Open GIS Consortium Inc.

Date: 2003-10-16

Reference number of this OpenGIS® project document: **OGC 03-010r9**

Version: 2.1.0

Category: OpenGIS® Recommendation Paper

Editor: Arliss Whiteside

Recommended XML encoding of coordinate reference system definitions

Copyright notice

Warning

This document is not an OGC Standard. It is distributed for review and comment. It is subject to change without notice and may not be referred to as an OGC Standard.

Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Document type: OpenGIS® Publicly Available Standard
Document subtype: Recommendation Paper
Document stage: Approved new version
Document language: English

File name: 03-010r9.doc

Contents

i. Preface

This OpenGIS® Recommendation Paper specifies basic XML encoding of data defining coordinate reference systems and coordinate operations. This encoding is expected to be adapted and used by multiple OGC Implementation Specifications, by the separate specification of Application Schemas. This document is a Recommendation Paper because the specified encoding is more general than an OpenGIS Implementation Specification and more specific than the OpenGIS Abstract Specification.

NOTE 1 This document does not specify all the things needed to ensure interoperability between different implementations of software using these CRS Schemas. Some of the additional things that should be specified to ensure interoperability are listed in Clause iv: Future work. These things may be specified in a separate OGC specification, or perhaps added in a revised version of this document. The CRS WG intends to do this work as soon as practical. A draft of such a document in posted as OGC pending document 03-056.

This Recommendation Paper replaces OpenGIS Recommendation Paper 01-014r5, titled "Recommended Definition Data for Coordinate Reference Systems and Coordinate Transformations". The key changes in this revised Recommendation Paper are:

a) Use XML schemas to specify the XML encoding, instead of using XML DTDs.

b) Derive the recommended XML schemas by encoding the UML model in OGC Abstract Specification Topic 2 "Spatial referencing by coordinates".

c) Derive the XML schemas by adapting the XML encoding rules described in Subclause A.5 of the N1316 draft of ISO 19118 "Geographic information - Encoding".

NOTE 2 ISO 19118 is supplemented by XML Schema documents posted on David Skogan's web page on ISO 19118 encoding: http://www.ifi.uio.no/~davids/encoding.

d) Build upon central parts of the GML 3.0 XML schemas, using some GML 3.0 schema documents and most GML 3 encoding patterns.

NOTE 3 Many of the GML 3 schema patterns are described in Subclauses 6.3, 7.1, 7.2, 8.1 through 8.3, and 8.6 of the GML 3.00 Implementation Specification.

Many key contents of this document are also provided in the attached set of files, in the file 03-010r9a.zip. These files include the six XML Schema documents (.xsd files) specifying the recommended XML encoding of coordinate reference system (CRS) and coordinate operation definition data. These six files are named referenceSystems.xsd, coordinateReferenceSystems.xsd, datums.xsd, coordinateSystems.xsd, coordinateOperations.xsd, and dataQuality.xsd. The attached files also include:

a) Current versions of the nine XML Schema documents from GML 3.0 that are used by these CRS schemas, and are needed to validate these CRS Schemas.

b) The example XML documents and corresponding XML Schema for Annex D "Standard contents of code lists".

c) The example XML documents for Annex E "XML document examples".

d) The example Application Schemas and XML documents for Annex F "Example application schemas".

This version of this document is the accepted new version of the previously accepted OGC Recommendation Paper 03-019r7.

ii. Contributors

The persons who contributed to this document included:

Name:	Arliss Whiteside
Address:	BAE SYSTEMS Mission Solutions 10920 Technology Place San Diego, CA 92127-1874
Phone:	858-592-1608
Email:	Arliss.Whiteside@baesystems.com

Name:	Dave Case
Address:	MITRE Corporation [to be supplied]
Phone:	703-883-6417
Email:	dwc@mitre.org

Name:	John Bobbitt
Address:	Petrotechnical Open Software Corporation 10777 Westheimer, Suite 275 Houston, TX 77042
Phone:	713-267-5174
Email:	bobbitt@posc.org

Name: Milan Trninic

Address: Galdos Systems, Inc.
200 – 1155 W Pender Street
Vancouver, B.C
Canada V6E2-P4

Phone: 604-484-2764

Email: mtrninic@galdosinc.com

iii. Changes to the OpenGIS® Abstract Specification

The OpenGIS Abstract Specification Topic 2 "Spatial Referencing by Coordinates" should be changed to use the revised UML model proposed in OGC 03-009r7.

iv. Future work

Improvements of this document are needed to:

a) Modify XML schemas to reflect any further changes in UML model (see further work clause in document 03-009r7)

b) Specify how to reference items in the EPSG and other well-known data bases of CRS-related definition data (tentatively using URNs)

c) Specify standard XML encodings of some well-known operation methods, coordinate operations, CRSs, units, etc., and specify how to reference these standard XML documents (perhaps using URLs)

d) Specify how to reference items in customized repositories or catalogs of CRS definition data (perhaps used by specific OGC Implementation Specifications)

NOTE The last three items listed above are clearly needed to support interoperability, see Note 1 in Clause i..

v. Background

The Coordinate Reference Systems (CRS) Working Group (formerly the Coordinate Transformation Working Group) has been developing XML Schemas specifying XML encoding of Coordinate Reference System (CRS) and Coordinate Transformation (CT) definition data. Those schemas were previously being developed largely without directly using any UML model, and largely by converting to XML Schemas the XML DTD

specified in OGC Recommendation Paper 01-014r5: Recommended Definition Data for Coordinate Reference Systems and Coordinate Transformations.

The N1316 draft of ISO 19118 requires XML encoding of geospatial data to be developed by converting a UML model of the data to be encoded into the corresponding XML schemas. This conversion must be done in a largely mechanical fashion, using a set of UML to XML Schema conversion rules. Subclause A.5 of the N1316 specifies a draft set of UML to XML schema conversion rules, but explicitly allows variations of those rules to be used, if those variations are documented.

Some prospective users of OGC-specified XML encoding strongly desire that all such XML encoding specifications be compliant with ISO 19118. The XML schemas previously being developed by the CRS WG were not compliant with ISO 19118, partially because they did not convert a UML model to XML schemas. In particular, that draft encoding did not directly convert the UML model developed for Topic 2 of the OGC Abstract Specification.

The previously approved OGC Recommendation Paper improves the relevant XML work done earlier by the Open GIS Consortium (OGC). The OpenGIS-accepted CT Implementation Specification already specifies a XML DTD for CRSs and CTs. The now-superseded GML 1 Recommendation Paper included an informative annex that specified a XML DTD for CRSs, including some CTs. These two XML DTDs are significantly different, and both appear to be incomplete.

Foreword

This OpenGIS© Recommendation Paper replaces previous Recommendation Paper numbered 03-010r7 and titled "Recommended XML encoding of coordinate reference system definitions".

This document is heavily based on OpenGIS© Abstract Specification Topic 2: Spatial Referencing by Coordinates, which is partially based on ISO 19111. This document uses XML Schemas as specified by the W3C. This document is also partially based on ISO 19118, and on version 3.00 of the Geography Markup Language (GML) Implementation Specification.

This document contains nine annexes. Annexes A and C are normative, and all the others are informative.

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

Introduction

This document specifies a standard XML encoding for data defining Coordinate Reference Systems (CRSs) and coordinate operations, specified using XML Schemas. This CRS and coordinate operation definition data will often be transferred between client and server software that implements various standardised interfaces and data formats. This specified general definition data encoding is intended for use in multiple OGC Implementation Specifications. That is, each of these specifications is expected to use a subset and/or superset of this standard definition data, by specifying and using Application Schemas that build on these XML Schemas.

The position or location of a point can be described using coordinates. Such coordinates are unambiguous only when the coordinate reference system on which those coordinates are based is fully defined. Each position is described by a set of coordinates based on a specified coordinate reference system. Coordinates are often used in datasets in which all coordinates belong to the same coordinate reference system. This paper specifies XML encoding of data defining coordinate reference systems for point coordinates.

The same point position will usually have different coordinates in different coordinate reference systems. There are a large number of different coordinate reference systems in current use. Coordinates from different datasets will thus often have different coordinate reference systems. In order to use together positions from different coordinate reference systems, known point coordinates often must be transformed into the corresponding coordinates in a different coordinate reference system. This paper specifies XML encoding of data defining such coordinate transformations

Recommended XML encoding of coordinate reference system definitions

1 Scope

This OpenGIS© standard specifies standard XML encodings of definition data for Coordinate Reference Systems (CRSs) and coordinate operations, specified using XML Schemas. This encoding is intended for use when transferring such definition data between client and server software that uses OpenGIS standard interfaces, as specified in other documents. The expected uses of this definition data transfer include those described in Annex B (informative).

Definition data encoding is specified herein for multiple types of CRSs, including:

a) Geocentric coordinate reference systems

b) Geographic coordinate reference systems

c) Projected coordinate reference systems

d) Engineering coordinate reference systems

e) Vertical coordinate reference systems

f) Temporal coordinate reference systems

g) Image coordinate reference systems

h) Derived coordinate reference systems

i) Compound coordinate reference systems, combining two or more other coordinate reference systems

Definition data encoding is also specified herein for multiple types of coordinate operations, including:

a) Parameterized coordinate transformations and conversions

b) Concatenated coordinate transformations, combining two or more coordinate transformations

c) Pass-through coordinate transformations, using another coordinate transformation

The current scope of this encoding does not include:

a) Vertical coordinate reference systems with time units

b) Specific well-known coordinate conversions and transformations

This OpenGIS standard specifies standard XML encoding of CRS and coordinate operation definition data applicable to multiple separate OpenGIS interface Implementation Specifications. Each such Implementation Specification should specify one or more subsets and/or supersets of the definition data specified herein, each to be used for one or more purposes. That is, for each type of XML document used, the Implementation Specification should specify one or more Application Schemas that are similar to the Application Schemas required to use GML.

Those OpenGIS standard interfaces are implemented by service software that performs functions for separate client software. Those Implementation Specifications, or profiles of those Implementation Specifications, can use any Distributed Computing Platform (DCP). CRS and/or coordinate operation definition data will often be transferred encoded in XML documents. However, other encodings can be used, such as Well Known Text (WKT).

2 Conformance

Conformance with this specification shall be checked using all the relevant tests specified in Annex A (normative). The framework, concepts, and methodology for testing, and the criteria to be achieved to claim conformance, are specified in ISO 19105: Geographic information — Conformance and Testing.

3 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this specification. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this specification are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

European Petroleum Survey Group: EPSG Geodesy Parameters V 6.3, available through EPSG: http://www.epsg.org/

ISO 8601, Data elements and interchange formats - Information interchange Representation of dates and times

ISO 19105, Geographic information – Conformance and testing

ISO 19109, Geographic Information – Rules for Application Schemas

ISO 19115, Geographic information – Metadata

OGC 03-073r1, The OpenGIS Abstract Specification, Topic 2: Spatial referencing by coordinates

OGC 02-023r4, OpenGIS Geography Markup Language (GML) Implementation Specification, version 3.00

OGC 03-009r7, Revised UML model for Abstract Specification Topic 2: Spatial referencing by coordinates

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

W3C Recommendation 2 May 2001: XML Schema Part 0: Primer, http://www.w3.org/TR/2001/REC-xmlschema-0-20010502/

W3C Recommendation 2 May 2001: XML Schema Part 1: Structures, http://www.w3.org/TR/2001/REC-xmlschema-1-20010502/

W3C Recommendation 2 May 2001: XML Schema Part 2: Datatypes, http://www.w3.org/TR/2001/REC-xmlschema-2-20010502/

4 Terms and definitions

For the purposes of this specification, the definitions given in Abstract Specification Topic 2 apply. In addition, the following terms and definitions apply.

4.1
Application Schema
conceptual schema for data required by one or more applications [ISO 19101]

4.2
GML Application Schema
an XML Schema written according to the GML 3 rules for Application Schemas, which defines a vocabulary of geographic objects for a particular domain of discourse [GML 3.0]

4.3
object
an XML document element of a type derived from AbstractGMLType [GML 3.0]

4.4
profile
specified logical subset of XML Schema specified elements and types, defined to enhance interoperability and to curtail ambiguity [adapted from GML 3.0]

4.5
sequence
finite, ordered collection of related items (objects or values) that may be repeated [ISO 19107]

4.6
set
unordered collection of related items (**objects** or values) with no repetition [ISO 19107]

4.7
Uniform Resource Identifier (URI)
simple and extensible means for identifying a resource; a short string or address; classified as a name, a locator, or both [RFC 2396]

5 Conventions

5.1 Symbols (and abbreviated terms)

API	Application Program Interface
CRS	Coordinate Reference System
CT	Coordinate Transformation
DCP	Distributed Computing Platform
DTD	Document Type Definition
EPSG	European Petroleum Survey Group
GIS	Geographic Information System
GML	Geography Markup Language
IETF	Internet Engineering Task Force
ISO	International Organization for Standardization
OGC	Open GIS Consortium
UML	Unified Modeling Language
WKT	Well Known Text
XML	eXtensible Markup Language
1D	One Dimensional
2D	Two Dimensional
3D	Three Dimensional

5.2 UML Notation

The diagrams that appear in this standard are presented using the Unified Modeling Language (UML) static structure diagram. The UML notations used in this standard are described in the diagram below.

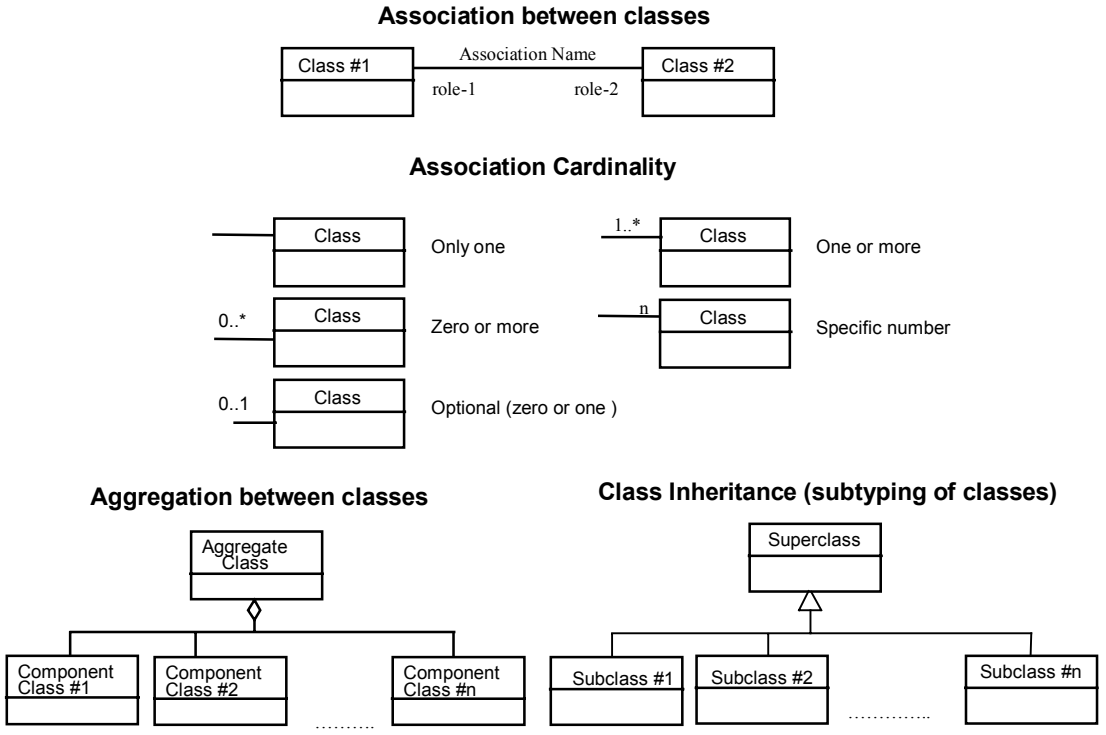


Figure 1 — UML notation

In these UML class diagrams, the class boxes with three compartments and a light background are the primary classes being shown in this diagram, often the classes from one UML package. The class boxes without compartments and with a gray background are other classes used by these primary classes, usually classes from other packages.

In this specification, the following four stereotypes of UML classes are used:

a) <<Abstract>> A polymorphic object class that cannot be instantiated.

b) <<DataType>> A descriptor of a set of values that lack identity (independent existence and the possibility of side effects). A DataType is a class with no operations whose primary purpose is to hold the information.

c) <<CodeList>> A flexible enumeration that uses string values for expressing a list of potential values.

d) <<Union>> Contains a list of attributes where only one of those attributes can be present at any time.

In this specification, the following standard data types are used:

a) String – A sequence of characters

b) Integer – An integer number

c) Double – A double precision floating point number

d) Boolean – A value specifying TRUE or FALSE

5.3 Document terms and definitions

The following specification terms and definitions are used in this document:

a) shall – verb form used to indicate a requirement to be strictly followed to conform to this specification, from which no deviation is permitted

b) should – verb form used to indicate desirable ability or use, without mentioning or excluding other possibilities

c) may – verb form used to indicate an action permissible within the limits of this specification

d) can – verb form used for statements of possibility

e) informative – a part of a document that is provided for explanation, but is not required

f) normative – a part of a standards document that is required

g) annex – an auxiliary part of a document, called an "appendix" in United States English

h) clause – a major part of a document, called a "section" or "paragraph" in United States English

i) subclause – a secondary part of a clause or annex, called a "subsection" in United States English

6 XML encoding overview

6.1 Introduction

The specified XML Schemas encode definition data for both Coordinate Reference Systems (CRSs) and Coordinate Operations (including coordinate Transformations and Conversions). This definition data includes identification and specification data, both included as needed. The definition data for a CRS includes or references definition data for a Coordinate System and a Datum, as appropriate. When applicable, definition data for a CRS includes or references definition data for a Coordinate Operation, and vice-versa.

The specified XML Schemas were prepared by converting the (revised) UML model for OGC Abstract Specification Topic 2: Spatial Referencing by Coordinates. Although most of the relevant information in that document was copied into these Schemas or into this document, Clauses 6 and 7 of Topic 2 contain some additional information applicable to these Schemas and their use.

NOTE The structure of the specified XML encoding closely follows the structure of the UML model, from which this XML encoding was converted.

6.2 Encoding structure

The specified XML encoding includes multiple alternative top level XML elements that can be used where needed. (That is, there is not a single top level element that may be the basis for all XML documents.) Most of these top level XML elements include identification information, allowing it to be referenced. The alternative top level XML elements include at least:

NOTE 1 A XML element that includes identification information is termed a "GML object" in GML 3. In some circles, an XML element with identity is termed a "module". Each valid XML document must include a single top level XML element, often but not necessarily an element with identity. That single top level XML element need not be defined in this specification.

a) All concrete XML elements in the substitution group headed by the abstract CoordinateReferenceSystem element. These elements can each be used to transfer the definition of one coordinate reference system of that type. These nine concrete XML elements are named:
    1) CompoundCRS
    2) GeocentricCRS
    3) GeographicCRS
    4) ProjectedCRS
    5) EngineeringCRS
    6) ImageCRS
    7) VerticalCRS
    8) TemporalCRS
    9) DerivedCRS
b) All concrete XML elements that are substitutable for the abstract CoordinateOperation element, namely:
    1) ConcatenatedOperation. This element should be used to encode the definition of a concatenated coordinate conversion, which combines a specified sequence of Transformations and/or Conversions.
    2) PassThroughOperation. This element should be used to encode the definition of a pass through coordinate conversion, which uses a specified Conversion or Transformation to convert a subset of the coordinates of a CompoundCRS.
    3) Transformation. This element may be used to encode the definition of an approximate coordinate transformation, from one specified source coordinate reference system to another specified target coordinate reference system.
    4) Conversion. This element may be used to encode the definition of an exact coordinate conversion, from one coordinate reference system to another coordinate reference system.

NOTE 2 The Conversion and Transformation elements should not be used for well-known coordinate operation methods with many instances, see Subclause 6.3.

The concrete XML elements that are substitutable for CoordinateReferenceSystem use multiple lower level XML elements containing data structures. These lower level elements include all five concrete elements that are substitutable for the abstract Datum XML element, named:

a) GeodeticDatum
b) VerticalDatum
c) TemporalDatum
d) EngineeringDatum
e) ImageDatum

These lower level XML elements also include all ten concrete elements that are substitutable for the abstract CoordinateSystem XML element, named:

a) EllipsoidalCS
b) VerticalCS
c) CartesianCS
d) ObliqueCartesianCS
e) LinearCS
f) PolarCS
g) SphericalCS
h) CylindricalCS
i) TemporalCS
j) UserDefinedCS

The concrete XML elements that are substitutable for the CoordinateOperation element use multiple lower level elements containing data structures, including the elements named:

a) CovarianceMatrix
b) CovarianceElement
c) OperationMethod
d) OperationParameter
e) OperationParameterGroup
f) ParameterValue
g) ParameterValueGroup

NOTE 3 The ParameterValue and ParameterValueGroup elements should not be used for well-known coordinate operation methods with many instances, see Subclause 6.3.

In addition to the concrete XML elements listed above, the Dictionary element in GML 3 is another alternative top level XML element. That Dictionary element can contain any combination of the concrete XML elements listed above, since all are substitutable for a Definition element in a Dictionary. A Dictionary element can also contain one or more UnitDefinition elements, as defined in units.xsd of GML 3. Also, any of these concrete elements or a Dictionary can be included inside a GenericMetaData element inside a metaDataProperty element, which can be included inside of many other XML elements.

6.3 Application schemas

As stated above, many of the concrete XML elements defined in these CRS Schemas can be used without Application Schemas, whenever no content extensions or restrictions are needed. An Application Schema shall be used whenever element contents extension is required, and should be used in most other cases to specify needed restrictions. That is, an Application Schema should be defined to extend and/or restrict elements as needed for a specific application, or a set of applications, to:

a) Add elements to contents of existing elements, for recording additional data about that item needed for that application.

b) Restrict the multiplicity of current contents elements, to eliminate flexibility not needed and perhaps confusing for that application.

c) Use a different element name, to be more easily understood in that specific application, primarily for elements that will be instantiated many times.

d) Specify standard contents and contents patterns for selected elements and attributes, as needed to improve interoperability.

e) Specify standard XML and other documents to be referenced or otherwise used, as needed to improve interoperability.

Application Schemas can thus be used for XML document contents extensions, restrictions, or both. Contents extension is expected to be often used to record additional data needed for applications. Contents restriction is expected to be frequently used to restrict contents, in order to increase interoperability and reduce ambiguity when greater flexibility is not needed for applications. Extensions of existing concrete elements can be defined by extending that concrete element. In many cases, restrictions of existing concrete elements can be done by extending the abstract element from which that concrete element is derived, by adding somewhat different but corresponding extensions.

An Application Schema can specify a single top level element for use in an XML document, with the XML elements and types that it uses. That single top level XML element can be an object with identity, but this is not required. Such an Application Schema will import and build upon one or more of the six XML Schemas specified in this document.

Application Schemas could define additional concrete elements using or extending other abstract elements, if needed. However, an additional concrete element using or extending an abstract element should not be defined if that concrete element is largely similar to an existing element, and thus probably should extend or use an existing concrete element. In many cases, the existing concrete elements that use an abstract element are believed to be largely exhaustive. This is particularly true when the existing concrete elements include one element that is quite general, such as the elements EngineeringCRS, DerivedCRS, EngineeringDatum, UserDefinedCS, OperationParameter, and OperationParameterGroup.

The Conversion, Transformation, ParameterValue, and ParameterValueGroup elements can be used for well-known coordinate operation methods, especially when only one instance of that element is needed for that operation method. However, these elements should not be used for well-known coordinate operation methods when many instances of that element are needed for one operation method. Instead, an Application Schema that defines operation-method-specialized element names and contents should be prepared for each such operation method. Subclauses F.3 and F.4 provide examples of such Application Schemas. For interoperability, a suitable geospatial information community should standardize each such Application Schema.

NOTE This use of Application Schemas follows the GML 3 patterns. This GML pattern is to generally use Application Schemas, especially when use of Application Schemas allows definition of XML Schema having: 1) complexTypes with more specific restrictions on the contents of elements, sometime in ways that allow XML parsers to more completely check for correct contents of XML documents, and 2) elements with more specific and understandable names, to make XML documents easier to understand by humans.

6.4 Profiles

Most Application Schemas and other uses of these CRS Schemas will use only a subset of the XML elements, types, and other capabilities defined in these CRS Schemas. Such a subset is termed a Profile, as specified in Subclause 7.16 of the GML 3 Implementation Specification. Briefly, a profile is a specified logical subset of the CRS Schemas plus the GML 3 schemas used with these CRS Schemas, selected to improve interoperability and reduce ambiguity. Such a profile should be specified by an Application Schema.

6.5 Namespace and version

All these XML Schema documents describe components in the http://www.opengis.net/gml namespace, for which the prefix "gml" is normally used.

Each XML Schema document carries a version attribute as defined in the XML Schema Recommendation. The format of the version attribute string is x.y.z where x denotes the major version number, while y and z denote a minor version numbers for that document. The current version is 3.1.0.

These XML Schemas use most of the GML 3 model and syntax specified in Subclause 7.2.1 of the GML 3.00 specification.

7 XML encoding

The standard XML encoding of CRS and coordinate operation definition data is specified in six XML Schema documents (using the file extension .xsd). These six XML schema files are named:

a) referenceSystems.xsd

b) coordinateReferenceSystems.xsd

c) datums.xsd

d) coordinateSystems.xsd

e) coordinateOperations.xsd

f) dataQuality.xsd

These XML schema files are listed in Annex C, and copies of these files are also attached to this document. These six XML schemas correspond to the six packages in the UML model that was converted. Each XML schema includes <documentation> elements that define the XML elements and attributes, largely copied from the UML model.

These XML Schemas encoding CRS and coordinate operation definition data use nine XML schemas that are specified by GML 3. These XML schemas also include <documentation> elements that define the XML elements and attributes. Of course, these CRS Schemas use only some of the elements and types defined in these GML 3 schemas. These nine GML 3 schema documents are named:

a) measures.xsd

b) units.xsd

c) geometryBasic2d.xsd

d) geometryBasic0d1d.xsd

e) temporal.xsd

f) dictionary.xsd

g) gmlBase.xsd

h) basicTypes.xsd

i) xlink.xsd

8 Supporting information

This clause introduces information provided in the annexes supporting the encoding described in Clauses 6 and 7:

- Annex A (normative) specifies the requirements for OpenGIS Implementation Specification conformance to this specification, and an abstract test suite for checking such conformance. Requirements are also specified for compliance of Application Schemas.
- Annex B (informative) describes the expected OpenGIS uses (or use cases) for transferring CRS and coordinate operation definition data.
- Annex C (normative) lists the six specified XML Schemas.
- Annex D (informative) specifies the standard contents of the three code lists used by these XML Schemas.
- Annex E (informative) provides example XML documents using the XML Schemas specified in this document.
- Annex F (informative) provides example application schemas based on these XML Schemas, with corresponding example XML documents and UML models.
- Annex G (informative) summarizes the process and rules used to convert the included UML model into the included XML Schemas.
- Annex H (informative) describes some example operation methods.
- Annex I (informative) summarizes the flexibility supported by the specified XML Schemas.

Annex A
(normative)

Conformance

A.1 Conformance requirements

Each OGC Implementation Specification that uses XML encoding to transfer data defining coordinate reference systems and/or coordinate operations shall transfer definition data that conforms to this Recommendation Paper. Each relevant data transfer situation specified by such a specification shall transfer data that contains the entire applicable subset of the definition data specified in this Paper. Each such data transfer should include any additional data needed. Each relevant OGC Implementation Specification shall clearly specify the contents, structure, and format of the XML encoded data transferred in each specified data transfer situation, usually partially specified as an Application Schema based on these CRS schemas.

NOTE 1 In many cases, an Implementation Specification will specify the Application Programming Interface (API) to service software. In those cases, each specified data transfer situation is each input and output argument of each operation in a UML model of the service interface. Of course, multiple operation arguments will often transfer the same possible data, and thus use the same subset of the definition data specified here. Also, multiple arguments may use the same subset of the definition data specified here, although different arguments use different subsets of that data.

NOTE 2 Many of the concrete XML elements defined in these CRS Schemas can be used without Application Schemas, if no contents extensions or restrictions are needed. However, the Conversion, Transformation, ParameterValue, and ParameterValueGroup elements should not be used for well-known coordinate operation methods having many element instances. Instead, an Application Schema that defines operation-method-specialized element names and contents should be prepared and standardized, see Subclause 6.3.

Whenever coordinate reference system and/or coordinate operation definition data is transferred using XML encoding, the data contents and structure specified herein shall be used wherever applicable. The data contents and structure aspects specified herein that shall be used include:

a) Name of each specified XML element and attribute

NOTE 3 When an Application Schema is used, the same name can be used in different namespaces.

b) Meaning of each specified name

c) Contents of each specified complexType

d) Sequence of elements included within each specified complexType

e) Multiplicity and optionality of each element and attribute in each specified complexType

f) Data type of each specified individual data item

When a data transfer situation requires a subset of the definition information specified here, a suitable subset profile can be used. When a data transfer situation requires a superset of the definition information specified here, a suitable Application Schema shall be specified, and its' use shall be required. Each such Application Schema shall conform to the Rules for Application Schemas specified in Subclause A.3. The changes permitted in an Application Schema include:

a) Add additional elements to a specified complexType, containing additional information

b) Omit a specified element, when not needed and that element is specified as being optional (minOccurs="0")

c) Remove some of the set of alternative elements in a specified <choice> data structure

d) Make an optional element required (minOccurs not specified, default ="1")

e) Reduce specified maximum number-of-repetitions of an element

f) Change data type of an element to a more restrictive type

g) Restrict the meaning of a specified name, to match a restriction of an Implementation Specification

h) Specify standard contents and contents patterns for selected elements and attributes, for interoperability.

i) Specify standard XML and other documents to be referenced or otherwise used, for interoperability.

Many possible changes to the definition data specified here are not allowed, such as:

a) Completely change the definition of a specified name

b) Expand the set of alternative contents in a specified <choice> data structure

c) Make optional an element or attribute required in a specified complexType

d) Increase maximum number-of-repetitions of an element

e) Change data type of a specified element to a less restrictive type

f) Change the required order of elements in a specified complexType

A.2 Abstract test suite

Conformance of each application of these CRS Schemas shall be tested by inspecting the specification of each transferred XML encoded data structure and individual data item. The tested specification of XML encoded data shall include all Application Schemas used. This testing shall be done for each XML element and attribute that can be included in each specified data transfer. For each such XML element and attribute, the following questions shall be answered:

a) What is the (complete) meaning of this XML element or attribute?

b) Is this meaning part of the definition of an XML element or attribute specified herein? If not related, this data structure or item IS conformant.

c) Is this meaning similar to the meaning of any XML element or attribute specified herein? If not similar, this data structure or item IS conformant.

d) Is this meaning the same as, or a restriction of, the most similar meaning specified herein? If not the same or restricted, this data structure or item is NOT conformant.

e) Is the name of this XML element or attribute the same as the name of the corresponding item specified herein? If not the same name, this data structure or item is NOT conformant.

f) Is the type of this XML element or attribute the same as the type of the corresponding item specified herein, a subtype of that type, or a type with all the relevant contents of that type? If the type is not the same or equivalent, this item is NOT conformant.

If an individual XML element or attribute with a simpleType is being inspected, the questions continue:

g) Is the data type of this item the same as, or a subset of, the data type of the corresponding item specified here? If not the same or a subset, this data item is NOT conformant.

h) Does this element have a specified multiplicity range that extends outside the allowed multiplicity of the corresponding element specified here? If a larger multiplicity range is allowed, this element is NOT conformant.

If a XML element with a complexType is being inspected, the questions continue:

g) Do the contents of this complexType include all or a subset of the XML elements and attributes included in the corresponding complexType specified here? If doesn't include all or a subset, this complexType is NOT conformant.

h) Do the contents of this complexType include the corresponding XML elements in the same required order? If not the same order, this complexType is NOT conformant.

i) If this complexType extends a complexType specified here, and the <documentation> element in that complexType specified here states constraints on inclusion of additional elements, and those constraints are not all satisfied, this complexType is NOT conformant.

j) For each XML element or attribute included in this complexType that has a corresponding item in the complexType specified here, is the element or attribute multiplicity (including optionality) compatible?

    1) If the multiplicity and optionality are the same, this item IS conformant.

    2) If an element or attribute is now omitted instead of optional, this item IS conformant.

    3) If an element or attribute is now required instead of optional, this item IS conformant.

4) If an element or attribute is now optional instead of required, this item is NOT conformant.
5) If an element is now not repeated instead of being repeated one or more times, this item IS conformant.
6) If an element can now be repeated instead of not being repeated, this item is NOT conformant.
7) If the <documentation> element in the complexType specified here states a constraint on the multiplicity of this item and this constraint is not satisfied, this item is NOT conformant.

A.3 Rules for application schemas

A.3.1 Introduction

An Application Schema is an XML Schema that imports and builds upon one or more of the CRS set of six XML Schemas specified in Annex C. Such a Schema defines one or more XML elements useful for transfer of encoded geospatial data. An Application Schema can specify a single top level element for use by an XML document, with the XML elements and types that it uses. That single top level XML element can be an object with identity, but this is not required. Such a Schema with its' imported Schemas defines a vocabulary for a particular domain of discourse by defining and describing the terms of that vocabulary (see ISO TC/211 19109).

Conformance of an application of these CRS Schemas shall be tested by inspecting each Application Schema used, if any. Notice that the CRS set of XML Schemas specified in Annex C can be used without an Application Schema, and such use is allowed but discouraged. To use those XML Schemas without an Application Schema, any defined XML concrete element can be used as the basis for an XML document. There are about 30 such concrete elements defined that may be directly useful, and are listed in Subclause 6.2. In addition, all of those concrete elements can be used inside a GML 3 Dictionary element. Furthermore, all of those concrete elements or a Dictionary can be used inside a GenericMetaData element inside a metaDataProperty element, which can be included in many other elements.

The remainder of this subclause specifies the requirements (or rules) for an Application Schema to be considered conformant with this Recommendation Paper. Notice that it is clearly possible to develop Application Schemas that use the CRS Schemas specified herein which are valid XML Schemas but do not follow all these rules, and are thus not conformant with this Recommendation Paper.

A.3.2 General rules

All conformant Application Schemas shall be constructed by building upon one or more of the CRS set of six XML Schemas specified in Annex C. Such a Schema shall be a valid XML Schema, as specified in the XML Schema specification.

Each application schema must declare a target namespace. This is the namespace in which the XML elements or terms of the vocabulary "live". This shall not be the GML namespace (http://www.opengis.net/gml). It is conventional for the namespace identifier to be a URL controlled by the application schema author's organization. A target namespace is declared in the application schema using the targetNamespace attribute of the schema element from XML Schema.

A.3.4 Import needed schemas

An Application Schema must import the necessary XML Schemas specified in this document and from GML 3, with the correct namespace assignment. For example, in order to define coordinate reference systems, it is necessary to import coordinateReferenceSystems.xsd, either directly or indirectly. Direct import is done by including the declaration:

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

Notice that the <import> element specifies that the components described in coordinateReferenceSystems.xsd are in the GML namespace http://www.opengis.net/gml. This namespace identifier must match the target namespace specified in the schema being imported, to ensure XML Schema validity.

The schemaLocation of the imported .xsd file can be a local reference or a URI reference to the file. A URI reference can be to some remote repository, such as the repository http://schemas.opengis.net/ on the OGC web site. The above example assumes that the coordinateReferenceSystems.xsd file is stored locally at a location relative to this Application Schemas .xsd file.

Alternately, necessary XML Schemas can be imported indirectly, by importing another Application Schema that imports the needed Schemas.

In addition, the required import of a GML schema may be provided by the import of an equivalent subset schema as described in Subclause 7.14 of the GML 3 Implementation Specification, or by the import of an equivalent schema from a GML profile. These are all equivalent schemas with respect to satisfying the schema import requirements.

The above example imports coordinateReferenceSystems.xsd, which (directly and indirectly) includes the other five CRS Schemas plus nine other GML 3 Schemas. For some Application Schemas, coordinateReferenceSystems.xsd may not be needed, but one or more of the other CRS Schemas may be needed.

A.3.5 GML objects and properties

The content models of almost all (about 30) concrete elements listed in Subclause 6.2 are derived from gml:DefinitionType, partially by restriction. These elements are ultimately derived from the AbstractGMLType and are thus GML Objects. These elements shall thus follow the GML class/property model, as specified in Subclause 7.2.2 of the GML 3 Implementation Specification. That is, the children of these elements must not be

elements whose content models derive directly or indirectly from AbstractGMLType. The children of these elements are properties that describe that component.

A.3.6 Global and local names

Note that elements included in complex types that are defined with local names in an Application Schema will prevent derivation by restriction in another namespace, unless the local names are dropped in the restriction. Such complex types are appropriate for elements intended for use “as is” in their own namespace, and should be declared to be final=”restriction”. Elements included in complex types by reference to global elements support derivation by restriction in another namespace, allowing restriction of cardinality, and/or replacement by a member of a substitution group. Such complex types designed for derivation by restriction are appropriate “library types” for elements in substitution groups that cross namespaces.

A.4 UML models for application schemas

Each Application Schema can be produced by converting a UML model (or part of such a model), as required to comply with ISO 19118. If such a UML model is encoded, the XML encoding rules used should be similar to the encoding rules used for this document, as described in Annex G.

To comply with this specification, each such UML model shall be based on the same UML model as these CRS Schemas. For Application Schemas, subclasses can be defined for most non-abstract classes in this UML model. A subclass can extend and/or restrict a current concrete class to:

a) Add UML attributes and/or navigable associations, for recording additional data about that class needed for that application.

b) Restrict the multiplicity of current attributes and/or navigable associations, to eliminate flexibility not needed and perhaps confusing for that application.

c) Use a different class name, to be more easily understood in that specific application, primarily for classes that will be instantiated many times.

d) Specify standard or default contents for selected UML attributes, for interoperability.

Application Schemas could define additional concrete subclasses of abstract classes in this UML model, if needed. However, additional concrete subclasses should not be defined that are largely similar to existing subclasses, and thus probably should be a subclass of an existing concrete subclass. In most cases, the existing concrete subclasses of an abstract class are believed to be largely exhaustive. This is particularly true when the existing subclasses include one subclass that is quite general, such as the classes SC_EngineeringCSR, SC_DerivedCRS, CD_EngineeringDatum, CS_UserDefinedCS, and CC_OperationParameter.

Annex B
(informative)

Expected uses of CRS definition data

B.1 Introduction

The expected OpenGIS uses (or use cases) for transferring CRS and coordinate operation definition data produce requirements to be satisfied by this XML encoding. Three broad uses of such definition data transfer have been identified:

a) Use to transfer definition of a Coordinate Reference System (CRS), used by other geospatial data

b) Use to transfer definition of a Coordinate Transformation (CT), that can be performed by a coordinate transformation service

c) Use to transfer lineage or history of other geospatial data

Additional OGC uses of the proposed CRS and coordinate operation definition data might be identified in the future. These expected OGC uses assume the OGC is standardizing software-to-software interfaces (or Application Programming Interfaces, APIs) and associated data transfer formats, but is not (currently) trying to standardize human-computer interfaces.

Each OGC standard interface must allow both server and client software to be written that implements that interface. Simplicity of the interfaces is highly desirable, to simplify client software. Simplicity of server implementation software is somewhat important, but not as important as interface simplicity.

The following subclauses first discuss the multiple uses of definition data, the alternate ways in which definition data can be transferred, and then the three data transfer uses listed above.

B.2 Multiple uses of definition data

CRS and CT definition data can be used in at least three broad overlapping ways, to:

a) Describe a specific CRS or CT to a human user. Note that different human users need different degrees of definition detail.

b) Uniquely identify a specific CRS or CT to software. For a CRS, such identification can be used by software to check if different geospatial datasets are recorded using the same CRS, or to find additional data about a CRS that is stored elsewhere.

c) Provide data for performing coordinate transformations and conversions, useful to transformation software. For a CT, such data might be used to perform that

transformation. For a CRS, such data might be used in transforming point positions to or from that CRS.

B.3 Alternative ways to transfer definition data

CRS and CT definition data can be transferred in three alternative ways:

a) Transfer only identifier and perhaps name, of each CRS or CT

b) Transfer complete specification, of each CRS or CT

c) Transfer partial specification with identifiers (and perhaps names) for remaining parts, of each CRS or CT

Only an identifier needs to be transferred for a complete CRS or CT, or for any part thereof, for any part that is well-known to the receiving software. Well-known usually means that some recognized authority has produced and published a complete specification of that part. Server software could have those well-known definitions coded into the software. Alternately, server software could be coded to access those definitions when needed from a separate service known to the server. Such a separate service may be maintained by the authority or by a third party.

In general, there will be several CRS and CT specification authorities that one server or client might use, separately and together. Of course, some software implementations may use no such authority, or only one such authority. One widely-used, publicly-available authority is the European Petroleum Survey Group (EPSG), and use of this authority is currently specified in several OGC Implementation Specifications. However, other and more private authorities exist and must be supported by some OGC standard interfaces, including military affiliated authorities (e.g., DIGEST). Somewhat private authorities are expected to be used for many engineering and image coordinate reference systems.

A complete CRS or CT specification must be transferred for a CRS or CT, or for any part thereof, for any part that is not well-known to the receiving software. Some server or client implementations could support no well-known CRS and/or CT definitions. More likely, some applications are expected to use some non-well-known CRS or CT definitions. For example, a grid coverage can use a CRS specific to that coverage. Also, an image coordinate transformation is likely to be specific to one image, and may not be supported by any authority that makes that CT well-known.

B.4 Use to transfer coordinate reference system definition

XML can be used to transfer the definition of a Coordinate Reference System (CRS) used by other geospatial data, especially data encoded using XML. In most cases, one geospatial dataset will use only one CRS. The definition of a CRS for a geospatial dataset can be transferred (usually through an OGC interface) for several different purposes, including:

a) Coordinate Transformation (CT) interface. The current Coordinate Transformation (CT) server interface allows use of XML to transfer definitions of CRSs. That is, a client can send the definition of one CRS that the client is requesting access, to server software. Similarly, the server software can send to a client the definition of one CRS that the client currently has access to.

b) Geography Markup Language (GML). The encoding of features in XML, now specified in the GML Implementation Specification, might use this CRS XML to define the CRS of a feature collection or feature.

c) Web Map Server (WMS) interface. A future version of the WMS interface might use XML to define the CRS that the client is requesting "map" data in. (The WMS interface does not currently use XML for this purpose.) In the current WMS interface, only well-known CRSs are supported, so only the identifier of that well-known CRS is transferred in a Get Map request.

d) Grid Coverage (GC) interface. A future version of the GC (access) interface might use XML to define the CRS used by a coverage, when requested by a client. (The current GC interface does not use XML for this purpose.) In the current draft GC interface, the CRS can be defined for one specific grid coverage, requiring transfer of a more complete specification of that CRS. That grid CRS is usually specified as a custom affine coordinate conversion or transformation from another CRS.

B.4.1 Current CRS transfer by low-level CT interface

The current low-level Coordinate Transformation (CT) Implementation Specification (OGC document 01-009) supports XML transfer of a CRS definition in one operation and in one attribute.

The createFromXML operation of the CS_CoordinateSystemFactory <<Interface>> class creates a CS_CoordinateSystem object from a XML character string. One server will implement one CS_CoordinateSystemFactory object. The signature of this UML operation is:

```
createFromXML (xml:CharacterString) : CS_CoordinateSystem
```

The "XML" read-only UML attribute of the CS_Info class allows a client to get an XML character string representation of an object, which can be either a CS_CoordinateSystem or a CS_Unit UML object. Objects of both the CS_CoordinateSystem and CS_Unit UML classes can be instantiated by multiple other objects visible to one client. Note that a CS_CoordinateSystem object can be created in several ways other than use of the createFromXML operation. The signature of this UML attribute is:

```
XML : CharacterString
```

In the createFromXML operation, and when the UML attribute is used to get XML for a CS_CoordinateSystem object, the XML DTD for CS_CoordinateSystem provided in Section 15.1.1 (pages 113 through 115) of 00-007r4 is used. Example XML using that XML DTD is provided in Section 15.1.2 (pages 116 and 117) of 01-009. (Because that XML DTD and example XML are each more than one page, they are not copied here.)

NOTE A future version of the Coordinate Transformation (CT) Implementation Specification could use XML in additional places, especially where use of WKT is now supported but use of XML is not now supported.

B.4.2 Current CRS transfer by ICT and high-level CT interfaces

The current draft high-level Coordinate Transformation (CT) Implementation Specification (OGC document 01-013r1) supports XML transfer of a CRS definition by two operations. The same two operations are supported by the draft Image Coordinate Transformation (ICT) interface (OGC document 00-045r1). These two operations are provided to clients by the one Ground Coordinate Transformation Service <<Interface>> object. The UML operation signatures of these two operations are:

```
addTransformation (metadata : TransformationMetadata,
    format : TextFormat) : TransformationID
transformationMetadata (transformation : TransformationID,
    format : TextFormat) : TransformationMetadata
```

XML is one possible format used by the Transformation Metadata <<DataType>> class that is used by these two operations. The Transformation Metadata class contains three UML attributes, with the signatures:

```
sourceCS : CoordinateSystemDefinition
targetCS : CoordinateSystemDefinition
transformation [0..1]: TransformationDefinition
```

The CoordinateReferenceSystem XML element, with all its contents, specified in this document could to be used for each Coordinate System Definition instance in the Transformation Metadata. (However, the Transformation XML element specified in this document, with all their contents, alternately could be used for complete Transformation Metadata, including both the source and target CoordinateReferenceSystems.)

B.5 Use to transfer coordinate transformation (CT) definition

XML can be used to transfer the definition of a Coordinate Transformation (CT) in the interfaces to Coordinate Transformation (CT) services. These interfaces include the accepted (low level) CT Implementation Specification, OGC document 01-009. These interfaces also include a high-level CT interface now proposed in document 01-013, plus draft Image Coordinate Transformation interfaces documented in 00-045r1. These CT interfaces use XML to transfer CT definitions with and without associated source and target CRSs.

B.5.1 Current CT transfer by low-level CT Interface

The current low-level Coordinate Transformation (CT) Implementation Specification (OGC document 01-009) supports XML transfer of a CT definition in one operation and one attribute.

The createFromXML operation of the CT_MathTransformFactory <<Interface>> class creates a CT_MathTransform object from a XML character string. One server will implement one CT_MathTransformFactory object. The UML signature of this operation is:

```
createFromXML (xml:CharacterString) : CT_MathTransform
```

The "XML" read-only UML attribute of the CT_MathTransform class allows a client to get an XML character string representation of this UML object. Objects of the CT_MathTransform class can be instantiated by multiple UML objects visible to one client. Note that a CT_MathTransform object can be created in several ways other than use of the createFromXML operation. The signature of this UML attribute is:

```
XML : CharacterString
```

For both of these XML uses, the XML DTD for CT_MathTransform provided in Section 15.1.1 (page 113) of 01-009 is used. Example XML using that XML DTD is not provided in 01-009. The XML DTD for CT_MathTransform now in Section 15.1.1 is:

```
<!DOCTYPE CT_MathTransform [
<!ELEMENT CT_MathTransform (
    CT_ConcatenatedTransform |
    CT_InverseTransform |
    CT_ParameterizedMathTransform |
    CT_PassThroughTransform) >

<!ELEMENT CT_ParameterizedMathTransform (CT_Parameter*)>
<!ATTLIST CT_ParameterizedMathTransform
    ClassName           CDATA    #REQUIRED
    >

<!ELEMENT CT_PassThroughTransform (CT_MathTransform)>
<!ATTLIST CT_PassThroughTransform
    FirstAffectedOrdinate   CDATA    #REQUIRED
    >

<!ELEMENT CT_ConcatenatedTransform (CT_MathTransform*)>
<!ELEMENT CT_InverseTransform (CT_MathTransform)>

<!ELEMENT CT_Parameter EMPTY>
<!ATTLIST CT_Parameter
    Name                CDATA    #REQUIRED
    Value               CDATA    #REQUIRED
    >
]>
```

NOTE This CT_MathTransform does not include any information on the source and target coordinate systems. Also, a future version of the low-level Coordinate Transformation (CT) Implementation Specification could use XML in additional places, especially where use of WKT is now supported but use of XML is not now supported.)

B.5.2 Current CT transfer by ICT and high-level CT interfaces

The current draft high-level Coordinate Transformation (CT) interface specification (OGC document 01-013) supports XML transfer of a CT definition by two operations. The same two operations are supported by the draft Image Coordinate Transformation (ICT) interface (OGC document 00-045r1). These two operations are provided to clients by the one Ground Coordinate Transformation Service <<Interface>> object. The signatures of these two UML operations are:

```
addTransformation (metadata : TransformationMetadata,
    format : TextFormat) : TransformationID
transformationMetadata (transformation : TransformationID,
    format : TextFormat) : TransformationMetadata
```

XML is one possible format used by the Transformation Metadata <<DataType>> class that is used by these two operations. The Transformation Metadata class contains three UML attributes, with the signatures:

```
sourceCS : CoordinateSystemDefinition
targetCS : CoordinateSystemDefinition
transformation [0..1]: TransformationDefinition
```

The Transformation XML element specified in this document, with all their contents, could be used for a complete Transformation Metadata instance, including both the source and target CoordinateReferenceSystems. The Conversion XML element, with all its' contents probably can also be used for each Transformation Metadata instance.

B.6 Use to transfer dataset lineage or history

XML can be used to transfer the lineage or history of geospatial data, especially data encoded using XML. Such lineage information is specified by ISO 19115: Geographic information – Metadata to be part of the useful metadata about a dataset, and that metadata could be recorded in XML. (The OGC encourages use of ISO 19115 Metadata, but there are no uses of XML to transfer dataset lineage or history in current draft or accepted OGC Implementation Specifications.)

The lineage of a dataset, or of a part of a larger dataset, is likely to include the original CRS of the positions in that data, plus the sequence of coordinate transformations used to change these positions into the CRS in which the data is now recorded. Alternately, one concatenated coordinate transformation could be recorded that includes the original CRS and the sequence of coordinate transformations used. Similar metadata might be recorded for data still in the original CRS, but planned to be converted into a different CRS.

Annex C
(normative)

XML schemas

C.1 General

This clause lists the six XML Schemas for encoding coordinate reference system and coordinate transformation definition data, namely:

a) referenceSystems.xsd

b) coordinateReferenceSystems.xsd

c) datums.xsd

d) coordinateSystems.xsd

e) coordinateOperations.xsd

f) dataQuality.xsd

NOTE The XML Schemas listed in this annex are directly copied from the XML Schema Document files attached to this document. If any differences are discovered, please notify the editor and the OGC.

These XML Schemas include <documentation> elements for most of the XML Schema types defined, and for some of the XML elements defined. Where a XML element or attribute does not include a <documentation> element but the type it uses does, the type's <documentation> element applies to all the elements which use that type. These <documentation> elements specify the meaning of the corresponding XML elements and attributes. In addition, some <documentation> elements specify constraints on component elements and attributes. Most of the stated constraints are considered needed to fully comply with OGC Abstract Specification Topic 2. All the contents of the <documentation> elements in these schemas are normative.

C.2 XML schema for reference systems encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified"
version="3.1.0" xml:lang="en">
   <annotation>
      <appinfo source="urn:opengis:specification:gml:schema-
referenceSystems"/>
      <documentation>
         <name>referenceSystems.xsd</name>
         <version>3.1.0</version>
         <scope>How to encode reference system definitions. </scope>
```

```
         <description>Builds on several other parts of GML 3 to encode
the data needed to define reference systems. Primary editor: Arliss
Whiteside. Last updated 2003/10/16. </description>
         <copyright>Copyright (c) 2002-2003 Open GIS Consortium, All
Rights Reserved.</copyright>
         <conformance>This schema encodes the Reference System (RS_)
package of the extended UML Model for OGC Abstract Specification Topic
2: Spatial Referencing by Coordinates. That UML model is adapted from
ISO 19111 - Spatial referencing by coordinates, as described in Annex C
of Topic 2. The SC_CRS class is also encoded here, to eliminate the
(circular) references from coordinateOperations.xsd to
coordinateReferenceSystems.xsd. The
RS_SpatialReferenceSystemUsingGeographicIdentifier class is not
encoded, since it is not applicable to coordinate positions. The
CI_Citation class is not directly encoded, since such information can
be included as metaDataProperty elements which are optionally allowed.
A modified version of the EX_Extent (DataType) class from ISO 19115 is
currently encoded here, using GML 3 schema types. (A more extensive
version of the EX_Extent package might be XML encoded in the future,
probably in a separate extent.xsd schema.) </conformance>
      </documentation>
   </annotation>
   <!-- ======================================================
       includes and imports
   ====================================================== -->
   <include schemaLocation="dictionary.xsd"/>
   <include schemaLocation="geometryBasic2d.xsd"/>
   <include schemaLocation="temporal.xsd"/>
   <!-- ======================================================
       elements and types
   ====================================================== -->
   <element name="_ReferenceSystem"
type="gml:AbstractReferenceSystemType" abstract="true"
substitutionGroup="gml:Definition"/>
   <!-- ====================================================== -->
   <complexType name="AbstractReferenceSystemBaseType" abstract="true">
      <annotation>
         <documentation>Basic encoding for reference system objects,
simplifying and restricting the DefinitionType as needed.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DefinitionType">
            <sequence>
               <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:remarks" minOccurs="0">
                  <annotation>
                     <documentation>Comments on or information about
this reference system, including source information. </documentation>
                  </annotation>
               </element>
               <element ref="gml:srsName"/>
            </sequence>
            <attribute ref="gml:id" use="required"/>
         </restriction>
      </complexContent>
```

```
   </complexType>
   <!-- ================================================== -->
   <element name="srsName" type="gml:SimpleNameType"
substitutionGroup="gml:name">

      <annotation>
         <documentation>The name by which this reference system is
identified. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <complexType name="AbstractReferenceSystemType" abstract="true">
      <annotation>
         <documentation>Description of a spatial and/or temporal
reference system used by a dataset. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractReferenceSystemBaseType">
            <sequence>
               <element ref="gml:srsID" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Set of alterative identifications
of this reference system. The first srsID, if any, is normally the
primary identification code, and any others are aliases.
</documentation>
                  </annotation>
               </element>
               <element ref="gml:validArea" minOccurs="0"/>
               <element ref="gml:scope" minOccurs="0"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="srsID" type="gml:IdentifierType">
      <annotation>
         <documentation>An identification of a reference system.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="referenceSystemRef" type="gml:ReferenceSystemRefType"
substitutionGroup="gml:dictionaryEntry"/>
   <!-- ================================================== -->
   <complexType name="ReferenceSystemRefType">
      <annotation>
         <documentation>Association to a reference system, either
referencing or containing the definition of that reference system.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DictionaryEntryType">
            <sequence>
               <element ref="gml:_ReferenceSystem" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
```

```
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="_CRS" type="gml:AbstractCRSType" abstract="true"
substitutionGroup="gml:_ReferenceSystem"/>
   <!-- ================================================== -->
   <complexType name="AbstractCRSType" abstract="true">
      <annotation>
         <documentation>Abstract coordinate reference system, usually
defined by a coordinate system and a datum. This abstract complexType
shall not be used, extended, or restricted, in an Application Schema,
to define a concrete subtype with a meaning equivalent to a concrete
subtype specified in this document. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractReferenceSystemType"/>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="crsRef" type="gml:CRSRefType"
substitutionGroup="gml:referenceSystemRef"/>
   <!-- ================================================== -->
   <complexType name="CRSRefType">
      <annotation>
         <documentation>Association to a CRS abstract coordinate
reference system, either referencing or containing the definition of
that CRS. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:ReferenceSystemRefType">
            <sequence>
               <element ref="gml:_CRS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <complexType name="SimpleNameType">
      <annotation>
         <documentation>The primary name of a reference system object.
The string in the CodeType contains the object identification name, and
the codeSpace attribute is not included. </documentation>
      </annotation>
      <simpleContent>
         <restriction base="gml:CodeType">
            <attribute name="codeSpace" type="anyURI"
use="prohibited"/>
         </restriction>
      </simpleContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="IdentifierType">
      <annotation>
         <documentation>An identification of a CRS object. The first
use of the IdentifierType for an object, if any, is normally the
```

```
primary identification code, and any others are aliases.
</documentation>
      </annotation>
      <sequence>
         <element ref="gml:name">
            <annotation>
               <documentation>The code or name for this Identifier,
often from a controlled list or pattern defined by a code space. The
optional codeSpace attribute is normally included to identify or
reference a code space within which one or more codes are defined. This
code space is often defined by some authority organization, where one
organization may define multiple code spaces. The range and format of
each Code Space identifier is defined by that code space authority.
Information about that code space authority can be included as
metaDataProperty elements which are optionally allowed in all CRS
objects. </documentation>
            </annotation>
         </element>
         <element ref="gml:version" minOccurs="0"/>
         <element ref="gml:remarks" minOccurs="0">
            <annotation>
               <documentation>Remarks about this code or alias.
</documentation>
            </annotation>
         </element>
      </sequence>
   </complexType>
   <!-- ================================================== -->
   <element name="version" type="string">
      <annotation>
         <documentation>Identifier of the version of the associated
codeSpace or code, as specified by the codeSpace or code authority.
This version is included only when the "code" or "codeSpace" uses
versions. When appropriate, the version is identified by the effective
date, coded using ISO 8601 date format. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="remarks" type="gml:StringOrRefType"
substitutionGroup="gml:description">
      <annotation>
         <documentation>Information about this object or code. Contains
text or refers to external text.  </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="scope" type="string">
      <annotation>
         <documentation>Description of domain of usage, or limitations
of usage, for which this CRS object is valid. </documentation>
      </annotation>
   </element>

   <!-- ================================================== -->
   <element name="validArea" type="gml:ExtentType">
      <annotation>
         <documentation>Area or region in which this CRS object is
valid. </documentation>
```

```
      </annotation>
   </element>
   <!-- ================================================== -->
   <complexType name="ExtentType">
      <annotation>
         <documentation>Information about the spatial, vertical, and/or
temporal extent of a reference system object. Constraints: At least one
of the elements "description", "boundingBox", "boundingPolygon",
"verticalExtent", and temporalExtent" must be included, but more that
one can be included when appropriate. Furthermore, more than one
"boundingBox", "boundingPolygon", "verticalExtent", and/or
temporalExtent" element can be included, with more than one meaning the
union of the individual domains. </documentation>
      </annotation>
      <sequence>
         <element ref="gml:description" minOccurs="0">
            <annotation>
               <documentation>Description of spatial and/or temporal
extent of this object. </documentation>
            </annotation>
         </element>
         <choice>
            <annotation>
               <documentation>Geographic domain of this reference
system object. </documentation>
            </annotation>
            <element ref="gml:boundingBox" minOccurs="0"
maxOccurs="unbounded">
               <annotation>
                  <documentation>Unordered list of bounding boxes (or
envelopes) whose union describes the spatial domain of this object.
</documentation>
               </annotation>
            </element>
            <element ref="gml:boundingPolygon" minOccurs="0"
maxOccurs="unbounded">
               <annotation>
                  <documentation>Unordered list of bounding polygons
whose union describes the spatial domain of this object.
</documentation>
               </annotation>
            </element>
         </choice>
         <element ref="gml:verticalExtent" minOccurs="0"
maxOccurs="unbounded">
            <annotation>
               <documentation>Unordered list of vertical intervals
whose union describes the spatial domain of this object.
</documentation>
            </annotation>
         </element>
         <element ref="gml:temporalExtent" minOccurs="0"
maxOccurs="unbounded">
            <annotation>
               <documentation>Unordered list of time periods whose
union describes the spatial domain of this object. </documentation>
            </annotation>
```

```
         </element>
      </sequence>
   </complexType>
   <!-- ================================================== -->
   <element name="boundingBox" type="gml:EnvelopeType">
      <annotation>
         <documentation>A bounding box (or envelope) defining the
spatial domain of this object. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="boundingPolygon" type="gml:PolygonType">
      <annotation>
         <documentation>A bounding polygon defining the horizontal
spatial domain of this object. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="verticalExtent" type="gml:EnvelopeType">
      <annotation>
         <documentation>An interval defining the vertical spatial
domain of this object. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="temporalExtent" type="gml:TimePeriodType">
      <annotation>
         <documentation>A time period defining the temporal domain of
this object. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
</schema>
```

C.3 XML schema for coordinate reference systems encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified"
version="3.1.0" xml:lang="en">
   <annotation>
      <appinfo source="urn:opengis:specification:gml:schema-
coordinateReferenceSystems"/>
      <documentation>
         <name>coordinateReferenceSystems.xsd</name>
         <version>3.1.0</version>
         <scope>How to encode coordinate reference system definitions.
</scope>
         <description>Builds on referenceSystems.xsd to encode the data
needed to define coordinate reference systems, including the specific
subtypes of coordinate reference systems. Primary editor: Arliss
Whiteside. Last updated 2003/10/16. </description>
         <copyright>Copyright (c) 2002-2003 Open GIS Consortium, All
Rights Reserved.</copyright>
         <conformance>This schema encodes the Coordinate Reference
System (SC_) package of the extended UML Model for OGC Abstract
```

```
Specification Topic 2: Spatial Referencing by Coordinates, with the
exception of the abstract "SC_CRS" class. The "SC_CRS" class is encoded
in referenceSystems.xsd, to eliminate the (circular) references from
coordinateOperations.xsd to coordinateReferenceSystems.xsd. That UML
model is adapted from ISO 19111 - Spatial referencing by coordinates,
as described in Annex C of Topic 2. </conformance>
      </documentation>
   </annotation>
   <!-- ======================================================
       includes and imports
   ====================================================== -->
   <include schemaLocation="coordinateSystems.xsd"/>
   <include schemaLocation="datums.xsd"/>
   <include schemaLocation="coordinateOperations.xsd"/>
   <!-- ======================================================
       elements and types
   ====================================================== -->
   <element name="_CoordinateReferenceSystem"
type="gml:AbstractCoordinateReferenceSystemType" abstract="true"
substitutionGroup="gml:_CRS"/>
   <!-- ====================================================== -->
   <complexType name="AbstractCoordinateReferenceSystemType"
abstract="true">
      <annotation>
         <documentation>A coordinate reference system consists of an
ordered sequence of coordinate system axes that are related to the
earth through a datum. A coordinate reference system is defined by one
datum and by one coordinate system. Most coordinate reference system do
not move relative to the earth, except for engineering coordinate
reference systems defined on moving platforms such as cars, ships,
aircraft, and spacecraft. For further information, see OGC Abstract
Specification Topic 2.

Coordinate reference systems are commonly divided into sub-types. The
common classification criterion for sub-typing of coordinate reference
systems is the way in which they deal with earth curvature. This has a
direct effect on the portion of the earth's surface that can be covered
by that type of CRS with an acceptable degree of error. The exception
to the rule is the subtype "Temporal" which has been added by analogy.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCRSType"/>
      </complexContent>
   </complexType>
   <!-- ====================================================== -->
   <element name="coordinateReferenceSystemRef"
type="gml:CoordinateReferenceSystemRefType"
substitutionGroup="gml:crsRef"/>
   <!-- ====================================================== -->
   <complexType name="CoordinateReferenceSystemRefType">
      <annotation>
         <documentation>Association to a coordinate reference system,
either referencing or containing the definition of that reference
system. </documentation>
      </annotation>
      <complexContent>
```

```
         <restriction base="gml:CRSRefType">
            <sequence>
               <element ref="gml:_CoordinateReferenceSystem"
minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="CompoundCRS" type="gml:CompoundCRSType"
substitutionGroup="gml:_CRS"/>
   <!-- ================================================== -->
   <complexType name="CompoundCRSType">
      <annotation>
         <documentation>A coordinate reference system describing the
position of points through two or more independent coordinate reference
systems. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCRSType">
            <sequence>
               <element ref="gml:includesCRS" minOccurs="2"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Ordered sequence of associations to
all the component coordinate reference systems included in this
compound coordinate reference system. </documentation>
                  </annotation>
               </element>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="includesCRS"
type="gml:CoordinateReferenceSystemRefType">
      <annotation>
         <documentation>An association to a component coordinate
reference system included in this compound coordinate reference system.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="compoundCRSRef" type="gml:CompoundCRSRefType"
substitutionGroup="gml:crsRef"/>
   <!-- ================================================== -->
   <complexType name="CompoundCRSRefType">
      <annotation>
         <documentation>Association to a compound coordinate reference
system, either referencing or containing the definition of that
reference system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CRSRefType">
            <sequence>
               <element ref="gml:CompoundCRS" minOccurs="0"/>
            </sequence>
```

```
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="GeographicCRS" type="gml:GeographicCRSType"
substitutionGroup="gml:_CoordinateReferenceSystem"/>
   <!-- ================================================== -->
   <complexType name="GeographicCRSType">
      <annotation>
         <documentation>A coordinate reference system based on an
ellipsoidal approximation of the geoid; this provides an accurate
representation of the geometry of geographic features for a large
portion of the earth's surface.</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateReferenceSystemType">
            <sequence>
               <element ref="gml:usesEllipsoidalCS"/>
               <element ref="gml:usesGeodeticDatum"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="usesEllipsoidalCS" type="gml:EllipsoidalCSRefType">

      <annotation>
         <documentation>Association to the ellipsoidal coordinate
system used by this CRS. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesGeodeticDatum" type="gml:GeodeticDatumRefType">
      <annotation>
         <documentation>Association to the geodetic datum used by this
CRS. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="geographicCRSRef" type="gml:GeographicCRSRefType"
substitutionGroup="gml:coordinateReferenceSystemRef"/>
   <!-- ================================================== -->
   <complexType name="GeographicCRSRefType">
      <annotation>
         <documentation>Association to a geographic coordinate
reference system, either referencing or containing the definition of
that reference system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateReferenceSystemRefType">
            <sequence>
               <element ref="gml:GeographicCRS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
```

```
   </complexType>
   <!-- ================================================== -->
   <element name="VerticalCRS" type="gml:VerticalCRSType"
substitutionGroup="gml:_CoordinateReferenceSystem"/>
   <!-- ================================================== -->
   <complexType name="VerticalCRSType">
      <annotation>
         <documentation>A 1D coordinate reference system used for
recording heights or depths. Vertical CRSs make use of the direction of
gravity to define the concept of height or depth, but the relationship
with gravity may not be straightforward. By implication, ellipsoidal
heights (h) cannot be captured in a vertical coordinate reference
system. Ellipsoidal heights cannot exist independently, but only as an
inseparable part of a 3D coordinate tuple defined in a geographic 3D
coordinate reference system. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateReferenceSystemType">
            <sequence>
               <element ref="gml:usesVerticalCS"/>
               <element ref="gml:usesVerticalDatum"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="usesVerticalCS" type="gml:VerticalCSRefType">
      <annotation>
         <documentation>Association to the vertical coordinate system
used by this CRS. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesVerticalDatum" type="gml:VerticalDatumRefType">
      <annotation>
         <documentation>Association to the vertical datum used by this
CRS. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="verticalCRSRef" type="gml:VerticalCRSRefType"
substitutionGroup="gml:coordinateReferenceSystemRef"/>
   <!-- ================================================== -->
   <complexType name="VerticalCRSRefType">
      <annotation>
         <documentation>Association to a vertical coordinate reference
system, either referencing or containing the definition of that
reference system. </documentation>
      </annotation>
      <complexContent>

         <restriction base="gml:CoordinateReferenceSystemRefType">
            <sequence>
               <element ref="gml:VerticalCRS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
```

```
   </complexType>
   <!-- ================================================== -->
   <element name="GeocentricCRS" type="gml:GeocentricCRSType"
substitutionGroup="gml:_CoordinateReferenceSystem"/>
   <!-- ================================================== -->
   <complexType name="GeocentricCRSType">
      <annotation>
         <documentation>A 3D coordinate reference system with the
origin at the approximate centre of mass of the earth. A geocentric CRS
deals with the earth's curvature by taking a 3D spatial view, which
obviates the need to model the earth's curvature. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateReferenceSystemType">
            <sequence>
               <choice>
                  <element ref="gml:usesCartesianCS"/>
                  <element ref="gml:usesSphericalCS"/>
               </choice>
               <element ref="gml:usesGeodeticDatum"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="usesCartesianCS" type="gml:CartesianCSRefType">
      <annotation>
         <documentation>Association to the Cartesian coordinate system
used by this CRS. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesSphericalCS" type="gml:SphericalCSRefType">
      <annotation>
         <documentation>Association to the spherical coordinate system
used by this CRS.</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="geocentricCRSRef" type="gml:GeocentricCRSRefType"
substitutionGroup="gml:coordinateReferenceSystemRef"/>
   <!-- ================================================== -->
   <complexType name="GeocentricCRSRefType">
      <annotation>
         <documentation>Association to a geocentric coordinate
reference system, either referencing or containing the definition of
that reference system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateReferenceSystemRefType">
            <sequence>
               <element ref="gml:GeocentricCRS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
```

```
   <!-- ================================================== -->
   <element name="_GeneralDerivedCRS"
type="gml:AbstractGeneralDerivedCRSType" abstract="true"
substitutionGroup="gml:_CoordinateReferenceSystem"/>
   <!-- ================================================== -->
   <complexType name="AbstractGeneralDerivedCRSType" abstract="true">
      <annotation>
         <documentation>A coordinate reference system that is defined
by its coordinate conversion from another coordinate reference system
(not by a datum). This abstract complexType shall not be used,
extended, or restricted, in an Application Schema, to define a concrete
subtype with a meaning equivalent to a concrete subtype specified in
this document. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateReferenceSystemType">
            <sequence>
               <element ref="gml:baseCRS"/>
               <element ref="gml:definedByConversion"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="baseCRS" type="gml:CoordinateReferenceSystemRefType">
      <annotation>
         <documentation>Association to the coordinate reference system
used by this derived CRS. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="definedByConversion"
type="gml:GeneralConversionRefType">
      <annotation>
         <documentation>Association to the coordinate conversion used
to define this derived CRS. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="generalDerivedCRSRef"
type="gml:GeneralDerivedCRSRefType"
substitutionGroup="gml:coordinateReferenceSystemRef"/>
   <!-- ================================================== -->
   <complexType name="GeneralDerivedCRSRefType">
      <annotation>
         <documentation>Association to a general derived coordinate
reference system, either referencing or containing the definition of
that reference system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateReferenceSystemRefType">
            <sequence>
               <element ref="gml:_GeneralDerivedCRS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
```

```
   <!-- ================================================== -->
   <element name="ProjectedCRS" type="gml:ProjectedCRSType"
substitutionGroup="gml:_GeneralDerivedCRS"/>
   <!-- ================================================== -->
   <complexType name="ProjectedCRSType">
      <annotation>
         <documentation>A 2D coordinate reference system used to
approximate the shape of the earth on a planar surface, but in such a
way that the distortion that is inherent to the approximation is
carefully controlled and known. Distortion correction is commonly
applied to calculated bearings and distances to produce values that are
a close match to actual field values. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralDerivedCRSType">
            <sequence>
               <element ref="gml:usesCartesianCS"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="projectedCRSRef" type="gml:ProjectedCRSRefType"
substitutionGroup="gml:generalDerivedCRSRef"/>
   <!-- ================================================== -->
   <complexType name="ProjectedCRSRefType">
      <annotation>
         <documentation>Association to a projected coordinate reference
system, either referencing or containing the definition of that
reference system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:GeneralDerivedCRSRefType">
            <sequence>
               <element ref="gml:ProjectedCRS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="DerivedCRS" type="gml:DerivedCRSType"
substitutionGroup="gml:_GeneralDerivedCRS"/>
   <!-- ================================================== -->
   <complexType name="DerivedCRSType">
      <annotation>
         <documentation>A coordinate reference system that is defined
by its coordinate conversion from another coordinate reference system
but is not a projected coordinate reference system. This category
includes coordinate reference systems derived from a projected
coordinate reference system. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralDerivedCRSType">
            <sequence>
               <element ref="gml:derivedCRSType"/>
               <element ref="gml:usesCS"/>
```

```
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="derivedCRSType" type="gml:DerivedCRSTypeType"/>
   <!-- ================================================== -->
   <complexType name="DerivedCRSTypeType">
      <annotation>
         <documentation>Type of a derived coordinate reference system.
</documentation>
      </annotation>
      <simpleContent>
         <restriction base="gml:CodeType">
            <attribute name="codeSpace" type="anyURI" use="required">
               <annotation>
                  <documentation>Reference to a source of information
specifying the values and meanings of all the allowed string values for
this DerivedCRSTypeType. </documentation>
               </annotation>
            </attribute>
         </restriction>
      </simpleContent>
   </complexType>
   <!-- ================================================== -->
   <element name="usesCS" type="gml:CoordinateSystemRefType">
      <annotation>
         <documentation>Association to the coordinate system used by
this CRS. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="derivedCRSRef" type="gml:DerivedCRSRefType"
substitutionGroup="gml:generalDerivedCRSRef"/>
   <!-- ================================================== -->
   <complexType name="DerivedCRSRefType">
      <annotation>
         <documentation>Association to a non-projected derived
coordinate reference system, either referencing or containing the
definition of that reference system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:GeneralDerivedCRSRefType">
            <sequence>
               <element ref="gml:DerivedCRS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="EngineeringCRS" type="gml:EngineeringCRSType"
substitutionGroup="gml:_CoordinateReferenceSystem"/>
   <!-- ================================================== -->
   <complexType name="EngineeringCRSType">
      <annotation>
         <documentation>A contextually local coordinate reference
system; which can be divided into two broad categories:
```

```
- earth-fixed systems applied to engineering activities on or near the
surface of the earth;
- CRSs on moving platforms such as road vehicles, vessels, aircraft, or
spacecraft.
For further information, see OGC Abstract Specification Topic 2.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateReferenceSystemType">
            <sequence>
               <element ref="gml:usesCS"/>
               <element ref="gml:usesEngineeringDatum"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="usesEngineeringDatum"
type="gml:EngineeringDatumRefType">
      <annotation>
         <documentation>Association to the engineering datum used by
this CRS. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="engineeringCRSRef" type="gml:EngineeringCRSRefType"
substitutionGroup="gml:coordinateReferenceSystemRef"/>
   <!-- ================================================== -->
   <complexType name="EngineeringCRSRefType">
      <annotation>
         <documentation>Association to an engineering coordinate
reference system, either referencing or containing the definition of
that reference system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateReferenceSystemRefType">
            <sequence>
               <element ref="gml:EngineeringCRS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="ImageCRS" type="gml:ImageCRSType"
substitutionGroup="gml:_CoordinateReferenceSystem"/>
   <!-- ================================================== -->
   <complexType name="ImageCRSType">
      <annotation>
         <documentation>An engineering coordinate reference system
applied to locations in images. Image coordinate reference systems are
treated as a separate sub-type because a separate user community exists
for images with its own terms of reference. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateReferenceSystemType">
            <sequence>
```

```
               <choice>
                  <element ref="gml:usesCartesianCS"/>
                  <element ref="gml:usesObliqueCartesianCS"/>
               </choice>
               <element ref="gml:usesImageDatum"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="usesObliqueCartesianCS"
type="gml:ObliqueCartesianCSRefType">
      <annotation>
         <documentation>Association to the oblique Cartesian coordinate
system used by this CRS.</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesImageDatum" type="gml:ImageDatumRefType">
      <annotation>
         <documentation>Association to the image datum used by this
CRS. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="imageCRSRef" type="gml:ImageCRSRefType"
substitutionGroup="gml:coordinateReferenceSystemRef"/>
   <!-- ================================================== -->
   <complexType name="ImageCRSRefType">
      <annotation>
         <documentation>Association to an image coordinate reference
system, either referencing or containing the definition of that
reference system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateReferenceSystemRefType">
            <sequence>
               <element ref="gml:ImageCRS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="TemporalCRS" type="gml:TemporalCRSType"
substitutionGroup="gml:_CoordinateReferenceSystem"/>
   <!-- ================================================== -->
   <complexType name="TemporalCRSType">
      <annotation>
         <documentation>A 1D coordinate reference system used for the
recording of time. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateReferenceSystemType">
            <sequence>
               <element ref="gml:usesTemporalCS"/>
               <element ref="gml:usesTemporalDatum"/>
            </sequence>
```

```
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="usesTemporalCS" type="gml:TemporalCSRefType">
      <annotation>
         <documentation>Association to the temporal coordinate system
used by this CRS. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesTemporalDatum" type="gml:TemporalDatumRefType">
      <annotation>
         <documentation>Association to the temporal datum used by this
CRS. </documentation>
      </annotation>

   </element>
   <!-- ================================================== -->
   <element name="temporalCRSRef" type="gml:TemporalCRSRefType"
substitutionGroup="gml:coordinateReferenceSystemRef"/>
   <!-- ================================================== -->
   <complexType name="TemporalCRSRefType">
      <annotation>
         <documentation>Association to a temporal coordinate reference
system, either referencing or containing the definition of that
reference system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateReferenceSystemRefType">
            <sequence>
               <element ref="gml:TemporalCRS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
</schema>
```

C.4 XML schema for datums encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/gml"
xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:gml="http://www.opengis.net/gml" elementFormDefault="qualified"
version="3.1.0" xml:lang="en">
   <annotation>
      <appinfo source="urn:opengis:specification:gml:schema-datums"/>
      <documentation>
         <name>datums.xsd</name>
         <version>3.1.0</version>
         <scope>How to encode datum definitions. </scope>
         <description>Builds on referenceSystems.xsd to encode the data
needed to define datums, including the specific subtypes of datums.
```

```
Primary editor: Arliss Whiteside. Last updated 2003/10/16.
</description>
         <copyright>Copyright (c) 2002-2003 Open GIS Consortium, All
Rights Reserved.</copyright>
         <conformance>This schema encodes the Datum (CD_) package of
the extended UML Model for OGC Abstract Specification Topic 2: Spatial
Referencing by Coordinates. That UML model is adapted from ISO 19111 -
Spatial referencing by coordinates, as described in Annex C of Topic 2.
</conformance>
      </documentation>
   </annotation>
   <!-- ====================================================
       includes and imports
   ===================================================== -->
   <include schemaLocation="referenceSystems.xsd"/>

   <!-- ====================================================
       elements and types
   ===================================================== -->
   <element name="_Datum" type="gml:AbstractDatumType" abstract="true"
substitutionGroup="gml:Definition"/>
   <!-- ==================================================== -->
   <complexType name="AbstractDatumBaseType" abstract="true">
      <annotation>
         <documentation>Basic encoding for datum objects, simplifying
and restricting the DefinitionType as needed. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DefinitionType">
            <sequence>
               <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:remarks" minOccurs="0">
                  <annotation>
                     <documentation>Comments on this reference system,
including source information. </documentation>
                  </annotation>
               </element>
               <element ref="gml:datumName"/>
            </sequence>
            <attribute ref="gml:id" use="required"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ==================================================== -->
   <element name="datumName" type="gml:SimpleNameType"
substitutionGroup="gml:name">
      <annotation>
         <documentation>The name by which this datum is identified.
</documentation>
      </annotation>
   </element>
   <!-- ==================================================== -->
   <complexType name="AbstractDatumType" abstract="true">
      <annotation>
         <documentation>A datum specifies the relationship of a
coordinate system to the earth, thus creating a coordinate reference
system. A datum uses a parameter or set of parameters that determine
```

```
the location of the origin of the coordinate reference system. Each
datum subtype can be associated with only specific types of coordinate
systems. This abstract complexType shall not be used, extended, or
restricted, in an Application Schema, to define a concrete subtype with
a meaning equivalent to a concrete subtype specified in this document.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractDatumBaseType">
            <sequence>
               <element ref="gml:datumID" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Set of alternative identifications
of this datum. The first datumID, if any, is normally the primary
identification code, and any others are aliases. </documentation>
                  </annotation>
               </element>
               <element ref="gml:anchorPoint" minOccurs="0"/>
               <element ref="gml:realizationEpoch" minOccurs="0"/>
               <element ref="gml:validArea" minOccurs="0"/>
               <element ref="gml:scope" minOccurs="0"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="datumID" type="gml:IdentifierType">
      <annotation>
         <documentation>An identification of a datum. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="anchorPoint" type="gml:CodeType">
      <annotation>
         <documentation>Description, possibly including coordinates, of
the point or points used to anchor the datum to the Earth. Also known
as the "origin", especially for engineering and image datums. The
codeSpace attribute can be used to reference a source of more detailed
on this point or surface, or on a set of such descriptions.
- For a geodetic datum, this point is also known as the fundamental
point, which is traditionally the point where the relationship between
geoid and ellipsoid is defined. In some cases, the "fundamental point"
may consist of a number of points. In those cases, the parameters
defining the geoid/ellipsoid relationship have been averaged for these
points, and the averages adopted as the datum definition.
- For an engineering datum, the anchor point may be a physical point,
or it may be a point with defined coordinates in another CRS. When
appropriate, the coordinates of this anchor point can be referenced in
another document, such as referencing a GML feature that references or
includes a point position.
- For an image datum, the anchor point is usually either the centre of
the image or the corner of the image.
- For a temporal datum, this attribute is not defined. Instead of the
anchor point, a temporal datum carries a separate time origin of type
DateTime. </documentation>
      </annotation>
```

```
   </element>
   <!-- ================================================== -->
   <element name="realizationEpoch" type="date">
      <annotation>
         <documentation>The time after which this datum definition is
valid. This time may be precise (e.g. 1997.0 for IRTF97) or merely a
year (e.g. 1983 for NAD83). In the latter case, the epoch usually
refers to the year in which a major recalculation of the geodetic
control network, underlying the datum, was executed or initiated. An
old datum can remain valid after a new datum is defined. Alternatively,
a datum may be superseded by a later datum, in which case the
realization epoch for the new datum defines the upper limit for the
validity of the superseded datum. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="datumRef" type="gml:DatumRefType"
substitutionGroup="gml:dictionaryEntry"/>
   <!-- ================================================== -->
   <complexType name="DatumRefType">
      <annotation>
         <documentation>Association to a datum, either referencing or
containing the definition of that datum. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DictionaryEntryType">
            <sequence>
               <element ref="gml:_Datum" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="EngineeringDatum" type="gml:EngineeringDatumType"
substitutionGroup="gml:_Datum"/>
   <!-- ================================================== -->
   <complexType name="EngineeringDatumType">
      <annotation>
         <documentation>An engineering datum defines the origin of an
engineering coordinate reference system, and is used in a region around
that origin. This origin can be fixed with respect to the earth (such
as a defined point at a construction site), or be a defined point on a
moving vehicle (such as on a ship or satellite). </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractDatumType"/>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="engineeringDatumRef"
type="gml:EngineeringDatumRefType" substitutionGroup="gml:datumRef"/>
   <!-- ================================================== -->
   <complexType name="EngineeringDatumRefType">
      <annotation>
         <documentation>Association to an engineering datum, either
referencing or containing the definition of that datum.
</documentation>
```

```
      </annotation>
      <complexContent>
         <restriction base="gml:DatumRefType">
            <sequence>
               <element ref="gml:EngineeringDatum" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="ImageDatum" type="gml:ImageDatumType"
substitutionGroup="gml:_Datum"/>
   <!-- ================================================== -->
   <complexType name="ImageDatumType">
      <annotation>
         <documentation>An image datum defines the origin of an image
coordinate reference system, and is used in a local context only. For
more information, see OGC Abstract Specification Topic 2.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractDatumType">
            <sequence>
               <element ref="gml:pixelInCell"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="pixelInCell" type="gml:PixelInCellType"/>
   <!-- ================================================== -->
   <complexType name="PixelInCellType">
      <annotation>
         <documentation>Specification of the way an image grid is
associated with the image data attributes. </documentation>
      </annotation>
      <simpleContent>
         <restriction base="gml:CodeType">
            <attribute name="codeSpace" type="anyURI" use="required">
               <annotation>
                  <documentation>Reference to a source of information
specifying the values and meanings of all the allowed string values for
this PixelInCellType. </documentation>
               </annotation>
            </attribute>
         </restriction>
      </simpleContent>
   </complexType>
   <!-- ================================================== -->
   <element name="imageDatumRef" type="gml:ImageDatumRefType"
substitutionGroup="gml:datumRef"/>
   <!-- ================================================== -->
   <complexType name="ImageDatumRefType">
      <annotation>
```

```
         <documentation>Association to an image datum, either
referencing or containing the definition of that datum.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DatumRefType">
            <sequence>
               <element ref="gml:ImageDatum" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="VerticalDatum" type="gml:VerticalDatumType"
substitutionGroup="gml:_Datum"/>
   <!-- ================================================== -->
   <complexType name="VerticalDatumType">
      <annotation>
         <documentation>A textual description and/or a set of
parameters identifying a particular reference level surface used as a
zero-height surface, including its position with respect to the Earth
for any of the height types recognized by this standard. There are
several types of Vertical Datums, and each may place constraints on the
Coordinate Axis with which it is combined to create a Vertical CRS.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractDatumType">
            <sequence>
               <element ref="gml:verticalDatumType" minOccurs="0"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->

   <element name="verticalDatumType" type="gml:VerticalDatumTypeType"/>
   <!-- ================================================== -->
   <complexType name="VerticalDatumTypeType">
      <annotation>
         <documentation>Type of a vertical datum. </documentation>
      </annotation>
      <simpleContent>
         <restriction base="gml:CodeType">
            <attribute name="codeSpace" type="anyURI" use="required">
               <annotation>
                  <documentation>Reference to a source of information
specifying the values and meanings of all the allowed string values for
this VerticalDatumTypeType. </documentation>
               </annotation>
            </attribute>
         </restriction>
      </simpleContent>
   </complexType>
   <!-- ================================================== -->
   <element name="verticalDatumRef" type="gml:VerticalDatumRefType"
substitutionGroup="gml:datumRef"/>
```

```
   <!-- ================================================== -->
   <complexType name="VerticalDatumRefType">
      <annotation>
         <documentation>Association to a vertical datum, either
referencing or containing the definition of that datum.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DatumRefType">
            <sequence>
               <element ref="gml:VerticalDatum" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="TemporalDatum" type="gml:TemporalDatumType"
substitutionGroup="gml:_Datum"/>
   <!-- ================================================== -->
   <complexType name="TemporalDatumBaseType" abstract="true">
      <annotation>
         <documentation>Partially defines the origin of a temporal
coordinate reference system. This type restricts the AbstractDatumType
to remove the "anchorPoint" and "realizationEpoch" elements.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:AbstractDatumType">
            <sequence>
               <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:datumName"/>
               <element ref="gml:datumID" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:validArea" minOccurs="0"/>
               <element ref="gml:scope" minOccurs="0"/>
            </sequence>
            <attribute ref="gml:id" use="required"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="TemporalDatumType">
      <annotation>
         <documentation>Defines the origin of a temporal coordinate
reference system. This type extends the TemporalDatumRestrictionType to
add the "origin" element with the dateTime type. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:TemporalDatumBaseType">
            <sequence>
               <element ref="gml:origin"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
```

```
   <!-- ================================================== -->
   <element name="origin" type="dateTime">
      <annotation>
         <documentation>The date and time origin of this temporal
datum. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="temporalDatumRef" type="gml:TemporalDatumRefType"
substitutionGroup="gml:datumRef"/>
   <!-- ================================================== -->
   <complexType name="TemporalDatumRefType">
      <annotation>
         <documentation>Association to a temporal datum, either
referencing or containing the definition of that datum.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DatumRefType">
            <sequence>
               <element ref="gml:TemporalDatum" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="GeodeticDatum" type="gml:GeodeticDatumType"
substitutionGroup="gml:_Datum"/>
   <!-- ================================================== -->
   <complexType name="GeodeticDatumType">
      <annotation>
         <documentation>A geodetic datum defines the precise location
and orientation in 3-dimensional space of a defined ellipsoid (or
sphere) that approximates the shape of the earth, or of a Cartesian
coordinate system centered in this ellipsoid (or sphere).
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractDatumType">
            <sequence>
               <element ref="gml:usesPrimeMeridian"/>
               <element ref="gml:usesEllipsoid"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="usesPrimeMeridian" type="gml:PrimeMeridianRefType">
      <annotation>
         <documentation>Association to the prime meridian used by this
geodetic datum. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesEllipsoid" type="gml:EllipsoidRefType">
      <annotation>
```

```
         <documentation>Association to the ellipsoid used by this
geodetic datum. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="geodeticDatumRef" type="gml:GeodeticDatumRefType"
substitutionGroup="gml:datumRef"/>
   <!-- ================================================== -->
   <complexType name="GeodeticDatumRefType">
      <annotation>
         <documentation>Association to a geodetic datum, either
referencing or containing the definition of that datum.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DatumRefType">
            <sequence>
               <element ref="gml:GeodeticDatum" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="PrimeMeridian" type="gml:PrimeMeridianType"
substitutionGroup="gml:Definition"/>
   <!-- ================================================== -->
   <complexType name="PrimeMeridianBaseType" abstract="true">
      <annotation>
         <documentation>Basic encoding for prime meridian objects,
simplifying and restricting the DefinitionType as needed.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DefinitionType">
            <sequence>
               <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:remarks" minOccurs="0">
                  <annotation>
                     <documentation>Comments on or information about
this prime meridian, including source information. </documentation>
                  </annotation>
               </element>
               <element ref="gml:meridianName"/>
            </sequence>
            <attribute ref="gml:id" use="required"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="meridianName" type="gml:SimpleNameType"
substitutionGroup="gml:name">
      <annotation>
         <documentation>The name by which this prime meridian is
identified. The meridianName most common value is â€œGreenwichâ€, and
```

```
that value shall be used when the greenwichLongitude value is zero.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <complexType name="PrimeMeridianType">
      <annotation>
         <documentation>A prime meridian defines the origin from which
longitude values are determined.</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:PrimeMeridianBaseType">
            <sequence>
               <element ref="gml:meridianID" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Set of alternative identifications
of this prime meridian. The first meridianID, if any, is normally the
primary identification code, and any others are aliases.
</documentation>
                  </annotation>
               </element>
               <element ref="gml:greenwichLongitude"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="meridianID" type="gml:IdentifierType">
      <annotation>
         <documentation>An identification of a prime meridian.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="greenwichLongitude" type="gml:AngleChoiceType">
      <annotation>
         <documentation>Longitude of the prime meridian measured from
the Greenwich meridian, positive eastward. The greenwichLongitude most
common value is zero, and that value shall be used when the
meridianName value is â€œGreenwichâ€. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="primeMeridianRef" type="gml:PrimeMeridianRefType"
substitutionGroup="gml:dictionaryEntry"/>
   <!-- ================================================== -->
   <complexType name="PrimeMeridianRefType">
      <annotation>
         <documentation>Association to a prime meridian, either
referencing or containing the definition of that meridian.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DictionaryEntryType">
            <sequence>
               <element ref="gml:PrimeMeridian" minOccurs="0"/>
            </sequence>
```

```
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="Ellipsoid" type="gml:EllipsoidType"
substitutionGroup="gml:Definition"/>
   <!-- ================================================== -->
   <complexType name="EllipsoidBaseType" abstract="true">
      <annotation>
         <documentation>Basic encoding for ellipsoid objects,
simplifying and restricting the DefinitionType as needed.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DefinitionType">
            <sequence>
               <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:remarks" minOccurs="0">
                  <annotation>
                     <documentation>Comments on or information about
this ellipsoid, including source information. </documentation>
                  </annotation>
               </element>
               <element ref="gml:ellipsoidName"/>
            </sequence>
            <attribute ref="gml:id" use="required"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="ellipsoidName" type="gml:SimpleNameType"
substitutionGroup="gml:name">
      <annotation>
         <documentation>The name by which this ellipsoid is identified.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <complexType name="EllipsoidType">
      <annotation>
         <documentation>An ellipsoid is a geometric figure that can be
used to describe the approximate shape of the earth. In mathematical
terms, it is a surface formed by the rotation of an ellipse about its
minor axis.</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:EllipsoidBaseType">
            <sequence>
               <element ref="gml:ellipsoidID" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Set of alternative identifications
of this ellipsoid. The first ellipsoidID, if any, is normally the
primary identification code, and any others are aliases.
</documentation>
```

```
                  </annotation>
               </element>
               <element ref="gml:semiMajorAxis"/>
               <element ref="gml:secondDefiningParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="ellipsoidID" type="gml:IdentifierType">
      <annotation>
         <documentation>An identification of an ellipsoid.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="semiMajorAxis" type="gml:LengthType">
      <annotation>
         <documentation>Length of the semi-major axis of the ellipsoid.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="ellipsoidRef" type="gml:EllipsoidRefType"
substitutionGroup="gml:dictionaryEntry"/>
   <!-- ================================================== -->
   <complexType name="EllipsoidRefType">
      <annotation>
         <documentation>Association to an ellipsoid, either referencing
or containing the definition of that ellipsoid. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DictionaryEntryType">
            <sequence>
               <element ref="gml:Ellipsoid" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="secondDefiningParameter"
type="gml:SecondDefiningParameterType"/>
   <!-- ================================================== -->
   <complexType name="SecondDefiningParameterType">
      <annotation>
         <documentation>Definition of the second parameter that defines
the shape of an ellipsoid. An ellipsoid requires two defining
parameters: semi-major axis and inverse flattening or semi-major axis
and semi-minor axis. When the reference body is a sphere rather than an
ellipsoid, only a single defining parameter is required, namely the
radius of the sphere; in that case, the semi-major axis "degenerates"
into the radius of the sphere.</documentation>
      </annotation>
      <choice>
         <element ref="gml:inverseFlattening"/>
         <element ref="gml:semiMinorAxis"/>
         <element ref="gml:isSphere"/>
```

```
      </choice>
   </complexType>
   <!-- ==================================================== -->
   <element name="inverseFlattening" type="gml:ScaleType">
      <annotation>
         <documentation>Inverse flattening value of the ellipsoid.
</documentation>
      </annotation>
   </element>
   <!-- ==================================================== -->
   <element name="semiMinorAxis" type="gml:LengthType">
      <annotation>
         <documentation>Length of the semi-minor axis of the ellipsoid.
</documentation>

      </annotation>
   </element>
   <!-- ==================================================== -->
   <element name="isSphere">
      <annotation>
         <documentation>The ellipsoid is degenerate and is actually a
sphere. The sphere is completely defined by the semi-major axis, which
is the radius of the sphere. </documentation>
      </annotation>
      <simpleType>
         <restriction base="string">
            <enumeration value="sphere"/>
         </restriction>
      </simpleType>
   </element>
   <!-- ==================================================== -->
</schema>
```

C.5 XML schema for coordinate systems encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/gml"
xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:gml="http://www.opengis.net/gml" elementFormDefault="qualified"
version="3.1.0" xml:lang="en">
   <annotation>
      <appinfo source="urn:opengis:specification:gml:schema-
coordinateSystems"/>
      <documentation>
         <name>coordinateSystems.xsd</name>
         <version>3.1.0</version>
         <scope>How to encode coordinate system definitions. </scope>
         <description>Builds on referenceSystems.xsd to encode the data
needed to define coordinate systems, including the specific subtypes of
coordinate systems. Primary editor: Arliss Whiteside. Last updated
2003/10/16. </description>
         <copyright>Copyright (c) 2002-2003 OpenGIS, All Rights
Reserved.</copyright>
         <conformance>This schema encodes the Coordinate System (CS_)
package of the extended UML Model for OGC Abstract Specification Topic
```

```
2: Spatial Referencing by Coordinates. That UML model is adapted from
ISO 19111 - Spatial referencing by coordinates, as described in Annex C
of Topic 2. </conformance>
      </documentation>
   </annotation>
   <!-- ======================================================
       includes and imports
   ====================================================== -->
   <include schemaLocation="referenceSystems.xsd"/>
   <!-- ======================================================
       elements and types
   ====================================================== -->
   <element name="CoordinateSystemAxis"
type="gml:CoordinateSystemAxisType"
substitutionGroup="gml:Definition"/>
   <!-- ====================================================== -->
   <complexType name="CoordinateSystemAxisBaseType" abstract="true">
      <annotation>
         <documentation>Basic encoding for coordinate system axis
objects, simplifying and restricting the DefinitionType as needed.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DefinitionType">
            <sequence>
               <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:remarks" minOccurs="0">
                  <annotation>
                     <documentation>Comments on or information about
this coordinate system axis, including data source information.
</documentation>
                  </annotation>
               </element>
               <element ref="gml:axisName"/>
            </sequence>
            <attribute ref="gml:id" use="required"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ====================================================== -->
   <element name="axisName" type="gml:SimpleNameType"
substitutionGroup="gml:name">
      <annotation>
         <documentation>The name by which this coordinate system axis
is identified. </documentation>
      </annotation>
   </element>
   <!-- ====================================================== -->
   <complexType name="CoordinateSystemAxisType">
      <annotation>
         <documentation>Definition of a coordinate system axis.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:CoordinateSystemAxisBaseType">
            <sequence>
```

```
               <element ref="gml:axisID" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Set of alternative identifications
of this coordinate system axis. The first axisID, if any, is normally
the primary identification code, and any others are aliases.
</documentation>
                  </annotation>
               </element>
               <element ref="gml:axisAbbrev"/>
               <element ref="gml:axisDirection"/>
            </sequence>
            <attribute ref="gml:uom" use="required"/>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="axisID" type="gml:IdentifierType">
      <annotation>
         <documentation>An identification of a coordinate system axis.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="axisAbbrev" type="gml:CodeType">
      <annotation>
         <documentation>The abbreviation used for this coordinate
system axis. This abbreviation can be used to identify the ordinates in
a coordinate tuple. Examples are X and Y. The codeSpace attribute can
reference a source of more information on a set of standardized
abbreviations, or on this abbreviation. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="axisDirection" type="gml:CodeType">
      <annotation>
         <documentation>Direction of this coordinate system axis (or in
the case of Cartesian projected coordinates, the direction of this
coordinate system axis at the origin). Examples: north or south, east
or west, up or down. Within any set of coordinate system axes, only one
of each pair of terms can be used. For earth-fixed CRSs, this direction
is often approximate and intended to provide a human interpretable
meaning to the axis. When a geodetic datum is used, the precise
directions of the axes may therefore vary slightly from this
approximate direction. Note that an EngineeringCRS can include specific
descriptions of the directions of its coordinate system axes. For
example, the path of a linear CRS axis can be referenced in another
document, such as referencing a GML feature that references or includes
a curve geometry. The codeSpace attribute can reference a source of
more information on a set of standardized directions, or on this
direction. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <attribute name="uom" type="anyURI">
      <annotation>
```

```
         <documentation>Identifier of the unit of measure used for this
coordinate system axis. The value of this coordinate in a coordinate
tuple shall be recorded using this unit of measure, whenever those
coordinates use a coordinate reference system that uses a coordinate
system that uses this axis.</documentation>
      </annotation>
   </attribute>
   <!-- ================================================== -->
   <element name="coordinateSystemAxisRef"
type="gml:CoordinateSystemAxisRefType"
substitutionGroup="gml:dictionaryEntry"/>
   <!-- ================================================== -->
   <complexType name="CoordinateSystemAxisRefType">
      <annotation>
         <documentation>Association to a coordinate system axis, either
referencing or containing the definition of that axis. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DictionaryEntryType">
            <sequence>
               <element ref="gml:CoordinateSystemAxis" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="_CoordinateSystem"
type="gml:AbstractCoordinateSystemType" abstract="true"
substitutionGroup="gml:Definition"/>
   <!-- ================================================== -->
   <complexType name="AbstractCoordinateSystemBaseType"
abstract="true">
      <annotation>
         <documentation>Basic encoding for coordinate system objects,
simplifying and restricting the DefinitionType as needed.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DefinitionType">
            <sequence>
               <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:remarks" minOccurs="0">
                  <annotation>
                     <documentation>Comments on or information about
this coordinate system, including data source information.
</documentation>
                  </annotation>
               </element>
               <element ref="gml:csName"/>
            </sequence>
            <attribute ref="gml:id" use="required"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
```

```
   <element name="csName" type="gml:SimpleNameType"
substitutionGroup="gml:name">
      <annotation>
         <documentation>The name by which this coordinate system is
identified. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <complexType name="AbstractCoordinateSystemType" abstract="true">
      <annotation>
         <documentation>A coordinate system (CS) is the set of
coordinate system axes that spans a given coordinate space. A CS is
derived from a set of (mathematical) rules for specifying how
coordinates in a given space are to be assigned to points. The
coordinate values in a coordinate tuple shall be recorded in the order
in which the coordinate system axes associations are recorded, whenever
those coordinates use a coordinate reference system that uses this
coordinate system. This abstract complexType shall not be used,
extended, or restricted, in an Application Schema, to define a concrete
subtype with a meaning equivalent to a concrete subtype specified in
this document. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateSystemBaseType">
            <sequence>
               <element ref="gml:csID" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Set of alternative identifications
of this coordinate system. The first csID, if any, is normally the
primary identification code, and any others are aliases.
</documentation>
                  </annotation>
               </element>
               <element ref="gml:usesAxis" maxOccurs="unbounded">
                  <annotation>
                     <documentation>Ordered sequence of associations to
the coordinate system axes included in this coordinate system.
</documentation>
                  </annotation>
               </element>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="csID" type="gml:IdentifierType">
      <annotation>
         <documentation>An identification of a coordinate system.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesAxis" type="gml:CoordinateSystemAxisRefType"
substitutionGroup="gml:dictionaryEntry">
      <annotation>
```

```
         <documentation>Association to a coordinate system axis.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="coordinateSystemRef"
type="gml:CoordinateSystemRefType"/>
   <!-- ================================================== -->
   <complexType name="CoordinateSystemRefType">
      <annotation>
         <documentation>Association to a coordinate system, either
referencing or containing the definition of that coordinate system.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DictionaryEntryType">
            <sequence>
               <element ref="gml:_CoordinateSystem" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="EllipsoidalCS" type="gml:EllipsoidalCSType"
substitutionGroup="gml:_CoordinateSystem"/>
   <!-- ================================================== -->
   <complexType name="EllipsoidalCSType">
      <annotation>
         <documentation>A two- or three-dimensional coordinate system
in which position is specified by geodetic latitude, geodetic
longitude, and (in the three-dimensional case) ellipsoidal height. An
EllipsoidalCS shall have two or three usesAxis associations.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateSystemType"/>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="ellipsoidalCSRef" type="gml:EllipsoidalCSRefType"
substitutionGroup="gml:coordinateSystemRef"/>
   <!-- ================================================== -->
   <complexType name="EllipsoidalCSRefType">
      <annotation>
         <documentation>Association to an ellipsoidal coordinate
system, either referencing or containing the definition of that
coordinate system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateSystemRefType">
            <sequence>
               <element ref="gml:EllipsoidalCS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
```

```
   <!-- ================================================== -->
   <element name="CartesianCS" type="gml:CartesianCSType"
substitutionGroup="gml:_CoordinateSystem"/>
   <!-- ================================================== -->
   <complexType name="CartesianCSType">
      <annotation>
         <documentation>A 1-, 2-, or 3-dimensional coordinate system.
Gives the position of points relative to orthogonal straight axes in
the 2- and 3-dimensional cases. In the 1-dimensional case, it contains
a single straight coordinate axis. In the multi-dimensional case, all
axes shall have the same length unit of measure. A CartesianCS shall
have one, two, or three usesAxis associations. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateSystemType"/>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="cartesianCSRef" type="gml:CartesianCSRefType"
substitutionGroup="gml:coordinateSystemRef"/>
   <!-- ================================================== -->
   <complexType name="CartesianCSRefType">
      <annotation>
         <documentation>Association to a Cartesian coordinate system,
either referencing or containing the definition of that coordinate
system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateSystemRefType">
            <sequence>
               <element ref="gml:CartesianCS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="VerticalCS" type="gml:VerticalCSType"
substitutionGroup="gml:_CoordinateSystem"/>
   <!-- ================================================== -->
   <complexType name="VerticalCSType">
      <annotation>
         <documentation>A one-dimensional coordinate system used to
record the heights (or depths) of points. Such a coordinate system is
usually dependent on the Earth's gravity field, perhaps loosely as when
atmospheric pressure is the basis for the vertical coordinate system
axis. A VerticalCS shall have one usesAxis association.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateSystemType"/>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="verticalCSRef" type="gml:VerticalCSRefType"
substitutionGroup="gml:coordinateSystemRef"/>
   <!-- ================================================== -->
```

```
   <complexType name="VerticalCSRefType">
      <annotation>
         <documentation>Association to a vertical coordinate system,
either referencing or containing the definition of that coordinate
system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateSystemRefType">
            <sequence>
               <element ref="gml:VerticalCS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="TemporalCS" type="gml:TemporalCSType"
substitutionGroup="gml:_CoordinateSystem"/>
   <!-- ================================================== -->
   <complexType name="TemporalCSType">
      <annotation>
         <documentation>A one-dimensional coordinate system containing
a single time axis, used to describe the temporal position of a point
in the specified time units from a specified time origin. A TemporalCS
shall have one usesAxis association. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateSystemType"/>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="temporalCSRef" type="gml:TemporalCSRefType"
substitutionGroup="gml:coordinateSystemRef"/>
   <!-- ================================================== -->
   <complexType name="TemporalCSRefType">
      <annotation>
         <documentation>Association to a temporal coordinate system,
either referencing or containing the definition of that coordinate
system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateSystemRefType">
            <sequence>
               <element ref="gml:TemporalCS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="LinearCS" type="gml:LinearCSType"
substitutionGroup="gml:_CoordinateSystem"/>
   <!-- ================================================== -->
   <complexType name="LinearCSType">
      <annotation>
         <documentation>A one-dimensional coordinate system that
consists of the points that lie on the single axis described. The
associated ordinate is the distance from the specified origin to the
```

```
point along the axis. Example: usage of the line feature representing a
road to describe points on or along that road. A LinearCS shall have
one usesAxis association. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateSystemType"/>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="linearCSRef" type="gml:LinearCSRefType"
substitutionGroup="gml:coordinateSystemRef"/>
   <!-- ================================================== -->
   <complexType name="LinearCSRefType">
      <annotation>
         <documentation>Association to a linear coordinate system,
either referencing or containing the definition of that coordinate
system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateSystemRefType">
            <sequence>
               <element ref="gml:LinearCS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="UserDefinedCS" type="gml:UserDefinedCSType"
substitutionGroup="gml:_CoordinateSystem"/>
   <!-- ================================================== -->
   <complexType name="UserDefinedCSType">
      <annotation>
         <documentation>A two- or three-dimensional coordinate system
that consists of any combination of coordinate axes not covered by any
other coordinate system type. An example is a multilinear coordinate
system which contains one coordinate axis that may have any 1-D shape
which has no intersections with itself. This non-straight axis is
supplemented by one or two straight axes to complete a 2 or 3
dimensional coordinate system. The non-straight axis is typically
incrementally straight or curved. A UserDefinedCS shall have two or
three usesAxis associations. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateSystemType"/>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="userDefinedCSRef" type="gml:UserDefinedCSRefType"
substitutionGroup="gml:coordinateSystemRef"/>
   <!-- ================================================== -->
   <complexType name="UserDefinedCSRefType">
      <annotation>
         <documentation>Association to a user-defined coordinate
system, either referencing or containing the definition of that
coordinate system. </documentation>
      </annotation>
```

```
      <complexContent>
         <restriction base="gml:CoordinateSystemRefType">
            <sequence>
               <element ref="gml:UserDefinedCS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="SphericalCS" type="gml:SphericalCSType"
substitutionGroup="gml:_CoordinateSystem"/>
   <!-- ================================================== -->
   <complexType name="SphericalCSType">
      <annotation>
         <documentation>A three-dimensional coordinate system with one
distance measured from the origin and two angular coordinates. Not to
be confused with an ellipsoidal coordinate system based on an ellipsoid
"degenerated" into a sphere. A SphericalCS shall have three usesAxis
associations. </documentation>
      </annotation>
      <complexContent>

         <extension base="gml:AbstractCoordinateSystemType"/>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="sphericalCSRef" type="gml:SphericalCSRefType"
substitutionGroup="gml:coordinateSystemRef"/>
   <!-- ================================================== -->
   <complexType name="SphericalCSRefType">
      <annotation>
         <documentation>Association to a spherical coordinate system,
either referencing or containing the definition of that coordinate
system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateSystemRefType">
            <sequence>
               <element ref="gml:SphericalCS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="PolarCS" type="gml:PolarCSType"
substitutionGroup="gml:_CoordinateSystem"/>
   <!-- ================================================== -->
   <complexType name="PolarCSType">
      <annotation>
         <documentation>A two-dimensional coordinate system in which
position is specified by the distance from the origin and the angle
between the line from the origin to a point and a reference direction.
A PolarCS shall have two usesAxis associations. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateSystemType"/>
```

```
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="polarCSRef" type="gml:PolarCSRefType"
substitutionGroup="gml:coordinateSystemRef"/>
   <!-- ================================================== -->
   <complexType name="PolarCSRefType">
      <annotation>
         <documentation>Association to a polar coordinate system,
either referencing or containing the definition of that coordinate
system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateSystemRefType">
            <sequence>
               <element ref="gml:PolarCS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="CylindricalCS" type="gml:CylindricalCSType"
substitutionGroup="gml:_CoordinateSystem"/>
   <!-- ================================================== -->
   <complexType name="CylindricalCSType">
      <annotation>
         <documentation>A three-dimensional coordinate system
consisting of a polar coordinate system extended by a straight
coordinate axis perpendicular to the plane spanned by the polar
coordinate system. A CylindricalCS shall have three usesAxis
associations. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateSystemType"/>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="cylindricalCSRef" type="gml:CylindricalCSRefType"
substitutionGroup="gml:coordinateSystemRef"/>
   <!-- ================================================== -->
   <complexType name="CylindricalCSRefType">
      <annotation>
         <documentation>Association to a cylindrical coordinate system,
either referencing or containing the definition of that coordinate
system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateSystemRefType">
            <sequence>
               <element ref="gml:CylindricalCS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
```

```
   <element name="ObliqueCartesianCS" type="gml:ObliqueCartesianCSType"
substitutionGroup="gml:_CoordinateSystem"/>
   <!-- ================================================== -->
   <complexType name="ObliqueCartesianCSType">
      <annotation>
         <documentation>A two- or three-dimensional coordinate system
with straight axes that are not necessarily orthogonal. An
ObliqueCartesianCS shall have two or three usesAxis associations.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateSystemType"/>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="obliqueCartesianCSRef"
type="gml:ObliqueCartesianCSRefType"
substitutionGroup="gml:coordinateSystemRef"/>
   <!-- ================================================== -->
   <complexType name="ObliqueCartesianCSRefType">
      <annotation>
         <documentation>Association to an oblique-Cartesian coordinate
system, either referencing or containing the definition of that
coordinate system. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateSystemRefType">
            <sequence>
               <element ref="gml:ObliqueCartesianCS" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
</schema>
```

C.6 XML schema for coordinate operations encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/gml"
xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:gml="http://www.opengis.net/gml" elementFormDefault="qualified"
version="3.1.0" xml:lang="en">
   <annotation>
      <appinfo source="urn:opengis:specification:gml:schema-
coordinateOperations"/>
      <documentation>
         <name>coordinateOperations.xsd</name>
         <version>3.1.0</version>
         <scope>How to encode coordinate operation definitions.
</scope>
         <description>Builds on referenceSystems.xsd to encode the data
needed to define coordinate operations, including Transformations,
Conversions, and other specific subtypes of operations. Primary editor:
Arliss Whiteside. Last updated 2003/10/16. </description>
```

```
         <copyright>Copyright (c) 2002-2003 OpenGIS, All Rights
Reserved.</copyright>
         <conformance>This schema encodes the Coordinate Operation
(CC_) package of the extended UML Model for OGC Abstract Specification
Topic 2: Spatial Referencing by Coordinates. That UML model is adapted
from ISO 19111 - Spatial referencing by coordinates, as described in
Annex C of Topic 2. </conformance>
      </documentation>
   </annotation>
   <!-- ======================================================
       includes and imports
   ====================================================== -->
   <include schemaLocation="coordinateReferenceSystems.xsd"/>
   <include schemaLocation="dataQuality.xsd"/>
   <!-- ======================================================
       elements and types
   ====================================================== -->
   <element name="_CoordinateOperation"
type="gml:AbstractCoordinateOperationType" abstract="true"
substitutionGroup="gml:Definition"/>
   <!-- ====================================================== -->
   <complexType name="AbstractCoordinateOperationBaseType"
abstract="true">
      <annotation>
         <documentation>Basic encoding for coordinate operation
objects, simplifying and restricting the DefinitionType as needed.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DefinitionType">
            <sequence>
               <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:remarks" minOccurs="0">
                  <annotation>
                     <documentation>Comments on or information about
this coordinate operation, including source information.
</documentation>
                  </annotation>
               </element>
               <element ref="gml:coordinateOperationName"/>
            </sequence>
            <attribute ref="gml:id" use="required"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ====================================================== -->
   <element name="coordinateOperationName" type="gml:SimpleNameType"
substitutionGroup="gml:name">
      <annotation>
         <documentation>The name by which this coordinate operation is
identified. </documentation>
      </annotation>
   </element>
   <!-- ====================================================== -->
   <complexType name="AbstractCoordinateOperationType" abstract="true">
      <annotation>
```

```
         <documentation>A mathematical operation on coordinates that
transforms or converts coordinates to another coordinate reference
system. Many but not all coordinate operations (from CRS A to CRS B)
also uniquely define the inverse operation (from CRS B to CRS A). In
some cases, the operation method algorithm for the inverse operation is
the same as for the forward algorithm, but the signs of some operation
parameter values must be reversed. In other cases, different algorithms
are required for the forward and inverse operations, but the same
operation parameter values are used. If (some) entirely different
parameter values are needed, a different coordinate operation shall be
defined.</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateOperationBaseType">
            <sequence>
               <element ref="gml:coordinateOperationID" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Set of alternative identifications
of this coordinate operation. The first coordinateOperationID, if any,
is normally the primary identification code, and any others are
aliases. </documentation>
                  </annotation>
               </element>
               <element ref="gml:operationVersion" minOccurs="0"/>
               <element ref="gml:validArea" minOccurs="0"/>
               <element ref="gml:scope" minOccurs="0"/>
               <element ref="gml:_positionalAccuracy" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Unordered set of estimates of the
impact of this coordinate operation on point position accuracy. Gives
position error estimates for target coordinates of this coordinate
operation, assuming no errors in source coordinates. </documentation>
                  </annotation>
               </element>
               <element ref="gml:sourceCRS" minOccurs="0"/>
               <element ref="gml:targetCRS" minOccurs="0"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="coordinateOperationID" type="gml:IdentifierType">
      <annotation>
         <documentation>An identification of a coordinate operation.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="operationVersion" type="string">
      <annotation>
         <documentation>Version of the coordinate transformation (i.e.,
instantiation due to the stochastic nature of the parameters).
Mandatory when describing a transformation, and should not be supplied
for a conversion. </documentation>
      </annotation>
   </element>
```

```
   <!-- ================================================== -->
   <element name="sourceCRS" type="gml:CRSRefType">
      <annotation>
         <documentation>Association to the source CRS (coordinate
reference system) of this coordinate operation. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="targetCRS" type="gml:CRSRefType">
      <annotation>
         <documentation>Association to the target CRS (coordinate
reference system) of this coordinate operation. For constraints on
multiplicity of "sourceCRS" and "targetCRS", see UML model of
Coordinate Operation package in OGC Abstract Specification topic 2.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="coordinateOperationRef"
type="gml:CoordinateOperationRefType"
substitutionGroup="gml:dictionaryEntry"/>
   <!-- ================================================== -->
   <complexType name="CoordinateOperationRefType">
      <annotation>
         <documentation>Association to a coordinate operation, either
referencing or containing the definition of that coordinate operation.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DictionaryEntryType">
            <sequence>
               <element ref="gml:_CoordinateOperation" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="ConcatenatedOperation"
type="gml:ConcatenatedOperationType"
substitutionGroup="gml:_CoordinateOperation"/>
   <!-- ================================================== -->
   <complexType name="ConcatenatedOperationType">
      <annotation>
         <documentation>An ordered sequence of two or more single
coordinate operations. The sequence of operations is constrained by the
requirement that the source coordinate reference system of step (n+1)
must be the same as the target coordinate reference system of step (n).
The source coordinate reference system of the first step and the target
coordinate reference system of the last step are the source and target
coordinate reference system associated with the concatenated operation.
Instead of a forward operation, an inverse operation may be used for
one or more of the operation steps mentioned above, if the inverse
operation is uniquely defined by the forward operation.</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateOperationType">
```

```
            <sequence>
               <element ref="gml:usesSingleOperation" minOccurs="2"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Ordered sequence of associations to
the two or more single operations used by this concatenated operation.
</documentation>
                  </annotation>
               </element>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="usesSingleOperation"
type="gml:SingleOperationRefType">
      <annotation>
         <documentation>Association to a single operation.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="concatenatedOperationRef"
type="gml:ConcatenatedOperationRefType"
substitutionGroup="gml:coordinateOperationRef"/>
   <!-- ================================================== -->
   <complexType name="ConcatenatedOperationRefType">
      <annotation>
         <documentation>Association to a concatenated operation, either
referencing or containing the definition of that concatenated
operation. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateOperationRefType">
            <sequence>
               <element ref="gml:ConcatenatedOperation" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="_SingleOperation"
type="gml:AbstractSingleOperationType" abstract="true"
substitutionGroup="gml:_CoordinateOperation"/>
   <!-- ================================================== -->
   <complexType name="AbstractSingleOperationType" abstract="true">
      <annotation>
         <documentation>A single (not concatenated) coordinate
operation. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractCoordinateOperationType"/>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="singleOperationRef" type="gml:SingleOperationRefType"
substitutionGroup="gml:coordinateOperationRef"/>
```

```
   <!-- ================================================= -->
   <complexType name="SingleOperationRefType">
      <annotation>
         <documentation>Association to a single operation, either
referencing or containing the definition of that single operation.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:CoordinateOperationRefType">

                     <sequence>
               <element ref="gml:_SingleOperation" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================= -->
   <element name="PassThroughOperation"
type="gml:PassThroughOperationType"
substitutionGroup="gml:_SingleOperation"/>
   <!-- ================================================= -->
   <complexType name="PassThroughOperationType">
      <annotation>
         <documentation>A pass-through operation specifies that a
subset of a coordinate tuple is subject to a specific coordinate
operation. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractSingleOperationType">
            <sequence>
               <element ref="gml:modifiedCoordinate"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Ordered sequence of positive
integers defining the positions in a coordinate tuple of the
coordinates affected by this pass-through operation. </documentation>
                  </annotation>
               </element>
               <element ref="gml:usesOperation"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================= -->
   <element name="modifiedCoordinate" type="positiveInteger">
      <annotation>
         <documentation>A positive integer defining a position in a
coordinate tuple. </documentation>
      </annotation>
   </element>
   <!-- ================================================= -->
   <element name="usesOperation" type="gml:OperationRefType">
      <annotation>
         <documentation>Association to the operation applied to the
specified ordinates. </documentation>
      </annotation>
```

```
   </element>
   <!-- ================================================== -->
   <element name="passThroughOperationRef"
type="gml:PassThroughOperationRefType"
substitutionGroup="gml:singleOperationRef"/>
   <!-- ================================================== -->
   <complexType name="PassThroughOperationRefType">
      <annotation>
         <documentation>Association to a pass through operation, either
referencing or containing the definition of that pass through
operation. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:SingleOperationRefType">
            <sequence>
               <element ref="gml:PassThroughOperation" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="_Operation" type="gml:AbstractOperationType"
abstract="true" substitutionGroup="gml:_SingleOperation"/>
   <!-- ================================================== -->
   <complexType name="AbstractOperationType" abstract="true">
      <annotation>
         <documentation>A parameterized mathematical operation on
coordinates that transforms or converts coordinates to another
coordinate reference system. This coordinate operation uses an
operation method, usually with associated parameter values. However,
operation methods and parameter values are directly associated with
concrete subtypes, not with this abstract type.

This abstract complexType shall not be directly used, extended, or
restricted in a compliant Application Schema. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractSingleOperationType"/>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="operationRef" type="gml:OperationRefType"
substitutionGroup="gml:singleOperationRef"/>
   <!-- ================================================== -->
   <complexType name="OperationRefType">
      <annotation>
         <documentation>Association to an abstract operation, either
referencing or containing the definition of that operation.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:SingleOperationRefType">
            <sequence>
               <element ref="gml:_Operation" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
```

```
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="_GeneralConversion"
type="gml:AbstractGeneralConversionType" abstract="true"
substitutionGroup="gml:_Operation"/>
   <!-- ================================================== -->
   <complexType name="AbstractGeneralConversionType" abstract="true">
      <annotation>
         <documentation>An abstract operation on coordinates that does
not include any change of datum. The best-known example of a coordinate
conversion is a map projection. The parameters describing coordinate
conversions are defined rather than empirically derived. Note that some
conversions have no parameters.

This abstract complexType is expected to be extended for well-known
operation methods with many Conversion instances, in Application
Schemas that define operation-method-specialized element names and
contents. This conversion uses an operation method, usually with
associated parameter values. However, operation methods and parameter
values are directly associated with concrete subtypes, not with this
abstract type. All concrete types derived from this type shall extend
this type to include a "usesMethod" element that references the
"OperationMethod" element. Similarly, all concrete types derived from
this type shall extend this type to include zero or more elements each
named "uses...Value" that each use the type of an element substitutable
for the "_generalParameterValue" element. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:AbstractOperationType">
            <sequence>
               <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:remarks" minOccurs="0"/>
               <element ref="gml:coordinateOperationName"/>
               <element ref="gml:coordinateOperationID" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:validArea" minOccurs="0"/>
               <element ref="gml:scope" minOccurs="0"/>
               <element ref="gml:_positionalAccuracy" minOccurs="0"
maxOccurs="unbounded"/>
            </sequence>
            <attribute ref="gml:id" use="required"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="generalConversionRef"
type="gml:GeneralConversionRefType"
substitutionGroup="gml:operationRef"/>
   <!-- ================================================== -->
   <complexType name="GeneralConversionRefType">
      <annotation>
         <documentation>Association to a general conversion, either
referencing or containing the definition of that conversion.
</documentation>
```

```
      </annotation>
      <complexContent>
         <restriction base="gml:OperationRefType">
            <sequence>
               <element ref="gml:_GeneralConversion" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="Conversion" type="gml:ConversionType"
substitutionGroup="gml:_GeneralConversion"/>
   <!-- ================================================== -->
   <complexType name="ConversionType">
      <annotation>
         <documentation>A concrete operation on coordinates that does
not include any change of Datum. The best-known example of a coordinate
conversion is a map projection. The parameters describing coordinate
conversions are defined rather than empirically derived. Note that some
conversions have no parameters.

This concrete complexType can be used with all operation methods,
without using an Application Schema that defines operation-method-
specialized element names and contents, especially for methods with
only one Conversion instance. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralConversionType">
            <sequence>
               <element ref="gml:usesMethod"/>
               <element ref="gml:usesValue" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Unordered list of composition
associations to the set of parameter values used by this conversion
operation. </documentation>
                  </annotation>
               </element>
            </sequence>
         </extension>
      </complexContent>

   </complexType>
   <!-- ================================================== -->
   <element name="usesMethod" type="gml:OperationMethodRefType">
      <annotation>
         <documentation>Association to the operation method used by
this coordinate operation. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesValue" type="gml:ParameterValueType">
      <annotation>
         <documentation>Composition association to a parameter value
used by this coordinate operation. </documentation>
      </annotation>
   </element>
```

```
   <!-- ================================================== -->
   <element name="conversionRef" type="gml:ConversionRefType"
substitutionGroup="gml:generalConversionRef"/>
   <!-- ================================================== -->
   <complexType name="ConversionRefType">
      <annotation>
         <documentation>Association to a concrete general-purpose
conversion, either referencing or containing the definition of that
conversion. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:GeneralConversionRefType">
            <sequence>
               <element ref="gml:Conversion" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="_GeneralTransformation"
type="gml:AbstractGeneralTransformationType" abstract="true"
substitutionGroup="gml:_Operation"/>
   <!-- ================================================== -->
   <complexType name="AbstractGeneralTransformationType"
abstract="true">
      <annotation>
         <documentation>An abstract operation on coordinates that
usually includes a change of Datum. The parameters of a coordinate
transformation are empirically derived from data containing the
coordinates of a series of points in both coordinate reference systems.
This computational process is usually "over-determined", allowing
derivation of error (or accuracy) estimates for the transformation.
Also, the stochastic nature of the parameters may result in multiple
(different) versions of the same coordinate transformation.

This abstract complexType is expected to be extended for well-known
operation methods with many Transformation instances, in Application
Schemas that define operation-method-specialized value element names
and contents. This transformation uses an operation method with
associated parameter values. However, operation methods and parameter
values are directly associated with concrete subtypes, not with this
abstract type. All concrete types derived from this type shall extend
this type to include a "usesMethod" element that references one
"OperationMethod" element. Similarly, all concrete types derived from
this type shall extend this type to include one or more elements each
named "uses...Value" that each use the type of an element substitutable
for the "_generalParameterValue" element. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:AbstractOperationType">
            <sequence>
               <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:remarks" minOccurs="0"/>
               <element ref="gml:coordinateOperationName"/>
```

```
               <element ref="gml:coordinateOperationID" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:operationVersion"/>
               <element ref="gml:validArea" minOccurs="0"/>
               <element ref="gml:scope" minOccurs="0"/>
               <element ref="gml:_positionalAccuracy" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:sourceCRS"/>
               <element ref="gml:targetCRS"/>
            </sequence>
            <attribute ref="gml:id" use="required"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="generalTransformationRef"
type="gml:GeneralTransformationRefType"
substitutionGroup="gml:operationRef"/>
   <!-- ================================================== -->
   <complexType name="GeneralTransformationRefType">
      <annotation>
         <documentation>Association to a general transformation, either
referencing or containing the definition of that transformation.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:OperationRefType">
            <sequence>
               <element ref="gml:_GeneralTransformation"
minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="Transformation" type="gml:TransformationType"
substitutionGroup="gml:_GeneralTransformation"/>
   <!-- ================================================== -->
   <complexType name="TransformationType">
      <annotation>
         <documentation>A concrete operation on coordinates that
usually includes a change of datum. The parameters of a coordinate
transformation are empirically derived from data containing the
coordinates of a series of points in both coordinate reference systems.
This computational process is usually "over-determined", allowing
derivation of error (or accuracy) estimates for the transformation.
Also, the stochastic nature of the parameters may result in multiple
(different) versions of the same coordinate transformation.

This concrete complexType can be used for all operation methods,
without using an Application Schema that defines operation-method-
specialized element names and contents, especially for methods with
only one Transformation instance. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralTransformationType">
            <sequence>
```

```
               <element ref="gml:usesMethod"/>
               <element ref="gml:usesValue" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>

                     <documentation>Unordered set of composition
associations to the set of parameter values used by this transformation
operation. </documentation>
                  </annotation>
               </element>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="transformationRef" type="gml:TransformationRefType"
substitutionGroup="gml:generalTransformationRef"/>
   <!-- ================================================== -->
   <complexType name="TransformationRefType">
      <annotation>
         <documentation>Association to a transformation, either
referencing or containing the definition of that transformation.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:GeneralTransformationRefType">
            <sequence>
               <element ref="gml:Transformation" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="_generalParameterValue"
type="gml:AbstractGeneralParameterValueType" abstract="true"/>
   <!-- ================================================== -->
   <complexType name="AbstractGeneralParameterValueType"
abstract="true">
      <annotation>
         <documentation>Abstract parameter value or group of parameter
values.

This abstract complexType is expected to be extended and restricted for
well-known operation methods with many instances, in Application
Schemas that define operation-method-specialized element names and
contents. Specific parameter value elements are directly contained in
concrete subtypes, not in this abstract type. All concrete types
derived from this type shall extend this type to include one "...Value"
element with an appropriate type, which should be one of the element
types allowed in the ParameterValueType. In addition, all derived
concrete types shall extend this type to include a "valueOfParameter"
element that references one element substitutable for the
"OperationParameter" element. </documentation>
      </annotation>
      <sequence/>
```

```
   </complexType>
   <!-- ================================================== -->
   <element name="parameterValue" type="gml:ParameterValueType"
substitutionGroup="gml:_generalParameterValue"/>
   <!-- ================================================== -->
   <complexType name="ParameterValueType">
      <annotation>
         <documentation>A parameter value, ordered sequence of values,
or reference to a file of parameter values. This concrete complexType
can be used for operation methods without using an Application Schema
that defines operation-method-specialized element names and contents,
especially for methods with only one instance. This complexType can be
used, extended, or restricted for well-known operation methods,
especially for methods with many instances. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <choice>
                  <element ref="gml:value"/>
                  <element ref="gml:dmsAngleValue"/>
                  <element ref="gml:stringValue"/>
                  <element ref="gml:integerValue"/>
                  <element ref="gml:booleanValue"/>
                  <element ref="gml:valueList"/>
                  <element ref="gml:integerValueList"/>
                  <element ref="gml:valueFile"/>
               </choice>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="value" type="gml:MeasureType">
      <annotation>
         <documentation>Numeric value of an operation parameter, with
its associated unit of measure. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="dmsAngleValue" type="gml:DMSAngleType">
      <annotation>
         <documentation>Value of an angle operation parameter, in
either degree-minute-second format or single value format.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="stringValue" type="string">
      <annotation>
         <documentation>String value of an operation parameter. A
string value does not have an associated unit of measure.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="integerValue" type="positiveInteger">
```

```
      <annotation>
         <documentation>Positive integer value of an operation
parameter, usually used for a count. An integer value does not have an
associated unit of measure. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="booleanValue" type="boolean">
      <annotation>
         <documentation>Boolean value of an operation parameter. A
Boolean value does not have an associated unit of measure.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="valueList" type="gml:MeasureListType">
      <annotation>
         <documentation>Ordered sequence of two or more numeric values
of an operation parameter list, where each value has the same
associated unit of measure. An element of this type contains a space-
separated sequence of double values. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="integerValueList" type="gml:integerList">
      <annotation>
         <documentation>Ordered sequence of two or more integer values
of an operation parameter list, usually used for counts. These integer
values do not have an associated unit of measure. An element of this
type contains a space-separated sequence of integer values.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="valueFile" type="anyURI">
      <annotation>
         <documentation>Reference to a file or a part of a file
containing one or more parameter values, each numeric value with its
associated unit of measure. When referencing a part of a file, that
file must contain multiple identified parts, such as an XML encoded
document. Furthermore, the referenced file or part of a file can
reference another part of the same or different files, as allowed in
XML documents. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="valueOfParameter"
type="gml:OperationParameterRefType">
      <annotation>
         <documentation>Association to the operation parameter that
this is a value of. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <!-- ================================================== -->
```

```
   <element name="parameterValueGroup"
type="gml:ParameterValueGroupType"
substitutionGroup="gml:_generalParameterValue"/>
   <!-- ================================================== -->
   <complexType name="ParameterValueGroupType">
      <annotation>
         <documentation>A group of related parameter values. The same
group can be repeated more than once in a Conversion, Transformation,
or higher level parameterValueGroup, if those instances contain
different values of one or more parameterValues which suitably
distinquish among those groups. This concrete complexType can be used
for operation methods without using an Application Schema that defines
operation-method-specialized element names and contents, especially for
methods with only one instance. This complexType can be used, extended,
or restricted for well-known operation methods, especially for methods
with many instances. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="gml:includesValue" minOccurs="2"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Unordered set of composition
associations to the parameter values and groups of values included in
this group. </documentation>
                  </annotation>
               </element>
               <element ref="gml:valuesOfGroup"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="includesValue"
type="gml:AbstractGeneralParameterValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>A composition association to a parameter value
or group of values included in this group. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="valuesOfGroup"
type="gml:OperationParameterGroupRefType">
      <annotation>
         <documentation>Association to the operation parameter group
for which this element provides parameter values. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="OperationMethod" type="gml:OperationMethodType"
substitutionGroup="gml:Definition"/>
   <!-- ================================================== -->
   <complexType name="OperationMethodBaseType" abstract="true">
      <annotation>
```

```
         <documentation>Basic encoding for operation method objects,
simplifying and restricting the DefinitionType as needed.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DefinitionType">
            <sequence>
               <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:remarks" minOccurs="0">
                  <annotation>
                     <documentation>Comments on or information about
this operation method, including source information.</documentation>
                  </annotation>
               </element>
               <element ref="gml:methodName"/>
            </sequence>
            <attribute ref="gml:id" use="required"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="methodName" type="gml:SimpleNameType"
substitutionGroup="gml:name">
      <annotation>
         <documentation>The name by which this operation method is
identified. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <complexType name="OperationMethodType">
      <annotation>
         <documentation>Definition of an algorithm used to perform a
coordinate operation. Most operation methods use a number of operation
parameters, although some coordinate conversions use none. Each
coordinate operation using the method assigns values to these
parameters. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:OperationMethodBaseType">
            <sequence>
               <element ref="gml:methodID" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Set of alternative identifications
of this operation method. The first methodID, if any, is normally the
primary identification code, and any others are aliases.
</documentation>
                  </annotation>
               </element>
               <element ref="gml:methodFormula"/>
               <element ref="gml:sourceDimensions"/>
               <element ref="gml:targetDimensions"/>
               <element ref="gml:usesParameter" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>
```

```
                    <documentation>Unordered list of associations to
the set of operation parameters and parameter groups used by this
operation method. </documentation>
                  </annotation>
               </element>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ==================================================== -->
   <element name="methodID" type="gml:IdentifierType">
      <annotation>
         <documentation>An identification of an operation method.
</documentation>
      </annotation>
   </element>
   <!-- ==================================================== -->
   <element name="methodFormula" type="gml:CodeType">
      <annotation>
         <documentation>Formula(s) used by this operation method. The
value may be a reference to a publication. Note that the operation
method may not be analytic, in which case this element references or
contains the procedure, not an analytic formula.</documentation>
      </annotation>
   </element>
   <!-- ==================================================== -->
   <element name="sourceDimensions" type="positiveInteger">
      <annotation>
         <documentation>Number of dimensions in the source CRS of this
operation method. </documentation>
      </annotation>
   </element>
   <!-- ==================================================== -->
   <element name="targetDimensions" type="positiveInteger">
      <annotation>
         <documentation>Number of dimensions in the target CRS of this
operation method. </documentation>
      </annotation>
   </element>
   <!-- ==================================================== -->
   <element name="usesParameter"
type="gml:AbstractGeneralOperationParameterRefType">
      <annotation>
         <documentation>Association to an operation parameter or
parameter group used by this operation method. </documentation>
      </annotation>
   </element>
   <!-- ==================================================== -->
   <element name="operationMethodRef" type="gml:OperationMethodRefType"
substitutionGroup="gml:dictionaryEntry"/>
   <!-- ==================================================== -->
   <complexType name="OperationMethodRefType">
      <annotation>
         <documentation>Association to a concrete general-purpose
operation method, either referencing or containing the definition of
that method. </documentation>
      </annotation>
      <complexContent>
```

```
         <restriction base="gml:DictionaryEntryType">
            <sequence>
               <element ref="gml:OperationMethod" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="_GeneralOperationParameter"
type="gml:AbstractGeneralOperationParameterType" abstract="true"
substitutionGroup="gml:Definition"/>
   <!-- ================================================== -->
   <complexType name="AbstractGeneralOperationParameterType"
abstract="true">
      <annotation>
         <documentation>Abstract definition of a parameter or group of
parameters used by an operation method. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:DefinitionType">
            <sequence>
               <element ref="gml:minimumOccurs" minOccurs="0"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="minimumOccurs" type="nonNegativeInteger">
      <annotation>
         <documentation>The minimum number of times that values for
this parameter group or parameter are required. If this attribute is
omitted, the minimum number is one. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="abstractGeneralOperationParameterRef"
type="gml:AbstractGeneralOperationParameterRefType"
substitutionGroup="gml:dictionaryEntry"/>
   <!-- ================================================== -->
   <complexType name="AbstractGeneralOperationParameterRefType">
      <annotation>
         <documentation>Association to an operation parameter or group,
either referencing or containing the definition of that parameter or
group. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:DictionaryEntryType">
            <sequence>
               <element ref="gml:_GeneralOperationParameter"
minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
```

```
   <!-- ================================================= -->
   <element name="OperationParameter" type="gml:OperationParameterType"
substitutionGroup="gml:_GeneralOperationParameter"/>
   <!-- ================================================= -->
   <complexType name="OperationParameterBaseType" abstract="true">
      <annotation>
         <documentation>Basic encoding for operation parameter objects,
simplifying and restricting the DefinitionType as needed.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:AbstractGeneralOperationParameterType">
            <sequence>
               <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:remarks" minOccurs="0">
                  <annotation>
                     <documentation>Comments on or information about
this operation parameter, including source information.
</documentation>
                  </annotation>
               </element>
               <element ref="gml:parameterName"/>
               <element ref="gml:minimumOccurs" minOccurs="0"/>
            </sequence>
            <attribute ref="gml:id" use="required"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================= -->
   <element name="parameterName" type="gml:SimpleNameType"
substitutionGroup="gml:name">
      <annotation>
         <documentation>The name by which this operation parameter is
identified. </documentation>
      </annotation>
   </element>
   <!-- ================================================= -->
   <complexType name="OperationParameterType">
      <annotation>
         <documentation>The definition of a parameter used by an
operation method. Most parameter values are numeric, but other types of
parameter values are possible. This complexType is expected to be used
or extended for all operation methods, without defining operation-
method-specialized element names.  </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:OperationParameterBaseType">
            <sequence>
               <element ref="gml:parameterID" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Set of alternative identifications
of this operation parameter. The first parameterID, if any, is normally
the primary identification code, and any others are aliases.
</documentation>
                  </annotation>
               </element>
```

```
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="parameterID" type="gml:IdentifierType">
      <annotation>
         <documentation>An identification of an operation parameter.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="operationParameterRef"
type="gml:OperationParameterRefType"/>
   <!-- ================================================== -->
   <complexType name="OperationParameterRefType">
      <annotation>
         <documentation>Association to an operation parameter, either
referencing or containing the definition of that parameter.
</documentation>
      </annotation>
      <complexContent>
         <restriction
base="gml:AbstractGeneralOperationParameterRefType">
            <sequence>
               <element ref="gml:OperationParameter" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="OperationParameterGroup"
type="gml:OperationParameterGroupType"
substitutionGroup="gml:_GeneralOperationParameter"/>
   <!-- ================================================== -->
   <complexType name="OperationParameterGroupBaseType" abstract="true">
      <annotation>
         <documentation>Basic encoding for operation parameter group
objects, simplifying and restricting the DefinitionType as needed.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:AbstractGeneralOperationParameterType">
            <sequence>
               <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
               <element ref="gml:remarks" minOccurs="0">
                  <annotation>
                     <documentation>Comments on or information about
this operation parameter group, including source information.
</documentation>
                  </annotation>
               </element>
               <element ref="gml:groupName"/>
               <element ref="gml:minimumOccurs" minOccurs="0"/>
            </sequence>
```

```
            <attribute ref="gml:id" use="required"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="groupName" type="gml:SimpleNameType"
substitutionGroup="gml:name">
      <annotation>
         <documentation>The name by which this operation parameter
group is identified. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <complexType name="OperationParameterGroupType">
      <annotation>
         <documentation>The definition of a group of parameters used by
an operation method. This complexType is expected to be used or
extended for all applicable operation methods, without defining
operation-method-specialized element names.  </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:OperationParameterGroupBaseType">
            <sequence>
               <element ref="gml:groupID" minOccurs="0"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Set of alternative identifications
of this operation parameter group. The first groupID, if any, is
normally the primary identification code, and any others are aliases.
</documentation>
                  </annotation>
               </element>
               <element ref="gml:maximumOccurs" minOccurs="0"/>
               <element ref="gml:includesParameter" minOccurs="2"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Unordered list of associations to
the set of operation parameters that are members of this group.
</documentation>
                  </annotation>
               </element>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="groupID" type="gml:IdentifierType">
      <annotation>
         <documentation>An identification of an operation parameter
group. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="maximumOccurs" type="positiveInteger">
      <annotation>
         <documentation>The maximum number of times that values for
this parameter group can be included. If this attribute is omitted, the
maximum number is one. </documentation>
```

```
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesParameter"
type="gml:AbstractGeneralOperationParameterRefType">
      <annotation>
         <documentation>Association to an operation parameter that is a
member of a group. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="operationParameterGroupRef"
type="gml:OperationParameterRefType"/>
   <!-- ================================================== -->
   <complexType name="OperationParameterGroupRefType">
      <annotation>
         <documentation>Association to an operation parameter, either
referencing or containing the definition of that parameter.
</documentation>
      </annotation>
      <complexContent>
         <restriction
base="gml:AbstractGeneralOperationParameterRefType">
            <sequence>
               <element ref="gml:OperationParameterGroup"
minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
</schema>
```

C.7 XML schema for data quality encoding

```
<?xml version="1.0" encoding="UTF-8"?>
<!-- edited with XML Spy v4.4 U (http://www.xmlspy.com) by Arliss J
Whiteside (BAE Systems) -->
<schema targetNamespace="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified"
version="3.1.0" xml:lang="en">
   <annotation>
      <appinfo source="urn:opengis:specification:gml:schema-
dataQuality"/>
      <documentation>
         <name>dataQuality.xsd</name>
         <version>3.1.0</version>
         <scope>How to encode positional data quality information.
</scope>
         <description>Builds on units.xsd to encode the data needed to
describe the positional accuracy of coordinate operations. Primary
editor: Arliss Whiteside. Last updated 2003/10/16. </description>
```

```
         <copyright>Copyright (c) 2002-2003 OpenGIS, All Rights
Reserved.</copyright>
         <conformance>This schema encodes the Data Quality (DQ) package
of the extended UML Model for OGC Abstract Specification Topic 2:
Spatial Referencing by Coordinates. That UML model is adapted from ISO
19111 - Spatial referencing by coordinates, as described in Annex C of
Topic 2. </conformance>
      </documentation>
   </annotation>
   <!-- ======================================================
       includes and imports
   ====================================================== -->
   <include schemaLocation="units.xsd"/>
   <!-- ======================================================
       elements and types
   ====================================================== -->
   <element name="_positionalAccuracy"
type="gml:AbstractPositionalAccuracyType" abstract="true"/>
   <!-- ====================================================== -->
   <complexType name="AbstractPositionalAccuracyType" abstract="true">
      <annotation>
         <documentation>Position error estimate (or accuracy) data.
</documentation>
      </annotation>
      <sequence>
         <element ref="gml:measureDescription" minOccurs="0"/>
      </sequence>
   </complexType>
   <!-- ====================================================== -->
   <element name="measureDescription" type="gml:CodeType">
      <annotation>
         <documentation>A description of the position accuracy
parameter(s) provided. </documentation>
      </annotation>
   </element>
   <!-- ====================================================== -->

   <element name="absoluteExternalPositionalAccuracy"
type="gml:AbsoluteExternalPositionalAccuracyType"
substitutionGroup="gml:_positionalAccuracy"/>
   <!-- ====================================================== -->
   <complexType name="AbsoluteExternalPositionalAccuracyType">
      <annotation>
         <documentation>Closeness of reported coordinate values to
values accepted as or being true. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractPositionalAccuracyType">
            <sequence>
               <element ref="gml:result"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ====================================================== -->
   <element name="relativeInternalPositionalAccuracy"
type="gml:RelativeInternalPositionalAccuracyType"
substitutionGroup="gml:_positionalAccuracy"/>
```

```
   <!-- ================================================== -->
   <complexType name="RelativeInternalPositionalAccuracyType">
      <annotation>
         <documentation>Closeness of the relative positions of two or
more positions to their respective relative positions accepted as or
being true. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractPositionalAccuracyType">
            <sequence>
               <element ref="gml:result"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="result" type="gml:MeasureType">
      <annotation>
         <documentation>A quantitative result defined by the evaluation
procedure used, and identified by the measureDescription.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="covarianceMatrix" type="gml:CovarianceMatrixType"
substitutionGroup="gml:_positionalAccuracy"/>
   <!-- ================================================== -->
   <complexType name="CovarianceMatrixType">
      <annotation>
         <documentation>Error estimate covariance matrix.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractPositionalAccuracyType">
            <sequence>
               <element ref="gml:unitOfMeasure" maxOccurs="unbounded">
                  <annotation>
                     <documentation>Ordered sequence of units of
measure, corresponding to the row and column index numbers of the
covariance matrix, starting with row and column 1 and ending with
row/column N. Each unit of measure is for the ordinate reflected in the
relevant row and column of the covariance matrix. </documentation>
                  </annotation>
               </element>
               <element ref="gml:includesElement"
maxOccurs="unbounded">
                  <annotation>
                     <documentation>Unordered set of elements in this
covariance matrix. Because the covariance matrix is symmetrical, only
the elements in the upper or lower diagonal part (including the main
diagonal) of the matrix need to be specified. Any zero valued
covariance elements can be omitted. </documentation>
                  </annotation>
               </element>
            </sequence>
         </extension>
      </complexContent>
```

```
   </complexType>
   <!-- ================================================== -->
   <element name="includesElement" type="gml:CovarianceElementType"/>
   <!-- ================================================== -->
   <complexType name="CovarianceElementType">
      <annotation>
         <documentation>An element of a covariance
matrix.</documentation>
      </annotation>
      <sequence>
         <element ref="gml:rowIndex"/>
         <element ref="gml:columnIndex"/>
         <element ref="gml:covariance"/>
      </sequence>
   </complexType>
   <!-- ================================================== -->
   <element name="rowIndex" type="positiveInteger">
      <annotation>
         <documentation>Row number of this covariance element value.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="columnIndex" type="positiveInteger">
      <annotation>
         <documentation>Column number of this covariance element value.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="covariance" type="double">
      <annotation>
         <documentation>Value of covariance matrix element.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
</schema>
```

Annex D
(informative)

Standard contents of code lists

D.1 Introduction

The XML Schemas specified in this document do not include definitions of the allowed values of the XML elements that encode the <<CodeList>> stereotyped classes specified in the UML model that was converted. Those XML elements are:

a) derivedCRSType, in coordinateReferenceSystems.xsd

b) pixelInCell, in datums.xsd

c) verticalDatumType, in datums.xsd

Those XML elements are each required to include a "codeSpace" attribute with type "anyURI". The value of that attribute must reference a source of information specifying the values and meanings of all the allowed string values for this element. An Application Schema is expected to specify such a source of information, and how that source shall be referenced, whenever that Application Schema uses an XML element converted from a <<CodeList>> stereotyped class.

This annex specifies the standard set of string values and their meanings for each of the three XML elements listed above. This annex first specifies one possible XML Schema for encoding a standard set of string values and their meanings in an XML document. That possible application schema is then used to record each of the three standard sets of string values and their meanings.

D.2 XML schema for code lists

An XML document can be used to encode all the allowed string values with their meanings for an XML element that encodes one <<CodeList>> stereotyped UML class. One possible XML Schema for encoding such a standard set of string values and their meanings is:

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/examples"
xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:ex="http://www.opengis.net/examples"
elementFormDefault="qualified" xml:lang="en">
   <annotation>
      <documentation>
         <name>codeListDictionary.xsd</name>
```

```
         <description>One possible GML Application Schema to XML encode
all the allowed string values and their meanings for an XML element
that encodes one CodeList stereotyped UML class. This schema encodes
the allowed string values and their meanings in a CodeListDictionary
that is based on gml:Dictionary. This GML Application Schema specifies
use of element names that are specialized for a CodeListDictionary, and
prohibits use of some gml:Dictionary elements that are not considered
useful in a CodeListDictionary. Primary editor: Arliss Whiteside. Last
updated 2003/09/18. </description>
      </documentation>
   </annotation>
   <!-- ======================================================
       includes and imports
   ====================================================== -->
   <import namespace="http://www.opengis.net/gml"
schemaLocation="../crsSchemas/base/dictionary.xsd"/>
   <!-- ======================================================
       elements and types
   ====================================================== -->
   <element name="CodeListDictionary"
substitutionGroup="gml:Dictionary">
      <annotation>
         <documentation>Encodes all allowed code values and their
meanings for an XML element that encodes one CodeList stereotyped UML
class. The gml:name element is used to encode one or more names for
this Code List Dictionary. The optional gml:description element can be
used to record a description of this Dictionary. The required gml:id
attribute allows this Dictionary to be referenced, if this Dictionary
is contained within another XML element. </documentation>
      </annotation>
      <complexType>
         <complexContent>
            <restriction base="gml:DictionaryType">
               <sequence>
                  <element ref="gml:description" minOccurs="0"/>
                  <element ref="gml:name" maxOccurs="unbounded"/>
                  <element ref="ex:codeEntry" maxOccurs="unbounded"/>
               </sequence>
               <attribute ref="gml:id" use="required"/>
            </restriction>
         </complexContent>
      </complexType>
   </element>
   <!-- ====================================================== -->
   <element name="codeEntry" substitutionGroup="gml:dictionaryEntry">
      <annotation>
         <documentation>Association to definition of one allowed code,
either including or referencing that code definition. For example, a
Code Definition in another Code List Dictionary can be referenced.
</documentation>
      </annotation>
      <complexType>
         <complexContent>
            <restriction base="gml:DictionaryEntryType">
               <sequence>
                  <element ref="ex:CodeDefinition" minOccurs="0"/>
               </sequence>
               <attributeGroup ref="gml:AssociationAttributeGroup"/>
```

```
            </restriction>
         </complexContent>
      </complexType>
   </element>
   <!-- ================================================== -->
   <element name="CodeDefinition" substitutionGroup="gml:Definition">
      <annotation>
         <documentation>Encodes one allowed code value with its
meaning. The gml:description is used to record the meaning of this
allowed code value, and is thus required. The required gml:id attribute
allows this Code Definition to be referenced by an anyURI value, if
this Code Definition is referenced from another Code List Dictionary,
or is directly referenced by a gml:CodeType. </documentation>
      </annotation>
      <complexType>
         <complexContent>
            <restriction base="gml:DefinitionType">
               <sequence>
                  <element ref="gml:description"/>
                  <element ref="ex:code" maxOccurs="unbounded"/>
               </sequence>
               <attribute ref="gml:id" use="required"/>
            </restriction>
         </complexContent>
      </complexType>
   </element>
   <!-- ================================================== -->
   <element name="code" type="gml:CodeType"
substitutionGroup="gml:name">
      <annotation>
         <documentation>Allowed value for the XML element to which this
dictionary applies. The string value is allowed to include embedded
spaces, as required for codes in Code Lists. The optional codeSpace
attribute can be omitted, or could contain the codeSpace value normally
used with this "code" string. </documentation>
      </annotation>
   </element>
</schema>
```

This XML Schema is written as a GML Application Schema that builds on GML 3, but uses a GML profile that includes only a small part of GML 3.

D.3 Standard contents of derivedCRSType

A standard set of allowed values and their meanings for the derivedCRSType element is specified in the <CodeList>> stereotyped class in the UML model that was converted. Those string values and their meanings are specified in the following UML document, using the XML Schema specified in Subclause D.2:

```
<?xml version="1.0" encoding="UTF-8"?>
<CodeListDictionary xmlns="http://www.opengis.net/examples"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
```

```
xsi:schemaLocation="http://www.opengis.net/ex codeListDictionary.xsd"
gml:id="derivedCRSType">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/07/08. -->
   <gml:description>Type of a derived coordinate reference system.
</gml:description>
   <gml:name>derivedCRSType</gml:name>
   <codeEntry>
      <CodeDefinition gml:id="engineering">
         <gml:description>A contextually local coordinate reference
system; which can be divided into two broad categories:
- earth-fixed systems applied to engineering activities on or near the
surface of the earth;
- CRSs on moving platforms such as road vehicles, vessels, aircraft, or
spacecraft. </gml:description>
         <code>engineering</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="image">
         <gml:description>An engineering coordinate reference system
applied to locations in images. </gml:description>
         <code>image</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="vertical">
         <gml:description>A coordinate reference system used for
recording of heights or depths. Vertical CRSs make use of the direction
of gravity to define the concept of height or depth, but the
relationship with gravity may not be straightforward.
</gml:description>
         <code>vertical</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="temporal">
         <gml:description>A coordinate reference system used for the
recording of time. </gml:description>
         <code>temporal</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="geographic">
         <gml:description>A coordinate reference system based on an
ellipsoidal approximation of the geoid; provides an accurate
representation of the geometry of geographic features for a large
portion of the earth's surface. </gml:description>
         <code>geographic</code>
      </CodeDefinition>
   </codeEntry>
</CodeListDictionary>
```

D.4 Standard contents of pixelInCell

A standard set of allowed values and their meanings for the pixelInCell element is specified in the <<CodeList>> stereotyped class in the UML model that was converted.

Those string values and their meanings are specified in the following UML document, using the XML Schema specified in Subclause D.2:

```
<?xml version="1.0" encoding="UTF-8"?>
<CodeListDictionary xmlns="http://www.opengis.net/examples"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/ex codeListDictionary.xsd"
gml:id="pixelInCell">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/06/27. -->
   <gml:description>Specification of the way the image grid is
associated with the image data attributes. </gml:description>
   <gml:name>pixelInCell</gml:name>
   <codeEntry>
      <CodeDefinition gml:id="cellCenter">
         <gml:description>The origin of the image coordinate system is
the center of a grid cell or image pixel. </gml:description>
         <code>cell center</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="cellCorner">
         <gml:description>The origin of the image coordinate system is
the corner of a grid cell, or half-way between the centres of adjacent
image pixel centres. </gml:description>
         <code>cell corner</code>
      </CodeDefinition>
   </codeEntry>
</CodeListDictionary>
```

D.5 Standard contents of verticalDatumType

A standard set of allowed values and their meanings for the verticalDatumType element is specified in the <<CodeList>> stereotyped class in the UML model that was converted. Those string values and their meanings are specified in the following UML document, using the XML Schema specified in Subclause D.2:

```
<?xml version="1.0" encoding="UTF-8"?>
<CodeListDictionary xmlns="http://www.opengis.net/examples"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/ex codeListDictionary.xsd"
gml:id="verticalDatumType">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/06/27. -->
   <gml:description>Type of a vertical datum.</gml:description>
   <gml:name>verticalDatumType</gml:name>
   <codeEntry>
      <CodeDefinition gml:id="geoidal">
         <gml:description>The zero value of the associated vertical
coordinate system axis is defined to approximate a constant potential
surface, usually the geoid. Such a reference surface is usually
```

```
determined by a national or scientific authority, and is then a well-
known, named datum. </gml:description>
         <code>geoidal</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="depth">
         <gml:description>The zero point of the vertical axis is
defined by a surface that has meaning for the purpose which the
associated vertical measurements are used for. For hydrographic charts,
this is often a predicted nominal sea surface (i.e. without waves or
other wind and current effects) that occurs at low tide. For some
examples, see OGC Abstract Specification Topic 2. </gml:description>
         <code>depth</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="barometric">
         <gml:description>Atmospheric pressure is the basis for the
definition of the origin of the associated vertical coordinate system
axis. For more information, see OGC Abstract Specification Topic 2.
</gml:description>
         <code>barometric</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="otherSurface">
         <gml:description>In some cases, e.g. oil exploration and
production, a geological feature, such as the top or bottom of a
geologically identifiable and meaningful subsurface layer, is used as a
vertical datum. Other variations to the above three vertical datum
types may exist and are all included in this type. </gml:description>
         <code>other surface</code>
      </CodeDefinition>
   </codeEntry>
</CodeListDictionary>
```

Annex E
(informative)

XML document examples

E.1 Introduction

This annex provides example XML documents using the XML schemas specified in this document. These examples include both identification and specification data for many geospatial entities. These XML examples omit some optional XML elements and attributes that might be included, and include some optional elements and attributes that might be omitted. This omission or inclusion was partially based on whether reasonable values were known for optional elements and attributes. The optional elements that are omitted in these examples XML include:

a) The “remarks” element in all IdentifierType and object elements.

b) The "scope" element in all elements that could include it.

Most of these XML examples assume that the XML Schemas specified in Annex C are accessible using the location coordinateReferenceSystems.xsd. These XML examples use patterns that are not specified in this document for values of the "gml:id", "gml:uom", "xlink:href", and "xlink:title" XML attributes.

EDITOR'S NOTE Some of the patterns now used for values of these attributes may be invalid or inappropriate. I urge reviewers to suggest any needed or desirable improvements.

NOTE For interoperability, the patterns or formats used for the values of these attributes must be specified somewhere, normally in or with an Application Schema. Use of an anyURI value with a form of urn:ogc:… assumes that the OGC has registered with IANA the ”ogc” part as a namespace authority in a URN. Until the ”ogc” or other value is so registered by the OGC, the “x-ogc” value should be used, where the “x” denotes an experimental namespace.

E.2 Example XML for geographic 2D coordinate reference system

This subclause provides an example XML document using the Coordinate Reference System subtype GeographicCRS XML element, with its’ contained elements, applied to a geographic 2D coordinate system. This example XML is applicable to the current low-level Coordinate Transformation (CT) Implementation Specification, document 01-009.

```
<?xml version="1.0" encoding="UTF-8"?>
<GeographicCRS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/gml
../crsSchemas/base/coordinateReferenceSystems.xsd" gml:id="EPSG4277">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/09/18. -->
   <srsName>OSGB 1936</srsName>
```

```
   <srsID>
      <name codeSpace="EPSG">4277</name>
      <version>6.0</version>
   </srsID>
   <validArea>
      <description>United Kingdom (UK) - Great Britain - England
Scotland Wales - onshore; Isle of Man. </description>
   </validArea>
   <usesEllipsoidalCS>
      <EllipsoidalCS gml:id="EPSG6402">
         <csName>ellipsoidal</csName>
         <csID>
            <name codeSpace="EPSG">6402</name>
            <version>6.0</version>
         </csID>
         <usesAxis>
            <CoordinateSystemAxis gml:id="EPSG9901"
gml:uom="urn:ogc:uom:degree">
               <axisName>Geodetic latitude</axisName>
               <axisID>
                  <name codeSpace="EPSG">9901</name>
                  <version>6.0</version>
               </axisID>
               <axisAbbrev>Lat</axisAbbrev>
               <axisDirection>north</axisDirection>
            </CoordinateSystemAxis>
         </usesAxis>
         <usesAxis>
            <CoordinateSystemAxis gml:id="EPSG9902"
gml:uom="urn:ogc:uom:degree">
               <axisName>Geodetic longitude</axisName>
               <axisID>
                  <name codeSpace="EPSG">9902</name>
                  <version>6.0</version>
               </axisID>
               <axisAbbrev>Lon</axisAbbrev>
               <axisDirection>east</axisDirection>
            </CoordinateSystemAxis>
         </usesAxis>
      </EllipsoidalCS>
   </usesEllipsoidalCS>
   <usesGeodeticDatum>
      <GeodeticDatum gml:id="EPSG6277">
         <datumName>OSGB 1936</datumName>
         <datumID>
            <name codeSpace="EPSG">6277</name>
            <version>6.0</version>
         </datumID>
         <usesPrimeMeridian>
            <PrimeMeridian gml:id="EPSG8901">
               <meridianName>Greenwich</meridianName>
               <meridianID>
                  <name codeSpace="EPSG">8901</name>
                  <version>6.0</version>
               </meridianID>
               <greenwichLongitude>
                  <angle uom="urn:ogc:uom:degree">0</angle>
               </greenwichLongitude>
```

```
            </PrimeMeridian>
         </usesPrimeMeridian>
         <usesEllipsoid>
            <Ellipsoid gml:id="EPSG7001">
               <ellipsoidName>Airy 1830</ellipsoidName>
               <ellipsoidID>
                  <name codeSpace="EPSG">7001</name>
                  <version>6.0</version>
               </ellipsoidID>
               <semiMajorAxis
uom="urn:ogc:uom:metre">6377563.396</semiMajorAxis>
               <secondDefiningParameter>
                  <inverseFlattening
uom="urn:ogc:uom:unity">299.3249646</inverseFlattening>
               </secondDefiningParameter>
            </Ellipsoid>
         </usesEllipsoid>
      </GeodeticDatum>
   </usesGeodeticDatum>
</GeographicCRS>
```

The above example XML just references the units urn:degree, urn:metre, and urn:unity (a scale factor unit). Definitions of those units can be included in the XML document by adding a Dictionary element in a metaDataProperty of this GeographicCRS. Such an expanded example XML document is:

```
<?xml version="1.0" encoding="UTF-8"?>
<GeographicCRS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/gml
../crsSchemas/base/coordinateReferenceSystems.xsd" gml:id="EPSG4277">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/09/18. -->
   <metaDataProperty>
      <GenericMetaData>
         <Dictionary gml:id="UnitsDictionary">
            <description>Units used in this XML document.</description>
            <name>Units Dictionary</name>
            <dictionaryEntry>
               <ConventionalUnit gml:id="degree">
                  <name>degree</name>
                  <name codeSpace="EPSG">9102</name>
                  <quantityType>angle</quantityType>
                  <conversionToPreferredUnit uom="#radian">
                     <factor>1.74532925199433E-02</factor>
                  </conversionToPreferredUnit>
               </ConventionalUnit>
            </dictionaryEntry>
            <dictionaryEntry>
               <BaseUnit gml:id="radian">
                  <name>radian</name>
                  <quantityType>angle</quantityType>
                  <unitsSystem xlink:href="urn:ToBeSupplied"/>
               </BaseUnit>
            </dictionaryEntry>
```

```
            <dictionaryEntry>
               <BaseUnit gml:id="metre">
                  <name>metre</name>
                  <name codeSpace="EPSG">9001</name>
                  <quantityType>length</quantityType>
                  <unitsSystem xlink:href="urn:SI"/>
               </BaseUnit>
            </dictionaryEntry>
            <dictionaryEntry>
               <BaseUnit gml:id="unity">
                  <name>unitless</name>
                  <quantityType>scale factor</quantityType>
                  <unitsSystem xlink:href="urn:ToBeSupplied"/>
               </BaseUnit>
            </dictionaryEntry>
         </Dictionary>
      </GenericMetaData>
   </metaDataProperty>
   <srsName>OSGB 1936</srsName>
   <srsID>
      <name codeSpace="EPSG">4277</name>
      <version>6.0</version>
   </srsID>
   <validArea>
      <description>United Kingdom (UK) - Great Britain - England
Scotland Wales - onshore; Isle of Man. </description>
   </validArea>
   <usesEllipsoidalCS>
      <EllipsoidalCS gml:id="EPSG6402">
         <csName>ellipsoidal</csName>
         <csID>
            <name codeSpace="EPSG">6402</name>
            <version>6.0</version>
         </csID>
         <usesAxis>
            <CoordinateSystemAxis gml:id="EPSG9901" gml:uom="#degree">
               <axisName>Geodetic latitude</axisName>
               <axisID>
                  <name codeSpace="EPSG">9901</name>
                  <version>6.0</version>
               </axisID>
               <axisAbbrev>Lat</axisAbbrev>
               <axisDirection>north</axisDirection>
            </CoordinateSystemAxis>
         </usesAxis>
         <usesAxis>
            <CoordinateSystemAxis gml:id="EPSG9902" gml:uom="#degree">
               <axisName>Geodetic longitude</axisName>
               <axisID>
                  <name codeSpace="EPSG">9902</name>
                  <version>6.0</version>
               </axisID>
               <axisAbbrev>Lon</axisAbbrev>
               <axisDirection>east</axisDirection>
            </CoordinateSystemAxis>
         </usesAxis>
      </EllipsoidalCS>
   </usesEllipsoidalCS>
```

```
   <usesGeodeticDatum>
      <GeodeticDatum gml:id="EPSG6277">
         <datumName>OSGB 1936</datumName>
         <datumID>
            <name codeSpace="EPSG">6277</name>
            <version>6.0</version>
         </datumID>
         <usesPrimeMeridian>
            <PrimeMeridian gml:id="EPSG8901">
               <meridianName>Greenwich</meridianName>
               <meridianID>
                  <name codeSpace="EPSG">8901</name>
                  <version>6.0</version>
               </meridianID>
               <greenwichLongitude>
                  <angle uom="#degree">0</angle>
               </greenwichLongitude>
            </PrimeMeridian>
         </usesPrimeMeridian>
         <usesEllipsoid>
            <Ellipsoid gml:id="EPSG7001">
               <ellipsoidName>Airy 1830</ellipsoidName>
               <ellipsoidID>
                  <name codeSpace="EPSG">7001</name>
                  <version>6.0</version>
               </ellipsoidID>
               <semiMajorAxis uom="#metre">6377563.396</semiMajorAxis>
               <secondDefiningParameter>
                  <inverseFlattening
uom="#unity">299.3249646</inverseFlattening>
               </secondDefiningParameter>
            </Ellipsoid>
         </usesEllipsoid>
      </GeodeticDatum>
   </usesGeodeticDatum>
</GeographicCRS>
```

E.3 Example XML for compound coordinate reference system

This subclause provides an example XML document using the Coordinate Reference System subtype CompoundCRS XML element, with its' contained elements, applied to a 3D compound coordinate reference system that combines a Projected and a Vertical CRS. Note that this Compound CRS Definition contains three other CRS definitions, for a Vertical CRS, a Geographic 2D CRS, and a Projected CRS.

```
<?xml version="1.0" encoding="UTF-8"?>
<CompoundCRS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/gml
../crsSchemas/base/coordinateReferenceSystems.xsd" gml:id="EPSG7405">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/09/18. -->
   <srsName>OSGB36 /British National Grid + ODN</srsName>
```

```
   <srsID>
      <name codeSpace="EPSG">7405</name>
      <version>6.0</version>
   </srsID>
   <validArea>
      <description>United Kingdom (UK) - Great Britain - England
Scotland Wales - onshore; Isle of Man. </description>
   </validArea>
   <includesCRS>
      <ProjectedCRS gml:id="EPSG27700">
         <srsName>OSGB 1936 / British National Grid</srsName>
         <srsID>
            <name codeSpace="EPSG">27700</name>
            <version>6.0</version>
         </srsID>
         <validArea>
            <description>United Kingdom (UK) - Great Britain - England
Scotland Wales - onshore; Isle of Man. </description>
         </validArea>
         <baseCRS>
            <GeographicCRS gml:id="EPSG4277">
               <srsName>OSGB 1936</srsName>
               <srsID>
                  <name codeSpace="EPSG">4277</name>
                  <version>6.0</version>
               </srsID>
               <validArea>
                  <description>United Kingdom (UK) - Great Britain -
England Scotland Wales - onshore; Isle of Man. </description>
               </validArea>
               <usesEllipsoidalCS>
                  <EllipsoidalCS gml:id="EPSG6402">
                     <csName>ellipsoidal</csName>
                     <csID>
                        <name codeSpace="EPSG">6402</name>
                        <version>6.0</version>
                     </csID>
                     <usesAxis>
                        <CoordinateSystemAxis gml:id="EPSG9901"
gml:uom="urn:degree">
                           <axisName>Geodetic latitude</axisName>
                           <axisID>
                              <name codeSpace="EPSG">9901</name>
                              <version>6.0</version>
                           </axisID>
                           <axisAbbrev>Lat</axisAbbrev>
                           <axisDirection>north</axisDirection>
                        </CoordinateSystemAxis>
                     </usesAxis>
                     <usesAxis>
                        <CoordinateSystemAxis gml:id="EPSG9902"
gml:uom="urn:degree">
                           <axisName>Geodetic longitude</axisName>
                           <axisID>
                              <name codeSpace="EPSG">9902</name>
                              <version>6.0</version>
                           </axisID>
                           <axisAbbrev>Lon</axisAbbrev>
```

```
                        <axisDirection>east</axisDirection>
                     </CoordinateSystemAxis>
                  </usesAxis>
               </EllipsoidalCS>
            </usesEllipsoidalCS>
            <usesGeodeticDatum>
               <GeodeticDatum gml:id="EPSG6277">
                  <datumName>OSGB 1936</datumName>
                  <datumID>
                     <name codeSpace="EPSG">6277</name>
                     <version>6.0</version>
                  </datumID>
                  <usesPrimeMeridian>
                     <PrimeMeridian gml:id="EPSG8901">
                        <meridianName>Greenwich</meridianName>
                        <meridianID>
                           <name codeSpace="EPSG">8901</name>
                           <version>6.0</version>
                        </meridianID>
                        <greenwichLongitude>
                           <angle uom="urn:degree">0</angle>
                        </greenwichLongitude>
                     </PrimeMeridian>
                  </usesPrimeMeridian>
                  <usesEllipsoid>
                     <Ellipsoid gml:id="EPSG7001">
                        <ellipsoidName>Airy 1830</ellipsoidName>
                        <ellipsoidID>
                           <name codeSpace="EPSG">7001</name>
                           <version>6.0</version>
                        </ellipsoidID>
                        <semiMajorAxis
uom="urn:metre">6377563.396</semiMajorAxis>
                        <secondDefiningParameter>
                           <inverseFlattening
uom="urn:unity">299.3249646</inverseFlattening>
                        </secondDefiningParameter>
                     </Ellipsoid>
                  </usesEllipsoid>
               </GeodeticDatum>
            </usesGeodeticDatum>
         </GeographicCRS>
      </baseCRS>
      <definedByConversion>
         <Conversion gml:id="EPSG19916">
            <coordinateOperationName>Transverse
Mercator</coordinateOperationName>
            <coordinateOperationID>
               <name codeSpace="EPSG">19916</name>
               <version>6.0</version>
            </coordinateOperationID>
            <usesMethod>
               <OperationMethod gml:id="EPSG9807">
                  <methodName>Transverse Mercator</methodName>
                  <methodID>
                     <name codeSpace="EPSG">9807</name>
                     <version>6.0</version>
```

```
                    </methodID>
                    <methodFormula>See Section 1.4.6 "Transverse
Mercator" of EPSG Guidance Note 7, December 2000. </methodFormula>
                    <sourceDimensions>2</sourceDimensions>
                    <targetDimensions>2</targetDimensions>
                    <usesParameter>
                       <OperationParameter gml:id="EPSG8801">
                          <parameterName>Latitude of natural
origin</parameterName>
                          <parameterID>
                             <name codeSpace="EPSG">8801</name>
                             <version>6.0</version>
                          </parameterID>
                       </OperationParameter>
                    </usesParameter>
                    <usesParameter>
                       <OperationParameter gml:id="EPSG8802">
                          <parameterName>Longitude of natural
origin</parameterName>
                          <parameterID>
                             <name codeSpace="EPSG">8802</name>
                             <version>6.0</version>
                          </parameterID>
                       </OperationParameter>
                    </usesParameter>
                    <usesParameter>
                       <OperationParameter gml:id="EPSG8805">
                          <parameterName>Scale factor at natural
origin</parameterName>
                          <parameterID>
                             <name codeSpace="EPSG">8805</name>
                             <version>6.0</version>
                          </parameterID>
                       </OperationParameter>
                    </usesParameter>
                    <usesParameter>
                       <OperationParameter gml:id="EPSG8806">
                          <parameterName>False Easting</parameterName>
                          <parameterID>
                             <name codeSpace="EPSG">8806</name>
                             <version>6.0</version>
                          </parameterID>
                       </OperationParameter>
                    </usesParameter>
                    <usesParameter>
                       <OperationParameter gml:id="EPSG8807">
                          <parameterName>False
Northing</parameterName>
                          <parameterID>
                             <name codeSpace="EPSG">8807</name>
                             <version>6.0</version>
                          </parameterID>
                       </OperationParameter>
                    </usesParameter>
                 </OperationMethod>
              </usesMethod>
              <usesValue>
                 <value uom="urn:degree">49</value>
```

```
                  <valueOfParameter xlink:href="#EPSG8801"
xlink:title="Latitude of natural origin"/>
               </usesValue>
               <usesValue>
                  <value uom="urn:degree">-2</value>
                  <valueOfParameter xlink:href="#EPSG8802"
xlink:title="Longitude of natural origin"/>
               </usesValue>
               <usesValue>
                  <value uom="urn:unity">0.999601272</value>
                  <valueOfParameter xlink:href="#EPSG8805"
xlink:title="Scale factor at natural origin"/>
               </usesValue>
               <usesValue>
                  <value uom="urn:metre">400000</value>
                  <valueOfParameter xlink:href="#EPSG8806"
xlink:title="False Easting"/>
               </usesValue>
               <usesValue>
                  <value uom="urn:metre">-100000</value>
                  <valueOfParameter xlink:href="#EPSG8807"
xlink:title="False Northing"/>
               </usesValue>
            </Conversion>
         </definedByConversion>
         <usesCartesianCS>
            <CartesianCS gml:id="EPSG4400">
               <csName>Cartesian</csName>
               <csID>
                  <name codeSpace="EPSG">4400</name>
                  <version>6.0</version>
               </csID>
               <usesAxis>
                  <CoordinateSystemAxis gml:id="EPSG9906"
gml:uom="urn:metre">
                     <axisName>Easting</axisName>
                     <axisID>
                        <name codeSpace="EPSG">9906</name>
                        <version>6.0</version>
                     </axisID>
                     <axisAbbrev>E</axisAbbrev>
                     <axisDirection>east</axisDirection>
                  </CoordinateSystemAxis>
               </usesAxis>
               <usesAxis>
                  <CoordinateSystemAxis gml:id="EPSG9907"
gml:uom="urn:metre">
                     <axisName>Northing</axisName>
                     <axisID>
                        <name codeSpace="EPSG">9907</name>
                        <version>6.0</version>
                     </axisID>
                     <axisAbbrev>N</axisAbbrev>
                     <axisDirection>north</axisDirection>
                  </CoordinateSystemAxis>
               </usesAxis>
            </CartesianCS>
```

```
         </usesCartesianCS>
      </ProjectedCRS>
   </includesCRS>
   <includesCRS>
      <VerticalCRS gml:id="EPSG5701">
         <srsName>Newlyn</srsName>
         <srsID>
            <name codeSpace="EPSG">5701</name>
            <version>6.0</version>
         </srsID>
         <usesVerticalCS>
            <VerticalCS gml:id="EPSG6499">
               <csName>Gravity-related</csName>
               <csID>
                  <name codeSpace="EPSG">6499</name>
                  <version>6.0</version>
               </csID>
               <usesAxis>
                  <CoordinateSystemAxis gml:id="EPSG9904"
gml:uom="urn:metre">
                     <axisName>Gravity-related height</axisName>
                     <axisID>
                        <name codeSpace="EPSG">9904</name>
                        <version>6.0</version>
                     </axisID>
                     <axisAbbrev>H</axisAbbrev>
                     <axisDirection>up</axisDirection>
                  </CoordinateSystemAxis>
               </usesAxis>
            </VerticalCS>
         </usesVerticalCS>
         <usesVerticalDatum>
            <VerticalDatum gml:id="EPSG5101">
               <datumName>Ordnance Datum Newlyn</datumName>
               <datumID>
                  <name codeSpace="EPSG">5101</name>
                  <version>6.0</version>
               </datumID>
               <verticalDatumType
codeSpace="verticalDatumTypeCodeList.xml">geoidal</verticalDatumType>
            </VerticalDatum>
         </usesVerticalDatum>
      </VerticalCRS>
   </includesCRS>
</CompoundCRS>
```

Again, the above example XML just references the units #degree, #metre, and #unity (a scale factor unit). Definitions of those units could be included in this XML document by adding a Dictionary element in a metaDataProperty of this CompoundCRS. This could be done in the same manner as shown in the second example XML document in Subclause E.2.

E.4 Simple example XML for compound coordinate reference system

The example XML document in the previous subclause includes many elements and attributes that are optional, and can thus be omitted when not needed. This subclause provides a simplified example XML document for the same 3D compound coordinate reference system, which omits most of the optional elements and attributes. This simplified example XML is intended to be adequate when the Projected CRS and the Vertical CRS are both well-known. That is, this simplified example assumes that server software can obtain the coordinate reference system specification and other data for these two coordinate reference systems using only the given "xlink:href" attribute values.

```
<?xml version="1.0" encoding="UTF-8"?>
<CompoundCRS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/gml
../crsSchemas/base/coordinateReferenceSystems.xsd" gml:id="EPSG7405">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/09/18. -->
   <srsName>OSGB36 /British National Grid + ODN</srsName>
   <srsID>
      <name codeSpace="EPSG">7405</name>
      <version>6.0</version>
   </srsID>
   <validArea>
      <description>United Kingdom (UK) - Great Britain - England
Scotland Wales - onshore; Isle of Man.
</description>
   </validArea>
   <includesCRS xlink:href="urn:ogc:srs:EPSG::27700" xlink:title="OSGB
1936 / British National Grid"/>
   <includesCRS xlink:href="urn:ogc:srs:EPSG::5701"
xlink:title="Newlyn"/>
</CompoundCRS>
```

E.5 Example XML for Transverse Mercator conversion

This subclause provides an example XML document using the Coordinate Operation concrete subtype "Conversion" XML element, with its' contained elements, here applied to an example Transverse Mercator map projection.

NOTE Subclause F.3.4 provides a corresponding example XML document using the example Transverse Mercator map projection XML Schema provided in Subclause F.3.3. That encoding of Transverse Mercator conversions is recommended, since multiple instances of the Transverse Mercator type of conversion are expected.

```
<?xml version="1.0" encoding="UTF-8"?>
<Conversion xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/gml
../crsSchemas/base/coordinateOperations.xsd" gml:id="EPSG19916">
```

```
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/09/18. -->
   <!-- SourceCRS: EPSG:4277 OSGB 1936 -->
   <!-- TargetCRS: EPSG:27700 OSGB 1936 / British National Grid -->
   <coordinateOperationName>Transverse
Mercator</coordinateOperationName>
   <coordinateOperationID>
      <name codeSpace="EPSG">19916</name>
      <version>6.0</version>
   </coordinateOperationID>
   <usesMethod>
      <OperationMethod gml:id="EPSG9807">
         <methodName>Transverse Mercator</methodName>
         <methodID>
            <name codeSpace="EPSG">9807</name>
            <version>6.0</version>
         </methodID>
         <methodFormula>See Section 1.4.6 "Transverse Mercator" of EPSG
Guidance Note 7, December 2000. </methodFormula>
         <sourceDimensions>2</sourceDimensions>
         <targetDimensions>2</targetDimensions>
         <usesParameter>
            <OperationParameter gml:id="EPSG8801">
               <parameterName>Latitude of natural
origin</parameterName>
               <parameterID>
                  <name codeSpace="EPSG">8801</name>
                  <version>6.0</version>
               </parameterID>
            </OperationParameter>
         </usesParameter>
         <usesParameter>
            <OperationParameter gml:id="EPSG8802">
               <parameterName>Longitude of natural
origin</parameterName>
               <parameterID>
                  <name codeSpace="EPSG">8802</name>
                  <version>6.0</version>
               </parameterID>
            </OperationParameter>
         </usesParameter>
         <usesParameter>
            <OperationParameter gml:id="EPSG8805">
               <parameterName>Scale factor at natural
origin</parameterName>
               <parameterID>
                  <name codeSpace="EPSG">8805</name>
                  <version>6.0</version>
               </parameterID>
            </OperationParameter>
         </usesParameter>
         <usesParameter>
            <OperationParameter gml:id="EPSG8806">
               <parameterName>False Easting</parameterName>
               <parameterID>
                  <name codeSpace="EPSG">8806</name>
                  <version>6.0</version>
               </parameterID>
            </OperationParameter>
```

```
         </usesParameter>
         <usesParameter>
            <OperationParameter gml:id="EPSG8807">
               <parameterName>False Northing</parameterName>
               <parameterID>
                  <name codeSpace="EPSG">8807</name>
                  <version>6.0</version>
               </parameterID>
            </OperationParameter>
         </usesParameter>
      </OperationMethod>
   </usesMethod>
   <usesValue>
      <value uom="urn:ogc:uom:degree">49</value>
      <valueOfParameter xlink:href="#EPSG8801" xlink:title="Latitude of
natural origin"/>
   </usesValue>
   <usesValue>
      <value uom="urn:ogc:uom:degree">-2</value>
      <valueOfParameter xlink:href="#EPSG8802" xlink:title="Longitude
of natural origin"/>
   </usesValue>
   <usesValue>
      <value uom="urn:ogc:uom:unity">0.999601272</value>
      <valueOfParameter xlink:href="#EPSG8805" xlink:title="Scale
factor at natural origin"/>
   </usesValue>
   <usesValue>
      <value uom="urn:ogc:uom:metre">400000</value>
      <valueOfParameter xlink:href="#EPSG8806" xlink:title="False
Easting"/>
   </usesValue>
   <usesValue>
      <value uom="urn:ogc:uom:metre">-100000</value>
      <valueOfParameter xlink:href="#EPSG8807" xlink:title="False
Northing"/>
   </usesValue>
</Conversion>
```

The above example contains most details within the usesMethod element. If that Transverse Mercator OperationMethod is sufficiently well-known or the details are available elsewhere, a much shorter example XML document can be used:

```
<?xml version="1.0" encoding="UTF-8"?>
<Conversion xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/gml
../crsSchemas/base/coordinateOperations.xsd" gml:id="EPSG19916">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/09/18. -->
   <!-- SourceCRS: EPSG:4277 OSGB 1936 -->
   <!-- TargetCRS: EPSG:27700 OSGB 1936 / British National Grid -->
   <coordinateOperationName>Transverse
Mercator</coordinateOperationName>
   <coordinateOperationID>
```

```
      <name codeSpace="EPSG">19916</name>
      <version>6.0</version>
   </coordinateOperationID>
   <usesMethod xlink:href="urn:ogc:method:EPSG::9807"
xlink:title="Transverse Mercator"/>
   <usesValue>
      <value uom="urn:degree">49</value>
      <valueOfParameter xlink:href="urn:ogc:parameter:EPSG::8801"
xlink:title="Latitude of natural origin"/>
   </usesValue>
   <usesValue>
      <value uom="urn:ogc:uom:degree">-2</value>
      <valueOfParameter xlink:href="urn:ogc:parameter:EPSG::8802"
xlink:title="Longitude of natural origin"/>
   </usesValue>
   <usesValue>
      <value uom="urn:ogc:uom:unity">0.999601272</value>
      <valueOfParameter xlink:href="urn:ogc:parameter:EPSG::8805"
xlink:title="Scale factor at natural origin"/>
   </usesValue>
   <usesValue>
      <value uom="urn:ogc:uom:metre">400000</value>
      <valueOfParameter xlink:href="urn:ogc:parameter:EPSG::8806"
xlink:title="False Easting"/>
   </usesValue>
   <usesValue>
      <value uom="urn:ogc:uom:metre">-100000</value>
      <valueOfParameter xlink:href="urn:ogc:parameter:EPSG::8807"
xlink:title="False Northing"/>
   </usesValue>
</Conversion>
```

This example assumes that information for the Transverse Mercator OperationMethod is available elsewhere. Example XML for this is given in the following subclause.

E.6 Example XML for operation method

This subclause provides an example XML document using the OperationMethod element, with data for the Transverse Mercator conversion method.

```
<?xml version="1.0" encoding="UTF-8"?>
<OperationMethod xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/gml
../crsSchemas/base/coordinateOperations.xsd" gml:id="EPSG9807">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/08/06. -->
   <methodName>Transverse Mercator</methodName>
   <methodID>
      <name codeSpace="EPSG">9807</name>
      <version>6.0</version>
   </methodID>
   <methodFormula>See Section 1.4.6 "Transverse Mercator" of EPSG
Guidance Note 7, December 2000. </methodFormula>
   <sourceDimensions>2</sourceDimensions>
```

```
   <targetDimensions>2</targetDimensions>
   <usesParameter>
      <OperationParameter gml:id="EPSG8801">
         <parameterName>Latitude of natural origin</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8801</name>
            <version>6.0</version>
         </parameterID>
      </OperationParameter>
   </usesParameter>
   <usesParameter>
      <OperationParameter gml:id="EPSG8802">
         <parameterName>Longitude of natural origin</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8802</name>
            <version>6.0</version>
         </parameterID>
      </OperationParameter>
   </usesParameter>
   <usesParameter>
      <OperationParameter gml:id="EPSG8805">
         <parameterName>Scale factor at natural origin</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8805</name>
            <version>6.0</version>
         </parameterID>
      </OperationParameter>
   </usesParameter>
   <usesParameter>
      <OperationParameter gml:id="EPSG8806">
         <parameterName>False Easting</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8806</name>
            <version>6.0</version>
         </parameterID>
      </OperationParameter>
   </usesParameter>
   <usesParameter>
      <OperationParameter gml:id="EPSG8807">
         <parameterName>False Northing</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8807</name>
            <version>6.0</version>
         </parameterID>
      </OperationParameter>
   </usesParameter>
</OperationMethod>
```

E.7 Example XML for CRS dictionary

This subclause provides an example XML document using the Dictionary element from the dictionary.xsd schema of GML 3, with its' contained elements, applied to the example CompoundCRS used in Subclause E.3 with all of its' components separated in the dictionary.

```
<?xml version="1.0" encoding="UTF-8"?>
<Dictionary xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/gml
../crsSchemas/base/coordinateReferenceSystems.xsd"
gml:id="CrsDictionary">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/09/18. -->
   <description>Example GML Dictinary of some coordinate reference
systems and components. </description>
   <name>CRS Dictionary</name>
   <dictionaryEntry>
      <CompoundCRS gml:id="EPSG7405">
         <srsName>OSGB36 /British National Grid + ODN</srsName>
         <srsID>
            <name codeSpace="EPSG">7405</name>
            <version>6.0</version>
         </srsID>
         <validArea>
            <description>United Kingdom (UK) - Great Britain - England
Scotland Wales - onshore; Isle of Man. </description>
         </validArea>
         <includesCRS xlink:href="#EPSG27700" xlink:title="OSGB 1936 /
British National Grid"/>
         <includesCRS xlink:href="#EPSG5701" xlink:title="Newlyn"/>
      </CompoundCRS>
   </dictionaryEntry>
   <dictionaryEntry>
      <ProjectedCRS gml:id="EPSG27700">
         <srsName>OSGB 1936 / British National Grid</srsName>
         <srsID>
            <name codeSpace="EPSG">27700</name>
            <version>6.0</version>
         </srsID>
         <validArea>
            <description>United Kingdom (UK) - Great Britain - England
Scotland Wales - onshore; Isle of Man. </description>
         </validArea>
         <baseCRS xlink:href="#EPSG4277" xlink:title="OSGB 1936"/>
         <definedByConversion xlink:href="#EPSG19916"
xlink:title="Transverse Mercator"/>
         <usesCartesianCS xlink:href="#EPSG4400"
xlink:title="Cartesian"/>
      </ProjectedCRS>
   </dictionaryEntry>
   <dictionaryEntry>
      <GeographicCRS gml:id="EPSG4277">
         <srsName>OSGB 1936</srsName>
         <srsID>
            <name codeSpace="EPSG">4277</name>
            <version>6.0</version>
         </srsID>
         <validArea>
            <description>United Kingdom (UK) - Great Britain - England
Scotland Wales - onshore; Isle of Man. </description>
         </validArea>
```

```
         <usesEllipsoidalCS xlink:href="#EPSG6402"
xlink:title="ellipsoidal"/>
         <usesGeodeticDatum xlink:href="#EPSG6277" xlink:title="OSGB
1936"/>
      </GeographicCRS>
   </dictionaryEntry>
   <dictionaryEntry>
      <EllipsoidalCS gml:id="EPSG6402">
         <csName>ellipsoidal</csName>
         <csID>
            <name codeSpace="EPSG">6402</name>
            <version>6.0</version>
         </csID>
         <usesAxis xlink:href="#EPSG9901" xlink:title="Geodetic
latitude"/>
         <usesAxis xlink:href="#EPSG9902" xlink:title="Geodetic
longitude"/>
      </EllipsoidalCS>
   </dictionaryEntry>
   <dictionaryEntry>
      <CoordinateSystemAxis gml:id="EPSG9901"
gml:uom="urn:ogc:uom:degree">
         <axisName>Geodetic latitude</axisName>
         <axisID>
            <name codeSpace="EPSG">9901</name>
            <version>6.0</version>
         </axisID>
         <axisAbbrev>Lat</axisAbbrev>
         <axisDirection>north</axisDirection>
      </CoordinateSystemAxis>
   </dictionaryEntry>
   <dictionaryEntry>
      <CoordinateSystemAxis gml:id="EPSG9902"
gml:uom="urn:ogc:uom:degree">
         <axisName>Geodetic longitude</axisName>
         <axisID>
            <name codeSpace="EPSG">9902</name>
            <version>6.0</version>
         </axisID>
         <axisAbbrev>Lon</axisAbbrev>
         <axisDirection>east</axisDirection>
      </CoordinateSystemAxis>
   </dictionaryEntry>
   <dictionaryEntry>
      <GeodeticDatum gml:id="EPSG6277">
         <datumName>OSGB 1936</datumName>
         <datumID>
            <name codeSpace="EPSG">6277</name>
            <version>6.0</version>
         </datumID>
         <usesPrimeMeridian xlink:href="#EPSG8901"
xlink:title="Greenwich"/>
         <usesEllipsoid xlink:href="#EPSG7001" xlink:title="Airy
1830"/>
      </GeodeticDatum>
   </dictionaryEntry>
   <dictionaryEntry>
```

```
      <PrimeMeridian gml:id="EPSG8901">
         <meridianName>Greenwich</meridianName>
         <meridianID>
            <name codeSpace="EPSG">8901</name>
            <version>6.0</version>
         </meridianID>
         <greenwichLongitude>
            <angle uom="urn:ogc:uom:degree">0</angle>
         </greenwichLongitude>
      </PrimeMeridian>
   </dictionaryEntry>
   <dictionaryEntry>
      <Ellipsoid gml:id="EPSG7001">
         <ellipsoidName>Airy 1830</ellipsoidName>
         <ellipsoidID>
            <name codeSpace="EPSG">7001</name>
            <version>6.0</version>
         </ellipsoidID>
         <semiMajorAxis
uom="urn:ogc:uom:metre">6377563.396</semiMajorAxis>
         <secondDefiningParameter>
            <inverseFlattening
uom="urn:ogc:uom:unity">299.3249646</inverseFlattening>
         </secondDefiningParameter>
      </Ellipsoid>
   </dictionaryEntry>
   <dictionaryEntry>
      <Conversion gml:id="EPSG19916">
         <coordinateOperationName>Transverse
Mercator</coordinateOperationName>
         <coordinateOperationID>
            <name codeSpace="EPSG">19916</name>
            <version>6.0</version>
         </coordinateOperationID>
         <usesMethod xlink:href="#EPSG9807" xlink:title="Transverse
Mercator"/>
         <usesValue>
            <value uom="urn:ogc:uom:degree">49</value>
            <valueOfParameter xlink:href="#EPSG8801"
xlink:title="Latitude of natural origin"/>
         </usesValue>
         <usesValue>
            <value uom="urn:ogc:uom:degree">-2</value>
            <valueOfParameter xlink:href="#EPSG8802"
xlink:title="Longitude of natural origin"/>
         </usesValue>
         <usesValue>
            <value uom="urn:ogc:uom:unity">0.999601272</value>
            <valueOfParameter xlink:href="#EPSG8805" xlink:title="Scale
factor at natural origin"/>
         </usesValue>
         <usesValue>
            <value uom="urn:ogc:uom:metre">400000</value>
            <valueOfParameter xlink:href="#EPSG8806" xlink:title="False
Easting"/>
         </usesValue>
         <usesValue>
            <value uom="urn:ogc:uom:metre">-100000</value>
```

```
            <valueOfParameter xlink:href="#EPSG8807" xlink:title="False
Northing"/>
         </usesValue>
      </Conversion>
   </dictionaryEntry>
   <dictionaryEntry>
      <OperationMethod gml:id="EPSG9807">
         <methodName>Transverse Mercator</methodName>
         <methodID>
            <name codeSpace="EPSG">9807</name>
            <version>6.0</version>
         </methodID>
         <methodFormula>See Section 1.4.6 "Transverse Mercator" of EPSG
Guidance Note 7, December 2000. </methodFormula>
         <sourceDimensions>2</sourceDimensions>
         <targetDimensions>2</targetDimensions>
         <usesParameter xlink:href="#EPSG8801" xlink:title="Latitude of
natural origin"/>
         <usesParameter xlink:href="#EPSG8802" xlink:title="Longitude
of natural origin"/>
         <usesParameter xlink:href="#EPSG8805" xlink:title="Scale
factor at natural origin"/>
         <usesParameter xlink:href="#EPSG8806" xlink:title="False
Easting"/>
         <usesParameter xlink:href="#EPSG8807" xlink:title="False
Northing"/>
      </OperationMethod>
   </dictionaryEntry>
   <dictionaryEntry>
      <OperationParameter gml:id="EPSG8801">
         <parameterName>Latitude of natural origin</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8801</name>
            <version>6.0</version>
         </parameterID>
      </OperationParameter>
   </dictionaryEntry>
   <dictionaryEntry>
      <OperationParameter gml:id="EPSG8802">
         <parameterName>Longitude of natural origin</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8802</name>
            <version>6.0</version>
         </parameterID>
      </OperationParameter>
   </dictionaryEntry>
   <dictionaryEntry>
      <OperationParameter gml:id="EPSG8805">
         <parameterName>Scale factor at natural origin</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8805</name>
            <version>6.0</version>
         </parameterID>
      </OperationParameter>
   </dictionaryEntry>
   <dictionaryEntry>
      <OperationParameter gml:id="EPSG8806">
```

```
         <parameterName>False Easting</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8806</name>
            <version>6.0</version>
         </parameterID>
      </OperationParameter>
   </dictionaryEntry>
   <dictionaryEntry>
      <OperationParameter gml:id="EPSG8807">
         <parameterName>False Northing</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8807</name>
            <version>6.0</version>
         </parameterID>
      </OperationParameter>
   </dictionaryEntry>
   <dictionaryEntry>
      <CartesianCS gml:id="EPSG4400">
         <csName>Cartesian</csName>
         <csID>
            <name codeSpace="EPSG">4400</name>
            <version>6.0</version>
         </csID>
         <usesAxis xlink:href="#EPSG9906" xlink:title="Easting"/>
         <usesAxis xlink:href="#EPSG9907" xlink:title="Northing"/>
      </CartesianCS>
   </dictionaryEntry>
   <dictionaryEntry>
      <CoordinateSystemAxis gml:id="EPSG9906"
gml:uom="urn:ogc:uom:metre">
         <axisName>Easting</axisName>
         <axisID>
            <name codeSpace="EPSG">9906</name>
            <version>6.0</version>
         </axisID>
         <axisAbbrev>E</axisAbbrev>
         <axisDirection>east</axisDirection>
      </CoordinateSystemAxis>
   </dictionaryEntry>
   <dictionaryEntry>
      <CoordinateSystemAxis gml:id="EPSG9907"
gml:uom="urn:ogc:uom:metre">
         <axisName>Northing</axisName>
         <axisID>
            <name codeSpace="EPSG">9907</name>
            <version>6.0</version>
         </axisID>
         <axisAbbrev>N</axisAbbrev>
         <axisDirection>north</axisDirection>
      </CoordinateSystemAxis>
   </dictionaryEntry>
</Dictionary>
```

E.8 Example XML for units dictionary

This subclause provides an example XML document using the Dictionary element from the dictionary.xsd schema of GML 3, with its' contained elements, applied to the units of measure used in the preceding XML examples.

```
<?xml version="1.0" encoding="UTF-8"?>
<Dictionary xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/gml
../crsSchemas/base/coordinateReferenceSystems.xsd"
gml:id="UnitsDictionary">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/09/18. -->
   <description>Example GML Dictinary of unit
definitions.</description>
   <name>Units Dictionary</name>
   <dictionaryEntry>
      <ConventionalUnit gml:id="degree">
         <name>degree</name>
         <name codeSpace="EPSG">9102</name>
         <quantityType>angle</quantityType>
         <conversionToPreferredUnit uom="#radian">
            <factor>1.74532925199433E-02</factor>
         </conversionToPreferredUnit>
      </ConventionalUnit>
   </dictionaryEntry>
   <dictionaryEntry>
      <BaseUnit gml:id="radian">
         <name>radian</name>
         <quantityType>angle</quantityType>
         <unitsSystem xlink:href="urn:ogc:ToBeSupplied"/>
      </BaseUnit>
   </dictionaryEntry>
   <dictionaryEntry>
      <BaseUnit gml:id="metre">
         <name>metre</name>
         <name codeSpace="EPSG">9001</name>
         <quantityType>length</quantityType>
         <unitsSystem xlink:href="urn:ogc:SI"/>
      </BaseUnit>
   </dictionaryEntry>
   <dictionaryEntry>
      <BaseUnit gml:id="unity">
         <name>unitless</name>
         <quantityType>scale factor</quantityType>
         <unitsSystem xlink:href="urn:ogc:ToBeSupplied"/>
      </BaseUnit>
   </dictionaryEntry>
</Dictionary>
```

E.9 Referencing a coordinate reference system

The coordinate reference system (CRS) used by coordinates is referenced in the geometry XML elements defined by GML, and in a number of other places. GML 2 was limited to use of only well-known CRSs, so this reference to a CRS was abbreviated by a single attribute name and value, such as:

```
srsName="EPSG:4326"
```

GML 3 still uses the srsName attribute, with type xsd:anyURI. This srsName might still be "EPSG:4326", or it can be a pointer to a more complete CRS definition stored somewhere else. That somewhere else could be any of several places, including:

a) Outside the XML document where it is referenced, such as:
   1) In a dictionary of multiple CRS definitions available electronically from a specified URL. In this case, the srsName attribute could reference the dictionary, and the specific item in that dictionary.
   2) In a dictionary of multiple CRS definitions not available electronically. However, the srsName attribute could still reference the dictionary, and the specific item in that dictionary.
   3) In a catalog or registry service which stores CRS definitions, probably available electronically. In this case, the srsName attribute could reference the service, and the specific item available from that service. (The value "**EPSG:4326**" can be considered to be a reference to the EPSG registry of CRS definitions.)

b) Inside the XML document where it is referenced, such as:
   1) In a dictionary of one or more CRS definitions stored as metadata in some XML element in that XML document. (Storing a dictionary of units as metadata is discussed in Subclause E.2.)
   2) As one or more CRS definitions included in some XML element specified by an Application Schema based on the GML and/or CRS schemas.

In all cases listed above, the remote CRS definition could be XML encoded as specified in this document. For example, a XML encoded dictionary of CRS definitions could be similar to the units Dictionary example given in Subclause E.7. When the CRS definition is stored outside the XML document where it is referenced (item a) above), the remote CRS definition would not need to be encoded in XML.

E.10 Example XML for image CRS

This subclause provides an example XML document using the ImageCRS element from the coordinateReferenceSystems.xsd schema, with its' contained elements, applied to an image coordinate reference system that might be used for most 2D images.

```
<?xml version="1.0" encoding="UTF-8"?>
<ImageCRS xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
```

```
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/gml
../crsSchemas/base/coordinateReferenceSystems.xsd" gml:id="ImageCRS1">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/09/18. -->
   <srsName>Generic image coordinate reference system</srsName>
   <usesCartesianCS>
      <CartesianCS gml:id="ImageCS1">
         <csName>2D Cartesian image coordinate system</csName>
         <usesAxis>
            <CoordinateSystemAxis gml:id="ImageRow"
gml:uom="urn:ogc:uom:PixelSpacing">
               <axisName>Image Row Axis</axisName>
               <axisAbbrev>R</axisAbbrev>
               <axisDirection>display down</axisDirection>
            </CoordinateSystemAxis>
         </usesAxis>
         <usesAxis>
            <CoordinateSystemAxis gml:id="ImageColumn"
gml:uom="urn:ogc:uom:PixelSpacing">
               <axisName>Image Column Axis</axisName>
               <axisAbbrev>C</axisAbbrev>
               <axisDirection>display right</axisDirection>
            </CoordinateSystemAxis>
         </usesAxis>
      </CartesianCS>
   </usesCartesianCS>
   <usesImageDatum>
      <ImageDatum gml:id="ImageDatum1">
         <datumName>Image Datum 1</datumName>
         <anchorPoint>image corner 1, 1</anchorPoint>
         <pixelInCell codeSpace="pixelInCellCodeList.xml">cell
center</pixelInCell>
      </ImageDatum>
   </usesImageDatum>
</ImageCRS>
```

Annex F
(informative)

Application schema examples

F.1 Introduction

This annex provides several example Application Schemas based on these CRS Schemas, each with a corresponding example XML document using that Application Schema plus the example UML model from which that Application Schemas was converted. For more information on Application Schemas, see Subclauses 6.3 and A.4.

These XML examples use patterns that are not specified in this document for values of the "gml:id", "gml:uom", "xlink:href", and "xlink:title" XML attributes.

EDITOR'S NOTE Some of the patterns now used for values of these attributes may be invalid or inappropriate. I urge reviewers to suggest any needed or desirable improvements.

NOTE For interoperability, the patterns or formats used for the values of these attributes must be specified somewhere, normally in or with the Application Schema.

F.2 Extended operation parameter definition

F.2.1 Introduction

Many needs are expected for encoding additional information describing coordinate reference systems and their components. This subclause provides an example of such extended encoding, applied to Operation Parameters. The following subclauses contain:

a) A draft class diagram of a UML package for an Extended Operation Parameter, which builds on the UML model in OGC Abstract Specification Topic 2.

b) A draft XML Schema for encoding an Extended Operation Parameter, produced by converting this UML package.

c) A XML encoding of the possible contents of the <<CodeList>> stereotyped ParameterType class in this UML package.

d) An example XML document based on this draft XML Schema for encoding an Extended Operation Parameter

F.2.2 UML package

Figure F.1 is a class diagram of an example UML package for an Extended Operation Method. This UML package builds on the UML model in OGC Abstract Specification Topic 2.

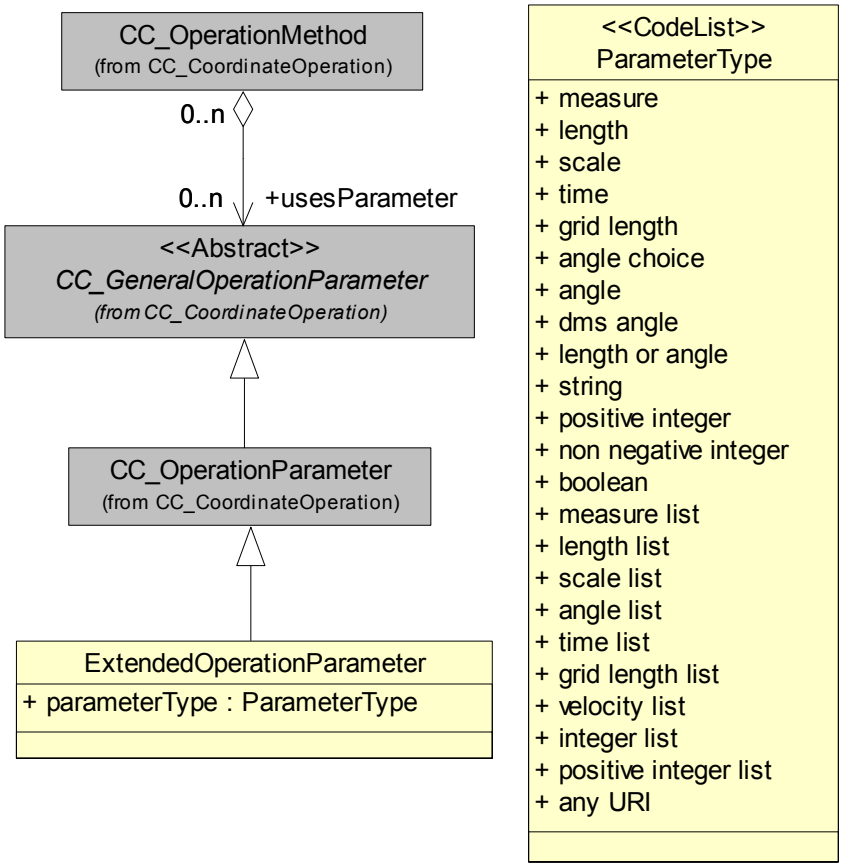


Figure F.1 — UML package for Extended Operation Method

F.2.3 Application schema

This subclause contains an example XML Schema for encoding an Extended Operation Parameter, produced by converting the above UML package. This XML Schema builds on the coordinateOperations.xsd XML Schema contained in Subclause C.6. This draft XML Schema is written following the same GML 3 patterns and ISO 19118 XML encoding rules as used in the XML Schemas in Annex C. This draft XML Schema is written as an Application Schema in a different namespace.

This example XML Schema is:

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/examples"
xmlns:ex="http://www.opengis.net/examples"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:gml="http://www.opengis.net/gml"
xmlns="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified"
version="0.2.0" xml:lang="en">
   <annotation>
      <documentation>
         <name>extendedOperationParameter.xsd</name>
         <version>0.2.0</version>
```

```
         <scope>How to encode extended information for operation
parameters. </scope>
         <description>Example Application Schema to encode extended
information for operation parameters. Builds on
coordinateOperations.xsd, and follows same GML 3 patterns and ISO 19118
encoding. Written in the "ex" namespace. Primary editor: Arliss
Whiteside. Last updated 2003/09/19. </description>
         <copyright>Copyright (c) 2003 OpenGIS, All Rights
Reserved.</copyright>
         <conformance>This schema encodes a draft Extended Operation
Parameter package that builds on the Coordinate Operation (CC_) package
of the extended UML Model for OGC Abstract Specification Topic 2:
Spatial Referencing by Coordinates. That draft package defines a
subtype of the CC_OperationParameter class for recording more
information. </conformance>
      </documentation>
   </annotation>
   <!-- ======================================================
       includes and imports
   ====================================================== -->
   <import namespace="http://www.opengis.net/gml"
schemaLocation="../crsSchemas/base/coordinateOperations.xsd"/>
   <!-- ======================================================
       elements and types
   ====================================================== -->
   <element name="ExtendedOperationParameter"
type="ex:ExtendedOperationParameterType"
substitutionGroup="gml:OperationParameter"/>
   <!-- ====================================================== -->
   <complexType name="ExtendedOperationParameterType">
      <annotation>
         <documentation>Extended definition of an operation parameter.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:OperationParameterType">
            <sequence>
               <element ref="ex:parameterType"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ====================================================== -->
   <element name="parameterType" type="ex:ParameterTypeType"/>
   <!-- ====================================================== -->
   <complexType name="ParameterTypeType">
      <annotation>
         <documentation>Data type of an operation parameter. Usually
refers to a data type defined in measures.xsd or allowed in the
ParameterValueType of coordinateOperations.xsd. </documentation>
      </annotation>
      <simpleContent>
         <restriction base="gml:CodeType">
            <attribute name="codeSpace" type="anyURI" use="required">
               <annotation>
                  <documentation>Reference to a source of information
specifying the values and meanings of all the allowed string values for
this ParameterTypeType. </documentation>
```

```
            </annotation>
         </attribute>
      </restriction>
   </simpleContent>
</complexType>
<!-- ================================================== -->
<element name="extendedOperationParameterRef"
type="ex:extendedOperationParameterRefType"
substitutionGroup="gml:operationParameterRef"/>
<!-- ================================================== -->
<complexType name="extendedOperationParameterRefType">
   <annotation>
      <documentation>Association to an Extended Operation Parameter,
either referencing or containing the definition of that Parameter.
</documentation>
   </annotation>
   <complexContent>
      <restriction base="gml:OperationParameterRefType">
         <sequence>
            <element ref="ex:ExtendedOperationParameter"
minOccurs="0"/>
         </sequence>
         <attributeGroup ref="gml:AssociationAttributeGroup"/>
      </restriction>
   </complexContent>
</complexType>
<!-- ================================================== -->
</schema>
```

F.2.4 Standard contents of parameterType

A standard set of allowed values and their meanings for the parameterType element is specified in the <<CodeList>> stereotyped class in the UML model that was converted. Those string values and their meanings are specified in the following UML document, using the XML Schema defined in Subclause D.2:

```
<?xml version="1.0" encoding="UTF-8"?>
<CodeListDictionary xmlns="http://www.opengis.net/examples"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xlink="http://www.w3.org/1999/xlink"
xsi:schemaLocation="http://www.opengis.net/ex codeListDictionary.xsd"
gml:id="parameterType">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/09/18. -->
   <gml:description>Data type of an operation parameter. Usually refers
to a data type defined in measures.xsd or allowed in the
ParameterValueType of coordinateOperations.xsd. </gml:description>
   <gml:name>parameterType</gml:name>
   <codeEntry>
      <CodeDefinition gml:id="measure">
         <gml:description>General numeric value of an operation
parameter, with its associated unit of measure. </gml:description>
         <code>measure</code>
      </CodeDefinition>
   </codeEntry>
```

```
   <codeEntry>
      <CodeDefinition gml:id="length">
         <gml:description>Value of a length (or distance) quantity,
with its units. Uses the MeasureType with the restriction that the unit
of measure referenced by uom must be suitable for a length, such as
metres or feet. </gml:description>
         <code>length</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="scale">
         <gml:description>Value of a scale factor (or ratio) that has
no physical unit. Uses the MeasureType with the restriction that the
unit of measure referenced by uom must be suitable for a scale factor,
such as one, percent, permil, or parts-per-million. </gml:description>
         <code>scale</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="time">
         <gml:description>Value of a time or temporal quantity, with
its units. Uses the MeasureType with the restriction that the unit of
measure referenced by uom must be suitable for a time value, such as
seconds or weeks. </gml:description>
         <code>time</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="gridLength">
         <gml:description>Value of a length (or distance) quantity in a
grid, where the grid spacing does not have any associated physical
units, or does not have a constant physical spacing. This grid length
will often be used in a digital image grid, where the base units are
likely to be pixel spacings. Uses the MeasureType with the restriction
that the unit of measure referenced by uom must be suitable for length
along the axes of a grid, such as pixel spacings or grid
spacings.</gml:description>
         <code>grid length</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="angleChoice">
         <gml:description>Value of an angle quantity provided in either
degree-minute-second format or single value format. </gml:description>
         <code>angle choice</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="angle">
         <gml:description>Value of an angle quantity recorded as a
single number, with its units. Uses the MeasureType with the
restriction that the unit of measure referenced by uom must be suitable
for an angle, such as degrees or radians. </gml:description>
         <code>angle</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="dmsAngle">
```

```
         <gml:description>Value of an angle operation parameter, in
either degree-minute-second format or single value format.
</gml:description>
         <code>dms angle</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="lengthOrAngle">
         <gml:description>Value of a length or angle quantity, where an
angle can be recorded in either degree-minute-second format or single
value format. Often used for horizontal ground coordinates.
</gml:description>
         <code>length or angle</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="string">
         <gml:description>String value of an operation parameter. A
string value does not have an associated unit of measure.
</gml:description>
         <code>string</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="positiveInteger">
         <gml:description>Positive integer value of an operation
parameter, usually used for a count. An integer value does not have an
associated unit of measure. </gml:description>
         <code>positive integer</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="nonNegativeInteger">
         <gml:description>Zero or positive integer value of an
operation parameter. An integer value does not have an associated unit
of measure. </gml:description>
         <code>non negative integer</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="boolean">
         <gml:description>Boolean value of an operation parameter. A
Boolean value does not have an associated unit of measure.
</gml:description>
         <code>boolean</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="measureList">
         <gml:description>Ordered sequence of two or more numeric
values of an operation parameter list, where each value has the same
associated unit of measure. An element of this type contains a space-
separated list of double values. </gml:description>
         <code>measure list</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
```

```
      <CodeDefinition gml:id="lengthList">
         <gml:description>Ordered sequence of two or more numeric
values of an operation parameter list of Length measures. Each value
has the same associated unit of measure suitable for a length, such as
metres or feet. An element of this type contains a space-separated list
of double values. </gml:description>
         <code>length list</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="scaleList">
         <gml:description>Ordered sequence of two or more numeric
values of an operation parameter list of Scale measures. Each value has
the same associated unit of measure suitable for a scale factor, such
as one, percent, permil, or parts-per-million. An element of this type
contains a space-separated list of double values. </gml:description>
         <code>scale list</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="angleList">
         <gml:description>Ordered sequence of two or more numeric
values of an operation parameter list of Angle measures, each recorded
as a single number. Each value has the same associated unit of measure
suitable for an angle, such as degrees or radians. An element of this
type contains a space-separated list of double values.
</gml:description>
         <code>angle list</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="timeList">
         <gml:description>Ordered sequence of two or more numeric
values of an operation parameter list of Time measures, each recorded
as a single number. Each value has the same associated unit of measure
suitable for a time value, such as seconds or days. An element of this
type contains a space-separated list of double values.
</gml:description>
         <code>time list</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="gridLengthList">
         <gml:description>Ordered sequence of two or more numeric
values of an operation parameter list of Grid Length measures. Each
value has the same associated unit of measure suitable for length along
the axes of a grid, such as pixel spacings or grid spacings. An element
of this type contains a space-separated list of double values.
</gml:description>
         <code>grid length list</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="velocityList">
         <gml:description>Ordered sequence of two or more numeric
values of an operation parameter list of Velocity measures. Each value
has the same associated unit of measure suitable for a velocity, such
```

```
as metres per second or miles per hour. An element of this type
contains a space-separated list of double values. </gml:description>
         <code>velocity list</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="integerList">
         <gml:description>Ordered sequence of two or more integer
values of an operation parameter list, usually used for counts. These
integer values do not have an associated unit of measure. An element of
this type contains a space-separated list of integer values.
</gml:description>
         <code>integer list</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="positiveIntegerList">
         <gml:description>Ordered sequence of two or more positive
integer values of an operation parameter list, usually used for counts.
These integer values do not have an associated unit of measure. An
element of this type contains a space-separated list of integer values.
</gml:description>
         <code>positive integer list</code>
      </CodeDefinition>
   </codeEntry>
   <codeEntry>
      <CodeDefinition gml:id="anyURI">
         <gml:description>Reference to a file or a part of a file
containing one or more parameter values, each numeric value with its
associated unit of measure. When referencing a part of a file, that
file must contain multiple identified parts, such as an XML encoded
document. Furthermore, the referenced file or part of a file can
reference another part of the same or different files, as allowed in
XML documents. </gml:description>
         <code>anyURI</code>
      </CodeDefinition>
   </codeEntry>
</CodeListDictionary>
```

F.2.5 Example XML document

An example XML document based on this example XML Schema for encoding Extended Operation Parameters applied to the Transverse Mercator Operation Method is:

NOTE Subclause E.5 provides a corresponding example XML document not using an Application Schema.

```
<?xml version="1.0" encoding="UTF-8"?>
<OperationMethod xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:ex="http://www.opengis.net/examples"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/examples
extendedOperationParameter.xsd" gml:id="EPSG9807">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/09/19. -->
   <methodName>Transverse Mercator</methodName>
```

```
   <methodID>
      <name codeSpace="EPSG">9807</name>
      <version>6.0</version>
   </methodID>
   <methodFormula>See Section 1.4.6 "Transverse Mercator" of EPSG
Guidance Note 7, December 2000. </methodFormula>
   <sourceDimensions>2</sourceDimensions>
   <targetDimensions>2</targetDimensions>
   <usesParameter>
      <ex:ExtendedOperationParameter gml:id="EPSG8801">
         <parameterName>Latitude of natural origin</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8801</name>
            <version>6.0</version>
         </parameterID>
         <ex:parameterType
codeSpace="parameterTypeCodeList.xml">AngleChoiceType</ex:parameterType
>
      </ex:ExtendedOperationParameter>
   </usesParameter>
   <usesParameter>
      <ex:ExtendedOperationParameter gml:id="EPSG8802">
         <parameterName>Longitude of natural origin</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8802</name>
            <version>6.0</version>
         </parameterID>
         <ex:parameterType
codeSpace="parameterTypeCodeList.xml">AngleChoiceType</ex:parameterType
>
      </ex:ExtendedOperationParameter>
   </usesParameter>
   <usesParameter>
      <ex:ExtendedOperationParameter gml:id="EPSG8805">
         <parameterName>Scale factor at natural origin</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8805</name>
            <version>6.0</version>
         </parameterID>
         <ex:parameterType
codeSpace="parameterTypeCodeList.xml">ScaleType</ex:parameterType>
      </ex:ExtendedOperationParameter>
   </usesParameter>
   <usesParameter>
      <ex:ExtendedOperationParameter gml:id="EPSG8806">
         <parameterName>False Easting</parameterName>
         <parameterID>
            <name codeSpace="EPSG">8806</name>
            <version>6.0</version>
         </parameterID>
         <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
      </ex:ExtendedOperationParameter>
   </usesParameter>
   <usesParameter>
      <ex:ExtendedOperationParameter gml:id="EPSG8807">
         <parameterName>False Northing</parameterName>
         <parameterID>
```

```
            <name codeSpace="EPSG">8807</name>
            <version>6.0</version>
         </parameterID>
         <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
      </ex:ExtendedOperationParameter>
   </usesParameter>
</OperationMethod>
```

F.3 Transverse Mercator conversion

F.3.1 Introduction

Standardized XML encoding is needed for a number of specific commonly-used types of coordinate conversions and transformations. This subclause provides an example of one such encoding, applied to one commonly-used conversion type, namely the Transverse Mercator map projection. The following subclauses contain:

a) A draft class diagram of a UML package for the Transverse Mercator type of map projection, which builds on the UML model in OGC Abstract Specification Topic 2.

b) A draft XML Schema for encoding a Transverse Mercator projection, produced by converting this UML package.

c) Two example XML documents based on this draft XML Schema for encoding an example Transverse Mercator map projection

F.3.2 UML package

Figure F.2 is a draft class diagram of a UML package for Transverse Mercator map projections. This class diagram is incomplete in that many of the needed association role names and multiplicities are not shown due to lack of space. This UML package builds on the UML model in OGC Abstract Specification Topic 2.

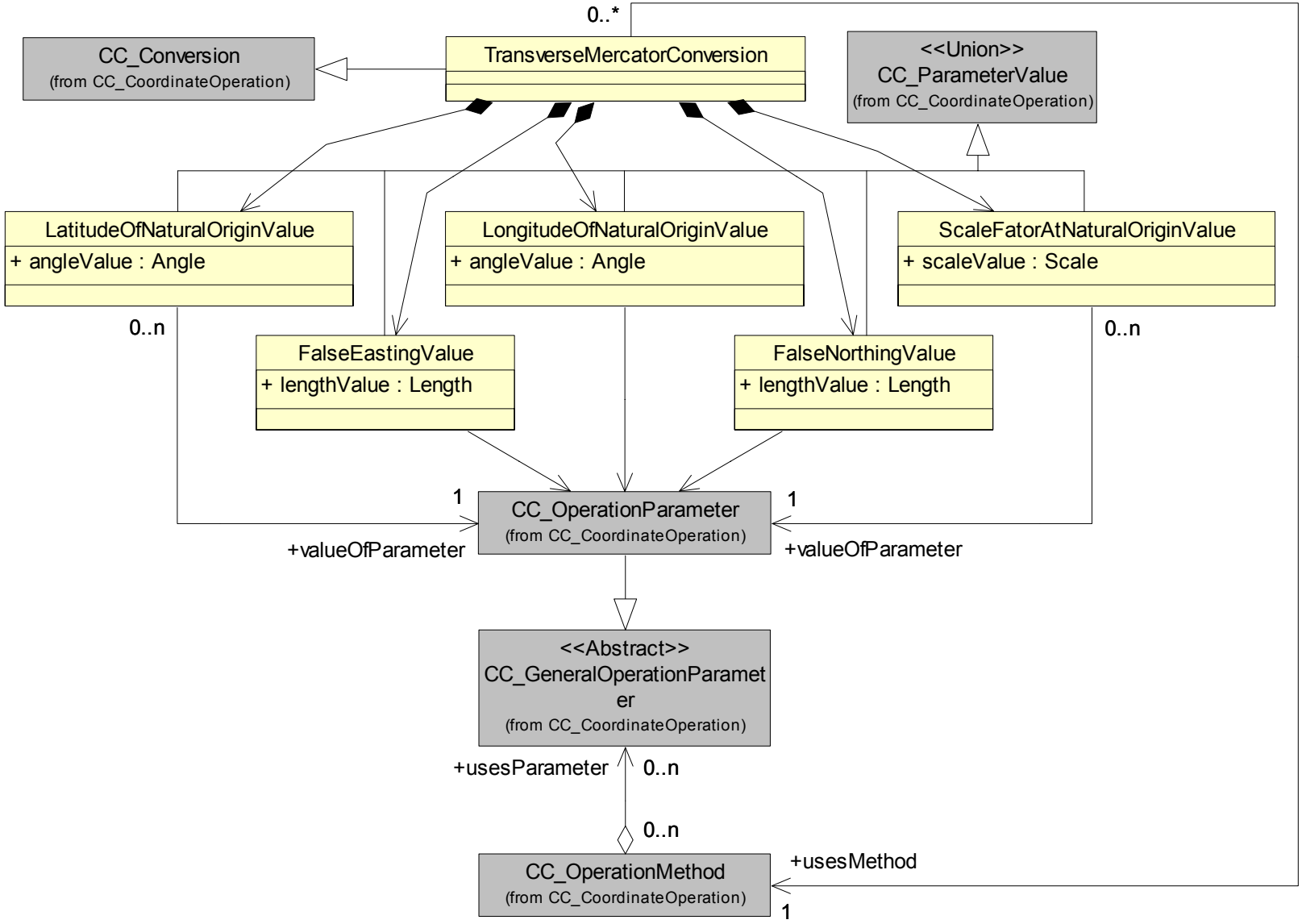


Figure F.2 — UML package for Transverse Mercator projection

F.3.3 Application schema

This subclause contains an example XML Schema for encoding a Transverse Mercator projection, produced by converting the above UML package. This XML Schema builds on the coordinateOperations.xsd XML Schema contained in Subclause C.6. This draft XML Schema is written following the same GML 3 patterns and ISO 19118 XML encoding rules as used in the XML Schemas in Annex C. This draft XML Schema is written as an application schema in a different namespace. Of course, it could be rewritten as an additional XML Schema in the GML namespace, and would be similar.

EDITORS NOTE: In this draft XML Schema, I included documentation element text based on my limited understanding of the Transverse Mercator map projection. I urge John Bobbitt, Roel Nicolai, and others to suggest improvements in the wording of these documentation elements.

This draft XML Schema is:

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/examples"
xmlns:ex="http://www.opengis.net/examples"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:gml="http://www.opengis.net/gml"
xmlns="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified"
xml:lang="en">
   <annotation>
      <documentation>
         <name>transverseMercator.xsd</name>
         <version>0.2</version>
         <scope>How to encode definition of specific Transverse
Mercator conversion. </scope>
         <description>Example Application Schema to encode the data
needed to define a specific Transverse Mercator type of map projection,
which is a coordinate conversion. Builds on coordinateOperations.xsd,
and follows same GML 3 patterns and ISO 19118 encoding. Written in the
"ex" namespace. Primary editor: Arliss Whiteside. Last updated
2003/09/19. </description>
         <reference>Guidance Note Number 7 "Coordinate Conversions and
Transformations including Formulas" (available through
http://www.epsg.org/), especially Section 1.4.6 "Transverse Mercator".
</reference>
         <copyright>Copyright (c) 2002-2003 OpenGIS, All Rights
Reserved.</copyright>
         <conformance>This schema encodes a draft Transverse Mercator
package that builds on the Coordinate Operation (CC_) package of the
extended UML Model for OGC Abstract Specification Topic 2: Spatial
Referencing by Coordinates. That draft package defines restricted
subtypes of the CC_Conversion and CC_ParameterValue classes as needed
for the Transverse Mercator map projection conversion. </conformance>
      </documentation>
   </annotation>
   <!-- ======================================================
       includes and imports
   ====================================================== -->
   <import namespace="http://www.opengis.net/gml"
schemaLocation="../crsSchemas/base/coordinateOperations.xsd"/>
   <!-- ======================================================
       elements and types
```

```
   ================================================== -->
   <element name="TransverseMercatorConversion"
type="ex:TransverseMercatorConversionType"
substitutionGroup="gml:_GeneralConversion"/>
   <!-- ================================================== -->
   <complexType name="TransverseMercatorConversionType">
      <annotation>
         <documentation>Specific Transverse Mercator map projection.
Uses the AbstractGeneralConversionType with restricted values for
included elements, including elements in the coordinateOperationID
element with the IdentifierType. If appropriate, the "codeSpace"
element should have the string value "EPSG", and the "code" element
should then have the appropriate EPSG code value. The other elements in
the IdentifierType can be omitted. The "coordinateOperationName"
element shall have a string value that names a specific Transverse
Mercator map projection. The "_PositionalAccuracy" and
"metaDataProperty" elements can be omitted. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralConversionType">
            <sequence>
               <element ref="gml:usesMethod"/>
               <element ref="ex:usesLatitudeOfNaturalOriginValue"/>
               <element ref="ex:usesLongitudeOfNaturalOriginValue"/>
               <element ref="ex:usesScaleFactorAtNaturalOriginValue"/>
               <element ref="ex:usesFalseEastingValue"/>
               <element ref="ex:usesFalseNorthingValue"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="transverseMercatorConversionRef"
type="ex:TranverseMercatorConversionRefType"
substitutionGroup="gml:generalConversionRef"/>
   <!-- ================================================== -->
   <complexType name="TranverseMercatorConversionRefType">
      <annotation>
         <documentation>Association to a Transverse Mercator
Conversion, either referencing or containing the definition of that
Conversion. </documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:GeneralConversionRefType">
            <sequence>
               <element ref="ex:TransverseMercatorConversion"
minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="usesLatitudeOfNaturalOriginValue"
type="ex:AngleValueType"
substitutionGroup="gml:_generalParameterValue">
```

```
      <annotation>
         <documentation>Value of the Latitude of the natural origin
parameter for a specific coordinate conversion. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesLongitudeOfNaturalOriginValue"
type="ex:AngleValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Value of the Longitude of the natural origin
(or central meridian) parameter for a specific coordinate conversion.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesScaleFactorAtNaturalOriginValue"
type="ex:ScaleValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Value of the scale factor at the natural origin
(on the central meridian) parameter for a specific coordinate
conversion. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesFalseEastingValue" type="ex:LengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Value of the false Easting coordinate of the
origin parameter for a specific coordinate conversion. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesFalseNorthingValue" type="ex:LengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Value of the false Northing coordinate of the
origin parameter for a specific coordinate conversion. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <complexType name="AngleValueType">
      <annotation>
         <documentation>Angle measure operation parameter value.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <choice>
                  <element ref="ex:angleValue"/>
                  <element ref="gml:dmsAngleValue"/>
               </choice>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
```

```
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="ScaleValueType">
      <annotation>
         <documentation>Scale measure operation parameter value.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:scaleValue"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="LengthValueType">
      <annotation>
         <documentation>Length measure operation parameter value.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:lengthValue"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="angleValue" type="gml:AngleType"
substitutionGroup="gml:value">
      <annotation>
         <documentation>Angle value of an operation parameter, recorded
as a single number, with a unit of measure suitable for an angle, such
as degrees or radians. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="scaleValue" type="gml:ScaleType"
substitutionGroup="gml:value">
      <annotation>
         <documentation>Scale factor value of an operation parameter,
with a unit of measure suitable for a scale factor, such as percent,
permil, or parts-per-million. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="lengthValue" type="gml:LengthType"
substitutionGroup="gml:value">
      <annotation>
```

```
         <documentation>Length value of an operation parameter, with a
unit of measure suitable for a length, such as metres or feet.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
</schema>
```

F.3.4 Example XML documents

An example XML document based on this example XML Schema for encoding an example Transverse Mercator map projection is:

```
<?xml version="1.0" encoding="UTF-8"?>
<TransverseMercatorConversion xmlns="http://www.opengis.net/examples"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/examples
transverseMercator.xsd" gml:id="EPSG19916">
   <!-- Example XML document. Primary editor: Arliss Whiteside. Last
updated 2003/09/19. -->
   <!-- SourceCRS: EPSG:4277 OSGB 1936 -->
   <!-- TargetCRS: EPSG:27700 OSGB 1936 / British National Grid -->
   <gml:coordinateOperationName>Transverse
Mercator</gml:coordinateOperationName>
   <gml:validArea>
      <gml:description>United Kingdom (UK) - Great Britain - England
Scotland Wales - onshore; Isle of Man. </gml:description>
   </gml:validArea>
   <gml:usesMethod xlink:href="urn:ogc:srs:EPSG::9807"/>
   <usesLatitudeOfNaturalOriginValue>
      <angleValue uom="urn:ogc:uom:degree">49</angleValue>
      <gml:valueOfParameter xlink:href="urn:ogc:parameter:EPSG::8801"/>
   </usesLatitudeOfNaturalOriginValue>
   <usesLongitudeOfNaturalOriginValue>
      <angleValue uom="urn:ogc:uom:degree">-2</angleValue>
      <gml:valueOfParameter xlink:href="urn:ogc:parameter:EPSG::8802"/>
   </usesLongitudeOfNaturalOriginValue>
   <usesScaleFactorAtNaturalOriginValue>
      <scaleValue uom="urn:ogc:uom:unity">0.999601272</scaleValue>
      <gml:valueOfParameter xlink:href="urn:ogc:parameter:EPSG::8805"/>
   </usesScaleFactorAtNaturalOriginValue>
   <usesFalseEastingValue>
      <lengthValue uom="urn:ogc:uom:metre">400000</lengthValue>
      <gml:valueOfParameter xlink:href="urn:ogc:parameter:EPSG::8806"/>
   </usesFalseEastingValue>
   <usesFalseNorthingValue>
      <lengthValue uom="urn:ogc:uom:metre">-100000</lengthValue>
      <gml:valueOfParameter xlink:href="urn:ogc:parameter:EPSG::8807"/>
   </usesFalseNorthingValue>
</TransverseMercatorConversion>
```

The above XML example assumes that the Application Schema specified in Subclause F.3.3 is accessible using the location transverseMercator.xsd. This example also assumes that (complete) information for the Transverse Mercator OperationMethod is available

elsewhere, referenced by `urn:ogc:srs:EPSG::9807`. Example XML for that OperationMethod information is given in Subclauses E.5 and F.2.4. Alternately, this OperationMethod information could be included in-line in the longer example XML document:

```
<?xml version="1.0" encoding="UTF-8"?>
<TransverseMercatorConversion xmlns="http://www.opengis.net/examples"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/examples
transverseMercator.xsd" gml:id="EPSG19916">
   <!-- Example XML document. Primary editor: Arliss Whiteside. Last
updated 2003/09/19. -->
   <!-- SourceCRS: EPSG:4277 OSGB 1936 -->
   <!-- TargetCRS: EPSG:27700 OSGB 1936 / British National Grid -->
   <gml:coordinateOperationName>Transverse
Mercator</gml:coordinateOperationName>
   <gml:coordinateOperationID>
      <gml:name codeSpace="EPSG">19916</gml:name>
      <gml:version>6.0</gml:version>
   </gml:coordinateOperationID>
   <gml:validArea>
      <gml:description>United Kingdom (UK) - Great Britain - England
Scotland Wales - onshore; Isle of Man. </gml:description>
   </gml:validArea>
   <gml:usesMethod>
      <gml:OperationMethod gml:id="EPSG9807">
         <gml:methodName>Transverse Mercator</gml:methodName>
         <gml:methodID>
            <gml:name codeSpace="EPSG">9807</gml:name>
            <gml:version>6.0</gml:version>
         </gml:methodID>
         <gml:methodFormula>See Section 1.4.6 "Transverse Mercator" of
EPSG Guidance Note 7, December 2000. </gml:methodFormula>
         <gml:sourceDimensions>2</gml:sourceDimensions>
         <gml:targetDimensions>2</gml:targetDimensions>
         <gml:usesParameter>
            <gml:OperationParameter gml:id="EPSG8801">
               <gml:parameterName>Latitude of natural
origin</gml:parameterName>
               <gml:parameterID>
                  <gml:name codeSpace="EPSG">8801</gml:name>
                  <gml:version>6.0</gml:version>
               </gml:parameterID>
            </gml:OperationParameter>
         </gml:usesParameter>
         <gml:usesParameter>
            <gml:OperationParameter gml:id="EPSG8802">
               <gml:parameterName>Longitude of natural
origin</gml:parameterName>
               <gml:parameterID>
                  <gml:name codeSpace="EPSG">8802</gml:name>
                  <gml:version>6.0</gml:version>
               </gml:parameterID>
            </gml:OperationParameter>
```

```
         </gml:usesParameter>
         <gml:usesParameter>
            <gml:OperationParameter gml:id="EPSG8805">
               <gml:parameterName>Scale factor at natural
origin</gml:parameterName>
               <gml:parameterID>
                  <gml:name codeSpace="EPSG">8805</gml:name>
                  <gml:version>6.0</gml:version>
               </gml:parameterID>
            </gml:OperationParameter>
         </gml:usesParameter>
         <gml:usesParameter>
            <gml:OperationParameter gml:id="EPSG8806">
               <gml:parameterName>False Easting</gml:parameterName>
               <gml:parameterID>
                  <gml:name codeSpace="EPSG">8806</gml:name>
                  <gml:version>6.0</gml:version>
               </gml:parameterID>
            </gml:OperationParameter>
         </gml:usesParameter>
         <gml:usesParameter>
            <gml:OperationParameter gml:id="EPSG8807">
               <gml:parameterName>False Northing</gml:parameterName>
               <gml:parameterID>
                  <gml:name codeSpace="EPSG">8807</gml:name>
                  <gml:version>6.0</gml:version>
               </gml:parameterID>
            </gml:OperationParameter>
         </gml:usesParameter>
      </gml:OperationMethod>
   </gml:usesMethod>
   <usesLatitudeOfNaturalOriginValue>
      <angleValue uom="urn:ogc:uom:degree">49</angleValue>
      <gml:valueOfParameter xlink:href="#EPSG8801"/>
   </usesLatitudeOfNaturalOriginValue>
   <usesLongitudeOfNaturalOriginValue>
      <angleValue uom="urn:ogc:uom:degree">-2</angleValue>
      <gml:valueOfParameter xlink:href="#EPSG8802"/>
   </usesLongitudeOfNaturalOriginValue>
   <usesScaleFactorAtNaturalOriginValue>
      <scaleValue uom="urn:ogc:uom:unity">0.999601272</scaleValue>
      <gml:valueOfParameter xlink:href="#EPSG8805"/>
   </usesScaleFactorAtNaturalOriginValue>
   <usesFalseEastingValue>
      <lengthValue uom="urn:ogc:uom:metre">400000</lengthValue>
      <gml:valueOfParameter xlink:href="#EPSG8806"/>
   </usesFalseEastingValue>
   <usesFalseNorthingValue>
      <lengthValue uom="urn:ogc:uom:metre">-100000</lengthValue>
      <gml:valueOfParameter xlink:href="#EPSG8807"/>
   </usesFalseNorthingValue>
</TransverseMercatorConversion>
```

F.4 Universal image geometry model transformation

F.4.1 Introduction

Standardized XML encoding is needed for a number of frequently-used types of image coordinate transformations. This subclause provides an example of one such encoding, applied to an example image coordinate transformation. That example type of image coordinate transformation is the one described in Section 6.5 of OGC Abstract Specification Topic 7: The Earth Imagery Case, namely the Universal Image Geometry Model (UIGM). That UIGM transformation is from a 3D ground coordinate reference system to a 2D image coordinate reference system, and has been simplified here for brevity. The following subclauses contain:

a) A draft class diagram of a UML package for this simplified UIGM transformation, which builds on the UML model in OGC Abstract Specification Topic 2.

b) Two draft XML Schemas for encoding this simplified UIGM transformation, produced by converting this UML package.

c) An example XML document based on this draft XML Schema for encoding an example UIGM transformation, plus an example XML document based on the Application Schema in Subclause F.2.3 for encoding the Operation Method used by this UIGM transformation.

F.4.2 UML package

Figures F.3 to F.7 contain the five parts of a draft class diagram of a UML package for this simplified UIGM transformation. Figure F.3 shows the top level of the class diagram, without showing the components of the SectionParametersGroup and MonoscopicErrorsGroup. This diagram is incomplete in that some of the needed association role names and multiplicities are not shown due to lack of space. Figure F.4 shows the top level within the SectionParametersGroup, without showing the components of the NormalizationParametersGroup and PolynomialGroup. Figure F.5 shows one example parameter value in the NormalizationParametersGroup, with a note listing the other nine parameter values. Figure F.6 shows two example parameter values in the PolynomialGroup, with a note listing the six other parameter values. Figure F.7 shows the complete contents of the MonoscopicErrorsGroup.

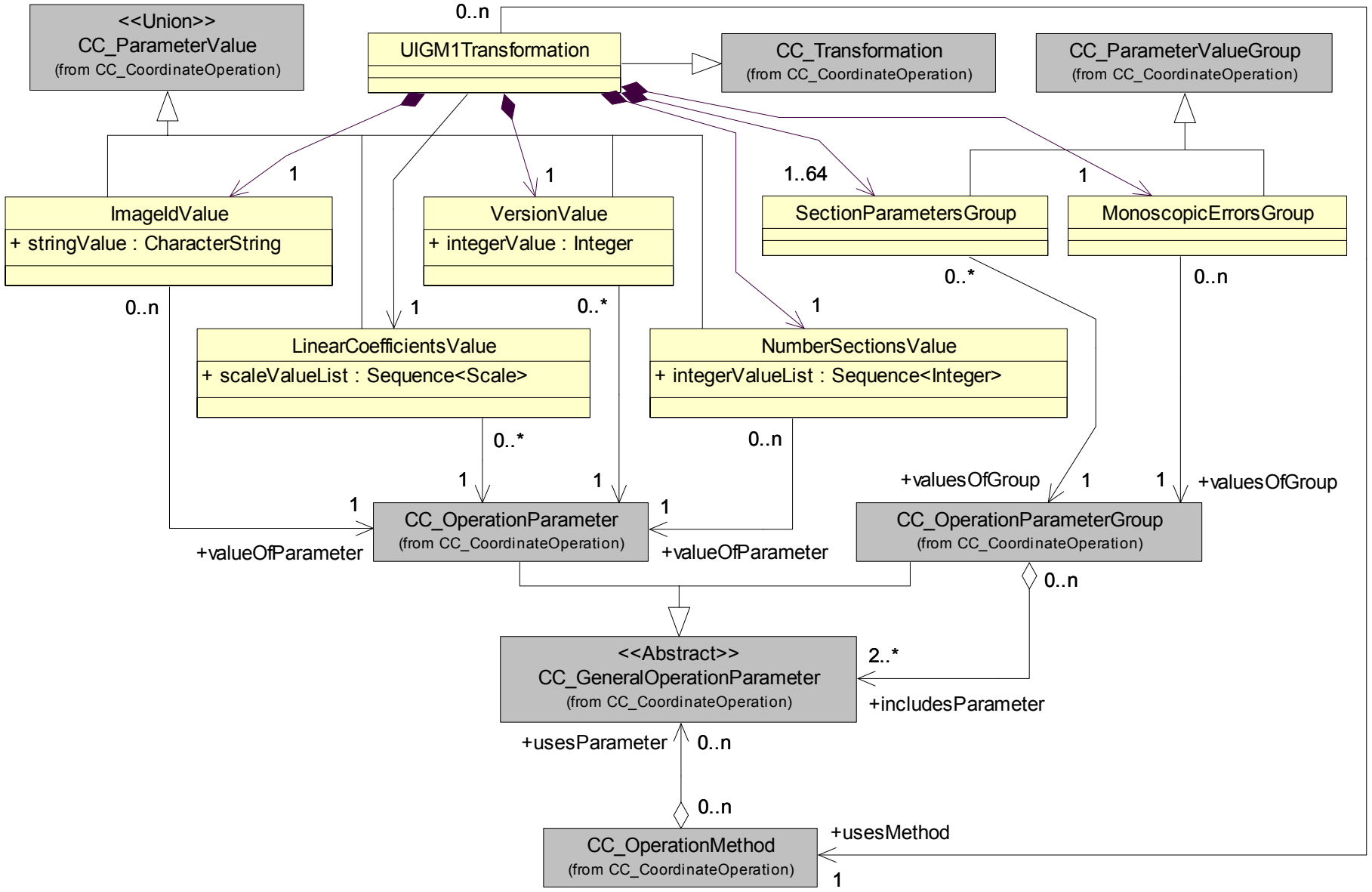


Figure F.3 — UML package for UIGM transformation, page 1

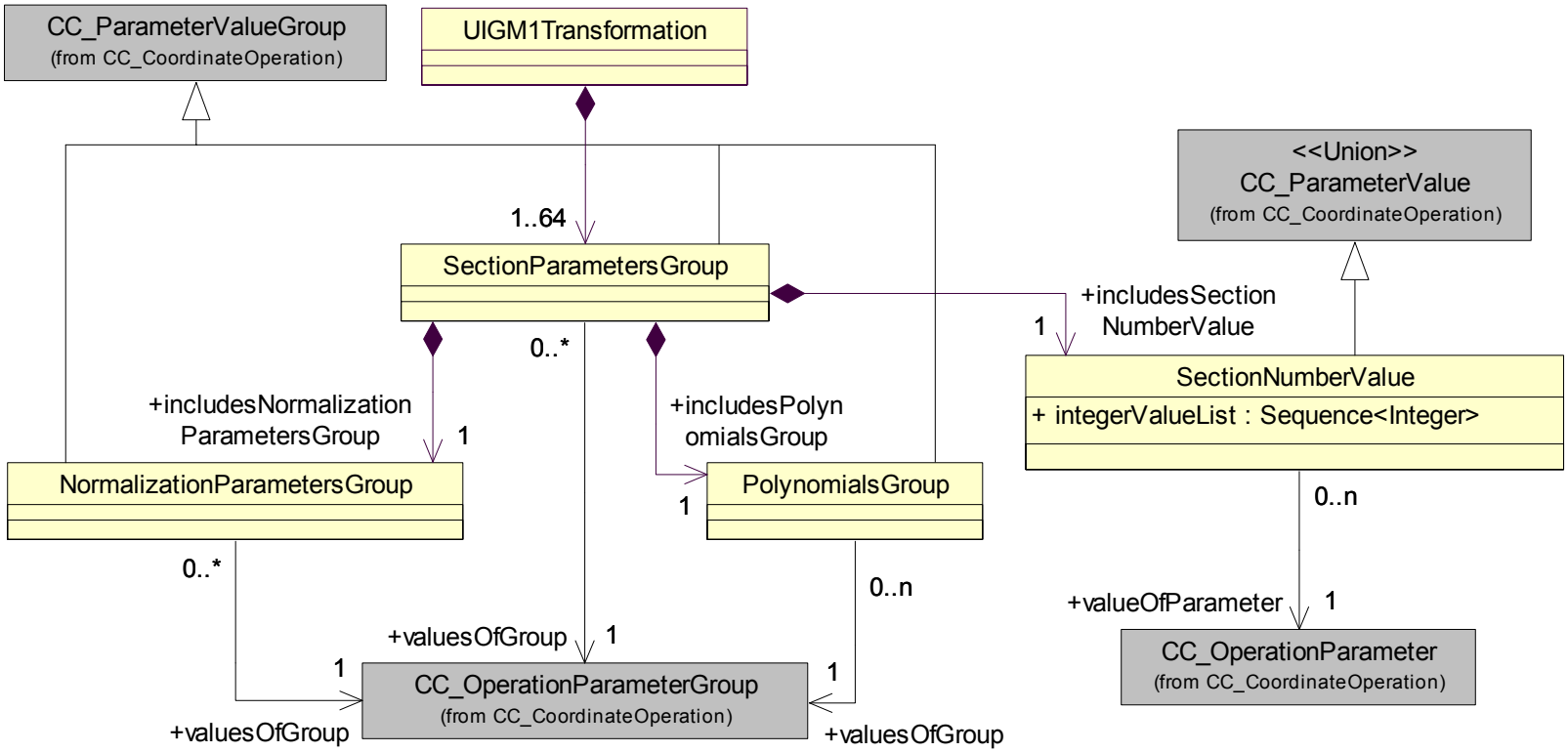


Figure F.4 — UML package for UIGM transformation, page 2

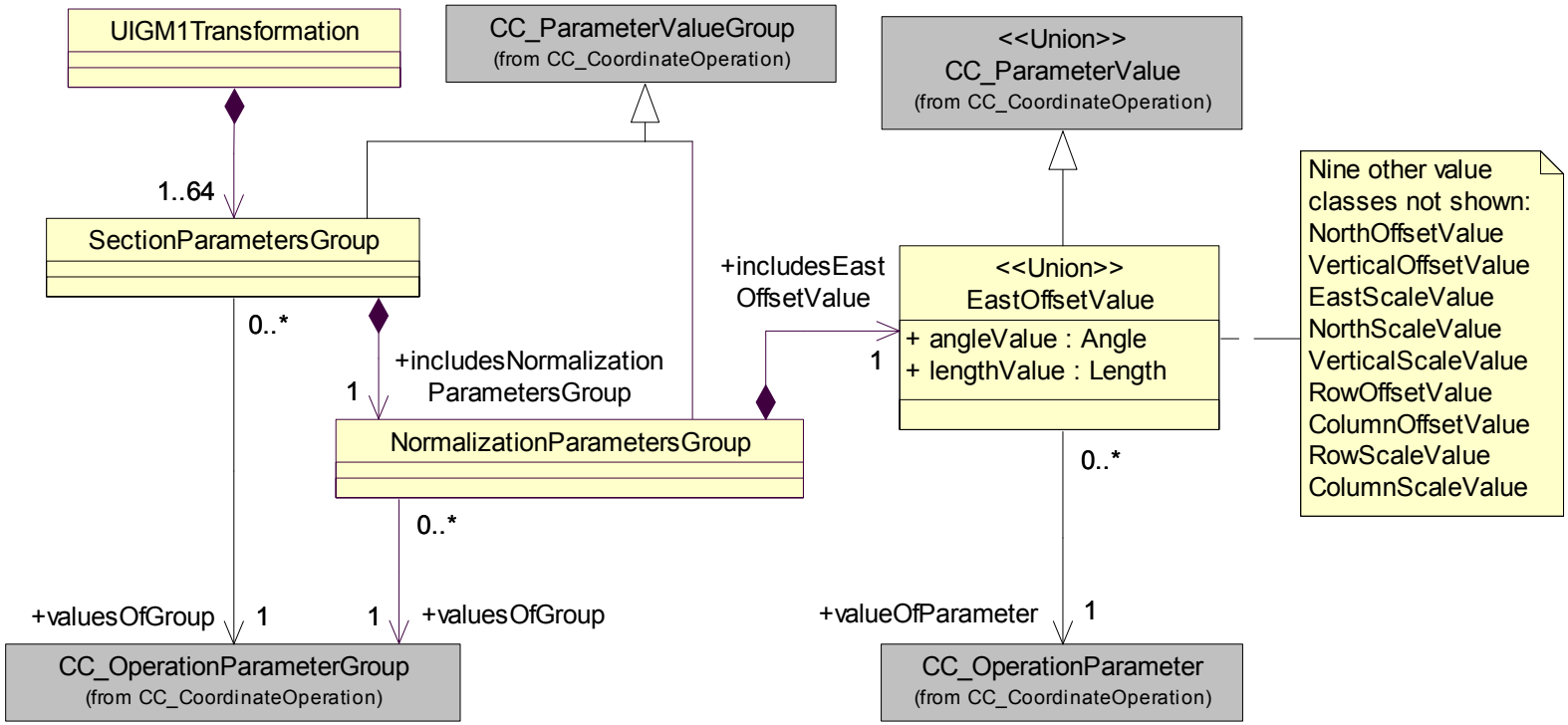


Figure F.5 — UML package for UIGM transformation, page 3

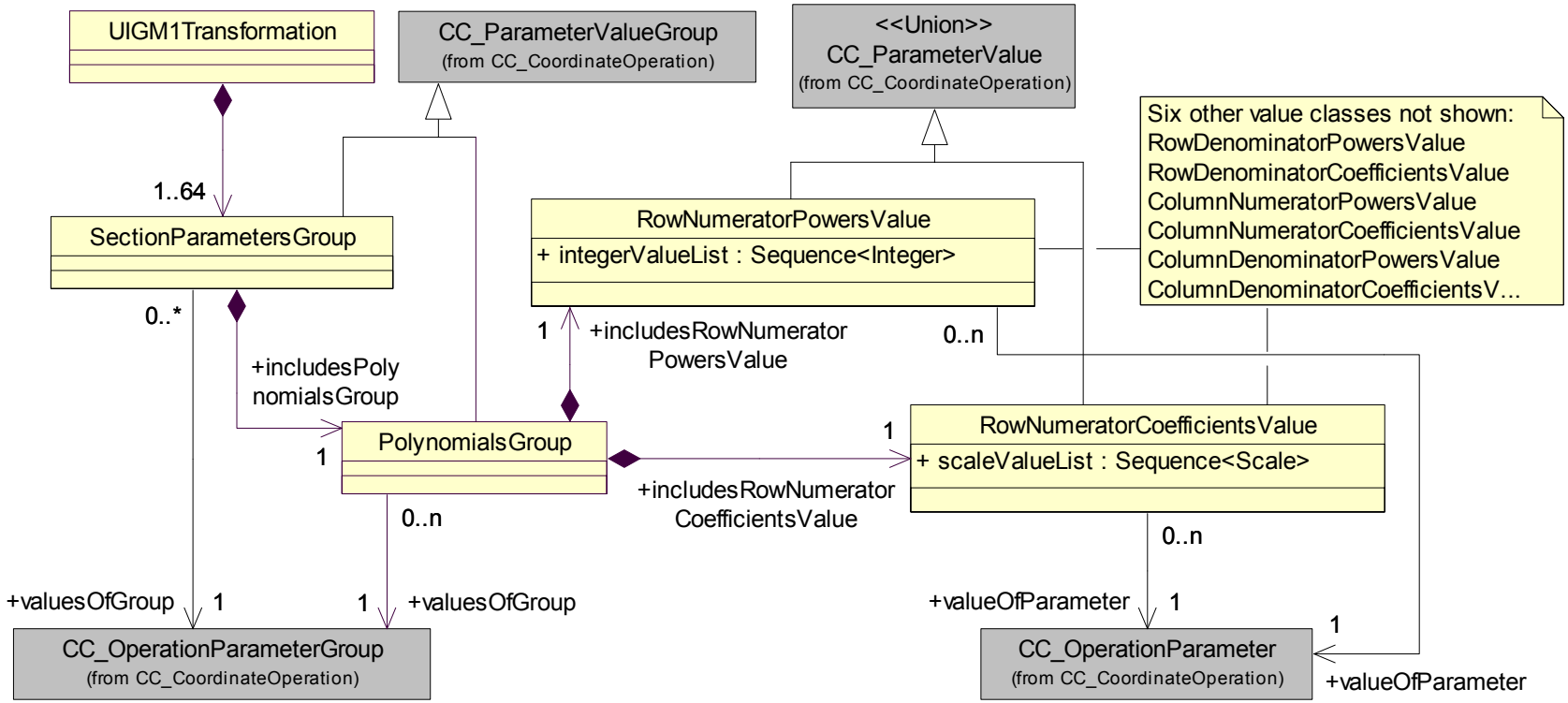


Figure F.6 — UML package for UIGM transformation, page 4

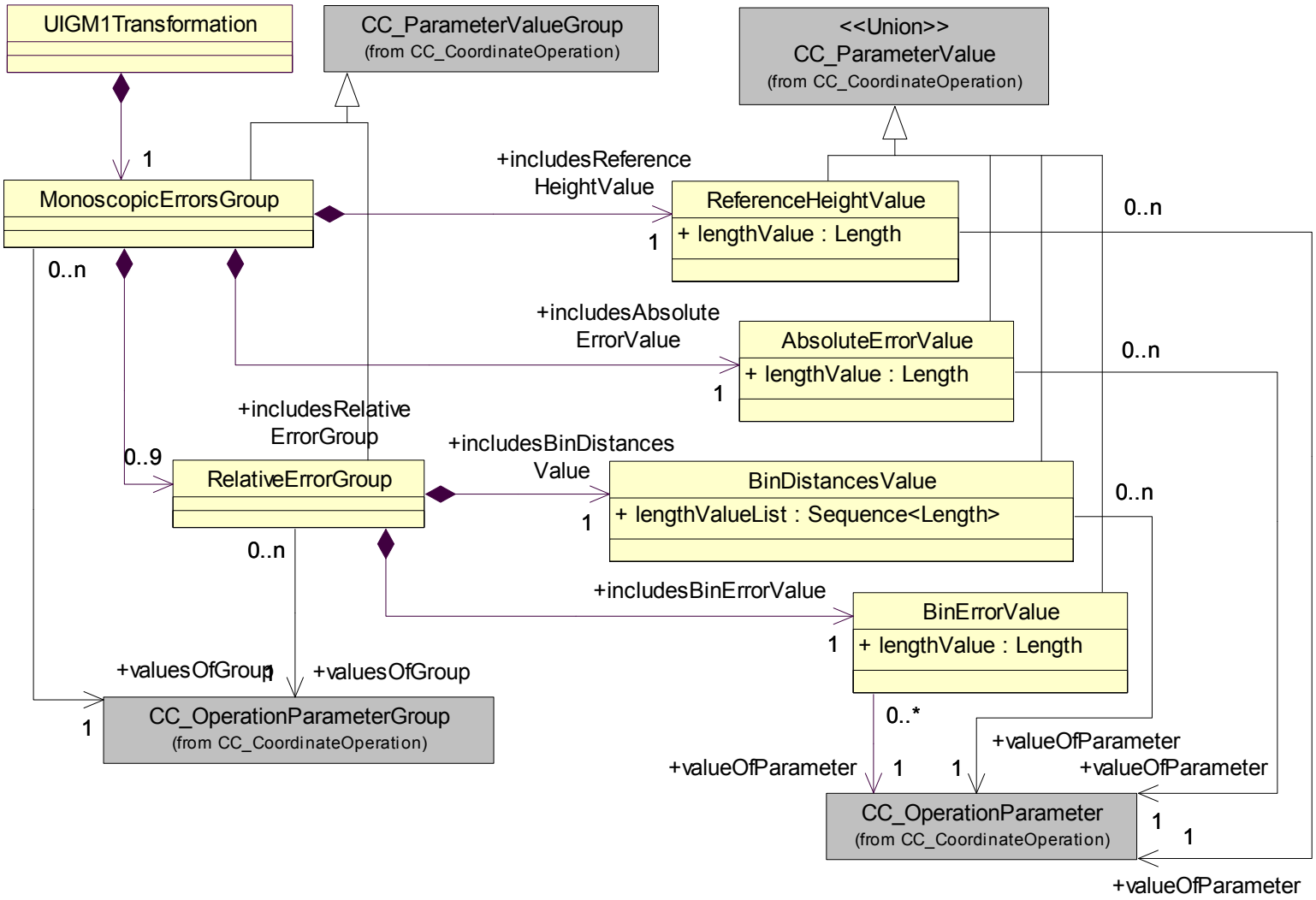


Figure F.7 — UML package for UIGM transformation, page 5

F.4.3 Application schemas

This subclause contains example XML Schemas for encoding this simplified UIGM transformation, produced by converting the above UML package. These XML Schemas build on the coordinateOperations.xsd contained in Subclause C.6. These draft XML Schemas are written following the same GML 3 patterns and ISO 19118 XML encoding rules as used in the XML Schemas in Annex C. These XML Schemas are written as Application Schema in a different namespace.

The first draft Application Schema is:

```
<?xml version="1.0" encoding="UTF-8"?>
<schema targetNamespace="http://www.opengis.net/examples"
xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:ex="http://www.opengis.net/examples"
elementFormDefault="qualified" xml:lang="en">
   <annotation>
      <documentation>
         <name>UIGM1transformation.xsd</name>
         <version>0.1.0</version>
         <scope>How to encode definition of Universal Image Geometry
Model for one image. </scope>
         <description>Example Application Schema to encode ground-to-
image coordinate transformation data for a specific image, using the
Universal Image Geometry Model type of coordinate transformation as
described in Section 6.5 of OGC Abstract Specification Topic 7 : The
Earth Imagery Case (OGC document 99-107). This example does not encode
data for the image correction tables, stereoscopic position error
estimates, and most information not used by the image geometry model.
Builds on coordinateOperations.xsd and typedValues.xsd, and follows
same GML 3 patterns and ISO 19118 encoding. Written in the "ex"
namespace. Primary editor: Arliss Whiteside. Last updated 2003/09/19.
</description>
         <copyright>Copyright (c) 2003 OpenGIS, All Rights
Reserved.</copyright>
         <conformance>This schema encodes a draft UIGM package that
builds on the Coordinate Operation (CC_) package of the extended UML
Model for OGC Abstract Specification Topic 2: Spatial Referencing by
Coordinates. That draft package defines restricted subtypes of the
CC_Transformation,  CC_ParameterValue, and CC_ParameterValueGroup
classes as needed for the UIGM transformation. </conformance>
      </documentation>
   </annotation>
   <!-- ======================================================
       includes and imports
   ====================================================== -->
   <include schemaLocation="typedValues.xsd"/>
   <import namespace="http://www.opengis.net/gml"
schemaLocation="../crsSchemas/base/coordinateOperations.xsd"/>
   <!-- ======================================================
       elements and types
   ====================================================== -->
```

```
   <element name="UIGM1Transformation"
type="ex:UIGM1TransformationType"
substitutionGroup="gml:_GeneralTransformation"/>
   <!-- ================================================== -->
   <complexType name="UIGM1TransformationType">
      <annotation>
         <documentation>Specific Universal Image Geometry Model type of
coordinate transformation. Extends the
AbstractGeneralTransformationType with restricted values for included
elements, including elements in the coordinateOperationID element with
the IdentifierType. If appropriate, the "codeSpace" element could have
the string value "UIGM1", and the "code" element should then identify
the specific image. The other elements in the IdentifierType can be
omitted. The "coordinateOperationName" element shall have a string
value that names a UIGM1 Transformation for a specific image and
specific ground coordinate reference system. The "_PositionalAccuracy"
and "metaDataProperty" elements can be omitted. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralTransformationType">
            <sequence>
               <element ref="gml:usesMethod">
                  <annotation>
                     <documentation>Association to the (UIGM1)
operation method used by this transformation operation.
</documentation>
                  </annotation>
               </element>
               <element ref="ex:usesImageIdValue"/>
               <element ref="ex:usesVersionValue"/>
               <element ref="ex:usesLinearCoefficientsValue"/>
               <element ref="ex:usesNumberSectionsValue"/>
               <element ref="ex:usesSectionParameters"/>
               <element ref="ex:usesMonoscopicErrors"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="UIGM1TransformationRef"
type="ex:UIGM1TransformationRefType"
substitutionGroup="gml:generalTransformationRef"/>
   <!-- ================================================== -->
   <complexType name="UIGM1TransformationRefType">
      <annotation>
         <documentation>Association to a UIGM1 Transformation, either
referencing or containing the definition of that Transformation.
</documentation>
      </annotation>
      <complexContent>
         <restriction base="gml:GeneralTransformationRefType">
            <sequence>
               <element ref="ex:UIGM1Transformation" minOccurs="0"/>
            </sequence>
            <attributeGroup ref="gml:AssociationAttributeGroup"/>
         </restriction>
      </complexContent>
```

```
   </complexType>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="usesImageIdValue" type="ex:StringValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Alphanumeric text identifying one specific
original image. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesVersionValue" type="ex:IntegerValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Increasing numbers of the Image Support Data
Version integer are used to identify versions with increasing quality
of the image geometry model data for the same original image. This
Version shall be â€œ0â€ before the original image support data is
adjusted. The minimum value is 0, and the maximum value is 9.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesLinearCoefficientsValue"
type="ex:ScaleListValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>The values of the coefficients of the
approximate linear sensor model, which is used to find the proper image
geometry model section for a ground coordinate position. The parameter
value shall contain an ordered list of eight double precision floating
point numbers, four for the section number in the image row axis
followed by four for the image column axis. These coefficients shall be
recorded with Scale units, but various implied units are used by the
various coefficients. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="usesNumberSectionsValue"
type="ex:IntegerListValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>The numbers of rows and columns of sections
into which the image geometry model is divided for this image. The
parameter value shall contain an ordered list of two small integers,
the first specifying the number of rows and the second specifying the
number of columns. For each integer, the minimum value is 1, and the
maximum value is 8. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="usesSectionParameters"
type="ex:SectionParametersType"
substitutionGroup="gml:_generalParameterValue"/>
   <!-- ================================================== -->
   <complexType name="SectionParametersType">
```

```
      <annotation>
         <documentation>Group of parameters for one section of the
universal image geometry model. There shall be from 1 up to 64 model
sections for one image. If the model for this image is not divided into
sections, there shall be only one repetition of this group of
parameters. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:includesSectionNumberValue"/>
               <element ref="ex:includesNormalizationParameters"/>
               <element ref="ex:includesPolynomials"/>
               <element ref="gml:valuesOfGroup"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="includesSectionNumberValue"
type="ex:IntegerListValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>The row and column numbers of this section of
the universal image geometry model for this image. The parameter value
contains an ordered list of two small integers, the first specifying
the row number and the second specifying the column number. For each
integer, the minimum value is 1, and the maximum value is
8.</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="includesNormalizationParameters"
type="ex:NormalizationParametersType"
substitutionGroup="gml:_generalParameterValue"/>
   <!-- ================================================== -->
   <complexType name="NormalizationParametersType">
      <annotation>
         <documentation>Group of ground position normalization
parameters and image position un-normalization parameters, for this
section of the universal image geometry model. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:includesEastOffsetValue"/>
               <element ref="ex:includesNorthOffsetValue"/>
               <element ref="ex:includesVerticalOffsetValue"/>
               <element ref="ex:includesEastScaleValue"/>
               <element ref="ex:includesNorthScaleValue"/>
               <element ref="ex:includesVerticalScaleValue"/>
               <element ref="ex:includesRowOffsetValue"/>
               <element ref="ex:includesColumnOffsetValue"/>
               <element ref="ex:includesRowScaleValue"/>
               <element ref="ex:includesColumnScaleValue"/>
               <element ref="gml:valuesOfGroup"/>
```

```
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="includesEastOffsetValue"
type="ex:AngleOrLengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>East position offset for normalizing ground
coordinates. The units shall be either angle or length units.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesNorthOffsetValue"
type="ex:AngleOrLengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>North position offset for normalizing ground
coordinates. The units shall be the same as for the East Offset, either
angle or length units. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesVerticalOffsetValue"
type="ex:LengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Vertical position offset for normalizing ground
coordinates. The units shall be length units. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesEastScaleValue"
type="ex:AngleOrLengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>East scale factor for normalizing ground
coordinates. The units shall be the same as for the East Offset, either
angle or length units. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesNorthScaleValue"
type="ex:AngleOrLengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>North scale factor for normalizing ground
coordinates. The units shall be the same as for the North Offset,
either angle or length units. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesVerticalScaleValue" type="ex:LengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
```

```
         <documentation>Vertical scale factor for normalizing ground
coordinates. The units shall be the same as for the Vertical Offset,
and shall be length units. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesRowOffsetValue" type="ex:GridLengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Image row position offset for un-normalizing
image coordinates. The units shall be one grid spacing.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesColumnOffsetValue"
type="ex:GridLengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Image column position offset for un-normalizing
image coordinates. The units shall be one grid spacing.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesRowScaleValue" type="ex:GridLengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Image row scale factors for un-normalizing
image coordinates. The units shall be one grid spacing.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesColumnScaleValue"
type="ex:GridLengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Image column scale factors for un-normalizing
image coordinates. The units shall be one grid spacing.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="includesPolynomials" type="ex:PolynomialsType"
substitutionGroup="gml:_generalParameterValue"/>
   <!-- ================================================== -->
   <complexType name="PolynomialsType">
      <annotation>
         <documentation>Numerator and denominator polynomial parameters
for this section of the universal image geometry model.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
```

```
               <element ref="ex:includesRowNumeratorPowersValue"/>
               <element
ref="ex:includesRowNumeratorCoefficientsValue"/>
               <element ref="ex:includesRowDenominatorPowersValue"/>
               <element
ref="ex:includesRowDenominatorCoefficientsValue"/>
               <element ref="ex:includesColumnNumeratorPowersValue"/>
               <element
ref="ex:includesColumnNumeratorCoefficientsValue"/>
               <element ref="ex:includesColumnDenominatorPowersValue"/>
               <element
ref="ex:includesColumnDenominatorCoefficientsValue"/>
               <element ref="gml:valuesOfGroup"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="includesRowNumeratorPowersValue"
type="ex:IntegerListValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Maximum powers of the three ground coordinates
in the numerator polynomial for computing the image row coordinate. The
parameter value shall contain an ordered list of three small integers,
corresponding to the East, North, and Vertical ground coordinate axes.
For each integer, the minimum value is 1. For the East and North axis
integers, the maximum value is 5. For the Vertical axis integer, the
maximum value is 3. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesRowNumeratorCoefficientsValue"
type="ex:ScaleListValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Polynomial coefficients in the numerator
polynomial for computing the image row coordinate. The parameter value
shall contain an ordered list of from 8 to 144 Scale measures.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesRowDenominatorPowersValue"
type="ex:IntegerListValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Maximum powers of the three ground coordinates
in the denominator polynomial for computing the image row coordinate.
The parameter value shall contain an ordered list of three small
integers, corresponding to the East, North, and Vertical ground
coordinate axes. For each integer, the minimum value is 1. For the East
and North axis integers, the maximum value is 5. For the Vertical axis
integer, the maximum value is 3. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
```

```
   <element name="includesRowDenominatorCoefficientsValue"
type="ex:ScaleListValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Polynomial coefficients in the denominator
polynomial for computing the image row coordinate. The parameter value
shall contain an ordered list of from 8 to 144 Scale measures.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesColumnNumeratorPowersValue"
type="ex:IntegerListValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Maximum powers of the three ground coordinates
in the numerator polynomial for computing the image column coordinate.
The parameter value shall contain an ordered list of three small
integers, corresponding to the East, North, and Vertical ground
coordinate axes. For each integer, the minimum value is 1. For the East
and North axis integers, the maximum value is 5. For the Vertical axis
integer, the maximum value is 3. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesColumnNumeratorCoefficientsValue"
type="ex:ScaleListValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Polynomial coefficients in the numerator
polynomial for computing the image column coordinate. The parameter
value shall contain an ordered list of from 8 to 144 Scale measures.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesColumnDenominatorPowersValue"
type="ex:IntegerListValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Maximum powers of the three ground coordinates
in the denominator polynomial for computing the image column
coordinate. The parameter value shall contain an ordered list of three
small integers, corresponding to the East, North, and Vertical ground
coordinate axes. For each integer, the minimum value is 1. For the East
and North axis integers, the maximum value is 5. For the Vertical axis
integer, the maximum value is 3. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesColumnDenominatorCoefficientsValue"
type="ex:ScaleListValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>Polynomial coefficients in the denominator
polynomial for computing the image column coordinate. The parameter
```

```
value shall contain an ordered list of from 8 to 144 Scale measures.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="usesMonoscopicErrors" type="ex:MonoscopicErrorsType"
substitutionGroup="gml:_generalParameterValue"/>
   <!-- ================================================== -->
   <complexType name="MonoscopicErrorsType">
      <annotation>
         <documentation>Group of parameters for horizontal error
estimates when a position in this one image is used to determine the
corresponding ground coordinates, using this universal image geometry
model for this image. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:includesReferenceHeightValue"/>
               <element ref="ex:includesAbsoluteErrorValue"/>
               <element ref="ex:includesRelativeError" minOccurs="0"
maxOccurs="9"/>
               <element ref="gml:valuesOfGroup"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="includesReferenceHeightValue"
type="ex:LengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>The value of the ground elevation or height
used to estimate the recorded horizontal error estimate when a position
in this one image is used to determine the corresponding ground
coordinates. This reference height is in the Vertical coordinate system
axis of the ground CRS used by the universal image geometry model for
this image. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesAbsoluteErrorValue" type="ex:LengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>The value of the horizontal absolute error
estimate when a position in this one (monoscopic) image is used to
determine the corresponding ground coordinates. This error estimate
shall be recorded as the Circular Error (CE) with 90% confidence,
always in one meter units. The minimum value is 0.0. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="includesRelativeError" type="ex:RelativeErrorType"
substitutionGroup="gml:_generalParameterValue"/>
   <!-- ================================================== -->
```

```
   <complexType name="RelativeErrorType">
      <annotation>
         <documentation>Relative error estimate for one distance bin
between two points. These error estimates are for use when multiple
positions in one (monoscopic) image are used to determine the
corresponding ground coordinates. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:includesBinDistancesValue"/>
               <element ref="ex:includesBinErrorValue"/>
               <element ref="gml:valuesOfGroup"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <element name="includesBinDistancesValue"
type="ex:LengthListValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>The minimum and maximum ground distances
between two points for this distance bin recorded for horizontal
relative error estimates. The parameter value shall contain an ordered
list of two Length measures, always in one meter units. The first value
specifies the bin minimum distance, and the second value specifies the
bin maximum distance. The minimum values are 0.0. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="includesBinErrorValue" type="ex:LengthValueType"
substitutionGroup="gml:_generalParameterValue">
      <annotation>
         <documentation>The value of the horizontal relative error
estimate between two points for this distance bin recorded for
horizontal relative error estimates. These error estimates are for use
when multiple positions in one (monoscopic) image are used to determine
the corresponding ground coordinates. The relative error estimate shall
be recorded as the Circular Error (CE) with 90% confidence, always in
one meter units. The minimum value is 0.0. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
</schema>
```

The above example Application Schema is shortened by building on a separate example Application Schema. This other Application Schema defines XML Schema complexTypes for a number of types of operation parameter values. The complexTypes defined include 8 parameter types used in the Application Schema above, plus 8 more types expected to be useful in other image geometry model transformations. This second draft XML Application Schema is:

```
<?xml version="1.0" encoding="UTF-8"?>
```

```
<schema targetNamespace="http://www.opengis.net/examples"
xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:ex="http://www.opengis.net/examples"
elementFormDefault="qualified" xml:lang="en">
   <annotation>
      <documentation>
         <name>typedValues.xsd</name>
         <version>0.1.0</version>
         <scope>How to encode operation parameter values with specific
types, including length, angle, and scale measures.. </scope>
         <description>Example Application Schema to encode operation
parameter values with specific types. Builds on measures.xsd, and
follows same GML 3 patterns. Written in the "ex" namespace. Primary
editor: Arliss Whiteside. Last updated 2003/09/19. </description>
         <copyright>Copyright (c) 2003 OpenGIS, All Rights
Reserved.</copyright>
      </documentation>
   </annotation>
   <!-- ======================================================
       includes and imports
   ====================================================== -->
   <import namespace="http://www.opengis.net/gml"
schemaLocation="../crsSchemas/base/coordinateOperations.xsd"/>
   <!-- ======================================================
       elements and types
   ====================================================== -->
   <complexType name="StringValueType">
      <annotation>
         <documentation>Alphanumeric text operation parameter value.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="gml:stringValue"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ===================================================== -->
   <complexType name="IntegerValueType">
      <annotation>
         <documentation>Integer operation parameter value.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="gml:integerValue"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
```

```
   <!-- ================================================== -->
   <complexType name="LengthValueType">
      <annotation>
         <documentation>Length measure operation parameter value.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:lengthValue"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="ScaleValueType">
      <annotation>
         <documentation>Scale measure operation parameter value.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:scaleValue"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="AngleValueType">
      <annotation>
         <documentation>Angle measure operation parameter value.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:angleValue"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="AngleOrLengthValueType">
      <annotation>
         <documentation>Angle or Length measure operation parameter
value, sometimes used for horizontal coordinate parameters.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <choice>
                  <element ref="ex:angleValue"/>
```

```
                  <element ref="ex:lengthValue"/>
               </choice>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="TimeValueType">
      <annotation>
         <documentation>Time measure operation parameter value.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:gridLengthValue"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="GridLengthValueType">
      <annotation>
         <documentation>Grid Length measure operation parameter value.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:gridLengthValue"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="VelocityValueType">
      <annotation>
         <documentation>Velocity measure operation parameter value.
</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:velocityValue"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="IntegerListValueType">
      <annotation>
         <documentation>Ordered sequence of two or more integer
operation parameter values. </documentation>
```

```
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="gml:integerValueList"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="LengthListValueType">
      <annotation>
         <documentation>Ordered sequence of two or more Length
operation parameter values.</documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:lengthValueList"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="ScaleListValueType">
      <annotation>
         <documentation>Ordered sequence of two or more Scale Factor
operation parameter values. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:scaleValueList"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="AngleListValueType">
      <annotation>
         <documentation>Ordered sequence of two or more Angle operation
parameter values. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:angleValueList"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="TimeListValueType">
```

```
      <annotation>
         <documentation>Ordered sequence of two or more Time operation
parameter values. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:timeValueList"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="GridLengthListValueType">
      <annotation>
         <documentation>Ordered sequence of two or more Grid Length
operation parameter values. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:gridLengthValueList"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <complexType name="VelocityListValueType">
      <annotation>
         <documentation>Ordered sequence of two or more Velocity
operation parameter values. </documentation>
      </annotation>
      <complexContent>
         <extension base="gml:AbstractGeneralParameterValueType">
            <sequence>
               <element ref="ex:velocityValueList"/>
               <element ref="gml:valueOfParameter"/>
            </sequence>
         </extension>
      </complexContent>
   </complexType>
   <!-- ================================================== -->
   <!-- ================================================== -->
   <element name="lengthValue" type="gml:LengthType"
substitutionGroup="gml:value">
      <annotation>
         <documentation>Length value of an operation parameter, with a
unit of measure suitable for a length, such as metres or feet.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="scaleValue" type="gml:ScaleType"
substitutionGroup="gml:value">
      <annotation>
```

```
         <documentation>Scale factor value of an operation parameter,
with a unit of measure suitable for a scale factor, such as one,
percent, permil, or parts-per-million. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="angleValue" type="gml:AngleType"
substitutionGroup="gml:value">
      <annotation>
         <documentation>Angle value of an operation parameter, recorded
as a single number, with a unit of measure suitable for an angle, such
as degrees or radians. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="timeValue" type="gml:TimeType"
substitutionGroup="gml:value">
      <annotation>
         <documentation>Time value of an operation parameter, recorded
as a single number, with a unit of measure suitable for a time value,
such as seconds or days. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="gridLengthValue" type="gml:GridLengthType"
substitutionGroup="gml:value">
      <annotation>
         <documentation>Grid length value of an operation parameter,
with a unit of measure suitable for length along the axes of a grid,
such as pixel spacings or grid spacings. Used when the grid spacing
does not have any associated physical units, or does not have a
constant physical spacing. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="velocityValue" type="gml:VelocityType"
substitutionGroup="gml:value">
      <annotation>
         <documentation>Velocity value of an operation parameter, with
a unit of measure suitable for a velocity, such as metres per second or
miles per hour. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="lengthValueList" type="gml:MeasureListType"
substitutionGroup="gml:valueList">
      <annotation>
         <documentation>Ordered sequence of two or more length values
of an operation parameter, with a unit of measure suitable for a
length, such as metres or feet. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="scaleValueList" type="gml:MeasureListType"
substitutionGroup="gml:valueList">
      <annotation>
```

```
         <documentation>Ordered sequence of two or more scale factor
values of an operation parameter, with a unit of measure suitable for a
scale factor, such as one, percent, permil, or parts-per-million.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="angleValueList" type="gml:MeasureListType"
substitutionGroup="gml:valueList">
      <annotation>
         <documentation>Ordered sequence of two or more angle values of
an operation parameter, each recorded as a single number, with a unit
of measure suitable for an angle, such as degrees or radians.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="timeValueList" type="gml:MeasureListType"
substitutionGroup="gml:valueList">
      <annotation>
         <documentation>Ordered sequence of two or more time values of
an operation parameter, each recorded as a single number, with a unit
of measure suitable for a time value, such as seconds or days.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="gridLengthValueList" type="gml:MeasureListType"
substitutionGroup="gml:valueList">
      <annotation>
         <documentation>Ordered sequence of two or more grid length
values of an operation parameter, with a unit of measure suitable for
length along the axes of a grid, such as pixel spacings or grid
spacings. Used when the grid spacing does not have any associated
physical units, or does not have a constant physical spacing.
</documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
   <element name="velocityValueList" type="gml:MeasureListType"
substitutionGroup="gml:valueList">
      <annotation>
         <documentation>Ordered sequence of two or more velocity values
of an operation parameter, with a unit of measure suitable for a
velocity, such as metres per second or miles per hour. </documentation>
      </annotation>
   </element>
   <!-- ================================================== -->
</schema>
```

F.4.4 Example XML documents

An example XML document based on the above two example Application Schemas for encoding this simplified UIGM transformation is:

```
<?xml version="1.0" encoding="UTF-8"?>
<UIGM1Transformation xmlns="http://www.opengis.net/examples"
xmlns:gml="http://www.opengis.net/gml"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/examples
UIGM1transformation.xsd" gml:id="AaaaAaaa">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/09/19. -->
   <gml:coordinateOperationName>Aaaa Aaaa</gml:coordinateOperationName>
   <gml:operationVersion>1</gml:operationVersion>
   <gml:sourceCRS xlink:href="urn:ogc:srs:EPSG::7405"
xlink:title="OSGB36 /British National Grid + ODN"/>
   <gml:targetCRS xlink:href="urn:ogc:srs:UIGM:ImageCRS"/>
   <gml:usesMethod xlink:href="urn:ogc:method:UIGM:MethodUIGM1"/>
   <usesImageIdValue>
      <gml:stringValue>AAAAAA</gml:stringValue>
      <gml:valueOfParameter
xlink:href="urn:ogc:parameter:UIGM:ImageID"/>
   </usesImageIdValue>
   <usesVersionValue>
      <gml:integerValue>1</gml:integerValue>
      <gml:valueOfParameter
xlink:href="urn:ogc:parameter:UIGM:Version"/>
   </usesVersionValue>
   <usesLinearCoefficientsValue>
      <scaleValueList uom="urn:ogc:uom:unity">9.999 9.999 9.999 9.999
9.999 9.999 9.999 9.999</scaleValueList>
      <gml:valueOfParameter
xlink:href="urn:ogc:parameter:UIGM:LinearCoefficients"/>
   </usesLinearCoefficientsValue>
   <usesNumberSectionsValue>
      <gml:integerValueList>1 1</gml:integerValueList>
      <gml:valueOfParameter
xlink:href="urn:ogc:parameter:UIGM:NumberSections"/>
   </usesNumberSectionsValue>
   <usesSectionParameters>
      <includesSectionNumberValue>
         <gml:integerValueList>1 1</gml:integerValueList>
         <gml:valueOfParameter
xlink:href="urn:ogc:parameter:UIGM:SectionNumber"/>
      </includesSectionNumberValue>
      <includesNormalizationParameters>
         <includesEastOffsetValue>
            <angleValue uom="urn:ogc:uom:degree">99.999</angleValue>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:EastOffset"/>
         </includesEastOffsetValue>
         <includesNorthOffsetValue>
            <angleValue uom="urn:ogc:uom:degree">9.999</angleValue>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:NorthOffset"/>
         </includesNorthOffsetValue>
         <includesVerticalOffsetValue>
            <lengthValue uom="urn:ogc:uom:metre">99.999</lengthValue>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:VerticalOffset"/>
         </includesVerticalOffsetValue>
```

```
         <includesEastScaleValue>
            <angleValue uom="urn:ogc:uom:degree">9.999</angleValue>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:EastScale"/>
         </includesEastScaleValue>
         <includesNorthScaleValue>
            <angleValue uom="urn:ogc:uom:degree">9.999</angleValue>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:NorthScale"/>
         </includesNorthScaleValue>
         <includesVerticalScaleValue>
            <lengthValue uom="urn:ogc:uom:metre">9.999</lengthValue>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:VerticalScale"/>
         </includesVerticalScaleValue>
         <includesRowOffsetValue>
            <gridLengthValue
uom="urn:ogc:uom:PixelSpacing">9999.99</gridLengthValue>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:RowOffset"/>
         </includesRowOffsetValue>
         <includesColumnOffsetValue>
            <gridLengthValue
uom="urn:ogc:uom:PixelSpacing">9999.99</gridLengthValue>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:ColumnOffset"/>
         </includesColumnOffsetValue>
         <includesRowScaleValue>
            <gridLengthValue
uom="urn:ogc:uom:PixelSpacing">999.99</gridLengthValue>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:RowScale"/>
         </includesRowScaleValue>
         <includesColumnScaleValue>
            <gridLengthValue
uom="urn:ogc:uom:PixelSpacing">999.99</gridLengthValue>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:ColumnScale"/>
         </includesColumnScaleValue>
         <gml:valuesOfGroup
xlink:href="urn:ogc:method:UIGM:NormalizationParameters"/>
      </includesNormalizationParameters>
      <includesPolynomials>
         <includesRowNumeratorPowersValue>
            <gml:integerValueList>1 1 1</gml:integerValueList>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:RowNumeratorPowers"/>
         </includesRowNumeratorPowersValue>
         <includesRowNumeratorCoefficientsValue>
            <scaleValueList uom="urn:ogc:uom:unity">0.999999 0.999999
0.999999 0.999999 0.999999 0.999999 0.999999 0.999999</scaleValueList>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:RowNumeratorCoefficients"/>
         </includesRowNumeratorCoefficientsValue>
         <includesRowDenominatorPowersValue>
            <gml:integerValueList>1 1 1</gml:integerValueList>
```

```
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:RowDenominatorPowers"/>
         </includesRowDenominatorPowersValue>
         <includesRowDenominatorCoefficientsValue>
            <scaleValueList uom="urn:ogc:uom:unity">0.999999 0.999999
0.999999 0.999999 0.999999 0.999999 0.999999 0.999999</scaleValueList>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:RowDenominatorCoefficients"/>
         </includesRowDenominatorCoefficientsValue>
         <includesColumnNumeratorPowersValue>
            <gml:integerValueList>1 1 1</gml:integerValueList>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:ColumnNumeratorPowers"/>
         </includesColumnNumeratorPowersValue>
         <includesColumnNumeratorCoefficientsValue>
            <scaleValueList uom="urn:ogc:uom:unity">0.999999 0.999999
0.999999 0.999999 0.999999 0.999999 0.999999 0.999999</scaleValueList>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:ColumnNumeratorCoefficients"/>
         </includesColumnNumeratorCoefficientsValue>
         <includesColumnDenominatorPowersValue>
            <gml:integerValueList>1 1 1</gml:integerValueList>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:ColumnDenominatorPowers"/>
         </includesColumnDenominatorPowersValue>
         <includesColumnDenominatorCoefficientsValue>
            <scaleValueList uom="urn:ogc:uom:unity">0.999999 0.999999
0.999999 0.999999 0.999999 0.999999 0.999999 0.999999</scaleValueList>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:ColumnDenominatorCoefficients"/>
         </includesColumnDenominatorCoefficientsValue>
         <gml:valuesOfGroup
xlink:href="urn:ogc:method:UIGM:Polynomials"/>
      </includesPolynomials>
      <gml:valuesOfGroup
xlink:href="urn:ogc:method:UIGM:SectionParameters"/>
   </usesSectionParameters>
   <usesMonoscopicErrors>
      <includesReferenceHeightValue>
         <lengthValue uom="urn:ogc:uom:metre">999</lengthValue>
         <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:ReferenceHeight"/>
      </includesReferenceHeightValue>
      <includesAbsoluteErrorValue>
         <lengthValue uom="urn:ogc:uom:metre">99.99</lengthValue>
         <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:AbsoluteError"/>
      </includesAbsoluteErrorValue>
      <includesRelativeError>
         <includesBinDistancesValue>
            <lengthValueList uom="urn:ogc:uom:metre">0
1000</lengthValueList>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:BinDistances"/>
         </includesBinDistancesValue>
         <includesBinErrorValue>
            <lengthValue uom="urn:ogc:uom:metre">9.99</lengthValue>
```

```
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:BinError"/>
         </includesBinErrorValue>
         <gml:valuesOfGroup
xlink:href="urn:ogc:method:UIGM:RelativeError"/>
      </includesRelativeError>
      <includesRelativeError>
         <includesBinDistancesValue>
            <lengthValueList uom="urn:ogc:uom:metre">1000
10000</lengthValueList>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:BinDistances"/>
         </includesBinDistancesValue>
         <includesBinErrorValue>
            <lengthValue uom="urn:ogc:uom:metre">9.99</lengthValue>
            <gml:valueOfParameter
xlink:href="urn:ogc:method:UIGM:BinError"/>
         </includesBinErrorValue>
         <gml:valuesOfGroup
xlink:href="urn:ogc:method:UIGM:RelativeError"/>
      </includesRelativeError>
      <gml:valuesOfGroup
xlink:href="urn:ogc:method:UIGM:MonoscopicErrors"/>
   </usesMonoscopicErrors>
</UIGM1Transformation>
```

The above XML example uses dummy values such as "Aaaa" in place of real values for some text string values. Similarly, this example also uses dummy values such as "99.99" in place of real values for some numerical values. This example assumes that the Application Schemas specified in Subclause F.4.3 are accessible using the location UIGM1transformation.xsd.

The above XML example also assumes that (complete) information for several items is available elsewhere. The definition of the sourceCRS and targetCRS are assumed to be available elsewhere, and can be encoded in XML as shown in the example XML in Subclauses E.3 and E.10. The definition of the simplified UIGM OperationMethod can be XML encoded using the example Application Schema from Subclause F.2.3, and could be:

```
<?xml version="1.0" encoding="UTF-8"?>
<OperationMethod xmlns="http://www.opengis.net/gml"
xmlns:gml="http://www.opengis.net/gml"
xmlns:ex="http://www.opengis.net/examples"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/examples
extendedOperationParameter.xsd" gml:id="MethodUIGM1">
   <!-- Primary editor: Arliss Whiteside. Last updated 2003/09/19. -->
   <remarks>This operation method implements the universal image
geometry model that transforms ground coordinates into georeferenced
image coordinates. This image geometry model uses one ratio of two
polynomial functions to compute the row image coordinate, and uses a
similar ratio of two different polynomials to compute the column image
coordinate. All four polynomials are functions of three ground
```

```
coordinates: two horizontal coordinates and one vertical coordinate. In
the polynomial functions, the three ground coordinates and two image
coordinates are each offset and scaled to have a range from -1.0 to
+1.0 over an image or image section. For brevity, this simplified
operation method specification does not include all geometry model
parameters or all optional XML elements. </remarks>
   <methodName>Universal Image Geometry Model Transformation
(simplified)</methodName>
   <methodFormula>See Section 6.5 of OGC Abstract Specification Topic 7
: The Earth Imagery Case ( OGC document 99-107). </methodFormula>
   <sourceDimensions>3</sourceDimensions>
   <targetDimensions>2</targetDimensions>
   <usesParameter>
      <ex:ExtendedOperationParameter gml:id="ImageID">
         <remarks>Alphanumeric text identifying one specific original
image. </remarks>
         <parameterName>Image ID</parameterName>
         <ex:parameterType
codeSpace="parameterTypeCodeList.xml">string</ex:parameterType>
      </ex:ExtendedOperationParameter>
   </usesParameter>
   <usesParameter>
      <ex:ExtendedOperationParameter gml:id="Version">
         <remarks>Increasing numbers of the Image Support Data Version
Number are used to identify versions with increasing quality of the
image geometry model data for the same original image. This Image
Support Data Version field shall be 0 before the original image support
data is adjusted. Minimum value is 0, maximum value is 9. </remarks>
         <parameterName>Image Support Data Version</parameterName>
         <ex:parameterType
codeSpace="parameterTypeCodeList.xml">nonNegativeInteger</ex:parameterT
ype>
      </ex:ExtendedOperationParameter>
   </usesParameter>
   <usesParameter>
      <ex:ExtendedOperationParameter gml:id="LinearCoefficients">
         <remarks>The values of the coefficients of the approximate
linear sensor model, which is used to find the proper image geometry
model section for a ground coordinate position. The parameter value
shall contain an ordered list of eight double precision floating point
numbers, four for the section number in the image row axis, followed by
four for the image column axis. These coefficients shall be recorded
with Scale units, but various implied units are used by the various
coefficients. </remarks>
         <parameterName>Linear Sensor Model
Coefficients</parameterName>
         <ex:parameterType
codeSpace="parameterTypeCodeList.xml">ScaleListType</ex:parameterType>
      </ex:ExtendedOperationParameter>
   </usesParameter>
   <usesParameter>
      <ex:ExtendedOperationParameter gml:id="NumberSections">
         <remarks>The numbers of rows and columns of sections into
which the image geometry model is divided for this image. The parameter
value shall contain an ordered list of two small integers, the first
specifying the number of rows and the second specifying the number of
```

```
columns. For each integer, the minimum value is 1, and the maximum
value is 8. </remarks>
         <parameterName>Number of Sections</parameterName>
         <ex:parameterType
codeSpace="parameterTypeCodeList.xml">integerList</ex:parameterType>
      </ex:ExtendedOperationParameter>
   </usesParameter>
   <usesParameter>
      <OperationParameterGroup gml:id="SectionParameters">
         <remarks>Parameters for one section of the universal image
geometry model. There shall be from 1 up to 64 model sections for one
image. If the model for this image is not divided into sections, there
shall be only one repetition of this group of parameters. </remarks>
         <groupName>Image Section Parameters</groupName>
         <maximumOccurs>64</maximumOccurs>
         <includesParameter>
            <ex:ExtendedOperationParameter gml:id="SectionNumber">
               <remarks>The row and column numbers of this section of
the universal image geometry model for this image. The parameter value
contains an ordered list of two small integers, the first specifying
the row number and the second specifying the column number. For each
integer, the minimum value is 1, and the maximum value is 8. </remarks>
               <parameterName>Section Number</parameterName>
               <ex:parameterType
codeSpace="parameterTypeCodeList.xml">integerList</ex:parameterType>
            </ex:ExtendedOperationParameter>
         </includesParameter>
         <includesParameter>
            <OperationParameterGroup gml:id="NormalizationParameters">
               <remarks>Ground position normalization parameters and
image position un-normalization parameters, for this section of the
universal image geometry model. </remarks>
               <groupName>Ground and Image Position Normalization
Parameters</groupName>
               <includesParameter>
                  <ex:ExtendedOperationParameter gml:id="EastOffset">
                     <remarks>East position offset for normalizing
ground coordinates. The units shall be either length or angle units.
</remarks>
                     <parameterName>East Ground Position
Offset</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthOrAngleType</ex:parameterTy
pe>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter gml:id="NorthOffset">
                     <remarks>North position offset for normalizing
ground coordinates. The units shall be the same as for the East Offset,
and either length or angle units. </remarks>
                     <parameterName>North Ground Position
Offset</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthOrAngleType</ex:parameterTy
pe>
                  </ex:ExtendedOperationParameter>
```

```
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter
gml:id="VerticalOffset">
                     <remarks>Vertical position offset for normalizing
ground coordinates. The units shall be length units. </remarks>
                     <parameterName>Vertical Ground Position
Offset</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter gml:id="EastScale">
                     <remarks>East scale factor for normalizing ground
coordinates. The units shall be the same as for the East Offset, either
length or angle units. </remarks>
                     <parameterName>East Ground Position
Scale</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthOrAngleType</ex:parameterTy
pe>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter gml:id="NorthScale">
                     <remarks>North scale factor for normalizing ground
coordinates. The units shall be the same as for the North Offset,
either length or angle units. </remarks>
                     <parameterName>North Ground Position
Scale</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthOrAngleType</ex:parameterTy
pe>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter
gml:id="VerticalScale">
                     <remarks>Vertical scale factor for normalizing
ground coordinates. The units shall be the same as for the Vertical
Offset, and shall be length units. </remarks>
                     <parameterName>Vertical Ground Position
Scale</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter gml:id="RowOffset">
                     <remarks>Image row position offset for un-
normalizing image coordinates. The units shall be one grid spacing.
</remarks>
                     <parameterName>Image Row Position
Offset</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">GridLengthType</ex:parameterType>
```

```
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter gml:id="ColumnOffset">
                     <remarks>Image column position offset for un-
normalizing image coordinates. The units shall be one grid spacing.
</remarks>
                     <parameterName>Image Column Position
Offset</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">GridLengthType</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter gml:id="RowScale">
                     <remarks>Image row scale factors for un-
normalizing image coordinates. The units shall be one grid spacing.
</remarks>
                     <parameterName>Image Row Position
Scale</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">GridLengthType</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter gml:id="ColumnScale">
                     <remarks>Image column scale factors for un-
normalizing image coordinates. The units shall be one grid spacing.
</remarks>
                     <parameterName>Image Column Position
Scale</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">GridLengthType</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
            </OperationParameterGroup>
         </includesParameter>
         <includesParameter>
            <OperationParameterGroup gml:id="Polynomials">
               <remarks>Numerator and denominator polynomial parameters
for this section of the universal image geometry model. </remarks>
               <groupName>Numerator and Denominator
Polynomials</groupName>
               <includesParameter>
                  <ex:ExtendedOperationParameter
gml:id="RowNumeratorPowers">
                     <remarks>Maximum powers of the three ground
coordinates in the numerator polynomial for computing the image row
coordinate. The parameter value shall contain an ordered list of three
small integers, corresponding to the East, North, and Vertical ground
coordinate axes. For each integer, the minimum value is 1. For the East
and North axis integers, the maximum value is 5. For the Vertical axis
integer, the maximum value is 3. </remarks>
                     <parameterName>Row Numerator Maximum
Powers</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">integerList</ex:parameterType>
```

```
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter
gml:id="RowNumeratorCoefficients">
                     <remarks>Polynomial coefficients in the numerator
polynomial for computing the image row coordinate. The parameter value
shall contain an ordered list of from 8 to 144 Scale measures.
</remarks>
                     <parameterName>Row Numerator Polynomial
Coefficients</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">ScaleListType</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter
gml:id="RowDenominatorPowers">
                     <remarks>Maximum powers of the three ground
coordinates in the denominator polynomial for computing the image row
coordinate. The parameter value shall contain an ordered list of three
small integers, corresponding to the East, North, and Vertical ground
coordinate axes. For each integer, the minimum value is 1. For the East
and North axis integers, the maximum value is 5. For the Vertical axis
integer, the maximum value is 3. </remarks>
                     <parameterName>Row Denominator Maximum
Powers</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">integerList</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter
gml:id="RowDenominatorCoefficients">
                     <remarks>Polynomial coefficients in the
denominator polynomial for computing the image row coordinate. The
parameter value shall contain an ordered list of from 8 to 144 Scale
measures. </remarks>
                     <parameterName>Row Denominator Polynomial
Coefficients</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">ScaleListType</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter
gml:id="ColumnNumeratorPowers">
                     <remarks>Maximum powers of the three ground
coordinates in the numerator polynomial for computing the image column
coordinate. The parameter value shall contain an ordered list of three
small integers, corresponding to the East, North, and Vertical ground
coordinate axes. For each integer, the minimum value is 1. For the East
and North axis integers, the maximum value is 5. For the Vertical axis
integer, the maximum value is 3. </remarks>
                     <parameterName>Column Numerator Maximum
Powers</parameterName>
```

```
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">integerList</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter
gml:id="ColumnNumeratorCoefficients">
                     <remarks>Polynomial coefficients in the numerator
polynomial for computing the image column coordinate. The parameter
value shall contain an ordered list of from 8 to 144 Scale measures.
</remarks>
                     <parameterName>Column Numerator Polynomial
Coefficients</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">ScaleListType</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter
gml:id="ColumnDenominatorPowers">
                     <remarks>Maximum powers of the three ground
coordinates in the denominator polynomial for computing the image
column coordinate. The parameter value shall contain an ordered list of
three small integers, corresponding to the East, North, and Vertical
ground coordinate axes. For each integer, the minimum value is 1. For
the East and North axis integers, the maximum value is 5. For the
Vertical axis integer, the maximum value is 3. </remarks>
                     <parameterName>Column Denominator Maximum
Powers</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">integerList</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter
gml:id="ColumnDenominatorCoefficients">
                     <remarks>Polynomial coefficients in the
denominator polynomial for computing the image column coordinate. The
parameter value shall contain an ordered list of from 8 to 144 Scale
measures. </remarks>
                     <parameterName>Column Denominator Polynomial
Coefficients</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">ScaleListType</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
            </OperationParameterGroup>
         </includesParameter>
      </OperationParameterGroup>
   </usesParameter>
   <usesParameter>
      <OperationParameterGroup gml:id="MonoscopicErrors">
         <remarks>Horizontal error estimates for when a position in
this one image is used to determine the corresponding ground
coordinates, using this universal image geometry model for this image.
</remarks>
         <groupName>Monoscopic Error Estimates</groupName>
```

```
         <includesParameter>
            <ex:ExtendedOperationParameter gml:id="ReferenceHeight">
               <remarks>The value of the ground elevation or height
used to estimate the recorded horizontal error estimate when a position
in this one image is used to determine the corresponding ground
coordinates. This reference height is in the Vertical coordinate system
axis of the ground CRS used by the universal image geometry model for
this image. </remarks>
               <parameterName>Monoscopic Error Estimate Reference
Height</parameterName>
               <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
            </ex:ExtendedOperationParameter>
         </includesParameter>
         <includesParameter>
            <ex:ExtendedOperationParameter gml:id="AbsoluteError">
               <remarks>The value of the horizontal absolute error
estimate when a position in this one (monoscopic) image is used to
determine the corresponding ground coordinates. This error estimate
shall be recorded as the Circular Error (CE) with 90% confidence,
always in one metre units. The minimum value is 0.0. </remarks>
               <parameterName>Monoscopic Absolute Error
Estimate</parameterName>
               <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
            </ex:ExtendedOperationParameter>
         </includesParameter>
         <includesParameter>
            <OperationParameterGroup gml:id="RelativeError">
               <remarks>Relative error estimate for one distance bin
between two points. These error estimates are for use when multiple
positions in one (monoscopic) image are used to determine the
corresponding ground coordinates. </remarks>
               <groupName>Bin Relative Error Estimates</groupName>
               <minimumOccurs>0</minimumOccurs>
               <maximumOccurs>9</maximumOccurs>
               <includesParameter>
                  <ex:ExtendedOperationParameter gml:id="BinDistances">
                     <remarks>The minimum and maximum ground distances
between two points for this distance bin recorded for horizontal
relative error estimates. The parameter value shall contain an ordered
list of two Length measures, always in one metre units. The first value
specifies the bin minimum distance, and the second value specifies the
bin maximum distance. The minimum values are 0.0. </remarks>
                     <parameterName>Monoscopic Relative Error Estimate
Bin Distances</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthListType</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
               <includesParameter>
                  <ex:ExtendedOperationParameter gml:id="BinError">
                     <remarks>The value of the horizontal relative
error estimate between two points for this distance bin recorded for
horizontal relative error estimates. These error estimates are for use
when multiple positions in one (monoscopic) image are used to determine
the corresponding ground coordinates. The relative error estimate shall
```

```
be recorded as the Circular Error (CE) with 90% confidence, always in
one metre units. The minimum value is 0.0. </remarks>
                     <parameterName>Bin Monoscopic Relative Error
Estimate</parameterName>
                     <ex:parameterType
codeSpace="parameterTypeCodeList.xml">LengthType</ex:parameterType>
                  </ex:ExtendedOperationParameter>
               </includesParameter>
            </OperationParameterGroup>
         </includesParameter>
      </OperationParameterGroup>
   </usesParameter>
</OperationMethod>
```

Annex G
(informative)

UML to XML schemas conversion process

G.1 General

This document describes an application of ISO 19118 Annex A "XML based encoding rule" to a UML model of Coordinate Reference System and Coordinate Operation definition data. The UML model converted to XML Schemas is based on OGC Abstract Specification Topic 2: Spatial Referencing by Coordinates (OGC 02-102). That UML model has been expanded and revised, to improve it and to slightly better support conversion to XML Schemas. That revised UML model is intended to replace the UML model now in Topic 2, and is currently documented in OGC document 03-009r7.

This conversion to XML Schemas was done in a manner that makes the results consistent with GML 3.0. Therefore, many of the details of many of the encoding rules used were adapted to produce XML Schemas consistent with the GML 3 schema patterns, and to use some of the XML elements and types defined in the GML 3 schemas.

NOTE Many of the GML 3 schema patterns are described in Subclauses 6.4, 7.1, 7.2. 8.1 through 8.3, and 8.6 of the GML 3.00 Implementation Specification.

This annex lists the "rules" used in this UML model to XML Schemas conversion process. Those rules are described in the following subclauses, for converting UML:

a) Packages
b) Classes
c) Attributes
d) Associations
e) Multiplicities
f) Other

EDITOR'S NOTE The following rules have not been revised to reflect all the changes made in this version of this document.

G.2 Rules for packages

The rules used to convert UML model packages to XML Schemas were:

Rule 1	Convert each UML package into a separate XML Schema Document. Name each XML Schema Document like the UML package, with spaces removed, the first character changed to lower case, and the word "System" made plural.
Example	UML package name: Coordinate Reference System XML Schema name: coordinateReferenceSystems.xsd
Reason(s)	Produce multiple (i.e., 6) XML Schema documents (not one), following GML patterns.
Exceptions	None

Rule 2	Begin each XML Schema Document with standard header information.
Example	<?xml version="1.0" encoding="UTF-8"?> <schema targetNamespace="http://www.opengis.net/gml" xmlns:gml="http://www.opengis.net/gml" xmlns="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified" version="3.0.0" xml:lang="en"> <annotation> <appinfo source="urn:opengis:specification:gml:schema-coordinateReferenceSystems:v3.0c3"/> <documentation> <name>coordinateReferenceSystems.xsd</name> <version>3.0.0</version> <scope>How to encode coordinate reference system definitions. </scope> <description>Builds on referenceSystems.xsd to encode the data needed to define coordinate reference systems, including the specific subtypes of coordinate reference systems. Primary editor: Arliss Whiteside. Last updated 2003/01/08. </description> <copyright>Copyright (c) 2002-2003 Open GIS Consortium, All Rights Reserved.</copyright> <conformance>This schema encodes the Coordinate Reference System (SC_) package of the extended UML Model for OGC Abstract Specification Topic 2: Spatial Referencing by Coordinates, with the exception of the abstract "SC_CRS" class. The "SC_CRS" class is encoded in referenceSystems.xsd, to eliminate the (circular) references from coordinateOperations.xsd to coordinateReferenceSystems.xsd. That UML model is adapted from ISO 19111 - Spatial referencing by coordinates, as described in Annex C of Topic 2. </conformance> </documentation> </annotation> <!-- ========== includes and imports ========== --> [Insert here needed <include> statements] <!-- ========== elements and types ========== --> [Insert here XML encoded UML classes, attributes, and associations] </schema>
Reason(s)	Produce XML Schema Documents that follow GML patterns.
Exceptions	None

Rule 3	Include "xsd:include" statements in each XML Schema Document as needed for other XML Schema Documents referenced.
Example	[In coordinateReferenceSystems.xsd:] <include schemaLocation="coordinateSystems.xsd"/> <include schemaLocation="datums.xsd"/> <include schemaLocation="coordinateOperations.xsd"/>
Reason(s)	Produce valid XML Schema Documents.
Exceptions	None

Rule 4	Remove suffix containing two-letter UML package abbreviation plus following underscore character from class names, as classes and attribute data types are converted to XML Schema elements.
Example	UML class name: SC_GeographicCRS XML element name: GeographicCRS
Reason(s)	Produce XML: Schema element names following the GML pattern.
Exceptions	None

Rule 5	Encode EX_Extent UML class in referenceSystems.xsd, based on specification of that class in ISO 19115 but using relevant GML 3 complexTypes.
Example	Not applicable
Reason(s)	Not create another XML Schema document, for a short XML encoding
Exceptions	None

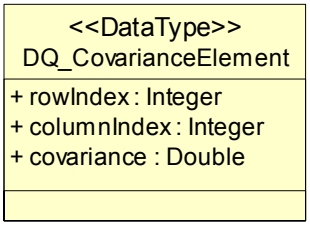
Rule 6	Move XML encoded version of SC_CRS class to referenceSystems.xsd from coordinateReferenceSystems.xsd
Example	Move _CRS element, crsRef element, and related complexTypes.
Reason(s)	Remove prohibited circular reference between coordinateReferenceSystems.xsd and coordinateOperations.xsd. (TBR)
Exceptions	None

G.3 Rules for classes

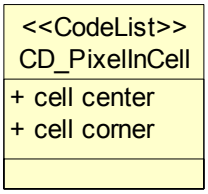
The rules used to convert UML model classes to XML Schemas were:

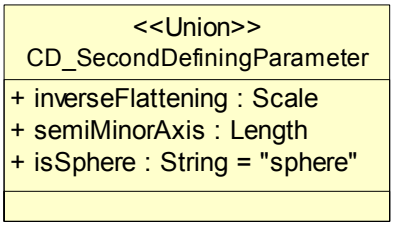
NOTE Most of these rules copy the documentation of each UML class into a <documentation> element of the XML complexType or element converted from this UML class attribute, in order to keep the UML class documentation for human understanding of the XML Schemas.

Rule 7	Convert each UML class with <<DataType>> stereotype to XML Schema global declaration of complexType, with same name augmented with "Type" suffix and with <documentation> element copying documentation of UML class.

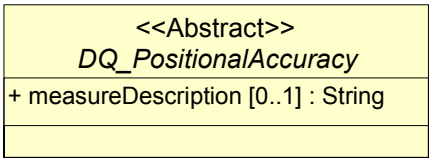
Example	UML class:
	 
	
	XML Schema:
	`<complexType name="CovarianceElementType">`
	`<annotation>`
	`<documentation>`An element of a covariance matrix.`</documentation>`
	`</annotation>`
	`<sequence>`
	[Insert here XML elements encoding UML attributes]
	`</sequence>`
	`</complexType>`
	`<!-- ========== -->`

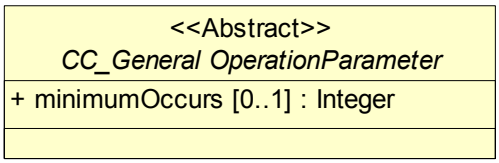
Reason(s)	Use XML Schema global complexType, with names following GML patterns.
Exceptions	a) Do not XML encode CI_Citation class, since such information can be included as metaDataProperty elements, which are optionally allowed. b) XML encode EX_Extent class in referenceSystems.xsd.
Applies to	UML classes: RS_Identifier, DQ_CovarianceElement, EX_Extent, CI_Citation

Rule 8	Convert each UML class with <<CodeList>> stereotype to XML Schema global declarations of: a) element with same name except first letter not capitalized, and having the following complexType. b) complexType with same name augmented with "Type" suffix, with standard contents for a <<CodeList>> class except including <documentation> element copying documentation of UML class.
Example	UML class:  XML Schema: <element name="pixelInCell" type="gml:PixelInCellType"/> <!-- ========== --> <complexType name="PixelInCellType"> <annotation> <documentation>Specification of the way an image grid is associated with the image data attributes. </documentation> </annotation> <simpleContent> <restriction base="gml:CodeType"> <attribute name="codeSpace" type="anyURI" use="required"> <annotation> <documentation>Reference to a source of information specifying the values and meanings of all the allowed string values for this PixelInCellType. </documentation> </annotation> </attribute> </restriction> </simpleContent> </complexType> <!-- ========== -->
Reason(s)	Allow the specific values allowed in a CodeList to be specified elsewhere and referenced here.
Exceptions	None
Applies to	UML classes: SC_DerivedCRSType, CD_PixelInCell, CD_VerticalDatumType

<table>
<tr><td>Rule 9</td><td>Convert each UML class with <<Union>> stereotype to XML Schema global declarations of:
a) element with same name except first letter not capitalized, and having the following complexType.
b) complexType with same name augmented with "Type" suffix, containing a <choice> construct and <documentation> element copying documentation of UML class.</td></tr>
<tr><td>Example</td><td>UML class:
 

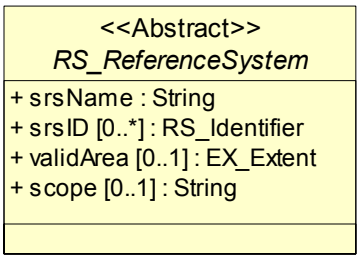
XML Schema:
<element name="secondDefiningParameter" type="gml:SecondDefiningParameterType"/>
<!-- ========== -->
<complexType name="SecondDefiningParameterType">
<annotation>
<documentation>Definition of the second parameter which defines the shape of an ellipsoid. An ellipsoid requires two defining parameters: semi-major axis and inverse flattening or semi-major axis and semi-minor axis. When the reference body is a sphere rather than an ellipsoid, only a single defining parameter is required, namely the radius of the sphere; in that case, the semi-major axis "degenerates" into the radius of the sphere.</documentation>
</annotation>
<choice>
[Insert here XML elements encoding UML attributes]
</choice>
</complexType>
<!-- ========== --></td></tr>
<tr><td>Reason(s)</td><td>Use XML Schema global element and complexType.</td></tr>
<tr><td>Exceptions</td><td>For CC_ParameterValue class, add to complexType <documentation> some guidance for Application Schemas.</td></tr>
<tr><td>Applies to</td><td>UML classes: CD_SecondDefiningParameter, CC_ParameterValue</td></tr>
</table>

Rule 10	Convert each UML class that is not a subclass of another class, has <<Abstract>> stereotype, and does not have (direct or inherited) identity, to XML Schema global declarations of: a) element with same name except first letter not capitalized, having the following complexType and with abstract="true". b) complexType with same name augmented with "Type" suffix, containing a <sequence> construct and <documentation> element copying documentation of UML class.
Example	UML class:  XML Schema: <element name="_positionalAccuracy" type="gml:AbstractPositionalAccuracyType" abstract="true"/> <!-- ========== --> <complexType name="AbstractPositionalAccuracyType" abstract="true"> <annotation> <documentation>Position error estimate (or accuracy) data.</documentation> </annotation> <sequence> [Insert here XML elements encoding UML attributes] </sequence> </complexType> <!-- ========== -->
Reason(s)	Use XML Schema global element and complexType, following GML patterns.
Exceptions	a) For CC_GeneralOperationParameter, extend gml:DefinitionType as described in following rule. b) For CC_GeneralParameterValue, add to complexType <documentation> some guidance for Applications Schemas.
Applies to	UML classes: CC_GeneralParameterValue, DQ_PositionalAccuracy

<table>
<tr><td>Rule 11</td><td>Convert CC_GeneralOperationParameter UML class (that is not a subclass of another class, has <<Abstract>> stereotype, and does not have (direct or inherited) identity), to XML Schema global declarations of:
a) element with same name augmented with "_" prefix, having the following complexType, with abstract="true", and in substitutionGroup of gml:Definition .
b) complexType with same name augmented with "Type" suffix, extending gml:DefinitionType, and with <documentation> element copying documentation of UML class.
c) element with same name augmented with "Ref" suffix and first character made lower case, having the following complexType and in substitutionGroup of gml:dictionaryEntry.
d) complexType with same name augmented with "RefType" suffix and first character made lower case, with contents restricting gml: DictionaryEntryType, substituting name of element a) above for "gml:Definition". Include <documentation> element adapted from gml:AssociationType.</td></tr>
<tr><td>Example</td><td>UML class:
 

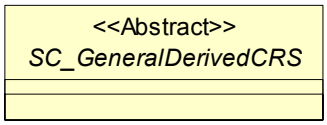
XML Schema:
<element name="_GeneralOperationParameter" type="gml:AbstractGeneralOperationParameterType" abstract="true" substitutionGroup="gml:Definition"/>
<!-- ========== -->
<complexType name="AbstractGeneralOperationParameterType" abstract="true">
<annotation>
<documentation>The definition of a parameter or group of parameters used by an operation method. </documentation>
</annotation>
<complexContent>
<extension base="gml:DefinitionType">
<sequence>
[Insert here XML elements encoding UML attributes]
</sequence>
</extension>
</complexContent>
</complexType>
<!-- ========== -->
<element name="abstractGeneralOperationParameterRef" type="gml:AbstractGeneralOperationParameterRefType" substitutionGroup="gml:dictionaryEntry"/>
<!-- ========== -->
<complexType name="AbstractGeneralOperationParameterRefType">
<annotation>
<documentation>Association to an operation parameter or group, either</td></tr>
</table>

	referencing or containing the definition of that parameter or group. </documentation> </annotation> <complexContent> <restriction base="gml:DictionaryEntryType"> <sequence> <element ref="gml:_GeneralOperationParameter" minOccurs="0"/> </sequence> <attributeGroup ref="gml:AssociationAttributeGroup"/> </restriction> </complexContent> </complexType> <!-- ========== -->
Reason(s)	Use XML Schema global element and complexType, following GML patterns.
Exceptions	None
Applies to	UML classes: CC_GeneralParameterValue, DQ_PositionalAccuracy

<table>
<tr><td>Rule 12</td><td>Convert each UML class that is not a subclass of another class, has <<Abstract>> stereotype, and has direct identity, to XML Schema global declarations of:
a) element with same name, having the corresponding complexType, with abstract="true", and in substitutionGroup of gml:Definition element.
b) complexType with same name augmented with "BaseType" suffix, with abstract="true", restricting gml:DefinitionType to contain one occurrence of the "xxxName" element encoding the "xxxName" UML attribute, instead of zero or more occurrences of the "gml:Name" element.
c) complexType with same name augmented with "Type" suffix, extending the above complexType, containing a <sequence> construct and <documentation> element copying documentation of this UML class.
d) element with same name augmented with "Ref" suffix and first character made lower case, having the following complexType, and in substitutionGroup of gml:dictionaryEntry.
e) complexType with same name augmented with "RefType" suffix and first character made lower case, with contents restricting gml: DictionaryEntryType and substituting name of element a) above for "gml:Definition". Include <documentation> element adapted from gml:AssociationType.</td></tr>
<tr><td>Example</td><td>UML class:
 

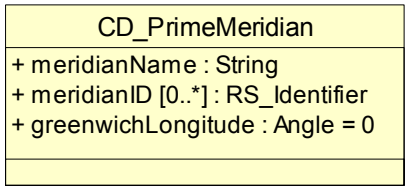
XML Schema:
<element name="_ReferenceSystem" type="gml:AbstractReferenceSystemType" abstract="true" substitutionGroup="gml:Definition"/>
<!-- ========== -->
<complexType name="AbstractReferenceSystemBaseType" abstract="true">
<annotation>
<documentation>Basic encoding for reference system objects, simplifying and restricting the DefinitionType as needed. </ documentation>
</annotation>
<complexContent>
<restriction base="gml:DefinitionType">
<sequence>
< element ref="gml:metaDataProperty" minOccurs="0" maxOccurs="unbounded"/>
< element ref="gml:srsName"/>
</ sequence>
< attribute ref="gml:id" use="required"/>
</ restriction>
</ complexContent>
</ complexType>
<!-- ========== --></td></tr>
</table>

	[Insert here XML encoding of "xxxName" UML attribute] <!-- ========== --> < complexType name="AbstractReferenceSystemType" abstract="true"> < annotation> < documentation>Description of a spatial and/or temporal reference system used by a dataset. </ documentation> </ annotation> < complexContent> < extension base="gml:AbstractReferenceSystemBaseType"> < sequence> [Insert here XML elements encoding UML associations and attributes, except xxxName] </ sequence> </ extension> </ complexContent> </ complexType> <!-- ========== --> < element name="referenceSystemRef" type="gml:ReferenceSystemRefType" substitutionGroup="gml:dictionaryEntry"/> <!-- ========== --> < complexType name="ReferenceSystemRefType"> < annotation> < documentation>Association to a reference system, either referencing or containing the definition of that reference system. </ documentation> </ annotation> <complexContent> <restriction base="gml:DictionaryEntryType"> < sequence> < element ref="gml:_ReferenceSystem" minOccurs="0"/> </ sequence> < attributeGroup ref="gml:AssociationAttributeGroup"/> </restriction> </complexContent> </ complexType> <!-- ========== -->
Reason(s)	Make encoded class substitutable for a gml:Definition and thus includable in a gml:Dictionary. Use XML Schema global elements and complexTypes, following GML patterns.
Exceptions	None
Applies to	UML classes: RS_ReferenceSystem, CD_Datum, CS_CoordinateSystem, CC_CoordinateOperation, CC_OperationMethod

<table>
<tr><td>Rule 13</td><td>Convert each UML class that is a subclass of another class, has <<Abstract>> stereotype, and inherited identity, to XML Schema global declarations of:
a) element with same name augmented with "_" prefix, having the following complexType, with abstract="true", and in substitutionGroup of element from superclass.
b) complexType with same name augmented with "Type" suffix and "Abstract" prefix, with abstract="true", extending complexType of superclass, containing a <sequence> construct and <documentation> element copying documentation of this UML class.
c) element with same name augmented with "Ref" suffix and first character made lower case, having the following complexType and in substitutionGroup of "…Ref" element from superclass.
d) complexType with same name augmented with "RefType" suffix and first character made lower case, with contents restricting "…RefType" complexType of superclass, substituting name of element a) above for "gml:_Object". Include <documentation> element adapted from gml:AssociationType.</td></tr>
<tr><td>Example</td><td>UML class:
 

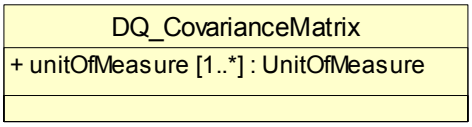
XML Schema:
<element name="_GeneralDerivedCRS" type="gml:AbstractGeneralDerivedCRSType" abstract="true" substitutionGroup="gml:_CoordinateReferenceSystem"/>
<!-- ========== -->
<complexType name="AbstractGeneralDerivedCRSType" abstract="true">
<annotation>
<documentation>A coordinate reference system that is defined by its coordinate conversion from another coordinate reference system (not by a datum).</documentation>
</annotation>
<complexContent>
<extension base="gml:AbstractCoordinateReferenceSystemType">
<sequence>
[Insert here XML elements encoding UML attributes and associations]
</sequence>
</extension>
</complexContent>
</complexType>
<!-- ========== -->
<element name="generalDerivedCRSRef" type="gml:GeneralDerivedCRSRefType" substitutionGroup="gml:coordinateReferenceSystemRef"/>
<!-- ========== -->
<complexType name="GeneralDerivedCRSRefType">
<annotation></td></tr>
</table>

	<documentation>Association to a general derived coordinate reference system, either referencing or containing the definition of that reference system.</documentation> </annotation> <complexContent> <restriction base="gml:CoordinateReferenceSystemRefType"> <sequence> <element ref="gml:_GeneralDerivedCRS" minOccurs="0"/> </sequence> <attributeGroup ref="gml:AssociationAttributeGroup"/> </restriction> </complexContent> </complexType> <!-- ========== -->
Reason(s)	Use XML Schema global elements and complexTypes, following GML patterns.
Exceptions	For the CC_Operation class, do not include in the primary complexType the elements encoding the associations to CC_OperationMethod and CC_ParameterValue. Instead, include the elements encoding these associations in both the Conversion and Transformation elements. Add to complexType <documentation> some guidance for Application Schemas.
Applies to	UML classes: SC_CRS, SC_CoordinateReferenceSystem, SC_GeneralDerivedCRS, CC_SingleOperation, CC_Operation

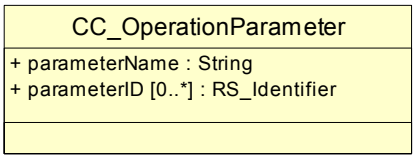
<table>
<tr><td>Rule 14</td><td>Convert each UML class that is not a subclass of another class, has no stereotype, and has direct identity, to XML Schema global declarations of:
a) element with same name, having the corresponding complexType and in substitutionGroup of gml:Definition element.
b) complexType with same name augmented with "BaseType" suffix, restricting gml:DefinitionType to contain one occurrence of the "xxxName" element encoding the "xxxName" UML attribute, instead of zero or more occurrences of the "gml:Name" element.
c) complexType with same name augmented with "Type" suffix, extending the above "BaseType" complexType, containing a <sequence> construct and <documentation> element copying documentation of this UML class.
d) element with same name augmented with "Ref" suffix and first character made lower case, having the following complexType, and in substitutionGroup of gml:dictionaryEntry.
e) complexType with same name augmented with "RefType" suffix and first character made lower case, with contents restricting gml: DictionaryEntryType and substituting name of element a) above for "gml:Definition". Include <documentation> element adapted from gml:AssociationType.</td></tr>
<tr><td>Example</td><td>UML class:
 

XML Schema:
<element name="PrimeMeridian" type="gml:PrimeMeridianType" substitutionGroup="gml:Definition"/>
<!-- ========== -->
<complexType name="PrimeMeridianBaseType" abstract="true">
<annotation>
<documentation>Basic encoding for prime meridian objects, simplifying and restricting the DefinitionType as needed. </documentation>
</annotation>
<complexContent>
<restriction base="gml:DefinitionType">
<sequence>
<element ref="gml:metaDataProperty" minOccurs="0" maxOccurs="unbounded"/>
<element ref="gml:meridianName"/>
</sequence>
<attribute ref="gml:id" use="required"/>
</restriction>
</complexContent>
</complexType>
<!-- ========== -->
[Insert here XML encoding of "xxxName" UML attribute]
<!-- ========== --></td></tr>
</table>

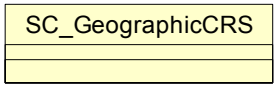
	<complexType name="PrimeMeridianType"> <annotation> <documentation>A prime meridian defines the origin from which longitude values are determined.</documentation> </annotation> <complexContent> <extension base="gml:PrimeMeridianBaseType"> <sequence> [Insert here XML elements encoding UML associations and attributes except xxxName] </sequence> </extension> </complexContent> </complexType> <!-- ========== -->
Reason(s)	Make encoded class substitutable for a gml:Definition and includable in a gml:Dictionary. Use XML Schema global elements and complexTypes, following GML patterns.
Exceptions	None
Applies to	UML classes: CD_Ellipsoid, CD_PrimeMeridian, CS_CoordinateSystemAxis, CC_OperationMethod

<table>
<tr><td>Rule 15</td><td>Convert each UML class that is a subclass of another class, has no stereotype, and no (direct or inherited) identity, to XML Schema global declarations of:
a) element with same name except first letter not capitalized, having the following complexType and in substitutionGroup of element from superclass.
b) complexType with same name augmented with "Type" suffix, extending complexType of superclass, and containing a <sequence> construct and <documentation> element copying documentation of UML class.</td></tr>
<tr><td>Example</td><td>UML class:
 

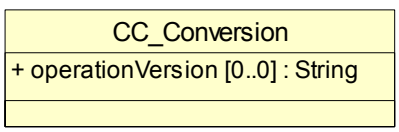
XML Schema:
<element name="covarianceMatrix" type="gml:CovarianceMatrixType" substitutionGroup="gml:_positionalAccuracy"/>
<!-- ========== -->
<complexType name="CovarianceMatrixType">
<annotation>
<documentation>Error estimate covariance matrix. </documentation>
</annotation>
<complexContent>
<extension base="gml:AbstractPositionalAccuracyType">
<sequence>
[Insert here XML elements encoding UML attributes]
</sequence>
</extension>
</complexContent>
</complexType>
<!-- ========== --></td></tr>
<tr><td>Reason(s)</td><td>Use XML Schema global element and complexType, following GML patterns.</td></tr>
<tr><td>Exceptions</td><td>For CC_ParameterValueGroup, add to <documentation> guidance for use by specific Conversions and Transformations.</td></tr>
<tr><td>Applies to</td><td>UML classes: DQ_CovarianceMatrix, DQ_AbsoluteExternalPositionAccuracy, DQ_RelativeInternalPositionAccuracy, CC_ParameterValueGroup</td></tr>
</table>

Rule 16	Convert each UML class that is a subclass of another class, has no stereotype, and has direct identity, to XML Schema global declarations of: a) element with same name, having the corresponding complexType and in substitutionGroup of gml:Definition element. b) complexType with same name augmented with "BaseType" suffix, restricting gml:DefinitionType complexType to contain one occurrence of the "xxxName" element encoding the "xxxName" UML attribute, instead of zero or more occurrences of the "gml:Name" element. c) complexType with same name augmented with "Type" suffix, extending the above "BaseType" complexType, containing a <sequence> construct and <documentation> element copying documentation of this UML class. d) element with same name augmented with "Ref" suffix and first character made lower case, having the following complexType. e) complexType with same name augmented with "RefType" suffix and first character made lower case, with contents restricting "RefType" of superclass, substituting name of element a) above for "gml:Definition". Include <documentation> element adapted from gml:AssociationType.
Example	UML class:  XML Schema: <element name="OperationParameter" type="gml:OperationParameterType" substitutionGroup="gml:_GeneralOperationParameter"/> <!-- ========== --> <complexType name="OperationParameterBaseType" abstract="true"> <annotation> <documentation>Basic encoding for operation parameter objects, simplifying and restricting the DefinitionType as needed. </documentation> </annotation> <complexContent> <restriction base="gml:AbstractGeneralOperationParameterType"> <sequence> <element ref="gml:metaDataProperty" minOccurs="0" maxOccurs="unbounded"/> <element ref="gml:parameterName"/> <element ref="gml:minimumOccurs" minOccurs="0"/> </sequence> <attribute ref="gml:id" use="required"/> </restriction> </complexContent> </complexType> <!-- ========== --> [Insert here XML encoding of "xxxName" UML attribute] <!-- ========== --> <complexType name="OperationParameterType">

	<annotation> <documentation>The definition of a parameter used by an operation method. Most parameter values are numeric, but other types of parameter values are possible. This complexType is expected to be used or extended for all operation methods, without defining operation-method-specialized element names.</documentation> </annotation> <complexContent> <extension base="gml:OperationParameterBaseType"> <sequence> [Insert here XML elements encoding UML associations and attributes, except xxxName] </sequence> </extension> </complexContent> </complexType> <!-- ========== --> <element name="operationParameterRef" type="gml:OperationParameterRefType"/> <!-- ========== --> <complexType name="OperationParameterRefType"> <annotation> <documentation>Association to an operation parameter, either referencing or containing the definition of that parameter. </documentation> </annotation> <complexContent> <restriction base="gml:AbstractGeneralOperationParameterRefType"> <sequence> <element ref="gml:OperationParameter" minOccurs="0"/> </sequence> <attributeGroup ref="gml:AssociationAttributeGroup"/> </restriction> </complexContent> </complexType> <!-- ========== -->
Reason(s)	Make encoded class substitutable for a gml:Definition and includable in a gml:Dictionary. Use XML Schema global elements and complexTypes, following GML patterns.
Exceptions	None
Applies to	UML classes: CC_OperationParameter, CC_OperationParameterGroup

Rule 17	Convert each UML class that is a subclass of another class, has no stereotype, and has inherited identity, to XML Schema global declarations of: a) element with same name, having following complexType, and in substitutionGroup of element from superclass. b) complexType with same name augmented with "Type" suffix, extending complexType of superclass, containing a <sequence> construct and <documentation> element copying documentation of this UML class. c) element with same name augmented with "Ref" suffix and first character made lower case, having the following complexType and in substitutionGroup of the "…Ref" element from superclass. d) complexType with same name augmented with "RefType" suffix and first character not capitalized, with contents restricting "…RefType" of superclass and substituting name of element a) above for "gml:Definition". Include <documentation> element adapted from gml:AssociationType.
Example	UML class:  XML Schema: <element name="GeographicCRS" type="gml:GeographicCRSType" substitutionGroup="gml:_CoordinateReferenceSystem"/> <!-- ========== --> <complexType name="GeographicCRSType"> <annotation> <documentation>A coordinate reference system based on an ellipsoidal approximation of the geoid; this provides an accurate representation of the geometry of geographic features for a large portion of the earth's surface.</documentation> </annotation> <complexContent> <extension base="gml:AbstractCoordinateReferenceSystemType"> <sequence> [Insert here XML elements encoding UML attributes and associations] </sequence> </extension> </complexContent> </complexType> <!-- ========== --> <element name="geographicCRSRef" type="gml:GeographicCRSRefType" substitutionGroup="gml:coordinateReferenceSystemRef"/> <!-- ========== --> <complexType name="GeographicCRSRefType"> <annotation> <documentation>Association to a geographic coordinate reference system, either referencing or containing the definition of that reference system. </documentation> </annotation> <complexContent> <restriction base="gml:CoordinateReferenceSystemRefType">

	<sequence> <element ref="gml:GeographicCRS" minOccurs="0"/> </sequence> <attributeGroup ref="gml:AssociationAttributeGroup"/> </restriction> </complexContent> </complexType> <!-- ========== -->
Reason(s)	Use XML Schema global elements and complexTypes, following GML patterns.
Exceptions	a) Do not XML encode RS_SpatailReferenceSystemUsingGeographicIdentifier class, since not relevant to coordinate reference systems. b) For CD_TemporalDatum class, first restrict CD_DatumType to eliminate prohibited attributes, and then extend it to add additional attribute. c) For CC_Conversion and CC_Transformation classes, also encode a "General…" element as specified in following rule.
Applies to	UML classes: RS_SpatailReferenceSystemUsingGeographicIdentifier, SC_CompoundCRS, SC_VerticalCRS, SC_GeographicCRS, SC_GeocentiricCRS, SC_EngineeringCRS, SC_ImageCRS, SC_TemporalCRS, SC_ProjectedCRS, SC_DerivedCRS, CD_ImageDatum, CD_EngineeringDatum, CD_GeodeticDatum, CD_TemporalDatum, CD_VerticalDatum, CS_EllipsoidalCS, CS_CartesianCS, CS_TemporalCS, CS_GravityRelatedCS, CS_UserDefinedCS, CS_LinearCS, CS_ObliqueCartesianCS, CS_PolarCS, CS_SphericalCS, CS_CylindricalCS, CC_ConcatenatedOperation, CC_PassThoughOperation, CC_OperationParameter

Rule 18	Convert CC_Conversion and CC_Transformation classes (each a subclass of another class, has no stereotype, and has inherited identity), to XML Schema global declarations of: a) element with same name augmented with "_General" prefix, having following complexType, with abstract="true", and in substitutionGroup of element from superclass. b) complexType with same name augmented with "AbstractGeneral" prefix and "Type" suffix, with abstract="true", and restricting AbstractOperationType to reflect constraints on multiplicity of sourceCRS and targetCRS stated as noted on those associations. For AbstractGeneralConversion element, omit operationVersion element to reflect "operationVersion [0..0] : String" UML attribute. For AbstractGeneral Transformation element, omit minOccurs="0" on operationVersion element to reflect "operationVersion : String" UML attribute. Include <documentation> element copying documentation of this UML class augmented with guidance on using this element in an Application Schema. c) element with same name augmented with "_General" prefix and "Ref" suffix and first character made lower case, having the following complexType and in substitutionGroup of "…Ref" element from superclass. d) complexType with same name augmented with augmented with "AbstractGeneral" prefix and "RefType" suffix and first character not capitalized, with contents restricting "…RefType" complexType of superclass, and substituting name of element a) above for "gml:Definition". Include <documentation> element adapted from gml:AssociationType. e) element with same name, having following complexType, and in substitutionGroup of element from item a) above. f) complexType with same name augmented with "Type" suffix, extending complexType of item b) above and containing a <sequence> construct. Include <documentation> element copying documentation of this UML class augmented with guidance on using this element in an Application Schema. g) element with same name augmented with "Ref" suffix and first character made lower case, having the following complexType and in substitutionGroup of "…Ref" element from item c) above. h) complexType with same name augmented with "RefType" suffix and first character not capitalized, with contents restricting "…RefType" complexType of item d) above and substituting name of element e) above for "gml:Definition". Include <documentation> element adapted from gml:AssociationType.
Example	UML class:  XML Schema: <element name="_GeneralConversion" type="gml:AbstractGeneralConversionType" abstract="true" substitutionGroup="gml:_Operation"/> <!-- == --> <complexType name="AbstractGeneralConversionType" abstract="true"> <annotation>

```
            <documentation>An abstract operation on coordinates that does not
include any change of datum. The best-known example of a coordinate conversion is
a map projection. The parameters describing coordinate conversions are defined
rather than empirically derived. Note that some conversions have no parameters.

This abstract complexType is expected to be extended for well-known operation
methods with many Conversion instances, in Application Schemas that define
operation-method-specialized element names and contents. This conversion uses an
operation method, usually with associated parameter values. However, operation
methods and parameters are directly associated with concrete subtypes, not with this
abstract type. All concrete types derived from this type shall extend this type to
include a "usesMethod" element that references the "OperationMethod" element.
Similarly, all concrete types derived from this type shall extend this type to include
zero or more elements each named "uses...Value" that each use the type of an
element substitutable for the "_generalParameterValue" element. </documentation>
        </annotation>
        <complexContent>
            <restriction base="gml:AbstractOperationType">
                <sequence>
                    <element ref="gml:metaDataProperty" minOccurs="0"
maxOccurs="unbounded"/>
                    <element ref="gml:remarks" minOccurs="0"/>
                    <element ref="gml:coordinateOperationName"/>
                    <element ref="gml:coordinateOperationID" minOccurs="0"
maxOccurs="unbounded"/>
                    <element ref="gml:validArea" minOccurs="0"/>
                    <element ref="gml:scope" minOccurs="0"/>
                    <element ref="gml:_positionalAccuracy" minOccurs="0"/>
                </sequence>
                <attribute ref="gml:id" use="required"/>
            </restriction>
        </complexContent>
    </complexType>
    <!-- ========================================================== -->
    <element name="generalConversionRef" type="gml:GeneralConversionRefType"
substitutionGroup="gml:operationRef"/>
    <!-- ========================================================== -->
    <complexType name="GeneralConversionRefType">
        <annotation>
            <documentation>Association to a general conversion, either referencing or
containing the definition of that conversion. </documentation>
        </annotation>
        <complexContent>
            <restriction base="gml:OperationRefType">
                <sequence>
                    <element ref="gml:_GeneralConversion" minOccurs="0"/>
                </sequence>
                <attributeGroup ref="gml:AssociationAttributeGroup"/>
            </restriction>
        </complexContent>
    </complexType>
    <!-- ========================================================== -->
    <element name="Conversion" type="gml:ConversionType"
substitutionGroup="gml:_GeneralConversion"/>
    <!-- ========================================================== -->
    <complexType name="ConversionType">
```

```
        <annotation>
            <documentation>A concrete operation on coordinates that does not
include any change of Datum. The best-known example of a coordinate conversion is
a map projection. The parameters describing coordinate conversions are defined
rather than empirically derived. Note that some conversions have no parameters.

This concrete complexType can be used with all operation methods, without using an
Application Schema that defines operation-method-specialized element names and
contents. This abstract complexType can also be used, extended, or restricted for
well-known operation methods, especially for methods with only one Conversion
instance. </documentation>
        </annotation>
        <complexContent>
            <extension base="gml:AbstractGeneralConversionType">
                <sequence>
                    <element ref="gml:usesMethod"/>
                    <element ref="gml:usesValue" minOccurs="0"
maxOccurs="unbounded"/>
                </sequence>
            </extension>
        </complexContent>
    </complexType>
    <!-- ================================================== -->
    <element name="usesMethod" type="gml:OperationMethodRefType">
        <annotation>
            <documentation>Association to the operation method used by this
conversion operation. </documentation>
        </annotation>
    </element>
    <!-- ================================================== -->
    <element name="usesValue" type="gml:ParameterValueType">
        <annotation>
            <documentation>Unordered set of composition associations to the set of
parameter values used by this conversion operation. </documentation>
        </annotation>
    </element>
    <!-- ================================================== -->
    <element name="conversionRef" type="gml:ConversionRefType"
substitutionGroup="gml:generalConversionRef"/>
    <!-- ================================================== -->
    <complexType name="ConversionRefType">
        <annotation>
            <documentation>Association to a concrete general-purpose conversion,
either referencing or containing the definition of that conversion. </documentation>
        </annotation>
        <complexContent>
            <restriction base="gml:GeneralConversionRefType">
                <sequence>
                    <element ref="gml:Conversion" minOccurs="0"/>
                </sequence>
                <attributeGroup ref="gml:AssociationAttributeGroup"/>
            </restriction>
        </complexContent>
    </complexType>
    <!-- ================================================== -->
```

Reason(s)	In addition to concrete element and complexType, provide abstract element and complexType to allow Application Schemas to restrict contents without using XML Schema restriction. Use XML Schema global elements and complexTypes, following GML patterns.
Exceptions	None
Applies to	UML classes: CC_Conversion, CC_Transformation

The following table summarizes the conditions under which the rules listed above are applicable.

Stereotype	Is Subclass?	Has Identity?	Rule Number
<<DataType>>			7
<<CodeList>>			8
<<Union>>			9
<<Abstract>>	No	No	10 and 11
<<Abstract>>	No	Direct	12
<<Abstract>>	No	Inherited	(none)
<<Abstract>>	Yes	No	(none)
<<Abstract>>	Yes	Direct	(none)
<<Abstract>>	Yes	Inherited	13
(none)	No	No	(none)
(none)	No	Direct	14
(none)	No	Inherited	(none)
(none)	Yes	No	15
(none)	Yes	Direct	16
(none)	Yes	Inherited	17 and 18

G.4 Rules for attributes

The rules used to convert UML model (class) attributes to XML Schemas were:

NOTE 1 Most of these rules copy the documentation of each UML attribute into a <documentation> element of the XML element converted from this UML attribute, in order to keep the UML attribute documentation for human understanding of the XML Schemas.

NOTE 2 Most of these rules use global XML elements (instead of local elements inside another element) for flexibility. Use of global elements allows Application Schemas in another namespace to restrict tan element containing only global elements.

Rule 19	Convert each UML attribute with type "Boolean" to XML Schema declarations of: a) Reference to following element inside <choice> or <sequence> construct of "…Type" complexType converted from class containing this attribute. b) Global element with same name, using type xsd:boolean, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + booleanValue : Boolean XML Schema: Inside <choice> or <sequence> construct: <element ref="gml:booleanValue"/> Global element declaration: <element name="booleanValue" type="boolean"> <annotation> <documentation>Boolean value of an operation parameter. A Boolean value does not have an associated unit of measure. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use xsd:boolean type.
Exceptions	None
Applies to	UML attributes: booleanValue

Rule 20	Convert each UML attribute with type "Date" to XML Schema declarations of: a) Reference to following element inside <sequence> or <choice> construct of "…Type" complexType converted from class containing this attribute. b) Global element with same name, using type xsd:date, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + realizationEpoch [0..1] : Date XML Schema: Inside <sequence> or <choice> construct: <element ref="gml:realizationEpoch" minOccurs="0"/> Global element declaration: <element name="realizationEpoch" type="date"> <annotation> <documentation>The time for which this datum definition is valid. This time may be precise (e.g. 1997.0 for IRTF97) or merely a year (e.g. 1983 for NAD83). In the latter case, the epoch usually refers to the year in which a major recalculation of the geodetic control network, underlying the datum, was executed or initiated. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use xsd:date type.
Exceptions	None
Applies to	UML attributes: realizationEpoch

Rule 21	Convert each UML attribute with type "DateTime" to XML Schema declarations of: a) Reference to following element inside <sequence> or <choice> construct of "…Type" complexType converted from class containing this attribute. b) Global element with same name, using type xsd:dateTime, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + origin : DateTime XML Schema: Inside <sequence> or <choice> construct: <element ref="gml:origin"/> Global element declaration: <element name="origin" type="dateTime"> <annotation> <documentation>The date and time origin of this temporal datum. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use xsd:dateTime type.
Exceptions	None
Applies to	UML attributes: origin

Rule 22	Convert each UML attribute with type "Integer" to XML Schema declarations of: a) Reference to following element inside <sequence> or <choice> construct of "…Type" complexType converted from class containing this attribute. b) Global element with same name, using type xsd:positiveInteger, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + modifiedCoordinate [1..*] : Integer XML Schema: Inside <sequence> or <choice> construct: <element ref="gml:modifiedCoordinate" maxOccurs="unbounded"/> Global element declaration: <element name="modifiedCoordinate" type="positiveInteger"> <annotation> <documentation>Ordered sequence of positive integers defining the positions in a coordinate tuple of the coordinates affected by this pass-through operation. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use xsd:positiveInteger type, since negative and zero integer values are not permitted for these UML attributes.
Exceptions	For the minimumOccurs element, use type nonNegativeInteger (not positiveInteger)
Applies to	UML attributes: modifiedCoordinate, integerValue, minimumOccurs, maximumOccurs

Rule 23	Convert each UML attribute with type "Sequence<Measure>" to XML Schema declarations of: a) Reference to following element inside <choice> or <sequence> construct of "…Type" complexType converted from class containing this attribute. b) Global element with same name, using type gml:MeasureListType, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + valueList : Sequence<Measure> XML Schema: Inside <choice> or <sequence> construct: <element ref="gml:valueList"/> Global element declaration: <element name="valueList" type="gml:MeasureListType"> <annotation> <documentation>Ordered sequence of two or more numeric values of an operation parameter list, where each value has the same associated unit of measure. An element of this type contains a space-separated list of double values. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use gml:MeasureListType type, from basicTypes.xsd.
Exceptions	None
Applies to	UML attributes: valueList

Rule 24	Convert each UML attribute with type "Sequence<Integer>" to XML Schema declarations of: a) Reference to following element inside <choice> or <sequence> construct of "…Type" complexType converted from class containing this attribute. b) global element with same name, using type gml:integerList, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + integerValueList : Sequence<Integer> XML Schema: Inside <choice> or <sequence> construct: <element ref="gml:integerValueList"/> Global element declaration: <element name="integerValueList" type="gml:integerList"> <annotation> <documentation>Ordered sequence of two or more integer values of an operation parameter list, usually used for counts. These integer values do not have an associated unit of measure. An element of this type contains a space-separated list of integer values. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use gml:integerList type, from basicTypes.xsd.
Exceptions	None
Applies to	UML attributes: integerValueList

Rule 25	Convert each UML attribute with type "Measure" to XML Schema declarations of: a) Reference to following two elements inside <choice> or <sequence> construct of "…Type" complexType converted from class containing this attribute. b) Global element with same name, using type gml:MeasureType, and with <documentation> element copying documentation of this UML attribute. c) Global element with name " dmsAngleValue", using type gml:DMSAngleType, and with <documentation> element modifying documentation of this UML attribute.
Example	UML attribute: + value : Measure XML Schema: Inside <choice> or <sequence> construct: <element ref="gml:value"/> <element ref="gml:dmsAngleValue"/> Global element declaration: <element name="value" type="gml:MeasureType"> <annotation> <documentation>Numeric value of an operation parameter, with its associated unit of measure. </documentation> </annotation> </element> <!-- ========== --> <element name="dmsAngleValue" type="gml:DMSAngleType"> <annotation> <documentation>Value of an angle operation parameter, in either degree-minute-second format or single value format. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use gml:MeasureType type (from basicTypes.xsd) and gml:DMSAngleType type (from units.xsd). Allow (parameter) values to be encoded in Degrees-Minutes-Seconds format.
Exceptions	None
Applies to	UML attributes: "value"

Rule 26	Convert each UML attribute with type "Length" to XML Schema declarations of: a) Reference to following element inside <choice> or <sequence> construct of "…Type" complexType converted from class containing this attribute. b) Global element with same name, using type gml:LengthType, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + semiMajorAxis : Length XML Schema: Inside <choice> or <sequence> construct: <element ref="gml:semiMajorAxis"/> Global element declaration: <element name="semiMajorAxis" type="gml:LengthType"> <annotation> <documentation>Length of the semi-major axis of the ellipsoid. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use gml:LengthType type, from measures.xsd.
Exceptions	None
Applies to	UML attributes: semiMajorAxis, semiMinorAxis

Rule 27	Convert each UML attribute with type "Angle" to XML Schema declarations of: a) Reference to following element inside <sequence> or <choice> construct of "…Type" complexType converted from class containing this attribute. b) Global element with same name, using type gml:AngleChoiceType, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + greenwichLongitude : Angle = 0 XML Schema: Inside <sequence> or <choice> construct: <element ref="gml:greenwichLongitude"/> Global element declaration: <element name="greenwichLongitude" type="gml:AngleChoiceType"> <annotation> <documentation>Longitude of the prime meridian measured from the Greenwich meridian, positive eastward. If the datum type is geodetic and the prime meridian name is not supplied, then the prime meridian name is taken to be "Greenwich" and the Greenwich longitude value is taken to be zero. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use gml:AngleChoiceType type, from measures.xsd.
Exceptions	None
Applies to	UML attributes: greenwichLongitude

Rule 28	Convert each UML attribute with type "Scale" to XML Schema declarations of: a) Reference to following element inside <choice> or <sequence> construct of "…Type" complexType converted from class containing this attribute. b) Global element with name validArea, using type gml:ScaleType, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + inverseFlattening : Scale XML Schema: Inside <choice> or <sequence> construct: <element ref="gml:inverseFlattening"/> Global element declaration: <element name="inverseFlattening" type="gml:ScaleType"> <annotation> <documentation>Inverse flattening value of the ellipsoid. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use gml:ScaleType type, from measures.xsd.
Exceptions	None
Applies to	UML attributes: inverseFlattening

Rule 29	Convert each UML attribute with type "UnitOfMeasure" to XML Schema declarations of: a) Reference to following attribute following <sequence> construct of "…Type" complexType converted from class containing this attribute. b) Global attribute with "uom" name, using type xsd:anyURI, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + axisUnitID : UnitOfMeasure XML Schema: following <sequence> construct: <attribute ref="gml:uom" use="required"/> Global element declaration: <attribute name="uom" type="anyURI"> <annotation> <documentation>Identifier of the unit of measure used for this coordinate system axis. </documentation> </annotation> </attribute> <!-- ========== -->
Reason(s)	Use uom attribute pattern, in global attribute for Application Schemas flexibility.
Exceptions	None
Applies to	UML attributes: axisUnitID

Rule 30	Convert each UML attribute with type of a <<CodeList>> stereotyped UML class to XML Schema declaration of reference to element converted from <<CodeList>> class, inside <sequence> or <choice> construct of "…Type" complexType converted from class containing this attribute.
Example	UML attribute: + pixelinCell : RS_PixelinCell XML Schema,: Inside <sequence> or <choice> construct: <element ref="gml:pixelInCell"/>
Reason(s)	Use relevant declared global elements.
Exceptions	None
Applies to	UML attributes: derivedCRSType, pixelinCell, verticalDatumType

Rule 31	Don't convert any UML attributes in each <<CodeList>> stereotyped UML class to any XML Schema declaration.
Example	UML attribute: + cell center XML Schema: (none)
Reason(s)	Allow separate specification of allowed valued of <<CodeList>> stereotyped UML classes.
Exceptions	None
Applies to	UML classes: SC_DerivedCRSType, CD_PixelinCell, CD_VerticalDatumType

Rule 32	Convert each UML attribute with type "RS_Identifier" to XML Schema declarations of: a) Reference to following element inside <sequence> or <choice> construct of "…Type" complexType converted from class containing this attribute. b) Global element with same name, using type gml:IdentifierType, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + srsID [0..*] : RS_Identifier XML Schema: Inside <sequence> construct: <element ref="gml:srsID" minOccurs="0" maxOccurs="unbounded"/> Global element declaration: <element name="srsID" type="gml:IdentifierType"> <annotation> <documentation>An identification of this reference system. The first srsID, if any, is normally the primary identification code, and any others are aliases.</documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use gml:IdentifierType type, in referenceSystems.xsd.
Exceptions	None
Applies to	UML attributes: srsID, datumID, meridianID, spheroidID, csID, axisID, coordinateOperationID, methodID, parameterID

Rule 33	Convert each UML attribute with type "DQ_PositionalAccuracy" to XML Schema reference to global element with same name and <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + positionalAccuracy [0..1] : DQ_PositionalAccuracy XML Schema: Inside <choice> or <sequence> construct: <element ref="gml:_positionalAccuracy" minOccurs="0"> <annotation> <documentation>Estimate of the impact of this coordinate operation on point position accuracy. Gives position error estimates for target coordinates of this coordinate operation, assuming no errors in source coordinates.</documentation> </annotation> </element>
Reason(s)	Use "_positionalAccuracy" global element, from dataQuality.xsd.
Exceptions	None
Applies to	UML attributes: positionalAccuracy

Rule 34	Convert each UML attribute with type EX_Extent to XML Schema declarations of: a) Reference to following element inside <sequence> or <choice> construct of "…Type" complexType converted from class containing this attribute. b) Global element with name validArea, using type ExtentType, and with <documentation> element generalising documentation of these UML attributes, in referenceSystems.xsd only.
Example	UML attribute: + validArea [0..1] : EX_Extent XML Schema: Inside <sequence> or <choice> construct: <element ref="gml:scope" minOccurs="0"/> Global element declaration, in referenceSystems.xsd only: <element name="validArea" type="gml:ExtentType"> <annotation> <documentation>Area or region in which this CRS object is valid. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Declare validArea element in only one place, use ExtentType type.
Exceptions	None
Applies to	UML classes: RS_ReferenceSystem, CD_Datum, CC_CoordinateOperation

Rule 35	Do not convert UML attribute with type CI_Citation to XML Schema.
Example	UML attribute: + authority [0..1] : CI_Citation XML Schema: (none)
Reason(s)	Whenever useful, citation information can be included in a metaDataProperty element in any XML elements that uses gml:Identifier XML element.
Exceptions	None
Applies to	UML attributes: "authority"

Rule 36	Convert each UML attribute with type "CharacterString" and attribute name not ending in "Name" to XML Schema declarations of: a) Reference to following element inside <sequence> or <choice> construct of "…Type" complexType converted from class containing this attribute. b) Global element with same name, using type xsd:string, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + version [0..1] : CharacterString XML Schema: Inside <sequence> or <choice> construct: <element ref="gml:version" minOccurs="0"/> Global element declaration: <element name="version" type="string"> <annotation> <documentation>Identifier of the version of the associated codeSpace or code, as specified by the codeSpace or code authority. This version is included only when the "code" or "codeSpace" uses versions. When appropriate, the version is identified by the effective date, coded using ISO 8601 date format. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use xsd:string type, in global element for flexibility.
Exceptions	UML attributes codeSpace, "scope", valueFile, anchorPoint, axisAbbrev, axisDirection, "formula", measureDescription, and "remarks", as specified in following six specialized rules.
Applies to	UML attributes: "code", "version", isSphere, coordinateOperationVersion, stringValue

Rule 37	Convert each UML attribute with type "CharacterString" and attribute name of "scope" to XML Schema declarations of: a) Reference to following element inside <sequence> or <choice> construct of "…Type" complexType converted from class containing this attribute. b) Global element with same name, using xsd:string type, and with <documentation> element generalising documentation of these UML attributes, in referenceSystems.xsd only.
Example	UML attribute: + scope [0..1] : CharacterString XML Schema: Inside <sequence> or <choice> construct: <element ref="gml:scope" minOccurs="0"/> Global element declaration, in referenceSystems.xsd only: <element name="scope" type="string"> <annotation> <documentation>Description of domain of usage, or limitations of usage, for which this CRS object is valid. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Declare "scope" global element in only one place, use xsd:string type.
Exceptions	None
Applies to	UML classes: RS_ReferenceSystem, CD_Datum, CC_CoordinateOperation

Rule 38	Convert each UML attribute with type "CharacterString" and attribute name of "valueFile" to XML Schema declarations of: a) Reference to following element inside <choice> or <sequence> construct of "…Type" complexType converted from class containing this attribute. b) Global element with same name, using type xsd:anyURI, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + valueFile : CharacterString XML Schema: Inside <choice> or <sequence> construct: <element ref="gml:valueFile"/> Global element declaration: <element name="valueFile" type="anyURI"> <annotation> <documentation>Reference to a file containing multiple parameter values, each numeric value with its associated unit of measure. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use xsd:anyURI type to reference a file, following XML Schema and GML patterns.
Exceptions	None
Applies to	UML attributes: valueFile

Rule 39	Convert each UML attribute with type "CharacterString" and attribute name of "formula" to XML Schema declarations of: a) Reference to following element inside <sequence> construct of "…Type" complexType converted from class containing this attribute. b) Global element with name "methodFormula", using type gml:CodeType, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + formula : CharacterString XML Schema: Inside <sequence> construct: <element ref="gml:methodFormula"/> Global element declaration: <element name="methodFormula" type="gml:CodeType"> <annotation> <documentation>Formula(s) used by this operation method. The value may be a reference to a publication. Note that the operation method may not be analytic, in which case this element references or contains the procedure, not an analytic formula.</documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use gml:CodeType type to allow referencing another document, following GML pattern. Change name "formula" to methodFormula to avoid conflict with "formula" element in units.xsd.
Exceptions	None
Applies to	UML attributes: formula

Rule 40	Convert each UML attribute with type "CharacterString" and attribute name of "codeSpace", "anchorPoint", "axisAbbrev", "axisDirection", or "measureDescription" to XML Schema declarations of: a) Reference to following element inside <sequence> construct of "…Type" complexType converted from class containing this attribute. b) Global element with same name, using type gml:CodeType, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + axisDirection : CharacterString XML Schema: Inside <sequence> construct: <element ref="gml:axisDirection"/> Global element declaration: <element name="axisDirection" type="gml:CodeType"> <annotation> <documentation>Direction of this coordinate system axis (or in the case of Cartesian projected coordinates, the direction of this coordinate system axis at the origin). Examples: north or south, east or west, up or down. Within any set of coordinate system axis, only one of each pair of terms can be used. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use gml:CodeType global type to allow referencing another document, following GML pattern.
Exceptions	None
Applies to	UML attributes: codeSpace, anchorPoint, axisAbbrev, axisDirection, measureDescription

Rule 41	Convert UML attributes named "code" and “codeSpace”, both of type "CharacterString" and in RS_Identifier class, to XML Schema reference to gml:name element inside <sequence> construct of "IdentifierType" complexType converted from RS_Identifier class. Include <documentation> element adapted from the documentation of these two UML attributes.
Example	UML attributes: + code : CharacterString + codeSapce [0..1] : CharacterString XML Schema: Inside <sequence> construct: <element ref="gml:name"> <annotation> <documentation>The code or name for this Identifier, often from a controlled list or pattern defined by a code space. The optional codeSpace attribute is normally included to identify or reference a code space within which one or more codes are defined. This code space is often defined by some authority organization, where one organization may define multiple code spaces. The range and format of each Code Space identifier is defined by that code space authority. Information about that code space authority can be included as metaDataProperty elements which are optionally allowed in all CRS objects. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use gml:name element that has meaning the same as this pair of UML attributes.
Exceptions	None
Applies to	UML attributes: code, codeSapce (only in RS_Identifier)

Rule 42	Convert UML attribute named "remarks", with type "CharacterString", and in RS_Identifier class, to XML Schema declarations of: a) Reference to following element inside <sequence> construct of "IdentifierType" complexType converted from RS_Identifier class. b) Global element with same name, using type gml: StringOrRefType, in "gml:description" substitutionGroup, and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + remarks [0..1] : CharacterString XML Schema: Inside <sequence> construct: <element ref="gml:remarks" minOccurs="0"> Global element declaration: <element name="remarks" type="gml:StringOrRefType" substitutionGroup="gml:description"> <annotation> <documentation>Information about this object or code. Contains text or refers to external text. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Define global element for Application Schemas flexibility. Use global type gml:StringOrRefType to allow substitution for gml:description, when referenced as described in the following rule.
Exceptions	None
Applies to	UML attributes: remarks (only in RS_Identifier)

Rule 43	Convert each UML attribute named "remarks", with type "CharacterString", and not in RS_Identifier class, to XML Schema declarations of reference to "gml:remarks" element defined in preceding rule, and copying documentation of this UML attribute. Put this reference to "gml:remarks" in the "AbstractXxxxBaseType" complexType converted from this class, immediately after the "gml:metaDataProperty" element.
Example	UML attribute: + remarks [0..1] : CharacterString (in RS_ReferenceSystem) XML Schema: Inside <sequence> construct of "AbstractReferenceSystemBaseType": <element ref="gml:metaDataProperty" minOccurs="0" maxOccurs="unbounded"/> <element ref="gml:remarks" minOccurs="0"> <annotation> <documentation>Comments on or information about this reference system, including source information. </documentation> </annotation> </element>
Reason(s)	Adapt gml:description global type, optional in all GML objects, to contain these general remarks on CRS objects.
Exceptions	None
Applies to	UML attributes: remarks (except in RS_Identifier)

Rule 44	Convert each UML attribute with type "CharacterString" and attribute name ending in "Name" to XML Schema declarations of: a) Reference to following element inside <sequence> construct of "…BaseType" complexType converted from class containing this attribute. b) Global element with same name, using SimpleNameType, in substitutionGroup "gml:name", and with <documentation> element copying documentation of this UML attribute.
Example	UML attribute: + srsName : CharacterString XML Schema: Inside <sequence> construct: <element ref="gml:srsName"/> Global element declaration: <element name="srsName" type="gml:SimpleNameType" substitutionGroup="gml:name"> <annotation> <documentation>The name by which this reference system is identified.</documentation> </annotation> </element>
Reason(s)	Allow restricting gml:DefintionType by complexTypes using "…Name" elements.
Exceptions	None
Applies to	UML attributes: srsName, datumName, ellipsoiidName, meridianName, csName, axisName, coordinateOperationName, methodName, parameterName

Rule 45	Insert global declaration of SimpleNameType that restricts gml:CodeType to prohibit inclusion of codeSpace attribute.
Example	XML Schema: <complexType name="SimpleNameType"> <annotation> <documentation>The primary name of a reference system object. The string in the CodeType contains the object identification name, and the codeSpace attribute is not included. </documentation> </annotation> <simpleContent> <restriction base="gml:CodeType"> <attribute name="codeSpace" type="anyURI" use="prohibited"/> </restriction> </simpleContent> </complexType> <!-- ========== -->
Reason(s)	Declare SimpleNameType global type derived from gml:CodeType, to support preceding rule. Provide <documentation> to support human understanding
Exceptions	None

G.5 Rules for associations

Most rules used to convert UML model (class) associations to XML Schemas are separately applied to each navigable end of each association. The rules used were:

Rule 46	Do not XML encode the non-navigable ends of UML associations (usually without role names)
Example	None
Reason(s)	There is no need to navigate association in this direction.
Exceptions	None
Applies to	UML association role names: None

Rule 47	Do not XML encode the ends of UML "derived" associations.
Example	UML role name: +usesDatum from SC_CoordinateReferenceSystem class XML Schema: (None)
Reason(s)	There is no need to navigate derived associations (instead of the basic associations).
Exceptions	None
Applies to	UML association role names:

The following rules for encoding associations apply to only the navigable end (always has a role name) of non-derived UML associations:

NOTE Most of these rules copy the documentation of each UML association role into a <documentation> element of the XML element converted from this UML role, in order to keep the UML association role documentation for human understanding of the XML Schemas.

Rule 48	Convert each navigable end of each composition UML association to XML Schema declarations of: a) Reference to following element inside <sequence> construct of the complexType converted from the class at the other end of this association. b) Global element with same name, using the complexType encoded for the class at this end of the association, and with <documentation> element copying documentation of this UML role name.
Example	UML role name: +usesValue from CC_Operation class XML Schema: Inside <sequence> construct: <element ref="gml:usesValue" minOccurs="0" maxOccurs="unbounded"/> Global element declaration: <element name="usesValue" type="gml:ParameterValueType"> <annotation> <documentation>Unordered list of composition associations to the set of parameter values used by this conversion operation. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Follow GML pattern for properties. Define global element for flexibility.
Exceptions	None
Applies to	UML association role names: +usesValue from CC_Operation, +includesValue from CC_ParameterValueGroup, +includesElement from DQ_CovarianceMatrix

Rule 49	Convert each navigable end of each aggregation of unspecified type of UML association to XML Schema declarations of: a) Reference to following element inside <sequence> construct of the complexType converted from the class at the other end of this association. b) Global element with same name, using the "xxxxRefType" encoded for the class at this end of this association, and with <documentation> element copying documentation of this UML role name.
Example	UML role name: +usesEllipsoid from CD_GeodeticDatum class XML Schema: Inside <sequence> construct: <element ref="gml:usesEllipsoid"/> Global element declaration: <element name="usesEllipsoid" type="gml:EllipsoidRefType"> <annotation> <documentation>Association to the ellipsoid used by this geodetic datum. </documentation> </annotation> </element> <!-- ========== -->
Reason(s)	Use "xxxxRefType" following GML pattern for general associations. Define global element for flexibility.
Exceptions	a) If new global element declaration would be a duplicate, do not duplicate it. b) If association has attached {XOR} note, see following rule. c) For all +usesDatum role names to concrete classes for specific types of datums, change XML element name from "usesDatum' to the class name on this end of the association prefixed by "uses". d) For all +usesCS role names to concrete classes for specific types of coordinate systems, change XML element name from "usesCS' to the class name on this end of the association prefixed by "uses". e) For +usesOperation from CC_ConcatenatedOperation, change XML element name from "usesOperation" to " usesSingleOperation".
Applies to	UML association role names: +includesCRS from SC_CompoundCRS, +baseCRS from SC_GeneralDerivedCRS, +usesDatum from SC_GeocentricCRS, +usesDatum from SC_GeographicCRS, +usesDatum from SC_VerticalCRS, +usesDatum from SC_TemporalCRS, +usesDatum from SC_EngineeringCRS, +usesDatum from SC_ImageCRS, +usesCS from SC_EngineeringCRS, +usesCS from SC_GeographicCRS, +usesCS from SC_VerticalCRS, +usesCS from SC_TemporalCRS, +usesCS from SC_ProjectedCRS, SC_DerivedCRS, +usesCS from +usesEllipsoid from CD_GeodeticDatum, +usesPrimeMeridian from CD_GeodeticDatum, +usesAxis from CS_CoordinateSystem, +sourceCRS from CC_CoordinateOperation, , +targetCRS from CC_CoordinateOperation, +usesOperation from CC_ConcatenatedOperation, +usesOperation from CC_PassThroughOperation, +definedByConversion from SC_GeneralDerivedCRS, +usesMethod from CC_Operation, +usesParameter from CC_OperationMethod, +includesParameter from CC_OperationParameterGroup, +valueOfParameter from CC_ParameterValue, +valuesOfGroup from CC_ParameterValueGroup

Rule 50	Convert each navigable end of an aggregation UML association with attached {XOR} note to XML Schema declarations of a reference to the appropriate element. Put this element inside a <choice> construct and without minOccurs="0", inside the <sequence> construct of the complexType converted from the class at the other end of this association.
Example	UML role name: +usesSphericalCS from SC_GeocentricCRS class and +usesCartesianCS from SC_GeocentricCRS class XML Schema: Inside <sequence> construct: <choice> <element ref="gml:usesCartesianCS"/> <element ref="gml:usesSphericalCS"/> </choice>
Reason(s)	Take advantage of <choice> construct in XML Schema.
Exceptions	If new global element declaration would be a duplicate, do not duplicate it.
Applies to	UML association role names: +usesSphericalCS from SC_GeocentricCRS, +usesCartesianCS from SC_GeocentricCRS, +usesCartesianCS from SC_ImageCRS, +usesObliqueCartesianCS from SC_ImageCRS

G.6 Rules for multiplicities

The rules used to convert UML model multiplicities to XML Schemas were:

Rule 51	Convert each UML multiplicity "0..*", on UML attributes and navigable association role names, to XML Schema declaration of minOccurs="0" maxOccurs="unbounded".
Example	UML model multiplicity: 0..* XML Schema element multiplicity: minOccurs="0" maxOccurs="unbounded"
Reason(s)	Use relevant XML Schema multiplicity constructs.
Exceptions	None

Rule 52	Convert each UML multiplicity "1..*", on UML attributes and navigable association roles, to XML Schema declaration of maxOccurs="unbounded".
Example	UML model multiplicity: 1..* XML Schema element multiplicity: maxOccurs="unbounded"
Reason(s)	Use relevant XML Schema multiplicity construct.
Exceptions	None

Rule 53	Convert each UML multiplicity "2..*", on navigable association roles, to XML Schema declaration of minOccurs="2" maxOccurs="unbounded".
Example	UML model multiplicity: 2..* XML Schema element multiplicity: minOccurs="2" maxOccurs="unbounded"
Reason(s)	Use relevant XML Schema multiplicity constructs.
Exceptions	None

Rule 54	Convert each UML multiplicity "0..1", on UML attributes and navigable association roles, to XML Schema declaration of minOccurs="0".
Example	UML model multiplicity: 0..1 XML Schema element multiplicity: minOccurs="0"
Reason(s)	Use relevant XML Schema multiplicity construct.
Exceptions	None

Rule 55	Don't convert each UML multiplicity "1", on navigable association roles, to any XML Schema declaration.
Example	UML association role multiplicity: 1 XML Schema element multiplicity: (none)
Reason(s)	Use relevant XML Schema multiplicity construct.
Exceptions	None

Rule 56	Don't convert each unspecified UML multiplicity, on UML attributes, to any XML Schema declaration.
Example	UML association role multiplicity: (none) XML Schema element multiplicity: (none)
Reason(s)	Use XML Schema multiplicity constructs.
Exceptions	None

G.7 Other rules

Other rules used to convert the UML model to XML Schemas were:

Rule 57	Remove each XML <sequence> construct in a complexType that contains no elements (that encode a UML attribute or association).
Example	Before: <extension base="gml:AbstractReferenceSystemType"> <sequence> </sequence> </extension> After: <extension base="gml:AbstractReferenceSystemType"/>
Reason(s)	Simplify XML Schemas.
Exceptions	None

Rule 58	In each XML Schema document, order element and corresponding type declarations for ease of top-down understanding.
Example	N/A
Reason(s)	Make XML Schema documents easier to understand.
Exceptions	None
Applies to	All six CRS Schema documents.

Annex H
(informative)

Coordinate operation methods

H.1 Introduction

This annex contains a non-exhaustive description of some conversion and transformation operation methods. It lists a number of methods defined in the EPSG v 6.3 well-known data set, plus a few other often used methods and some methods applicable to the transformation of image coordinates.

Each operation method should uniquely specify the algorithm to be used for a coordinate transformation. This specification may comprise two algorithms, forward and inverse, as is sometimes used for map projection algorithms. Each conversion and transformation, and each operation method, should use a well-known data set in referencing such algorithms.

NOTE Of course, referencing a well-known algorithm does not imply that software which implements these algorithms has correctly implemented it, or has implemented all referenced algorithms. Similarly, referencing a well-known set of parameter values does not imply that software which implements these values uses the correct values.

H.2 EPSG defined operation methods

The well-known data set from EPSG (version 6.3) specifies a number of operation methods. Please note that the EPSG data set is neither prescriptive, nor exhaustive. This document mentions a small subset of the methods in the EPSG data set. Methods not listed in this document, but listed in the EPSG data set, can easily be implemented using the OperationMethod and OperationParameter elements, making use of the method name and parameter names specified in the EPSG data set.

These operation methods are defined making use of well-defined operation parameters. When a coordinate operation is specified referencing an EPSG defined operation method, the detailed specification in an XML document should adhere to the EPSG definitions of the operation parameters.

The detailed definition of these operation method algorithms, with their formulas and a worked example is included in the EPSG data set, available on the Web, through the reflector: http://www.epsg.org/

These and other information on coordinate operation methods is available on: http://www.remotesensing.org/geotiff/proj_list/

See also:

http://www.posc.org/Epicentre.2_2/DataModel/ExamplesofUsage/eu_cs.html.

H.3. Other operation methods

H.3.1 Introduction

The following operation methods are not specified in any well-known data set but are implied in the specification of Coordinate Systems and Coordinate Reference Systems.

a) Polar / Cartesian (2D) conversion

b) Spherical / Cartesian (3D) conversion

c) Cylindrical / Cartesian conversion

d) Linear to Cartesian (2D) conversion

e) Linear to Cartesian (3D) conversion

f) Geographic3D to Geographic2D/GravityRelatedHeight conversion

H.3.2 Polar / Cartesian (2D) conversion

This method converts two-dimensional polar coordinates to plane Cartesian coordinates and vice versa (the inverse algorithm is implied in this transformation method).

H.3.3 Spherical / Cartesian (3D) conversion

This method converts spherical coordinates (sometimes referred to as polar 3D coordinates) to 3D Cartesian coordinates and vice versa (the inverse algorithm is again implied in this transformation method). Please bear in mind that when the spherical coordinate system is used in a local context (i.e., in an EngineeringCRS); the converted Cartesian coordinate system can only be used in the same context: there is no datum change involved. Transformation to a Geocentric Cartesian system is possible only when the spherical coordinate system is also geocentric.

H.3.4 Cylindrical / Cartesian conversion

This method converts (3D) cylindrical coordinates to 3D Cartesian coordinates and vice versa. The area of use of the cylindrical coordinate system is unlikely to be other than local. The Cartesian coordinate system will therefore also be associated with an EngineeringCRS. A further (or indeed a one-step) transformation to a Geocentric system will be incorrect, although it may seem mathematically correct.

H.4 Image coordinate transformation methods

H.4.1 Introduction

This subclause discusses the following non-exhaustive list of coordinate transformation types applicable to image coordinate reference systems:

a) Ground-to-image transformations

b) Single-image-to-ground transformations

c) Elevation coverage with single-image-to-ground transformations

d) Elevation coverage for 2D to 3D coordinate transformations

e) Elevation coverage with single ground-to-image transformations

H.4.2 Ground-to-image transformations

This set of operation methods defines transformations used for ground-to-image coordinate transformations, with one method used for each image geometry model type. The input to such a transformation is usually 3D ground coordinates, and the output is usually 2D image coordinates. These methods will usually use parameters for directly transforming 3D ground coordinates to 2D image coordinates.

H.4.3 Single-image-to-ground transformations

This set of operation methods defines transformations used for single (or monoscopic) image-to-ground transformations, with one operation method used for each image geometry model type. These methods could use parameters for directly transforming 2D image coordinates to multiple 3D ground coordinates. However, these parameterized transformations could use parameters for directly transforming 3D ground coordinates to 2D image coordinates (like ground-to-image transformations).

The output from such a transformation is usually 3D ground coordinates, and the input can be compound 2D image plus 3D ground coordinates. In that case, the 3D ground coordinates are used to provide a fixed elevation value, to be used with the 2D image input coordinates. The horizontal position is included with each elevation to facilitate ground coordinate transformations. Inclusion of the horizontal position also allows the client to provide an approximate horizontal ground position, when known. Server software implementing such transformations is allowed to make use of this approximate horizontal position, to speed computation.

H.4.4 Elevation coverage with single-image-to-ground transformation

This operation method defines a transformation using an elevation coverage with a single-image-to-ground transformation. One operation method can be used for any

elevation coverage that uses the same OGC specified (grid) coverage interface. A transformation parameter should reference one elevation coverage from one external elevation coverage service. This assumes that interface implementations will first use a separate single-image-to-ground transformation to compute two or more points along the image ray. The implementation will then intersect this ray with ground shape defined by elevation coverage.

The output from this transformation is usually 3D ground coordinates, and the input can be compound 2D image plus 3D ground coordinates (plus the separately specified elevation coverage). In that case, the input 3D ground coordinates are used to provide an approximate elevation value, to be used with the 2D image input coordinates. The horizontal position is included with each elevation to facilitate ground coordinate transformations. Inclusion of the horizontal position also allows the client to provide an approximate horizontal ground position, when known. Server software implementing such transformations is allowed to make use of this approximate horizontal position, to speed computation.

H.4.5 Elevation coverage for 2D to 3D coordinate transformation

This operation method defines a transformation using an elevation coverage for 2D to 3D coordinate transformations. One operation method can be used for any elevation coverage that uses the same OGC specified (grid) coverage interface. A transformation parameter should reference one elevation coverage from one external elevation coverage service. The input to this transformation is 2D horizontal coordinates (plus the separately specified elevation coverage), and the output is 3D coordinates. This transformation can be used in a Concatenated Transformation with a ground-to-image transformation, to go from 2D ground coordinates to 2D image coordinates.

H.4.6 Elevation coverage with single ground-to-image transformation

This operation method defines a transformation using an elevation coverage with a single ground-to-image transformation. One operation method can be used for any elevation coverage that uses the same OGC specified (grid) coverage interface. A transformation parameter should reference one elevation coverage from one external elevation coverage service. The input to this transformation is 2D horizontal ground coordinates (plus the separately specified elevation coverage), and the output is usually 2D image coordinates. An implementation of this parameterized transformation is expected to first use the elevation coverage to obtain the third ground coordinate, and then use a separate implementation of a ground-to-image transformation.

Annex I
(informative)

Schema flexibility

I.1 Introduction

This annex summarizes the flexibility supported by the CRS set of XML Schemas specified in Annex C. Much of this flexibility applies to the Application Schemas that can and should be developed using these CRS Schemas. However, considerable flexibility is supported without using an Application Schema, just using a selected XML element as the basis for an XML document.

NOTE 1 Specification flexibility will reduce interoperability whenever different implementations support different subsets of the allowed flexibility. To maximise interoperability, each Implementation Specification using this specification should specify the subset required to be implemented (especially by a server), for each flexibility area allowed by this specification. Some of this subset specification can be done in the Application Schema(s) specified by that Implementation Specification.

NOTE 2 Many of the concrete XML elements defined in these CRS Schemas can be used without Application Schemas, when no contents extensions or restrictions are needed. However, the Conversion, Transformation, ParameterValue, and ParameterValueGroup elements should not be used for well-known coordinate operation methods having many instances. Instead, an Application Schema that defines operation-method-specialized element names and contents should be prepared and standardized, see Subclause 6.3.

I.2 Application Schema flexibility

The CRS Schemas specified in Annex C support considerable flexibility in an Application Schema. That flexibility includes:

a) Defining elements that can be attached as metadata to each (of about 30) concrete elements with identity (or GML objects).

b) Extending most complexTypes by adding elements selected and/or defined to record additional data about the elements using that complexType.

c) Restricting most complexTypes to reduce the allowed multiplicity of an included element, or restrict an included element to a selected element defined in the substitutionGroup of the currently included element.

d) Extending some abstract complexTypes by adding elements deliberately not included in the abstract type, to facilitate definition of differently named and/or structured elements in Application Schemas. Those complexTypes include:

   1) AbstractGeneralConversionType

   2) AbstractGeneralTransformationType

   3) AbstractGeneralParameterValueType

NOTE 1 Such use of Application Schemas is discussed in Subclause 6.3, and example Application Schemas extending two of these three complexTypes is provided in Subclauses F.3 and F.4.

e) Using or extending some abstract complexTypes and elements to define additional concrete subtypes. Those elements and complexTypes include:

   1) _CoordinateReferenceSystem, with AbstractCoordinateReferenceSystemType
   2) _GeneralDerivedCRS, with AbstractGeneralDerivedCRSType
   3) _CRS, with AbstractCRSType
   4) _Datum, with AbstractDatumType
   5) _CoordinateSystem, with AbstractCooordinateSystemType

NOTE 2 These abstract complexTypes shall not be used or extended (in an Application Schema) to define a concrete subtype with a meaning equivalent to a concrete subtype specified in this document. If needed, these abstract complexTypes can be extended in an Application Schema to add more contents. Also if needed, these abstract complexTypes may be used or extended (in an Application Schema) to define an additional concrete subtype with a different meaning.

EDITORS NOTE These CRS schemas currently allow such uses and extensions because XML Schemas cannot preclude such uses. If appropriate, constraints could be added to the <documentation> elements for these complexTypes to prohibit undesirable additional concrete subtypes.

I.3 Other flexibility

In addition to flexibility provided by preparing an Application Schema, the CRS Schemas specified in Annex C support considerable flexibility without using an Application Schema. That flexibility includes:

a) Units of measure (uom) used for each:

   1) "value" element in ParameterValueType, even for a single parameter
   2) "uom" attribute in CoordinateSystemAxisType
   3) "result" element in AbsoluteExternalPositionalAccuracyType and RelativeInternalPositionalAccuracyType

b) Subtypes of AbstractPositionalAccuracyType used in AbstractCoordinateOperationType and all three of its' concrete subtypes.

c) A Dictionary element can contain any combination of the concrete XML elements listed in Subclause 6.2, since all are substitutable for a Definition element in a Dictionary. A Dictionary element can also contain one or more UnitDefinition elements, as defined in units.xsd of GML 3. Furthermore, any of these concrete elements or a Dictionary can be included inside a GenericMetaData element inside a metaDataProperty element, which can be inside of many other XML elements.

d) Defining new and different sets of standardized values to be used as the contents of many elements with the gml:CodeType and xsd:string data types. Those elements include:

   1) derivedCRSType, in DerivedCRSType
   2) pixelInCell, in ImageDatumType
   3) verticalDatumType, in VerticalDatumType
   4) axisDirection, in CoordinateSystemAxisType
   5) axisAbbrev, in CoordinateSystemAxisType
   6) "scope", in AbstractReferenceSystemType, AbstractDatumType, AbstractCoordinateOperationType, and all of their subtypes
   7) anchorPoint, in each of four subtypes of AbstractDatumType
   8) measureDescription, in each of three subtypes of AbstractPositionalAccuracyType

Bibliography

[1] ISO 19111, Geographic information – Spatial referencing by coordinates

[2] ISO 19118, Geographic information – Encoding

[3] Version N1316 of ISO CD 19118: Geographic information - Encoding is supplemented by XML Schema documents posted on David Skogan's web page on ISO 19118 encoding: http://www.ifi.uio.no/~davids/encoding.

[4] OGC 99-107, Abstract Specification Topic 7: The Earth Imagery Case

[5] OGC 00-045r1, Draft RFC on Image Coordinate Transformations

[6] OGC 01-004, Implementation Specification: Grid Coverage

[7] OGC 01-009, Implementation Specification: Coordinate Transformation Services

[8] OGC 01-013r1, High-Level Ground Coordinate Transformation Interface

[9] OGC 01-068r3, Web Map Service Implementation Specification