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A Conceptual Framework of Representing Semantics for 3D Cadastre in Singapore

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Outline

- Background
- LandXML
- Ontology
- Formalization
- Supporting LandXML with OWL
- Applications
- Conclusions

Background

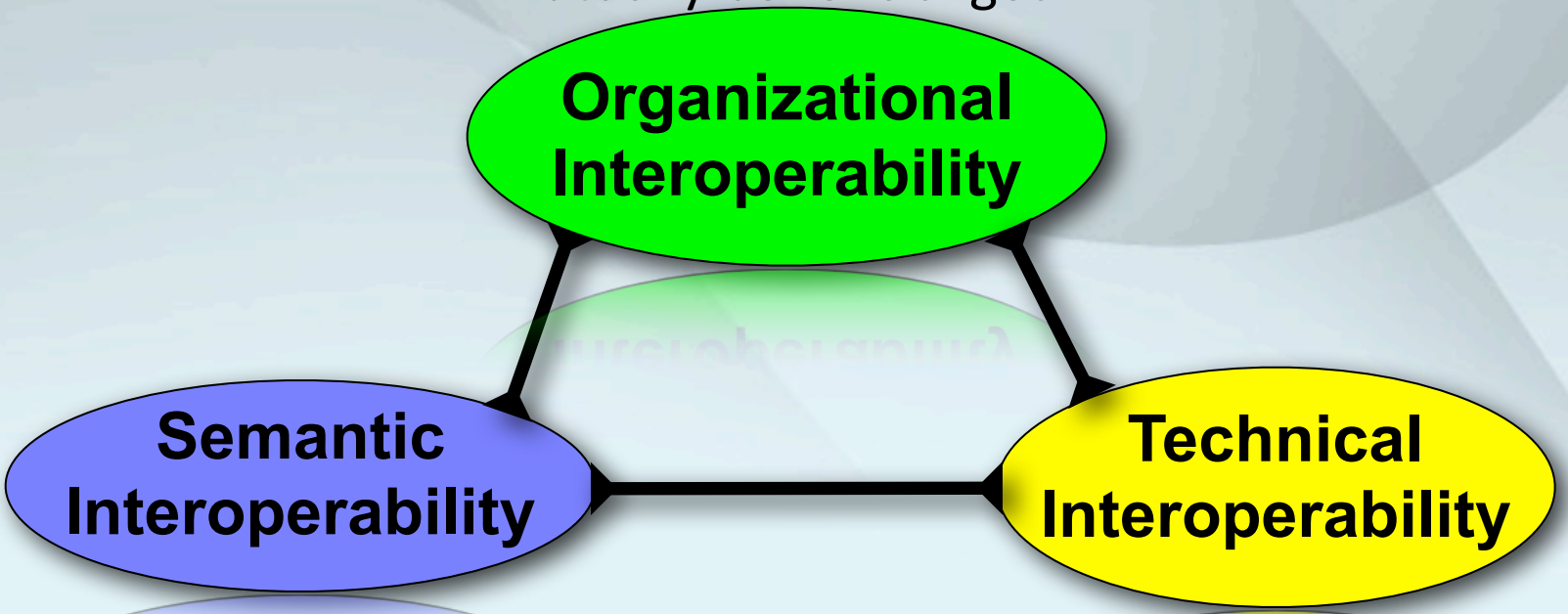
- The Land Survey Division of Singapore Land Authority (SLA) is embarking on 3D Cadastre and Automated Cadastral Job Processing Initiatives
- Land surveyors in Singapore to submit cadastral jobs in LandXML in 2015
- to consider BIM (Building Information Modeling) from the AEC (Architecture, Engineering and Construction) Industry for populating 3D Cadastral Database

Two Issues Arise

- Interoperability
  - between AEC domain and Cadastral domain
- Automation
  - LandXML only captures data not knowledge
  - knowledge is needed for computer systems to automate and to integrate data

Interoperability

"coordinated processes in which different organizations achieve a previously agreed and mutually beneficial goal"



"precise meaning of exchanged information which is preserved and understood by all parties"

"planning of technical issues involved in linking computer systems and services"

(source: European Interoperability Framework)

in Singapore

- Organizational Interoperability (OI) - being undertaken by Whole-of-Government Initiative called SG-SPACE (Singapore Geospatial Collaborative Environment)
- Technical Interoperability (TI) - implementing Open Standards such as IFC, gbXML, LandXML
- Semantic Interoperability - has received much less attention than OI and TI

Can I have the BIM models of *outlets*?

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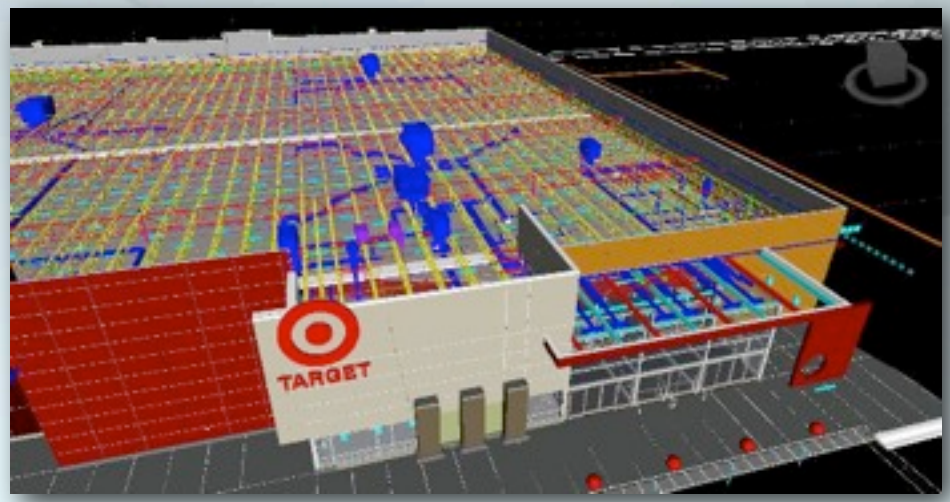
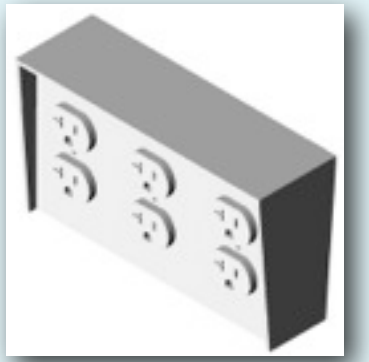
What “outlet” do you mean?

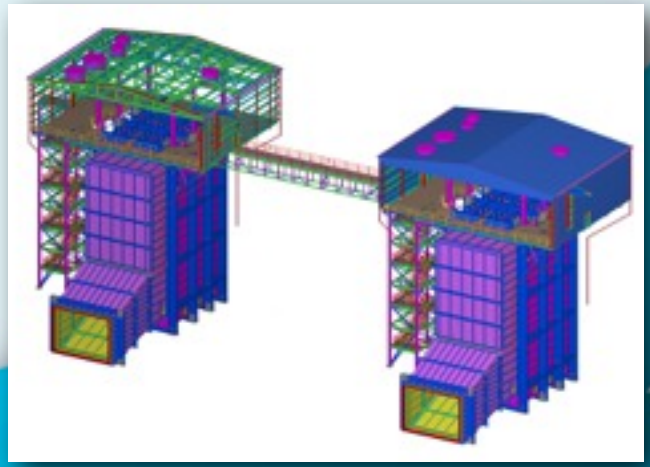
market place?



channel?



electronic device points?



Why Automation?

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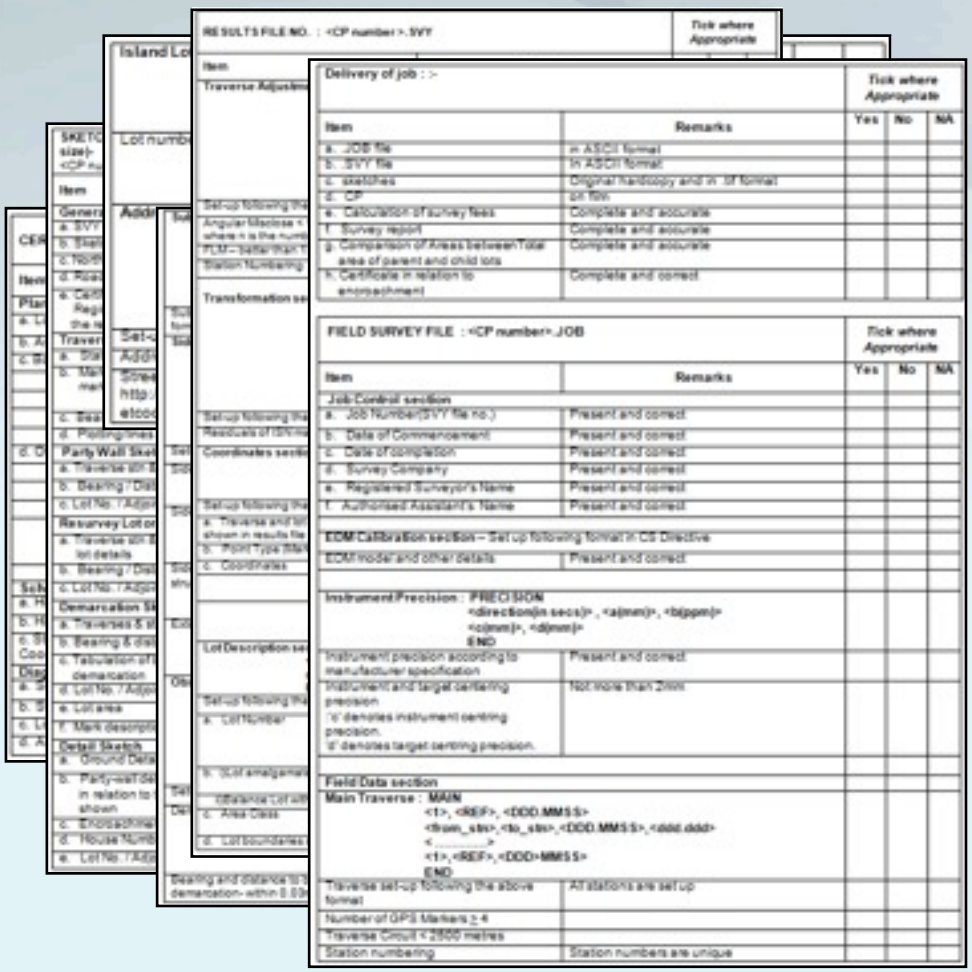
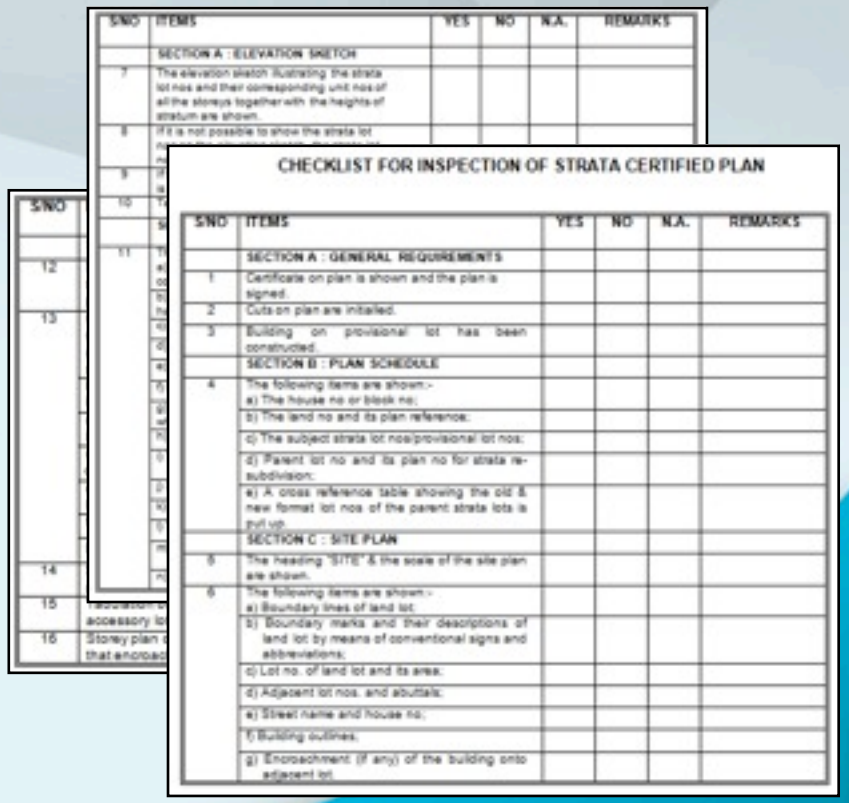
- Laborious Check Lists



- Check List for Certified Plan



- Check List for Strata Certified Plan

Too Many Forms

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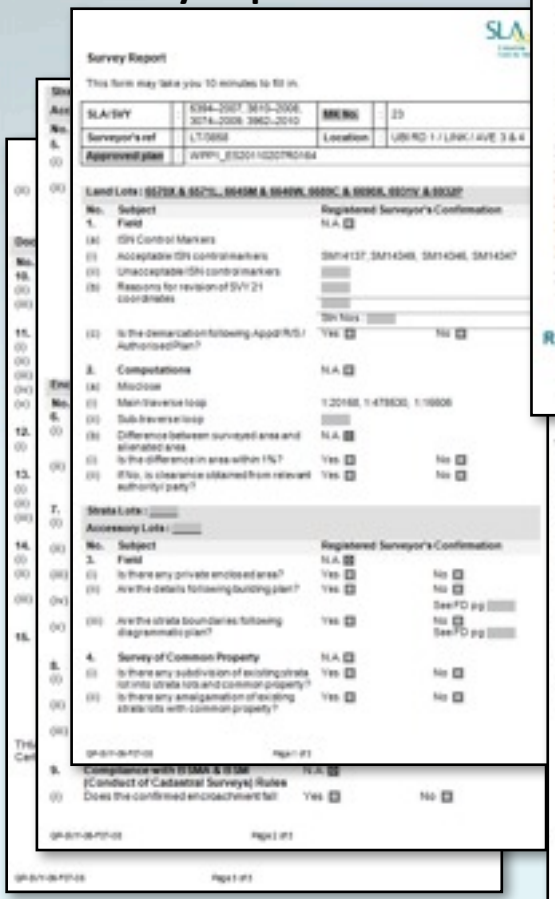
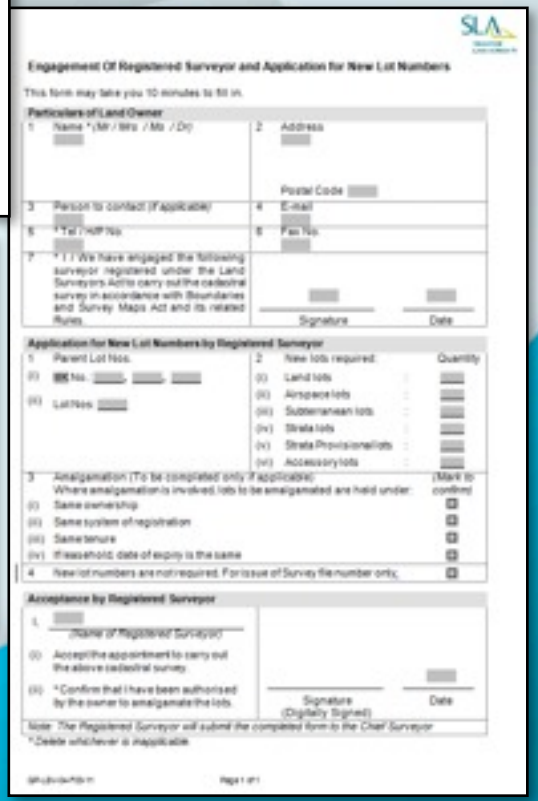
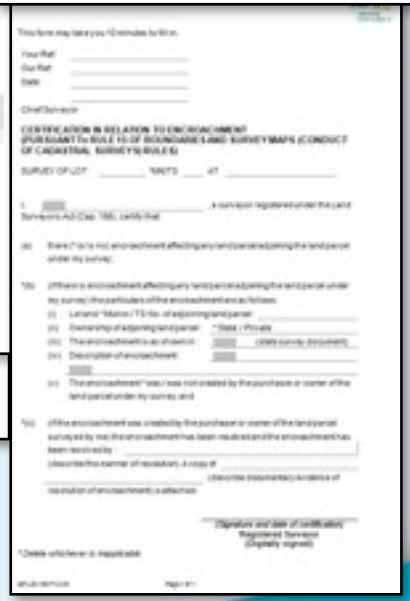
- Survey Report



- List of Forms

- Engagement of RS and Application for New Lot Numbers





- Request for SVY 21 Coordinates

- Encroachment Report

Avoidable Errors

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Major Errors

No.	Item
1.	Lot number : Incorrect lot number and check alphabet
2.	Lot boundaries : Not set up or incorrectly set up in the survey documents
3.	Demarcation: a. Not following the original position of boundary b. Deviation from request for survey(RS) plan c. Incomplete d. Encroachment is not resolved
4.	Details : e. Not fully picked up f. Encroachment details not clearly defined g. Wall details not described as party wall or garden wall h. No offsets or radiations to details and party wall i. Details not described in Field Book
5.	SVY21 datum and ISN survey: j. Failure to install or connect to for 4 ISN markers k. Failure to adopt ISN survey procedures
6.	Area : Incorrect computation
7.	Coordinates are not consistent with SVY21 values
8.	Strata lot boundaries : Not agreeing with Building Plan or the approved or authorised subdivision plans
9.	Floppy diskette containing lot/strata information l. Not submitted m. Incorrect format used for uploading in Lot Base System

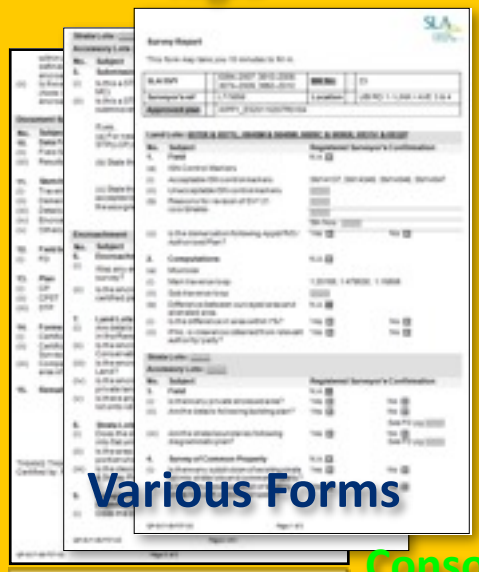
Minor Errors

No.	Item
1.	Boundary marks wrongly described
2.	House numbers not shown on plan
3.	Adjacent lot numbers and boundaries not shown or outdated
4.	Extreme coordinates omitted or incorrectly shown on plan
5.	Incorrect road names
6.	Incorrect cadastral map numbers and grids
7.	Incorrect Section 14(4) plan reference
8.	Incorrect references of records
9.	IRAS notification of addresses not submitted
10.	Incorrect height on Elevation Sketch

Source: Most Frequent Errors @ http://www.sla.gov.sg/

Intelligent Digital Data File: LandXML

Rigid



Various Forms

*.JOB

*.SVY

in-house formats

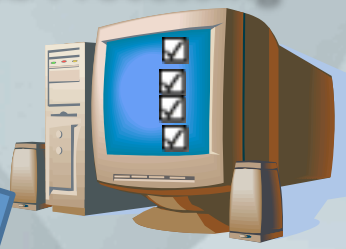
Consolidated

Parse-able and Exchangeable

LandXML

Automatic Checks

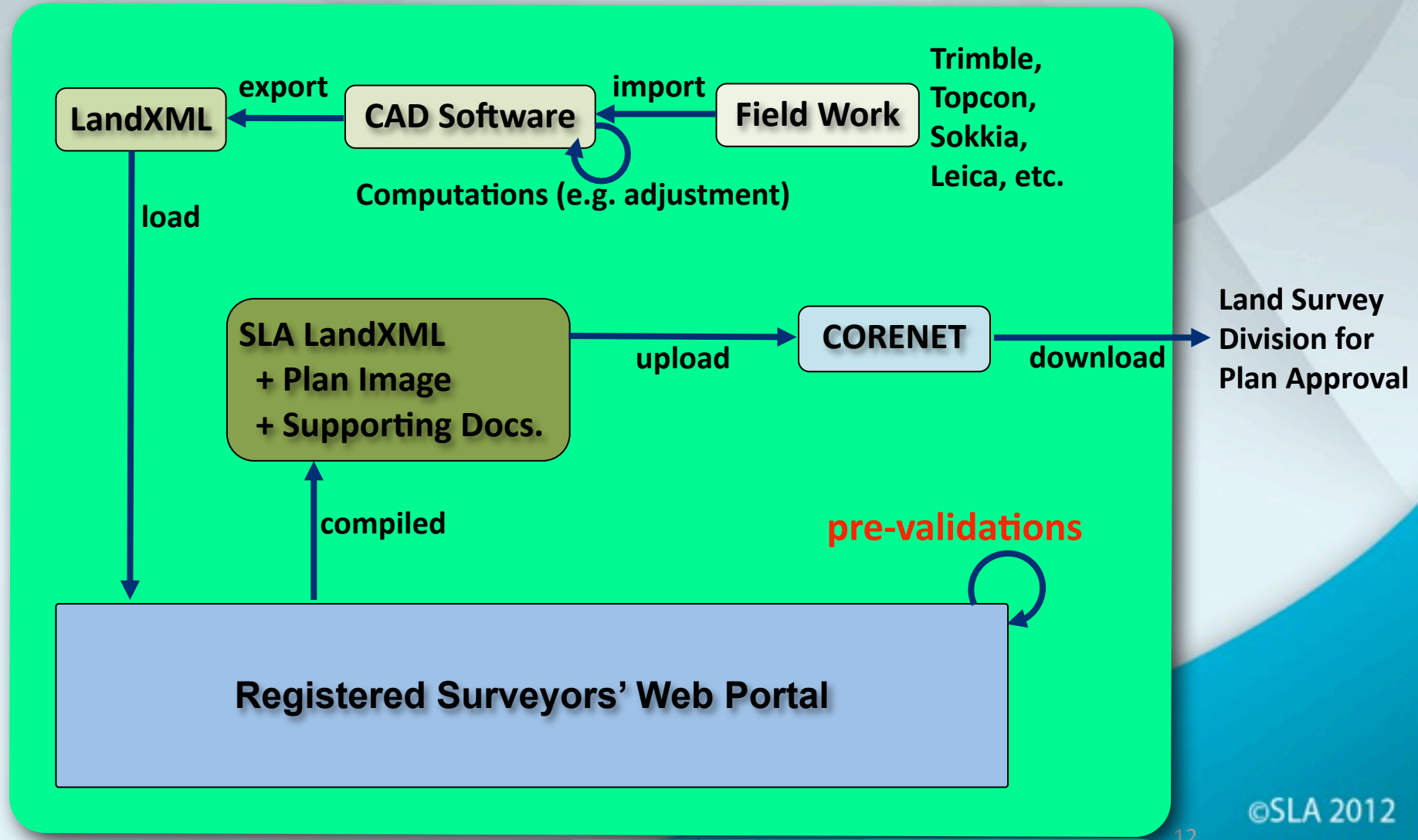
Job Processing



Direct Read and Update in CAD

Drafting

Submissions through Registered Surveyors Web Portal



What is in SLA LandXML?

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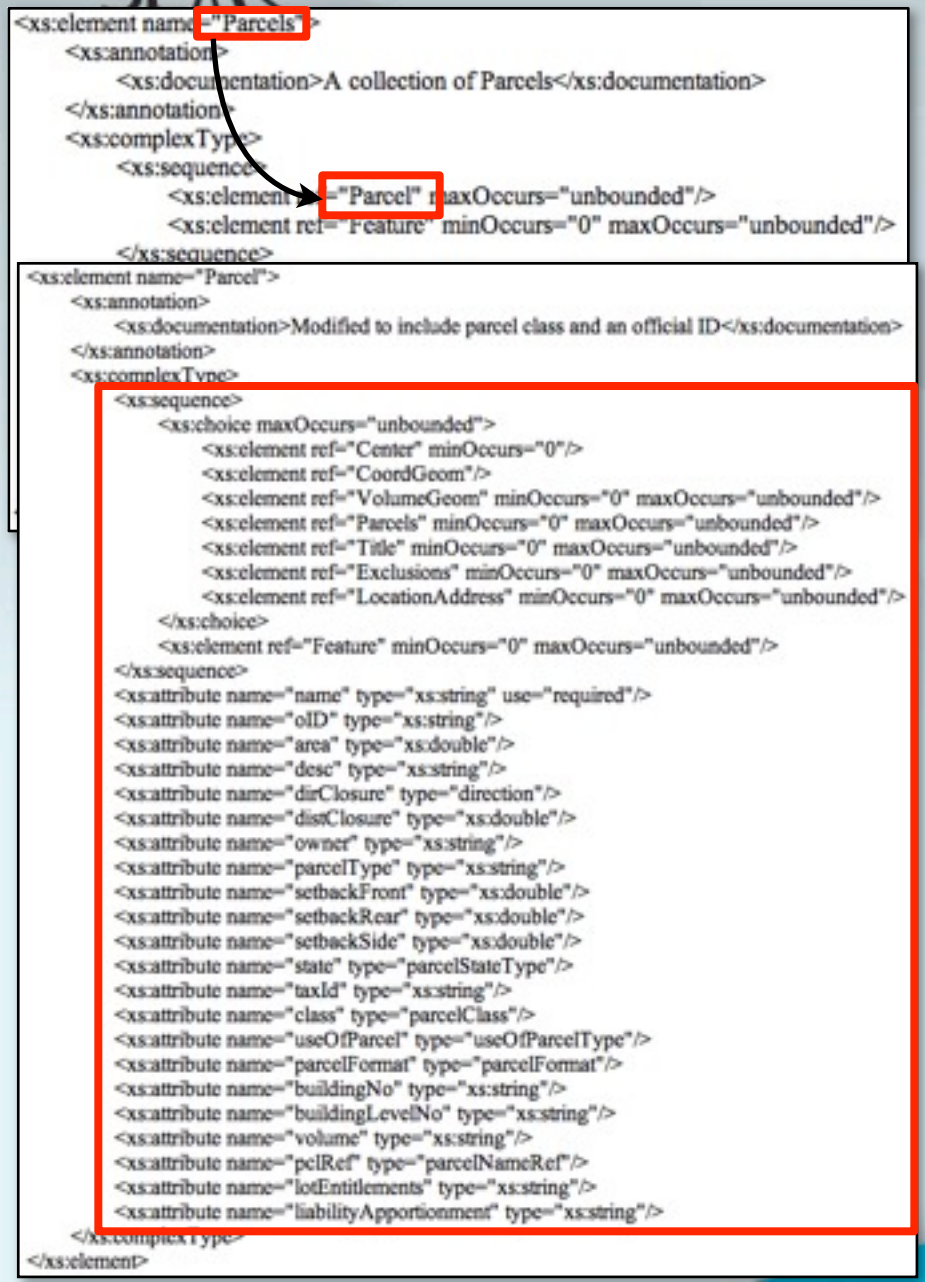
- Survey Plan Descriptions
- Address Information
- Surveyor's Details
- Survey Document Descriptions (e.g. Survey Report, Encroachment)
- Administrative Information
- Dimensions of Lots and Identifiers
- Amendment History
- Equipment Information (e.g. EDM Calibration, Instrument Precisions)
- Observation Details
- Survey Mark Descriptions

LandXML captures data not semantics



```
<xs:element name="Parcels">
    <xs:annotation>
        <xs:documentation>A collection of Parcels</xs:documentation>
    </xs:annotation>
    <xs:complexType>
        <xs:sequence>
            <xs:element ref="Parcel" maxOccurs="unbounded"/>
            <xs:element ref="Feature" minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
```

```
<xs:element name="Parcel">
    <xs:annotation>
        <xs:documentation>Modified to include parcel class and an official ID</xs:documentation>
    </xs:annotation>
    <xs:complexType>
        <xs:sequence>
            <xs:choice maxOccurs="unbounded">
                <xs:element ref="Center" minOccurs="0"/>
                <xs:element ref="CoordGeom"/>
                <xs:element ref="VolumeGeom" minOccurs="0" maxOccurs="unbounded"/>
                <xs:element ref="Parcels" minOccurs="0" maxOccurs="unbounded"/>
                <xs:element ref="Title" minOccurs="0" maxOccurs="unbounded"/>
                <xs:element ref="Exclusions" minOccurs="0" maxOccurs="unbounded"/>
                <xs:element ref="LocationAddress" minOccurs="0" maxOccurs="unbounded"/>
            </xs:choice>
            <xs:element ref="Feature" minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="name" type="xs:string" use="required"/>
        <xs:attribute name="oID" type="xs:string"/>
        <xs:attribute name="area" type="xs:double"/>
        <xs:attribute name="desc" type="xs:string"/>
        <xs:attribute name="dirClosure" type="direction"/>
        <xs:attribute name="distClosure" type="xs:double"/>
        <xs:attribute name="owner" type="xs:string"/>
        <xs:attribute name="parcelType" type="xs:string"/>
        <xs:attribute name="setbackFront" type="xs:double"/>
        <xs:attribute name="setbackRear" type="xs:double"/>
        <xs:attribute name="setbackSide" type="xs:double"/>
        <xs:attribute name="state" type="parcelStateType"/>
        <xs:attribute name="taxId" type="xs:string"/>
        <xs:attribute name="class" type="parcelClass"/>
        <xs:attribute name="useOfParcel" type="useOfParcelType"/>
        <xs:attribute name="parcelFormat" type="parcelFormat"/>
        <xs:attribute name="buildingNo" type="xs:string"/>
        <xs:attribute name="buildingLevelNo" type="xs:string"/>
        <xs:attribute name="volume" type="xs:string"/>
        <xs:attribute name="pclRef" type="parcelNameRef"/>
        <xs:attribute name="lotEntitlements" type="xs:string"/>
        <xs:attribute name="liabilityApportionment" type="xs:string"/>
    </xs:complexType>
</xs:element>
```

- captures data

Example:

```
<Parcels name="lots submitted">
   <Parcel name="U123456X" class="Strata Lot"/>
   <Parcel name="45678Y" class="Land Lot" />
</ Parcels>
```

- not semantics

e.g. how to define the semantic relationship between Strata lot and Land lot?

Automated Cadastral Job Processing

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- only supported with knowledge and rules, automated cadastral job processing can be fully achieved
- use ontology, which describes the declarative knowledge (facts) and procedural knowledge (rules) to support automation and integration

Objectives

- initiate a first step to develop and formalize Ontology for 3D Cadastre in Singapore
- demonstrate the formalization step to engineer the ontology
- support LandXML with Web Ontology Language (OWL)

Ontology

- originated in philosophy to refer to the science of what is, i.e. the kinds and structures of objects, properties, events, processes, and relations in every area of reality
- In the geospatial domain, ontology describes human-made and natural features, categories, relations, and processes at different scales or spatial granularities (Smith 2003)
- In information sciences, “an explicit specification of a conceptualization” (Gruber, 1993)

Web Ontology Language (OWL)

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- is used to formalize ontology, so that computer systems are able to process the knowledge

```
<xs:element name="Parcel">
    <xs:annotation>
        <xs:documentation>Modified to include parcel class and an official ID</xs:documentation>
    </xs:annotation>
    <xs:complexType>
        <xs:sequence>
            <xs:choice maxOccurs="unbounded">
                <xs:element ref="Center" minOccurs="0"/>
                <xs:element ref="CoordGeom"/>
                <xs:element ref="VolumeGeom" minOccurs="0" maxOccurs="unbounded"/>
                <xs:element ref="Parcels" minOccurs="0" maxOccurs="unbounded"/>
                <xs:element ref="Title" minOccurs="0" maxOccurs="unbounded"/>
                <xs:element ref="Exclusions" minOccurs="0" maxOccurs="unbounded"/>
                <xs:element ref="LocationAddress" minOccurs="0" maxOccurs="unbounded"/>
            </xs:choice>
            <xs:element ref="Feature" minOccurs="0" maxOccurs="unbounded"/>
        </xs:sequence>
        <xs:attribute name="name" type="xs:string" use="required"/>
        <xs:attribute name="oID" type="xs:string"/>
        <xs:attribute name="area" type="xs:double"/>
        <xs:attribute name="desc" type="xs:string"/>
        <xs:attribute name="dirClosure" type="direction"/>
        <xs:attribute name="distClosure" type="xs:double"/>
        <xs:attribute name="owner" type="xs:string"/>
        <xs:attribute name="parcelType" type="xs:string"/>
        <xs:attribute name="setbackFront" type="xs:double"/>
        <xs:attribute name="setbackRear" type="xs:double"/>
        <xs:attribute name="setbackSide" type="xs:double"/>
        <xs:attribute name="state" type="parcelStateType"/>
        <xs:attribute name="taxId" type="xs:string"/>
        <xs:attribute name="class" type="parcelClass"/>
        <xs:attribute name="useOfParcel" type="useOfParcelType"/>
        <xs:attribute name="parcelFormat" type="parcelFormat"/>
        <xs:attribute name="buildingNo" type="xs:string"/>
        <xs:attribute name="buildingLevelNo" type="xs:string"/>
        <xs:attribute name="volume" type="xs:string"/>
        <xs:attribute name="pclRef" type="parcelNameRef"/>
        <xs:attribute name="lotEntitlements" type="xs:string"/>
        <xs:attribute name="liabilityApportionment" type="xs:string"/>
    </xs:complexType>
</xs:element>
```

XML

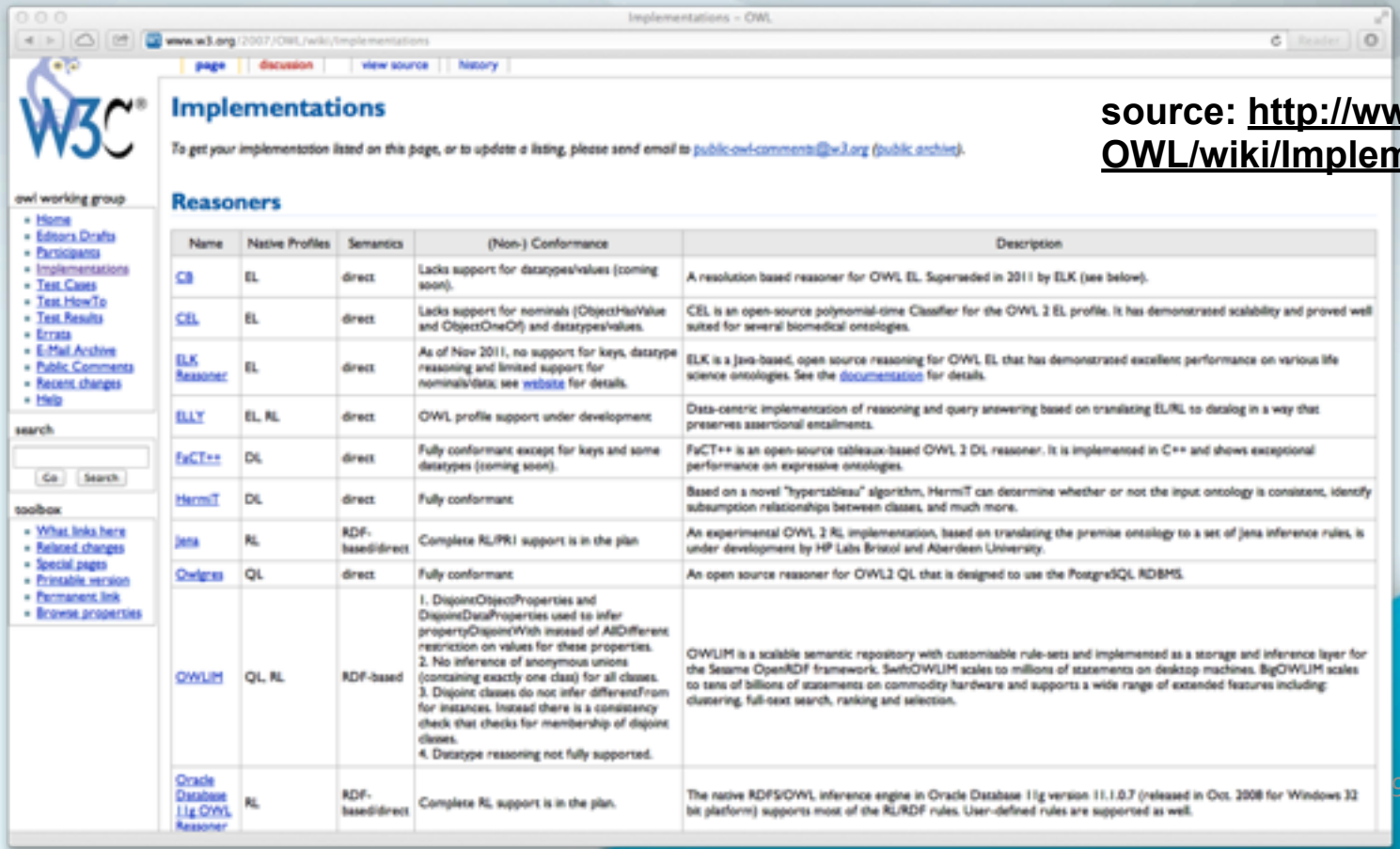
```
<owl:Class rdf:about="3DCadastralOntology;StrataLot">
    <owl:equivalentClass>
        <owl:Class>
            <owl:intersectionOf rdf:parseType="Collection">
                <rdf:Description rdf:about="3DCadastralOntology;Parcel"/>
                <rdf:Description rdf:about="3DCadastralOntology;Stratum"/>
            </owl:intersectionOf>
        </owl:Class>
    </owl:equivalentClass>
    <rdfs:subClassOf rdf:resource="3DCadastralOntology;3DParcel"/>
</owl:Class>
```

OWL

- similar to XML, but supports rich semantics

Reasoners

- a computer program that is able to infer logical consequences from a set of rules or facts described in the ontology (OWL)



Implementations - OWL

www.w3.org/2007/OWL/wiki/Implementations

page | discussion | view source | history

Implementations

To get your implementation listed on this page, or to update a listing, please send email to public-owl-comments@w3.org (public archive).

owl working group

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- Related changes
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Reasoners

Name	Native Profiles	Semantics	(Non-) Conformance	Description
CB	EL	direct	Lacks support for datatypes/values (coming soon).	A resolution based reasoner for OWL EL. Superseded in 2011 by ELK (see below).
CEL	EL	direct	Lacks support for nominals (ObjectHasValue and ObjectOneOf) and datatypes/values.	CEL is an open-source polynomial-time Classifier for the OWL 2 EL profile. It has demonstrated scalability and proved well suited for several biomedical ontologies.
ELK Reasoner	EL	direct	As of Nov 2011, no support for keys, datatype reasoning and limited support for nominals/data; see website for details.	ELK is a Java-based, open source reasoning for OWL EL that has demonstrated excellent performance on various life science ontologies. See the documentation for details.
ELLY	EL, RL	direct	OWL profile support under development	Data-centric implementation of reasoning and query answering based on translating EL/RL to datalog in a way that preserves assertional entailments.
FaCT++	DL	direct	Fully conformant except for keys and some datatypes (coming soon).	FaCT++ is an open-source tableaux-based OWL 2 DL reasoner. It is implemented in C++ and shows exceptional performance on expressive ontologies.
HermiT	DL	direct	Fully conformant	Based on a novel "hypertableau" algorithm, HermiT can determine whether or not the input ontology is consistent, identify subsumption relationships between classes, and much more.
Jena	RL	RDF-based/direct	Complete RL/PR1 support is in the plan	An experimental OWL 2 RL implementation, based on translating the premise ontology to a set of Jena inference rules, is under development by HP Labs Bristol and Aberdeen University.
Owlgres	QL	direct	Fully conformant	An open source reasoner for OWL2 QL that is designed to use the PostgreSQL RDBMS.
OWLIM	QL, RL	RDF-based	1. DisjointObjectProperties and DisjointDataProperties used to infer propertyDisjointWith instead of AllDifferent restriction on values for these properties. 2. No inference of anonymous unions (containing exactly one class) for all classes. 3. Disjoint classes do not infer differentFrom for instances. Instead there is a consistency check that checks for membership of disjoint classes. 4. Datatype reasoning not fully supported.	OWLIM is a scalable semantic repository with customisable rule-sets and implemented as a storage and inference layer for the Sesame OpenRDF framework. SwiftOWLIM scales to millions of statements on desktop machines. BigOWLIM scales to tens of billions of statements on commodity hardware and supports a wide range of extended features including: clustering, full-text search, ranking and selection.
Oracle Database 11g OWL Reasoner	RL	RDF-based/direct	Complete RL support is in the plan.	The native RDFS/OWL inference engine in Oracle Database 11g version 11.1.0.7 (released in Oct. 2008 for Windows 32 bit platform) supports most of the RL/RDF rules. User-defined rules are supported as well.

source: http://www.w3.org/2007/OWL/wiki/Implementations

Legislative Documents

- Our judicial framework recognizes 3D
  - completeness, minimized ambiguity, and consistency
  - but, contain hidden knowledge, need domain experts to explicate


LAND TITLES ACT
(CHAPTER 157)
An Act which makes provision for the registration of titles to land.
[1st March 1994]
PART I
PRELIMINARY
Short title
1. This Act may be cited as the Land Titles Act.
Division into Parts
2. This Act is divided into Parts, as follows:


LAND TITLES (STRATA) ACT
(CHAPTER 158)
An Act to facilitate the subdivision of land into strata and the collective sale of property, and the disposition of titles thereto and for purposes connected therewith.
[15th May 1968]
PART I
PRELIMINARY
Short title
1. This Act may be cited as the Land Titles (Strata) Act.
Application
2. Except as hereinafter provided, this Act applies only to registered land.
Interpretation
3.—(1) In this Act, unless the context otherwise requires —
"accessory lot" means a lot intended for separate proprietorship and use with any other specified lot or lots for any purpose;
"assurance" includes any transfer, lease, charge, mortgage, transmission application or any other application for vesting made under this Act;


BOUNDARIES AND SURVEY MAPS ACT
(CHAPTER 21)
An Act to provide for the demarcation of land, the establishment and maintenance of boundary marks and the publication of certain survey maps.
[14th October 1998]
PART I
PRELIMINARY
Short title
1. This Act may be cited as the Boundaries and Survey Maps Act.
Interpretation
3.—(1) In this Act, unless the context otherwise requires —
"approved co-ordinates" means co-ordinates approved by the Chief Surveyor or approved under section 7(c) which are capable of describing and ascertaining the boundaries of any land in relation to survey control marks;
"authorised surveyor" means a surveyor who is employed by the Authority, whether or not registered under section 12 of the Land Surveyors Act (Cap. 156);

Formalization

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"land" means —
(a) the surface of any defined parcel of the earth, all substances thereunder and so much of the column of airspace above the surface whether or not held apart from the surface as is reasonably necessary for the proprietor's use and enjoyment, and includes any estate or interest therein and all vegetation growing thereon and structures affixed thereto; or
....
....

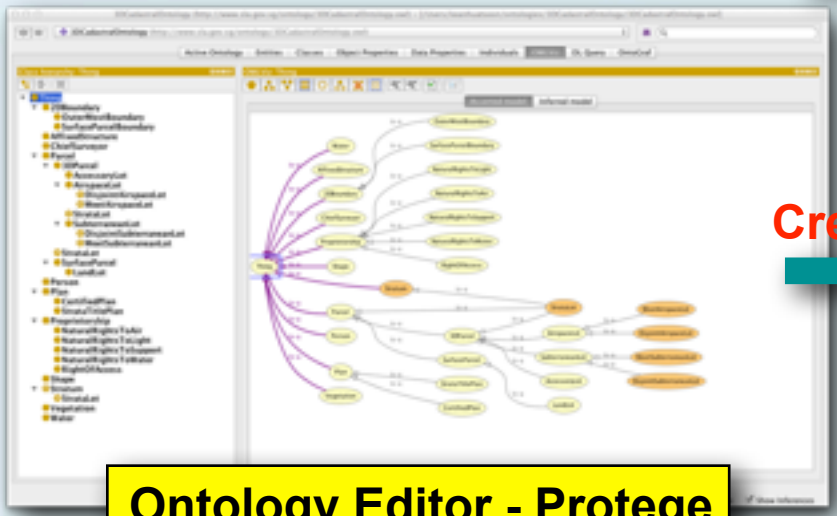
Legislative Texts

Formalization

```
subClassOf (:LandLot :SurfaceParcel)
subClassOf (:AirspaceLot :3DParcel)
subClassOf (:SubterraneanLot :3DParcel)
.....
.....
DataPropertyDomain (:hasLotNumber :Parcel)
DataPropertyRange (:hasLotNumber xsd:long)
FunctionalDataProperty (:hasLotNumber)
.....
.....
EquivalentClasses(
    :StrataLot
ObjectIntersectionOf (:Stratum :Parcel)
          )
.....
.....
```

Functional Syntax

Visualization



Ontology Editor - Protege

Creation

```
<owl:Class rdf:about="3DCadastralOntology;StrataLot">
    <owl:equivalentClass>
        <owl:Class>
            <owl:intersectionOf rdf:parseType="Collection">
                <rdf:Description rdf:about="3DCadastralOntology;Parcel"/>
                <rdf:Description rdf:about="3DCadastralOntology;Stratum"/>
            </owl:intersectionOf>
        </owl:Class>
    </owl:equivalentClass>
    <rdfs:subClassOf rdf:resource="3DCadastralOntology;3DParcel"/>
</owl:Class>
.....
.....
```

OWL

Legislative Texts

Land Titles Act (Chapter 157)

"land" means —
(a) the surface of any defined parcel of the earth, all substances thereunder and so much of the column of airspace above the surface whether or not held apart from the surface as is reasonably necessary for the proprietor's use and enjoyment, and includes any estate or interest[3] therein and all vegetation growing thereon and structures affixed thereto; or
(b) any parcel of airspace or any subterranean space whether or not held apart from the surface of the earth and described with certainty by reference to a plan approved by the Chief Surveyor and filed with the Authority, and includes any estate or interest therein and all vegetation growing thereon and structures affixed thereto,
and where the context so permits, the proprietorship of land includes natural rights to air, light, water and support and the right of access to any highway on which the land abuts;

Boundaries and Survey Maps Act (Chapter 25)

"land" includes —
(a) a parcel of land which is in the actual possession of the owner by himself or other person holding by, through or under him;
(b) land covered by water;
(c) a building or a structure erected on land;
(d) any parcel of airspace or any subterranean space whether or not held apart from the surface of the earth; and
(e) any estate or interest in land;

Land Titles (Strata) Act (Chapter 158)

"lot" means a stratum which is shown as a lot on a strata title plan, and includes a lot specified as an accessory lot on any such plan
and
"stratum" means any part of land consisting of a space of any shape below, on or above the surface of the land, or partly below and partly above the surface of the land, the dimensions of which are delineated;
and
"accessory lot" means a lot intended for separate proprietorship and use with any other specified lot or lots for any purpose;

Some Examples on Functional Syntax

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generalization axioms

```
subClassOf (:LandLot :SurfaceParcel)
subClassOf (:AirspaceLot :3DParcel)
subClassOf (:SubterraneanLot :3DParcel)
subClassOf (:3DParcel :Parcel)
subClassOf (:SurfaceParcel :Parcel)
```

Defining Properties (relationships)

```
DataPropertyDomain (:hasLotNumber :Parcel)
DataPropertyRange (:hasLotNumber xsd:long)
FunctionalDataProperty (:hasLotNumber)

ObjectPropertyDomain (:isShownOn :Parcel)
ObjectPropertyRange (:isShownOn :Plan)

ObjectPropertyDomain (:isApprovedBy :Plan)
ObjectPropertyRange (:isApprovedBy :ChiefSurveyor)

subClassOf (:CertifiedPlan :Plan)
subClassOf (:StrataTitlePlan :Plan)
```

Expressions

```
EquivalentClasses(
            :DisjointSubterraneanLot
ObjectIntersectionOf(
ObjectAllValuesFrom (:disjoint :SurfaceParcel)
            :SubterraneanLot
)
)
```

```
EquivalentClasses(
            :MeetSubterraneanLot
ObjectIntersectionOf(
ObjectAllValuesFrom (:meet :SurfaceParcel)
            :SubterraneanLot
)
)
```

Result: Classes and Properties in Protege

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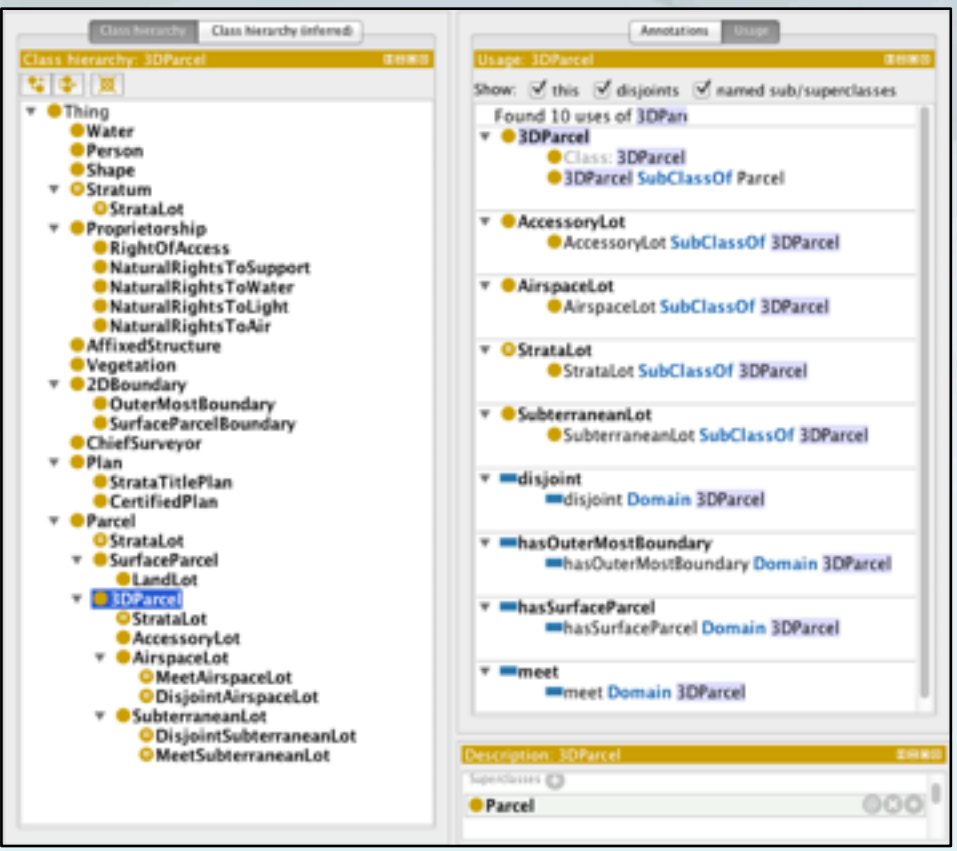
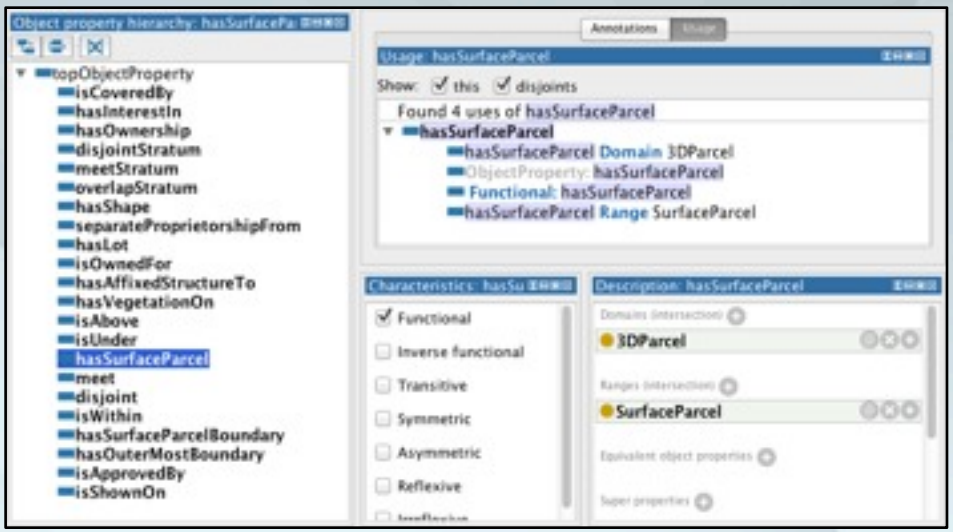
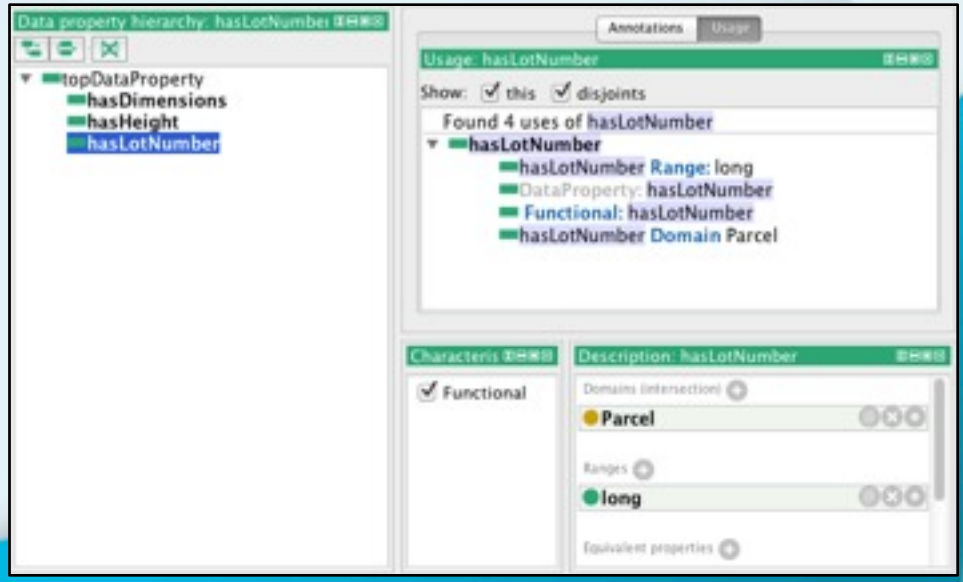
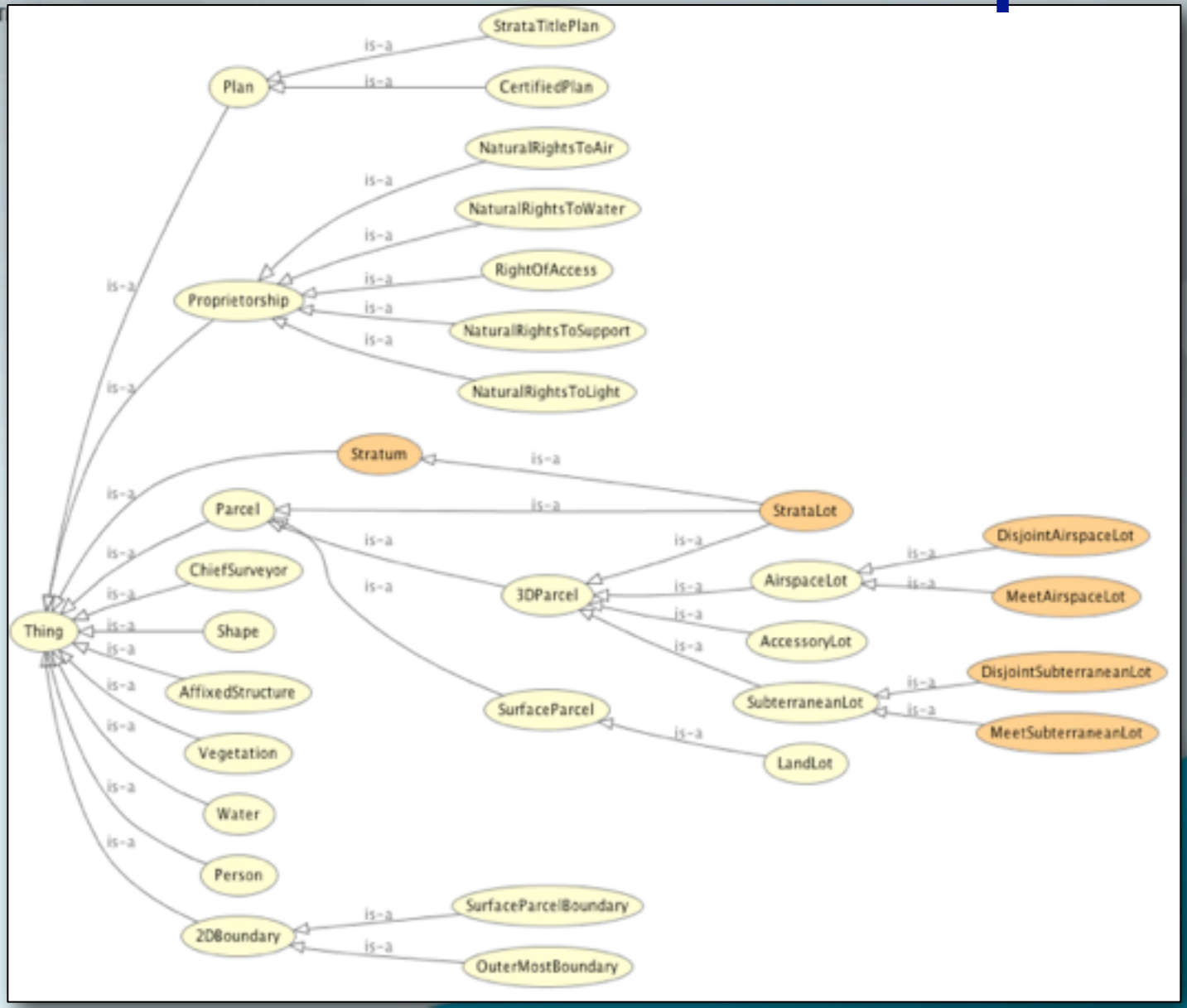






Overview of the Ontology (Generalization relationship only)



Complete Ontology in Graph

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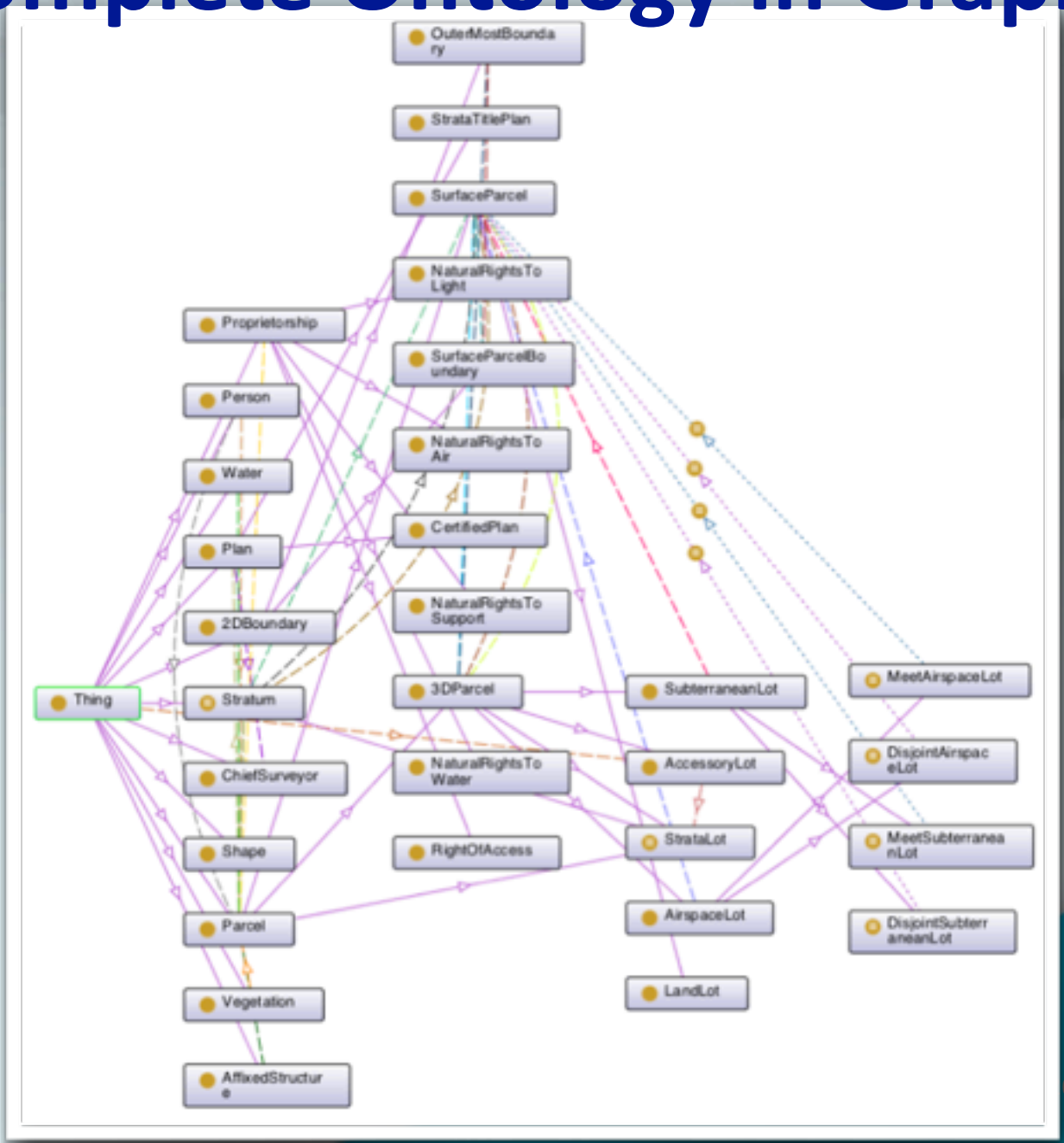

Ontology in OWL

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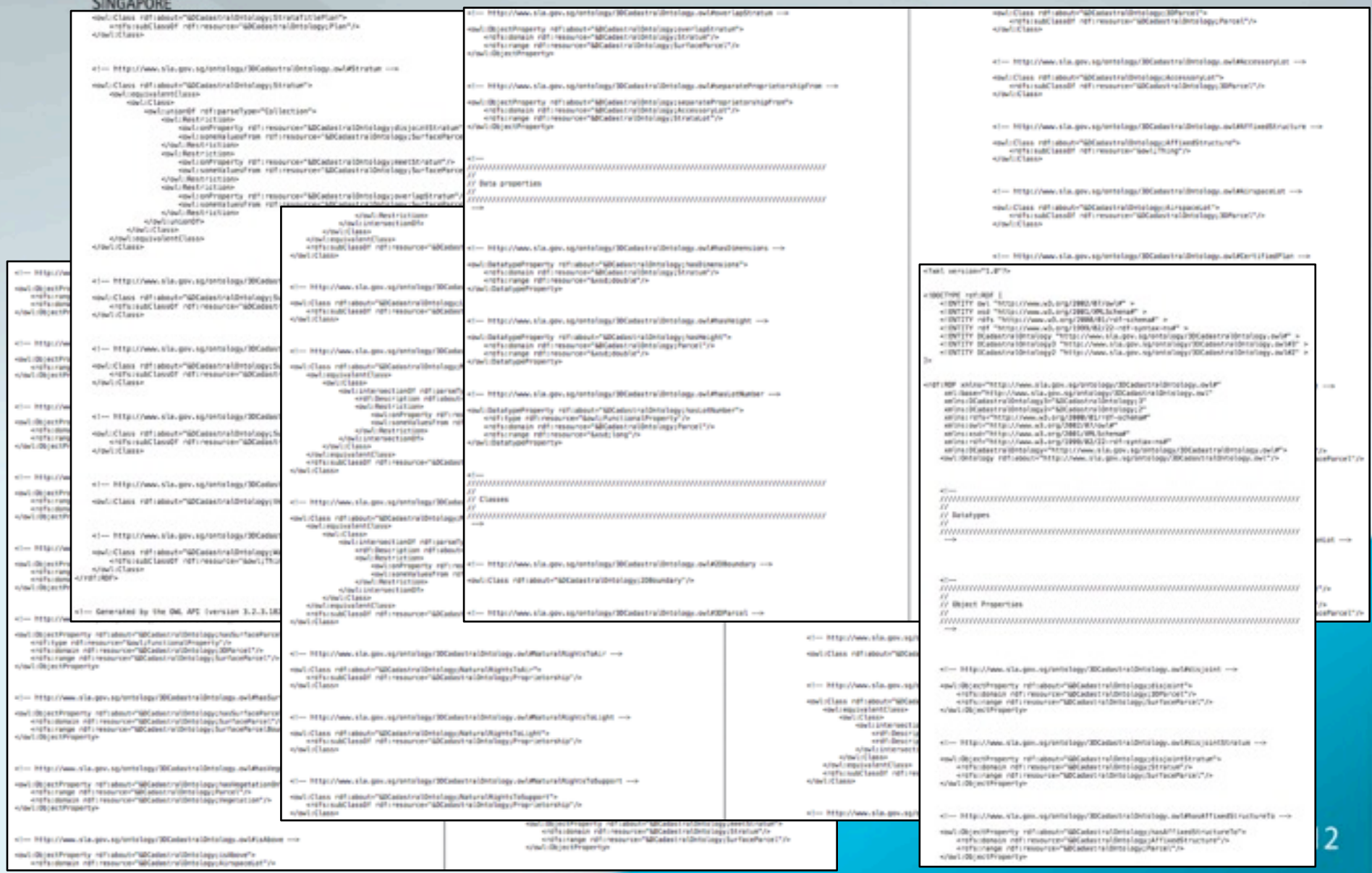

LandXML Schema

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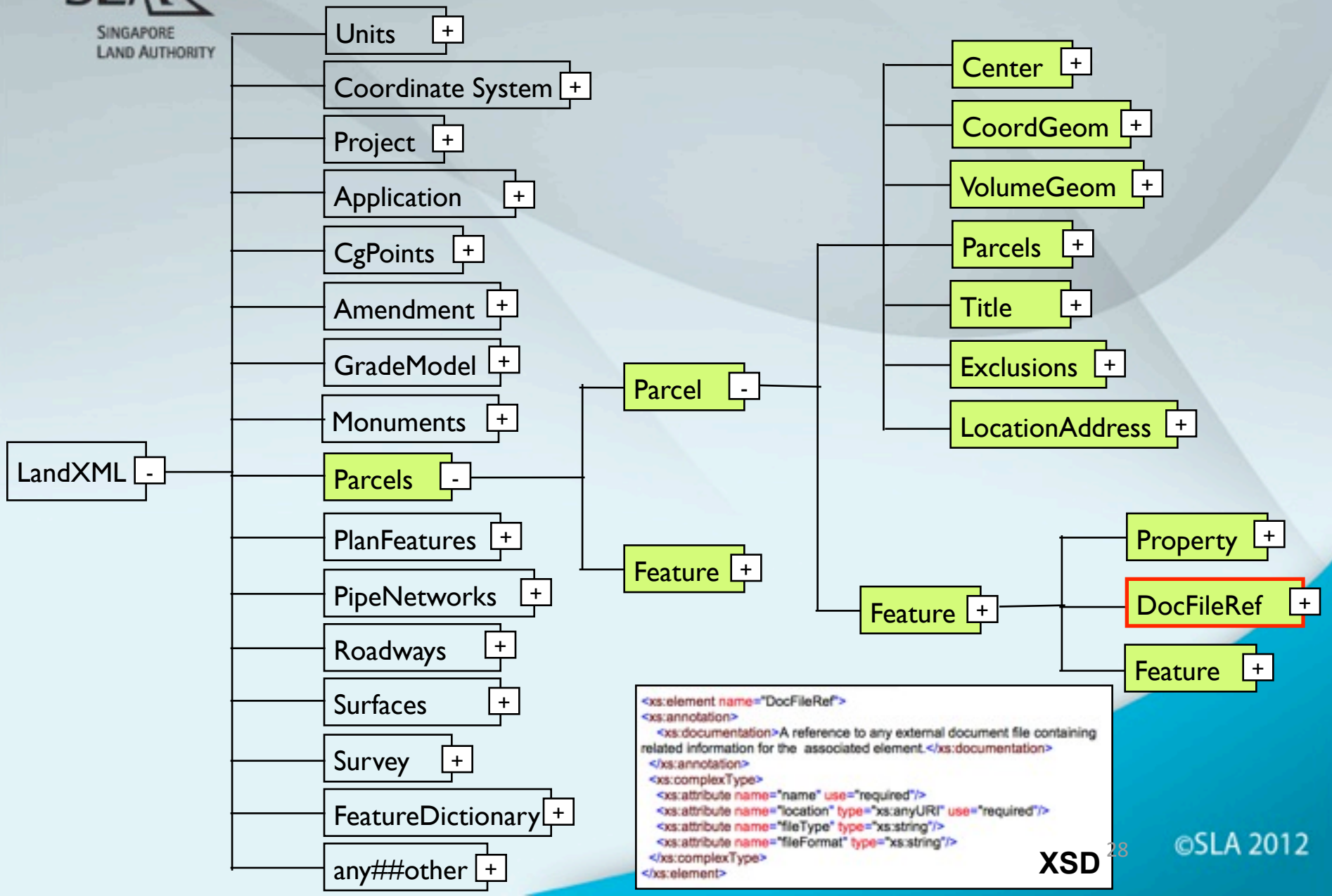


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<xs:annotation>
  <xs:documentation>A reference to any external document file containing
related information for the  associated element.</xs:documentation>
 </xs:annotation>
 <xs:complexType>
  <xs:attribute name="name" use="required"/>
  <xs:attribute name="location" type="xs:anyURI" use="required"/>
  <xs:attribute name="fileType" type="xs:string"/>
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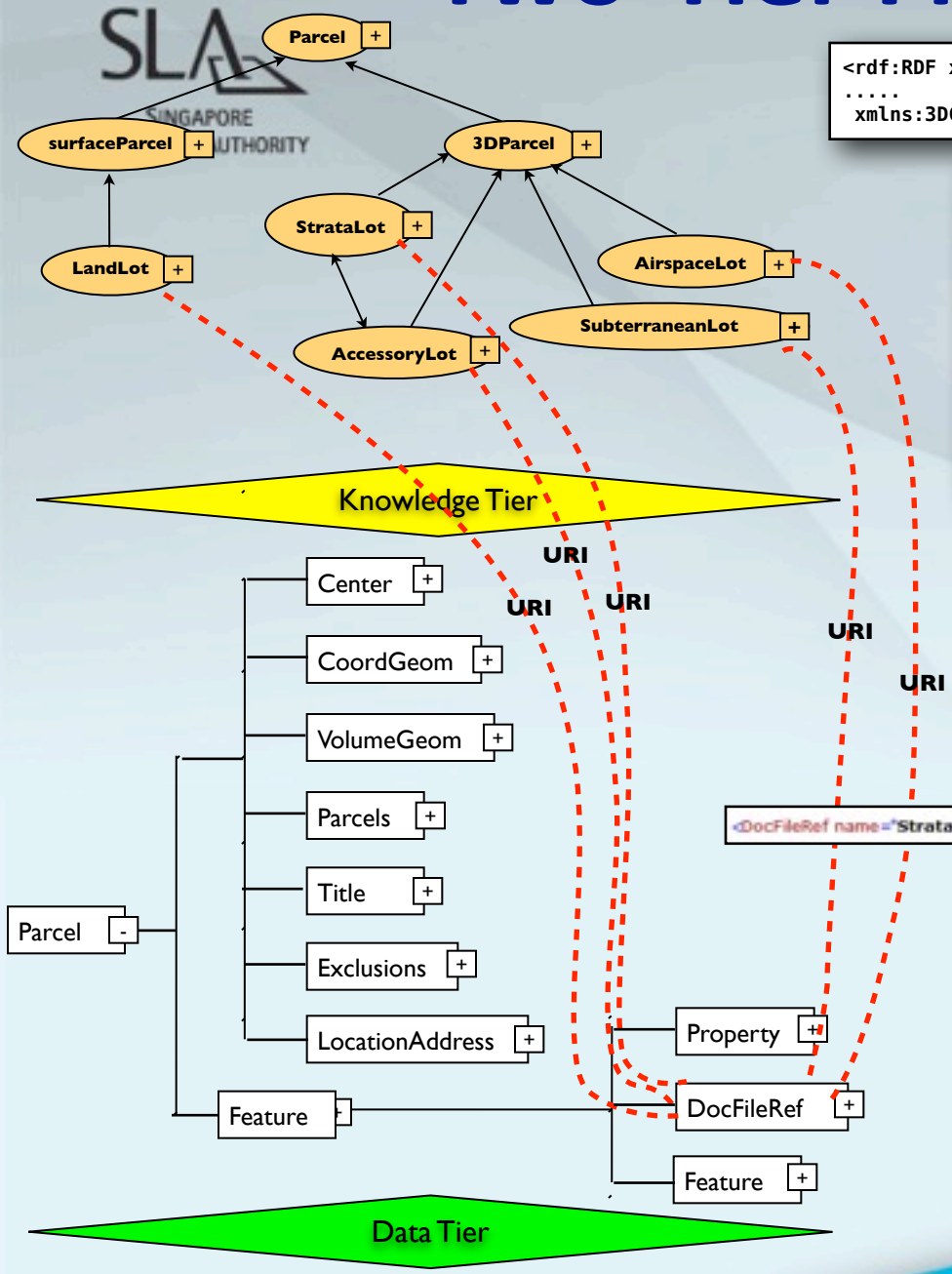
XSD

Two-Tier Framework

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<rdf:RDF xmlns="http://www.sla.gov.sg/ontology/3DCadastralOntology.owl#"
.....
 xmlns:3DCadastralOntology="http://www.sla.gov.sg/ontology/3DCadastralOntology.owl#">
```

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<owl:Class rdf:about="3DCadastralOntology;StrataLot">
    <owl:equivalentClass>
        <owl:Class>
            <owl:intersectionOf rdf:parseType="Collection">
                <rdf:Description rdf:about="3DCadastralOntology;Parcel"/>
                <rdf:Description rdf:about="3DCadastralOntology;Stratum"/>
            </owl:intersectionOf>
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.....
.....
```

OWL

```
<DocFileRef name="StrataLot" location="http://www.sla.gov.sg/ontology/3DCadastralOntology.owl#StrataLot" />
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LandXML

Applications

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- ontology serves as facts and rules for checking the integrity and consistency of data in the LandXML
- ontology makes the semantics of cadastral dataset explicit. This will facilitate the integration of cadastral dataset with other data sources

Conclusions

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- supported LandXML with Semantics
- developing ontology is an on-going process
- just initiated a first step towards developing a formalized ontology for 3D Cadastre in Singapore
- more concepts are needed over time, and the framework should be tested with real case study

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Thank You!

soon_kean_huat@sla.gov.sg