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initial design to develop a cadastral system that supports digital cadastre, 3D and provenance for Singapore

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5th International Workshop on 3D Cadastres
Athens, Greece
18 – 20 October 2016

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Outline

- Background
  - Existing cadastral processes in Singapore
- Cadastral Survey Management System
  - Digital Cadastre with SG LandXML
  - SG LADM
  - 3D
  - Provenance Management
- Conclusion

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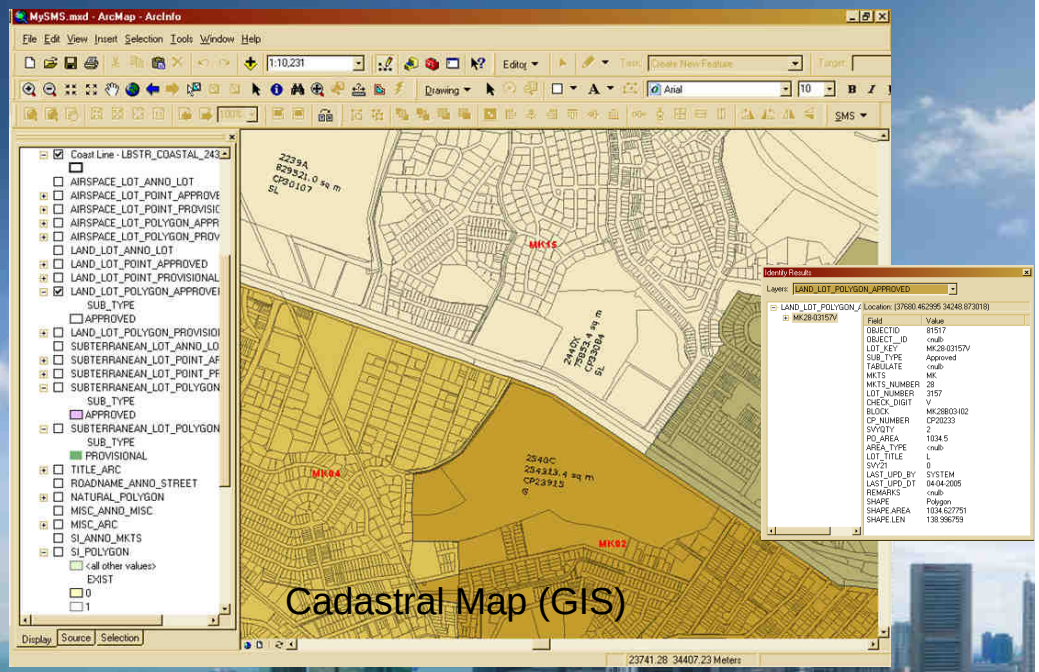
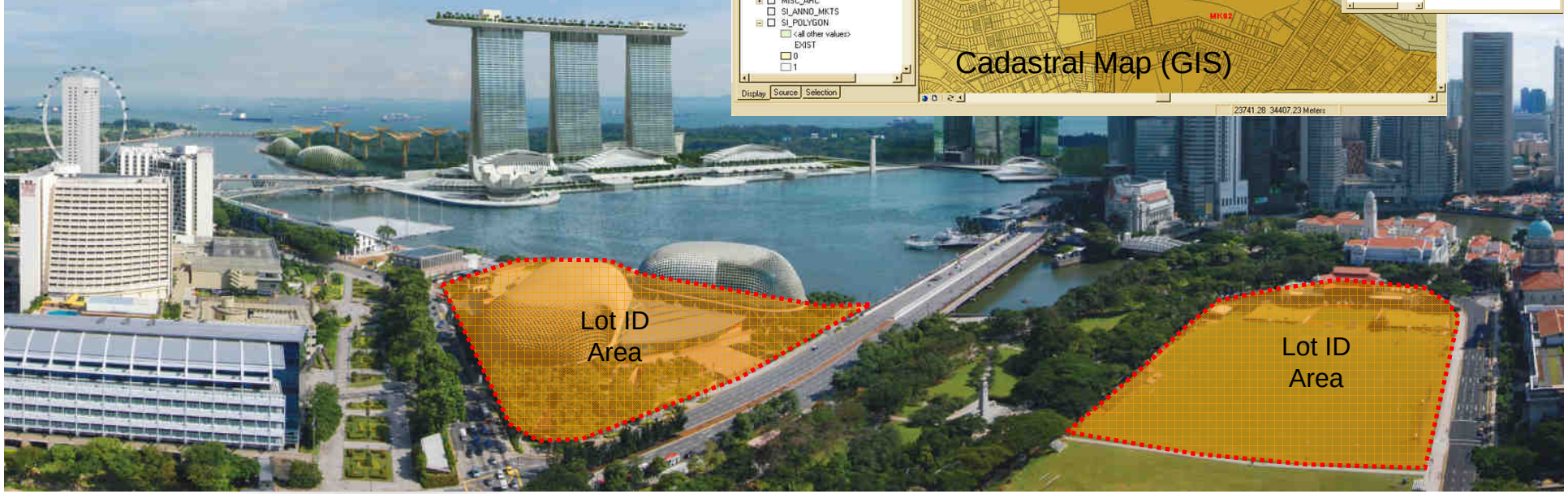
Cadastre is in 2D

Certified Plan (CP)



Cadastral Map (GIS)



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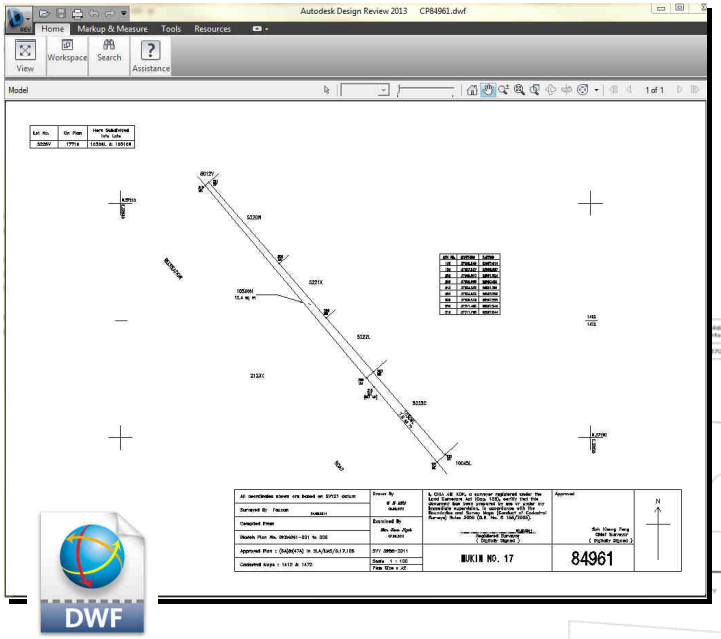
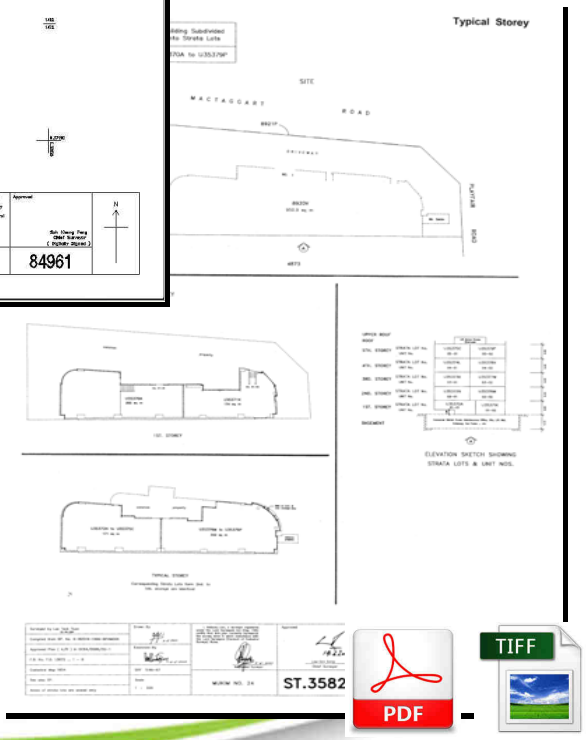
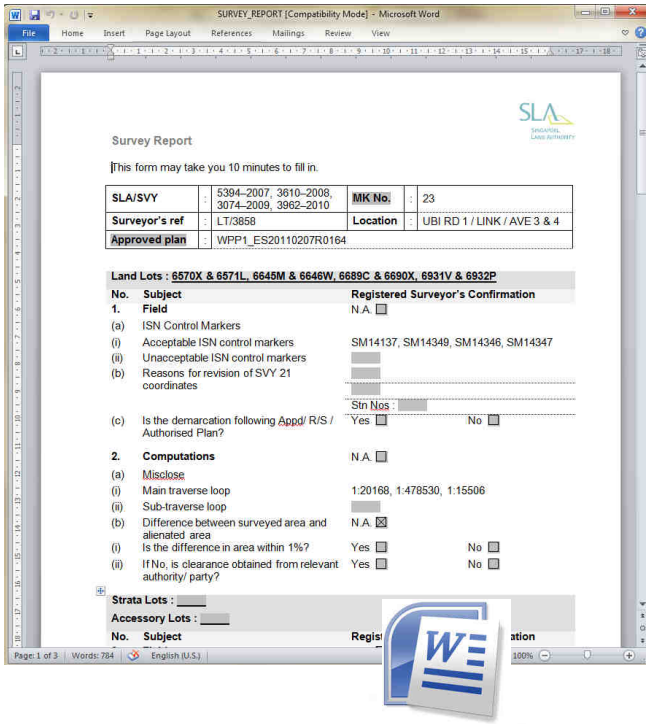
The world is 3D

Iluma

Existing cadastral submissions in machine-non-processable formats







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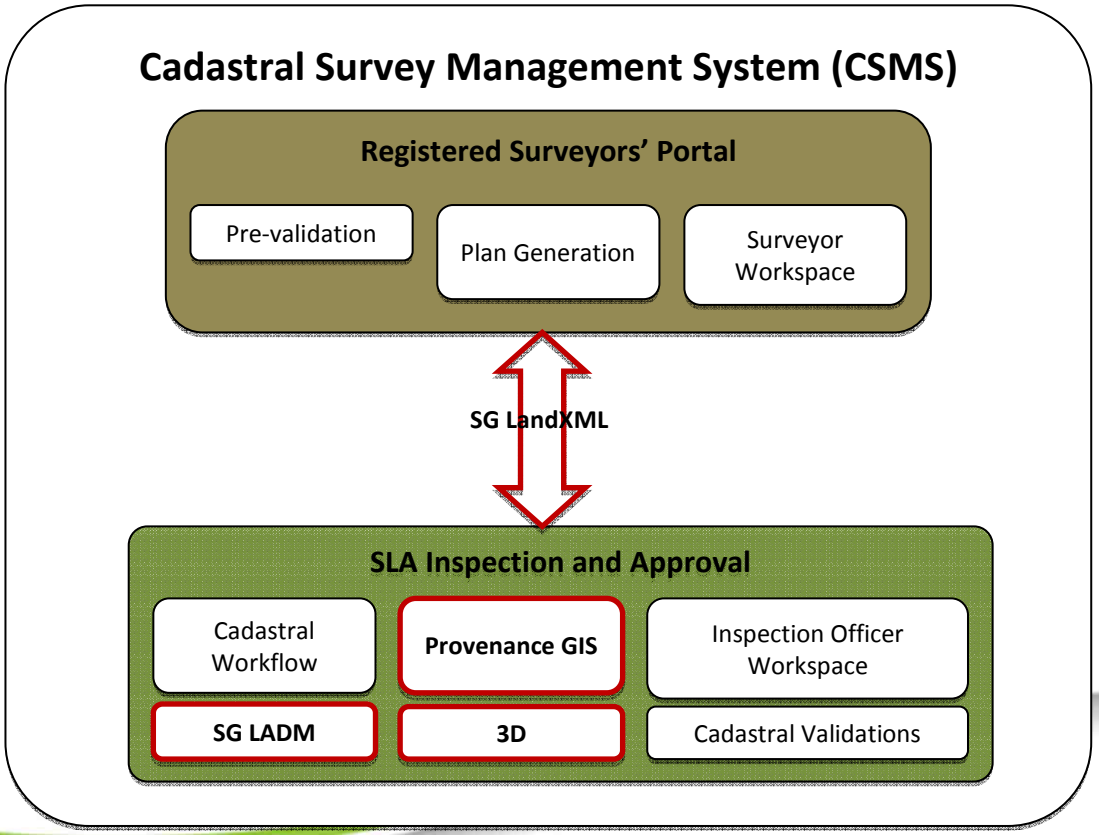
Time consuming with eye ball inspection

Three thrusts to tackle

- Adding Vertical Dimension and Time
  - 3D Cadastres
  - Provenance Management
- Adopting Open Standards for Automation and Data Interoperability
  - LandXML
  - ISO LADM
- Providing a Proactive Communication Platform
  - Registered Surveyor Submission Portal
  - Pre-validation and Interactive Communication

Cadastral Survey Management System

The Singapore Land Authority (SLA) has embarked on the design and development of CSMS project



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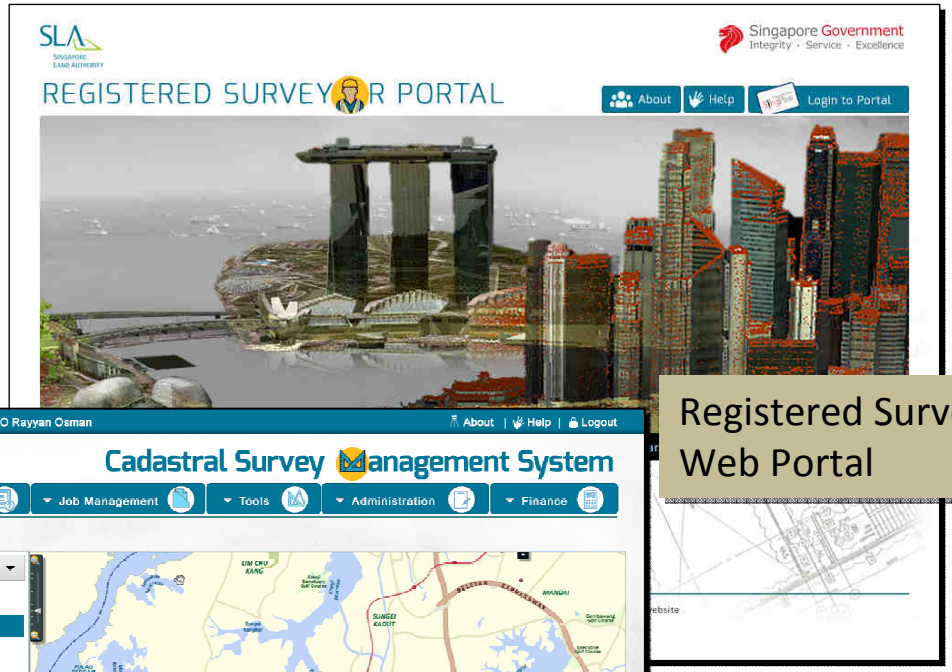
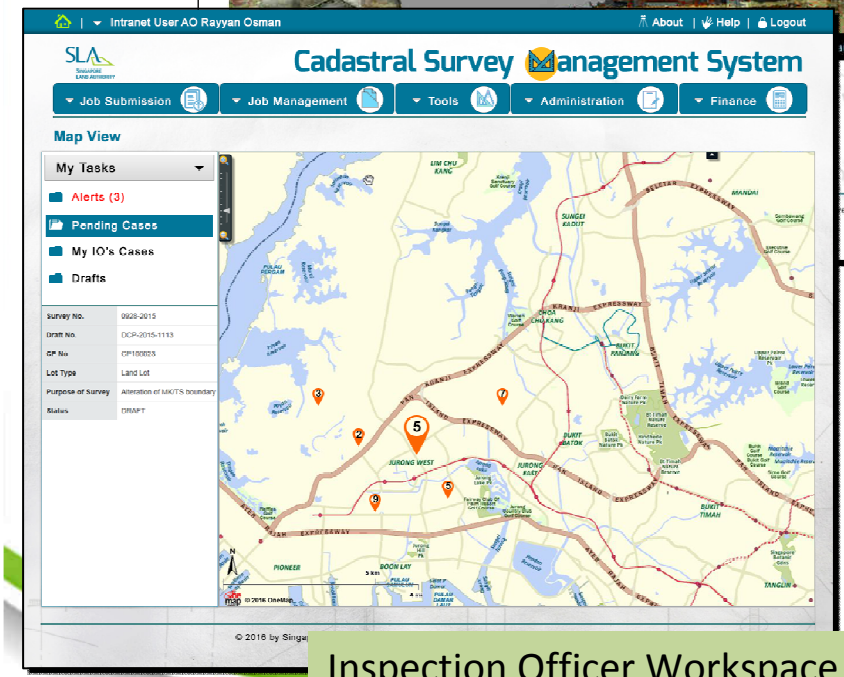
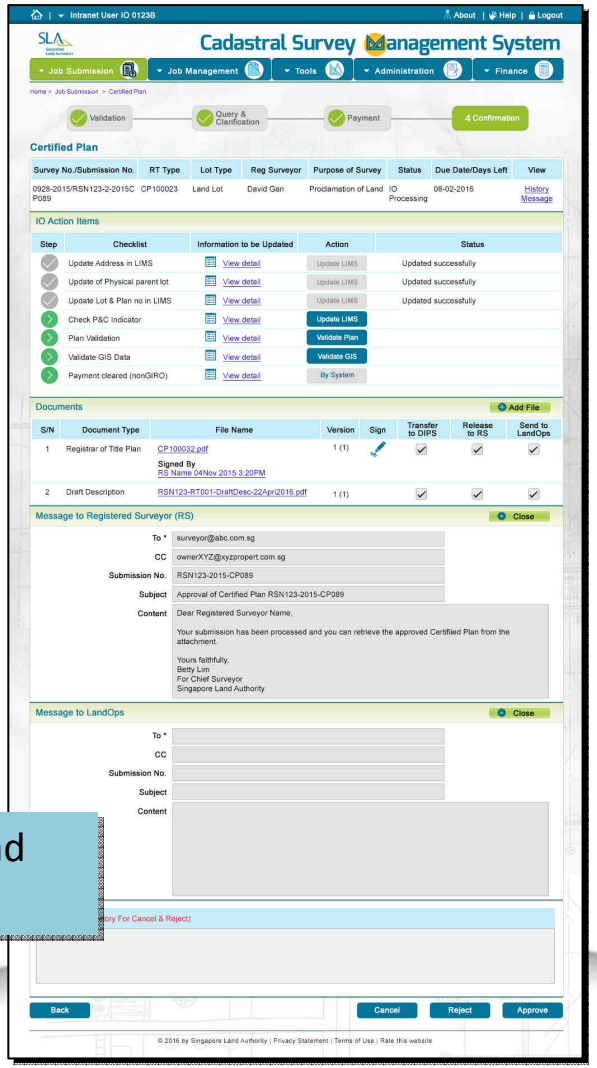
CSMS mock-ups



Registered Surveyors' Web Portal



Inspection Officer Workspace

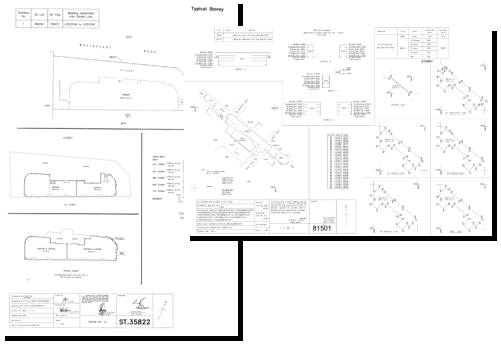


Job Processing and Management

Innovation in Cadastre

Together with Australia and New Zealand, Singapore have been streamlining cadastral processes based on LandXML

Paper Plan → **Image Plan** → **LandXML**



SG LandXML

Singapore Custom Features are mostly defined through additional <Feature> or <PlanFeature>

Transformation Parameters and

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   <Feature name="Parameters">
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      <Property label="b1" value="-0.547919" />
      <Property label="a2" value="212.398250" />
      <Property label="b2" value="-88.061250" />
   </Feature>
   <Feature name="Residuals">
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         <Property label="station" value="1" />
         <Property label="northing" value="-0.001" />
         <Property label="easting" value="0.002" />
      </Feature>
      <Feature name="Residual">
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         <Property label="northing" value="-0.001" />
         <Property label="easting" value="0.000" />
      </Feature>
      ... as many as control
   </Feature>
   <Feature name=" Misclose">
      <Property label="anglularMisclose" value="-16" />
      <Property label="miscloseRatio" value=" 1:65787" />
   </Feature>
</Feature>
```

Leveling Details

```
<Feature name="LevelingDetails">
  <Feature name="Header">
    <Property label="from" value="VCP80172"/>
    <Property label="to" value="VCP80172"/>
  </Feature>
  <Feature name="VcpIntegrityCheck">
    <Feature name="VCP">
      <Property label="stn" value="VCP80172"/>
      <Property label="bs" value="1.463"/>
      <Property label="al" value="110.891"/>
    </Feature>
    <Feature name="detail">
      <Property label="stn" value="W2"/>
      <Property label="is" value="1.462"/>
      <Property label="rf" value="0.001"/>
      <Property label="rl" value="110.892"/>
      <Property label="al" value="110.894"/>
      <Property label="rmk" value="witness mark 2"/>
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      <Property label="is" value="1.492"/>
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      <Property label="rmk" value="witness mark 1"/>
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  </Feature>
  <Feature name="detail">
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    <Property label="rl" value="110.891"/>
    <Property label="al" value="110.891"/>
  </Feature>
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    <Property label="bs" value="1.196"/>
    <Property label="is" value=""/>
    <Property label="fs" value="1.412"/>
    <Property label="rf" value="+.126"/>
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Encroachments

```
<PlanFeatures name="Encroachments">
   <PlanFeature name ="E1" desc="area enclosed by fence">
      <CoordGeom>
         <IrregularLine>
            <Start>38244.076 30474.841</Start>
            <End>38243.939 30475.207</End>
            <PntList2D>
               38244.076 30474.841
               38246.938 30476.324
               38246.938 30476.324
               38244.076 30474.841
            </PntList2D>
         </IrregularLine>
      </CoordGeom>
      <Feature name="encProps">
         <Property label="code" value="fence" />
         <Property label="geomType" value="polygon" />
         <Property label="pclRef" value="MK18-40001B" />
         <Property label="occRef" value="fence1" />
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      </Feature>
   </PlanFeature>
</PlanFeatures>
```

Control Points

```
<CgPoints>
   <CgPoint name="42" latitude="1.31437521" longitude="103.8451443"
      ellipsoidHeight="-">32962.452 29316.093 3.557</CgPoint>
</CgPoints>
<Monuments>
   <Monument name="VCP80188" pntRef="42" type="BT" category="control"
      desc="Thomson Road/Suffolk Road">
      <Feature>
         <Feature name="W1">
            <Property label ="MarkType" value="BT"/>
            <Property label ="RelativeHeight" value="-0.701"/>
            <Property label ="ReducedLevel" value="2.856"/>
         </Feature>
         <Feature name="W2">
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            <Property label ="RelativeHeight" value="-0.193"/>
            <Property label ="ReducedLevel" value="3.364"/>
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            <Property label ="ReducedLevel" value="2.525"/>
         </Feature>
         <Feature name="W4">
            <Property label ="MarkType" value="BT"/>
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         <DocFileRef name="LocationMap_80188.jpg" location="." fileFormat="JPEG"/>
         <DocFileRef name="SitePlan_80188.jpg" location="." fileFormat="JPEG"/>
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   </Monument>
</Monuments>
```

Using algebra to define lineage

```
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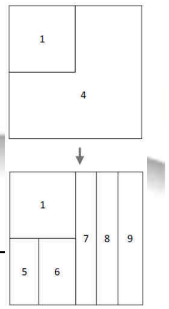
    label="lineage"
    value="P2+P3=P4;P4=P5+P6+P7+P8+P9;P1+P6=P10"/>
```



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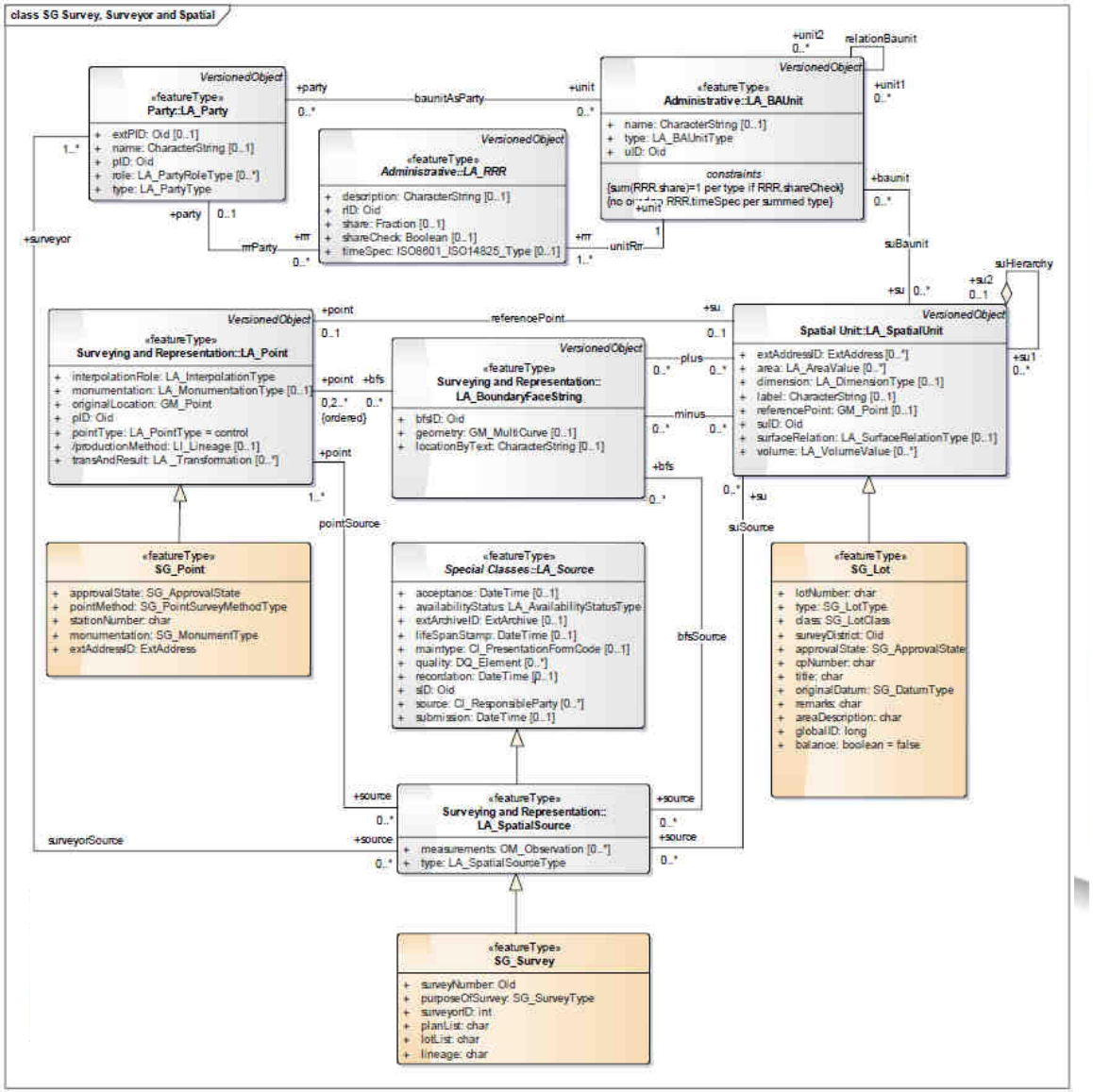
SG LADM

- Completed with Conceptual Design
- Constructing the physical structure



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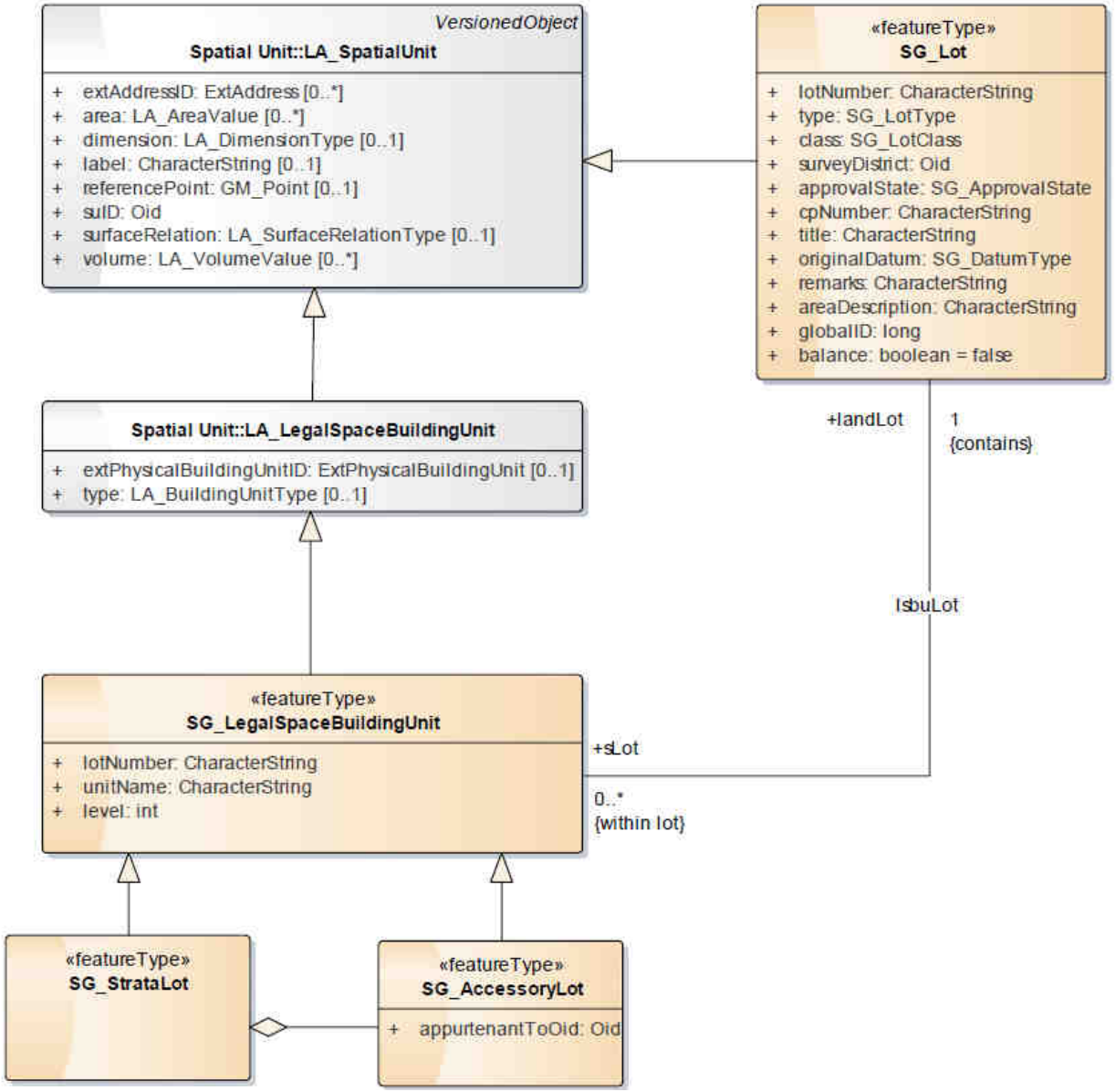
SG LADM (LA_SpatialUnit)



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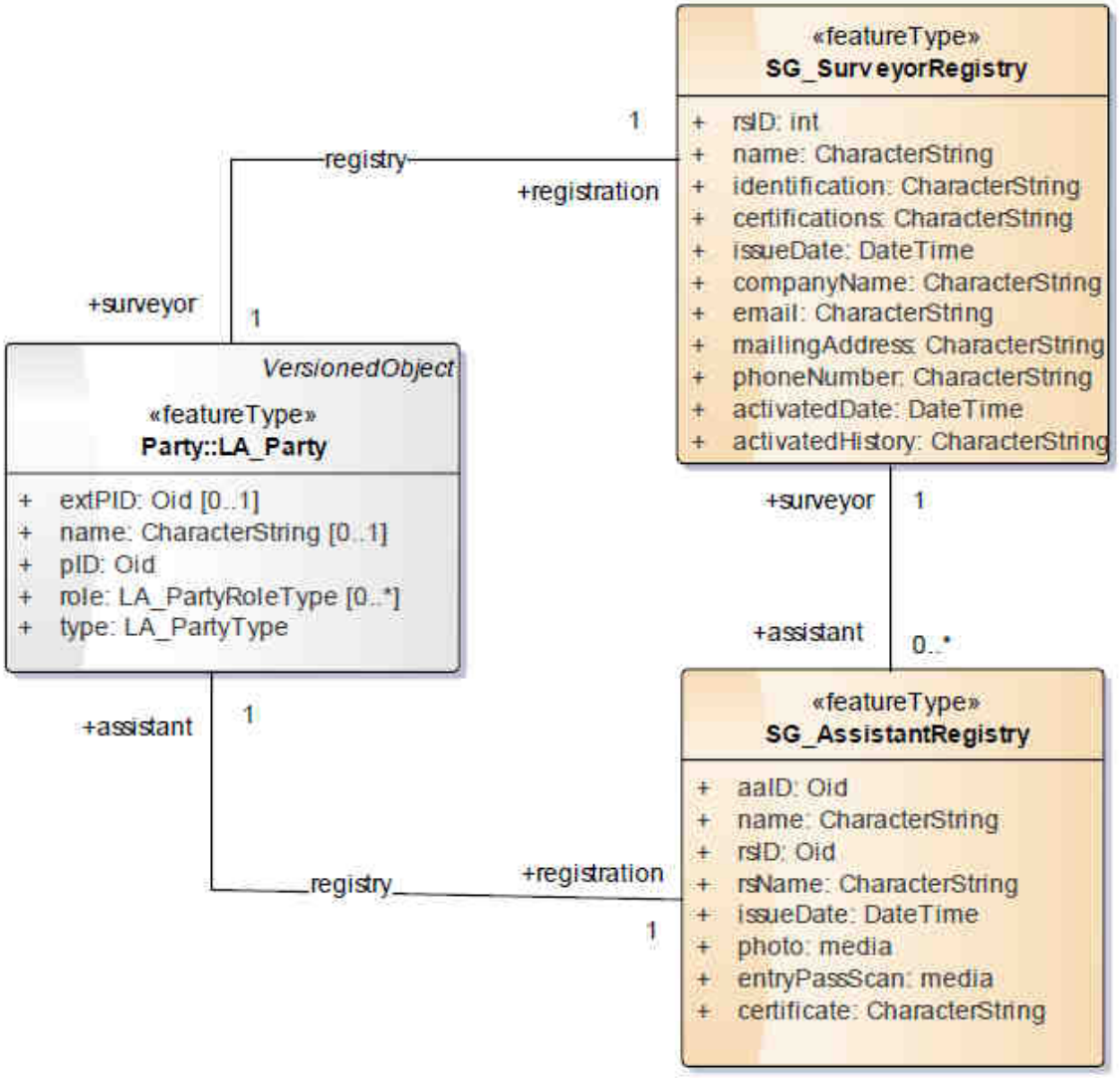
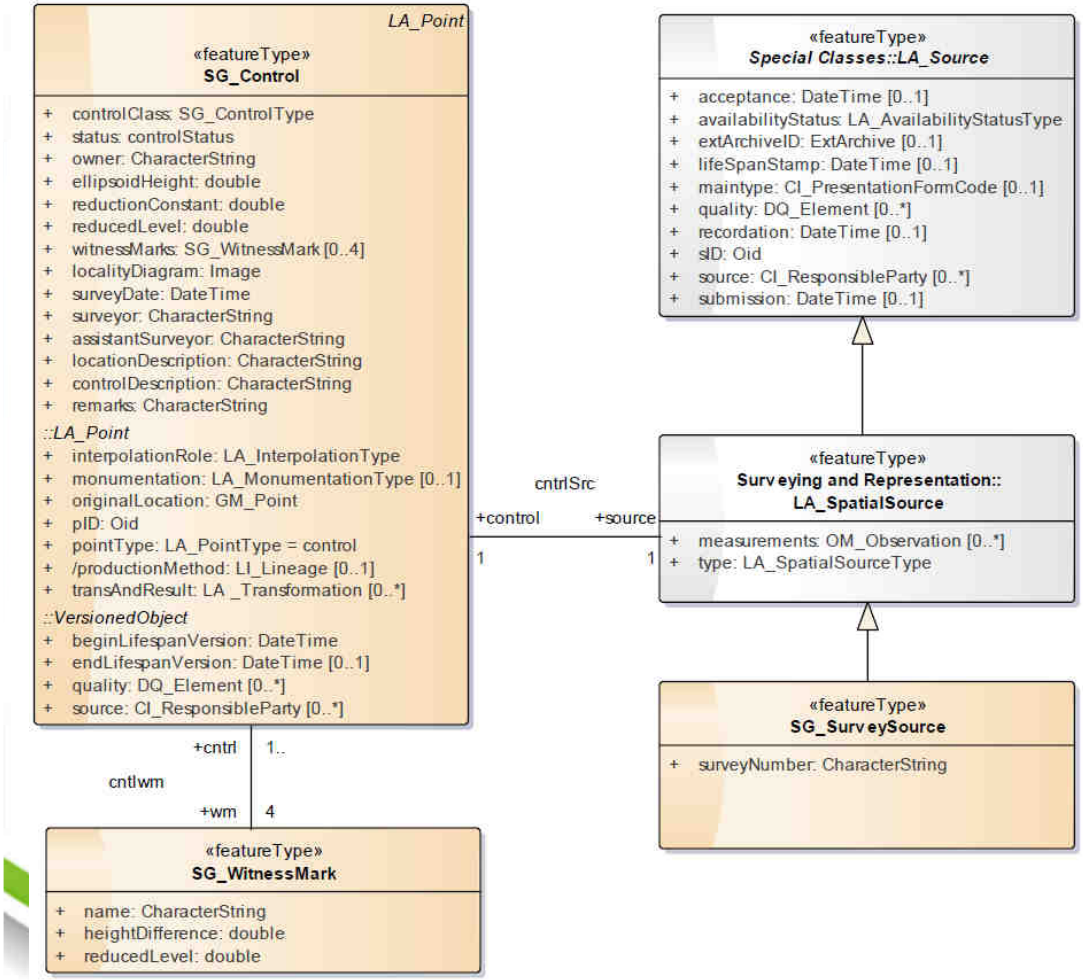
SG LADM (LA_Party)

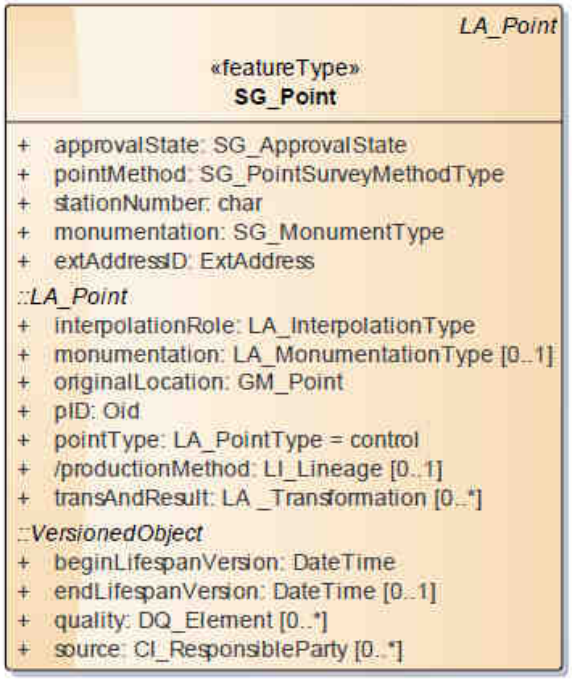


SG LADM (LA_Point)

Control Point



Boundary Point



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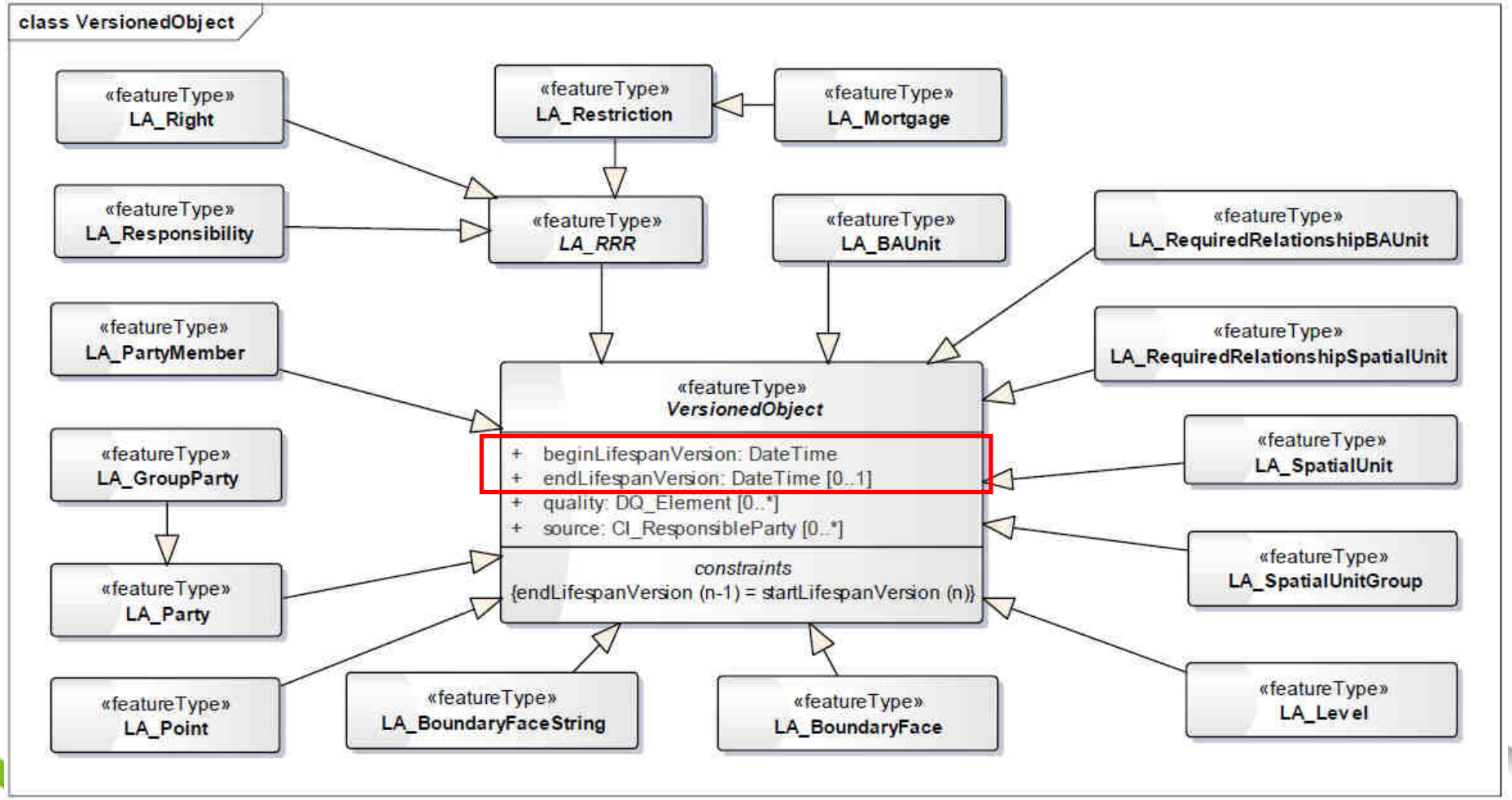
SG LADM (VersionedObject)



Parcel evolves in different approval states

*All lots are linked with Parent-Child Relationship.

Once a child lot is created in the Allocated Tier, the existing lot in the Allocated Tier will be moved to the Development Tier.

The Development Tier has 5 Layers: Development Approved Lots, RT Lots, Activation Lots and Interim Lots. These layers are exclusive, meaning that a lot exists in one layer will not appear in other layers in the Development Tier

Any lots in the Development Tier, once approved, will be moved to the Approved Tier

Lots in the Development Tier that do not become approved lots will move to the History Tier, e.g. Interim Lots

Any lots in the Approved Tier that their associated CP Plan is no longer current, will be moved to the History Tier

Allocation-of-Lot-Numbers Lots

Allocated Tier only has one layer in which each parcel lot is associated with the most current lot number. A new cadastral lot will be created in this layer when a new lot number is allocated during the allocation of lot number stage.

Development Approved Lots

The Development Approved Lots layer contains Approved lots that are being taken certain action (e.g. subdivision)

Lots are linked with Parent-Child Relationship

RT Lots

The RT Lots layer contains lots that have RT Plan Numbers. Once a RT Plan is approved, the respective lots will be created in this layer

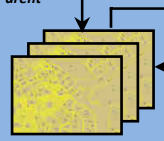
Lots are linked with Parent-Child Relationship

Activation Lots

The Activation Lots layer contains live lots. Once a lot is made live, the lot will be created in to this layer

Lots are linked with Parent-Child Relationship

Interim Lots



The Interim Lots layer contains lots that have lot numbers but do not even exist

Submitted Lots

The Submitted Lots layer contains lots that are submitted by RSs to CSMS. Once the RS submitted his job, the respective lots will be populated here. The layer is mainly used for field survey checks.

Final Approved Lots

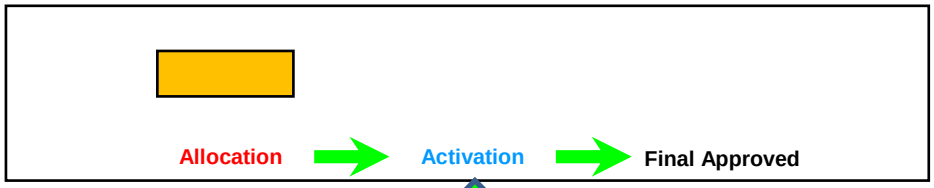
The Approved Lots layer contains all lots that are approved, i.e. have CP Plan Numbers. Once a CP is approved, the respective lots will be created in this layer

History Lots

The History Lots layer contains old lots that are no longer used/valid or no longer under certain action. These include RT lots, non-Approved lots or Activation lots that have new CP number, Approved lots that are dead, interim lots and unused lots. These lots should be retrievable for investigation.

Provenance Management

Approval States



Query and Analyze

Oracle Spatial (SG LADM)

Geometry	Lot #	ApprovalState	CreatedDate	BeginLifeSpan	EndLifeSpan	Parent Lot#	etc.
(j1, k1, l1, j2, k2, l2...)	4	Final Approved	May 4, 2015	Oct 3, 2015		1	

Integrate

Working Table Space

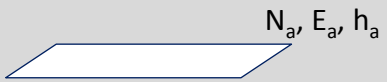
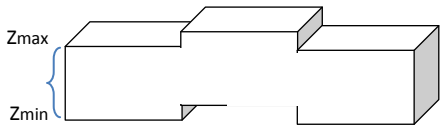
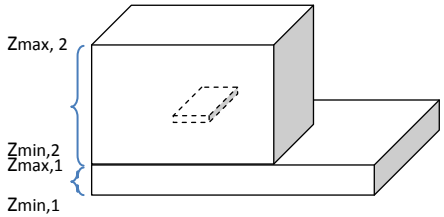
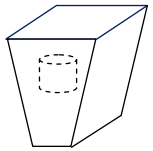
Geometry	Lot #	ApprovalState	CreatedDate	BeginLifeSpan	EndLifeSpan	Parent Lot#	etc.
(a1, b1, c1, a2, b2, c2...)	4	Activation	May 4, 2015	Jun 1, 2015	Oct 3, 2015	1	

Geometry	Lot #	ApprovalState	CreatedDate	BeginLifeSpan	EndLifeSpan	Parent Lot#	etc.
(p1, q1, r1, p2, q2, r2...)	4	Allocation	May 4, 2015	May 4, 2015	Jun 1, 2015	1	

History

The model is critical for complex spatio-temporal queries and analysis, for example, by allowing the comparisons for the spatial, temporal and attribute changes of a lot since it is allocated

2D and 3D parcel representations

#	Lot Categories	Examples
1	**2D Lot** (no z/elevation) (most existing cadastres have this type of lot. It is still important to include this type in 3D cadastral database)	
2	**Surface Lot** (with z/elevation, which is based on terrain or a constant z) (this type has limited depth or height) (referred as BoundaryFaceString in LADM)	
3	**Polygonal Sliced Lot** (standard 3D parcels. This type includes airspace, subterranean, strata/building format)	
4	**Single-valued Stepped Lot** (any x, y location, only one range (Z_{min}, Z_{max}) (diff levels of top/bottom, but one volume)	
5	**Multi-valued Stepped Lot** (any x, y location, can have more than one range [Z_{min}, Z_{max}]) (diff levels of top/bottom, and one than one volume)	
6	**More Complex 3D** (Polygonal Sliced + Single-valued Stepped + Multi-valued Stepped) + (curved surface, slanted wall)	

Constitute majority of parcels

(after Thompson, et al 2015)

2D and 3D LandXML encoding

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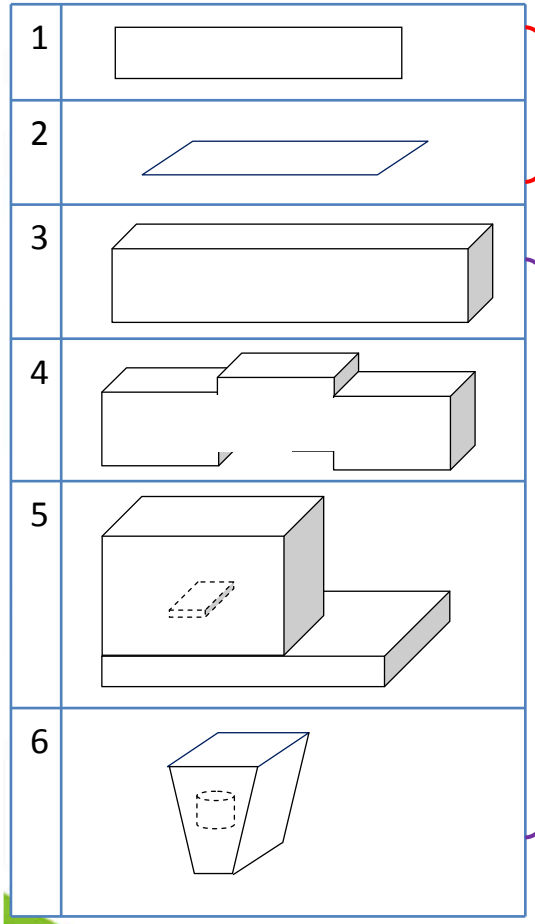


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      state="created" parcelType="single">
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    …
  </CoordGeom>
  <VolumeGeom>
    <CoordGeom desc="Face3D">
      …
    </CoordGeom>
    <CoordGeom desc="Face3D">
      …
    </CoordGeom>
    …
  </VolumeGeom>
</Parcel>
```

Parcel
CoordGeom
VolumeGeom
CoordGeom
CoordGeom
etc.

Simple Faces Method

```
<Parcel class="Footprint" name="25/1">
  <CoordGeom desc="Polygon2D">...</CoordGeom>
</Parcel>
<Parcel class="BoundaryFace" name="25/2">
  <CoordGeom desc="Polygon3D">...</CoordGeom>
</Parcel>
…
<Parcel class="LOT" name="25"
      parcelFormat="Volumetric">
  <Parcels>
    <Parcel pclRef="25/1" />
    <Parcel pclRef="25/2" />
          ....
  </Parcels>
</Parcel>
```

Parcel "25/1"
CoordGeom
Parcel "25/2"
CoordGeom
etc.
Parcel "25"
<pclRef> Parcel "25/1"
<pclRef> Parcel "25/2"
etc.

Nested Parcels Method (Referencing)

Converting 170 over subterranean lots from plans to 3D GIS

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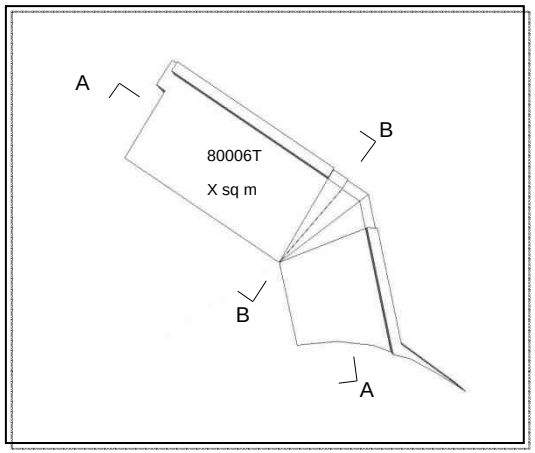
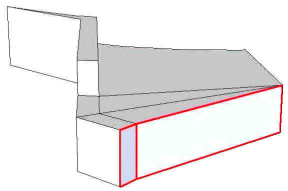
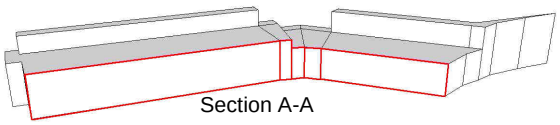
Plan



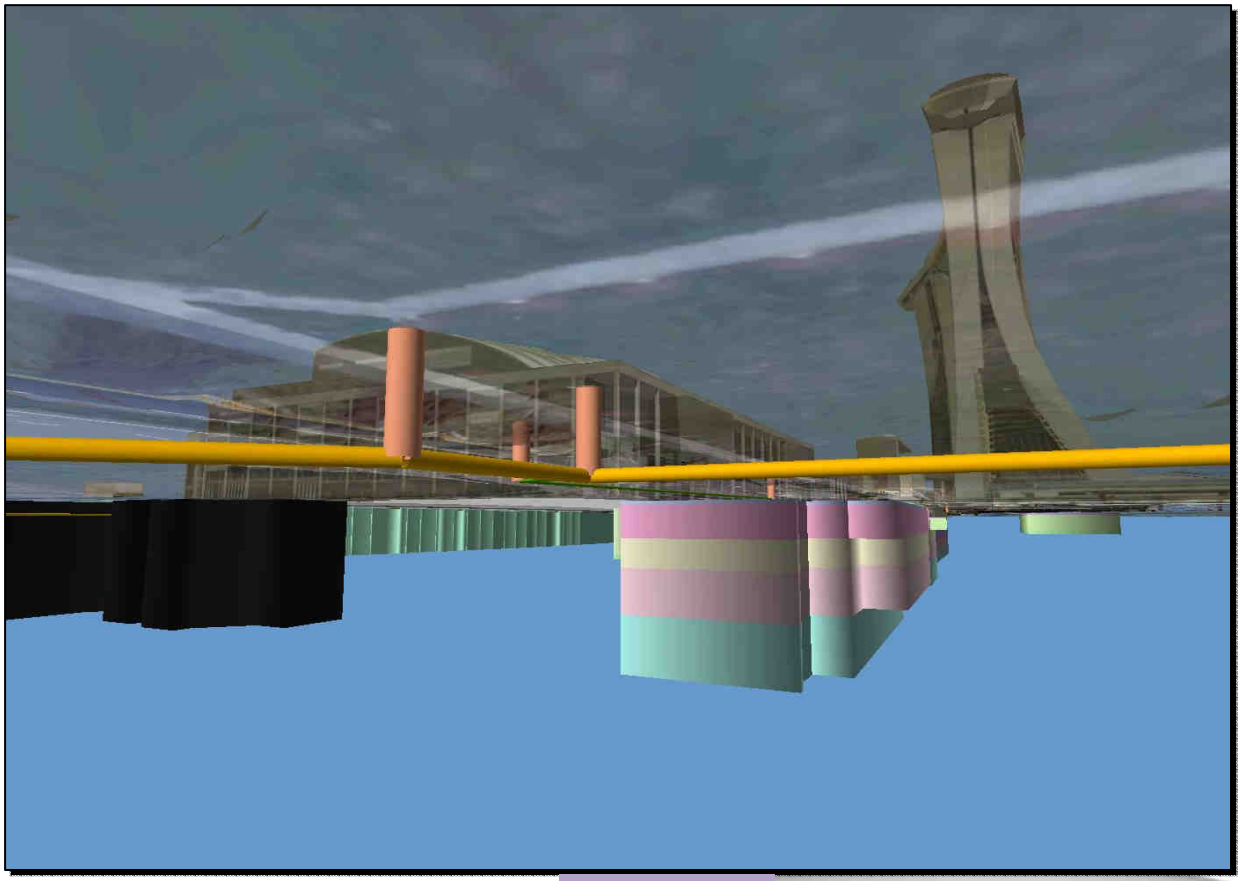
Sketching



Section B-B



Section A-A



3D GIS

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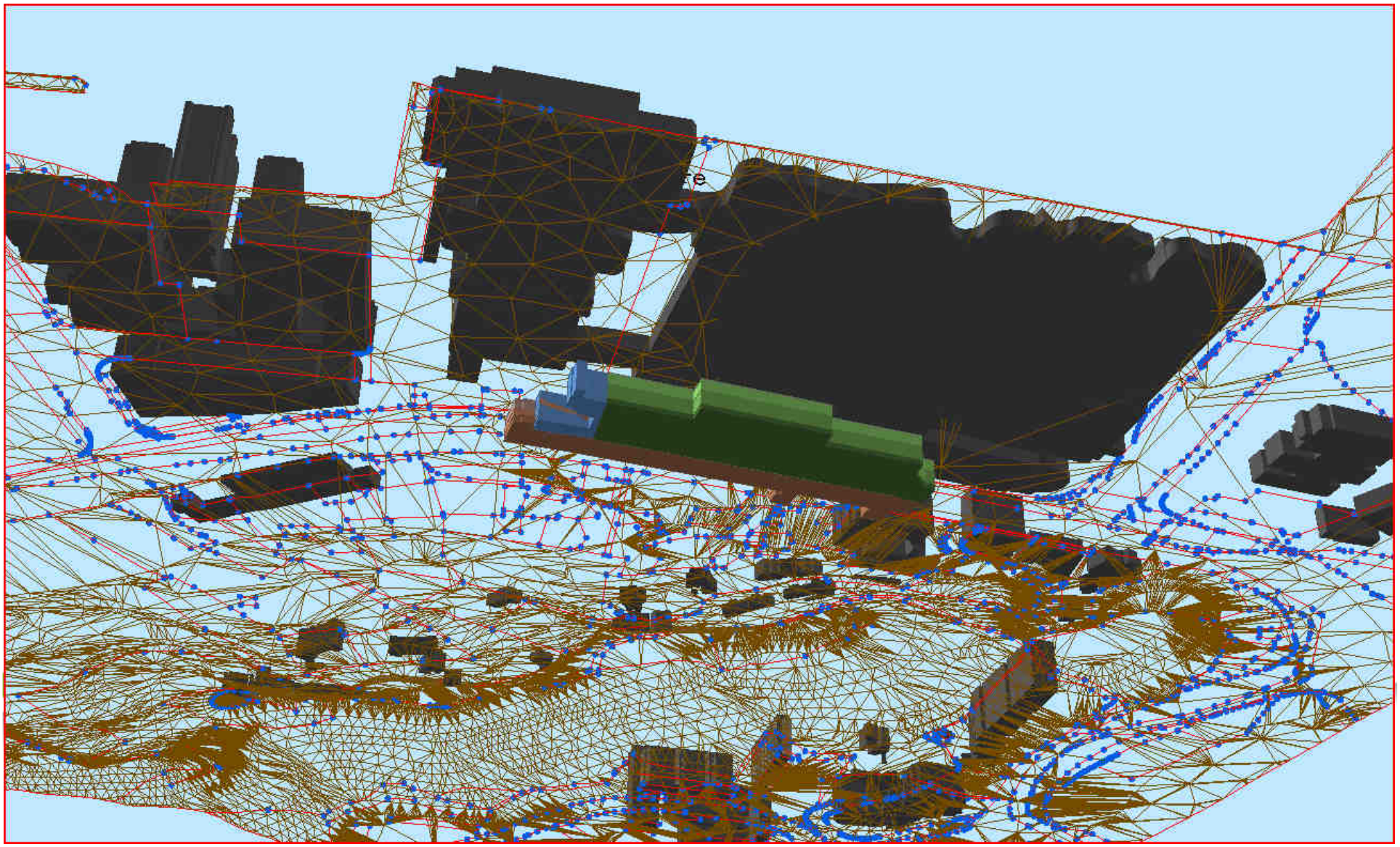
By 2020: a 3D digital cadastral system with provenance for Singapore



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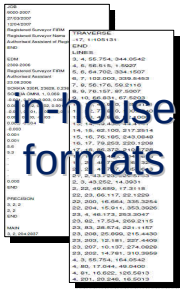
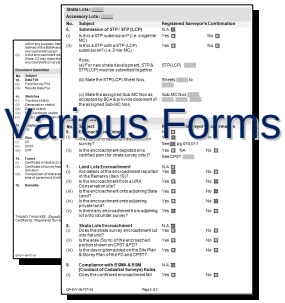
Thank you!

soon_kean_huat@sla.gov.sg

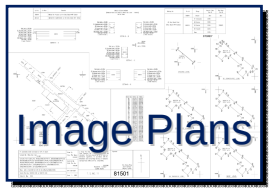
SINGAPORE LAND AUTHORITY

LandXML





Consolidated



Parse-able & Exchangeable

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LandXML

- Faster issuance of Titles
- Intelligently access data files
- Automate plan checking process
- Consistent checking by automation
- Directly read in CAD for drafting
- Reduce queries and clarifications

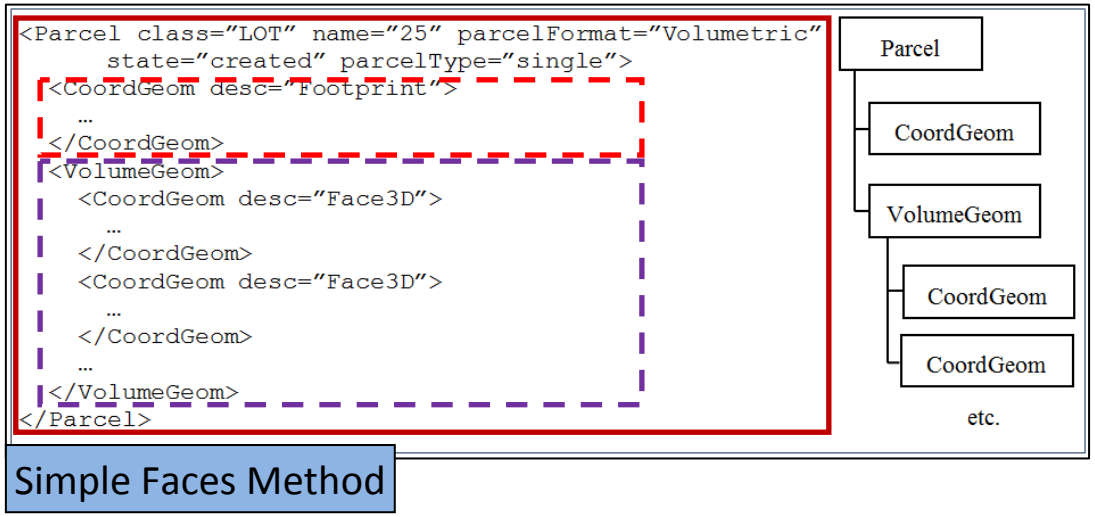
Pros and Cons

Pros

- Object-based with footprint being separated from the complete 3D geometry
- Can easily read and extract footprint and/or 3d geometry of lot

Cons

- Common faces encoded twice (could result in inconsistency)
- Increase validation checks
- Larger file size



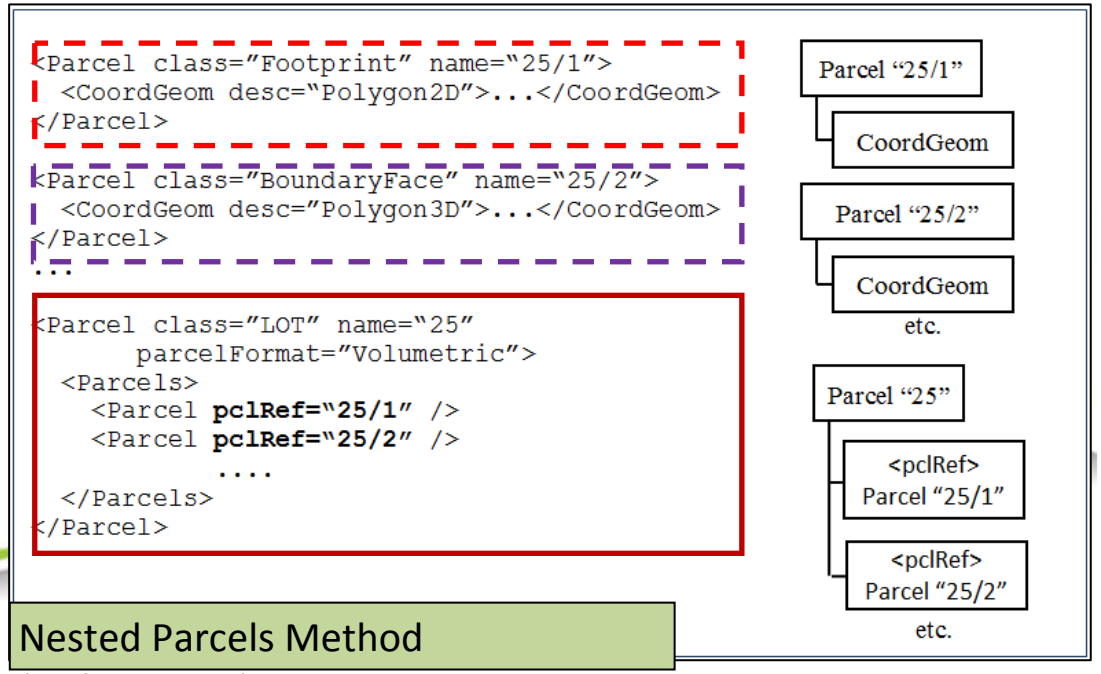
Simple Faces Method

Pros

- More acceptable by GIS and CAD software (as <VolumeGeom> is not used)
- Enable representation of topological structure
- Reduce file size

Cons

- More procedural steps required to read and extract (as 3D geometry is formed thru referencing)



Nested Parcels Method