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Maximize Utility of Sensor Derived Data Through Metadata

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Overview

- Sensor Uses
- What is Metadata?
- Data Fusion, Lineage, Provenance
- Sensor Ontology
- Synthetic Sensors and Metadata
- Standards and Interoperability
- Metadata Usage Example

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Sensor Uses

- Quickly discover sensors and sensor data
  - location, observables, quality, ability to task
- Obtain sensor information in a standard encoding
  - understandable by me and my software
- Readily access sensor observations
  - common manner, and in a form specific to my needs
- Task sensors, to meet my specific needs
- Subscribe to and receive alerts / notifications
  - sensor measures /computes a particular phenomenon

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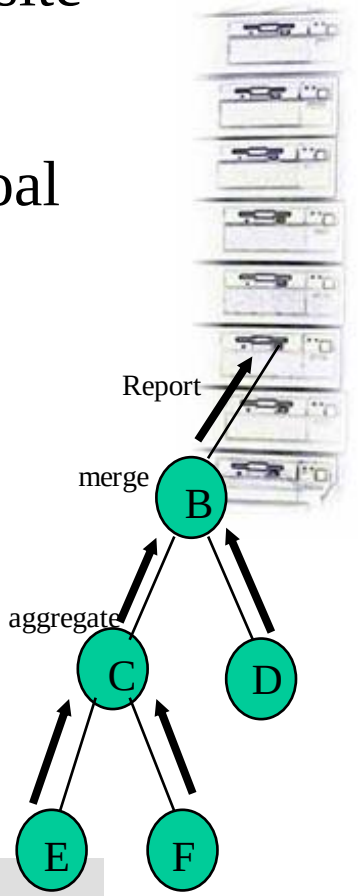
What is Metadata?

- The term is used with varying definitions
  - structured information that facilitates the understanding, identification, discovery, description, lineage, pedigree, localization, context, or otherwise makes it easier to retrieve, use, assess or manage an information resource.

- Metadata Classification
  - Based on Syntax and semantics
    - what does data look like
    - how is it organized
    - what real-world entity is it representing
  - Based on Use
    - management
    - discovery
    - application

Data Fusion

- Form of Structural Metadata
  - acquisition, filtering, correlation, aggregation, integration of *relevant* information to form a composite data item
  - Models for integration vary depending on the end goal (e.g., greedy, best fit, Bayesian, ontological, etc.)
  - Centralized, decentralized, distributed models have been implemented
  - Data Fusion is a “process” in metadata, aiding in lineage of synthetic measurement



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Data Lineage and Provenance

Form of Definitional Metadata

- Data Lineage
  - where it comes from
  - where it flows to
  - how it's transformed as it moves within a system
- Data Provenance
  - from the French *provenir*, “to come from”
  - chronology of *ownership* or location of an object
  - Most important who, where, why, what for an object

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Sensors and Ontology

- Form of Highly structured metadata defining:
  - An explicit specification of a conceptualization
  - a description of the *concepts* and *relationships* that exist for a domain or a community

- How is this related to Metadata?
  - Metadata typically describes an individual sensor
  - Ontology describes how to organize and use metadata within a domain
  - Ontology provides additional means for integrating sensor data into actionable information space
  - Specialized highly structured formalized version of metadata

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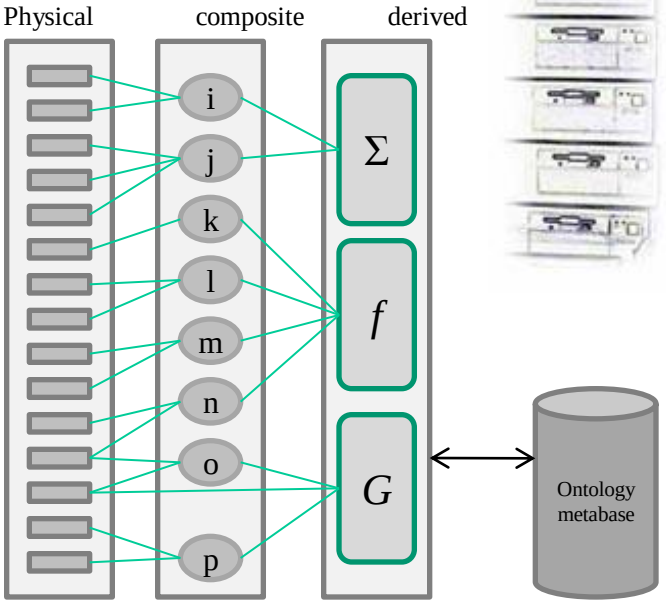
Synthetic Sensors

- A Sensor
  - Physical device (transducer and processing) to measure a physical quantity and possibly convert to an observable signal
  - Require metadata in some form to make measurements useful
- A Virtual Sensor
  - A model built strictly from data, vice an explicate system model that is based on equations that describe the system.
    - two major uses:
      - Monitor unreliable sensors.
      - Replace expensive sensors with cheaper measuring devices.
- A Synthetic Sensor
  - A sensor built using raw and or other synthetic measurements using metadata, protocols and algorithms to produce a composite measure
    - Used when physical sensors unavailable, unreliable, to slow, to costly
    - No means to install (space, weight, power)
    - To hostile (jet engine)



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Sensor Standards

- Standards come in two forms
  - Defacto closed – produced by a proprietary organization
  - Open by Consensus (standards bodies, IEEE, etc.)
- Example Sensor Metadata Standards
  - TEDS (transducer description, basic operations)
  - TransducerML (characterization of sensors, extended ops)
  - SensorML (Sensor and environment, web enabling)
  - IEEE 1451 (family of standards for sensors, actuators,)
  - IHAL (instrument descriptions vendor neutral)

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Example Metadata Representation

- SensorML:
  - XML encoding for describing sensor processes
    - Including sensor tasking, measurement, and post-processing of observations
    - Detectors, actuators, sensors, etc. are modeled as physical processes
  - Open Standard
    - Approved by Open Geospatial Consortium in 2007
    - Supported by Open Source software (COTS development ongoing)
  - Not just a metadata language
    - enables on-demand execution of algorithms
  - Describes
    - Sensor Systems
    - Processing algorithms and workflows

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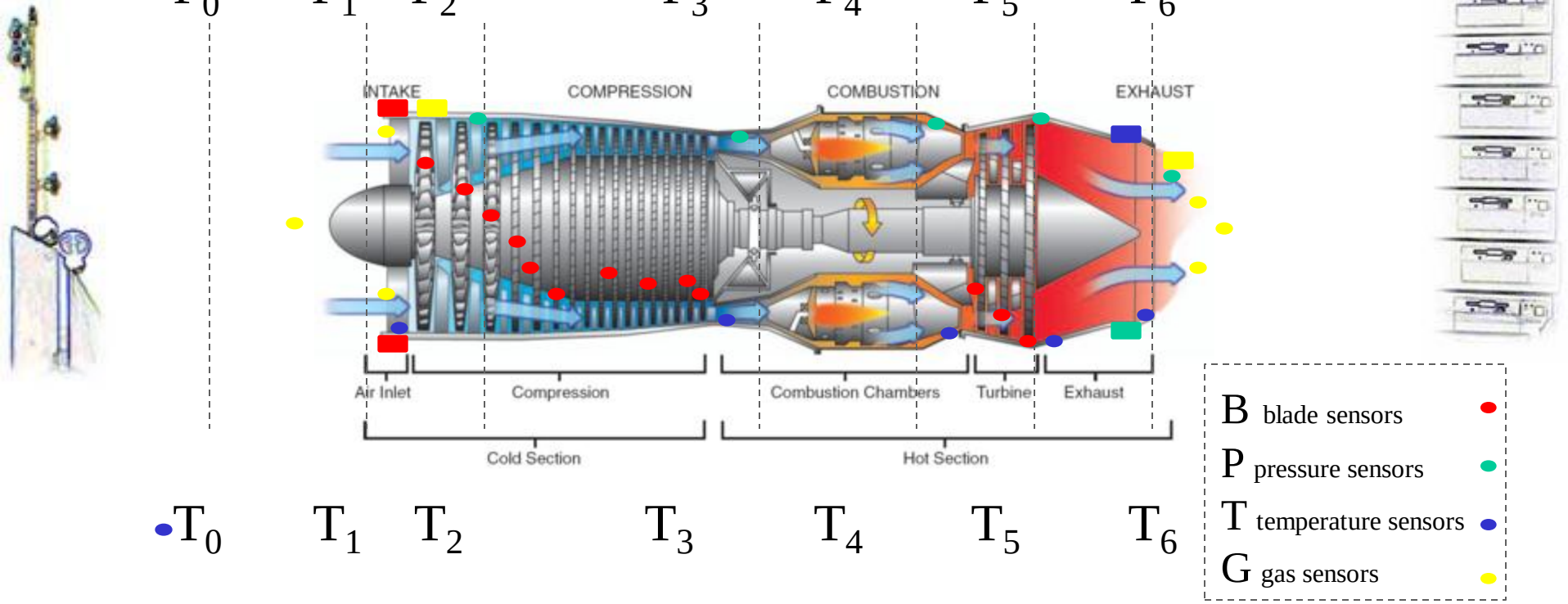
Example use of Metadata - Jet Engine Testing System



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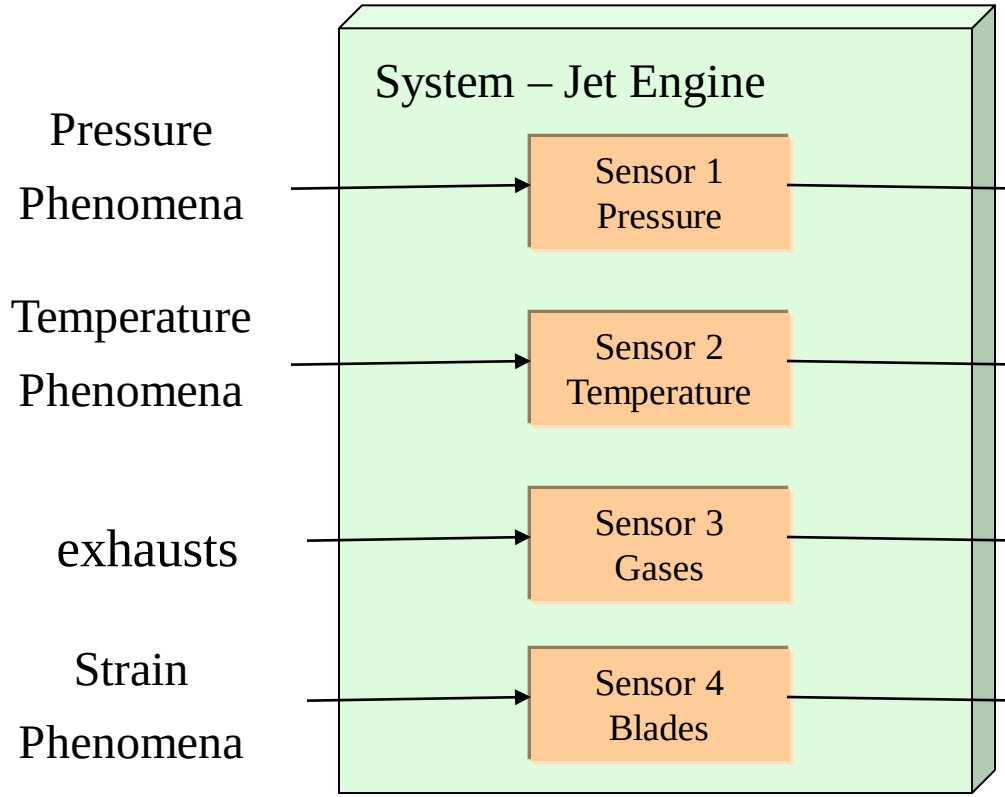
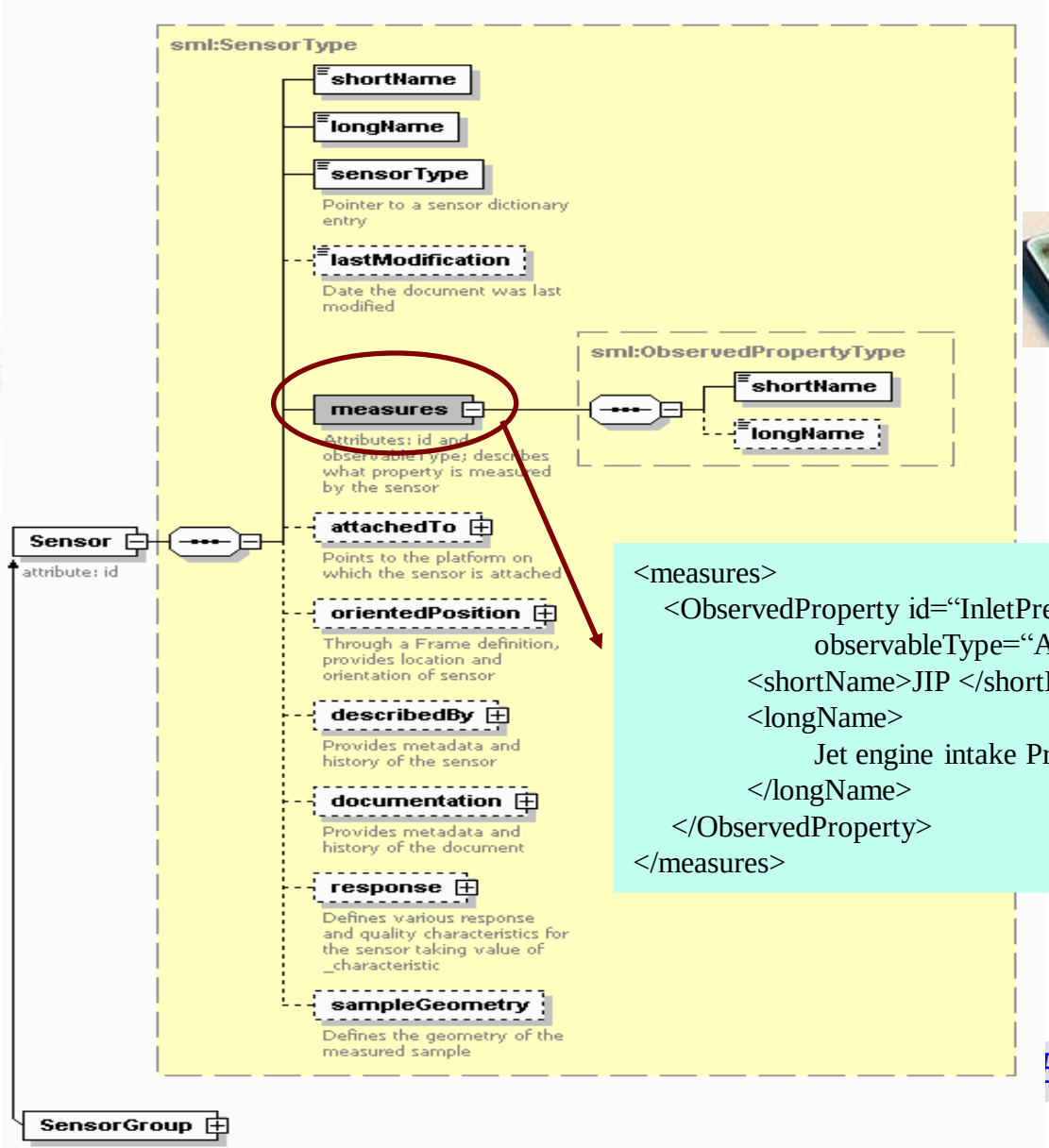
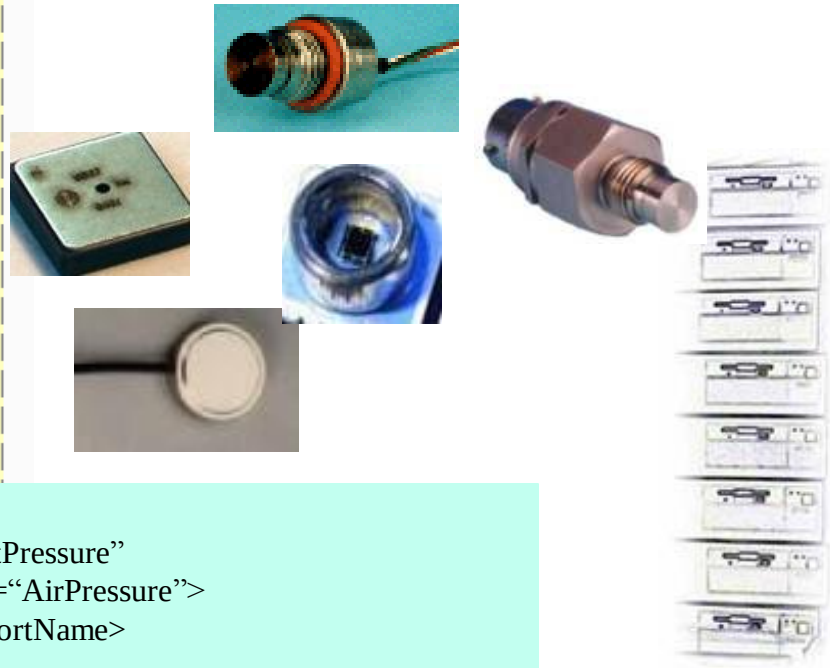
SensorML



Measurement Definition




```
<measures>
   <ObservedProperty id="InletPressure"
                     observableType="AirPressure">
            <shortName>JIP </shortName>
            <longName>
                  Jet engine intake Pressure designated P1
            </longName>
    </ObservedProperty>
</measures>
```



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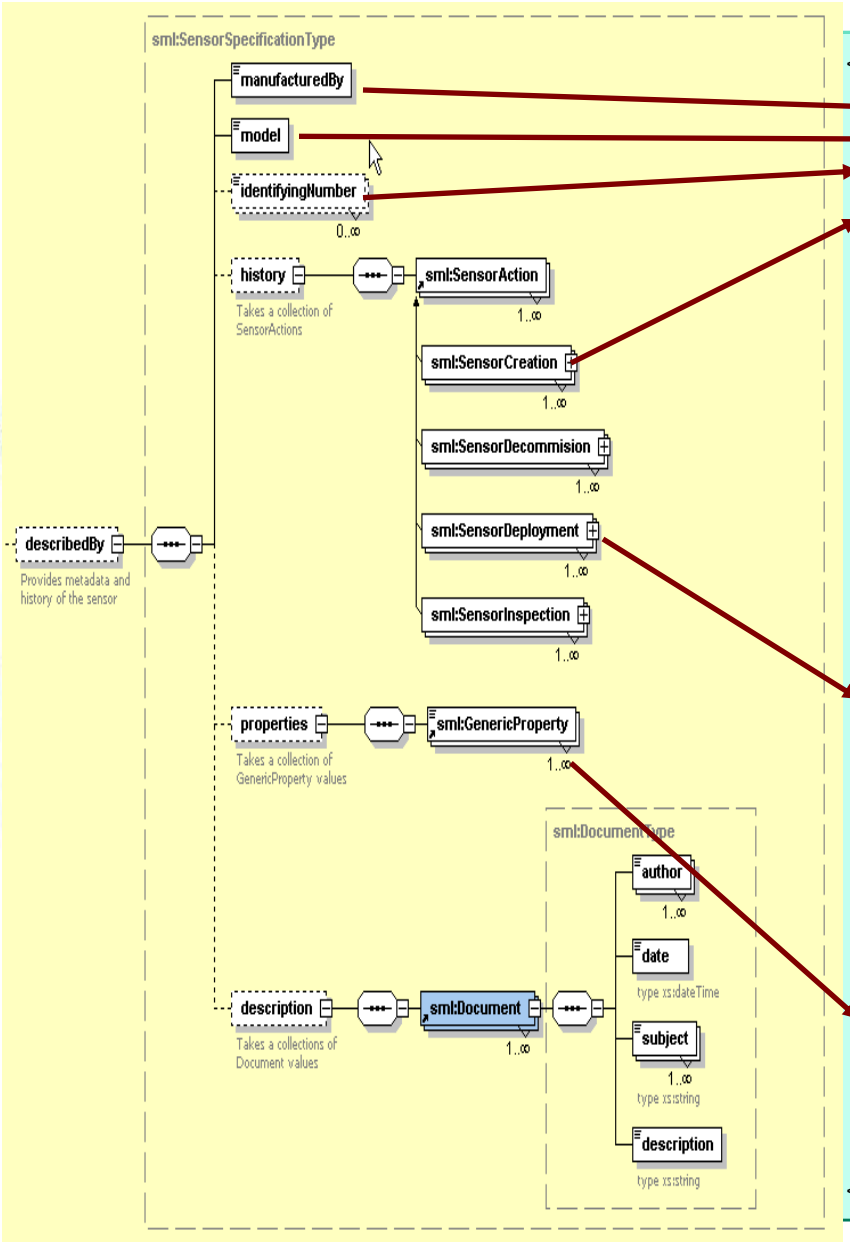
Sensor Description




```
<describedBy>
 <SensorSpecification>
  <manufacturedBy> JTest </ manufacturedBy>
  <model> JT-P1 </model>
  <identifyingNumber type="serialNumber"> JT-P1-s123987 </identifyingNumber>
  <history>
   <SensorCreation>
    <byWhom>
                <Person>
                 <fullName John Doe </fullName>
                </Person>
    </byWhom>
    <when> 2011-5-01 </when>
    <supportingDocuments>
                <Reference id="JT-P1-12-09">
                 <authors>
                  <Persons>
                   <fullName> Joe Jetson </fullName>
                  </Person>
                 </authors>
                 <publishingDate> 2008-01-15 </publishingDate>
                 <documentTitle> Blueprints for Pressure sensor JT-PN </ documentTitle>
                </Reference>
    </supportingDocuments>
   </SensorCreation>
   <SensorDeployment>
     <byWhom>
       <Person>
        <fullName Jack Engineer </fullName>
       </Person>
      </byWhom>
     <where> Jet Test Stand at JT Facility Bldg 1171, Dartmouth, MA </where>
      <when> 2012-05-05 </when>
      <description> Attached to Cowling inlet at Outer edge at degree 0 </description>
   </SensorDeployment>
  </history>
 <properties>
  <genericProperty name="sensorTechnology" dataType="xs:string"> high pressure </genericProperty>
  <genericProperty name="measurementMethod" dataType="xs:string"> EPA accepted </genericProperty>
  <genericProperty name="membraneThickness" dataType="xs:double" uom="#mil">1.0 </genericProperty>
  <genericProperty name="probeSolutionType" dataType="xs:string"> Piezoresistive </genericProperty>
 </properties>
 </SensorSpecification>
</describedBy>
```

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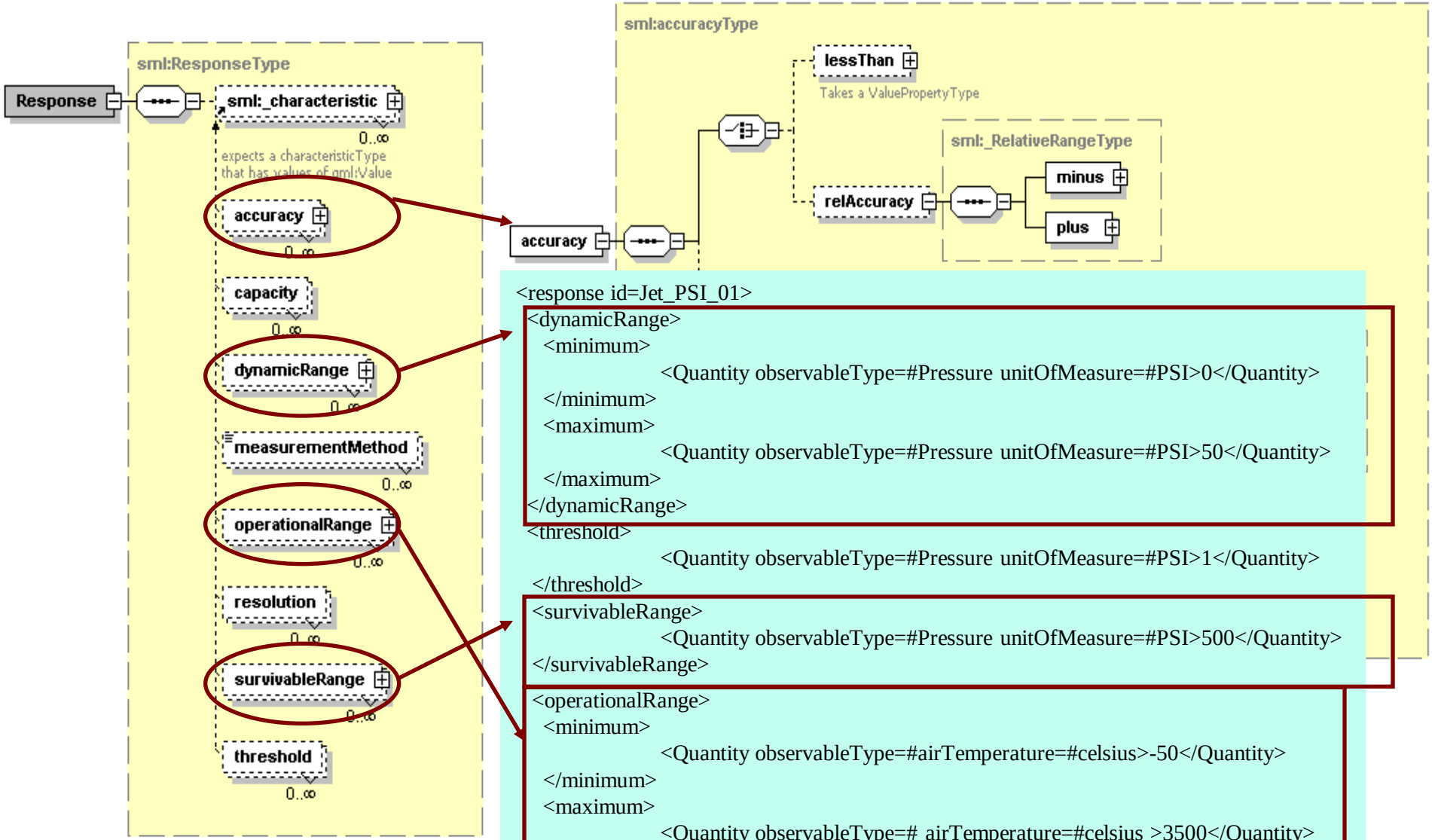
Sensor Response




```
<response id=Jet_PSI_01>
 <dynamicRange>
  <minimum>
            <Quantity observableType=#Pressure unitOfMeasure=#PSI>0</Quantity>
  </minimum>
  <maximum>
            <Quantity observableType=#Pressure unitOfMeasure=#PSI>50</Quantity>
  </maximum>
 </dynamicRange>
 <threshold>
            <Quantity observableType=#Pressure unitOfMeasure=#PSI>1</Quantity>
 </threshold>
 <survivableRange>
            <Quantity observableType=#Pressure unitOfMeasure=#PSI>500</Quantity>
 </survivableRange>
 <operationalRange>
  <minimum>
            <Quantity observableType=#airTemperature=#celsius>-50</Quantity>
  </minimum>
  <maximum>
            <Quantity observableType=# airTemperature=#celsius >3500</Quantity>
  </maximum>
 </operationalRange>
</response>
```

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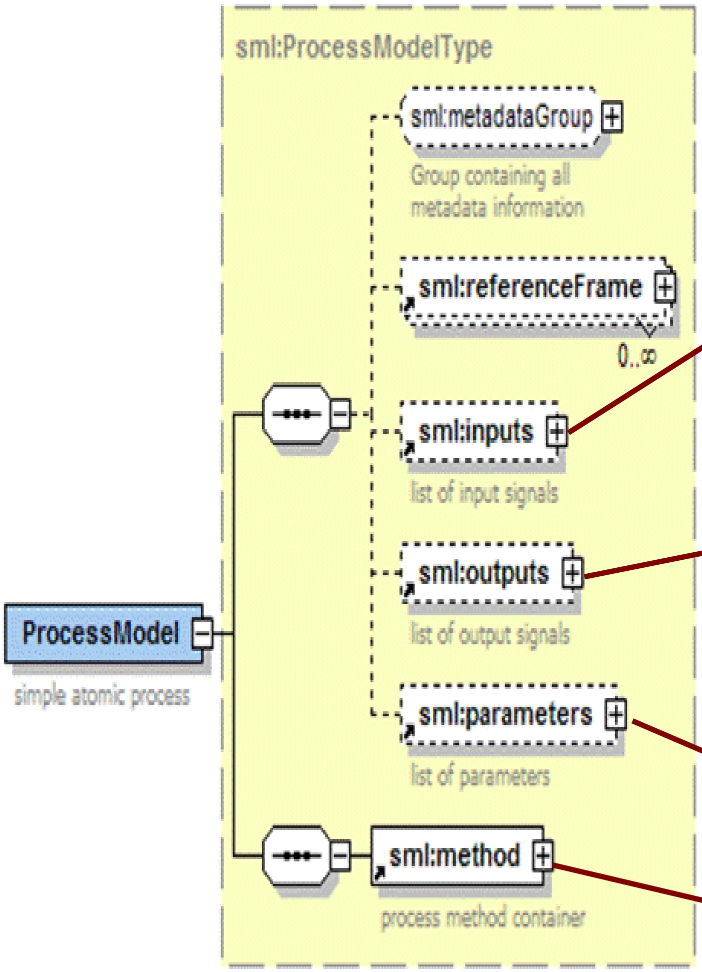
Process Model Elements




```
<processes>
  <ProcessList>
           <!--~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~-->
           <!-- Description of Pressure Transducer -->
           <!--~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~-->
   <process name="Pressure">
    <Transducer id="JT-P1-001">
           - details omitted for brevity -..
     <inputs>
      <InputList>
       <input name="pressure">
        <swe:Quantity definition="jet:umd:phenomenon:pressure"/>
       </input>
      </InputList>
     </inputs>

     <outputs>
      <OutputList>
       <output name="measuredPressure">
        <swe:Quantity definition="jet:umd:phenomenon:pressure"/>
       </output>
      </OutputList>
     </outputs>

     <parameters>
      <ParameterList>
       <steadyStateResponse>
           - details omitted for brevity -
       </steadyStateResponse>
      </ParameterList>
     </parameters>
     <method xlink:href="jet:umd:process:pressure"/>
    </Transducer>
   </process>
```

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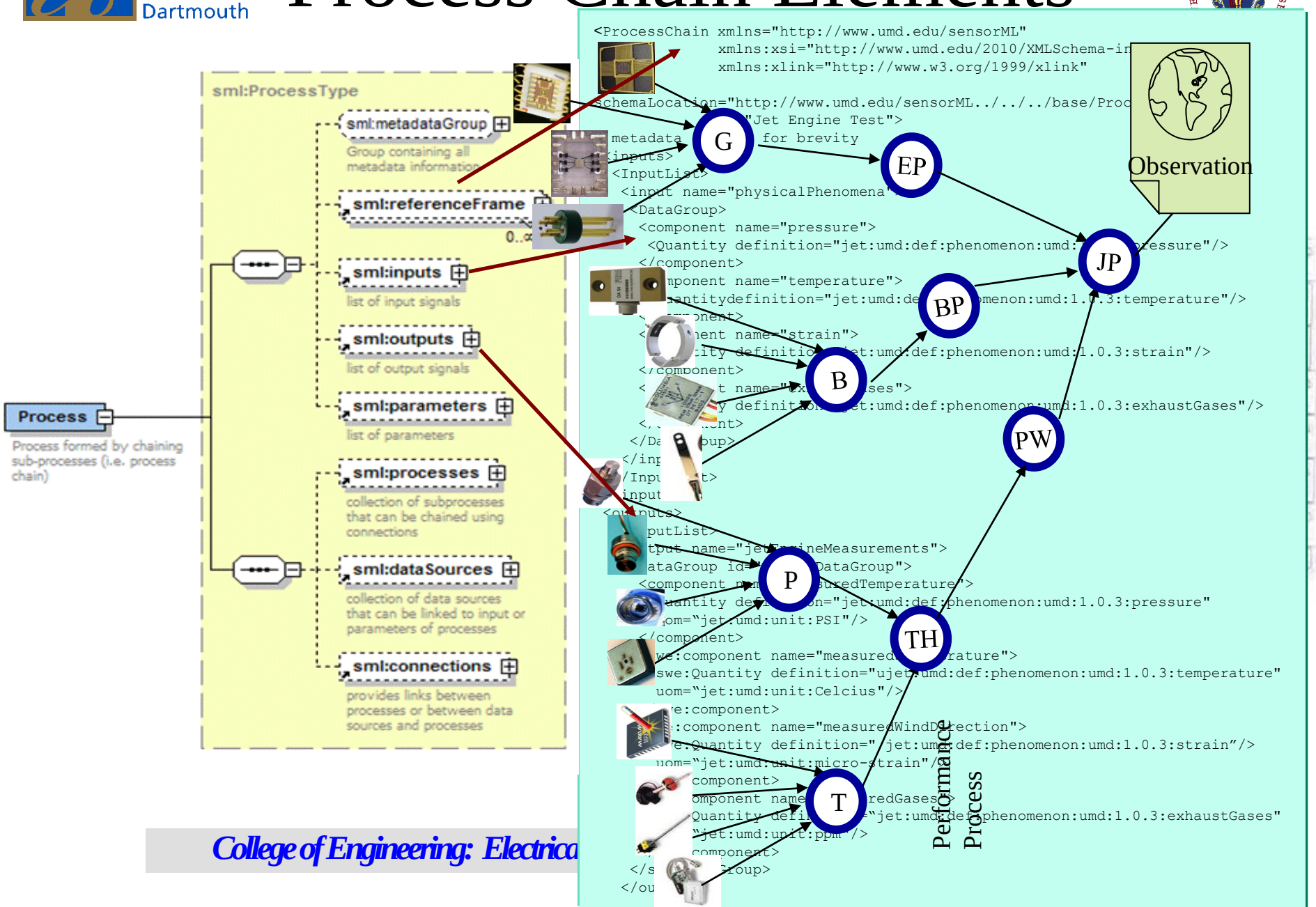
Process Chain Elements



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Why is Metadata Important for Test Community?

- Discovery of sensors and processes / plug-n-play sensors
- Observation lineage and provenance
- On-demand processing
- Alert Processing
- Reconfiguration support
- Calibration / recalibration support
- Re-use / re-define use of raw / processed measurements
- Intelligent, autonomous sensor network

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Sharing Sensor Metadata

- Joint Sensor Database (NASA – ASWG)
  - Multiagency data repository for sharing sensor related R&D and uses (initiated in 2010)
  - Home grown formats, not using standards
- Data Involved
  - Sensor specifications
  - Sensor applications (where applied successfully)
- Other means to share

  Create a Joint T&E Sensor repository using standard metadata???

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Questions

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Relevant Links

Open Geospatial Consortium Standard Documents

http://www.opengeospatial.org/standards

OGC Approved Schema

http://schemas.opengis.net/

Sensor Web Enablement Working Group

http://www.opengeospatial.org/projects/groups/sensorweb

SensorML information

http://vast.uah.edu/SensorML

SensorML Public Forum

http://mail.opengeospatial.org/mailman/listinfo/sensorml

IEEE 1451

http://www.nist.gov/el/isd/ieee/ieee1451.cfm

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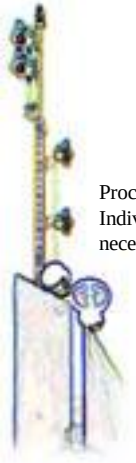
SensorML Processes

Non-Physical Processes

Processes where physical location or physical interface of the process is not important (e.g. a fast-Fourier process)

Physical Processes

Processes where physical location or physical interface of the process is important (e.g. a sensor system)



Atomic Processes

Processes that are considered Indivisible either by design or necessity

<<ProcessType>>
ProcessModel

+ name : string
+ description[0..1] : string
+ metadataGroup
+ input [0..*] : anyData
+ output [1..*] : anyData
+ parameter [0..*] : anyData
+ method : ProcessMethod

<<ProcessType>>
Component

+ name : string
+ description[0..1] : string
+ metadataGroup
+ input [0..*] : anyData
+ output [1..*] : anyData
+ parameter [0..*] : anyData
+ spatialReferenceFrame[0..1] : EngineeringCRS
+ temporalReferenceFrame [0..1] : TemporalCRS
+ boundedBy [0..1] : Envelope
+ position [0..1] : Position
+ interface [0..1] : InterfaceDefinition
+ method : ProcessMethod

Composite Processes

Processes that are composed of other processes connected in some logical manner

<<ProcessType>>
ProcessChain

+ name : string
+ description[0..1] : string
+ metadataGroup
+ input [0..*] : anyData
+ output [1..*] : anyData
+ parameter [0..*] : anyData
+ component [1..*] : Process
+ connection [0..*] : Link

<<ProcessType>>
System

+ name : string
+ description[0..1] : string
+ metadataGroup
+ input [0..*] : anyData
+ output [1..*] : anyData
+ parameter [0..*] : anyData
+ spatialReferenceFrame[0..1] : EngineeringCRS
+ temporalReferenceFrame [0..1] : TemporalCRS
+ boundedBy [0..1] : Envelope
+ position [0..1] : Position
+ interface [0..1] : InterfaceDefinition
+ component [1..*] : Process
+ connection [0..*] : Link