An Ontology for Sensor Networks

W3C Semantic Sensor Networks Incubator Group

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Outline

- W3C Incubator group
- Starting points
- Sensor ontology
- Semantic annotation
- Outcomes

W3C Incubator Activity

- W3C : international web standards organisation
  - XML, HTML, CCS, OWL, Web Accessibility, …
- Incubator group
  - one-year (maximum two) exploratory group
  - potentially leading to other W3C activities or standards
  - collaborative research project and report - potential input to a standard, but not a standard itself
- Incubator groups are lightweight and initiated by W3C Members
- Incubator groups can use W3C infrastructure (mailing lists, communications tools, Web site, wiki, etc.)

W3C Semantic Sensor Network Incubator Group (SSN-XG)

- March 1, 2009 - September 3, 2010

- Chartered to
  - develop ontologies for semantically describing sensors
  - investigate mapping from these ontologies to existing standards and from documents complying with standards to the ontologies

- 33 participants from 18 W3C member organisations and 7 invited experts

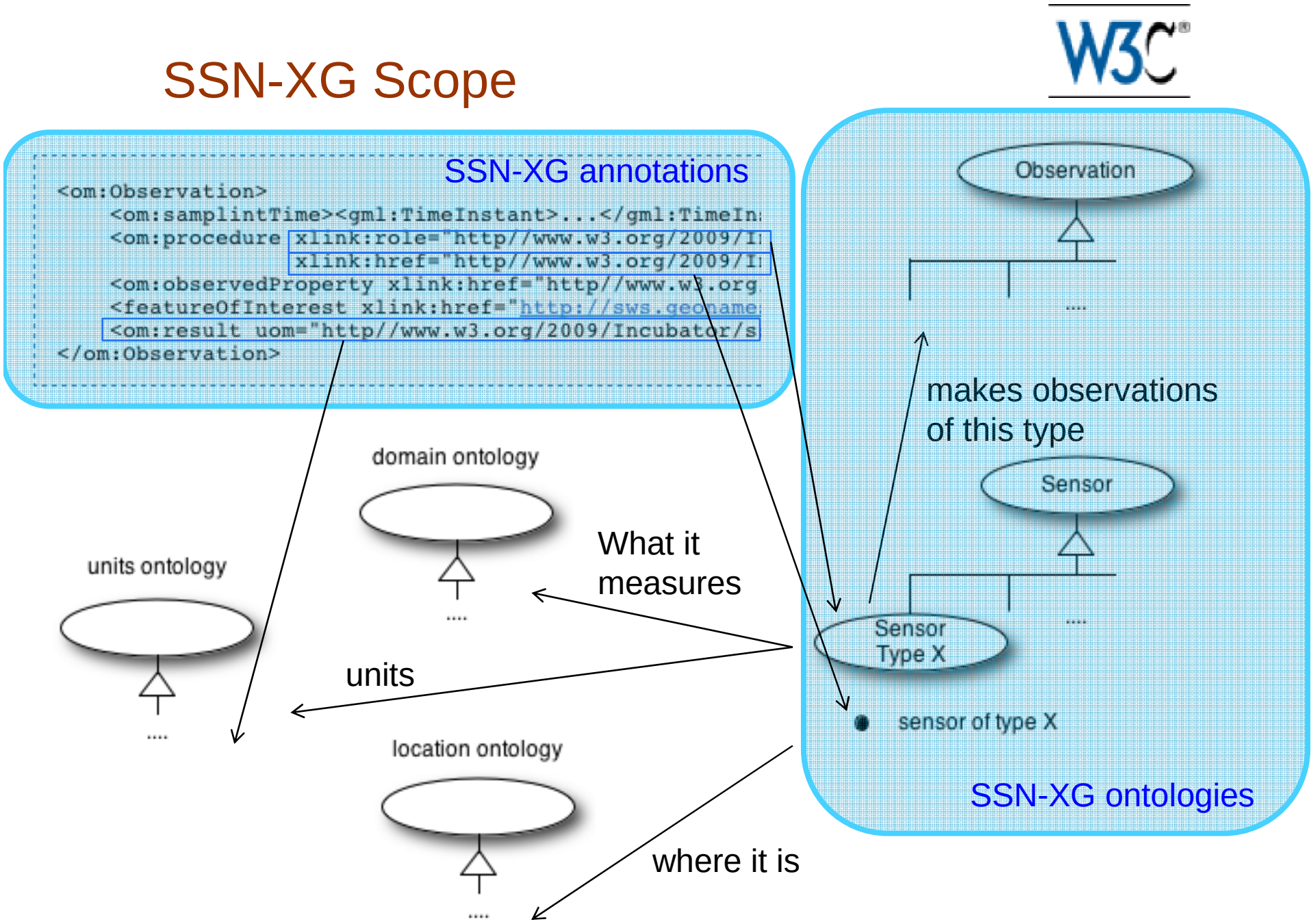
- Weekly phone+IRC meetings
- Face to face meeting October 2009
  - (8th International Semantic Web Conference)

Semantics and Ontologies

- Semantics = machine-readable metadata for mark-up,
  logical inference, query processing, linked data…

- For the incubator group this means
  - ontologies for: sensors (us), observations (us),
    domain concepts (not us), other data sources + services (not us)
  - Semantic annotation of documents in existing standards
  - reasoning / processing services to infer relationships and hierarchies,
    orchestrate queries and workflows, etc
- Semantics (/ontologies) as
  - meta data / knowledge bases
  - high level language for query or programming
  - resource for reasoning
- OWL2 ontologies – decidable, existing reasoners, …

SSN-XG Scope


SSN-XG annotations
<om:Observation>
<om:samplintTime><gml:TimeInstant>...</gml:TimeIn
<om:procedure xlink:role="http//www.w3.org/2009/I
xlink:href="http//www.w3.org/2009/I
<om:observedProperty xlink:href="http//www.w3.org
<featureOfInterest xlink:href="http://sws.geoname
<om:result uom="http//www.w3.org/2009/Incubator/s
</om:Observation>
Observation
....
makes observations of this type
Sensor
....
Sensor Type X
sensor of type X
SSN-XG ontologies
domain ontology
....
What it measures
units ontology
....
units
location ontology
....
where it is

Starting points

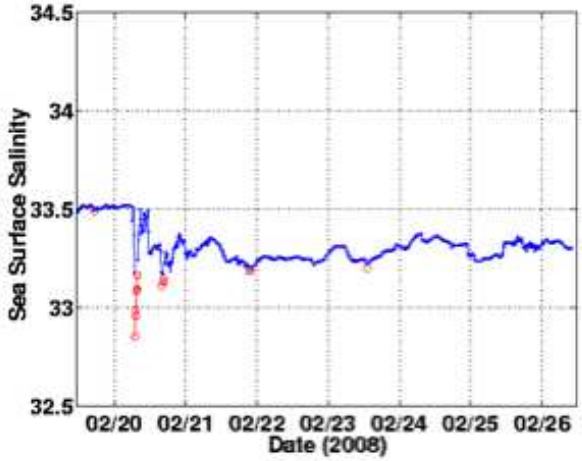
- SensorML (OGC)
- O&M (OGC, ISO)
- Other ontologies
  - OntoSensor
  - MMI Device
  - CSIRO sensor ontology
  - Observation ontologies
  - …

- Lots more on our wiki

Observation Model (O&M)

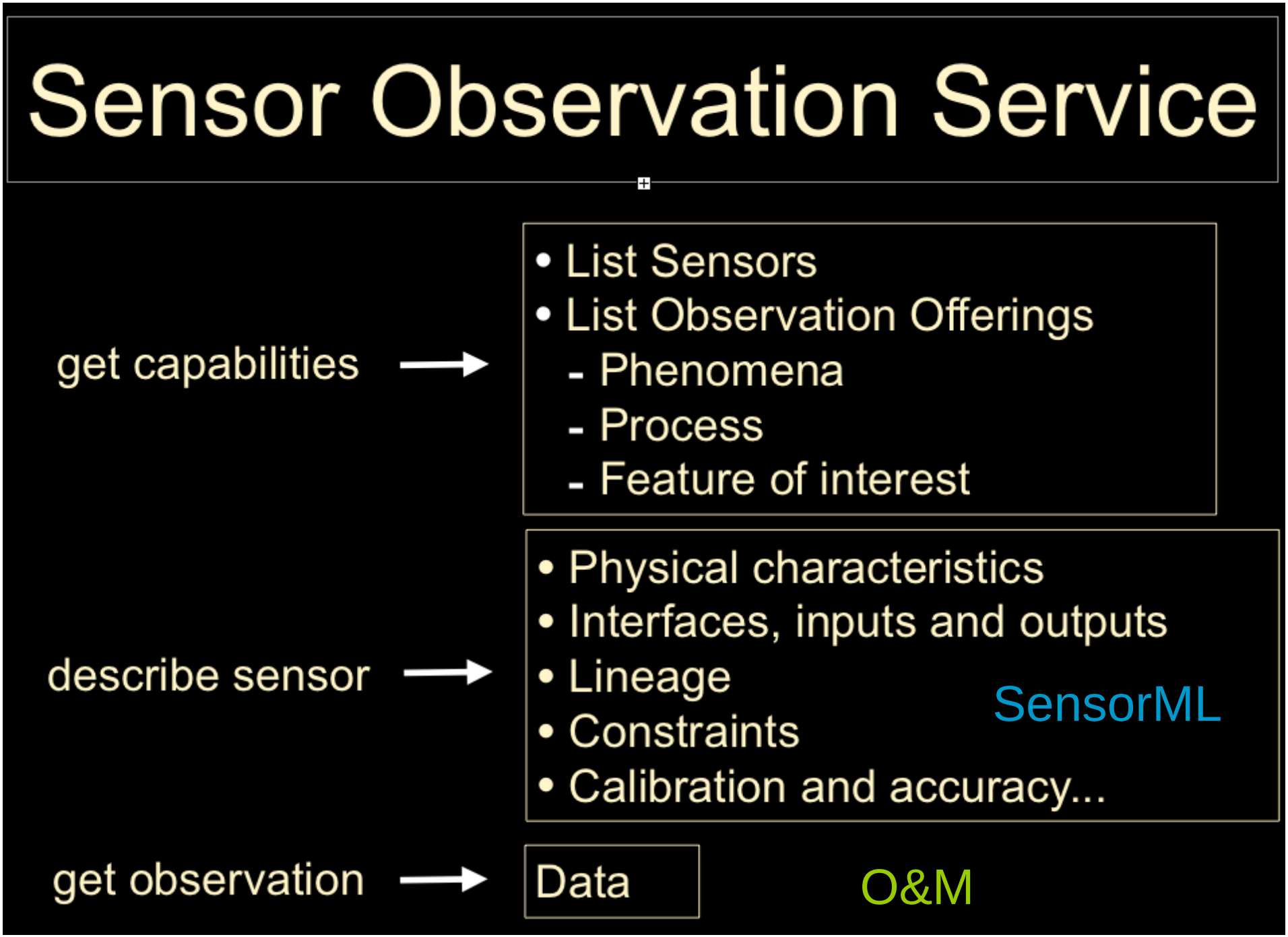
Procedure

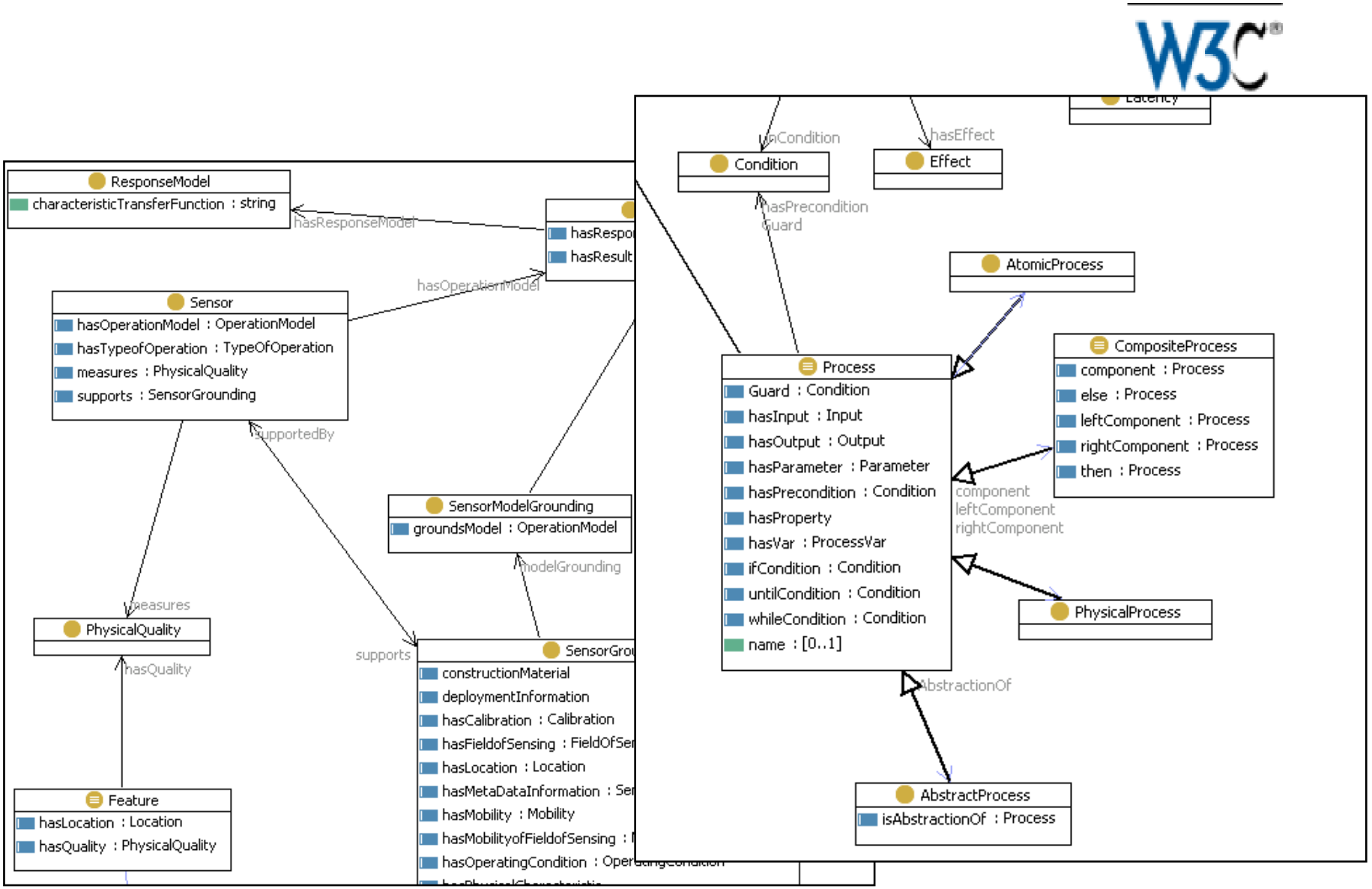
Feature of Interest = Monterey Bay



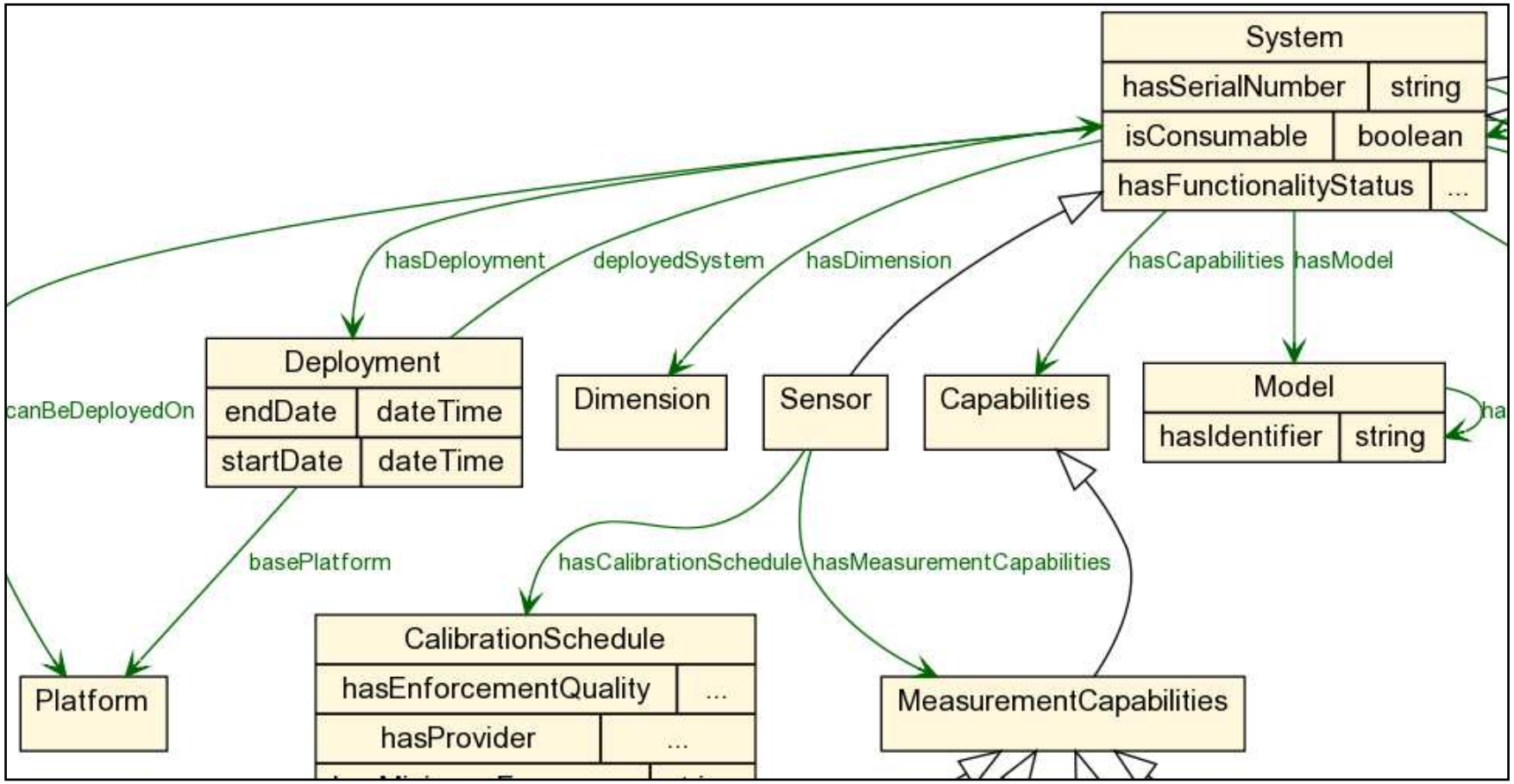
Estimation value of a property

Salinity = property related to the feature of interest

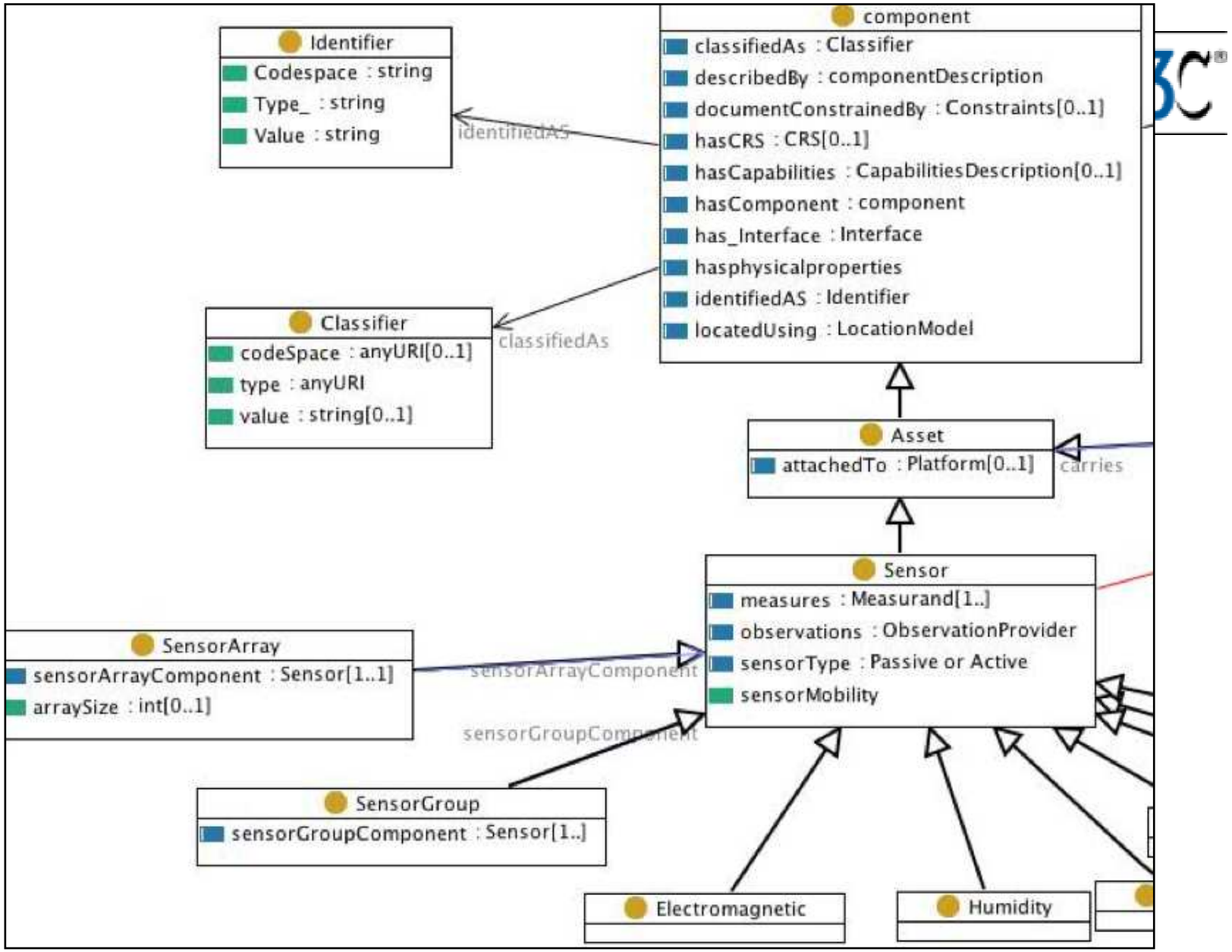

Sensor Observation Service
get capabilities
• List Sensors
• List Observation Offerings
- Phenomena
- Process
- Feature of interest
describe sensor
• Physical characteristics
• Interfaces, inputs and outputs
• Lineage
• Constraints
• Calibration and accuracy...
SensorML
get observation
Data
O&M



Semantic Sensor Network Ontology,
Michael Compton and Holger Neuhaus (CSIRO Australia)

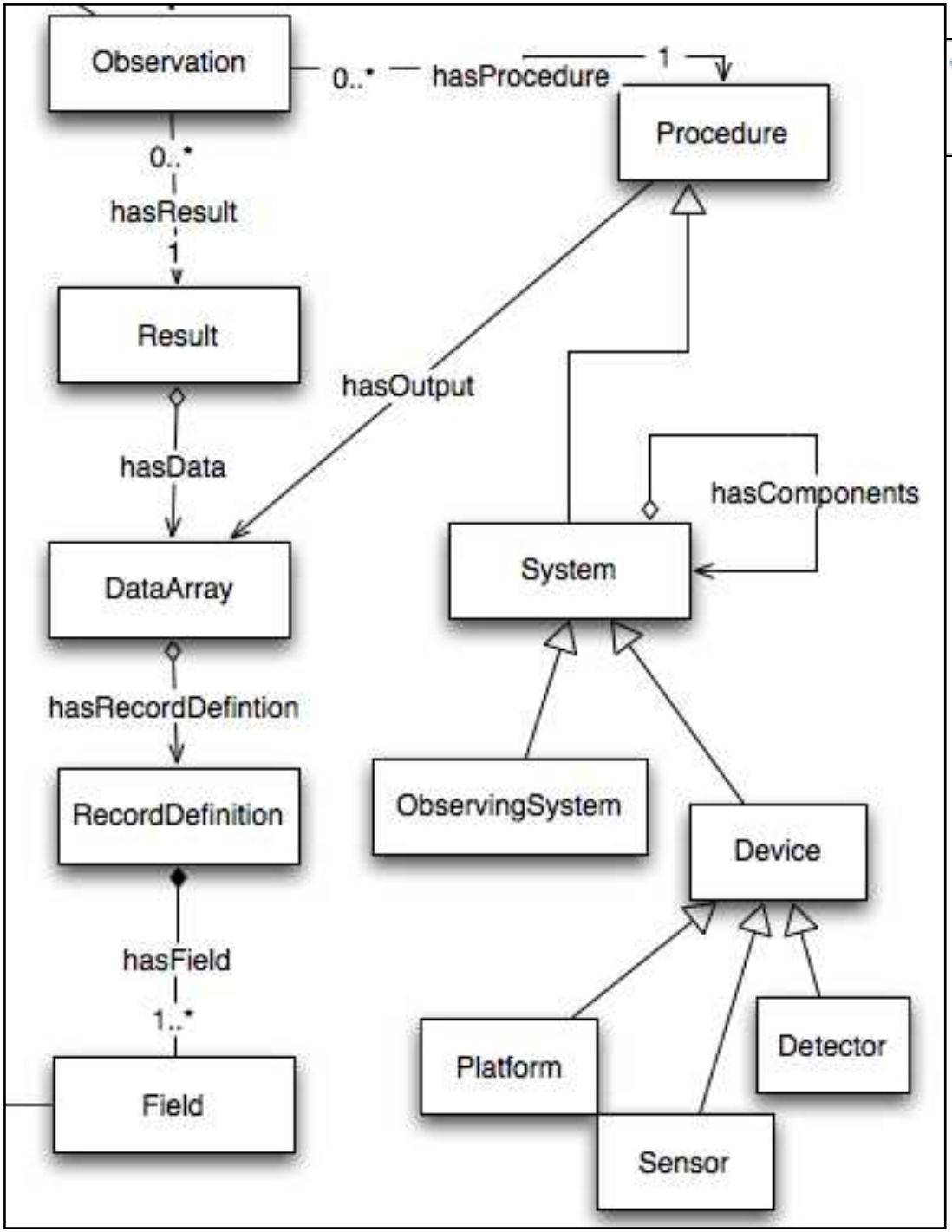


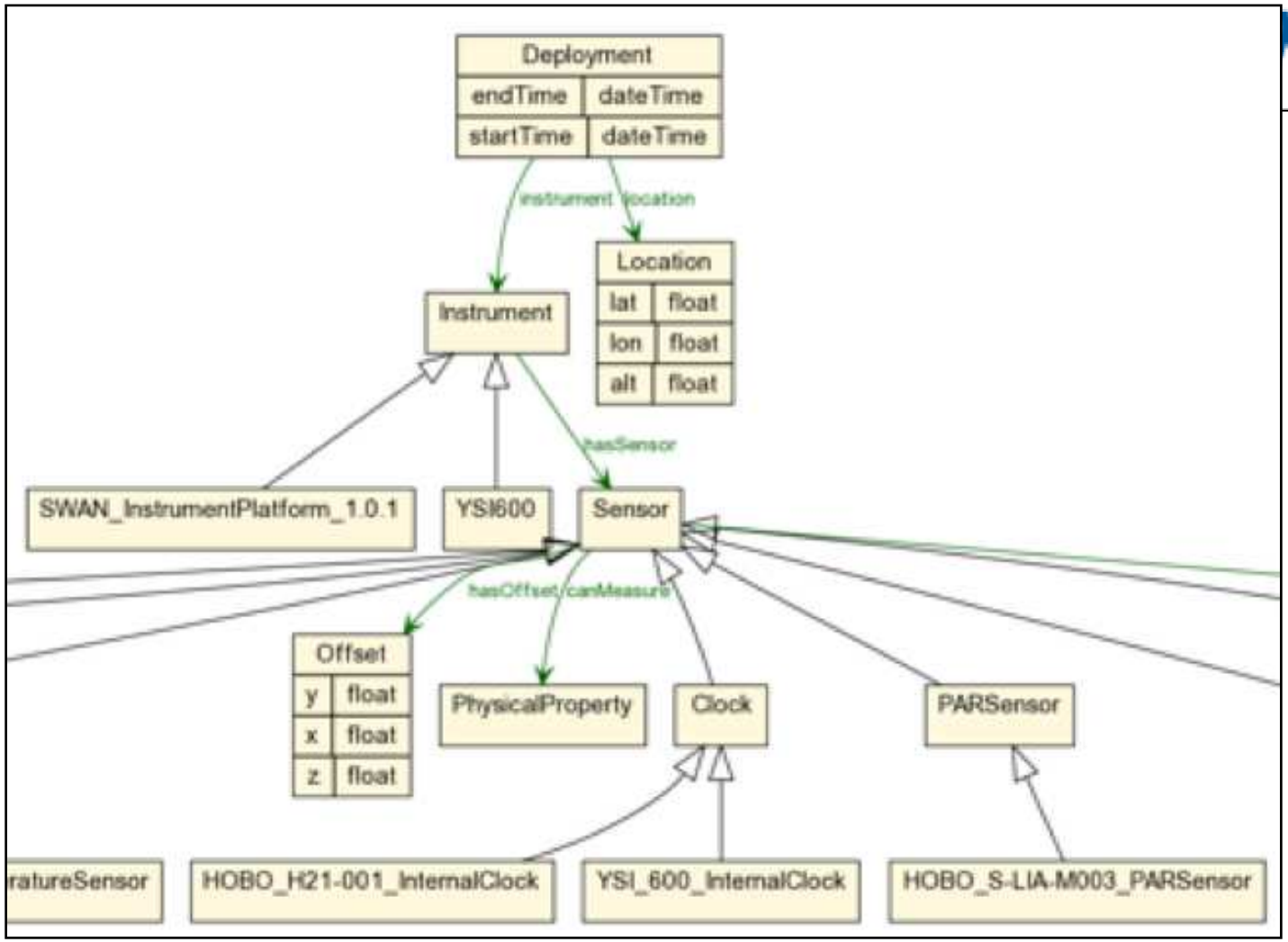
Device Ontology MMI



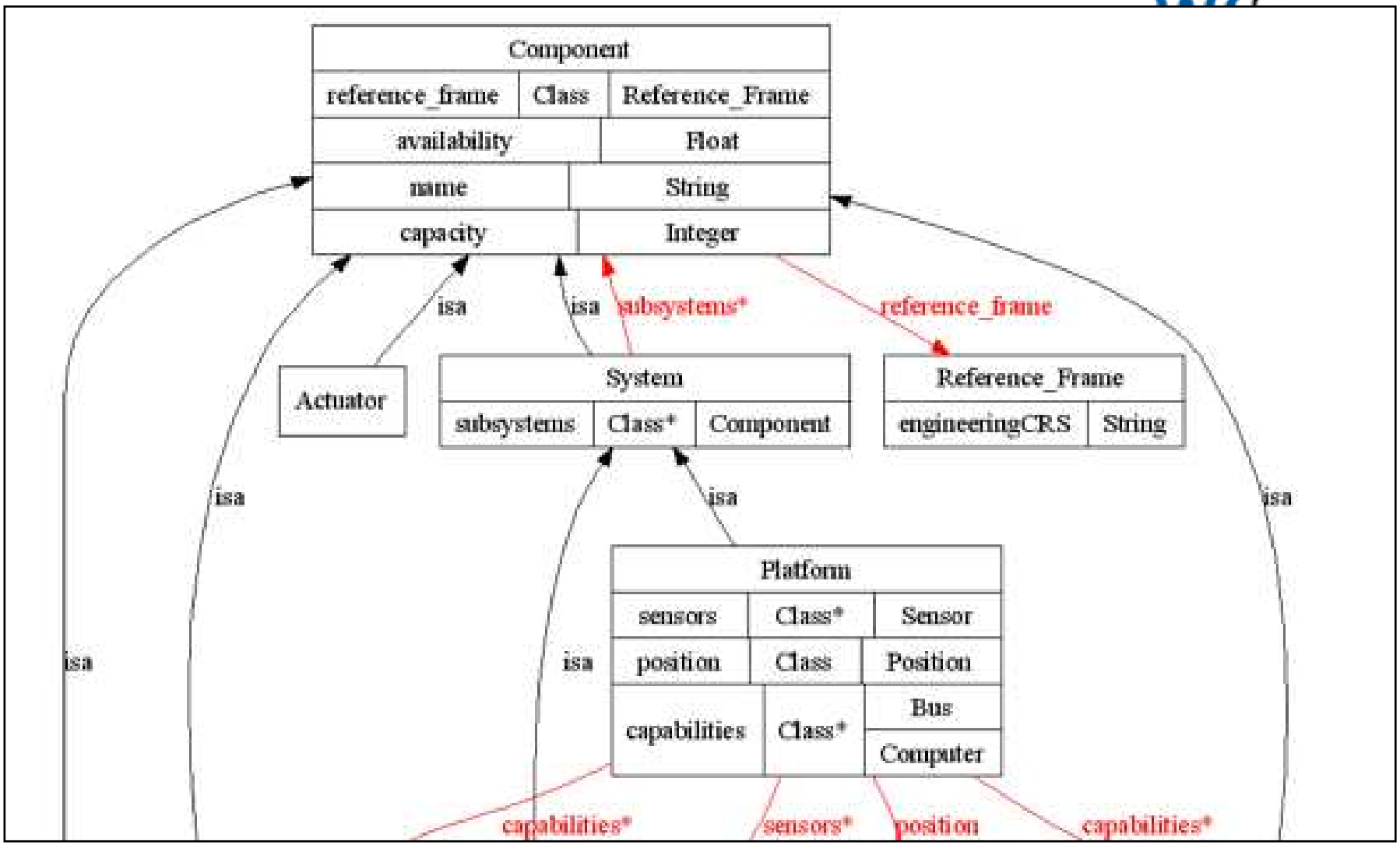
OntoSensor - U of Memphis - Center for Advanced Sensor

OOSTethys Model

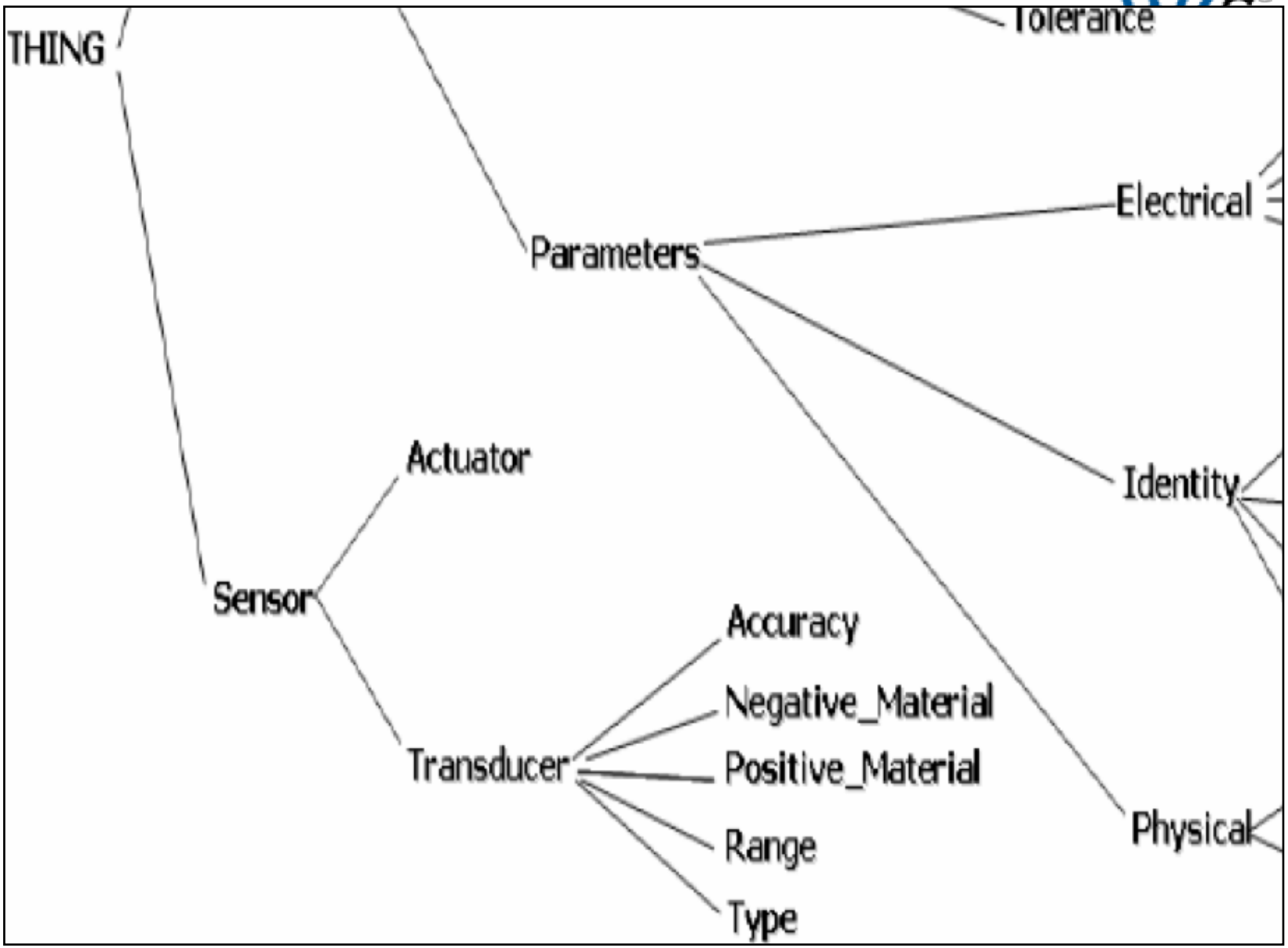




CESN Ontology - CESN at UMass Boston



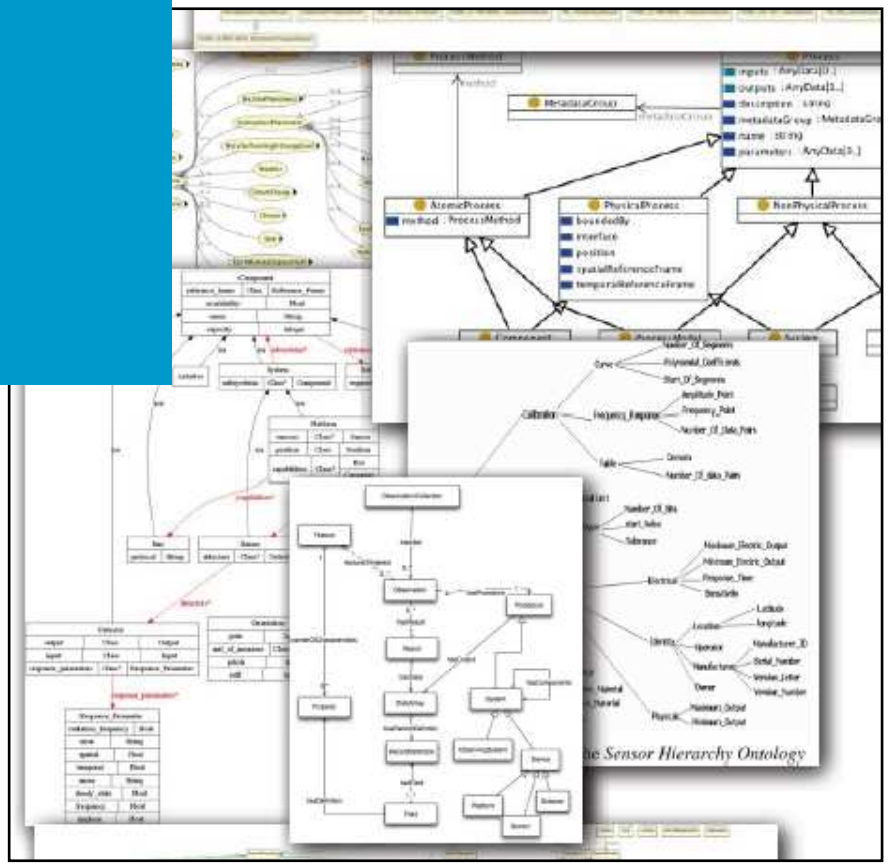
SWAMO Sensor Platform - Al Underbrink (Sentar)



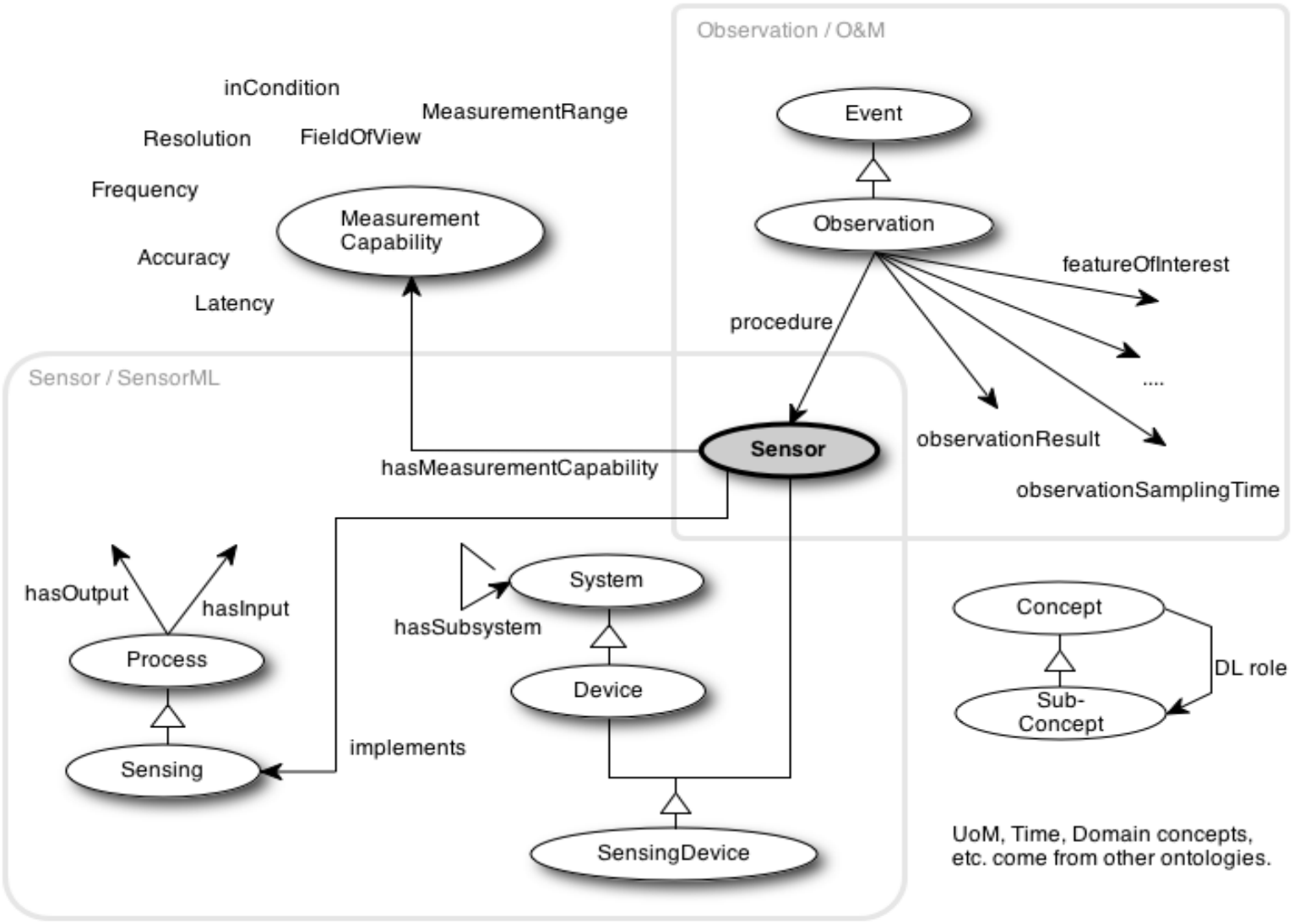
Sensor Hierarchy Ontology - Eid1 et. al., MCRLab, U. of Ottawa

Criteria to assess existing ontologies

- **Primary purpose/target**
- **Status**
- **Key concept**
- **Range of subject matter**
- **Level of sophistication**
- **Adoption**
- **Incorporation Concepts**



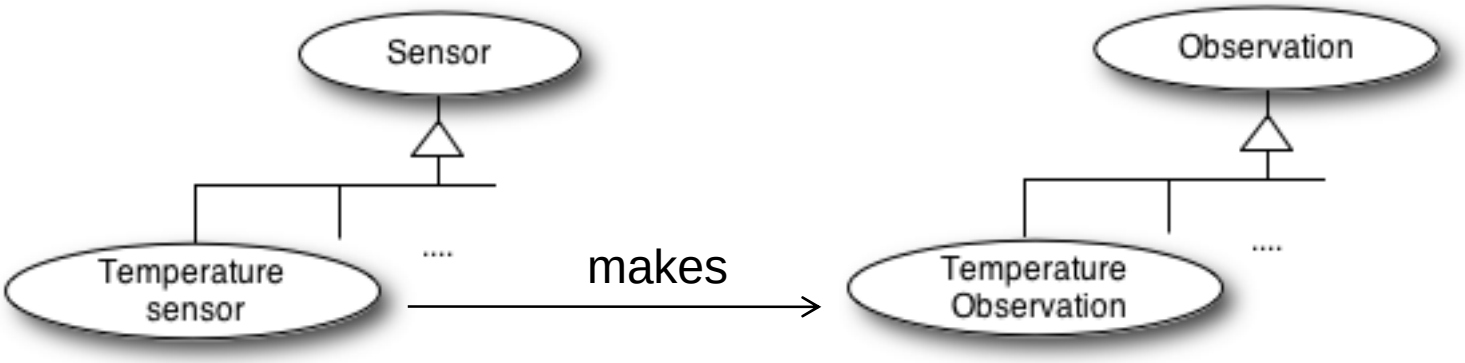
Ontology – basic structure



Also adding:
physical properties, power use, connectors, lifetime, etc (of devices/systems)
mobility, availability, operational ranges, callibration, ...

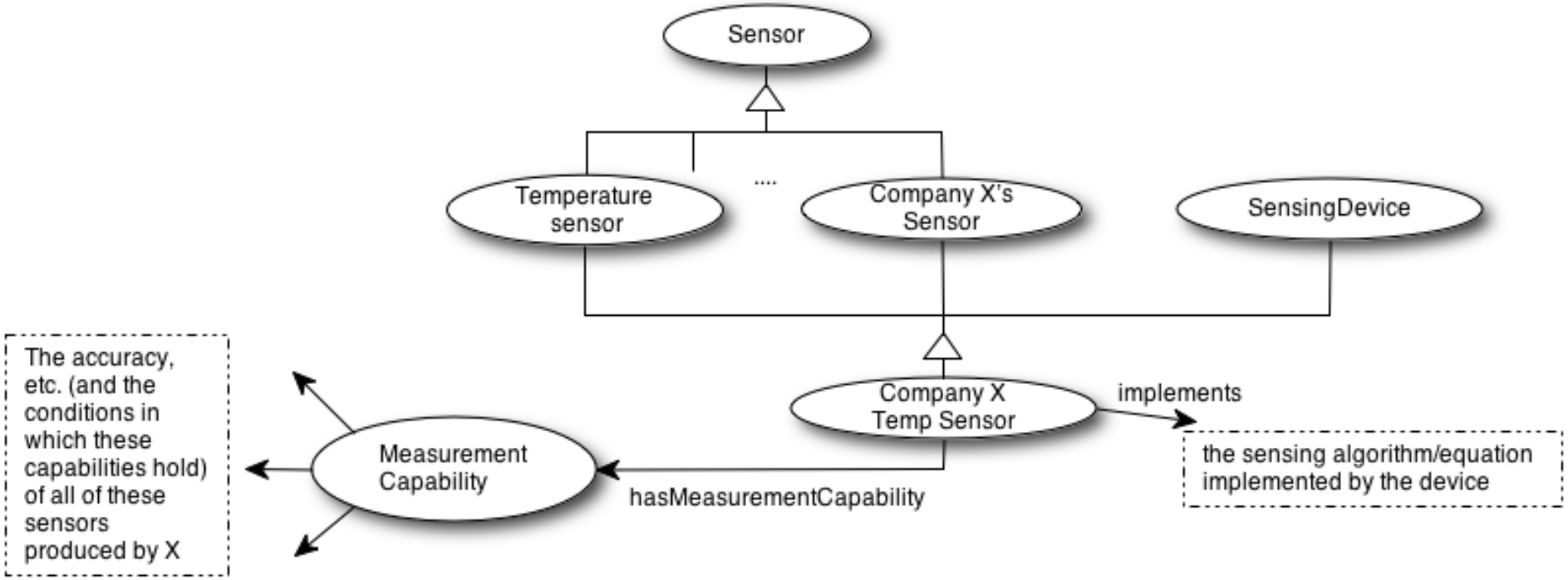
The Ontology Can Express (I)

- Types / concepts
  - e.g., the concept ‘temperature sensor’
  - hierarchies of sensing concepts into to which sensors can be classified



The Ontology Can Express (II)

- Specify a particular type of sensor (OWL concepts / TBox)
  - company X's device abc, is a sensor of Y, has accuracy …

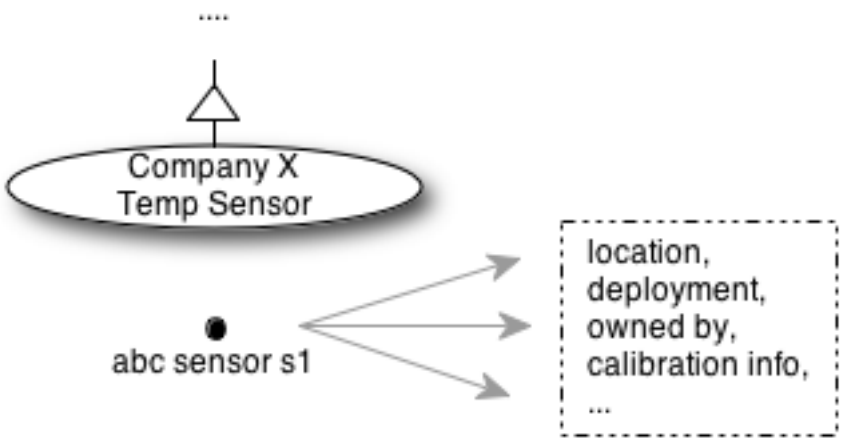


Properties of all abc devices – the particulars for abc instances belong in OWL individuals

The Ontology Can Express (III)

- Sensor instances (OWL individuals / ABox)
  - sensor s1 is an abc device from company X – and (soon) it's at location (x,y), was installed in deployment d, is owned by …

The instances all have the properties specified of the concept, so the abc instances inherit all the capabilities and restrictions specified for the concept in the Tbox.



The Ontology Can Express (IV)

- Sensor types as logical assertions
  - E.g. a reliable sensor has accuracy a in these conditions, has latency l, and was last serviced less than 6 months ago…

$$ReliableXSensor \sqsubseteq XSensor \sqcap$$
$$\exists\, hasMeasurementCapability.\exists\, withAccuracy \ldots$$
$$\exists\, inCondition \ldots$$
$$\sqcap \quad \ldots$$
$$\ldots$$

- DL reasoner can classify concepts and instances accordingly
  - classification, search, verification (x is a reliable sensor)

Semantic Annotation

An **Annotation** is an addition made to information in a book, document, online record, video, or other information.

A **Web annotation** is an online annotation associated with a web resource, typically a web page or XML document.

A **Semantic Annotation** is a web annotation which adds information to a web resource that is described in an ontology.

Mechanics of Semantic Annotation

Use of XLink for encoding Semantic Annotation

Attribute	Definition
xlink:href	link to instance
xlink:role	link to ontology concept
xlink:arcrole="http://www.w3.org/ns/sawsdl#modelReference"	specifies that xlink is currently being used as a model reference (or semantic annotation)

RDF Interpretation of XLink Semantic Annotation

Attribute	Description	Intended RDF
xlink:href	Identifier of the resource which is the target of the association, given as a URI	rdf:about of range resource
xlink:role	Nature of the target resource, given as a URI	rdf:about of class of range resource
xlink:arcrole	Role or purpose of the target resource in relation to the present resource, given as a URI	rdf:about of object property linking domain element to range resource
xlink:title	Text describing the association or the target resource	rdfs:comment

Example of Semantic Annotation (within SOS GetCapabilities)

- Sensor Availability

```
<sos:time><gml:TimePeriod
      xlink:role="http://www.isi.edu/~pan/damltime/time-entry.owl#Interval"
      xlink:arcrole="http://www.w3.org/ns/sawsdl#modelReference">
      <gml:beginPosition
            xlink:role="http://www.isi.edu/~pan/damltime/time-entry.owl#begins"
            xlink:arcrole="http://www.w3.org/ns/sawsdl#modelReference">
            2005-10-18T19:54:13.000Z
      </gml:beginPosition>
      <gml:endPosition
            xlink:role="http://www.isi.edu/~pan/damltime/time-entry.owl#ends"
            xlink:arcrole="http://www.w3.org/ns/sawsdl#modelReference">
            2005-10-18T19:54:13.000Z
      </gml:endPosition>
</gml:TimePeriod></sos:time>
```

- Property (or observable)

```
<sos:observedProperty
      xlink:href="http://knoesis.wright.edu/ssw/ont/weather.owl#AirTemperature"
      xlink:role="http://www.w3.org/2009/SSN-XG/Ontologies/SensorBasis.owl#Property"
      xlink:arcrole="http://www.w3.org/ns/sawsdl#modelReference"/>
```

- Location (as a Feature)

```
<sos:featureOfInterest
      xlink:href="http://sws.geonames.org/5248611/"
      xlink:role="http://www.w3.org/2009/SSN-XG/Ontologies/SensorBasis.owl#Location"
      xlink:arcrole="http://www.w3.org/ns/sawsdl#modelReference"/>
```

- Sensor ID

```
<sos:procedure
      xlink:href="http://knoesis.wright.edu/ssw/System_C1988"
      xlink:role="http://www.w3.org/2009/SSN-XG/Ontologies/SensorBasis.owl#Sensor"
      xlink:arcrole="http://www.w3.org/ns/sawsdl#modelReference"/>
```

Outcomes

- Reviewed existing ontologies and annotation techniques
- Built a sensor ontology
  - Core sensor and observation concepts
  - Other ontologies outside SSN-XG scope
- Investigated annotation
  - See also: Laurent Lefort “Review of semantic enablement techniques used in geospatial and semantic standards for legacy and opportunistic mashups”, Australian Ontology Workshop, 2009
- Final documents and deliverables coming soon
- Check out our wiki

Contacts and Web sites

- **Wiki**:
  http://www.w3.org/2005/Incubator/ssn/wiki
- **Charter**:
  http://www.w3.org/2005/Incubator/ssn/charter

- **Co-Chairs**
  - Holger Neuhaus: Holger.Neuhaus@csiro.au
  - Amit Sheth : Amit.Sheth@wright.edu
  - Kerry Taylor: Kerry.Taylor@csiro.au

Participants

- **CSIRO**: Michael Compton, Holger Neuhaus, Kerry Taylor, Laurent Lefort, Simon Cox (also at JRC)
- **SURA / Oceans IE**: Luis Bermudez
- **Kno.e.sis Center**: Cory Henson, Amit Shet
- IAM Group, **University of Southampton**: Kevin R. Page
- **University of Surrey / SENSI**: Payam Barnaghi
- **Technische Universität Darmstadt**: Arthur Herzog
- **Pennsylvania State University**: Krzysztof Janowicz
- **UPM Ontological Engineering Group**: Oscar Corcho
- **CTIC Foundation**: Rodrigo García, Víctor Peláez
- **MBARI / MMI Project**: John Graybeal
- And others…

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Holger Neuhaus holger.nuehaus@csiro.au
Luis Bermudez bermudez@sura.org
Simon Cox simon.cox@jrc.ec.europa.eu

Thank you

Related Projects

- SENSEI http://www.sensei-project.eu/
- SemSorGrid4Env http://www.semsorgrid4env.eu/
- 4WARD http://www.4ward-project.eu/
- ASPIRE http://www.fp7-aspire.eu/
- WISEBED - Wireless Sensor Network Testbeds, http://www.wisebed.eu/

- See also http://rwi.future-internet.eu/index.php/Participants_Page

A language to describe sensors
SSN-XG Sensor Ontology

- Ontology for describing sensors and observations
  - *not* a taxonomy of all concepts relating to sensing,
  - an ontology in which sensor types and instances can be specified
- ➔ an ontology covering SensorML, O&M and other bits

- Framework for sensors and for applications to plug in:
  - domain ontology
  - location ontology
  - time ontology
  - UoM ontology, *etc.*
- Support for *e.g.* MathML, external links to extend OWL
- Align SensorML, O&M and the DOLCE (upper ontology)