The Common Instrument Middleware Architecture (CIMA) Instrument Ontology & Applications

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Common Instrument Middleware Architecture

NMI

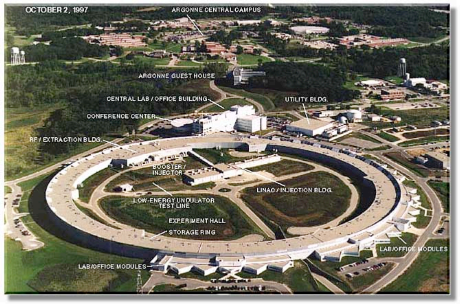
CIMA Project Goals

Project supported by the NSF Middleware Initiative to:

- Integrate instruments and sensors as real-time data sources into grid computing environments through a Service Oriented Architecture
  - Improve accessibility and throughput in instrumentation investments
  - Promote sharing across institutions and disciplines
- Develop a methodology for describing instrument capabilities and functions
  - improve flexibility and lifetime of data acquisition and analysis applications
- Move production of metadata as close to instruments as possible and facilitate the automatic production of metadata
  - Improve data management, provenance and reuse

CIMA Reference Implementation Applications

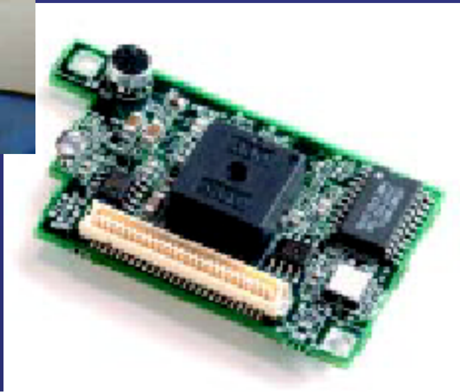
- Synchrotron X-Ray crystallography
  - Argonne APS ChemMatCARS & DND-CAT
  - Also lab systems through CrystalGrid (global network of crystallography labs)



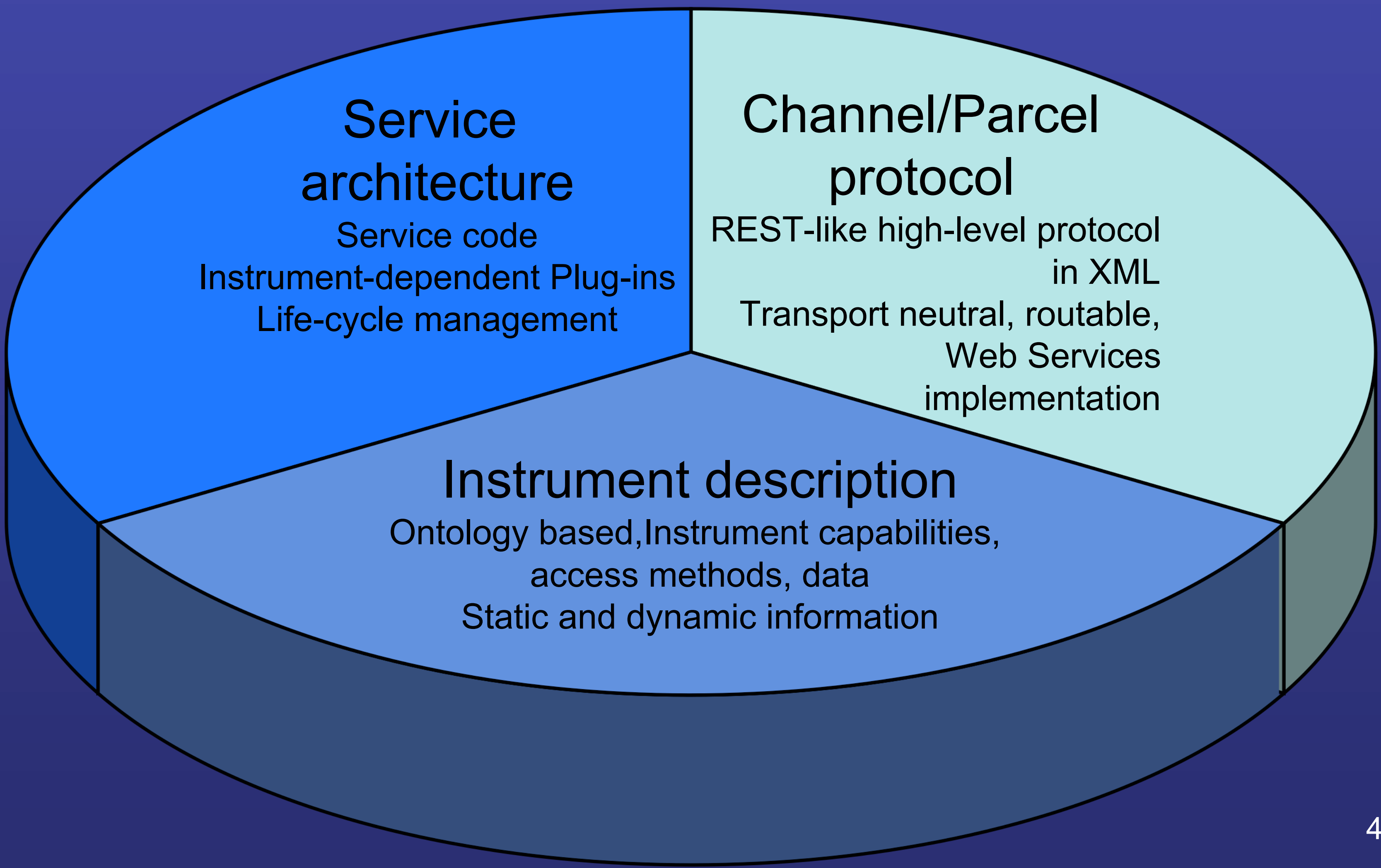
- TOF-MS
  - Identification of proteins and other macromolecules

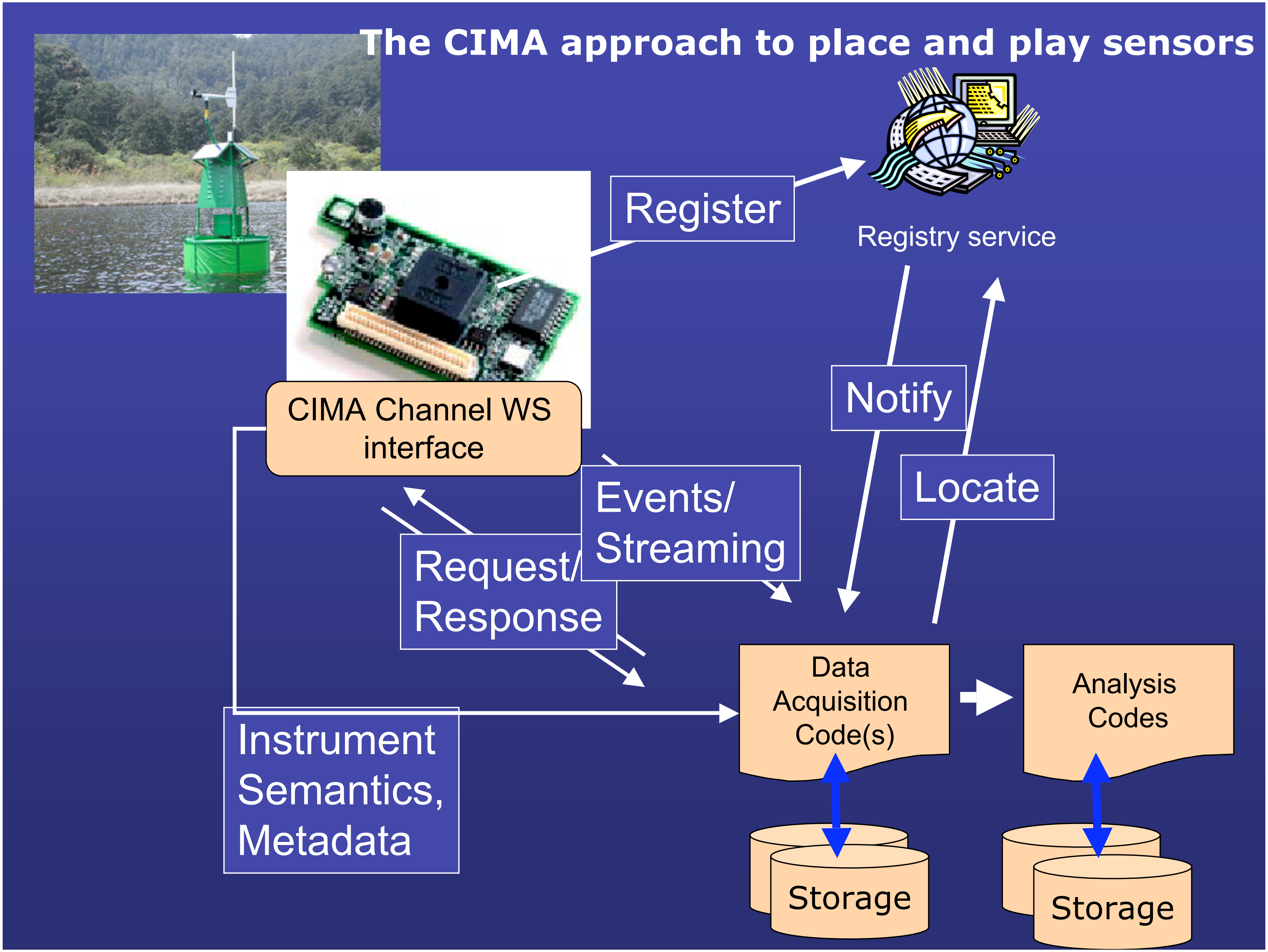
- Robotic telescopes
  - Star variability
  - Looking for killer asteroids?

- Sensor networks
  - Ecological observation (LTER lake buoys, GBR platforms)
  - Low power wireless sensor network elements

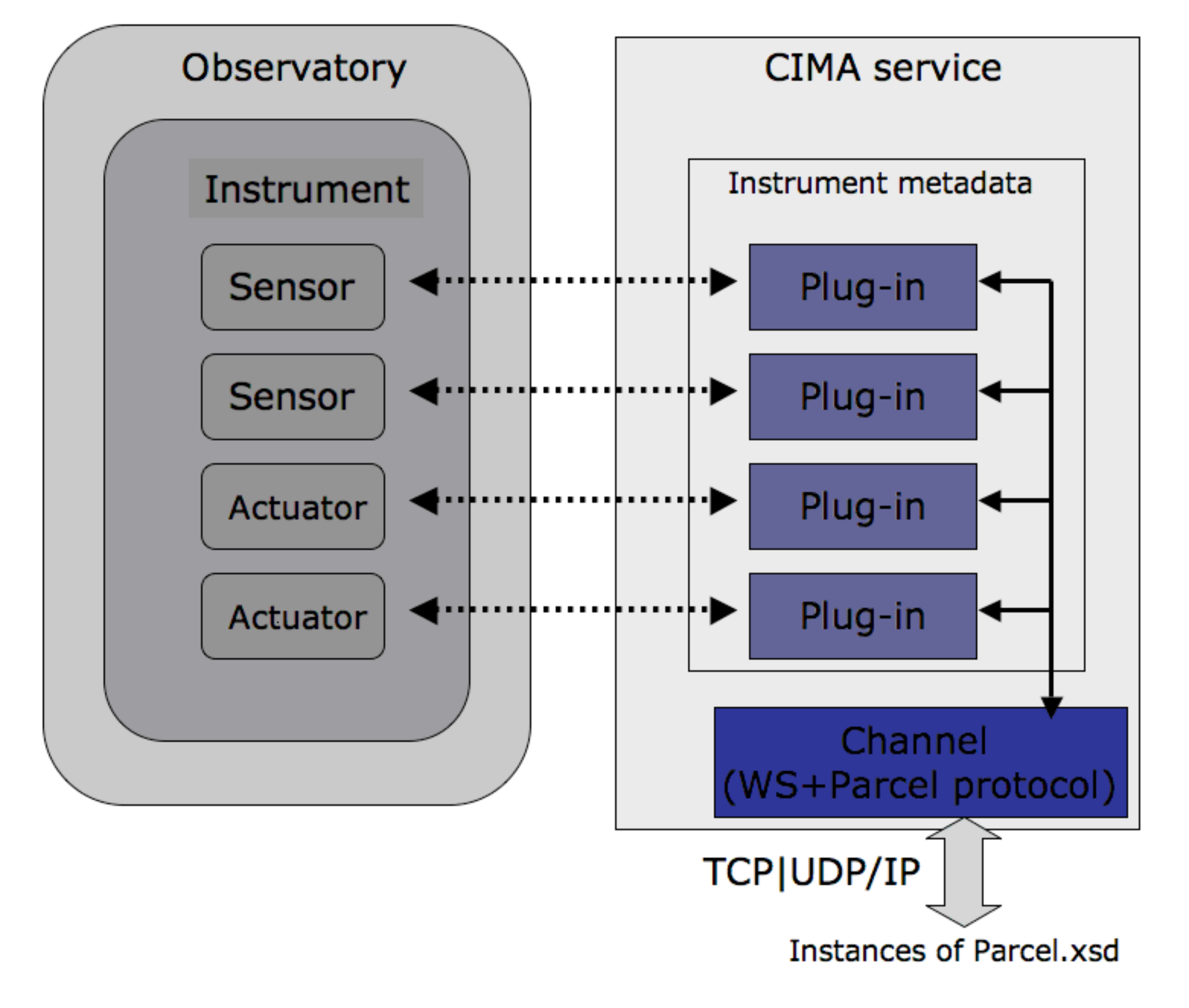


CIMA Components




The CIMA approach to place and play sensors
Register
Registry service
CIMA Channel WS interface
Notify
Locate
Events/ Streaming
Request/ Response
Data Acquisition Code(s)
Analysis Codes
Instrument Semantics, Metadata
Storage
Storage

Correspondence between CIMA Service & Instruments



Motivation for Building a CIMA Ontology

- CIMA's goals include:
  - making instruments and sensors accessible in real time by end-users
  - facilitating search and discovery of instruments and their features
- To support CIMA's goals, we need a standardized vocabulary to describe instruments
  - must be extensible, to describe new features, new classes of instruments and sensors,
  - must offer flexibility in machine processing

Automation from the CIMA Ontology

- Locate experimental resources based on high-level specification of goals
- Support user interactions with facility and capabilities
- Generate data acquisition strategy and code
- Build user-appropriate interfaces
- Automate production of high quality metadata

Requirements for CIMA Ontology

- Ontology must describe
  - CIMA instruments and sensors and their physical and logical location,
  - phenomena detected by instruments/sensors,
  - communication between instruments and sensors and the CIMA plugins

- Ontology must be extensible, support automatic reasoning, and integrate with Semantic Web.

→ **Web Ontology Language (OWL)**

Advantages of OWL

- OWL is the emerging standard for semantic markup of Web content (Semantic Web).

- OWL supports consistency checking.
  - instrument descriptions can be checked to determine whether they comply with the standards and rules as specified by the ontology

- Query processors available for OWL:
  - Give me all instruments located in Bloomington, IN.
  - Give me instruments that measure temperature.

Scope and Organization of the CIMA Ontology

- Models instruments and sensors, their physical location and logical organization.
  - data products (what it does)
  - control functions (how can I modify its behavior)
  - functional model of hardware (how it works)
  - response model of sensors and actuators (mapping real world to readings and control tokens)
  - Hardware life cycle (calibration, validation, faults, maintenance)
- Models communication with sensors
  - access as network service (how I get to it)

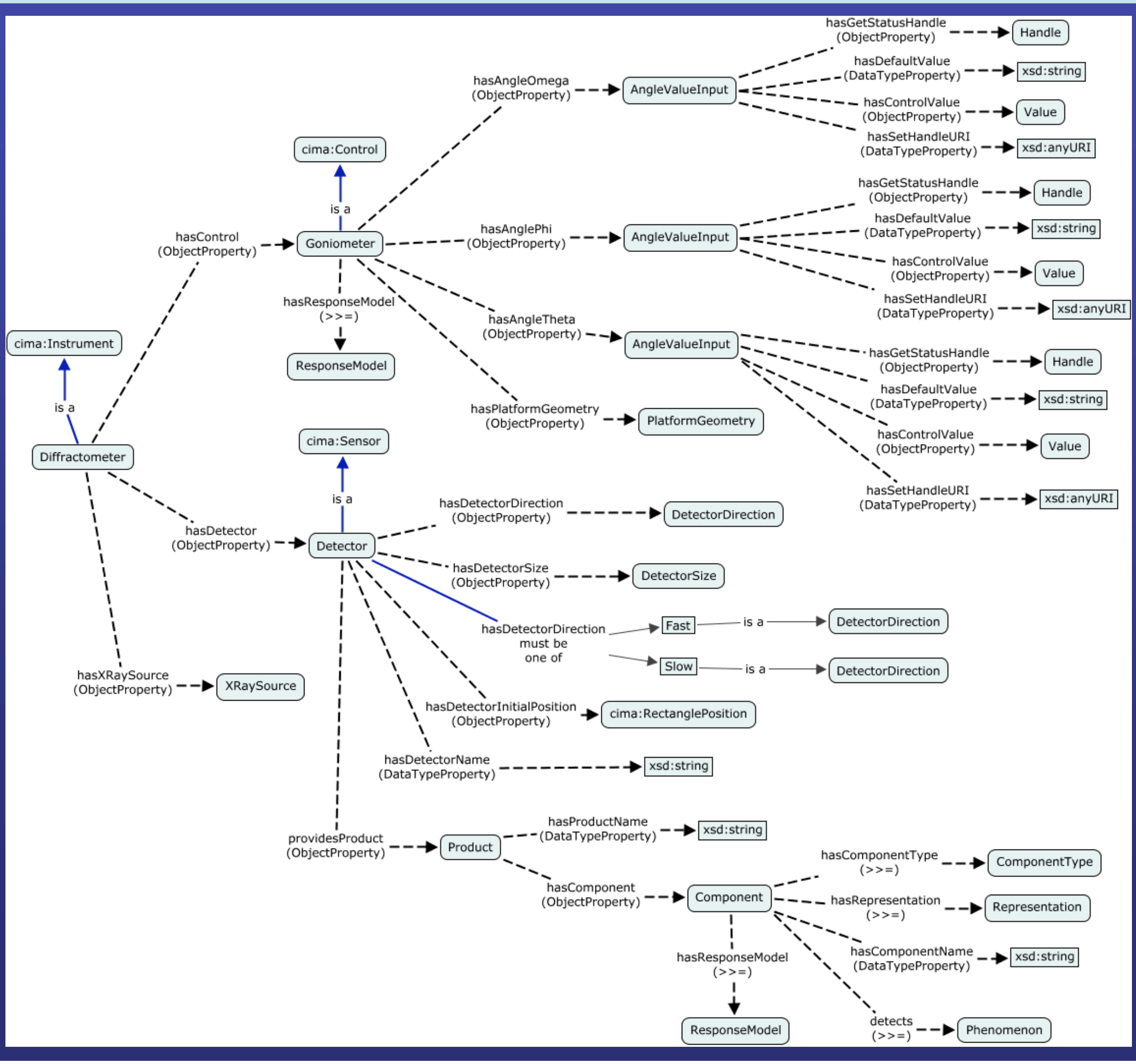
Scope and Organization of the CIMA Ontology (cont.)

- Models physical phenomena that can be detected by instruments and sensors.
  - pressure,
  - electric current,
  - light, etc.

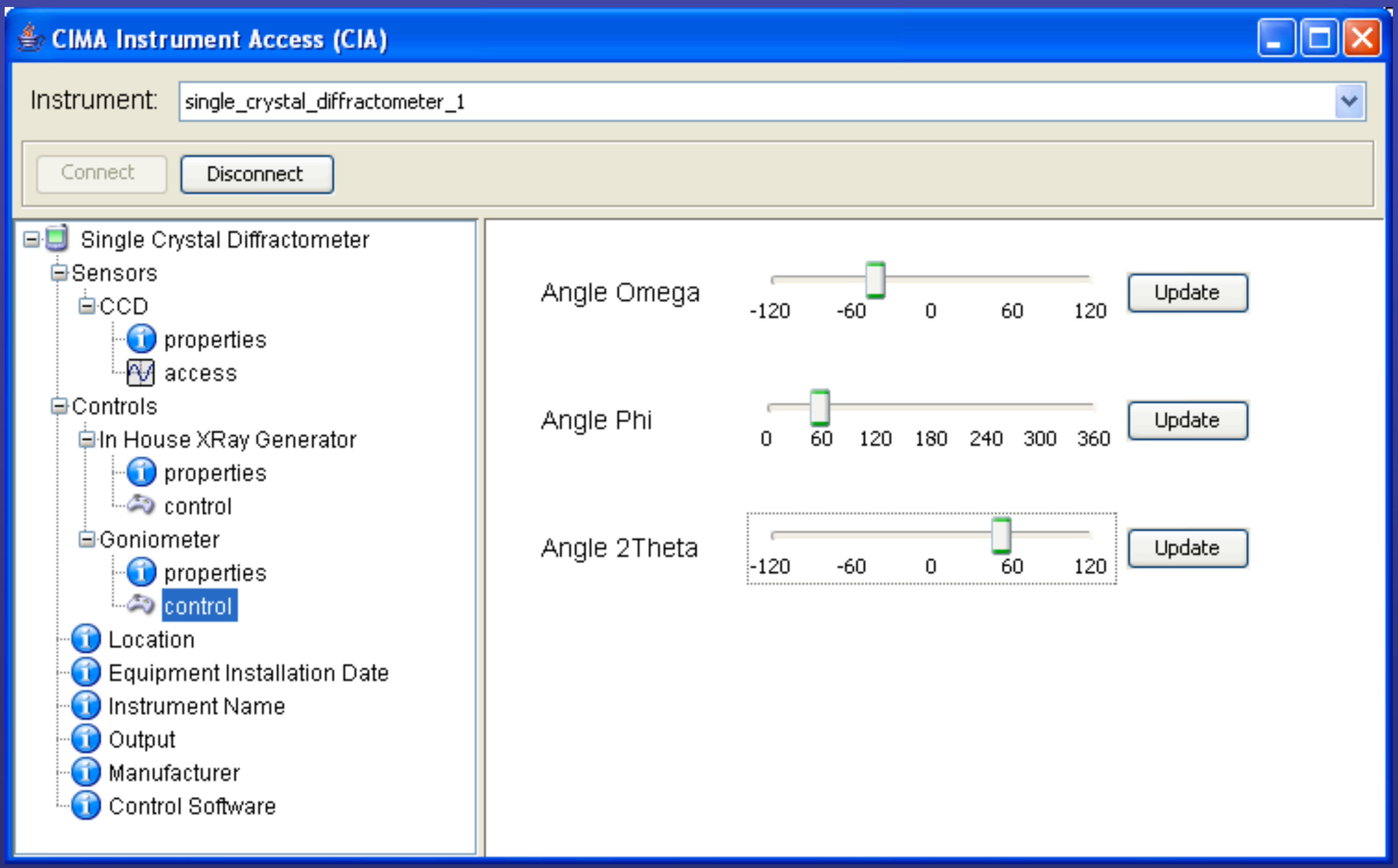
- Models units and supports conversion between SI base and derived units.
  - Centigrade to Kelvin to Fahrenheit
  - meters to miles, etc.

- Is divided into a base ontology for modeling any instruments and sensors and a CIMA specific ontology.
  - 120 classes
  - 100 properties
  - 40 instances

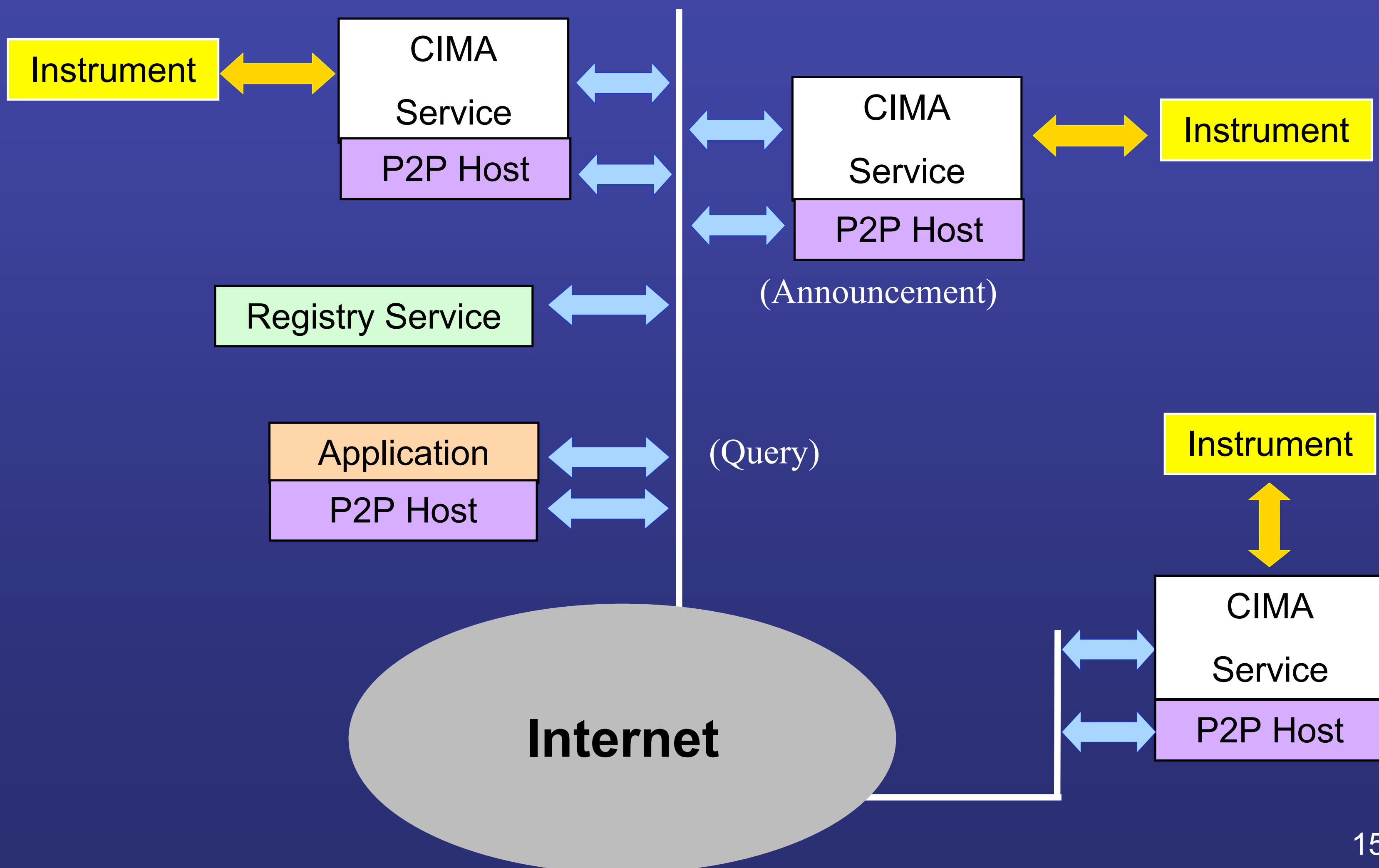
Visualized Excerpt of CIMA Ontology



CIMA Instrument Access (CIA) Prototype

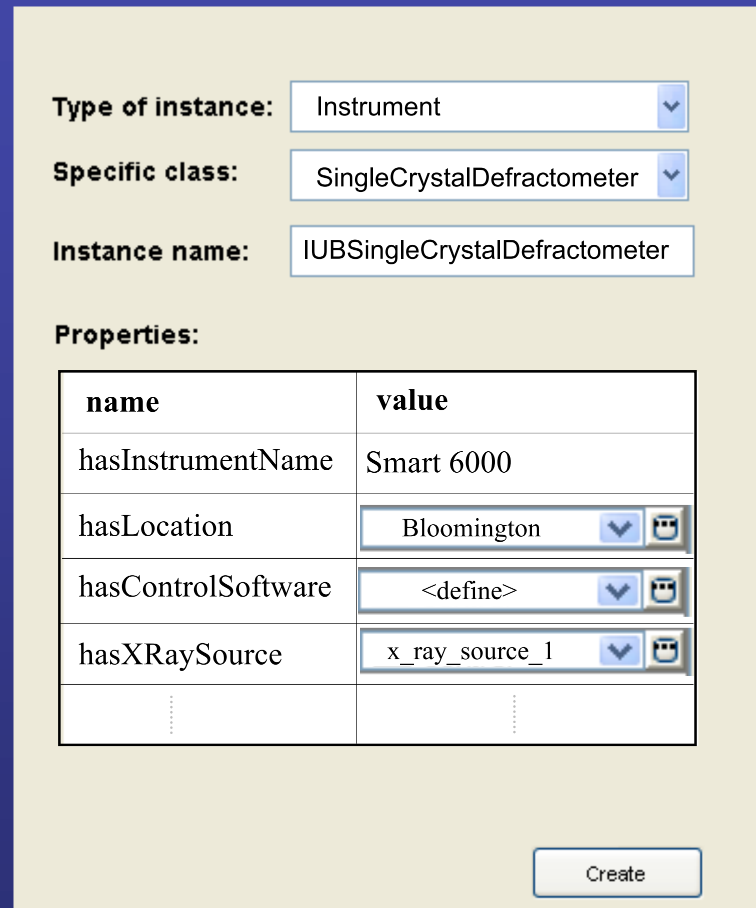


Registry and Peer-to-Peer Organization and Search



CIMA Instance Editor (under development)

- User specifies property values of new instance.
  - may be left blank
  - may be selected from a list
  - may be specified as string or number
- Property values may be complex
  - requires separate specification in table format



OWL Tools used in CIMA

- Pellet to check for consistency and to process RDQL queries.

Query: Give me all instruments in Bloomington, Indiana.

```
SELECT ?x
WHERE (?x cima:hasLocation cima:BloomingtonIN),
           (?x rdf:type cima:Instrument)
USING
  cima FOR <http://www.cs.indiana.edu/~treichhe/cima#>,
  owl FOR <http://www.w3.org/2002/07/owl#>,
  rdf FOR <http://www.w3.org/1999/02/22-rdf-syntax-ns#>,
  rdfs FOR <http://www.w3.org/2000/01/rdf-schema#>
```

Query result:

<http://www.cs.indiana.edu/~treichhe/cima#LabJackThermocouple>

Issues

- Creating instrument descriptions
  - Manually from a template
  - Assisted, using an instance editor
    - Leverage existing descriptions
    - Co-extension of the ontology
- Management and extension of the ontology
- Handling of dynamic property values
  - Difficult if a registry is used
  - Not too difficult with P2P lookup

Summary & Status

- CIMA Ontology & Applications
  - basic instrument and CIMA-specific ontology has been built
  - initial description of a CIMA instrument implemented
  - initial version of CIMA Access Tool has been implemented
  - initial design CIMA Description Editor exists

- Next step:
  - apply ontology to build descriptions of a variety of sensors & actuators
  - Set up registry to manage instrument descriptions and provide search capability
  - Evaluate Peer-to-Peer architecture for service location queries

Thank You! Questions?

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NSF Middleware Initiative: www.nsf-middleware.org

CIMA project: www.instrument-middleware.org

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