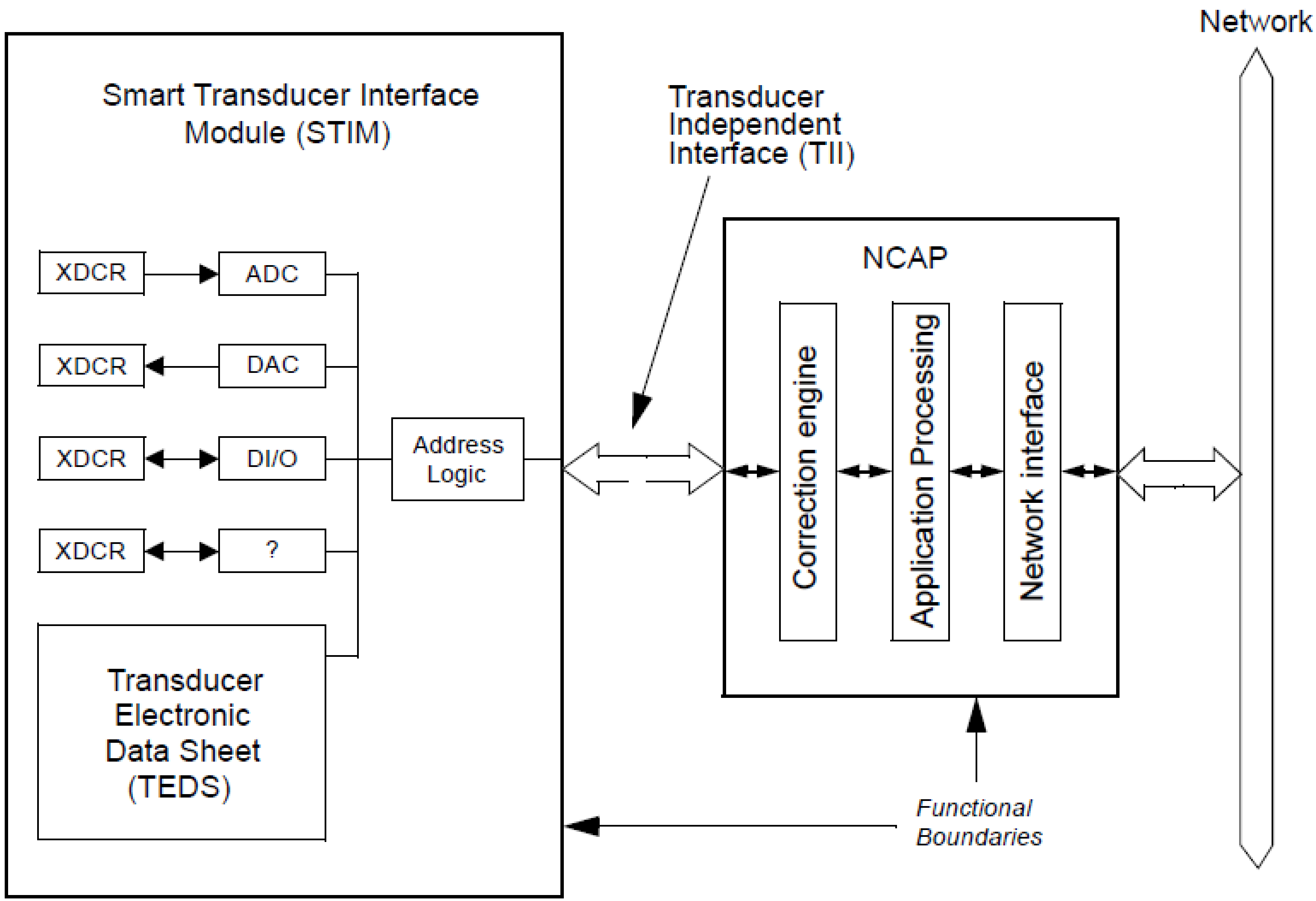


Electronic data sheet (NIST example)

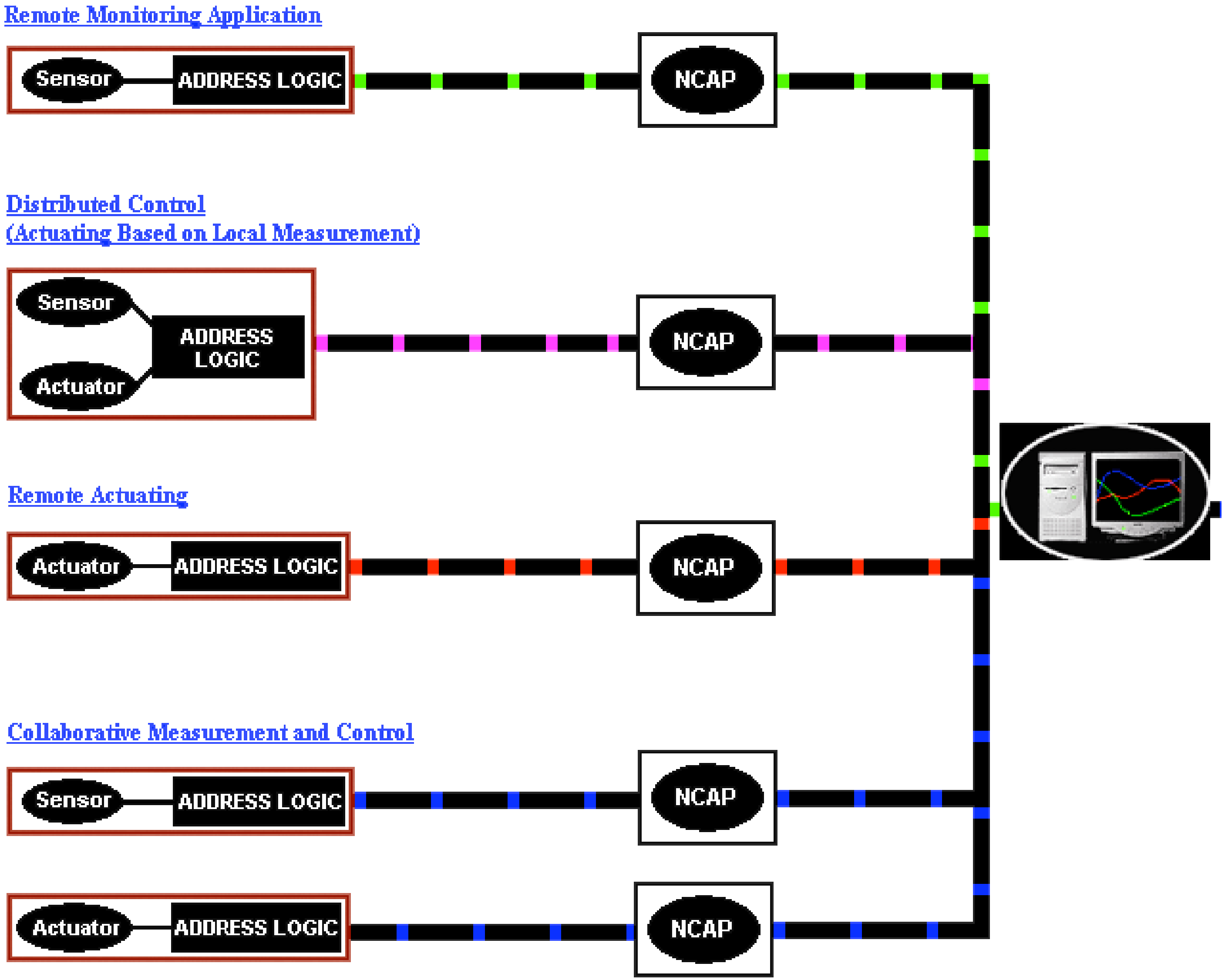
Basic TEDS	Manufacturer ID	43 (Acme Accelerometer Company)
	Model Number	7115
	Version Letter	B
	Serial Number	X001891
Standard and Extended TEDS (fields will vary according to transducer type)	Calibration Date	Jan 29, 2000
	Sensitivity @ ref. condition (S ref)	1.0094 E+03 mV/g
	Physical measurement range	± 50 g
	Electrical output range	± 5 V
	Reference frequency (f ref)	100.0 Hz
	Quality factor @ fref (Q)	300 E-3
	Temperature coefficient	-0.48 %/°C
	Reference temperature (T ref)	23 °C
	Sensitivity direction (x,y,z)	x
User Area	Sensor Location	Strut 3A
	Calibration due date	April 15, 2002

Figure 2. Example TEDS for Accelerometer

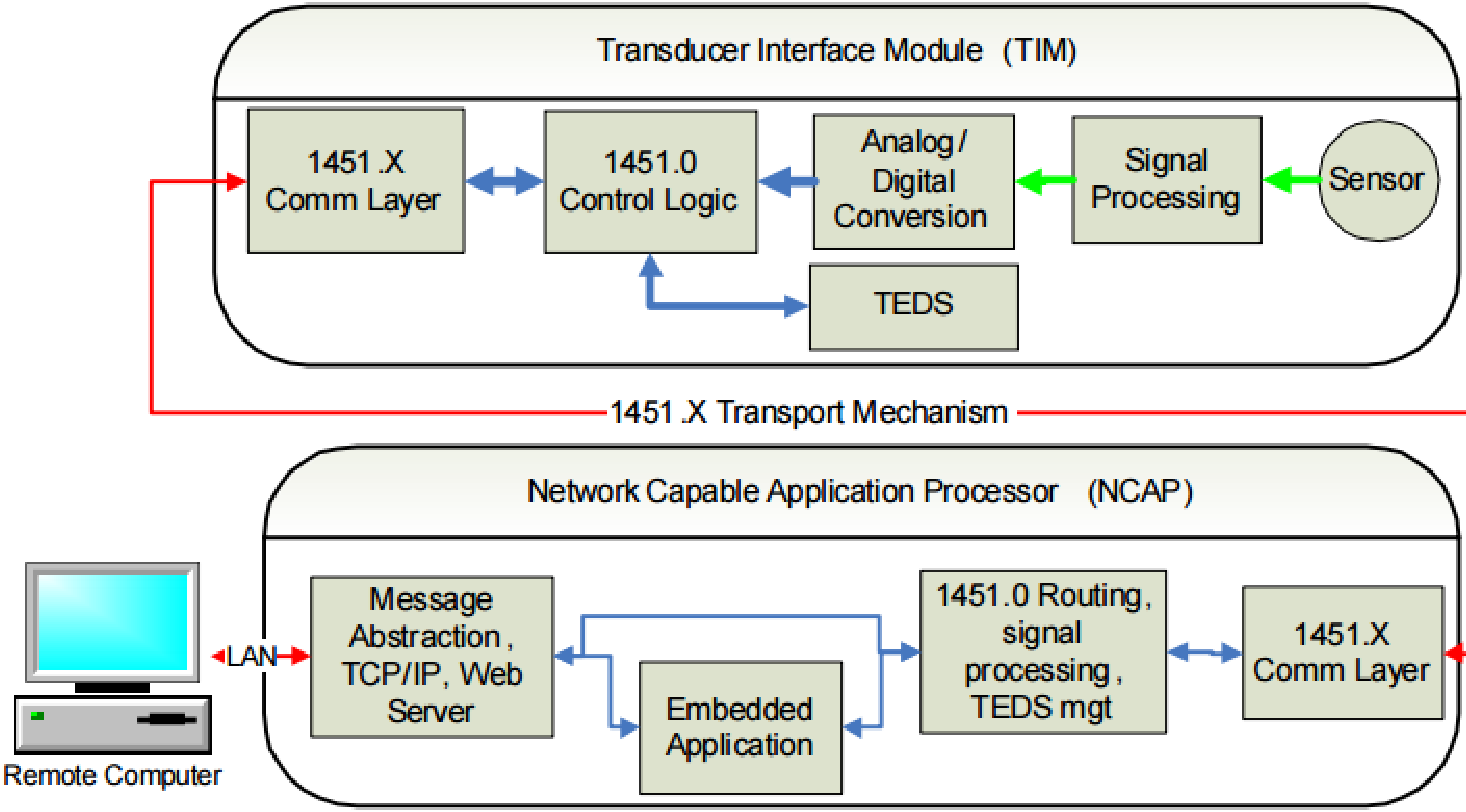
Implementation



Use cases of IEEE 1451

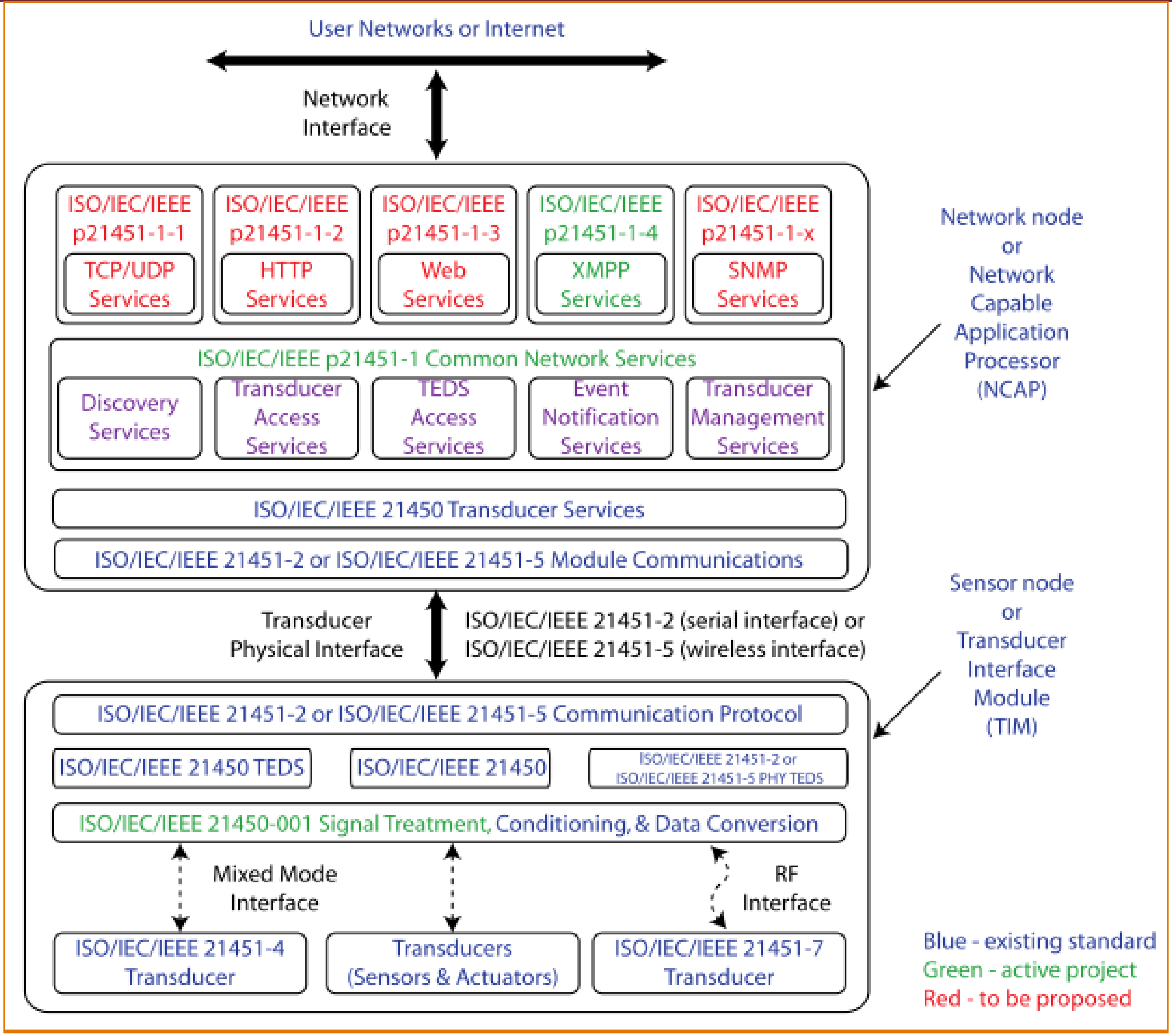


IEEE 1451 concept



IEEE1451 Standard Description

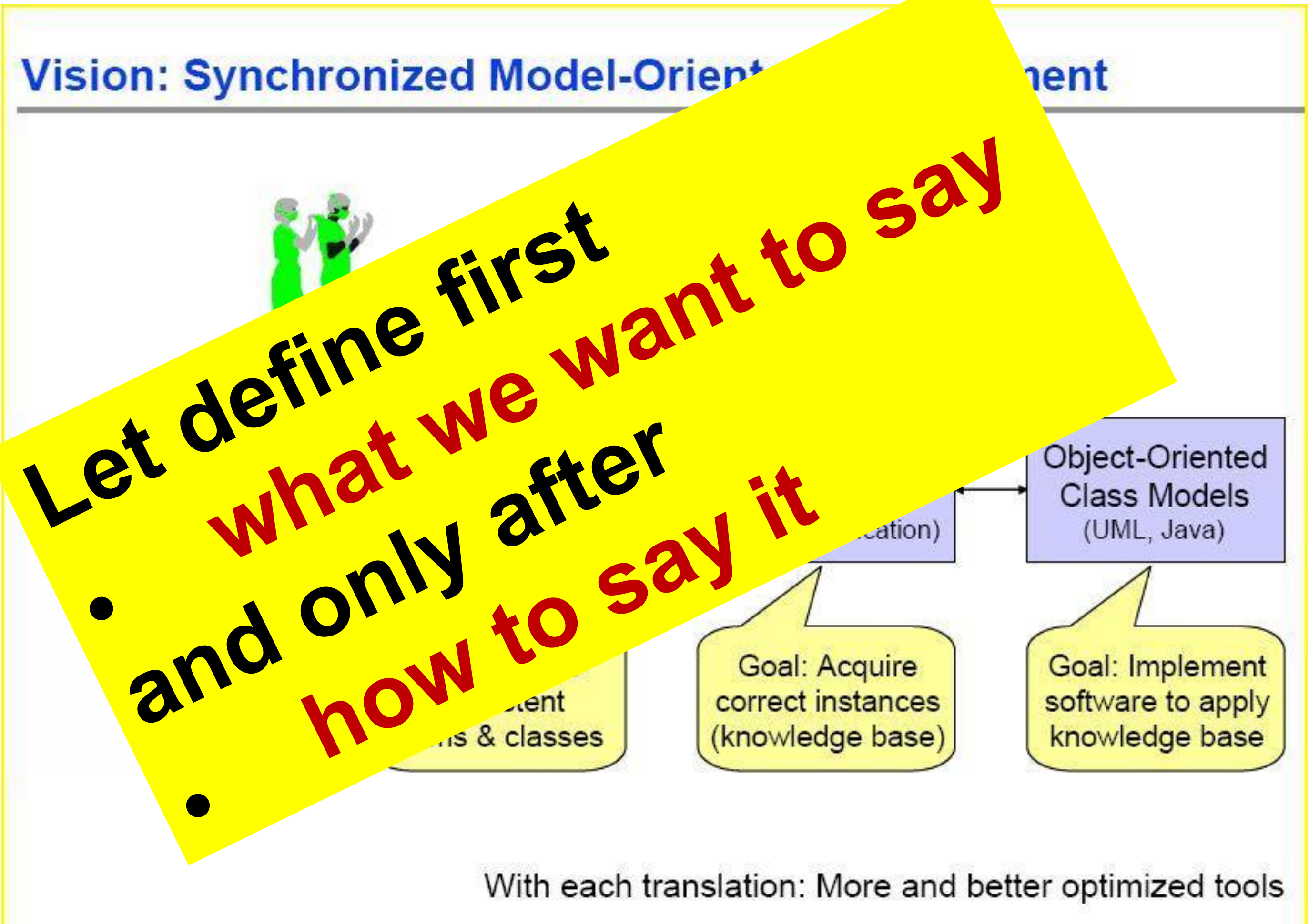
IEEE 1451 standards



STARTING POINT: FORMALIZED CONCEPTS

Design and analysis need clear concepts

From ontologies to metamodels

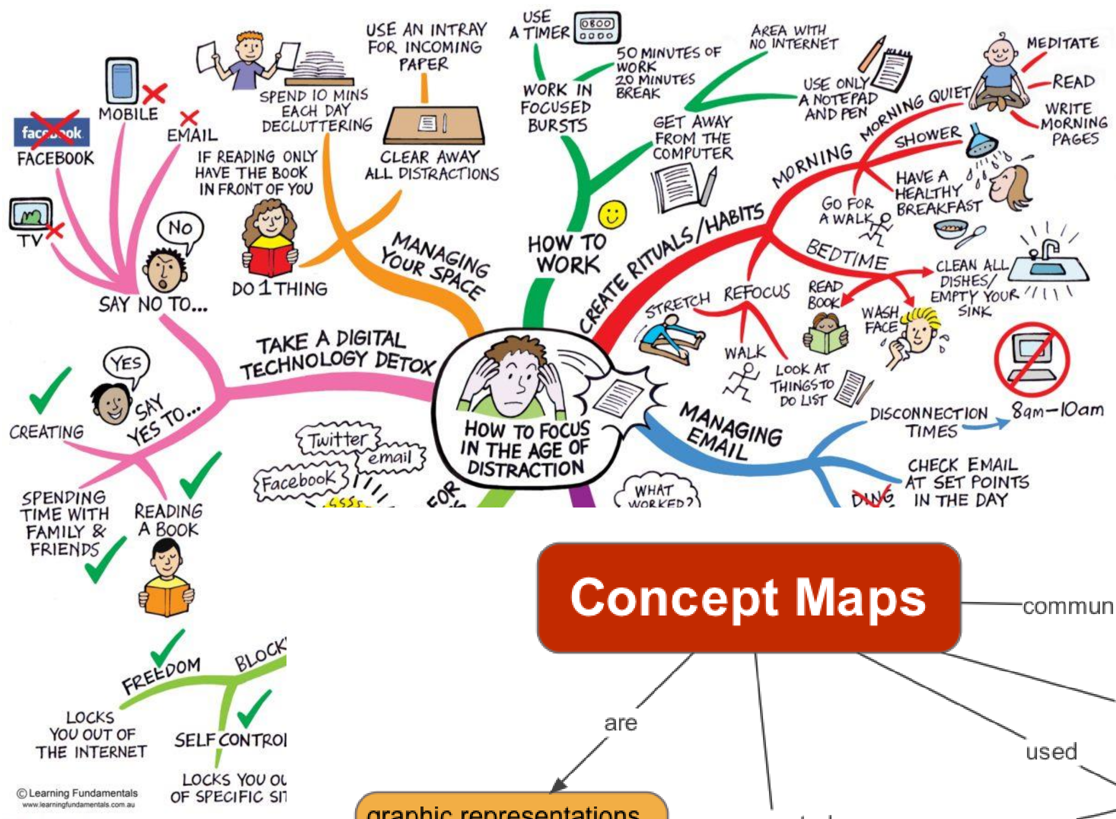


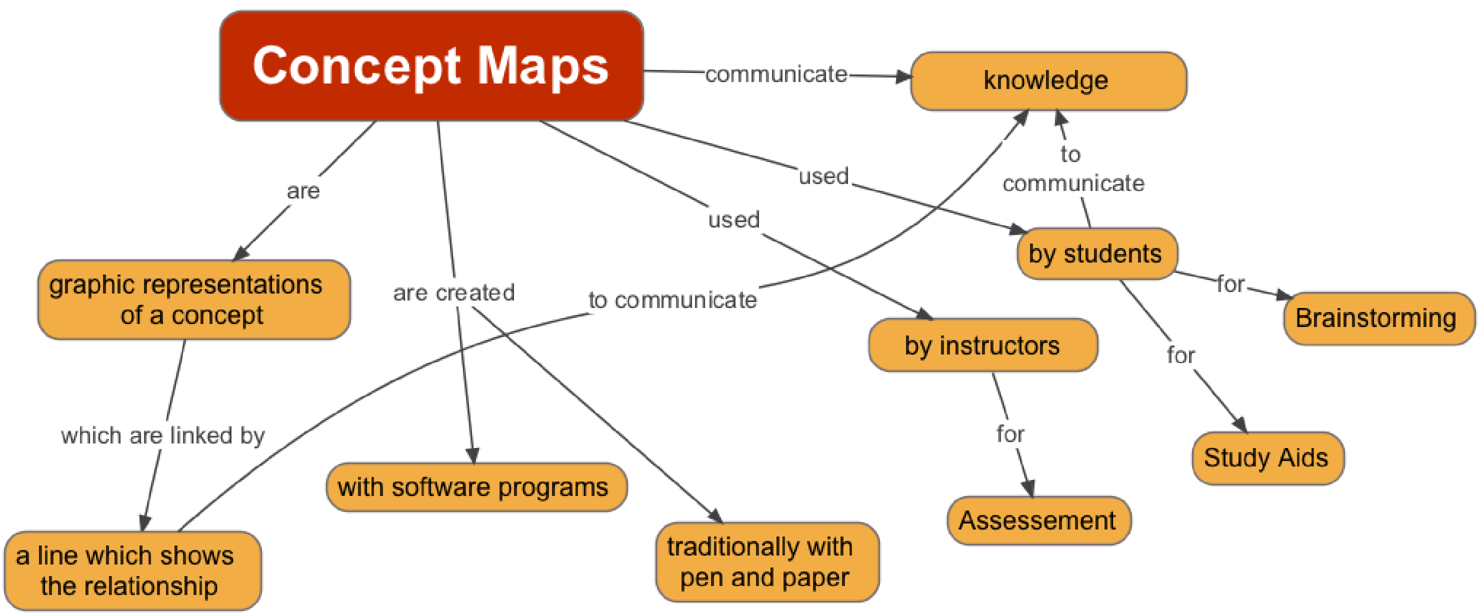
Let define first
- what we want to say

and only after
- how to say it

H. Knublauch:
Ontology Design and Software Technology, Colloquium - Stanford Medical Informatics, 2003

Hierarchical data representation





Ontology

A data model that

- represents a domain and
- Has a logic in the background
- is used to reason about
  - the objects in that domain and
  - the relations between them.

Ontologies generally describe:

- **Individuals:**
  basic objects
- **Classes:**
  sets, collections, or types of objects
- **Attributes:**
  properties, features… that objects can have and share
- **Relations: ways that objects can be related**

Reasoning :

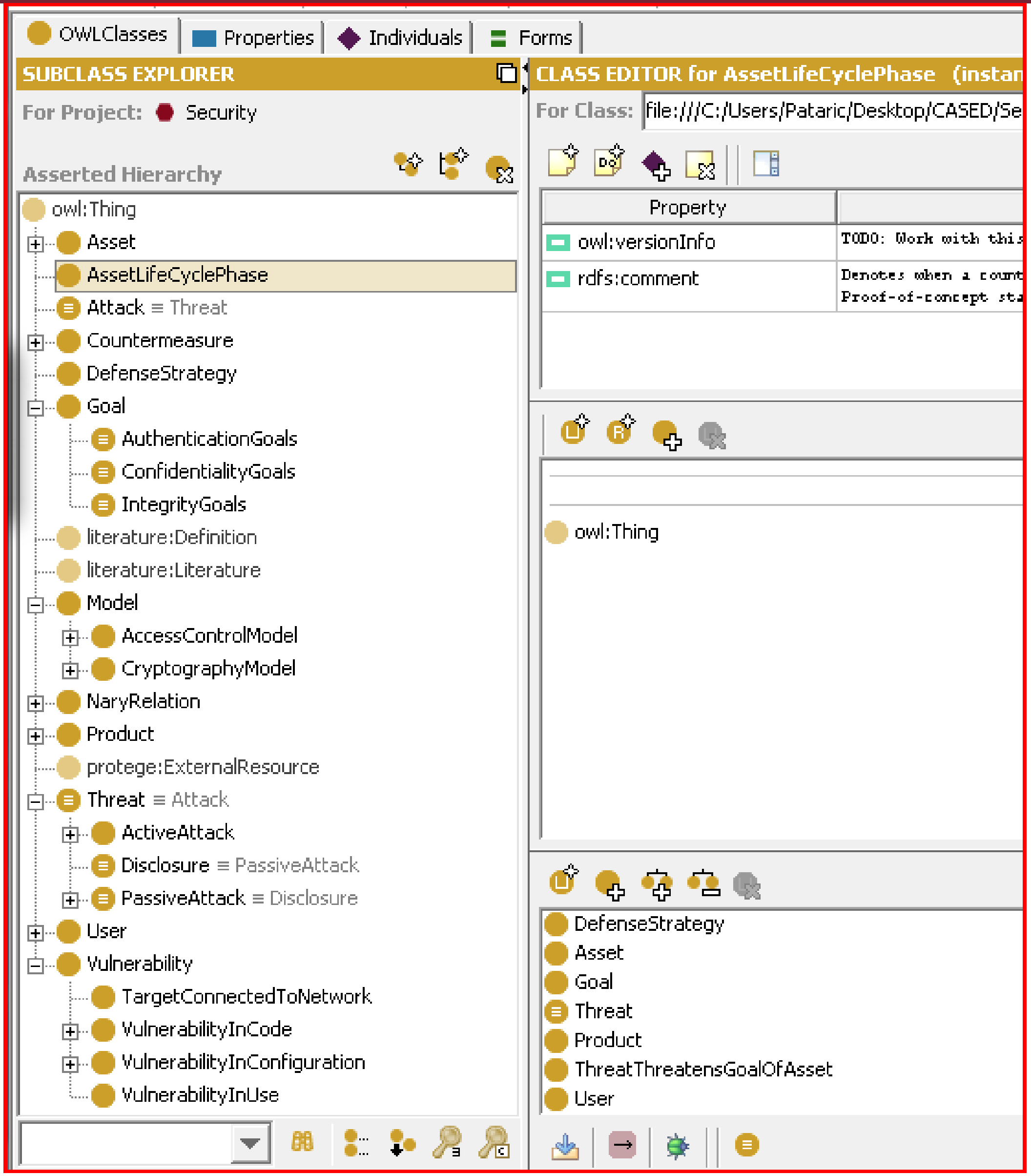
Concept space traversal

- **subsumption test wrt. different profiles**
- **consistency check: satisfiability**
- **circular containment of classes**

Ontology foundations

- Ontology
  - Formal description of concepts (terminology)
  - OWL 2: ontology language for the Semantic Web
  - Reusable knowledge models
- Description Logic (DL)
  - knowledge representation,
    - similar to rule languages
  - decidable, efficient decision problems
  - justifications for inferences
  - terminology (concepts & properties, TBox) and data / cases (individuals, ABox) are separated
  - schema language with complex constraints
- OWL 2 is based on the DL “SROIQ”.

Example: part of the security ontology



A. Herzog et al:

An Ontology of Information Security

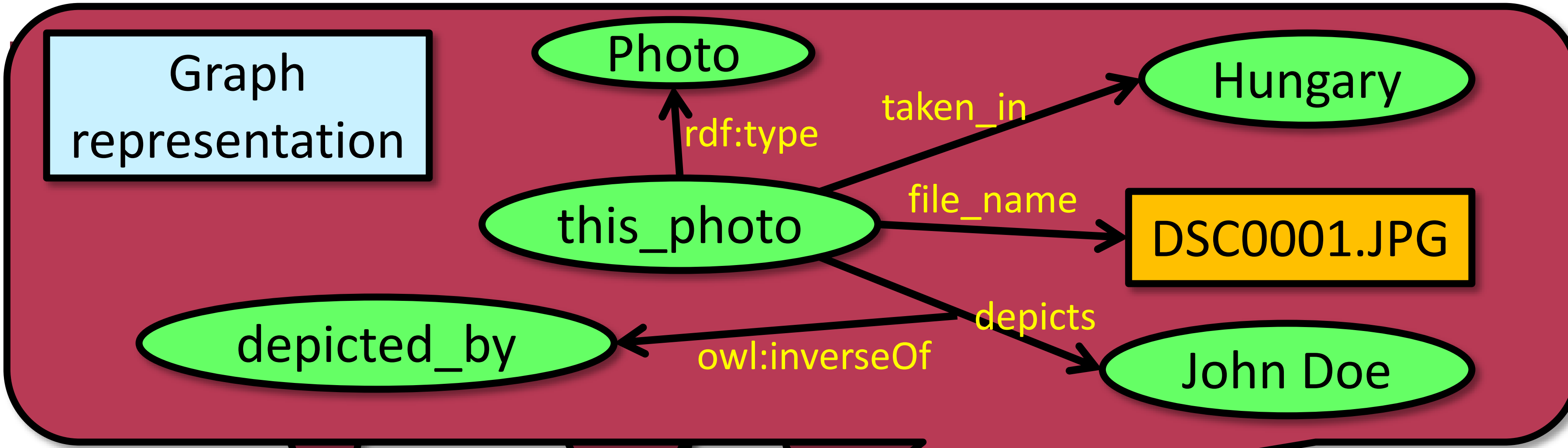
Int. J. of Inf. Security and Privacy (1), 4

RESOURCE DESCRIPTION FRAMEWORK (RDF)

Resource Description Framework

- W3C: Resource Description Framework (**RDF**)
- *Graph based* structure
  - Node: **rdf:Resource** → something we talk about
    - e.g. a document, this photo, a table or "something"
  - Edge: **rdf:Property** → relation type between resources
    - e.g depicts, taken_in, type etc.
- Node name and relation type name: **IRI** (Internationalized Resource Identifier)
- **Literal** nodes: 5^^xsd:integer, „John"

RDF Statements



- Example triples
  - (this_photo, taken_in, Hungary)
  - (this_photo, file_name, „DSC0001.JPG”)
  - (this_photo, depicts, John Doe)
  - (this_photo, has_type, Photo)
  - (rdf:type, rdf:type, rdf:Property)

Object is an rdf:Literal

rdf:type is defined in the RDF standard

WEB ONTOLOGY LANGUAGE (OWL 2)

Formal Background

- Axiomatic language

$\mathcal{S}$: Mother ≡ ∃child.Person // have child who is a person

$\mathcal{R}$: ObjectProperty knows // everybody knows oneself

Characteristics: Reflexive

$\mathcal{O}$: Visibility ≡ {p

$\mathcal{I}$: child ≡ pare

$\mathcal{Q}$: FootballCoa

// a footbal

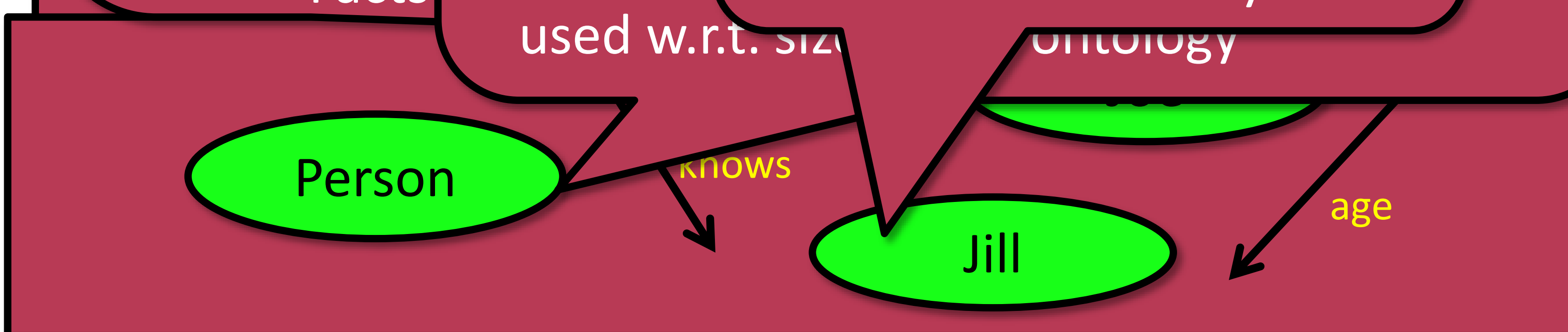
$(\mathcal{D})$: Individual

Facts

OWL2 EL profile:

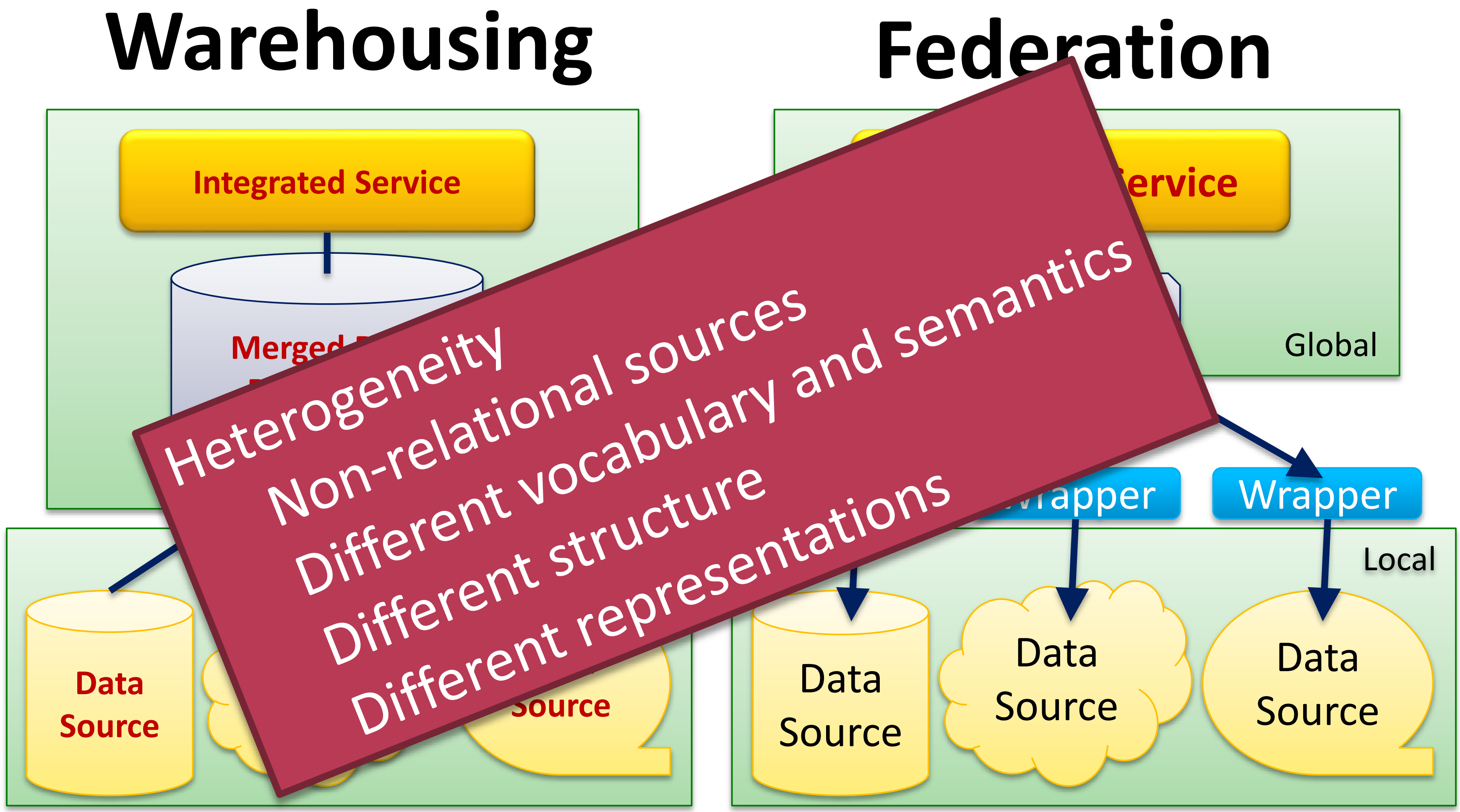
- useful fo ... rge number
- only exis
- polinom ... used w.r.t. siz ... ontology

OWL defines the semantics of some new relation types, e.g. owl:intersectionOf or owl:cardinality



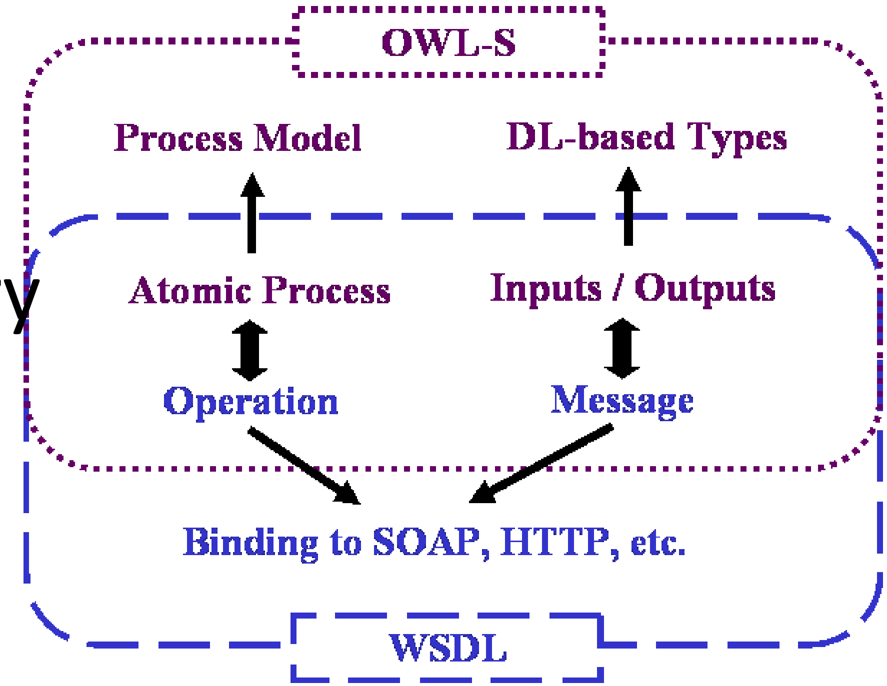
SEMANTIC INTEGRATION

Data integration



Semantic Service Integration

- Ontology-based Semantic Data Integration
  - Local scheme explained with linked ontologies
  - Semantic mapping between schemes
- Semantic Web Services
  - OWL-S
    - Process Model, DL types
- Semantic Service Discovery



SEMANTIC DATA REPRESENTATION

Problems to be solved:

- Transducer metadata as knowledge
  - Store and query
  - Search & discovery
- Application-generated data as "derived sensor" data

- Approach:
- Semantic framework to describe knowledge

Semantic Sensor Network (SSN)

- W3C Incubator Group (2009-2011)
- http://www.w3.org/2005/Incubator/ssn/

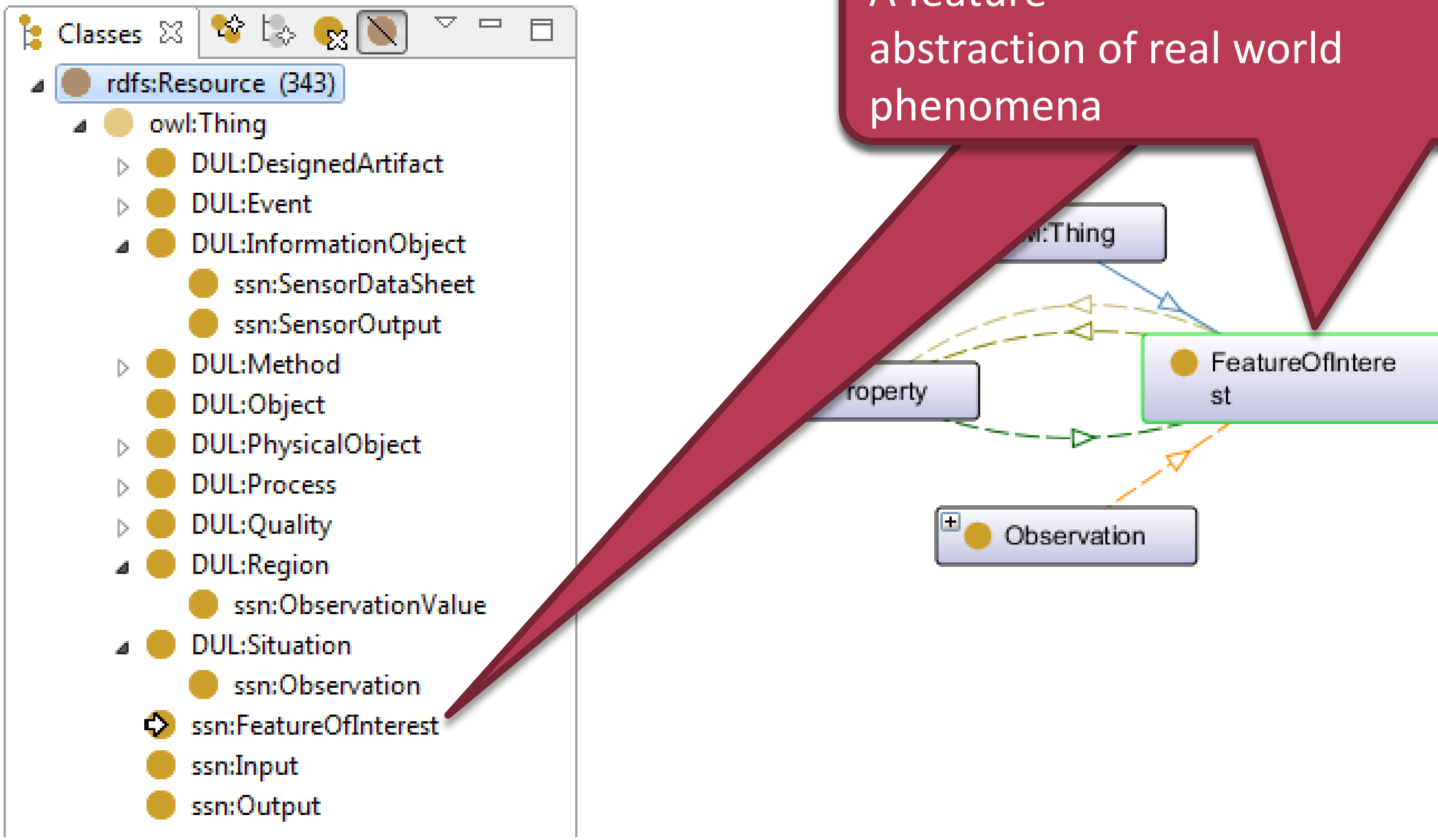
- Describes capabilities of sensors and sensor networks
  - Formal ontology in OWL 2
  - Built on DOLCE Ultra Lite (DUL) upper ontology
- Covers:
  - system, deployment, sensing device, process
  - observed phenomenon (e.g. wind)
  - sensor type (e.g. ultrasonic wind sensor)
  - property (e.g. wind direction)
  - meaning (e.g. blows from direction)
  - unit of measure (e.g. radian)
  - operating / survival range (e.g. temperature, humidity, power...)

SSN – Feature of Interest

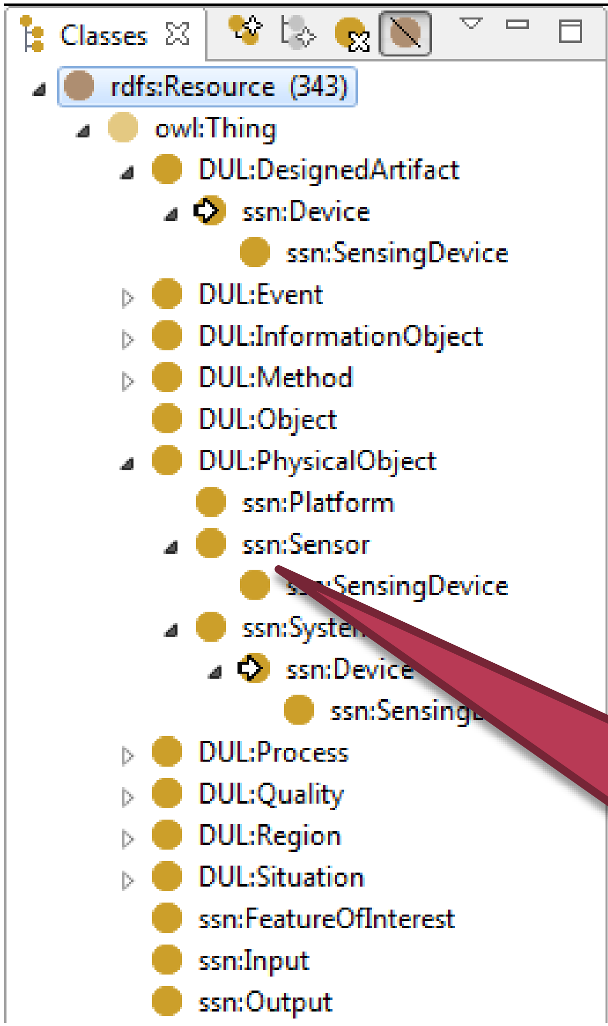
A feature

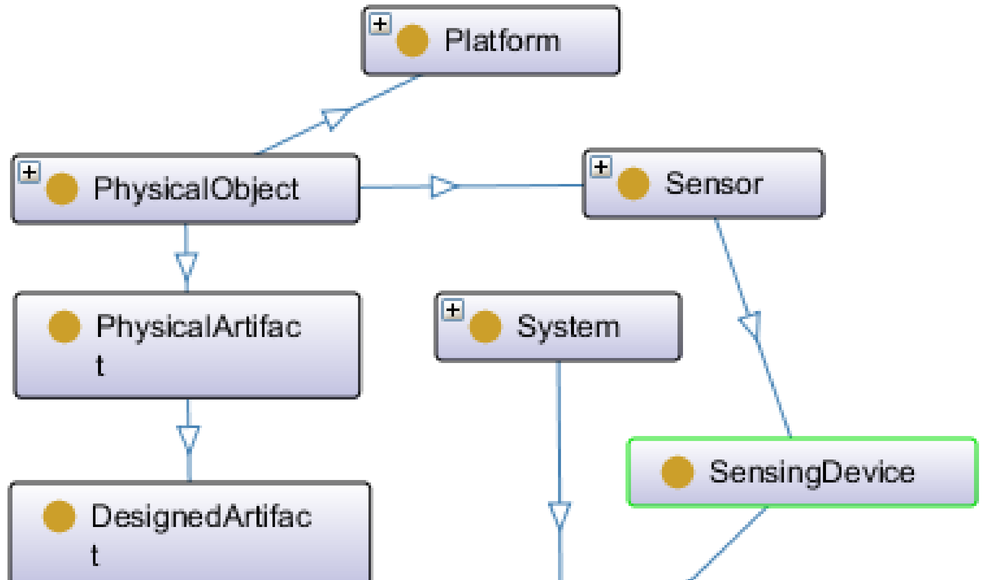
abstraction of real world

phenomena



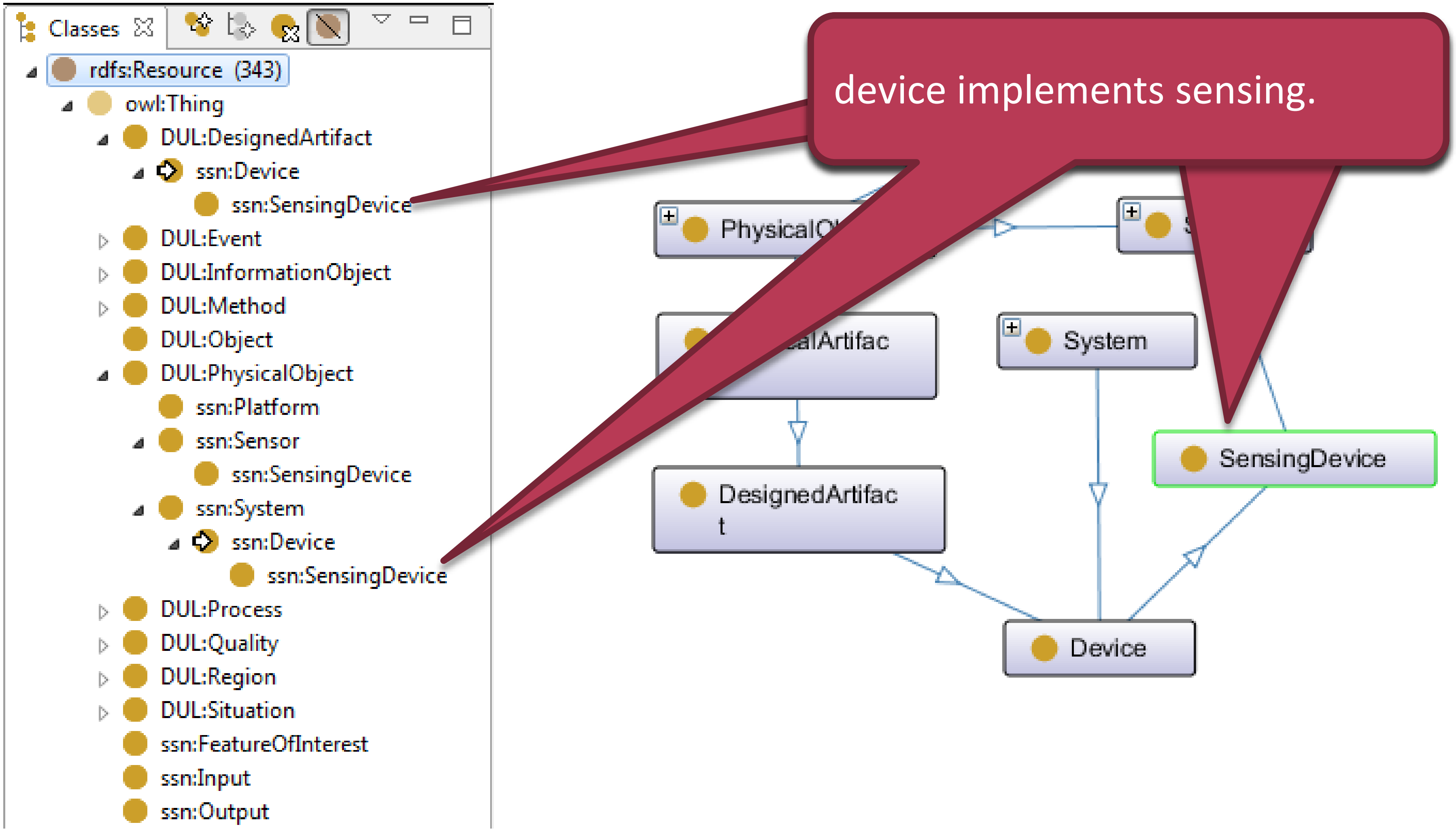
SSN – Sensor



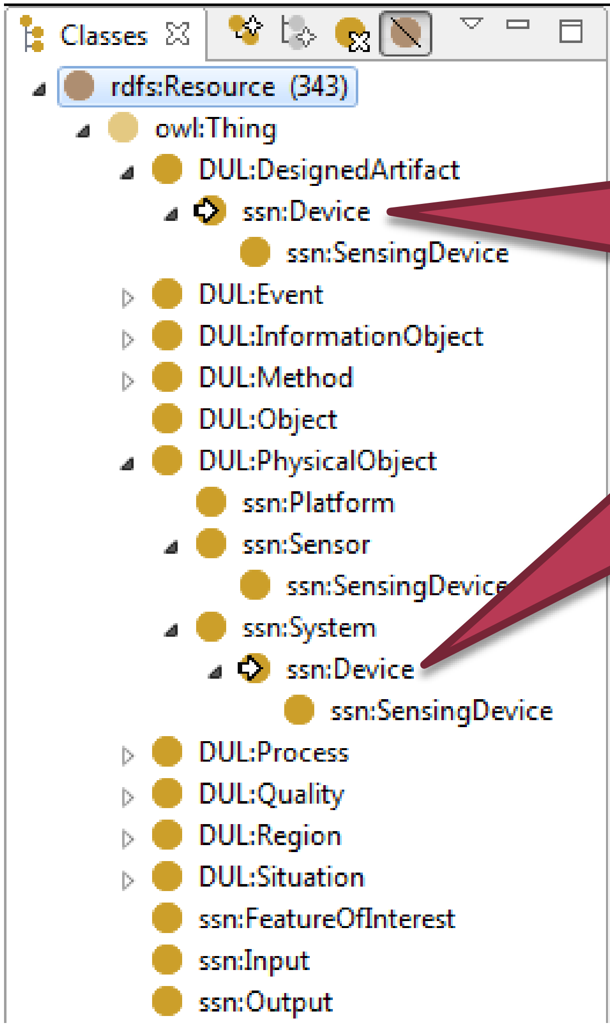


- sensing method
- observes some
  Property of a FeatureOfInterest.

SSN – Sensing Device

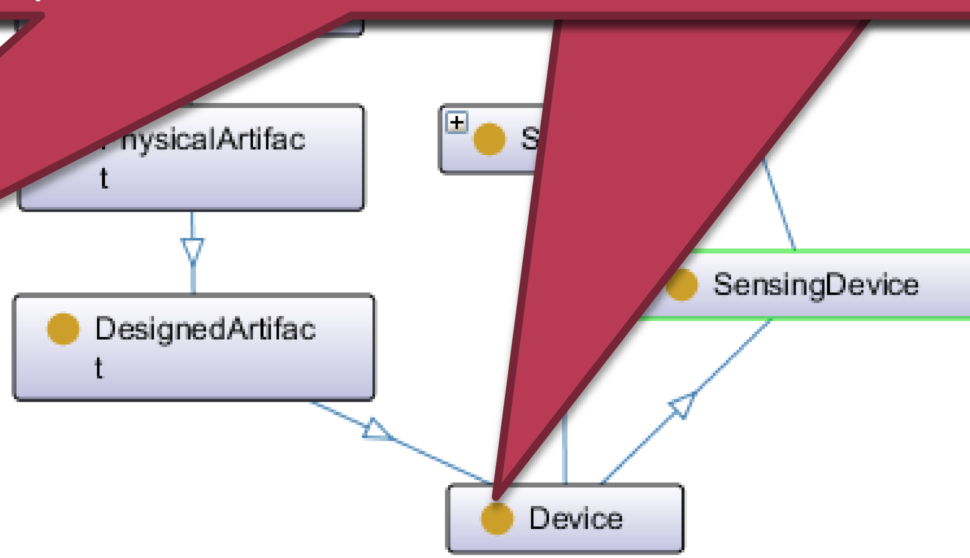


SSN –Device

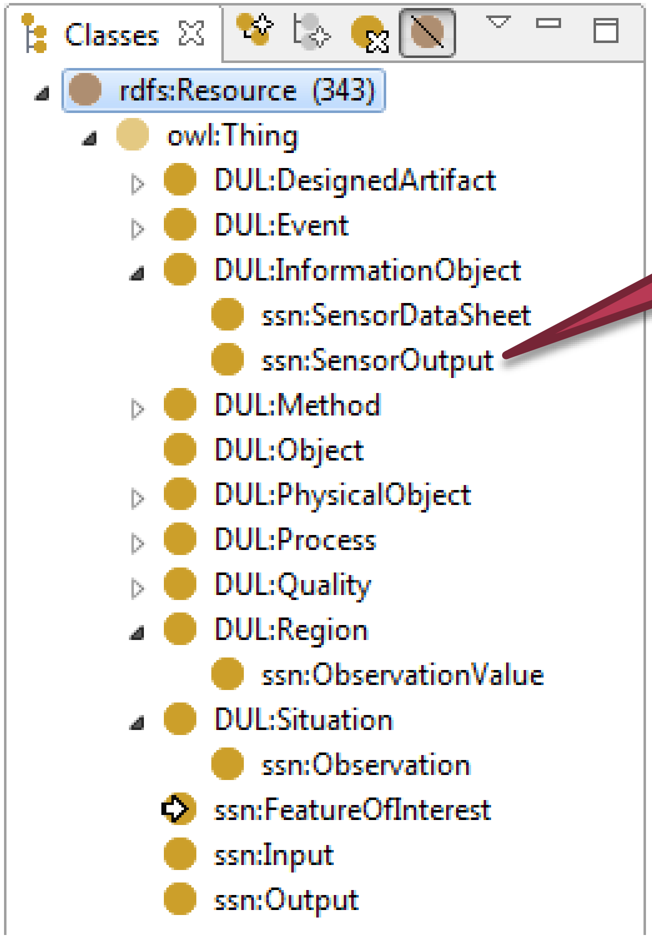


A device

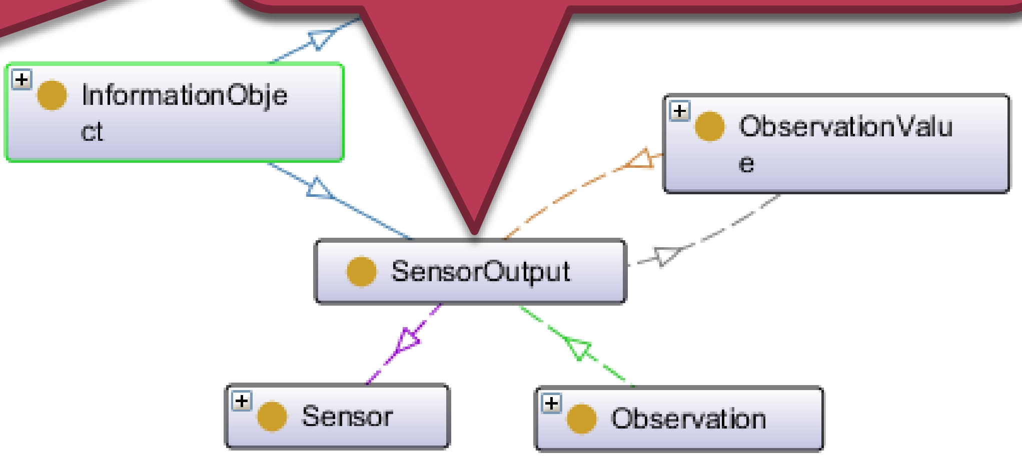
- physical piece of technology - a system in a box
- may be built of smaller devices and SW components



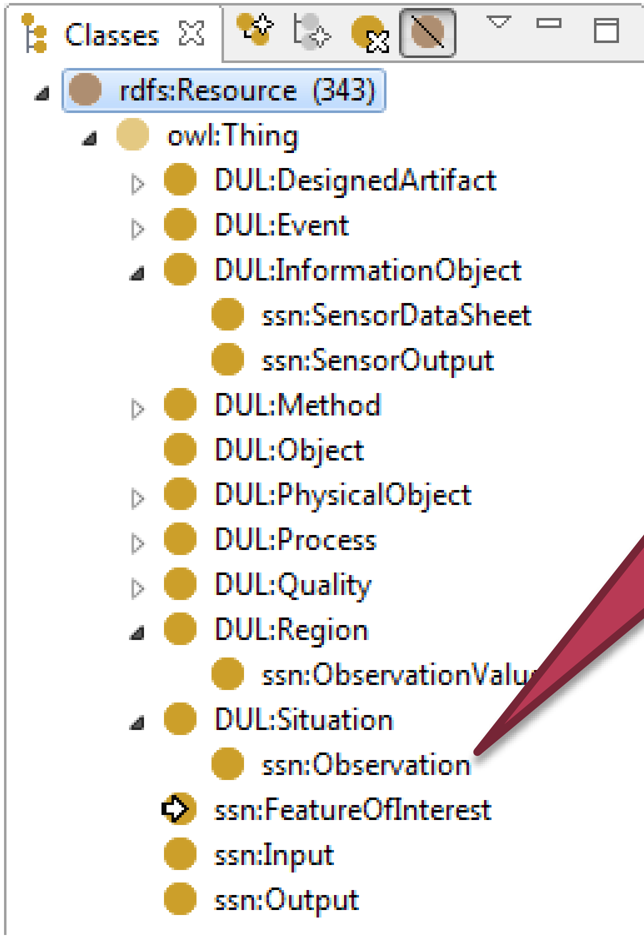
SSN – SensorOutput



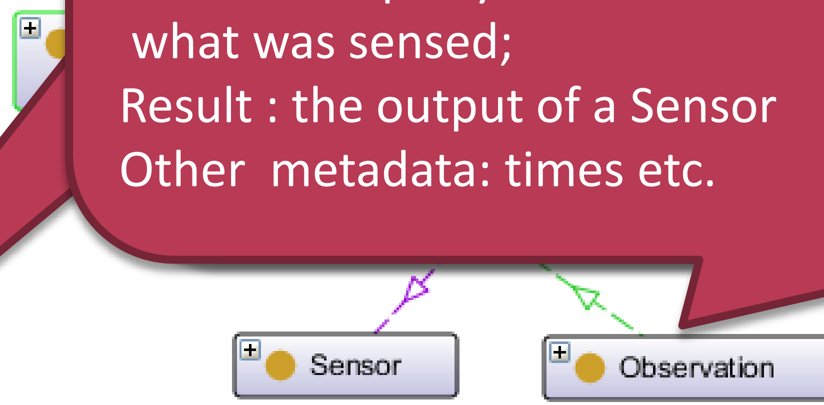
A sensor outputs a piece of information (an observed value), ObservationValue.



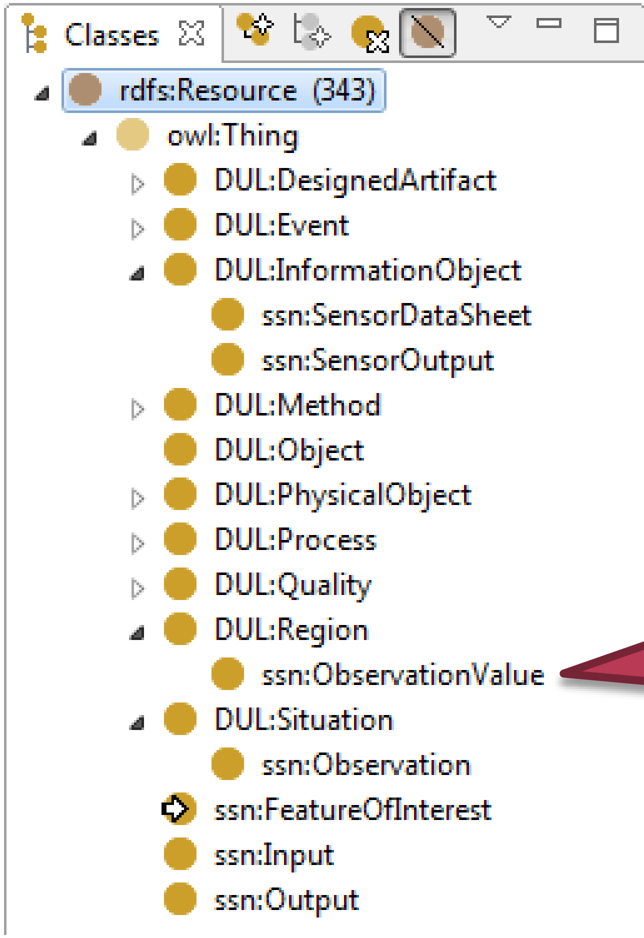
SSN – Observation

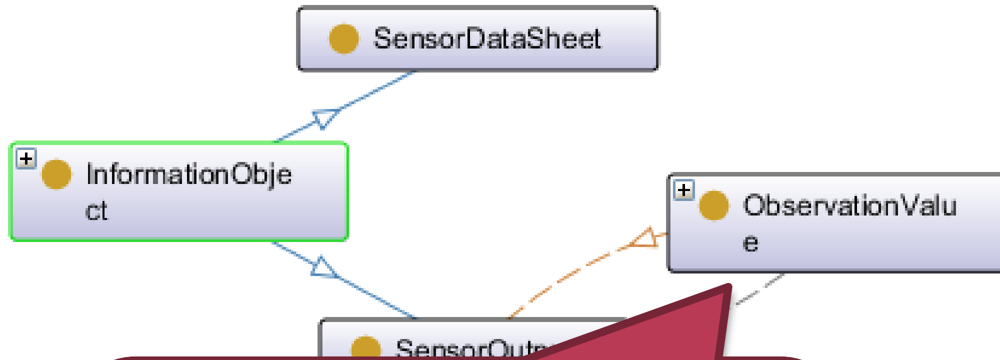


Sensing method estimated or calculated:
value of a Property of a FeatureOfInterest.
Links to Sensing and Sensor:
what made the Observation and how;
Links to Property and Feature
what was sensed;
Result : the output of a Sensor
Other metadata: times etc.



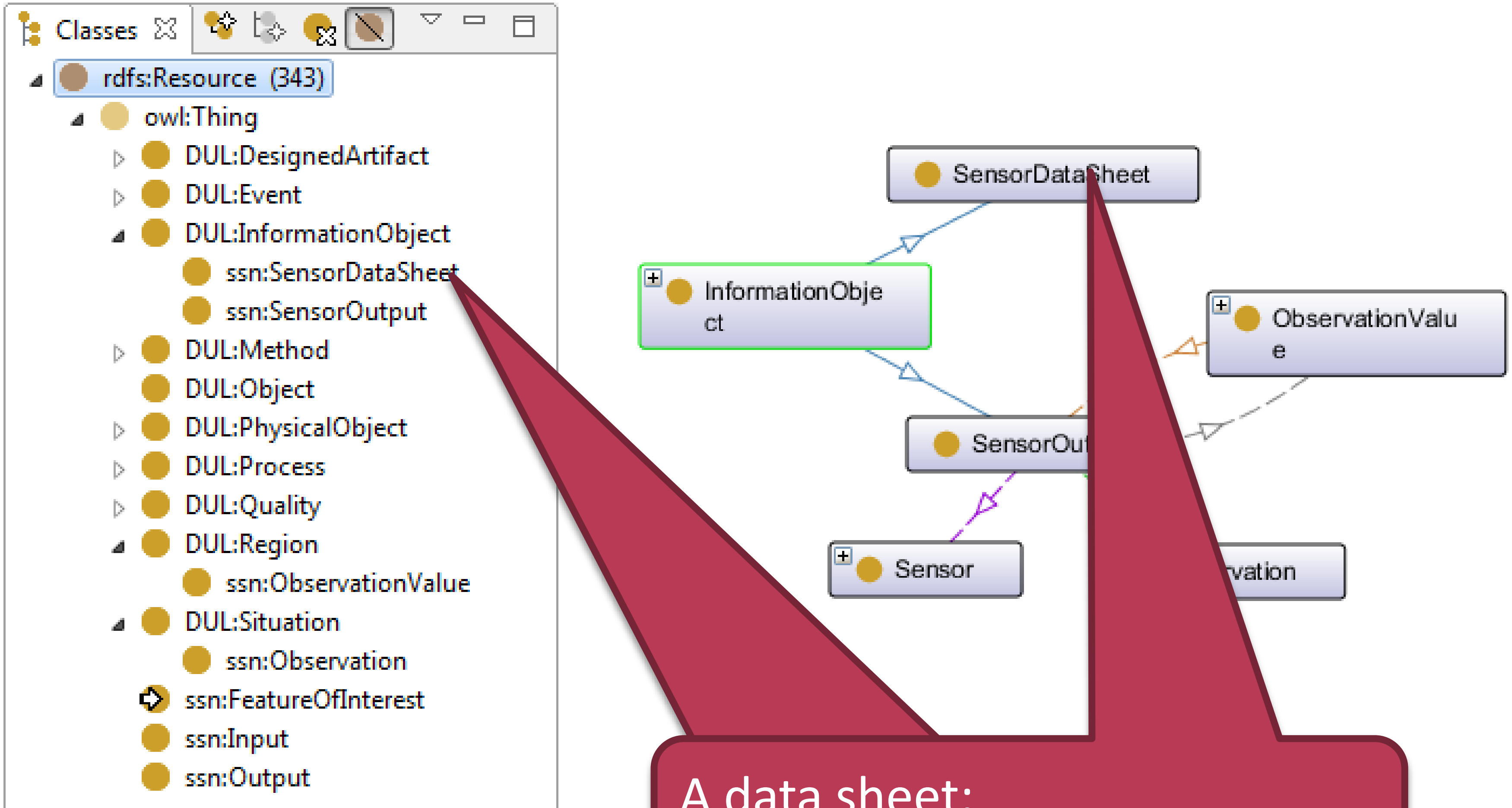
SSN – ObservationValue





The value of the result of an Observation =
some value for a Feature.

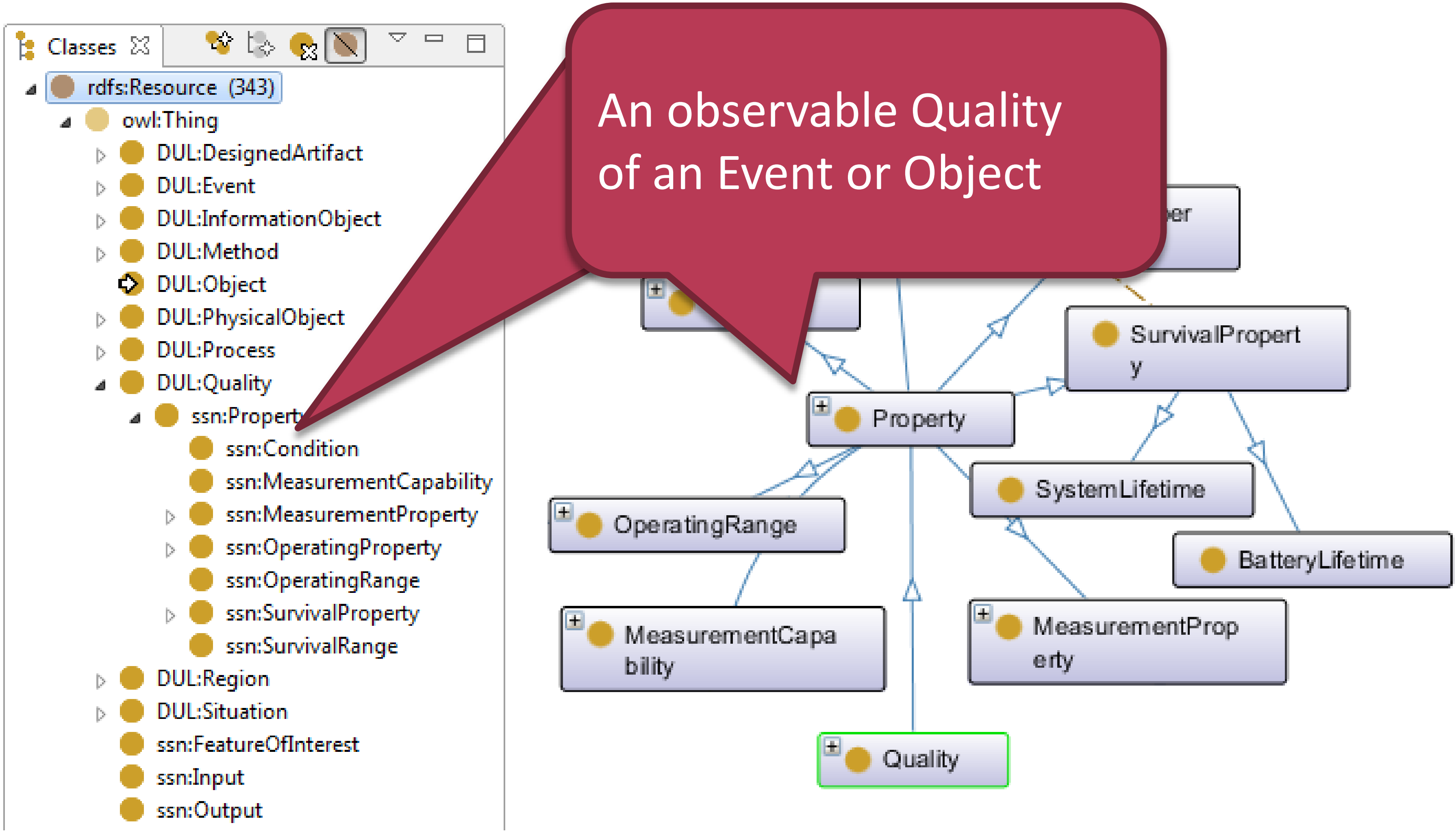
SSN – SensorDataSheet



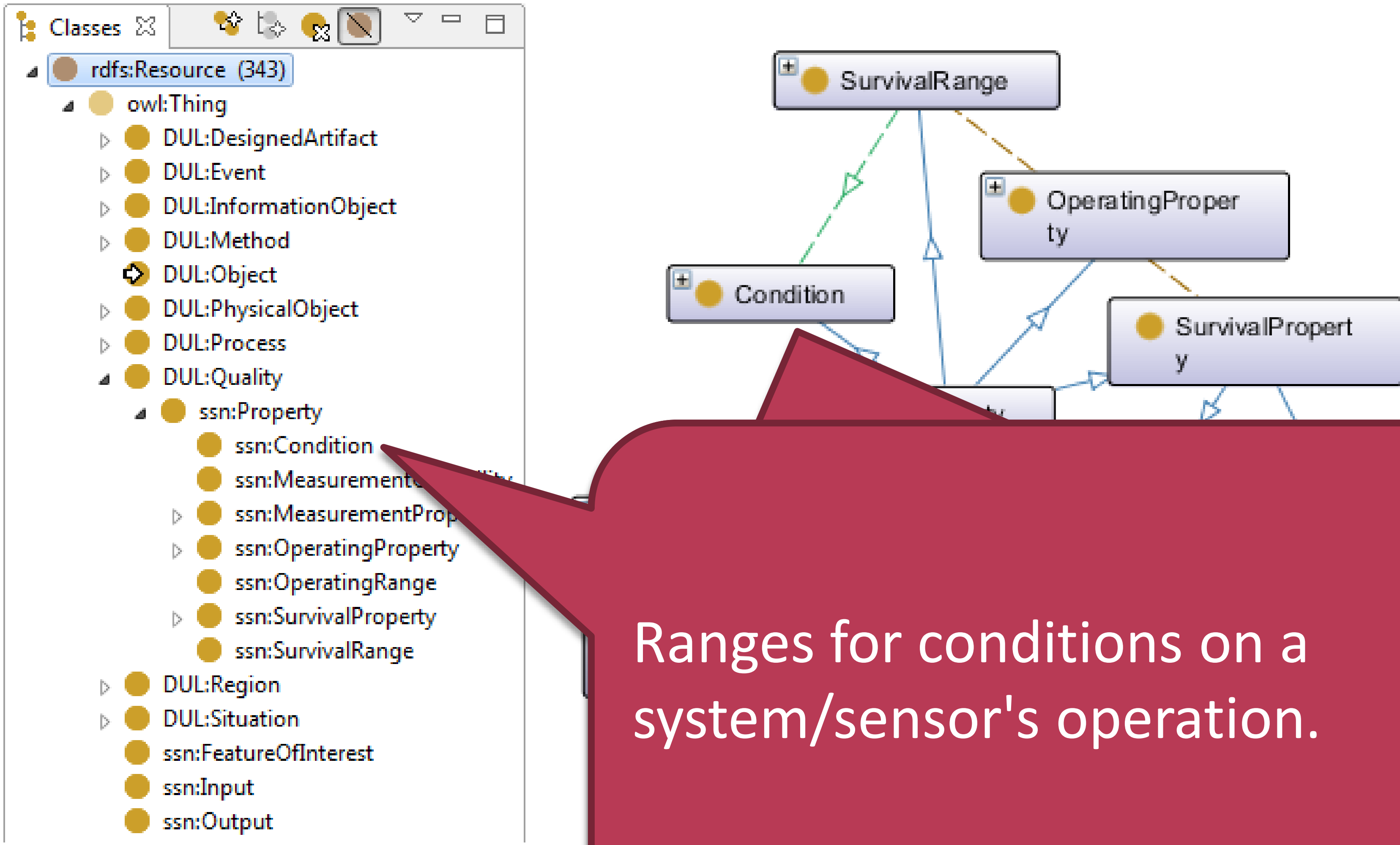
A data sheet:
properties of a sensor.

SSN - Property

An observable Quality of an Event or Object

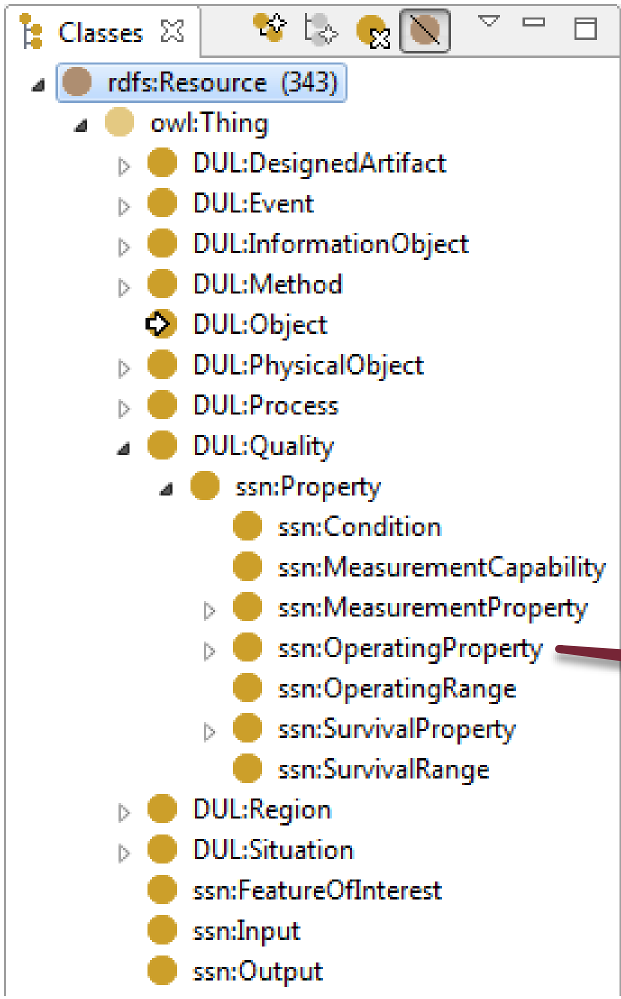


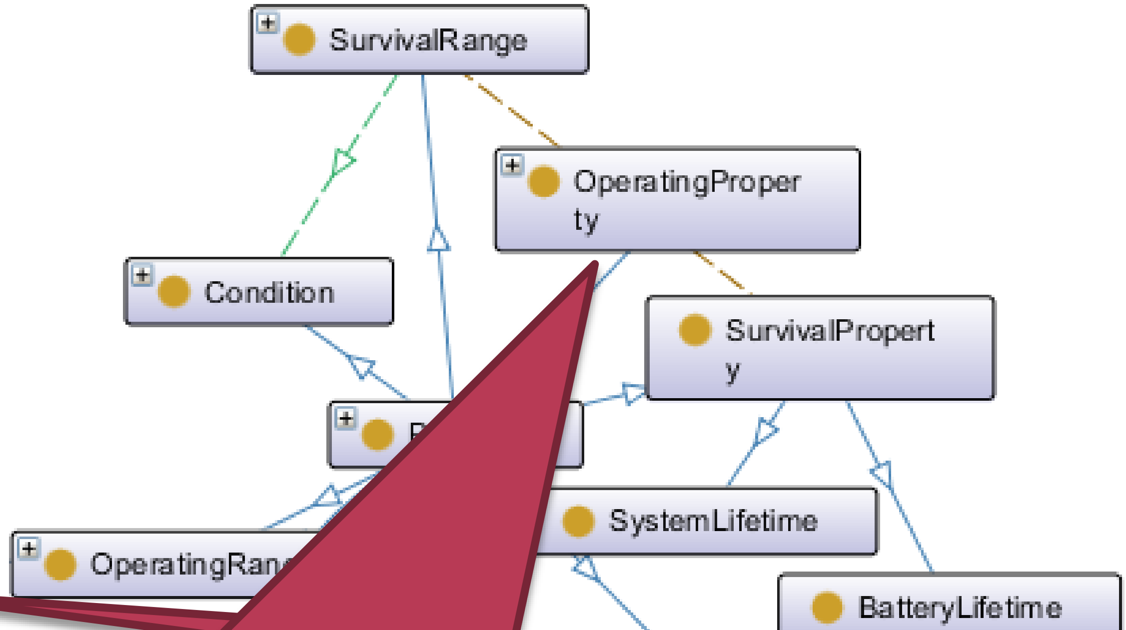
SSN - Condition



Ranges for conditions on a system/sensor's operation.

SSN - OperatingProperty

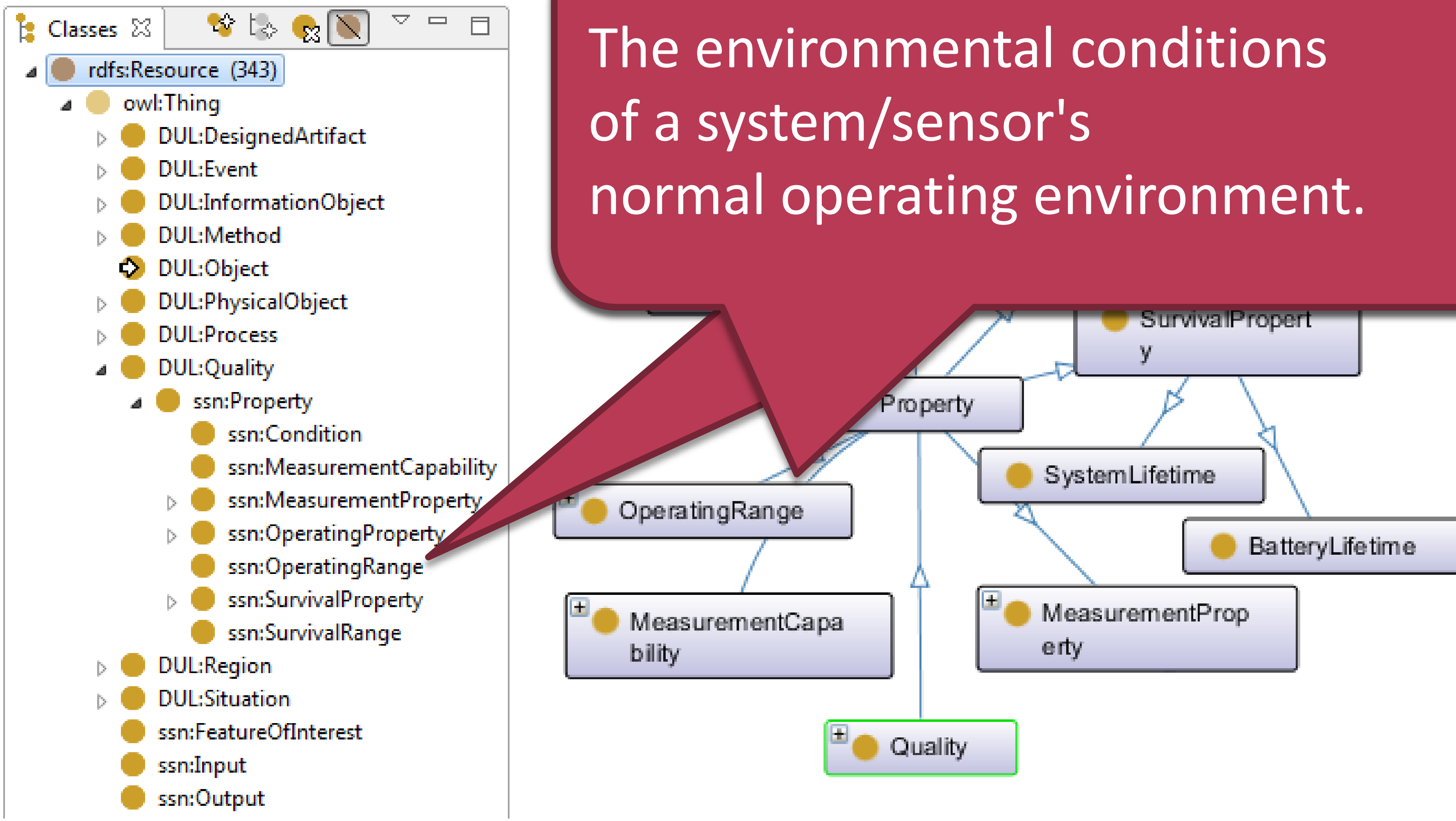




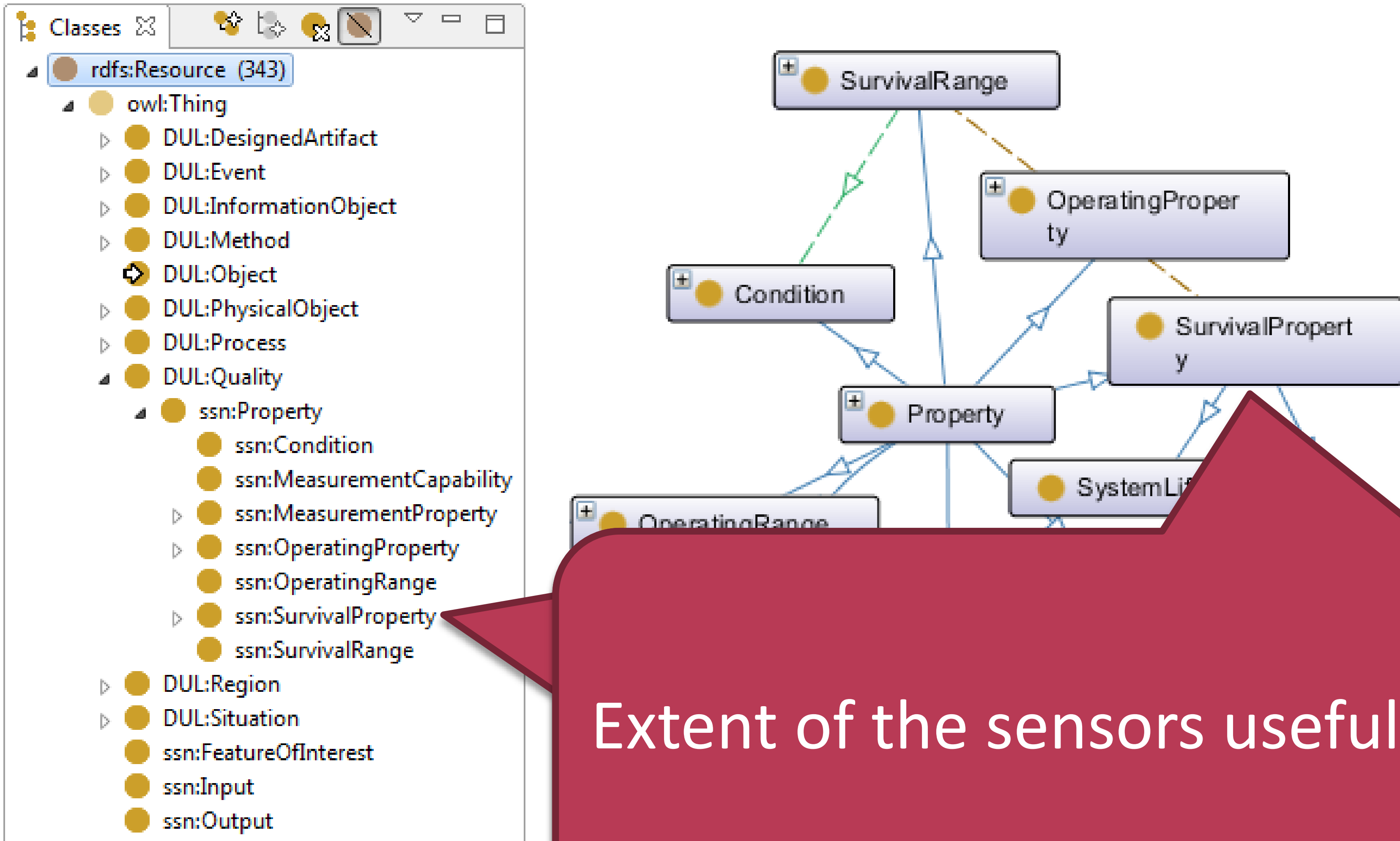
An identifiable characteristic
of the environmental and other conditions
in which the sensor is intended to operate.

SSN - OperatingRange

The environmental conditions
of a system/sensor's
normal operating environment.

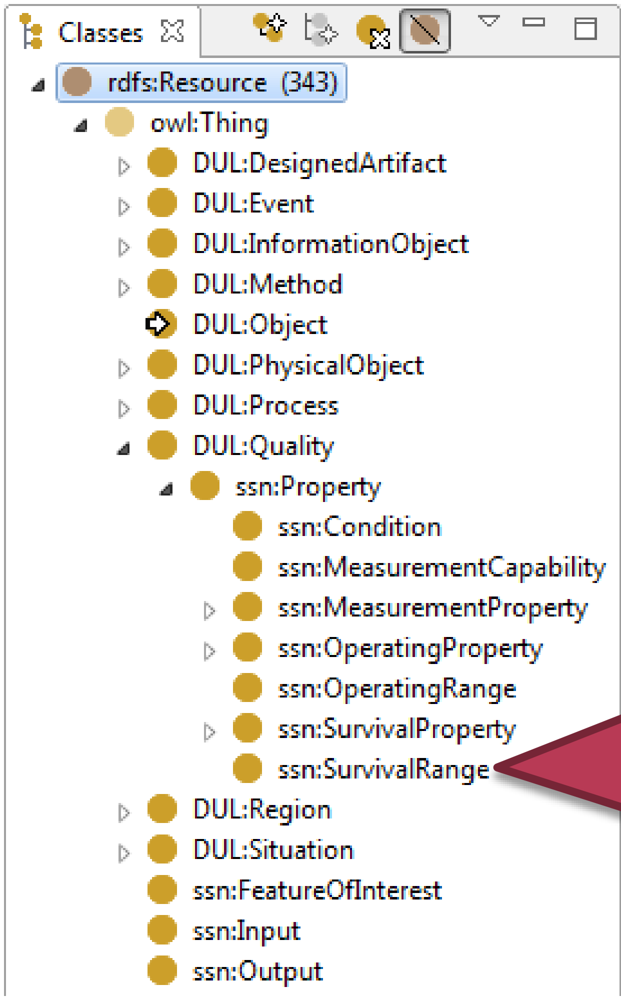


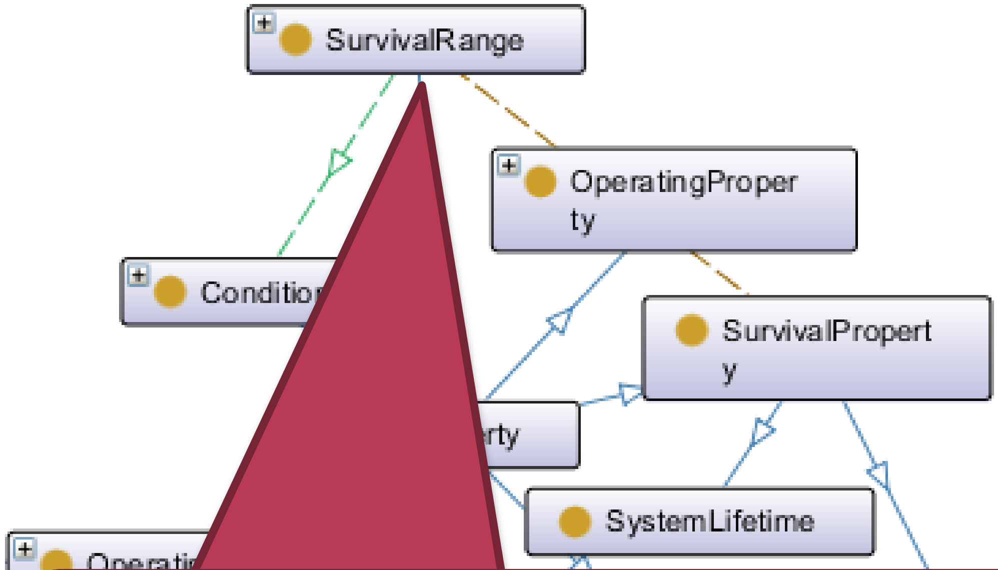
SSN - SurvivalProprty



Extent of the sensors useful life.

SSN – SurvivalRange

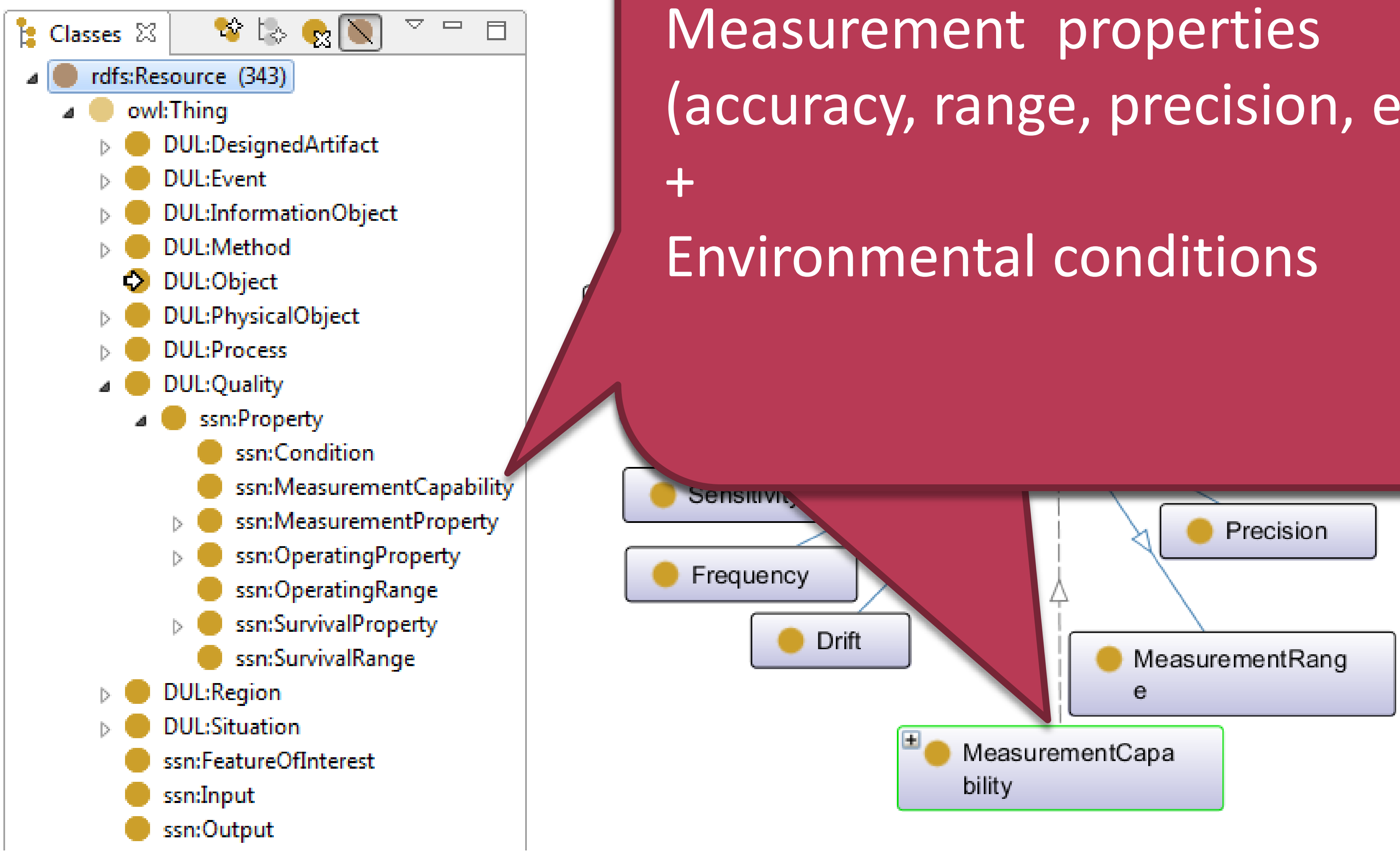




The conditions a sensor can be exposed to no damage:
i.e., the sensor continues to operate as defined using MeasurementCapability.

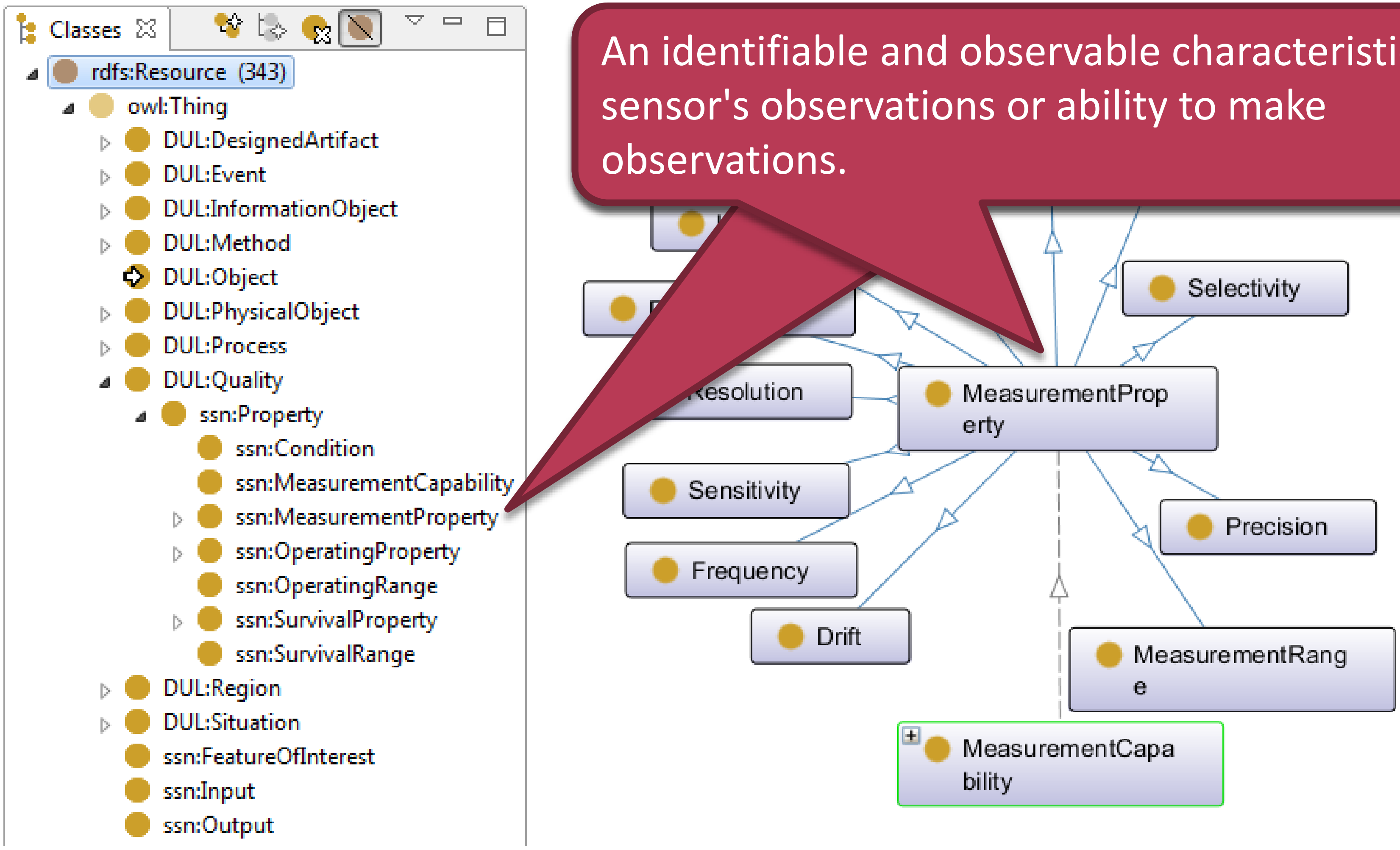
SSN - Measurement Capability

Measurement properties
(accuracy, range, precision, etc)
+
Environmental conditions

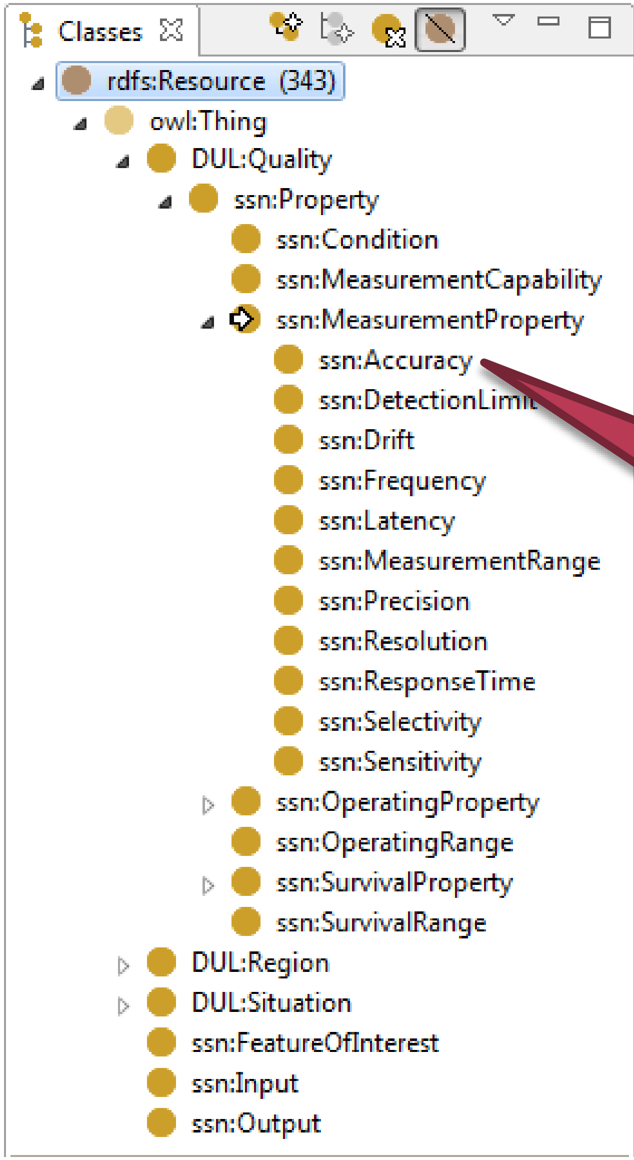


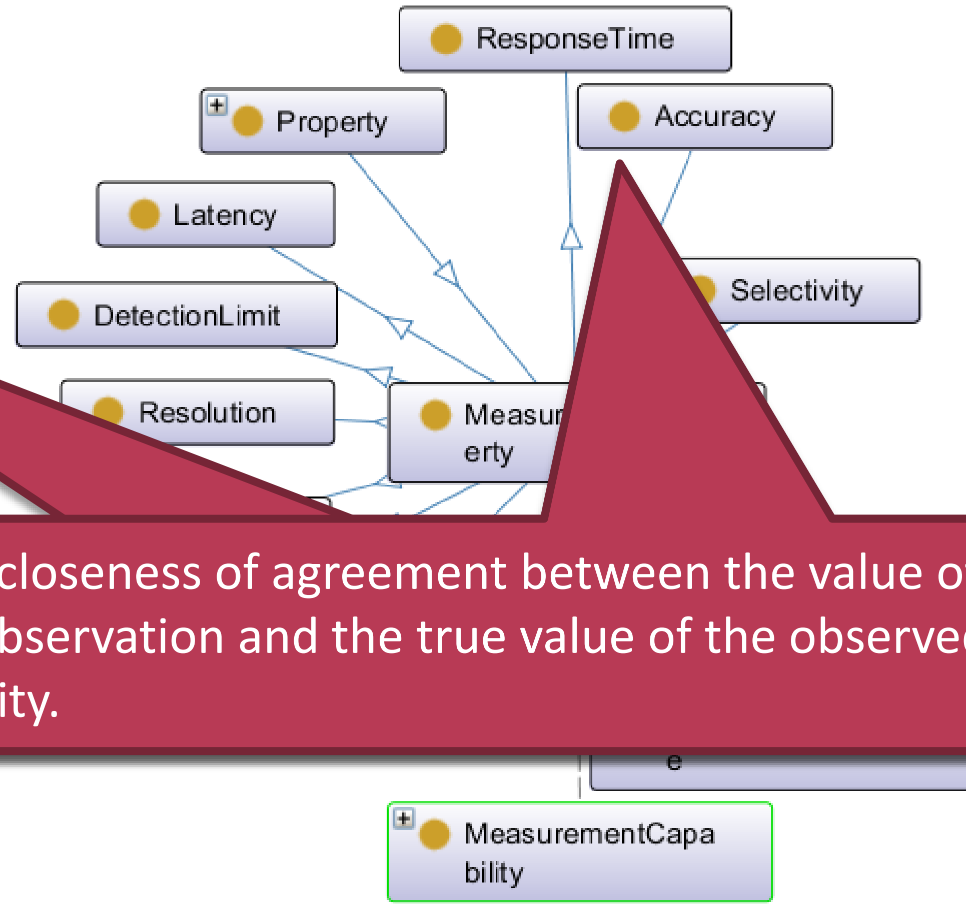
SSN - Measurement Property

An identifiable and observable characteristic of a sensor's observations or ability to make observations.



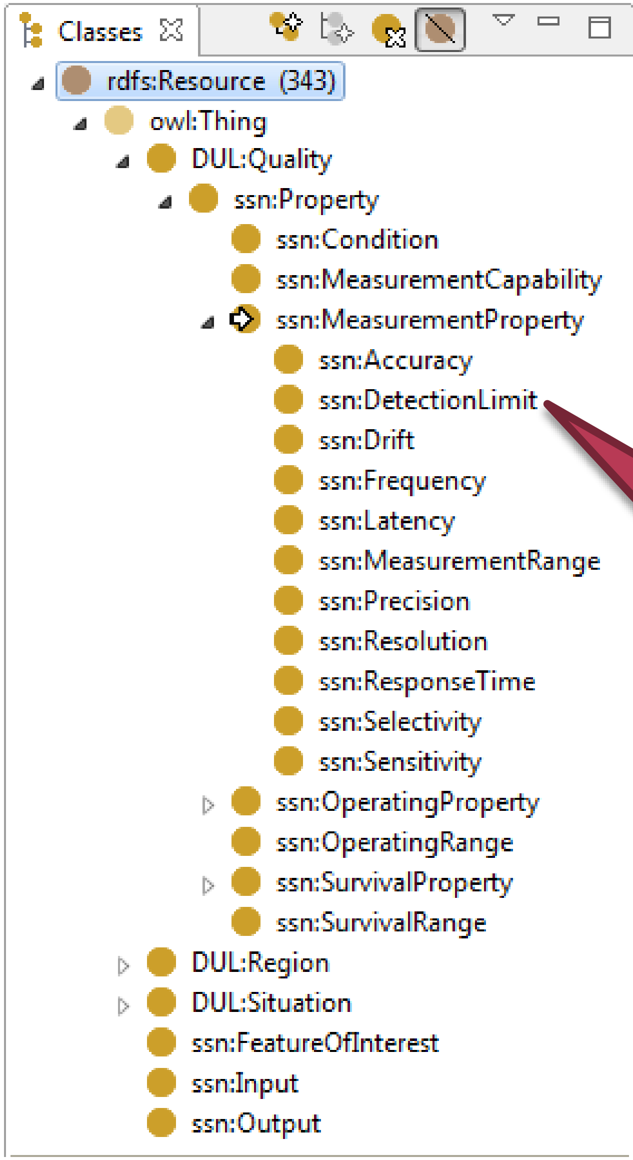
SSN - Accuracy

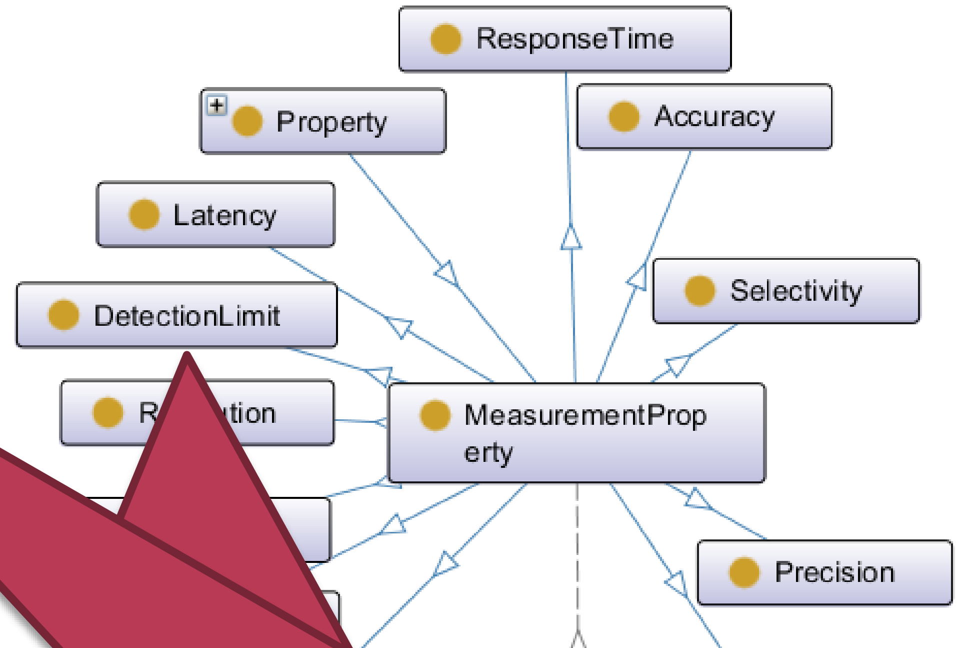




The closeness of agreement between the value of an observation and the true value of the observed quality.

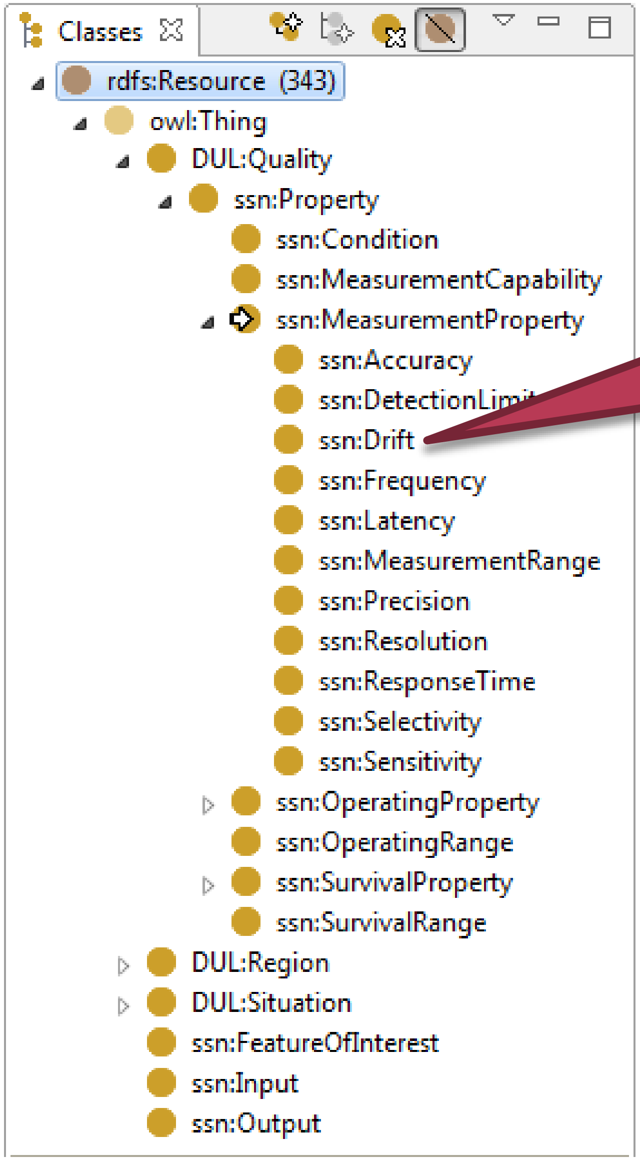
SSN - DetectionLimit



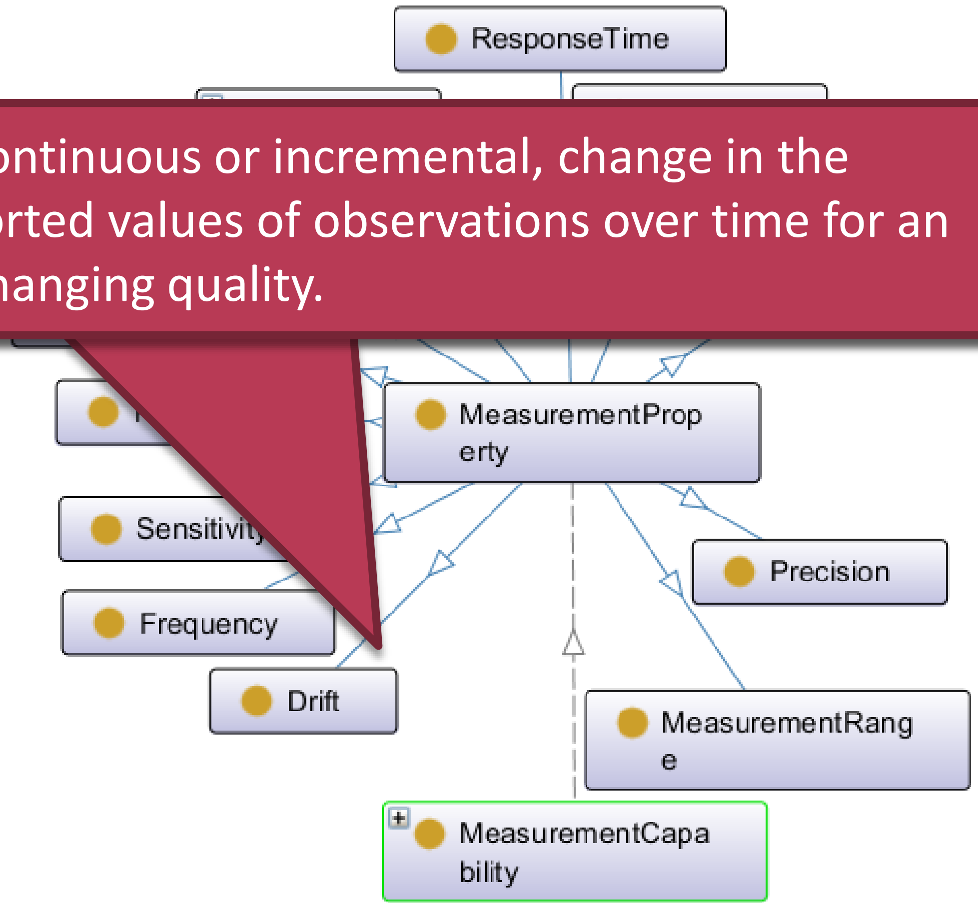


An observed value for which the probability of falsely claiming the absence of a component in a material is Î², given a probability Î± of falsely claiming its presence.

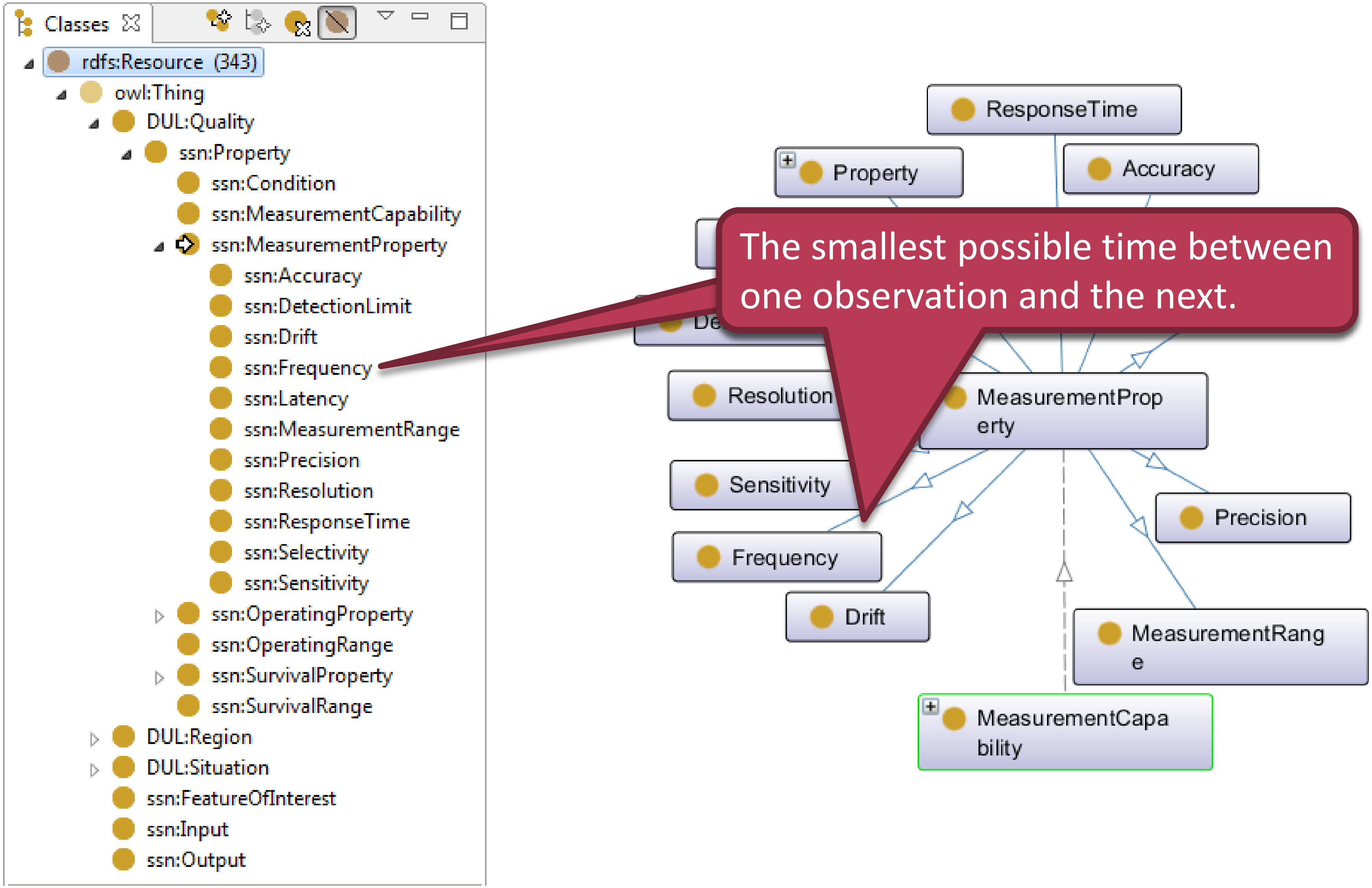
SSN - Drift



A, continuous or incremental, change in the reported values of observations over time for an unchanging quality.

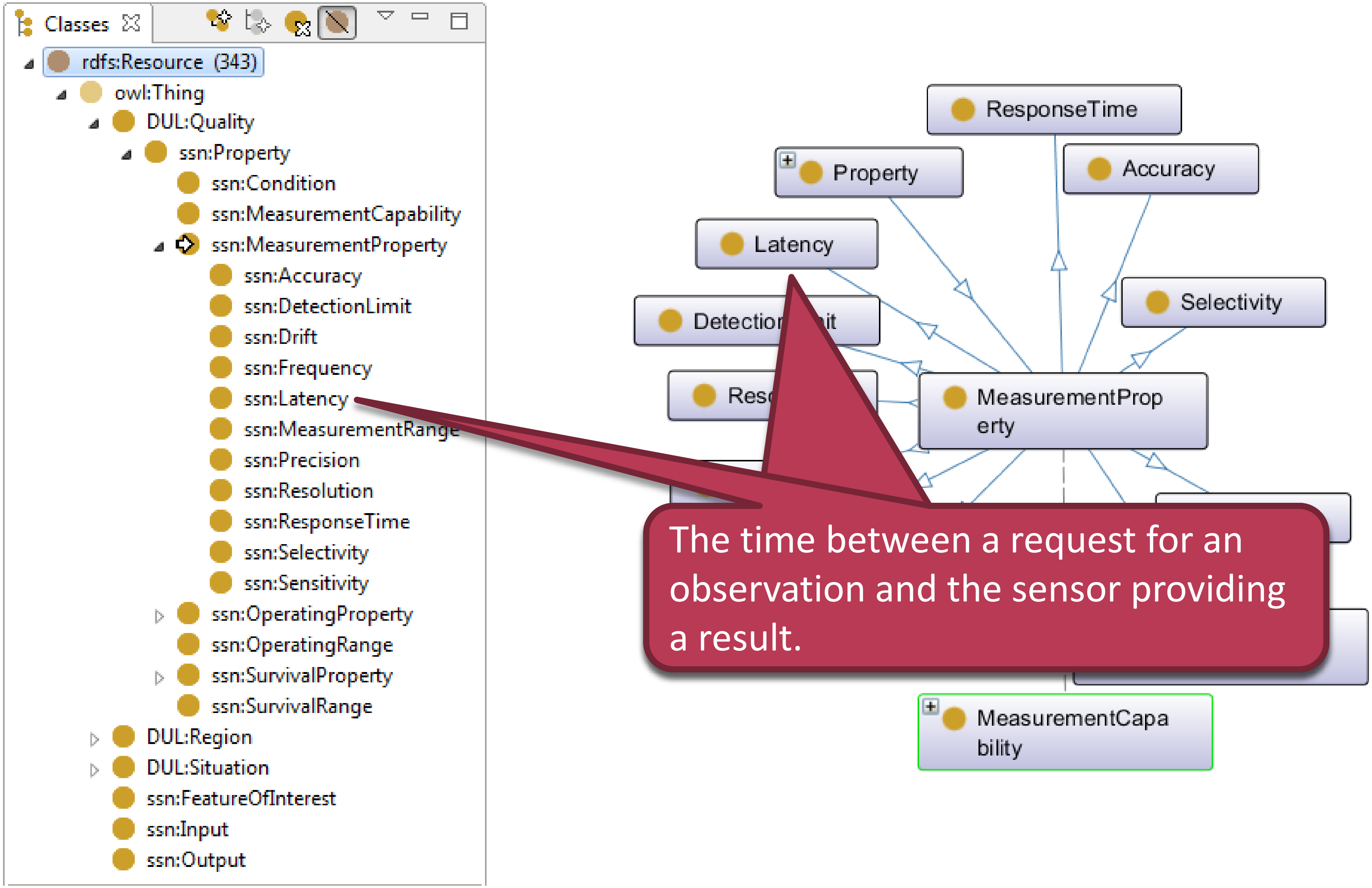


SSN - Frequency



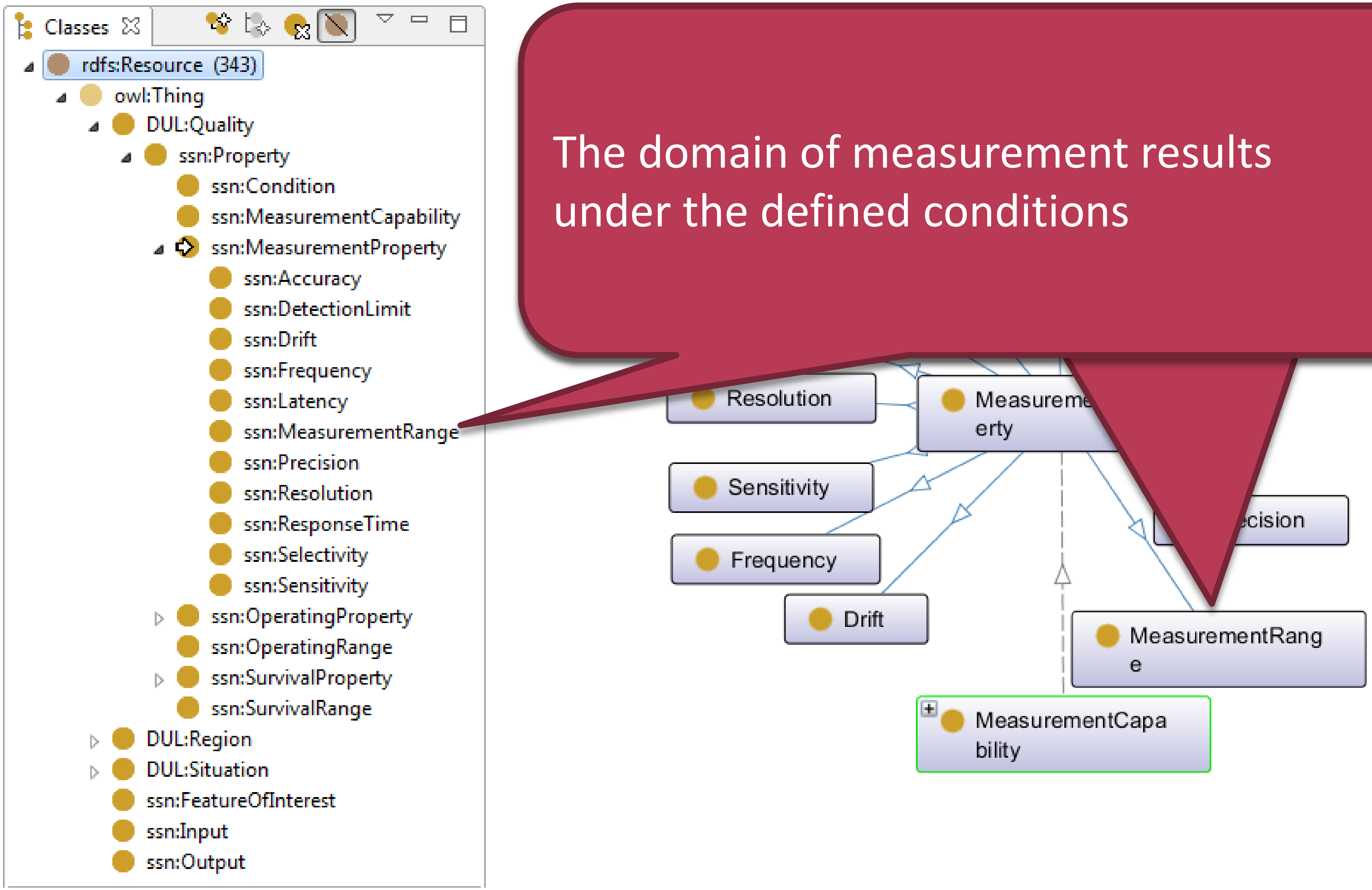
The smallest possible time between one observation and the next.

SSN - Latency



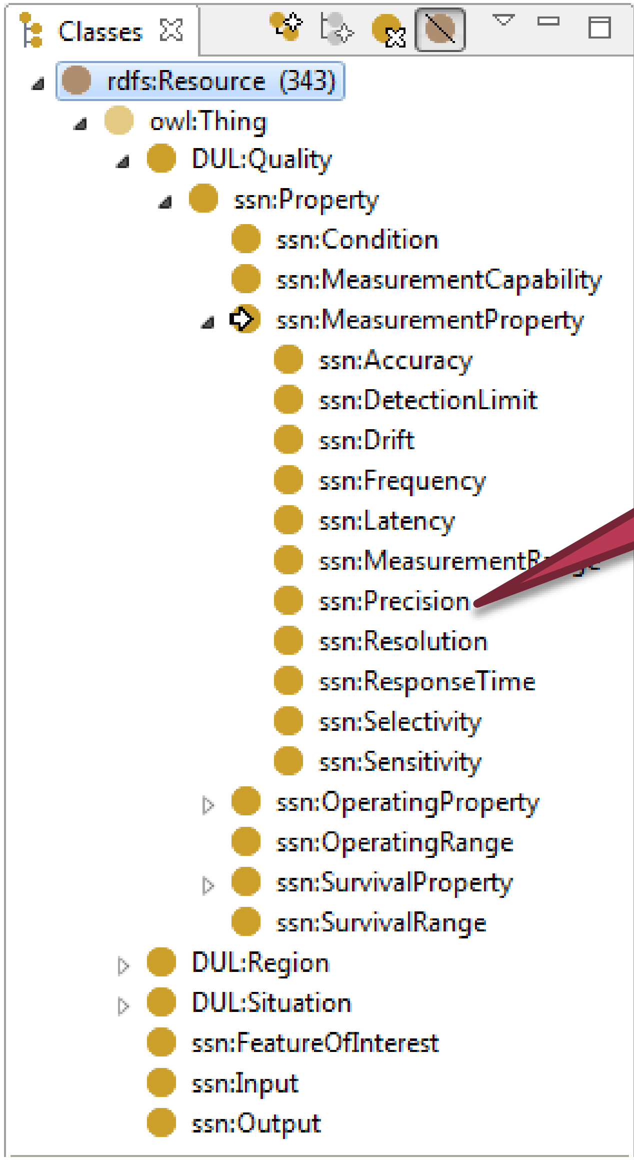
The time between a request for an observation and the sensor providing a result.

SSN - Measurement Range

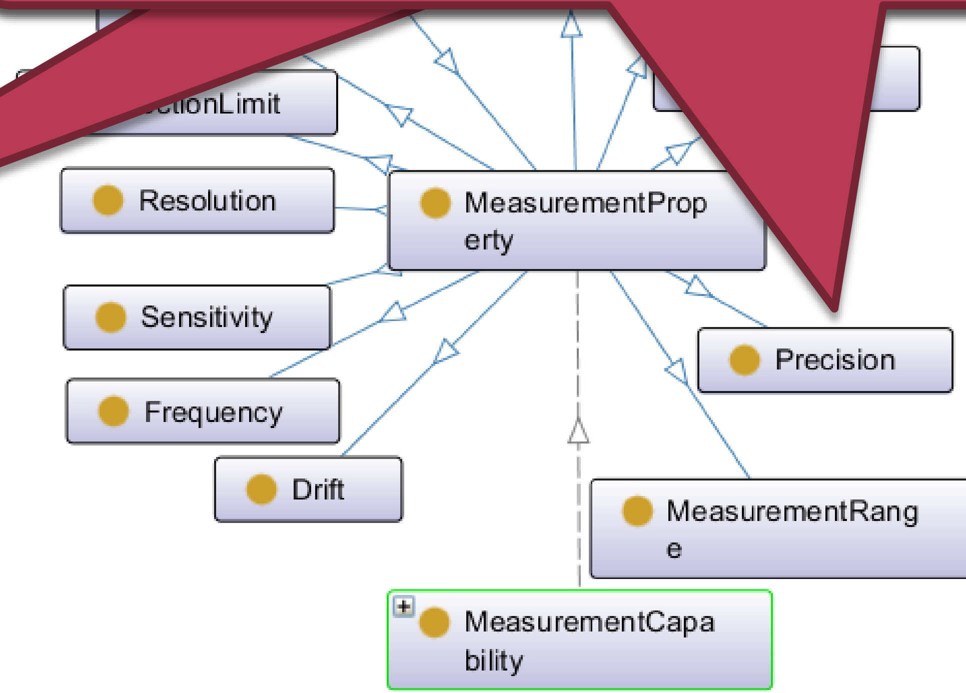


The domain of measurement results under the defined conditions

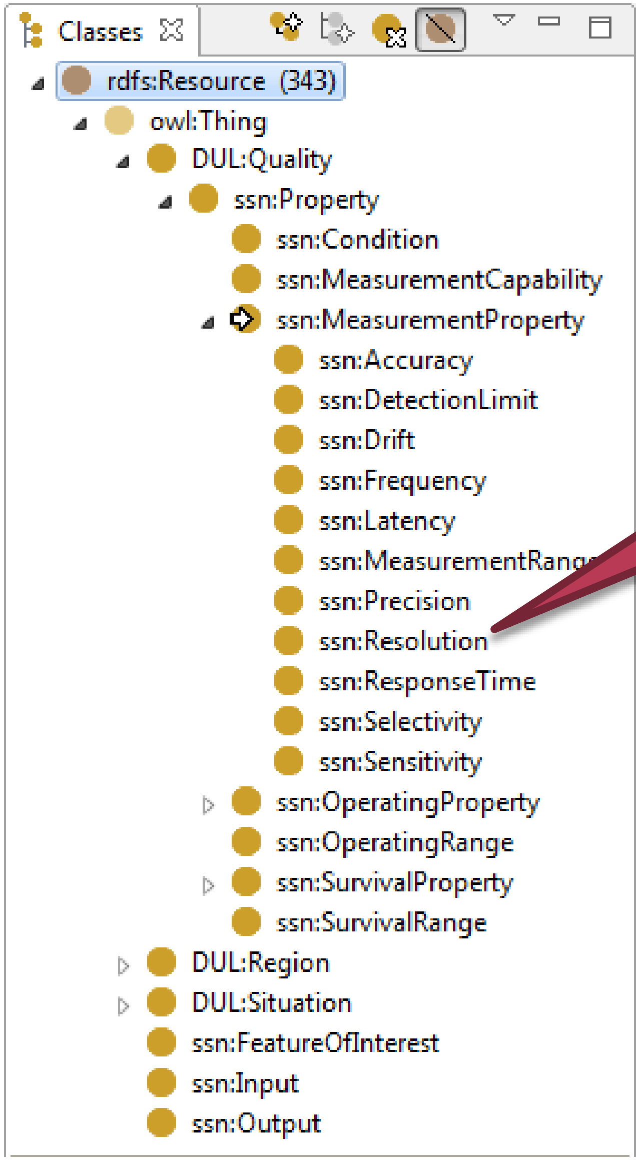
SSN - Precision



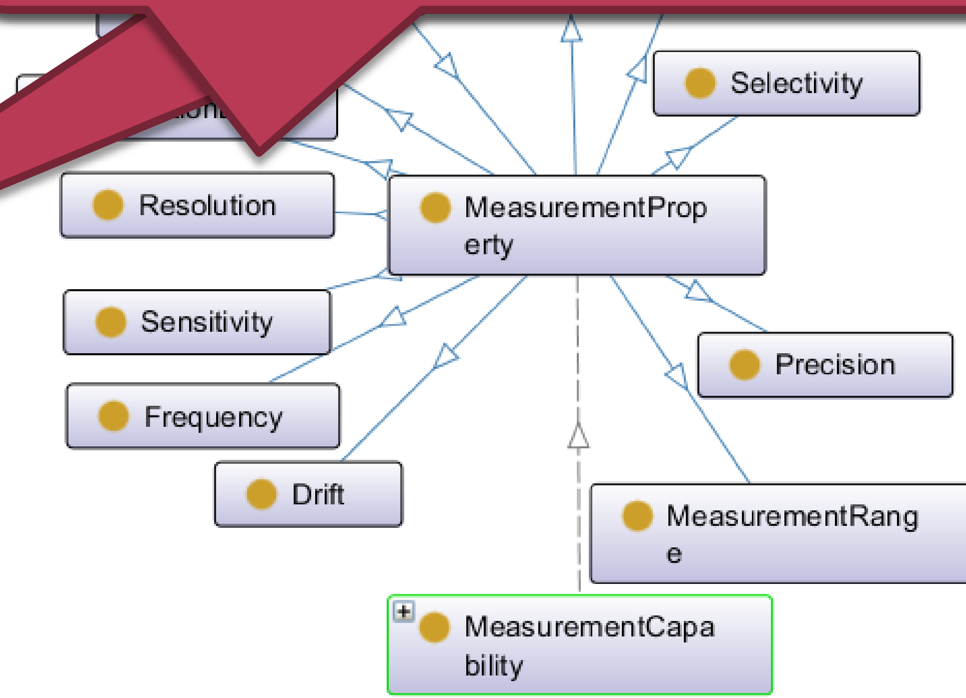
The closeness of replicated observations on an unchanged quality value:
a measure of a reproducibility



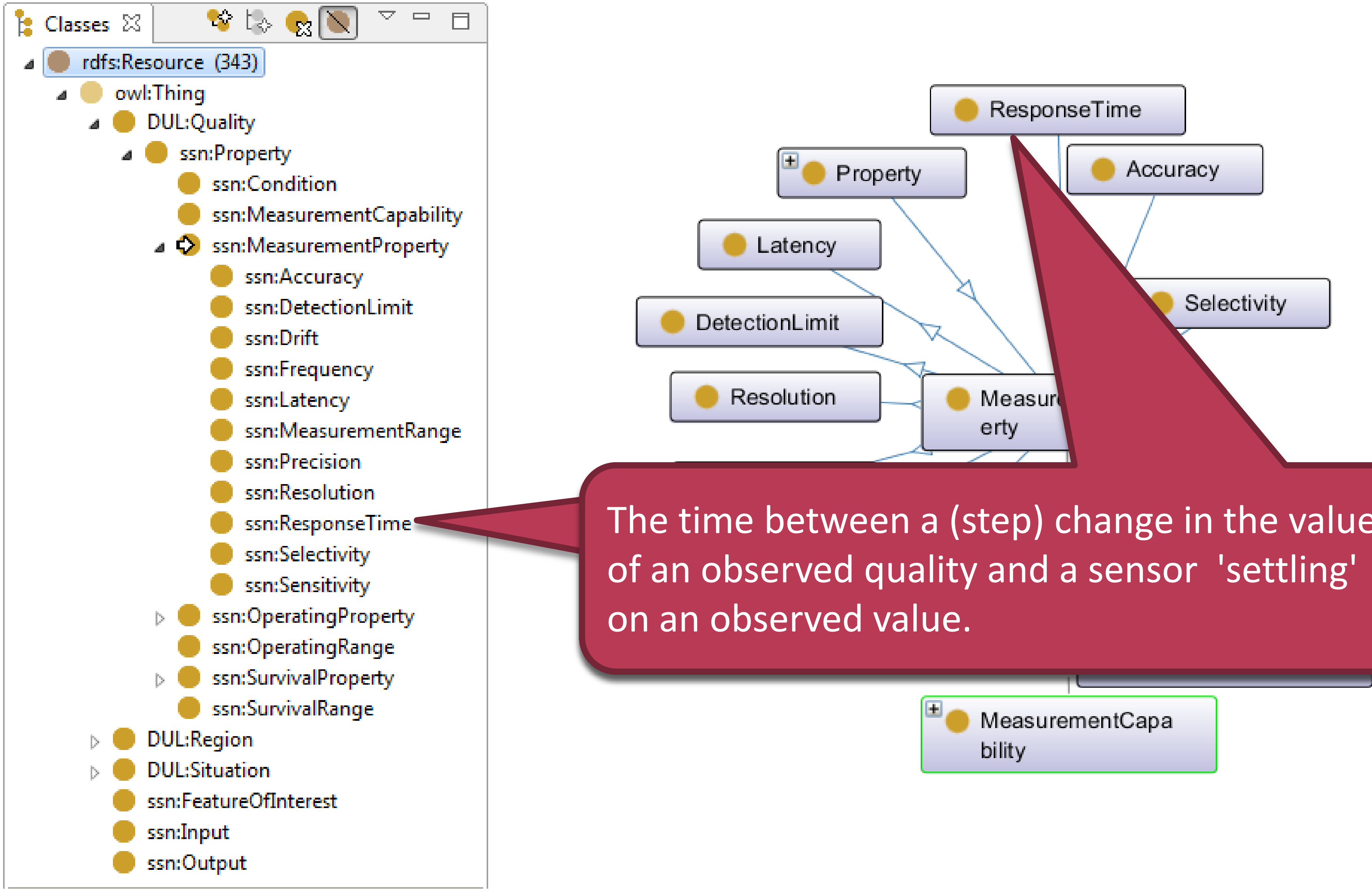
SSN - Resolution



The smallest difference in observation results.

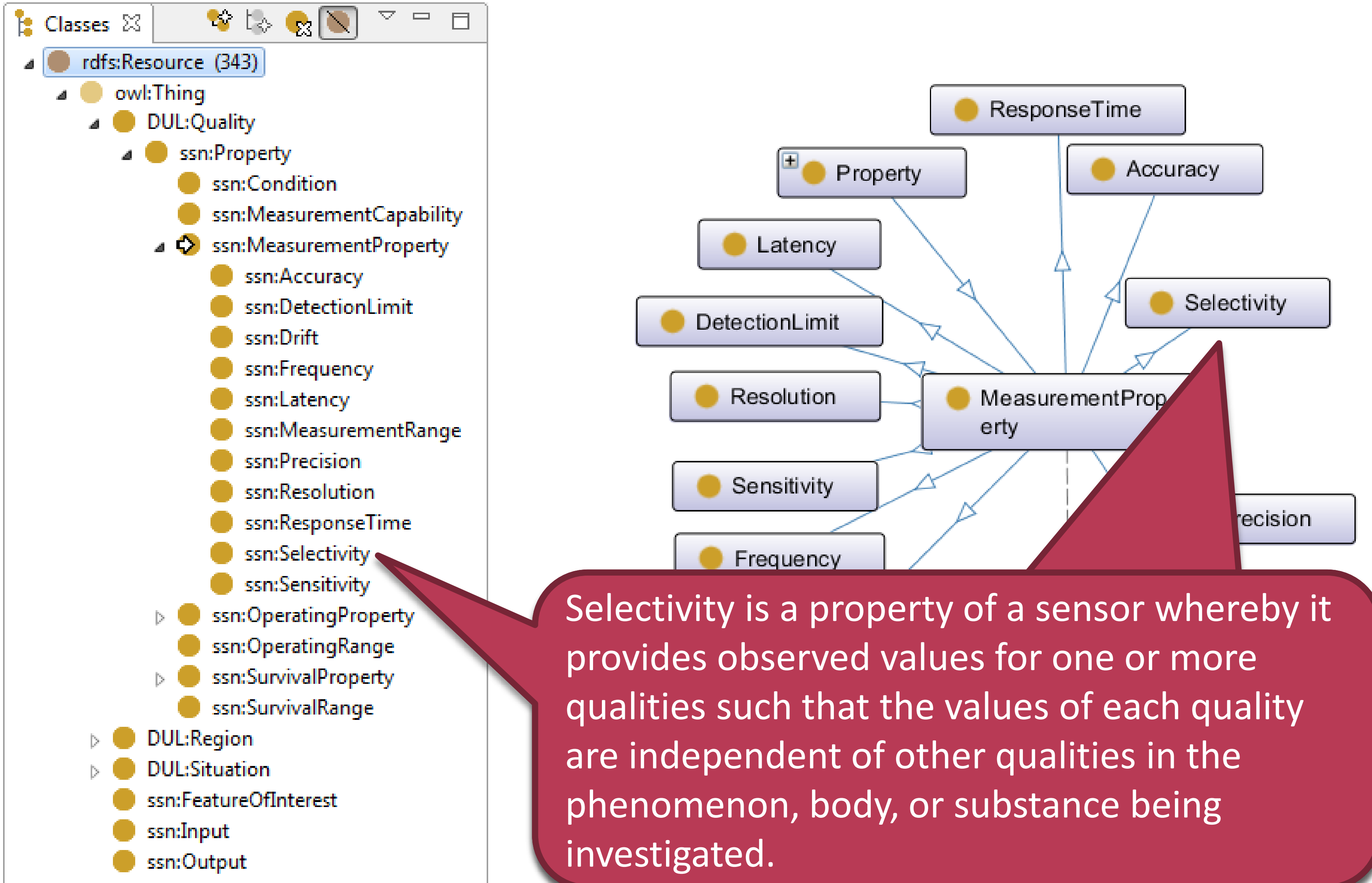


SSN – ResponseTime



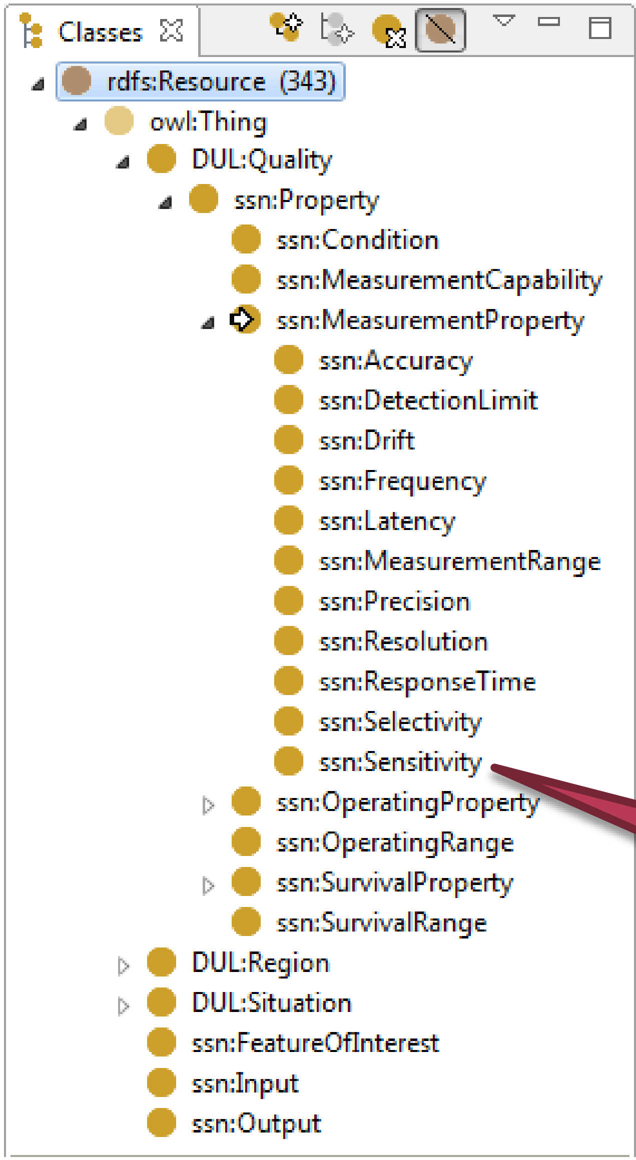
The time between a (step) change in the value of an observed quality and a sensor 'settling' on an observed value.

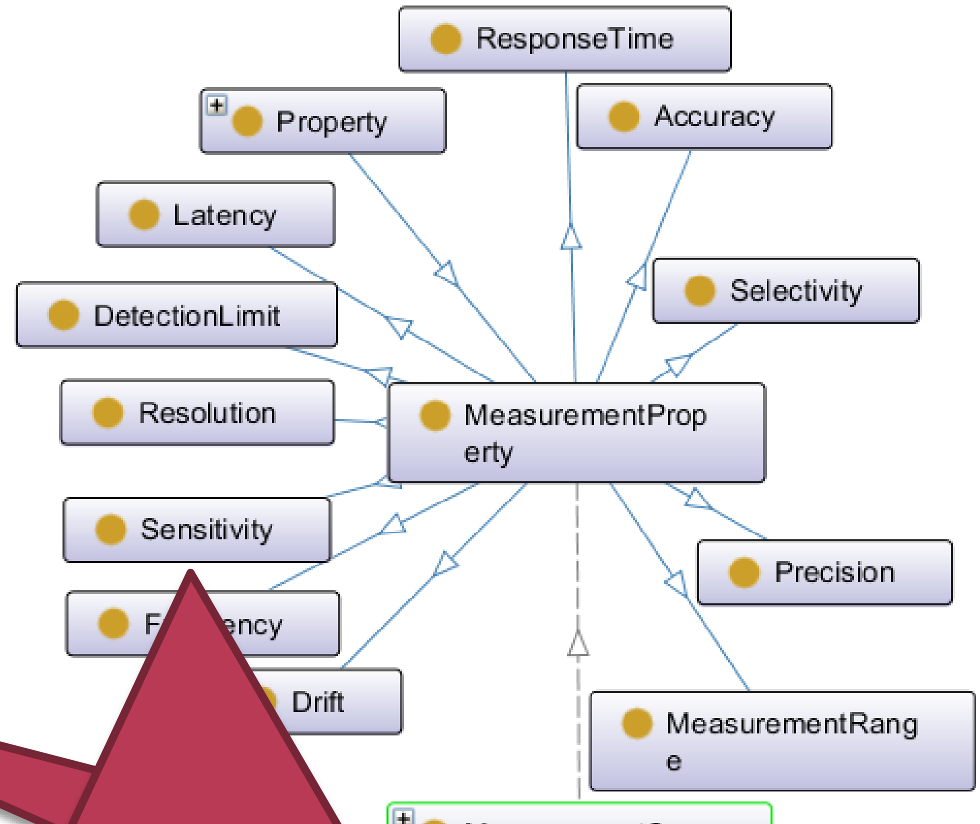
SSN - Selectivity



Selectivity is a property of a sensor whereby it provides observed values for one or more qualities such that the values of each quality are independent of other qualities in the phenomenon, body, or substance being investigated.

SSN - Sensitivity

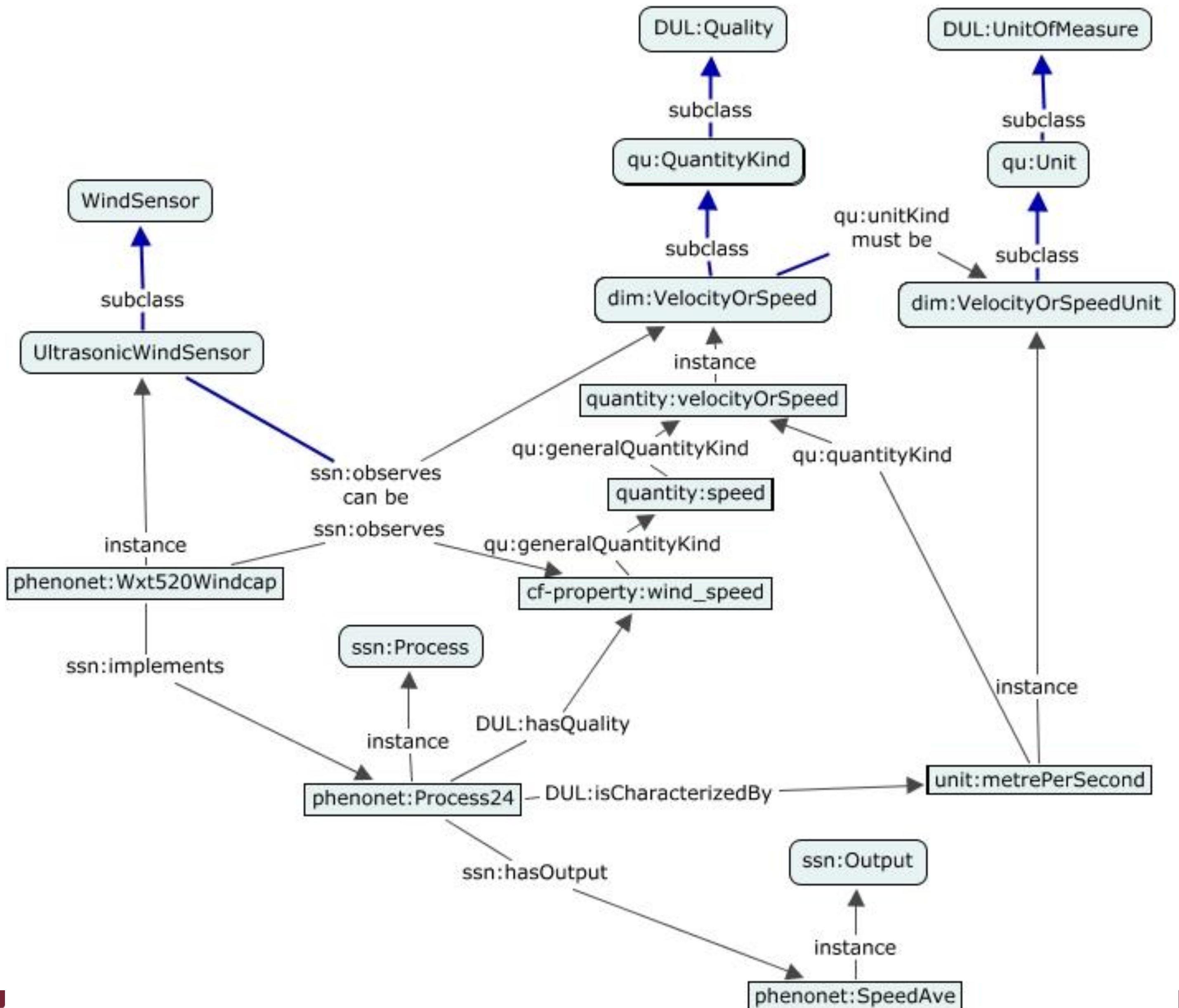




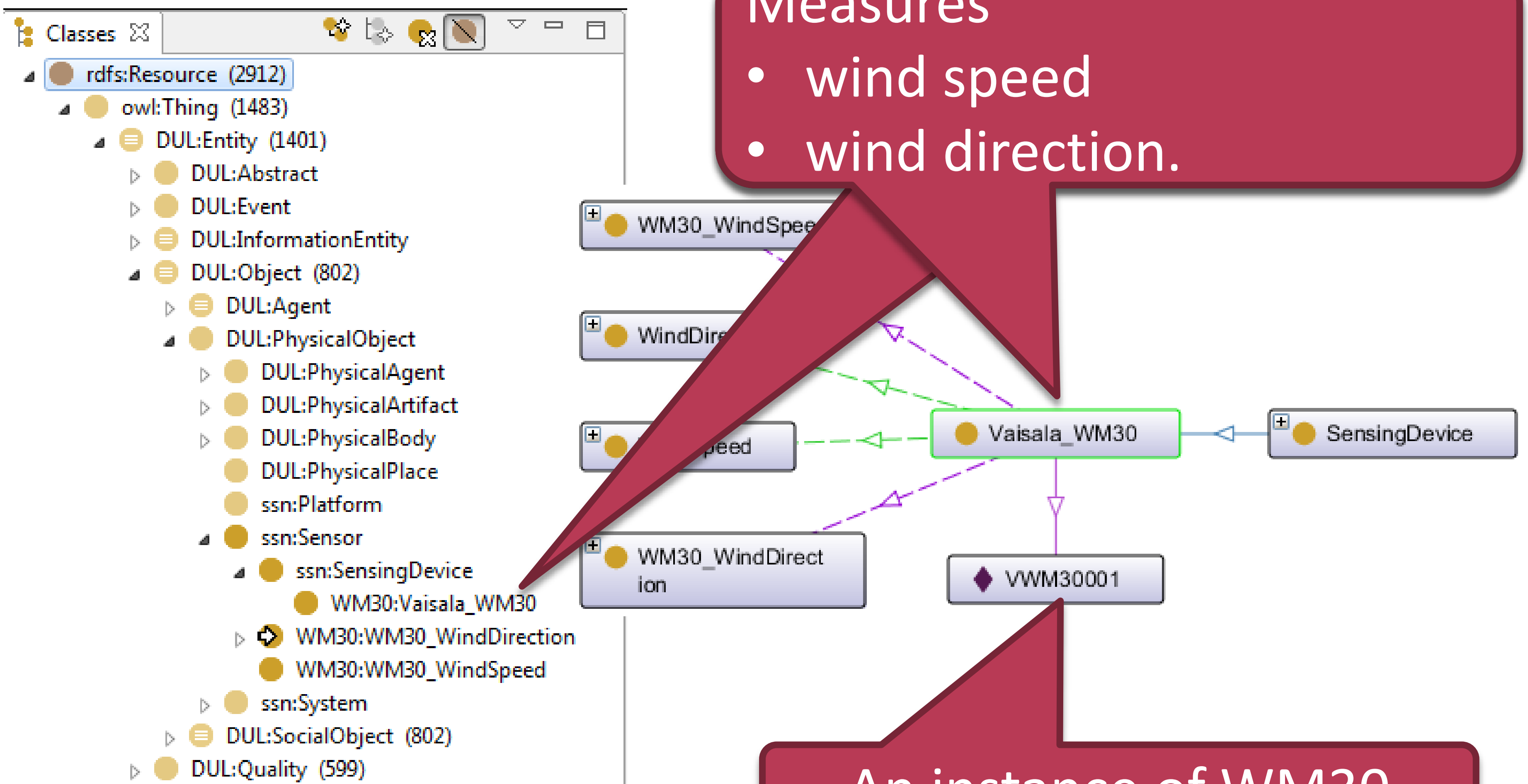
Sensitivity is the quotient of the change in a result of sensor and the corresponding change in a value of a quality being observed.

EXAMPLE: WIND SENSOR

SSN example: wind sensor



SSN – Wind Sensor

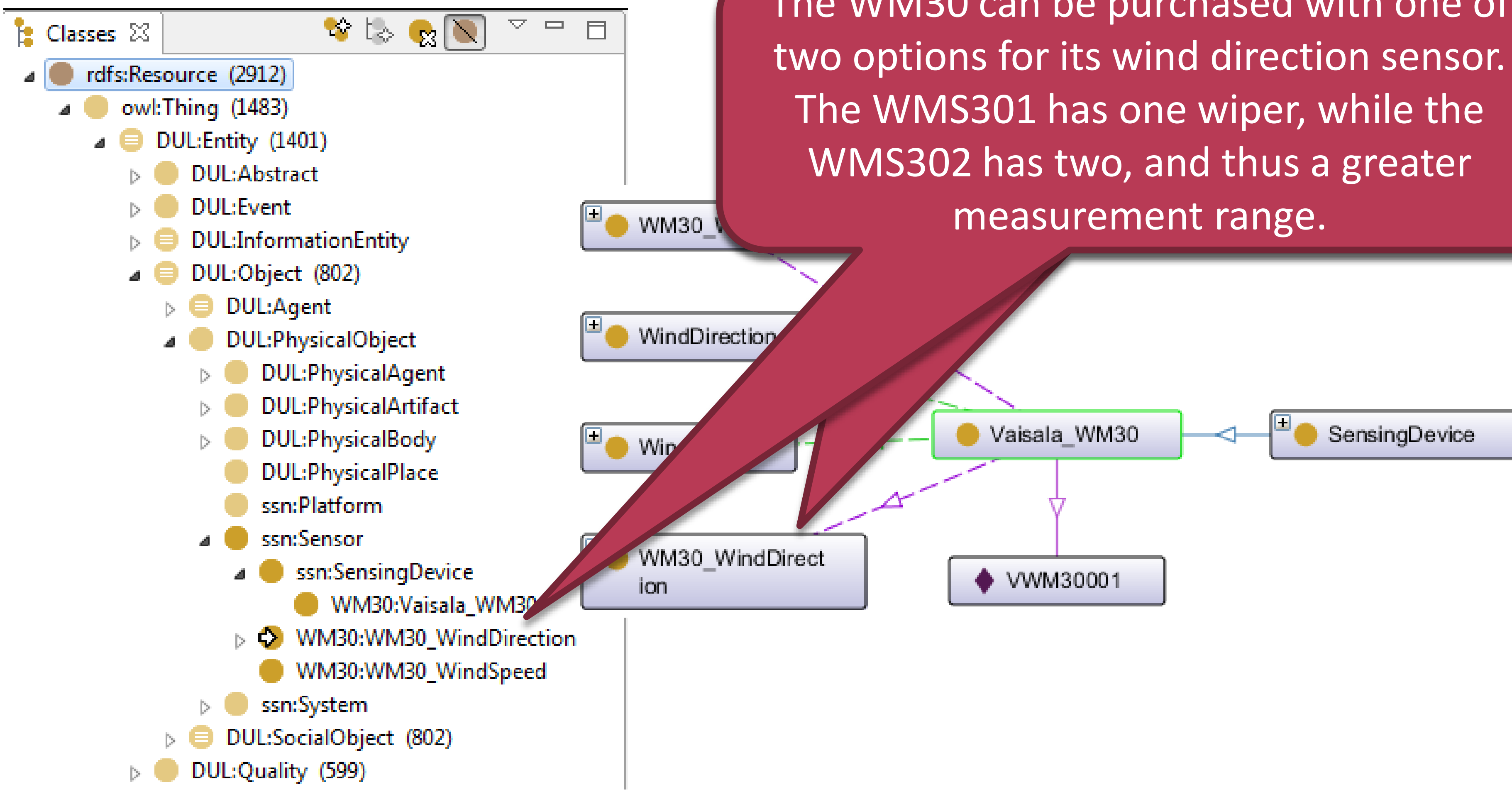


Measures
- wind speed
- wind direction.

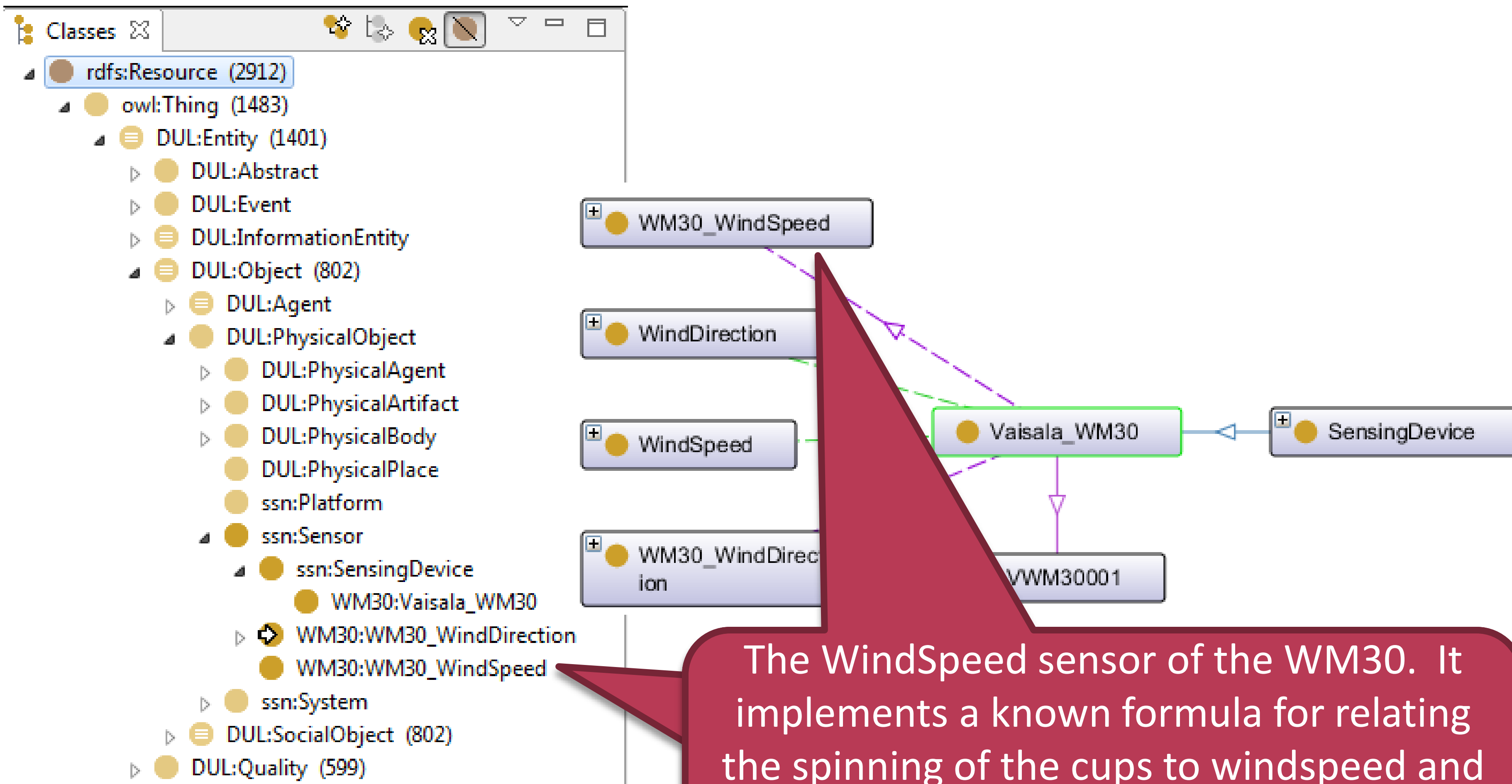
An instance of WM30

SSN – Wind Sensor

The WM30 can be purchased with one of two options for its wind direction sensor. The WMS301 has one wiper, while the WMS302 has two, and thus a greater measurement range.



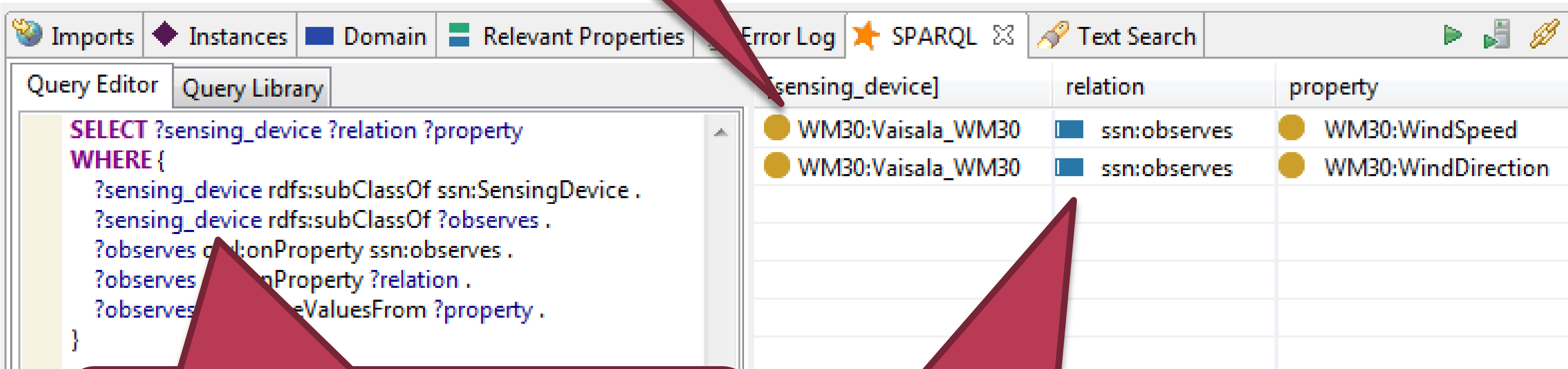
SSN – Wind Sensor



The WindSpeed sensor of the WM30. It implements a known formula for relating the spinning of the cups to windspeed and has different accuracies in different conditions.

SSN – Query

Result: set of triples



Get the all sensing device and the observed properties of it

(sensing_device, relation, property)
→
(Viasala_WM30, observes, WindSpeed)

MEASUREMENTS IN IT INFRASTRUCTURES

SSN – Sensing Device in IT

SPARQL Execution

Help

Query | Saved Queries

Default Graph IRI

Query

```
PREFIX ssn: <http://purl.oclc.org/NET/ssnx/ssn#>
SELECT *
WHERE {
    ?sensing_device a ssn:SensingDevice .
    ?sensing_device ssn:onPlatform ?platform .
    ?sensing_device ssn:observes ?observes .
    ?platform a ?platform_is_a.
}
```

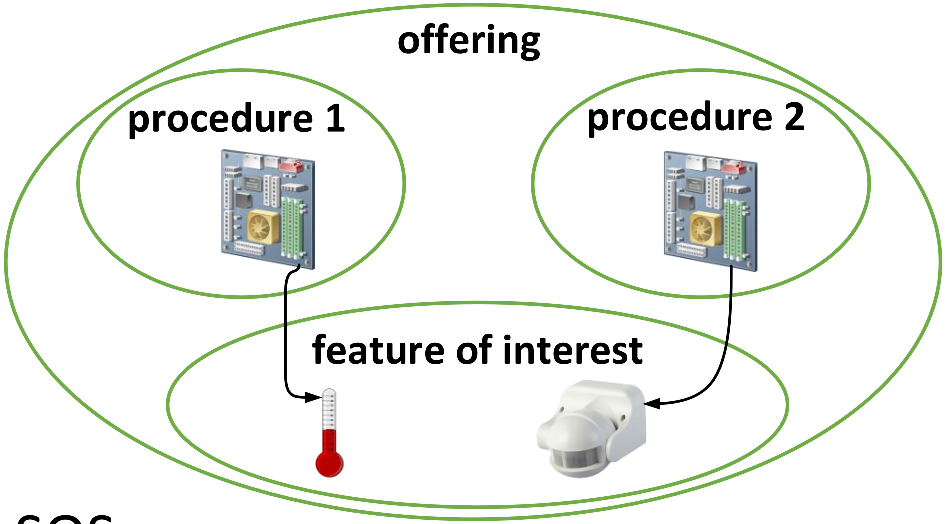
Execute | Save | Load | Clear

sensing_device	platform	observes	platform_is_a
http://cloudpaw/cwpoc1#beren.ftslab.local_ESXi	http://cloudpaw/cwpoc1#beren.ftslab.local	http://inf.mit.bme.hu/ontologies/cloudperf/vmware#Metric	http://inf.mit.bme.hu/ontologies/cloudperf/virtualization#PhysicalMachine
http://cloudpaw/cwpoc1#Clearwater_ESXi	http://cloudpaw/cwpoc1#Clearwater	http://inf.mit.bme.hu/ontologies/cloudperf/vmware#Metric	http://inf.mit.bme.hu/ontologies/cloudperf/virtualization#VirtualDomain
http://cloudpaw/cwpoc1#elrond.ftslab.local_ESXi	http://cloudpaw/cwpoc1#elrond.ftslab.local	http://inf.mit.bme.hu/ontologies/cloudperf/vmware#Metric	http://inf.mit.bme.hu/ontologies/cloudperf/virtualization#PhysicalMachine
http://cloudpaw/cwpoc1#luthien.ftslab.local_ESXi	http://cloudpaw/cwpoc1#luthien.ftslab.local	http://inf.mit.bme.hu/ontologies/cloudperf/vmware#Metric	http://inf.mit.bme.hu/ontologies/cloudperf/virtualization#PhysicalMachine

ONTOLOGIES AS STORAGE SCHEMA MODELS

Sensor Observation Service (SOS)

- Abstracts sensor data and communication
  - Self-describing sensor information database
  - Stores sensor data with geographic relevance
  - Efficient data queries
    - temporal or spatial filters
- Members of the CPS
  - direct communication with the SOS



RDF datastore

- Resource Description Framework (RDF)
- Stores statements:

  { subject, predicate, object } triples
- OWL → RDF
  - ABox axioms:
    - { Instance1 rdf:type Class1 }
    - { Instance1 hasProperty “value”^^xsd:string }
  - OWL: schema, RDF: data
- NoSQL, graph-based databases
  - SPARQL: query language, based on pattern matching
  - OWL reasoning

Architecture