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OGC® EO Data Access Best Practice

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Abstract

This OGC Best Practice document provides conventions and recommendations on how to utilize OGC services to provide access to Earth Observation data.

Keywords

ogcdoc, eo, earth observation, data access, wcs, eo-wcs

Submitting organizations

The following organizations have submitted this Best Practice to the Open GeoSpatial Consortium, Inc.:

- EOX IT Services GmbH
- German Aerospace Center (DLR)
- GeoSolutions S.A.S.
- European Space Agency (ESA)
- Jacobs University Bremen

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Changes to the OGC ® Abstract Specification

The OGC ® Abstract Specification does not require any changes to accommodate the technical contents of this (part of this) document.

Future Work

Please send any suggestions for future work to the document editor or contributors named above.

Foreword

This OGC Best Practice document details proposed configuration and instantiation conventions and recommendations on how to utilize OGC services for access to Earth Observation (EO) data. These proposed conventions and recommendations have been developed in the European Space Agency (ESA) funded project Evolution of EO Online Data Access Services (EVO-ODAS).

It is defined how to utilize WCS with EO products including generic conventions and recommendations for data and metadata mapping and conversions which are to be used in concrete tailorings for specific missions. It further considers how to link to other services like CSW, WMS, and WPS.

Suggested additions, changes, and comments on this draft document are welcome and encouraged. Such suggestions may be submitted by email message, by creating an issue or a pull request at the GitHub repository, or by making suggested changes in an edited copy of this document.

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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 standard set forth in this document, and to provide supporting documentation.

Introduction

The Earth Observation Data Access Best Practice document at hand provides a detailed look at the access to EO data from an OGC perspective.

EO data is typically available as raster data or, in OGC terminology, as coverages. Thus the main OGC service relevant for the data access task is the Web Coverage Service (WCS). Nonetheless further OGC services like the Web Map Service (WMS) and the Web Map Tile Service (WMTS) for visualization, the Catalog Service (CSW, OpenSearch) for discovery, or the Web Processing Service (WPS) for processing need to be taken into account in order to provide a well integrated solution for data consumers.

A WCS 2.0 Earth Observation Application Profile (EO-WCS) [OGC 10-140r2] has been adopted by OGC defining a profile of WCS 2.0 for use on Earth Observation data. Naturally the present document focuses on EO-WCS but makes sure to not forget the surroundings to put it into context.

Centered around WCS and EO-WCS this Best Practice document defines conventions and makes recommendations for the following topics:

- Cross Service Interaction - TODO
- Grouping of Associated Data
- Collection and Product Registration
- Condense Coverage Description Information
- Uniform Coverage Grouping
- WCS Masking Extension
- rangeType Description Enhancements

OGC® EO Data Access Best Practice

Chapter 1. Scope

This OGC Best Practice document details configuration and instantiation conventions for access to Earth Observation (EO) data. It defines how to utilize WCS with EO products including generic conventions and recommendations for data and metadata mapping and conversion which are to be used in concrete tailoring for specific missions. It further considers how to link to other services like CSW, WMS, and WPS.

TODO

Chapter 2. Normative references

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

OGC 06-121r9, *OGC Web Services Common Standard*, version 2.0

OGC 09-146r2, *OGC® Coverage Implementation Schema* (renamed from *OGC® GML Application Schema - Coverages*), version 1.0
Conformance classes used: *gml-coverage*, *gml*, *multipart*, *special-format*

OGC 09-110r4, *OGC® WCS 2.0 Interface Standard- Core: Corrigendum*, version 2.0
Conformance classes used: *core*

OGC 10-140r2, *OGC® Web Coverage Service 2.0 Interface Standard - Earth Observation Application Profile*, version 1.1
Conformance classes used: *eowcs*, *eowcs_geteocoverageset*, *eowcs_get-kvp*, *eowcs_soap*,

OGC 11-053r1, *OGC® Web Coverage Service Interface Standard - CRS Extension*, version 1.0
Conformance classes used: *crs*, *crs-gridded-coverage*

OGC 12-039, *OGC® Web Coverage Service Interface Standard - Scaling Extension*, version 1.0
Conformance classes used: *scaling*

OGC 12-040, *OGC® Web Coverage Service Interface Standard - Range Subsetting Extension*, version 1.0
Conformance classes used: *record-subsetting*

OGC 12-049, *OGC® Web Coverage Service Interface Standard - Interpolation Extension*, version 1.0
Conformance classes used: *interpolation*

OGC 09-147r3, *OGC® Web Coverage Service 2.0 Interface Standard - KVP Protocol Binding Extension - Corrigendum*, version 1.0
Conformance classes used: *get-kvp*

OGC 09-149r1, *OGC® Web Coverage Service 2.0 Interface Standard - XML/SOAP Protocol Binding Extension*, version 1.0
Conformance classes used: *soap*

OGC 12-100r1, *OGC® GML Application Schema - Coverages - GeoTIFF Coverage Encoding Profile*, version 1.0
Conformance classes used: *geotiff-coverage*

OGC 14-100r2, *OGC® CF-netCDF 3.0 encoding using GML Coverage Application Schema*, version 2.0
Conformance classes used: *CF-netCDF-1.6 GML encoding*, *CF-netCDF-1.6 data format*, *CF-netCDF-1.6 multipart data encoding*

OGC 12-108, *OGC® GML Application Schema - Coverages JPEG2000 Coverage Encoding Extension*, version 1.0
Conformance classes used: *jpeg2000-coverage*

OGC 10-157r4, *OGC® Earth Observation Metadata profile of Observations & Measurements*, version 1.1
Conformance classes used: *eop*, *sar*, *opt*

Chapter 3. Terms and definitions

This document uses the standard terms defined in Subclause 5.3 of [OGC 06-121r9], 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 standard.

For the purposes of this document, the terms and definitions given in the above references, particularly EO-WCS [10-140r1], apply. In addition, the following terms and definitions apply. An arrow "→" indicates that the following term is defined in this Clause.

3.1. Coverage

digital representation of a spatio-temporally varying phenomenon as defined in

3.2. Dataset

2-D → EO Coverage

A Dataset usually represents observations obtained by satellite instruments.

3.3. Dataset Series

collection of → EO Coverages

3.4. EO Coverage

Rectified Grid → Coverage or Referenceable Grid → Coverage having an → EO Metadata record and a WGS84 bounding box

3.5. EO Metadata

→ EO Coverage's metadata record

3.6. Stitched Mosaic

→ EO Coverage composed from subsets of one or more co-referenced → Datasets

3.7. EO Product

An EO Product contains one or more related → EO Product Datasets plus metadata and

optionally auxiliary data like → EO Product Quicklooks.

3.8. EO Product Dataset

One or more files each containing one or more → EO Coverages.

3.9. EO Product Quicklook

A visual representation of a usually reduced → EO Product Dataset encoded in an image format. The → EO Product Dataset may combine different bands.

3.10. Lineage record

Data structure documenting an operation that has been applied to the → coverage it is part of

3.11. refers to

contains or references, in its → EO Metadata element as defined in [OGC 10-157r4], the → EO Metadata element of

Chapter 4. Conventions

4.1. UML notation

Unified Modeling Language (UML) static structure diagrams appearing in this specification are used as described in Subclause 5.2 of OGC Web Services Common [OGC 06-121r9].

4.2. Data dictionary tables

The UML model data dictionary is specified herein in a series of tables. The contents of the columns in these tables are described in Subclause 5.5 of [OGC 06-121r9]. The contents of these data dictionary tables are normative, including any table footnotes.

4.3. Namespace prefix conventions

The following namespaces are used in this document. The prefix abbreviations used constitute conventions used here, but are **not** normative. The namespaces to which the prefixes refer are normative, however.

Table 1. Namespace mappings

Prefix	Namespace URI	Description
xsd	http://www.w3.org/2001/XMLSchema	XML Schema namespace
ows	http://www.opengis.net/ows/2.0	OWS Common 2.0
gml	http://www.opengis.net/gml/3.2	GML 3.2.1
gmlcov	http://www.opengis.net/gmlcov/1.0	Coverages Implementation Schema 1.0
wcs	http://www.opengis.net/wcs/2.0	WCS 2.0
eop	http://www.opengis.net/eop/2.1	Earth Observation Metadata Profile of Observations and Measurements
opt	http://www.opengis.net/opt/2.1	Optical Earth Observation Metadata Profile of Observations and Measurements (extension of eop)
sar	http://www.opengis.net/sar/2.1	SAR Earth Observation Metadata Profile of Observations and Measurements (extension of eop)
wcseo	http://www.opengis.net/wcs/wcseo/1.1	WCS Application Profile - Earth Observation 1.1

Prefix	Namespace URI	Description
scal	http://www.opengis.net/wcs/scaling/1.0 (schema uses http://www.opengis.net/WCS_service-extension_scaling/1.0)	WCS Scaling Extension
int	http://www.opengis.net/wcs/interpolation/1.0 (schema uses http://www.opengis.net/WCS_service-extension_interpolation/1.0	WCS Interpolation Extension
crs	http://www.opengis.net/wcs/crs/1.0	WCS CRS Extension
gmd	http://www.isotc211.org/2005/gmd	ISO 19139 Metadata
gmi	http://standards.iso.org/iso/19115/-2/gmi/1.0 or http://www.isotc211.org/2005/gmi	ISO 19139-2 Metadata
mdb	http://standards.iso.org/iso/19115/-3/mdb/1.0	ISO 19115-3 Metadata

4.4. Multiple representations

When multiple representations of the same information are given in a specification document these are consistent. Should this not be the case then this is considered an error, and the XML Schema shall take precedence.

Chapter 5. Cross Service Interaction

5.1. Overview

We propose to address the cross service interaction item by giving recommendations on how to structure the data offered in the various services as well as how to explicitly link between them. These explicit link recommendations include these services: OpenSearch, WMS, WMTS, WCS, and DS-EO.

An example for a data structuring recommendation is that for a collection there should be an EO-WMS layer and an EO-WCS DatasetSeries provided both reusing the ID of the collection. Thus clients know that a product viewed via a GetMap request with TIME parameter can be downloaded via a GetEOCoverageSet request using the same TIME parameter value.

First explicit linking recommendations are given in the "EVO-ODAS Recommendation on building a discovery interface using OpenSearch Technical Note" [RD49] by GeoSolutions. The recommendation there is to use `link` elements with a `rel` attribute of value `wms` ,`wmts`, `wcs`, `wfs`, or `ds-eo` in Atom results to link to the EO Product in the respective service. Note that it also includes recommendations on how to structure these links in order to link to a single product. In short the recommendation is to link to a tailored Capabilities document like e.g., `http://u.rl?service=WMS&acceptVersions=1.3.0&request=GetCapabilities&time=2015-10-02T10:00:00Z&elevation=150`. This covers all links from OpenSearch to any other service.

In the same way recommendations will be given from (EO-)WMS, WMTS, (EO-)WCS, and DS-EO to the respective four other services using for example `wms:DataURL`, in the layer specification of the WMS Capabilities linking to the corresponding EO-WCS DatasetSeries.

TODO

Chapter 6. Coverage Collections

WCS originally was perceived to give access to single coverages taken from a flat set of coverage offerings in the server.

This approach was based on the classical subdivision into metadata services (i.e., catalogs) and data services, connected through some loose coupling (which effectively was never standardized beyond the recommendation to use URLs).

With the progress of requirements and technology it is more and more considered important to merge data and metadata perspectives with the vision of a common integrated information space.

For WCS, this means in particular to further structure a server's offering of coverages along various criteria.

Early on EO-WCS has provided a lead in this by introducing both uniform and non-uniform coverage groupings together with dedicated search functionality which is able to perform a focused search within coverage subsets.

With OGC Coverage Implementation Schema (CIS) 1.1 comes massively enhanced support for structuring coverages. Therefore, a harmonization task has to be accomplished to relate both concepts, which may well lead to an extension of functionality for fully exploiting all benefits.

In the following subsections, we discuss EO-relevant grouping concepts, based on CIS and EO-WCS.

6.1. Grouping of Associated Data

6.1.1. Overview

Modeling the grouped data as coverage itself would directly allow GetCoverage requests but would require rather big changes to WCS. Thus we propose to follow and extend the approach already established in EO- WCS and reuse the concept of DatasetSeries.

As described in the section "Encoding of Multiple Coverages in One File" 3.1.2 above we propose to use `Reference` elements in `Metadata` elements also for associated data. Together with the GetEOCoverageRequest operation and a `mediaType` of `multipart/related` this could be suitable to be used for data access to whole EO Products.

The first part of the multipart response would look like the example below but additionally include `Reference` elements to the associated data inside `Metadata` elements of the `DatasetSeries` element. Of course the second part of the multipart response needs to include all the referenced files.

```
<?xml version="1.0" encoding="UTF-8"?>
<wcseo:EOCoverageSet numberMatched="3" numberReturned="3" xmlns:ows=
"http://www.opengis.net/ows/2.0" xmlns:gml="http://www.opengis.net/gml/3.2"
xmlns:gmlcov="http://www.opengis.net/ mlcov/1.0" xmlns:swe=
"http://www.opengis.net/swe/2.0" xmlns:wcs="http://www.opengis.net/wcs/2.0"
xmlns:wcseo="http://www.opengis.net/wcs/wcseo/1.1" xmlns:eop=
"http://www.opengis.net/eop/2.1" xmlns:om="http://www.opengis.net/om/2.0"
xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:xsi=
"http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation=
"http://www.opengis.net/wcs/wcseo/1.1
http://schemas.opengis.net/wcs/wcseo/1.1/wcsEOAll.xsd">
  <wcseo:RectifiedDataset gml:id="someEOCoverage1">
    <gml:boundedBy>
    ...
    </gml:boundedBy>
    <gml:domainSet>
    ...
    </gml:domainSet>
    <gml:rangeSet>
      <gml:File>
        <gml:rangeParameters xlink:arcrole="fileReference" xlink:href=
"cid:coverage.meta4;someEOCoverage1.tif" xlink:role=
"http://www.opengis.net/spec/GMLCOV_geotiff-coverages/1.0/conf/geotiff-
coverage" />
        <gml:fileReference>
cid:coverage.meta4;someEOCoverage1.tif</gml:fileReference>
        <gml:fileStructure />
        <gml:mimeType>image/tiff</gml:mimeType>
      </gml:File>
    </gml:rangeSet>
    <gmlcov:rangeType>
    ...
    </gmlcov:rangeType>
    <gmlcov:metadata>
      <gmlcov:Extension>
        <wcseo:EOMetadata>
          <eop:EarthObservation gml:id="eop_someEOCoverage1">
          ...
          </eop:EarthObservation>
          <wcseo:lineage>
            <wcseo:referenceGetEOCoverageSet>
              <ows:Reference xlink:href="
http://www.someWCS.org?SERVICE=WCS&amp;amp;VERSION=2.0.1&amp;amp;REQUEST=GetEOCoverageS
et&amp;amp;EOID=someDatasetSeries1&amp;amp;PACKAGEFORMAT=application/metalink4+xml&amp;
MEDIATYPE=multipart/related" />
            </wcseo:referenceGetEOCoverageSet>
```

```
            <gml:timePosition>2016-05-17T12:25:40Z</gml:timePosition>
          </wcseo:lineage>
        </wcseo:EOMetadata>
      </gmlcov:Extension>
    </gmlcov:metadata>
  </wcseo:RectifiedDataset>
  <wcseo:RectifiedDataset gml:id="someEOCoverage2">
    <gml:boundedBy>
    ...
    </gml:boundedBy>
    <gml:domainSet>
    ...
    </gml:domainSet>
    <gml:rangeSet>
      <gml:File>
        <gml:rangeParameters xlink:arcrole="fileReference" xlink:href=
"cid:coverage.meta4;someEOCoverage2.tif" xlink:role=
"http://www.opengis.net/spec/GMLCOV_geotiff-coverages/1.0/conf/geotiff-
coverage" />
        <gml:fileReference>
cid:coverage.meta4;someEOCoverage2.tif</gml:fileReference>
        <gml:fileStructure />
        <gml:mimeType>image/tiff</gml:mimeType>
        </gml:File>
    </gml:rangeSet>
    <gmlcov:rangeType>
    ...
    </gmlcov:rangeType>
    <gmlcov:metadata>
      <gmlcov:Extension>
        <wcseo:EOMetadata>
          <eop:EarthObservation gml:id="eop_someEOCoverage2">
          ...
          </eop:EarthObservation>
          <wcseo:lineage>
            <wcseo:referenceGetEOCoverageSet>
              <ows:Reference xlink:href="
http://www.someWCS.org?SERVICE=WCS&amp;amp;VERSION=2.0.1&amp;amp;REQUEST=GetEOCoverageS
et&amp;amp;EOID=someDatasetSeries1&amp;amp;PACKAGEFORMAT=application/metalink4+xml&amp;
MEDIATYPE=multipart/related" />
            </wcseo:referenceGetEOCoverageSet>
            <gml:timePosition>2016-05-17T12:25:40Z</gml:timePosition>
          </wcseo:lineage>
        </wcseo:EOMetadata>
      </gmlcov:Extension>
    </gmlcov:metadata>
  </wcseo:RectifiedDataset>
```

```
  <wcseo:DatasetSeries>
    <wcseo:DatasetSeriesId>someDatasetSeries1</wcseo:DatasetSeriesId>
    <eop:Footprint gml:id="footprint_someDatasetSeries1">
    ...
    </eop:Footprint>
    <gml:TimePeriod gml:id="someDatasetSeries1_timeperiod">
    ...
    </gml:TimePeriod>
    <ows:Metadata>
      <wcseo:EOMetadata>
        <ows:Reference xlink:href="http://www.someCatalogue.org/eop-
metadatafrom-someDatasetSeries1" xlink:role=
"http://standards.iso.org/iso/19115/-3/mdb/1.0" xlink:title="ISO 19115-3
Metadata" />
        <wcseo:lineage>
          <wcseo:referenceGetEOCoverageSet>
          <ows:Reference xlink:href="http://www.someWCS.org?SERVICE=WCS
&amp;VERSION=2.0.1&amp;REQUEST=GetEOCoverageSet&amp;EOID=someDatasetSeries1&amp
;PACKAGEFORMAT=application/metalink4+xml&amp;MEDIATYPE=multipart/related"/>
        </wcseo:referenceGetEOCoverageSet>
        <gml:timePosition>2016-05-17T12:25:40Z</gml:timePosition>
        </wcseo:lineage>
      </wcseo:EOMetadata>
    </ows:Metadata>
    <wcseo:rectifiedDataset>
      <wcs:CoverageId>someEOCoverage1</wcs:CoverageId>
    </wcseo:rectifiedDataset>
    <wcseo:rectifiedDataset>
      <wcs:CoverageId>someEOCoverage2</wcs:CoverageId>
    </wcseo:rectifiedDataset>
  </wcseo:DatasetSeries>
</wcseo:EOCoverageSet>
```

An additional consideration is to harmonize this proposal with EO-O&M as adopted by EO-WCS. EO-O&M is designed to define a catalog record for one EO product including links to various raster or vector features like measurements, browses, masks, etc.

TODO

6.2. Collection and Product Registration

6.2.1. Overview

We propose to include a high level description of a HTTP REST API to programmatic register collections and products in ODA Systems.

The API needs to specify the request and response structure as well as the payloads. Both, particularly the payload, depend heavily on the functionality available in concrete implementations. Thus we propose to evaluate the suitability to specify collection and product registration including suitability to specify a minimal set of services an ODA System has to support.

The GeoServer REST API 20 serves as basis for our proposal.

TODO

6.3. Uniform Coverage Grouping

6.3.1. Overview

We propose to carefully review to which extent the forthcoming CIS 1.1 is prepared for this.

The new partitioning functionality of CIS 1.1 requires all partitions to share the same range type partitions which is exactly what is ask for in this item. On the other side it requires partitions to not overlap which would require to use real 3D coverages in order to group 2D EO coverages.

This needs to be further reviewed in order to harmonize with the concepts of EO-WCS. In any case this might be best suited to be integrated and documented in the solution to the "General Coverage Grouping" item detailed in section 3.3.1 below.

TODO

Chapter 7. Condense Coverage Description Information

7.1. Overview

OpenSearch is the designated EVO-ODAS endorsed search service. Thus we propose to extend OpenSearch in a way to allow clients to specify the verbosity of the answer using a new parameter named `view`. Several allowed values are defined in that proposal ranging from `full` for everything to `geotime` for a very limited view only including id, name, bbox, start, and end.

Additionally, there is the idea of adding histogram like functionality i.e., requesting summary information for defined buckets like months.

It should be noted that there exists an alternative approach to searching which is based on XPath enabling traversal and subsetting of a server's XML information hierarchy.

OpenSearch and XPath are not competing, but complementary approaches: OpenSearch empowers users to do human-centric search through keywords. XPath, conversely, enables fine-grain drilling into the server's information structure and, hence, is suitable in particular for machine-to-machine communication.

Both search types, therefore, are important for versatile coverage services. In EVO-ODAS, the OpenSearch avenue will be elaborated.

Although XPath looks like a promising approach there are some difficulties particularly from an implementation point of view. In general, an XML document can only be subsetted using XPath once it has been generated. This approach wouldn't scale well on server implementations. Of course particular queries can be computed on the fly but to allow generic XPath queries is quite challenging.

Another issue is, that XPath returns subsets of XML documents without maintaining overlying hierarchy. While it is simple to retrieve a list of coverage IDs for certain search criteria it is difficult if not impossible to retrieve for the same list of coverages tailored coverage descriptions only containing ID, phenomenon time, and footprint.

Further challenges arise when the query is supposed to contain time or spatial subsetting.

TODO

Chapter 8. WCS Masking Extension

8.1. Overview

We propose to extend the GetCoverage request with parameters to request a masking via a mask coverage or polygons e.g. given as GeoJSON or shapefile. The coverage of polygons can be given by reference or, if small enough, included directly in the request in case of polygons as WKT.

The response shall use a defined NoData value for areas outside of the mask.

In the frame of EVO-ODAS this will be described in the EO Data Access Best Practice. Later on this might be promoted to an actual WCS extension.

TODO

Chapter 9. rangeType Description Enhancements

9.1. Overview

The rangeType component of a coverage describes the common data type all this coverage's range values (such as pixels) share. In programming languages, this typically consists of differentiating between signed integer, unsigned integer, float, etc.

The rangeType concept, however, goes far beyond such classical data typing; adopting OGC O&M definitions, a comprehensive semantics description can be expressed indicating the range value type (which can be a classical data type such as "non-negative integer", but can also denote application semantics such as "radiation", "SAR") given by a URL, a definition of the unit of measure of the values, null values, and several more can be expressed.

In the basic, domain-agnostic OGC Coverage Implementation Schema (CIS, formerly known as GML Application Schema, GMLCOV) only these general items are defined. EO-WCS 1.1 extends this range type description, as it is used in WCS 2, with EO-specific detail information.

The extension includes elements to specify the measured physical properties (`wcseo:dataSemantics`), the data types of stored numbers (`wcseo:dataType`), the conversion from stored numbers to physical properties (`wcseo:dataType2dataSemantics`), as well as a hint for how to generate a RGB version (`wcseo:RGBgenerationHint`).

The additional range type information is provided via the `wcseo:rangeTypeExtension` element which is either included once for the whole range type under the `swe:DataRecord` element or separately for each channel, often referred to as band, under each `swe:DataRecord/swe:field/swe:Quantity` element. It may also be included in both locations for example when there is one common RGB generation hint but the data conversion is specific for each band.

The new elements are introduced one by one in the following sections and extensive examples are given below.

9.2. Physical Properties

The `wcseo:rangeTypeExtension` element first includes the `wcseo:dataSemantics` element of type `anyURI`. This element holds an URI preferably resolving to a description of the observed physical property like `http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#Visible`.

This element needs to be synchronized with the `definition` attribute of each `swe:Quantity` element as well as the unit of measure defined via the `code` attribute of

the swe:uom element again of each swe:Quantity element.

XML instance examples included with the OGC schemas make use of http://www.opengis.net/def/property/OGC/0/Radiance for the definition attribute which doesn't resolve to something useful as expected. Another URI used in OGC examples is http://sweet.jpl.nasa.gov/2.0/physRadiation.owl#Radiance. The latest version of this at the time of writing is http://sweet.jpl.nasa.gov/2.3/propEnergyFlux.owl#Radiance.

It is suspected that the ESA funded projects RARE, SMAAD, OBEOS, and/or PRODTREES define URIs to describe physical properties as well. However, a web research didn't bring up anything useful in this direction. Thus, for the time being, the examples given use the SWEET ontologies defined by the NASA Jet Propulsion Laboratory (http://sweet.jpl.nasa.gov).

An example for a unit of measure code is W.m-2.sr-1 as defined by http://sweet.jpl.nasa.gov/2.3/reprSciUnits.owl#wattPerMeterSquaredPerSteradian for radiance as used above.

SWE Common mandates the usage of units as defined by http://aurora.regenstrief.org/UCUM. However, this server is not accessible anymore and seems to be moved to http://unitsofmeasure.org/ucum.html.

Another physical property example is spectral radiance with URI http://sweet.jpl.nasa.gov/2.3/propEnergyFlux.owl#SpectralRadiance and unit of measure code W.m-2.sr-1.nm-1 as defined by http://sweet.jpl.nasa.gov/2.3/reprSciUnits.owl#wattPerMeterSquaredPerSteradianPerWavelength.

9.3. Data Types

The wcseo:rangeTypeExtension element further includes the wcseo:dataType element, again of type anyURI. This element again holds an URI preferably resolving to a description of the data type. Examples of such URIs are http://www.opengis.net/def/dataType/OGC/1.1/nonNegativeInteger, http://www.opengis.net/def/dataType/OGC/0/unsignedInt, or http://www.opengis.net/def/property/netcdf/1.0/unsignedShort.

The data type is also implicitly provided via the actual coverage encoding. However, to describe it explicitly in the wcseo:rangeTypeExtension element allows clients to retrieve it also in coverage descriptions and without need to understand and parse the actual coverage encoding format.

9.4. Conversion from Data Types to Physical Properties

In order to be able to convert the stored numbers to the value of the actual measured

physical property the wcseo:dataType2dataSemantics element is added to the wcseo:rangeTypeExtension. It describes the conversion via two real number intervals and a type.

wcseo:intervalFrom gives the interval of values stored in the coverage, wcseo:intervalTo specifies the interval the stored values are converted to, and wcseo:type defines which conversion method to use. Both intervals are given via two real numbers and the type via anyURI.

The example below describes a linear transformation, as typically used for optical data, from [1,4095] to [390.0000,780.0000] i.e. for a value x between 1 and 4095 the actual measured value y is calculated as: y = 390 + (x-1) * (780-390) / (4095-1)

```
<wcseo:dataType2dataSemantics>
  <wcseo:intervalFrom>1 4095</wcseo:intervalFrom>
  <wcseo:intervalTo>390.0000 780.0000</wcseo:intervalTo>
  <wcseo:type>
http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#Linear</wcseo:type>
</wcseo:dataType2dataSemantics>
```

Another example, given below, describes the inverse to a logarithmic transformation as for example sometimes used for radar data. The transformation of stored values x in the interval [1,65535] to observed values y in the interval [2,1000000000] is given by y = 2 * e^(((x-1)*(ln(1000000000)-ln(2)))/(65535-1)).

```
<wcseo:dataType2dataSemantics>
  <wcseo:intervalFrom>1 65535</wcseo:intervalFrom>
  <wcseo:intervalTo>2 1000000000</wcseo:intervalTo>

<wcseo:type>http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#ExponentialFunct
ion</wcseo:type>
</wcseo:dataType2dataSemantics>
```

9.5. Hint for RGB Generation

The last element in the wcseo:rangeTypeExtension element is the wcseo:RGBgenerationHint element. It is meant to provide a hint for clients wanting to visualize the data. It includes the elements wcseo:bandSequence, wcseo:intervalFrom, wcseo:intervalTo, and wcseo:type. The first is a list of three band names or band arithmetic instructions delimited by spaces used for the three bands to generate the RGB version. The names used shall be equal to name attributes of the respective swe:field element. The other three elements are comparable to the ones used in the data conversion above.

The example below describes the RGB generation from a single band product by reusing the single band three times and logarithmically stretching the interval [100,10000000] to [1,255] i.e. value x is converted to y using y = ((ln(x)-ln(100))*(255-1))/(ln(10000000)-ln(100))+1.

```
<wcseo:RGBgenerationHint>
  <wcseo:bandSequence>gray gray gray</wcseo:bandSequence>
  <wcseo:intervalFrom>100 10000000</wcseo:intervalFrom>
  <wcseo:intervalTo>1 255</wcseo:intervalTo>
  <wcseo:type>
http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#Logarithmic</wcseo:type>
</wcseo:RGBgenerationHint>
```

9.6. Recommended definitions

This section details our recommendations for the most commonly used data as well as for data not covered here. Of course data providers are free to choose any definitions, it's just highly recommended to use resolvable URIs providing meaningful descriptions ideally machine as well as human readable.

9.6.1. `wcseo:dataSemantics`, `swe:Quantity/@definition`, and `swe:uom/@code`

The non-exhaustive list below provides recommendations for the values of the three items `wcseo:dataSemantics`, `definition` attribute of `swe:Quantity`, and `code` attribute of `swe:Quantity/swe:uom` for the most common use cases.

- Panchromatic
  - `wcseo:dataSemantics`
    - `http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#Visible`
  - `definition`
    - `http://sweet.jpl.nasa.gov/2.3/propEnergyFlux.owl#SpectralRadiance`
  - `code`
    - `W.m-2.sr-1.nm-1`
- RGB
  - `wcseo:dataSemantics`
    - `http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#Red`
    - `http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#Green`
    - `http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#Blue`
  - `definition`
    - `http://sweet.jpl.nasa.gov/2.3/propEnergyFlux.owl#SpectralRadiance`

    - code
        - W.m-2.sr-1.nm-1

- SAR
    - wcseo:dataSemantics
        - http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#CBand
    - definition
        - http://sweet.jpl.nasa.gov/2.3/propSpaceMultidimensional.owl#RadarCrossSection
    - code
        - dB

- Further URIs
    - wcseo:dataSemantics
        - Most concepts in http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl
    - definition
        - http://sweet.jpl.nasa.gov/2.3/propEnergyFlux.owl#Radiance
        - http://sweet.jpl.nasa.gov/2.3/propEnergyFlux.owl#Intensity
    - code
        - W.m-2.sr-1
        - W.m-2

9.6.2. wcseo:dataType

The wcseo:dataType needs to match the data type actually used in the coverage encoding like GeoTIFF. The non-exhaustive list below provides recommendations for URIs to use. Further definitions can be retrieved using the base URIs from the examples given below.

- http://www.opengis.net/def/dataType/OGC/0/unsignedByte
- http://www.opengis.net/def/dataType/OGC/0/unsignedShort
- http://www.opengis.net/def/dataType/OGC/0/unsignedInt
- http://www.opengis.net/def/dataType/OGC/0/unsignedLong
- http://www.w3.org/2001/XMLSchema#unsignedByte
- http://www.w3.org/2001/XMLSchema#unsignedShort
- http://www.w3.org/2001/XMLSchema#integer
- http://www.w3.org/2001/XMLSchema#nonNegativeInteger
- http://www.w3.org/2001/XMLSchema#double

Other possible but not recommended values are provided in the list below.

- http://www.opengis.net/def/dataType/OGC/1.1/nonNegativeInteger
  http://www.opengis.net/def/property/netcdf/1.0/unsignedShort

9.6.3. wcseo:type in wcseo:dataType2dataSemantics and wcseo:RGBgenerationHint

Recommendations for possible values for the wcseo:type element used to define data conversions are provided below.

- http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#Linear
- http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#Logarithmic
- http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#ExponentialFunction

9.6.4. wcseo:bandSequence

The wcseo:bandSequence element used in the wcseo:RGBgenerationHint is defined as type NameTriple which is a space delimited list of three elements of type anyURI. Typically these three elements each reference a name attribute of a swe:field element. An additional option is to define three arithmetic expression like "band1"*1/3+"band2"*2/3. Note that the arithmetic expressions themselves need to be URL-encoded and particularly must not include spaces. A valid example would be band1%2F3%2Bband2%2A2%2F3 band1%2A2%2F3%2Bband2%2F3 %28band1%2Bband3%29%2F2.

9.6.5. swe:DataRecord/@definition

The non-exhaustive list below provides recommendations for the value of the definition` attribute of swe:DataRecord.

- http://www.opengis.net/def/property/OGC-EO/0/opt/SpectralMode/PANCHROMATIC
- http://www.opengis.net/def/property/OGC-EO/0/opt/SpectralMode/COLOR
- http://www.opengis.net/def/property/OGC-EO/0/opt/SpectralMode/MULTISPECTRAL
- http://www.opengis.net/def/property/OGC-EO/0/sar/PolarizationMode/HH
- http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#Monochromatic
- http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#Polychromatic

The list below shows other possible but not recommended URIs.

- http://www.opengis.net/def/ogc-eo/opt/SpectralMode/PANCHROMATIC
- http://www.opengis.net/def/ogc-eo/opt/SpectralMode/COLOR
- http://www.opengis.net/def/order/OGC-EO/0/SpectralBandColorComposition
- http://www.opengis.net/def/order/OGC-EO/0/SpectralBandComposition

9.6.6. swe:field/@name vs. swe:field/swe:Quantity/swe:identifier

The name attribute of swe:field is defined as type NCName. This mainly means that it must not include characters like : (colon), @, $, %, &, /, +, ,, ;, or any whitespace characters. If further must not start with a number, minus, or dot.

The range subsetting extension of WCS [OGC 12-040] uses this name attribute in its RangeComponent element to select bands for retrieval.

Coverages, however, may use not NCName compliant IDs for their bands. It is, for example, quite common to identify variables within a netCDF file with strings including blanks or colons.

The swe:field element includes in its swe:Quantity element a swe:identifier element which is of type anyURI and can potentially hold any complex ID given it is URL-encoded.

For coverages using non NCName IDs for their bands it is recommended to provide the full IDs, potentially URL-encoded, in the swe:identifier element. It is further recommended to use the respective first word (NCNAME type substring i.e. starting from it's first character up to and excluding the first character which is not allowed in an NCName) of the IDs for the name attributes.

For example an ID of gray band should use gray for the name attribute and gray%20band for the swe:identifier element.

9.6.7. swe:nilValue/@reason

The recommendations for the value of the reason attribute of swe:nilValue are given below.

- http://www.opengis.net/def/nil/OGC/0/unknown
- http://www.opengis.net/def/nil/OGC/0/BelowDetectionRange
- http://www.opengis.net/def/nil/OGC/0/AboveDetectionRange
- http://www.opengis.net/def/nil/OGC/0/inapplicable
- http://www.opengis.net/def/nil/OGC/0/missing
- http://www.opengis.net/def/nil/OGC/0/template
- http://www.opengis.net/def/nil/OGC/0/withheld

9.7. Examples

The following provides an example gmlcov:rangeType element including additional range type information for RGB generation on swe:DataRecord level as well as data conversion information on swe:Quantity level.

```
<gmlcov:rangeType>
  <swe:DataRecord definition="http://www.opengis.net/def/property/OGC-
EO/0/opt/SpectralMode/PANCHROMATIC">
    <swe:extension>
      <wcseo:rangeTypeExtension>
        <wcseo:RGBgenerationHint>
          <wcseo:bandSequence>gray gray gray</wcseo:bandSequence>
          <wcseo:intervalFrom>1 4095</wcseo:intervalFrom>
          <wcseo:intervalTo>1 255</wcseo:intervalTo>
```

```
<wcseo:type>http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#Logarithmic</wcs
eo:type>
        </wcseo:RGBgenerationHint>
      </wcseo:rangeTypeExtension>
    </swe:extension>
    <swe:label>Gray Channel/Band</swe:label>
    <swe:field name="gray">
      <swe:Quantity definition=
"http://sweet.jpl.nasa.gov/2.3/propEnergyFlux.owl#SpectralRadiance">
        <swe:extension>
          <wcseo:rangeTypeExtension>

<wcseo:dataSemantics>http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#Visibl
e</wcseo:dataSemantics>

<wcseo:dataType>http://www.opengis.net/def/dataType/OGC/0/unsignedShort</wcseo:
dataType>
            <wcseo:dataType2dataSemantics>
              <wcseo:intervalFrom>1 4095</wcseo:intervalFrom>
              <wcseo:intervalTo>390.0000 780.0000</wcseo:intervalTo>

<wcseo:type>http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#Linear</wcseo:ty
pe>
            </wcseo:dataType2dataSemantics>
          </wcseo:rangeTypeExtension>
        </swe:extension>
        <swe:identifier>gray</swe:identifier>
        <swe:label>Gray Channel/Band</swe:label>
        <swe:description>Gray Channel/Band</swe:description>
        <swe:nilValues>
          <swe:NilValues>
            <swe:nilValue reason="http://www.opengis.net/def/nil/OGC/0/unknown
">0</swe:nilValue>
          </swe:NilValues>
        </swe:nilValues>
        <swe:uom code="W.m-2.sr-1.nm-1"/>
        <swe:constraint>
          <swe:AllowedValues>
            <swe:interval>0 4095</swe:interval>
            <swe:significantFigures>4</swe:significantFigures>
          </swe:AllowedValues>
        </swe:constraint>
      </swe:Quantity>
    </swe:field>
  </swe:DataRecord>
</gmlcov:rangeType>
```

The following is an example of a multispectral range type.

```
<gmlcov:rangeType>
  <swe:DataRecord definition="http://www.opengis.net/def/property/OGC-
EO/0/opt/SpectralMode/MULTISPECTRAL">
    <swe:extension>
      <wcseo:rangeTypeExtension>
        <wcseo:RGBgenerationHint>
          <wcseo:bandSequence>red green blue</wcseo:bandSequence>
          <wcseo:intervalFrom>1 65535</wcseo:intervalFrom>
          <wcseo:intervalTo>1 255</wcseo:intervalTo>

<wcseo:type>http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#Logarithmic</wcs
eo:type>
        </wcseo:RGBgenerationHint>
      </wcseo:rangeTypeExtension>
    </swe:extension>
    <swe:label>Multispectral product</swe:label>
    <swe:field name="blue">
      <swe:Quantity definition=
"http://sweet.jpl.nasa.gov/2.3/propEnergyFlux.owl#SpectralRadiance">
        <swe:extension>
          <wcseo:rangeTypeExtension>

<wcseo:dataSemantics>http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#Blue</
wcseo:dataSemantics>

<wcseo:dataType>http://www.opengis.net/def/dataType/OGC/0/unsignedShort</wcseo:
dataType>
            <wcseo:dataType2dataSemantics>
              <wcseo:intervalFrom>1 65535</wcseo:intervalFrom>
              <wcseo:intervalTo>455.0 492.0</wcseo:intervalTo>

<wcseo:type>http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#Linear</wcseo:ty
pe>
            </wcseo:dataType2dataSemantics>
          </wcseo:rangeTypeExtension>
        </swe:extension>
        <swe:identifier>blue</swe:identifier>
        <swe:label>Blue Channel/Band</swe:label>
        <swe:description>Blue Channel/Band</swe:description>
        <swe:nilValues>
          <swe:NilValues>
            <swe:nilValue reason="http://www.opengis.net/def/nil/OGC/0/unknown
">0</swe:nilValue>
          </swe:NilValues>
```

```
        </swe:nilValues>
        <swe:uom code="W.m-2.sr-1.nm-1"/>
        <swe:constraint>
          <swe:AllowedValues>
            <swe:interval>0 65535</swe:interval>
            <swe:significantFigures>5</swe:significantFigures>
          </swe:AllowedValues>
        </swe:constraint>
      </swe:Quantity>
    </swe:field>
    <swe:field name="green">
      <swe:Quantity definition=
"http://sweet.jpl.nasa.gov/2.3/propEnergyFlux.owl#SpectralRadiance">
        <swe:extension>
          <wcseo:rangeTypeExtension>

<wcseo:dataSemantics>http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#Green<
/wcseo:dataSemantics>

<wcseo:dataType>http://www.opengis.net/def/dataType/OGC/0/unsignedShort</wcseo:
dataType>
            <wcseo:dataType2dataSemantics>
              <wcseo:intervalFrom>1 65535</wcseo:intervalFrom>
              <wcseo:intervalTo>492.0 557.0</wcseo:intervalTo>

<wcseo:type>http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#Linear</wcseo:ty
pe>
            </wcseo:dataType2dataSemantics>
          </wcseo:rangeTypeExtension>
        </swe:extension>
        <swe:identifier>green</swe:identifier>
        <swe:label>Green Channel/Band</swe:label>
        <swe:description>Green Channel/Band</swe:description>
        <swe:nilValues>
          <swe:NilValues>
            <swe:nilValue reason="http://www.opengis.net/def/nil/OGC/0/unknown
">0</swe:nilValue>
          </swe:NilValues>
        </swe:nilValues>
        <swe:uom code="W.m-2.sr-1.nm-1"/>
        <swe:constraint>
          <swe:AllowedValues>
            <swe:interval>0 65535</swe:interval>
            <swe:significantFigures>5</swe:significantFigures>
          </swe:AllowedValues>
        </swe:constraint>
      </swe:Quantity>
```

```
    </swe:field>
    <swe:field name="yellow">
      <swe:Quantity definition=
"http://sweet.jpl.nasa.gov/2.3/propEnergyFlux.owl#SpectralRadiance">
        <swe:extension>
          <wcseo:rangeTypeExtension>

<wcseo:dataSemantics>http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#Yellow
</wcseo:dataSemantics>

<wcseo:dataType>http://www.opengis.net/def/dataType/OGC/0/unsignedShort</wcseo:
dataType>
            <wcseo:dataType2dataSemantics>
              <wcseo:intervalFrom>1 65535</wcseo:intervalFrom>
              <wcseo:intervalTo>557.0 597.0</wcseo:intervalTo>

<wcseo:type>http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#Linear</wcseo:ty
pe>
            </wcseo:dataType2dataSemantics>
          </wcseo:rangeTypeExtension>
        </swe:extension>
        <swe:identifier>yellow</swe:identifier>
        <swe:label>Yellow Channel/Band</swe:label>
        <swe:description>Yellow Channel/Band</swe:description>
        <swe:nilValues>
          <swe:NilValues>
            <swe:nilValue reason="http://www.opengis.net/def/nil/OGC/0/unknown
">0</swe:nilValue>
          </swe:NilValues>
        </swe:nilValues>
        <swe:uom code="W.m-2.sr-1.nm-1"/>
        <swe:constraint>
          <swe:AllowedValues>
            <swe:interval>0 65535</swe:interval>
            <swe:significantFigures>5</swe:significantFigures>
          </swe:AllowedValues>
        </swe:constraint>
      </swe:Quantity>
    </swe:field>
    <swe:field name="orange">
      <swe:Quantity definition=
"http://sweet.jpl.nasa.gov/2.3/propEnergyFlux.owl#SpectralRadiance">
        <swe:extension>
          <wcseo:rangeTypeExtension>

<wcseo:dataSemantics>http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#Orange
</wcseo:dataSemantics>
```

```
<wcseo:dataType>http://www.opengis.net/def/dataType/OGC/0/unsignedShort</wcseo:
dataType>
            <wcseo:dataType2dataSemantics>
              <wcseo:intervalFrom>1 65535</wcseo:intervalFrom>
              <wcseo:intervalTo>597.0 622.0</wcseo:intervalTo>

<wcseo:type>http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#Linear</wcseo:ty
pe>
            </wcseo:dataType2dataSemantics>
          </wcseo:rangeTypeExtension>
        </swe:extension>
        <swe:identifier>orange</swe:identifier>
        <swe:label>Orange Channel/Band</swe:label>
        <swe:description>Orange Channel/Band</swe:description>
        <swe:nilValues>
          <swe:NilValues>
            <swe:nilValue reason="http://www.opengis.net/def/nil/OGC/0/unknown
">0</swe:nilValue>
          </swe:NilValues>
        </swe:nilValues>
        <swe:uom code="W.m-2.sr-1.nm-1"/>
        <swe:constraint>
          <swe:AllowedValues>
            <swe:interval>0 65535</swe:interval>
            <swe:significantFigures>5</swe:significantFigures>
          </swe:AllowedValues>
        </swe:constraint>
      </swe:Quantity>
    </swe:field>
    <swe:field name="red">
      <swe:Quantity definition=
"http://sweet.jpl.nasa.gov/2.3/propEnergyFlux.owl#SpectralRadiance">
        <swe:extension>
          <wcseo:rangeTypeExtension>

<wcseo:dataSemantics>http://sweet.jpl.nasa.gov/2.3/stateSpectralBand.owl#Red</w
cseo:dataSemantics>

<wcseo:dataType>http://www.opengis.net/def/dataType/OGC/0/unsignedShort</wcseo:
dataType>
            <wcseo:dataType2dataSemantics>
              <wcseo:intervalFrom>1 65535</wcseo:intervalFrom>
              <wcseo:intervalTo>622.0 780.0</wcseo:intervalTo>

<wcseo:type>http://sweet.jpl.nasa.gov/2.3/reprMathFunction.owl#Linear</wcseo:ty
pe>
```

```
            </wcseo:dataType2dataSemantics>
          </wcseo:rangeTypeExtension>
        </swe:extension>
        <swe:identifier>red</swe:identifier>
        <swe:label>Red Channel/Band</swe:label>
        <swe:description>Red Channel/Band</swe:description>
        <swe:nilValues>
          <swe:NilValues>
            <swe:nilValue reason="http://www.opengis.net/def/nil/OGC/0/unknown
">0</swe:nilValue>
          </swe:NilValues>
        </swe:nilValues>
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        <swe:constraint>
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            <swe:interval>0 65535</swe:interval>
            <swe:significantFigures>5</swe:significantFigures>
          </swe:AllowedValues>
        </swe:constraint>
      </swe:Quantity>
    </swe:field>
  </swe:DataRecord>
</gmlcov:rangeType>
[#conclusions,reftext='10']
== Conclusions
```

This section summarizes intended use and benefits of EO-WCS 1.1.

Among others, this might mention that EO-WCS 1.0 has inspired coverage extensions, and it can be expected that EO-WCS 1.1 work will have a similar impact.

TODO

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- [8] OGC 09-025r2, OpenGIS Web Feature Service 2.0 Interface Standard - With Corrigendum, version 2.0.2

Annex A: Revision History

Date	Release	Author	Paragraph modified	Description
TBD	0.0.1	Stephan Meißl	All	Draft proposal from ESA project EVO-ODAS