

# A Semantic Testbed for Smart Grid Information Standards

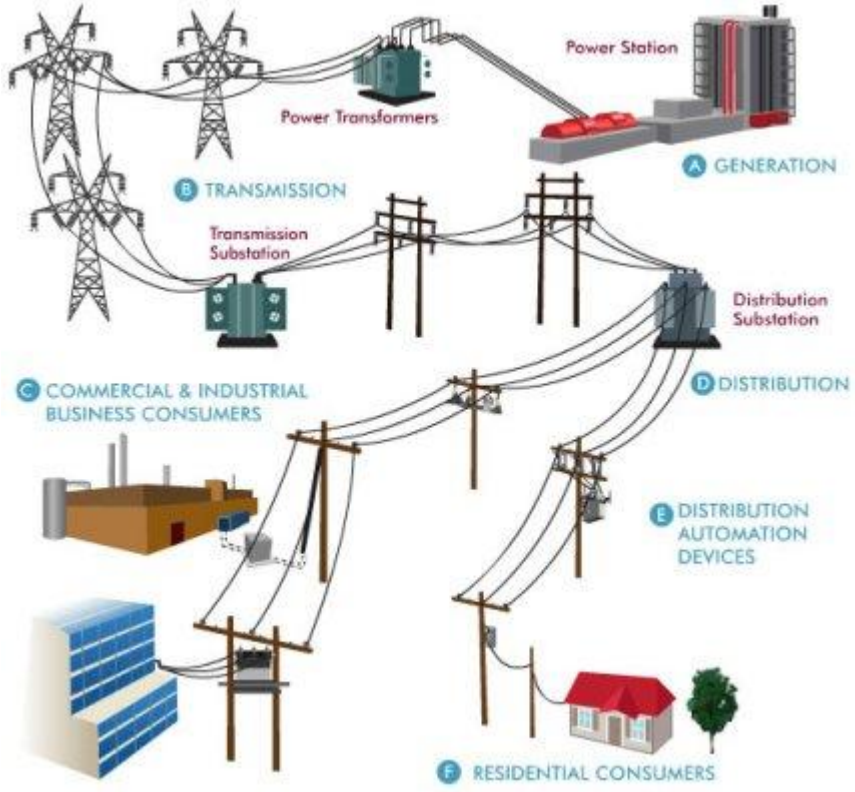
Steve Ray

Testbeds for Smart Grids and Smart Cities

April 1, 2015

# Electrical Grid

Models of electricity



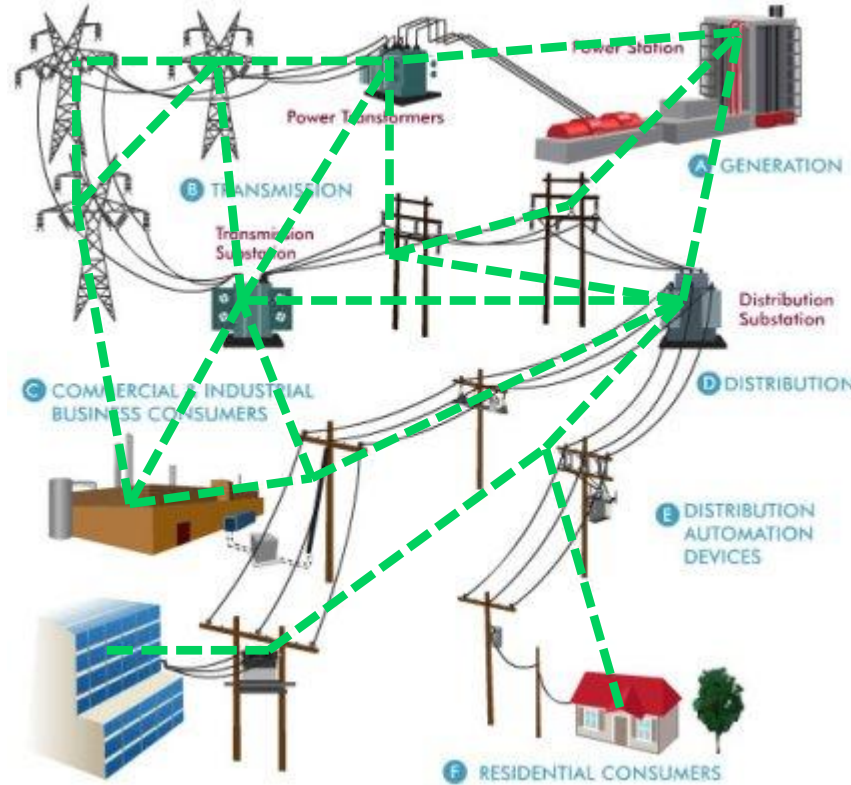
Electricity



# Smart Electrical Grid

Models of electricity

Models of information

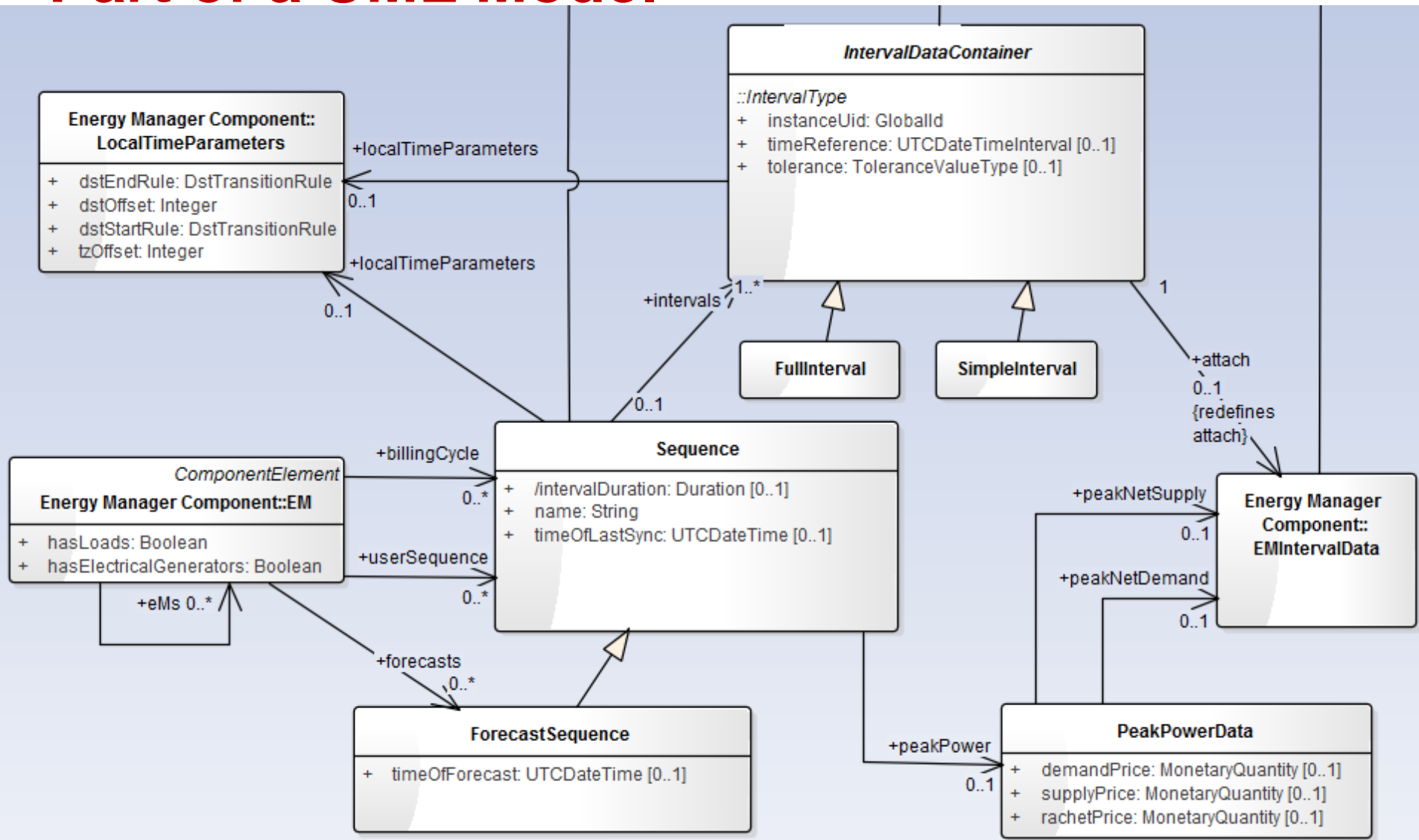


— Electricity  
- - - Information

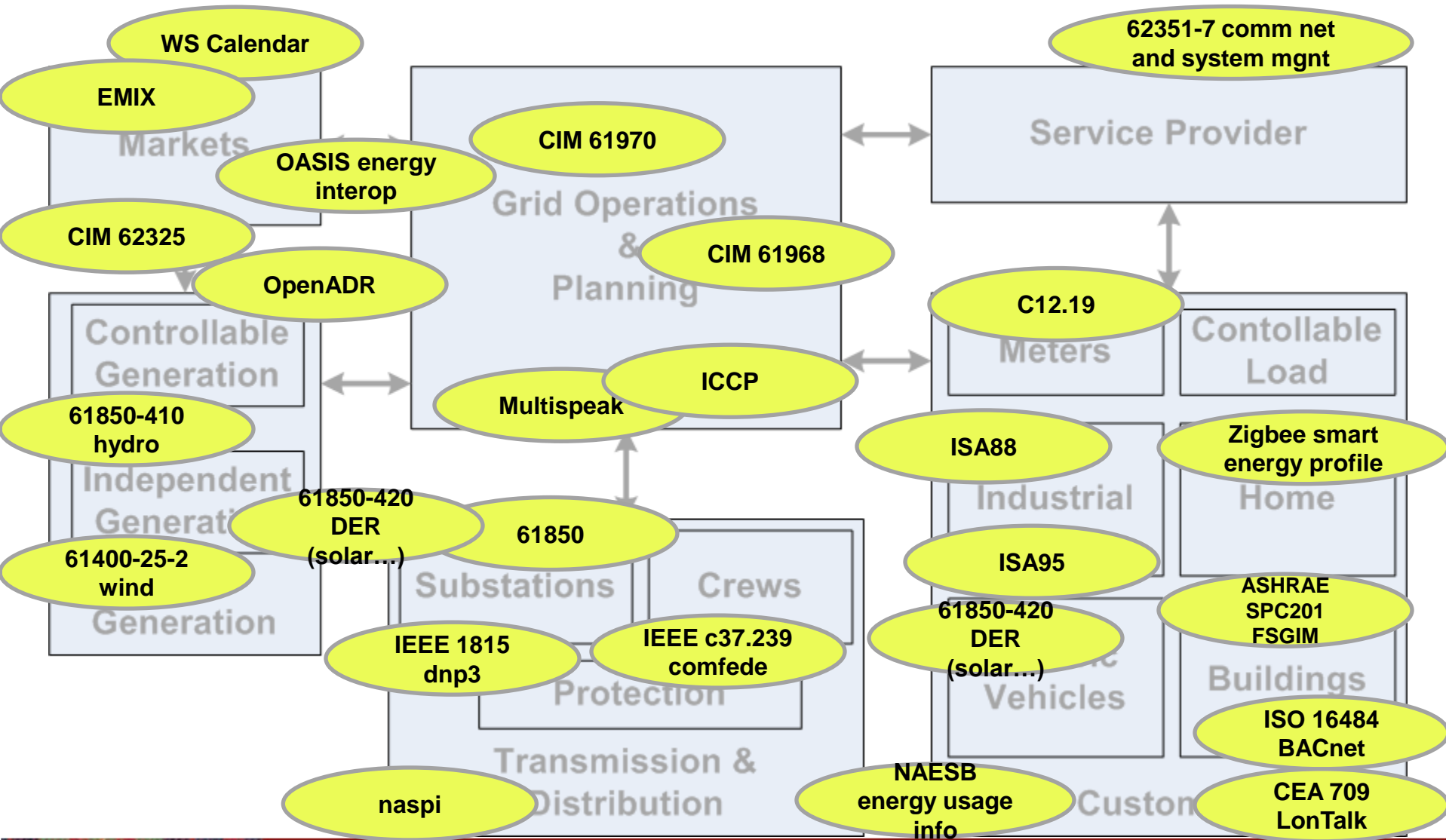


# How is Smart Grid Information Modeled?

# Part of a UML Model



# Some Smart Grid Information Standards



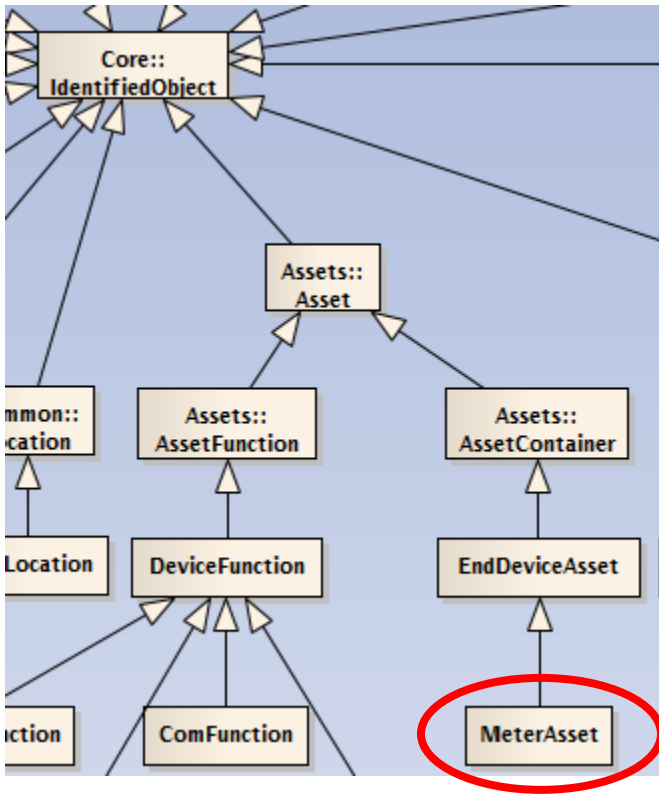
# Challenge

- How to test whether an information standard (i.e. information model)
  1. is self consistent? (verification testing)
  2. is compatible with other standards? (to support interoperability)
    - How to reconcile vocabularies, concepts and relations among all the smart grid information standards?
  
- Information models are engineered artifacts designed within a stated or unstated context

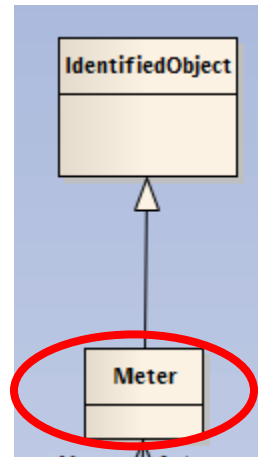
# “Meter”

## Do they all really mean the same thing?

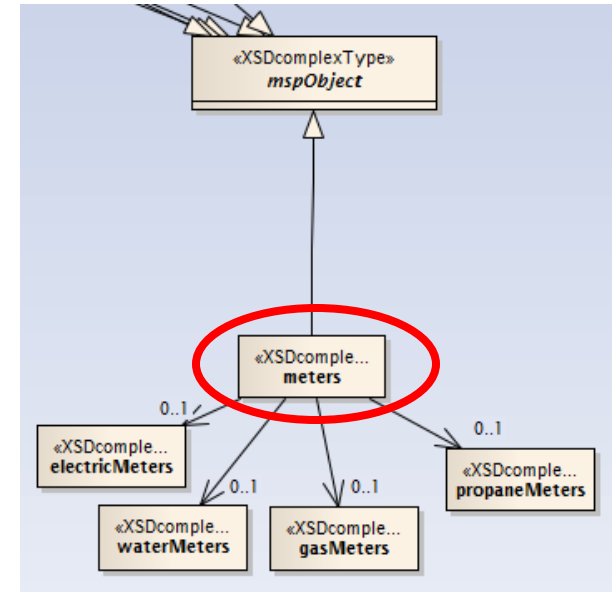
IEC 61968



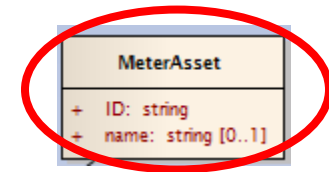
IEC 61970



Multispeak V4.1



NAESB PAP10





# What's the risk?

- You might have **connectivity** but not **interoperability**
- Misunderstanding of information flowing between systems

*By Robin Lloyd  
CNN Interactive Senior Writer*

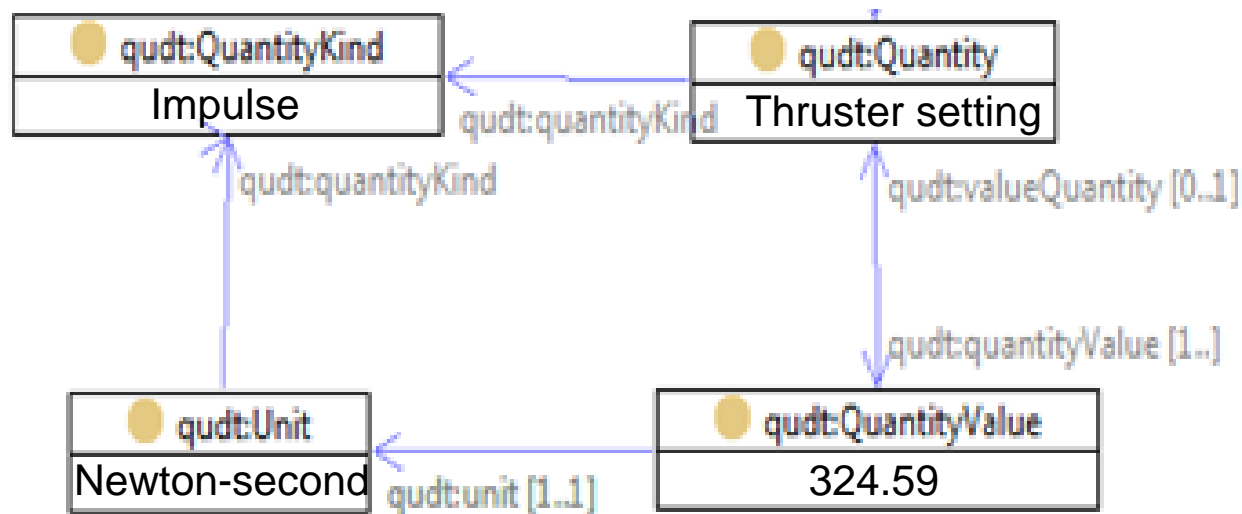
Sep. 30, 1999

(CNN) -- NASA lost a \$125 million Mars orbiter because a Lockheed Martin engineering team used English units of measurement while the agency's team used the more conventional metric system for a key spacecraft operation, according to a review finding released Thursday.

- “Set Thruster to 324.59”

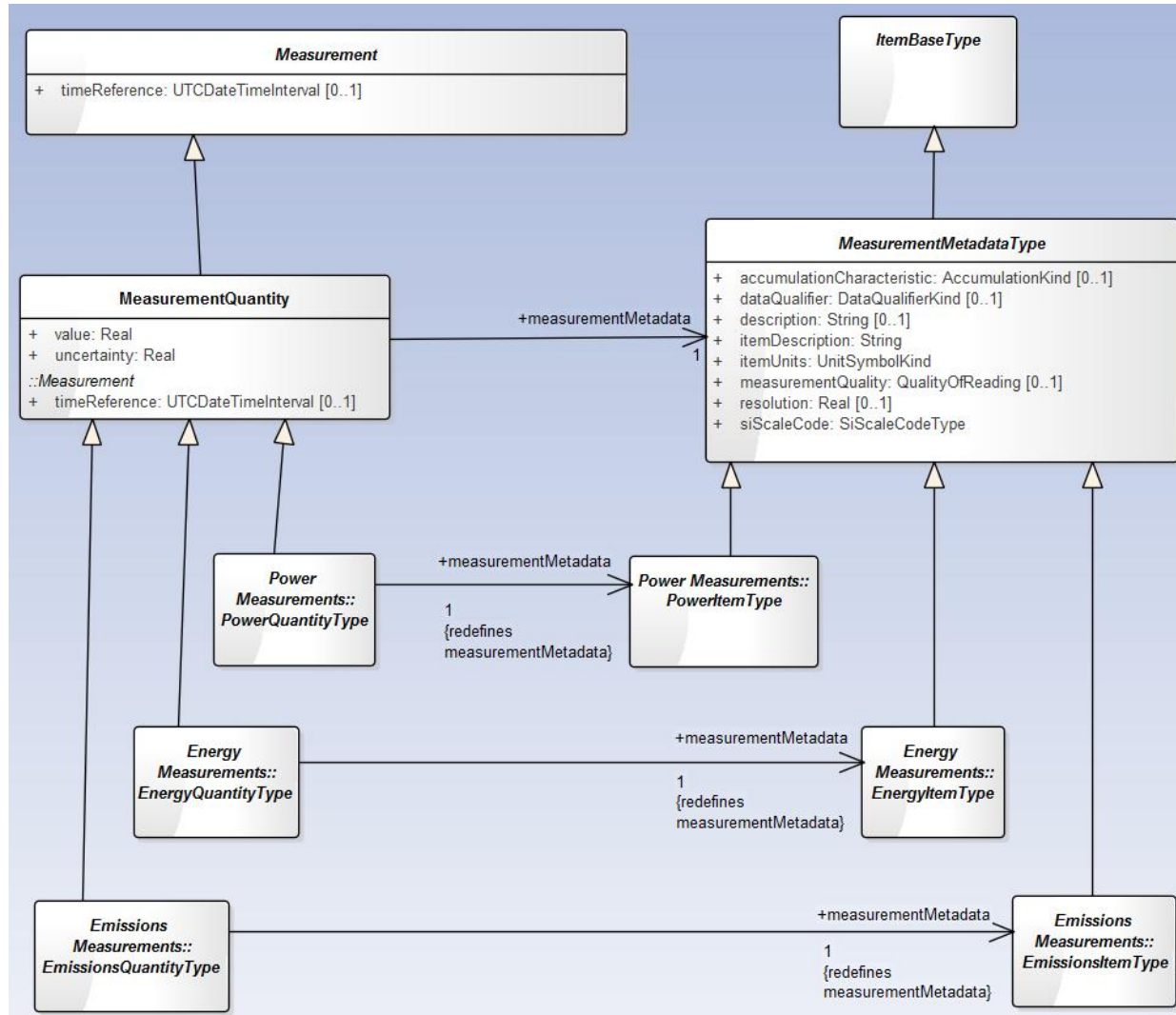
# Need context (a.k.a. metadata)

“Set Thruster to 324.59”



(...without even getting into uncertainty)

# ASHRAE SPC201 Standard (excerpt)



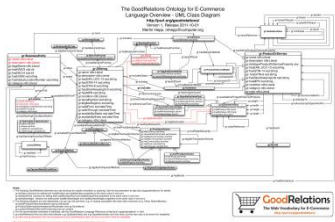
# Semantic Testbed

## Testing the integrity of a standard

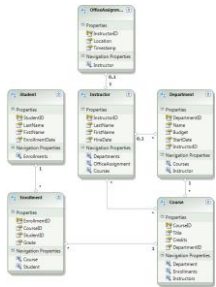
### Standards



Text

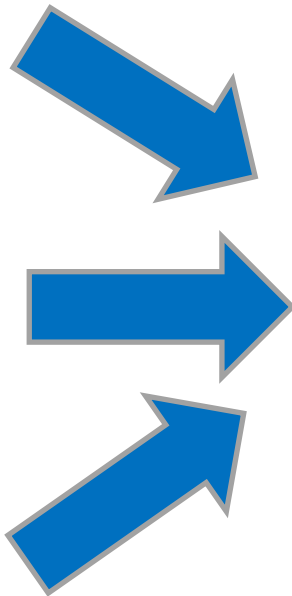


UML



XSD

Model Transformation



Semantic representation  
Web Ontology Language  
(OWL)



Carnegie Mellon University  
Silicon Valley

Custom Query Manager Editor

Model Name:

Model Version:

Query Classification:

Query Name:

Query Prefix:

```
SELECT DISTINCT ?externalClass ?range ?property
WHERE {
  ?r owl:allValuesFrom ?range .
  ?r owl:onProperty ?property .
```

Model Verification Testing

# Multiple Smart Grid Standards

Carnegie Mellon University  
Silicon Valley



## Custom Query Manager Editor

Model Name	FSGIM
Model Version	EI EMIX FSGIM
Query Classification	OpenADR

# Pick-lists of queries



## Custom Query Manager Editor

Model Name	<input type="text" value="FSGIM"/>
Model Version	<input type="text" value="3745"/>
Query Classification	<input type="text" value="Class"/>
Query Name	<input type="text" value="-- Please select an option --"/>
Query Prefix	<input type="text" value="-- Please select an option --"/> Classes defined but never referred to in a relation Classes that share substantially the same properties Display the UML package hierarchy for the class containing "string" Identify all external classes pointing to FSGIM classes Navigate up superclasses to find the ultimate parent class, for all classes containing a given string Superclasses that have no properties

# Sample Query

Model Name	OpenADR ▾
Model Version	201307 ▾
Query Classification	xsd ▾
Query Name	Finding in-line complex type definitions ▾
Query Prefix	PREFIX composite: <http://www.topbraid.org/2007/05/composite.owl#>PREFIX smf: <http://topbraid.org/sparqlmotionfunctions#>PREFIX xsd:
Query	<pre>SELECT ?subject ?parentName WHERE {   ?subject a xsd:ComplexType .   OPTIONAL {     ?subject xsd:name ?name .   } .   FILTER (!smf:isBound(?name)) .   OPTIONAL {     ?parent composite:child ?subject .     ?parent xsd:name ?parentName .   } . }</pre>
Result Display	<input checked="" type="radio"/> Truncated <input type="radio"/> Complete
<input type="button" value="Execute Query"/> <input type="button" value="Save Query"/> <input type="button" value="Clear Results"/>	

## Query Result

subject	parentName
<a href="#">file:///OpenADR/input/oadr_ei_20b.xsd#r-61-1</a>	<a href="#">eventResponses</a>
<a href="#">file:///OpenADR/input/oadr_20b.xsd#r-100-1</a>	<a href="#">oadrTransports</a>
<a href="#">file:///OpenADR/input/oadr_20b.xsd#r-110-1</a>	<a href="#">oadrInfo</a>

# Viewing and Navigation between classes

Selected Resource ✕

## AbstractMeasure

### Annotations

**comment:** Abstract measurement class. Each measurement has a unit of measure, uom. WXXM allows more than one uom -- eg F/C/K for temperature. FSGIM only allows one choice of uom for a physical quantity.

**label:** AbstractMeasure

### Class Axioms

**subClassOf:** [Thing](#)

- powerOfTenMultiplier max 1
- powerOfTenMultiplier min 0
- powerOfTenMultiplier only [SiScaleCodeType](#)
- uom exactly 1
- uom only [UnitSymbolKind](#)
- has Value exactly 1
- has Value only [Real](#)

### Properties

**http://uml.topquadrant.com/owl/uml/smg/uml2owl#belongsToGeneratedPackage:** [Documentr-1-0-3-2-1-0](#)

**type:** [Class](#)

Close



# Benefits

- Exhaustively searches a standard to find errors that might escape human detection
  - Orphan definitions (defined but never used)
  - Opportunities for model refactoring (similar classes)
  - Disallowed changes to imported standards
  - Redundant classes and properties
  - Non-standard data type definitions

# After Verification Testing

- Model Healing
  - Recommendations to correct errors
  - Automatic error correction for native OWL specifications
- Conformance Testing
  - Does a particular implementation properly represent the information according to the standard?
  - Generation of reference data sets
- Standards Harmonization
  - Checking for missing information
    - Information present in one standard but not in another
  - Mapping among different ways of modeling the same information

**Thank you**

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