

PRACTICAL MDA: USING MODEL-DRIVEN ARCHITECTURE TO DEVELOP AND IMPLEMENT INFORMATION STANDARDS

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Service Oriented Architecture Definitions

- ▣ “Service Oriented Architecture (SOA) is a paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains”

OASIS Reference Model for Service Oriented Architecture 1.0 - (emphasis mine)

- ▣ “Set of services that a business wants to expose to its customers and partners or other portions of the organization”

Source: IBM - (emphasis mine)

Information Modeling in SOA

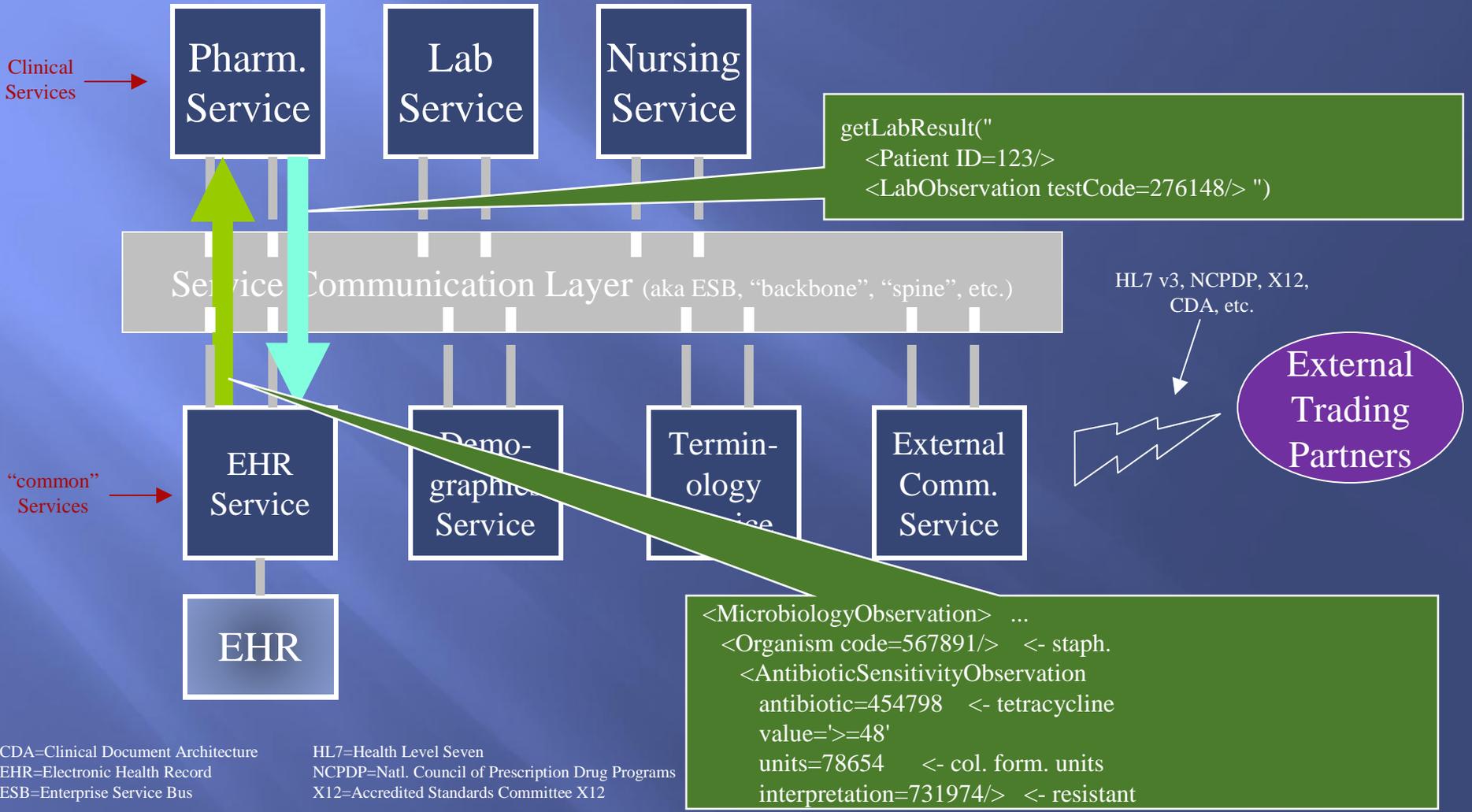
- ▣ In order for a SOA to work, it is critical that service providers have a common understanding of the structure and meaning of the data being exchanged
- ▣ Therefore, a “model” of some kind is needed
 - What form should this model take?
- ▣ Is it possible to have a single, agreed upon model?
 - What about different technological requirements?
 - What about different viewpoints?

Information Architecture

- ▣ Information Architecture is the analysis and design of the data used in information systems
 - Modeling semantics and reference knowledge common to a wide range of artifacts
 - Leveraging the semantics to ensure consistency across models/artifacts
 - Using the same semantics as a basis for logical and physical database model generation, software component and service generation, rule development (e.g., in production rule-based systems), etc.
- ▣ It's all about logical consistency, validation, and reuse
- ▣ It's also about ensuring interoperability within an enterprise and between that enterprise and its trading partners

A Health Care SOA Scenario

Note that these services might be "home-grown" or commercial products



CDA=Clinical Document Architecture
 EHR=Electronic Health Record
 ESB=Enterprise Service Bus

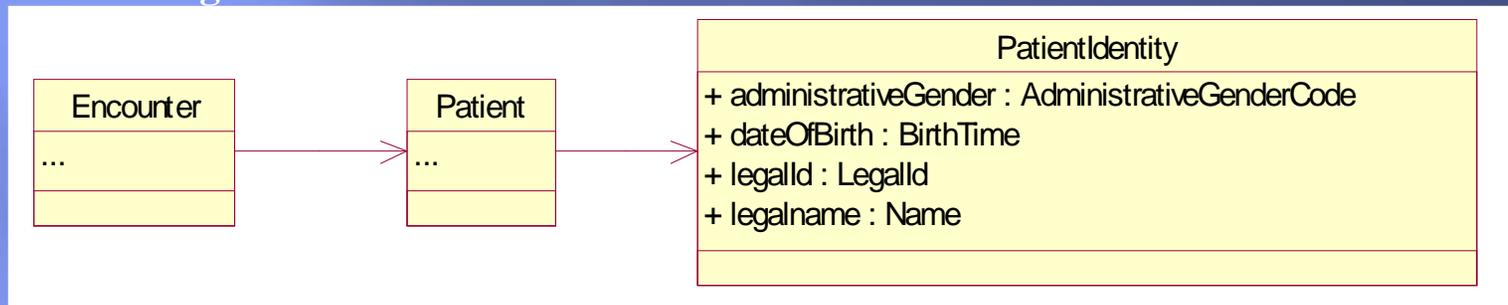
HL7=Health Level Seven
 NCPDP=Natl. Council of Prescription Drug Programs
 X12=Accredited Standards Committee X12

Model Transformations

- ▣ How can one static data model meet all the implementation needs (database, domain model, payload structure)?
- ▣ Answer: Model transformations
 - Computational Independent Model (CIM)
 - ▣ Conceptual model, aka Domain Analysis Model
 - Platform Specific Model (PSM)
 - ▣ Adds concepts needed by a type of platform, e.g., keys
 - Platform “Model”
 - ▣ Language used by platform, e.g., DDL, WSDL, CORBA
- ▣ Model Driven Architecture (MDA) and Unified Modeling Language (UML) provide tools for automating model transformations

UML Transformed to Other Languages

Class Diagram



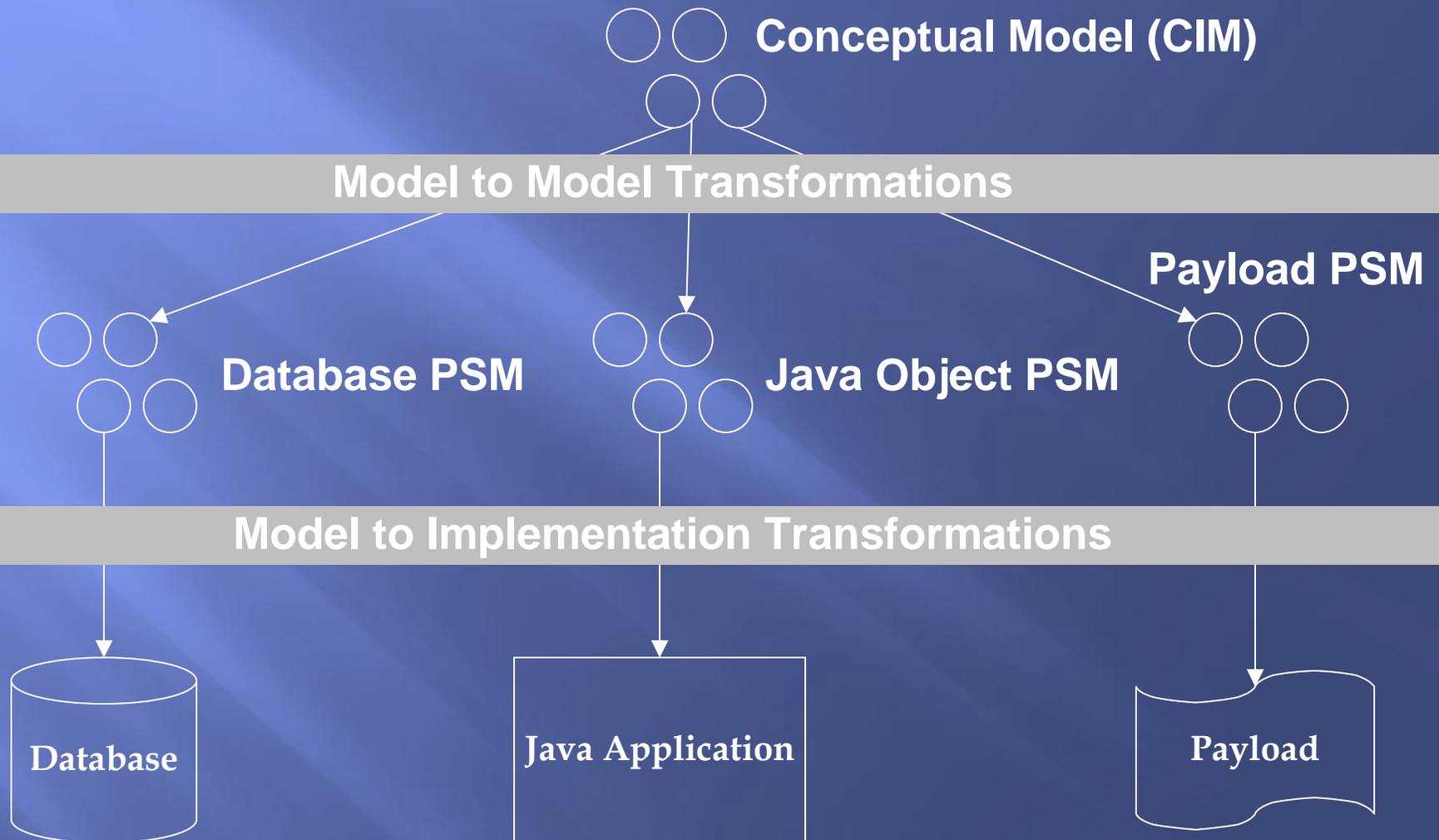
XML Schema Definition

```
<xs:element name="PatientIdentity" type="Validentity"
substitutionGroup="personIdentity" />
- <xs:complexType name="PatientIdentity">
- <xs:complexContent>
- <xs:extension base="PersonIdentity">
- <xs:sequence>
- <xs:element name="administrativeGender"
type="AdministrativeGenderCode">
- <xs:annotation>
  <xs:documentation>A value representing the gender (sex) of a
person. The allowable values for this field as specified by the DS DAT
for Demographics are: F (Female), M (Male) and UN
(unspecified).</xs:documentation>
</xs:annotation>
...
```

Java

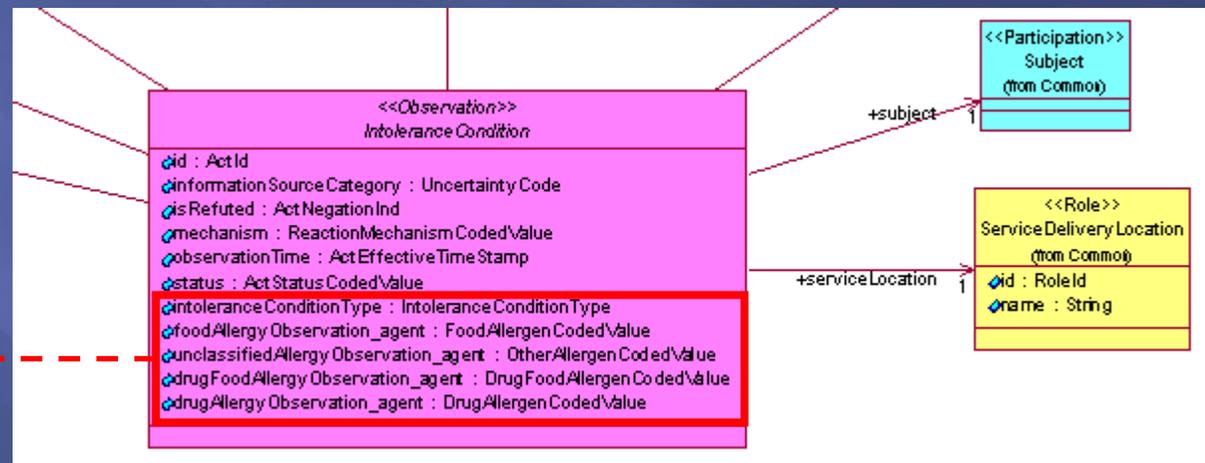
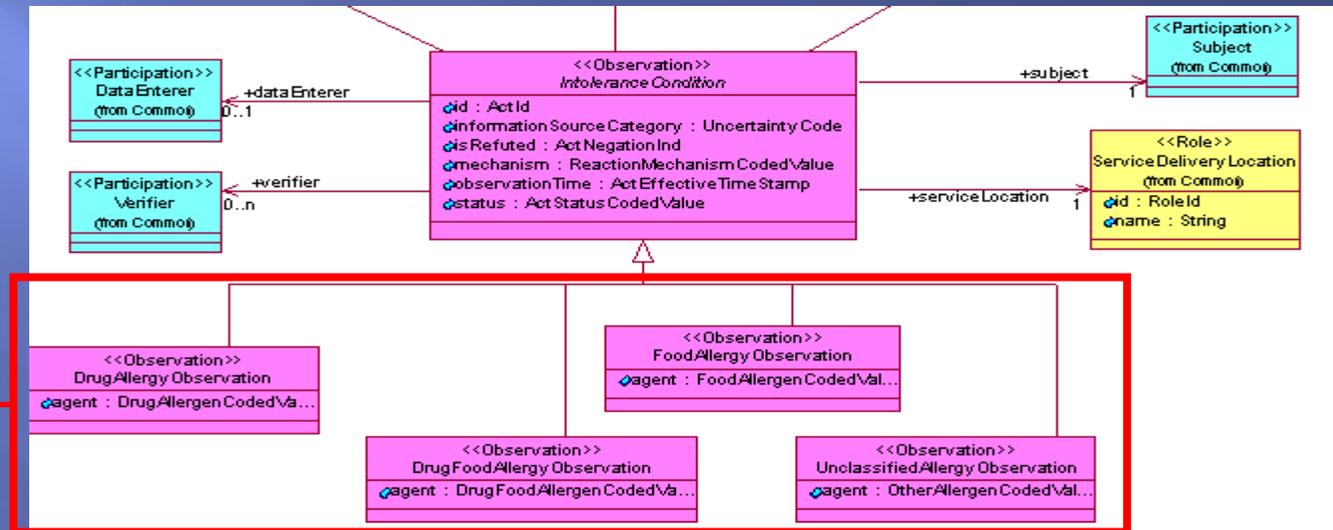
```
public interface PatientIdentity extends
personSRDTs.PersonIdentity
{
  livingSubject.AdministrativeGenderCode
getAdministrativeGender();
  void
setAdministrativeGender(livingSubject.AdministrativeGenderCode
administrativeGender);
  livingSubject.AdministrativeGenderCode
addNewAdministrativeGender();
  livingSubject.BirthTime getDateOfBirth();
  void setDateOfBirth(livingSubject.BirthTime dateOfBirth);
  livingSubject.BirthTime addNewDateOfBirth();
  ...
}
```

MDA Transforms to Other Models



CIM to PSM Example

Note the transformation from one model that has four subclasses to distinguish the type of the allergy, to another model that has a single class which uses an allergy type to distinguish the type of allergy

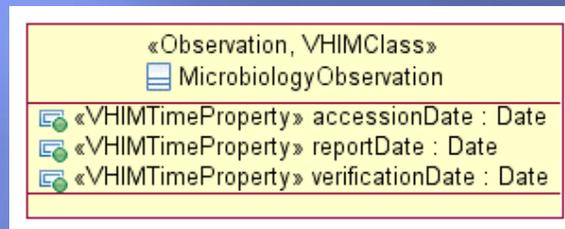


Transformations and Standards

- ▣ A “standard”, whether promulgated by a Standards Development Organization, or issued by a policy making body (e.g., FDA) can be considered a “platform”!
- ▣ In the Federal Health Information Model (FHIM), the HL7 Reference Information Model (RIM) is used as a UML Profile, allowing a rigorous transformation to/from HL7 version 3 artifacts
 - One can import and export HL7 Model Interchange Format (MIF) files to/from the UML model
- ▣ This can also be used to model other Standards
 - NCPDP SCRIPT* has been reverse- and forward- engineered
- ▣ The Model-Driven Health Tools (MDHT) project uses MDA to generate multiple artifacts from a single model (more later)

* NCPDP SCRIPT is a messaging standard used to convey pharmacy insurance claim information

Align Classes with HL7 v3



The Class Code and Mood Code are explicitly identified in the model; allowing for computable transformations to/from HL7 v3 message structures

Properties | Tasks | Console | Bookmarks | Problems

<Class> «Observation, VHIMClass» VHIM UML2 Style Guide::UML2::Microb

Keywords: |

Applied Stereotypes:

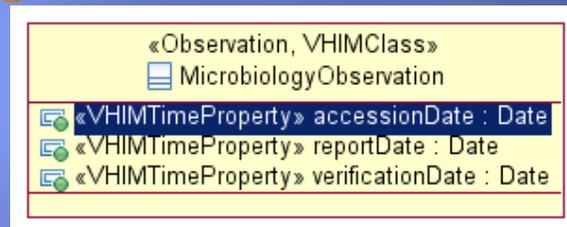
Stereotype	Profile	Required
Observation	RIM	False
VHIMClass	VHIM	False

Apply Stereotypes... | Unapply Stereotypes

Stereotype Properties:

Property	Value
Observation	
classCode	40 - OBS
moodCode	1 - EVN
VHIMClass	
client	Entries: 1
convertToChoice	False
hl7Mood	2 - event (occurrence)
isEntryClass	False
isMultiObservation	False
updateMode	Entries: 0

Align Attributes with HL7 v3 (cont.)



The HL7 RIM Attribute and constrained datatype are identified in stereotype properties, not in the model itself

Properties | Tasks | Console | Bookmarks | Problems

General | Stereotypes | Documentation | Constraints | Advanced

<Property> «VHIMTimeProperty» accessionDate

Keywords:

Applied Stereotypes:

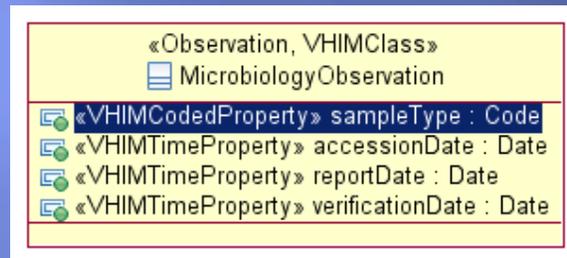
Stereotype	Profile	Required
VHIMTimeProperty	VHIM	False

Apply Stereotypes... | Unapply Stereotypes

Stereotype Properties:

Property	Value
<input type="checkbox"/> VHIMTimeProperty	
canBeImprecise	False
client	Entries: 1
hl7Attribute	48 - effectiveTime
hl7Datatype	65 - TS
hl7ObservationClassName	
updateMode	Entries: 0

Mechanism to Align with Terminology



The model explicitly links to both the VHA Unique concept Identifier (VUID) and to the HL7 value set

Properties window for <<Property>> «VHIMCodedProperty» sampleType

Keywords:

Applied Stereotypes:

Stereotype	Profile	Required
VHIMCodedProperty	VHIM	False

Apply Stereotypes... Unapply Stereotypes

Stereotype Properties:

Property	Value
VHIMCodedProperty	
client	Entries: 1
hl7Attribute	24 - code
hl7Datatype	12 - CD
hl7ObservationClassName	
updateMode	Entries: 0
valueSetVuid	12345
vocabularyDomainMnemonic	SMPLTYP
vocabularyDomainName	ActSampleType

Use of UML Profile in MDHT

MDHT presents the UML Profile information in a modeler-friendly data-entry screen, but

The screenshot shows the MDHT software interface with the following details:

- Windows: Properties, Problems, Tasks, Console
- Header: <<codeSystemConstraint>> <Property> code : CE
- Left Panel: General, **CDA Tools** (highlighted in red), Documentation, Advanced
- General Tab:
 - Vocabulary Constraints: Concept Domain, Code System, Value Set
 - Code System: Select Code System... X CodeSystems::LOINC
 - Name: LOINC, ID: 2.16.840.1.113883.6.1, Version: 2.26
 - Binding: Static, Code: 48765-2, Code Display Name: Allergies, adverse reactions, alerts
 - Validation: Severity: SHALL, Rule ID(s):
 - Validation Rule: CCD Alerts Section SHALL contain [1..1] code/@code = "48765-2" Allergies, adverse reactions, alerts (CodeSystem: 2.16.840.1.113883.6.1 LOINC STATIC 2.26)
 - Custom Message:

Publishing IGs

- ▣ The UML model created with template definitions is automatically transformed to DITA XML (OASIS standard), which is then published to PDF and Eclipse Help HTML format.
- ▣ Automatic generation of example XML instance snippets for each template, included in the published IG.
- ▣ Separate developer documentation: Includes the complete aggregate list of all inherited elements and conformance rules. Thus, a developer does not need to "follow the breadcrumbs" of template conformance references. Example provided in PDF output.

Help Screen Example

The screenshot shows a Windows Internet Explorer browser window with the address bar displaying <http://cdatools.org/infocenter/index.jsp>. The browser has several tabs open, including 'Structured Doc...', 'MDHT Templa...', 'Help - OHT...', and 'MDHT Model...'. The search bar contains the text 'rio time zone'. The main content area is titled 'CDA Tools Design Pilot > CLINICAL STATEMENT TEMPLATES'. It features a left-hand navigation pane with a tree view containing items like 'Acknowledgments', 'INTRODUCTION', 'DOCUMENT TEMPLATES', 'SECTION TEMPLATES', 'CLINICAL STATEMENT TEMPLATES', 'TB Result Observation', 'TB Result Organizer', 'CLASSES', and 'REFERENCES'. The 'TB Result Organizer' item is selected and highlighted. The main content area displays the following text:

Development Only. The Normative content for these specifications may be found on the HL7, IHE, and HITSP web sites.

TB Result Organizer

[Organizer: templateId 2.16.840.1.113883.10.20.15.3.21]

The tuberculosis result organizer identifies an observation set, contained within the result organizer as a set of result observations. It contains information applicable to all of the contained result observations. It is particularly useful to group a number of tests, such as culture results, that are performed on a common specimen.

1. Conforms to [CCD Result Organizer](#) template (templateId: 2.16.840.1.113883.10.20.1.32)
2. **SHALL** contain [1..1] code, which **SHALL** be selected from ValueSet 2.16.840.1.114222.4.11.3205 Lab Test Result Name (TB) DYNAMIC
3. **SHALL** contain [1..1] component such that it
 - a. **SHALL** contain [1..1] [TB Result Observation](#) (templateId: 2.16.840.1.113883.10.20.15.3.13)

Figure 1. TB Result Organizer example

```
<?xml version="1.0" encoding="UTF-8"?>
<ClinicalDocument xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="urn:h...
  <component>
    <structuredBody>
      <component>
        <section>
          <entry>
            <organizer moodCode="EVN">
              <templateId root="2.16.840.1.113883.10.20.1.32"/>
            </organizer>
          </entry>
        </section>
      </component>
    </structuredBody>
  </component>
</ClinicalDocument>
```

The browser's status bar at the bottom indicates 'Internet | Protected Mode: On' and a zoom level of 100%.

Generated XML Example

Figure 1. TB Result Organizer example

```
<?xml version="1.0" encoding="UTF-8"?>
<ClinicalDocument xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="urn:h
  <component>
    <structuredBody>
      <component>
        <section>
          <entry>
            <organizer moodCode="EVN">
              <templateId root="2.16.840.1.113883.10.20.1.32"/>
              <templateId root="2.16.840.1.113883.10.20.15.3.21"/>
              <id root="35428f7f-f994-44e4-a83c-d6eb374b1982"/>
              <code codeSystem="2.16.840.1.113883.6.1" codeSystemName="LOINC"/>
              <statusCode/>
            <component>
              <observation classCode="OBS" moodCode="EVN">
                <templateId root="2.16.840.1.113883.10.20.1.31"/>
                <templateId root="2.16.840.1.113883.10.20.15.3.13"/>
                <id root="b7e48f8f-bda4-4d9c-be57-151c25a655c7"/>
                <code codeSystem="2.16.840.1.113883.6.1" codeSystemName="LOINC"/>
                <statusCode code="completed"/>
                <effectiveTime>
                  <low value="1972"/>
                  <high value="2008"/>
                </effectiveTime>
                <interpretationCode/>
                <methodCode/>
              </observation>
            </component>
          </organizer>
        </entry>
      </section>
    </component>
  </structuredBody>
</ClinicalDocument>
```

Developer Documentation (PDF)

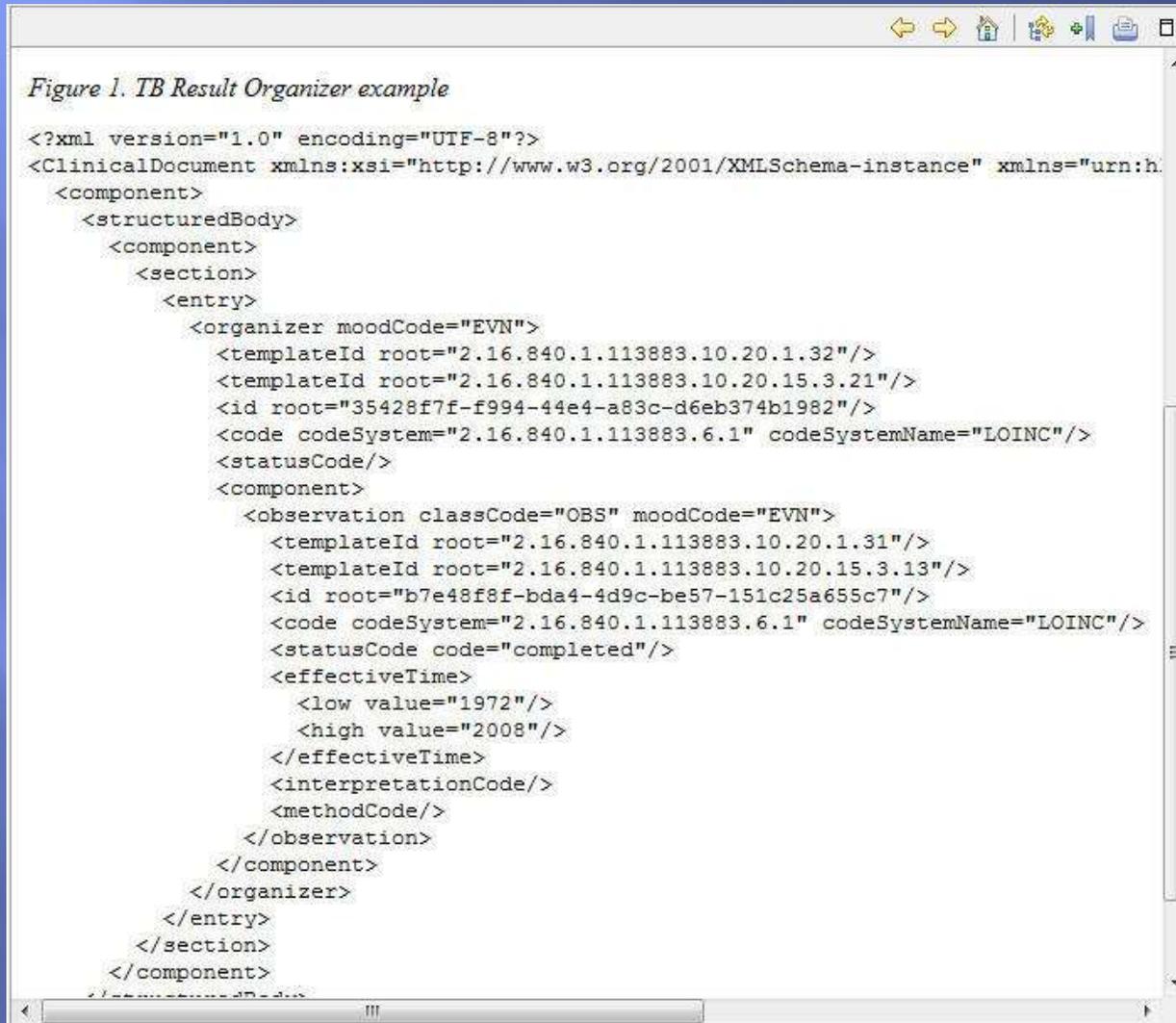
TB Result Organizer

[Organizer: templateId 2.16.840.1.113883.10.20.15.3.21]

The tuberculosis result organizer identifies an observation set, contained within the result organizer as a set of result observations. It contains information applicable to all of the contained result observations. It is particularly useful to group a number of tests, such as culture results, that are performed on a common specimen.

1. Conforms to *CDA Organizer*
2. Conforms to *CCD Result Organizer* template (templateId: 2.16.840.1.113883.10.20.1.32)
3. [CDA] SHALL contain [1..1] @classCode, where its data type is *x_ActClassDocumentEntryOrganizer*
4. [CCD] SHALL contain [1..1] @moodCode = "EVN"
5. [CDA] MAY contain [0..1] @nullFlavor, where its data type is *NullFlavor*
6. [CDA] MAY contain [0..*] realmCode, where its data type is *CS*
7. [CDA] MAY contain [0..1] typeId, where its data type is *InfrastructureRootTypeId*
8. [CDA] MAY contain [0..*] templateId, where its data type is *II*
9. [CCD] SHALL contain [1..*] id
10. [TBPN] SHALL contain [1..1] code, which SHALL be selected from ValueSet 2.16.840.1.114222.4.11.3205
Lab Test Result Name (TB) DYNAMIC
11. [CCD] SHALL contain [1..1] statusCode
12. [CDA] MAY contain [0..1] effectiveTime, where its data type is *IVL_TS*
13. [CDA] MAY contain [0..1] subject, where its type is *CDA Subject*
14. [CCD] SHOULD contain [1..*] component such that it
 - a. SHALL contain [1..1] *CDA Specimen*
15. [CDA] MAY contain [0..*] performer, where its type is *CDA Performer2*
16. [CDA] MAY contain [0..*] author, where its type is *CDA Author*
17. [CDA] MAY contain [0..*] informant, where its type is *CDA Informant12*
18. [CDA] MAY contain [0..*] participant, where its type is *CDA Participant2*
19. [CDA] MAY contain [0..*] reference, where its type is *CDA Reference*
20. [CDA] MAY contain [0..*] precondition, where its type is *CDA Precondition*
21. [CDA] MAY contain [0..*] component, where its type is *CDA Component4*
22. [CCD] SHALL contain [1..*] component such that it
 - a. SHALL contain [1..1] *CCD Result Observation* (templateId: 2.16.840.1.113883.10.20.1.31)
23. [TBPN] SHALL contain [1..1] component such that it
 - a. SHALL contain [1..1] *TB Result Observation* (templateId: 2.16.840.1.113883.10.20.15.3.13)
24. [CCD] SHOULD satisfy: The value for 'code' in a result organizer SHOULD be selected from LOINC

Generate XML Example



The image shows a screenshot of a text editor window with a standard toolbar at the top. The window contains XML code for a TB Result Organizer example. The code is as follows:

```
<?xml version="1.0" encoding="UTF-8"?>
<ClinicalDocument xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="urn:h
  <component>
    <structuredBody>
      <component>
        <section>
          <entry>
            <organizer moodCode="EVN">
              <templateId root="2.16.840.1.113883.10.20.1.32"/>
              <templateId root="2.16.840.1.113883.10.20.15.3.21"/>
              <id root="35428f7f-f994-44e4-a83c-d6eb374b1982"/>
              <code codeSystem="2.16.840.1.113883.6.1" codeSystemName="LOINC"/>
              <statusCode/>
            </organizer>
            <component>
              <observation classCode="OBS" moodCode="EVN">
                <templateId root="2.16.840.1.113883.10.20.1.31"/>
                <templateId root="2.16.840.1.113883.10.20.15.3.13"/>
                <id root="b7e48f8f-bda4-4d9c-be57-151c25a655c7"/>
                <code codeSystem="2.16.840.1.113883.6.1" codeSystemName="LOINC"/>
                <statusCode code="completed"/>
                <effectiveTime>
                  <low value="1972"/>
                  <high value="2008"/>
                </effectiveTime>
                <interpretationCode/>
                <methodCode/>
              </observation>
            </component>
          </entry>
        </section>
      </component>
    </structuredBody>
  </component>
</ClinicalDocument>
```

Developer Documentation (PDF)

TB Result Organizer

[Organizer: templateId 2.16.840.1.113883.10.20.15.3.21]

The tuberculosis result organizer identifies an observation set, contained within the result organizer as a set of result observations. It contains information applicable to all of the contained result observations. It is particularly useful to group a number of tests, such as culture results, that are performed on a common specimen.

1. Conforms to *CDA Organizer*
2. Conforms to *CCD Result Organizer* template (templateId: 2.16.840.1.113883.10.20.1.32)
3. [CDA] SHALL contain [1..1] @classCode, where its data type is *x_ActClassDocumentEntryOrganizer*
4. [CCD] SHALL contain [1..1] @moodCode = "EVN"
5. [CDA] MAY contain [0..1] @nullFlavor, where its data type is *NullFlavor*
6. [CDA] MAY contain [0..*] realmCode, where its data type is *CS*
7. [CDA] MAY contain [0..1] typeId, where its data type is *InfrastructureRootTypeId*
8. [CDA] MAY contain [0..*] templateId, where its data type is *II*
9. [CCD] SHALL contain [1..*] id
10. [TBPN] SHALL contain [1..1] code, which SHALL be selected from ValueSet 2.16.840.1.114222.4.11.3205
Lab Test Result Name (TB) DYNAMIC
11. [CCD] SHALL contain [1..1] statusCode
12. [CDA] MAY contain [0..1] effectiveTime, where its data type is *IVL_TS*
13. [CDA] MAY contain [0..1] subject, where its type is *CDA Subject*
14. [CCD] SHOULD contain [1..*] component such that it
 - a. SHALL contain [1..1] *CDA Specimen*
15. [CDA] MAY contain [0..*] performer, where its type is *CDA Performer2*
16. [CDA] MAY contain [0..*] author, where its type is *CDA Author*
17. [CDA] MAY contain [0..*] informant, where its type is *CDA Informant12*
18. [CDA] MAY contain [0..*] participant, where its type is *CDA Participant2*
19. [CDA] MAY contain [0..*] reference, where its type is *CDA Reference*
20. [CDA] MAY contain [0..*] precondition, where its type is *CDA Precondition*
21. [CDA] MAY contain [0..*] component, where its type is *CDA Component4*
22. [CCD] SHALL contain [1..*] component such that it
 - a. SHALL contain [1..1] *CCD Result Observation* (templateId: 2.16.840.1.113883.10.20.1.31)
23. [TBPN] SHALL contain [1..1] component such that it
 - a. SHALL contain [1..1] *TB Result Observation* (templateId: 2.16.840.1.113883.10.20.15.3.13)
24. [CCD] SHOULD satisfy: The value for 'code' in a result organizer SHOULD be selected from LOINC

Developer Integrated Help

The screenshot displays the Eclipse IDE interface for UML Modeling. The main editor shows XML code for a CCD document. A tooltip is visible over a comment line, providing integrated help for the comment. The bottom panel shows a table of validation errors and warnings.

```
<observation classCode="OBS" moodCode="EVN">
  <templateId root="2.16.840.1.113889.10.20.15.3.13" />
  <id nullFlavor="NI" />
  <code code="43419-1" codeSystem="2.16.840.1.113889.6.1" displayName="Tuber...
  <statusCode code="completed" />
  <effectiveTime value="20081201" />
  <value xsi:type="PQ" value="10" unit="mm" />
</observation>
</entry>
<entry typeCode="DRIV">
  <!-- TB Result Organizer -->
  <!-- Multiple annotations found at this line:
  - CCD Result Organizer SHALL satisfy: Contains one or more sources of information.
  - TBPB TB Result Organizer SHALL contain [1..1] code, which SHALL be selected from ValueSet
  2.16.840.1.114222.4.11.3205 Lab Test Result Name (TB) DYNAMIC
  <statusCode code="completed" />
  <effectiveTime value="20081215" />
  <!-- Specimen collection date-->
</specimen>
```

Multiple annotations found at this line:
- CCD Result Organizer SHALL satisfy: Contains one or more sources of information.
- TBPB TB Result Organizer SHALL contain [1..1] code, which SHALL be selected from ValueSet 2.16.840.1.114222.4.11.3205 Lab Test Result Name (TB) DYNAMIC

Description	Resource	Path	Location	Type
Errors (5 items)				
CCD Result Observation SHALL satisfy: Contains one or more sources of information.	TemplateTooli...	/Sample CDA Docu...	line 346	Validation Me
CCD Result Observation SHALL satisfy: Contains one or more sources of information.	TemplateTooli...	/Sample CDA Docu...	line 375	Validation Me
CCD Result Organizer SHALL satisfy: Contains one or more sources of information.	TemplateTooli...	/Sample CDA Docu...	line 357	Validation Me
Diagnosis of org.openhealthtools.mdht.uml.cda.pilot.ir	TemplateTooli...	/Sample CDA Docu...	line 5	Validation Me
TBPB TB Result Organizer SHALL contain [1..1] code, w	TemplateTooli...	/Sample CDA Docu...	line 357	Validation Me
Warnings (5 items)				
CCD Result Observation SHOULD contain [0..*] interpre	TemplateTooli...	/Sample CDA Docu...	line 346	Validation Me
CCD Result Observation SHOULD contain [0..*] interpre	TemplateTooli...	/Sample CDA Docu...	line 375	Validation Me

MDA / UML Style Benefits

- ▣ Because we're using MDA, the UML Style for the CIM can be simpler
 - Models are more computationally independent; HL7-isms and XML-isms not in the diagrams
 - Easier for Subject Matter Experts to understand and validate
 - Ability to automate Quality Assurance checks based on the semantics of the model, not just structure
 - This is done through Eclipse extensions using the Eclipse Modeling Framework (EMF) Validation Framework
 - Semantic equivalence between generated artifacts
 - Easier to determine mappings / transforms between platforms

Lessons Learned

- ▣ There will be a time between the As-Is and the To-Be where you have a mixture of both
 - Need to simultaneously maintain transforms to/from the UML model and HL7 v2 Electronic Data Interchange format, HL7 v3 XML, and CDA XML
 - “As-Is” systems do not understand the “To-Be” concepts and constructs – these need to be removed from As-Is artifacts
- ▣ One challenge was the mapping to/from HL7 v2 data types and HL7 v3
 - Certain v2 data types are needed for “backward compatibility”

Summary

- ▣ To design a SOA, you need
 - Dynamic (Behavioral) Models
 - Static (Information) Models
 - Terminology Models
- ▣ UML can be used effectively for the first two
 - Enables the benefits of Model Driven Architecture
 - Link to terminology in UML Profile
 - ▣ Further exploration of the linkages between Information and Terminology modeling is needed
- ▣ Model Transformations allow a single model to satisfy multiple purposes
- ▣ Standards can be developed in UML using MDA to generate artifacts in different formats for different audiences