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OWS-7 Motion Imagery Discovery and Retrieval Engineering Report

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Preface

This document presents the metadata requirements for motion imagery discovery and retrieval, with a focus on geometrical metadata required for motion imagery change detection, of the OWS 7 Sensor Fusion Enablement (SFE) Thread. The SFE thread builds on the OGC Sensor Web Enablement framework that has achieved a degree of maturity through previous OWS interoperability initiatives and deployments worldwide. OWS-7 will focus on integrating the SWE interfaces and encodings with workflow and web processing services to achieve sensor fusion. OWS 7 SFE will continue the development of Secure SWE architecture and continue the interoperability of SWE and CCSI. Emphasis for OWS 7 SFE is on the following: 1) Motion Video Fusion – geolocating of motion video for display and processing, and change detection of motion video using Web Processing Service with rules; 2) Dynamic Sensor Tracking and Notification -- tracking sensors and notify users based on a geographic Area of Interest; and 3) CCSI-SWE Best Practice -- building on OWS-6 and developing an ER to be considered by the OGC Technical Committee as a Best Practice. ThisTemplate for OGC IP Engineering ReportMotion Imagery Discovery and Retrieval Engineering Report (ER) documents the metadata used to tag geolocation of Motion Imagery for discovery, retrieval and linkage with other data sources over the same location. This ER should be coordinated with Feature/Decision Fusion Authoritative Data Source Directory ER, and with Aviation Architecture ER, in terms of cross-thread catalogs & registries issues, content, and usage.

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Motion Imagery Discovery and Retrieval Engineering Report

1 Introduction

1.1 Scope

This Motion Imagery Discovery and Retrieval Engineering Report (ER) documents the metadata used to tag geolocation of Motion Imagery (MI) for discovery, retrieval and linkage with other data sources over the same location, especially the metadata information required to geometrically co-register multiple motion images at pixel level so that data recorded at different times (e.g., different days) and/or by different providers for common or overlapped FOVs can be compared and pixel level changes among the different images can be accurately detected and delineated. This ER reflects one of the achievements during the OWS 7 Sensor Fusion Enablement (SFE) thread, which builds on the OGC Sensor Web Enablement framework that has achieved a degree of maturity through previous OWS interoperability initiatives and deployments worldwide.

1.2 Document contributor contact points

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1.3 Revision history

Date	Release	Editor	Primary clauses modified	Description
2010-03-26	0.0.0	W.Yang & L.Di	Initial Draft	Initial Draft
2010-07-05	1.0.0	W. Yang & L. Di	Various	Texts, tables, figues, XML scheme

1.4 Future work

Future work may include but is not limited to:

- Harmonization with other SWE reports
- Refinement of the UML models

- XML scheme for metadata data encoding

2 References

3 Terms and definitions

4 Conventions

5 Topic overview

This document reports the activity of the OWS 7 Sensor Fusion Enablement (SFE) thread, which focuses motion video fusion, dynamic sensor tracking and notification, and CCSI-SWE Best Practice. This ER documents the metadata required to geolocate Motion Imagery (MI) for discovery, retrieval and linkage with other data sources over the same location. Specifically, this ER specifies the metadata information a MI data provider shall supply in order for the user to be able to discover, retrieval, and especially determine the earth location of the data so that a MI data set can be linked with other data sources, including other MI data, recorded both during the same time period and at different times to enable video fusion, change detection, and dynamic sensor tracking and notification. This ER should be coordinated with Feature/Decision Fusion Authoritative Data Source Directory ER, and with Aviation Architecture ER, in terms of cross-thread catalogs & registries issues, content, and usage.

6 Motion Imagery Metadata

6.1 Introduction

Motion Imagery is defined by [DoD, 2009] as “imagery (a likeness or representation of any natural or man-made feature or related object or activity) utilizing sequential or continuous streams of images that enable observation of the dynamic, (temporal), behavior of objects within the scene”. The most unique distinction between motion imagery and other types of imagery, such as still digital imagery and earth resources satellite imagery is that motion imagery is recorded in high temporal rate, e.g., more than a dozen frames per second, for a field of view (FOV) or largely overlapped FOVs so that the temporal dynamics of the subjects, such as a moving person or vehicle, in the FOV or FOVs can be captured. Motion imagery can be classified into different types based on different criteria, such as the wavelength, spatial resolution, bit-depth, data processing level, and use-scenario. Different metadata models can be used to describe the details of different categories of motion imagery. This ER focuses on motion imagery’s discovery and retrieval metadata information needed for sensor fusion enablement, especially information required to geometrically co-register multiple motion images so that data recorded at different times (e.g., different days) and/or by different providers for common or overlapped FOVs can be compared at individual pixel level and changes among the different images can be accurately detected and delineated.

6.2 Geometrical metadata for physical sensor model

6.2.1 Introduction

Geometrical coregistration of multiple motion imageries can be performed using different methods. The first, and usually the most accurate, method involves vigorous construction of physical sensor model. In this method, the spatial positions of each pixel in multiple motion imageries having the overlapped FOVs, in reference to a 3-dimensional (3D) Earth Coordinate Reference System (CRS), can be determined using the video camera's interior and exterior parameters and the multiple imageries can thus be accurately co-registered at pixel level. The second method using functional fitting to computing pixel's location in a 3D Earth CRS from pixel's position in an image CRS. It is also possible, although not common, that function fitting is conducted among image CRSes of multiple motion imageries without having Earth CRS involved and the co-registered imageries can be used to detection changes. Further geopostioning will be needed in order to relate the imageries and/or the detected change information to other geospatial information. The third method involves using control points to develop relationships between pixel's Earth CRS position and image CRS position. Similar to the second method, it is also possible the functional relationships of pixel locations are developed among different MI images without involving an Earth CRS.

This clause discusses metadata items needed for construction of physical sensor model. The metadata requirements for the other two methods are discussed in clauses 6.3 and 6.4, respectively.

6.2.2 Platform metadata

All platform geometrical metadata are conditional. They are required if none of the following three conditions are met: 1) the video camera's position and attitude are recorded directly in reference to an Earth fixed coordinate reference system CRS at all times; 2) the motion imagery can be geopositioned using the function fitting method, in which case the fitting function parameters shall be provided (see clause 6.3); and 3) the motion imagery can be geopositioned using control points, in which case the metadata about control points shall be provided (see clause 6.4). This clause lists the platform geometrical metadata needed for geopositioning motion imagery using the rigorous sensor modeling method:

1. Platform position (conditional)
   This metadata item provides the direct position of the platform onto which a video camera is mount, in an Earth Coordinate Reference System (CRS) such as EPSG:4326 (CRS code 4326 defined by the European Petroleum Survey Group). This

metadata is not required when video camera's position is not provided in relation to a platform position. Depending on the nature of a platform, this metadata item may either be time-variant or time-invariant. When platform is a moving object, the position shall be provided for each frame of a MI or be provided, together with platform's velocity and acceleration, for all frames or for a subset of enough frames to allow computation of positions for other frames. When platform is earth fixed, only one position value is necessary for all frames of a MI dataset. In most cases, if a platform is stationary, for instance, a building or an observation tower, video camera's position is usually directly determined in an Earth CRS and thus platform position information is not necessary.

2. Platform velocity (conditional)
   When a platform is a moving object such as a moving land vehicle, this metadata item provides velocity vectors of the platform along with the three axes of a reference Earth CRS. The metadata, together with platform acceleration and time information, is used to compute platform position for the time when a MI is recorded. The metadata is not required when video camera's position is not provided in relation to platform position or when platform position is known for all frames (including the stationary platform case). When required, this metadata shall be provided for each frame or a subset of enough frames, with platform acceleration included, to allow computation of platform positions for frames with which position data are not directly provided.
3. Platform acceleration (conditional)
   When a platform is a moving object such as a moving land vehicle, this metadata item provides acceleration vectors of the platform along with the three axes of the selected CRS. The metadata, together with platform velocity, is used to compute platform position. This metadata is not required when video camera's position is not provided in relation to platform position or when platform position is known for all frames (including the stationary platform case). When required, this metadata shall be provided for each frame or a subset of enough frames, with platform velocity included, to allow computation of platform positions for frames with which position data are not directly provided.
4. Platform attitude (conditional)
   This metadata item provides the attitude of a platform, either in the form of a 3x3 matrix showing the attitude angles along with a reference Earth CRS axes or a sequence of rotation angles, along with the order of rotation, in reference to the platform's nominal attitude at rest. Depending on the nature of a platform, this metadata item may either be time-variant or time-invariant. When platform is a moving object, the attitude shall be provided for each frame of a MI or a subset of frames of a MI. When platform is earth fixed, only one set of attitude values is needed for all frames of a MI. In most cases, if a platform is stationary, e.g., a building or an observation tower, video camera's attitude is usually directly determined in an Earth CRS and thus platform attitude information is not necessary.

6.2.3 Sensor operation and mounting metadata

The sensor, i.e., video camera, operation and mounting metadata are used together with the platform geometrical data to determine the light of sight (LOS) of a sensor. The metadata are time-variant and their values shall be provided for each frame of motion imagery or for a subset of enough frames to allow interpolation, unless a video camera is fixed on a stationary platform, in which case one set of time-invariant values are necessary.

1. Sensor position (required)
   This metadata item provides the direct position of a video camera, either in relation to the platform position or direct Earth measured location. When this position is a relative to the position of a platform or to a gimbal which itself is mounted onto a platform or possibly another gimbal, the position shall be provided as the offset vectors to the platform position or the position of the first gimbal onto which the camera is mounted.
2. Sensor attitude (required)
   This metadata item provides the attitude of video camera, either in the form of a 3x3 matrix showing the attitude angles along with the CRS axes or a sequence of rotation angles along with the order of rotation. This set of parameters shall be provided either in relation to a local CRS, which can be associated to platform CRS or a gimbal CRS, or directly in relation to an Earth CRS.
3. Gimbal postion and attitude (conditional)
   This metadata item provides the position and attitude of gimbal to which a video camera is mounted. When a video camera is mounted on a gimbal, which, in turn, is mounted on a platform, the position and attitude of the gimbal may or may not be required, depending on whether the camera's position and attitude is provided in relation to gimbal. When the position and attitude of a video camera are provided in reference to its mounting gimbal (i.e., not provided directly in reference to platform or the Earth), the position and attitude of gimbal, which is mounted on platform, in reference to the platform shall be provided.
   It should be noted that theoretically multiple gimbals can be used in mounting a sensor to a platform. That is, a sensor is mounted on a gimbal, which itself is mounted on another gimbal. The second gimbal may also be mounted on to another gimbal and so on so forth. When multiple gimbals are used, the successive mounting relationship (i.e., attitudes of each gimbal in relation to a previous gimbal) must be provided until reach the platform). In OWS-7, it is assumed that at most one gimbal is used.
4. Calibrated or effective focal length (optional)
   This metadata item provides a video camera's actual effective focal length when a motion imagery is recorded. If a video camera's lens is fixed (i.e., non-zooming lens), this parameter is the camera's calibrated focal length. If a video camera uses a zoom lens but the lens' zooming is fixed during recording, the actually fixed effective

local length shall be provided. In all other cases, the time-variant effective focal length for each video frame is necessary. It is expected that all the motion imagery used in this initiative shall be recorded using a single fixed focal length.

5. Recording spatial resolution: (required)
   This metadata item provides a video camera's effective spatial resolution, in terms of number of rows and column in a scene. The metadata may also be provided using a more formal sensor detector layout parameter set, in which case the set of parameters shall include the dimensions of detector plane, number of detectors along each dimension, distance between adjacent detectors, detector size, and detector shape. In the current initiative, it is expected that the spatial resolution expressed in numbers of rows and columns shall be enough. Some video cameras allow variable spatial resolutions to be used for different recording purposes. It is expected that all motion imagery used in this initiative shall be provided with the same spatial resolution. Thus, only one row number and one column number shall be used.
6. Viewing angle across the row direction (required)
   This metadata item provides the viewing angle across the row direction of a frame, i.e., the FOV along the center row or along the line between two center rows.
7. Vertical viewing angle across the column direction (required)
   This metadata item provides the viewing angle across the column direction of a frame, i.e., the FOV along the center column or along the line between two center columns.
8. Focal point distance or slant range (optional)
   This metadata item provides the distance between the video camera's position and the scene. The distance can be approximate if it is difficult to obtain an accurate value.

6.3 Fitting function metadata

6.3.1 Introduction

Functional fitting is also frequently used to relate the pixel coordinate values in a motion imagery to those in an Earth CRS or in another motion imagery so that pixel locations expressed in one CRS can be transformed to those in another CRS. A fitting function is expressed in a set of polynomials or rational polynomials. Fitting functions are time-variant except when video camera is fixed in an Earth CRS or when the relative positions of the multiple video cameras used in recording are kept unchanged. This clause defines metadata items required to provide unambiguous fitting function information.

6.3.2 Polynomial metadata

1. Dimension names for independent and dependent variables (required)

Dimension names identify the CRS coordinate axis names, either of an Earth CRS (e.g., y, x, or latitude, longitude) or a reference image's CRS (e.g., row, column, or line, sample), as dependent variables and the CRS coordinate axis names in the of the CRS (e.g., row, column, or line, sample) of the image to be geolocated or registered, as independent variable.

2. Power of polynomial (required)

   This metadata item provides an integer value representing the power of polynomial.

3. Coefficients of polynomial (required)

   This metadata item provides a record of floating point values as coefficients for each item in a polynomial function.

4. Scale factor (optional)

   This metadata item provides an optional scale factor for transforming the normalized variable to its true value.

5. Translation value for polynomial coefficients (optional)

   This metadata item provides an optional offset for translating the normalized variable to its true value.

6. Rational polynomial numerator and denominator identification (optional)

   This metadata item provides information to identify whether a polynomial is a numerator polynomial or a denominator polynomial when the fitting function is a rational polynomial.

6.4 Control point metadata

6.4.1 Introduction

The geometrical relationship between pixel locations in a motion image CRS and locations in either an Earth CRS or in another reference motion imagery CRS can be provided through a set of control points. The control points are usually referred to as ground control points (GCP), although they may locate in above ground objects such as buildings. For change motion imagery change detection, all pixels of MI frames may not necessarily be associated to an Earth CRS (although general geopositioning of a frame in an Earth location is always needed) and only frame-to-frame registrations are required to allow detection of changes between images. This clause defines the metadata required to provide information for such control points.

6.4.2 Control point metadata

1. Target coordinate reference system (required)

This metadata item provides identification information for the CRS associated with control point position values. The CRS is either an Earth CRS or the CRS of a reference motion imagery on to which another motion imagery is to be geometrically registered.

2. Number of control points (required)

   This metadata item identifies the number of control points for a motion imagery frame. Although the minimum requirement on the number of control points is three, a much larger number is usually needed.

3. Position of control points in target CRS (required)

   This metadata item provides control point position values in the identified Earth CRS or the reference image CRS to which the motion imagery is to be registered.

4. Control point locations in source imagery (required)

   This metadata item provides position coordinate values of control points, expressed in row and column or line and sample, in the source image to geolocated or registered.

5. Quality of GCP (optional)

   This metadata item provides control point accuracy information through a covariance matrix.

6.5 Radiometric metadata

6.5.1 Introduction

Radiometric metadata are necessary to determine the reflectance of the scene in a MI frame. In some cases, changes in MI are not caused by the relocation/moving of an geometry (e.g., the appearance of an new object) but by the change in color/brightness of the same geometry (e.g., ground digging/refilling). Radiometric metadata are needed in order to determine whether changes in a scene’s color/brightness are caused disturbance in the scene or by other factors such as changes in illumination. Radiometric metadata include those from video camera setting/operation and those from environment.

6.5.2 Radiometric metadata items

1. Video camera aperture (required)
   This metadata item provides lens aperture value of a video camera during recording. The value of this metadata is time-variant but may be set to a fixed value for a specific series of motion imagery.

2. Video camera shutter speed (required)
   This metadata item provides shutter speed value of a video camera during recording. The value of this metadata is time-variant but may be set to a fixed value for a specific series of motion imagery.
3. Calibration coefficients (optional)
   The calibration coefficients are used to convert digital numbers recorded in the MI frames to radiance values reflected from the scene. These coefficients are typically provided as scale and offset in linear conversion equations. The reflected radiance together with the illumination (see the next metadata item) can be used to determine the reflectance of each pixel in the MI scene.
4. Ambient illumination (optional),
   The ambient illumination, either a passive (e.g., solar radiation) or an active source (e.g., artificial lights), together with the aperture and shutter speed, can be used to derive the radiance recorded by an image.
5. Cloud percent (optional)
   Percent cloud coverage provides an estimation of the ambient illumination when accurate measurement of illumination is not available.
6. Atmospheric visibility (optional)
   This metadata item provides the greatest horizontal distance at which selected objects can be seen, identified, and/or measured with instrumentation.

6.6 Environmental metadata

6.6.1 Introduction

Environmental metadata of a MI are those related to the environment of around the scene recorded in the MI. Information on the environments of a MI is in some cases important to MI discovery and retrieval and particularly to MI change detection. For instance, a scene may appear to have changed due to wind effect and shadows caused by the terrain slope/aspect and ground objects (e.g., trees) may cause pseudo change effects. Some radiometric metadata items, such as illumination and atmospheric visibility, are also about the scene environment. This clause describes environmental metadata not included in the previous clauses.

6.6.2 Environmental metadata

1. Digital terrain model (optional)

   Digital elevation model (DEM) covering both the location of the target (field of view) and the location of sensor, as well as the space between the target and the sensor location, are used to determine the intersection of the light of sight (LOS) from the sensor to the target scene. In most cases, it is assumed that there is nothing blocking the view from the video sensor to the main target. It is possible that the scene may be partially blocked by objects, including terrain, between the sensor and the scene. High resolution DEM data, such as the heights of buildings and trees, are extremely useful in determine the intersection of LOS at the scene. The metadata item refers to the digital terrain model of the area, covering both the location of the target (field of view) and the location of sensor, and the space in-between the two.

2. Wind speed (optional)

   Wind speed provides additional information on scene variation. Two images of the same unchanged scene may appear different when one is recorded in calm condition while another is recorded in windy condition (assuming changes to be detected does not include scene wind-induced variations).

3. Humidity (optional)

   Different humidity conditions may cause variations in color and brightness in motion imageries. Humidity information can be used as a criterion in selecting motion imagery pairs for change detection.

4. Temperature (optional)

   Similar to the humidity, different temperature conditions may cause variations in color and brightness in motion imageries.

5. Soil moisture (optional)

   Soil moisture affects the color and brightness of a scene. This metadata helps radiometric calibration/registration of two scenes. A disturbed location in a scene in the field, e.g., a newly buried improvised explosive device, may appear to have similar tone with that of a scene recorded after a precipitation event.

6. Land cover/use type and scheme (optional)

   Land use/cover type presented in the scene helps change detection algorithm in depicting variations in a scene and interpretation of variations. Different land use/cover types require different criteria in defining change versus no change. Land use/cover metadata should be associated with certain land use/cover classification scheme. Different land use/cover schemes provide different levels and/or purpose of classification. In most motion imagery change detection use cases, high level and detailed land use/cover classification scheme, such as the Anderson Level III and Level IV (Anderson et al, 1976), is needed.

6.7 Discovery and retrieval metadata

6.7.1 Introduction

Most critical information needed for discovery and retrieval of MI data includes the spatial and temporal locations of the imagery. Additional metadata information, such as the spatial position of the video camera used in recording, the description of the target being recorded in the MI and of the camera, and viewing geometry, also provides important discovery and retrieval information. Many environmental metadata can be used as discovery and retrieval criteria. Thus, most of discovery and retrieval metadata items are already included in the previous clauses, especially those related to the geometrical and dynamical configurations of the sensor and its mounting platform from which accurate geopositioning of MI can be derived. In this clause, additional metadata items related to the discovery and retrieval are listed so that they may be used independent of geometrical correction. All metadata items listed in this clause are optional except for the image identification and the spatial and temporal metadata, although in many cases additional metadata are used together with spatio-temporal information for more specific discovery and accurate retrieval of a particular MI or frames with a MI.

6.7.2 Discovery and retrieval metadata

1. Image identifier (required)

   The metadata item provides the unique identification of a motion imagery.

2. Observation date and time (required)

   The observation date/time information is one of the most important and frequently used discovery and retrieval metadata. This information is included in the dynamics parameters of the sensor and/or platform. The date/time stamp should either be directly recorded together with each MI frame or be interpolated, when frame rate is high (e.g., 24 frames per second), from closest frames. In either case, the MI provider should make this information available for each individual MI frame so that it is searchable by date/time.

3. Geographic bounding rectangle of the scene (required)

   This metadata item provides the spatial bounding of the scene recorded in the motion imagery. The bounding rectangle may be expressed either in a two-dimensional horizontal Earth CRS or a three-dimensional Earth CRS. This metadata does not tell earth locations of individual pixels, unless the motion imagery is georectified to an Earth CRS. It instead provides overall spatial extent information of a motion imagery so that the imagery can be searched according to geographic location.

4. Mission description (optional):

   This metadata item provides a description of the purpose of the motion imagery recording mission.

5. Sensor identification (optional):

   This metadata item provides sensor identification information that may be used for discovery and retrieval of motion imagery recorded by a particular sensor.

6. Sensor type (optional)

This metadata item tells the type of the sensor used in taking the motion imagery.

7. Sensor description (optional)

   This metadata item provides any other additional description information of the sensor.

8. Sensor geometry (optional)

   This metadata item provides information on sensor looking geometry. This is a general description of viewing geometry in addition the accurate sensor geometrical information needed in physical sensor model.

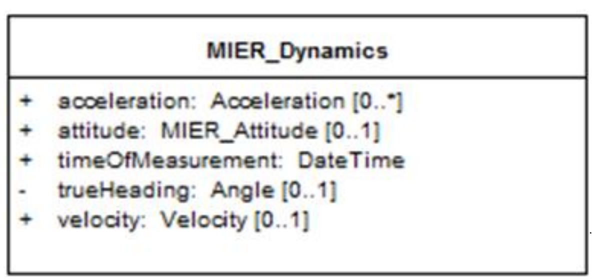
7 UML Diagrams for Motion Imagery Metadata

7.1 Introduction

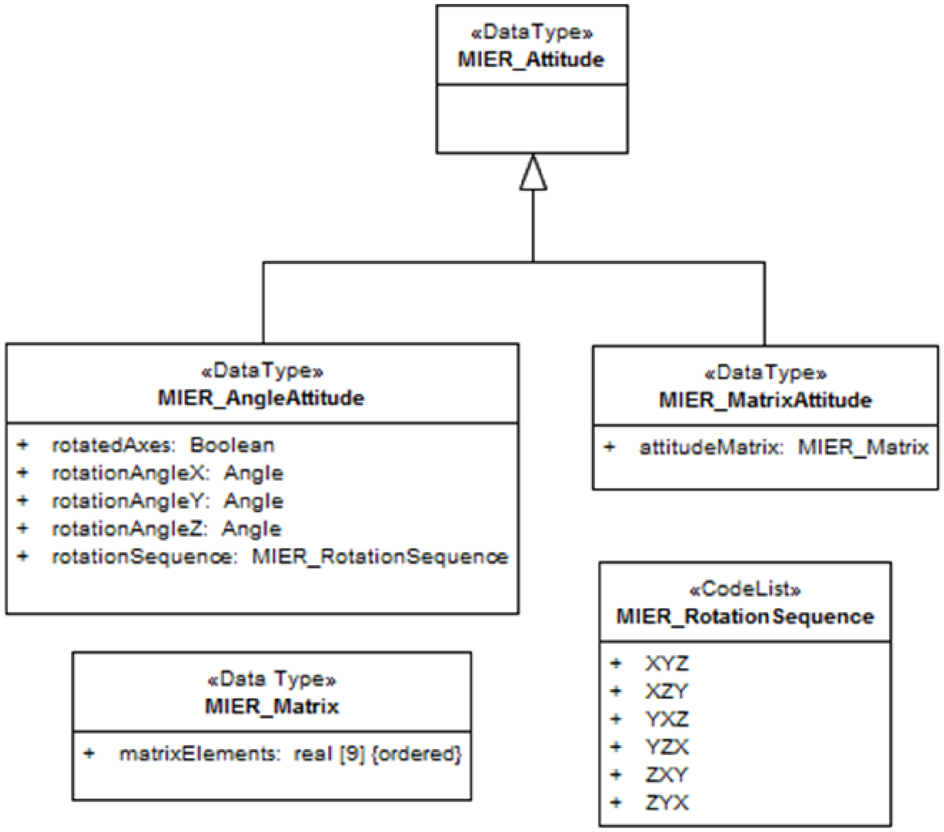
This clause describes the modular/hierarchical relationships among different metadata components and the data types of metadata items, using UML class diagrams. The geometrical metadata class diagrams are mainly derived from the ISO 19130. It should be noted that the diagrams, including the data types defined in the diagrams, are informative. Significant efforts are required to harmonize the structure with other SFE and OWS documents in order to make the UML diagrams as OGC standard.

7.2 Platform metadata UML diagrams

The platform's velocity, acceleration, and attitude metadata item together provide platform dynamics information. Figure 1 shows the UML class diagram for platform dynamics.



The UML class diagram for attitude is shown in Figure 2. This class is a data type class. The attitude can be applied for any objects, including a sensor (i.e., a video camera), a platform, or a gimbal. Thus, in (rare) cases when a video camera's attitude information is directly provided without referencing to a mounting platform, this UML class can be used to provide metadata of the camera's attitude.



The dynamics information and the position information combined provide a complete set of platform geometrical information. Additional non-geometrical metadata information shall further be provided to describe a platform, such as citation and platform identifier defined in ISO 19115-2 [ISO, 2008], for discovery and retrieval purpose. Figure 3 shows the UML class diagram of platform complete geometrical information and additional non-geometrical metadata for discovery and retrieval. The later will be further discussed in clause 6.7.

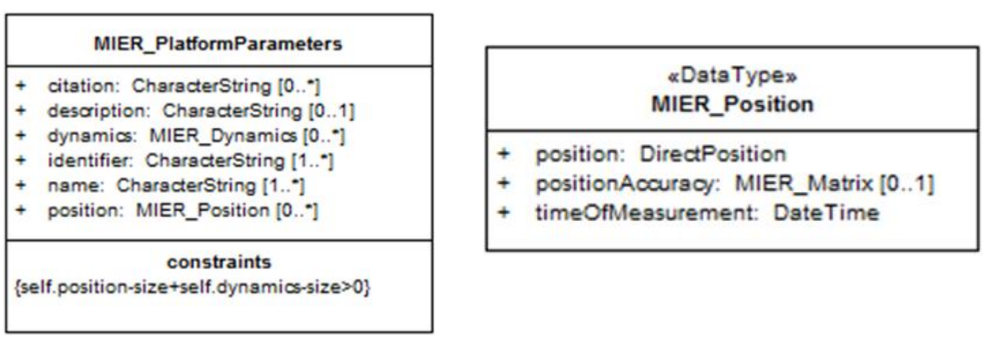


Figure 3: The platform information class diagram

7.3 Sensor metadata UML diagrams

The sensor attitude is described in the same to that of the platform, i.e., Figure 2, the UML diagram for attitude. The sensor's position, orientation, and mounting relationship are shown in UML class diagram Figure 4.

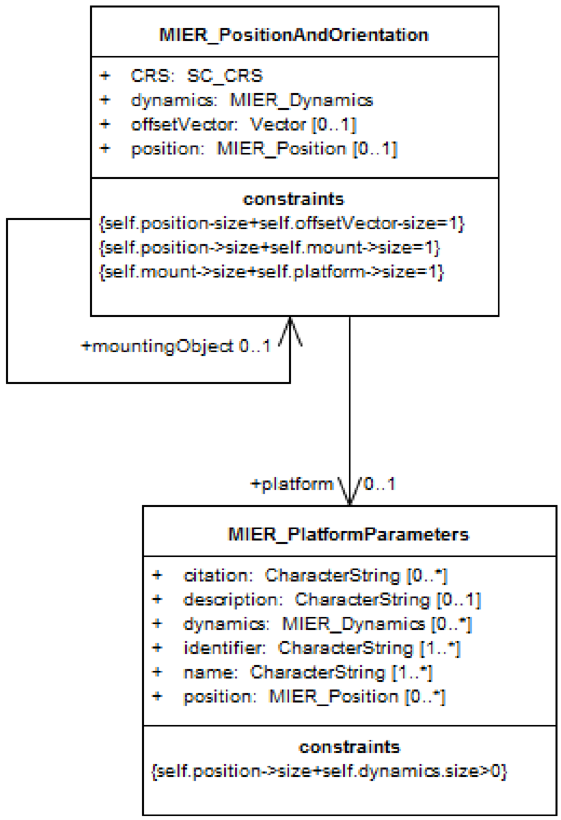


Figure 4: The position, orientation, and mounting class diagram

A more complete sensor metadata UML class diagram is shown in Figure 5, which includes some more metadata items related to the sensor operation and radiometric calibration.

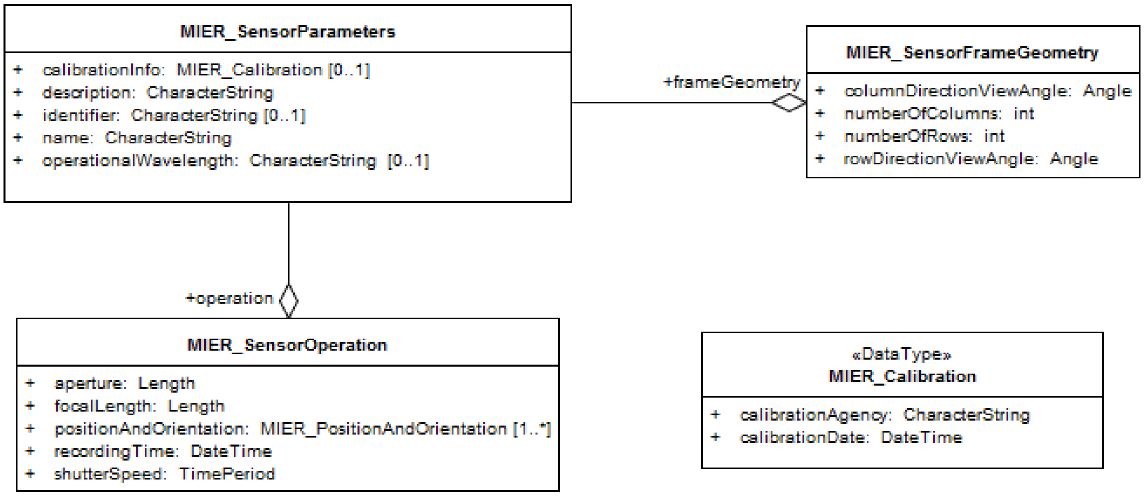


Figure 5: The sensor parameters class diagram

7.4 Functional fitting and control point UML diagrams

The UML diagrams for geometrical rectification/registration using the control point method and the polynomial fitting function are shown in Figures 6 and 7, respectively.

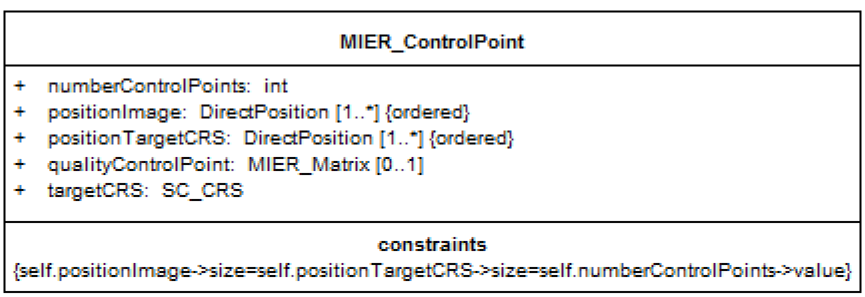


Figure 6: The control point class diagram

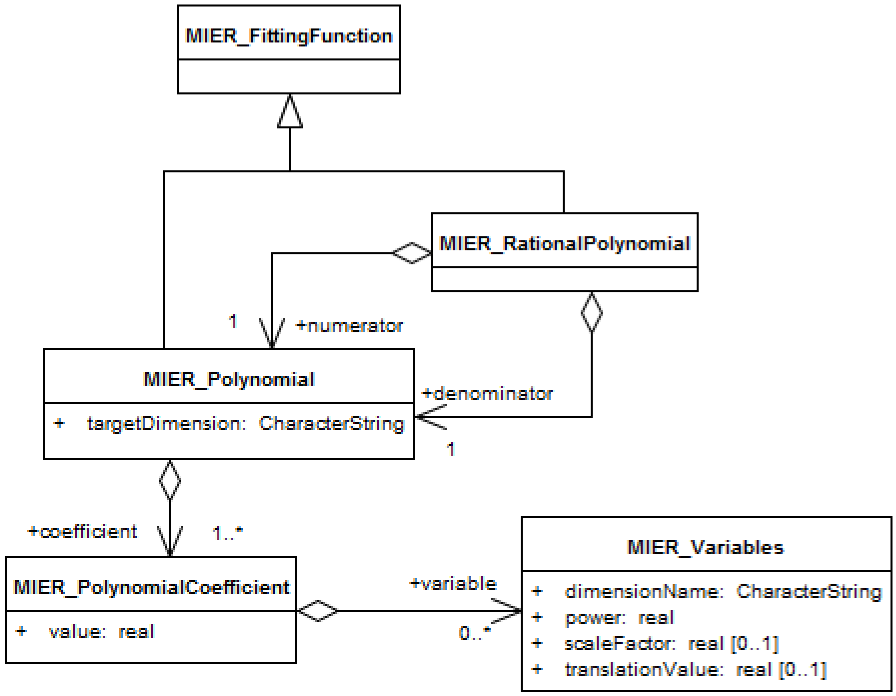


Figure 7: The fitting function class diagram

7.5 Environmental metadata UML diagram

The UML diagram class for environmental metadata is shown in Figure 8.

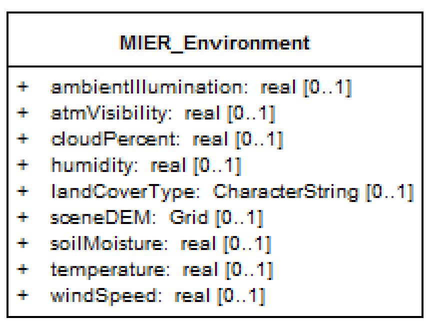


Figure 8: The environmental metadata class diagram

7.6 Motion discovery and retrieval metadata UML diagram

The complete UML class diagram for motion imagery retrieval and discovery metadata, with an emphasis on geometrical rectification and/or registration of multiple imageries for change detection, is shown is figure 9.

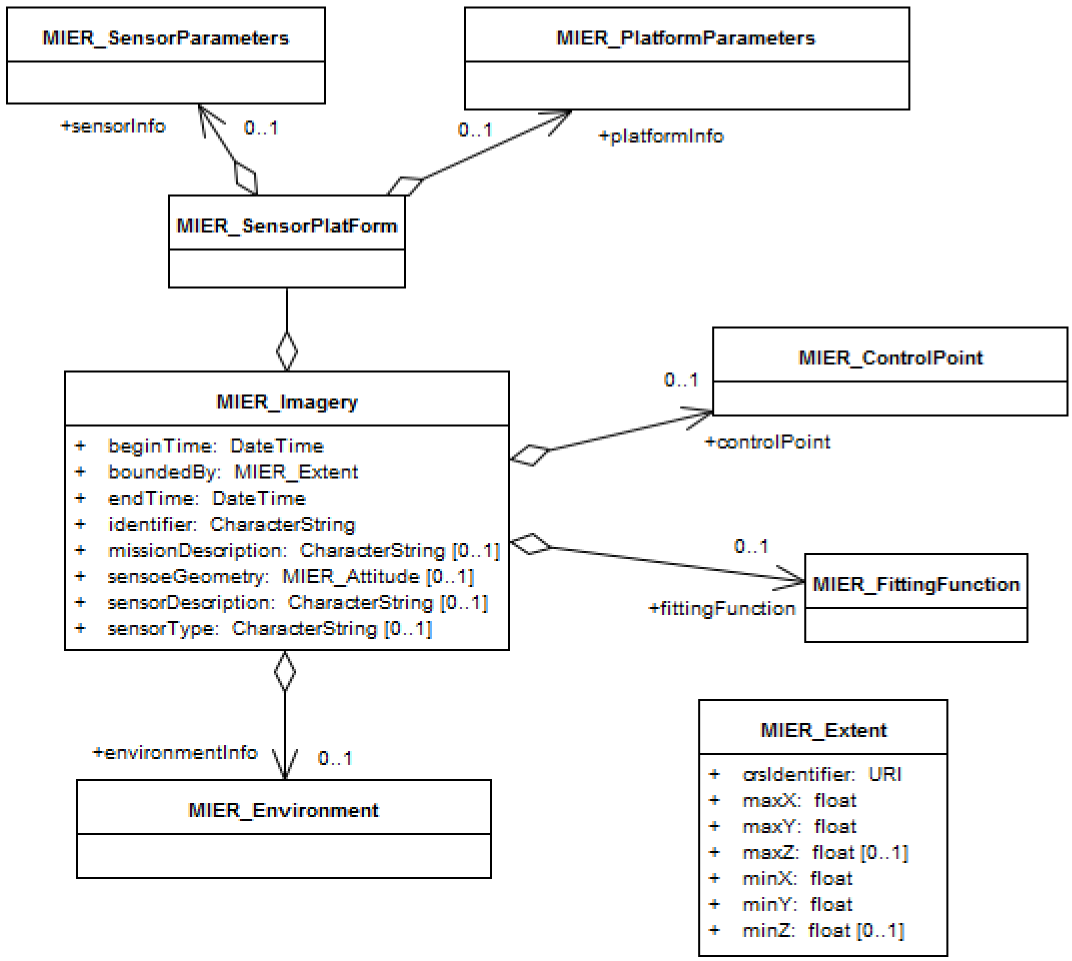


Figure 9: The motion imagery metadata UML class diagram

8 Motion Imagery encoding XML scheme

The XML encoding scheme for motion imagery discovery and retrieval as shown in Figure 9 is as the following:

```
<?xml version="1.0" encoding="ISO-8859-1"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema">
	<xs:element name="MIER_MatrixAttitude" type="MIER_MatrixAttitude"/>
	<xs:complexType name="MIER_MatrixAttitude">
		<xs:complexContent>
			<xs:extension base="MIER_Attitude">
				<xs:sequence>
					<xs:element name="attitudeMatrix" type="xs:string" minOccurs="1" maxOccurs="1"/>
				</xs:sequence>
			</xs:extension>
		</xs:complexContent>
	</xs:complexType>
	<xs:element name="MIER_Matrix" type="MIER_Matrix"/>
	<xs:complexType name="MIER_Matrix">
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9 Summary and discussion

This engineering report documents the metadata requirement needed to discover and retrieve motion imageries to perform accurate pixel level change detection. The focus of the document is on the geometrical metadata needed for geopositioning of a motion imagery to an Earth coordinate system and for geometrical coregistration of multiple motion imageries. Other metadata information that impacts change detection, such as radiometric parameters during sensor operation and environmental illumination, is also included. The geometrical metadata and the related UML class diagrams are drawn mainly from the ISO 19130, image sensor models for geopositioning. While the metadata information described in this report represents an ideal case on requiring the motion imagery providers/consumers to supply/use metadata to achieve accurate data fusion and change detection result, it should be noted that in real world cases it is unlikely for providers to collect and provide and for consumers to obtain and process all such information. During the course of the OWS SFE project, a relatively controlled experiment environment was set. The motion imageries were recorded from almost the same paths during very similar environmental conditions. The process of pushing original imageries to SOS, searching for and access to the imageries in SOS, the fusion and change detection, and the pushing of fusion/detection result back to SOS, was simplified to certain degree to avoid vigorous catalogue registration, publishing, updating and vigorous searching, scene matching, and geopositioning. The controlled experiment loosened the requirement on metadata information. More experiments will be needed to test use cases with less a prior knowledge on motion imagery collection. Another topic worth of discussion and future work is the encoding scheme of motion imagery metadata. The current scheme is created from UML models primarily derived ISO 19130 standard. There are several other schemas including GML, SWE, SensorML, and other ISO TC211 standards. Creation (or adoption/harmonization) of a consensus scheme needs efforts beyond one OWS initiative.

Annex A Metadata Tables

Table 1 Platform Metadata Table

ID	Parameter	Definition	Units	Obligation	Description
1	Platform Position, X Vector Component	X component of the platform position in an Earth CRS	Length (meter or kilometer)	Conditional, required if sensor position is not directly defined in an Earth CRS	This parameter provides the X coordinate value of platform position in an Earth XYZ CRS.
2	Platform Position, Y Vector Component	Y component of the platform position in an Earth CRS	Length (meter or kilometer)	Conditional, required if sensor position is not directly defined in an Earth CRS	This parameter provides the Y coordinate value of platform position in an Earth XYZ CRS.
3	Platform Position, Z Vector Component	Z component of the platform position in an Earth CRS	Length (meter or kilometer)	Conditional, required if sensor position is not directly defined in an Earth CRS	This parameter provides the vertical, Z, coordinate value of platform position in an Earth XYZ CRS.
4	Platform Velocity Vector's X Component	X component of the platform velocity in an Earth CRS	Velocity (m/s)	Conditional, required if sensor position is not directly defined in an Earth CRS and platform position is not given.	This parameter provides platform velocity vector's X component in an Earth XYZ CRS.
5	Platform Velocity Vector's Y Component	Y component of the platform velocity in an Earth CRS	Velocity (m/s)	Conditional, required if sensor position is not directly defined in an Earth CRS and platform position is	This parameter provides platform velocity vector's Y component in an Earth XYZ CRS.

				not given.	
6	Platform Velocity Vector's Z Component	Z component of the platform velocity in an Earth CRS	Velocity (m/s)	Conditional, required if sensor position is not directly defined in an Earth CRS and platform position is not given.	This parameter provides platform velocity vector's Z component in an Earth XYZ CRS.
7	Platform Acceleration Vector's X Component	X component of the platform velocity in an Earth CRS.	Acceleration (m/s^2)	Conditional, required if sensor position is not directly defined in an Earth CRS and platform position is not given.	This parameter provides platform acceleration vector's X component in an Earth XYZ CRS.
8	Platform Acceleration Vector's Y Component	Y component of the platform velocity in an Earth CRS	Acceleration (m/s^2)	Conditional, required if sensor position is not directly defined in an Earth CRS and platform position is not given.	This parameter provides platform acceleration vector's Y component in an Earth XYZ CRS.
9	Platform Acceleration Vector's Z Component	Z component of the platform velocity in an Earth CRS.	Acceleration (m/s^2)	Conditional, required if sensor position is not directly defined in an Earth CRS and platform position is not given.	This parameter provides platform acceleration vector's Z component in an Earth XYZ CRS.
10	Platform Attitude Roll Angle	The roll angle of the platform.	Angle (radian)	Conditional, required if sensor attitude is provided in reference to the platform's coordinate reference system. Roll, pitch, and yaw angles may also be replaced with a matrix of nine angles between the three platform CRS axes and the three axes of an Earth CRS, as defined in item 14.	This parameter provides the platform's roll angle, which is the angle the platform rotates along its X axis, positive clockwise when looking at the positive direction of the X axis. See the obligation column for more information on this parameter.
11	Platform Attitude Pitch Angle	The pitch angle of the platform	Angle (radian)	Conditional, required if sensor attitude is provided in reference to the platform's coordinate reference system. Roll, pitch, and yaw angles	This parameter provides the platform's pitch angle, which is the angle the platform rotates along its Y axis, positive

				may also be replaced with a matrix of nine angles between the three platform CRS axes and the three axes of an Earth CRS, as defined in item 14.	clockwise when looking at the positive direction of the Y axis. See the obligation column for more information on this parameter.
12	Platform Attitude Yaw Angle	The yaw angle of the platform	Angle (radian)	Conditional, required if sensor attitude is provided in reference to the platform's coordinate reference system. Roll, pitch, and yaw angles may also be replaced with a matrix of nine angles between the three platform CRS axes and the three axes of an Earth CRS, as defined in item 14.	This parameter provides the platform's yaw angle, which is the angle the platform rotates along its Z axis, positive clockwise when looking at the positive direction of the Z axis. See the obligation column for more information on this parameter.
13	Platform True Heading	The platform's true heading angle in reference to the North platform	Angle (radian)	Conditional, required if sensor attitude is provided in reference to the platform's coordinate reference system and when the platform's heading information is not provided by platform attitude angles or rotations angles.	
14	Platform Attitude Angle Matrix	Platform attitude angle matrix.	Angles (radians)	Conditional, required when sensor attitude is defined in platform CRS. This parameter matrix may also be replaced by the platform's roll, pitch, and yaw angle parameters (items 10-12). Either this matrix or the roll, pitch, yaw angles are needed if platform attitude is required.	This parameter set provides a matrix of nine angles between the three platform CRS axes and the three axes of an Earth CRS, in the form of {{xX,xY,xZ}, {yX,yY,yZ}, {zX,zY,zZ}}, where (x,y,z) is platform CRS and (X,Y,Z) is an Earth CRS

Table 2 Sensor Metadata Table

ID	Parameter	Definition	Units	Obligation	Description
1	Sensor Position, X Vector Component	X component of the sensor position, either in an Earth CRS or in the CRS of the platform onto which the sensor is mount.	Length (meter or kilometer)	Required	This parameter provides the X coordinate value of sensor.
2	Sensor Position, Y Vector Component	Y component of the sensor position, either in an Earth CRS or in the CRS of the platform onto which the sensor is mount.	Length (meter or kilometer)	Required	This parameter provides the Y coordinate value of sensor.
3	Sensor Position, Z Vector Component	Z component of the sensor position, either in an Earth CRS or in the CRS of the platform onto which the sensor is mount.	Length (meter or kilometer)	Required	This parameter provides the vertical, Z, coordinate value of sensor.
4	Sensor Line of Sight	The line of sight (LOS) of a sensor measured in two angles: view angle and azimuthal angle (v, ϕ).	Angles (radian, radian)	Required if sensor attitude is not provided in sensor roll, pitch, yaw parameters (items 5-7) and not provided in a nine-element sensor attitude matrix (item 8).	This set of two parameters provides the direction of senos LOS. The view angle is measured from the projection of LOS in the XY plane of a CRS, either platform or Earth, toward

					the CRS' Z axis. The azimuthal angle is measured in the CRS' XY plane, from X axis clockwise when looking toward the positive direction of the X axis.
5	Sensor Attitude Roll angle	Roll angle of sensor in reference to either the CRS of its mounting platform or an Earth CRS.	Angle (radian)	Required when neither sensor LOS (item 4) nor the nine-angle sensor attitude matrix (item 8) is provided.	This parameter provides sensor attitude's roll angle, which is the angle the sensor rotates, in reference to its nominal position (i.e., when sensor's CRS is aligned with its external reference CRS, either platform or Earth CRS), along its X axis, positive clockwise when looking at the positive direction of the X axis.
6	Sensor Attitude Pitch angle	Pitch angle of sensor in reference to either the CRS of its mounting platform or an Earth CRS.	Angle (radian)	Required when neither sensor LOS (item 4) nor the nine-angle sensor attitude matrix (item 8) is provided.	This parameter provides sensor attitude's pitch angle, which is the angle the sensor rotates, in reference to its nominal position (i.e., when sensor's CRS is aligned with its external reference CRS, either platform or Earth CRS), along its Y axis, positive clockwise when looking at the positive direction of the Y axis.
7	Sensor Attitude Yaw angle	Yaw angle of sensor in reference to either the CRS of its mounting platform or an Earth CRS.	Angle (radian)	Required when neither sensor LOS (item 4) nor the nine-angle sensor attitude matrix (item 8) is provided.	This parameter provides sensor attitude's yaw angle, which is the angle the sensor rotates, in reference to its nominal position (i.e., when sensor's CRS is aligned with its external reference CRS, either platform or Earth CRS), along its Z axis, positive clockwise when looking at the

					positive direction of the Z axis.
8	Sensor Attitude Angle Matrix	Sensor attitude angle matrix.	Angles (radians)	Conditional, required when neither sensor line of sight (item 4) nor sensor roll, pitch, yaw parameters (items 5-7) are provided.	This parameter set provides a matrix of nine angles between the three sensor CRS axes and the three axes of the CRS the sensor is located (either platform CRS or an Earth CRS). The matrix is in the form of {{xX,xY,xZ}, {yX,yY,yZ}, {zX,zY,zZ}}, where (x,y,z) is sensor CRS and (X,Y,Z) is either platform CRS or an Earth CRS
9	Gimbal Attitude Roll Angle	The roll angle of gimbal	Angle (radian)	Conditional, required if gimbal is used to mount the sensor and the sensor's attitude is defined in relation to the gimbal. Gimal attitude may also be provided in the form of a nine-element matrix (item 12).	This parameter provides the roll angle of a gimbal on to which a sensor is mount.
10	Gimbal Attitude Pitch Angle	The pitch angle of gimbal.	Angle (radian)	Conditional, required if gimbal is used to mount the sensor and the sensor's attitude is defined in relation to the gimbal. Gimal attitude may also be provided in the form of a nine-element matrix (item 12).	This parameter provides the pitch angle of a gimbal on to which a sensor is mount.
11	Gimbal Attitude Yaw Angle	The yaw angle of gimbal	Angle (radian)	Conditional, required if gimbal is used to mount the sensor and the sensor's attitude is defined in relation to the gimbal. Gimal attitude may also be provided in the form of a nine-element matrix (item 12).	This parameter provides the yaw angle of a gimbal on to which a sensor is mount.
12	Gimbal Attitude	Gimbal attitude angle	Angles	Conditional, required if gimbal is used to mount the sensor and the	This parameter set provides a matrix of nine angles between the

	Angle Matrix	matrix.	(radians)	sensor's attitude is defined in relation to the gimbal. Gimal attitude may also be provided by its roll, pitch and yaw parameters (items 9-11).	three gimbal CRS axes and the three axes of the CRS the gimbal is located (either platform CRS or an Earth CRS). The matrix is in the form of {{xX,xY,xZ}, {yX,yY,yZ}, {zX,zY,zZ}}, where (x,y,z) is gimbal CRS and (X,Y,Z) is either platform CRS or an Earth CRS
13	Calibrated Effective Focal Length	The calibrated effective focal length	Length (mm)	Required	This parameter provides information on focal length. For fixed lens this is the calibrated effective focal length. For zoom length, this is the actual focal length used when a video image frame is recorded.
14	Horizontal Spatial Resolution	The number of pixel elements along the sensor's horizontal direction.	Int (unitless)	Required	This parameter provides number of pixels along the sensor's horizontal direction (when sensor is at nominal attitude).
15	Vertical Spatial Resolution	The number of pixel elements along the sensor's vertical direction.	Int (unitless)	Required	This parameter provides number of pixels along the sensor's vertical direction (when sensor is at nominal attitude).
16	Horizontal Field of View	The field of view, measured at an angle, across the sensor's horizontal direction.	Angle (radian)	Required	This parameter provides sensor's field of view along its horizontal direction (when sensor is at nominal attitude).
17	Vertical Field of View	The field of view, measured at an angle, across the sensor's	Angle (radian)	Required	This parameter provides sensor's field of view along its vertical direction (when sensor is at

		vertical direction.			nominal attitude).

Table 3 Fitting Metadata Table

ID	Parameter	Definition	Units	Obligation	Description
1	Dimension Name	The dimension names representing dependent and independent variables	CharacterString (unitless)	Required	This parameter provides the names of dimensions representing dependent and independent variables in the fitting function. The dependent variables are usually, i.e., in the forward mapping approach, the target CRS axis names (e.g., latitude, longitude) and the independent variables the names of the CRS of the imagery to be geopositioned or co-registered (e.g., line sample).
2	Power	The power of polynomial	Integer (unitless)	Required	This parameter provides the power of the fitting polynomial function.
3	Coefficients	Polynomial coefficients	Real (unitless)	Required	This parameter provides the coefficient for each term in the polynomial fitting function.
4	Scale	The scale factor to an independent variable.	Real (unitless)	Optional	This parameter provides the scale factor to an independent variable.
5	Translation	The translation coefficient.	Real (unitless)	Optional	This parameter provides the translation or offset coefficient to an independent variable.
6	Numerator/denominator	An identifier for numerator/deno	Integer (unitless)	Conditional, required for	This parameter identifies, in rational function fitting, a polynomial either being numerator or being denominator.

	identification	minator		rational function fitting	

Table 4 Control Point Metadata Table

ID	Parameter	Definition	Units	Obligation	Description
1	Target CRS	The identifier for the target CSR.	URI (unitless)	Required	This parameter provides the identification of the target CRS to which an MI is to be rectified or co-registered.
2	Number of control points	The number of control points	Integer (unitless)	Required	This parameter provides total number of control points available for rectification or registration.
3	Control point position in target CRS	The position coordinate values of control points in target CRS.	DirectPosition	Required	This parameter provides an array of direction position values of the control points in the target CRS.
4	Control point position in source image	The position coordinate values of control points in source image.	DirectPosition	Required	This parameter provides an array of direction position values of the control points in the source image, usually the row/column (or line/sample) numbers.
5	Quality	The quality of control points.	Real	Optional	This parameter provides the quality covariance matrix of the control points.

Table 5 Radiometric and Environmental Metadata

ID	Parameter	Definition	Units	Obligation	Description
1	Calibration scale factor	The scale factor digital number to radiance conversion.	Real (Radiance unit, e.g., $Wsr^{-1}m^{-2}$)	Optional	This parameter provides the scale factor in converting image digital number to radiance (e.g., Radiance=scale*DN+offset)
2	Calibration offset value	The offset value in digital number to radiance conversion.	Real (Radiance unit, e.g., $Wsr^{-1}m^{-2}$)	Optional	This parameter provides the offset value in converting image digital number to radiance. (e.g., Radiance=scale*DN+offset)
3	Ambient illumination	The ambient illumination of the scene recorded.	Real (Radiance unit)	Optional	This parameter provides illumination on the scene recorded by in a motion imagery.
4	Cloud percent	The cloud percentage in the sky.	Real (unitless)	Optinal	This parameter provides an estimation of the cloud percentage in the sky during the recording period.
5	DTM	The digital terrain model of the scene.	Real (length)	Optional	This parameter provides the digital terrain model data, usually in gridded format of the scene, in the area being imaged. Ideally the DTM also cover the location of the sensor and the space between sensor and the scene.
6	Wind speed	The wind speed during recording.	Real (Velocity)	Optional	This parameter provides the wind speed during the time of recording, ideally including the direction of the wind.

7	Humidity	The atmospheric humidity.	Real (unitless, i.e., percentage, or humidity unit)	Optional	This parameter provides the humidity value for the scene during the recording time period.
8	Temperature	Surface or air temperature.	Real (temperature unit)	Optional	This parameter provides the temperature, either air temperature (together with height) or at the ground surface.
9	Soil moisture	The soil moisture value.	Real (relative or absolute moisture unit)	Optional	This parameter provides the estimation or measurement of soil moisture, if bare soil is shown in the imagery and is a subject of observation.
10	Land use/cover type	The land use and/or land cover type.	CharacterString	Optional	This parameter provides the land use and/or land cover (LULC) type of the scene. Ideally the LULC information is provided in a gridded format. If LULC grid is not available, a description of the dominant LULC is also helpful.

* Radiometric metadata include sensor operation, such as aperture and shutter speed, are not included in this table.

Table 6 Discovery and retrieval metadata

ID	Parameter	Definition	Units	Obligation	Description
1	Identifier	The identifier of a motion imagery.	CharacterString	Required	This parameter provides a unique identifier of a motion imagery.
2	Image start time	The start time of the image recording.	DateTime	Required	This parameter provides the start time of the image being recorded.
3	Image end time	The end time of the image recording.	DateTime	Required	This parameter provides the end time of the image being recorded.
4	Geographic extent	The geographic coverage of the imagery.	Real (length)	Required	This parameter provides the spatial coverage of the imagery. The values should be provided together with a 2D or 3D CRS. At least four values are needed (i.e., 2D CRS)
5	Mission description	A description of the imaging mission	CharacterString	Optional	This parameter provides a description, in free text, of the purpose of the motion imagery recording mission.
6	Sensor identification	Identification of the sensor.	CharacterString	Optional	This parameter provides the identification information of the sensor used in the image recording.
7	Sensor type	The type of	CharacterString	Optional	This parameter tells the type of the sensor used in recording.

		sensor			
8	Sensor description	Description of the sensor.	CharacterString	Optional	This parameter provides a description of the sensor used in recording the imagery.
9	Sensor geomerty	The orientation of the sensor.	CharacterString	Optional	This parameter provides a description of the general orientation of the sensor, such as north, east, and southeast.

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