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YANG Geo Location

Abstract

This document defines a generic geographical location object YANG grouping. The geographical location grouping is intended to be used in YANG models for specifying a location on or in reference to the Earth or any other astronomical object.

Status of This Memo

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1. Introduction

In many applications we would like to specify the location of something geographically. Some examples of locations in networking might be the location of data center, a rack in an internet exchange point, a router, a firewall, a port on some device, or it could be the endpoints of a fiber, or perhaps the failure point along a fiber.

Additionally, while this location is typically relative to The Earth, it does not need to be. Indeed it is easy to imagine a network or device located on The Moon, on Mars, on Enceladus (the moon of Saturn) or even a comet (e.g., 67p/churyumov-gerasimenko).

Finally, one can imagine defining locations using different frames of reference or even alternate systems (e.g., simulations or virtual realities).

This document defines a geo-location YANG grouping that allows for all of the above data to be captured.

This specification conforms to [ISO.6709.2008].

The YANG data model described in this document conforms to the Network Management Datastore Architecture defined in [RFC8342].

1.1. Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

2. The Geo Location Object

2.1. Frame of Reference

The frame of reference (reference-frame) defines what the location values refer to and their meaning. The referred to object can be any astronomical body. It could be a planet such as The Earth or Mars, a moon such as Enceladus, an asteroid such as Ceres, or even a comet such as 1P/Halley. This value is specified in astronomical-body and is defined by the International Astronomical Union (http://www.iau.org), The default astronomical-body value is earth.

In addition to identifying the astronomical body we also need to define the meaning of the coordinates (e.g., latitude and longitude) and the definition of 0-height. This is done with a geodetic-datum value. The default value for geodetic-datum is wgs-84 (i.e., the

World Geodetic System, [WGS84]), which is used by the Global Positioning System (GPS) among many others. We define an IANA registry for specifying standard values for the geodetic-datum.

In addition to the geodetic-datum value we allow refining the coordinate and height accuracy using coord-accuracy and height-accuracy respectively. When specified these values override the defaults implied by the geodetic-datum value.

Finally, we define an optional feature which allows for changing the system for which the above values are defined. This optional feature adds an alternate-system value to the reference frame. This value is normally not present which implies the natural universe is the system. The use of this value is intended to allow for creating virtual realities or perhaps alternate coordinate systems. The definition of alternate systems is outside the scope of this document.

2.2. Location

This is the location on or relative to the astronomical object. It is specified using 2 or 3 coordinates values. These values are given either as latitude, longitude, and an optional height, or as Cartesian coordinates of x, y and z. For the standard location choice latitude and longitude are specified as fractions of decimal degrees, and the height value is in fractions of meters. For the Cartesian choice x, y and z are in fractions of meters. In both choices the exact meanings of all of the values are defined by the geodetic-datum value in the Section 2.1.

2.3. Motion

Support is added for objects in relatively stable motion. For objects in relatively stable motion the grouping provides a 3-dimensional vector value. The components of the vector are v-north, v-east and v-up which are all given in fractional meters per second. The values v-north and v-east are relative to true-north as defined by the reference frame for the astronomical body, v-up is perpendicular to the plane defined by v-north and v-east, and is pointed away from the center of mass.

To derive the 2-dimensional heading and speed one would use the following formulas:

```
           ,------------------------------
speed =  V  v_{north}^{2} + v_{east}^{2}

heading = arctan(v_{east} / v_{north})
```

For some applications that demand high accuracy, and where the data is infrequently updated this velocity vector can track very slow movement such as continental drift.

Tracking more complex forms of motion is outside the scope of this work. The intent of the grouping being defined here is to identify where something is located, and generally this is expected to be somewhere on or relative to the Earth (or another astronomical body). At least two options are available to YANG models that wish to use this grouping with objects that are changing location frequently in non-simple ways, they can add additional motion data to their model directly, or if the application allows it can require more frequent queries to keep the location data current.

2.4. Nested Locations

When locations are nested (e.g., a building may have a location which houses routers that also have locations) the module using this grouping is free to indicate in its definition that the reference-frame is inherited from the containing object so that the reference-frame need not be repeated in every instance of location data.

2.5. Non-location Attributes

During the development of this module, the question of whether it would support data such as orientation arose. These types of attributes are outside the scope of this grouping because they do not deal with a location but rather describe something more about the object that is at the location. Module authors are free to add these non-location attributes along with their use of this location grouping.

2.6. Tree

The following is the YANG tree diagram [RFC8340] for the geo-location grouping.

```
module: ietf-geo-location
  grouping geo-location
    +-- geo-location
       +-- reference-frame
       |  +-- alternate-system?    string {alternate-systems}?
       |  +-- astronomical-body?   string
       |  +-- geodetic-system
       |     +-- geodetic-datum?    string
       |     +-- coord-accuracy?    decimal64
       |     +-- height-accuracy?   decimal64
       +-- (location)?
       |  +--:(ellipsoid)
       |  |  +-- latitude?    decimal64
       |  |  +-- longitude?   decimal64
       |  |  +-- height?      decimal64
       |  +--:(cartesian)
       |     +-- x?           decimal64
       |     +-- y?           decimal64
       |     +-- z?           decimal64
       +-- velocity
       |  +-- v-north?   decimal64
       |  +-- v-east?    decimal64
       |  +-- v-up?      decimal64
       +-- timestamp?         types:date-and-time
       +-- valid-until?       types:date-and-time
```

3. YANG Module

```
<CODE BEGINS> file "ietf-geo-location@2019-02-17.yang"
module ietf-geo-location {
  namespace "urn:ietf:params:xml:ns:yang:ietf-geo-location";
  prefix geo;
  import ietf-yang-types { prefix types; }

  organization
    "IETF NETMOD Working Group (NETMOD)";
  contact
    "Christian Hopps <chopps@chopps.org>";

  // RFC Ed.: replace XXXX with actual RFC number and
  // remove this note.

  description
    "This module defines a grouping of a container object for
     specifying a location on or around an astronomical object (e.g.,
     The Earth).

     Copyright (c) 2019 IETF Trust and the persons identified as
     authors of the code.  All rights reserved.

     Redistribution and use in source and binary forms, with or
     without modification, is permitted pursuant to, and subject to
     the license terms contained in, the Simplified BSD License set
     forth in Section 4.c of the IETF Trust's Legal Provisions
     Relating to IETF Documents
     (https://trustee.ietf.org/license-info).

     This version of this YANG module is part of RFC XXXX
     (https://www.rfc-editor.org/info/rfcXXXX); see the RFC itself
     for full legal notices.

     // RFC Ed.: replace XXXX with actual RFC number and
     // remove this note.

     The key words 'MUST', 'MUST NOT', 'REQUIRED', 'SHALL', 'SHALL
     NOT', 'SHOULD', 'SHOULD NOT', 'RECOMMENDED', 'NOT RECOMMENDED',
     'MAY', and 'OPTIONAL' in this document are to be interpreted as
     described in BCP 14 (RFC 2119) (RFC 8174) when, and only when,
     they appear in all capitals, as shown here.";

  revision 2019-02-17 {
    description "Initial Revision";
    reference "RFC XXXX: YANG Geo Location";
  }

  feature alternate-systems {
    description
      "This feature means the device supports specifying locations
```

```
     using alternate systems for reference frames.";
}

grouping geo-location {
 description
    "Grouping to identify a location on an astronomical object.";

  container geo-location {
    description
      "A location on an astronomical body (e.g., The Earth)
       somewhere in a universe.";

    container reference-frame {
      description
        "The Frame of Reference for the location values.";

      leaf alternate-system {
        if-feature alternate-systems;
        type string;
        description
          "The system in which the astronomical body and
           geodetic-datum is defined. Normally, this value is not
           present and the system is the natural universe; however,
           when present this value allows for specifying alternate
           systems (e.g., virtual realities). An alternate-system
           modifies the definition (but not the type) of the other
           values in the reference frame.";
      }
      leaf astronomical-body {
        type string {
          pattern '[ -@\[-\^_-~]*';
        }
        default "earth";
        description
          "An astronomical body as named by the International
           Astronomical Union (IAU) or according to the alternate
           system if specified. Examples include 'sun' (our star),
           'earth' (our planet), 'moon' (our moon), 'enceladus' (a
           moon of Saturn), 'ceres' (an asteroid),
           '67p/churyumov-gerasimenko (a comet). The value should
           be comprised of all lower case ASCII characters not
           including control characters (i.e., values 32..64, and
           91..126). Any preceding 'the' in the name should not be
           included.";
      }
      container geodetic-system {
        description
          "The geodetic system of the location data.";
        leaf geodetic-datum {
```

```
        type string {
          pattern '[ -@\[-\^_-~]*';
        }
        default "wgs-84";
        description
          "A geodetic-datum defining the meaning of latitude,
           longitude and height. The default is 'wgs-84' which is
           used by the Global Positioning System (GPS). The value
           SHOULD be comprised of all lower case ASCII characters
           not including control characters (i.e., values 32..64,
           and 91..126). The IANA registry further restricts the
           value by converting all spaces (' ') to dashes ('-')";
      }
      leaf coord-accuracy {
        type decimal64 {
          fraction-digits 6;
        }
        description
          "The accuracy of the latitude longitude pair for
           ellipsoidal coordinates, or the X, Y and Z components
           for Cartesian coordinates. When coord-accuracy is
           specified it overrides the geodetic-datum implied
           accuracy.";
      }
      leaf height-accuracy {
        type decimal64 {
          fraction-digits 6;
        }
        units "meters";
        description
          "The accuracy of height value for ellipsoidal
           coordinates, this value is not used with Cartesian
           coordinates. When specified it overrides the
           geodetic-datum implied default.";
      }
    }
  }
  choice location {
    description
      "The location data either in lat/long or Cartesian values";
    case ellipsoid {
      leaf latitude {
        type decimal64 {
          fraction-digits 16;
        }
        units "decimal degrees";
        description
          "The latitude value on the astronomical body. The
           definition and precision of this measurement is
```

```
          indicated by the reference-frame value.";
     }
     leaf longitude {
       type decimal64 {
         fraction-digits 16;
       }
       units "decimal degrees";
       description
         "The longitude value on the astronomical body. The
          definition and precision of this measurement is
          indicated by the reference-frame.";
     }
     leaf height {
       type decimal64 {
         fraction-digits 6;
       }
       units "meters";
       description
         "Height from a reference 0 value. The precision and '0'
          value is defined by the reference-frame.";
     }
   }
   case cartesian {
     leaf x {
       type decimal64 {
         fraction-digits 6;
       }
       units "meters";
       description
         "The X value as defined by the reference-frame.";
     }
     leaf y {
       type decimal64 {
         fraction-digits 6;
       }
       units "meters";
       description
         "The Y value as defined by the reference-frame.";
     }
     leaf z {
       type decimal64 {
         fraction-digits 6;
       }
       units "meters";
       description
         "The Z value as defined by the reference-frame.";
     }
   }
 }
```

```
    container velocity {
      description
        "If the object is in motion the velocity vector describes
         this motion at the the time given by the timestamp";

      leaf v-north {
        type decimal64 {
          fraction-digits 12;
        }
        units "meters per second";
        description
          "v-north is the rate of change (i.e., speed) towards
           truth north as defined by the ~geodetic-system~.";
      }

      leaf v-east {
        type decimal64 {
          fraction-digits 12;
        }
        units "meters per second";
        description
          "v-east is the rate of change (i.e., speed) perpendicular
           to truth-north as defined by the ~geodetic-system~.";
      }

      leaf v-up {
        type decimal64 {
          fraction-digits 12;
        }
        units "meters per second";
        description
          "v-up is the rate of change (i.e., speed) away from the
           center of mass.";
      }
    }
    leaf timestamp {
      type types:date-and-time;
      description "Reference time when location was recorded.";
    }
    leaf valid-until {
      type types:date-and-time;
      description
        "The timestamp for which this geo-location is valid until.
         If unspecified the geo-location has no specific expiration
         time.";
    }
  }
}
```

```
}
<CODE ENDS>
```

4. ISO 6709:2008 Conformance

[ISO.6709.2008] provides an appendix with a set of tests for conformance to the standard. The tests and results are given in the following table along with an explanation of non-applicable tests.

Test	Description	Pass Explanation
A. 1.2.1	elements reqd. for a geo. point location	CRS is always indicated
A. 1.2.2	Description of a CRS from a register	CRS register is defined
A. 1.2.3	definition of CRS	N/A - Don't define CRS
A. 1.2.4	representation of horizontal position	lat/long values conform
A. 1.2.5	representation of vertical position	height value conforms
A. 1.2.6	text string representation	N/A - No string format

Table 1: Conformance Test Results

For test A.1.2.1 the YANG geo location object either includes a CRS (reference-frame) or has a default defined ([WGS84]).

For A.1.2.3 we do not define our own CRS, and doing so is not required for conformance.

For A.1.2.6 we do not define a text string representation, which is also not required for conformance.

5. Usability

The geo-location object defined in this document and YANG module have been designed to be usable in a very broad set of applications. This includes the ability to locate things on astronomical bodies other than The Earth, and to utilize entirely different coordinate systems and realities.

Many systems make use of geo-location data, and so it's important to be able describe this data using this geo-location object defined in this document.

5.1. Portability

In order to verify portability while developing this module the following standards and standard APIs and were considered.

5.1.1. IETF URI Value

[RFC5870] defines a standard URI value for geographic location data. It includes the ability to specify the geodetic-value (it calls this crs) with the default being wgs-84 [WGS84]. For the location data it allows 2 to 3 coordinates defined by the crs value. For accuracy it has a single u parameter for specifying uncertainty. The u value is in fractions of meters and applies to all the location values. As the URI is a string, all values are specifies as strings and so are capable of as much precision as required.

URI values can be mapped to and from the YANG grouping, with the caveat that some loss of precision (in the extremes) may occur due to the YANG grouping using decimal64 values rather than strings.

5.1.2. W3C

See https://w3c.github.io/geolocation-api/#dom-geolocationposition.

W3C Defines a geo-location API in [W3CGEO]. We show a snippet of code below which defines the geo-location data for this API. This is used by many application (e.g., Google Maps API).

```
interface GeolocationPosition {
  readonly attribute GeolocationCoordinates coords;
  readonly attribute DOMTimeStamp timestamp;
};

interface GeolocationCoordinates {
  readonly attribute double latitude;
  readonly attribute double longitude;
  readonly attribute double? altitude;
  readonly attribute double accuracy;
  readonly attribute double? altitudeAccuracy;

  readonly attribute double? speed;
};
```

Figure 1: Snippet Showing Geo-Location Definition

5.1.2.1. Compare with YANG Model

Field	Type	YANG	Type
accuracy	double	coord-accuracy	dec64 fr 6

Field	Type	YANG	Type
altitude	double	height	dec64 fr 6
altitudeAccuracy	double	height-accuracy	dec64 fr 6
heading	double	v-north, v-east	dec64 fr 12
latitude	double	latitude	dec64 fr 16
longitude	double	longitude	dec64 fr 16
speed	double	v-north, v-east	dec64 fr 12
timestamp	DOMTimeStamp	timestamp	string

Table 2

accuracy (double) Accuracy of latitude and longitude values in meters.

altitude (double) Optional height in meters above the [WGS84] ellipsoid.

altitudeAccuracy (double) Optional accuracy of altitude value in meters.

heading (double) Optional Direction in decimal deg from true north increasing clock-wise.

latitude, longitude (double) Standard lat/long values in decimal degrees.

speed (double) Speed along heading in meters per second.

timestamp (DOMTimeStamp) Specifies milliseconds since the Unix EPOCH in 64 bit unsigned integer. The YANG model defines the timestamp with arbitrarily large precision by using a string which encompasses all representable values of this timestamp value.

W3C API values can be mapped to the YANG grouping, with the caveat that some loss of precision (in the extremes) may occur due to the YANG grouping using decimal64 values rather than doubles.

Conversely, only YANG values for The Earth using the default wgs-84 [WGS84] as the geodetic-datum, can be directly mapped to the W3C values, as W3C does not provide the extra features necessary to map the broader set of values supported by the YANG grouping.

5.1.3. Geography Markup Language (GML)

ISO adopted the Geography Markup Language (GML) defined by OGC 07-036 as [ISO.19136.2007]. GML defines, among many other things, a position type gml:pos which is a sequence of double values. This sequence of values represent coordinates in a given CRS. The CRS is either inherited from containing elements or directly specified as attributes srsName and optionally srsDimension on the gml:pos.

GML defines an Abstract CRS type which Concrete CRS types derive from. This allows for many types of CRS definitions. We are concerned with the Geodetic CRS type which can have either ellipsoidal or Cartesian coordinates. We believe that other non-Earth based CRS as well as virtual CRS should also be representable by the GML CRS types as well.

Thus GML gml:pos values can be mapped directly to the YANG grouping, with the caveat that some loss of precision (in the extremes) may occur due to the YANG grouping using decimal64 values rather than doubles.

Conversely, YANG grouping values can be mapped to GML as directly as the GML CRS available definitions allow with a minimum of Earth-based geodetic systems fully supported.

GML also defines an observation value in gml:Observation which includes a timestamp value gml:validTime in addition to other components such as gml:using gml:target and gml:resultOf. Only the timestamp is mappable to and from the YANG grouping. Furthermore gml:validTime can either be an Instantaneous measure (gml:TimeInstant) or a time period (gml:TimePeriod). The instantaneous gml:TimeInstant is mappable to and from the YANG grouping timestamp value, and values down to the resolution of seconds for gml:TimePeriod can be mapped using the using the valid-for node of the YANG grouping.

5.1.4. KML

KML 2.2 [KML22] (formerly Keyhole Markup Language) was submitted by Google to Open Geospatial Consortium (OGC) https://www.opengeospatial.org/ and was adopted. The latest version as of this writing is KML 2.3 [KML23]. This schema includes geographic location data in some of its objects (e.g., kml:Point or kml:Camera objects). This data is provided in string format and corresponds to the [W3CGEO] values. The timestamp value is also specified as a string as in our YANG grouping.

KML has some special handling for the height value useful for visualization software, kml:altitudeMode. These values for kml:altitudeMode include indicating the height is ignored (clampToGround), in relation to the location's ground level (relativeToGround), or in relation to the geodetic datum (absolute). The YANG grouping can directly map the ignored and absolute cases, but not the relative to ground case.

In addition to the kml:altitudeMode KML also defines two seafloor height values using kml:seaFloorAltitudeMode. One value is to ignore the height value (clampToSeaFloor) and the other is relative (relativeToSeaFloor). As with the kml:altitudeMode value, the YANG grouping supports the ignore case but not the relative case.

The KML location values use a geodetic datum defined in Annex A by the GML Coordinate Reference System (CRS) [ISO.19136.2007] with identifier LonLat84_5773. The altitude value for KML absolute height mode is measured from the vertical datum specified by [WGS84].

Thus the YANG grouping and KML values can be directly mapped in both directions (when using a supported altitude mode) with the caveat that some loss of precision (in the extremes) may occur due to the YANG grouping using decimal64 values rather than strings. For the relative height cases the application doing the transformation is expected to have the data available to transform the relative height into an absolute height which can then be expressed using the YANG grouping.

6. IANA Considerations

6.1. Geodetic System Value Registry

This registry allocates names for standard geodetic systems. Often these values are referred to using multiple names (e.g., full names or multiple acronyms values). The intent of this registry is to provide a single standard value for any given geodetic system.

The values SHOULD use an acronym when available, they MUST be converted to lower case, and spaces MUST be changed to dashes "-".

Each entry should be sufficient to define the 3 coordinate values (2 if height is not required). So for example the wgs-84 is defined as WGS-84 with the geoid updated by at least [EGM96] for height values. Specific entries for [EGM96] and [EGM08] are present if a more precise definition of the data is required.

It should be noted that [RFC5870] also creates a registry for Geodetic Systems (it calls CRS); however, this registry has a very strict modification policy. The authors of [RFC5870] have the stated goal of making CRS registration hard to avoid proliferation of CRS values. As our module defines alternate systems and has a broader (beyond earth) scope, the registry defined below is meant to be more easily modified.

The allocation policy for this registry is First Come First Served, [RFC8126] as the intent is simply to avoid duplicate values.

The initial values for this registry are as follows.

Name	Description
me	Mean Earth/Polar Axis (Moon)
mola-vik-1	MOLA Height, IAU Viking-1 PM (Mars)
wgs-84-96	World Geodetic System 1984 [WGS84] w/ EGM96
wgs-84-08	World Geodetic System 1984 [WGS84] w/ [EGM08]
wgs-84	World Geodetic System 1984 [WGS84] (EGM96 or better)

Table 3

7. Security Considerations

This document defines a common geo location grouping using the YANG data modeling language. The grouping itself has no security or privacy impact on the Internet, but the usage of the grouping in concrete YANG modules might have. The security considerations spelled out in the YANG 1.1 specification [RFC7950] apply for this document as well.

8. Normative References

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9. Informative References

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Appendix A. Examples

Below is a fictitious module that uses the geo-location grouping.

```
module example-uses-geo-location {
  namespace
    "urn:example:example-uses-geo-location";
  prefix ugeo;
  import ietf-geo-location { prefix geo; }
  organization "Empty Org";
  contact "Example Author <eauthor@example.com>";
  description "Example use of geo-location";
  revision 2019-02-02 { reference "None"; }
  container locatable-items {
    description "container of locatable items";
    list locatable-item {
      key name;
      description "A of locatable item";
      leaf name {
        type string;
        description "name of locatable item";
      }
      uses geo:geo-location;
    }
  }
}
```

Figure 2: Example YANG module using geo location.

Below is a the YANG tree for the fictitious module that uses the geo-location grouping.

```
module: example-uses-geo-location
  +--rw locatable-items
     +--rw locatable-item* [name]
        +--rw name            string
        +--rw geo-location
           +--rw reference-frame
           |  +--rw alternate-system?    string {alternate-systems}?
           |  +--rw astronomical-body?   string
           |  +--rw geodetic-system
           |     +--rw geodetic-datum?    string
           |     +--rw coord-accuracy?    decimal64
           |     +--rw height-accuracy?   decimal64
           +--rw (location)?
           |  +--:(ellipsoid)
           |  |  +--rw latitude?    decimal64
           |  |  +--rw longitude?   decimal64
           |  |  +--rw height?      decimal64
           |  +--:(cartesian)
           |     +--rw x?           decimal64
           |     +--rw y?           decimal64
           |     +--rw z?           decimal64
           +--rw velocity
           |  +--rw v-north?   decimal64
           |  +--rw v-east?    decimal64
           |  +--rw v-up?      decimal64
           +--rw timestamp?         types:date-and-time
           +--rw valid-until?       types:date-and-time
```

Below is some example YANG XML data for the fictitious module that uses the geo-location grouping.

```
<locatable-items xmlns="urn:example:example-uses-geo-location">
  <locatable-item>
    <name>Gaetana's</name>
    <geo-location>
      <latitude>40.73297</latitude>
      <longitude>-74.007696</longitude>
    </geo-location>
  </locatable-item>
  <locatable-item>
    <name>Pont des Arts</name>
    <geo-location>
      <timestamp>2012-03-31T16:00:00Z</timestamp>
      <latitude>48.8583424</latitude>
      <longitude>2.3375084</longitude>
      <height>35</height>
    </geo-location>
  </locatable-item>
  <locatable-item>
    <name>Saint Louis Cathedral</name>
    <geo-location>
      <timestamp>2013-10-12T15:00:00-06:00</timestamp>
      <latitude>29.9579735</latitude>
      <longitude>-90.0637281</longitude>
    </geo-location>
  </locatable-item>
  <locatable-item>
    <name>Apollo 11 Landing Site</name>
    <geo-location>
      <timestamp>1969-07-21T02:56:15Z</timestamp>
      <reference-frame>
        <astronomical-body>moon</astronomical-body>
        <geodetic-system>
          <geodetic-datum>me</geodetic-datum>
        </geodetic-system>
      </reference-frame>
      <latitude>0.67409</latitude>
      <longitude>23.47298</longitude>
    </geo-location>
  </locatable-item>
  <locatable-item>
    <name>Reference Frame Only</name>
    <geo-location>
      <reference-frame>
        <astronomical-body>moon</astronomical-body>
        <geodetic-system>
          <geodetic-datum>me</geodetic-datum>
        </geodetic-system>
      </reference-frame>
    </geo-location>
```

```
  &lt;/locatable-item&gt;
&lt;/locatable-items&gt;
```

Figure 3: Example XML data of geo location use.

Appendix B. Acknowledgements

We would like to thank Jim Biard and Ben Koziol for their reviews and suggested improvements. We would also like to thank Peter Lothberg for the motivation as well as help in defining a broadly useful geographic location object, and Acee Lindem and Qin Wu for their work on a geographic location object that led to this documents creation.

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