S-100WG2-10.3A

Product Specification Interoperability Design
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Executive Summary:	This paper describes the design principles and constraints for an S-100 interoperability solution.
Related Documents:	(1) Product Specification Interoperability Analysis
Related Projects:	(1) S-100; (2) S-101; (3) S-102; (3) S-111; (4) S-112; (5) S-122; (6) S-124; (7) S-411; (8) S-412.

1 Introduction

1.1 Background/overview

The "Interoperability Analysis" (related document (1)) described the potential issues arising in interoperation and harmonized portrayal of S-100-based products and other data layers expected to be used in ECDIS and similar systems. This paper describes the principles and constraints upon which the solution is based, the catalogue design, and processing model for the solution.

This paper is structured anticipating implementation in two phases. The simpler interoperation methods will be implemented first. The more complex methods not required at first, but are still described in this paper as potential enhancements which will be refined based on experience with the simpler methods.

This document is organized as follows:

- Constraints and interoperability paradigm are described in Sections 2 and 3. This material is common to Phases 1 and 2.
- Details for each phase are described in Sections 4-11. The description of each phase consists of 4 sections, describing the levels, catalogue model, and processing for that phase (i.e., Sections 4-7 describe Phase 1 and Sections 8-11 describe Phase 2).
- Settings and parameters are described in Section 12, following the details for Phases 1 and 2. Since the setting model is currently the same for both Phase 1 and 2, this section is common to both phases.
- Refinements, supporting processes, and implications are addressed in a closing section that also covers both phases.

1.2 Scope

The scope of the current version of this document is limited to the design of the interoperability catalogue solution, including a description of the paradigm, principles and constraints upon which the design is based. A draft list of requirements will be submitted separately.

1.3 Terms

Interoperability catalogue (IC)
: A machine-readable file or collection of files describing how an ECDIS or other system must combine data products conforming to different product specifications for display purposes.

1.4 Abbreviations

AML Additional Military Layer
DQWG IHO Data Quality Working Group
ECDIS Electronic Chart Display and Information System

ECS Electronic Charting System
FC Feature catalogue
INS Integrated Navigation System
IC Interoperability catalogue
PC Portrayal catalogue
PPU Portable Pilot Unit
PS S-100-based Product Specification
UKCM Underkeel clearance Management

1.5 References

[1] Guideline on Software Quality Assurance and Human-Centered Design for E-Navigation, IMO Circular MSC.1/Circ.1512, 13 July 2015.

2 Constraints

2.1 Unpredictable product specification updates

Product specification update cycles are unknown and unsynchronized. Product specifications including feature and portrayal catalogues may be updated at unpredictable intervals which are different for different products.

2.2 Additional data products

At present there is a general idea of the overlay data products which will need to interoperate, but the set is not completely specified - more data products may be added later.

2.3 Full information availability

Even if data or portrayals are blended or overlaid, the complete data from all products on the screen must be available to the ECDIS user one way or another.

2.4 Limited and variable user experience and attention

The bulk of the user population is expected to consist of masters and bridge officers, who will have competing demands on their time and attention during route monitoring and will need to focus on sailing the vessel rather than tinkering with the ECDIS. Bridge officers' attention to the ECDIS can be expected to vary significantly depending on external conditions. The amount of user attention to the display will also vary depending on task – more attention can be expected to be given to display adjustments, searching and processing of information on the display during planning than during route monitoring.

2.5 Other significant information

Radar/ARPA and AIS are often also present in addition to the S-100 datasets.

2.6 Local versus global interoperation

This issue concerns whether data producers can determine whether or not the interoperability catalogue can be applied to their data. That is, whether a producer can specify, e.g., in dataset metadata, that the interoperation catalogue not be used with the dataset. Since this has the potential to lead to varying simultaneous presentations to the end user, which would furthermore not be under user control, it was decided not to include such producer-controlled blocking in the design. Another consideration is that the interoperability catalogue is customizable, and potentially such selective blocking might be overridden by someone else in the supply chain, all the way down to the end user.

A derivation is providing for producers to block specific parts of the interoperability solution, such as feature substitution. This would be even more complex than blocking the whole catalogue and is also excluded.

3 Paradigm

3.1 The ENC is part of a data ecosystem

Though the ENC dataset is the basic information for safe navigation, information in other data products may provide superior details, accuracy, resolution, or timeliness, and offer significant additional benefits to the end user. Interoperation rules may therefore act on appropriate slices of the ENC. Appropriate weight must be given to requirements of SOLAS V and controlling ECDIS standards such as IEC 62288 relating to the use of certified nautical data in ECDIS.

3.2 Catalogue ownership

There will be a single interoperation catalogue in use for all S-100 products intended for use on an ECDIS. The base catalogue will be published, distributed, and maintained by IHO on the IHO web site. It may be redistributed by any HO, data vendor, or OEM.

3.3 Catalogue development

Project teams developing individual product specification are not required to develop interoperability rules at any level, but are encouraged to make their specifications "interoperability-ready" and provide helpful information which interoperability catalogue developers would be able to readily integrate, such as identifying a display plane for each feature class or providing information about the layers they would wish to suppress. Interoperability catalogues may use this information as-is, or override it if warranted by interoperability considerations.

3.4 Catalogue maintenance

The IC should be designed so as to minimize the need for updating when a FC or PC of a product specification which is in the IC is updated.

If different versions of a data product are simultaneously present on ECDIS, the preferred situation is that the same interoperation catalogue applies to all versions, but in case of product specification updates that are not backwards-compatible where interoperability is concerned, an update to the interoperation catalogue is allowed.

The consequence is that interoperability rules should, wherever possible, operate on feature categories or themes, instead of specific feature types in individual product specifications.

3.5 Substitutability and extensibility

The interoperation catalogue will be extensible and substitutable by equivalent catalogues or presentations developed by manufacturers.

3.6 Customizations

The interoperation catalogue supplied by the IHO is the minimum requirement and must remain functionally intact on the system, but OEMs can provide their own versions in addition to the IHO catalogue, to facilitate custom product interoperations.

In principle, other authorized parties such as end users (including ship owners, operators, and shipboard officers) may also develop their own additional versions. While extensive end user customization is allowed in theory, end-user customization is in practice expected to be limited to defining new pre-defined combinations for loading by the ECDIS. End-user customization is expected to be via a user interface provided by OEMs which removes the need for end-user familiarity with XML.

3.7 Interoperation as operational requirement

Interoperation will be expected to be part of a future S-mode as envisaged by IEC and CIRM, i.e., not a ‘one size fits all’ solution but a structured solution that is flexible enough to allow for manufacturer innovation.

3.8 Support for human-centered design

The interoperability solution must support the application of human-centered design and usability testing techniques to minimize the cognitive load on the mariner and ensure that mariners’ displays are fit-for-purpose under different conditions and circumstances.

3.9 Potential changes to product specifications

The design will address as many considerations as possible on its own and in machine readable form, but some changes to S-100 and/or product specifications may be needed. Changes would be in the form of adding feature categories, additional attributes, metadata at the dataset or feature level, alternate portrayals, and similar changes. They would not be fundamental changes e.g., they might extend the application schema with additional meta-features but not delete existing features.

Changes to the FC should be minimized if possible, e.g. interoperation information should be in metadata rather than added to the FC.

3.10 Support for different levels of interoperation

The catalogue must support a fixed set (Levels 1-4) of interoperation levels, defined later in this document. The catalogue must permit a 'no-interoperability' display in which use of the interoperability catalogue is switched off and the ENC is treated as the main product with the other data products as independent overlays.

This document describes all four levels, but the current notional roadmap for S-100 interoperability consists of two phases:

- Phase 1 will consist of implementation of interoperation levels 1 and 2.
- Phase 2 will consist of adding interoperation levels 3 and 4.

The descriptions of the catalogue provided later in this document describe both Phase-1 and Phase-2 catalogues.

3.11 User control

Users must have control over what products are loaded – that is, they may load an additional product, or turn off one or more of the data products in a predefined combination.

Users must be able to change the level of interoperability in effect on a display by means of a simple control action, e.g., using a UI slider control, button, etc.

4 Interoperability Levels – Phase 1

4.1 Level 0 – Overlays – no explicit interoperability

Interoperability catalogues are not used. ENC is treated as the main product on the screen, and all other products are overlays. Information layer priority continues to conform to the relevant IMO and IEC performance standards.

Data product overlays may be portrayed using transparency so as not to obscure lower layers, but transparency values are generally not adjusted using rules based on data content or feature types. They may be adjusted using context information such as the number of stacked layers or light level mode.

Level 0 interoperability is effectively equivalent to what systems do today. It is also the default fallback if a product not listed in the interoperability catalogue is loaded.

Note: There is an implicit assumption here that portrayal catalogues assign features to only over/under-radar display planes. If display planes are given more complex semantics and continue to be defined in portrayal catalogues, Level 0 is likely to merge into Level 1.

4.2 Level 1 – Interleaving

The ENC is still treated as the main product, but feature layers from other products may be interleaved with ENC feature layers to prevent ENC data from being obscured. There is no other interoperability-related processing of feature data at this level.

4.3 Level 2 – Type-based selectivity and feature class replacement

The ENC is still treated as the main product, but feature types in other products may be determined to be superior to specific ENC feature types, in the sense that the features in the other product contain more details, have higher-resolution data values, etc., than the equivalent features in the ENC. In this level of interoperability,

global suppression of equivalent ENC features in favor of the superior layer is allowed – all instances of the specified ENC feature type are suppressed and the superior feature layer is displayed.

Selection of replaced and replacement features in this level uses only feature type (and data product) information. Attribute values are not considered. Further, the only operation is replacement of instances as a whole, no combination of replaced and replacement information is done.

5 Interoperability overview for Phase 1

Interoperability processing can either precede or follow 'portrayal processing' (for the purposes of this paper, the final stage of portrayal (rendering) is distinguished from portrayal processing). A mixed processing model, where interoperability processing is done both before and after portrayal processing, is also possible.

Interoperability before regular portrayal processing: Feature data from S-101 and other S-100-based datasets is an input to the interoperability processor, along with the interoperability catalogue and context parameters. The interoperability processor filters and interleaves feature data according to the IC and interoperability level selected by the user and passes the resultant feature data to the portrayal processor, which uses the portrayal catalogue for individual products to generate drawing instructions for the display processor.

Interoperability after regular portrayal processing: Feature data from S-101 and other S-100-based datasets flows to the portrayal processor. The portrayal processor transforms them into drawing instructions. The drawing instructions flow to the interoperability processor. The interoperability processor filters and interleaves the drawing instructions according to the IC and interoperability level selected by the user and passes the resultant drawing instructions to the display processor.

In all cases, the context parameters indicate the set of products which are to be loaded (in the form of a user-selected predefined combination) and the user-selected level of interoperability.

Both processing options are shown in Figure 1. Details of the processing model are described in Section 7.

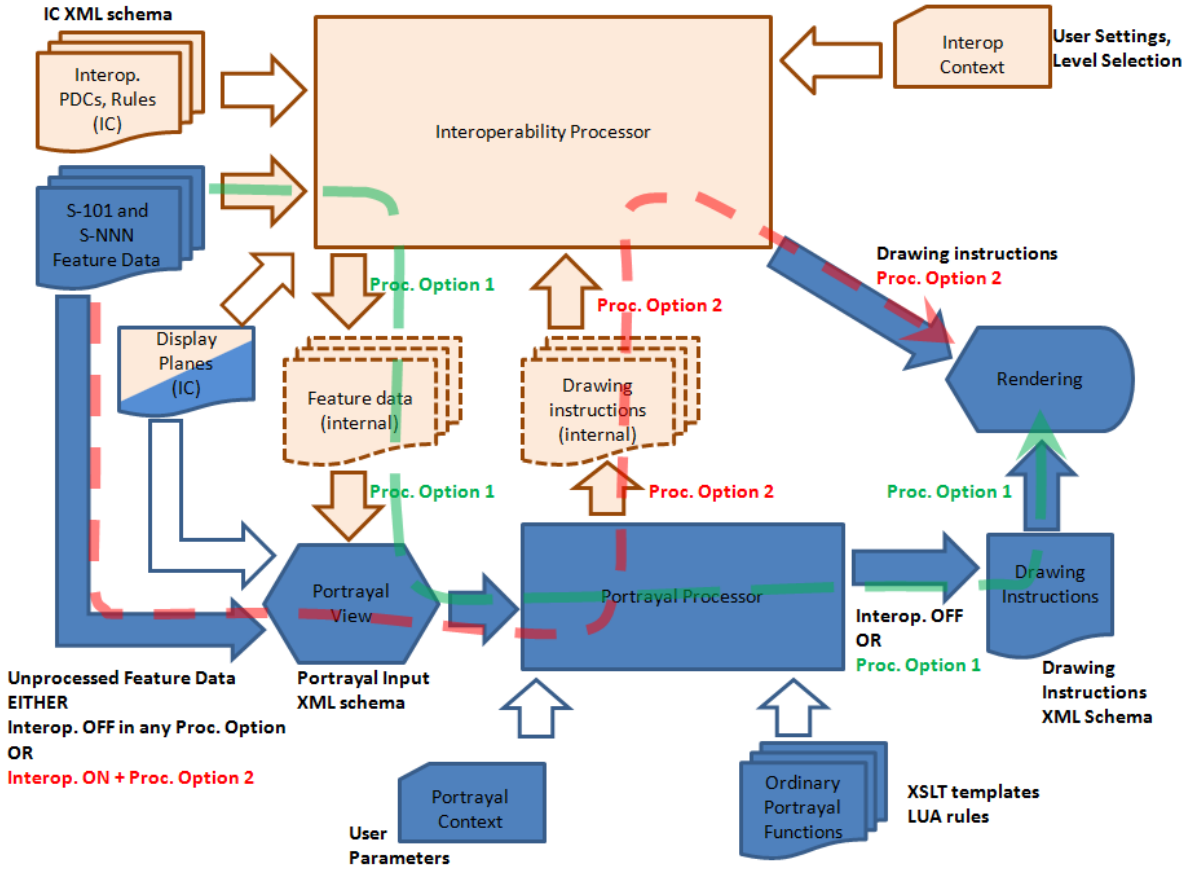

Figure 1. Interoperability Processing Overview for Phase 1

Blue: ordinary portrayal processing; beige: interoperability processing; mixed: both interoperability and ordinary portrayal. Filled block arrows: feature data; hollow block arrows: parameters or control information. The green dashed arrow shows the processing stream when interoperability precedes portrayal processing; the red dashed arrow when interoperability follows portrayal.

In "level 0" all interoperability processing is turned off. In this case, feature data is passed through unchanged to ordinary portrayal processing. Display plane information from the IC is also passed through since it specifies the layering which must be done by the display.

In **level 1 processing**, feature types from different products, including S-101, are interleaved as specified by display plane and drawing priority information contained in the interoperability catalogue[1]. The output of interoperability processing is either the original feature data (processing option 1) or drawing instructions (processing option 2), accompanied by display plane and drawing priority information, which is passed through to the portrayal processor.

In **level 2 processing**, level 1 functionality is allowed as well as suppression of all features of a specified feature type in a specified product, with another feature type from a different product being displayed instead. Filtering by attribute values and geometry type is also possible (filtering has been added in this revision).The output of interoperability processing is the same as level 1 with certain feature types suppressed.

[1]This will require certain changes to the portrayal model of S-100 Edition 2.0.0/3.0.0 which are described later in this document.

6 Catalogue model for Phase 1 Interoperability

6.1 UML model

The interoperability catalogue is a subtype of the **CT_Catalogue** class defined in ISO 19115-1 and consists of header information and subsections encoding display planes, feature priorities, feature interleaving, and available predefined combinations:

- display planes, indicating display priority, viewing group, and drawing order;
- predefined combinations and operations on feature types or feature instances for each combination;

Figure 2 depicts the UML model of the catalogue. Classes, attributes, and roles are defined in Section 6.1.4.

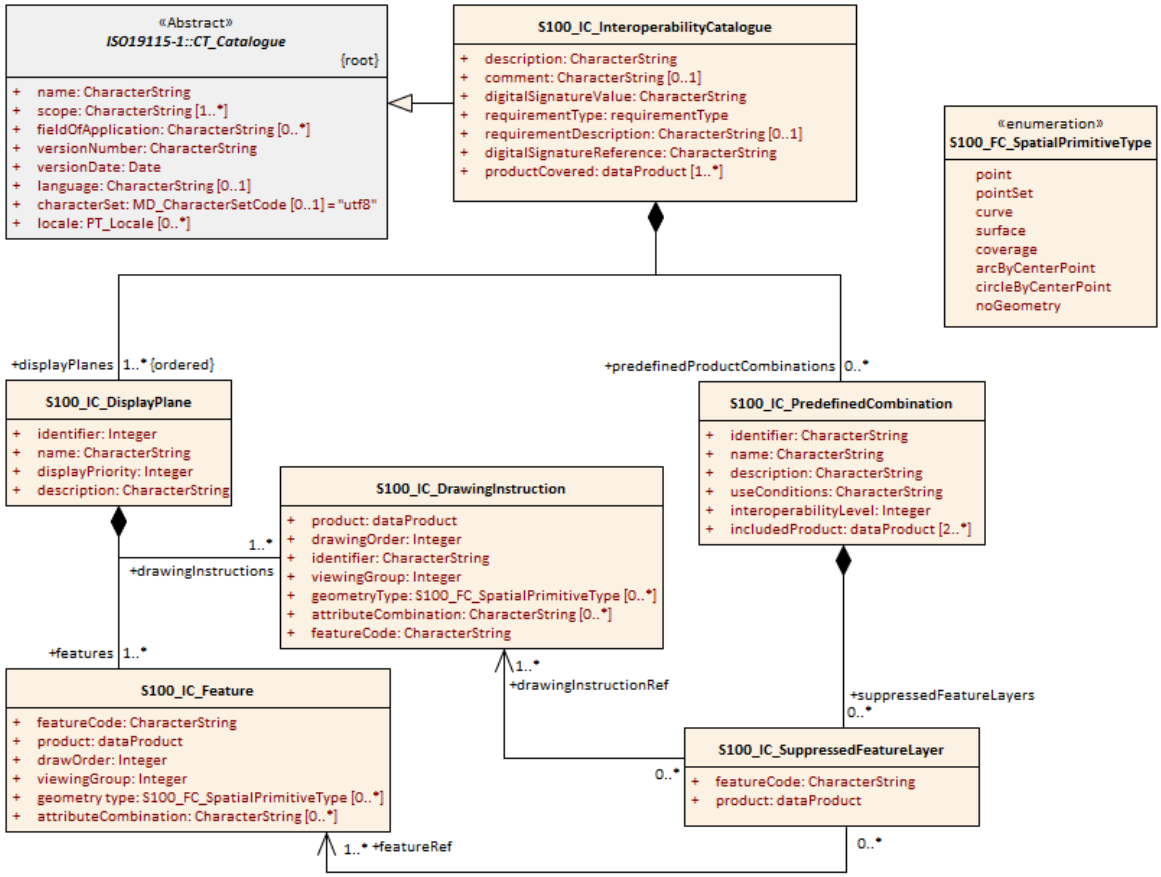

Figure 2. Interoperability catalogue model - Phase 1 (Levels 1 and 2)

6.1.1 Catalogue header information

The header information consists of elements providing identifying and descriptive information and indicates the source of the requirement upon which this catalogue is based. It also contains a list of all the data products covered by the catalogue.

6.1.2 Display planes

Each catalogue can have one or more display planes as defined by class **S100_IC_DisplayPlane**. **S100_DisplayPlane** assigns subsets of feature types to display planes and defines the viewing group, drawing order, and significance for each feature type in the plane in an **S100_IC_Feature** element. A portrayable feature type may be referenced in more than one **S100_IC_DisplayPlane; the entries in different display planes must be distinguished by different attribute-value combinations**. The portrayal of feature types not

mentioned in any **S100_IC_Feature** component is undefined[2] until ordinary portrayal processing. The display priority for the plane as a whole is provided in the **S100_IC_DisplayPlane** element. Any interleaving of feature layers for level 1 interoperability is handled by specifying the appropriate display plane, priority, and drawing order in this section. An **S100_IC_DisplayPlane** element may include more than one feature type.

6.1.3 Predefined combinations

Each catalogue can have zero or more predefined combinations (PDCs) as defined by class **S100_IC_PredefinedCombination**, each defining the interoperation of a specified set of data products. The products covered by a **S100_IC_PredefinedCombination** element are listed in the repeatable attribute **includedProduct**.

6.1.3.1 Operations in PDCs

In Phase 1, each PDC can specify only two type of interaction between its listed products:

1) Replacement of an entire feature layer, i.e., all instances of a specified feature type in a product (level 2 interoperability).The types to be suppressed and the types which replace them are specified by **S100_IC_SuppressedFeatureLayer** elements. Types to be suppressed are indicated by data product (attribute **product**) and the feature type's code in the corresponding feature catalogue (attribute **featureCode**). The replacement feature type is indicated by one of the following methods, corresponding respectively to the 'interoperability before portrayal processing' and 'interoperability after portrayal processing' approaches described in Section 5.
    a. A reference to an **S100_IC_Feature** element defined in the display planes section (which contains the product and feature type as attributes).
    b. A reference to an **S100_IC_DrawingInstruction** element defined in the display planes section (which contains the group to which the drawing instruction corresponding to that feature belongs).
2) Replacement of subsets of feature layers, i.e., all instances of a defined subset of instances of a specified feature type. The types are indicated as above, but further qualified by specifying attribute-value combinations as filters.

6.1.3.2 Interoperability level

The **interoperabilityLevel** attribute in each **S100_IC_PredefinedCombination** element specifies the highest level of interoperability operations that are encoded in the element.**S100_IC_PredefinedCombination** elements of are permitted to also include operations of a lower level of interoperability.

[2]E.g., it may have a display plane and drawing order assigned in the portrayal catalogue, or may be associated to another feature and contribute to the portrayal of that feature if so specified in the relevant portrayal rule, or ignored for portrayal purposes.

6.1.4 Classes, attributes, and datatypes

Table 1. S100_IC_DisplayPlane

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_DisplayPlane	Each display plane identifies all features and their draw orders within the plane. Display priority defines the order in which display planes are rendered.	-	-	Composition component of S100_IC_InteroperabilityCatalogue, container displayPlanes
Attribute	identifier	unique identifier of the display plane	1	Integer	must be unique
Attribute	name	Name of display plane	1	CharacterString	under radar, over radar, etc.
Attribute	displayPriority	display prioritycontrols the order in which the output of the portrayal functions is processed by the rendering engine. Priorities with smaller numerical values will be processed first.	1	Integer	Ref. S-100 § 9-12.1
Attribute	description	description of the display plane	1	CharacterString	
Composition	features	Container for one or more S100_IC_Feature elements	1..*	<sequence>S100_IC_ Feature	One or more S100_IC_Feature elements
Composition	drawingInstructions	Container for S100_IC_DrawingInstruction elements	1..*	<sequence>S100_IC_ DrawingInstruction	

Table 2. S100_IC_DrawingInstruction

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_DrawingInstruction	Information that guides the relative layering and drawing order of drawing instruction during portrayal.	-	-	
Attribute	product	A data product	1	dataProduct	
Attribute	drawingOrder	The drawing order of the group	1	Integer	
Attribute	identifier	Internal identifier of the instruction group.	1	CharacterString	This may map to viewing groups, but it is just an identifier for now to keep things simple.
Attribute	viewingGroup	The viewing group of the feature type	1	Integer	Ref. S-100 § 9-12.1
Attribute	geometryType	The type of spatial primitive that indicates the location.	0..*	S100_FC_SpatialPrimitiveType	
Attribute	attributeCombination	Describes attribute-value filters to be applied to the specified features	0..*	CharacterString	See Section 6.3

Attribute	featureCode	the code assigned to the feature type in feature catalogue for the product indicated in the product attribute	1	CharacterString	Corresponds to the feature reference for drawing instructions in S-100 Part 9.

Table 3. S100_IC_Feature

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_Feature	Information that guides the relative layering and drawing order of feature types during portrayal.	--	--	
Attribute	featureCode	the code assigned to the feature type in feature catalogue for the product indicated in the product attribute	1	CharacterString	
Attribute	product	A data product	1	Enumeration dataProduct	
Attribute	drawOrder	Drawing order of feature type in the display plane	1	Integer	
Attribute	viewingGroup	The viewing group of the feature type	1	Integer	Ref. S-100 § 9-12.1
Attribute	geometryType	The type of spatial primitive that indicates the location.	0..*	S100_FC_SpatialPrimitiveType	
Attribute	attributeCombination	Describes attribute-value filters to be applied to the specified features	0..*	CharacterString	See Section 6.3

Table 4. S100_IC_InteroperabilityCatalogue

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_InteroperabilityCatalogue	An interoperability catalogue contains operations and rules for the interoperation of a set of S-100-based data products.	-	-	Specialization of CT_Catalogue (ISO 19115-1)
Attribute	description	Description of the catalogue	1	CharacterString	
Attribute	comment	Any additional comments	0..1	CharacterString	
Attribute	digitalSignatureReference	Reference for digital signature algorithm	1	CharacterString	Reference to the appropriate digital signature algorithm
Attribute	digitalSignatureValue	Digital Signature of the file	1	CharacterString	

Attribute	requirementType	The type of authority or requestor responsible for the specifications, rules, or requirements based on which this catalogue was prepared.	1	Enumeration	
Attribute	requirementDescription	Description of the source of the requirements or specifications upon which this catalogue is based. This might be the name of the country, company, OEM, port, pilot, etc.	1	CharacterString	
Attribute	productCovered	The products covered by this catalogue	1..*	Enumeration	
Attribute	name	The name for the catalogue	1	CharacterString	Inherited from CT_Catalogue
Attribute	scope	Subject domain of the catalogue	1..*	CharacterString	Inherited from CT_Catalogue
Attribute	fieldOfApplication	Description of the use to which this catalogue may be put	0..*	CharacterString	Inherited from CT_Catalogue
Attribute	versionNumber	The version number of the product specification	1	CharacterString	Inherited from CT_Catalogue
Attribute	versionDate	The version date of the product specification	1		Inherited from CT_Catalogue
Attribute	language	The language used for this catalogue	0..1	CharacterString	Inherited from CT_Catalogue
Attribute	locale	provides information about alternatively used localised character strings	0..1	PT_Locale (ISO 19115)	Inherited from CT_Catalogue
Attribute	characterSet	Character set used in the catalogue	0..1	MD_CharacterSetCode (ISO 19115)	Inherited from CT_Catalogue value=utf8
Composition	displayPlanes	Container for one or more S100_IC_DisplayPlane elements	1..*	<sequence>S100_IC_ DisplayPlane	ordered list of one or more S100_IC_DisplayPlane elements
Composition	predefinedProductCombinations	Container for predefined product combinations and the interoperability operations for each	0..*	<sequence>S100_IC_ PredefinedCombinatio n	sequence of S100_IC_PredefinedCombination elements

Table 5. S100_IC_PredefinedCombination

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_PredefinedCombination	Pre-defined combinations are identifiable pre-set collections of recommended and optional S-NNN data products which are expected to be loaded by the user under specific conditions or for specified tasks. Each pre-defined combination is basically a package of data products, display priorities, context parameters, user settings, portrayal catalogues, etc. An ECDIS or other system can allow the user to initiate the loading of multiple data products and activate multiple parameter settings as a single action, by selecting one of a list of pre-defined combinations, instead of loading and unloading individual data products.	-	-	Composition component of S100_IC_InteroperabilityCatalogue
Attribute	identifier	Identifier of the predefined combination	1	--	E.g., sequence number, UUID or URN unique to the PDC in the catalogue. May be globally unique, but must be unique within the catalogue at least
Attribute	name	Name of combination	1	CharacterString	
Attribute	description	Brief description of combination	1	CharacterString	
Attribute	useConditions	Conditions for which the combination is designed	1	CharacterString	
Attribute	interoperabilityLevel	The highest level of interoperability functionality encoded within an instance of this type	1	Integer	
Attribute	includedProduct	Products loaded in this combination and referenced by operations and rules that apply to this combination.	2..*	Enumeration dataProduct	A combination must use at least 2 data products

Table 6. S100_IC_SuppressedFeatureLayer

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_SuppressedFeatureLayer	Describes operations for suppressing all instances of a feature type in one product by features from another product.	--	--	
Attribute	featureCode	feature type code in the FC for the product mentioned in attribute **product**	1	CharacterString	
Attribute	product	the data product for the type being replaced	1	Enumeration dataProduct	

Role	featureRef	references to replacement features' display specifications in the display planes section of the interoperability catalogue	1..*	<reference>S100_IC_Feature	Replacement by multiple feature types is intended for associated feature types, e.g., different feature types for a traffic separation scheme. If the reference is empty, the type is suppressed without being replaced.
Role	drawingInstructionRef	reference to S100_DrawingInstruction element	1..*	<reference>S100_IC_DrawingInstruction	

Table 7. dataProduct

Role Name	Name	Description	Code	Remarks
Enumeration	dataProduct	List of data products	--	Data products conforming to the specification identified by the item name, in the IHO list of S-100 based product specifications
Literal	S-101	ENC data product		
Literal	S-102	Bathymetry data product		
Literal	S-111	Surface Current data product		
Literal	S-122	Marine Protected Areas data product		
Literal	S-124	Navigational Warnings data product		
Literal	S-411	Ice Information data product		
Literal	S-412	Weather overlay data product		
Literal	HYBRID	Hybridized features created during interoperability processing		Defined for interoperability processing, not in the IHO list.

Table 8. requirementType

Role Name	Name	Description	Code	Remarks
Enumeration	requirementType	The source of the catalogue or the person or party according to whose recommendations the catalogue was prepared.	--	
Literal	IHO	Original IHO interoperability catalogue		
Literal	OEM	Prepared according to requirements specified by OEM or systems integrator		

Literal	national	Prepared according to requirements specified by a national government, group of national governments (e.g., the European Union), or governmental agency such as a national shipping authority or the USCG.		
Literal	local	Prepared according to requirements specified by a sub-national governmental authority such as a state, province, or county.		
Literal	port	Prepared according to requirements specified by a harbormaster's office or port authority		
Literal	company	Prepared according to requirements specified by the owner, charterer, or operator		
Literal	pilot	Prepared according to requirements specified by the vessel’s master		
Literal	master	Prepared according to requirements specified by a pilot		
Literal	other	Other source		

6.2 Interoperability levels and the catalogue

Which parts of the catalogue are used depends on the interoperability level:

- In level 0, interoperability is turned off.
- In level 1 (Interleaving), only display planes are used and the only components within the catalogue that are required are **S100_IC_DisplayPlane** and its **S100_IC_Feature** components.
- In level 2 (Type-based selectivity and feature class replacement), in addition to level 1 components, predefined combinations and feature layer suppression information are the only required elements within the catalogue.

Figure 3 shows which parts of the catalogue are active in different levels.

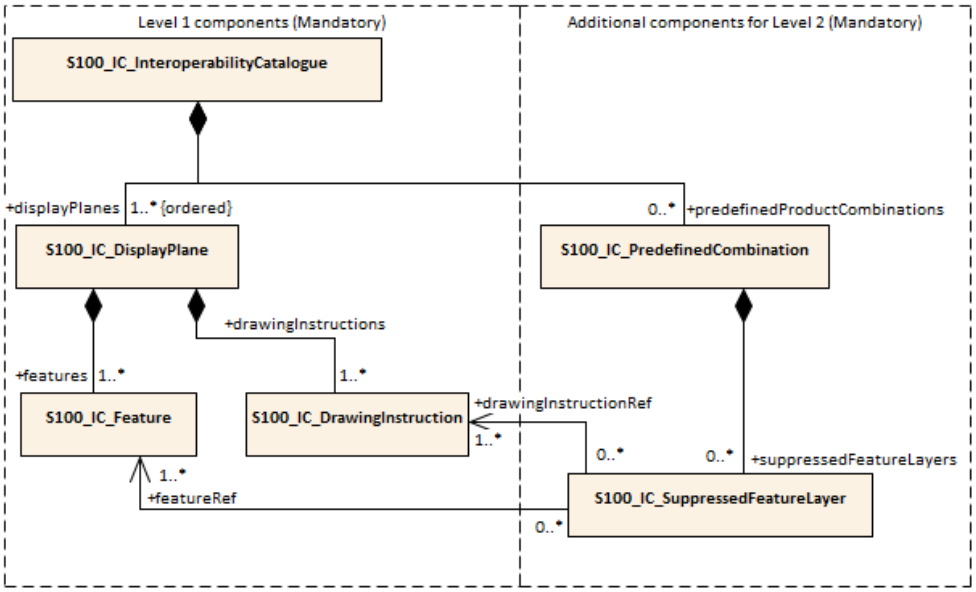

Figure 3. Catalogue components used in Levels 1 and 2

6.3 Attribute-value combination filters

Attribute-value combination filters (the **attributeCombination** attribute of S100_IC_Feature) are strings of the form <attr><op><value>, where:

a) <attr> is the camel case code of the attribute

b) <op> is one of “=”, “!=”, “in”, “notIn”, “gt”, “ge”, “lt”, “le”, “null”

c) <value> is a decimal number, integer, numeric code, or string, or a list of values. Strings must be enclosed in double quotes: “” with embedded double-quotes or \ characters preceded by a \ character.

The <attr>, <op>, and <value> components are separated by blank or tab characters[3].

7 Processing model for Phase 1

7.1 Interoperability processing overview

Figure 4 shows the processing steps and input to each step from parts of the interoperability catalogue, for the “Interoperability before portrayal” processing option. Figure 5 shows the steps and inputs for the “Interoperability

[3] More expressive filter expressions can be developed if required or as part of Phase 2.

after portrayal" processing option. In both cases, the flow depends on the interoperability level selected by the mariner.

In all levels of processing except level 0 (interoperability off), data products to be loaded are selected by the system according to the list in the predefined combination selected by the mariner selection from among those listed in the catalogue. The mariner may also select additional data products from the optional load set.

Feature data from products not listed in the interoperability catalogue are passed through to portrayal processing as described in S-100 Part 9 (stage **Portrayal Processing**) without any intermediate stages in interoperability processing, and displayed by ordinary S-100 portrayal processing according to their individual portrayal catalogues.

In level 0 processing, interoperability is turned off and all data products loaded are passed through to S-100 **Portrayal Processing** to be portrayed as overlays to ENC data according to their individual portrayal catalogues.

In level 1 processing, the only interoperability processing is interleaving of feature layers by means of display plane information, and **Interleave Feature Layers** is the only interoperability processing before feature data is passed to S-100 **Portrayal Processing**. The only input from the interoperability catalogue is display plane and drawing order information from **S100_IC_DisplayPlane** elements in the catalogue.

In level 2 processing, feature type suppression operations (stage **Suppress Feature Types**) precede interleaving operations.

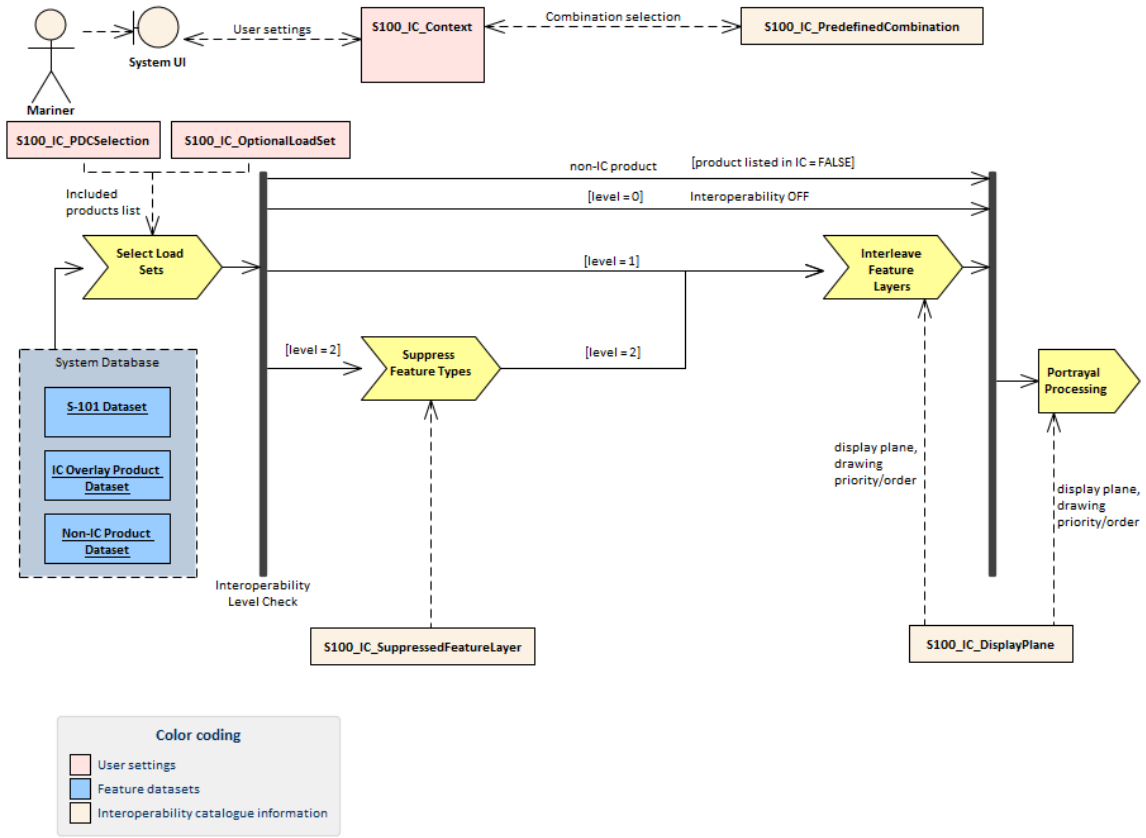

Figure 4. Interoperability processing model – Option 1 (Interoperability before portrayal).

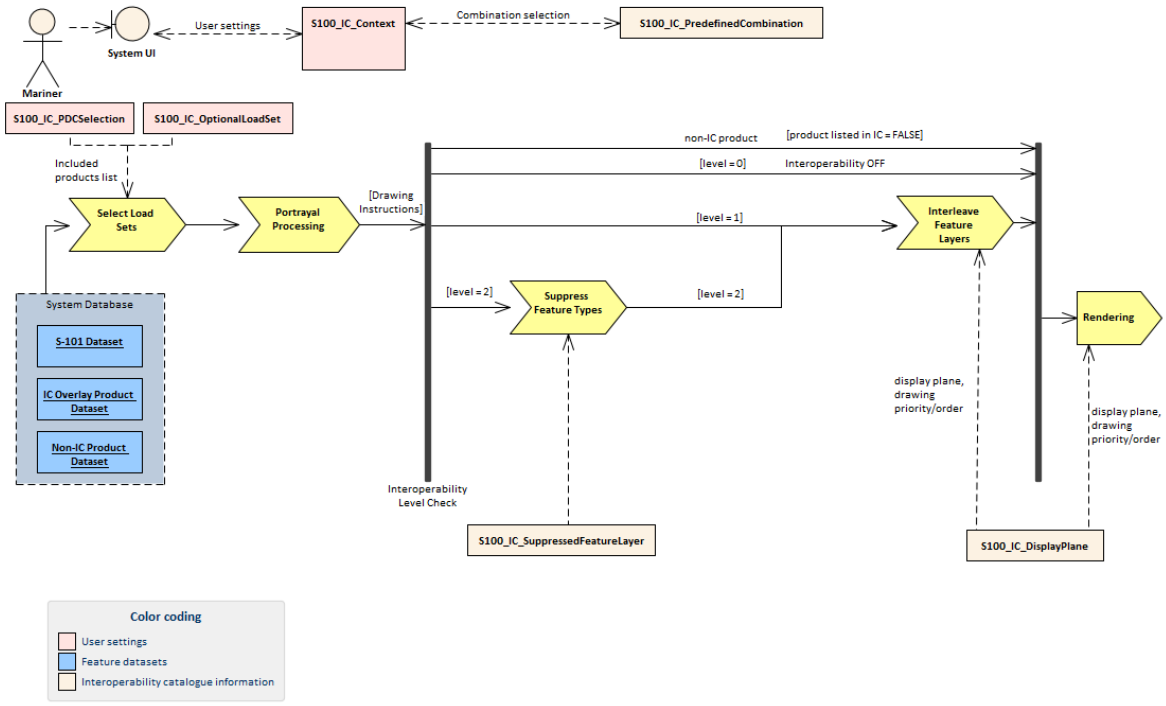

Figure 5. interoperability processing model - Option 2 (Interoperability after portrayal).

Table 9. Stages in interoperability processing

Stage	Description	Level	IC information	Context information	Remarks
Select Load Sets	Select data products to be loaded	All	included product list from S100_IC_ PredefinedCombination. includedProduct	S100_IC_PDCSelection identifies the S100_IC_ PredefinedCombination	-
Portrayal Processing	Ordinary S-100 portrayal processing	All	hybrid PC, display planes		Except final display processing / rendering
Interleave Feature Layers	Assign display plane and drawing order to feature data	1, 2	S100_IC_DisplayPlane		
Suppress Feature Types	Suppress all instances of a specified feature type in a product	2	S100_IC_Suppressed FeatureLayer		
Rendering	Display processing	All	S100_IC_DisplayPlane		

8 Interoperability Levels – Phase 2

8.1 Level 3 – Attribute value-based selectivity and feature hybridization

The ENC is treated as one of the components of the data stack, and selected feature instances from other products may be treated as being superior to or enhancing selected ENC feature instances. The feature instances are selected using selector expressions that use feature type and values of thematic attributes. The

geometry of the superior/enhancing feature instance must be spatially equal to that of the ENC feature instance (within specified tolerances).

The interoperability result is that the ENC feature instance is either suppressed or replaced by the other feature instance or hybridized with it (i.e., their attributes are combined in some way). In Level 3, only thematic attributes can be combined.

Hybridization may consist of adjustments to attributes of one of the ENC/other feature instances, such as re-calculation of values of numeric attribute, addition of listed values to an enumeration attribute. Hybridization may also result in an instance of a different feature type with an enhanced set of thematic attributes, some of which may be new attributes generated from attribute values of the original instances.

The interoperability product will include a hybrid feature catalogue and portrayal catalogue defining the feature types and portrayals for new hybrid features. Their structures will be the same as regular feature and portrayal catalogues.

8.2 Level 4 – Spatial operations

This level is the same as Level 3, but permitted spatial queries (to determine related subsets) and operations (to define the interoperation result) are explicitly defined using an adequate set of spatially-capable rules.

This means that the ENC and other-product feature(s) need not be spatially equal, they need only be related to one another by the spatial query. For hybridization, in addition to thematic attributes, feature geometry can also be combined using spatial operations.

Note: The spatial queries for determining related ENC/other-product features can be defined in terms of explicit rules such as positions within X m, or X mm at product scale for point features, 99% overlap for area features, or some other adequate explicit rule.

8.3 Levels and interoperation rules

A catalogue may define different interoperation rules of different levels for any given combination of feature or feature instances. For any given combination, the rule applied will be the highest-level rule whose conditions are satisfied and which is at or below the highest interoperation level currently allowed by the end user.

9 Interoperability overview for Phase 2

In addition to Phase 1 processing, the interoperability processor output stream of feature data can contain both original feature instances (conforming to the feature types of the input data products) and new instances which conform to new hybrid feature types that are defined in the hybrid feature catalogue. An overview of the processing model for Phase 2 and how it fits with portrayal processing is shown in Figure 6. This figure is the same as Figure 1 with the addition of components representing the hybrid feature catalogue and hybrid portrayal functions.

The options for processing flows are also the same as for Phase 1, as described in Section 5.

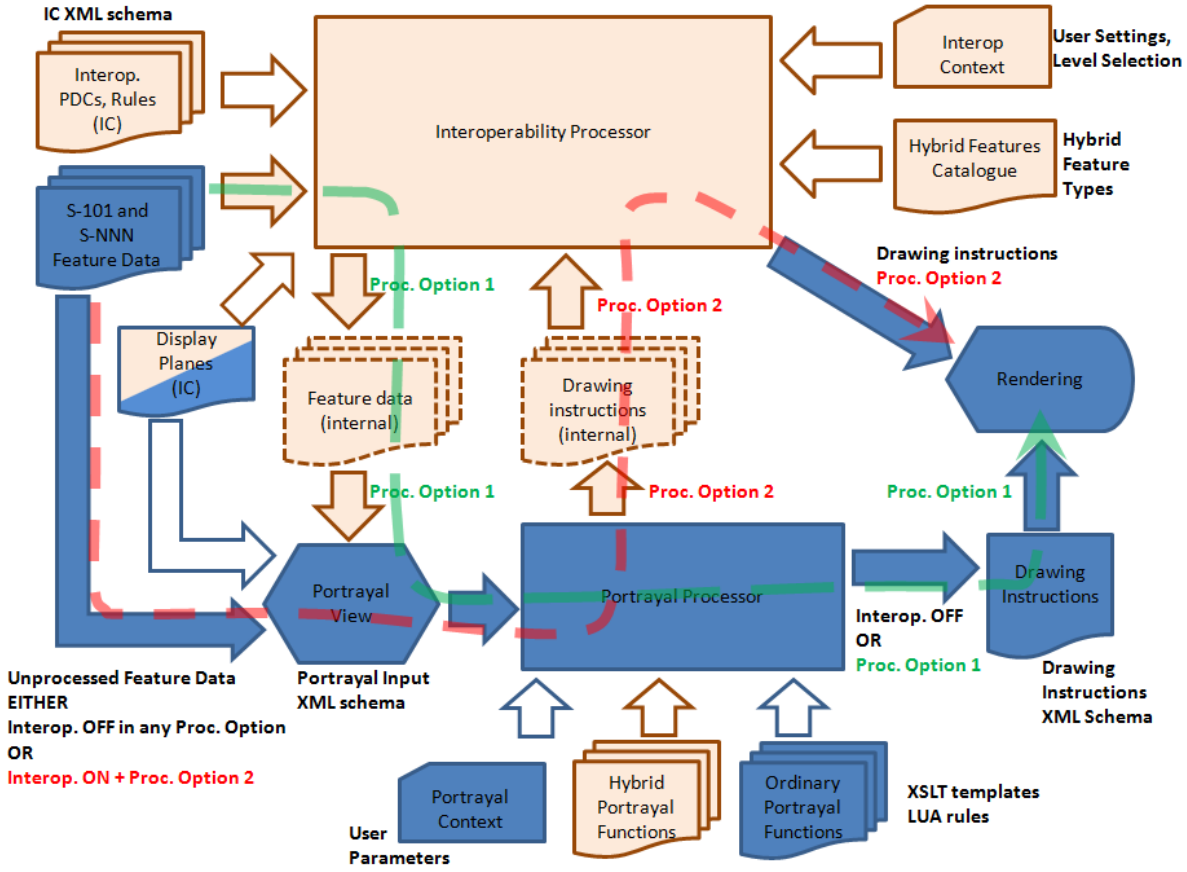

Figure 6. Interoperability Processing Overview for Phase 2.

Blue: ordinary portrayal processing; beige: interoperability processing; mixed: both interoperability and ordinary portrayal. Filled block arrows: feature data; hollow block arrows: parameters or control information. The green dashed arrow shows the processing stream when interoperability precedes portrayal processing; the red dashed arrow when interoperability follows portrayal.

In level 3 processing, two additional functionalities are possible:

a) Conditional selection of feature instances, based on a selection query defined in terms of feature type and attribute values. In level 3 processing, the query expression must consist of only thematic attributes, and the instances must have spatially equal geometry (their locations or extents must be spatially equal).

b) Combinations of feature instances which satisfy the selector expression are replaced in the output stream by an instance of a hybrid feature type. Each hybrid feature type is constructed from two or more feature types and some form of combination of the thematic attributes of the original instances. The geometry is the same as the common geometry of the instances in the input combination of instances.

In level 4 processing, the selection queries and hybridization rules include spatial operations as well as thematic attributes. The geometry of the output instance is constructed from the spatial attributes of the relevant input set of instances. Functionality belonging to levels 1, 2, and 3 processing is also allowed (for feature types and instances not affected by level 4 rules).

10 Catalogue model for Phase 2 Interoperability

10.1 UML model

The interoperability catalogue is a subtype of the **CT_Catalogue** class defined in ISO 19115-1 and consists of header information and the subsections described in Phase 1 plus the additional subsections described below:

- operations on feature instances for a predefined combination;
- rules for combining feature data into new features, used by certain operations in the predefined combination section;
- feature and portrayal catalogues for the new features generated according to the combination rules.

Figure 7 depicts the UML model of the catalogue. Classes, attributes, and roles added in Phase 2 are defined in Section 10.1.6.

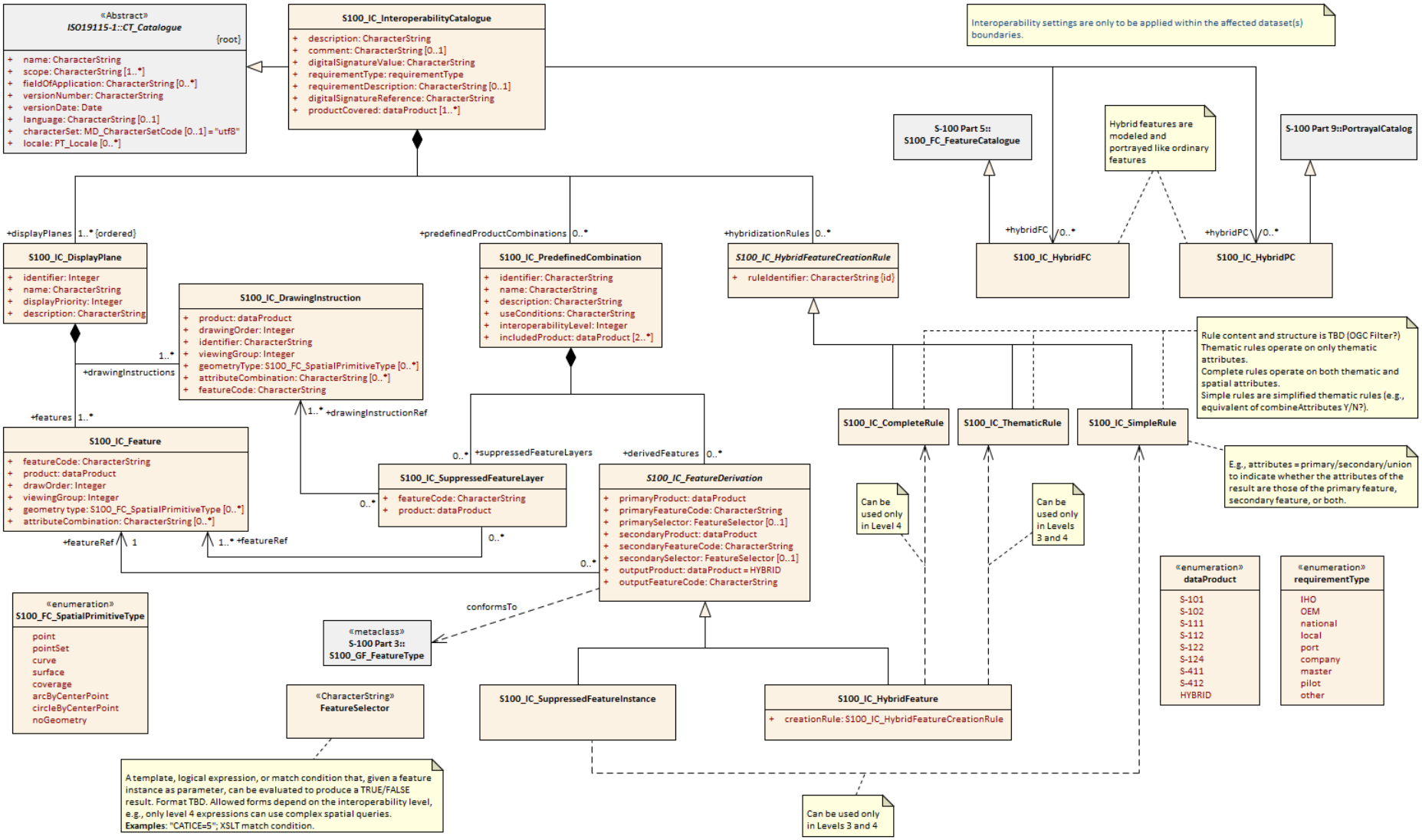

Figure 7. Interoperability catalogue model – Phase 2 (Levels 1-4)

10.1.1 Catalogue header information

Header information is the same as in Phase 1.

10.1.2 Display planes

Display planes are the same as in Phase 1.

10.1.3 Predefined combinations

As in Phase 1, each catalogue can have zero or more predefined combinations (PDCs) defined by **S100_IC_PredefinedCombination**.

10.1.3.1 Operations in PDCs

In addition to the operations specified for Phase 1, a PDC can specify the following types of interaction between its listed products.

1) Operations on selected instances of a feature type or conversion of input feature data into new feature data involving only thematic attributes (level 3 interoperability).
2) Operations involving operations on spatial attributes (and possibly thematic attributes as well). This is level 4 interoperability.

The simplest operations on instances are replacement of selected instances from one product by selected instances from another product. These are described by **S100_IC_SuppressedFeatureInstance** elements. More complex operations, including conversion of input feature instances into new features(hybridization) are described by **S100_IC_HybridFeature** elements. The replacement and hybridization rules are described in alater section.

10.1.3.2 Selection of feature instances

S100_IC_SuppressedFeatureInstance and **S100_IC_HybridFeature** elements specify the feature types on which they operate by indicating the product and feature types of two products. Selection of feature instances is done by evaluating a filter expression (type **FeatureSelector**, a string expression conforming to the specified [TBD] format) with the feature instance as input parameter.

For level 3 interoperability, spatial equality is an implied criterion in determining each input instance set of feature instances to be converted to new feature data uses spatial equality as an implicit criterion for set membership, i.e., only coincident instances (to a system-determined tolerance) are combined, and the geometry of the output is the same as the geometry of any instance in the input set.

For level 4 interoperability, complex spatial operations are permitted but there is an implicit assumption that the members of the input instance set are meaningfully related spatially[4] (e.g., 95% common area). In level 4 interoperability, the spatial attributes of the output instance may be generated by applying spatial operators (e.g., spatial union, intersection, etc.) to the spatial attributes of the input instance set. The allowed spatial operations are [TBD].

10.1.3.3 Interoperability level

As in Phase 1, the **interoperabilityLevel** attribute in each **S100_IC_PredefinedCombination** element specifies the highest level of interoperability operations that are encoded in the element. **S100_IC_PredefinedCombination** elements are permitted to also include operations of a lower level of interoperability.

10.1.4 Hybridization rules

Hybridization rules define how a set of feature instances is combined to create a hybrid feature type. In the simplest form of hybridization, the hybrid feature would bind all the attributes of the input types to a single output

[4] In principle an instance may be a member of more than one conversion input set.

feature type. (This assumes that there are no collisions between the thematic attributes of the input types.) More complex hybridization rules can handle collisions, e.g. by defining a preference order for colliding attributes, including all the values if the input types bind the same enumerated attribute, or adding uncertainty metadata if numeric attribute values are different.

The hybridization rules require two feature instances as input and produce a single feature instance as output[5]. The formal specification and rule language for hybridization will be described later.

10.1.4.1 Simple hybridization rule

Simple rules treat thematic attributes uniformly, for example by binding the attributes of both primary and secondary input instances to the output instance, or preferring the attribute bindings of the primary instance to those of the secondary instance in case of a difference in the values of common attributes. Location/extent spatial attributes of all input instances must be spatially equal and are passed through unchanged.

10.1.4.2 Thematic hybridization rule

Thematic rules treat thematic attributes on an individual basis, for example, use specified attributes from the primary input instance and specified attributes from the secondary input instance. Combination operations on attribute values may be specified (e.g., *OutputFeature.depthValue = maximum(ProductA.FeatureX.depthValue , ProductB.FeatureY.depthValue*) Location/extent spatial attributes of all input instances must be spatially equal and are passed through unchanged.

10.1.4.3 Complete hybridization rule

Complete rules allow selection of input sets using complex spatial queries as well as spatial equality and selector expressions on attribute values. The output can combine thematic attributes in any of the ways allowed by thematic hybridization rules. In addition, it may generate complex spatial from the input spatial primitives by applying selected spatial operations to the input instances. The allowed spatial operations will be identified later (tentatively, the spatial operations defined in S-58 6.0.0).

10.1.5 Hybrid feature and portrayal catalogues

Hybrid feature and portrayal catalogues are physically separate files from the main interoperability catalogue, but the main catalogue links to them by encoding the names of the hybrid catalogue files which are used by the feature creation rules defined in it. The hybrid feature and portrayal catalogues conform to the structures required by S-100 Parts 5 and 9 respectively.

[5]Can easily be generalized for more instances in both input and output.

10.1.6 Classes, attributes, and datatypes added in Phase 2

The following additions are made to the classes, attributes, and datatypes specified for Phase 1.

Table 10. S100_IC_CompleteRule

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_CompleteRule	Rule describing how a set of feature instances is combined to create a hybrid feature type.Complete rules may operate on both thematic and spatial attributes.	-	-	Subclass of S100_IC_HybridFeatureCreationRule
Attribute	ruleIdentifier	Rule identifier	1	CharacterString	Inherited from S100_IC_HybridFeatureCreationRule Mandatory unique ID used for references.

Note: Selector and rule language are TBD.

Table 11. S100_IC_FeatureDerivation

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_FeatureDerivation	Derived features are created by consolidating features from 2 or more different products into one final view, so the changes can include geometry, attribution and/or portrayal (depending on the interoperability level).	--		Abstract class. Individual primary and secondary inputs are suppressed from being rendered and only the resulting derived feature is added to the data stack. The resulting derived feature does not need to have any hybrid characteristics i.e. one restricted area replaced with another restricted area will use regular PC/FC of the primary product. However if the result feature needs to be supported by any custom FC or PC elements they must be defined under hybrid FC and hybrid PC accordingly. A rule for creating the feature must be described in the rules section.
Attribute	primaryProduct	one of the two interoperating data products	1	Enumeration dataProduct	

Attribute	primaryFeatureCode	feature type code in the FC for the product mentioned in primaryProduct	1	CharacterString	
Attribute	primarySelector	Selection expression for instances of the first feature type.	0..1	FeatureSelector	If omitted, all instances of the type are included. In L3 processing, may contain only thematic attributes and the primary and secondary instance geometries must be spatially equal. L3 Example: CATICE=5 In L4 processing, expressions may also contain spatial attributes. L4 Example: CATICE=5 AND WITHIN(<primary>, <secondary>)
Attribute	secondaryProduct	the other interoperating data product	1	Enumeration dataProduct	
Attribute	secondaryFeatureCode	feature type code in the FC for the product mentioned in secondaryProduct	1	CharacterString	
Attribute	secondarySelector	Selection expression for instances of the second feature type.	0..1	FeatureSelector	If omitted, all instances of the type are included. In L3 processing, may contain only thematic attributes and the primary and secondary instance geometries must be spatially equal. L3 Example: CATICE=5 In L4 processing, expressions may also contain spatial attributes. L4 Example: CATICE=5 AND WITHIN(<secondary>, <primary>)
Attribute	outputProduct	data product of the resulting hybrid feature	1	Enumeration dataProduct	default value = HYBRID, to indicate the result is a hybrid feature.
Attribute	outputFeatureCode	feature type code in the hybrid FC	1	CharacterString	
Role	featureRef	reference to the output feature's display specification in the display planes section of the interoperability catalogue	1	<reference>S100_IC_ Feature	

Notes: S100_IC_FeatureDerivation is an abstract super-class for different types of feature hybridization operations.

Table 12. S100_IC_HybridFC

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_HybridFC	Feature catalogue defining any "hybrid feature types" that are created by combining feature types from two or more products for the purposes of an interoperable display.	-	S100_FC_FeatureCatalogue	The IC contains references to local resources (files) containing hybrid FCs.
Attributes and Roles	(See S-100 Part 5)				

Table 13. S100_IC_HybridFeature

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_HybridFeature	Feature created by combining feature types from two or more products for the purposes of an interoperable display.	-	S100_IC_FeatureDerivation	Sub-class of S100_IC_FeatureDerivation
Attribute	creationRule	Reference to a rule defined in the hybridization rules section of the catalogue	1	<reference>S100_IC_HybridfeatureCreationRule	
Attribute	primaryProduct primaryFeatureCode primarySelector secondaryProduct secondaryFeatureCode secondarySelector outputProduct outputFeatureCode	(See S100_IC_FeatureDerivation)		--	Inherited from S100_IC_FeatureDerivation
Role	featureRef	(See S100_IC_FeatureDerivation)	1	<reference>S100_IC_Feature	Inherited from S100_IC_FeatureDerivation

Table 14. S100_IC_HybridFeatureCreationRule

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_HybridFeatureCreationRule	Hybrid feature creation rule captures the entire data filtering logic (i.e. finding all features to be operated on) as well as the entire processing logic.	-	--	Abstract class.

Attribute	ruleIdentifier	Rule identifier	1	CharacterString	Mandatory unique ID used for references.

Notes: S100_IC_HybridFeatureCreationRule is an abstract super-class for different types of hybridization rules.This functionality needs to be worked out but OGC Filter seems to be the ideal option for defining data filtering logic.

Overall, the output from execution of S100_IC_HybridFeatureCreationRule is a set of hybrid features for which predefined FC, PC and display plane definitions already exist so such feature will be suitable for passing to the portrayal engine for processing just like any other S100 features.

Table 15. S100_HybridPC

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_HybridPC	Portrayal catalogue defining portrayal rules for the "hybrid feature types" defined in a Hybrid Features Catalogue.	-	(S-100 Part 9) PortrayalCatalog	The IC contains references to local resources (files or folders) defining hybrid PCs.
Attributes and Roles	(See S-100 Part 9)				

Table 16. S100_IC_InteroperabilityCatalogue

The following roles are added to the specification for Phase 1.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_InteroperabilityCatalogue	An interoperability catalogue contains operations and rules for the interoperation of a set of S-100-based data products.	-	-	Specialization of CT_Catalogue (ISO 19115-1)
Role	hybridFC	Reference to hybrid feature catalogue used by operations in this interoperability catalogue	0..*	CharacterString	URI referencing a local file containing the hybrid FC.
Role	hybridPC	Reference to hybrid portrayal catalogue used by operations in this interoperability catalogue	0..*	CharacterString	URI referencing the local file containing the main file for the hybrid portrayal catalogue.
Composition	hybridizationRules	Container for hybridization rules	0..*	<sequence>S100_IC_ HybridizationRule	sequence of non-abstract specializations of S100_IC_HybridizationRule

Table 17. S100_IC_PredefinedCombination

The following composition is added to the specification for Phase 1.

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_PredefinedCombination	Pre-defined combinations are identifiable pre-set collections of recommended and optional S-NNN data products which are expected to be loaded by the user under specific conditions or for specified tasks. Each pre-defined combination is basically a package of data products, display priorities, context parameters, user settings, portrayal catalogues, etc. An ECDIS or other system can allow the user to initiate the loading of multiple data products and activate multiple parameter settings as a single action, by selecting one of a list of pre-defined combinations, instead of loading and unloading individual data products.	-	-	Composition component of S100_IC_InteroperabilityCatalogue
Composition	derivedFeatures	Container for S100_SuppressedFeatureInstance or S100_IC_HybridFeature elements (concrete specializations of S100_IC_DerivedFeature)	0..*	<sequence> of sub-classes of S100_IC_DerivedFeature	sequence of S100_SuppressedFeatureInstance or S100_IC_HybridFeature elements

Table 18. S100_IC_SimpleRule

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_SimpleRule	Rule describing how a set of feature instances is combined to create a hybrid feature type. Simple rules may operate only on thematic attributes. Simple rules treat thematic attributes uniformly during hybridization and therefore do not mention specific attributes. Location/extent spatial attributes of all input features must be spatially equal.	-	-	Subclass of S100_IC_HybridFeatureCreationRule
Attribute	ruleIdentifier	Rule identifier	1	CharacterString	Inherited from S100_IC_HybridFeatureCreationRule Mandatory unique ID used for references.

Table 19. S100_IC_SuppressedFeatureInstance

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_SuppressedFeatureInstance	Operations for replacement of feature instances in one product by instances in another product. The “secondary” product replaces the “primary”.			Sub-class of S100_IC_FeatureDerivation

Attribute	primaryProduct primaryFeatureCode primarySelector secondaryProduct secondaryFeatureCode secondarySelector outputProduct outputFeatureCode	(See S100_IC_FeatureDerivation)		--	Inherited from S100_IC_FeatureDerivation If attributes bindings of the result are the same as secondary product type, the outputProduct and outputFeatureCode can be the same as the secondaryProduct and secondaryFeatureCode; if the attribute binds change, the outputProduct must be HYBRID and the outputFeatureCode must be the code of a feature type defined in the hybrid FC.
Role	featureRef	(See S100_IC_FeatureDerivation)	1	<reference>S100_IC_Feature	Inherited from S100_IC_FeatureDerivation

Table 20. S100_IC_ThematicRule

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_ThematicRule	Rule describing how a set of feature instances is combined to create a hybrid feature type.Thematic rules may operate on only thematic attributes. The input features are required to have spatially equal geometry within a tolerance set by the system.	-	-	Subclass of S100_IC_HybridFeatureCreationRule
Attribute	ruleIdentifier	Rule identifier	1	CharacterString	Mandatory unique ID used for references.

Table 21. FeatureSelector

Type	Name	Description	Derivation	Remarks
datatype	FeatureSelector	A template, logical expression, or match condition that, given a feature instance as parameter, can be evaluated to produce a TRUE/FALSE result	subtype of CharacterString Format and expression language are TBD	Examples: "CATICE=5"; XSLT match condition.

10.2 Interoperability levels and the catalogue

Which parts of the catalogue are used depends on the interoperability level:

- Levels 0, 1, and 2 are as defined in Section 6.2.
- In level 3 processing, in addition to level 1 and 2 components, feature instance suppression operations and rules and feature hybridization operations and rules are added. Hybrid feature and portrayal catalogues must be defined that describe the hybridized types and their portrayal. The rules may be thematic rules or simple rules, but spatial operations and rules are not included.
- In level 4 processing, in addition to level 1, 2, and 3 components, spatial queries and hybridization operations are permitted and complete rules are also allowed.

Figure 8 shows which parts of the catalogue are active in different levels.

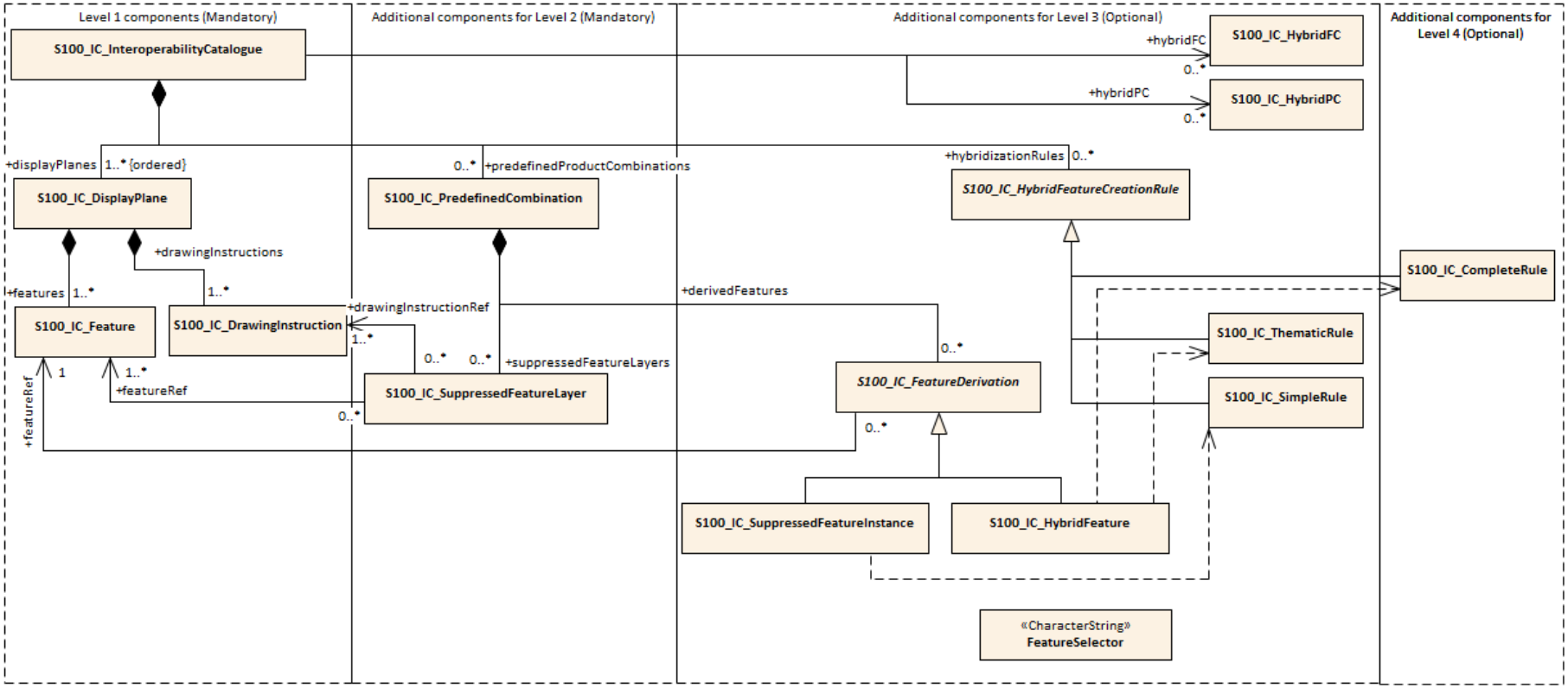

Figure 8. Parts of catalogue used in levels 1 through 4.

11 Processing model for Phase 2

11.1 Interoperability processing overview

Figure 9 shows the processing steps and input to each step from parts of the interoperability catalogue[6]. The flow depends on the interoperability level selected by the mariner.

As is Phase 1 interoperability, data products to be loaded are selected as specified in the predefined combination selected by the mariner. The mariner may also select additional data products from the optional load set.

Processing of feature data from products not listed in the interoperability catalogue, levels 0, 1, and 2 interoperability takes place as before.

In level 3 processing, operations for suppressing feature instances (**Suppress Feature Instances**) are added, as are operations for hybridization of thematic attributes (**Combine Thematic Attributes**). Additional processing to adjust feature and information associations for remaining features may be needed and this is done in the "**Combine Associations**" stage. The order of processing steps is **Suppress Feature Types** ->**Suppress Feature Instances** ->**Combine Thematic Attributes** ->**Interleave Feature Layers**.

In level 4 processing, any additional processing needed to generate spatial primitives for the output hybridized feature is done in the **Combine Spatial Attributes** stage between suppression of feature instances and combination of thematic attributes. The processing flow is **Suppress Feature Types** ->**Suppress Feature Instances** ->**Combine Spatial Attributes** ->**Combine Thematic Attributes** ->**Interleave Feature Layers.**

[6] This figure corresponds to the "Interoperability before Portrayal" processing option. The differences between this option and the "Interoperability after portrayal" option would be analogous to the differences between Figures 4 and 5, specifically, moving "Portrayal Processing" to follow immediately after selection of load sets and adding a final "Rendering" step.

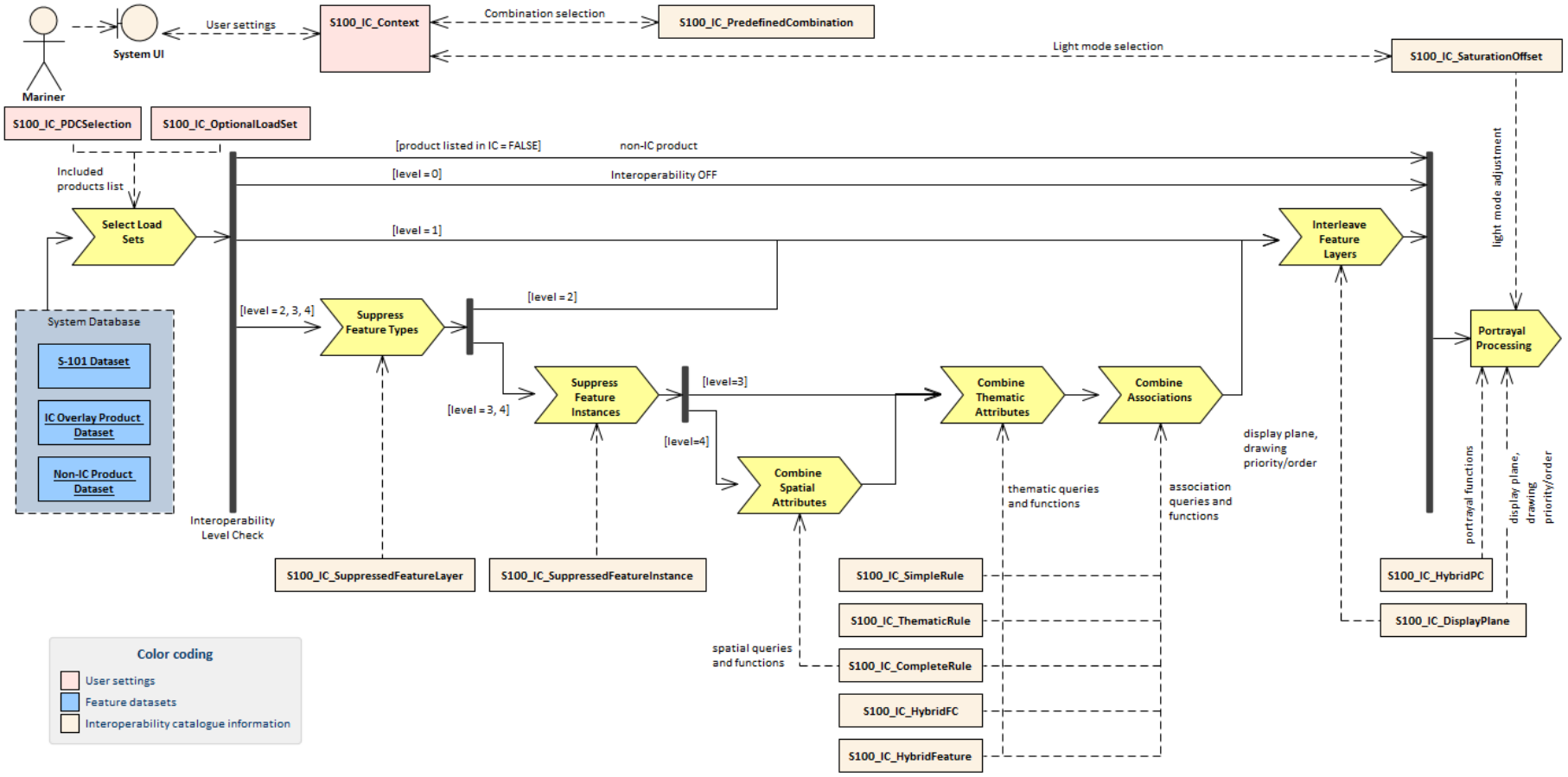

Figure 9. Interoperability processing model – Phase 2 (Option 1 – Interoperability before Portrayal).

Table 22. Stages in interoperability processing

Stage	Description	Level	IC information	Context information	Remarks
Select Load Sets	Select data products to be loaded	All	included product list from S100_IC_ PredefinedCombination. includedProduct	S100_IC_PDCSelection identifies the S100_IC_ PredefinedCombination	-
Portrayal Processing	Ordinary S-100 portrayal processing	All	hybrid PC, display planes		Except final display processing / rendering
Interleave Feature Layers	Assign display plane and drawing order to feature data	1, 2, 3, 4	S100_IC_DisplayPlane		
Suppress Feature Types	Suppress all instances of a specified feature type in a product	2,3,4	S100_IC_Suppressed FeatureLayer		
Suppress Feature Instances	Suppress selected instances of a specified feature type in a product	3,4	S100_IC_Suppressed FeatureInstance		Applies feature selector expressions encoded in primarySelector and secondarySelector attributes.
Combine Thematic Attributes	Select instances for hybridization and generate thematic attributes of a derived feature	3,4	S100_IC_SimpleRule, S100_IC_ThematicRule, S100_IC_CompleteRule (L4 only), S100_IC_HybridFeature, S100_IC_HybridFC		Selection step skipped if preceded by **Combine Spatial Attributes** (L4 processing)
Combine Associations	Adjust associations	3, 4	S100_IC_SimpleRule, S100_IC_ThematicRule, S100_IC_CompleteRule (L4 only), S100_IC_HybridFeature, S100_IC_HybridFC		
Combine Spatial Attributes	Select instances for hybridization and generate spatial attributes of hybrid feature	4	S100_IC_CompleteRule		Complete rules incorporate thematic as well as spatial queries and functions.
Rendering	Display processing	All	S100_IC_DisplayPlane		Not shown in Figure 9, which depicts Option 1 processing

12 Settings and parameters relating to interoperability

Context parameters for interoperability are user settings for:-

- interoperability level selected by the mariner
- the predefined combination selected for loading by the mariner and any additional products to be loaded

The interoperability context is depicted in the figure below. Context settings are in a separate context XML file (or files) managed by the end-user system user interface. This allows OEMs to define a “default context” as well as persistent alternative contexts (e.g., for different navigation scenarios).

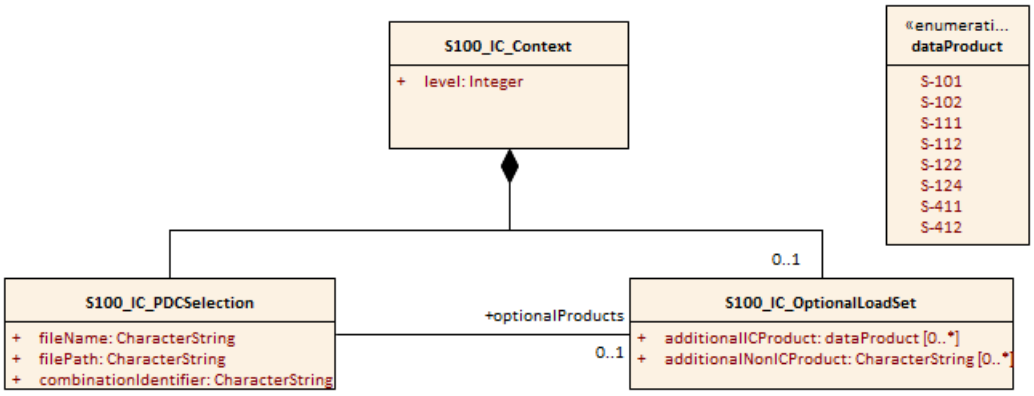

Figure 10. Context parameters / user settings

Enumeration *dataProduct* is defined in Table 7**Error! Reference source not found.**.

Table 23. S100_IC_Context

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_Context	Interoperability user settings and other context parameters	--		Can be saved as a file in XML or other format and thereby act as a persistent store for context parameters.
Attribute	level	Interoperability level set by user	1	Integer	
Composition	--	Reference to the selected predefined combination from an interoperability catalogue	1	S100_IC_PDCSelection	
Composition	--	List of additional products which may be loaded with the selected predefined combination.	0..1	S100_IC_OptionalLoadSet	

Table 24. S100_IC_PDCSelection

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_PDCSelection	The predefined combination selected by the user.			
Attribute	fileName	Name of catalogue file	1	CharacterString	
Attribute	filePath	Path to interoperability catalogue folder relative to root of interoperability catalogue distribution set	1	CharacterString	
Attribute	combinationIdentifier	The ID of the predefined combination in the named catalogue file	1	CharacterString	Must be the same as theidentifier attribute of an S100_IC_PredefinedCombination element in the referenced catalogue.
Role	optionalProducts	Optional products associated with the selected predefined combination	0..1	S100_OptionalLoadSet	

Table 25. S100_IC_OptionalLoadSet

Role Name	Name	Description	Mult	Type	Remarks
Class	S100_IC_OptionalLoadSet	Products optionally loaded with the selected predefined combination	--		
Attribute	additionalICProduct	additional products included in the interoperability catalogue	0..*	Enumeration dataproduct	
Attribute	additionalNonICProduct	additional products not includedin the interoperability catalogue	0..*	CharacterString	

13 Refinements, supporting processes and artifacts, and consequences

13.1 Design refinements

13.1.1 Drop-in architecture

Partition the catalogue so that instead of updating a single XML file, it is possible to "drop in" PDCs, or even levels, or rules. (E.g., use a multi-file /multi-folder structure like the portrayal catalogue). The tradeoff between improved catalogue maintainability and more complex catalogue architecture should be evaluated.

13.1.2 Collective rules

A. Add a simplified suppression rule specification that uses themes or viewing groups instead of feature types - e.g., ProductA/viewgrpX suppresses ProductB/viewgrpY. Separate viewing group assignments from the IC XML file.

B. Allow rules to be defined in terms of supertypes, interpreted as applying to all instances of the type or any of its descendants. This might be particularly useful if the rule operates only on common attributes.

C. Extend feature selector format to allow collective selection of associated features, e.g., for replacing all the features of a traffic separation scheme by a group of other features.

This type of refinement should reduce the size of the catalogue as well as mitigate the need for updates when a new feature is added to a feature catalogue.

13.1.3 Hybridization of more than two types

The interoperability catalogue at present envisages in most cases only operations on pairs of feature types (e.g., hybridizing a primary feature from one product with a secondary feature type from another product). Item (C) in Section 13.1.2 will allow hybridization of more than two types; it can be further generalized to allow hybridization of features from multiple products.

13.1.4 Additional products

The products covered by interoperability are currently a fixed set described by the enumeration *dataProduct*. In order to allow OEMs and others to integrate more products, this enumeration will be converted to a codelist of type open enumeration or open dictionary.

13.2 Supporting processes, artifacts and specifications

The appropriateness of S-100 metadata for interoperability catalogues remains to be evaluated.

Business processes for maintaining the interoperability catalogue will need to be developed, including for adding a new product to the interoperability catalogue.

Effects on best practices for creating data sets will need to be evaluated and updated or supplemented with a “best practices for interoperability” document.

13.3 Catalogue support for user experience design

The interoperability catalogue is designed to allow extensive customization of portrayal as well as feature concepts in the temporary situation when different products are on-display simultaneously, thereby facilitating user-centered design and testing. Processes for testing and best practices for portrayal and hybridization design should be developed as the interoperability specification matures and undergoes initial testing.

13.4 Changes to S-100 and product specifications

13.4.1 Display planes and drawing priority in the portrayal model

In S-100 Edition 2.0.0 and 3.0.0, display plane and drawing order are defined in the portrayal catalogues. The interoperability solution design includes display plane information in the interoperability catalogue. It remains to be determined whether the display plane and drawing priority information in the interoperability catalogue is instead of or in addition to similar information in the portrayal catalogues for individual products. Appropriate changes to the portrayal processing model of Edition 2.0.0/3.0.0 will be needed, e.g., to accept display plane and

drawing priority data as another input stream or as part of feature data, instead of defining it in the portrayal catalogue.