

OGC Testbed-13
DCAT/SRIM Engineering Report

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Publication Date: 2018-01-08

Approval Date: 2017-12-07

Posted Date: 2017-11-15

Reference number of this document: OGC 17-040

Reference URL for this document: <http://www.opengis.net/doc/PER/t13-UG002>

Category: Public Engineering Report

Editor: Stephen McCann, Roger Brackin, Gobe Hobona

Title: OGC Testbed 13: DCAT/SRIM Engineering Report

OGC Engineering Report

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Chapter 1. Summary

This engineering report captures the requirements, solutions, and implementation experiences of the Semantic Registry work package in Testbed-13. The engineering report describes the implementation of a RESTful Semantic Registry that supports the Semantic Registry Information Model (SRIM) which is based on the Data Catalog (DCAT) specification. A discussion of the applicability of the SRIM to the United States Geological Survey (USGS) and the National Geospatial Intelligence Agency (NGA) metadata is also presented, including an analysis of a set of controlled vocabularies from both organizations. Best Practice guidelines for the use of SRIM are also provided. The engineering report discusses the application of Shapes Constraint Language (SHACL) to aspects of Linked Data. Recognizing the benefits that asynchronous access has to offer web services, a description of the work undertaken by the testbed in implementing publish/subscribe functionality between a Semantic Registry and a Catalogue Service for the Web (CSW) is also presented.

1.1. Requirements

The work presented in this engineering report addresses the following requirements:

1. SRIM applicability to USGS and NGA metadata: Testbed-13 was tasked with investigating the applicability of SRIM to a number of sponsor-provided metadata sets.
2. SRIM Best Practices: Testbed-13 was tasked with producing a Best Practice document for creating metadata for datasets and services by mapping ISO 19115 to SRIM.
3. SHACL: Testbed-13 was tasked with investigating the application of SHACL shapes for defining application profiles, form generation and data entry, data validation, and quality control of linked data information.
4. Pub/Sub Support: Testbed-13 was tasked with extending the Semantic Registry concept with publish/subscribe support for harvested catalogues or other instances of Semantic Registries.
5. Controlled Vocabularies: Testbed-13 was tasked with exploring in detail the kind of metadata needed to enable search on controlled vocabularies by defining an ontology that addresses all aspects listed above.
6. Registry Application Programming Interface (API): Testbed-13 was tasked with developing a Representational State Transfer (REST) API to search and access vocabulary metadata and their terms.

1.2. Key Findings and Prior-After Comparison

Previous work on the semantic registry was carried out as part of the [Semantic Portrayal, Registry and Mediation Engineering Report](http://docs.opengeospatial.org/per/16-059.html) [http://docs.opengeospatial.org/per/16-059.html] for Testbed 12. This designed a Semantic Registry data model using the W3C Data Catalog Vocabulary (DCAT), Dublin Core Metadata Terms vocabulary and the W3C Provenance, Authoring and Versioning ontology.

Under Testbed 13, the extensibility of the Semantic Registry data model has been demonstrated by developing a Map and Layer profile of SRIM. This profile was used to demonstrate the applicability of SRIM to ISO 19139 and ISO 19115-3 metadata.

In addition, SHACL has been used for the first time to describe the data model and perform validation, ensuring data integrity.

1.3. What does this ER mean for the Working Group and OGC in general

This engineering report is important to the OGC Geosemantics Domain Working Group because it advances the semantic enablement of geospatial catalogues, potentially providing a bridge between the geospatial, Linked Data and semantic web communities. The work presented in the ER will also inform the development of a Best Practice specification for DCAT and GeoDCAT within the OGC.

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1.5. Future Work

This engineering report concludes that a standard for a RESTful semantic registry service, that uses SHACL for validation at data-ingest, is feasible and needed. Future OGC testbeds therefore should advance this concept by designing the requirements and test suites for a RESTful semantic registry service standard, that also uses SHACL for validation at data-ingest. With regard to PubSub CSW, this testbed demonstrated how the OGC PubSub specification could be implemented alongside an OGC Catalogue Service. Future OGC testbeds should therefore explore the potential for developing further bindings in addition to those already supported by the PubSub 1.0 standard.

1.6. Foreword

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

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

Chapter 2. References

The following normative documents are referenced in this document.

- [Data Catalog Vocabulary \(DCAT\)](https://www.w3.org/TR/vocab-dcat/) [https://www.w3.org/TR/vocab-dcat/]
- [Friend of a Friend Vocabulary \(FOAF\)](http://xmlns.com/foaf/spec/) [http://xmlns.com/foaf/spec/]
- [OGC 12-168r6, OGC® Catalogue Services 3.0 - General Model, June 2016](http://docs.openeospatial.org/is/12-168r6/12-168r6.html) [http://docs.openeospatial.org/is/12-168r6/12-168r6.html]
- [OGC 07-006r1, OpenGIS Catalogue Service Implementation Specification 2.0.2, February 2007](http://portal.openeospatial.org/files/?artifact_id=20555) [http://portal.openeospatial.org/files/?artifact_id=20555]
- [OGC 16-137r2, OGC Testbed-12 PubSub / Catalog Engineering Report](http://docs.openeospatial.org/per/16-137r2.html) [http://docs.openeospatial.org/per/16-137r2.html]
- [OGC 16-059, OGC Testbed-12 Semantic Portrayal, Registry and Mediation Engineering Report](http://docs.openeospatial.org/per/16-059.html) [http://docs.openeospatial.org/per/16-059.html]
- [OGC 06-121r9, OGC® Web Services Common Standard](https://portal.openeospatial.org/files/?artifact_id=38867&version=2) [https://portal.openeospatial.org/files/?artifact_id=38867&version=2]
- [ISO 25964-1:2011\(en\) Information and documentation - Thesauri and interoperability with other vocabularies - Part 1: Thesauri for information retrieval](https://www.iso.org/obp/ui/#iso:std:iso:25964:-1:ed-1:v1:en) [https://www.iso.org/obp/ui/#iso:std:iso:25964:-1:ed-1:v1:en]
- [ISO/TS 19115-3:2016, Geographic information - Metadata - Part 3: XML schema implementation for fundamental concepts, August 2016](https://www.iso.org/standard/32579.html) [https://www.iso.org/standard/32579.html]
- [ISO/IEC 19763-1:2015 Information technology—Metamodel framework for interoperability \(MFI\)— Part 1: Framework](https://www.iso.org/standard/64637.html) [https://www.iso.org/standard/64637.html]
- [W3C SHACL, Shapes Constraint Language, July 2017](https://www.w3.org/TR/shacl/) [https://www.w3.org/TR/shacl/]

Chapter 3. Terms and definitions

For the purposes of this report, the definitions specified in Clause 4 of the OWS Common Implementation Standard [OGC 06-121r9] shall apply. In addition, the following terms and definitions apply.

3.1. interoperability

capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units [ISO 19119]

3.2. metadata

data about data

3.3. model

abstraction of some aspects of a universe of discourse [ISO 19109]

3.4. ontology

a formal specification of concrete or abstract things, and the relationships among them, in a prescribed domain of knowledge [ISO/IEC 19763]

3.5. profile

set of one or more base standards and - where applicable - the identification of chosen clauses, classes, subsets, options and parameters of those base standards that are necessary for accomplishing a particular function [ISO 19101, ISO 19106]

Chapter 4. Conventions

4.1. Abbreviated terms

- CSW Catalogue Service for the Web
- DCAT Data Catalogue
- eb-RIM electronic business Registry Information Model
- OGC Open Geospatial Consortium
- OWL Web Ontology Language
- OWS OGC Web Services
- RDF Resource Description Framework
- SDI Spatial Data Infrastructure
- SQL Structured Query Language
- SRIM Semantic Registry Information Model
- UML Unified Modeling Language

Chapter 5. Overview

This engineering report is organized into the following main sections:

- **Introduction:** This section introduces the Semantic Registry, OGC Catalogue Services and the architecture adopted for the semantics part of Testbed-13.
- **SRIM applicability to USGS and NGA metadata:** This section presents a cross walk from capabilities metadata of a Web Map Service (WMS) Layer (as described by the schema of a GetCapabilities response) to properties of an SRIM Item. The section proposes a Layer and Map Profile Design and makes recommendations for changes to the SRIM.
- **SRIM Best Practices:** This section presents best practices for the use of SRIM. The best practices cover the use of identifiers, documentation of lineage and recording of associations.
- **SHACL:** This section provides an overview of SHACL and presents examples.
- **Pub/Sub Support:** This section describes the Testbed-13 implementation of a Publish-Subscribe solution involving the Semantic Registry and CSW.
- **Controlled Vocabularies:** This section presents a classification of vocabulary types, and discusses various aspects of controlled vocabularies; using sponsor-provided controlled vocabularies as a reference. Aspects discussed include relationships between vocabularies, statistical information about vocabularies, schema encoding, expressiveness, preferred prefixes, preferred namespaces, governance metadata and versioning information.
- **Design of the Controlled Vocabulary Ontology:** This section proposes an ontology for describing controlled vocabularies.
- **Semantic Registry API:** This section describes the RESTful API of the Semantic Registry.
- **Appendix A** presents mappings between DCAT and SRIM.
- **Appendix B** presents example GetRecord requests/responses in ISO 19139 and ISO 19115-3 format.

Chapter 6. Introduction

6.1. Semantic Registry

Amongst the achievements of Testbed-12 was the development of a new ontology called the Semantic Registry Information Model (SRIM). SRIM is a superset of DCAT and some of its derivatives namely DCAT-AP and GeoDCAT-AP. It draws on aspects of ISO 19135, the ISO item registration standard, to extend the `dcat:Dataset` class by offering an extension of this class called the `srim:Item` which addresses limitations of DCAT such as support for services. SRIM also leverages other well-known metadata standards such as Dublin Core and ISO 19115. It also offers detailed metadata to facilitate semantic search of geospatial data, schema, schema mappings, and other artifacts.

Another achievement was development of an initial version of the Semantic Registry Service (initially referred to as DCAT REST API) with the purpose of enabling metadata interchange between multiple catalogues. The Semantic Registry Service implemented a RESTful API based on the Hypermedia Application Language (HAL) with JSON-LD as the payload. HAL is a draft specification of the Internet Engineering Task Force (IETF). The Semantic Registry Service REST API followed the principle that every endpoint of the API should offer and SRIM-based Linked Data representation of the resources.

6.2. OGC Catalogue Service

The OGC Catalogue Services specification provides a general interface model that describes a set of abstract service interfaces that support the discovery, access, maintenance and organization of catalogues of geospatial information resources (OGC 12-168r6). The interfaces are designed to enable client applications or end-users to find information that exists in distributed computing environments. Amongst the bindings offered by the Catalogue Service standard is HTTP, which is arguably the most widely adopted of the Catalogue Service bindings. The HTTP binding is more commonly referred to as Catalogue Services for the Web (CSW).

6.3. Architecture

To integrate components within this work package, the architecture presented in [Figure 1](#) was implemented. The illustration shows how a CSW was deployed and extended to act as a notification publisher. The illustration also shows how a Semantic Registry was deployed and configured to act as a subscriber.

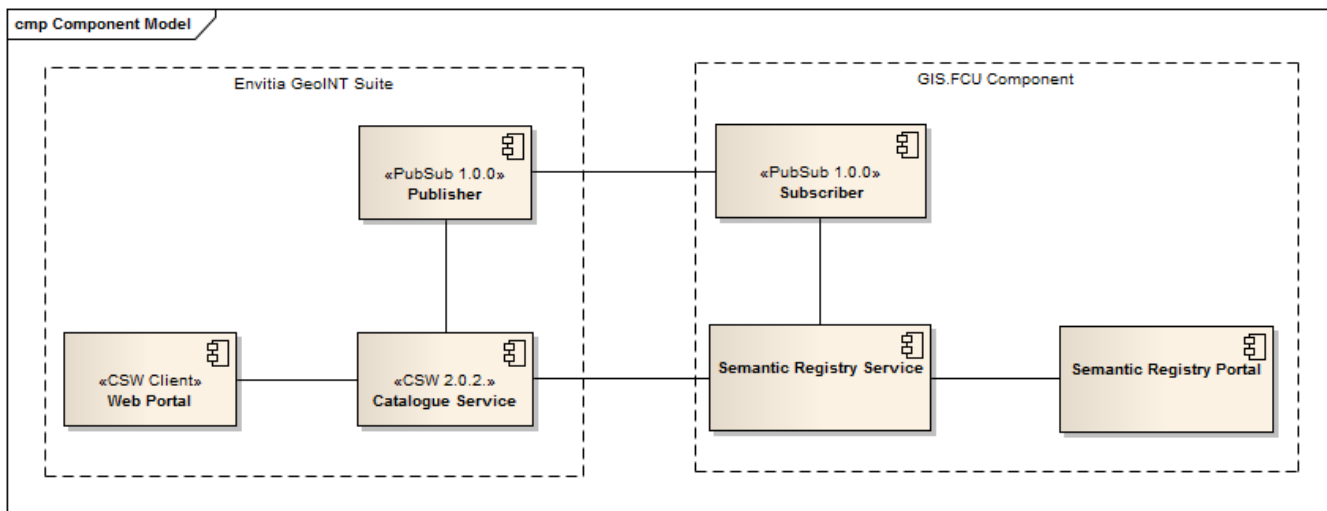


Figure 1. High level architecture

Chapter 7. SRIM applicability to USGS and NGA metadata

Testbed-13 was tasked with investigating the applicability of SRIM to a number of sponsor-provided metadata sets. To support this investigation, an SRIM Layer and Map Profile was developed.

Layers and Maps are very commonplace, but there is no standard way to describe their metadata. While Layer and Map instances can both be described at a high level through dcat:Dataset, they have their own specific metadata.

Within the context of a WMS, the relationship between a map and a layer is that a map is the result of a request to portray information represented by a layer.

Testbed-13 sought to investigate a profile for Layer and Map that extends the Registry Item and relates to Datasets, Services and Portrayal Information developed for the Semantic Registry and Semantic Portrayal Service.

In order to design a Layer and Map profile that extends the Registry Item, it is necessary to first determine how well an SRIM Item can describe layers and maps. The following sections describe the approach taken to design the Layer and Map profile.

7.1. Layer to SRIM Item cross walk

To assess how well an SRIM Item can describe a Layer, the testbed designed a cross walk from capabilities metadata of a WMS Layer (as described by the schema of a GetCapabilities response) to properties of an SRIM Item. [Table 1](#) presents the cross walk.

Table 1. LayerToSRIMItem Cross Walk

WMS Layer property	Definition	SRIM Equivalent
Name	A unique label given to a layer to enable it to be requested as a resource	@id
Title	A human-readable string for presentation in a menu	dct:title
Abstract	A narrative description of the map layer	dct:description
KeywordList	A list of words or phrases to aid in catalogue searches	dcat:keyword
CRS	Coordinate Reference System	dct:spatial
EX_GeographicBoundingBox	The minimum bounding latitude and longitude coordinates of the data represented in the layer	dct:spatial

BoundingBox	One or more minimum bounding rectangles enclosing the data represented by the layer	dct:spatial
Dimension	An indication of the dimensions supported by the data. Any new Dimension declaration in the child with the same name attribute as one inherited from the parent replaces the value declared by the parent.	dct:spatial
Attribution	Provides a way to identify the source of the geographic information used in a Layer or collection of Layers.	prov:qualifiedAttribution
AuthorityURL	A reference to the definition document for Identifier values	dct:rightsHolder
Identifier	An identifier for the layer.	dct:identifier
MetadataURL	A reference to descriptive information (metadata) about the layer	
DataURL	A reference to the data that is rendered by the layer	
FeatureListURL	A reference to the list of features represented in a Layer.	
Style	Zero or more Styles may be advertised for a Layer or collection of layer	
MinScaleDenominator	The MinScaleDenominator defines the lower bound of the range of scale denominators of maps for which a Layer is appropriate.	
MaxScaleDenominator	The MaxScaleDenominator defines the upper bound of the range of scale denominators of maps for which a Layer is appropriate.	
Layer	a layer nested within another	
queryable	An indicator of whether the layer can be queried, for example through the WMS GetFeatureInfo operation	

cascaded	A Layer is said to have been “cascaded” if it was obtained from an originating server and then included in the service metadata of a different server.	
opaque	An indication of whether the layer fills no-data areas or presents them as transparent regions	
noSubsets	An indicator of whether the layer can be clipped to a subset of the full Bounding Box	
fixedWidth	An indicator of whether the layer can be rendered with an arbitrary width	
fixedHeight	An indicator of whether the layer can be rendered with an arbitrary height	

7.2. Modeling the concept of a Map

The testbed participants considered how a Map could be modelled. The WMS standard defines a layer as a basic unit of geographic information that may be requested as a map from a server. The WMS standard defines a map as a portrayal of geographic information as a digital image file suitable for display on a computer screen. These definitions lead to the following assumptions in relation to how a Map might be modelled:

- A map can be uniquely identifiable, to enable it to be retrieved from servers and catalogues.
- A map can be composed of one or more layers
- A map can have a legend, typically derived from the styles of the layers from which the map is built
- A map covers a spatial extent in a specified coordinate reference system
- A map can cover a specific temporal extent
- A map can have a maximum scale denominator
- A map can have a minimum scale denominator

Historically essential map elements have been the data frame, legend, title, North arrow, scale and citation. Taking each of these in turn, the SRIM represents each as follows:

- A map title can be represented through the dct:title element
- A map citation can be represented through the dct:description
- The scale of a map is represented in the WMS and WMTS specifications but is not currently represented in the SRIM.
- The North arrow (or orientation) is not currently represented in the SRIM.

- The legend of a map is represented in the WMS and WMTS specifications but is not currently represented in the SRIM.

The testbed also reviewed the Web Map Context standard and observed that it introduces the concept of the Window Size which presents the size in pixels of the map the Context document describes.

7.3. Layer and Map Profile Design

Based on the cross walk and analysis presented in this chapter, the testbed designed a Layer and Map profile as shown in [Figure 2](#).

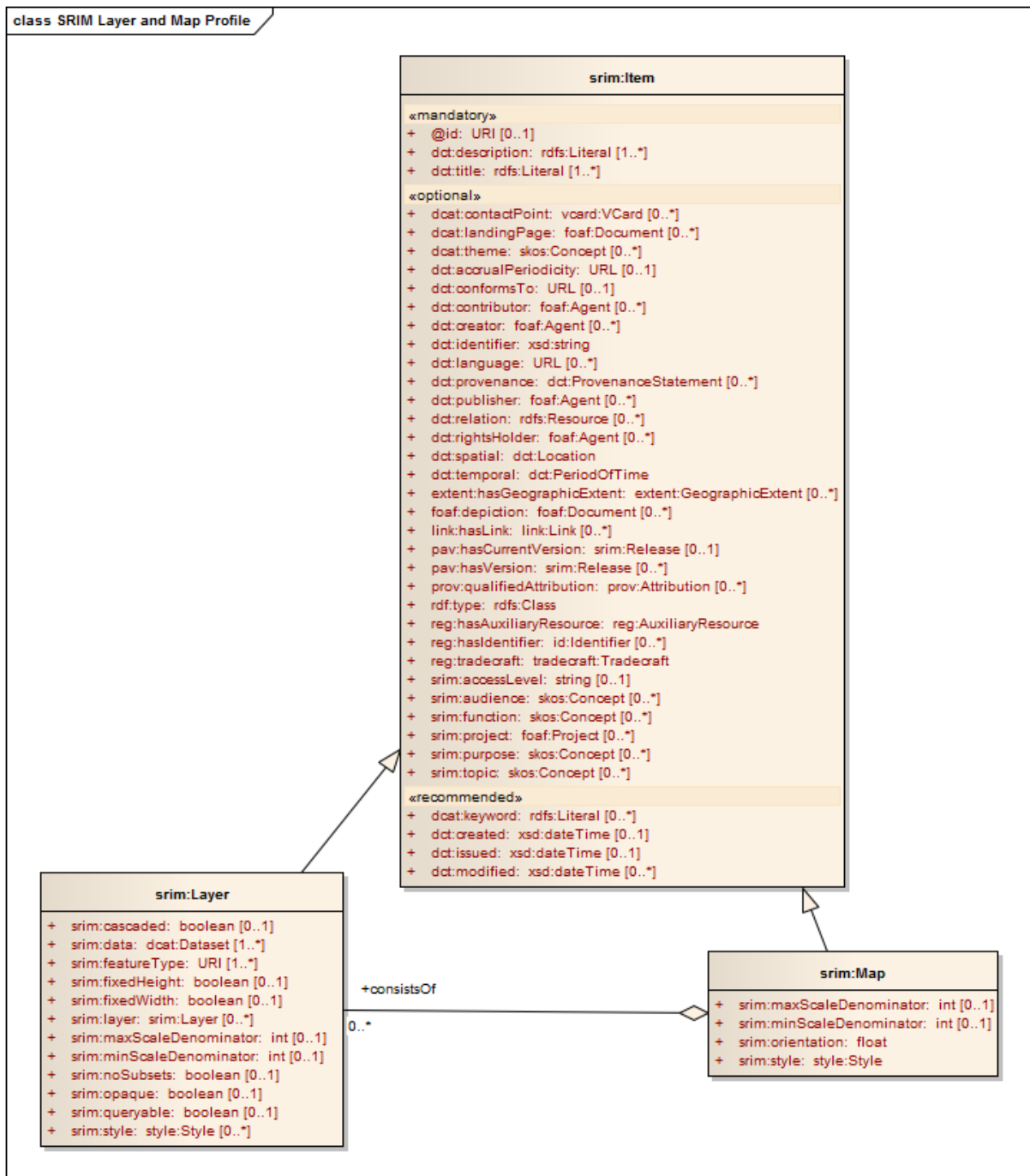


Figure 2. Layer and map profile of the SRIM

7.4. Recommendations for changes to the SRIM

This section presents recommendations based on work done to apply the SRIM to USGS and NGA metadata.

1. It was observed that the multiplicity of the modification date property of an SRIM Item is zero-to-one. Given that an item can be modified multiple times, the SRIM should be changed to allow the multiplicity of an SRIM Item to be zero-to-many.
2. The `dct:identifier` property is labelled as a "Third party identifier" but described as "the main identifier for the register item, e.g. the URI or other unique identifier in the context of the Register". The label appears to contradict the description of this property. The SRIM Item definition should be revised to label the `dct:identifier` as "the main identifier for the register item".
3. The `dct:identifier` property has a multiplicity of zero-to-one. As this property is the main identifier of the register item, it should be mandatory and have a multiplicity of one.
4. SRIM Item has the multiplicity of `pav:hasVersion` as zero-to-one. However `pav:hasVersion` is described as referring to "a version of the register item, and stores a version number and release notes in addition to other version information". As the register item can have multiple previous versions, the multiplicity of the `pav:hasVersion` property should be revised to zero-to-many.
5. SRIM Item has the multiplicity of `pav:hasCurrentVersion` as zero-to-many. However, `pav:hasCurrentVersion` is described as referring to "the current version of the register item". It would be unusual for there to be multiple current versions of the same item. The multiplicity should therefore be revised to zero-to-one.

Chapter 8. SRIM Best Practices

Testbed-13 was tasked with identifying best practice for producing metadata for datasets and services through mapping ISO 19115 to SRIM. This section presents the best practice guidelines, which have been informed by work carried out during the testbed as well as related literature.

The ISO 19139 namespace prefixes used in the section include:

- gmd = "http://www.isotc211.org/2005/gmd"

The ISO 19115-3 namespace prefixes used in the section include:

- mdb = "http://standards.iso.org/iso/19115/-3/mdb/1.0"
- mri = "http://standards.iso.org/iso/19115/-3/mri/1.0"
- cit = "http://standards.iso.org/iso/19115/-3/cit/1.0"

8.1. Use of resolvable URIs as identifiers

Each registered item, register or other resource should be identifiable through a Uniform Resource Identifier (URI) that is resolvable.

The justification is to enable applications to uniquely identify resources without risk of ambiguity.

This guidance relates to transformation of the following ISO 19139 metadata fields to SRIM:

- gmd:MD_Metadata/gmd:fileIdentifier
- gmd:MD_Metadata/gmd:identificationInfo/gmd:MD_DataIdentification/gmd:citation/gmd:Citation/gmd:identifier

This guidance relates to transformation of the following ISO 19115-3 metadata fields to SRIM:

- mdb:MD_Metadata/mdb:metadataIdentifier
- mdb:MD_Metadata/mdb:identificationInfo/mri:MD_DataIdentification/mri:citation/cit:Citation/cit:identifier

8.2. Adopt a consistent scheme for URIs

A consistent scheme should be used for specifying the URIs used with SRIM encoded metadata.

The justification is that consistency in URI patterns allows collections of metadata records to be copied or moved between networks. For example, in organizations that have multiple air-gapped networks, a consistent URI scheme allows for the base of a URI to be replaced without affecting the rest of the URIs and thus is path relative to other resources.

This guidance relates to transformation of the following ISO 19139 metadata fields to SRIM:

- gmd:MD_Metadata/gmd:fileIdentifier

- gmd:MD_Metadata/gmd:identificationInfo/gmd:MD_DataIdentification/gmd:citation/gmd:Citation/gmd:identifier

This guidance relates to transformation of the following ISO 19115-3 metadata fields to SRIM:

- mdb:MD_Metadata/mdb:metadataIdentifier
- mdb:MD_Metadata/mdb:identificationInfo/mri:MD_DataIdentification/mri:citation/cit:CI_Citation/cit:identifier

8.3. Use of controlled vocabularies

Controlled vocabularies should be used to tag the registered item if such vocabularies are available. Such controlled vocabularies should be represented in RDF-based languages (e.g. OWL, SKOS etc).

The justification is that controlled vocabularies facilitate search and discovery of resources.

This guidance relates to transformation of the following ISO 19139 metadata fields to SRIM:

- gmd:MD_Metadata/gmd:identificationInfo/gmd:MD_DataIdentification/gmd:descriptiveKeywords/gmd:MD_Keywords/gmd:keyword

This guidance relates to transformation of the following ISO 19115-3 metadata fields to SRIM:

- mdb:MD_Metadata/mdb:identificationInfo/mri:MD_DataIdentification/mri:descriptiveKeywords

8.4. Use of Item Classes

The type of registered item should be specified, through Item Classes to enable an application to group similar registered items together.

The justification for this is that in some cases an application or user may require a single type of registered item (e.g. services only, dataset only). In such situations the Item Class would help to filter out those registered items that are not of that type, thus improving the speed of discovery.

This guidance relates to transformation of the following ISO 19139 metadata fields to SRIM:

- gmd:MD_Metadata/gmd:hierarchyLevel
- gmd:MD_Metadata/gmd:hierarchyLevelName

This guidance relates to transformation of the following ISO 19115-3 metadata fields to SRIM:

- mdb:MD_Metadata/mdb:metadataScope/mdb:MD_MetadataScope/mdb:resourceScope
- mdb:MD_Metadata/mdb:metadataScope/mdb:MD_MetadataScope/mdb:name

8.5. Capture lineage and provenance of items

The provenance of the registered item and other lineage information should be recorded, with changes and version information specified.

The justification for this is that change control and versioning are key aspects of any registry. Deletion of registered items should be avoided and instead version and status information should be captured.

This guidance relates to transformation of the following ISO 19139 metadata fields to SRIM:

- gmd:MD_Metadata/gmd:dataQualityInfo/gmd:DQ_DataQuality/gmd:lineage
- gmd:MD_Metadata/gmd:identificationInfo/gmd:MD_DataIdentification/gmd:citation/gmd:Citation/gmd:edition
- gmd:MD_Metadata/gmd:identificationInfo/gmd:MD_DataIdentification/gmd:citation/gmd:Citation/gmd:editionDate

This guidance relates to transformation of the following ISO 19115-3 metadata fields to SRIM:

- mdb:MD_Metadata/mdb:metadataScope/mdb:MD_MetadataScope/mdb:resourceLineage
- mdb:MD_Metadata/mdb:identificationInfo/mri:MD_DataIdentification/mri:citation/cit:CI_Citation/cit:edition
- mdb:MD_Metadata/mdb:identificationInfo/mri:MD_DataIdentification/mri:citation/cit:CI_Citation/cit:editionDate

8.6. Recording of associations between related items

Associations between registered items should be identified and the type of relationship specified.

The justification is that typed associations in the form of predicates in an RDF graph can be traversed in support of inference. This improves the precision of searches.

This guidance relates to transformation of the following ISO 19139 metadata fields to SRIM:

- gmd:MD_Metadata/gmd:parentIdentifier
- gmd:MD_Metadata/gmd:identificationInfo/srv:SV_ServiceIdentification/srv:operatesOn

This guidance relates to transformation of the following ISO 19115-3 metadata fields to SRIM:

- mdb:MD_Metadata/mdb:parentMetadata/cit:CI_Citation/cit:identitier

Chapter 9. SHACL

SHACL is a language for describing RDF graph structures such that they can be validated against a set of conditions that are provided as "shapes" and other constructs serialized in RDF. SHACL is a standard of the World Wide Web Consortium (W3C).

The RDF graphs used to validate other graphs through SHACL are referred to as "shapes graphs" and those that are validated against a shapes graph are referred to as "data graphs". An [RDF shape](https://semanticarts.com/blog/rdf-shapes/) [https://semanticarts.com/blog/rdf-shapes/] can therefore be considered to be a formal specification of how data is, how data should be, or how data must be.

A shapes graph is an RDF graph containing zero or more shapes that is used within a SHACL validation process to validate a data graph. A shapes graph specifies classes, properties, their associated cardinalities, data-types and range of expressions that are allowed in a valid dataset.

Just as shape graphs can be used as a validation tool, they can also be viewed as a description of the data graphs that comply with the conditions set out in the shapes graphs. Such a descriptive ability can potentially be used in non-validation functions such as user interface building, code generation and data integration.

A shape is a collection of constraints that may be applied to certain nodes. Shapes can be used to constrain the classes and properties used in an RDF graph. A shape determines how to validate a node in a graph based on the values of properties and other characteristics of the node.

9.1. sh:Shape

A shape adopts the following properties.

property name	description	range
sh:targetClass	Links a shape to a class, indicating that all instances of the class must conform to the shape.	rdfs:Class
sh:targetNode	Links a shape to individual nodes, indicating that these nodes must conform to the shape.	sh:Target
sh:targetObjectsOf	Links a shape to a property, indicating that all objects of triples that have the given property as their predicate must conform to the shape.	rdf:Property
sh:targetSubjectsOf	Links a shape to a property, indicating that all subjects of triples that have the given property as their predicate must conform to the shape.	rdf:Property

property name	description	range
sh:message	A human-readable message (possibly with placeholders for variables) explaining the cause of the result	xsd:string
sh:severity	Defines the severity that validation results produced by a shape must have. Defaults to sh:Violation.	sh:Severity
sh:deactivated	If set to true for a shape then the shape is deactivated and all nodes conform to it.	xsd:boolean

9.2. Examples

To demonstrate the application of SHACL to data validation, the testbed prepared a SHACL document that describes part of the SRIM schema. Each property of an SRIM class is described in terms of its qualified identifier, data type, the minimum number of occurrences and the maximum number of occurrences.

SRIM Schema Subset in SHACL

```

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix schema: <http://schema.org/> .
@prefix sh: <http://www.w3.org/ns/shacl#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix srим: <http://www.opengis.net/ont/testbed12/srim#> .
@prefix dct: <http://purl.org/dc/terms/> .
@prefix dcat: <http://www.w3.org/ns/dcat#> .
@prefix vcard: <http://www.w3.org/2006/vcard/ns#> .
@prefix pav: <http://purl.org/pav/> .

srим:ItemShape
  a sh:NodeShape ;
  sh:targetClass srим:Item ;
  sh:property [
    sh:path dct:identifier;
    sh:minCount 1 ;
    sh:maxCount 1 ;
  ] ;
  sh:property [
    sh:path rdf:type;
    sh:minCount 1 ;
    sh:maxCount 1 ;
  ] ;
  sh:property [
    sh:path dct:title;
    sh:minCount 1 ;
  ] ;

```

```

] ;
sh:property [
  sh:path dct:description;
  sh:minCount 1 ;
] ;
sh:property [
  sh:path dcat:contactPoint;
  sh:node vcard:VCardShape ;
] ;
sh:property [
  sh:path dct:created;
  sh:maxCount 1 ;
] ;
sh:property [
  sh:path dct:issued;
  sh:maxCount 1 ;
] ;
sh:property [
  sh:path dct:modified;
  sh:maxCount 1 ;
] ;

sh:property [
  sh:path pav:hasVersion;
  sh:node srim:ReleaseShape ;
] ;

.

vcard:VCardShape
  a sh:NodeShape ;
  sh:property [
    sh:path vcard:fn ;
    sh:minCount 1 ;
    sh:maxCount 1 ;
    sh:datatype xsd:string ;
  ] ;
  sh:property [
    sh:path vcard:hasEmail ;
    sh:minCount 1 ;
  ] .

srim:ReleaseShape
  a sh:NodeShape ;
  sh:property [
    sh:path rdf:id ;
    sh:minCount 1 ;
    sh:maxCount 1 ;
  ] ;
  sh:property [
    sh:path pav:version ;
  ] ;

```

```

    sh:minCount 1 ;
    sh:maxCount 1 ;
  ] ;
  sh:property [
    sh:path dct:issued ;
    sh:maxCount 1 ;
  ] ;
  sh:property [
    sh:path pav:versionOf ;
    sh:maxCount 1 ;
  ] .

```

The SHACL document was applied to the following SRIM example document. The example document describes an instance of an SRIM Item. In this case the registered item is a dataset on "U.S. Widget Manufacturing Statistics".

SRIM implementation example

```

@prefix dash: <http://datashapes.org/dash#> .
@prefix schema: <http://schema.org/> .
@prefix pav: <http://purl.org/pav/> .
@prefix org: <http://www.w3.org/ns/org#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .
@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix voaf: <http://purl.org/vocommons/voaf#> .
@prefix skos: <http://www.w3.org/2004/02/skos/core#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix vcard: <http://www.w3.org/2006/vcard/ns#> .
@prefix dct: <http://purl.org/dc/terms/> .
@prefix madsrdf: <http://www.loc.gov/mads/rdf/v1#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix srim: <http://www.opengis.net/ont/testbed12/srim#> .
@prefix dctype: <http://purl.org/dc/dcmitype/> .
@prefix vann: <http://purl.org/vocab/vann/> .
@prefix dcat: <http://www.w3.org/ns/dcat#> .
@prefix prov: <http://www.w3.org/ns/prov#> .
@prefix foaf: <http://xmlns.com/foaf/0.1/> .

[
  a srim:Item ;
  dct:accrualPeriodicity "R/P1Y" ;
  dct:description "This dataset provides national statistics on the production
of widgets" ;
  dct:identifier "http://dx.doi.org/10.7927/H4PZ56R2" ;
  dct:issued "2011-11-22"^^xsd:date ;
  dct:language <http://id.loc.gov/vocabulary/iso639-1/en> ;
  dct:modified "2011-11-19T12:00:00Z"^^xsd:date ;
  dct:publisher [ a foaf:Organization ;
    foaf:name "\n\t\t\t\t\tWidget Services\n\t\t\t\t\t"
  ] ;
] ;

```

```

dct:spatial      "United States" ;
dct:temporal    "2009-09-01T12:00:00Z/2010-05-31T12:00:00Z"^^xsd:dateTime ;
dct:title       "U.S. Widget Manufacturing Statistics" ;
dcat:contactPoint
  [ a            vcard:Individual ;
    vcard:fn      "Jane Doe" ;
    vcard:hasEmail "mailto:jane.doe@agency.gov"
  ] ;
dcat:distribution
  [ a            dcat:Distribution ;
    dct:description "Widgets data as a CSV file" ;
    dct:format      "CSV" ;
    dct:title       "widgets.csv" ;
    dcat:downloadURL
  "https://data.agency.gov/datasets/widgets-statistics/widgets.csv"
  ] ;
dcat:distribution
  [ a            dcat:Distribution ;
    dct:description "A fully queryable REST API with JSON and
XML output" ;
    dct:format      "API" ;
    dct:title       "Widgets REST API" ;
    dcat:accessURL  "https://data.agency.gov/api/widgets-
statistics/"
  ] ;
dcat:distribution
  [ a            dcat:Distribution ;
    dct:description "Widgets data as a zipped CSV file with
attached data dictionary" ;
    dct:format      "Zipped CSV" ;
    dct:title       "widgets-all.zip" ;
    dcat:downloadURL
  "https://data.agency.gov/datasets/widgets-statistics/widgets-all.zip"
  ] ;
dcat:distribution
  [ a            dcat:Distribution ;
    dct:description "Widget data as a JSON feed" ;
    dct:format      "JSON" ;
    dct:title       "widgets-all.json" ;
    dcat:downloadURL "http://www.agency.gov/feeds/widgets-
all.json"
  ] ;
dcat:distribution
  [ a            dcat:Distribution ;
    dct:license
  "http://creativecommons.org/publicdomain/zero/1.0/" ;
    dct:rights      "This dataset has been given an international
public domain dedication for worldwide reuse"
  ] ;
dcat:keyword     "manufacturing" , "factory" , "widget" ;
dcat:landingPage "http://agency.gov/widgets/data" ;
dcat:theme       [ a            skos:Concept ;
                  skos:prefLabel "manufacturing"
                ]
].

```

The result of validating the data graph against the shapes graph is a validation report. The validation report presents the result of the validation and can report on the conformance of the SRIM document to the constraints specified in the SHACL document.

An example of a validation report where the data graph conforms to the shapes graph is shown below.

Example SHACL Validation Report 1

```
[ a sh:ValidationReport ;
  sh:conforms true ;
] .
```

An example of a validation report where the data graph does not conform to the shapes graph is shown below. The validation report was triggered by removing the title property from the data graph. The removal violates the minimum occurrence constraint of the title property stated in the shapes graph.

Example SHACL Validation Report 2

```
[ a sh:ValidationReport ;
  sh:conforms false ;
  sh:result [

    a sh:ValidationResult ;
    sh:resultSeverity sh:Violation ;
    sh:sourceConstraintComponent sh:MinCountConstraintComponent ;
    sh:sourceShape _:n2815 ;
    sh:focusNode _:n2939 ;
    sh:resultPath dct:title ;
    sh:resultMessage "Less than 1 values" ;

  ]
] .
```

Chapter 10. Pub/Sub Support

The OGC Publish/Subscribe (PubSub) standard is an interface specification for the core components and concepts of the Publish/Subscribe message exchange pattern within OGC Web Services. It is intended to complement and not to replace the request-reply message exchange pattern that is adopted by most OGC web service standards. The standard enables subscription management capabilities such as creation, renewing and canceling of subscriptions. The standard is independent of message delivery protocols such as Atom [IETF RFC 5023] and binding technologies such as REST. Testbed-12 introduced a PubSub extension for CSW, focused primarily on CSW 2.0.2 but also taking into consideration implications for the ISO Application Profile, the eBRIM Application Profile, the OpenSearch extension, the SOAP binding, and DCAT. Testbed-13 was tasked with implementing publish/subscribe support to support harvesting between CSW and Semantic Registries.

The process supported by the PubSub standard recognizes roles that include a subscriber, publisher, sender and receiver. Within this workflow a Subscriber first creates a subscription on behalf of a Receiver by transmitting a subscribe request to a Publisher. The subscription may include a filter criteria that evaluates to a boolean when an event occurs that meets its criteria. Each time or at some client-configurable interval when the filter criteria is met, the Publisher instructs the Sender to transmit a notification to the Receiver. The Sender then sends the notification to the Receiver. An illustration of this workflow is presented in [Figure 3](#). It is important that the aforementioned roles are not mutually exclusive and it is possible for components to assume two roles in one. For example, it is possible for a single component to assume the roles of both subscriber and receiver. It is also possible for a component to assume the roles of both a publisher and sender.

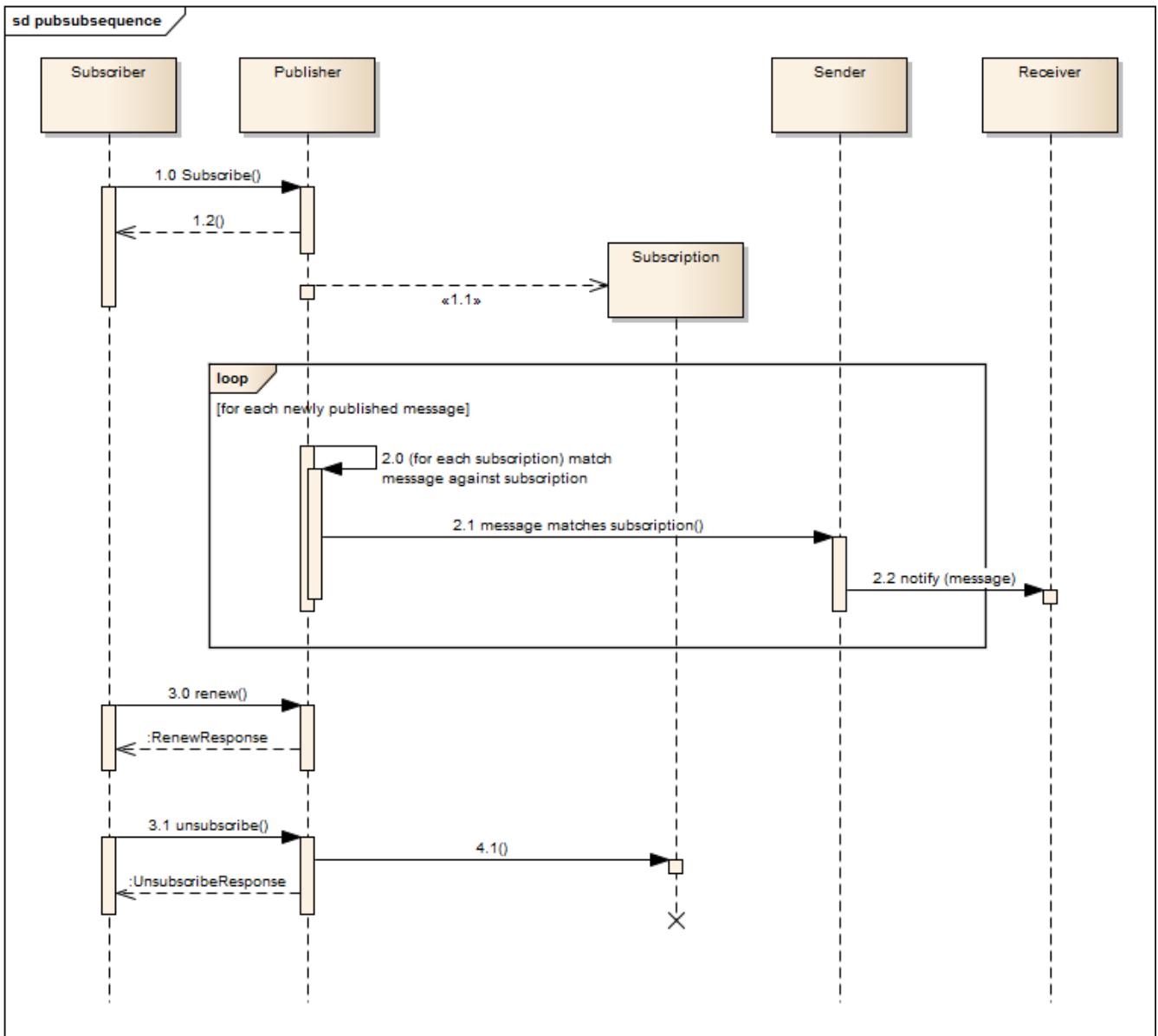


Figure 3. Generic PubSub sequence

10.1. Testbed-13 Implementation of PubSub

The publish/subscribe model of interaction was implemented in Testbed-13. As illustrated in [Figure 4](#), the implementation included a CSW, extended with pubsub support to serve in the roles of a publisher and a sender. The implementation also included a Semantic Registry, enabled to serve in the roles of a subscriber and a receiver.

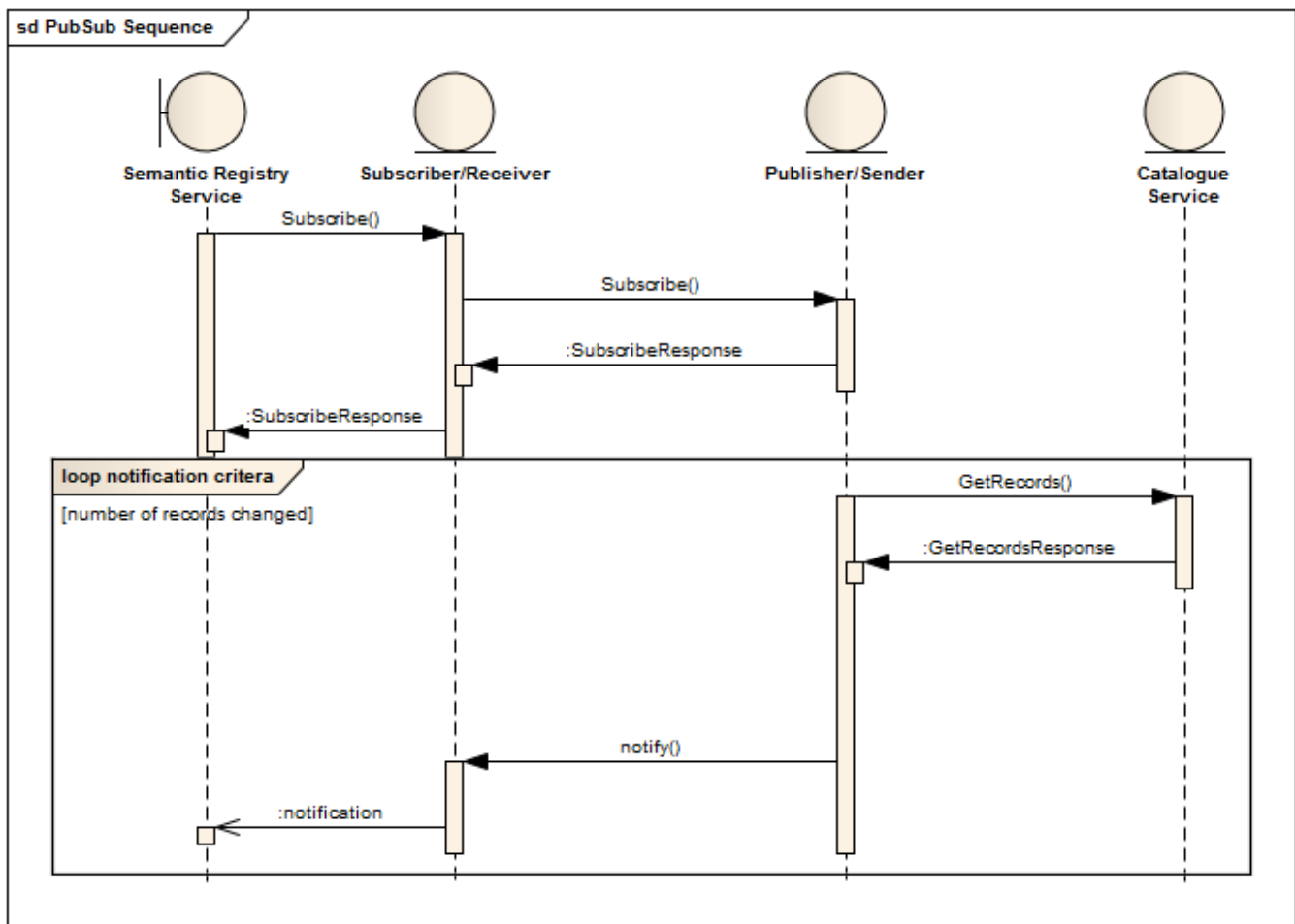


Figure 4. PubSub sequence between the Semantic Registry and CSW

OGC PubSub 1.0.0 offers a core model which can be implemented using a variety of bindings. The SOAP/WSDL binding of OGC PubSub 1.0.0, which is a separate OGC standard, applies the OASIS WS-Notification standard for transmitting notifications. WS-Notification is a family of related specifications creating and transmitting notifications through web services and using a topic-based publish/subscribe pattern. As a key requirement of testbed-13 was to explore the potential for a RESTful semantic registry, it was decided not to adopt the SOAP/WSDL binding of the PubSub specification but to focus on sending notifications in the form of ISO 19139 MD_Metadata (as returned by the subscription filter) instead.

10.2. ISO 19115-3 Metadata

One of the requirements of this testbed was to demonstrate the ability to return GetRecords responses in the ISO 19115-3 format. To do this, a servlet filter was placed in front of the CSW-ISO endpoint which performed an XSLT transformation on the ISO 19139 metadata already held within the catalogue in order to convert it into ISO 19115-3 metadata. The XSLT scripts were provided by the International Organization for Standardization (ISO).

10.2.1. Transformation Filter

For the data to be transformed into ISO 19115-3, several criteria must be met:

- The request must be a GetRecords request.
- The request method must be HTTP POST, and contain the XML GetRecords query in the request

body.

- The `outputSchema` attribute of the `GetRecords` must be <http://standards.iso.org/iso/19115/-3/mdb/1.0>

If the request meets these criteria, the response is intercepted and an XSLT transformation performed on the original `GetRecordsResponse`. The new ISO 19115-3 elements replace the original ISO 19139 elements and the response continues back to the client.

A sequence diagram showing this flow is shown below.

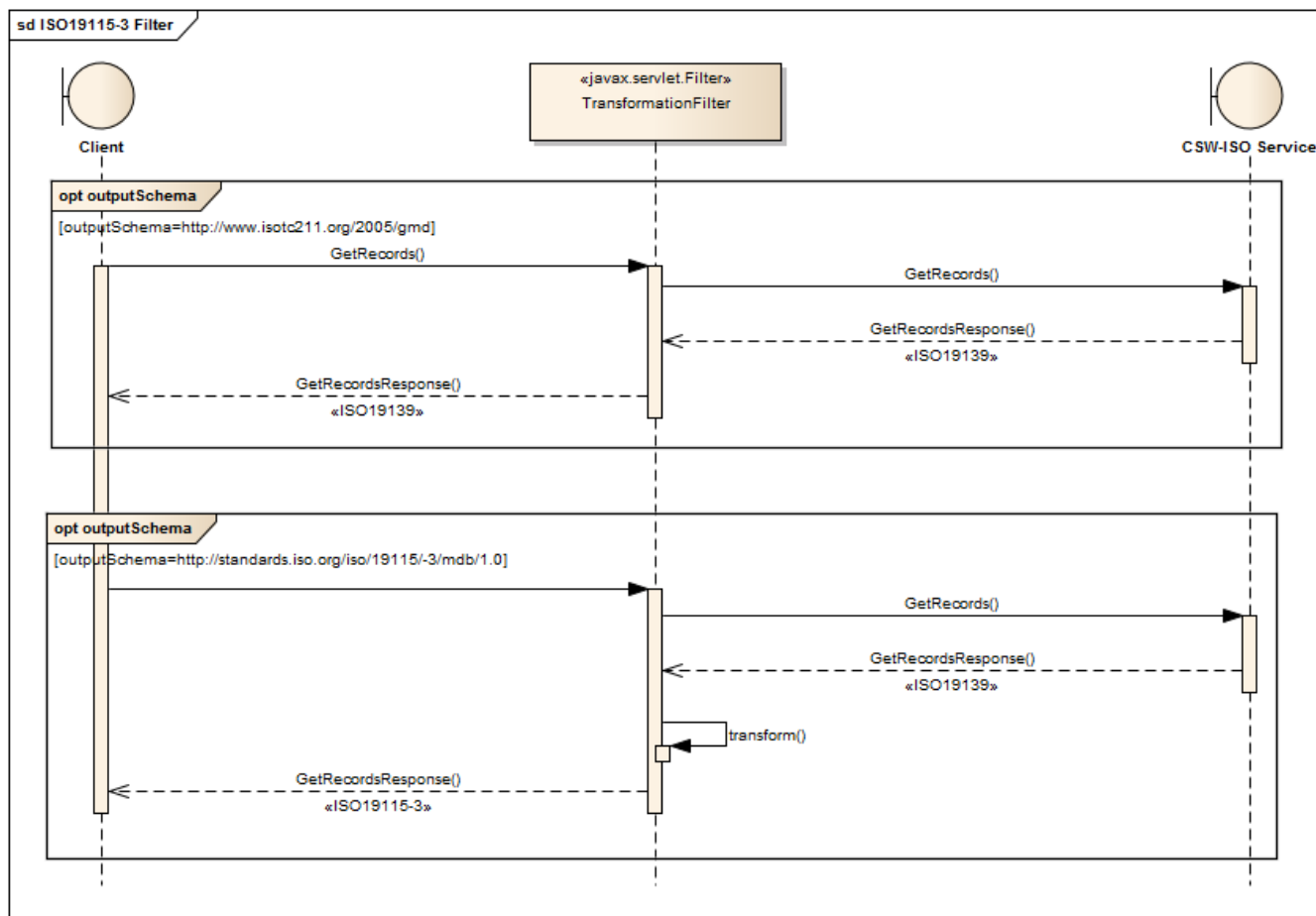


Figure 5. PubSub sequence showing transformation of ISO 19139 into ISO 19115-3

All request/response cycles pass through the transformation filter, but only those that meet the criteria are intercepted, processed, and the response transformed.

10.2.2. XSLT Transformation Scripts

The XSLT transformation scripts can be found as a resource on the ISO web site.

- <http://iso.org/iso/19115/resources/transforms/ISO19139> [http://iso.org/iso/19115/resources/transforms/ISO19139].

XSLT Script Changes

The scripts were successfully tested using the commercially available XML Spy application, but when it came to running them within a Java application it was found that errors were reported causing the transformation to fail. Specifically, the `import` and `include` statements were causing

issues because the Saxon XSLT engine failed if a stylesheet was imported more than once.

To resolve this problem, all `import` and `include` statements were removed from sub-scripts and placed in the root script. This meant that each stylesheet was imported only once and the issue was resolved successfully.

XSLT Stylesheet Hierarchy

The stylesheets were organized into the following folders:

```
xslt
|  fromISO19139.xsl
|  toISO19139.xsl
|
+---mapping
|    CI_Citation.xsl
|    CI_ResponsibleParty.xsl
|    core.xsl
|    defaults.xsl
|    DQ.xsl
|    SRV.xsl
|
\---utility
     create19115-3Namespaces.xsl
     dateTime.xsl
     multiLingualCharacterStrings.xsl
```

The `import` and `include` statements were moved into the `fromISO19139.xsl` stylesheet.

Example GetRecords requests and the corresponding responses can be found in [Appendix B](#).

Chapter 11. Controlled Vocabularies

A controlled vocabulary can be defined as an organized collection of terms used to index content in order to facilitate information retrieval. In a cross community environment, various users may prefer to use different terms to refer to concepts. Without a controlled vocabulary it can be difficult for users to retrieve documents and other resources if they are completely unfamiliar with the terminology used to catalogue information resources. Controlled vocabularies provide guidance to users by labelling information resources with terms that users within a specific domain are likely to be familiar with. Such terms are organized into an index that includes preferred and alternate terms to allow for variation.

In the Linked Data community, controlled vocabularies are designed to be machine-processable. Over the years a number of approaches have emerged for implementing controlled vocabularies with different levels of machine-interpretability. Examples of such standards include codelists, ontologies, taxonomies and thesauri. A number of specifications have also emerged to standardize how some of the aforementioned approaches are implemented, for example the Resource Description Framework (RDF), Web Ontology Language (OWL) and Simple Knowledge Organization System (SKOS). Whereas some of the standards can be considered emerging or domain-specific, others have become mainstream through endorsement in major government programs (e.g. data.gov.uk) and used by mass market services (e.g. Google Search and LinkedIn).

As the popularity of controlled vocabularies has grown, so has the need to find efficient ways of searching them. There remains however several issues that limit search on controlled vocabularies, for example:

- Some controlled vocabularies are not publicly available on the World Wide Web. Testbed-12 observed that the USGS National Map Theme Thesaurus was such an example.
- Unique identification schemes are not always applied to terms in the controlled vocabulary.
- Overlap and duplication of some terms.

Testbed-12 recommended that to address some of the aforementioned issues, it is necessary to define concepts in SKOS encoding with unique identifiers that are resolvable. The testbed also recommended grouping alternate labels under the same concept and providing SKOS mappings to other vocabularies to enable semantic search across taxonomies. Once the concepts have been encoded in SKOS, it is necessary for them to be made publicly available to encourage uptake and reuse. The testbed also observed that controlled vocabularies without an assigned authority are at risk of not being reused.

To address the aforementioned issues, Testbed-13 was tasked with defining an ontology that explores in detail the type of metadata needed to enable search on controlled vocabularies. The ontology, which we have named the Controlled Vocabulary Ontology (CVO) is presented later in this section. The following subsections describe aspects of controlled vocabularies that were explored during the testbed. The subsections also make reference to the following existing specifications:

- SKOS provides a model for expressing the basic structure and content of concept schemes such as thesauri, classification schemes, subject heading lists, taxonomies, folksonomies, and other similar types of controlled vocabulary.

- The PROV (short for provenance) Family of Documents defines a model, corresponding serializations and other supporting definitions to enable the inter-operable interchange of provenance information in heterogeneous environments such as the Web.
- Vocabulary of a Friend (VOAF) is a vocabulary specification providing elements allowing the description of vocabularies (RDFS vocabularies or OWL ontologies) used in the Linked Data Cloud.

11.1. Classification of vocabulary types

There are several different types of controlled vocabularies. Many different, though consistent, definitions have been proposed for the types of controlled vocabularies. In this section, we present some of the definitions.

- A controlled list is a list of terms used to control terminology [1].
- A taxonomy is a hierarchical arrangement of entities in which there is a formal relationship, typically one of derivation, between every pair of terms [2].
- A synonym ring is a set of terms considered equivalent for the purpose of information retrieval [1].
- An authority file is a set of established names or headings and cross-references to the preferred form from variant or alternate forms [1].
- An ontology is a formal specification of concrete or abstract things, and the relationships among them, in a prescribed domain of knowledge [ISO/IEC 19763-1:2015]
- Alphanumeric classification schemes are controlled codes (letters or numbers, or both letters and numbers) that represent concepts or headings [1].
- A folksonomy is a neologism referring to an assemblage of concepts represented by terms and names (called tags) that are compiled through social tagging [1].
- A thesaurus is a controlled and structured vocabulary in which concepts are represented by terms, organized so that relationships between concepts are made explicit, and preferred terms are accompanied by lead-in entries for synonyms or quasi-synonyms [ISO 25964-1:2011]

Given that there are different types of controlled vocabularies within and outside of the sponsor community, it can be inferred that the CVO should offer a property that specifies the type of controlled vocabulary.

11.1.1. Sponsor-provided controlled vocabularies

The following is a list of controlled vocabularies provided by Testbed-13 sponsors:

- [NSG Core Vocabulary](https://nsgreg.nga.mil/doc/view?i=4362&month=6&day=15&year=2017) [https://nsgreg.nga.mil/doc/view?i=4362&month=6&day=15&year=2017]
- [NSG Taxonomy \(NTAX\)](http://api.nsgreg.nga.mil/taxonomy/ntax) [http://api.nsgreg.nga.mil/taxonomy/ntax]
- [USGS Thesaurus](https://www2.usgs.gov/science/about/thesaurus/USGSThesaurus.rdf) [https://www2.usgs.gov/science/about/thesaurus/USGSThesaurus.rdf]
- [USGS GIS NHD](https://cegis.usgs.gov/ttl/GISNHD.ttl) [https://cegis.usgs.gov/ttl/GISNHD.ttl]
- [USGS Surface Water Ontology \(SWO\)](https://cegis.usgs.gov/ttl/SWO.ttl) [https://cegis.usgs.gov/ttl/SWO.ttl]

- [USGS USTopographic](https://cegis.usgs.gov/ttl/USTopographic.ttl) [https://cegis.usgs.gov/ttl/USTopographic.ttl]

11.2. Relationships to other vocabularies

To determine the namespaces of concepts imported by the referenced controlled vocabularies, the testbed used Apache Jena's RDFCat facility to convert the supplied controlled vocabularies into Turtle format. The following observations were made.

The NCV imports concepts from the following namespaces

- ncv: <http://api.nsgreg.nga.mil/vocabulary/ncv>
- dct: <http://purl.org/dc/terms/>
- ncvx: <http://api.nsgreg.nga.mil/ontology/ncvx/1.0/>
- regx: <http://api.nsgreg.nga.mil/ontology/regx/1.0/>
- rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
- rdfs: <http://www.w3.org/2000/01/rdf-schema#>
- skos: <http://www.w3.org/2004/02/skos/core#>
- owl: <http://www.w3.org/2002/07/owl#>

The NGA NTAX imports concepts from the following namespaces

- owl: <http://www.w3.org/2002/07/owl#>
- rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
- rdfs: <http://www.w3.org/2000/01/rdf-schema#>
- ISO 19150-2: <http://def.isotc211.org/iso19150-2/2012/base#>
- Dublin Core terms: <http://purl.org/dc/terms/>
- SKOS: <http://www.w3.org/2004/02/skos/core#>

The USGS SWO imports concepts from the following namespaces

- cegis swo: <http://cegis.usgs.gov/SWO#>
- owl: <http://www.w3.org/2002/07/owl#>
- rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
- rdfs: <http://www.w3.org/2000/01/rdf-schema#>
- wgs84_pos: http://www.w3.org/2003/01/geo/wgs84_pos#
- xsd: <http://www.w3.org/2001/XMLSchema#>

The USGS Thesaurus imports concepts from the following namespaces

- dct: <http://purl.org/dc/terms/>
- rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
- skos: <http://www.w3.org/2004/02/skos/core#>

- rdfs: <http://www.w3.org/2000/01/rdf-schema#>
- dc: <http://purl.org/dc/elements/1.1/>

The USGS USTopographic ontology imports concepts from the following namespaces

- cegis ontology: <http://cegis.usgs.gov/Ontology#>
- dcterms: <http://purl.org/dc/terms/>
- geo: <http://www.geonames.org/ontology#>
- ogc: <http://www.opengeospatial.org/standards/sfa#>
- owl: <http://www.w3.org/2002/07/owl#>
- rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
- rdfs: <http://www.w3.org/2000/01/rdf-schema#>
- topo: <http://cegis.usgs.gov/Ontology/Topography/>
- xml: <http://www.w3.org/XML/1998/namespace>
- xsd: <http://www.w3.org/2001/XMLSchema#>

None of the controlled vocabularies were observed to extend others, however the following relevant observations were made:

- Feature, Function, Flow, SpatialExtent, SurfaceWaterNetwork and Temporality from the USGS SWO are specializations of owl:Thing. All other concepts have been modeled as specializations of these six concepts or their subclasses.
- Documentation and Topography from the USGS USTopographic ontology are specializations of owl:Thing. All other concepts have been modeled as specializations of these two concepts or their subclasses.
- GIS-NHD from the USGS GIS-NHD ontology is a specialization of owl:Thing. All other concepts have been modeled as specializations of this concept or its subclasses.
- Most of the concepts in the NTAX are specializations of the Entity abstract class or its subclasses, for example FeatureEntity, InformationEntity, ActorEntity and others.

These observations suggest there are some differences between the approach taken for the NTAX and the approach taken for the USGS controlled vocabularies. The USGS controlled vocabularies are modularized, with individual modules focusing on specific domains (e.g. topography, hydrography, surface water). In contrast, the NTAX describes concepts across multiple domains.

To enable the search and discovery of controlled vocabularies, the CVO should therefore provide an indicator of whether a controlled vocabulary extends, imports, specializes other vocabularies.

11.3. Statistical information about vocabularies

The testbed examined statistical information for each of the referenced controlled vocabularies. The review of the statistics was intended to provide an indicator of the types of axioms that are typically used by the referenced controlled vocabularies, this would enable the identification of the statistics that are optional though recommended. Using the Ontology metrics view of Protege

version 5.0.0 beta, the following statistics can be extracted.

- AnnotationAssertion axiom count
- AnnotationAssertion count
- Axiom count
- Class count
- ClassAssertion axiom count
- Data property count
- DataPropertyDomain axiom count
- DataPropertyRange axiom count
- DifferentIndividuals axiom count
- DisjointClasses axiom count
- Individual count
- Logical axiom count
- Object property count
- ObjectPropertyDomain axiom count
- ObjectPropertyRange axiom count
- SubClassOf axiom count

Such statistical information can help a user decide whether to make use of a controlled vocabulary, for example if the user is operating in austere environments with intermittent connectivity. The CVO should therefore provide such statistical information.

11.4. Schema encoding

The referenced controlled vocabularies are distributed in the following encodings and schema:

- NCV is distributed as SKOS and serialized in both RDF/XML and N3 Triples.
- NTAX is distributed as OWL with some predicates from SKOS and serialized in both RDF/XML and N3 Triples.
- SWO is distributed as RDF Turtle
- USGS thesaurus is distributed as SKOS and serialized in both RDF/XML
- USGS USTopographic is distributed as RDF Turtle
- USGS NHD is distributed as RDF Turtle

11.5. Expressiveness

The testbed observed that the Protege application describes expressivity in terms of Description Logic (DL). Using the Ontology metrics facility within Protege, the testbed determined that the DLs adopted by the referenced controlled vocabularies included AL, ALC, AL(D), ALCH and ALCH(D).

The DL AL (Attributive Language) was introduced by Schmidt-Schauß and Smolka [3] as a minimal language. The DL ALC was introduced by Schmidt-Schauß and Smolka [3] as the “smallest” DL that is propositionally closed, i.e., that provides for all Boolean connectives. The DL AL(D) extends AL with a concrete domain concept constructor. ALCH extends ALC with role hierarchies. ALCH(D) extends AL with functional roles, concrete domain roles, role hierarchies and a concrete domain concept constructor. Table 2 presents a summary of the expressivity of the referenced vocabularies.

Table 2. Expressivity of the referenced controlled vocabularies.

vocabulary	Expressivity
NCV	ALCO
NTAX	ALC
USGS Thesaurus	AL
USGS GIS NHD	AL(D)
USGS SWO	ALCH
USGS USTogographic	ALCH(D)

To facilitate search and discovery of controlled vocabularies, the CVO should therefore offer a property that indicates the expressivity of the vocabulary.

11.6. Preferred prefix and namespace URI

It is good practice for ontologies to adopt consistent prefixes for representing their namespaces. Information modelling initiatives typically specify a preferred prefix for each namespace that is used. The base namespace URI used by the referenced controlled vocabularies are:

- NCV <http://api.nsgreg.nga.mil/vocabulary/ncv>
- NTAX <http://api.nsgreg.nga.mil/taxonomy/ntax>
- SWO <http://cegis.usgs.gov/SWO/>
- USGS thesaurus <http://www.usgs.gov/science/USGSThesaurus>
- USGS USTopographic <http://cegis.usgs.gov/Ontology>
- USGS NHD <http://cegis.usgs.gov/surfacewater/GISNHD/>

The CVO should therefore offer a property for specifying the preferred prefix and namespace URI of a controlled vocabulary.

11.7. Governance metadata

Simperl and Tempich (2009) observed that governance frameworks cover the organization, control, steering and diffusion aspects of corporate system development. Organizational aspects describe the different roles and their responsibilities required for the development and maintenance of a system in an organization. Steering involves the definition of processes and activities performed by roles in order to achieve the overall goals of the system. Control involves the definition and application of indicators required to monitor a system. In the case of controlled vocabularies such indicators could include metrics on concepts or other statistics, for example. Diffusion involves the

definition of suitable mechanisms for making the system (in this case a controlled vocabulary) available to all intended users.

The sub-organization within NGA that is responsible for the governance of the NCV and NTAX is the Geospatial Intelligence Standards Working Group (GWG). Proposed additions or changes to the NCV are reviewed by the GEOINT Content Standards Board (GCSB), which serves as a steering board within this context. Editions of both the NTAX and NCV are disseminated through the NSG Standards Registry. Changes to the NCV are registered in a spreadsheet with the fields shown in [Table 3](#).

Table 3. NCV Changes field descriptions

Field name	Description	SKOS/PROV/VOAF equivalent
Event	The Control Body decision event at which this Enumerated Type Term was revised.	None
Action	The type of change made to the Enumerated Type Term; one of: Add, Clarify (changes that are "editorial" in nature and do not change the essence of the Enumerated Type Term), Supersede (replacement of the Enumerated Type Term by another Enumerated Type Term), or Retire.	None
Justification	An explanation of the basis for the change to the Enumerated Type Term.	None
Change	A description, if applicable, of the specifics of the change.	None
Item Identifier	A positive integer (i.e., greater than zero) that is used to uniquely denote the Enumerated Type Term within the register and is intended for information processing.	URI of resource
Label	A textual value that is used to denote the Enumerated Type Term in data interchange.	skos:altLabel
(Revised) Name	The post-change compact and human-readable designator that is used to denote the Enumerated Type Term.	skos:prefLabel
(Revised) Definition	The post-change precise statement of the nature, properties, scope, or essential qualities of the Enumerated Type Term.	skos:definition

Field name	Description	SKOS/PROV/VOAF equivalent
(Revised) Description	The post-change statement of the nature, properties, scope, or non-essential qualities of the Enumerated Type Term that are not specified by the definition.	dct:description
Values Complete?	A Boolean that identifies post-change that the set of specified domain values is complete.	None
(Previous) Name	The pre-change compact and human-readable designator that is used to denote the Enumerated Type Term.	skos:prefLabel
(Previous) Definition	The pre-change precise statement of the nature, properties, scope, or essential qualities of the Enumerated Type Term.	skos:definition
(Previous) Description	The pre-change statement of the nature, properties, scope, or non-essential qualities of the Enumerated Type Term that are not specified by the definition.	dct:description

The table presented above shows that there are several fields that do not have equivalents in SKOS, PROV or VOAF. The CVO will therefore need to introduce properties where there no equivalent fields and to reuse properties where equivalent fields exist.

The RDF serialization of the NCV introduces the following predicates to support governance. None of the ontologies reviewed were found to offer properties that were equivalent to these fields. Therefore the CVO will have to apply the NCV fields as they are. The fields are presented in [Table 4](#).

Table 4. NCV fields used as predicates

Predicate	Description
regx:itemStatus	An attribute stating whether the concept is valid or not
regx:dateAccepted	An attribute stating the date on which the concept was accepted

11.8. Versioning information

This section presents predicates relating to versioning that were identified in the referenced controlled vocabularies.

NTAX at Ontology level

- owl:versionIRI "http://api.nsgreg.nga.mil/taxonomy/ntax/base17Feb" ;

- owl:versionInfo "base17Feb" ;

USTogographic at Ontology level

- owl:versionIRI

At concept level

- owl:versionInfo

None of the other controlled vocabularies were found to offer versioning information.

Chapter 12. Design of the Controlled Vocabulary Ontology

Having reviewed the controlled vocabularies provided by the testbed sponsors, the CVO was designed as shown in [Figure 6](#). This ontology addresses the requirement to define "an ontology that explores in detail the type of metadata needed to enable search on controlled vocabularies" which is stated in the Testbed-13 CFP. As illustrated the CVO imports SKOS, PROV and VOA. As illustrated the CVO imports SKOS, PROV and VOA.

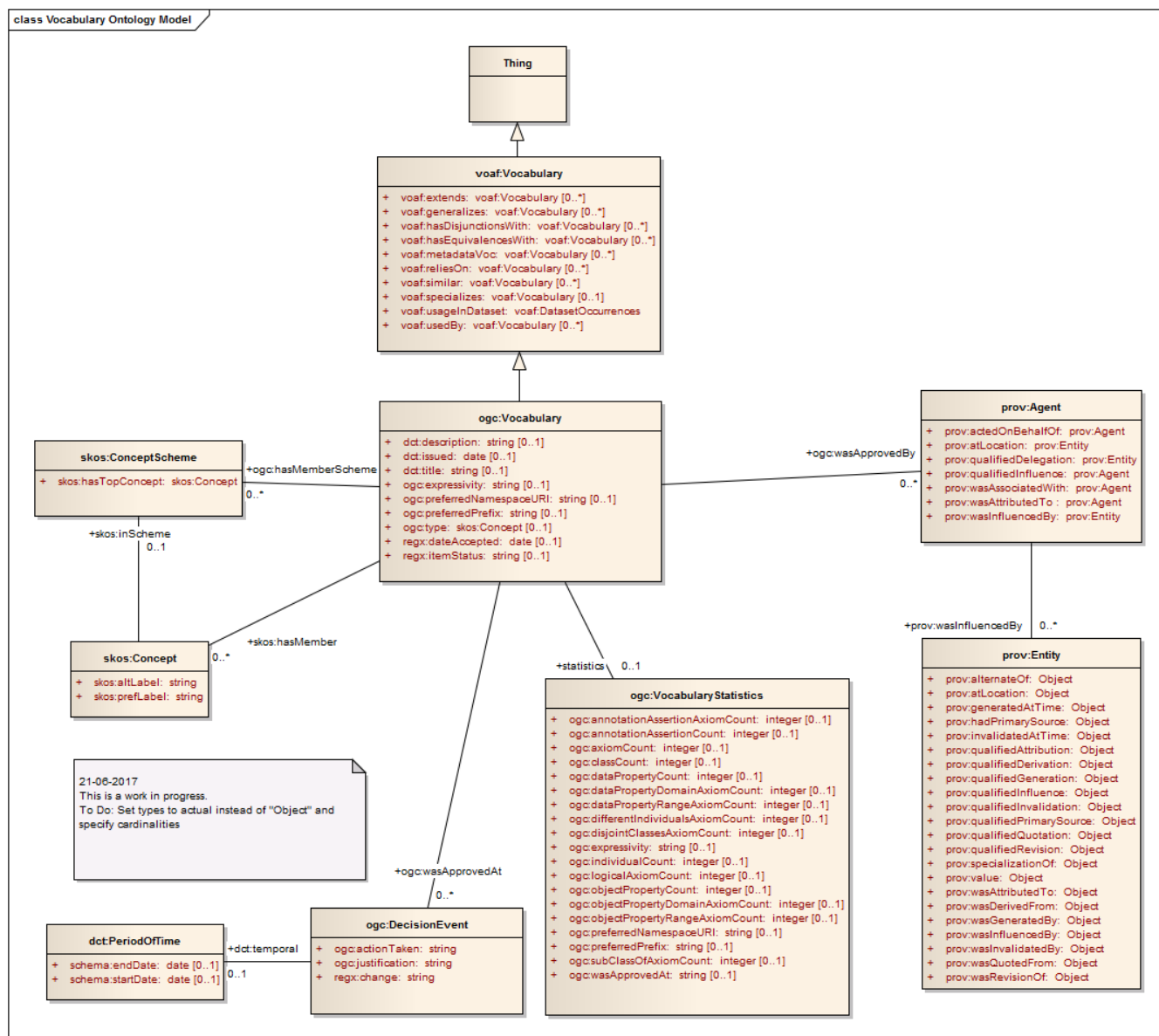


Figure 6. Controlled Vocabulary Ontology

12.1. Classes and Properties

12.1.1. ogc:VocabularyStatistics

The properties of the ogc:VocabularyStatistics class are presented in [Table 5](#).

Table 5. Properties of the ogc:VocabularyStatistics class

Name	Description	Range	Cardinality
ogc:annotationAssertionAxiomCount	number of annotation assertion axioms	xsd:integer	0..1
ogc:annotationAssertionCount	number of annotation assertions	xsd:integer	0..1
ogc:axiomCount	number of axioms	xsd:integer	0..1
ogc:classCount	number of classes	xsd:integer	0..1
ogc:dataPropertyCount	number of data properties	xsd:integer	0..1
ogc:dataPropertyDomainAxiomCount	number of data property domain axioms	xsd:integer	0..1
ogc:dataPropertyRangeAxiomCount	number of data property range axioms	xsd:integer	0..1
ogc:differentIndividualsAxiomCount	number of differentIndividuals axioms	xsd:integer	0..1
ogc:disjointClassesAxiomCount	number of disjointClasses axioms	xsd:integer	0..1
ogc:expressivity	an indicator of the breadth of ideas that can be represented through the controlled vocabulary	xsd:string	0..1
ogc:individualCount	number of individuals	xsd:integer	0..1
ogc:logicalAxiomCount	number of logical axioms	xsd:integer	0..1
ogc:objectPropertyCount	number of object properties	xsd:integer	0..1
ogc:objectPropertyDomainAxiomCount	number of object property domain axioms	xsd:integer	0..1
ogc:objectPropertyRangeAxiomCount	number of object property range axioms	xsd:integer	0..1
ogc:preferredNamespaceURI	the URI of the preferred namespace of the controlled vocabulary	xsd:string	0..1
ogc:preferredPrefix	the prefix of the preferred namespace of the controlled vocabulary	xsd:string	0..1
ogc:subClassOfAxiomCount	number of subClassOf axioms	xsd:integer	0..1

Name	Description	Range	Cardinality
ogc:wasApprovedAt	the name of the event or organization at which the controlled vocabulary was approved	xsd:string	0..1

12.1.2. ogc:DecisionEvent

The properties of the ogc:DecisionEvent class are presented in [Table 6](#).

Table 6. Properties of the ogc:DecisionEvent class

Name	Description	Range	Cardinality
ogc:actionTaken	Derived from the NSG Core Vocabulary Changes register. Described as the type of change made to the Enumerated Type Term; one of: Add, Clarify (changes that are "editorial" in nature and do not change the essence of the Enumerated Type Term), Supersede (replacement of the Enumerated Type Term by another Enumerated Type Term), or Retire.	xsd:string	1..1
ogc:justification	An explanation of the basis for the change to the Enumerated Type Term.	xsd:string	1..1
regx:change	A description, if applicable, of the specifics of the change.	xsd:string	1..1

12.1.3. ogc:Vocabulary

The properties of the ogc:Vocabulary class are presented in [Table 7](#).

Table 7. Properties of the ogc:Vocabulary class

Name	Description	Range	Cardinality
dct:description	An abstract of the resource.	xsd:string	0..1
dct:issued	The date the vocabulary was issued.	xsd:date	0..1

Name	Description	Range	Cardinality
dct:title	A name given to the vocabulary.	xsd:string	0..1
ogc:expressivity	The expressiveness of the vocabulary. This would typically be based on but not limited to Description Logic.	xsd:string	0..1
ogc:preferredNamespaceURI	The preferred namespace for use in serializations of the vocabulary.	xsd:string	0..1
ogc:preferredPrefix	The preferred prefix for use in serializations of the vocabulary.	xsd:string	0..1
ogc:type	The type of vocabulary (e.g. thesaurus, taxonomy etc).	skos:Concept	0..*
regx:dateAccepted	An attribute stating the date on which the concept was accepted. Adopted from the NSG Core Vocabulary Changes register.	xsd:date	0..1
regx:itemStatus	An attribute stating whether the concept is valid or not. Adopted from the NSG Core Vocabulary Changes register.	xsd:string	0..1

Chapter 13. Semantic Registry API

Testbed-13 was tasked with developing a REST API to enable search and access of vocabulary metadata and their terms. Following guidelines from Testbed-12 REST User Guide (OGC 16-057) and the Testbed-12 REST Architecture Engineering Report (OGC 16-035), the testbed implemented a Semantic Registry API that allowed for artifacts to be registered and published using the SRIM. This section presents the API.

The starting point of the work was to refer to the Semantic Registry API implemented in testbed-12. It was observed however that the testbed-12 implementation was based on the draft IETF HAL specification, which has since expired [<https://datatracker.ietf.org/doc/draft-kelly-json-hal/>]. It was therefore decided to avoid any HAL-specific requirements, while abiding to the REST principles recommended by the Testbed-12 REST User Guide and the Testbed-12 REST Architecture Engineering Report.

To support the design and implementation of the Semantic Registry API, the testbed deployed an instance of Apache Fuseki - an open source implementation of a REST-style SPARQL Service.

13.1. Semantic Registry Implementation

The Semantic Registry API was implemented as a RESTful API which supports SPARQL queries. The implementation was based on the specification described in the Testbed-12 Semantic Portrayal, Registry and Mediation Engineering Report (OGC 16-059), however some additional details were required to supplement those in the specification which caused some difficulties during implementation. For example, it was very helpful to read the W3C Data Catalog Vocabulary (DCAT) Recommendation (2014) as there are many concepts common to both SRIM and DCAT but which use different terms, such as "register" vs. "catalog" , and "item" vs. "dataset".

In this testbed, GIS.FCU used the open source RDF database, [BrightStarDB](http://brightstardb.com/) [http://brightstardb.com/], which is a non-SQL based, triple store database. It supports Microsoft's .NET Framework and has rich APIs allowing good integration into applications.

Several components were implemented during this testbed:

- USGS Metadata transformation template.
- CSW Data Publish transformation API.
- RDF Triple Store.
- RESTful SPARQL endpoint supporting registry operations.

The semantic registry API may be accessed using the endpoint URL, <http://140.134.48.46/SRIM/testbed13/>.

The metadata held within the registry was derived from metadata downloaded from the U.S. Open Data Portal (<https://catalog.data.gov/dataset>).

- Metadata HTML Page, <https://catalog.data.gov/harvest/object/6e1b7728-d106-44e4-9f2b-b24bf0d50416/html>.

- Metadata XML Page, <https://catalog.data.gov/harvest/object/6e1b7728-d106-44e4-9f2b-b24bf0d50416/>.

13.2. REST Principles

Representational State Transfer (REST) is a hybrid architectural style for network-based hypermedia systems. The architectural style is characterized by a set of principles which conforming applications abide by, though to different degrees. These principles include:

- Uniquely identifiable resources: The concept of a resource is the key abstraction in REST. Any information that can be named is considered a resource and should be identifiable by a URI; with each REST server locatable through a Uniform Resource Locator (URL).
- Manipulation of resources through representations: Resource representations held by the client should be sufficient to enable the client, if authorized, to manipulate the resource.
- Messages are self-descriptive: Each message should have enough information about itself to enable an application to process it, without requiring additional information.
- Client-Server: This principle relates to the separation of concerns, particularly with regard to the user interface and server-side data storage concerns.
- Stateless: Communication between clients and servers should be stateless, without reliance on any storage capabilities of the server nor dependence on any previous requests.
- Cache: Data within a response should be implicitly or explicitly labelled as cacheable or non-cacheable, such that a client may reuse the data later for similar requests.
- Layered System: This principle requires that an application is built from hierarchical layers (i.e. tiers) such that the behavior of a component is only visible to the component it interacts with in the next layer.
- Hypermedia as the engine of application state (HATEOAS): This principle requires that client applications navigate an application through hypermedia links. The response to each request provides links through which the client may interact with the server further or navigate further into the application.

The above-listed principles have a number of implications for the Semantic Registry. First, the use of URIs to identify resources is consistent with resource identification in semantic web and linked data applications, such as the Semantic Registry. Second, the requirement for self-describing messages is consistent with the increasing adoption of JSON-LD in semantic web applications. Third, separation of client and server concerns is consistent with the approach taken by the Semantic Registry in that the service does not rely or dictate any client behavior. Finally, semantic web applications such as the Semantic Registry are implemented to allow placement within a multi-tier (layered) system.

13.2.1. SPARQL Queries

The metadata RDF in SRIM/DCAT vocabulary can be generated via the SPARQL endpoint, <http://140.134.48.13/SRIM/testbed13/sparql>.

An example of a SPARQL query is <http://140.134.48.46/SRIM/testbed13/sparql?>

query=CONSTRUCT%20{?s%20?p%20?o}%20WHERE%20{?s%20?p%20?o}

The RDF result includes the namespace addresses and dataset information. In this testbed, there are only nine attributes (URI, Creator, Description, Issued date, Language, Modified date, Title, Distribution, and keyword) transformed from ISO 19139 to SRIM. The keywords of the datasets from the USGS website were not clearly typed, which caused difficulty when implementing the transformation. In this testbed, we used an XML String to define the RDF type of each keyword, due to the vague understanding of the concept of keyword. However, it could be improved through use of `skos:concept` to define the links between each keyword and outside vocabularies and resources.

RDF namespace declarations:

```
<rdf:RDF xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
xmlns:foaf="http://xmlns.com/foaf/0.1/"
xmlns:owl="http://www.w3.org/2002/07/owl#"
xmlns:org="http://www.w3.org/ns/org#"
xmlns:skos="http://www.w3.org/2004/02/skos/core#"
xmlns:gr="http://purl.org/goodrelations/v1#"
xmlns:vcard="http://www.w3.org/2006/vcard/ns#"
xmlns:dct="http://purl.org/dc/terms/"
xmlns:prov="http://www.w3.org/ns/prov#"
xmlns:dcap="http://www.w3.org/ns/dcap#"
xmlns:srim="http://www.opengis.net/ont/testbed12/srim#"
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
data-lifestyle-extension="available">
```

Dataset information generated from USGS metadata:

```

<srim:Item rdf:about="http://www.opengeospatial.org/testbed-13/Item/01ba6dc5-2e23-4fc9-a314-b5cb6694bc35">
  < dct:created rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
2017/10/3</dct:created>
  < dct:description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
>LEFT(T23,1000)</dct:description>
  < dct:issued rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
2016/11/29</dct:issued>
  < dct:language rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
eng</dct:language>
  < dct:modified rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
2017/10/3</dct:modified>
  < dct:title rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Geochemical
Database for the Brackish Groundwater Assessment of the United States</dct:title>
  < dcat:distribution rdf:resource=
"http://www.opengis.net/ont/testbed13/distribution/0202cc39-2aae-476f-89e7-54a1a999bf31"/>
  < dcat:keyword rdf:datatype="http://www.w3.org/2001/XMLSchema#string">USGS Science
Data Catalog (SDC)</dcat:keyword>
</srim:Item>

```

This testbed used the following mapping rule to transform the USGS metadata from ISO 19139 into SRIM.

Table 8. USGS Metadata, ISO 19139 to SRIM Mapping

USGS Field	SRIM Class 1	SRIM Field 1	SRIM Class 2	SRIM Field 2	SRIM Field 3
Data Identification	srim:Item	rdf:id			
Abstract: See http://geonames.usgs.gov for additional information.	srim:Item	dct:description			
Purpose: The Geographic Names Information ... and customized files upon request.	srim:Item	dct:description			
Language: eng; USA	srim:Item	dct:language			
Citation:	N/A				

USGS Field	SRIM Class 1	SRIM Field 1	SRIM Class 2	SRIM Field 2	SRIM Field 3
Title: Geographic Names Information System (GNIS) - National Geospatial Data Asset (NGDA) Geographic Names Information System (GNIS)	srim:Item	dct:title			
Date: 1981-05-01	N/A				
Date Type: Publication Date	N/A				
Organisation Name: U.S. Geological Survey	srim:Item	dct:publisher	org:Organization	foaf:name	
Role: Publisher	N/A				
Contact Info:	N/A				
City: Reston	N/A				
Administrative Area: VA	N/A				
Organisation Name: U.S. Geological Survey	N/A				
Role: Originator	N/A				
Organisation Name:	N/A				
Role:	N/A				
Contact Info:	N/A				
Online Resource: http://geonames.usgs.gov/	srim:Item	dct:publisher	org:Organization		
Point Of Contact:	N/A				
Individual Name: Louis A. Yost	srim:Item	dcat:contactPoint	vcard:Individual	vcard:fn	
Organisation Name: U.S. Geological Survey	srim:Item	dcat:contactPoint	vcard:Individual	vcard:organization-name	

USGS Field	SRIM Class 1	SRIM Field 1	SRIM Class 2	SRIM Field 2	SRIM Field 3
Position Name: Chief, Geographic Names Project	srim:Item	dcat:contactPoint	vcard:Individual	vcard:title	
Role: Point Of Contact	N/A				
Contact Info: Voice: 703 648 4552	srim:Item	dcat:contactPoint	vcard:Individual	vcard:hasTelephone	vcard:hasValue
Delivery Point: 523 National Center	srim:Item	dcat:contactPoint	vcard:Individual	vcard:hasAddress	vcard:street-address
City: Reston	srim:Item	dcat:contactPoint	vcard:Individual	vcard:hasAddress	vcard:locality
Administrative Area: Virginia	srim:Item	dcat:contactPoint	vcard:Individual	vcard:hasAddress	vcard:region
Postal Code: 20192	srim:Item	dcat:contactPoint	vcard:Individual	vcard:hasAddress	vcard:postal-code
E-Mail Address: gnis_manager@usgs.gov [mailto:gnis_manager@usgs.gov]	srim:Item	dcat:contactPoint	vcard:Individual	vcard:hasEmail	
Representation Type: Vector	N/A				
Keyword Collection:	N/A				
Keyword: National Geospatial Data Asset	srim:Item	dcat:keyword			
Keyword: NGDA	srim:Item	dcat:keyword			
Keyword: Cultural Resources Theme	srim:Item	dcat:keyword			
Associated Thesaurus: NGDA Portfolio Themes	N/A				
Keyword: location	srim:Item	dcat:keyword			
Keyword: economy	srim:Item	dcat:keyword			
Keyword: society	srim:Item	dcat:keyword			
Keyword: environment	srim:Item	dcat:keyword			
Keyword: structure	srim:Item	dcat:keyword			

USGS Field	SRIM Class 1	SRIM Field 1	SRIM Class 2	SRIM Field 2	SRIM Field 3
Keyword: imageryBaseMap sEarthCover	srIm:Item	dcat:keyword			
Keyword: inlandWaters	srIm:Item	dcat:keyword			
Keyword: transportation	srIm:Item	dcat:keyword			
Keyword: utilitiesCommu nication	srIm:Item	dcat:keyword			
Keyword: Feature identification	srIm:Item	dcat:keyword			
Keyword: Geographic feature	srIm:Item	dcat:keyword			
Keyword: Geographical feature	srIm:Item	dcat:keyword			
Keyword: Geographic name	srIm:Item	dcat:keyword			
Keyword: Geographical name	srIm:Item	dcat:keyword			
Keyword: Feature name	srIm:Item	dcat:keyword			
Keyword: Official feature name	srIm:Item	dcat:keyword			
Keyword: Place name	srIm:Item	dcat:keyword			
Keyword: Variant name	srIm:Item	dcat:keyword			
Keyword: Feature coordinates	srIm:Item	dcat:			
Keyword: Feature state	srIm:Item	dcat:keyword			
Keyword: Feature county	srIm:Item	dcat:keyword			
Keyword: Feature class	srIm:Item	dcat:keyword			
Keyword: Feature history	srIm:Item	dcat:keyword			
Keyword: Feature description	srIm:Item	dcat:keyword			
Keyword: Feature designation	srIm:Item	dcat:keyword			

USGS Field	SRIM Class 1	SRIM Field 1	SRIM Class 2	SRIM Field 2	SRIM Field 3
Associated Thesaurus: None	N/A				
Keyword: United States	srim:Item	dcat:keyword			
Keyword: State	srim:Item	dcat:keyword			
Keyword: County	srim:Item	dcat:keyword			
Keyword: Territory	srim:Item	dcat:keyword			
Keyword: Outlying Area	srim:Item	dcat:keyword			
Keyword: Topographic Map	srim:Item	dcat:keyword			
Keyword: Commonwealth	srim:Item	dcat:keyword			
Keyword: Parish	srim:Item	dcat:keyword			
Keyword: Borough	srim:Item	dcat:keyword			
Keyword: Census Area	srim:Item	dcat:keyword			
Keyword: Municipio	srim:Item	dcat:keyword			
Keyword: District	srim:Item	dcat:keyword			
Keyword: Populated Place	srim:Item	dcat:keyword			
Keyword: Antarctica	srim:Item	dcat:keyword			
Associated Thesaurus: Geographic Names Information System, USGS, Reston, VA	N/A				
Keyword: Current	srim:Item	dcat:keyword			
Keyword: Historical	srim:Item	dcat:keyword			
Associated Thesaurus: None	N/A				
Spatial Extent:	N/A				
West Bounding Longitude: -180.00	srim:Item	extent:hasGeographicExtent	extent:northBoundLatitude	xsd:decimal	

USGS Field	SRIM Class 1	SRIM Field 1	SRIM Class 2	SRIM Field 2	SRIM Field 3
East Bounding Longitude: 180.00	srIm:Item	extent:hasGeographicExtent	extent:southBoundLatitude	xsd:decimal	
North Bounding Latitude: 72.00	srIm:Item	extent:hasGeographicExtent	extent:westBoundLongitude	xsd:decimal	
South Bounding Latitude: -90.00	srIm:Item	extent:hasGeographicExtent	extent:eastBoundLongitude	xsd:decimal	
Constraints: Although ... warrant the delivery of this product in computer-readable format.	srIm:Item	srIm:accessLevel			
Legal Constraints:	N/A				
Use Constraints: Other Restrictions	N/A				
Other Constraints: Use Constraints: None. Acknowledgement of the U.S. Geological Survey would be appreciated in products derived from these data.	N/A				
Legal Constraints:	N/A				
Access Constraints: Other Restrictions	N/A				
Other Constraints: Access Constraints: None	N/A				
Distribution	N/A				
Distribution Format:	dcat:Distribution	dct:format			
Format Name: WAF	N/A				
Format Version:	N/A				
Distribution Format:	N/A				

USGS Field	SRIM Class 1	SRIM Field 1	SRIM Class 2	SRIM Field 2	SRIM Field 3
Format Name: HTML	dcat:Distribut ion	dct:format			
Format Version:	N/A				
Distribution Format:	N/A				
Format Name: ASCII	dcat:Distribut ion	dct:format			
Format Version:	N/A				
Distribution Format:	N/A				
Format Name: Arc SDE	dcat:Distribut ion	dct:format			
Format Version:	N/A				
Distribution Format:	N/A				
Format Name: XML.	dcat:Distribut ion	dct:format			
Format Version:	N/A				
Distribution Format:	N/A				
URL: http://thor-f5.er.usgs.gov/ngtoc/metadata/waf/geographic_names/gnis/	dcat:Distribut ion	dcat:accessURL			
Name:	N/A				
Description:	N/A				
Transfer Options:	N/A				
URL: http://geonames.usgs.gov/pls/gnispublic	dcat:Distribut ion	dcat:accessURL			
Name:	N/A				
Description:	N/A				
Transfer Options:	N/A				
URL: http://geonames.usgs.gov/pls/gnispublic	dcat:Distribut ion	dcat:accessURL			
Name:	N/A				
Description:	N/A				
Transfer Options:	N/A				

USGS Field	SRIM Class 1	SRIM Field 1	SRIM Class 2	SRIM Field 2	SRIM Field 3
URL: http://services.nationalmap.gov/arcgis/services/geonames/MapServer/WMServer	dcat:Distribut ion	dcat:accessURL			
Name:	N/A				
Description:	N/A				
Transfer Options:	N/A				
URL: http://geonames.usgs.gov/pls/gnis/x?fname=&state=&cnty=&cell=&ftype=	dcat:Distribut ion	dcat:accessURL			

13.3. Semantic Registry API Resources

In this testbed, six operations were implemented for metadata insert, update, delete and query.

- Capability
- Registers
- Register
- Items
- Item
- SPARQL

13.3.1. Capabilities

The `capabilities` endpoint describes and provides access to the capabilities metadata of the registry service.

Table 9. Semantic Registry REST API - Capabilities

HTTP Method	GET
Endpoint	http://140.134.48.46/SRIM/testbed13/capabilities [http://140.134.48.46/SRIM/testbed13/capabilities]

Response	<pre> { "itemClasses": [{ "description": "Dataset class", "id": "dcat:Dataset", "title": "Dataset", "type": "srim:ItemClass", "uri": "http://www.w3.org/ns/dcat#Dataset" }, { "description": "Service class", "id": "srim:Service", "title": "Service", "type": "srim:ItemClass", "uri": "http://www.opengis.net/ont/testbed12/srim#Service" }] } </pre>
-----------------	--

13.3.2. Registers

The registers endpoint presents all controlled collections of items of information.

Table 10. Semantic Registry REST API - Registers - HTTP GET

HTTP Method	GET
Endpoint	http://140.134.48.46/SRIM/testbed13/register[http://140.134.48.46/SRIM/testbed13/register]
Response	<pre> { "results": [{ "@id": "portrayal", "@type": "srim:Register", "dct:title": "Portrayal Register", "dct:description": "OGC Testbed 12 Register for portrayal information" }, { "@id": "schemas", "@type": "srim:Register", "dct:title": "Schema Register", "dct:description": "Register for schemas" }, { "@id": "datasets", "@type": "srim:Register", "dct:title": "Testbed12 Datasets Register", "dct:description": "Testbed 12 catalog for datasets and services harvested from multiple CSW instances" }] } </pre>

Table 11. Semantic Registry REST API - Registers - HTTP POST

HTTP Method	POST
--------------------	------

Endpoint	http://140.134.48.46/SRIM/testbed13/registers[http://140.134.48.46/SRIM/testbed13/registers]
Request Body	<pre> ``{ "id": "urn:example-register-002", "uri": "urn:example-register-002", "type": "srim:Register", "title": "Vocabulary Register002", "description": "Register for Controlled Vocabularies", "publisher": { "name": "Image Matters LLC", "uri": "http://www.imagemattersllc.com", "type": "org:Organization" } } </pre>
Response	<pre> ``{ "@context": { "dcat": "http://www.w3.org/ns/dcat#", "dct": "http://purl.org/dc/terms/", "dctype": "http://purl.org/dc/dcmitype/", "foaf": "http://xmlns.com/foaf/0.1/", "madsrdf": "http://www.loc.gov/mads/rdf/v1#", "org": "http://www.w3.org/ns/org#", "owl": "http://www.w3.org/2002/07/owl#", "rdf": "http://www.w3.org/1999/02/22-rdf-syntax-ns#", "rdfs": "http://www.w3.org/2000/01/rdf-schema#", "schema": "http://schema.org/", "srim": "http://www.opengis.net/ont/testbed12/srim#", "vann": "http://purl.org/vocab/vann/", "vcard": "http://www.w3.org/2006/vcard/ns#", "voaf": "http://purl.org/vocommons/voaf#", "xsd": "http://www.w3.org/2001/XMLSchema#" }, "@id": "http://www.opengeospatial.org/testbed-13/register/urn:example-register-44", "@type": "srim", "dct:description": "Register for Controlled Vocabularies", "dct:title": "Vocabulary Register", "dct:issued": "2017-08-14", "dct:modified": "2017-08-14" } </pre>

13.3.3. Register

The register endpoint enables the retrieval, update, and deletion of an instance of a single controlled collection of items of information.

Table 12. Semantic Registry REST API - Register - HTTP GET

HTTP Method	GET
Endpoint	http://140.134.48.46/SRIM/testbed13/register/urn:example-register-002[http://140.134.48.46/SRIM/testbed13/register/urn:example-register-002]

Response	<pre> { "@id": "schemas", "@type": "srim:Register", "dct:title": "Schema Register", "dct:description": "Register for schemas", "dct:issued": "2016-11-08", "dct:created": "2016-11-08T02:51:42.981Z", "dct:modified": "2016-11-08T02:51:42.981Z", "publisher": [{ "name": "Image Matters LLC", "uri": "http://www.imagemattersllc.com", "type": "org:Organization" }], "itemClass": ["schema:SchemaMapping", "schema:Schema"] } </pre>
-----------------	--

Table 13. Semantic Registry REST API - Register - HTTP PUT

HTTP Method	PUT
Endpoint	http://140.134.48.46/SRIM/testbed13/register/urn:example-register-002[http://140.134.48.46/SRIM/testbed13/register/urn:example-register-002]
Request Body	<pre> { "id": "urn:example-register-002", "uri": "urn:example-register-002", "type": "srim:Register", "title": "New updated title", "description": "Register for Controlled Vocabularies", "issued": "2016-10-17", "created": "2016-10-17T19:28:16.168Z", "modified": "2016-10-17T19:28:16.168Z" } </pre>
Response	<pre> { "@id": "http://www.opengeospatial.org/testbed-13/register/urn:example-register-18", "@type": "srim:Register", "dct:title": "New updated title", "dct:description": "Register for Controlled Vocabularies", "dct:issued": "2016-11-08", "dct:created": "2016-11-08T02:51:42.981Z", "dct:modified": "2016-11-08T02:51:42.981Z" } </pre>

Table 14. Semantic Registry REST API - Register - HTTP DELETE

HTTP Method	DELETE
Request	http://140.134.48.46/SRIM/testbed13/register/urn:example-register-002[http://140.134.48.46/SRIM/testbed13/register/urn:example-register-002]
Response	HTTP/1.1 200 OK

13.3.4. Items

The items endpoint enables the creation and listing of collections of items of information.

Table 15. Semantic Registry REST API - Items - HTTP GET

HTTP Method	GET
Endpoint	http://140.134.48.46/SRIM/testbed13/register/urn:example-register-001/items[http://140.134.48.46/SRIM/testbed13/register/urn:example-register-001/items]

Response

```
``{
  "results":[
    {
      "id":"2fe9867e7a22473bc2ec25dac3d959c7",
      "uri":"urn:x-envitia:TB12:NMF:nmf-G1470659423089",
      "type":"dcat:Dataset",
      "title":"Murres as indicators of a changing Arctic",
      "description":"The two species of murres, thick-billed Uria lomvia and
common U. aalge, both have circumpolar distributions, breeding in Arctic, sub-
Arctic and temperate seas from alifornia and N Spain to N Greenland, high Arctic
Canada, Svalbard, Franz Josef Land and Novaya Zemlya (Box 4.3 Fig. 1).
Conservation of Arctic Flora and Fauna, CAFF 2013 - Akureyri . Arctic
Biodiversity Assessment. Status and Trends in Arctic biodiversity. -
Birds(Chapter 4) page 163",
      "created":"2016-10-10T16:09:47.684Z"
    },
    {
      "id":"2373c7d58a4d54f0093bfb9b9f9d6c21",
      "uri":"urn:x-envitia:TB12:NMF:nmf-G1470659422925",
      "type":"dcat:Dataset",
      "title":"Avian biodiversity in different regions of the Arctic",
      "description":"Figure 4.1. Avian biodiversity in different regions of the
Arctic. Charts on the inner circle show species numbers of different bird groups
in the high Arctic, on the outer circle in the low Arctic. The size of the
charts is scaled to the number of species in each region, which ranges from 32
(Svalbard) to 117 (low Arctic Alaska). CAFF 2013. Arctic Biodiversity
Assessment. Status and Trends in Arctic biodiversity. Conservation of Arctic
Flora and Fauna, Akureyri - Birds (Chapter 4) page 145",
      "created":"2016-10-10T16:09:45.791Z"
    },
    {
      "id":"a267316b5c5171893b1771e71b7c5a19",
      "uri":"urn:x-envitia:TB12:NMF:nmf-G1470659423365",
      "type":"dcat:Dataset",
      "title":"Cumulative numbers of marine fish.",
      "description":"Cumulative numbers of marine fish diversity (n = 633,
Appendix 6.2) in the Arctic Ocean and adjacent seas (AOAS) from 1758 to the
present. Species are broadly grouped according to zoogeographic pattern (cf.
Section 6.3.1): Arctic (A, blue symbols) and non-Arctic (I£ AB, B, WD, red
symbols). Grey bars denote periods with many descriptions of new Arctic species.
Note that 75% of the non-Arctic species known to science were described by 1912,
whereas the same proportion for Arctic species was only reached in 1976. See
text for further information. Conservation of Arctic Flora and Fauna, CAFF 2013
- Akureyri . Arctic Biodiversity Assessment. Status and Trends in Arctic
biodiversity. - Fishes(Chapter 6) page 220",
      "created":"2016-10-10T16:09:50.824Z"
    },
    {
      "id":"d52e1c753f61dc577dce3ea5c5b818c8",
      "uri":"urn:x-envitia:TB12:NMF:nmf-G1470659423695",
      "type":"dcat:Dataset",
      "title":"Diversity of Arctic marine phytoplankton: based on surveys in the
Russian Arctic",
      "description":"The number of species depends partly on what has been
studied. Proportions vary somewhat around the Arctic, but diatoms and
dinoflagellates are the most diverse groups everywhere. The greatest sampling
effort has been in the Laptev Sea, Hudson Bay, and the Norwegian sector of the
Barents Sea. Species shown are among the most commonly recorded. Published in
the Life Linked to Ice released in 2013, page 26. Life Linked to Ice: A guide to
sea-ice-associated biodiversity in this time of rapid change. CAFF Assessment
Series No. 10. Conservation of Arctic Flora and Fauna, Iceland. ISBN: 978-9935-
431-25-7.",
      "created":"2016-10-10T16:09:54.199Z"
    }
  ]
}
```

Table 16. Semantic Registry REST API - Items - HTTP POST

HTTP Method	POST
Endpoint	http://140.134.48.46/SRIM/testbed13/register/urn:example-register-001/items[http://140.134.48.46/SRIM/testbed13/register/urn:example-register-001/items]
Request Body	<pre> { "id": "urn:example-item-25", "uri": "urn:example-item-25", "type": "dcat:Dataset", "title": "Example Item", "description": "This is an example item", "language": ["iso639-2:eng"], "characterSet": "http://def.seegrid.csiro.au/isotc211/iso19115/2003/code/CharacterSet/utf8", "distribution": [{ "title": "Example Distribution", "accessURL": "http://example.com/example-distribution", "type": "dcat:Distribution" }] } </pre>
Response	<pre> { "@id": "6b28163ce062d31533b6f0af1ab3b9e3", "@uri": "urn:example-item-25", "@type": "dcat:Dataset", "dct:title": "Example Item", "dct:description": "This is an example item", "dct:created": "2016-10-17T19:28:18.848Z", "dct:language": ["iso639-2:eng"], "dct:characterSet": "http://def.seegrid.csiro.au/isotc211/iso19115/2003/code/CharacterSet/utf8", "dct:distribution": { "title": "Example Distribution", "accessURL": "http://example.com/example-distribution", "type": "dcat:Distribution" } } </pre>

13.3.5. Item

The item endpoint enables the creation and description of a single item of information.

Table 17. Semantic Registry REST API - Item - HTTP GET

HTTP Method	GET
Endpoint	http://140.134.48.46/SRIM/testbed13/item/urn:example-item-30[http://140.134.48.46/SRIM/testbed13/item/urn:example-item-30]

Response	<pre> { "Id": "urn:example-item-30", "type": "dcat:Dataset", "title": "Example Item", "description": "This is an example item", "Issued": "2017/8/22", "modified": "2017/8/22", "language": ["iso639-2:eng"], "characterSet": "http://def.seegrid.csiro.au/isotc211/iso19115/2003/code/CharacterSet/utf8", "Created": "2017/8/22", "keyword": ["keywordSSSS"], "distribution": [] } </pre>
-----------------	---

Table 18. Semantic Registry REST API - Item - HTTP PUT

HTTP Method	PUT
Endpoint	http://140.134.48.46/SRIM/testbed13/item/urn:example-item-30[http://140.134.48.46/SRIM/testbed13/item/urn:example-item-30]
Request Body	<pre> { "id": "a22e8128788dc41d7deec94a4d52fe7e", "uri": "urn:example-item-4", "type": "dcat:Dataset", "title": "New updated title", "description": "This is an example item", "created": "2016-10-17T19:28:05.628Z", "language": ["iso639-2:eng"], "keyword": ["Added keyword"], "characterSet": "http://def.seegrid.csiro.au/isotc211/iso19115/2003/code/CharacterSet/utf8", "distribution": [{ "title": "Example Distribution", "accessURL": "http://example.com/example-distribution", "type": "dcat:Distribution" }] } </pre>

Response	<pre> { "@id": "a22e8128788dc41d7deec94a4d52fe7e", "@uri": "urn:example-item-4", "@type": "dcat:Dataset", "dct:title": "New updated title", "dct:description": "This is an example item", "dct:created": "2016-10-17T19:28:05.628Z", "dct:modified": "2016-10-17T19:28:06.106Z", "dct:language": ["iso639-2:eng"], "dct:keyword": ["Added keyword"], "dct:characterSet": "http://def.seegrid.csiro.au/isotc211/iso19115/2003/code/CharacterSet/utf8", "dcat:distribution": [{ "dct:title": "Example Distribution", "dcat:accessURL": "http://example.com/example-distribution", "@type": "dcat:Distribution" }] } </pre>
-----------------	--

Table 19. Semantic Registry REST API - Item - HTTP DELETE

HTTP Method	DELETE
Request	http://140.134.48.46/SRIM/testbed13/item/urn:example-item-30[http://140.134.48.46/SRIM/testbed13/item/urn:example-item-30]
Response	HTTP/1.1 200 OK

13.3.6. SPARQL

The SPARQL endpoint provides the ability to search the semantic registry using SPARQL queries.

Table 20. Semantic Registry REST API - SPARQL - HTTP GET

HTTP Method	GET
Request	http://140.134.48.46/SRIM/testbed13/sparql?query=select%20*%20where{?s%20?p%20?o}[http://140.134.48.46/SRIM/testbed13/sparql?query=select * where{?s ?p ?o}]

Response

```
``<?xml version="1.0" encoding="utf-8"?>
<sparql xmlns="http://www.w3.org/2005/sparql-results#">
  <head>
    <variable name="s"/>
    <variable name="p"/>
    <variable name="o"/>
  </head>
  <results>
    <result>
      <binding name="s">
        <uri>\http://www.opengeospatial.org/testbed-13/Item/urn:example-item-
29</uri>
      </binding>
      <binding name="p">
        <uri>\http://www.w3.org/ns/dcat#keyword[]</uri>
      </binding>
      <binding name="o">
        <literal
datatype="http://www.w3.org/2001/XMLSchema#string">keywordSSSS</literal>
        </binding>
      </result>
      <result>
        <binding name="s">
          <uri>\http://www.opengeospatial.org/testbed-13/Item/urn:example-item-
30</uri>
        </binding>
        <binding name="p">
          <uri>\http://www.w3.org/ns/dcat#keyword</uri>
        </binding>
        <binding name="o">
          <literal
datatype="http://www.w3.org/2001/XMLSchema#string">keywordSSSS</literal>
          </binding>
        </result>
        <result>
          <binding name="s">
            <uri>\http://www.opengeospatial.org/testbed-13/Item/urn:example-item-
29</uri>
          </binding>
          <binding name="p">
            <uri>\http://purl.org/dc/terms/issued</uri>
          </binding>
          <binding name="o">
            <literal
datatype="http://www.w3.org/2001/XMLSchema#string">2017/8/22</literal>
            </binding>
          </result>
          <result>
            <binding name="s">
              <uri>\http://www.opengeospatial.org/testbed-13/Item/urn:example-item-
30</uri>
            </binding>
            <binding name="p">
              <uri>\http://purl.org/dc/terms/issued</uri>
            </binding>
            <binding name="o">
              <literal
datatype="http://www.w3.org/2001/XMLSchema#string">2017/8/22</literal>
              </binding>
            </result>
            <result>
              <binding name="s">
                <uri>\http://www.opengeospatial.org/testbed-13/register/urn:example-
```

Endpoint	<code>http://140.134.48.46/SRIM/testbed13/sparql?query=CONSTRUCT%20{?s%20?p%20?o}%20WHERE%20{?s%20?p%20?o}[http://140.134.48.46/SRIM/testbed13/sparql?query=CONSTRUCT%20{?s ?p ?o} WHERE {?s ?p ?o}]</code>
-----------------	---

Response

```
`<?xml version="1.0" encoding="utf-8"?>
<!DOCTYPE RDF [

<!ENTITY rdf 'http://www.w3.org/1999/02/22-rdf-syntax-ns#'><!ENTITY rdfs
'http://www.w3.org/2000/01/rdf-schema#'><!ENTITY xsd
'http://www.w3.org/2001/XMLSchema#'>]>
<rdf:RDF xmlns:ns0="http://www.w3.org/ns/dcat#"
xmlns:ns1="http://www.opengis.net/ont/testbed12/srim#"
xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
xmlns:xsd="http://www.w3.org/2001/XMLSchema#">
  <rdf:Description rdf:about="http://www.opengeospatial.org/testbed-
13/Item/urn:example-item-29">
    <ns2:created rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
xmlns:ns2="http://purl.org/dc/terms/">2017/8/22</ns2:created>
    <ns3:description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
xmlns:ns3="http://purl.org/dc/terms/">This is an example item</ns3:description>
    <ns4:issued rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
xmlns:ns4="http://purl.org/dc/terms/">2017/8/22</ns4:issued>
    <ns5:language rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
xmlns:ns5="http://purl.org/dc/terms/">iso639-2:eng</ns5:language>
    <ns6:modified rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
xmlns:ns6="http://purl.org/dc/terms/">2017/8/22</ns6:modified>
    <ns7:title rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
xmlns:ns7="http://purl.org/dc/terms/">Example Item</ns7:title>
    <ns1:characterSet
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">\http://def.seegrid.csiro
.au/isotc211/iso19115/2003/code/CharacterSet/utf8</ns1:characterSet>
    <rdf:type
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">dcat:Dataset</rdf:type>
    <ns0:distribution
rdf:resource="http://www.opengis.net/ont/testbed13/distribution/ec30189f-9866-
427a-a7de-fbf0476ab1bb"/>
    <ns0:distribution
rdf:resource="http://www.opengis.net/ont/testbed13/distribution/fae7c4f3-5ea9-
4880-b8c3-8a2a67cbdf47"/>
    <ns0:keyword
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">keywordSSSS</ns0:keyword>
  </rdf:Description>
  <ns1:Item rdf:about="http://www.opengeospatial.org/testbed-
13/Item/urn:example-item-30">
    <ns8:created rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
xmlns:ns8="http://purl.org/dc/terms/">2017/8/22</ns8:created>
    <ns9:description rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
xmlns:ns9="http://purl.org/dc/terms/">This is an example item</ns9:description>
    <ns10:issued rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
xmlns:ns10="http://purl.org/dc/terms/">2017/8/22</ns10:issued>
    <ns11:language rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
xmlns:ns11="http://purl.org/dc/terms/">iso639-2:eng</ns11:language>
    <ns12:modified rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
xmlns:ns12="http://purl.org/dc/terms/">2017/8/22</ns12:modified>
    <ns13:title rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
xmlns:ns13="http://purl.org/dc/terms/">Example Item</ns13:title>
    <ns1:characterSet
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">\http://def.seegrid.csiro
.au/isotc211/iso19115/2003/code/CharacterSet/utf8</ns1:characterSet>
    <ns0:distribution
rdf:resource="http://www.opengis.net/ont/testbed13/distribution/88e59e18-7dd7-
4892-b5e0-546c176bcc58"/>
    <ns0:keyword
rdf:datatype="http://www.w3.org/2001/XMLSchema#string">keywordSSSS</ns0:keyword>
  </ns1:Item>
  <ns1:Register rdf:about="http://www.opengeospatial.org/testbed-
```

13.4. Semantic Registry to PubSub Integration

A series of manual steps were used to demonstrate the ability of the semantic registry to harvest from a PubSub CSW.

13.4.1. 1. Confirm registry is empty

The registry was first shown to be empty by using the [Postman](https://www.getpostman.com/) [https://www.getpostman.com/] REST client to send an HTTP request to the semantic registry.

<http://140.134.48.46/SRIM/testbed13/register/urn:example-register-001/items>

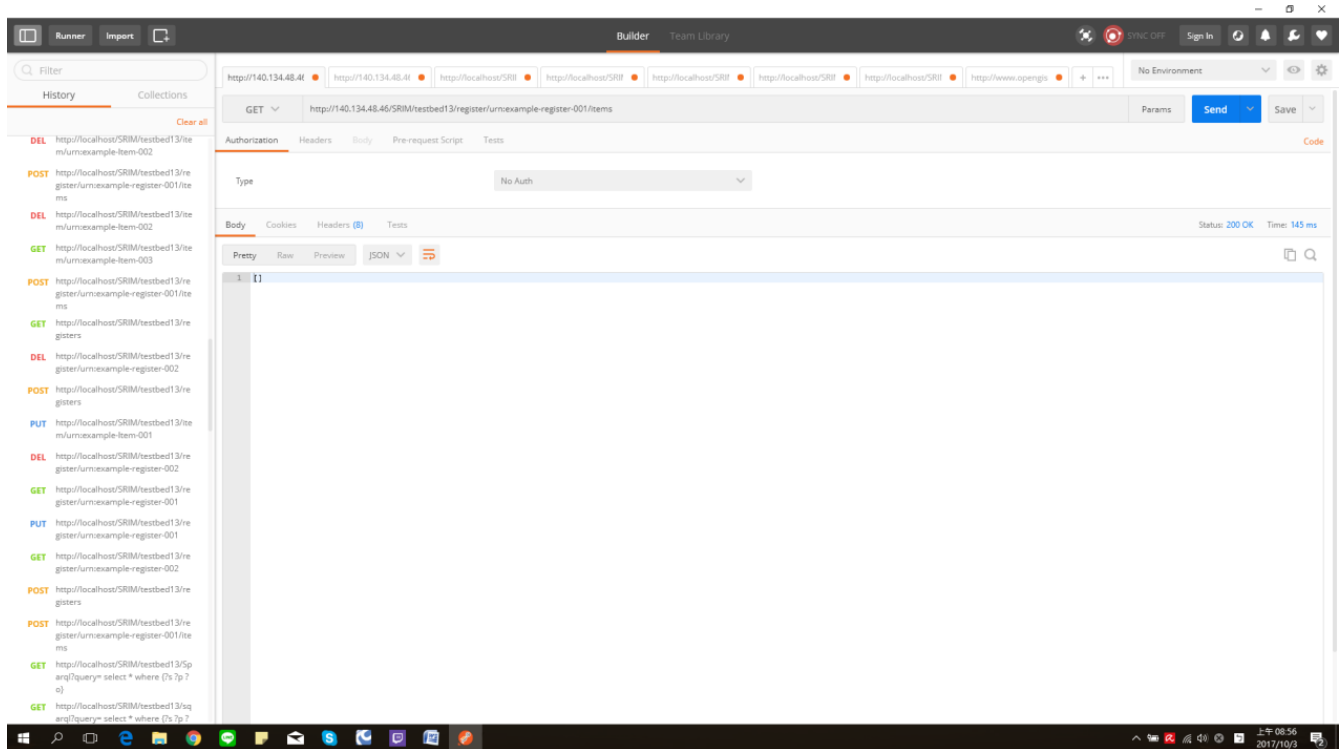


Figure 7. Request demonstrating that the registry is empty.

13.4.2. 2. Subscribe to notifications from the PubSub

The Postman tool was next used to send a Subscribe request to the PubSub. The Subscribe request contained the endpoint (DeliveryLocation) where notifications were to be sent.

```

POST http://86.188.147.117:10080/pubsubsw/PubSubServlet?request=Subscribe&version=1.0.0&service=PubSub
Authorization Headers (1) Body Pre-request Script Tests
form-data x-www-form-urlencoded raw binary XML (text/xml)
1 <?xml version="1.0" encoding="UTF-8"?>
2 <pubsub:Subscribe xmlns="http://www.opengis.net/pubsub/1.0"
3   xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:gco="http://www.isotc211.org/2005/gco"
4   xmlns:gml="http://www.opengis.net/gml/3.2" xmlns:ows="http://www.opengis.net/ows/1.1"
5   xmlns:gts="http://www.isotc211.org/2005/gts" xmlns:gmd="http://www.isotc211.org/2005/gmd"
6   xmlns:gsr="http://www.isotc211.org/2005/gsr" xmlns:gss="http://www.isotc211.org/2005/gss"
7   xmlns:pubsub="http://www.opengis.net/pubsub/1.0"
8   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
9   <pubsub:PublicationIdentifier>GIS.FCU</pubsub:PublicationIdentifier>
10
11   <!-- pubsub:Filter must contain an ogc:Filter wrapped in CDATA as pubsub specification states this is a string -->
12   <pubsub:Filter>
13     <![CDATA[
14       <ogc:Filter>
15         <ogc:PropertyIsLike escapeChar="#" matchCase="false" singleChar="#" wildcard="#">
16           <ogc:PropertyName>Title</ogc:PropertyName>
17           <ogc:Literal>*</ogc:Literal>
18         </ogc:PropertyIsLike>
19       </ogc:Filter>
20     ]]>
21   </pubsub:Filter>
22
23   <pubsub:FilterLanguageId>Filter</pubsub:FilterLanguageId>
24
25   <!-- Delivery location is where you want the notification sent -->
26   <pubsub:DeliveryLocation>http://140.134.48.46/SRIM/testbed13/catchdata</pubsub:DeliveryLocation>

```

Figure 8. Subscribe request to the PubSub, showing the notification endpoint.

The **SubscriptionResponse** received from the PubSub showed that the subscription was successful. The response contains the unique identifier of the subscription, as well as confirmation of the delivery location and filter.

```

1 <?xml version="1.0" encoding="UTF-8" standalone="yes"?>
2 <pubsub:SubscriptionResponse xmlns:gco="http://www.isotc211.org/2005/gco" xmlns:gml="http://www.opengis.net/gml/3.2" xmlns:gts="http://www.isotc211.org/2005/gts" xmlns:pubsub="http://www.opengis.net/pubsub/1.0" xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:gmd="http://www.isotc211.org/2005/gmd">
3   <pubsub:Subscription>
4     <pubsub:SubscriptionIdentifier>7000bdc6-202b-4619-a767-5f41540f0b0c</pubsub:SubscriptionIdentifier>
5     <pubsub:PublicationIdentifier>GIS.FCU</pubsub:PublicationIdentifier>
6     <pubsub:FilterLanguageId>Filter</pubsub:FilterLanguageId>
7     <pubsub:Filter xsi:type="gco:string" xmlns:gco="http://www.w3.org/2001/XMLSchema" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">&lt;ogc:Filter&gt;
8       &lt;ogc:PropertyIsLike escapeChar="#" matchCase="false" singleChar="#" wildcard="#"&gt;
9         &lt;ogc:PropertyName&gt;Title&lt;/ogc:PropertyName&gt;
10        &lt;ogc:Literal&gt;*&lt;/ogc:Literal&gt;
11      &lt;/ogc:PropertyIsLike&gt;
12    &lt;/ogc:Filter&gt;</pubsub:Filter>
13     <pubsub:DeliveryLocation xmlns:gss="http://www.isotc211.org/2005/gss" xmlns:gsr="http://www.isotc211.org/2005/gsr" xmlns:ows="http://www.opengis.net/ows/1.1" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">http://140.134.48.46/SRIM/testbed13/catchdata</pubsub:DeliveryLocation>
14   </pubsub:Subscription>
15 </pubsub:SubscriptionResponse>

```

Figure 9. SubscribeResponse received from the PubSub.

The lower half of the screenshot shows that a valid SubscriptionResponse was received, confirming that the SRIM will be notified of any content changes in the PubSub CSW.

13.4.3.3. Notification Received

As content was added to the PubSub CSW, notifications were received by the middle tier transformer which parsed the ISO 19139 metadata. The metadata was transformed into SRIM and inserted into the back-end triple store.

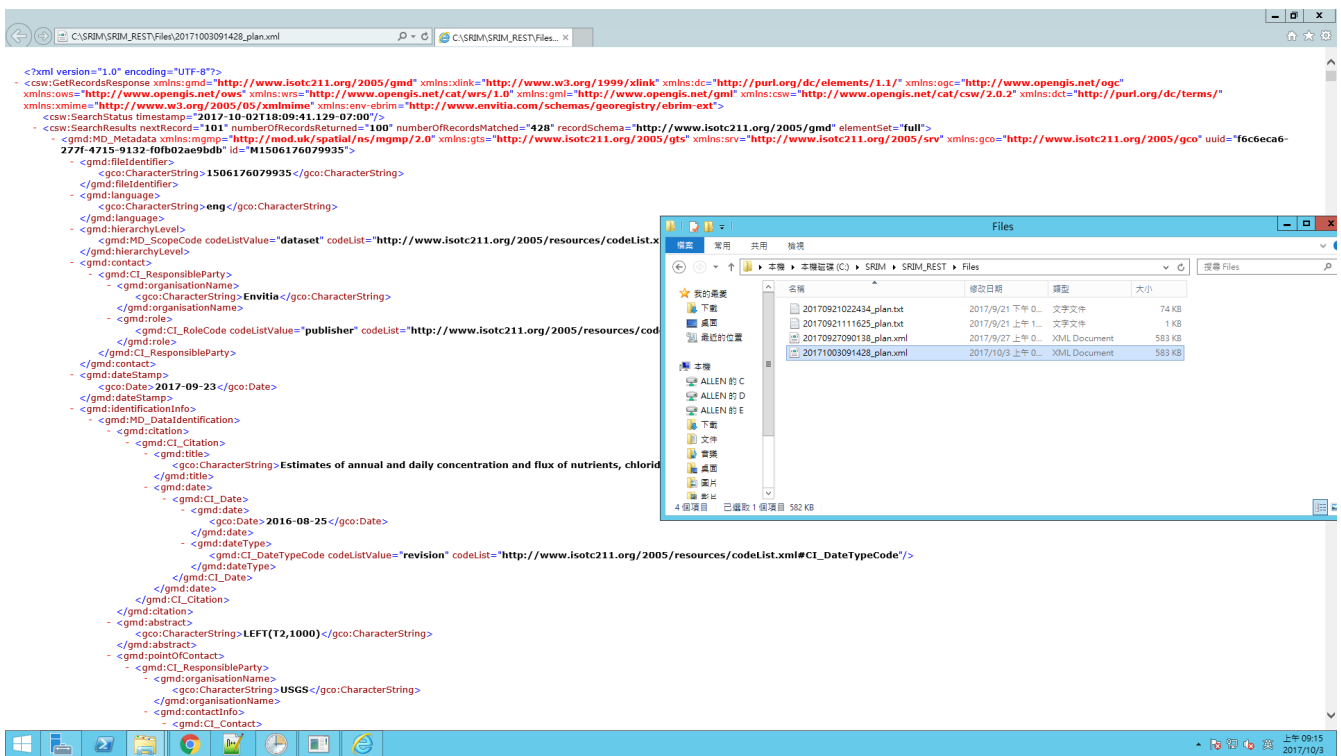


Figure 10. Notification received from the PubSub.

13.4.4. 4. Confirmation

The original request from Step 1 above was repeated using Postman. This demonstrated that items from the PubSub had been successfully received, transformed from ISO 19139 into SRIM, and inserted into the registry.

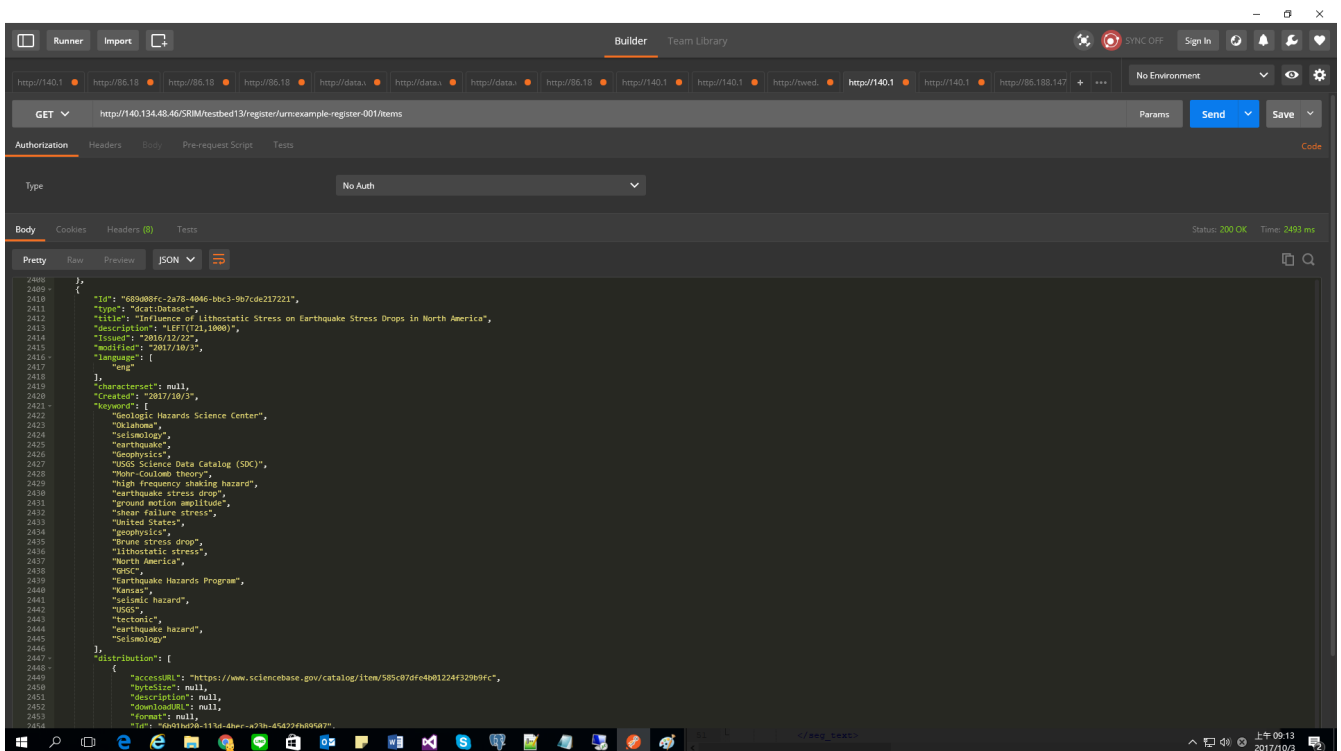


Figure 11. Request demonstrating that the registry now contains metadata.

A SPARQL query can also be used to retrieve the items from the registry.

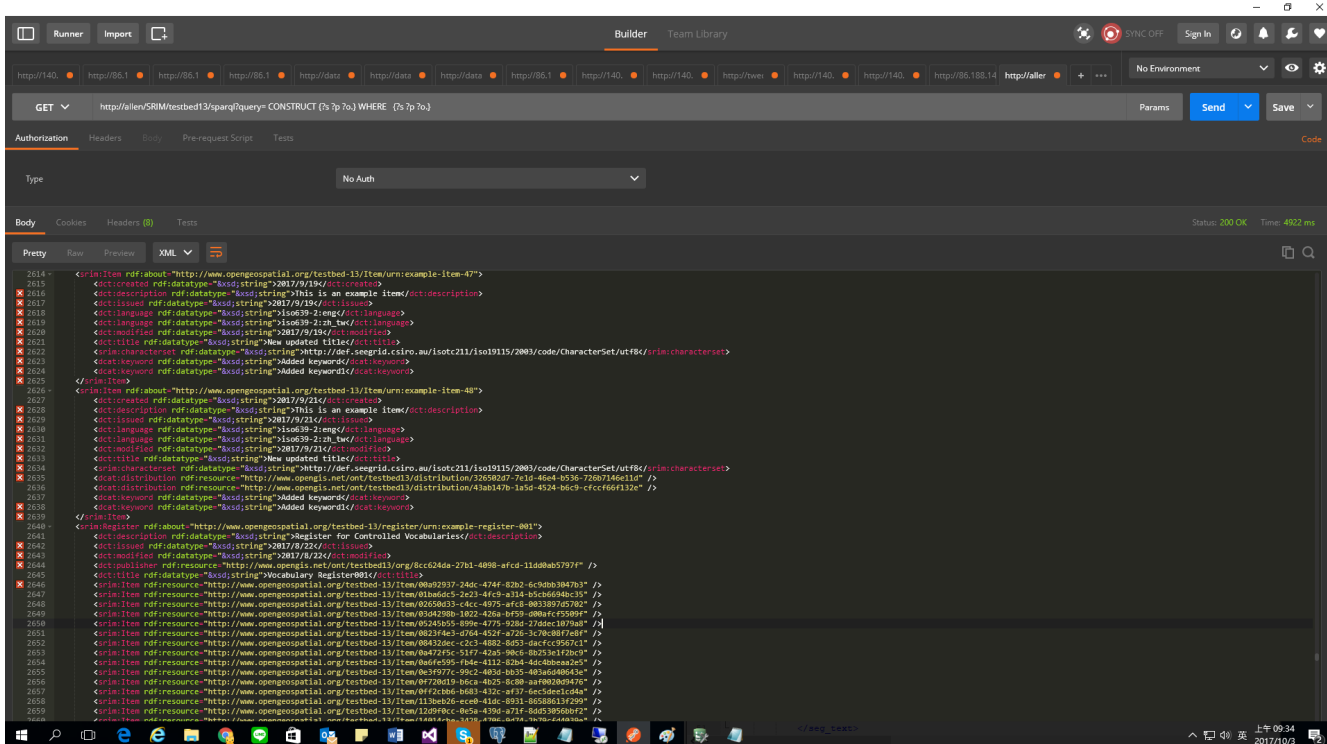


Figure 12. An example SPARQL query request and response.

13.5. Status codes

The Semantic Registry uses response status codes defined in HTTP to indicate the success or failure of an operation. The response body of a successful request has a 2XX response (e.g. 200, 202 etc). 4XX or 5XX HTTP response codes (e.g. 404, 500 etc) indicate a failed operation.

The following table shows a list of status codes commonly used by RESTful applications.

Table 21. HTTP Status codes

Code	Name	Description
200	OK	The request operation has succeeded.
201	Created	The request operation successfully resulted in creation of a new resource.
202	Accepted	The request has been accepted for processing, but the processing is on-going.
204	No Content	The server has fulfilled the request but does not need to return an entity-body, and might want to return updated metainformation.

Code	Name	Description
304	Not Modified	If the client has performed a conditional GET request and access is allowed, but the document has not been modified, the server SHOULD respond with this status code.
400	Bad Request	Due to malformed syntax, the request could not be understood by the server.
401	Unauthorized	The request requires user authentication.
403	Forbidden	The server understood the request, but is refusing to fulfill it.
404	Not Found	The server has not found anything matching the Request-URI.
409	Conflict	Due to a conflict with the current state of the resource, the request could not be completed.
500	Internal Server Error	The server encountered an unexpected condition which prevented it from fulfilling the request.

Chapter 14. Findings and Recommendations

This testbed found that the SRIM offers a viable model for implementing a semantic registry that is accessible through a RESTful API. The testbed also found that SHACL offers capability that could allow documents based on SRIM, DCAT or other Linked Data specifications to be validated. This engineering report concludes that a standard for a RESTful semantic registry service, that uses SHACL for validation at data-ingest, is feasible and needed.

Familiarization with a number of technologies would be beneficial to any future implementor of a semantic registry including *RDF/XML*, *Turtle*, *SPARQL*, *ISO 19115* and *ISO 19139*, as well as *SRIM* and *DCAT*.

This testbed only implemented the first level of SRIM - *Register*, *Item* and *Distribution*. Interoperability would be improved if more vocabularies were included in the future, such as *foaf:agent*, *org:organization*, and other linked data vocabularies.

The back-end database, *BrightStarDB*, was chosen because of the development environment used to implement the semantic registry (C# .NET Framework).

14.1. Recommendation 1

Future OGC testbeds should design the requirements and Abstract Test Suites for a RESTful semantic registry service standard, that also uses SHACL for validation at data-ingest.

14.2. Recommendation 2

The work presented in this engineering report successfully demonstrated how the OGC PubSub specification could be implemented alongside an OGC Catalogue Service in order to enable the catalogue service to support publish, subscribe and notification capabilities. It was observed that other than the OGC PubSub core standard, which is based on XML, the only other binding offered is SOAP. Future work should explore the possibility of implementing alternative bindings such as [Linked Data Notifications](https://www.w3.org/TR/ldn/) [https://www.w3.org/TR/ldn/] which is based on REST and encoded in JSON for Linked Data (JSON-LD). This engineering report therefore recommends that future OGC testbeds should explore the potential for a binding of the OGC PubSub standard based on Linked Data Notifications.

14.3. Recommendation 3

The successful implementation of a PubSub Extension to CSW in Testbed-13, by building on the lessons learnt in Testbed-12, also demonstrates that there is sufficient understanding of the requirements and issues involved in offering PubSub support through CSW. This engineering report therefore recommends that the OGC Catalogue SWG should develop an extension standard for Catalogue Services version 3.0 to support PubSub.

14.4. Recommendation 4

Testbed-13 has been the first testbed to implement ISO 19115-3 support in CSW. This has been achieved through use of XSLT scripts provided by ISO. This enabled participants to better understand the requirements for catalogue services to support this relatively new ISO standard. Testbed participants noted that Section 6.3.1 of the Catalogue Services version 3.0 standard makes references to ISO 19115:2003, ISO 19115-1:2014, ISO/TS 19139:2007 and ISO 19119 without making any reference to ISO 19115-3:2016. The Catalogue Services version 3.0 standard also states that "Where a catalogue service advertises such application schemas, catalogues that handle geographic dataset descriptions should conform to published metadata standards and encodings, e.g. ISO 19115:2003, and support XML encoding per ISO 19139 or profiles thereof. Service metadata elements should be consistent with ISO 19119[6] or 19115:2014". This means change requests for updating the Catalogue Services version 3.0 general model (OGC 12-168r6) are required. In light of the release of ISO 19115-3 and its successful testing, this engineering report recommends that the Catalogue SWG should begin to design modifications to the Catalogue Services standard and its profiles that are currently based on ISO 19139 in order to upgrade them to ISO 19115-3.

14.5. Recommendation 5

The CVO that is proposed in this engineering report brings together several concepts that have not previously been supported in metadata specifications, for example statistics and expressivity of controlled vocabularies. Providing such information could improve the resource discovery and retrieval experience. This engineering report therefore recommends that the Geosemantics DWG develops a Best Practice document for the use of CVO to describe controlled vocabularies.

Appendix A: Mappings

This section presents mappings between SRIM and related metadata specifications.

DCAT to SRIM

Table 22. DCAT to SRIM Cross Walk

DCAT Class	DCAT Attribute	SRIM Class	SRIM Attribute
dcat:Catalog	dct:title	srim:Register	dct:title
dcat:Catalog	dct:description	srim:Register	dct:description
dcat:Catalog	dct:issued	srim:Register	dct:issued
dcat:Catalog	dct:modified	srim:Register	dct:modified
dcat:Catalog	dct:language	srim:Register	dct:language
dcat:Catalog	dct:license	srim:Register	dct:license
dcat:Catalog	dct:rights	srim:Register	dct:rights
dcat:Catalog	dct:spatial	srim:Register	dct:spatial
dcat:Catalog	foaf:homepage	srim:Register	dcat:landingPage
dcat:Catalog	dcat:dataset	srim:Register	srim:Item
dcat:Catalog	dcat:record	srim:Register	srim:entry
dcat:Catalog	dcat:themeTaxonomy	srim:Register	dcat:themeTaxonomy
dcat:Catalog	dct:publisher	srim:Register	dct:publisher
dcat:CatalogRecord	dct:title		
dcat:CatalogRecord	dct:description		
dcat:CatalogRecord	dct:issued		
dcat:CatalogRecord	dct:modified		
dcat:CatalogRecord	foaf:primaryTopic		
dcat:Dataset	dct:title	srim:Item	dct:title
dcat:Dataset	dct:description	srim:Item	dct:description
dcat:Dataset	dct:issued	srim:Item	dct:issued
dcat:Dataset	dct:modified	srim:Item	dct:modified
dcat:Dataset	dct:language	srim:Item	dct:language
dcat:Dataset	dct:publisher	srim:Item	dct:publisher
dcat:Dataset	dct:accrualPeriodicity	srim:Item	dct:accrualPeriodicity
dcat:Dataset	dct:identifier	srim:Item	dct:identifier

DCAT Class	DCAT Attribute	SRIM Class	SRIM Attribute
dcat:Dataset	dct:spatial	srim:Item	dct:spatial
dcat:Dataset	dct:temporal	srim:Item	dct:temporal
dcat:Dataset	dcate:theme	srim:Item	dcate:theme
dcat:Dataset	dcate:keyword	srim:Item	dcate:keyword
dcat:Dataset	dcate:contactPoint	srim:Item	dcate:contactPoint
dcat:Dataset	dcate:distribution	srim:servicebody	dcate:distribution
dcat:Dataset	dcate:landingPage	srim:Item	dcate:landingPage
dcate:Distribution	dct:title	dcate:Distribution	dct:title
dcate:Distribution	dct:description	dcate:Distribution	dct:description
dcate:Distribution	dct:issued		
dcate:Distribution	dct:modified		
dcate:Distribution	dct:license	dcate:Distribution	dct:license
dcate:Distribution	dct:rights	dcate:Distribution	dct:rights
dcate:Distribution	dcate:accessURL	dcate:Distribution	dcate:accessURL
dcate:Distribution	dcate:downloadURL		
dcate:Distribution	dcate:byteSize	dcate:Distribution	dcate:byteSize
dcate:Distribution	dcate:mediaType	dcate:Distribution	dcate:mediaType
dcate:Distribution	dct:format	dcate:Distribution	dct:format
skos:Concept	skos:inScheme	skos:Concept	skos:inScheme
foaf:Agent	foaf:Person/ foaf:Organization	foaf:Agent	foaf:name

SRIM to DCAT

Table 23. SRIM to DCAT Cross Walk

SRIM Class	SRIM Attribute	DCAT Class	DCAT Attribute
srim:Register	srim:alias		
srim:Register	dct:title	dcate:Catalog	dct:title
srim:Register	dct:description	dcate:Catalog	dct:description
srim:Register	dct:publisher	dcate:Catalog	dct:publisher

SRIM Class	SRIM Attribute	DCAT Class	DCAT Attribute
srим:Register	srим:item	dcat:Catalog	dcat:dataset
srим:Register	srим:itemClass		
srим:Register	dct:conformsTo		
srим:Register	rdf:id		
srим:Register	dcat:landingPage	dcat:Catalog	foaf:homepage
srим:Register	dct:language	dcat:Catalog	dct:language
srим:Register	dct:license	dcat:Catalog	dct:license
srим:Register	dct:issued	dcat:Catalog	dct:issued
srим:Register	dct:modified	dcat:Catalog	dct:modified
srим:Register	dcat:themeTaxonomy	dcat:Catalog	dcat:themeTaxonomy
srим:Register	srим:entry	dcat:Catalog	dcat:record
srим:Register	dct:rights	dcat:Catalog	dct:rights
srим:Register	dct:spatial	dcat:Catalog	dct:spatial
srим:Register	dct:temporal		
srим:RegisterEntry	dct:identifier		
srим:RegisterEntry	foaf:primaryTopic	dcat:CatalogRecord	foaf:primaryTopic
srим:RegisterEntry	dct:issued	dcat:CatalogRecord	dct:issued
srим:RegisterEntry	dct:modified	dcat:CatalogRecord	dct:modified
srим:RegisterEntry	prov:wasGeneratedBy		
srим:RegisterEntry	srим:status		
srим:RegisterEntry	dct:title	dcat:CatalogRecord	dct:title
srим:RegisterEntry	dct:description	dcat:CatalogRecord	dct:description
srим:RegisterEntry	rdf:id		
srим:RegisterEntry	dct:language		
srим:RegisterEntry	dct:source		
srим:RegisterEntry	pav:previousVersion		
srим:ItemClass	rdf:id		
srим:ItemClass	srим:name		

SRIM Class	SRIM Attribute	DCAT Class	DCAT Attribute
srim:ItemClasses	dct:title		
srim:ItemClasses	dct:description		
srim:ItemClasses	srim:technicalStandard		
srim:Item	rdf:id		
srim:Item	rdf:type		
srim:Item	dct:title	dcat:Dataset	dct:title
srim:Item	dct:description	dcat:Dataset	dct:description
srim:Item	dcat:contactPoint	dcat:Dataset	dcat:contactPoint
srim:Item	dct:publisher	dcat:Dataset	dct:publisher
srim:Item	dcat:keyword	dcat:Dataset	dcat:keyword
srim:Item	"dcat:theme subproperty of dct:subject"	dcat:Dataset	dcat:theme
srim:Item	dct:created		
srim:Item	dct:issued	dcat:Dataset	dct:issued
srim:Item	dct:modified	dcat:Dataset	dct:modified
srim:Item	dct:identifier	dcat:Dataset	dct:identifier
srim:Item	id:hasIdentifier		
srim:Item	pav:hasVersion		
srim:Item	pav:hasCurrentVersion		
srim:Item	dct:type(resourceType in JSON)		
srim:Item	dct:spatial	dcat:Dataset	dct:spatial
srim:Item	dct:temporal	dcat:Dataset	dct:temporal
srim:Item	dcat:landingPage	dcat:Dataset	dcat:landingPage
srim:Item	dct:language	dcat:Dataset	dct:language
srim:Item	dct:rightsHolder		
srim:Item	dct:creator		
srim:Item	dct:contributor		
srim:Item	prov:qualifiedAttribution(attribution in JSON)		
srim:Item	srim:purpose		

SRIM Class	SRIM Attribute	DCAT Class	DCAT Attribute
srим:Item	srим:audience		
srим:Item	srим:topic		
srим:Item	srим:project		
srим:Item	srим:function		
srим:Item	link:hasLink		
srим:Item	dct:relation		
srим:Item	srим:accessLevel		
srим:Item	dct:accrualPeriodicity	dcat:Dataset	dct:accrualPeriodicity
srим:Item	dct:conformsTo		
srим:Item	extent:hasGeographicExtent		
srим:Item	foaf:depiction		
srим:Item	dct:provenance		
prov:Activity	rdf:id		
vcard:Address	vcard:street-address		
vcard:Address	vcard:locality		
vcard:Address	vcard:region		
vcard:Address	vcard:postal-code		
vcard:Address	vcard:country-name		
foaf:Agent	foaf:name		
foaf:Agent	rdf:id		
prov:Attribution	prov:agent		
prov:Attribution	prov:role		
skos:Concept	rdf:id		
skos:Concept	skos:prefLabel		
skos:Concept	rdf:type		
skos:Concept	skos:inScheme		
skos:Concept	skos:definition		
skos:ConceptScheme	rdf:id		
skos:ConceptScheme	dct:title		
skos:ConceptScheme	skos:definition		

SRIM Class	SRIM Attribute	DCAT Class	DCAT Attribute
foaf:Document	rdf:id		
foaf:Document	dct:title		
foaf:Document	dct:descripti on		
vcard:Email	vcard:hasValu e		
extent:Geogra phicExtent	extent:northB oundLatitude		
extent:Geogra phicExtent	extent:southB oundLatitude		
extent:Geogra phicExtent	extent:westBo undLongitude		
extent:Geogra phicExtent	extent:eastBo undLongitude		
id:Identifier	id:code		
id:Identifier	id:codespace		
id:Identifier	id:authority		
dct:LicenseDo cument	rdf:id		
dct:LicenseDo cument	dct:descripti on		
link:Link	link:href		
link:Link	link:rel		
link:Link	dct:title		
link:Link	dct:descripti on		
link:Link	dct:format		
link:Link	link:mediaTyp e		
link:Link	link:hrefLang		
dct:Location	rdf:id		
dct:Location	locn:geograph icName		
dct:Location	dct:descripti on		
gr:OpeningHou rsSpecificati on	rdfs:label		
gr:OpeningHou rsSpecificati on	gr:opens		
gr:OpeningHou rsSpecificati on	gr:closes		
gr:OpeningHou rsSpecificati on	gr:hasOpening HoursDayOfWee k		

SRIM Class	SRIM Attribute	DCAT Class	DCAT Attribute
org:Organization	org:subOrganizationOf		
dct:PeriodOfTime	schema:startDate		
dct:PeriodOfTime	schema:endDate		
dct:PeriodOfTime	rdf:id		
vcard:Phone	vcard:hasValue		
foaf:Project	rdf:id		
foaf:Project	foaf:name		
dct:ProvenanceStatement	dct:description		
dct:ProvenanceStatement	dct:title		
dct:ProvenanceStatement	rdf:id		
srим:Release	rdf:id		
srим:Release	pav:version		
srим:Release	adms:versionNotes		
srим:Release	dct:issued		
srим:Release	pav:versionOf		
dct:RightsStatement	skos:definition		
dct:RightsStatement	rdf:id		
dct:Standard	rdf:id		
dct:Standard	dct:title		
dct:Standard	pav:version		
dct:Standard	dct:description		
vcard:VCard	vcard:fn		
vcard:VCard	vcard:hasEmail		
vcard:VCard	rdf:id		
vcard:VCard	vcard:organization-name		
vcard:VCard	vcard:hasTelephone		
vcard:VCard	vcard:title		
vcard:VCard	dcat:landingPage		
vcard:VCard	vcard:address		

SRIM Class	SRIM Attribute	DCAT Class	DCAT Attribute
vcard:VCard	gr:hasOpeningHoursSpecification		
dcat:Dataset	dcat:distribution		
dcat:Distribution	dcat:accessURL	dcat:Distribution	dcat:accessURL
dcat:Distribution	dcat:mediaType	dcat:Distribution	dcat:mediaType
dcat:Distribution	dct:description	dcat:Distribution	dct:description
dcat:Distribution	dct:conformsTo		
dcat:Distribution	dct:title	dcat:Distribution	dct:title
dcat:Distribution	dcat:byteSize	dcat:Distribution	dcat:byteSize
dcat:Distribution	dct:language		
dcat:Distribution	dct:format	dcat:Distribution	dct:format
dcat:Distribution	foaf:page		
dcat:Distribution	dct:license	dcat:Distribution	dct:license
dcat:Distribution	dct:rights	dcat:Distribution	dct:rights
dcat:Distribution	adms:representationTechnique		
dct:FileFormat	rdfs:label		
dct:FileFormat	pav:version		
srim:Service	srim:operatesOn		
srim:APIDocument	dcat:accessURL		
srim:APIDocument	dcat:mediaType		
srim:APIDocument	dcat:format		
srim:APIDocument	dct:title		
srim:APIDocument	dct:description		

Appendix B: ISO 19139 to ISO 19115-3 Transformations

This section presents an example of a `GetRecordsResponse` in ISO 19139 before and after transformation into ISO 19115-3.

GetRecordsResponse (ISO 19139)

GetRecords Request

The GetRecords query below requested the response to contain the data in ISO 19139 format by specifying the `outputSchema` attribute value as the GMD namespace:

```
outputSchema="http://www.isotc211.org/2005/gmd"
```

```
<?xml version="1.0" encoding="UTF-8"?>
<csw:GetRecords
  xmlns:ogc="http://www.opengis.net/ogc"
  xmlns:csw="http://www.opengis.net/cat/csw/2.0.2"
  xmlns:gml="http://www.opengis.net/gml"
  xmlns:gmd="http://www.isotc211.org/2005/gmd"
  service="CSW" version="2.0.2" resultType="results" outputFormat="application/xml"
  outputSchema="http://www.isotc211.org/2005/gmd" startPosition="1" maxRecords="200">
  <csw:Query typeName="gmd:MD_Metadata">
    <csw:ElementSetName>full</csw:ElementSetName>
    <csw:Constraint version="1.1.0">
      <ogc:Filter>
        <ogc:PropertyIsEqualTo>
          <ogc:PropertyName>Title</ogc:PropertyName>
          <ogc:Literal>Ice Cores of the National Ice Core Laboratory</ogc:Literal>
        </ogc:PropertyIsEqualTo>
      </ogc:Filter>
    </csw:Constraint>
  </csw:Query>
</csw:GetRecords>
```

GetRecordsResponse

```
<?xml version="1.0" encoding="UTF-8"?>
<csw:GetRecordsResponse xmlns:csw="http://www.opengis.net/cat/csw/2.0.2" xmlns:dc=
"http://purl.org/dc/elements/1.1/" xmlns:dct="http://purl.org/dc/terms/" xmlns:env-
ebri="http://www.envitia.com/schemas/georegistry/ebri-ext" xmlns:gmd=
"http://www.isotc211.org/2005/gmd" xmlns:gml="http://www.opengis.net/gml" xmlns:ogc=
"http://www.opengis.net/ogc" xmlns:ows="http://www.opengis.net/ows" xmlns:wrs=
"http://www.opengis.net/cat/wrs/1.0" xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xmime="http://www.w3.org/2005/05/xmlmime">
```

```

<csw:SearchStatus timestamp="2017-09-07T04:25:01.712-07:00"/>
<csw:SearchResults elementSet="full" nextRecord="0" numberOfRecordsMatched="1"
numberOfRecordsReturned="1" recordSchema="http://www.isotc211.org/2005/gmd">
  <gmd:MD_Metadata id="M1501170734777" uuid="a6799c19-c831-434f-8b6a-33699300bca8"
xmlns:gco="http://www.isotc211.org/2005/gco" xmlns:gts=
"http://www.isotc211.org/2005/gts" xmlns:mgmp="http://mod.uk/spatial/ns/mgmp/2.0"
xmlns:srv="http://www.isotc211.org/2005/srv">
    <gmd:fileIdentifier>
      <gco:CharacterString>1501170734777</gco:CharacterString>
    </gmd:fileIdentifier>
    <gmd:language>
      <gco:CharacterString>eng</gco:CharacterString>
    </gmd:language>
    <gmd:hierarchyLevel>
      <gmd:MD_ScopeCode codeList=
"http://www.isotc211.org/2005/resources/codeList.xml#MD_ScopeCode" codeListValue=
"dataset"/>
    </gmd:hierarchyLevel>
    <gmd:contact>
      <gmd:CI_ResponsibleParty>
        <gmd:organisationName>
          <gco:CharacterString>Envitia</gco:CharacterString>
        </gmd:organisationName>
        <gmd:role>
          <gmd:CI_RoleCode codeList=
"http://www.isotc211.org/2005/resources/codeList.xml#CI_RoleCode" codeListValue=
"publisher"/>
        </gmd:role>
      </gmd:CI_ResponsibleParty>
    </gmd:contact>
    <gmd:dateStamp>
      <gco:Date>2017-07-27</gco:Date>
    </gmd:dateStamp>
    <gmd:identificationInfo>
      <gmd:MD_DataIdentification>
        <gmd:citation>
          <gmd:CI_Citation>
            <gmd:title>
              <gco:CharacterString>Ice Cores of the National Ice Core
Laboratory</gco:CharacterString>
            </gmd:title>
            <gmd:date>
              <gmd:CI_Date>
                <gmd:date>
                  <gco:Date>2013-03-08</gco:Date>
                </gmd:date>
                <gmd:dateType>
                  <gmd:CI_DateTypeCode codeList=
"http://www.isotc211.org/2005/resources/codeList.xml#CI_DateTypeCode" codeListValue=
"revision"/>
                </gmd:dateType>
              </gmd:CI_Date>
            </gmd:date>
          </gmd:CI_Citation>
        </gmd:citation>
      </gmd:MD_DataIdentification>
    </gmd:identificationInfo>
  </gmd:MD_Metadata>
</csw:SearchResults>

```

```

    </gmd:CI_Date>
    </gmd:date>
    </gmd:CI_Citation>
  </gmd:citation>
  <gmd:abstract>
    <gco:CharacterString>The U.S. National Ice Core Laboratory (NICL) is a
    facility for storing, curating, and studying ice cores recovered from the polar
    regions of the world. It provides scientists with the capability to conduct
    examinations and measurements on ice cores, and it preserves the integrity of these
    ice cores in a long-term repository for current and future
    investigations.</gco:CharacterString>
  </gmd:abstract>
  <gmd:pointOfContact>
    <gmd:CI_ResponsibleParty>
      <gmd:organisationName>
        <gco:CharacterString>USGS</gco:CharacterString>
      </gmd:organisationName>
      <gmd:contactInfo>
        <gmd:CI_Contact>
          <gmd:phone/>
          <gmd:address>
            <gmd:CI_Address>
              <gmd:deliveryPoint/>
              <gmd:city/>
              <gmd:postalCode/>
              <gmd:electronicMailAddress>
                <gco:CharacterString>sbristol@usgs.gov</gco:CharacterString>
              </gmd:electronicMailAddress>
            </gmd:CI_Address>
          </gmd:address>
          <gmd:onlineResource>
            <gmd:CI_OnlineResource>
              <gmd:linkage>
                <gmd:URL>http://www.usgs.gov</gmd:URL>
              </gmd:linkage>
            </gmd:CI_OnlineResource>
          </gmd:onlineResource>
        </gmd:CI_Contact>
      </gmd:contactInfo>
      <gmd:role>
        <gmd:CI_RoleCode codeList=
"http://www.isotc211.org/2005/resources/codeList.xml#CI_RoleCode" codeListValue=
"originator"/>
      </gmd:role>
    </gmd:CI_ResponsibleParty>
  </gmd:pointOfContact>
  <gmd:descriptiveKeywords>
    <gmd:MD_Keywords>
      <gmd:keyword>
        <gco:CharacterString>Collection</gco:CharacterString>
      </gmd:keyword>
    </gmd:MD_Keywords>
  </gmd:descriptiveKeywords>

```

```

    <gmd:keyword>
      <gco:CharacterString>USGS Science Data Catalog
(SDC)</gco:CharacterString>
    </gmd:keyword>
    <gmd:type>
      <gmd:MD_KeywordTypeCode codeList=
"http://metadata.dgiwg.org/codeListRegistry?MD_KeywordTypeCode" codeListValue="theme
"/>
    </gmd:type>
  </gmd:MD_Keywords>
</gmd:descriptiveKeywords>
<gmd:resourceConstraints>
  <gmd:MD_SecurityConstraints>
    <gmd:classification>
      <gmd:MD_ClassificationCode codeList=
"http://www.isotc211.org/2005/resources/codeList.xml#MD_ClassificationCode"
codeListValue="unclassified"/>
    </gmd:classification>
  </gmd:MD_SecurityConstraints>
</gmd:resourceConstraints>
<gmd:language>
  <gco:CharacterString>eng</gco:CharacterString>
</gmd:language>
<gmd:topicCategory>
  <gmd:MD_TopicCategoryCode>environment</gmd:MD_TopicCategoryCode>
</gmd:topicCategory>
<gmd:extent>
  <gmd:EX_Extent>
    <gmd:geographicElement>
      <gmd:EX_GeographicBoundingBox>
        <gmd:westBoundLongitude>
          <gco:Decimal>-179.99999999994</gco:Decimal>
        </gmd:westBoundLongitude>
        <gmd:eastBoundLongitude>
          <gco:Decimal>179.999988540844</gco:Decimal>
        </gmd:eastBoundLongitude>
        <gmd:southBoundLatitude>
          <gco:Decimal>-89.0000000000073</gco:Decimal>
        </gmd:southBoundLatitude>
        <gmd:northBoundLatitude>
          <gco:Decimal>83.6235961786649</gco:Decimal>
        </gmd:northBoundLatitude>
      </gmd:EX_GeographicBoundingBox>
    </gmd:geographicElement>
  </gmd:EX_Extent>
</gmd:extent>
</gmd:MD_DataIdentification>
</gmd:identificationInfo>
<gmd:distributionInfo>
  <gmd:MD_Distribution>
    <gmd:distributor>

```



```

    <gmd:MD_Distributor>
      <gmd:distributorContact>
        <gmd:CI_ResponsibleParty>
          <gmd:organisationName>
            <gco:CharacterString>USGS</gco:CharacterString>
          </gmd:organisationName>
          <gmd:positionName/>
          <gmd:role>
            <gmd:CI_RoleCode codeList=
"http://www.isotc211.org/2005/resources/codelist.xml#CI_RoleCode" codeListValue=
"distributor"/>
          </gmd:role>
        </gmd:CI_ResponsibleParty>
      </gmd:distributorContact>
    </gmd:MD_Distributor>
  </gmd:distributor>
  <gmd:transferOptions>
    <gmd:MD_DigitalTransferOptions>
      <gmd:onLine>
        <gmd:CI_OnlineResource>
          <gmd:linkage>
            <gmd:URL>https://www.sciencebase.gov/catalog/item/513a2eaae4b09608cc166c1b</gmd:URL>
          </gmd:linkage>
        </gmd:CI_OnlineResource>
      </gmd:onLine>
    </gmd:MD_DigitalTransferOptions>
  </gmd:transferOptions>
</gmd:MD_Distribution>
</gmd:distributionInfo>
<gmd:metadataConstraints>
  <gmd:MD_SecurityConstraints>
    <gmd:classification>
      <gmd:MD_ClassificationCode codeList=
"http://www.isotc211.org/2005/resources/codelist.xml#MD_ClassificationCode"
codeListValue="unclassified"/>
    </gmd:classification>
  </gmd:MD_SecurityConstraints>
</gmd:metadataConstraints>
</gmd:MD_Metadata>
</csw:SearchResults>
</csw:GetRecordsResponse>

```

GetRecordsResponse (ISO 19115-3)

GetRecords Request

The GetRecords query below requested the response to contain the data in ISO 19115-3 format by specifying the `outputSchema` attribute value as the MDB namespace:

```
outputSchema="http://standards.iso.org/iso/19115/-3/mdb/1.0"
```

```
<?xml version="1.0" encoding="UTF-8"?>
<csw:GetRecords
  xmlns:ogc="http://www.opengis.net/ogc"
  xmlns:csw="http://www.opengis.net/cat/csw/2.0.2"
  xmlns:gml="http://www.opengis.net/gml"
  xmlns:gmd="http://www.isotc211.org/2005/gmd"
  service="CSW" version="2.0.2" resultType="results" outputFormat="application/xml"
  outputSchema="http://standards.iso.org/iso/19115/-3/mdb/1.0" startPosition="1"
  maxRecords="200">
  <csw:Query typeNames="mdb:MD_Metadata">
    <csw:ElementSetName>full</csw:ElementSetName>
    <csw:Constraint version="1.1.0">
      <ogc:Filter>
        <ogc:PropertyIsEqualTo>
          <ogc:PropertyName>Title</ogc:PropertyName>
          <ogc:Literal>Ice Cores of the National Ice Core Laboratory</ogc:Literal>
        </ogc:PropertyIsEqualTo>
      </ogc:Filter>
    </csw:Constraint>
  </csw:Query>
</csw:GetRecords>
```

GetRecordsResponse

```
<?xml version="1.0" encoding="UTF-8"?>
<csw:GetRecordsResponse
  xmlns:csw="http://www.opengis.net/cat/csw/2.0.2"
  xmlns:dc="http://purl.org/dc/elements/1.1/"
  xmlns:dct="http://purl.org/dc/terms/"
  xmlns:env-ebrim="http://www.envitia.com/schemas/georegistry/ebrim-ext"
  xmlns:gmd="http://www.isotc211.org/2005/gmd"
  xmlns:gml="http://www.opengis.net/gml"
  xmlns:ogc="http://www.opengis.net/ogc"
  xmlns:ows="http://www.opengis.net/ows"
  xmlns:wrs="http://www.opengis.net/cat/wrs/1.0"
  xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:xmime="http://www.w3.org/2005/05/xmlmime">
  <csw:SearchStatus timestamp="2017-09-07T04:25:01.928-07:00"/>
  <csw:SearchResults elementSet="full" nextRecord="0" numberOfRecordsMatched="1"
  numberOfRecordsReturned="1" recordSchema="http://www.isotc211.org/2005/gmd">
    <mdb:MD_Metadata
      xmlns:cat="http://standards.iso.org/iso/19115/-3/cat/1.0"
      xmlns:cit="http://standards.iso.org/iso/19115/-3/cit/1.0"
      xmlns:gco="http://standards.iso.org/iso/19115/-3/gco/1.0"
      xmlns:gcx="http://standards.iso.org/iso/19115/-3/gcx/1.0"
      xmlns:gex="http://standards.iso.org/iso/19115/-3/gex/1.0"
      xmlns:gml="http://www.opengis.net/gml/3.2"
```

```

xmlns:lan="http://standards.iso.org/iso/19115/-3/lan/1.0"
xmlns:mac="http://standards.iso.org/iso/19115/-3/mac/1.0"
xmlns:mas="http://standards.iso.org/iso/19115/-3/mas/1.0"
xmlns:mcc="http://standards.iso.org/iso/19115/-3/mcc/1.0"
xmlns:mco="http://standards.iso.org/iso/19115/-3/mco/1.0"
xmlns:mda="http://standards.iso.org/iso/19115/-3/mda/1.0"
xmlns:mdb="http://standards.iso.org/iso/19115/-3/mdb/1.0"
xmlns:mdq="http://standards.iso.org/iso/19157/-2/mdq/1.0"
xmlns:mds="http://standards.iso.org/iso/19115/-3/mds/1.0"
xmlns:mdt="http://standards.iso.org/iso/19115/-3/mdt/1.0"
xmlns:mex="http://standards.iso.org/iso/19115/-3/mex/1.0"
xmlns:mmi="http://standards.iso.org/iso/19115/-3/mmi/1.0"
xmlns:mpe="http://standards.iso.org/iso/19115/-3/mpe/1.0"
xmlns:mrc="http://standards.iso.org/iso/19115/-3/mrc/1.0"
xmlns:mrd="http://standards.iso.org/iso/19115/-3/mrd/1.0"
xmlns:mri="http://standards.iso.org/iso/19115/-3/mri/1.0"
xmlns:mrl="http://standards.iso.org/iso/19115/-3/mrl/1.0"
xmlns:mrs="http://standards.iso.org/iso/19115/-3/mrs/1.0"
xmlns:msr="http://standards.iso.org/iso/19115/-3/msr/1.0"
xmlns:srv="http://standards.iso.org/iso/19115/-3/srv/2.0"
xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
<mdb:metadataIdentifier>
  <mcc:MD_Identifier>
    <mcc:code>
      <gco:CharacterString>1501170734777</gco:CharacterString>
    </mcc:code>
  </mcc:MD_Identifier>
</mdb:metadataIdentifier>
<mdb:defaultLocale>
  <lan:PT_Locale>
    <lan:language>
      <lan:LanguageCode codeList="codeListLocation#LanguageCode" codeListValue=
"eng">eng</lan:LanguageCode>
    </lan:language>
    <lan:characterEncoding gco:nilReason="unknown"/>
  </lan:PT_Locale>
</mdb:defaultLocale>
<mdb:metadataScope>
  <mdb:MD_MetadataScope>
    <mdb:resourceScope>
      <mcc:MD_ScopeCode codeList="codeListLocation#MD_ScopeCode" codeListValue=
"dataset">dataset</mcc:MD_ScopeCode>
    </mdb:resourceScope>
  </mdb:MD_MetadataScope>
</mdb:metadataScope>
<mdb:contact>
  <cit:CI_Responsibility>
    <cit:role>
      <cit:CI_RoleCode codeList="codeListLocation#CI_RoleCode" codeListValue=
"publisher">publisher</cit:CI_RoleCode>

```

```

</cit:role>
<cit:party>
  <cit:CI_Organisation>
    <cit:name>
      <gco:CharacterString>Envitia</gco:CharacterString>
    </cit:name>
  </cit:CI_Organisation>
</cit:party>
</cit:CI_Responsibility>
</mdb:contact>
<mdb:dateInfo>
  <cit:CI_Date>
    <cit:date>
      <gco:DateTime>2017-07-27T00:00:00</gco:DateTime>
    </cit:date>
    <cit:dateType>
      <cit:CI_DateTypeCode codeList="codeListLocation#CI_DateTypeCode"
codeListValue="creation">creation</cit:CI_DateTypeCode>
    </cit:dateType>
  </cit:CI_Date>
</mdb:dateInfo>
<mdb:identificationInfo>
  <mri:MD_DataIdentification>
    <mri:citation>
      <cit:CI_Citation>
        <cit:title>
          <gco:CharacterString>Ice Cores of the National Ice Core
Laboratory</gco:CharacterString>
        </cit:title>
        <cit:date>
          <cit:CI_Date>
            <cit:date>
              <gco:DateTime>2013-03-08T00:00:00</gco:DateTime>
            </cit:date>
            <cit:dateType>
              <cit:CI_DateTypeCode codeList="codeListLocation#CI_DateTypeCode"
codeListValue="revision">revision</cit:CI_DateTypeCode>
            </cit:dateType>
          </cit:CI_Date>
        </cit:date>
      </cit:CI_Citation>
    </mri:citation>
    <mri:abstract>
      <gco:CharacterString>The U.S. National Ice Core Laboratory (NICL) is a
facility for storing, curating, and studying ice cores recovered from the polar
regions of the world. It provides scientists with the capability to conduct
examinations and measurements on ice cores, and it preserves the integrity of these
ice cores in a long-term repository for current and future
investigations.</gco:CharacterString>
    </mri:abstract>
    <mri:pointOfContact>

```

```

<cit:CI_Responsibility>
  <cit:role>
    <cit:CI_RoleCode codeList="codeListLocation#CI_RoleCode"
codeListValue="originator">originator</cit:CI_RoleCode>
  </cit:role>
  <cit:party>
    <cit:CI_Organisation>
      <cit:name>
        <gco:CharacterString>USGS</gco:CharacterString>
      </cit:name>
      <cit:contactInfo>
        <cit:CI_Contact>
          <cit:address>
            <cit:CI_Address>
              <cit:deliveryPoint/>
              <cit:city/>
              <cit:postalCode/>
              <cit:electronicMailAddress>
                <gco:CharacterString>
sbristol@usgs.gov</gco:CharacterString>
              </cit:electronicMailAddress>
            </cit:CI_Address>
          </cit:address>
          <cit:onlineResource>
            <cit:CI_OnlineResource>
              <cit:linkage>
                <gco:CharacterString>
http://www.usgs.gov</gco:CharacterString>
              </cit:linkage>
            </cit:CI_OnlineResource>
          </cit:onlineResource>
        </cit:CI_Contact>
      </cit:contactInfo>
    </cit:CI_Organisation>
  </cit:party>
</cit:CI_Responsibility>
</mri:pointOfContact>
<mri:topicCategory>
  <mri:MD_TopicCategoryCode>environment</mri:MD_TopicCategoryCode>
</mri:topicCategory>
<mri:extent>
  <gex:EX_Extent>
    <gex:geographicElement>
      <gex:EX_GeographicBoundingBox>
        <gex:westBoundLongitude>
          <gco:Decimal>-179.99999999994</gco:Decimal>
        </gex:westBoundLongitude>
        <gex:eastBoundLongitude>
          <gco:Decimal>179.999988540844</gco:Decimal>
        </gex:eastBoundLongitude>
        <gex:southBoundLatitude>

```

```

        <gco:Decimal>-89.00000000000073</gco:Decimal>
    </gex:southBoundLatitude>
    <gex:northBoundLatitude>
        <gco:Decimal>83.6235961786649</gco:Decimal>
    </gex:northBoundLatitude>
</gex:EX_GeographicBoundingBox>
</gex:geographicElement>
</gex:EX_Extent>
</mri:extent>
<mri:descriptiveKeywords>
    <mri:MD_Keywords>
        <mri:keyword>
            <gco:CharacterString>Collection</gco:CharacterString>
        </mri:keyword>
        <mri:keyword>
            <gco:CharacterString>USGS Science Data Catalog
(SDC)</gco:CharacterString>
        </mri:keyword>
        <mri:type>
            <mri:MD_KeywordTypeCode codeList=
"http://metadata.dgiwg.org/codeListRegistry?MD_KeywordTypeCode" codeListValue="theme
"/>
        </mri:type>
    </mri:MD_Keywords>
</mri:descriptiveKeywords>
<mri:resourceConstraints>
    <mco:MD_SecurityConstraints>
        <mco:classification>
            <mco:MD_ClassificationCode codeList=
"http://www.isotc211.org/2005/resources/codeList.xml#MD_ClassificationCode"
codeListValue="unclassified"/>
        </mco:classification>
    </mco:MD_SecurityConstraints>
</mri:resourceConstraints>
<mri:defaultLocale>
    <lan:PT_Locale>
        <lan:language>
            <lan:LanguageCode codeList="codeListLocation#LanguageCode"
codeListValue="eng">eng</lan:LanguageCode>
        </lan:language>
        <lan:characterEncoding gco:nilReason="unknown"/>
    </lan:PT_Locale>
</mri:defaultLocale>
</mri:MD_DataIdentification>
</mdb:identificationInfo>
<mdb:distributionInfo>
    <mrd:MD_Distribution>
        <mrd:distributor>
            <mrd:MD_Distributor>
                <mrd:distributorContact>
                    <cit:CI_Responsibility>

```

```

        <cit:role>
          <cit:CI_RoleCode codeList="codeListLocation#CI_RoleCode"
codeListValue="distributor">distributor</cit:CI_RoleCode>
        </cit:role>
      <cit:party>
        <cit:CI_Organisation>
          <cit:name>
            <gco:CharacterString>USGS</gco:CharacterString>
          </cit:name>
          <cit:individual>
            <cit:CI_Individual>
              <cit:positionName/>
            </cit:CI_Individual>
          </cit:individual>
        </cit:CI_Organisation>
      </cit:party>
    </cit:CI_Responsibility>
  </mrd:distributorContact>
</mrd:MD_Distributor>
</mrd:distributor>
<mrd:transferOptions>
  <mrd:MD_DigitalTransferOptions>
    <mrd:onLine>
      <cit:CI_OnlineResource>
        <cit:linkage>
          <gco:CharacterString>https://www.sciencebase.gov/catalog/item/513a2eaae4b09608cc166c1b
</gco:CharacterString>
        </cit:linkage>
      </cit:CI_OnlineResource>
    </mrd:onLine>
  </mrd:MD_DigitalTransferOptions>
</mrd:transferOptions>
</mrd:MD_Distribution>
</mdb:distributionInfo>
<mdb:metadataConstraints>
  <mco:MD_SecurityConstraints>
    <mco:classification>
      <mco:MD_ClassificationCode codeList=
"http://www.isotc211.org/2005/resources/codeList.xml#MD_ClassificationCode"
codeListValue="unclassified"/>
    </mco:classification>
  </mco:MD_SecurityConstraints>
</mdb:metadataConstraints>
</mdb:MD_Metadata>
</csw:SearchResults>
</csw:GetRecordsResponse>

```

Appendix C: Revision History

Table 24. Revision History

Date	Release	Editor	Primary clauses modified	Descriptions
June 15, 2016	0.1	G. Hobona	all	initial version
September 30, 2017	1.0	S. McCann	all	Draft ER

Appendix D: Bibliography

[1] Harping, P.: Introduction to Controlled Vocabularies: Terminology for Art, Architecture, and Other Cultural Works. Getty Publications, (2010)

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[3] Schmidt-Schauß, M. and Smolka, G.: Attributive concept descriptions with complements, *Artificial Intelligence*,48, pp. 1-26 (1991)

[4] Vatant, B., Rozat, L., Vandenbussche, P.: Vocabulary of a Friend (VOAF) - version 2.3, Open Knowledge International, <http://lov.okfn.org/vocommons/voaf/v2.3>, (2013)