Open Geospatial Consortium Inc.

Date: 2007-03-20

Reference number of this document: OGC 07-032

Version: 0.0.0

Category: Discussion Paper

Editor: Arliss Whiteside

Frame image geopositioning metadata GML 3.2 application schema

Warning

This document is not an OGC Standard. This document is an OGC Discussion Paper and is therefore not an official position of the OGC membership. It is distributed for review and comment. It is subject to change without notice and may not be referred to as an OGC Standard. Further, an OGC Discussion Paper should not be referenced as required or mandatory technology in procurements.

Document type:	OpenGIS® Discussion Paper
Document subtype:	Draft GML Application Schema
Document stage:	Initial Draft
Document language:	English

Contents

Page

Figures

Page

Tables

Page

i. Preface

This document specifies a GML 3.2 Application Schema for frame image geopositioning metadata. This schema is one of many possible specific sensor model extensions of the Image Geopositioning Metadata (IGM) GML 3.2 Application Schema [OGC 07-031]. (The IGM Application Schema does not specify geopositioning metadata for any specific sensor models, requiring extension for each specific sensor model.) This frame image geopositioning metadata schema is used by the separately specified Image Geopositioning Service (IGS) interface [OGC06-054r3], but is specified separately because it is expected to also be used by other services.

This document is submitted for consideration as an OGC Discussion Paper, because it is being used to demonstrate the Image Geopositioning Service (IGS) interface. This document is based on the frame sensor model supported by the Socet Set photogrammetric software marketed commercially by BAE Systems. This document is not ready for standardization by the OGC. A future frame image geopositioning metadata specification that is ready for standardization by the OGC is expected to be significantly improved, although some parts may be largely unchanged.

The planned demonstration in support of the RFC of the Image Geopositioning Service (IGS) [OGC 06-054r2] will use a Profile of that specification and the Image Geopositioning Metadata (IGM) GML 3.2 Application Schema [OGC 06-055r2]. That Application Profile will use only one image sensor model, the frame image geopositioning metadata specified in this document. That demonstration Application Profile will include only a (subset) profile of the other abilities specified in [OGC 06-054r2] and [OGC 06-055r2], as described in Annex D of this document.

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

ii. Document terms and definitions

This document uses the specification terms defined in Subclause 5.3 of [OGC 06-121r3], which is based on the ISO/IEC Directives, Part 2. Rules for the structure and drafting of International Standards. In particular, the word “shall” (not “must”) is the verb form used to indicate a requirement to be strictly followed to conform to this specification.

iii. Submitting organizations

The following organizations submitted this document to the Open Geospatial Consortium Inc.

BAE Systems E&IS

iv. Document contributor contact points

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

Name	Organization
Arliss Whiteside	BAE Systems E&IS

v. Revision history

Date	Release	Editor	Primary clauses modified	Description
2007-01-20	0.0.0	Arliss Whiteside	All	First complete version

vi. Changes to the OGC Abstract Specification

The OpenGIS® Abstract Specification does not require any changes to accommodate the technical contents of this document.

vii. Future work

Improvements in this document are desirable for:

a) Examples. Extension is desirable to include more example XML documents.

b) Consistency. Improvement is needed to make this frame image geopositioning metadata more consistent with other frame image metadata, such as that specified in ISO CD 19130.2 (a draft).

c) Reuse. Improvement is needed to define parts of this frame image geopositioning metadata to allow reuse by image geometry metadata for other sensors.

Foreword

This document does not replace any previous OGC document, in whole or in part. This Frame Image Geopositioning Metadata GML 3.2 Application Schema extends the Image Geopositioning Metadata (IGM) GML 3.2 Application Schema [OGC06-055r2]. Both of these GML 3.2 Application Schemas are used by the separately specified Image Geopositioning Service (IGS), and can be used by other services.

This schema is one of many possible specific sensor model extensions of the Image Geopositioning Metadata (IGM) GML 3.2 Application Schema [OGC07-031]. The IGM Application Schema does not specify geopositioning metadata for any specific sensor models, requiring extension for each specific sensor model.

This Application Schema uses small profiles (or subsets) of GML 3.2 (ISO 19136) and ISO 19139, although those profiles are not yet formally specified. For GML, the profile used is a subset of the GML grid CRSs and simple features profiles currently specified for GML 3.1.1. For ISO 19139, the profile is a subset of the ISO 19139 profile that is used by GML 3.2 (ISO 19136).

This document includes four annexes; Annexes A, B, and C are normative, and Annexes D and E are informative.

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

Recipients of this document are requested to submit, with their comments, notification of any relevant patent claims or other intellectual property rights of which they may be aware that might be infringed by any implementation of the specification set forth in this document, and to provide supporting documentation.

Introduction

This document specifies a GML 3.2 Application Schema for frame image geopositioning metadata, for XML encoding of the georeferencing coordinate transformation parameters of an unrectified frame image. A frame image is one whose entire two-dimensional extent was collected at one time. A georeferencing coordinate transformation can transform position coordinates between a specific ground-based (or object) Coordinate Reference System (CRS) and the image CRS.

This Frame Image Geopositioning Metadata GML Application Schema extends the Image Geopositioning Metadata (IGM) GML 3.2 Application Schema for frame images. Both of these GML 3.2 Application Schemas are used by the separately specified Image Geopositioning Service (IGS), which adjusts the georeferencing coordinate transformations of images. Both of these GML 3.2 Application Schemas are separately specified because they are expected to also be used by other services.

Frame image geopositioning metadata GML 3.2 application schema

1 Scope

This document specifies a GML 3.2 Application Schema for frame image geopositioning metadata, for XML encoding of the georeferencing coordinate transformation parameters of an unrectified frame image. A frame image is one whose entire two-dimensional (2D) extent was collected at one time. A georeferencing coordinate transformation can transform position coordinates between a specific ground-based (or object) Coordinate Reference System (CRS) and the image CRS.

This Frame Image Geopositioning Metadata GML Application Schema extends the Image Geopositioning Metadata (IGM) GML 3.2 Application Schema [OGC06-055r2] for frame images. Both of these GML 3.2 Application Schemas are used by the separately specified Image Geopositioning Service (IGS) [OGC 06-054r2], which adjusts the georeferencing coordinate transformations of images. Both of these GML 3.2 Application Schemas are separately specified because they are expected to also be used by other services.

This schema is one of many possible specific sensor model extensions of the Image Geopositioning Metadata (IGM) GML 3.2 Application Schema. The IGM Application Schema specifies an XML schema for encoding image georeferencing coordinate transformations with associated parameter error statistics. However, that specified encoding is general, and does not specify geopositioning metadata for any specific sensor models. The specified georeferencing coordinate transformations can be extended to use many possible image geometry (or sensor) models, each encoded using an extension of that IGM Application Schema.

2 Compliance

Compliance with this specification shall be checked using all the relevant tests specified in Annex A (normative).

3 Normative references

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

OGC 07-031, *OpenGIS® Image geopositioning metadata GML 3.2 application schema*, version 0.0.3

NOTE This IGM Specification contains a list of normative references that are also applicable to this Implementation Specification.

In addition to this document, this specification includes several normative XML Schema Document files as specified in Annex B.

4 Terms and definitions

For the purposes of this specification, the definitions specified in Clause 4 of the OpenGIS® Abstract Specification Topic 2 [OGC 05-103] and in OWS Common Implementation Specification [OGC 06-121r3] shall apply. In addition, the following terms and definitions apply.

4.1
focal plane
(approximate) plane in which an optical camera lens focus images of objects, and in which the image is collected

4.2
local space rectangular
coordinate reference system (CRS) that uses a 3D Cartesian coordinate system with the origin at a selected position on the earth ellipsoid, whose X,Y plane (for Z=0) is tangent to the earth ellipsoid at that position with the Y axis pointing North and the X axis pointing East

NOTE A Local Space Rectangular (LSR.) CRS is an EngineeringCRS.

4.3
universal space rectangular
coordinate reference system (CRS) that uses a 3D Cartesian coordinate system with the origin at the centre of a selected earth ellipsoid.

NOTE A Universal Space Rectangular (USR.) CRS is a GeodeticCRS. A USR is alternately termed Earth Centered Fixed (ECF) or Earth Centered Earth Fixed (ECEF)

4.4
absolute accuracy
absolute external accuracy
statistic which gives the uncertainty of a point with respect to the datum required by a product specification (adapted from OGC 00-115)

NOTE This definition implies that the effects of all error sources, both random and systematic, are considered.

4.5
accuracy
degree to which information on a map or in a digital database matches true or accepted values (adapted from OGC 00-115)

4.6
check point
point with known object (or ground) position used to check the geopositioning of one or more images

NOTE The known position of a check point is not used in the geopositioning. The position of a check point is measured in one or more of the images geopositioned.

4.7

control point

point with known object (or ground) position used to geoposition one or more images

NOTE The known position of a control point is used in the geopositioning. The position of a control point is measured in one or more of the images being geopositioned.

4.8

covariance matrix

detailed form of position accuracy data, sometimes called a variance-covariance matrix (adapted from OGC 00-115)

NOTE 1 For three object (or ground) coordinates, a covariance matrix is a 3 by 3 matrix, with the matrix rows and columns each corresponding to the three coordinates. For two horizontal coordinates, a covariance matrix is a 2 by 2 matrix, with the matrix rows and columns each corresponding to the two horizontal coordinates. Similarly, for two image coordinates, a covariance matrix is a 2 by 2 matrix, with the matrix rows and columns each corresponding to the two image coordinates.

NOTE 2 The covariance matrix cells contain the expected average values of the product of the error in the matrix row coordinate times the simultaneous error in the matrix column coordinate. For absolute accuracy, the diagonal matrix cells contain the error variances of the corresponding coordinates, or the squares of the standard deviations. The off-diagonal cells contain the covariances between the errors in the corresponding coordinates; these covariances will be zero when the errors in different coordinates are not statistically correlated. All covariance matrices are symmetrical, meaning that the same cell values appear on both sides of the diagonal cells.

4.9

frame image

image whose entire 2D extent was collected at one time

NOTE A frame camera is the classical photogrammetric camera. A frame camera takes a two-dimensional image during the time of the exposure. If this image is a film image, it must be scanned for digital processing. A digital camera outputs a digital image without additional processing steps. In both cases, the image is a two-dimensional matrix of pixels. (Adapted from ISO CD 19130-2)

4.10

image geopositioning

adjustment of the parameter values of image georeferencing coordinate transformations to produce correct coordinates in a coordinate reference system that is related to the earth or other imaged object

4.11

object point

ground point

point with position on the imaged object(s), often the earth

4.12

photogrammetry

science of mensuration and geometric adjustment of an aerial photograph or satellite image (adapted from OGC 00-115)

NOTE 1 Photogrammetry requires a mathematical model of the image formation process, computation of the internal geometry of an image, and subsequent correction of imagery based upon the ground relationship for every part of the image. This correction of imagery is based on computational algorithms and measurement of geometrical position in an image.

NOTE 2 Effective photogrammetry makes use of ground control points by which aerial photographs are carefully compared and registered to the locations and characteristics of features identified in ground-level surveys.

4.13
relative accuracy
relative internal accuracy
evaluation of random errors in determining the positional accuracy of one point feature with respect to another feature (adapted from OGC 00-115)

4.14
tie point
point with measured position in one or more images, used to geoposition those images

NOTE The estimated object (or ground) position of a tie point is not known before the geopositioning.

4.15
transformation
approximate transformation of position coordinates from one Spatial Reference System (SRS) to another

NOTE For example, this term is used when the transformation coefficients are determined by least squares adjustment. This term is strictly used only when the transformation is known only approximately. This term is loosely used when the transformation is known either approximately or exactly.

5 Conventions

5.1 Abbreviated terms

CRS	Coordinate Reference System
GML	Geography Markup Language
IGM	Image Geopositioning Metadata
IGS	Image Geopositioning Service
ISO	International Organization for Standardization
LSR	Local Space Rectangular
OGC	Open Geospatial Consortium
OWS	OGC Web Service, or Open Web Service
TBD	To Be Determined
TBR	To Be Reviewed
UML	Unified Modeling Language
URI	Universal Resource Identifier
URL	Uniform Resource Locator
URN	Universal Resource Name
USR	Universal Space Rectangular
XML	Extensible Markup Language

1D	One Dimensional
2D	Two Dimensional
3D	Three Dimensional

5.2 UML notation

Many of the diagrams that appear in this specification are presented using the Unified Modeling Language (UML) static structure diagram, as described in Subclause 5.2 of [OGC 06-121r3].

5.3 Platform-neutral and platform-specific specifications

As specified in Subclause 5.4 of OWS Common [OGC 06-121r3], this document includes both platform-neutral and platform-specific specifications.

EXAMPLES 1 Platform-neutral specifications are contained in Subclauses 8.2 and 9.2.

EXAMPLES 2 Platform-specific specifications for XML encoding are contained in Subclauses 8.3 and 9.3.

6 Frame image geopositioning metadata overview

6.1 Frame image geopositioning metadata

This document specifies a GML 3.2 Application Schema for frame image geopositioning metadata, for XML encoding of the georeferencing coordinate transformation parameters of an unrectified frame image. A frame image is one whose entire two-dimensional (2D) extent was collected at one time. A georeferencing coordinate transformation can transform position coordinates between a specific ground-based (or object) Coordinate Reference System (CRS) and the image CRS.

This Frame Image Geopositioning Metadata GML Application Schema extends the Image Geopositioning Metadata (IGM) GML 3.2 Application Schema [OGC07-031] for frame images. Both of these GML 3.2 Application Schemas are used by the separately specified Image Geopositioning Service (IGS) [OGC 06-054r2], which adjusts the georeferencing coordinate transformations of images. Both of these GML 3.2 Application Schemas are separately specified because they are expected to also be used by other services.

This schema is one of many possible specific sensor model extensions of the Image Geopositioning Metadata (IGM) GML 3.2 Application Schema. The IGM Application Schema specifies an XML schema for encoding image georeferencing coordinate transformations with associated parameter error statistics. However, that specified encoding is general, and does not specify geopositioning metadata for any specific sensor models. The specified georeferencing coordinate transformations can be extended to use many possible image geometry (or sensor) models, each encoded using an extension of the IGM Application Schema.

The IGM Application Schema also encodes object point positions measured in one of more images and optional object coordinates, with associated position error statistics. These object points can be tie points, control points, and check points. Error statistics are represented as variance-covariance matrices, representing both absolute and relative accuracies. These covariance matrices are used to represent correlations between the accuracies of different parameters, coordinates, and positions. Those parts of the IGM Application Schema are not extended here.

6.2 UML model packages

This Frame Image Geopositioning Metadata GML Application Schema is specified in two parts, corresponding to two UML packages with two corresponding XML Schema Documents. The two UML packages are listed and briefly described in Table 1. The classes in each package are shown in the Figure 1, together with the dependencies on other packages.

Table 1 — Image geopositioning metadata UML model packages

Package Name	Description
FIG_ImageGeometry	Records frame image orientation data, allowing multiple adjustments of orientation data
FSC_SensorCalibration	Records frame sensor calibration data, allowing multiple adjustments of interior orientation data

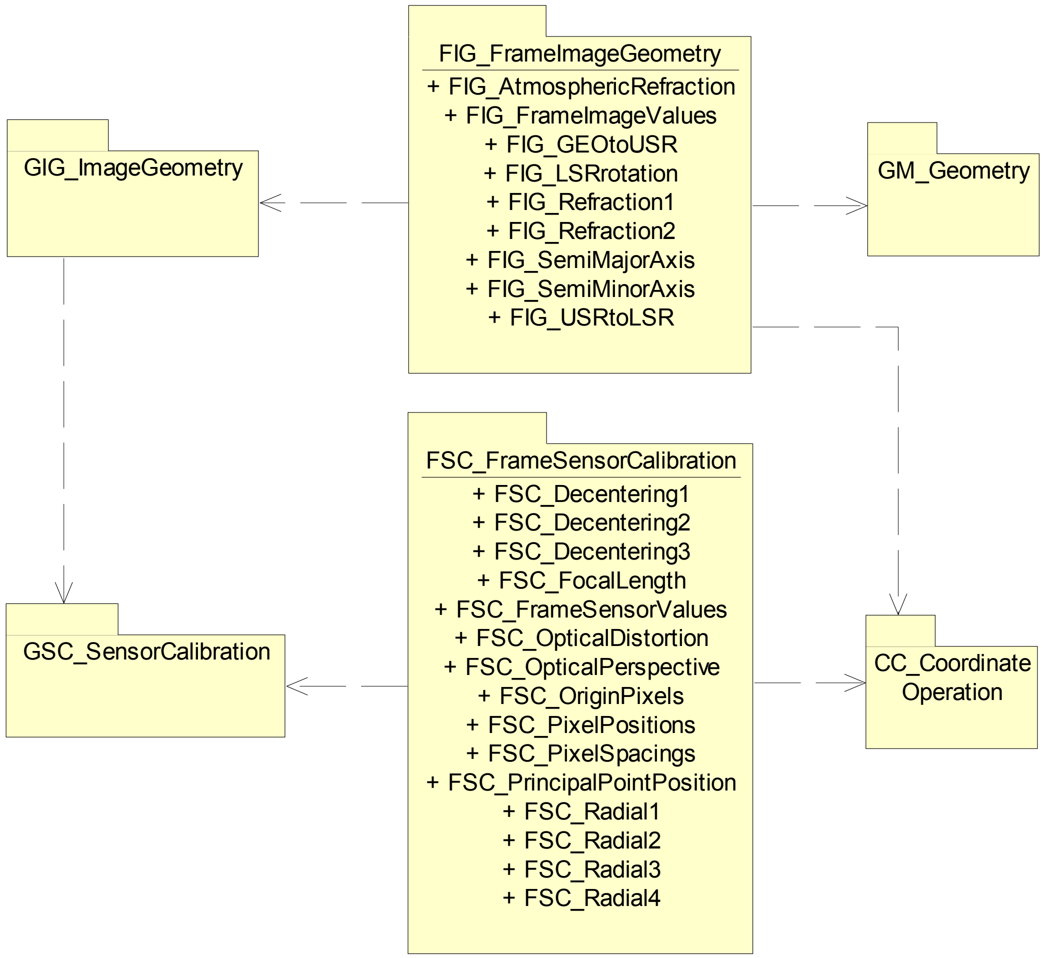

Figure 1 — Frame image geopositioning metadata UML packages

6.3 Default values

This document also specifies some default values for this Frame image geopositioning metadata. Some of the specified metadata quantities often use default values, especially as inputs to the Triangulate operation of the Image Geopositioning Service (IGS). When default values are used and properly referenced by this Frame image geopositioning metadata, transfer of this default metadata may not be required.

Clause 12 specifies default values for the AdjustableParameters list, and for CovarianceMatrix data structures that may be used for:

a) Measured Object Positions

b) Measured Image Positions

c) Initial values of the default AdjustableParameters

7 Frame image geopositioning transformation

7.1 Introduction

This clause specifies the frame image geopositioning (or georeferencing) coordinate transformation used by this Frame Image Geopositioning Metadata GML 3.2 Application Schema. More specifically, the parameter values for each frame image are XML encoded by this Frame Image Geopositioning Metadata GML 3.2 Application Schema. In addition, those parameters are described by an OperationMethod encoded in XML using part of the coordinateOperations XML Schema Document specified in GML 3.2.

7.2 Frame image OperationMethod formulas

7.2.1 Introduction

This subclause specifies the formulas (or equations) used by this frame image geopositioning (or georeferencing) coordinate transformation. These formulas are referenced in the GML encoding of the OperationMethod for this frame image geopositioning coordinate transformation. These formulas are divided into a sequence of computation steps for transforming any object (or ground) position coordinates in any geographic CRS, into the corresponding digital image position coordinates in an ImageCRS. In most cases, the stated equations use the parameter names that are used in this Frame Image Geopositioning Metadata GML Application Schema (instead of the briefer symbols often used in photogrammetry).

NOTE 1 The equations stated below rarely use matrix multiplication and addition notation, although such matrix notation is often used in photogrammetry. Non-matrix equations are used to maximize clarity, since not all persons are familiar with matrix notation, and several different matrix notations could be used.

NOTE 2 The Image Geopositioning Metadata GML Application Schema encodes the complete image georeferencing transformation for one image as one ObjectImageTransformation, instead of using a ConcatenatedOperation which combines multiple transformations. This was done because some image sensors are modelled using a single transformation, and allowing either one transformation or a concatenated operation that combined several transformations would complicate this Application Schema. This frame image geopositioning transformation is thus specified here as a single transformation, although it could be specified as a combination of seven transformations. Each of those seven possible transformations is described here, each using a separate parameter group.

7.2.2 Geographic to USR conversion (GEOtoUSR parameter group)

The coordinates of any position in any geographic CRS is converted into the corresponding position in the object (or ground) Universal Space Rectangular (USR) 3D CRS. This coordinate conversion changes latitude, longitude, and height above the ellipsoid coordinates into coordinates in the 3D Cartesian CRS with its origin at the centre of the ellipsoid for that geographic CRS. The Z axis in these USR coordinates points toward the north pole, the X axis points toward the PrimeMeridian, and the Y axis points toward + 90 degrees longitude.

The equations used for converting geographic CRS coordinates to the corresponding USR 3D coordinates shall be equivalent to:

$$\text{EccentricitySquared} = [2 * \text{InverseFlattening} - 1.0] / \text{InverseFlattening}^2$$

$$\text{Curvature} = \text{SemiMajorAxis} / \text{squareRoot}[1 - \text{EccentricitySquared} * \sin^2(\text{Latitude})]$$

USR(X) = [Curvature + Height] * cos(Latitude) * cos(Longitude)

USR(Y) = [Curvature + Height] * cos(Latitude) * sin(Longitude)

USR(Z) = [Curvature * [1 – EccentricitySquared] + Height] * sin(Latitude)

Where:

EccentricitySquared is the square of the earth ellipsoid's first eccentricity

SemiMajorAxis is the length of the earth ellipsoid's semi-major axis (or the radius of the equator)

InverseFlattening is the second defining parameter of many ellipsoids

NOTE 1 The InverseFlattening is an alternative parameter to the length of the earth ellipsoid's semi-minor axis (or the polar distance from the ellipsoid's center). The InverseFlattening is used here because it is used to define the ellipsoid used by the WGS 84 coordinate reference system, which is normally used by this frame image sensor model.

Curvature is the earth ellipsoid's radius of curvature in the prime vertical plane through the point at Latitude, Longitude

USR(X), USR(Y), USR(Z) are the point coordinates in the object (or ground) USR 3D CRS

Longitude, Latitude are the point horizontal coordinates in the geographic CRS

Height is the point vertical coordinate above the ellipsoid for this geographic CRS

NOTE 2 This 3D geographic CRS and USR 3D CRS are both GeodeticCRSs using the same GeodeticDatum (with the same Ellipsoid and PrimeMeridian). This 3D geographic CRS uses an EllipsoidalCS, while this USR 3D CRS uses a right-handed orthogonal CartesianCS. The definition of this USR 3D CRS is explicitly referenced but NOT explicitly specified.

7.2.3 USR to LSR conversion (USRtoLSR parameter group)

The computed position in the USR 3D CRS is transformed into the corresponding position in the Local Space Rectangular (LSR) 3D CRS for an image. This coordinate conversion includes a translation and rotation. The X-Y plane when Z=0 of this LSR CRS is tangent to the ellipsoid of the 3D GeodeticCRS, at the nadir point on that ellipsoid directly under the nominal (initial estimate) image exposure station. The Y axis in that plane points North, and the X axis points East.

The equations used for transforming USR 3D coordinates to the corresponding LSR 3D coordinates shall be equivalent to:

OffsetUSR(X) = USR(X) – LSRorigin(X)

OffsetUSR(Y) = USR(Y) – LSRorigin(Y)

OffsetUSR(Z) = USR(Z) – LSRorigin(Z)

LSR(X) = LSRrotationMatrix(1,1) * OffsetUSR(X)
+ LSRrotationMatrix(1,2) * OffsetUSR(Y)
+ LSRrotationMatrix(1,3) * OffsetUSR(Z)

LSR(Y) = LSRrotationMatrix(2,1) * OffsetUSR(X)
+ LSRrotationMatrix(2,2) * OffsetUSR(Y)
+ LSRrotationMatrix(2,3) * OffsetUSR(Z)

LSR(Z) = LSRrotationMatrix(3,1) * OffsetUSR(X)
+ LSRrotationMatrix(3,2) * OffsetUSR(Y)
+ LSRrotationMatrix(3,3) * OffsetUSR(Z)

Where:

OffsetUSR(X), OffsetUSR(Y), OffsetUSR(Z) are the point coordinates in the LSR 3D CRS before rotation so the X,Y plane is tangent to the earth ellipsoid

USR(X), USR(Y), USR(Z) are the point coordinates in the object (or ground) USR 3D CRS

LSRorigin(X), LSRorigin(Y), LSRorigin(Z) are the coordinates in the USR 3D CRS of the nadir point on the earth ellipsoid directly under the nominal (initial estimate) image exposure station

LSR(X), LSR(Y), LSR(Z) are the point coordinates in the LSR 3D CRS (after rotation so the X,Y plane when Z=0 is tangent to the earth ellipsoid at the LSRorigin, with the Y axis in that plane pointing North and the X axis pointing East)

LSRrotationMatrix(n,n) the n,n matrix element in the 3 by 3 coordinate rotation matrix from the USR 3D CRS to the LSR 3D CRS

NOTE 1 The LSRorigin and LSRrotationMatrix parameters can be, and often are, computed once from the latitude and longitude of the nadir point on the earth ellipsoid directly under the nominal (initial estimate) image exposure station

NOTE 2 The OffsetUSR 3D CRS and LSR 3D CRS are EngineeringCRSs that use a CartesianCS. The definition of the OffsetUSR 3D CRS (before rotation) is NOT explicitly specified or referenced. The definition of the LSR 3D CRS (after rotation) IS explicitly referenced

7.2.4 Atmospheric refraction correction (AtmosphericRefraction parameter group)

The computed Z coordinate of the computed position in the LSR 3D CRS is optionally corrected for atmospheric refraction of the imaging rays. This is done using an atmospheric refraction algorithm documented in the 1974 paper in Photogrammetric Engineering, titled "Refraction Compensation", by R.B. Forrest and W.F. DeRouchie. That paper's two-parameter model for the elevation correction is adapted, namely:

$$dLSR(Z) = 2 * K1 * (LSR(Z) + K2)^2$$

Where:

dLSR(Z) is the correction added to the LSR(Z) coordinate

LSR(Z) is the computed Z coordinate in the LSR 3D CRS

K1 and K2 are parameter values externally interpolated from a table giving these parameter values as a function of the (estimated) camera height SensorPosition(Z). K1 has units of inverse meters, while K2 has units of meters.

7.2.5 Sensor orientation transformation (SensorOrientation parameter group)

The corrected computed position in the LSR 3D CRS is transformed into the corresponding position in the sensor (or camera) 3D CRS using a CartesianCS. This coordinate transformation includes a translation and rotation. This sensor 3D Cartesian CRS is centered at the sensor optics position when the frame image was collected. The Z axis of this 3D Cartesian CRS is aligned with the sensor optics axis and points away from the earth, so that Z values are always negative. The X and Y axes of this 3D Cartesian CRS are in the directions of the x and y image axes in the focal plane.

The equations used for transforming LSR 3D coordinates to the corresponding sensor 3D Cartesian coordinates shall be equivalent to:

OffsetLSR(X) = LSR(X) – SensorPosition(X)

OffsetLSR(Y) = LSR(Y) – SensorPosition(Y)

OffsetLSR(Z) = LSR(Z) – SensorPosition(Z)

Sensor(X) = Rotation(1,1) * OffsetLSR(X)
+ Rotation(1,2) * OffsetLSR(Y)
+ Rotation(1,3) * OffsetLSR(Z)

Sensor(Y) = Rotation(2,1) * OffsetLSR(X)
+ Rotation(2,2) * OffsetLSR(Y)
+ Rotation(2,3) * OffsetLSR(Z)

Sensor(Z) = Rotation(3,1) * OffsetLSR(X)
+ Rotation(3,2) * OffsetLSR(Y)
+ Rotation(3,3) * OffsetLSR(Z)

Rotation(1,1) = cos(Phi) * cos(Kappa)

Rotation(1,2) = cos(Omega) * sin(Kappa) + sin(Omega) * sin(Phi) * cos(Kappa)

Rotation(2,3) = sin(Omega) * sin(Kappa) – cos(Omega) * sin(Phi) * cos(Kappa)

Rotation(2,1) = – cos(Phi) * sin(Kappa)

Rotation(2,2) = cos(Omega) * cos(Kappa) – sin(Omega) * sin(Phi) * sin(Kappa)

Rotation(2,3) = sin(Omega) * cos(Kappa) + cos(Omega) * sin(Phi) * sin(Kappa)

Rotation(3,1) = sin(Phi)

Rotation(3,2) = sin(Omega) * cos(Phi)

Rotation(3,3) = cos(Omega) * cos(Phi)

Omega = SensorAttitude(1)

Phi = SensorAttitude(2)

Kappa = SensorAttitude(3)

Where:

OffsetLSR(X), OffsetLSR(Y), OffsetLSR(Z) are the point coordinates in the sensor (or image) LSR 3D CRS before rotation into the sensor coordinates

LSR(X), LSR(Y), LSR(Z) are the point coordinates in the object (or ground) LSR 3D CRS (after rotation so the X,Y plane is tangent to the earth ellipsoid)

SensorPosition(X), SensorPosition(Y), SensorPosition(Z) are the coordinates of nadir point on the earth ellipsoid directly under the nominal (initial estimate) image exposure station, in the object USR 3D CRS

Sensor(X), Sensor(Y), Sensor(Z) are the point coordinates in the sensor 3D Cartesian CRS (after rotation so the Z axis is aligned with the sensor optics axis and pointing away from the earth, with the X and Y axes of in the directions of the x and y image axes in the focal plane)

Rotation(n,n) is the n,n matrix element in the 3 by 3 coordinate rotation matrix from the object (or ground) USR 3D CRS to the LSR CRS whose X,Y plane is tangent to the earth ellipsoid at the LSRorigin position

Omega and SensorAttitude(1) is the rotation angle around the X axis in the TBD direction, which is applied first to the OffsetLSR coordinates

Phi and SensorAttitude(2) is the rotation angle around the Y axis in the TBD direction, which is applied second to the OffsetLSR coordinates

Kappa and SensorAttitude(3) is the rotation angle around the Z axis in the TBD direction, which is applied third to the OffsetLSR coordinates

NOTE 1 The Rotation(n,n) parameters can be, and often are, computed once from the Omega, Phi, and Kappa angles.

NOTE 2 The Sensor 3D CRS before and after rotation are EngineeringCRSs that use a 3D CartesianCS. The definition of the OffsetLSR 3D CRS before rotation is NOT explicitly specified or referenced.

7.2.6 Optical perspective projection (OpticalPerspective parameter group)

The computed position in the sensor (or camera) 3D Cartesian CRS are transformed into the corresponding position in the camera focal plane 2D CRS. This coordinate transformation is a perspective projection. The equations used for transforming sensor 3D Cartesian coordinates to the corresponding camera focal plane 2D coordinates shall be equivalent to:

Projected(x) = PrincipalPointPosition(x) – FocalLength * Sensor(X) / Sensor(Z)

Projected(y) = PrincipalPointPosition(y) – FocalLength * Sensor(Y) / Sensor(Z)

Where:

Projected(x), Projected(y) are the point coordinates in the camera focal plane 2D coordinate reference system, with origin at the center of the fiducial mark positions and direction defined by fiducial mark(s), having (focal plane) length units

PrincipalPointPosition(x), PrincipalPointPosition(y) are the position coordinates of the camera lens principal point in the camera focal plane 2D coordinates

FocalLength is the calibrated focal length (perspective distance to focal plane) of this frame camera, converted if needed into the units of the camera focal plane 2D coordinates

Sensor(X), Sensor(Y), Sensor(Z) are the point coordinates in the sensor 3D Cartesian CRS

NOTE The camera focal plane 2D CRS is an EngineeringCRS that uses a 3D CartesianCS. The definition of that camera focal plane 2D CRS IS explicitly specified or referenced.

7.2.7 Optical distortion corrections (OpticalDistortion parameter group)

The computed position in the camera focal plane 2D CRS is optionally corrected for optical (or lens) distortion. The equations used for these optical distortion corrections shall be equivalent to:

Rsquared = [Projected(x) – SymmetryPoint(1)]^2
+ [Projected(y) – SymmetryPoint(2)]^2

DeltaRoverR = Radial1 + Rsquared * [Radial2 + Rsquared * [Radial3
+ Rsquared * Radial4]]

Corrected(x) = Projected(x) * [1 + DeltaRoverR]
+ [Decentering(1) * [Rsquared + 2 * Projected(x)^2]
+ 2 * Decentering(2) * Projected(x) * Projected(y)]]

Corrected(y) = Projected(y) * [1 + DeltaRoverR]
+ [2 * Decentering(1) * Projected(x) * Projected(y)
+ Decentering(2) * [Rsquared + 2 * Projected(y)^2]]

Where:

Rsquared is the square of the radial image space distance, of the point position from the optical distortion symmetry point, having (focal plane) length units squared

Projected(x), Projected(y) are the point coordinates in the camera focal plane 2D coordinate reference system, with origin at the center of the fiducial mark positions and direction defined by fiducial mark(s), having (focal plane) length units

SymmetryPoint(1), SymmetryPoint(2) are the optical distortion symmetry point coordinates in the camera focal plane 2D coordinates, having (focal plane) length units

DeltaRoverR is the radial distance correction divided by the radial image space distance, having scale units (ratio of the same units)

Radial1, Radial2, Radial3, Radial4 are optical radial distortion parameters, with Radial1 having scale units, Radial2 having inverse length units squared, Radial3 having inverse length units to the fourth power, and Radial4 having inverse length units to the sixth power

Corrected(x), Corrected(y) are the point coordinates in the camera focal plane 2D CRS after correction for optical distortions

Decentering(1), Decentering(2) are optical decentering distortion parameters, both having inverse length units

7.2.8 Focal plane to digital image transformation (PixelPositions parameter group)

The computed corrected position in the frame camera focal plane CRS is transformed into the corresponding position coordinates in the digital image, where those image coordinates are in the ImageCRS of each specific image. The equations used for transforming corrected focal plane coordinates to the corresponding image coordinates shall be equivalent to:

Row = OriginPixels(1) + PixelSpacings(1,1) * Corrected(x)
+ PixelSpacings(1,2) * Corrected(y)

Column = OriginPixels(2) + PixelSpacings(2,1] * Corrected(x]
+ PixelSpacings(2,2) * Corrected(y)

Where:

Row, Column are the point coordinates in the ImageCRS with its origin in the center of the first pixel in the image file

Corrected(x), Corrected(y) are the point coordinates in the camera focal plane 2D CRS after correction for optical distortions, with focal plane length units

OriginPixels(1), OriginPixels(2) are the x and y coordinates of the image position of the pixel positions origin in the camera focal plane 2D coordinate reference system, with origin at the center of the fiducial mark positions and direction defined by fiducial mark(s), having focal plane length units

PixelSpacings(n,n) is the n,n matrix element in the inverse of the 2 by 2 matrix of the 2D spacings between row and column pixel centers in the corrected focal plane x and y coordinate reference system

This Frame Image Geopositioning Metadata shall always use an ImageCRS with its origin in the center of the first pixel in the image file, as specified in Subclause 10.2 of [OGC 05-096r1]. That ImageCRS definition shall be referenced in the igm:ObjectImageTransformation for this image using the URN value "urn:ogc:def:crs:OGC:0.0:ImageCRSpixelCenter:TBD". This image CRS shall be for the image whose alphanumeric character string identifier is substituted for the "TBD" in this URN.

NOTE The Socet Set frame sensor model does NOT always use an image CRS with positions in the center of each pixel.

7.3 Frame image OperationMethod GML encoding

This frame image geopositioning (or georeferencing) coordinate transformation uses an OperationMethod that is XML encoded as specified in the attached frameOperationMethod.xml file. That XML encoding uses part of the coordinateOperations XML Schema Document specified in GML 3.2. That xml file is designed to be consistent with the Image Geopositioning Metadata (IGM) GML 3.2 Application Schema specified in [OGC 06-055r2]. That frame image geopositioning OperationMethod uses an OperationParameterGroup for each of the frame image geopositioning steps specified above in Subclause 7.2.

8 Frame image geometry package

8.1 Introduction

The image geometry part of the Frame Image Geopositioning Metadata GML Application Schema extends the ImageGeometry part of the Image Geopositioning Metadata GML Application Schema to support (unrectified) frame images. Specifically, this extension specifies a FrameImageValues subclass of the abstract StationarySensorParameters class that is specific for frame sensors, and adds the needed parameter value data. Similarly in GML, this extension specifies a FrameImageValues element that is in the AbstractStationarySensorParameters substitutionGroup, and includes the needed additional parameter value XML elements.

8.2 UML model

The UML class diagram for the FIG_FrameImageGeometry package is shown in Figure 2, together with the ISO 191XX UML classes that are directly inherited from. The new classes defined in this FIG_FrameImageGeometry package are described in Table 2 through Table 10.

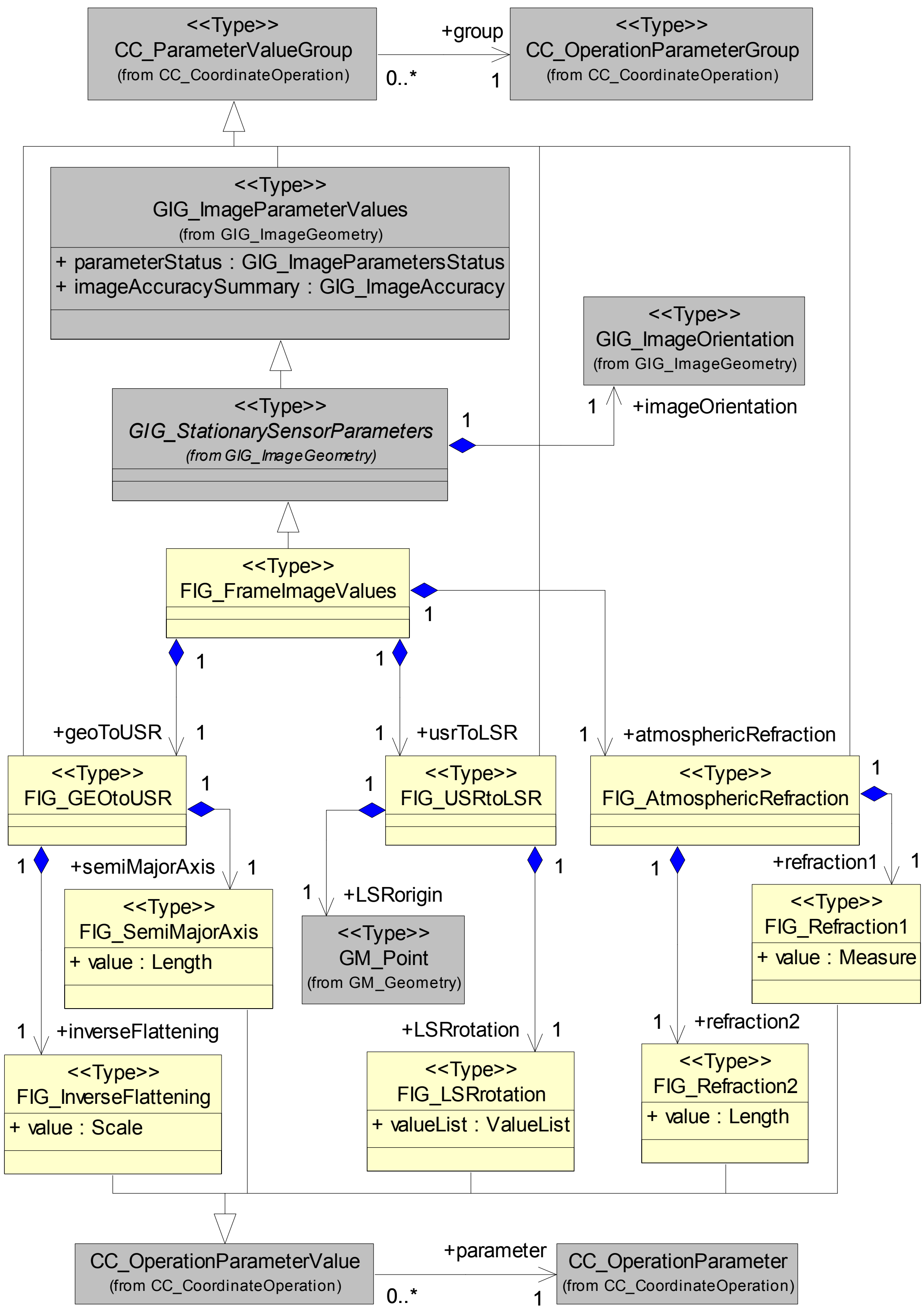

Figure 2 — FIG_FrameImageGeometry package UML class diagram

This UML class diagram shows that FrameImageValues is a concrete subclass of the abstract StationarySensorValues class. That FrameSensorValues class has composition associations to the GEOtoUSR, USRtoLSR, and AtmosphericRefraction classes. All four of these classes are subclasses of the CC_ParameterValueGroup class defined in [ISO

19111]. These composition associations are specializations of the composition "parameterValue" role association from an instance of the CC_ParameterValueGroup class to other instances of the same class, through the CC_GeneralParameterValue abstract class.

The GEOtoUSR, USRtoLSR, and AtmosphericRefraction classes contain frame image model parameters, organized in three parameter groups.

a) The GEOtoUSR class includes semiMajorAxis and inverseFlattening composition associations to the SemiMajorAxis and InverseFlattening classes. These parameter values are for the ellipsoid of the geographic CRS.

b) The USRtoLSR class includes LSRorigin and LSRrotation composition associations to the LSRorigin and LSRrotation classes. These parameter values are for the coordinate transformation from USR to LSR coordinates for this image.

c) The AtmosphericRefraction class includes composition associations to the two parameters for atmospheric refraction corrections in the LSR CRS.

Table 2 — Defining elements of FIG_FrameImageValues class

Description:	Group of parameter values for one adjustment of one image using the Socet Set frame sensor model, including all exterior orientation parameters.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GSC_ImageParameterValues
Association roles:	Eight associations inherited from GSC_ImageParameterValues, plus associations to:
	geoToUSR to FIG_GEOtoUSR [1] (Composition association to values of geographic to USR CRS transformation group of parameters)
	usrToLSR to FIG_USRtoLSR [1] (Composition association to values of USR to LSR transformation group of parameters)
	atmosphericRefraction to FIG_AtmosphericRefraction [0..1] (Composition association to values atmospheric refraction correction group of parameters)
Public attributes:	Two attributes inherited from GSC_ImageParameterValues.

Table 3 — Defining elements of FIG_GEOtoUSR class

Description:	Values of the parameters group for the coordinate transformation from a 3D geographic GeodeticCRS to the corresponding 3D Universal Space Rectangular (USR) GeodeticCRS.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_ParameterValueGroup
Association roles:	semiMajorAxis to FIG_SemiMajorAxis [1] (Composition association to the length of the semi-major axis of an ellipsoid)
	inverseFlatenning to FIG_InverseFlattening [1] (Composition association to the inverse flattening parameter of an ellipsoid)
	group to CC_OperationParameterGroup [1] (Inherited association to operation parameter group for this group of parameter values)
	geoToUSR from FIG_FrameImageValues [0..1] (Composition association from the frame image values parameter group)
Public attributes:	None

Table 4 — Defining elements of FIG_SemiMajorAxis class

Description:	Length of the semi-major axis of an ellipsoid.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_OperationParameterValue
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value)
	semiMajorAxis from FIG_GEOtoUSR [1] (Composition association from the GEO to USR parameter group)
Public attributes:	

Attribute name	UML identifier	Data type	Oblig ation	Maximum occurrence	Attribute description
Value	value	Length	M	1	Length of the semi-major axis of an ellipsoid.

Table 5 — Defining elements of FIG_InverseFlatteningclass

Description:	Value of the inverse flattening parameter of an ellipsoid.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_ OperationParameterValue
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value)
	inverseFlattening from FIG_GEOtoUSR [1] (Composition association from the GEO to USR parameter group)
Public attributes:	

Attribute name	UML identifier	Data type	Oblig ation	Maximum occurrence	Attribute description
Value	value	Scale	M	1	Value of the inverse flattening parameter of an ellipsoid.

Table 6 — Defining elements of FIG_USRtoLSR class

Description:	Values of the parameters group for the coordinate transformation from a Universal Space Rectangular (USR) 3D GeodeticCRS to the object (ground) Local Space Rectangular (LSR) 3D EngineeringCRS for an image. This LSR EngineeringCRS is tangent to the ellipsoid of the 3D GeodeticCRS, at the nadir point on that ellipsoid under the nominal (initial estimate) image exposure station.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_ParameterValueGroup
Association roles:	LSRorigin to GM_Point [1] (Composition association to the origin of the LSR CRS for an image) LSRrotation to FIG_LSRrotation [1] (Composition association to the length of the semi-minor axis of an ellipsoid) group to CC_OperationParameterGroup [1] (Inherited association to operation parameter group for this group of parameter values) usrToLSR from FIG_FrameImageValues [0..1] (Composition association from the frame image values parameter group)
Public attributes:	None

Table 7 — Defining elements of FIG_LSRrotation class

Description:	Value of the rotation matrix from a Universal Space Rectangular (USR) 3D GeodeticCRS to the Local Space Rectangular (LSR) 3D EngineeringCRS for an image.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_ OperationParameterValue
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value) LSRrotation from FIG_USRtoLSR [1] (Composition association from the GEO to USR parameter group)
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Value List	valueList	Value List [a]	M	1	Value of the 3 by 3 rotation matrix for the USR 3D CRS to the LSR 3D CRS coordinate transformation.

a This valueList shall contain nine matrix elements all with unity units, based only on the latitude and longitude in the 3D geographic GeodeticCRS of the LSR CRS origin.

Table 8 — Defining elements of FIG_AtmosphericRefraction class

Description:	Values of the atmospheric refraction correction group of parameters.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_ParameterValueGroup
Association roles:	refraction1 to FIG_Refraction1 [1] (Composition association to the value of atmospheric refraction correction parameter K1) refraction2 to FIG_Refraction2 [1] (Composition association to the value of atmospheric refraction correction parameter K2) group to CC_OperationParameterGroup [1] (Inherited association to operation parameter group for this group of parameter values) atmosphericRefraction from FIG_FrameImageValues [0..1] (Composition association from the frame image values parameter group)
Public attributes:	None

Table 9 — Defining elements of FIG_Refraction1 class

Description:	Value of atmospheric refraction correction parameter K1.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_OperationParameterValue
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value) refraction1 from FIG_AtmosphericRefraction [1] (Composition association from the atmospheric refraction correction parameter group)
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Value	value	Measure [a]	M	1	Value of atmospheric refraction parameter K1.

a Measure is specified in ISO 19103. This Measure shall have units of inverse meters.

Table 10 — Defining elements of FIG_Refraction2 class

Description:	Value of atmospheric refraction correction parameter K2.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_ OperationParameterValue
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value) refraction2 from FIG_AtmosphericRefraction [1] (Composition association from the atmospheric refraction correction parameter group)
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Value	value	Length [a]	M	1	Value of atmospheric refraction parameter K2.

a Length is specified in ISO 19103. This Length shall have units of meters.

8.3 XML encoding

The FIG_ImageGeometry UML package is encoded in the fsmImageGeometry.xsd XML Schema Document, which imports the coordinateOperations.xsd and geometryBasic2d.xsd XML Schema Documents from GML 3.2. The contents of the fsmImageGeometry.xsd XML Schema Document shall be as specified in the attached file.

EXAMPLE A template XML document for a specific ImageParameterValues element in the AbstractGeneralParameterValue substitutionGroup, using this FrameImageValues specialization and encoded inline in an ObjectImageTransformation element, is provided in the attached file named templateFrameObjectImageTransformation.xml

9 Frame sensor calibration package

9.1 Introduction

The sensor calibration part of the Frame Image Geopositioning Metadata GML Application Schema extends the SensorCalibration part of the Image Geopositioning Metadata GML Application Schema to support frame image sensors. Specifically, this extension specifies a FrameSensorValues subclass of the abstract SensorParameterParameters class that is specific for frame sensors, and adds the needed parameter value data. Similarly in GML, this extension specifies a FrameSensorValues element that is in the AbstractSensorParameterValues substitutionGroup, and includes the needed additional parameter value XML elements.

9.2 UML model

The UML class diagram for the FSC_FrameSensorCalibration package is shown in Figure 3 and Figure 4, together with the ISO 191XX UML classes that are directly inherited from. The new classes defined in this FSC_FrameSensorCalibration package are described in Table 11 through Table 24.

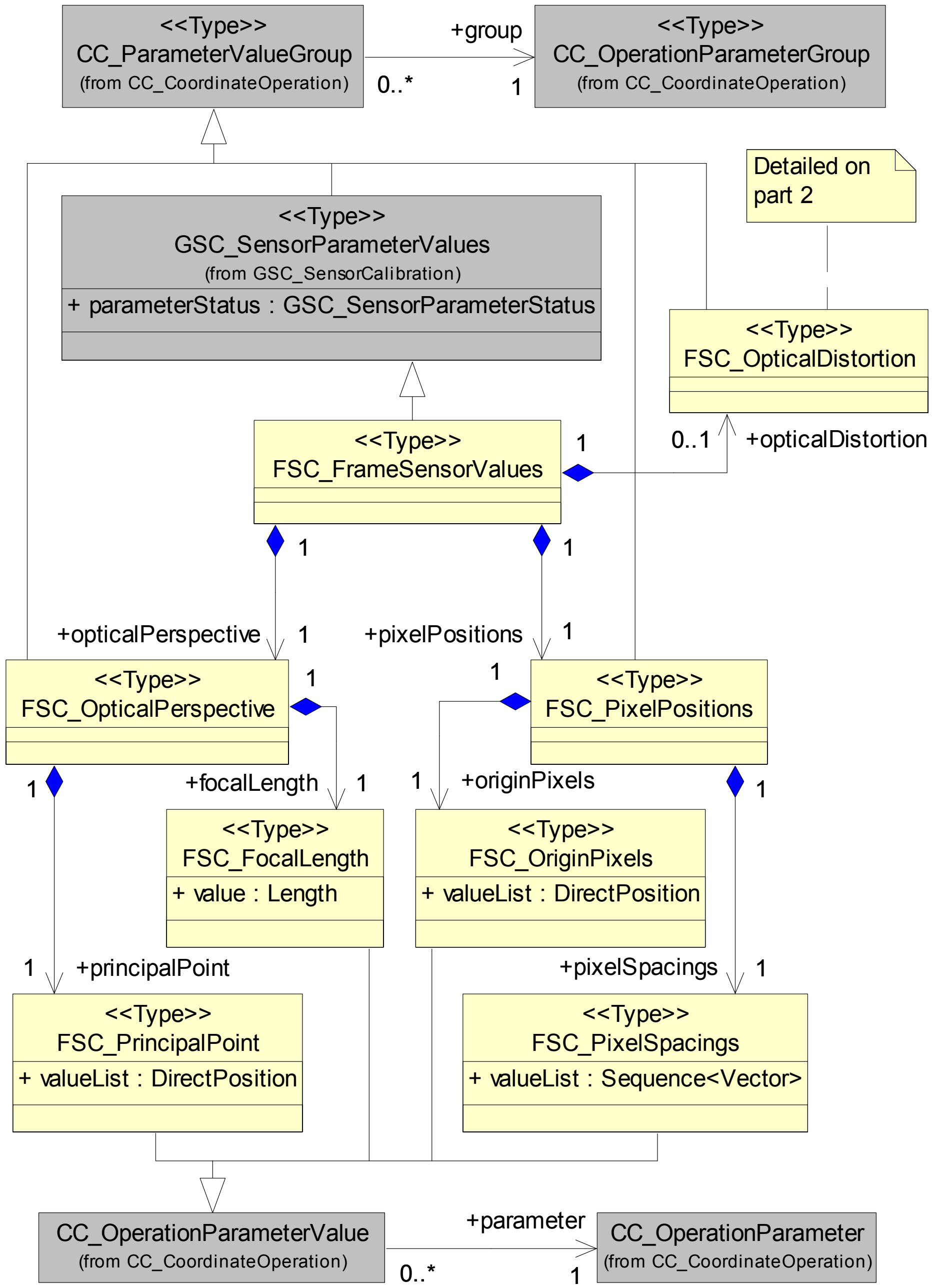

Figure 3 — FSC_FrameSensorCalibration package UML class diagram part 1

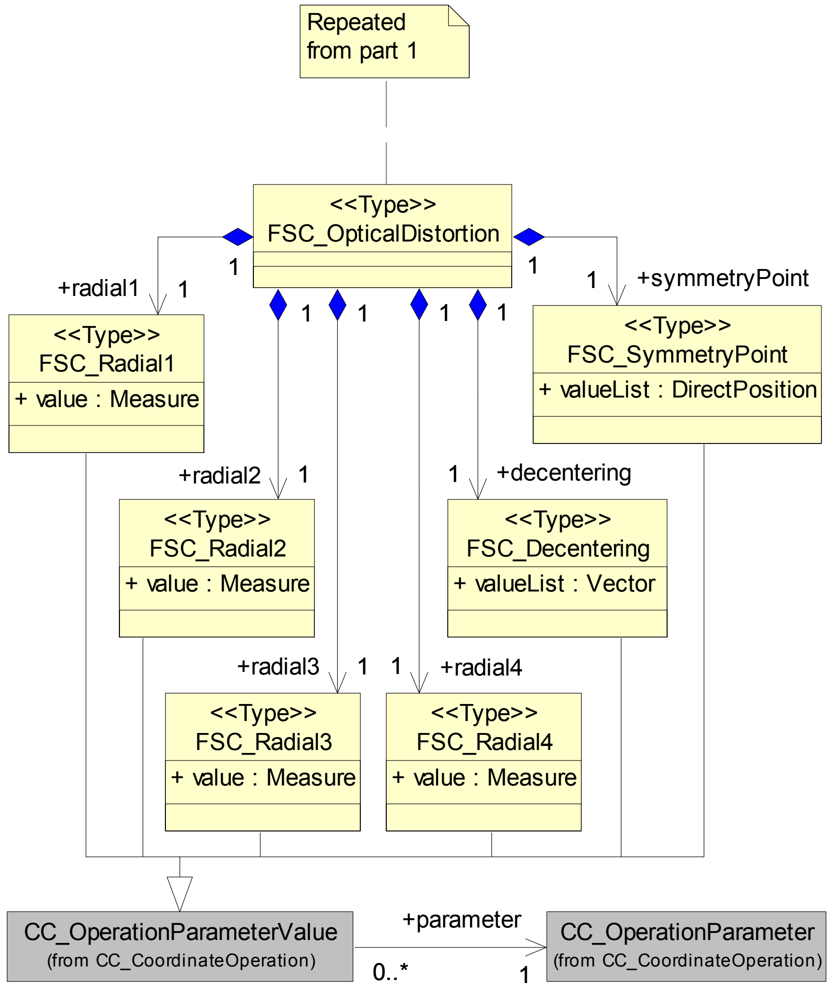

Figure 4 — FSC_FrameSensorCalibration package UML class diagram part 2

This UML class diagram shows that FrameSensorValues is a concrete subclass of the abstract SensorParameterValues class. That FrameSensorValues class has composition associations to the OpticalPerspective, OpticalDistortion, and PixelPositions classes. All four of these classes are subclasses of the CC_ParameterValueGroup class defined in [ISO 19111]. These composition associations are specializations of the composition "parameterValue" role association from an instance of the CC_ParameterValueGroup class to other instances of the same class, through the CC_GeneralParameterValue abstract class.

The OpticalPerspective, OpticalDistortion, and PixelPositions classes contain the frame sensor model parameters, organized in three parameter groups.

a) The OpticalPerspective class includes focalLength and prinicpalPointPosition composition associations to the FocalLength and PrinicalPointPosition classes. These parameter values are for the optical perspective coordinate transformation to positions in the focal plane.

b) The PixelPositions class includes originPixels and pixelSpacings composition associations to the OriginPixels and PixelSpacings classes. These parameter values are for the coordinate transformation from positions in the focal plane to pixel indices positions in the image CRS.

c) The OpticalDistortion class includes composition associations to the six parameters for optical distortion corrections in the focal plane.

Table 11 — Defining elements of FSC_FrameSensorValues class

Description:	Group of all calibrated parameter values for one frame camera (imaging sensor) and sensor configuration, including all interior orientation parameters.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	GSC_SensorParameterValues
Association roles:	Five associations inherited from GSC_SensorParameterValues, plus associations to:
	opticalPerspective to FSC_OpticalPerspective [1] (Composition association to values of optical perspective group of parameters)
	opticalDistortion to FSC_OpticalDistortion [0..1] (Composition association to values of optical distortion group of parameters)
	pixelPositions to FSC_PixelPositions [1] (Composition association to values of pixel positions group of parameters)
Public attributes:	One attribute inherited from GSC_SensorParameterValues.

Table 12 — Defining elements of FSC_OpticalPerspective class

Description:	Values of the optical perspective group of parameters.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_ParameterValueGroup
Association roles:	focalLength to FSC_FocalLength [1] (Composition association to focal length value in this group of parameter values)
	principalPoint to FSC_PrincipalPoint [1] (Composition association to principal point position in this group of parameter values)
	group to CC_OperationParameterGroup [1] (Inherited association to operation parameter group for this group of parameter values)
	opticalPerspective from FSC_FrameSensorValues [1] (Composition association from frame sensor values using this parameter value group)
Public attributes:	None

Table 13 — Defining elements of FSC_FocalLength class

Description:	Focal length (perspective distance to focal plane) of frame camera.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_OperationParameterValue
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value) focalLength from FSC_OpticalPerspective [1] (Composition association from optical perspective using this parameter value)
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Value	value	Length	M	1	Focal length (perspective distance to focal plane) of frame camera.

Table 14 — Defining elements of FSC_PrincipalPoint class

Description:	Position of principal point (center of optical perspective) in frame camera, in focal plane CRS.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_ OperationParameterValue
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value) principalPoint from FSC_OpticalPerspective [1] (Composition association from optical perspective using this parameter value)
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Value List	valueList	DirectPosition [a]	M	1	Position coordinates of principal point in frame camera, in focal plane CRS.

a DirectPosition is specified in ISO 19107. This DirectPosition contains two coordinates in the 2D focal plane CRS.

Table 15 — Defining elements of FSC_PixelPositions class

Description:	Values of the (physical) pixel positions group of parameters, in corrected focal plane coordinates.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_ParameterValueGroup
Association roles:	originPixels to FSC_ OriginPixels [1] (Composition association to pixels origin value in this group of parameter values) pixelSpacings to FSC_PixelSpacings [1] (Composition association to pixel spacings value in this group of parameter values) group to CC_OperationParameterGroup [1] (Inherited association to operation parameter group for this group of parameter values) pixelPositions from FSC_FrameSensorValues [1] (Composition association from frame sensor values using this parameter value group)
Public attributes:	None

Table 16 — Defining elements of FSC_OriginPixels class

Description:	Position of the origin of corrected focal plane coordinates, in the digital image CRS.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_OperationParameterValue
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value) originPixels from FSC_PixelPositions [1] (Composition association from optical perspective using this parameter value)
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Value List	valueList	DirectPosition [a]	M	1	Image position of the origin of corrected focal plane coordinates.

a DirectPosition is specified in ISO 19107. This DirectPosition contains the two pixel coordinates (or indices) of the origin of corrected focal plane coordinates, in the (pixel index) digital image CRS.

Table 17 — Defining elements of FSC_PixelSpacings class

Description:	Inverse of 2D Spacings between row (or line) and column (or sample) pixel centers in corrected focal plane x and y coordinates.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_ OperationParameterValue
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value)
	pixelSpacings from FSC_PixelPositions [1] (Composition association from optical perspective using this parameter value)
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Value List	valueList	Sequence<Vector> [a]	M	1	Inverse of spacings in corrected focal plane between row (or line) and column (or sample) pixel center positions.

a Vector is specified in ISO 10103. This sequence contains two Vectors giving the inverse of the matrix containing the spacings between row (or line) and column (or sample) pixel center positions, with each Vector in corrected focal plane x and y coordinates.

Table 18 — Defining elements of FSC_OpticalDistortion class

Description:	Values of the optical distortion group of parameters.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_ParameterValueGroup
Association roles:	radial1 to FSC_Radial1 [1] (Composition association to radial 1 parameter in this group of parameter values)
	radial2 to FSC_Radial2 [1] (Composition association to radial 2 parameter in this group of parameter values)
	radial3 to FSC_Radial3 [1] (Composition association to radial 3 parameter in this group of parameter values)
	radial4 to FSC_Radial4 [1] (Composition association to radial 4 parameter in this group of parameter values)
	symmetryPoint to FSC_SymmetryPoint [1]1 (Composition association to symmetry point parameter in this group of parameter values)
	decentering to FSC_Decentering [1] (Composition association to decentering 1 parameter in this group of parameter values)
	group to CC_OperationParameterGroup [1] (Inherited association to operation parameter group for this group of parameter values)
	opticalDistortion from FSC_FrameSensorValues [1] (Composition association from frame sensor values using this parameter value group)
Public attributes:	None

Table 19 — Defining elements of FSC_Radial1 class

Description:	Frame sensor radial optical distortion correction first parameter.				
Stereotype:	Type				
Class attribute:	Concrete				
Inheritance from:	CC_OperationParameterValue				
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value) radial1 from FSC_OpticalDistortion [1] (Composition association from optical distortion using this parameter value)				
Public attributes:					
Attribute name	**UML identifier**	**Data type**	**Obligation**	**Maximum occurrence**	**Attribute description**
Value	value	Measure [a]	M	1	Frame sensor radial optical distortion correction first parameter.
a Measure is specified in ISO 19103. This Measure shall have scale units (ratio of the same units).					

Table 20 — Defining elements of FSC_Radial2 class

Description:	Frame sensor radial optical distortion correction second parameter.				
Stereotype:	Type				
Class attribute:	Concrete				
Inheritance from:	CC_OperationParameterValue				
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value) radial2 from FSC_OpticalDistortion [1] (Composition association from optical distortion using this parameter value)				
Public attributes:					
Attribute name	**UML identifier**	**Data type**	**Obligation**	**Maximum occurrence**	**Attribute description**
Value	value	Measure [a]	M	1	Frame sensor radial optical distortion correction second parameter.
a Measure is specified in ISO 19103. This Measure shall have inverse focal-plane-length-units squared.					

Table 21 — Defining elements of FSC_Radial3 class

Description:	Frame sensor radial optical distortion correction third parameter.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_OperationParameterValue
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value) radial3 from FSC_OpticalDistortion [1] (Composition association from optical distortion using this parameter value)
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Value	value	Measure [a]	M	1	Frame sensor radial optical distortion correction third parameter.

a Measure is specified in ISO 19103. This Measure shall have inverse focal-plane-length-units to the fourth power.

Table 22 — Defining elements of FSC_Radial4 class

Description:	Frame sensor radial optical distortion correction fourth parameter.
Stereotype:	Type
Class attribute:	Concrete
Inheritance from:	CC_OperationParameterValue
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value) radial4 from FSC_OpticalDistortion [1] (Composition association from optical distortion using this parameter value)
Public attributes:	

Attribute name	UML identifier	Data type	Obligation	Maximum occurrence	Attribute description
Value	value	Measure [a]	M	1	Frame sensor radial optical distortion correction fourth parameter.

a Measure is specified in ISO 19103. This Measure shall have inverse focal-plane-length-units to the sixth power.

Table 23 — Defining elements of FSC_SymmetryPoint class

Description:	Position of lens distortion symmetry point in frame camera, in focal plane CRS.				
Stereotype:	Type				
Class attribute:	Concrete				
Inheritance from:	CC_ OperationParameterValue				
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value) symmetryPoint from FSC_OpticalDistortion [1] (Composition association from optical perspective using this parameter value)				
Public attributes:					
Attribute name	**UML identifier**	**Data type**	**Obligation**	**Maximum occurrence**	**Attribute description**
Value List	valueList	DirectPosition [a]	M	1	Position coordinates of lens distortion symmetry point in frame camera, in focal plane CRS.
a DirectPosition is specified in ISO 19107. This DirectPosition contains two coordinates in the 2D focal plane CRS.					

Table 24 — Defining elements of FSC_Decentering class

Description:	Frame sensor decentering optical distortion correction first parameters.				
Stereotype:	Type				
Class attribute:	Concrete				
Inheritance from:	CC_OperationParameterValue				
Association roles:	parameter to CC_OperationParameter [1] (Inherited association to operation parameter for this parameter value) decentering from FSC_OpticalDistortion [1] (Composition association from optical distortion using this parameter value)				
Public attributes:					
Attribute name	**UML identifier**	**Data type**	**Obligation**	**Maximum occurrence**	**Attribute description**
Value List	valueList	Vector [a]	M	1	Frame sensor decentering optical distortion correction parameters.
a Vector is specified in ISO 19107. This Vector contains parameters for the 2D focal plane coordinates but in inverse focal-plane-length-units.					

9.3 XML encoding

The FSC_FrameSensorCalibration UML package is encoded in the frameSensorCalibration.xsd XML Schema Document, which imports the igmSensorCalibration.xsd XML Schema Document. The contents of the frameSensorCalibration.xsd XML Schema Document shall be as specified in the attached file.

EXAMPLE A template XML document for a specific SensorParameterValues element in the AbstractGeneralParameterValue substitutionGroup, using this FrameSensorValues specialization, is provided in the attached file named templateFrameSensorParameterValues.xml

10 IGM data packages for frame images

This clause specifies the frame-image specific-contents of two types of data packages (or files) in which image geopositioning metadata (IGM) encoded using GML 3.2 should be packaged for effective data transfer and retrieval. These are the ObjectImageTransformation and SensorParameterValues data package types, whose contents are outlined in Tables 38 and 39 of [OGC 07-031]. More complete versions of those tables for the frame sensor model are provided in Table 25 and Table 26.

NOTE See Clause 13 of [OGC 07-031] for explanation of the table rows.

Table 25 — ObjectImageTransformation package type

Root element	igm:ObjectImageTransformation
Inline encode	One fsm:FrameImageValues, containing: One igm:ImageAccuracySummary Zero or one gml:Polygon, computed using this group of image parameter values, included when image footprint is recorded Zero or more igm:ImagePosition with position error estimates, computed using this group of image parameter values, each containing: One gml:Point Zero or one igm:CovarianceMatrix, containing: One igm:Matrix concrete subtype One igm:ImageOrientation, containing: One gml:Point One gml:Vector One fsm:GEOtoUSR, containing: One fsm:SemiMajorAxis One fsm:InverseFlattening One fsm:USRtoLSR, containing: One fsm:LSRorigin One fsm:LSRrotation Zero or one fsm:AtmosphericRefraction, containing: One fsm:RefractionK1 One fsm:RefractionK2
Number	One for each adjustment of each image collected from different position or attitude
Search by	gml:identifier, gml:description, gml:remarks for root element or fsm:FrameImageValues,
Profile	frameObjectImageTransformationPackage.xsd, which uses igmImagePositionFilePackage.xsd
Template	templateFrameObjectImageTransformationPackage.xml
File name	transformationFile999.999.xml

Table 26 — SensorParameterValues package type

Root element	igm:FrameSensorValues
Inline encode	One fsm:OpticalPerspectiveValues, containing: One fsm:FocalLength One fsm:PrincipalPoint Zero or one fsm:OpticalDistortion, containing: One fsm:Radial1 One fsm:Radial2 One fsm:Radial3 One fsm:Radial4 One fsm:SymmetryPoint One fsm:Decentering One fsm:PixelPositions, containing: One fsm:OriginPixels One fsm:PixelSpacings
Number	One for each adjustment of each image sensor (or sensor configuration for image sensors having multiple configurations)
Search by	gml:identifier, gml:description, gml:remarks for root element, TBD
Profile	frameSensorParameterValuesPackage.xsd
Template	templateFrameSensorParameterValuesPackage.xml
File name	sensorParametersFile999.999.xml

NOTE This Frame Image Geopositioning Metadata specifies no additional GML objects that include a gml:id attribute or gml:identifier and gml:name elements (as discussed in Annex C of the Image Geopositioning Metadata specification).

11 Default values for frame images

11.1 Introduction

This clause specifies some default values for this Frame image geopositioning metadata. Some of the specified metadata quantities often use default values, especially as inputs to the Triangulate operation of the Image Geopositioning Service (IGS). When default values are used and properly referenced by this Frame image geopositioning metadata, transfer of this default data may not be required, such as for inputs to the Triangulate operation.

11.2 AdjustableParameters default

The contents of the AdjustableParameters list will be the same for many adjustments of many frame images, so default contents are specified for this list. This AdjustableParameters list is encoded by the GIG_AdjustableParameters class defined in Table 11 of OGC 07-031, and by the igm:AdjustableParameters element defined in igmImageGeometry.xsd attached to that document.

The default contents of the AdjustableParameters list are to adjust all and only the six values in the ImageOrientation data structure. This ImageOrientation data structure is encoded by the GIG_ImageOrientation class defined in Table 9 of OGC 07-031, and by the igm:ImageOrientation in igmImageGeometry.xsd attached to that document.

This default AdjustableParameters list is specified by the attached XML document defaultAdjustableParameter.xml, which contains:

```
<?xml version="1.0" encoding="UTF-8"?>
<AdjustableParameters xmlns=http://www.opengis.net/igm/0.0
xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.opengis.net/igm/0.0
igmImageGeometry.xsd"
gml:id="AdjustableParametersDefault">
   <gml:description>This default AdjustableParameters list specifies
adjusting all and only the six values in the ImageOrientation data
structure. </gml:description>
   <gml:identifier
codeSpace="IGM">AdjustableParametersDefault</gml:identifier>
   <parameters>SensorPositionAny1 SensorPositionAny2
SensorPositionAny3  SensorAttitudeAny1 SensorAttitudeAny2
SensorAttitudeAny3</parameters>
</AdjustableParameters>
```

11.3 Image orientation CovarianceMatrix defaults

The contents of the CovarianceMatrix data structure will often be the same for sets of initial values in the ImageOrientation data structure. This CovarianceMatrix data structure is encoded by the GCM_CovarianceMatrix class defined in Table 28 of OGC 07-031, and by the igm:CovarianceMatrix element defined in igmCovarianceMatrix.xsd attached to that document. This ImageOrientation data structure is encoded by the GIG_ImageOrientation class defined in Table 9, and by the igm:ImageOrientation in igmImageGeometry.xsd attached to that document.

The default contents of this CovarianceMatrix data structure is a diagonal matrix, with six rows and six columns (corresponding to the six adjustable parameters discussed above). The default CovarianceMatrix for initial ImageOrientation values is specified by the attached XML document defaultOrientationCovarianceMatrix.xml, which contains:

```
<?xml version="1.0" encoding="UTF-8"?>
<CovarianceMatrix xmlns="http://www.opengis.net/igm/0.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:gco="http://www.isotc211.org/2005/gco"
xsi:schemaLocation="http://www.opengis.net/igm/0.0
igmCovarianceMatrix.xsd"
id="CovarianceMatrixOrientationDefault">
   <measureDescription>
      <gco:CharacterString>This default CovarianceMatrix for sets of
initial values in the ImageOrientation data structure specifies a
diagonal matrix with the same value for the position coordinates, and a
different value for the attitude values. The position coordinate
variances correspond to a standard deviation of about 5337 metres, and
the attitude variances correspond to a standard deviation of about
1.089 radians. </gco:CharacterString>
   </measureDescription>
   <matrixSize>6</matrixSize>
```



```
    <adjustedParameters>SensorPositionAny1 SensorPositionAny2
SensorPositionAny3  SensorAttitudeAny1 SensorAttitudeAny2
SensorAttitudeAny3</adjustedParameters>
    <result>
        <DiagonalMatrix>
            <valueUnit>m m m r r r</valueUnit>
            <valuesList>28490000 28490000 28490000 1.186 1.186 1.186
</valuesList>
        </DiagonalMatrix>
    </result>
</CovarianceMatrix>
```

11.4 Measured position CovarianceMatrix defaults

The contents of the CovarianceMatrix data structure will often be the same for all measured ImagePositions, and for all measured ObjectPositions. This CovarianceMatrix data structure is encoded by the GCM_CovarianceMatrix class defined in Table 28 of OGC 07-031, and by the igm:CovarianceMatrix element defined in igmCovarianceMatrix.xsd attached to that document.

Measured ImagePositions are encoded by the GOP_ImagePosition class defined in Table 22 of OGC 07-031, and by the igm:ImagePosition element defined in igmObjectPoint.xsd attached to that document. Similarly, measured ObjectPositions are encoded by the GOP_ObjectPosition class defined in Table 23 of OGC 07-031, and by the igm:ObjectPosition element defined in igmObjectPoint.xsd.

The default contents of these CovarianceMatrix data structures are diagonal matrices. For measured image positions, this diagonal matrix has the same value for both image coordinates. For measured object positions, this diagonal matrix has the same value for both horizontal coordinates, and a larger value for the vertical coordinate.

The default CovarianceMatrix for measured image positions is specified by the attached XML document defaultImageCovarianceMatrix.xml, which contains:

```
<?xml version="1.0" encoding="UTF-8"?>
<CovarianceMatrix xmlns="http://www.opengis.net/igm/0.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:gco="http://www.isotc211.org/2005/gco"
xsi:schemaLocation="http://www.opengis.net/igm/0.0
igmCovarianceMatrix.xsd"
id="CovarianceMatrixImageDefault">
    <measureDescription>
        <gco:CharacterString>This default CovarianceMatrix for measured
image positions specifies a diagonal matrix with the same value for
both image coordinates. That variance corresponds to a standard
deviation of 0.5 pixel spacing. </gco:CharacterString>
    </measureDescription>
    <matrixSize>2</matrixSize>
    <adjustedParameters>row column</adjustedParameters>
    <result>
        <DiagonalMatrix>
            <valueUnit>rowSpacing columnSpacing</valueUnit>
            <valuesList>0.25 0.25</valuesList>
        </DiagonalMatrix>
    </result>
```



```
</CovarianceMatrix>
```

The default CovarianceMatrix for measured object positions is specified by the attached XML document defaultObjectCovarianceMatrix.xml, which contains:

```
<?xml version="1.0" encoding="UTF-8"?>
<CovarianceMatrix xmlns="http://www.opengis.net/igm/0.0"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:gco="http://www.isotc211.org/2005/gco"
xsi:schemaLocation="http://www.opengis.net/igm/0.0
igmCovarianceMatrix.xsd"
id="CovarianceMatrixObjectDefault">
   <measureDescription>
      <gco:CharacterString>This default CovarianceMatrix for measured
object positions specifies a diagonal matrix with the same value for
both horizontal coordinates, and a larger value for the vertical
coordinate. The horizontal variances correspond to a standard deviation
of 1 metre, and the vertical variance corresponds to a standard
deviation of 5 metres. </gco:CharacterString>
   </measureDescription>
   <matrixSize>3</matrixSize>
   <adjustedParameters>X Y Z</adjustedParameters>
   <result>
      <DiagonalMatrix>
         <valueUnit>m m m</valueUnit>
         <valuesList>1 1 25</valuesList>
      </DiagonalMatrix>
   </result>
</CovarianceMatrix>
```

Annex A
(normative)

Abstract test suite

An abstract test suite is not provided in this draft version of this Application Schema, but should be included in version 1.0.0.

Annex B
(normative)

XML Schema Documents

The Frame image geopositioning metadata GML Application Schema specified in this document includes three normative XML Schema Documents, which are bundled in the zip file with this document. The first two of these XML Schema Documents roughly match the two UML packages described in Clauses 8 and 9, and are named:

frameSensorModel.xsd

frameImageGeometry.xsd

frameAll.xsd

These XML Schema Documents import and build upon parts of many of the GML 3.2.0 XML Schema Documents specified in [OGC 05-105] which are also bundled in the zip file with this document.

NOTE The informative attachments to this document include the (subset) profiles XML Schema Documents referenced in Clause 10, and bundled in the zip file with this document, namely:

frameObjectImageTransformationPackage.xsd

frameSensorParameterValuesPackage.xsd

All these XML Schema Documents contain documentation of the meaning of each element and attribute, and this documentation shall be considered normative as specified in Subclause 11.6.3 of [OGC 06-121r3].

Annex C
(normative)

More definition identifier URNs in OGC namespace

C.1 Overview

This frame image geometry metadata makes use of some of the definition identifier URNs in the OGC namespace that are specified in [OGC 06-023r1] and [OGC 05-096r1]. This annex provides the normative specification and URNs for some additional definitions in the OGC namespace, which are expected to be used for image geometry metadata.

The definitions of additional objects defined by the OGC shall use the URNs listed in Table C.1.

Table C.1 — Additional URNs defined by OGC

URN	Object name & gml:id	Definition specified in
urn:ogc:def:crs:IGM:0.0:focalPlaneMM	focalPlaneMM	Subclause C.2
urn:ogc:def:datum:IGM:0.0:imageDatumPlain	imageDatumPlain	Subclause C.3
urn:ogc:def:cs:IGM:0.0:image2dSquareCS	image2dSquareCS	Subclause C.4
urn:ogc:def:axis:IGM:0.0:xImage	xImage	Subclause C.5
urn:ogc:def:axis:IGM:0.0:yImage	yImage	Subclause C.6
urn:ogc:def:units:IGM:0.0:pixelSpacingPerMM	pixelSpacingPerMM	Subclause C.7
urn:ogc:def:crs:IGM:0.0:imageLSRcrs:AA99 [a]	imageLSRcrs:AA99 [a]	Subclause C.8
urn:ogc:def:cs:IGM:0.0:perpendicular3dCS	perpendicular3dCS	Subclause C.9
urn:ogc:def:axis:IGM:0.0:X3D	X3D	Subclause C.10
urn:ogc:def:axis:IGM:0.0:Y3D	Y3D	Subclause C.11
urn:ogc:def:axis:IGM:0.0:Z3D	Z3D	Subclause C.12
urn:ogc:def:datum:IGM:0.0:imageLSRdatum:AA99	imageLSRdatum:AA99	Subclause C.13
urn:ogc:def:crs:IGM:0.0:USR:WGS84	USR:WGS84	Subclause C.14
urn:ogc:def:crs:IGM:0.0:WGS84:AA99	WGS84:AA99	Subclause C.15
a This "AA99" shall be replaced by the image identifier alphanumeric character string.		

C.2 focalPlaneMM CRS

The URN value "urn:ogc:def:crs:IGM:0.0:focalPlaneMM" shall reference the definition of the CRS for the focal plane of a camera (or imaging sensor) with position coordinates measured in millimeters (mm) relative to the origin position specified by that camera. The definition of this focal plane CRS shall be the same as can be XML encoded using GML 3.2 as:


```
<ImageCRS gml:id="focalPlaneMM">
   <identifier
codeSpace="urn:ogc:def:crs:IGM:0.0:">focalPlaneMM</identifier>
   <!-- Specifies the URN that can be used to reference this CRS. -->
   <remarks>This CRS definition can be used for any size image, since
no image size is specified. This CRS definition is designed to be used
for ungeorectified images, and is not expected to be used for a
georectified image. </remarks>
   <scope>One image</scope>
   <cartesianCS xlink:href="urn:ogc:def:cs:OGC:1.0:image2dSquareCS"/>
   <imageDatum xlink:href="urn:ogc:def:datum:OGC:1.0:ImageDatumPlain"/>
</ImageCRS>
```

C.3 imageDatumPlain datum

The URN value "urn:ogc:def:datum:IGM:0.0:imageDatumPlain" shall reference the definition of the image datum for the focal plane of a camera (or imaging sensor) with position coordinates stated in millimeters (mm) relative to the origin position specified by that camera. The definition of this image datum shall be the same as can be XML encoded using GML 3.2 as:

```
<ImageDatum gml:id="ImageDatumPlain">
   <identifier
codeSpace="urn:ogc:def:datum:IGM:0.0:">ImageDatumPlain</identifier>
   <!-- Specifies the URN that can be used to reference this datum. -->
   <name>Origin of image coordinates</name>
   <remarks>2D image datum with the origin at the 0, 0 position.
</remarks>
   <scope>One image</scope>
   <anchorDefinition>TBD</anchorDefinition>
   <pixelInCell
codeSpace="urn:ogc:def:pixelInCell:OGC:1.0:">cellCenter</pixelInCell>
</ImageDatum>
```

C.4 image2dSquareCS coordinate system

The URN value "urn:ogc:def:cs:IGM:0.0:image2dSquareCS" shall reference the definition of the coordinate system for the focal plane of a camera (or imaging sensor) with position coordinates measured in millimeters (mm) relative to the origin position specified by that camera. The definition of this coordinate system shall be the same as can be XML encoded using GML 3.2 as:

```
<CartesianCS gml:id="image2dSquareCS">
   <identifier
codeSpace="urn:ogc:def:cs:IGM:0.0:">image2dSquareCS</identifier>
   <!-- Specifies the URN that can be used to reference this CS. -->
   <name>2D square image coordinate system</name>
   <remarks>2D coordinate system for use by an image. This CS can be
used for an image of any size, since no size is defined. The coordinate
system is assumed to be square, with the same distance units in each
direction. </remarks>
   <axis xlink:href="urn:ogc:def:axis:IGM:0.0:x"/>
   <axis xlink:href="urn:ogc:def:axis:IGM:0.0:y"/>
</CartesianCS>
```

C.5 xImage axis

The URN value "urn:ogc:def:axis:IGM:0.0:xImage" shall reference the definition of the first axis in the image coordinates for the focal plane of a camera (or imaging sensor) with position coordinates stated in millimeters (mm) relative to the origin position specified by that camera. The definition of this axis shall be the same as can be XML encoded using GML 3.2 as:

```
<CoordinateSystemAxis gml:id="xImage" gml:uom="mm">
   <identifier
codeSpace="urn:ogc:def:axis:IGM:0.0:">xImage</identifier>
   <!-- Specifies the URN that can be used to reference this axis. -->
   <name>Image x axis with millimeter units</name>
   <axisAbbrev>x</axisAbbrev>
   <axisDirection
codeSpace="urn:ogc:def:axisDirection:OGC:1.0:">rowPositive</axisDirecti
on>
</CoordinateSystemAxis>
```

C.6 yImage axis

The URN value "urn:ogc:def:axis:IGM:0.0:yImage" shall reference the definition of the second axis in the image coordinates for the focal plane of a camera (or imaging sensor) with position coordinates stated in millimeters (mm) relative to the origin position specified by that camera. The definition of this axis shall be the same as can be XML encoded using GML 3.2 as:

```
<CoordinateSystemAxis gml:id="yImage" gml:uom="mm">
   <identifier
codeSpace="urn:ogc:def:axis:IGM:0.0:">yImage</identifier>
   <!-- Specifies the URN that can be used to reference this axis. -->
   <name>Image y axis with millimeter units</name>
   <axisAbbrev>y</axisAbbrev>
   <axisDirection
codeSpace="urn:ogc:def:axisDirection:OGC:1.0:">columnPositive</axisDire
ction>
</CoordinateSystemAxis>
```

C.7 pixelSpacingsPerMM unit

The URN value "urn:ogc:def:units:IGM:0.0:pixelSpacingPerMM" shall reference the definition of pixel spacing per mm units. The definition of this PixelSpacingPerMM shall be the same as can be XML encoded using GML 3.2 as:

```
<DerivedUnit gml:id="PixelSpacingPerMM">
   <identifier codeSpace="TBD">PixelSpacingPerMM</identifier>
   <!-- Specifies the URN that can be used to reference this unit. -->
   <name>Ratio of pixel spacing distance to one millimeter</name>
   <name codeSpace="urn:ogc:def:units:IGM:0.0:">PixelSpacing/mm</name>
   <quantityType>Ratio of units</quantityType>
   <catalogSymbol>PixelSpacing/mm</catalogSymbol>
   <derivationUnitTerm uom="urn:ogc:def:uom:OGC:1.0:GridSpacing"
exponent="1"/>
   <derivationUnitTerm uom="mm" exponent="-1"/>
```



```
</DerivedUnit>
```

C.8 imageLSRcrs:AA99 CRS

The URN value "urn:ogc:def:crs:IGM:0.0:imageLSRcrs:AA99" shall reference the definition of the Local Space Rectangular (LSR) coordinate reference system (CRS) for the image with the alphanumeric image identifier that is substituted for the "AA99". This LSR CRS is tangent to an ellipsoid at the point on that ellipsoid which is directly under the original estimated position of the image sensor when that image was collected. The definition of this LSR CRS shall be the same as can be XML encoded using GML 3.2 as:

```
<GeodeticCRS gml:id="imageLSRcrs">
   <identifier
codeSpace="urn:ogc:def:crs:IGM:0.0:">imageLSRcrs</identifier>
   <name>LSR coordinate reference system, tangent to an ellipsoid at
point on that ellipsoid directly under the original estimated camera
position when an image was collected</name>
   <scope>One image</scope>
   <cartesianCS xlink:href="urn:ogc:def:cs:IGM:0.0:perpendicular3dCS"/>
   <geodeticDatum></geodeticDatum>
</GeodeticCRS>
```

C.9 perpendicular3dCS coordinate system

The URN value "urn:ogc:def:cs:IGM:0.0:perpendicular3dCS" shall reference the definition of a 3D Cartesian coordinate system with perpendicular axes. The definition of this coordinate system shall be the same as can be XML encoded using GML 3.2 as:

```
<CartesianCS gml:id="perpendicular3dCS">
   <identifier
codeSpace="urn:ogc:def:cs:IGM:0.0:">perpendicular3dCS</identifier>
   <!-- Specifies the URN that can be used to reference this CS. -->
   <name>Three dimensional Cartesian coordinate system</name>
   <axis xlink:href="urn:ogc:def:axis:IGM:0.0:X3D"/>
   <axis xlink:href="urn:ogc:def:axis:IGM:0.0:Y3D"/>
   <axis xlink:href="urn:ogc:def:axis:IGM:0.0:Z3D"/>
</CartesianCS>
```

C.10 X3D axis

The URN value "urn:ogc:def:axis:IGM:0.0:X3D" shall reference the definition of the first axis in a 3D Cartesian coordinate system with perpendicular axes. The definition of this axis shall be the same as can be XML encoded using GML 3.2 as:

```
<CoordinateSystemAxis gml:id="X3D" gml:uom="mm">
   <identifier codeSpace="urn:ogc:def:axis:IGM:0.0:">X3D</identifier>
   <!-- Specifies the URN that can be used to reference this axis. -->
   <name>X axis of a 3D local space rectangular (LSR) CRS</name>
   <axisAbbrev>X</axisAbbrev>
   <axisDirection
codeSpace="urn:ogc:def:axisDirection:OGC:1.0:">east</axisDirection>
</CoordinateSystemAxis>
```


C.11 Y3D axis

The URN value "urn:ogc:def:axis:IGM:0.0:Y3D" shall reference the definition of the second axis in a 3D Cartesian coordinate system with perpendicular axes. The definition of this axis shall be the same as can be XML encoded using GML 3.2 as:

```
<CoordinateSystemAxis gml:id="Y3D" gml:uom="mm">
   <identifier codeSpace="urn:ogc:def:axis:IGM:0.0:">Y3D</identifier>
   <!-- Specifies the URN that can be used to reference this axis. -->
   <name>Y axis of a 3D local space rectangular (LSR) CRS</name>
   <axisAbbrev>Y</axisAbbrev>
   <axisDirection
codeSpace="urn:ogc:def:axisDirection:OGC:1.0:">north</axisDirection>
</CoordinateSystemAxis>
```

C.12 Z3D axis

The URN value "urn:ogc:def:axis:IGM:0.0:Z3D" shall reference the definition of the third axis in a 3D Cartesian coordinate system with perpendicular axes. The definition of this axis shall be the same as can be XML encoded using GML 3.2 as:

```
<CoordinateSystemAxis gml:id="Z3D" gml:uom="mm">
   <identifier codeSpace="urn:ogc:def:axis:IGM:0.0:">Z3D</identifier>
   <!-- Specifies the URN that can be used to reference this axis. -->
   <name>Z axis of a 3D local space rectangular (LSR) CRS</name>
   <axisAbbrev>Z</axisAbbrev>
   <axisDirection
codeSpace="urn:ogc:def:axisDirection:OGC:1.0:">up</axisDirection>
</CoordinateSystemAxis>
```

C.13 imageLSRdatum:AA99 datum

The URN value "urn:ogc:def:datum:IGM:0.0:imageLSRdatum:AA99" shall reference the definition of the datum used by the LSR coordinate reference system for the image with the alphanumeric image identifier that is substituted for the "AA99". This LSR CRS is tangent to an ellipsoid at point on that ellipsoid directly under the original estimated camera position when an image was collected. The definition of this LSR CRS shall be the same as can be XML encoded using GML 3.2 as:

```
<GeodeticDatum gml:id="imageLSRdatum">
   <identifier
codeSpace="urn:ogc:def:crs:IGM:0.0:">imageLSRdatum:AA99</identifier>
   <!-- Specifies the URN that can be used to reference this datum,
with "AA99" replaced by the alphanumeric image identifier. -->
   <name>Datum used by LSR coordinate reference system, tangent to an
ellipsoid at point on that ellipsoid directly under the original
estimated camera position when an image was collected</name>
   <scope>One image</scope>
   <primeMeridian nilReason="unknown"/>
   <ellipsoid nilReason="unknown"/>
</GeodeticDatum>
```


C.14 USR:WGS84 CRS

The URN value "urn:ogc:def:crs:IGM:0.0:USR:WGS84" shall reference the definition of the geodetic CRS using the 3D Cartesian coordinate system with perpendicular axes defined as "urn:ogc:def:cs:IGM:0.0:perpendicular3dCS", with the datum used by the WGS84 CRS, which is defined by the EPSG using code 6326.

C.15 WGS84:AA99 CRS

The URN value "urn:ogc:def:crs:IGM:0.0:WGS84:AA99" shall reference the definition of the WGS 84 3D CRS, defined as "urn:ogc:def:crs:EPSG:6.8:4979", attaching the image name to which the related position value applies.

Annex D
(informative)

Control values for frame images

D.1 Required control values

The demonstration triangulation using this frame image geopositioning metadata requires that two Control Values be input to the Triangulate operation, which is specified in the Image Geopositioning Service (IGS) [OGC 07-030]. These required Control Values shall be as specified in Table D.1.

Table D.1 — Required Control Values for IGS Triangulate operation

ControlValue name	Definition	"metadata" value	Value format
MinimumObjectPosition	Approximate minimum object position for set of images being triangulated	Reference to WGS 84 3D CRS	gml:pos [a]
MaximumObjectPosition	Approximate maximum object position for set of images being triangulated	Reference to WGS 84 3D CRS	gml:pos [a]
a Three coordinate values shall be separated by single spaces in one character string, with the related "metadata" value providing the srsName value. For the WGS 84 3D CRS, the coordinate values are listed Latitude in decimal degrees first, Longitude in decimal degrees second, and Ellipsoidal height in meters third.			

NOTE These required control values provide data that is theoretically computable from the InputData to the Triangulate operation, supplemented by suitable elevation data. However, such computations are not implemented for this demonstration.

D.2 XML encoding of frame image control values

EXAMPLE A template example of the XML encoding of this frame image set of ControlValues is:

```
<ControlValues>
    <ControlValue name="MinimumObjectPostion"
metadata="urn:ogc:def:crs:EPSG:6.8:4979">999 999 999</ControlValue>
    <ControlValue name="MaximumObjectPostion"
metadata="urn:ogc:def:crs:EPSG:6.8:4979">999 999 999</ControlValue>
</ControlValues>
```

D.3 OperationsMetadata encoding of frame image control values

A specified in Subclause 8.3.3 of [OGC 06-054r3], each ControlValue quantity implemented by the server shall be specified by an ows:Parameter element that is included for the Triangulate operation. Each of these ows:Parameter elements shall provide the quantity name, meaning, units if any, allowed values, and default value if any.

EXAMPLE A template example of the XML encoding of the Triangulate operation using this set of ControlValues is:

```
<Operation name="Triangulate">
    <DCP>
```

```
        <HTTP>
            <Post></Post>
        </HTTP>
    </DCP>
    <Parameter name="MinimumObjectPosition">
        <AnyValue/>
        <Meaning>Approximate minimum object position for group of images being
triangulated. Shall include one for triangulation, with the "metadata" value
referencing the WGS 84 3D CRS (urn:ogc:crs:EPSG:6.8:4979). </Meaning>
        <DataType>urn:ogc:def:dataType:OGC:1.1:anyURI</DataType>
    </Parameter>
    <Parameter name="MaximumObjectPosition">
        <AnyValue/>
        <Meaning>Approximate maximum object position for group of images being
triangulated. Shall include one for triangulation, with the "metadata" value
referencing the WGS 84 3D CRS (urn:ogc:crs:EPSG:6.8:4979). </Meaning>
        <DataType>urn:ogc:def:dataType:OGC:1.1:anyURI</DataType>
    </Parameter>
</Operation>
```

Annex E
(informative)

IGS demonstration profiles

The planned demonstration in support of the RFC for the Image Geopositioning Service (IGS) [OGC 07-030] will use profiles of that specification and of the Image Geopositioning Metadata (IGM) GML 3.2 Application Schema [OGC 07-031]. The implemented abilities were selected to match the Socet Set triangulation software that is wrapped with the IGS interface. Those profiles will use only one image sensor model, the frame image sensor model specified in this document.

The abilities specified in the Image Geopositioning Service (IGS) [OGC 07-030] that are not implemented in this demonstration profile include:

a) Adjustment of SensorParameterValues

b) Plain XML (non-SOAP) encoding of Triangulate operation request and response

c) Referencing data stored outside the Triangulate operation request and response

d) GetCapabilities operation (just providing a Capabilities document)

e) The optional “store” and responseHandler in Triangulate operation request

The abilities specified in the Image Geopositioning Metadata (IGM) GML 3.2 Application Schema [OGC 07-031] that are not implemented in this demonstration profile include:

a) IdentificationImage objects

b) EqualParameters lists

c) “footprint” Polygon objects

d) AdjustableParameters lists (used default values)

e) Any GeodeticCRS for ObjectPositions (only WGS 84 3D used)

f) Optional parts of ImageAccuracy and AdjustmentSummary objects

g) Most <<CodeList>> values, such as “invalid”, “removed”, and “validated” in ImagePositionStatus and ObjectPointStatus

h) Some types of CovarianceMatrices

The informative attachments to this document include example XML documents for the demonstration, namely:

a) IGS Capabilities document (templateFrameImageDemoCapabilities.xml)

b) Triangulate operation request encoded using SOAP (templateFrameImageDemoTriangulate.xml)

c) Triangulate operation response encoded using SOAP (templateFrameImageDemoTriangulateResponse.xml)

Bibliography

[1] ASPRS 2004, Manual of Photogrammetry, Fifth Edition, American Society for Photogrammetry and Remote Sensing, 2004

[2] OGC 00-115, OGC Abstract Specification Topic 15: Image Exploitation Services

[3] OGC 05-094r1, GML 3.1.1 CRS support profile

[4] OGC 06-054r2, OpenGIS® Image Geopositioning Service Implementation Specification

[5] PE 1974, Refraction Compensation, by R.B. Forrest and W.F. DeRouchie, Photogrammetric Engineering 1974

