

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

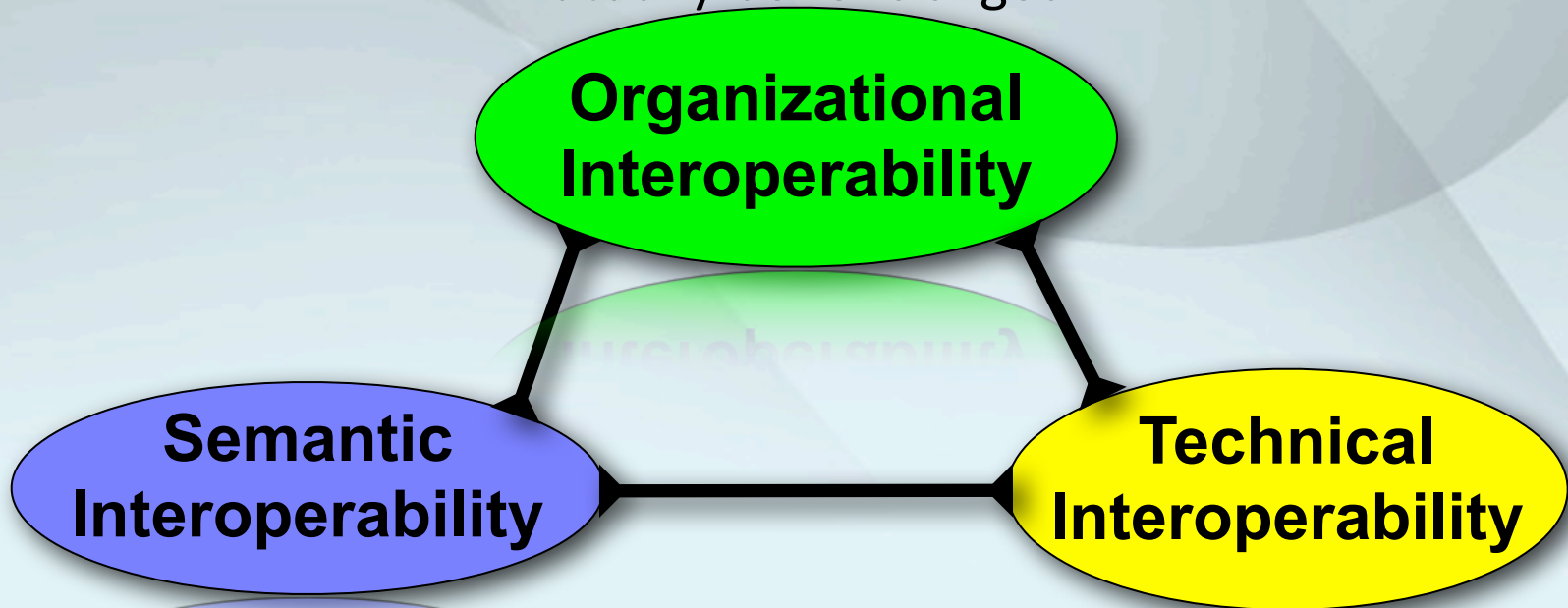
- The Land Survey Division of Singapore Land Authority (SLA) is embarking on 3D Cadastre and Automated Cadastral Job Processing Initiatives
- Land surveyors in Singapore to submit cadastral jobs in LandXML in 2015
- to consider BIM (Building Information Modeling) from the AEC (Architecture, Engineering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



**Organizational
Interoperability**

**Semantic
Interoperability**

**Technical
Interoperability**

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

“planning of technical issues involved in linking computer systems and services”

in Singapore

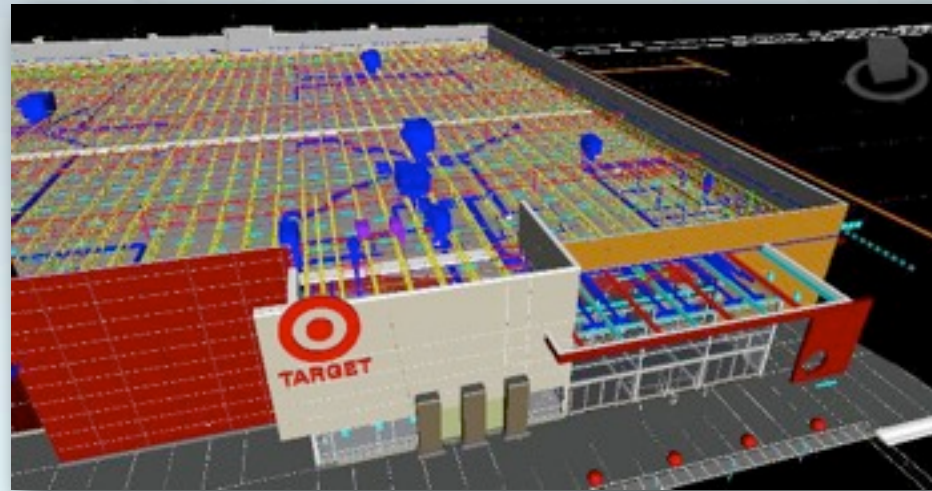
- Organizational Interoperability (OI) - being undertaken by Whole-of-Government Initiative called SG-SPACE (Singapore Geospatial Collaborative Environment)
- Technical Interoperability (TI) - implementing Open Standards such as IFC, gbXML, LandXML
- Semantic Interoperability - has received much less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

Can I have the BIM models of *outlets*?

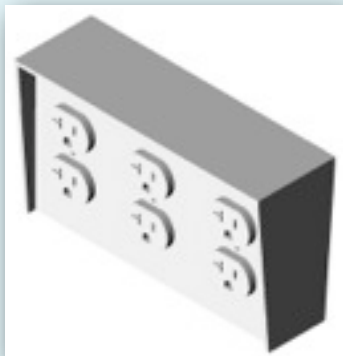


What “outlet” do you mean?

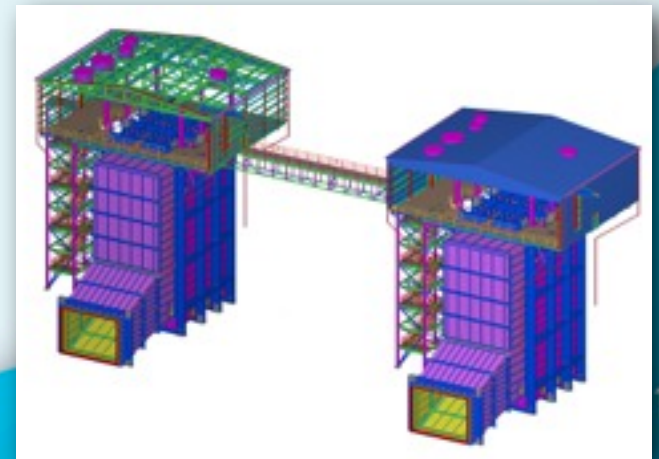
market place?



channel?



electronic
device points?



Why Automation?

■ Laborious Check Lists

RESULTS FILE NO. : <CP number>-SVY

Item where Appropriate

Island Lot

Lot number

SKETCH size) <CP number>-SVY

Item

General

Address

Set-up following the Angular Method n where n is the number of stations

Transformation set

Set-up following the Method of least squares

Coordinates section

Set-up following the Inverse and/or shown in results file

Lot Description set

Set-up following the

Lot area

Mark description

Detail Sketch

Ground Data

Particulars in relation to shown

Enroadment

HOUSE NO

Lot No

Setting and distance to demarcation within 0.03

Delivery of job :-

Item	Remarks	Tick where Appropriate		
		Yes	No	NA
a. JOB file	in ASCII format			
b. SVY file	in ASCII format			
c. sketches	Original hardcopy and in .dxf format or file			
d. CP				
e. Calculation of survey fees	Complete and accurate			
f. Survey report	Complete and accurate			
g. Comparison of Areas between Total area of parent and child lots	Complete and accurate			
h. Certificate in relation to encroachment	Complete and correct			

FIELD SURVEY FILE : <CP number>-JOB

Item where Appropriate

Item	Remarks	Tick where Appropriate		
		Yes	No	NA
Job Control section				
a. JOB Number (SVY file no.)	Present and correct			
b. Date of Commencement	Present and correct			
c. Date of completion	Present and correct			
d. Survey Company	Present and correct			
e. Registered Surveyor's Name	Present and correct			
f. Authorized Assistant's Name	Present and correct			
EDM Calibration section - set up following format in CP Directive				
EDM model and other details	Present and correct			
Instrument/Precision : PRECISION				
<direction> secs> , <ajmm> , <bjppm> <cgmm> , <djmm>				
END				
Instrument precision according to manufacturer specification	Present and correct			
Instrument and target centring precision	Not more than 2mm			
'0' denotes instrument centring precision.				
'1' denotes target centring precision.				
Field Data section				
Main Traverse : MAIN				
<1> , <REF> , <DDD> MMS>				
<Bwn_s> , <to_s> , <DDD> MMS> , <side ddd>				
<.....>				
<1> , <REF> , <DDD> MMS>				
END				
Traverse set-up following the above format	At stations are set up			
Number of GPS Markers ≥ 4				
Traverse circuit < 2500 metres				
Station numbering	Station numbers are unique			

■ Check List for Certified Plan

S/NO	ITEMS	YES	NO	N.A.	REMARKS
SECTION A : ELEVATION SKETCH					
7	The elevation sketch illustrating the strata lot nos and their corresponding unit nos of all the storeys together with the heights of stratum are shown.				
8	If it is not possible to show the strata lot nos, the following information is provided.				
9					
10					
11					
12					
13					
14					
15					
16					

CHECKLIST FOR INSPECTION OF STRATA CERTIFIED PLAN

S/NO	ITEMS	YES	NO	N.A.	REMARKS
SECTION A : GENERAL REQUIREMENTS					
1	Certificate on plan is shown and the plan is signed.				
2	Cuts on plan are intailed.				
3	Building on provisional lot has been constructed.				
SECTION B : PLAN SCHEDULE					
4	The following items are shown:- a) The house no or block no; b) The land no and its plan reference; c) The subject strata lot nos/provisional lot nos; d) Parent lot no and its plan no for strata re-subdivision; e) A cross reference table showing the old & new format lot nos of the parent strata lots is put up.				
SECTION C : SITE PLAN					
5	The heading 'SITE' & the scale of the site plan are shown.				
6	The following items are shown:- a) Boundary lines of land lot; b) Boundary marks and their descriptions of land lot by means of conventional signs and abbreviations; c) Lot no. of land lot and its area; d) Adjacent lot nos. and abuttals; e) Street name and house no. f) Building outlines; g) Encroachment (if any) of the building onto adjacent lot.				

■ Check List for Strata Certified Plan

Too Many Forms

- Survey Report

Survey Report

This form may take you 10 minutes to fill in.

SLA/SVY	6394-2007-3610-2008, 3610-2009, 3602-2010	MRNG	23
Surveyor's ref	L75883	Location	UBI RD 1 / LARK AVE 3 & 4
Appointed date	WPHN_032014020704164		

Land Lots: (S270 & S270L, S245M & S245V, S200C & S200S, S201V & S201T)

No.	Subject	Registered Surveyor's Confirmation
1. Field	N.A. <input type="checkbox"/>	
(a) IGH Control Markers		
(i) Acceptable IGH control markers	S270127, S21426S, S21426L, S21426T	
(ii) Unacceptable IGH control markers		
(b) Reasons for revision of SVY 21 coordinates		
(i) <input type="checkbox"/> Yes <input type="checkbox"/> No		
(ii) Is the demarcation following App'd R/S/1 Authorized Plan?	Yes <input type="checkbox"/> No <input type="checkbox"/>	
3. Computations	N.A. <input type="checkbox"/>	
(a) Misclose		
(i) Main traverse loop	1:20168, 1:47800, 1:16806	
(ii) Sub-traverse loop		
(b) Difference between surveyed area and situated area	N.A. <input type="checkbox"/>	
(i) Is the difference in area within 1%?	Yes <input type="checkbox"/> No <input type="checkbox"/>	
(ii) If No, is clearance obtained from relevant authority/ party?	Yes <input type="checkbox"/> No <input type="checkbox"/>	

Streets/Lots: _____

Accessory Lots: _____

No.	Subject	Registered Surveyor's Confirmation
1. Field	N.A. <input type="checkbox"/>	
(i) Is there any private enclosed area?	Yes <input type="checkbox"/> No <input type="checkbox"/>	
(ii) Are the details following building plan?	Yes <input type="checkbox"/> No <input type="checkbox"/>	
(i) Are the strata boundaries following diagrammatic plan?	Yes <input type="checkbox"/> No <input type="checkbox"/>	
(ii) See PD pg <input type="checkbox"/>		
(iii) See PD pg <input type="checkbox"/>		

4. Survey of Common Property

(i) Is there any subdivision of existing strata lots into strata lots and common property?	Yes <input type="checkbox"/> No <input type="checkbox"/>
(ii) Is there any amalgamation of existing strata lots with common property?	Yes <input type="checkbox"/> No <input type="checkbox"/>

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- Encroachment Report

Forms

We have listed the forms that Registered Surveyors may be required to fill for your easy reference and action. Please click on the relevant link:

- [EDM Calibration Booking Form](#)
- [Checklist for Cadastral Survey under SVY21 Datum](#)
- [Checklist for Inspection of Strata Certified Plan](#)
- [Checklist for RT plan under SVY21](#)
- [Calculation of Survey Fee Payable to Chief Surveyor](#)
- [Engagement of Registered Surveyor and Application for New Lot Numbers](#)
- [Survey Report](#)
- [Comparison of Areas](#)
- [Certificate in relation to Encroachment](#)
- [Request for ISN Markers](#)
- [Request for Survey Document Number](#)
- [Request for SVY21 Coordinates](#)
- [Submission of ISN/GPS Observation](#)
- [Application Form for SiREN Services](#)
- [Authorisation for Deduction of Survey Fees](#)

Reference Documents

- [Certificate of Employment of Assistants of Registered Surveyor](#)
- [Notice to enter Land / Flat to do Boundary Survey](#)

Request for SVY 21 Coordinates

This form may take you 10 minutes to fill in.

Year built: _____
 Our lot: _____
 Date: _____

Chief Surveyor: _____

DECLARATION IN RELATION TO ENCROACHMENT (SUBJECT TO RULE 11-1 OF BOUNDARIES AND SURVEY MAPS (PRODUCT OF CADASTRAL SURVEYS) RULES)

SURVEY OF LOT: _____

1. _____ a boundary registered under the Land Survey Act Cap. 163, 163(1)(a)

2. There is no encroachment affecting any land parcel within the land parcel within my survey.

3. If there is an encroachment affecting land parcel within the land parcel within my survey, the particulars of the encroachment are as follows:

- Lot(s) affected: _____
- Ownership of adjoining land parcel: _____ (Area / Perch)
- The encroachment is an interest: _____ (Date of survey document)
- Description of encroachment: _____

4. The encroachment was not created by the purchaser in or over the land parcel under my survey and _____

5. If the encroachment was created by the purchaser in or over the land parcel surveyed by me, the encroachment has been resolved and the encroachment has been rectified by _____ (Date of survey document). A copy of _____ (Description of encroachment) is attached.

Signature and date of (Co)Registrar/Registered Surveyor (Digitally signed)

Request for SVY 21 Coordinates

This form may take you 10 minutes to fill in.

Registered Surveyor: _____
 Please enter Professional number (only): _____

Non-Registered Surveyor: _____
 Customer Name: _____

E-mail Address: _____

Phone Number: _____

Lot Numbers: _____

Requested by Registered Surveyor / Non-Registered Surveyor

- Request for SVY 21 Coordinates

- List of Forms

- Engagement of RS and Application for New Lot Numbers

Engagement Of Registered Surveyor and Application for New Lot Numbers

This form may take you 10 minutes to fill in.

Particulars of Land Owner

1 Name * (Mr / Mrs / Ms / Dr)	2 Address
3 Person to contact (if applicable)	4 E-mail
5 Tel No (H/F)	6 Fax No

7 * I / We have engaged the following surveyor/s registered under the Land Survey Act to carry out the cadastral survey in accordance with Boundaries and Survey Maps Act and its related Rules.

Signature: _____ Date: _____

Application for New Lot Numbers by Registered Surveyor

1 Parent Lot No.	2 New lots required	Quantity
(i) <input type="checkbox"/> No	(i) Land lots	
(ii) Lot Nos	(ii) Airspace lots	
	(iii) Supermanan lots	
	(iv) Strata lots	
	(v) Strata Provisional lots	
	(vi) Accessory lots	

3 Amalgamation (To be completed only if applicable). Where amalgamation is involved, lots to be amalgamated are held under: (Mark to confirm)

- Same ownership
- Same system of registration
- Same tenure
- If above (i) to (iii), date of expiry is the same

4 New lot numbers are not required. For issue of Survey fee number only.

Acceptance by Registered Surveyor

I, _____ (Name of Registered Surveyor)

(i) Accept the appointment to carry out the above cadastral survey.

(ii) Confirm that I have been authorized by the owner to amalgamate the lots.

Signature (Digitally Signed) _____ Date _____

Note: The Registered Surveyor will submit the completed form to the Chief Surveyor
 *Decide whether it is applicable.

Avoidable Errors

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

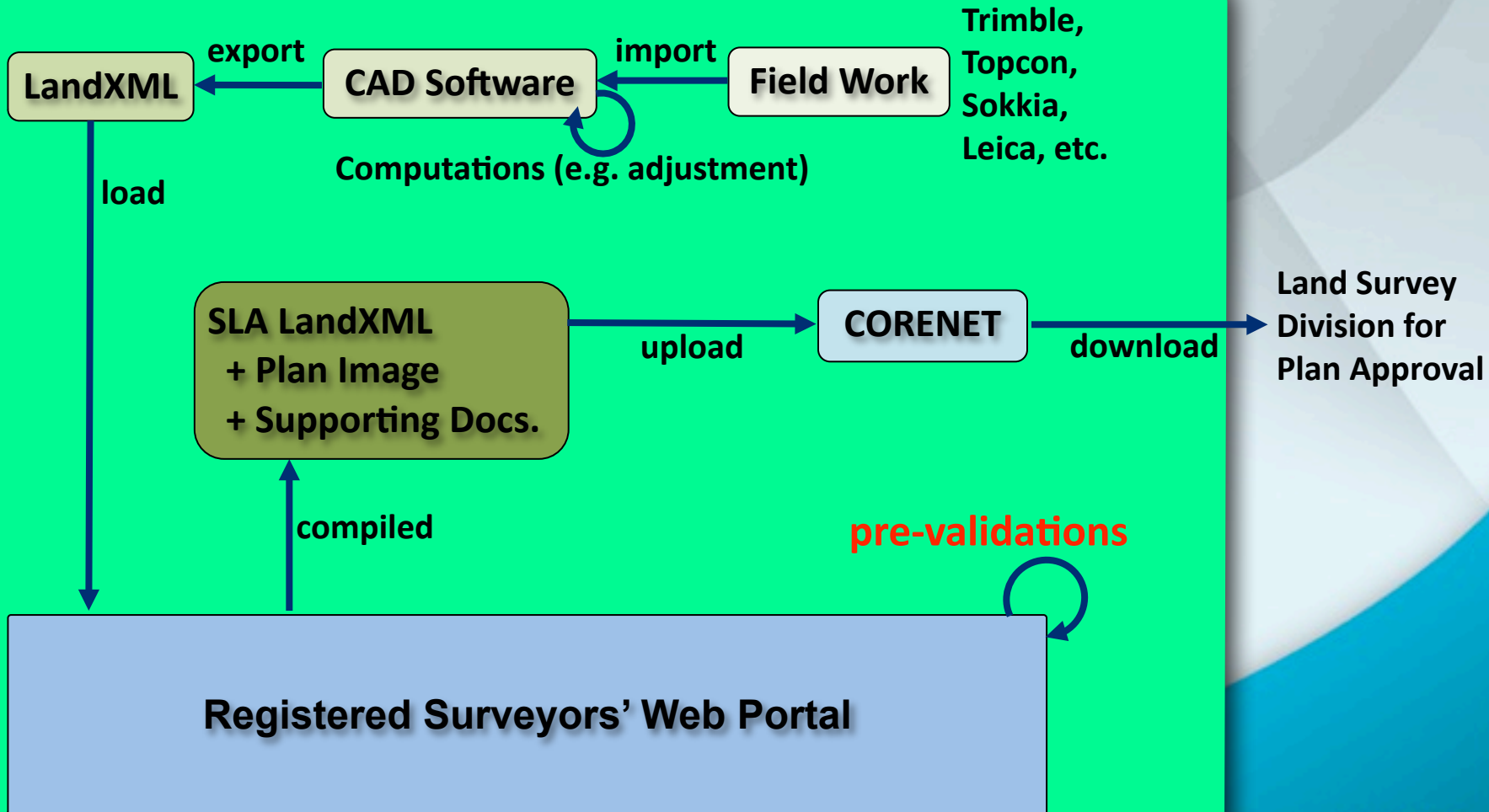
Minor Errors

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/>

Submissions through Registered Surveyors Web Portal



What is in SLA LandXML?

**Survey Plan
Descriptions**

**Address
Information**

**Surveyor's
Details**

**Survey Document
Descriptions (e.g.
Survey Report,
Encroachment)**

**Administrative
Information**

**Amendment
History**

**Equipment Information (e.g.
EDM Calibration, Instrument
Precisions)**

**Dimensions of
Lots and
Identifiers**

**Observation
Details**

**Survey Mark
Descriptions**

LandXML captures data not semantics

- 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?

```
<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:complexType>  
</xs:element>
```

```
<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="oldID" type="xs:string"/>  
    <xs:attribute name="area" type="xs:double"/>  
    <xs:attribute name="desc" type="xs:string"/>  
    <xs:attribute name="dirClosure" type="xs:string"/>  
    <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>
```

Automated Cadastral Job Processing



- 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)

- 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="disClosure" 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>
```

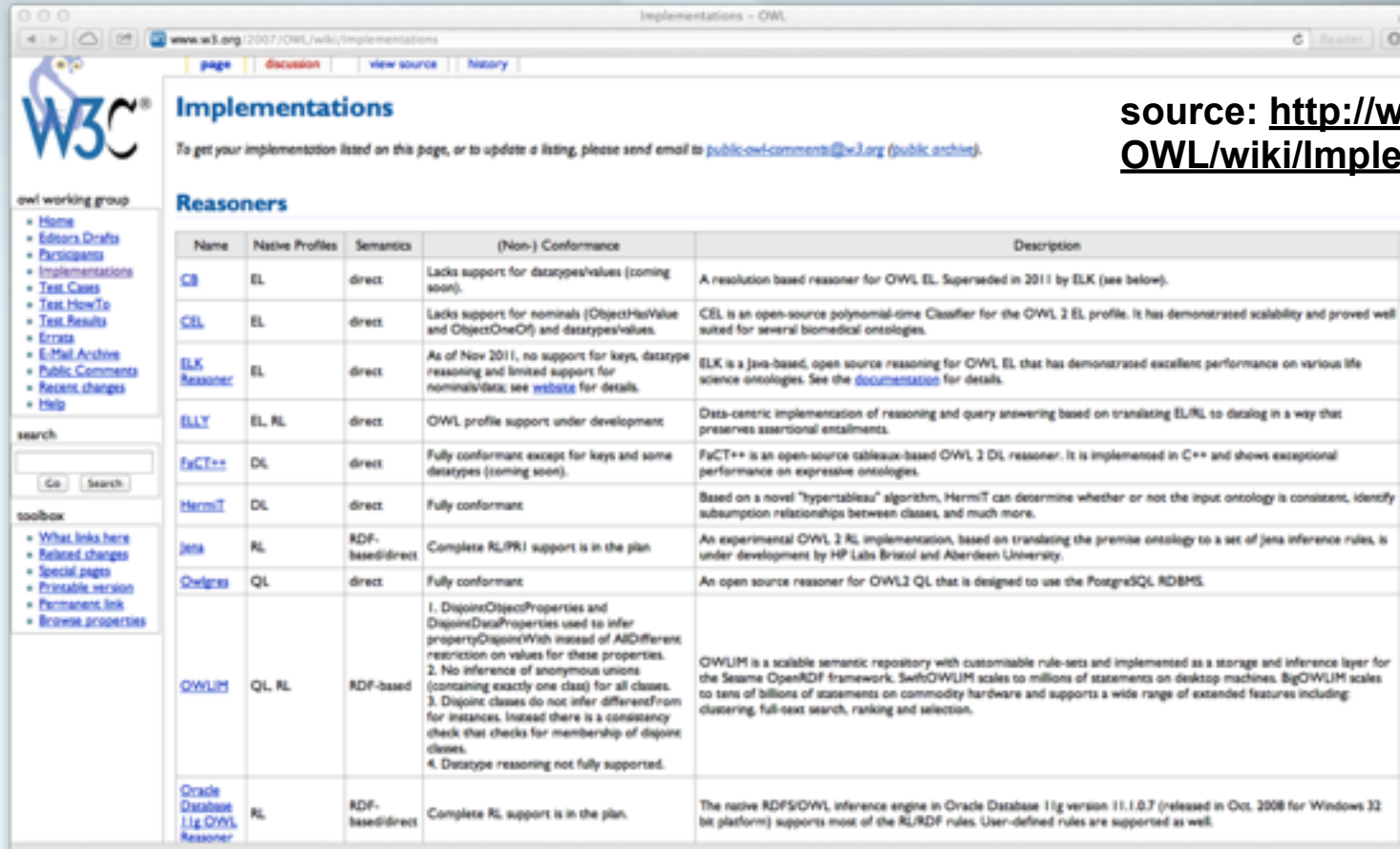
OWL

- 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)

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



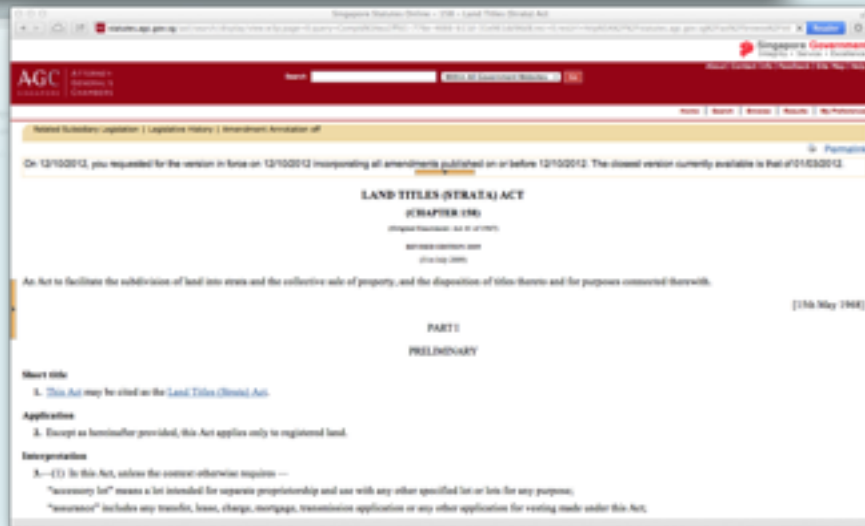
The screenshot shows the W3C website page titled "Implementations - OWL". It features a navigation menu with "page", "discussion", "view source", and "history". Below the title "Implementations", there is a note: "To get your implementation listed on this page, or to update a listing, please send email to public-owl-comments@w3.org (public archive)." The main content is a table titled "Reasoners" with the following columns: Name, Native Profiles, Semantics, (Non-) Conformance, and Description.

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/RL 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.
Owlegs	QL	direct	Fully conformant	An open source reasoner for OWL2 QL that is designed to use the PostgreSQL RDBMS.
OWLIM	QL, RL	RDF-based	<ol style="list-style-type: none"> DisjointObjectProperties and DisjointDataProperties used to infer propertyDisjointWith instead of AllDifferent restriction on values for these properties. No inference of anonymous unions (containing exactly one class) for all classes. Disjoint classes do not infer differentFrom for instances. Instead there is a consistency check that checks for membership of disjoint classes. 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 RDF/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.

Legislative Documents

- Our judicial framework recognizes 3D

- completeness, minimized ambiguity, and consistency
- but, contain hidden knowledge, need domain experts to explicate



Formalization

“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

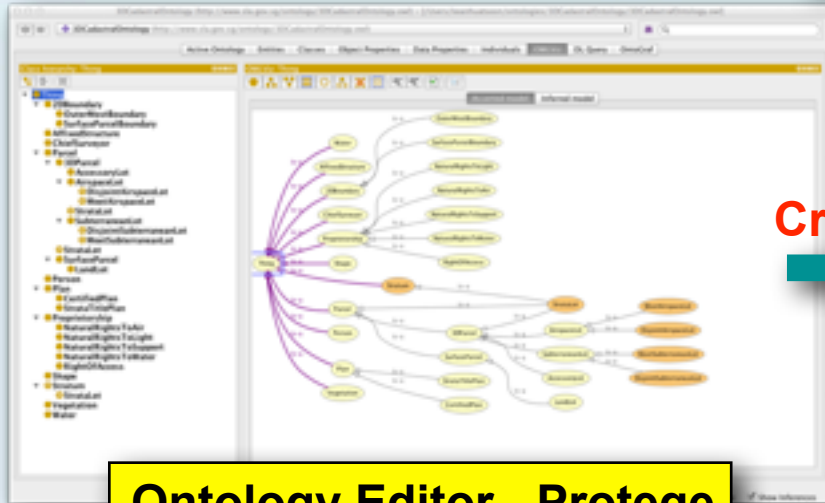


```

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 interest³ 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



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

Class hierarchy: 3DParcel

- Thing
 - Water
 - Person
 - Shape
 - Stratum
 - StrataLot
 - Proprietorship
 - RightOfAccess
 - NaturalRightsToSupport
 - NaturalRightsToWater
 - NaturalRightsToLight
 - NaturalRightsToAir
 - AffixedStructure
 - Vegetation
 - 2DBoundary
 - OuterMostBoundary
 - SurfaceParcelBoundary
 - ChiefSurveyor
 - Plan
 - StrataTitlePlan
 - CertifiedPlan
 - Parcel
 - StrataLot
 - SurfaceParcel
 - LandLot
 - 3DParcel
 - StrataLot
 - AccessoryLot
 - AirspaceLot
 - MeetAirspaceLot
 - DisjointAirspaceLot
 - SubterraneanLot
 - DisjointSubterraneanLot
 - MeetSubterraneanLot

Object property hierarchy: hasSurfaceParcel

- topObjectProperty
 - isCoveredBy
 - hasInterestIn
 - hasOwnership
 - disjointStratum
 - meetStratum
 - overlapStratum
 - hasShape
 - separateProprietorshipFrom
 - hasLot
 - isOwnedFor
 - hasAffixedStructureTo
 - hasVegetationOn
 - isAbove
 - isUnder
 - hasSurfaceParcel
 - meet
 - disjoint
 - isWithin
 - hasSurfaceParcelBoundary
 - hasOuterMostBoundary
 - isApprovedBy
 - isShownOn

Usage: hasSurfaceParcel

Show: this disjoints

Found 4 uses of hasSurfaceParcel

- hasSurfaceParcel
 - hasSurfaceParcel Domain 3DParcel
 - ObjectProperty: hasSurfaceParcel
 - Functional: hasSurfaceParcel
 - hasSurfaceParcel Range SurfaceParcel

Characteristics: hasSurfaceParcel

- Functional
- Inverse functional
- Transitive
- Symmetric
- Asymmetric
- Reflexive
- Irreflexive

Description: hasSurfaceParcel

Domains Intersection: 3DParcel

Ranges Intersection: SurfaceParcel

Data property hierarchy: hasLotNumber

- topDataProperty
 - hasDimensions
 - hasHeight
 - hasLotNumber

Usage: hasLotNumber

Show: this disjoints

Found 4 uses of hasLotNumber

- hasLotNumber
 - hasLotNumber Range: long
 - DataProperty: hasLotNumber
 - Functional: hasLotNumber
 - hasLotNumber Domain Parcel

Characteristics: hasLotNumber

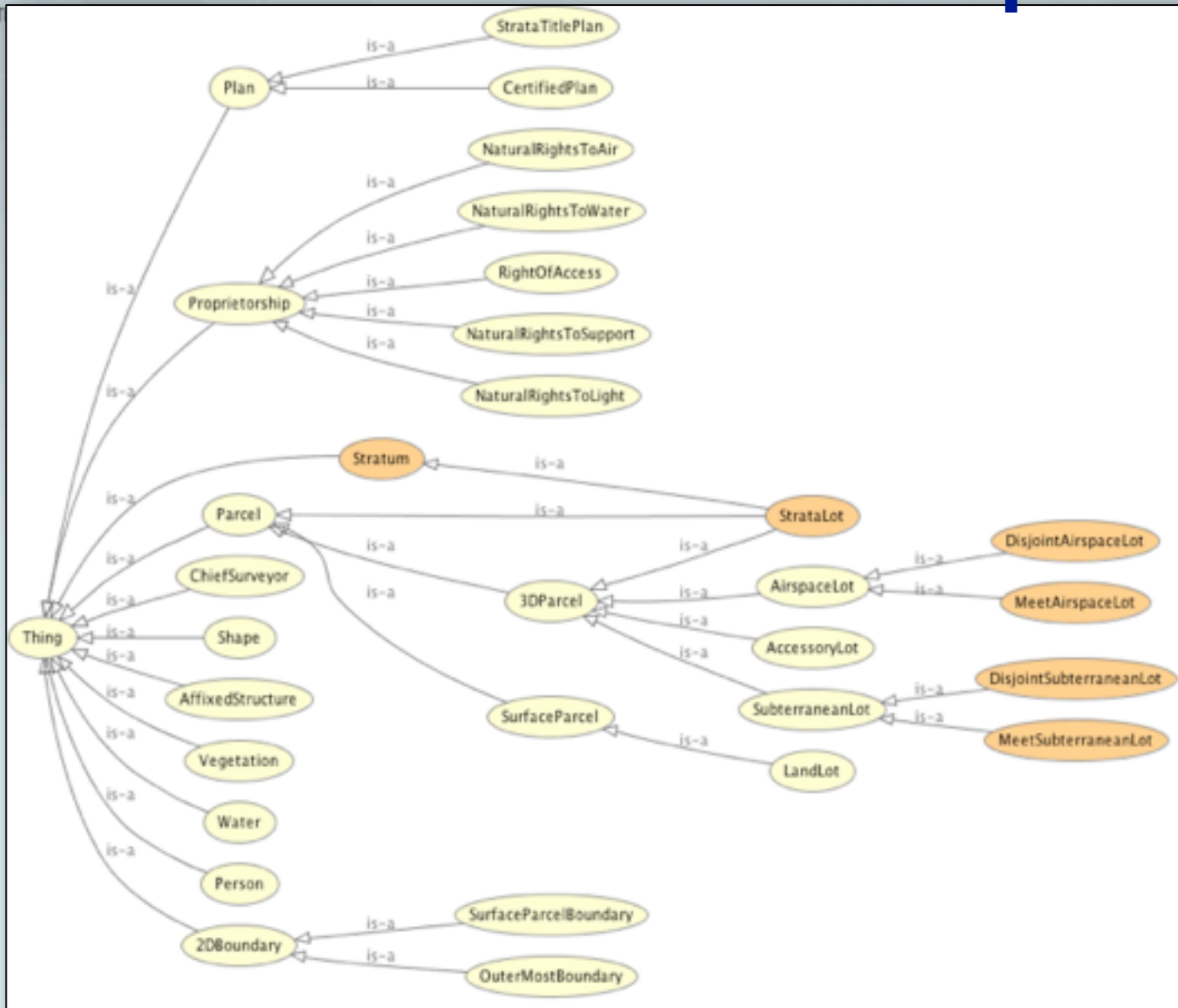
- Functional

Description: hasLotNumber

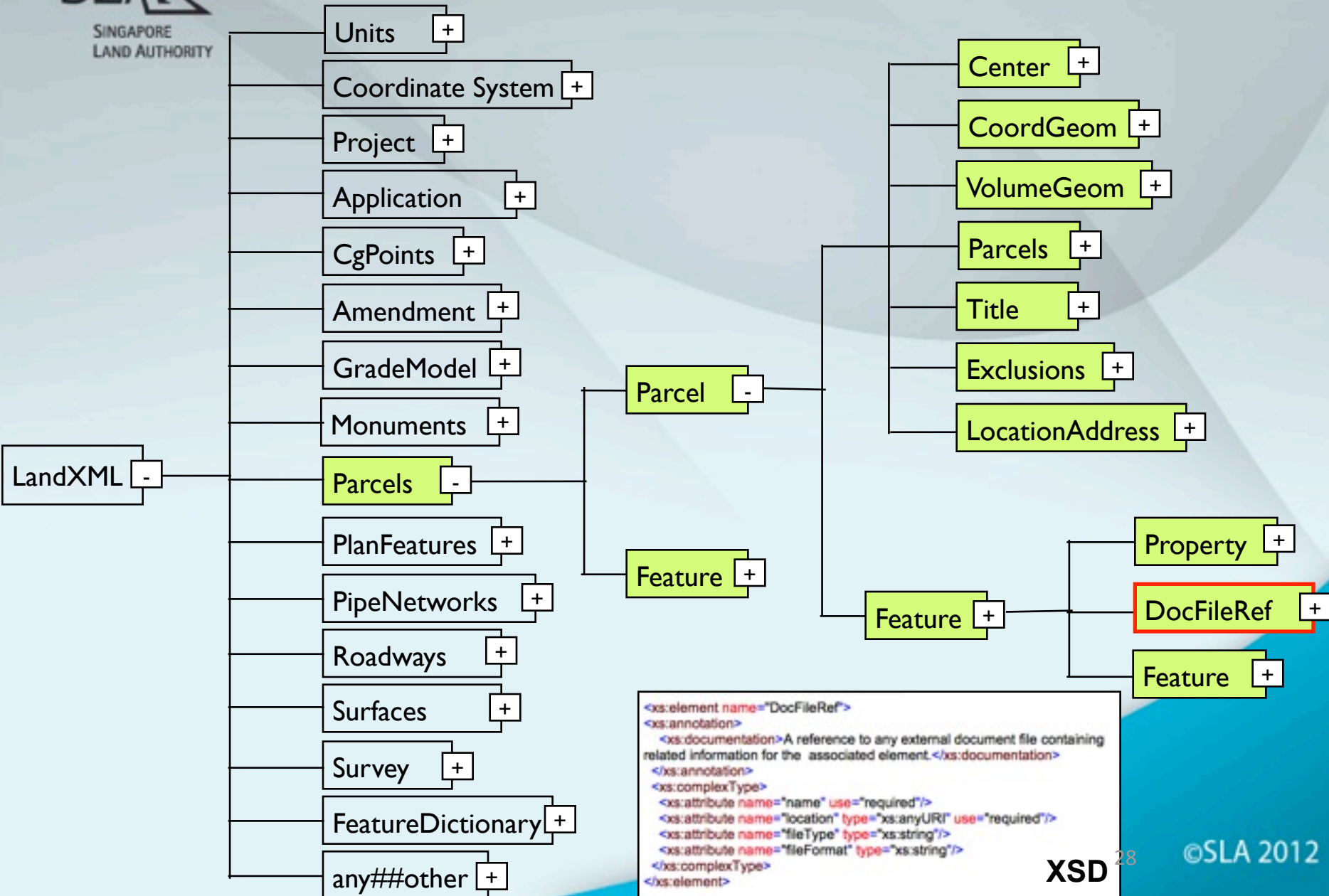
Domains Intersection: Parcel

Ranges: long

Overview of the Ontology (Generalization relationship only)



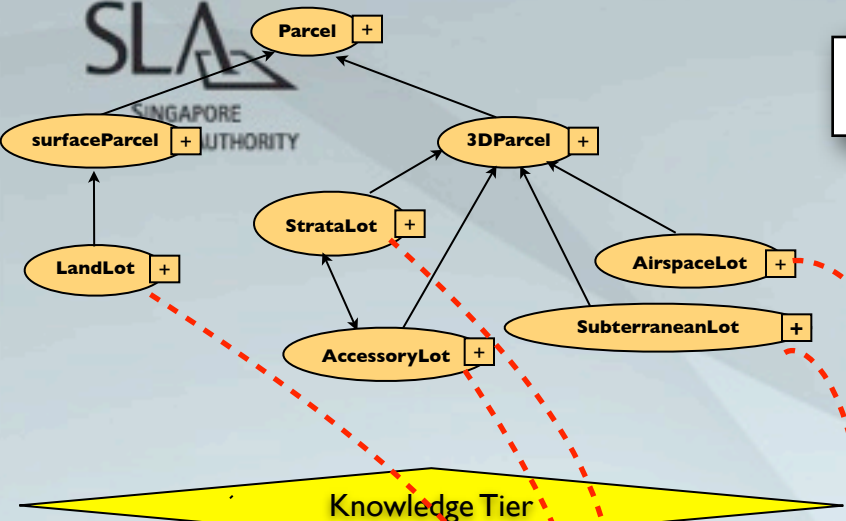
LandXML Schema



```

<xs:element name="DocFileRef">
  <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"/>
    <xs:attribute name="fileFormat" type="xs:string"/>
  </xs:complexType>
</xs:element>
  
```

Two-Tier Framework



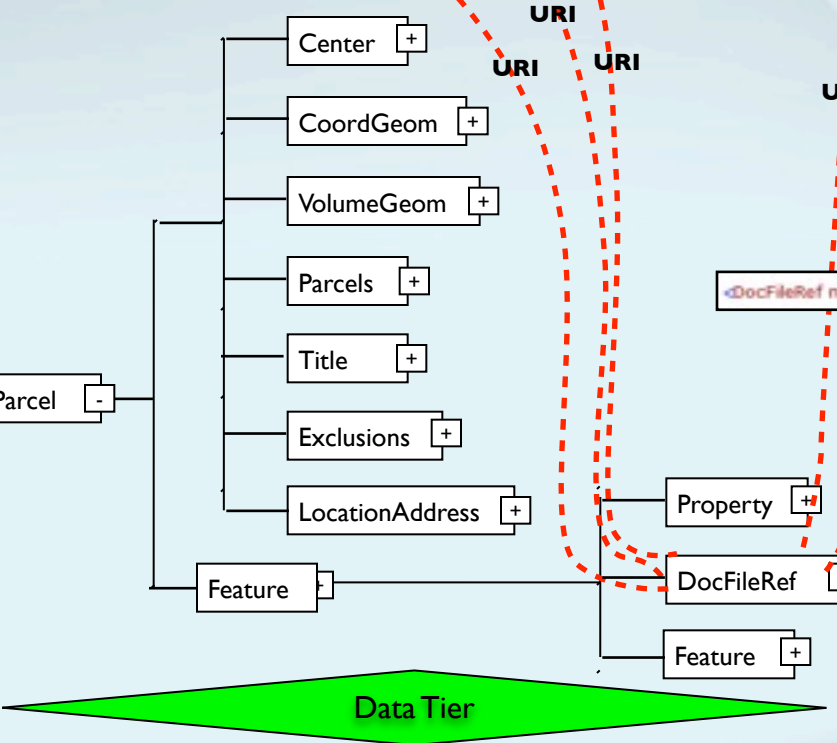
```

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

```

<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



URI
URI
URI
URI

```

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

LandXML

Data Tier

Applications

- 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

- 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

Thank You!

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