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GML 3.1.1 PIDF-LO Shape Application Schema for use by the Internet Engineering Task Force (IETF)

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Warning

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i. Preface

This document defines an application schema of the Geography Markup Language (GML) version 3.1.1 for XML encoding of various geometric shapes required in the Presence Information Description Format (IETF RFC 3863) Location Object extension – or PIDF-LO (IETF RFC 4119).

PIDF-LO serves as a document for the representation of Location Information (LI). This LI identifies the spatial location of a Target; the Target being a generic entity that is likely to be either a person or a Device. LI is a component of the Target's presence information.

The LI that forms the core of a PIDF-LO document originates in the Location Generator (LG). Depending on the specific circumstances, particularly the type of access network, the LG can use any number of methods to determine LI. The range of technologies available for determining LI are numerous and range from user-provided LI, to automatic methods such as wire mapping, radio timing, and GPS.

PIDF-LO is designed to be consumed in a wide range of applications. In some cases the information is presented to a user, maybe in a graphical representation, as a way of identifying the location of the Target. Other applications use LI as input to assist in providing a service.

Suggested additions, changes, and comments on this draft report are welcome and encouraged. Such suggestions may be submitted by email message or by making suggested changes in an edited copy of this document.

ii. Document terms and definitions

This document uses the specification terms defined in Subclause 5.3 of [OGC 05-008]. In particular, the word “shall” (not “must”) is the verb form used to indicate a requirement to be strictly followed to conform to this specification.

iii. Document contributor contact points

This document was originally authored by Martin Thomson, Andrew Corporation, and submitted to the IETF GeoPRIV Working Group for use in a variety internet standards.

All questions regarding this document should be directed to the editor or the contributors:

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iv. Revision history

Date	Release	Editor	Primary clauses modified	Description
4/6/06	.8	Martin Thomson	Original Version	This document defines a set of shapes for the representation of uncertainty for PIDF-LO geodetic location information.
9/25/06	.9	Carl Reed	Put into OGC template	
1/8/07	.9	Carl Reed	Fix various TBDs	Provide correct schema locations, fix various TBDs.
4/10	1.0	Carl Reed	Various	Reflect agreement on proper namespace to use for this application schema.

v. Changes to OGC Specifications

The previously approved OGC™ Specifications do not need changes to accommodate the technical contents of this document.

vi. Future work

Improvements in this document may be desirable. There will be a 30-day public comment period to solicit input and comments from the broader geospatial community.

vii. Differences from GML version 3.1.1

Not applicable for this first version.

Foreword

This document specifies a n application schema based on the existing OpenGIS Geography Markup Language (GML) Implementation Specification version 3.1.1 [OGC 03-105r1 and 04-092r4], and does not modify it.

This document includes 1 annex. Annex B is informative.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. The OGC shall not be held responsible for identifying any or all such patent rights.

Introduction

This document defines a GML application schema (AS) for encoding specific geometric shapes as required in PIDF-LO, specifically for such location service and mobile emergency service requirements for ellipses, prisms, and spheres. This XML schema is based on the OGC Geography Markup Language (GML) version 3.1.1 using the separately specified GML-pidf-lo-shape.xsd. In this document, the following two dimensional shapes are either clarified or defined: Polygon, Circle, Ellipse and Arc Band and the following three dimensional shapes are defined: Sphere, Ellipsoid and Prism.

Specifically, this document defines how geodetic location information is specified in a PIDF-LO [IETF RFC4119] document.

RFC4119 specifies that the feature schema from version 3.1.1 of GML be supported by all implementations. However, this is not practical for a number of reasons.

The feature schema, and the schema that it relies upon, includes a sizable proportion of the GML data types. This includes parts of the geometry and temporal schema that are rarely applicable in the domain where PIDF-LO is used. This means that implementations are required to support portions of the GML specification that are not and, in some cases, cannot be used.

GML is structured to be used within an application schema. An application schema being a schema constructed for a particular application that both limits GML to what is applicable and provides application-specific types. PIDF-LO does not define such a schema. As a result this increases the complexity of implementation and decreases the usability of GML within PIDF-LO. If PIDF-LO is to be usable in the internet domain, it requires that such a schema is defined.

This document defines an application schema and profile for using GML within PIDF-LO. This includes a small subset of GML geometry that is expanded by a new schema that defines additional geometries.

These geometries, or shapes, are designed to provide a simple representation of shapes that are in common usage. In particular, these shapes are useful for the representation of uncertainty that arises from location determination technologies. A range of these shapes arise from wireless location technologies, and others are suited to geodetic representations of civic features, such as buildings and residential allotments. These shapes enable easy translation from location information in other document formats into the PIDF-LO form.

GML 3.1.1 PIDF-LO shape profile

1 Scope

This GML 3.1.1 application schema (AS) is defined for encoding specific geometric shapes required for presence information as defined by the IETF in a number of internet standards for the IPV-6, location services, and mobile computing.

This GML PIDF-LO Application Schema uses the separately specified geoshape.xsd profile of GML 3.1.1, specified to support multiple other profiles for encoding location data for use in various internet standards.

2 Compliance

Location Information for use in PIDF and other internet standards encoded using this profile shall produce XML documents that are fully compliant with normative XML Schema Documents associated with this specification:

GML-pidf-lo-shape.xsd

XML documents compliant with this profile shall import the XML Schema Documents, which are available following approval of this document at:

<http://schemas.opengis.net/gml/3.1.1/profiles/geoshape/0.0.9/>

3 Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of this document. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the normative document referred to applies.

OGC 03-105r1, *OpenGIS Geography Markup Language (GML) Implementation Specification*, Version 3.1.0,

OGC 04-092r4, *GML 3.1.1 schemas*

OGC 05-010, *URNs of definitions in ogc namespace* (Recommendation Paper), Version 1.0.0

IETF RFC 4119 - Peterson, J., "A Presence-based GEOPRIV Location Object Format," December 2005.

3GPP TS 23.032 , “*Universal Geographical Area Description (GAD)*,” December 2004.

US National Imagery and Mapping Agency, “*Department of Defense (DoD) World Geodetic System 1984 (WGS 84), Third Edition*,” January 2000.

W3C, *Extensible Markup Language (XML) 1.0* (Second Edition), W3C Recommendation, 6 October 2000, <http://www.w3.org/TR/REC-xml>

W3C, *XML Schema Part 1: Structures*, <http://www.w3.org/TR/xmlschema-1>

W3C, *XML Schema Part 2: Datatypes*, <http://www.w3.org/TR/xmlschema-2>

W3C, *Namespaces in XML*, <http://www.w3.org/TR/1999/REC-xml-names-19990114>

W3C, *XLink* (Maler, E., DeRose, S., and D. Orchard, “XML Linking Language (XLink) Version 1.0,” June 2001.)

ISO 19757-3 2005, “Document Schema Definitions Languages (DSDL): Part 3 - Rule-based validation - Schematron,” 2005.

In addition to this document, this specification includes several normative XML Schema files. Following approval of this document, these schemas will be posted online at the URL: <http://schemas.opengis.net/gml/3.1.1/profiles/geoshape/0.0.9/>. These XML Schema files are also bundled with the present document. In the event of a discrepancy between the bundled and online versions of the XML Schema files, the online files shall be considered authoritative.

4 Terms and definitions

For the purposes of this specification, the definitions specified in Clause 4 of the OWS Common Implementation Specification [OGC 05-008] shall apply. In addition, the following terms and definitions apply.

4.1

PIDF

Presence information description format.

5 Conventions

5.1 Abbreviated terms

The abbreviated terms used in this document include:

3GPP - 3rd Generation Partnership Project

GML - Geography Markup Language

IETF – Internet Engineering Task Force

LI Location Information

OGC Open Geospatial Consortium

PIDF Presence Information Data Format

PIDF-LO PIDF - Location Object

5.2 UML notation

None.

5.3 Namespaces

When referring to XML element, attribute and type definitions by name, this document uses namespace prefixes to distinguish between elements in different namespaces. The `gml:` prefix refers to elements from the `http://www.opengis.net/gml` namespace [OGC.GML-3.1.1] (Cox, S., Daisey, P., Lake, R., Portele, C., and A. Whiteside, “Geographic information - Geography Markup Language (GML),” April 2004.); the `gs:` prefix refers to elements from the <http://www.opengis.net/pidflo/1.0> namespace.

6 GML PIDF-LO Shape Application Schema

6.1 Background

GML 3.1.1 includes 6 XML Schema Documents for encoding geoshape (location) information for use in various internet standards, namely: (listed alphabetically)

- a) `geometryPrimitives.xsd`,
- b) `geometryBasic2d.xsd`,
- c) `geometryBasic0d1d.xsd`,
- d) `measures.xsd`,
- e) `gmlBase.xsd`,
- f) `basicTypes.xsd`.

This set of geoshape XML Schema Documents does not use all the other GML 3.1.1 XML Schema Documents, and does not use all the abilities specified in the documents it does use.

6.2 Overview

PIDF-LO serves as a document for the representation of Location Information (LI). This LI identifies the spatial location of a Target; the Target being a generic entity that is likely to be either a person or a Device. LI is a component of the Target's presence information. Specifically, this document defines the following two dimensional shapes are either clarified or defined: Polygon, Circle, Ellipse and Arc Band and the following three dimensional shapes are defined: Sphere, Ellipsoid and Prism.

The LI that forms the core of a PIDF-LO document originates in the Location Generator (LG). Depending on the specific circumstances, particularly the type of access network, the LG can use any number of methods to determine LI. The range of technologies available for determining LI are numerous and range from user-provided LI, to automatic methods such as wire mapping, radio timing, and GPS.

PIDF-LO is designed to be consumed in a wide range of applications. In some cases the information is presented to a user, maybe in a graphical representation, as a way of identifying the location of the Target. Other applications use LI as input to assist in providing a service.

This GML 3.1.1 AS is defined for encoding specific geometric shapes. This GML 3.1.1 PIDF-LO Application Schema utilizes a profile of GML that retains the following XML elements, attributes, and types used by the following elements/abridged version of:

geometryPrimitives.xsd, geometryBasic2d.xsd, geometryBasic0d1d.xsd, measures.xsd, gmlBase.xsd, and basicTypes.xsd. Note that units.xsd and dictionary.xsd are excluded from this profile.

6.3 Considerations specific to this Application Schema

6.3.1 About Location Information used in PIDF

Two forms of LI are defined for use in PIDF-LO. Geodetic information consists of coordinates that identify a location in a particular coordinate reference system; and civic addresses that identify a location based on civic norms (countries, cities, streets, etc...). This document is concerned with geodetic LI only.

The remainder of this section introduces location concepts that affect how geodetic LI is represented and interpreted.

6.3.2 Coordinate Reference Systems

A coordinate reference system (CRS) specifies how coordinates are interpreted. For the shapes defined in this document, only the two- and three-dimensional WGS84 coordinate reference systems (latitude, longitude, and perhaps altitude) are mandatory, see Section 7.1.2 (**Coordinate Reference Systems**). The shapes defined in this document

assume one or both of these CRSs and may not be applicable to other coordinate reference systems.

6.3.3 Uncertainty

Under ideal circumstances, LI would describe a point in space unambiguously. However, in reality, automatic location determination methods are imprecise for a variety of reasons.

Uncertainty can be quantified in measurement in a number of ways, usually depending on the method that is used to determine LI. An area or volume is the most common way of representing uncertainty. For example, an ellipsoid is common for representing uncertainty in GPS measurements; polygons may be used when LI is converted from a civic address form; or a circle or ellipse is often used to describe the coverage area of a radio antenna.

Even if location determination results in a single point, uncertainty may be specified as a distance from that point. This form of uncertainty indicates the furthest distance from the given point that the actual Target is expected to be located given certain sources of measurement error. This still effectively defines a circular area, or spherical volume, in which the Target could be located.

This document assumes that any method for determining location is subject to uncertainty. The absence of uncertainty does not indicate that there is none, or that the measurement was infinitely precise; instead, the absence of uncertainty data indicates that the value of uncertainty could not be (or was not) provided.

6.3.4 Confidence

Confidence is also used in some cases to express the innate variability of location determination. Variability in determining location cannot always be addressed by uncertainty. Confidence is a statistical measure indicating the probability that the given region of uncertainty actually covers the Target's actual location.

Confidence is typically affected by variation in measurement parameters. However, confidence can also account for the chance of human error in the form of data entry errors or exceptional software faults. Likewise, confidence can cover the probability of intentional modification of LI (location fraud) beyond the capability of providers or protocol to prevent.

The application of confidence is controversial. Location determination methods do not often directly provide this sort of information, and likewise many applications do not use the value in any way. In most cases the confidence cannot be used to make a decision. For instance, one such decision that uses confidence is whether or not the LI can be used; however, many applications rely on the assumption that any LI is better than none, so uncertainty is not considered.

Because uncertainty is difficult to manage, this document does not define a parameter for conveying confidence. Individual applications MAY recommend a target level of confidence, but this information is not included in the core geodetic shape formats.

6.4 XML schema documents

This GML 3.1.1 PIDF-LO Shape Application Schema is specified in the GML-pidf-lo-shape.xsd normative XML Schema Documents included in the zip file with this text document, which are named.

a) GML-pidf-lo-shape.xsd.zip

All these XML Schema Documents contain documentation of the meaning of each element and attribute, and this documentation shall be considered normative as specified in Subclause 11.6.3 of [OGC 05-008].

These XML Schema Documents are bundled in a zip file with this document. After OGC acceptance of this specification as OGC Best Practices, these XML Schema Documents will also be posted online at the URL

<http://schemas.opengis.net/gml/3.1.1/profiles/geoshape/0.0.9>

In the event of a discrepancy between the bundled and online versions of the XML Schema Documents, the online files shall be considered authoritative.

7 XML encoding for PIDF-LI Shape Application Schema

7.1 General Information

7.1.1 GML Version and Profile

This document is based on the version 3.1.1 schema of GML. This document updates IETF RFC 4119.

This document restricts the required set of GML. A profile schema is included in Section 7.3 (**GML Schema Profile**). This profile follows the guidelines of [OGC.GML-3.1.1] and is a copy of the GML schema with portions removed. GML compliant implementations may use the full GML schema or the `geometryPrimitives.xsd` schema in place of this profile, as identified by:

```
urn:opengis:specification:gml:schema-  
xsd:geometryPrimitives:3.1.1.
```

The GML profile defined in Section 7.3 (**GML Schema Profile**) removes all unused parts of GML from the schema definition. In particular, this includes cross references using W3C Xlink. The `gml:id` attribute is retained so that geometry objects may still be the target of a reference.

7.1.2 Coordinate Reference Systems

Implementations shall support the following coordinate reference systems based on WGS 84. These are identified using the European Petroleum Survey Group (EPSG) Geodetic Parameter Dataset, as formalized by the following Open Geospatial Consortium (OGC) URNs:

- 3D: WGS 84 (latitude, longitude, altitude), as identified by the URN `urn:ogc:def:crs:EPSG::4979`. This is a three dimensional CRS.
- 2D: WGS 84 (latitude, longitude), as identified by the URN `urn:ogc:def:crs:EPSG::4326`. This is a two dimensional CRS.

The most recent version of the EPSG Geodetic Parameter Dataset should be used. The CRS shall be specified using the above unversioned URN notation only; implementations do not need to support user-defined CRSs.

Implementations **MUST** specify the CRS using the `srsName` attribute on the outermost geometry element. The CRS must not be respecified or changed for any sub-elements. The `srsDimension` attribute should be omitted, since the number of dimensions in these CRSs is known.

7.1.3 Units of Measure

GML permits a range of units of measure for all parameters. This document restricts this set to a single length unit and two angle units.

Length measures shall be specified using metres, which is identified using the URN

```
urn:ogc:def:uom:EPSG::9001.
```

Angular measures **MUST** use either degrees or radians. Measures in degrees **MUST** be identified by the URN:

```
urn:ogc:def:uom:EPSG::9102.
```

Measures in radians **MUST** be identified by the URN

```
urn:ogc:def:uom:EPSG::9101.
```

The units of measure shall be specified on the property element that contains the value.

7.1.4 Approximations

The shapes provided in this document are primarily intended to represent areas of uncertainty. Uncertainty is a product of the inexact science of determining a location estimate. These estimates are subject to a range of errors. For these shapes, using approximations in processing this data does not significantly affect the quality of the data.

Several approximation methods are described in this document that can be used to reduce the complexity of algorithms that use these shapes. Applications and algorithms that rely on this data should tolerate small errors that could arise from approximation.

The guidance in this document on approximation techniques are not appropriate for shapes that cover large areas, or for applications where greater precision is required. Any guidance on approximations is appropriate to the application of these shapes to personal location, but might not be appropriate in other application domains.

7.1.5 Lines and Distances

In this document, all lines and measurements are formed by straight lines. When joining two points, linear interpolation is used, that is, the shortest path in space rather than the path across the surface of the ellipsoid (geodesic interpolation). Likewise for distances, the distance is the length of the shortest path in space.

Implementations may use geodesic interpolation between points and for distance measurement. A geodesic is a line that follows the surface of a geoid or ellipsoid, which in this context is usually the WGS 84 ellipsoid. Geodesic interpolation can produce a small difference from straight line interpolation. For use in uncertainty this error can be accepted, but it is recommended that this variation is constrained to approximately 3% of the total distance.

For WGS84, the error between a geodesic and a straight line at the equator reaches 3% of the distance of the line at a length of approximately 382km at the equator. This distance becomes approximately 131km in the East-West direction at 70 degrees latitude (North or South). Therefore, for the representation of uncertainty it is recommended that the maximum distance between two points in a shape be less than 130km. Shapes that have an absolute latitude of more than 70 degrees should be smaller before any approximation is used.

7.1.6 Planar Approximation

A common approximation used for geodesy applications treats the surface of the ellipsoid as if it were a plane over a small area. This approximation is more intuitive and simplifies mathematical operations. Implementations MAY use this approximation method in interpreting the shapes in this document providing that the size of the shape is within the guidelines in Section 7.1.5 (Lines and Distances).

7.2 Geometry

This document defines a set of geometry that is appropriate for the encoding of the sorts of LI described in Section 6.3.1 (About Location Information). This section describes how geometries can be represented using the application schema defined in Section 7.3 (Application Schema). Pre-existing GML geometries, `gml:Point` and `gml:Polygon` are also described with examples.

This section clarifies the usage of the zero dimensional Point. The following two dimensional shapes are either clarified or defined: Polygon, Circle, Ellipse and Arc Band. The following three dimensional shapes are defined: Sphere, Ellipsoid and Prism.

A description of the Point, Circle, Ellipse, Sphere, Ellipsoid, Polygon and Arc Band, including descriptions of their parameters and explanatory diagrams, can be found in [3GPP.TS23032].

7.2.1 Point

The point shape type is the simplest form of geodetic LI, which is natively supported by GML. The `gml:Point` element is used when there is no known uncertainty. A point also forms part of a number of other geometries.

A point may be specified using either WGS 84 (latitude, longitude) or WGS 84 (latitude, longitude, altitude). This is shown in the following examples:

```
<gml:Point srsName="urn:ogc:def:crs:EPSG::4326"
           xmlns:gml="http://www.opengis.net/gml">
  <gml:pos>-34.407 150.883</gml:pos>
</gml:Point>

<gml:Point srsName="urn:ogc:def:crs:EPSG::4979"
           xmlns:gml="http://www.opengis.net/gml">
  <gml:pos>-34.407 150.883 24.8</gml:pos>
</gml:Point>
```

7.2.2 Polygon

A polygon uses the `gml:Polygon` element. A polygon is specified by a sequence of points. A polygon requires at least four points, where the first and last point shall be the same.

Points specified in a polygon shall be coplanar. However, implementations should be prepared to accept small variations that might occur depending on whether the the polygon is specified on a plane in space, or only relative to the ellipsoid. To avoid implementation complexity, implementations may choose to not support polygons that include varying altitude. Therefore, two polygon forms are permitted: polygons specified using EPSG 4326, and polygons specified using EPSG 4979 with a constant altitude value.

Interpolation between points is linear, as defined for the `gml:LinearRing` element. Note that this interpolation is different for that specified in 3GPP, “Universal Geographical Area Description (GAD) which uses geodesic interpolation. Since geodesic interpolation is non-trivial to implement and some error is acceptable in both Universal Geographical Area Description (GAD) and this document, implementations SHOULD minimize this error by ensuring that the sides of polygons are as short as possible.

Note: 3GPP, “Universal Geographical Area Description (GAD), limits the number of unique points to 15 for a polygon. Therefore, if interoperability is required, polygons should not have more than 16 points in total.

The following example shows a polygon that is specified using EPSG 4326 and the `gml:pos` element. No altitude is included in this example, indicating that altitude is unknown.

```
<gml:Polygon srsName="urn:ogc:def:crs:EPSG::4326"
  xmlns:gml="http://www.opengis.net/gml">
  <gml:exterior>
    <gml:LinearRing>
      <gml:pos>42.556844 -73.248157</gml:pos>
      <gml:pos>42.549631 -73.237283</gml:pos>
      <gml:pos>42.539087 -73.240328</gml:pos>
      <gml:pos>42.535756 -73.254242</gml:pos>
      <gml:pos>42.542969 -73.265115</gml:pos>
      <gml:pos>42.553513 -73.262075</gml:pos>
      <gml:pos>42.556844 -73.248157</gml:pos>
    </gml:LinearRing>
  </gml:exterior>
</gml:Polygon>
```

The following alternative example shows the same polygon with a constant altitude included that is specified using EPSG 4979 and the `gml:posList` element.

```
<gml:Polygon srsName="urn:ogc:def:crs:EPSG::4979"
  xmlns:gml="http://www.opengis.net/gml">
  <gml:exterior>
    <gml:LinearRing>
      <gml:posList>
        42.556844 -73.248157 36.6
        42.549631 -73.237283 36.6
        42.539087 -73.240328 36.6
        42.535756 -73.254242 36.6
        42.542969 -73.265115 36.6
        42.553513 -73.262075 36.6
        42.556844 -73.248157 36.6
      </gml:posList>
    </gml:LinearRing>
  </gml:exterior>
</gml:Polygon>
```

The `gml:posList` element is interpreted as a list with the dimension of the CRS indicating how many values are required for each point.

7.2.3 Polygon Upward Normal

The upward normal of a polygon determines the orientation of the surface. The upward normal of a polygon is important for the definition of the Prism.

GML-3.1.1 describes the upward normal of a surface as a unit vector pointing to the side of the surface from which the exterior boundary appears counterclockwise. It is recommended therefore that polygons are specified in a counterclockwise direction, so that their upward normal corresponds to an actual *up*.

The upward normal can also be determined using the *Right Hand Rule*. Take your right hand and curl the fingers in the predominant direction that the polygon is defined; your thumb then points in the direction of the upward normal.

Polygons with four or more unique points that are specified with constant altitude are unlikely to be perfectly coplanar. An approximate method for determining the upward normal of a polygon that is not guaranteed to be coplanar is described in Annex A (Calculating the Upward Normal of a Polygon).

7.2.4 Circle

The circular area is used for coordinates in two-dimensional CRSs to describe uncertainty about a point. The definition is based on the one-dimensional geometry in GML, `gml:CircleByCenterPoint`.

The centre point of a circular area shall be specified using a two dimensional CRS; in three dimensions, the orientation of the circle cannot be specified correctly using this representation. A point with uncertainty that is specified in three dimensions SHOULD use the Sphere shape type.

```
<gs:Circle srsName="urn:ogc:def:crs:EPSG::4326"
  xmlns:gs="http://www.opengis.net/pidflo/1.0"
  xmlns:gml="http://www.opengis.net/gml">
  <gml:pos>
    42.5463 -73.2512
  </gml:pos>
  <gml:radius uom="urn:ogc:def:uom:EPSG::9001">
    850.24
  </gml:radius>
</gs:Circle>
```

7.2.5 Ellipse

An elliptical area describes an ellipse in two dimensional space. The ellipse is described by a center point, the length of its semi-major and semi-minor axes, and the orientation of the semi-major axis.

Like the circular area (**Circle**), the ellipse shall be specified using a two dimensional CRS.

```
<gs:Ellipse srsName="urn:ogc:def:crs:EPSG::4326"
  xmlns:gs="http://www.opengis.net/pidflo/1.0"
  xmlns:gml="http://www.opengis.net/gml">
  <gml:pos>
    42.5463 -73.2512
  </gml:pos>
  <gs:semiMajorAxis uom="urn:ogc:def:uom:EPSG::9001">
    1275
  </gs:semiMajorAxis>
  <gs:semiMinorAxis uom="urn:ogc:def:uom:EPSG::9001">
    670
  </gs:semiMinorAxis>
  <gs:orientation uom="urn:ogc:def:uom:EPSG::9102">
```

```

    43.2
  </gs:orientation>
</gs:Ellipse>

```

The `gml:pos` element indicates the position of the center, or origin, of the ellipse.

The `gs:semiMajorAxis` and `gs:semiMinorAxis` elements are the length of the semi-major and semi-minor axes respectively.

The `gs:orientation` element is the angle by which the semi-major axis is rotated from the first axis of the CRS towards the second axis. For WGS 84, the orientation indicates rotation from Northing to Easting, which, if specified in degrees, is roughly equivalent to a compass bearing (if magnetic north were the same as the WGS North Pole).

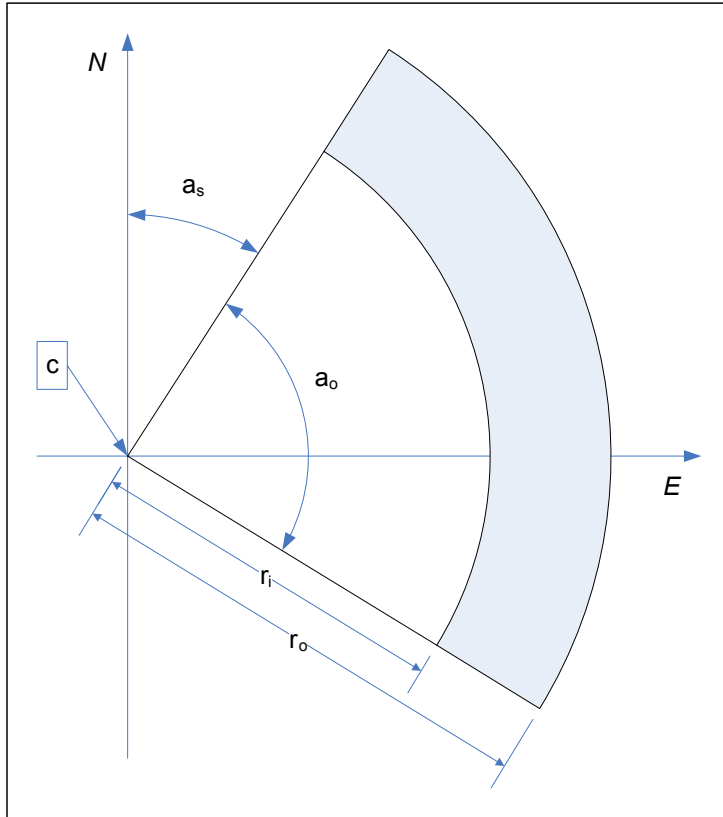
Note: An ellipse with equal major and minor axis lengths is a circle.

7.2.6 Arc Band

An arc band is a section of a circular area that is constrained to an arc between two radii. The arc band shape is most useful when radio timing technologies are used to determine location, based on a single wireless transmitter. These technologies provide a result that is a range from the transmitter, which might also be constrained in direction.

An arc band is defined by the center point of the circle, an inner and outer radius, a start angle, and an opening angle.

The following figure shows a sample arc band, with the center point c , inner radius r_i , outer radius r_o , start angle a_s , and opening angle a_o indicated.



The center point, `gml:pos`, shall be specified in a two dimensional CRS.

The inner radius, `gs:innerRadius`, defines the minimum distance from the center point. The outer radius, `gs:outerRadius`, defines the maximum distance from the center point.

The start angle, `gs:startAngle`, and opening angles, `gs:openingAngle`, define where the arc begins and ends. The arc covers an arc the size of the opening (or included) angle that begins at the start (or offset) angle. Angles are measured clockwise from North (Northing to Easting).

The following example includes an arc band shape. This arc band starts at 266 degrees and has a 120 degree opening; therefore, the end of the band is at a 26 degree bearing.

```
<gs:ArcBand srsName="urn:ogc:def:crs:EPSG::4326"
  xmlns:gs="http://www.opengis.net/pidflo/1.0"
  xmlns:gml="http://www.opengis.net/gml">
  <gml:pos>
    42.5463 -73.2512
  </gml:pos>
  <gs:innerRadius uom="urn:ogc:def:uom:EPSG::9001">
    1661.55
  </gs:innerRadius>
  <gs:outerRadius uom="urn:ogc:def:uom:EPSG::9001">
    2215.4
```

```

</gs:outerRadius>
<gs:startAngle uom="urn:ogc:def:uom:EPSG::9102">
  266
</gs:startAngle>
<gs:openingAngle uom="urn:ogc:def:uom:EPSG::9102">
  120
</gs:openingAngle>
</gs:ArcBand>

```

Note: An arc band with an inner radius of zero, and equal start and opening angles is a circle.

7.2.7 Sphere

The sphere is a volume that provides the same information as a circle in three dimensions. The sphere shall be specified using a three dimensional CRS.

The following example shows a sphere shape, which is identical to the circle example, except for the addition of an altitude in the provided coordinates.

```

<gs:Sphere srsName="urn:ogc:def:crs:EPSG::4979"
  xmlns:gs="http://www.opengis.net/pidflo/1.0"
  xmlns:gml="http://www.opengis.net/gml">
  <gml:pos>
    42.5463 -73.2512 26.3
  </gml:pos>
  <gs:radius uom="urn:ogc:def:uom:EPSG::9001">
    850.24
  </gs:radius>
</gs:Sphere>

```

7.2.8 Ellipsoid

The ellipsoid is a volume that is based on the ellipse shape, with the addition of a third dimension. A single value, vertical uncertainty, is added to the ellipse to form an ellipsoid.

A full specification of an ellipsoid would include three angles in order to be able to orient the ellipsoid in three dimensions. This representation is limited to a single orientation angle, which is the same value that is used for the ellipse. This limits the major and minor axes of the base ellipse to a plane that is parallel to the surface of the WGS 84 ellipsoid at the given latitude and longitude. Implementations may also choose to place these axes on the surface of the WGS 84 ellipsoid. The difference between these two interpretations is not considered significant.

The third length measurement, `gs:vertical`, indicates the length of the third axis of the ellipsoid, which is a line that is always perpendicular to the surface of the WGS 84 ellipsoid, that is, it is vertical.

This ellipsoid representation is similar to that described in 3GPP TS 23.032.

The following example shows an ellipsoid.

```

<gs:Ellipsoid srsName="urn:ogc:def:crs:EPSG::4979"
  xmlns:gs="http://www.opengis.net/pidflo/1.0"
  xmlns:gml="http://www.opengis.net/gml">
  <gml:pos>
    42.5463 -73.2512 26.3
  </gml:pos>
  <gs:semiMajorAxis uom="urn:ogc:def:uom:EPSG::9001">
    7.7156
  </gs:semiMajorAxis>
  <gs:semiMinorAxis uom="urn:ogc:def:uom:EPSG::9001">
    3.31
  </gs:semiMinorAxis>
  <gs:verticalAxis uom="urn:ogc:def:uom:EPSG::9001">
    28.7
  </gs:verticalAxis>
  <gs:orientation uom="urn:ogc:def:uom:EPSG::9102">
    142
  </gs:orientation>
</gs:Ellipsoid>

```

Note: An ellipsoid with equal major, minor and vertical axis lengths is a sphere.

7.2.9 Prism

The prism is a volume that is commonly used to represent a shape that has a constant cross section along one axis. For the purposes of PIDF-LO, a prism is most useful when representing a building, or single floor of a building.

A prism is defined by its base, which is a two dimensional surface specified using a three dimensional CRS, and a height. The height is a scalar value that is projected in the direction of the upward normal of the base surface, see Section 7.2.3 (Polygon Upward Normal).

It is strongly recommended that the base shape for a prism is level, that is, it exists at the same altitude for all points. Implementations may reject prisms that have a base that is not at the same altitude.

The following hexagonal prism might be used to represent a floor of a building in geodetic form.

```

<gs:Prism srsName="urn:ogc:def:crs:EPSG::4979"
  xmlns:gs="http://www.opengis.net/pidflo/1.0"
  xmlns:gml="http://www.opengis.net/gml">
  <gs:base>
    <gml:Polygon>
      <gml:exterior>
        <gml:LinearRing>
          <gml:posList>
            42.556844 -73.248157 36.6
            42.549631 -73.237283 36.6
            42.539087 -73.240328 36.6
            42.535756 -73.254242 36.6
            42.542969 -73.265115 36.6
            42.553513 -73.262075 36.6
          </gml:posList>
        </gml:LinearRing>
      </gml:exterior>
    </gml:Polygon>
  </gs:base>
</gs:Prism>

```

```

        42.556844 -73.248157 36.6
    </gml:posList>
</gml:LinearRing>
</gml:exterior>
</gml:Polygon>
</gs:base>
<gs:height uom="urn:ogc:def:uom:EPSG::9001">
    2.4
</gs:height>
</gs:Prism>

```

The Circle and Ellipse shapes do not have a defined upward normal, so they cannot be used as the base of a Prism.

7.3 Application Schema

```

<?xml version="1.0"?>
<xs:schema
  targetNamespace="http://www.opengis.net/pidflo/1.0"
  xmlns:gs="http://www.opengis.net/pidflo/1.0"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml"
  elementFormDefault="qualified"
  attributeFormDefault="unqualified">

  <xs:annotation>
    <xs:appinfo
      source="urn:ietf:params:xml:schema:pidf:geopriv10:geoShape">
      Geodetic Shapes for PIDF-LO
    </xs:appinfo>
    <xs:documentation
      source="http://www.opengeospatial.org/ ">
      This document defines geodetic shape types for
      PIDF-LO.
    </xs:documentation>
  </xs:annotation>

  <xs:import namespace="http://www.opengis.net/gml"
    schemaLocation="geometryPrimitives.xsd"/>

  <xs:element name="Circle" type="gs:CircleType"
    substitutionGroup="gml:_Surface"/>
  <xs:complexType name="CircleType">
    <xs:complexContent>
      <xs:extension base="gml:AbstractSurfaceType">
        <xs:sequence>
          <xs:group ref="gs:centerGroup"/>
          <xs:element name="radius"
            type="gml:LengthType"/>
        </xs:sequence>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>

```



```

<xs:element name="Ellipse" type="gs:EllipseType"
    substitutionGroup="gml:_Surface"/>
<xs:complexType name="EllipseType">
    <xs:complexContent>
        <xs:extension base="gml:AbstractSurfaceType">
            <xs:sequence>
                <xs:group ref="gs:centerGroup"/>
                <xs:element name="semiMajorAxis"
type="gml:LengthType"/>
                <xs:element name="semiMinorAxis"
type="gml:LengthType"/>
                <xs:element name="orientation"
type="gml:AngleType"/>
            </xs:sequence>
        </xs:extension>
    </xs:complexContent>
</xs:complexType>

<xs:element name="ArcBand" type="gs:ArcBandType"
    substitutionGroup="gml:_Surface"/>
<xs:complexType name="ArcBandType">
    <xs:complexContent>
        <xs:extension base="gml:AbstractSurfaceType">
            <xs:sequence>
                <xs:group ref="gs:centerGroup"/>
                <xs:element name="innerRadius"
type="gml:LengthType"/>
                <xs:element name="outerRadius"
type="gml:LengthType"/>
                <xs:element name="startAngle"
type="gml:AngleType"/>
                <xs:element name="openingAngle"
type="gml:AngleType"/>
            </xs:sequence>
        </xs:extension>
    </xs:complexContent>
</xs:complexType>

<xs:element name="Prism" type="gs:PrismType"
    substitutionGroup="gml:_Solid"/>
<xs:complexType name="PrismType">
    <xs:complexContent>
        <xs:extension base="gml:AbstractSolidType">
            <xs:sequence>
                <xs:element name="base"
type="gml:SurfacePropertyType"/>
                <xs:element name="height"
type="gml:LengthType"/>
            </xs:sequence>
        </xs:extension>
    </xs:complexContent>
</xs:complexType>

<xs:element name="Sphere" type="gs:SphereType"
    substitutionGroup="gml:_Solid"/>
<xs:complexType name="SphereType">
    <xs:complexContent>
        <xs:extension base="gml:AbstractSolidType">

```

```

        <xs:sequence>
          <xs:group ref="gs:centerGroup"/>
          <xs:element name="radius"
type="gml:LengthType"/>
        </xs:sequence>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>

  <xs:element name="Ellipsoid" type="gs:EllipsoidType"
    substitutionGroup="gml:_Solid"/>
  <xs:complexType name="EllipsoidType">
    <xs:complexContent>
      <xs:extension base="gml:AbstractSolidType">
        <xs:sequence>
          <xs:group ref="gs:centerGroup"/>
          <xs:element name="semiMajorAxis"
type="gml:LengthType"/>
          <xs:element name="semiMinorAxis"
type="gml:LengthType"/>
          <xs:element name="verticalAxis"
type="gml:LengthType"/>
          <xs:element name="orientation"
type="gml:AngleType"/>
        </xs:sequence>
      </xs:extension>
    </xs:complexContent>
  </xs:complexType>

  <xs:group name="centerGroup">
    <xs:choice>
      <xs:element ref="gml:pos"/>
      <xs:element ref="gml:pointProperty"/>
    </xs:choice>
  </xs:group>

</xs:schema>

```

7.4 GML Schema Profile

This section defines a profile of GML that follows the recommendations in Section 22 of GML-3.1.1. The *copy and delete* method has been employed to generate this schema. The profile includes abridged versions of the files:

```

geometryPrimitives.xsd, geometryBasic2d.xsd,
geometryBasic0d1d.xsd, measures.xsd, gmlBase.xsd, and
basicTypes.xsd.

```

Note that `units.xsd` and `dictionary.xsd` are excluded from this profile.

For the purposes of brevity, all comments and annotations from the original GML schema have been removed. Schematron validation has also been removed.

7.4.1 geometryPrimitives.xsd

The following file is the profile version of geometryPrimitives.xsd.

```

<?xml version="1.0"?>
<schema xmlns="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml"
  targetNamespace="http://www.opengis.net/gml"
  version="3.1.1" elementFormDefault="qualified">

  <include schemaLocation="geometryBasic2d.xsd"/>

  <element name="Curve" type="gml:CurveType"
    substitutionGroup="gml:_Curve"/>
  <complexType name="CurveType">
    <complexContent>
      <extension base="gml:AbstractCurveType">
        <sequence>
          <element ref="gml:segments"/>
        </sequence>
      </extension>
    </complexContent>
  </complexType>

  <element name="_CurveSegment"
    type="gml:AbstractCurveSegmentType"
    abstract="true"/>
  <complexType name="AbstractCurveSegmentType"
    abstract="true">
    <sequence/>
    <attribute name="numDerivativesAtStart"
      type="integer"
      use="optional" default="0"/>
    <attribute name="numDerivativesAtEnd" type="integer"
      use="optional" default="0"/>
    <attribute name="numDerivativeInterior"
      type="integer"
      use="optional" default="0"/>
  </complexType>

  <element name="segments"
    type="gml:CurveSegmentArrayPropertyType"/>
  <complexType name="CurveSegmentArrayPropertyType">
    <sequence>
      <element ref="gml:_CurveSegment"
        minOccurs="0" maxOccurs="unbounded"/>
    </sequence>
  </complexType>

  <element name="LineStringSegment"
    type="gml:LineStringSegmentType"
    substitutionGroup="gml:_CurveSegment"/>
  <complexType name="LineStringSegmentType">
    <complexContent>
      <extension base="gml:AbstractCurveSegmentType">
        <sequence>
          <choice>

```

```

        <choice minOccurs="2" maxOccurs="unbounded">
            <element ref="gml:pos"/>
            <element ref="gml:pointProperty"/>
        </choice>
        <element ref="gml:posList"/>
    </choice>
</sequence>
<attribute name="interpolation"
            type="gml:CurveInterpolationType"
fixed="linear"/>
</extension>
</complexContent>
</complexType>

<element name="ArcByCenterPoint"
type="gml:ArcByCenterPointType"
    substitutionGroup="gml:_CurveSegment"/>
<complexType name="ArcByCenterPointType">
    <complexContent>
        <extension base="gml:AbstractCurveSegmentType">
            <sequence>
                <choice>
                    <element ref="gml:pos"/>
                    <element ref="gml:pointProperty"/>
                </choice>
                <element name="radius" type="gml:LengthType"/>
                <element name="startAngle" type="gml:AngleType"
                    minOccurs="0"/>
                <element name="endAngle" type="gml:AngleType"
                    minOccurs="0"/>
            </sequence>
            <attribute name="interpolation"
                type="gml:CurveInterpolationType"
fixed="circularArcCenterPointWithRadius"/>
            <attribute name="numArc" type="integer"
                use="required" fixed="1"/>
        </extension>
    </complexContent>
</complexType>

<element name="CircleByCenterPoint"
    type="gml:CircleByCenterPointType"
    substitutionGroup="gml:ArcByCenterPoint"/>
<complexType name="CircleByCenterPointType">
    <complexContent>
        <extension base="gml:ArcByCenterPointType"/>
    </complexContent>
</complexType>

<element name="Surface" type="gml:SurfaceType"
    substitutionGroup="gml:_Surface"/>
<complexType name="SurfaceType">
    <complexContent>
        <extension base="gml:AbstractSurfaceType">
            <sequence>
                <element ref="gml:patches"/>
            </sequence>

```

```

        </extension>
    </complexContent>
</complexType>

    <element name="_SurfacePatch"
type="gml:AbstractSurfacePatchType"
    abstract="true"/>
    <complexType name="AbstractSurfacePatchType"
abstract="true">
        <sequence/>
    </complexType>

    <element name="patches"
type="gml:SurfacePatchArrayPropertyType"/>
    <complexType name="SurfacePatchArrayPropertyType">
        <sequence minOccurs="0" maxOccurs="unbounded">
            <element ref="gml:_SurfacePatch"/>
        </sequence>
    </complexType>

    <element name="PolygonPatch"
type="gml:PolygonPatchType"
        substitutionGroup="gml:_SurfacePatch"/>
    <complexType name="PolygonPatchType">
        <complexContent>
            <extension base="gml:AbstractSurfacePatchType">
                <sequence>
                    <element ref="gml:exterior" minOccurs="0"/>
                </sequence>
                <attribute name="interpolation"
                    type="gml:SurfaceInterpolationType"
                    fixed="planar"/>
            </extension>
        </complexContent>
    </complexType>

    <element name="Rectangle" type="gml:RectangleType"
        substitutionGroup="gml:_SurfacePatch"/>
    <complexType name="RectangleType">
        <complexContent>
            <extension base="gml:AbstractSurfacePatchType">
                <sequence>
                    <element ref="gml:exterior"/>
                </sequence>
                <attribute name="interpolation"
                    type="gml:SurfaceInterpolationType"
                    fixed="planar"/>
            </extension>
        </complexContent>
    </complexType>

    <element name="PolyhedralSurface"
type="gml:PolyhedralSurfaceType"
        substitutionGroup="gml:Surface"/>
    <complexType name="PolyhedralSurfaceType">
        <complexContent>
            <restriction base="gml:SurfaceType">
                <sequence>

```

```

        <element ref="gml:PolygonPatches"/>
    </sequence>
</restriction>
</complexContent>
</complexType>

<element name="PolygonPatches"
    type="gml:PolygonPatchArrayPropertyType"
    substitutionGroup="gml:patches"/>
<complexType name="PolygonPatchArrayPropertyType">
    <complexContent>
        <restriction
base="gml:SurfacePatchArrayPropertyType">
            <sequence minOccurs="0" maxOccurs="unbounded">
                <element ref="gml:PolygonPatch"/>
            </sequence>
        </restriction>
    </complexContent>
</complexType>

<element name="_Solid" type="gml:AbstractSolidType"
abstract="true"
    substitutionGroup="gml:_GeometricPrimitive"/>
<complexType name="AbstractSolidType">
    <complexContent>
        <extension
base="gml:AbstractGeometricPrimitiveType"/>
    </complexContent>
</complexType>

<element name="Solid" type="gml:SolidType"
    substitutionGroup="gml:_Solid"/>
<complexType name="SolidType">
    <complexContent>
        <extension base="gml:AbstractSolidType">
            <sequence>
                <element name="exterior"
type="gml:SurfacePropertyType"
                    minOccurs="0"/>
            </sequence>
        </extension>
    </complexContent>
</complexType>

<simpleType name="CurveInterpolationType">
    <restriction base="string">
        <enumeration value="linear"/>
        <enumeration value="geodesic"/>
        <enumeration value="circularArc3Points"/>
        <enumeration
value="circularArcCenterPointWithRadius"/>
    </restriction>
</simpleType>

<simpleType name="SurfaceInterpolationType">
    <restriction base="string">
        <enumeration value="planar"/>
    </restriction>
</simpleType>

```

```

    </simpleType>
</schema>

```

7.4.2 geometryBasic2d.xsd

The following file is the profile version of geometryBasic2d.xsd.

```

<?xml version="1.0"?>
<schema xmlns="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml"
  targetNamespace="http://www.opengis.net/gml"
  version="3.1.1" elementFormDefault="qualified">

  <include schemaLocation="geometryBasic0d1d.xsd"/>

  <element name="_Surface" type="gml:AbstractSurfaceType"
    abstract="true"
    substitutionGroup="gml:_GeometricPrimitive"/>
  <complexType name="AbstractSurfaceType">
    <complexContent>
      <extension
base="gml:AbstractGeometricPrimitiveType"/>
    </complexContent>
  </complexType>

  <element name="surfaceProperty"
type="gml:SurfacePropertyType"/>
  <complexType name="SurfacePropertyType">
    <sequence>
      <element ref="gml:_Surface"/>
    </sequence>
  </complexType>

  <element name="Polygon" type="gml:PolygonType"
    substitutionGroup="gml:_Surface"/>
  <complexType name="PolygonType">
    <complexContent>
      <extension base="gml:AbstractSurfaceType">
        <sequence>
          <element ref="gml:exterior" minOccurs="0"/>
        </sequence>
      </extension>
    </complexContent>
  </complexType>

  <element name="_Ring" type="gml:AbstractRingType"
abstract="true"
    substitutionGroup="gml:_Geometry"/>
  <complexType name="AbstractRingType" abstract="true">
    <complexContent>
      <extension base="gml:AbstractGeometryType"/>
    </complexContent>
  </complexType>

```

```

    <element name="exterior"
type="gml:AbstractRingPropertyType"/>
  <complexType name="AbstractRingPropertyType">
    <sequence>
      <element ref="gml:_Ring"/>
    </sequence>
  </complexType>

  <element name="LinearRing" type="gml:LinearRingType"
    substitutionGroup="gml:_Ring"/>
  <complexType name="LinearRingType">
    <complexContent>
      <extension base="gml:AbstractRingType">
        <sequence>
          <choice>
            <choice minOccurs="4" maxOccurs="unbounded">
              <element ref="gml:pos"/>
              <element ref="gml:pointProperty"/>
            </choice>
            <element ref="gml:posList"/>
          </choice>
        </sequence>
      </extension>
    </complexContent>
  </complexType>

</schema>

```

7.4.3 geometryBasic0d1d.xsd

The following file is the profile version of geometryBasic0d1d.xsd.

```

<?xml version="1.0"?>
<schema xmlns="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml"
  targetNamespace="http://www.opengis.net/gml"
  version="3.1.1" elementFormDefault="qualified">

  <include schemaLocation="measures.xsd"/>

  <element name="_Geometry"
type="gml:AbstractGeometryType"
  abstract="true" substitutionGroup="gml:_GML"/>
  <complexType name="GeometryPropertyType">
    <sequence>
      <element ref="gml:_Geometry"/>
    </sequence>
  </complexType>

  <complexType name="GeometryArrayPropertyType">
    <sequence>
      <element ref="gml:_Geometry"
        minOccurs="0" maxOccurs="unbounded"/>
    </sequence>
  </complexType>

```



```

    <complexType name="AbstractGeometryType"
    abstract="true">
      <complexContent>
        <extension base="gml:AbstractGMLType">
          <attribute name="gid" type="string"
    use="optional"/>
        </extension>
      </complexContent>
    </complexType>

    <attributeGroup name="SRSReferenceGroup">
      <attribute name="srsName" type="anyURI"
    use="optional"/>
      <attribute name="srsDimension" type="positiveInteger"
    use="optional"/>
      <attributeGroup ref="gml:SRSInformationGroup"/>
    </attributeGroup>

    <attributeGroup name="SRSInformationGroup">
      <attribute name="axisLabels" type="gml:NCNameList"
    use="optional"/>
      <attribute name="uomLabels" type="gml:NCNameList"
    use="optional"/>
    </attributeGroup>

    <element name="_GeometricPrimitive"
    type="gml:AbstractGeometricPrimitiveType"
    abstract="true"
    substitutionGroup="gml:_Geometry"/>
    <complexType name="AbstractGeometricPrimitiveType"
    abstract="true">
      <complexContent>
        <extension base="gml:AbstractGeometryType"/>
      </complexContent>
    </complexType>

    <element name="Point" type="gml:PointType"
    substitutionGroup="gml:_GeometricPrimitive"/>
    <complexType name="PointType">
      <complexContent>
        <extension
    base="gml:AbstractGeometricPrimitiveType">
          <sequence>
            <element ref="gml:pos"/>
          </sequence>
        </extension>
      </complexContent>
    </complexType>

    <element name="pointProperty"
    type="gml:PointPropertyType"/>
    <complexType name="PointPropertyType">
      <sequence>
        <element ref="gml:Point"/>
      </sequence>

```

```

</complexType>

  <element name="_Curve" type="gml:AbstractCurveType"
abstract="true"
      substitutionGroup="gml:_GeometricPrimitive"/>
  <complexType name="AbstractCurveType" abstract="true">
    <complexContent>
      <extension
base="gml:AbstractGeometricPrimitiveType"/>
    </complexContent>
  </complexType>

  <element name="curveProperty"
type="gml:CurvePropertyType"/>
  <complexType name="CurvePropertyType">
    <sequence>
      <element ref="gml:_Curve"/>
    </sequence>
  </complexType>

  <element name="LineString" type="gml:LineStringType"
      substitutionGroup="gml:_Curve"/>
  <complexType name="LineStringType">
    <complexContent>
      <extension base="gml:AbstractCurveType">
        <sequence>
          <choice>
            <choice minOccurs="2" maxOccurs="unbounded">
              <element ref="gml:pos"/>
              <element ref="gml:pointProperty"/>
            </choice>
            <element ref="gml:posList"/>
          </choice>
        </sequence>
      </extension>
    </complexContent>
  </complexType>

  <element name="pos" type="gml:DirectPositionType"/>
  <complexType name="DirectPositionType">
    <simpleContent>
      <extension base="gml:doubleList"/>
    </simpleContent>
  </complexType>

  <element name="posList"
type="gml:DirectPositionListType"/>
  <complexType name="DirectPositionListType">
    <simpleContent>
      <extension base="gml:doubleList">
        <attribute name="count" type="positiveInteger"
use="optional"/>
      </extension>
    </simpleContent>
  </complexType>

  <element name="Envelope" type="gml:EnvelopeType"/>

```

```

    <complexType name="EnvelopeType">
      <choice>
        <sequence>
          <element name="lowerCorner"
type="gml:DirectPositionType"/>
          <element name="upperCorner"
type="gml:DirectPositionType"/>
        </sequence>
        <element ref="gml:pos" minOccurs="2"
maxOccurs="2"/>
      </choice>
      <attributeGroup ref="gml:SRSReferenceGroup"/>
    </complexType>
  </schema>

```

7.4.4 measures.xsd

The following file is the profile version of measures.xsd.

```

<?xml version="1.0"?>
<schema xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:gml="http://www.opengis.net/gml"
targetNamespace="http://www.opengis.net/gml"
version="3.1.1" elementFormDefault="qualified">

  <include schemaLocation="gmlBase.xsd"/>

  <element name="measure" type="gml:MeasureType"/>
  <complexType name="LengthType">
    <simpleContent>
      <restriction base="gml:MeasureType"/>
    </simpleContent>
  </complexType>

  <element name="angle" type="gml:MeasureType"/>
  <complexType name="AngleType">
    <simpleContent>
      <restriction base="gml:MeasureType"/>
    </simpleContent>
  </complexType>

</schema>

```

7.4.5 gmlBase.xsd

The following file is the profile version of gmlBase.xsd.

```

<?xml version="1.0"?>
<schema xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:gml="http://www.opengis.net/gml"
targetNamespace="http://www.opengis.net/gml"
version="3.1.1" elementFormDefault="qualified">

  <include schemaLocation="basicTypes.xsd"/>

```

```

    <element name="_Object" abstract="true"/>

    <element name="_GML" type="gml:AbstractGMLType"
abstract="true"
      substitutionGroup="gml:_Object"/>
    <complexType name="AbstractGMLType" abstract="true">
      <attribute ref="gml:id" use="optional"/>
    </complexType>

    <attribute name="id" type="ID"/>
  </schema>

```

7.4.6 basicTypes.xsd

The following file is the profile version of basicTypes.xsd.

```

<?xml version="1.0"?>
<schema xmlns="http://www.w3.org/2001/XMLSchema"
  xmlns:gml="http://www.opengis.net/gml"
  targetNamespace="http://www.opengis.net/gml"
  version="3.1.1" elementFormDefault="qualified">

  <simpleType name="SignType">
    <restriction base="string">
      <enumeration value="-"/>
      <enumeration value="+"/>
    </restriction>
  </simpleType>

  <simpleType name="booleanList">
    <list itemType="boolean"/>
  </simpleType>

  <simpleType name="NameList">
    <list itemType="Name"/>
  </simpleType>

  <simpleType name="doubleList">
    <list itemType="double"/>
  </simpleType>

  <simpleType name="integerList">
    <list itemType="integer"/>
  </simpleType>

  <complexType name="MeasureType">
    <simpleContent>
      <extension base="double">
        <attribute name="uom" type="anyURI"
use="required"/>
      </extension>
    </simpleContent>
  </complexType>

  <simpleType name="NCNameList">
    <list itemType="NCName"/>
  </simpleType>

```

```
</simpleType>  
</schema>
```

Annex A
(normative)

Abstract test suite

None.

Annex B (informative)

For a polygon that is guaranteed to be convex and coplanar, the upward normal can be found by finding the vector cross product of adjacent edges.

For more general cases the Newell method of approximation described in (Sunday, D., “Fast polygon area and Newell normal computation,” 2002.) may be applied. In particular, this method can be used if the points are only approximately coplanar, and for non-convex polygons.

This method can be condensed to the following set of equations:

$$U_x = \sum_1^n y_i (z_{i+1} - z_{i-1})$$

$$U_y = \sum_1^n z_i (x_{i+1} - x_{i-1})$$

$$U_z = \sum_1^n x_i (y_{i+1} - y_{i-1})$$

For these formulae, the polygon is made of points (x_1, y_1, z_1) through (x_n, y_n, z_n) . Each array is treated as circular, that is, $x_0 = x_n$ and $x_{n+1} = x_1$.

Note: This method assumes a cartesian coordinate system, this should not be applied to coordinates specified in the WGS 84 (latitude, longitude, altitude) CRS. Coordinates specified in a geographic CRS are transformed to a cartesian, geocentric CRS (such as EPSG 4978) before this method is applied, see (European Petroleum Survey Group, “Coordinate Conversions and Transforms including Formulas,” August 2006 - <http://www.epsg.org/guides/docs/G7-2.pdf>) and (WGS 84) for details.