2012 Model Based Enterprise Summit

The Digital Future Today

Using open CAD formats to bridge the gap between today's and tomorrow's standards

CAPVIDIA

Tomasz Luniewski

CAPVIDIA

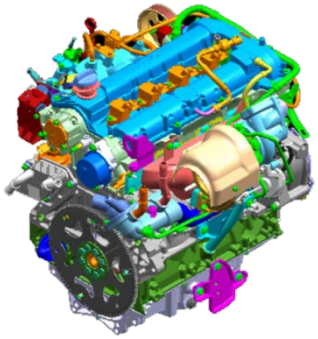
- Founded in 1994 (Belgium, Russia, USA, China, Japan)
- Development of engineering software applications
- CAD data translation and CFD services
- 80 programmers & engineers (20% PhD)
- Name reflects company activities

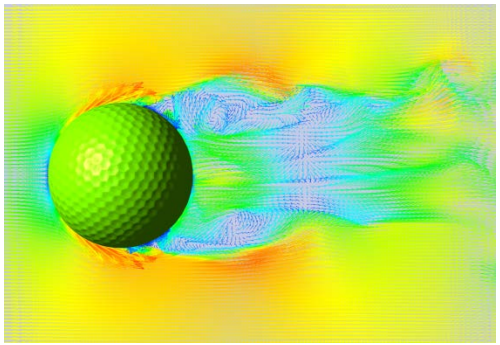
  Cap – capturing

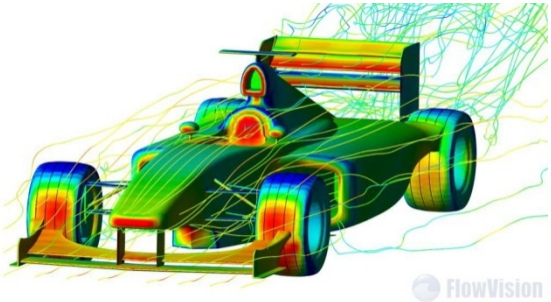
  Vidia – knowledge (Sanskrit)

Applications Areas:

- 3D CAD data translation, validation, quality assessment
- CFD simulations - FlowVision







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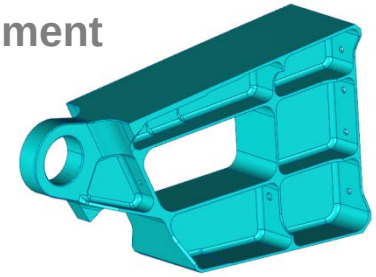
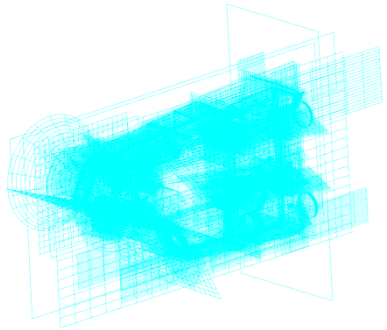
Model Based Definition (MBD)

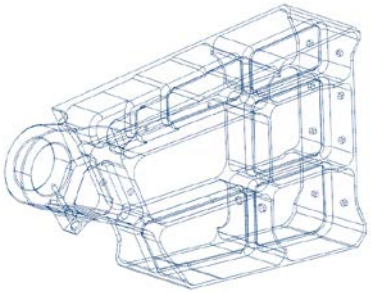
Model Based Enterprise (MBE)

- **Multi-CAD/CAM/CMM environment**
- **Standards**

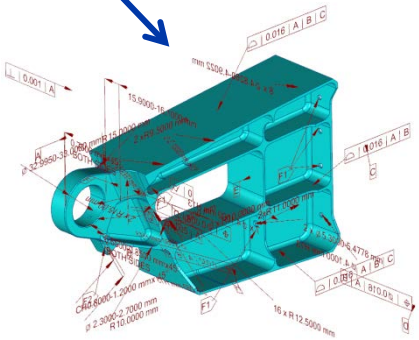




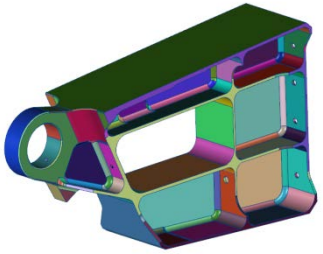
Geometry



Topology



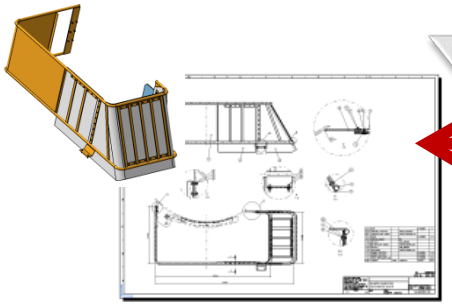
PMI (GD&T, FT&A)



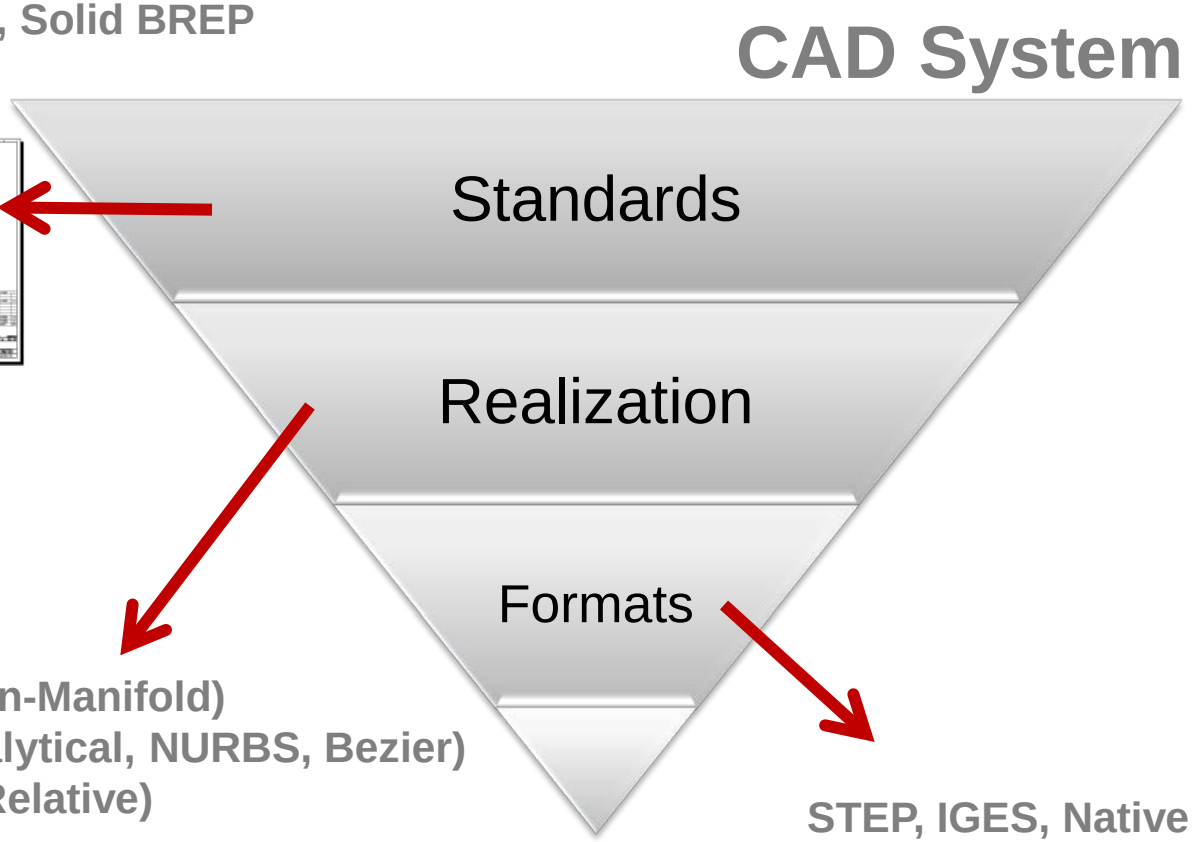
Attributes

Standards Today

Methods: Free Surface, Solid BREP



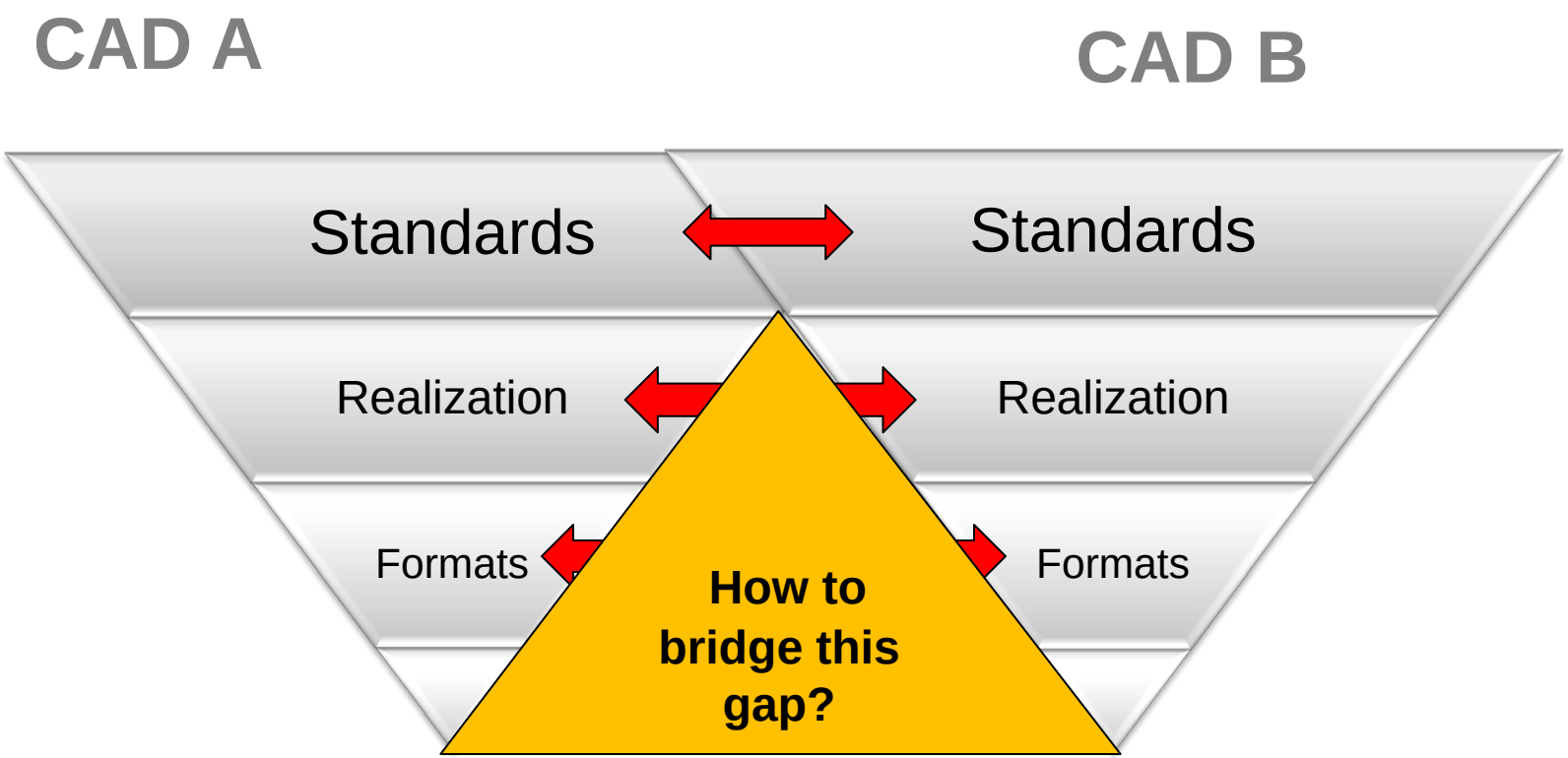
- DIN
- JSO
- ASME Y14.5
- Etc.



- Kernels (Manifold, Non-Manifold)
- Entity Definitions (Analytical, NURBS, Bezier)
- Tolerance (Absolute, Relative)

STEP, IGES, Native

CAD systems cmpability



Interoperability Today

3D CAD *visualization*

- 3DXML
- 3DPDF
- JT
- STL, VRML, etc.

3D CAD *data exchange* (native CAD formats, STEP, IGES)

- IGES, STEP - 3D Geometry/Metadata non semantic

Work in progress

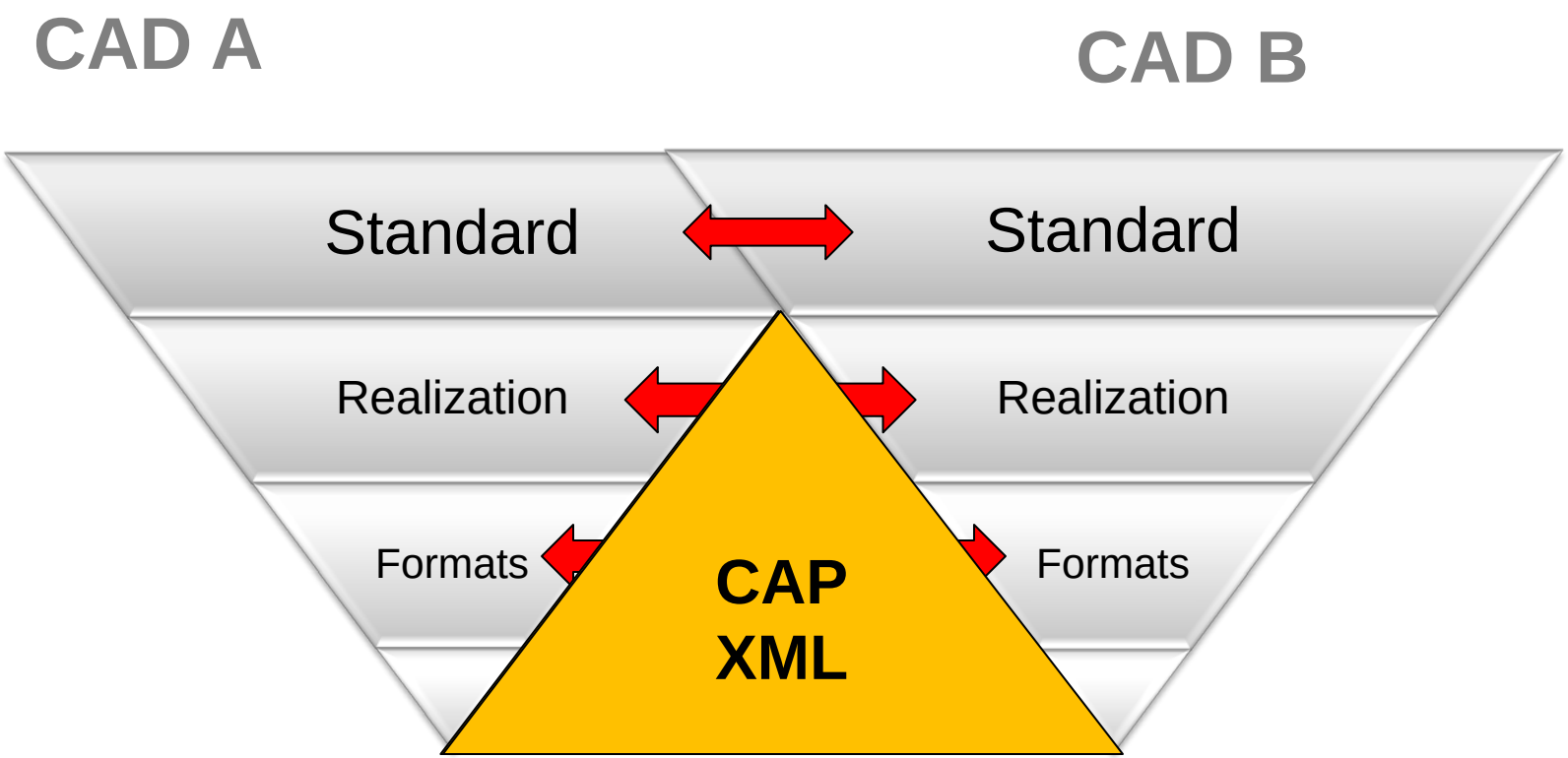
- STEP AP242 - 3D Geometry/Metadata semantic and non semantic
- STEP P28 - Data in xml format

MBE Challenges

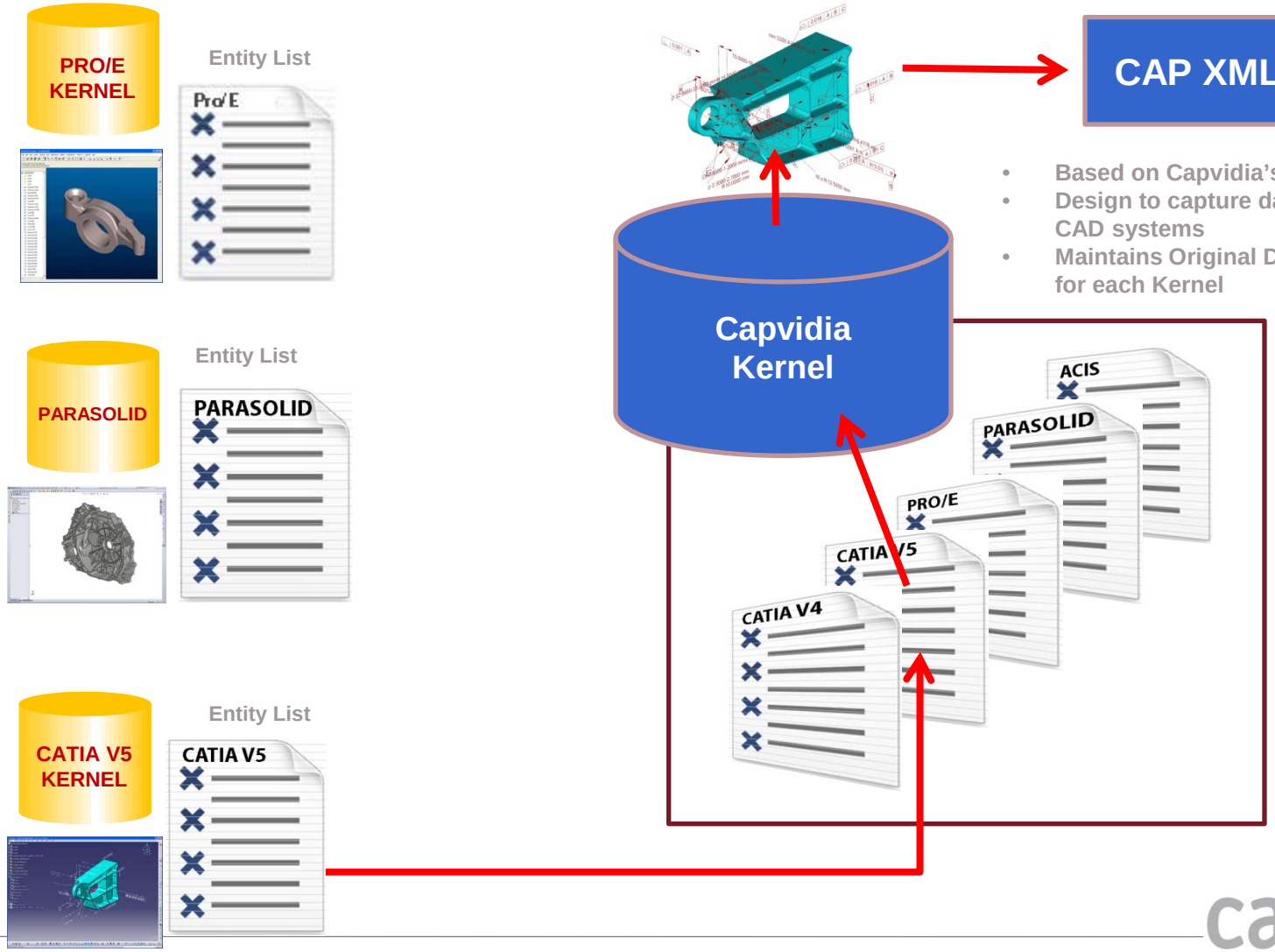
Exchanging 3D geometry with metadata keeping semantic relations as they are defined in native CAD system

Provide open/standard based data exchange mechanisms for mainstream and downstream applications, production processes and long term archiving

Solution


CAD A
CAD B
Standard
Standard
Realization
Realization
Formats
Formats
CAP
XML

How we handle different native CAD data



- Based on Capvidia's Geometry Kernel
- Design to capture data structures from all CAD systems
- Maintains Original Data Entity Definition for each Kernel

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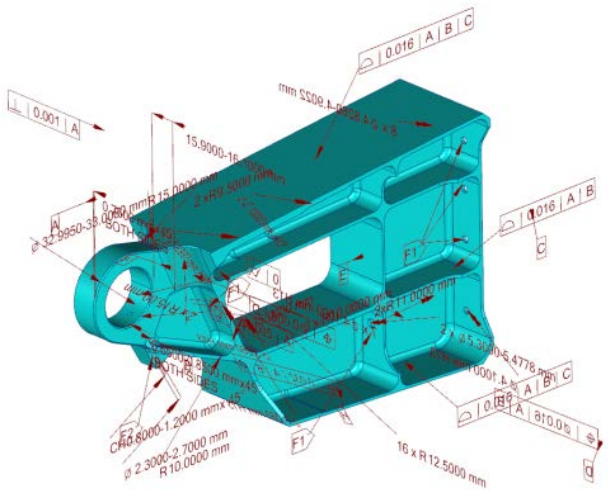
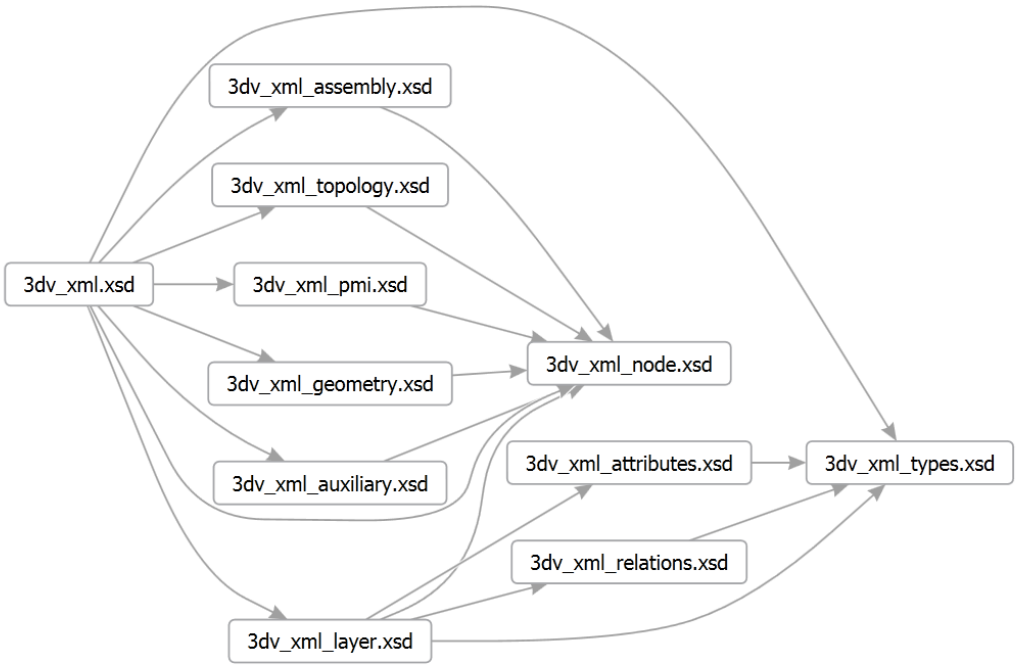
CAP XML Structure/Schemas

CAP XML schemas

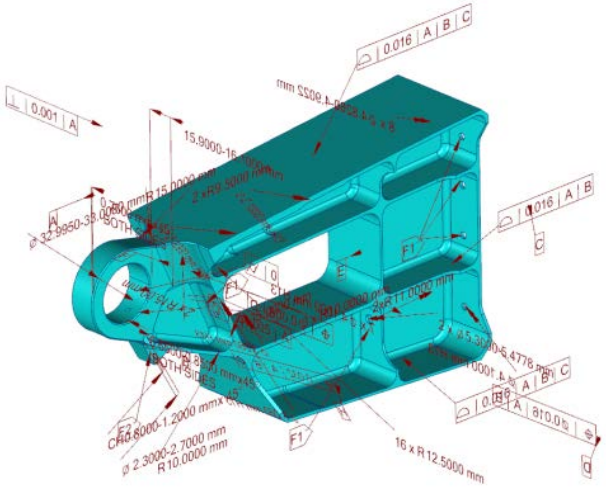


NAS6606D27.CADPart
(Native Format)

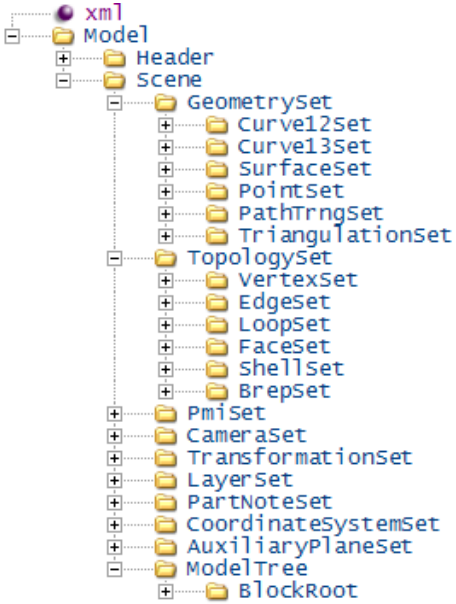


CAP XML Structure/Schemas

CAP XML format



NAS6606D27.CADPart
(Native Format)




```xml
<?xml version="1.0" encoding="utf-8"?>
<Model>
  <Header Version="16.20121206" Author="ilya" Organization="" SourceSystem=
  <Scene>
    <GeometrySet>
      <Curve12Set Number="24">...</Curve12Set>
      <Curve13Set Number="12">...</Curve13Set>
      <SurfaceSet Number="6">...</SurfaceSet>
      <PointSet Number="8">...</PointSet>
    </GeometrySet>
    <TopologySet>
      <VertexSet Number="8">...</VertexSet>
      <EdgeSet Number="12">...</EdgeSet>
      <LoopSet Number="6">...</LoopSet>
      <FaceSet Number="6">
        <Face id="175" Parent="127" Label=" @.53" Color="191 191 191">...</
        <Face id="178" Parent="127" Label=" @.123" Color="191 191 191" Turn
        <Face id="179" Parent="127" Label=" @.143" Color="191 191 191">...<
        <Face id="177" Parent="127" Label=" @.103" Color="191 191 191">...<
        <Face id="174" Parent="127" Label=" @.27" Color="191 191 191" Turne
        <Face id="176" Parent="127" Label=" @.79" Color="191 191 191" Turne
          <Surface>
            <Id>129</Id>
          </Surface>
          <Loops Number="1">
            <Id>139</Id>
          </Loops>
          <BackRefs Number="1">
            <Id>677</Id>
          </BackRefs>
        </Face>
      </FaceSet>
      <ShellSet Number="1">
        <Shell id="677" Parent="127" Closed="1">
          <Faces Number="6">
            <Id>175</Id>
            <Id>179</Id>
            <Id>177</Id>
            <Id>174</Id>
            <Id>178</Id>
            <Id>176</Id>
          </Faces>
        </Shell>
      </ShellSet>
      <BrepSet Number="1">
        <Brep id="127" Parent="2" Color="191 191 191" Type="6">
          <Shells Number="1">
            <Id>677</Id>
          </Shells>
          <Faces Number="6">...</Faces>
          <Loops Number="6">...</Loops>
          <Edges Number="12">...</Edges>
          <Vertices Number="8">...</Vertices>
        </Brep>
      </BrepSet>
    </TopologySet>
    <LayerSet Number="13">...</LayerSet>
    <ModelTree>
      <BlockRoot id="2" Parent="0" Label="Model Entities" OriginMassProp="-
        <Breps Number="1">
          <Id>127</Id>
        </Breps>
        <Layers Number="8">...</Layers>
      </BlockRoot>
    </ModelTree>
  </Scene>
</Model>
```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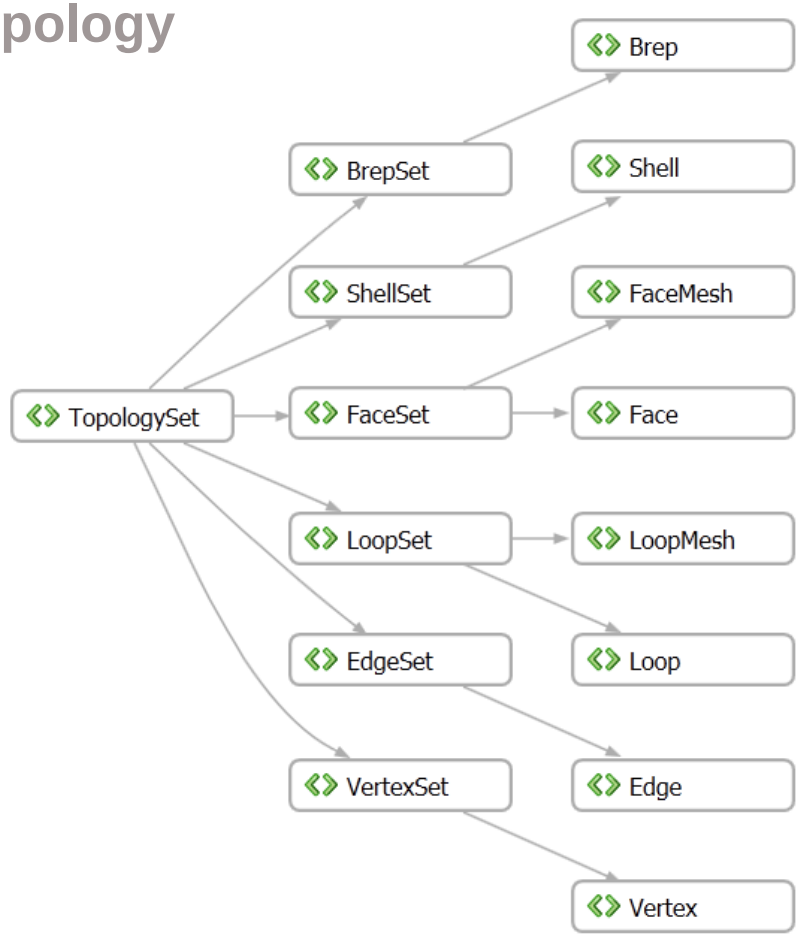
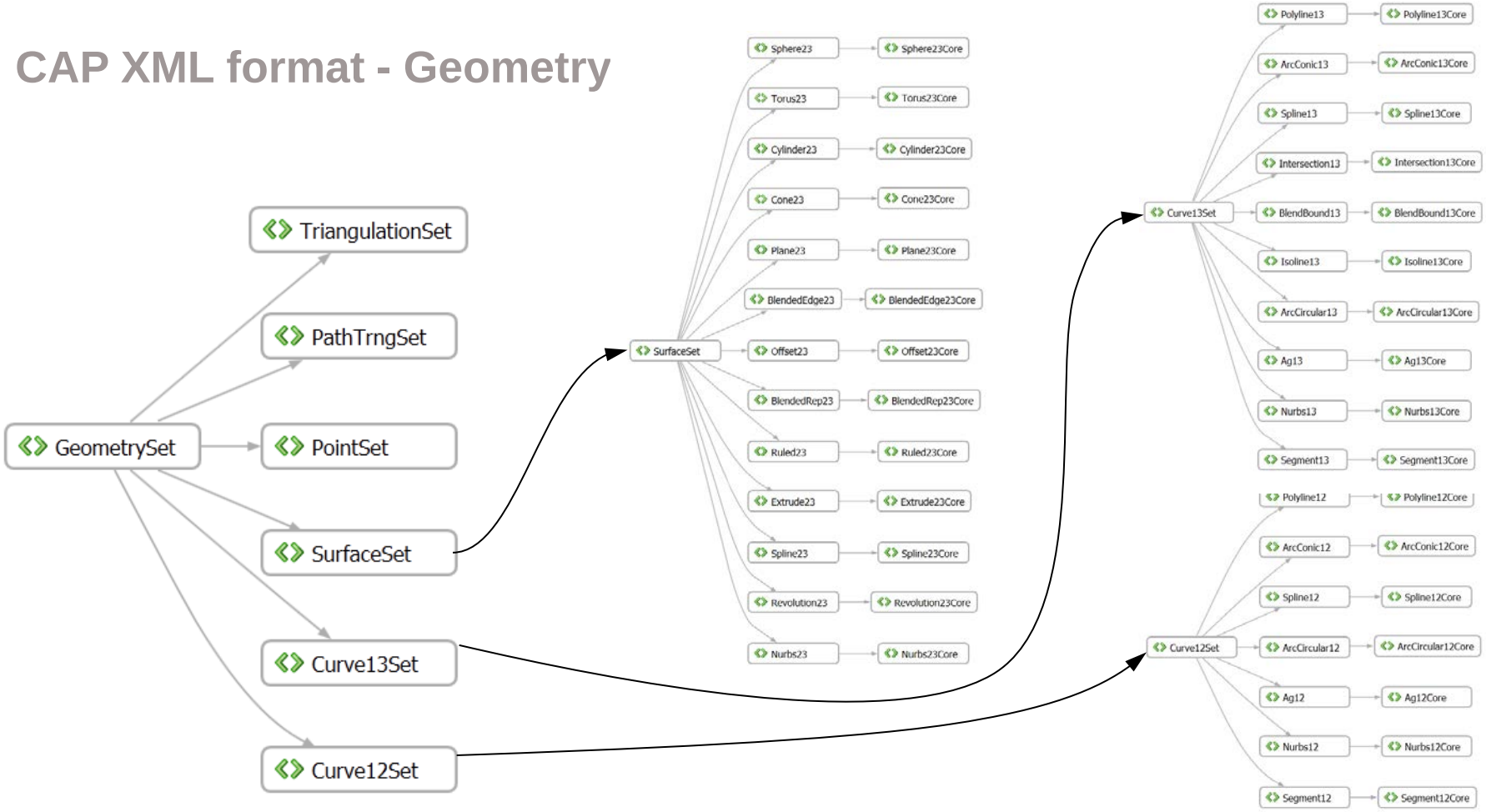
CAP XML Structure/Schemas

CAP XML format - Topology



CAP XML Structure/Schemas

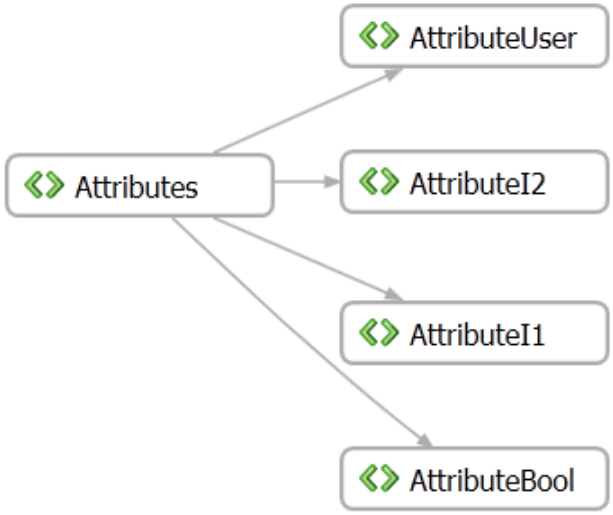
CAP XML format - Geometry



CAP XML Structure/Schemas

CAP XML format - Attributes

In addition to the standard attributes a third part application can specify an arbitrary "custom" attribute (AttributeUser).




```
      <Id>246</Id>
      <Id>248</Id>
    </DirectRefs>
    <BackRefs Number="1">
      <Id>113</Id>
    </BackRefs>
  </Edge>
  <Edge id="459" Parent="453">
    <Attributes Number="4">
      <AttributeBool Name="name 1" Value="1"/>
      <AttributeI1 Name="name 2" Value="10"/>
      <AttributeI2 Name="name 3" Value="10 20"/>
      <AttributeUser Name="name 4" NameUserAttribute="UserAttributeType">
        <UserData Size="14">
          c2FtcGxlIHNOcmluZwA=
        </UserData>
      </AttributeUser>
    </Attributes>
    <DirectRefs Number="3">
      <Id>452</Id>
      <Id>455</Id>
      <Id>455</Id>
    </DirectRefs>
  </Edge>
</EdgeSet>
<LoopSet Number="2">
  <Loop id="120" Parent="121" Label=" @CrvOnSrf.39" Type="2">
    <TurnEdgeFlags Number="2">
      0 0
    </TurnEdgeFlags>
    <DirectRefs Number="4">
      <Id>204</Id>
      <Id>205</Id>
      <Id>212</Id>
      <Id>213</Id>
    </DirectRefs>
```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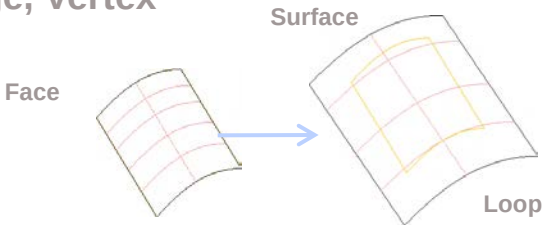
CAP XML Structure/Schemas

CAP XML schemas - Constrains

Using constrains in the xsd-schemas allows to specify certain restrictions on the values of the element (or attribute) and to establish a correct relationship between elements.

- BlockRoot – Layer
- BlockRoot, Block, Subfigure – Block, Subfigure, SubfigureInstance, Brep
- Brep – Shell, Face, Loop, Edge, Vertex
- Shell – Face
- Face – Loop, Surface
- Loop – Edge, Curve12




```xml
<xs:element name="Block" type="BlockType">

  <!-- Block is parent of Block, Subfigure, SubfigureInstance --
  <xs:key name="BlockIdKey">
    <xs:selector xpath="."/>
    <xs:field xpath="@id"/>
  </xs:key>
  <xs:keyref name="BlockBlockParentKeyRef" refer="BlockIdKey">
    <xs:selector xpath="Blocks/Block"/>
    <xs:field xpath="@Parent"/>
  </xs:keyref>
  <xs:keyref name="BlockSubfigureParentKeyRef" refer="BlockIdKey
    <xs:selector xpath="Blocks/Subfigure"/>
    <xs:field xpath="@Parent"/>
  </xs:keyref>
  <xs:keyref name="BlockSubfigureInstanceParentKeyRef" refer="Bl
    <xs:selector xpath="Parts/SubfigureInstance"/>
    <xs:field xpath="@Parent"/>
  </xs:keyref>

</xs:element>
```

```xml
<!-- Parametric face connected with surface -->
<xs:key name="SceneSurfaceIdKey">
  <xs:selector xpath="GeometrySet/SurfaceSet/*"/>
  <xs:field xpath="@id"/>
</xs:key>
<xs:keyref name="SceneFaceParametricSurfaceKeyRef" refer="SceneSurfaceIdKey">
  <xs:selector xpath="TopologySet/FaceSet/Face/Surface/Id"/>
  <xs:field xpath="."/>
</xs:keyref>

<!-- Parametric loop connected with 2d curves -->
<xs:key name="SceneCurve12IdKey">
  <xs:selector xpath="GeometrySet/Curve12Set/*"/>
  <xs:field xpath="@id"/>
</xs:key>
<xs:keyref name="SceneLoopParametricCurve12KeyRef" refer="SceneCurve12IdKey">
  <xs:selector xpath="TopologySet/LoopSet/Loop/Curves12/Id"/>
  <xs:field xpath="."/>
</xs:keyref>
```

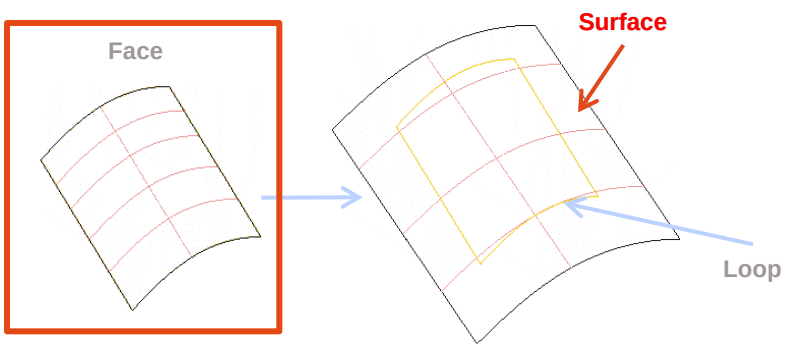
```xml
<!-- Brep is parent of Vertex, Edge, Loop, Face, Shell -->
<xs:key name="TopologySetBrepIdKey">
  <xs:selector xpath="BrepSet/Brep"/>
  <xs:field xpath="@id"/>
</xs:key>
<xs:keyref name="TopologySetVertexParentKeyRef" refer="TopologySetBrepIdKey">
  <xs:selector xpath="VertexSet/Vertex"/>
  <xs:field xpath="@Parent"/>
</xs:keyref>
<xs:key name="TopologySetVertexIdKey">
  <xs:selector xpath="VertexSet/Vertex"/>
  <xs:field xpath="@id"/>
</xs:key>
<xs:keyref name="TopologySetBrepVertexKeyRef" refer="TopologySetVertexIdKey">
  <xs:selector xpath="BrepSet/Brep/Vertices/Id"/>
  <xs:field xpath="."/>
</xs:keyref>
<xs:keyref name="TopologySetEdgeParentKeyRef" refer="TopologySetBrepIdKey">
  <xs:selector xpath="EdgeSet/Edge"/>
  <xs:field xpath="@Parent"/>
</xs:keyref>
<xs:key name="TopologySetEdgeIdKey">
  <xs:selector xpath="EdgeSet/Edge"/>
  <xs:field xpath="@id"/>
</xs:key>
<xs:keyref name="TopologySetBrepEdgeKeyRef" refer="TopologySetEdgeIdKey">
  <xs:selector xpath="BrepSet/Brep/Edges/Id"/>
  <xs:field xpath="."/>
</xs:keyref>
<xs:keyref name="TopologySetLoopParentKeyRef" refer="TopologySetBrepIdKey">
  <xs:selector xpath="LoopSet/Loop | LoopSet/LoopMesh"/>
  <xs:field xpath="@Parent"/>
</xs:keyref>
<xs:key name="TopologySetLoopIdKey">
  <xs:selector xpath="LoopSet/Loop | LoopSet/LoopMesh"/>
  <xs:field xpath="@id"/>
</xs:key>
<xs:keyref name="TopologySetBrepLoopKeyRef" refer="TopologySetLoopIdKey">
  <xs:selector xpath="BrepSet/Brep/Loops/Id"/>
  <xs:field xpath="."/>
</xs:keyref>
<xs:keyref name="TopologySetFaceParentKeyRef" refer="TopologySetBrepIdKey">
  <xs:selector xpath="FaceSet/Face | FaceSet/FaceMesh"/>
  <xs:field xpath="@Parent"/>
</xs:keyref>
<xs:key name="TopologySetFaceIdKey">
  <xs:selector xpath="FaceSet/Face | FaceSet/FaceMesh"/>
  <xs:field xpath="@id"/>
</xs:key>
<xs:keyref name="TopologySetBrepFaceKeyRef" refer="TopologySetFaceIdKey">
  <xs:selector xpath="BrepSet/Brep/Faces/Id"/>
  <xs:field xpath="."/>
</xs:keyref>
<xs:keyref name="TopologySetShellParentKeyRef" refer="TopologySetBrepIdKey">
  <xs:selector xpath="ShellSet/Shell"/>
  <xs:field xpath="@Parent"/>
</xs:keyref>
<xs:key name="TopologySetShellIdKey">
  <xs:selector xpath="ShellSet/Shell"/>
  <xs:field xpath="@id"/>
</xs:key>
<xs:keyref name="TopologySetBrepShellKeyRef" refer="TopologySetShellIdKey">
  <xs:selector xpath="BrepSet/Brep/Shells/Id"/>
  <xs:field xpath="."/>
</xs:keyref>
```

CAP XML Structure/Schemas

CAP XML schemas - validation example

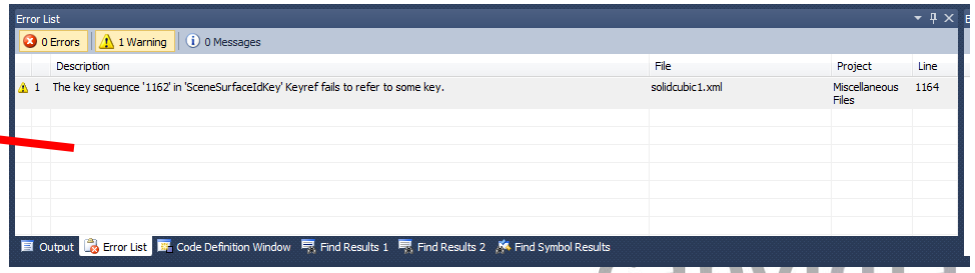
```
<Scene>
  <GeometrySet>
    <Curve12Set Number="24">...</Curve12Set>
    <Curve13Set Number="12">...</Curve13Set>
    <SurfaceSet Number="6">
      <Nurbs23 id="116" Parent="2" Label=" @NurbsSrf.31">
        <Nurbs23Core Order="4 4">...</Nurbs23Core>
        <BackRefs Number="5">
          <Id>175</Id>
          <Id>418</Id>
          <Id>426</Id>
          <Id>434</Id>
          <Id>442</Id>
        </BackRefs>
      </Nurbs23>
      <Nurbs23 id="154" Parent="2" Label=" @NurbsSrf.107">...</Nurbs23>
      <Nurbs23 id="164" Parent="2" Label=" @NurbsSrf.[illegible]">...</Nurbs23>
      <Nurbs23 id="142" Parent="2" Label=" @NurbsSrf.[illegible]">...</Nurbs23>
      <Nurbs23 id="102" Parent="2" Label=" @NurbsSrf.[illegible]">...</Nurbs23>
      <Nurbs23 id="129" Parent="2" Label=" @NurbsSrf.57">...</Nurbs23>
    </SurfaceSet>
    <PointSet Number="8">...</PointSet>
  </GeometrySet>
  <TopologySet>
    <VertexSet Number="8">...</VertexSet>
    <EdgeSet Number="12">...</EdgeSet>
    <LoopSet Number="6">...</LoopSet>
    <FaceSet Number="6">
      <Face id="175" Parent="127" Label=" @.53" Color="191 191 191">
        <Surface>
          <Id>1162</Id>
        </Surface>
        <Loops Number="1">
          <Id>126</Id>
        </Loops>
        <BackRefs Number="1">
          <Id>677</Id>
        </BackRefs>
      </Face>
```

1162?



Face must be connected with surface:
Face/Surface/Id -> SurfaceSet/*/@id

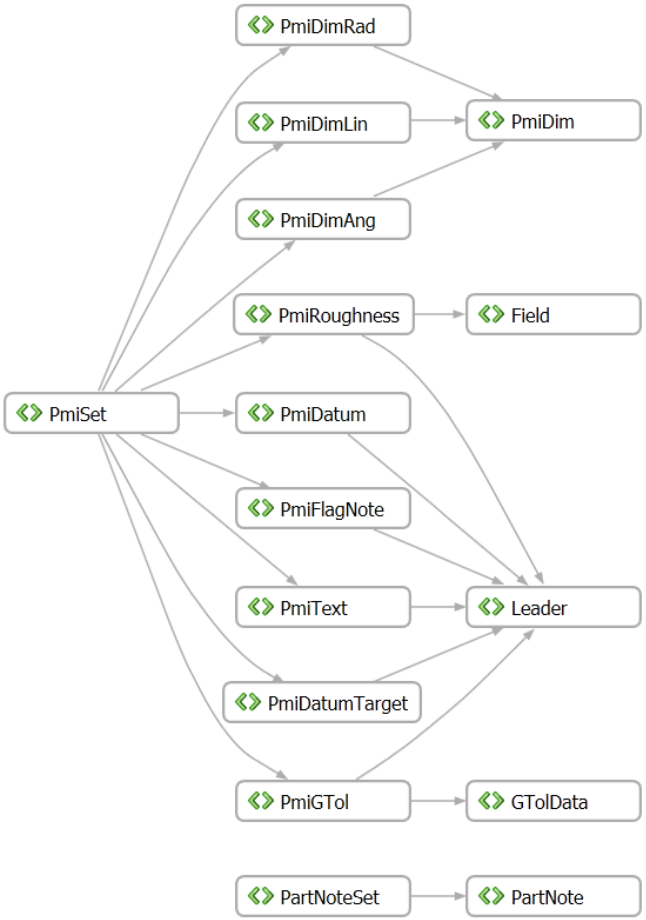
Error: Face 175 is connected with an entity 1162 which is not presented in the SurfaceSet



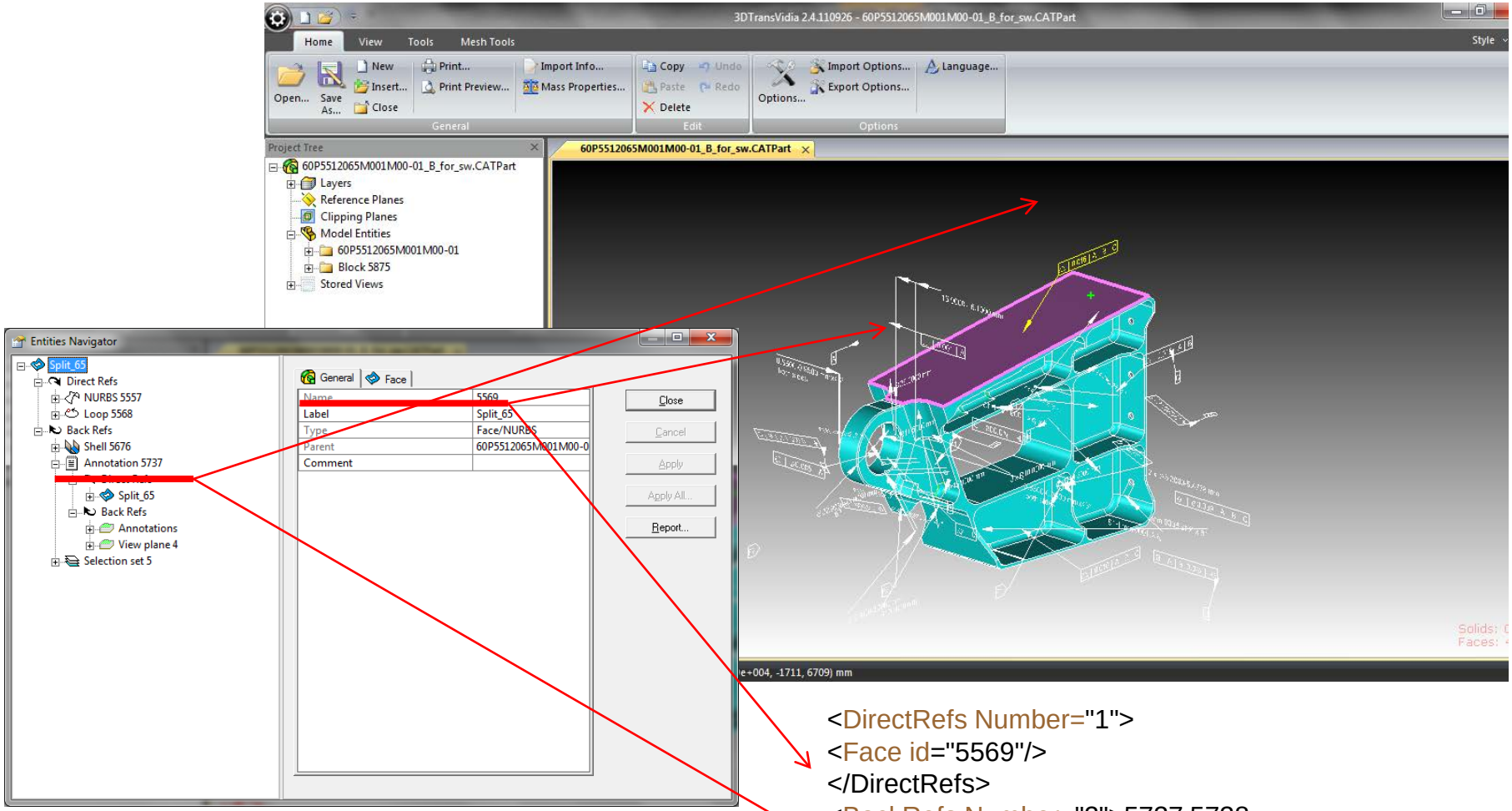
CAP XML Data Format

CAP XML format - PMI Metadata

- Roughness – roughness
- GTol – geometric tolerance
- Text – text annotation
- FlagNote – flag note
- Datum - datum
- DatumTarget – datum target
- Dimensions:
    - DimAng - angular dimension
    - DimLin – linear dimension
    - DimRad – radial dimension
- PartNote – part notes and standard notes



References/Semantics in CAP XML




```
<DirectRefs Number="1">
<Face id="5569"/>
</DirectRefs>
<BackRefs Number="2">5737 5738
</BackRefs>
```

CAP XML – support of mixed model definition

Parametric

Metadata

Triangulation

Wire-Frame

CMM Points

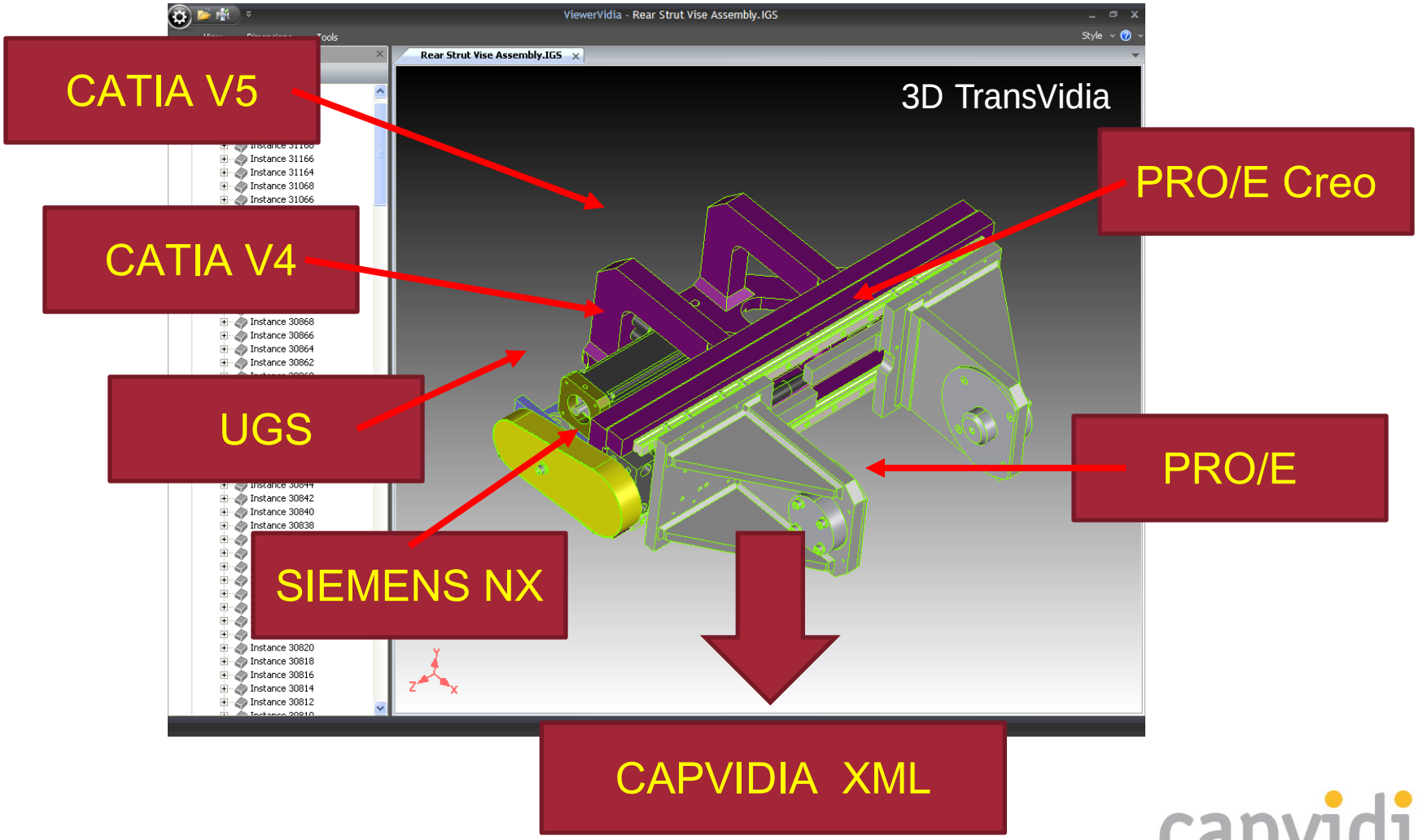
```
<Model>
<Header>
</Header>
<Scene>
Topology objects
Geometry objects
        • Points
        • Curves 2d
        • Curves 3d
        • Surfaces
        • Transformation
Auxiliary objects
Relations
Features
Metadata
        • Text – text annotation
        • FlagNote – flag note
        • Roughness – roughness
        • Datum - datum
        • DatumTarget – datum target
        • GTol – geometric tolerance
        • DimAng - angular dimension
        • DimLin – linear dimension
        • DimRad – radial dimension
Triangulation
Wire-Frame
CMM
</Scene>
```

```
<Brep id="123" ...>
<Shells>
    <Shell ...> ... </Shell>
</Shells>
<Faces>
      <Face id="34"/>
</Faces>
</Brep>
```

```
<Face id="10" ...>
  <DirectRefs ...>
    <Nurbs23 id="100"... >
          <BackRefs Number="2">1012
          </BackRefs>
    </Nurbs23>
  </DirectRefs>
</Face>
   <Face id="12" ...>
  <DirectRefs ...>
     <Nurbs23 id="100"/>
  </DirectRefs>
</Face>
```

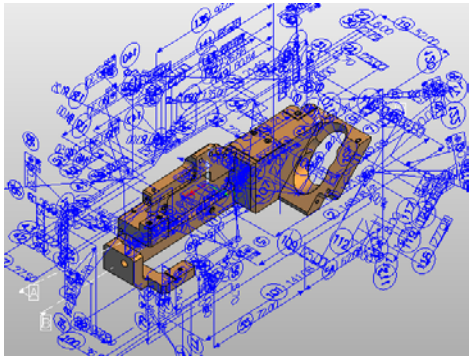
```
<Points ">
30612.634628846 -1269.21177250052 6666.02342780258
30612.6119637385 -1269.21823690379 6665.35717922205
30612.5892986309 -1269.22470130706 6664.69093064152
30612.5666335234 -1269.23116571033 6664.02468206099
</Points>
```

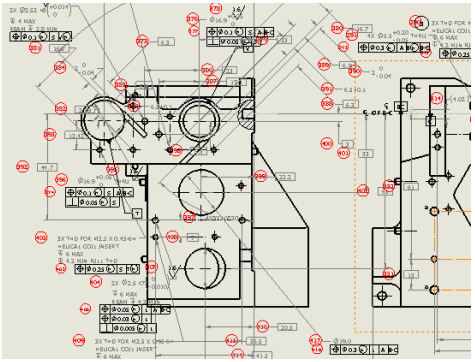
CAP XML – support of mixed model definition

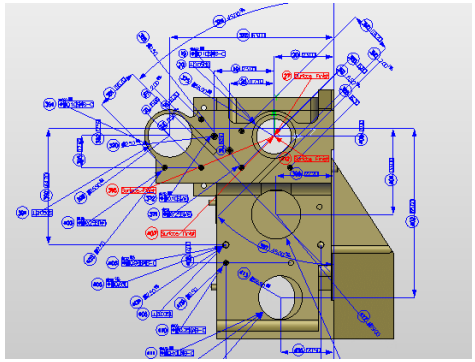


Integration with CMM software

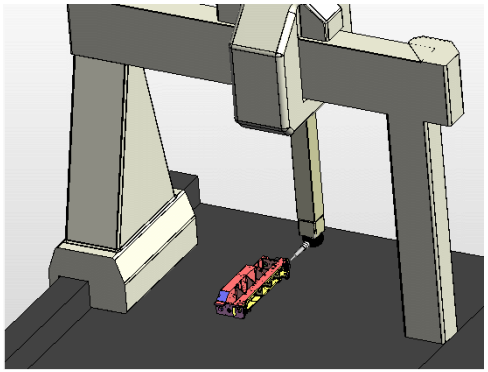
PAS TECHNOLOGY
CMM Programming Automation

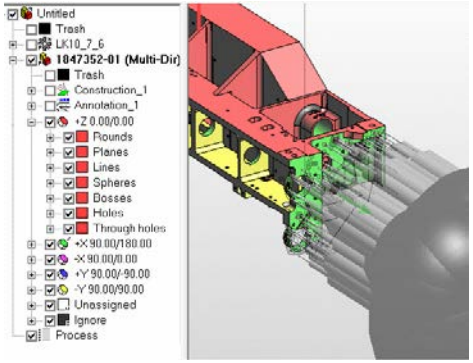






	View	Measurement Too	Dim	F'ic	Type	Data	Lower Tol	Upper Tol
23	Drawing View1	CMM Machine	3 Z		Perpendicula	0.0000	0.0050	
24	Drawing View1	CMM Machine	3 Z B-B-C		True Positior	0.0000	0.0500	
25	Drawing View1	CMM Machine	4 Z B-B-C		True Positior	0.0000	0.2500	
26	Drawing View1	CMM Machine	5		Coordinate	204.2000		
27	Drawing View1	CMM Machine	6		Diameter	2.5000	-0.0010	0.0010
28	Drawing View1	Special Gauge	6_1		General	3X THD FOR M		
29	Drawing View1	CMM Machine	11		Linear	323.5000		
30	Drawing View1	CMM Machine	12		Coordinate	234.5000		
31	Drawing View1	CMM Machine	13		Coordinate	322.5000		
32	Drawing View1	CMM Machine	14		Diameter	2.5000	-0.0010	0.0000
33	Drawing View1	CMM Machine	16 Z B-B-C		True Positior	0.0000	0.2500	
34	Drawing View1	CMM Machine	17		Diameter	2.5000	-0.0010	0.0010
35	Drawing View1	Special Gauge	17_1		General	2X THD FOR M		
36	Drawing View1	Go/NoGo Gauge	17_2		General	X 0.45-6H		
37	Drawing View1	Optical Gauge	17_3		General	HELICAL COIL INSERT		
38	Drawing View1	Caliper	17_4		General	THRU		
39	Drawing View1	Micrometer	17_5		General	± 4.2 MIN FULL THD		
40	Drawing View17	CMM Machine	18		Linear	6.3000		
41	Drawing View1	CMM Machine	18 D B-B-C		True Positior	0.0000	0.2500	
42	Drawing View17	CMM Machine	19		Linear	23.0000		
43	Drawing View17	CMM Machine	19 S A-B-C		True Positior	0.0000	0.1000	
44	Drawing View1	CMM Machine	19 Z B-B-C		True Positior	0.0000	0.2500	
45	Drawing View17	CMM Machine	20		Linear	23.0000		
46	Drawing View17	CMM Machine	20 S		Perpendicula	0.0000	0.0500	
47	Drawing View1	CMM Machine	21		Linear	4.0200	0.0000	0.0120
48	Drawing View1	Height Gauge	21_2		General	REAM ±3 MIN		





capvidia
software/engineering/applications

Summary

Benefits CAP XML:

- Open XML format
- Human and machine readable
- Flexible and easy to extended
- Used for over 10 years in Capvidia applications
- Covers well all CAD systems structures
- Compact
- Bi-directional compatibility with STEP 242

DMSC, Inc.

Statement of Intent
For Cooperation Under the Terms of a Memorandum of Understanding

The ***Dimensional Metrology Standards Consortium (DMSC, Inc.),*** a not-for-profit standards developing corporation, and ***Capvidia,*** a private software developing company, are pursuing a Memorandum of Understanding (MoU) for collaborative development work.

Capvidia will contribute to the DMSC a set of XML Schemas of their Open CAP-XML data format, which pertains to the exchange of Product Definition with Product Manufacturing Information (PMI) using the XML format.

In turn, the DMSC, as an ANSI accredited standards developing organization, will harmonize the contribution with its Quality Information Framework (QIF) as well as prepare and progress the contribution for national and/or international standardization.

The QIF is a suite of integrated XML Schema-based standards enabling the seamless flow of information within computer-aided quality measurement systems. Under the terms of the MoU, the expected outcome from this collaboration will produce an XML based exchange solution for product definition plus PMI that will not only satisfy the CAD to Metrology use case, but meet many other CAD to Manufacturing needs as well.

The final results of this collaborative effort is expected to be a submittal as an American National Standard, and later as an ISO Standard.

Standards Today

Well defined standards for 3D Geometry and Metadata

- 2D Drawing and rules how to present 3D model in 2D (paper) space

Functional Dimensioning, Annotation and Tolerance Standards

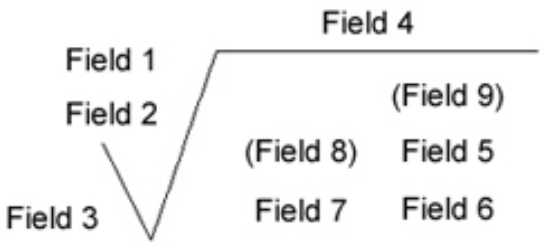
- DIN, ISO
- JSO
- ASME Y14.5

Implementation in native CAD systems (GD&T FTA)

- Native file
- STEP
- IGES
- 3D PDF

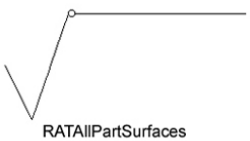
CAP XML Data Format

Roughness Description



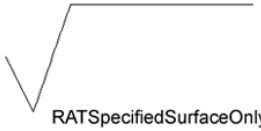
Roughness - obType

ROTNotDefined


RATAllPartSurfaces

ROTMachiningMandatory

ROTMachiningForbidden


RATSpecifiedSurfaceOnly

RATBasicSurface


```
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apType="0" nLeader="0">
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<Font Type="Arial Unicode MS,  20, Bold"/>
</PmiBase>
<Field Text="111"/>
<Field Text=""/>
<Field Text="333"/>
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<Field Text="555"/>
<Field Text="666"/>
<Field Text="M"/>
<Field Text=""/>
<Field Text=""/>
<DirectRefs Number="1">
<Face id="63"/>
</DirectRefs>
<BackRefs Number="2">86 87 </BackRefs>
</PmiRoughness>
```
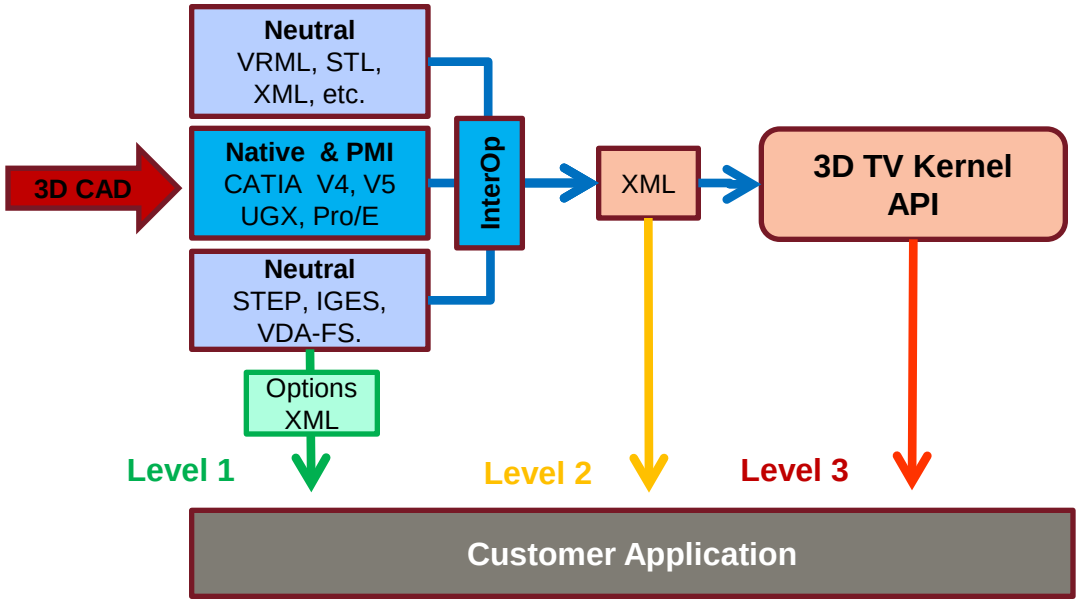
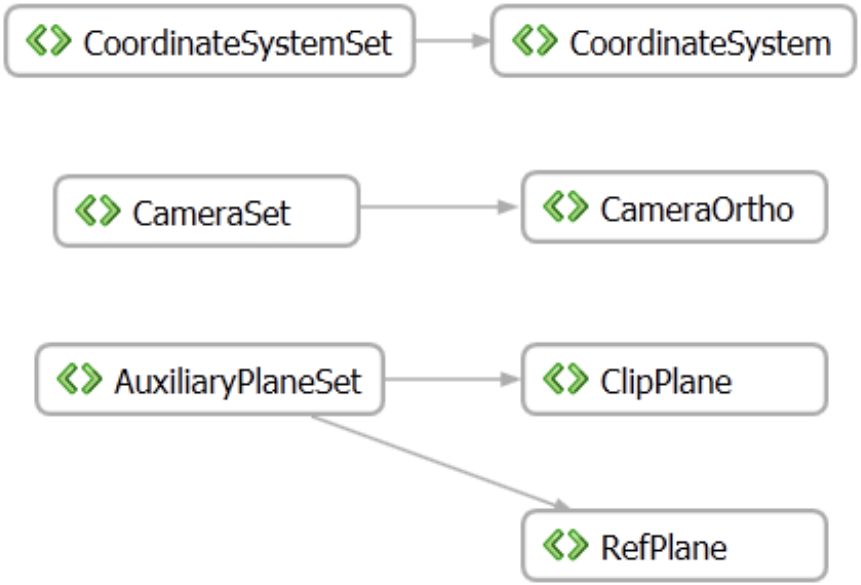


attribute	description
id	Unique id
Parent	Parent object
Color	Color red green blue 0-255 separated by spaces
obType	Roughness Obtention Type
apType	Roughness Applicability Type
nLeader	Number of leader
Note3D	1-3d annotation, 0 – 2d annotation (internal 3dv type)

Capvidia components - integration levels



Level	Integration Strategy	Programming Difficulty Level	Estimated Implementation time
1	Using standard CAD data formats (STEP, IGES) and controlling the kernel functions through Option XML file (text file), command line	**no programming**	days
2	Using Capvidia XML data format to communicate with the Kernel (import/export)	programming	weeks
3	Using Kernel API to directly access provided functions	advanced programming	months

CAP XML Data Format

CAP XML format - Auxiliary objects