GO-1 Application Objects

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i. Preface

This document is the Open Geospatial Consortium Application Objects Implementation Specification. This specification is a result of the OGC Geographic Objects Initiative, which was established to develop an open set of common, lightweight, language-independent abstractions for describing, managing, rendering, and manipulating geometric and geographic objects within an application programming environment. This document defines that set of vendor-neutral, object-oriented geometric and geographic object abstractions for the application space. It provides both an abstract object specification (in UML) and a programming-language specific profile (in Java) to that specification. The language-specific bindings serve as an open Application Program Interface (API).

ii. Submitting organizations

The following organisations submitted this Implementation Specification to the Open GIS Consortium Inc. in response to the OGC Call for Participation (CFP) in the Geographic Objects Phase One (GO-1) Initiative:

a) SYS Technologies
b) Northrop Grumman Information Technology
c) Pennsylvania State University

iii. Submission contact points

All questions regarding this submission should be directed to the editor or the submitters:

<table>
<thead>
<tr>
<th>CONTACT</th>
<th>COMPANY</th>
<th>EMAIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eric Bertel</td>
<td>SYS Technologies</td>
<td><a href="mailto:eric@polexis.com">eric@polexis.com</a></td>
</tr>
<tr>
<td>Greg Reynolds</td>
<td>SYS Technologies</td>
<td><a href="mailto:greynolds@polexis.com">greynolds@polexis.com</a></td>
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### iv. Revision history

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v. Changes to the OpenGIS® Abstract Specification

The OpenGIS® Abstract Specification does not require changes to accommodate this OpenGIS® specification.

vi. Future Work

The Application Objects specification defines a set of core packages that support a small set of Geometries, a basic set of renderable Graphics that correspond to those Geometries, 2D device abstractions (displays, mouse, keyboard, etc.), and supporting classes. Implementation of these APIs will support the needs of many users of geospatial and graphic information. These APIs support the rendering of geospatial datasets, provide fine-grained symbolization of geometries, and support dynamic, event and user driven animation of geo-registered graphics.

We anticipate the need for extensions to this specification to support more specialized applications. It is likely that the core packages will warrant some granular enhancements, which would constitute revisions to the specification. Some extensions, however, will constitute major new capability areas. Implementing these extensions as a revision to this Application Objects specification would not be advisable, especially if the extension introduces a capability that not all implementers would want to support. These new capability areas should be defined in separate "extension" specifications that include the core specification by reference. Implementations would be declared compliant with one or more of these extensions, and consumers could choose a product that meets their applications' need.

We recommend that future work on new Application Object-dependent specifications be considered for the following extensions:

- 3D - to support 3D Geometries and 3D Graphics for objects such as surfaces and solids, perhaps the integration of standard 3D models such as VRML, and other 3D concepts.
Advanced 2D - to support the more advanced 2D Geometries and 2D Graphics including those defined by Topic 1 (ISO-19107).

Immediate Mode Rendering - to add an optional "call back" method to allow the application programmer to render Graphics using lightweight, transient calls during the physical rendering process (which is useful to support the rendering of extensive amounts of graphical information, but not easily supported by some implementations, such as distributed or client/server map engines). This allows an application programmer to reuse Geometry and Graphics objects to render many similar items (e.g., thousands of CurveSegments) and avoid the overhead of modelling them in memory, prior to render time. In addition to the performance considerations, this also allows for scale and location-dependent rendering to be done by the application, such as rendering sparse representations of grid data, where application logic must be used to calculate the correct placement of the graphics.

Additional data sources - GO-1 has been architected to accommodate non-geospatial data models. The integration of non-GIS information models (engineering, modelling and simulation, etc.) into the GO-1 framework should be pursued.

We recommend that future work on new Application Object core specification be considered in the following areas:

A well-defined mechanism for allowing individual implementations to add new graphical primitives and corresponding graphic style interfaces.

A more extensive investigation into the differences in requirements and capabilities of graphical vs. analytic geometry descriptions.

The API will eventually need to be extended to give the Canvas the ability to span multiple processes and correctly align its state between those processes (e.g. a Canvas that is served to multiple network clients). The X protocol is a good example of an architecture that handles this situation.

Furthermore, we recommend that the work from GO-1 be considered for inclusion in the following OGC work areas:

Style Layer Descriptor (SLD) - The GO-1 GraphicStyle can express certain concepts not found in SLD (e.g. ArrowStyle, FillStyle, FillPattern, Symbology). The SLD specification should be expanded to express these concepts.

Coordinate Reference System (CRS) and Coordinate Transformation (CT) – The GO-1 API introduces the Projection object family, which extends the OGC Conversion object; the MathTransform object family as a decorator to the OGC Operation object family; and a pattern using a default Factory in concert with an AuthorityFactory. With the exception of Projection, all of these
additions are implemented from the OGC 01-009 implementation specification (Coordinate Transformation Services).

In the future, a sub-profile of existing 19107 interfaces should be defined that allows implementations to support only Simple Features for SQL (99-049). As a related compliance issue, the conversion process between Simple Features and 19107 Geometry should be explored.

Web services providing for delivery of asynchronous messages between peers is envisioned as a future need. Such a Web Notification Service should be readily interoperable with the event notification mechanisms provided by GO-1.
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 Inc. shall not be held responsible for identifying any or all such patent rights.

This document consists of the following parts, under the main body:

• Clause 1: Scope
• Clause 2: Conformance
• Clause 3: Normative references
• Clause 4: Terms and definitions
• Clause 5: Conventions
• Clause 6: Design and Specification for Application Objects
• Clause 7: Behaviours
• Annex Documents: Detailed Implementation Specifications for Application Objects in External, Javadoc Documents
• Bibliography
Introduction

This document describes architectural and implementation issues concerning the development of a suite of software objects that facilitate the development of applications with geospatial content, as elucidated during the Geographic Objects Phase 1 Initiative (GO-1) conducted under the auspices of the Open Geospatial Consortium Interoperability program (OGC IP). The particular implementation focus of this initiative is interface definition and code organization in the Java programming language.

The bases of the interface definition are the object models defined in *The OpenGIS Abstract Specification Topic 1: Feature Geometry (ISO-19107 Spatial Schema) Version 5* (OGC 01-101r5) and *The OpenGIS Abstract Specification Topic 2: Spatial Referencing By Coordinates* (Open GIS Consortium Inc). These models provide the architectural bridge between the OGC GO-1 application-domain specification and other OGC service-domain specifications.
OpenGIS® Interface — Application Objects

1 Scope

This OGC document describes the specification for Application Objects. These are the Java and other implementations of objects and interfaces that can be used to implement geospatial applications.

Application Objects are oriented on the application domain (e.g. user-facing, localized processes and operations), and less so on the service domain (e.g. centralized processes and operations that are not necessarily exposed to the user). The focus for interoperability in recent years has been toward coarse-grained, loosely coupled web services. Application Objects provides a complementary API-based approach that can yield improved functionality over web services, at the expense of increased coupling. Both approaches can be valid within various enterprise IT environments.

While this specification outlines certain service interfaces, it does not require the use of any particular service implementation. A GO-1 application may derive its data from one or more services as defined by any of the OGC service specifications. It may also act as a client to transformation or other processing services when they become available. The OGC web services defined to date are effectively standalone.

2 Conformance

This document recognises two broad categories of conformance, *API conformance* and *functional conformance*. API conformance is the ability of an application to invoke all of the required operations without any unexpected returned values or states. API conformance does not require that the component actually do anything. Functional conformance mandates not only that the required operations can be invoked, but also that the component performs the operations in a standard and universally understood manner.

Because this API is intended to be used in a wide range of deployment environments, the primary focus of this document is upon API conformance. API conformance can be specified and tested in a manner that is implementation-neutral. When an operation is invoked, it either succeeds, or fails to produce the intended result. There is no ambiguity.

Functional conformance is more difficult and far more implementation-dependent. What is acceptable in one environment may not be adequate in another. For example, a high-performance, low-power display might be designed to render lines in only a few colours and styles. This would be inadequate for a more feature-rich unit used to develop cartographic imagery. Such differences in functionality should be invisible to a generic API. A rigid definition of functional conformance would limit component developers'
ability to tailor their products to the requirements of their respective developer communities.

Even within the domain of API conformance, there is a wide spectrum of developer objectives and corresponding application types. Not all of these would benefit by incorporating every interface specified below. In the remainder of this section we describe various categories of conformance, and suggest the kinds of applications that might benefit most from each one.

Crucial to this notion are the object classes and interfaces that form natural suites of related functionality, or packages, that define the substance of the various conformance classes. Certain suites, like the Spatial Objects, can be implemented as compliant standalone object libraries. Others, like the Display Objects, are dependent upon one or more other frameworks, and compliant implementations of these must also comply with the specifications of the frameworks on which they depend. To utilize them implies a conformance to the object suites upon which they depend as well.

Even within a framework, there is variation among environments as to which operations and perhaps even which objects may be necessary or useful. Future versions of this specification may provide additional flexibility to implementers by defining different conformance profiles. Simpler profiles would offer less functionality, simpler implementation, and fewer resource requirements than the more extensive profiles.
2.1 Conformance Overview

In order for a GO-1 implementation to be conformant, FeatureStore and FeatureCanvas both require a conformant implementation of Features. Topic 1 - Feature Geometry conformance is required for GO-1 FeatureCollection and Graphics API’s. Topic 2 - Spatial Referencing by Coordinates conformance is required for GO-1 Canvas. For an implementation of Features to be conformant, it requires conformance to Filter Encoding and Styled Layer Descriptor.

The figure below illustrates the aforementioned conformance relationships. Spatial conformance is shaded green, and feature conformance is shaded blue.
2.2 Spatial and Feature Conformance

Feature, Geometry, Coordinate Reference System, and related entities constitute the spatial and feature objects defined by GO-1. These build upon the body of work that has resulted in the OGC Abstract Specification Topic 1 (ISO-19107), OGC Abstract Specification Topic 2, OGC Abstract Specification Topic 5, OGC Simple Features for SQL (OGC 99-049), and other OGC Discussion and Recommendation Papers.

Direct support of spatial objects confers interoperability with local conforming data sources and with remote services, like WFS, that provide an encoded stream of features per the definitions in these documents. The interoperability includes both the geometric properties of objects (Geometry) and the non-geometric properties (Feature attributes).

Feature conformance in GO-1 requires Spatial and Feature Conformance as well as implementation of the FeatureCanvas API.

In javadocs, implementations shall use the annotation “SPATIAL” for identifying Spatial conformance and “FEATURE” for Feature conformance.

2.3 Data Provider Conformance

FeatureStore and related entities constitute the data provider interfaces defined by GO-1. This interface builds upon the efforts of the OpenSource community (in particular GeoTools) to provide a standardized mechanism for data providers to provide queriable access to data. The interfaces prevent the client from having to know anything about the implementation of the data connection.

FeatureStore conformance in GO-1 also requires Feature conformance.

In javadocs, implementations shall use the annotation “DATA_PROVIDER” for identifying this conformance level.

2.4 Display Object Conformance

The Display Objects described in this document include the Canvas, Graphic, GraphicStyle and the objects of the Event model. The Canvas is the rendering surface that the user sees and interacts with. Graphics objects are the entities that a Canvas manipulates and renders according to the styling attributes of a GraphicStyle object. Events provide user input to the Canvas, and both control and notification between objects on the Canvas. Together, these constitute the display subsystem of an application.

This specification recognizes two different levels of Display Object Conformance, basic Display Objects and Display Objects with Events and Editing. In the first level, conforming implementations correctly display Graphic primitives according to their associated GraphicStyle. In the second level of conformance, an implementation additionally correctly fires events when the user interacts with the Canvas and the editability properties of Graphics are fully supported.
Both of these levels of conformance require the implementation of the Canvas, Graphic, and GraphicStyle interfaces. Only in the second level are implementations required to handle the event model described here. The following sections are required for Display Objects with Events and Editing:Events, and all sub sections.

- **7.2.1 Graphic Editability**

Display Object conformance confers a number of benefits upon applications that implement it. Some of these benefits are:

1. Implementations have a variety of architectural and design decisions already made for them. They implement patterns and benefit from best practices as identified by participants in the GO-1 initiative.

2. Among the patterns of interest are a consistent means of ingesting data from a variety of OGC-specified sources.

3. Users of these systems will find familiar user interaction paradigms and control semantics as they move between applications.

4. Applications loosely coupled to their display subsystems may connect with any of a number of local or remote displays, and may therefore provide a means to coordinate control or share information among a variety of distributed sites.

5. Thus display system conformance confers interoperability with respect to the display and user interface subsystem.

In API documentation the annotation “DISPLAY_OBJECT” for identifying Display Object conformance level, and “EDITABLE_DISPLAY_OBJECT” for Editable Display Objects with Events.

### 2.5 OGC Service Conformance

The GO-1 specification does not mandate or exclude any particular web services. The OGC web services defined to date are effectively standalone. An application may conform to any one of them independently, without necessarily conforming to others.

### 2.6 Coordinate Transformations

#### 2.6.1 Coordinate Transformations

GO-1 implementations should support coordinate transformations. Below is a suggested list of coordinate transformations that could be supported.

- Geocentric to Geocentric
- Geocentric to Geographic
- Geographic to Geocentric

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2.6.2 Operation Methods

GO-1 implementations should support operation methods. The following operation methods are suggested.

- Molodenski Transform (7 parameter).
- Abridged Molodenski Transform (7 parameter).
- Geocentric Translation (3 parameter).
- Helmert Transform (7 parameter, with identifiers for Position Vector and Coordinate Frame Rotation variants).
- Affine Transform 2D.
- Polynomial Transform (described by NIMA TR 8350.2). Grid-Based Transform (NADCON and NTv2).

2.6.3 Required Datum

Conformant GO-1 implementations are required to support the following Datum.


3 Normative references

The following normative documents contain provisions that, through reference in this text, constitute provisions of this part of OGC 03-064. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of OGC 03-064 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

(Normative references are included in the Bibliography.)
4 Terms and definitions

For the purposes of this document, the terms and definitions given in Section 5.1 below apply.

5 Conventions

5.1 Symbols (and abbreviated terms)

API Application Program Interface
COTS Commercial Off The Shelf
CRS Coordinate Reference System
CS Coordinate System
GO-1 Geographic Objects, Phase 1
ISO International Organisation for Standardisation
OGC Open GIS Consortium
SLD Styled Layer Descriptor
SRS Spatial Reference System
UML Unified Modelling Language
XML eXtended Markup Language
1D One Dimensional
2D Two Dimensional
3D Three Dimensional

5.2 UML Notation

The diagrams that appear in this standard are presented using the Unified Modelling Language (UML) static structure diagram. The UML notations used in this standard are described in the diagram below.
In this standard, the following three stereotypes of UML classes are used:

a) **<<Interface>>** A definition of a set of operations that is supported by objects having this interface. An Interface class cannot contain any attributes.

b) **<<DataType>>** A descriptor of a set of values that lack identity (independent existence and the possibility of side effects). A DataType is a class with no operations whose primary purpose is to hold the information.

c) **<<CodeList>>** is a flexible enumeration that uses string values for expressing a list of potential values.

In this standard, the following standard data types are used:

a) **CharacterString** – A sequence of characters

b) **Integer** – An integer number

c) **Double** – A double precision floating point number

d) **Float** – A single precision floating point number
6. Application Object Definitions

6.1 Factory

The GO-1 CommonFactory class supports a getCapabilities() operation that allows it to describe the supported features. An application attempting to use a given implementation can invoke this method to determine whether an implementation is suitable for rendering its graphic information, or whether it would have to do extra work in order to use the implementation.

For example, the CommonFactory.getCapabilities() method returns an object that implements the CommonCapabilities interface. This object may then be queried about support for specific features.

The CommonFactory is the gateway into the GO-1 implementation. To access other factories used in GO-1, they are first obtained from the CommonFactory. For example, CommonFactory.getCRSAuthorityFactory() returns the CRSAuthorityFactory object from the CommonFactory implementation.

6.1.1 Graphic Object Creation

Graphic objects are created by invocation of the DisplayFactory.createGraphic() method. The Factory pattern, which is used extensively throughout GO-1, insulates client code from all details of the created class internals. Graphic creation methods may instantiate Graphic objects based on ISO-19107 geometries presented to them, but they may also be created using Shapefiles, or other formats for setting the geometry and geospatial location of a Graphic.

In order to ascertain display capabilities, the DisplayFactory.getCapabilities() method is used to obtain capabilities related to graphic primitives and styles. Among the kinds of information an application may discover are various types of graphical rendering that the implementation is capable of doing, e.g., kinds of stroke and fill patterns available, support for blinking or backlighting, colour palette, line join styles and end caps, etc.
6.2 Display Objects

Display objects mediate the dynamic interactions of geospatial, graphical, or other data with the application. The particular role of such objects in the context of the present specification involves interaction with end users: displaying the data on a user-viewable device, and accepting user or programmatic input to control the application.

6.2.1 Canvas

6.2.1.1 General Description

The Canvas class defines a common abstraction for the display and user manipulation of geospatial information. It contains and manages a collection of Graphic objects that may be rendered as a map or represent features on a map, and maintains display context.

The DisplayFactory creates instances of this class. The Factory pattern, which is used extensively throughout GO-1, insulates client code from all details of the created class internals.
A Canvas is associated with an output device such as a window or a portion of a window on a display screen, or an image buffer. The Canvas is responsible for intelligent handling of the viewable area of the window, including panning, zooming, growing, and shrinking, repaints of "dirty" areas in the image due to external window changes, and visual changes in the Graphics due to editing, animation, or filtering.

6.2.1.3 Input Device

A Canvas may be associated with one or more input devices such as a mouse, keyboard, eye tracker, or gesture reader. These devices allow the user to manipulate the Graphic objects held by the Canvas and to interact with the Canvas in other ways. The Canvas manages the input events from these devices. See section 6.1.2 for a description of how events are to be handled.
6.2.1.4 Coordinate Reference System

The Canvas maintains two coordinate reference systems (CRS):

1. The Canvas *display CRS* is associated with the geometry of the display device, and generally uses display coordinates such as *pixels*.

2. The Canvas *objective CRS* is associated with the data modelled by the Canvas, and is generally associated with model coordinates, such as *points*.

Most computer screens are a rectangular array of pixels, and would use a CRS backed by a CartesianCS for the display CRS. A planetarium or IMAX theatre is a spherical display, and might require a spherical coordinate reference system.

The Canvas objective CRS is typically a ProjectedCRS for a rendered map, but could be a GeographicCRS if simple lat/lon rendering is desired, or a non-georeferenced CoordinateReferenceSystem, such as an isometric projection of an EngineeringCRS.

The Canvas must provide accessors for two MathTransform objects, the first which specifies the particular transformation method from the objective CRS to the display CRS, and the second which specifies the transformation method from the display CRS to the objective CRS (note this latter transformation can be provided by MathTransform.invert() method which is part of OGC 01-009 specification). This MathTransform shall be invertible, in order to get the transformation method from the display CRS to the objective CRS. For example if the ProjectedCRS defines objects in grid coordinates, the first transform can convert the grid coordinates of a ProjectedCRS to screen coordinates of the display CRS. Alternately an implementation can choose to utilize as the objective CRS a non-projected CoordinateReferenceSystem, such as a GeospatialCRS, a GeographicCRS, or an EngineeringCRS.

Before adding a Graphic to a Canvas the user is responsible to ensure that the CoordinateReferenceSystem of the Graphic is supported by the implementation, by using CommonCapabilities.getSupportedCoordinateReferenceSystems().

If the Graphic CoordinateReferenceSystem is not supported, then the client must transform the Graphic to an appropriate CoordinateReferenceSystem prior to adding it.

If the Graphic CoordinateReferenceSystem is supported, but is different than the objective CRS of the Canvas, the Canvas will transform the original Graphic object to a new Graphic object, discard the original Graphic object, and return a reference
to the new Graphic object. The client is responsible to update its internal reference to the new Graphic object.

6.2.1.5 Z-Order and Rendering of Graphics

The Canvas controls the visual layering, or z-order, of the Graphic objects it contains. The z-order allows Graphics to overlap and occlude each other in a controllable way. The Canvas may optimise its display by not rendering Graphics that are fully occluded.

Furthermore, when an input device selects a location on the display, the z-order allows the Canvas to designate the topmost Graphic (i.e., the highest z-order value for all Graphics at that coordinate location) as the object of interest.

In the general case of a distributed, asynchronous environment, the z-order cannot be designated deterministically by software external to the Canvas. To maximise the control of the situation, GraphicStyle objects have a z-order hint that the application can set, and the Canvas can read. When a Graphic is added to a Canvas, the Canvas gets the Graphic's z-order hint and attempts to place the Graphic at that z-order location. The z-order is defined as a double to permit a large range of values.
6.2.1.6 Canvas State

To interact with the Canvas, outside entities must be aware of certain properties that provide context for graphical operations. Collectively, these properties comprise the Canvas state, and are contained in instances of CanvasState or one of its subclasses. This object describes only the viewing area or volume of the Canvas, not any state or other information about the data contained within it. When an instance of CanvasState is returned from Canvas methods, it contains a "snapshot" of the current state of the canvas. Its values never change, even if the state of the Canvas itself does.

Entities that are interested in reading Canvas state must implement the CanvasListener interface. CanvasListener includes the canvasChanged() method, which is called by a Canvas when its state has changed. The Canvas passes a populated CanvasState data object to the canvasChanged() method.

If an entity needs to change the state of a Canvas, it must implement the CanvasHandler interface. This interface provides a mechanism for multiple entities to change Canvas properties without contention or deadlock. The Canvas enables exactly one CanvasHandler at a time. When a CanvasHandler is enabled, the Canvas passes it a CanvasController, through which the entity can modify
Canvas state values. The CanvasController remains active until another CanvasHandler is enabled.

This architecture assumes a Canvas that is in a single process. However, if the Canvas spans multiple processes, then a state alignment issue occurs, where a process may not detect a change initiated by another process. This specification does not address this latter scenario.

6.2.1.7 Specialized 2D Canvas Interfaces

In the majority of cases, a Canvas will be a representation of the earth, either in a projected coordinate system or in a geographic coordinate system. In these cases, the Canvas will additionally implement the Map2DCanvas interface. Such a canvas will return instances of Map2DState (which extends CanvasState) from its getState() method. And if a CanvasHandler is added to a Map2D, the CanvasController that is passed to it will be an instance of Map2DController.

![Diagram of Canvas, CanvasState, and Map2DController](image)

Figure 6 - Map2D, Map2DState, and Map2DController

If the user knows that the Canvas will be an instance of Map2D, then these classes can be used to control the various 2D parameters of the Canvas.

For example, in a projected geographic CRS, a class implementing Map2DState shall provide access to the following properties:

- `pixelWidth` - width in pixels of the visible map window
- `pixelHeight` - height in pixels of the visible map window
- `center` - the DirectPosition center point of the map
- `width` - the map width in map width units
- `scale` - the ratio of map space to real world space
- `envelope` - the visible geographic map boundary
6.2.2 Events

6.2.2.1 Model and Rationale

The general paradigm for control by input devices is similar to the Java Event model, and works as follows:

For each control device (e.g., a mouse or keyboard), there is specialized Event object type. (In Java, for example, there are the KeyEvent and MouseEvent classes. Other language implementations of GO-1 will use different classes as appropriate.) When the device changes state (e.g., a mouse button is pressed), the system sends an instance of that Event to the Canvas. The actual mechanism through which the event is delivered to the Canvas is system and language dependent. However, a conforming implementation of the Canvas interface must handle the event as described below.

A Canvas maintains a stack of EventHandlers for each event type (keyboard, mouse, etc). When it receives an event, the Canvas passes it to the first Handler on the corresponding stack. Each Handler implements specialized functionality – the system’s response to the Event - that it executes when it receives an Event. Then it can either consume the Event, or by not consuming it, allow it to be passed to the next handler in the stack. Thus the response of the system to a control input depends directly on the flow of Events through the Handler stack.

The stacks of event handlers on a Canvas are represented as instances of the EventManager interface. Methods on this interface allow the application to control what Handlers are on a given stack, and in which order. This flexible arrangement allows the application to establish different modal responses for different states of the system, such as selection mode vs. editing mode.

This design is explained in greater detail in the following sections.

6.2.2.2 GO-1 Event Management

The GO-1 model for responding to user-actuated controls, programmatic state changes, and other asynchronous events is mediated through a general-purpose framework based on the Java Event model. In the Java model, a physical or programmatic change constitutes an event, which is represented by an Event object that contains information about the event and identifies the source of the event. Objects can implement an appropriate EventListener interface and register with the event source in order to receive events generated by that source. Some event sources, such as those that generate mouse or keyboard events, are present by default in the underlying system. Others may be implemented in the application or in library packages. Event sources per se are not a part of the response system documented here, but they motivate one important aspect of its organisation: for each source in a GO-1 implementation there is an event handling subsystem whose structure is described by the following paragraphs.
6.2.2.3 EventHandler Stack

For each event chain, there is at least one EventHandler object. The Handlers do the actual work of mediating the system’s response to an event. For example, a MouseHandler implements a mouseClicked() operation that may cause an object to be selected or highlighted.

A Handler implements the EventListener interface appropriate to its source, but it does not register as a listener. Instead, it implements the interface in order to inherit (and perhaps override) the relevant event handling methods.

As noted above, each EventHandler object has a stack of Handlers. When it receives an event, the EventHandler object invokes the appropriate action method against the top Handler on the stack. The Handler performs whatever specialized function this method implements, and then optionally consumes the event. If the event is not consumed, the EventHandler object invokes the method against the next handler on the stack, and so on until the event is consumed. Thus an event may trigger a series of responses that varies according to the arrangement of EventHandlers on the stack.

This mechanism may be used to implement modal behaviours in response to input events, such as a change from selection behaviours to editing behaviours in the application’s response to mouse gestures.

6.2.2.4 EventManager

EventManagers are concerned primarily with maintaining the stack of Handlers. They have methods to enable, push, pop, find, remove, and replace Handlers on the stack.

Canvas objects are loosely coupled with EventManager objects. The EventManager pattern is extensible to accommodate input devices beyond the traditional keyboard and mouse (such as eye tracker, gesture reader, etc.). Canvas support of particular EventManager implementations is determined through Canvas.findEventManager(Class eventManagerClass), where eventManagerClass is a class that extends EventManager, and whose implementation satisfies the various Event operations for that device.

Much of the user input will be processed by the Canvas, which manages its own event managers. The Graphic class, described under Graphical Data Objects below, also have event manages similar to the Canvas.

6.2.2.5 Event Types

There are several event flags in GO-1. There are four required for Display Object conformance; GRAPHIC_CHANGED, GRAPHIC_SELECTED, GRAPHIC_DESELECTED, and GRAPHIC_DISPOSED.
6.3 Graphical Data Objects

A graphical rendering environment differs from a general geospatial processing environment in several respects. For one thing, due to their inherently limited resolution and other physical constraints, raster display devices can only accurately depict a limited set of geometries. For another, each display device and corresponding software system may have its own notion of how to style the objects that it renders.

The most significant differences are more general, and incorporate the above particulars. Displays are often compact, high-performance, and necessarily specialized devices that raise issues familiar from the earlier days of general-purpose computing. Very robust, immensely flexible, and therefore large object systems intended to meet every possible functional requirement are both irrelevant and overly expensive in terms of memory requirements and processing overhead. Items that constitute the primary focus of functionality in a general context, such as a map, may be nothing more than a graphical background in a display system.

The classes described here are therefore lighter weight and less general than the ISO Geometry classes described in Section 6.3.1 (from the OGC Topic, i.e. ISO-19107). Nonetheless, they seek to retain the semantics and many of the behaviours of objects already defined by published or existing OGC standards. Where appropriate, they are defined as restrictions of the more general objects, and are typically instantiated via factory objects that take corresponding general-purpose spatial objects as arguments.
6.3.1 Graphic Overview

Graphic objects contain the information needed by a Canvas to create a visual display. Similar in some respects to a Java 2 Shape, they contain geometric data, styling information (See GraphicStyle, Section 6.2.2), and geospatial coordinate location.

There are two broad categories of Graphics: primitives and aggregates. Primitive types are based on a simple rendered object (or an Icon, Text, or an Image) or are based on a primitive 2D ISO Geometry object, and includeGraphicLineString, GraphicPolygon, GraphicScaledImage, GraphicIcon, GraphicArc, and GraphicLabel. Aggregates are collections of primitives as represented by AggregateGraphic.

While the layout of each primitive graphic object corresponds to ISO-19107 Geometry, translation of Geometry objects to Graphic primitives is left to the implementation.
A Canvas knows how to read the attributes and geometric data from each Graphic type, and how to apply the styling information in the Graphic to create a visual representation. Graphics also contain a z-order hint, which the Canvas uses to help manage visual layering of the Graphics it displays.

Geometry objects are portable between implementations of the GO-1 specification. For example, an external program shall be able to create Geometry objects in one implementation but apply those Geometry objects to Graphic objects in any implementation of Canvas or Graphic.

Graphic objects are instantiated with a Factory pattern.

### 6.3.2 Primitives

#### GraphicLabel

- `setText(text : String) : void`
- `getText() : String`
- `setPosition(coord : DirectPosition) : void`
- `getRotation(unit : Unit) : double`
- `getAnchorAnchor(xAnchor : XAnchor) : void`
- `getAnchorAnchor(yAnchor : YAnchor) : void`
- `setRotation(rotation : double, unit : Unit) : void`
- `getRotation(unit : Unit) : double`
- `isAllowingRotation() : boolean`
- `setAllowingRotation(newValue : boolean) : void`

#### GraphicIcon

- `setIcon(icon : Icon) : void`
- `getIcon() : Icon`
- `setPosition(coord : DirectPosition) : void`
- `getPosition() : DirectPosition`
- `setRotation(angle : double, unit : Unit) : void`
- `getRotation(unit : Unit) : double`
- `getOffset(offset : Point2D) : void`
- `getOffset() : Point2D`
- `isAllowingRotation() : boolean`
- `setAllowingRotation(newValue : boolean) : void`

#### GraphicScaledImage

- `setScaleImage(image : RenderedImage) : void`
- `getScaledImage() : RenderedImage`
- `setUpperLeft(coord : DirectPosition) : void`
- `getUpperLeft() : DirectPosition`
- `setLowerRight(coord : DirectPosition) : void`
- `getLowerRight() : DirectPosition`
- `setIntensity(intensity : int) : void`
- `getIntensity() : int`
- `setTransparency(transparency : int) : void`
- `getTransparency() : int`
- `setCRS(crs : CoordinateReferenceSystem) : void`
- `getCRS() : CoordinateReferenceSystem`

#### GraphicLineString

- `getPoints() : DirectPosition[]`
- `setPoint(coords : DirectPosition[]) : void`
- `editPoint(coord : DirectPosition) : void`
- `deletePoint(index : int) : void`
- `getPoint(index : int) : DirectPosition`
- `setPoint(index : int, coord : DirectPosition) : void`
- `isClosed() : boolean`
- `isAllowingNewVertices() : boolean`
- `setAllowingNewVertices(newValue : boolean) : void`
- `setPathType(pathType : PathType) : void`
- `getPathType() : PathType`

#### Figure 8 – GraphicLabel, GraphicIcon, GraphicScaledImage, GraphicLineString

The palette of primitive shapes available to a Graphic is limited to a set that is sufficient for manipulation and rendering in graphical environments. Graphic objects themselves are subclassed according to the kind of geometry that they implement, and include the following:
GraphicLineString defines a common abstraction for implementations of 1-D lines made of one or more line segments. A settable PathType attribute determines the interpolation between segment endpoints.

GraphicScaledImage provides an abstraction for implementing projected images defined by an upper and lower corner point. This class includes methods for setting the image transparency and intensity as well as the image data. There are also methods for setting and getting the CoordinateReferenceSystem of the underlying Envelope, which specifies the projection of the image.

GraphicIcon defines a common abstraction for implementations to render icons on a drawing surface. The position of the icon in the CoordinateReferenceSystem is idealised as a single point attribute. The alignment of the icon to this point is specified as a pixel offset from the icon’s upper left corner. The rotation of the label is measured positively as a clockwise angle, starting from a reference line within the CoordinateReferenceSystem.

GraphicLabel defines a common abstraction for implementations to render text on a drawing surface. The position of the label in the CoordinateReferenceSystem is idealised as a single point attribute. The alignment the label to this point is specified by the x-anchor and y-anchor. The rotation of the label is measured positively as a clockwise angle, starting from a reference line within the CoordinateReferenceSystem.
GraphicArc provides definitions for closed circles and ellipses, as well as circular or elliptical arcs. Various settable attributes control its size, width, height, and orientation, and whether the object can be rotated or resized by the user. In this context width always refers to the major axis and height to the minor axis. Orientation start and end angles are defined counter-clockwise from the x-axis.
**GraphicPolygon**

+ getExteriorPoint(index : int) : DirectPosition
+ addExteriorPoint(position : DirectPosition) : void
+ insertExteriorPoint(index : int, position : DirectPosition) : void
+ setExteriorPoint(index : int, position : DirectPosition) : DirectPosition
+ removeExteriorPoint(index : int) : DirectPosition
+ getExteriorRing() : DirectPosition[]
+ setExteriorRing(newVertices : DirectPosition[]) : void
+ getNumExteriorPoints() : int
+ getInteriorPoint(index : int, interiorRingIndex : int) : DirectPosition
+ addInteriorPoint(interiorRingIndex : int, position : DirectPosition) : void
+ setInteriorPoint(index : int, interiorRingIndex : int, position : DirectPosition) : DirectPosition
+ removeInteriorPoint(index : int, interiorRingIndex : int) : DirectPosition
+ getInteriorRing(interiorRingIndex : int) : DirectPosition[]
+ setInteriorRing(interiorRingIndex : int, newVertices : DirectPosition[]) : void
+ getNumInteriorPoints(interiorRingIndex : int) : int
+ addInteriorRing(verticies : DirectPosition[]) : int
+ removeInteriorRing(interiorRingIndex : int) : void
+ getNumInteriorRings() : int
+ getAllInteriorPoints() : DirectPosition[]
+ getPolygonSymbolizer() : PolygonSymbolizer
+ setPathType(pathType : PathType) : void
+ getPathType() : PathType
+ isAllowingNewVertices() : boolean
+ setAllowingNewVertices(newValue : boolean) : void
+ insertInteriorPoint(index : int, interiorRingIndex : int, position : DirectPosition) : void

**Figure 10 - GraphicPolygon**

**GraphicPolygon** defines a common abstraction for a graphic representation of polygons with holes. A GraphicPolygon consists of an exterior ring of vertices, and a set of non-mutually overlapping interior rings of vertices. The exterior and interior rings of a polygon are defined by a list of DirectPosition objects. Technically speaking these rings are required to be closed such that first and last points coincide. However, this interface allows the user to create rings that are not closed. In such cases it is left up to the implementation to derive an additional segment between the first and last vertex. Implementers are responsible for validating that the arrays of points represent paths that do not cross themselves, that the interior rings are non-overlapping, and that they are indeed interior to the exterior ring.

### 6.3.3 Aggregates

**AggregateGraphic** defines a common abstraction for implementations of aggregated Graphic objects. This abstraction makes no assumptions about how the Graphics are stored within the aggregate. For example, the Graphics may be stored in an array such that the Graphic in the zero element of the array is considered the front most (highest z-order) object and the Graphic in the largest element of the array is considered the bottommost (lowest z-order) object. Alternatively, the Graphics may be stored in a
more efficient data structure.

This abstraction makes no assumptions about thread safety. Implementations of Graphic that are to be used in a multi-threaded environment must address thread safety by using synchronised methods or by invoking all methods from a single thread.

6.3.4 Symbols

A symbol can be depicted on a map using one of two techniques, pictorial or abstract. Pictorial symbols are those that are designed to replicate or look like the feature they represent, such as a cross to identify a hospital or a ship to symbolize a port. They do not necessarily have a direct connection to what they identify. Abstract symbols are usually represented by a geometric shape, and bear no relationship to the form of the object they symbolize.

Symbols can be further defined in terms of their dimension; point (no-dimension), line (1-dimensional), area (2-dimensional), and volume (3-dimensional). Other visual attributes used to describe a symbol include a combination of size, shape, orientation, color, and pattern. Most or all of these symbol attributes are pre-determined when a symbology standard is applied.

Currently there exist a large number of symbology standards covering a broad range of public and private sector applications. Some of these standards are currently under development, while new standards are being proposed. Our approach seeks to provide generic support for both existing and future standards, without mandating the use of any specific standard.
6.3.4.1 Symbology

GO-1 uses a canonical approach to represent standard symbology sets. Tag names and corresponding data type values are explicitly typed in advance, and described in Appendix B. Some tags are well known and defined by existing accepted standards. Others must be derived from best industry practices, existing conventions, or consensus. Additions to the symbology tags presented in this document are expected and encouraged, and stakeholders are urged to collaborate on additions and revisions. Prior to acceptance of this proposed standard, the content of Appendix B is subject to revision. Tags defined post-acceptance of this specification may be subject to deprecation, but should not be modified or deleted. An XML schema to describe tags for a supported Symbology would look like the following.

```xml
<?xml version="1.0"?>
<xs:schema xmlns:xs="http://www.w3.org/2001/XMLSchema"
  targetNamespace="http://www.polexis.com/site"
  xmlns:site="http://www.polexis.com/site"
  xmlns:slid="http://www.opengis.net/sld"
  elementFormDefault="qualified">  
  <xs:element name="tag" type="symbologyTag">  
    <xs:complexType name="symbologyTag">  
      <xs:sequence>  
        <xs:element name="name" type="xs:string"/>  
        <xs:element name="type" type="xs:string"/>  
        <xs:element name="description" type="xs:string" use="optional"/>  
      </xs:sequence>  
    </xs:complexType>  
  </xs:element>  
</xs:schema>
```

6.3.4.2 Visibility Tag

A “visibility” tag modifier can be optionally appended to any tag name. The data type for visibility is Boolean. Presence of a visibility value of Boolean.TRUE would mean that component should be rendered, and a value of Boolean.FALSE would mean don’t
display the component. The following snippet would turn off the AdditionalInformation indicator for the MIL-STD 2525 symbol use case in Section 7.5.2.

```java
symbology.setSymbologyProperty(symInfo, "AdditionalInformation", "RAF418");
symbology.setSymbologyProperty(symInfo, "AdditionalInformation.visibility", Boolean.FALSE);
```

### 6.3.5 Path Type

Path types describe how lines are rendered with respect to the modelled surface of the earth. The categories of path type are:

- Global, consisting of *rhumbline* and *great circle* types
- Unprojected, consisting of *pixel straight* and *spline* types
- Vector

PathType serves as the base class for objects that represent the various methods for computing a path between two locations. Singleton instances of PathType will exist to represent, for example, a path of constant bearing (rhumbline), or a great circle path. Path type is an algorithmic sequence of interpolation and projection.

- For *rhumbline*, *great circle*, and *vector*, first *interpolation* is done on the vertices, which gives in-between points. These in-between points are then *projected* into the Canvas display CRS, which converts them to display points.
- For *pixel-straight* and *spline*, the vertices are first *projected* into the Canvas display CRS as display points. These display points are *interpolated*, which generates in-between display points.

For each path type, an implementation will iteratively apply the respective algorithms until the appropriate display resolution is reached.

<table>
<thead>
<tr>
<th>Path Type</th>
<th>Interpolation Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>rhumbline</td>
<td>constant bearing</td>
</tr>
<tr>
<td>great circle</td>
<td>geodesic</td>
</tr>
<tr>
<td>Vector</td>
<td>linear in world space (interpolation before projection)</td>
</tr>
<tr>
<td>pixel-straight</td>
<td>linear in display space (interpolation after projection)</td>
</tr>
<tr>
<td>Spline</td>
<td>cubic in display space (interpolation after projection)</td>
</tr>
</tbody>
</table>

Table 1 – Path Types
The **Global path type** methods calculate a path between two locations, considering the shape of the earth. The in-between points of the path satisfy two conditions:

1. The in-between points are the same regardless of the way the current path is displayed (i.e., the path is independent of map projection, Canvas, or other considerations affecting rendering or portrayal).

2. The in-between points are calculated along a surface that the points are projected onto, such as the surface of the 3D earth.

The second condition implies that altitude is not taken into account when calculating Global paths. Hence, paths of this type are well suited for navigation of surface ships or vehicles.

This specification defines four path types:

- Great Circle Ellipsoidal
- Great Circle Spherical
- Rhumbline Ellipsoidal
- Rhumbline Spherical

Great circle uses the shortest line on the surface of the earth, assuming either a spherical or an ellipsoidal earth model. Rhumbline uses a line of constant bearing along the surface of the earth, also using either a spherical or an ellipsoidal model.

The **Unprojected path type** methods calculate a path between two locations, not considering the shape of the earth, but considering the surface of the Canvas.

The methods are:

- Pixel Straight
- Continuous Spline

Pixel straight connects each sequential point with the shortest line on the Canvas. Continuous Spline uses an interpolation method to connect more than two points.

The **Vector path type** considers the surface of the earth, but connects sequential point locations with the shortest direct line, even if it travels below the curved surface of the 3D earth.
6.3.6 Graphic Attributes

6.3.6.1 Viewability

A Graphic may unconditionally be set invisible using its visible attribute. It can be made conditionally invisible based on a range specified by maxScale and/or minScale. If maxScale is set, and the Canvas exceeds that scale, the Graphic is made invisible. Similarly if minScale is set and the Canvas drops below that scale, the Graphic is made invisible. The invisible state does not change the transparency values of GraphicStyle components, but instead overrides their effect. The z-order hint is used by the Canvas to place the Graphic in the z-order [see Graphics Section].

6.3.6.2 Symbology

Symbology when defined supersedes any of the other symbolizer objects [see Symbology Section].

6.3.6.3 Highlight

Highlight attributes control whether a Graphic can blink, and if so, at what rate through blinking and blinkPattern.

6.3.6.4 Editability

Editability attributes allow the Graphic to be edited or selected through user interaction with the Canvas, usually using mouse gestures. Editability includes autoEdit, dragSelect, selected, and pickable. See Graphic Editability section for a more thorough description.

6.3.7 GraphicStyle

6.3.7.1 Relationship to Graphic

The GraphicStyle class allows a Graphic to be visually decorated. Each Graphic contains a GraphicStyle object. If a particular property on a GraphicStyle is not set then a default value is used.

Most rendering style attributes are defined in one of the four subclasses of GraphicStyle, each of which is tailored for the needs of specific graphic types. LineSymbolizer maintains attributes that apply to line-stroked Graphics, such as GraphicLineString and open GraphicArcs. PolygonSymbolizer extends LineSymbolizer to maintain fill attributes for filled stroked objects, such as GraphicPolygon and closed GraphicArcs. TextSymbolizer governs rendering of labels. PointSymbolizer is used for rendering other objects that are anchored to a single point and painted in a pixel-wise manner without regard to map location; it is the GraphicStyle used by GraphicIcon.
A number of basic rendering attributes are maintained within the Graphic itself. These include visibility and Z order, selection state, pickability and drag selectability, editability, and highlighting.

Outside of GraphicStyle, the Symbology interface governs rendering that will conform to a defined symbology set. A Graphic may maintain a Symbology object, and when it does so, this overrides any conflicting style attributes set within the GraphicStyle object.

6.3.7.2 Relationship to OGC SLD

The GraphicStyle class and its subclasses have been developed to be as symmetric as possible with SLD [14]. As such, SLD styles have many similar properties to a GraphicStyle. However, SLD style properties, such as color or line thickness, can be functions of feature properties, and thus vary from feature to feature. GraphicStyles are fixed until explicit API calls change their values. GraphicStyle contains concepts not found in SLD (e.g. Text BackgroundColor, ArrowStyle, DashArray, FillStyle, FillPattern). It is recommended that the SLD specification be expanded to express these concepts. See Future Work section.

The SLD-analogous interfaces are:

- LineSymbolizer is closely related to SLD LineSymbolizer in that it decorates lines.
- PolygonSymbolizer is closely related to SLD PolygonSymbolizer in that it decorates polygonal shapes.
- PointSymbolizer is closely related to the SLD PointSymbolizer in that it decorates icons.
- TextSymbolizer is closely related to the SLD TextSymbolizer. The TextSymbolizer.FONT component is defined as the Java implementation of Font, as it more accurately defines and distinguishes the concepts of character and glyph than does the SLD model.

6.3.7.3 GraphicStyle Elements

The following table details the properties of the various symbolizer interfaces, their types, and their default values.

<table>
<thead>
<tr>
<th>Interface</th>
<th>Element</th>
<th>Type</th>
<th>Default</th>
</tr>
</thead>
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<td></td>
</tr>
</tbody>
</table>
Table 2 – GraphicStyle Elements

6.3.7.4 GraphicStyle Events

GraphicStyleListeners may be registered on any GraphicStyle object to be notified of attribute changes. Implementations may do so for several purposes, such as knowing to repaint a Graphic for modification of a styling attribute. This may also be used for propagating a change in an attribute among Graphics that do not share the same GraphicStyle object. For example, note that AggregateGraphic objects are required to maintain a GraphicStyle object even though its attributes will not apply to rendering any of its constituent Graphics. However, it would be allowable to assign it an object of one of the four symbolizer types. Children that have diverse GraphicStyles could listen for changes to a certain attribute (say, stroke color), and update their own styles if such a GraphicStyleEvent is detected.

6.3.7.5 Graphic Selectability

Many systems for displaying geometric shapes allow the user to edit those shapes by using the mouse to change, add, or remove vertices. For such systems, the editability attributes of a Graphic allow the user to toggle on and off this behaviour. Here is a description of the relevant accessor methods:

- get/setDragSelectable - Many systems allow the user to select objects on the screen by dragging a bounding area, such as a box, with a mouse gesture. This property, if set to true, allows the graphic to be included in selection sets created in this way.
get/setPickable - Many systems allow the user to select individual objects by gesturing (mouse clicking) over the object. This property, if true, allows the graphic to be selected in this way.

get/setSelected - For systems that allow individual graphics to be selected in the display (usually with a mouse gesture or by choosing an item from a list), this property sets or queries whether the given graphic is currently selected. Systems that have no notion of selection may always have a value of false for this property and the set method will have no effect.

6.3.8 Graphic Events

When a Graphic object changes or receives mouse or keyboard interaction it fires a GraphicEvent. A GraphicEvent can be received by objects that implement the GraphicListener interface. A client may receive GraphicEvents by creating an object that implements the GraphicListener interface and registering it with a Graphic via its addGraphicListener() method.

Graphic objects that are aggregations (i.e. AggregateGraphic) can register AggregationListeners to listen for AggregationChangeEvent’s. These events are notifications when elements are added, removed, or (if applicable) reordered within the aggregation.

Whenever a Graphic is selected, a GraphicChangeEvent must be fired by the implementation.

6.4 Spatial Objects

Spatial objects are those that contain geometric or location information. GO-1 utilizes spatial objects to provide this information to Graphic objects.

6.4.1 Geometry

GO-1 supports a “simple geometry” profile of the robust model for geospatial geometry developed and published by the International Standards Organisation as ISO-19107 which was adopted with modifications in OGC Topic 1: Feature Geometry [5]. The ISO model provides an international standard for realizable geometry. This model has been implemented, with some minor changes, in the Open GIS Consortium Geographic Markup Language (GML) specification version 3.0 [12].

ISO-19107 is an all-inclusive model, intended to address the most demanding needs of a geospatial application. Many applications, in particular graphics subsystems, do not need the full capabilities of this model. The sections below identify the components of the ISO-19107 Geometry model that are the focus of GO-1.

GO-1 has adopted a subset of ISO-19107 Geometry for handling simple 0, 1 and 2 dimensional geometric primitives. The full semantic and detailed structures of these
geometries are documented in the ISO-19107 specification. Context diagrams and brief descriptions of the geometries most relevant to GO-1 requirements are provided below.

Note: Except where noted, all descriptive text accompanying the context diagrams in this section is taken directly from [5].
The adjacent figure depicts the top-level Java interfaces of the GO-1 geometry model. These Java interfaces are generated directly from the ISO-19107 geometry models. These
are the top-level interfaces for the key geometries that are the focus of GO-1. These interfaces are briefly described below.

Geometry is the root class of the geometric object taxonomy and supports interfaces common to all geographically referenced geometric objects. Geometry instances are sets of direct positions in a particular coordinate reference system. A Geometry can be regarded as an infinite set of points that satisfies the set operation interfaces for a set of direct positions, TransfiniteSet<DirectPosition>.

Primitive is the abstract root class of the geometric primitives. Its main purpose is to define the basic "boundary" operation that ties the primitives in each dimension together. A Primitive is a geometric object that is not decomposed further into other primitives in the system. This includes curves and surfaces, even though they are composed of curve segments and surface patches, respectively. This composition is a strong aggregation: curve segments and surface patches cannot exist outside the context of a primitive.

Complex is set of disjoint geometric primitives such that the boundary of each primitive can be represented as the union of other geometric primitives within the complex.

6.4.1.1 DirectPosition

Point is the basic data type for a geometric object consisting of one and only one point.

![Diagram of DirectPosition and Bearing](image-url)
DirectPosition object data types hold the coordinates for a position within some CoordinateReferenceSystem (CoordinateReferenceSystem is described in Section 6.3.2). DirectPositions, as a data type, are utilized by in other objects, such as Geometry. When part of a Geometry, a DirectPosition will have the same CoordinateReferenceSystem as that Geometry.

Bearing is a data type used to represent direction in the coordinate reference system. In a 2D coordinate reference system, this can be accomplished using a "angle measured from true north" or a 2D vector point in that direction. In a 3D coordinate reference system, two angles or any 3D vector is possible. If both a set of angles and a vector are given, then they shall be consistent with one another.
6.4.1.2 CurveSegment and Conic

**Curve** is a descendent subtype of **Primitive** through **OrientablePrimitive**. It is the basis for 1-dimensional geometry. A curve is a continuous image of an open interval.

**Curves** are continuous, connected, and have a measurable length in terms of the coordinate system. The orientation of the **Curve** is determined by this parameterization, and is consistent with the tangent function, which approximates the derivative function of the parameterization and shall always point in the "forward" direction.

A **Curve** is composed of one or more **CurveSegments**. Each **CurveSegment** within a **Curve** may be defined using a different interpolation method. The **CurveSegments** are connected to one another, with the end point of each segment except the last being the start point of the next segment in the segment list.

The **Conic** object represents any general conic curve, with the constraint that the eccentricity is less than or equal to unity. In two dimensions, a non-negative eccentricity of less than one will generate a closed ellipse. An eccentricity of exactly one results in a parabola, and a negative eccentricity yields a hyperbola.

---

**GenericCurve**

+ asLineString( maxSpacing : double, maxOffset : double ) : LineString
+ getConstruciveParam( cp : double ) : DirectPosition
+ getEndConstruciveParam() : double
+ getEndParam() : double
+ getEndPoint() : DirectPosition
+ getParam( s : double ) : DirectPosition
+ getParamForPoint( p : DirectPosition ) : ParamForPoint
+ getStartConstruciveParam() : double
+ getStartParam() : double
+ getStartPoint() : DirectPosition
+ getTangent( s : double ) : double[]
+ length( cparam1 : double, cparam2 : double ) : double
+ length( point1 : Position, point2 : Position ) : double

**CurveSegment**

+ getBoundary() : CurveBoundary
+ getCurve() : Curve
+ getInterpolation() : CurveInterpolation
+ getNumDerivativeInterior() : int
+ getNumDerivativesAtEnd() : int
+ getNumDerivativesAtStart() : int
+ getSamplePoints() : PointArray
+ reverse() : CurveSegment

**Curve**

+ getSegments() : List
6.4.1.3 CompositeCurve and Ring

A CompositeCurve is a Composite with all the geometric properties of a Curve. Essentially, a composite curve is a list of OrientableCurves agreeing in orientation in a manner such that each curve (except the first) begins where the previous one ends.

A Ring is used to represent a single connected component of a SurfaceBoundary. It consists of a number of references to OrientableCurves connected in a cycle (an object whose boundary is empty).

A Ring is structurally similar to a CompositeCurve in that the endPoint of each OrientedCurve in the sequence is the startPoint of the next OrientableCurve in the sequence. Since the sequence is circular, there is no exception to this rule. Each ring, like all boundaries, is a cycle and does not intersect itself.

Even though each Ring is topologically simple, the boundary need not be simple. The easiest case of this is where one of the interior rings of a surface is tangent to its exterior ring. Implementations may enforce stronger restrictions on the interaction of boundary elements.

The basic difference between a CompositeCurve and a Ring is that a CompositeCurve may be open (the end of the last OrientableCurve does not touch the beginning of the first OrientableCurve) or closed (the end of the last OrientableCurve touches the beginning of the first OrientableCurve), however a Ring is always closed.
Figure 16 – CompositeCurve and Ring

6.4.1.4 SurfaceBoundary

A SurfacePatch defines a homogeneous portion of a Surface. The multiplicity of the segmentation association specifies that each SurfacePatch shall be in at most one Surface.

A SurfacePatch is a homogeneous portion of a Surface. The multiplicity of the segmentation association specifies that each SurfacePatch shall be in at most one Surface. Surface is a subclass of Primitive and is the basis for 2-dimensional geometry. Unorientable surfaces such as the Möbius band are not allowed. The orientation of a surface chooses an "up" direction through the choice of the upward normal, which, if the surface is not a cycle, is the side of the surface from which the exterior boundary appears counterclockwise. Reversal of the surface orientation reverses the curve orientation of each boundary component, and interchanges the conceptual "up" and "down" direction of the surface. If the surface is the boundary of a solid, the "up" direction is usually outward. For closed surfaces, which have no boundary, the up direction is that of the surface patches, which must be consistent with one another. Its included SurfacePatches describe the interior structure of a Surface.

A SurfaceBoundary consists of a number of Rings, corresponding to the various components of its boundary. In the normal 2D case, one of the Rings is distinguished as
being the exterior boundary. There is exactly one exterior Ring and zero or more interior Rings. None of the Rings may touch or intersect each other.

Figure 17 - SurfaceBoundary

6.4.1.5 Aggregate

Arbitrary aggregations of geometric objects are possible. These are not assumed to have any additional internal structure and are used to "collect" pieces of geometry of a specified type. Operations on these aggregations shall be the accumulators that are derived from the class operations of their elements. Applications may use aggregates for objects that use multiple geometric objects in their representations.

Figure 18 - Aggregate
The **Aggregate** gathers geometric objects. Since it will often use orientation modification, the curve reference and surface references do not go directly to the Curve and Surface, but are directed to OrientableCurve and OrientableSurface.

Most geometric objects cannot be held in collections that are strong aggregations. For this reason, the collections described in this clause are all weak aggregations, and shall use references to include geometric objects.

### 6.4.1.6 Envelope

Envelope is often referred to as a minimum bounding box or rectangle. Regardless of dimension, a Envelope can be represented without ambiguity as two DirectPositions. To encode a Envelope, it is sufficient to encode these two points. The lower corner refers to the DirectPosition whose coordinates are the minimum numeric values, and the upper corner refers to the DirectPosition whose coordinates are the maximum numeric values. The terms lower and upper should not be interpreted as spatially above and/or below.

![Envelope](image)

### Figure 19 - Envelope

#### 6.4.1.7 Geometry Mutability

The geometric primitive interfaces defined in this specification include methods that allow the API user to change the underlying geometry of a primitive over time. For example, the Point interface includes a setPosition(...) method. However, the writers of this specification recognize that not all implementations of geometry will be changeable. For this reason, the Geometry base class also includes a method, isMutable(), that can be called at runtime to determine whether the underlying implementation allows changes of the geometry. A return value of true indicates that the object can be changed by calling its set methods. A return value of false indicates that the set methods will throw an UnsupportedOperationException and that the values in the object will never change. If a user of a geometry requires a copy that will never change, he can make a private copy using the clone() method, or the toImmutable() method can be used to make a copy that is guaranteed never to change.

### 6.4.2 Coordinate Reference System Model

The GO-1 Coordinate Reference System (CRS) definition is derived from and is fundamentally consistent with the content of OGC documents 03-009 and 03-010. The CRS interface, like those for other geometry interfaces, has been derived from UML
models using automated tools. This process and the resulting interfaces are more completely described in the document that reports upon that effort.

Also, like the other Spatial Object classes, CRS objects are instantiated by a family of factories that hides the details of object creation from client applications or libraries.

Note: Except where noted, all descriptive text accompanying the context diagrams in this section is taken directly from [5] and [28].

6.4.2.1 Coordinate System

A CoordinateSystem is the set of coordinate system axes that spans a given coordinate space. A CoordinateSystem is derived from a set of (mathematical) rules for specifying how coordinates in a given space are to be assigned to points. The coordinate values in a coordinate tuple shall be recorded in the order in which the coordinate system axes associations are recorded, whenever those coordinates use a coordinate reference system that uses this coordinate system, and no other specification of axis order is provided.
Figure 20 - Coordinate System

**CartesianCS** defines a 1-, 2-, or 3-dimensional coordinate system. It gives the position of points relative to orthogonal straight axes in the 2- and 3-dimensional cases. In the 1-dimensional case, it contains a single straight coordinate axis. In the multi-dimensional case, all axes shall have the same length unit of measure. A CartesianCS shall have one, two, or three `usesAxis` associations.

**ObliqueCartesianCS** defines a 2- or 3-dimensional coordinate system with straight axes that are not necessarily orthogonal.
EllipsoidalCS defines a 2- or 3-dimensional coordinate system in which position is specified by geodetic latitude, geodetic longitude and (in the three-dimensional case) ellipsoidal height, associated with one or more geographic coordinate reference systems.

SphericalCS defines a 3-dimensional coordinate system with one distance, measured from the origin, and two angular coordinates. Not to be confused with an ellipsoidal coordinate system based on an ellipsoid ‘degenerated’ into a sphere.

CylindricalCS defines a 3-dimensional coordinate system consisting of a polar coordinate system extended by a straight coordinate axis perpendicular to the plane spanned by the polar coordinate system.

PolarCS defines a 2-dimensional coordinate system in which position is specified by distance to the origin and the angle between the line from origin to point and a reference direction.

VerticalCS defines a 1-dimensional coordinate system used to record the heights (or depths) of points dependent on the Earth’s gravity field.

LinearCS defines a 1-dimensional coordinate system that consists of the points that lie on the single axis described. The associated ordinate is the distance from the specified origin to the point along the axis. Example: usage of the line feature representing a road to describe points on or along that road.

TimeCS defines a 1-dimensional coordinate system containing a single time axis and used to describe the temporal position of a point in the specified time units from a specified time origin.

UserDefinedCS defines a two- or three-dimensional coordinate system that consists of any combination of coordinate axes not covered by any other Coordinate System type. An example is a multi-linear coordinate system which contains one coordinate axis that may have any 1-D shape which has no intersections with itself. This non-straight axis is supplemented by one or two straight axes to complete a 2 or 3 dimensional coordinate system. The non-straight axis is typically incrementally straight or curved.

### 6.4.2.2 Reference System

ReferenceSystem provides a description of a spatial and temporal reference system used by a dataset.
Figure 2 - Reference System

**Identifier** provides an identification of a reference system object. The first use of an **Identifier** for an object, if any, is normally the primary identification code, and any others are aliases.

### 6.4.2.3 Datum

**Datum** is commonly used to specify a relationship of a coordinate system to the earth, thus creating a coordinate reference system. A datum uses a parameter or set of parameters that determine the location of the origin, the orientation, and the scale of a coordinate reference system. The `anchorPoint` property of **Datum** is a description, possibly including coordinates, of the point or points used to anchor the datum to the Earth.
Figure 21 - Datum
Ellipsoid is a geometric figure that can be used to describe the approximate shape of the earth. In mathematical terms, it is a surface formed by the rotation of an ellipse about its minor axis.

EngineeringDatum defines the origin and axes directions of an engineering coordinate reference system. Normally used in a local context only.

GeodeticDatum references an Ellipsoid which models the shape of the earth. Due to irregularities in the surface of the Earth, some ellipsoids limit the portion of the earth’s surface that can be accurately modelled. A GeodeticDatum references a PrimeMeridian that defines the origin from which longitude values are determined.

ImageDatum defines the origin of an image coordinate reference system. This is used in a local context only. For an image datum, the anchor point is usually either the centre of the image or the corner of the image.

VerticalDatum defines the surface of zero altitude. An example would be Mean Sea Level.

TemporalDatum defines the zero time for some epoch, accessed by getOrigin(). In Java, this would be Jan 1, 1970.

6.4.2.4 Coordinate Reference System

CoordinateReferenceSystem consists of an ordered sequence of coordinate system axes that are related to the earth (or another physical object) through a datum. A coordinate reference system is defined by one datum and by one coordinate system. Most coordinate reference systems do not move, except for EngineeringCRS objects defined with respect to moving platforms such as cars, ships, aircraft, and spacecraft. There are several sub-classes of CoordinateReferenceSystem (see figure below).
Figure 22 - Coordinate Reference System model from Topic 2
For GO-1, the common `CoordinateReferenceSystem` subtypes of primary interest are:

- **ProjectedCRS** — A 2D coordinate reference system used to approximate the shape of the earth on a planar surface, but in such a way that the distortion that is inherent to the approximation is carefully controlled and known. Distortion correction is commonly applied to calculated bearings and distances to produce values that are a close match to actual field values.

- **GeographicCRS** — A coordinate reference system based on an ellipsoidal approximation of the geoid; this provides an accurate representation of the geometry of geographic features for a large portion of the earth's surface.
- ImageCRS — An engineering coordinate reference system applied to locations in images. Image coordinate reference systems are treated as a separate sub-type because a separate user community exists for images with its own terms of reference.

- EngineeringCRS — A contextually local coordinate reference system; which can be divided into two broad categories:
  1) Earth-fixed systems applied to engineering activities on or near the surface of the earth;
  2) CRSs on moving platforms such as road vehicles, vessels, aircraft, or spacecraft.

The GO-1 specification implements Topic 2 by combining the two abstract objects SC_CRS and SC_CoordinateReferenceSystem into a single interface CoordinateReferenceSystem. This allows the child interface CompoundCRS to hold instances of itself. Furthermore, an implementation can iterate over instances of CoordinateReferenceSystem without type-checking. The inherited methods CompoundCRS.getDatum() and CompoundCRS.getCoordinateSystem() may return null values for CompoundCRS.

6.4.2.5 Map Projection

A map projection mediates the transformation of coordinates between the spatial CoordinateReferenceSystem and a corresponding flat representation. A ProjectedCRS maintains a Projection object that defines such a transformation process.

![Diagram of Projection]

Implementers may need to define concrete realizations of Projection for each supported projection, but details of how each will translate spatial coordinates to either display coordinates or intermediate grids are optional. Implementation of some projections will be mandatory, but most will be optional.
6.4.2.6 Coordinate Operations

CoordinateOperation represents a mathematical operation on coordinates that transforms or converts coordinates to another coordinate reference system. Many but not all coordinate operations (from CRS A to CRS B) uniquely define the inverse operation (from CRS B to CRS A). In some cases, the operation method algorithm for the inverse operation is the same as for the forward algorithm, but the signs of some operation parameter values must be reversed. In other cases, different algorithms are required for the forward and inverse operations, but the same operation parameter values are used. If (some) entirely different parameter values are needed, a different coordinate operation shall be defined.

Operation is a parameterised mathematical operation on coordinates that transforms or converts coordinates to another coordinate reference system. This coordinate operation thus uses an operation method, usually with associated parameter values.

Transformation objects define an operation on coordinates that usually includes a change of Datum. They may also mediate conversion from a ProjectedCRS (which has a datum) to a flat screen. The parameters of a coordinate transformation are empirically derived from data containing the coordinates of a series of points in both coordinate reference systems. This computational process is usually "over-determined", allowing derivation of error (or accuracy) estimates for the transformation. Also, the stochastic nature of the parameters may result in multiple (different) versions of the same coordinate transformation.
Conversion objects define an operation on coordinates that does not include any change of Datum. The best-known example of a coordinate conversion is a map projection. The parameters describing coordinate conversions are defined rather than empirically derived. Note that some conversions have no parameters.

**Figure 25 - Operation Parameter**

*OperationParameter* is the definition of a parameter used by an operation method. Most parameter values are numeric, but other types of parameter values are possible.
OperationMethod is the definition of an algorithm used to perform a coordinate operation. Most operation methods use a number of operation parameters, although some coordinate conversions use none. Each coordinate operation using the method assigns values to these parameters.

The MathTransform object does the work of applying formulae to coordinate values. A MathTransform does not know or care how the coordinates relate to positions in the real world. MathTransform objects are intended to be generic in nature; they may be agnostic to the spatial-coordinate domain, and may be equally applicable to non-spatial-coordinate domains.

A CoordinateOperation contains a source CoordinateReferenceSystem, a target CoordinateReferenceSystem, and a MathTransform. The MathTransform transforms from the source coordinate values to the target coordinate values.

CoordinateOperation exposes to a user the operation, allowing a user to analyse the operation from a spatial coordinate context. MathTransform is the backend implementation of an operation, but has no provision for user analysis.

MathTransform objects consisting of algorithms (or chains of algorithms) that have identical inputs and identical outputs are themselves interchangeable. Substituting a MathTransform object with an interchangeable MathTransform object will not affect the behaviour of the containing CoordinateOperation. An implementation is allowed to do so if deemed desirable.
6.4.2.7 Relative Coordinates

A technique exists to support relative coordinates. This technique can only be used in GO-1 implementations that support the restriction that all DirectPositions within a Geometry have the same CoordinateReferenceSystem.

The technique proposed to accomplish this uses Geometry, which always has a current CoordinateReferenceSystem. The method Geometry.transform(CoordinateReferenceSystem, MathTransform), returns another Geometry instance in the given CoordinateReferenceSystem transformed from the first Geometry instance using the given MathTransform.

The original Geometry has a reference to the new Geometry, which has a reference to the new CoordinateReferenceSystem. Thus a Geometric object can effectively “move” to any given CoordinateReferenceSystem.

If Geometry GA in CoordinateReferenceSystem A desires to transform to a particular target CoordinateReferenceSystem C, but only has an intermediate CoordinateReferenceSystem B and MathTransforms A-to-B and B-to-C, the methods MathTransformFactory.createConcatenatedTransform(
MathTransform, MathTransform) and MathTransformFactory.createPassThroughTransform(int, MathTransform, int) can be utilised to create MathTransform A-to-C, and thereby eliminate the need to instantiate the intermediate Geometry G_B object.

6.4.3 Reference System Factories and Authority Factories

The GO-1 specification for CoordinateReferenceSystem, CoordinateSystem, Datum, and Operation has a layered factory pattern consisting of a Factory and one or more implementations of an AuthorityFactory. CRSFactory, CSFactory, DatumFactory create objects using a properties java.util.Map object for many of the required parameters. The CRSAuthorityFactory, CSAuthorityFactory, DatumAuthorityFactory, and CoordinateOperationAuthorityFactory objects are intended to connect to real-world authority databases, such as the European Petroleum Survey Group (EPSG) or the International Hydrographic Organization (IHO). Each CRSAuthorityFactory (for example) wraps the CRSFactory and delegates implementation-specific creation tasks.

For information on the CoordinateReferenceSystems, CoordinateSystems, Projections, and Datums supported by an implementation, one may query its CommonFactory. This object also provides supported Geometry types.

All reference system objects are immutable once created. For ProjectedCRS and other GeneralDerivedCRS objects this presents a complication, in that the Conversion returned by getConversionFromBase must always return the same object, and the CoordinateOperationFactory createOperation methods require that the ProjectedCRS be passed in as a parameter. Thus, one may not pass the required Projection object into the ProjectedCRS through its constructor, and the ProjectedCRS may not hold a pointer to the Projection. Instead, the CoordinateOperationFactory must create the Projection the first time a call is made to createOperation (passing in at least the ProjectedCRS and its base GeographicCRS). It will then store this Projection (typically within a Map) for retrieval on subsequent calls to createOperation in which the same two CoordinateReferenceObjects plus the relevant OperationMethod are passed in.

It follows from the creation mechanism that implementations of ProjectedCRS will need to define get methods for internal use in order to pass parameters to the CoordinateOperationFactory. However, in general CoordinateReferenceSystem objects do not expose their properties directly, but rather through Operation objects that involve them. To obtain access to parameters for a ProjectedCRS via the GO-1 API, one obtains the Projection via getConversionFromBase, queries it for its ParameterValues, examines the array for
the ParameterValue corresponding to the attribute of interest, then queries that ParameterValue for its actual value.
6.5 Features

6.5.1 Model and Rationale

The feature model in GeoAPI is based on the OGC abstract specification for features (Topic 5), but draws much influence from the practical lessons learned by various open-source efforts, most notably GeoTools and Deegree.

Figure 27 - Feature, FeatureCollection, and FeatureType

Note that a FeatureCollection is itself a Feature, as in the OGC abstract specification, which allows a FeatureCollection to have a FeatureType and attributes of its own. But beyond the Feature methods, there are a large number of the methods in the FeatureCollection interface that come from extending the Java Collection interface. Extending the Java interface allows for easy interoperability with other Java collections.

In order to unambiguously define feature events and transaction semantics, instances of Feature must belong to at most one FeatureCollection. (The containing feature collection is returned from the getFeatureCollection() method on Feature.) Different instances of the Feature interface may represent the same conceptual feature, but must belong to different FeatureCollections. Nothing in this specification prevents the implementor from sharing attribute state between two such features. Indeed
two feature objects may compare as equal using the equals() method and not have the same parent FeatureCollection.

6.5.2 Feature Attributes and Geometry

As shown in the diagrams above, a Feature has any number of attributes whose values can be retrieved by invoking one of the two getAttribute(...) methods. The attributes can be retrieved by integer index or by the name of the attribute. The return value of these methods is an Object, which means that primitive values (int, double, etc) are wrapped in their corresponding wrapper class (Integer, Double, etc).

This model for attributes differs slightly from a literal interpretation of OGC Topic 5. In Topic 5, features have attribute objects, and the attribute objects have values. Here, we allow the user to get the attribute value directly from the feature.

Features have methods for retrieving two special attributes, bounds and ID. The getID method must return a non-null String whose value uniquely identifies the feature within the scope of the current Java virtual machine. If possible, the ID should be universally unique, but this is not a requirement. The bounds of the feature give the extent of the geometry of this feature (or the extent of the union of the geometries of child features, if the feature is itself a feature collection).

Feature geometry is treated just like any other attribute. It has a name and an index and is retrieved using the getAttribute method of Feature. A feature may have several attributes which are geometries, but one of those geometries is used to render the feature. In such cases, the "default" geometry attribute should be indicated by the return value of getDefaultShapeAttribute of the feature's FeatureType. The value of geometry attributes should be an instance of one of the subclasses of org.opengis.spatialschema.geometry.primitive.Primitive. (However, some producers and consumers of features may wish to exchange geometry in the form of other Java objects, such as those from the Java Topology Suite, so this specification does not absolutely require that geometric attributes be subclasses of Primitive.)

6.5.3 FeatureTypes

Every feature has a corresponding FeatureType that describes it. In particular, the FeatureType lists the following:

- The attributes of the Feature, including their name and type
- The name of the FeatureType, encoded as an instance of GenericName
- A preferred namespace prefix to use when encoding the feature as GML
- An indicator as to whether features of this type are also FeatureCollections
- If the features are FeatureCollections, a list of types of features that could potentially be children of the feature.
The information about the attributes of features are stored in instances of the FeatureAttributeDescriptor interface. This interface gives the name, the data type (as an instance of the DataType enumeration class), and other metadata necessary to fully specify the type, such as attribute size.

Every FeatureType has a name. These names are provided as instances of the GenericName interface. GenericName is a base class for two "concrete" classes:

- **LocalName** - This is a simple name that has one part that is just a string. This string has no inherent scope. A typical use for a LocalName is for name of an XML element.

- **ScopedName** - This is a name that has two parts, a scope, and a LocalName. The scope is itself a GenericName and thus may either be a LocalName or a ScopedName. In typical cases, the scope of a ScopedName will a LocalName representing the namespace URI of an XML element and the LocalName of the ScopedName will be the name of the XML element.

### 6.5.4 Modifying Features

The features in this specification can be modified using the setAttribute(...) method. Feature instances may be backed by data in some sort of persistent backing store, so calling setAttribute(...) should cause changes to be written to the persistent store. Feature collections can also be modified using the methods inherited from Java's Collection interface (such as add(...), remove(...), etc). Such changes should also be written to the persistent store.

### 6.5.5 FeatureCollections

A FeatureCollection represents any grouping of Features. This may be the return value of a query on a server, or it may be a collection created by the API user. In either
case, the members of a FeatureCollection can be enumerated by invoking the
iterator() method. This returns a Java iterator over the members of the Collection.
FeatureCollections may often be backed by a persistent store of some kind. In such
cases, the methods that modify the collection, such as add(...) and remove(...), are
required to make modifications to the persistent store. Such modifications take place
within the context of the current transaction the FeatureCollection. See the section
below for more information about transactions.
Also, because FeatureCollections are often backed by a persistent store, network
connections may have to be established to provide access to the members. Because of
this, there is a close() method on FeatureCollection that can be invoked to indicate
to the implementation that the caller no longer has need of the data contained within the
FeatureCollection, and any resources, such as network connections, can be cleaned
up.
Note that the members of a FeatureCollection may themselves be instances of the
FeatureCollection interface. This gives rise to the possibility that there would be
hierarchies of Features contained within a FeatureStore.
The FeatureCollection interface extends the Java Collection interface, which is the
base class for both unordered Sets and ordered Lists. Implementors of the
FeatureCollection interface are encouraged to implement a more specific subclass
(such as Set or List) if their collection does have those semantics. This might allow, for
example, random access of the collection elements if the user knows that the collection is
a List.

6.5.6 Feature Events

The FeatureCollections in this specification provide a mechanism that allows the API
user to register for notification of certain events, namely the addition, removal, or
changing of features within that collection.

```java
FeatureCollection
- +addFeatureListener(f: FeatureListener) : void
- +removeFeatureListener(f: FeatureListener) : void

FeatureListener
- +featuresAdded(e: FeatureEvent) : void
- +featuresRemoved(e: FeatureEvent) : void
- +featuresChanged(e: FeatureEvent) : void

FeatureEvent
- +FeatureEvent(source: FeatureCollection, ids: List)
- +getFeatureIds() : List
- +getFeatureCollection() : FeatureCollection
```

Figure 29 - Feature Listeners

FeatureCollections that support event listeners should invoke the appropriate listener
methods when the features they contain are modified, added, or removed. Note that it is
possible that two distinct FeatureCollections could contain a Feature that represents
the same conceptual feature. If this feature were modified in one collection, an intelligent implementation should notify listeners on both FeatureCollections that the feature has changed.

6.5.7 Transactions

An instance of Transaction represents a set of operations performed on various FeatureStores, where the entire set of operations can be rolled back or committed at the same time. The constant Transaction.AUTO_COMMIT is used to request immediate change, or during event notification to indicate the persistent state has changed. When a FeatureCollection is using a Transaction its contents may still be modified, but the changes are simply not persisted until the Transaction's commit() method is called.

![Transaction and Transaction.State](image)

The following pseudo-code demonstrates how transactions might be used by a client.

```java
FeatureStore featureStore = ...;
FeatureCollection features = featureStore.getFeatures(...);
Feature feature1 = new DefaultFeature(...);

// Set to auto-commit
features.setTransaction(Transaction.AUTO_COMMIT);
// Add feature1 to the collection. It is immediately persisted.
features.add(feature1);

// Set to a new transaction
Transaction t = new DefaultTransaction();
features.setTransaction(t);

features.remove(feature1);
// feature1 is removed, but the change has not be persisted
features.rollback();
// the remove of feature1 has been canceled, features is
// restored to its previous state
```

Event notification for a FeatureCollection is largely unaffected by transactions. However, two additional notifications are needed:

- Transaction.commit() causes the firing of an event to indicate persistent state change for other FeatureCollections that may have common members.
Transaction.rollback() fires an event for listeners on the current FeatureCollection indicating the state of the feature collection has changed. Other FeatureCollections that may have common members do not receive events if a transaction is rolled back.

Another pseudo-code example demonstrates how events are fired for collections containing common members:

FeatureStore featureStore = ...;
FeatureCollection featuresA = featureStore.getFeatures(...);
FeatureCollection featuresB = featuresA.clone();
// we now have two FeatureCollections w/ the same contents

// Create listeners and add them to the collections
FeatureListener listenerA = new MyFeatureListener(...);
FeatureListener listenerB = new MyFeatureListener(...);
featuresA.addListener( listenerA );
featuresB.addListener( listenerB );

featuresA.setTransaction( Transaction.AUTO_COMMIT );
Transaction transaction = new DefaultTransaction();
featuresB.setTransaction( transaction );

featuresA.remove( feature1 );
// feature1 is removed from both featuresA and featuresB
// listenerA and listenerB recieve event
featuresB.add( feature1 );
// listenerB recieves notification
featuresB.add( feature2 );
// listenerB recieves notification
featuresB.commit();
// listenerA recieves notification

6.5.8 Transaction from the implementors perspective

The writers of this specification expect that the Transaction interface will be implemented one time in a utility library since all of the behavior of the Transaction class can be performed independent of backing store implementation. The "interesting" code for implementors is in the implementation of the Transaction.State interface and the implementation of FeatureCollection.setTransaction(...). The following Figure illustrates the sequence of events that occurs when a transaction is set on a feature collection. Steps 3, 4, 7, and 11 are the steps that have logic specific to a given data source. (See the class Javadocs for more detailed information about the contract of these interfaces.)
6.5.9 Transaction field and method detail

- **AUTO_COMMIT** - Constant used to request that any modifications to a feature or a feature collection should occur immediately. This member follows the "Special Case" design pattern.
- **close()** - Disposes of any resources held by the transaction. If changes are pending on the current transaction, they are rolled back.
commit() - Makes all changes since the previous commit/rollback permanent. This method returns a LockResult indicating the success of any lock operations made during the course of the transaction.

rollback() - Undoes all changes performed since the last commit or rollback.

getAuthorizations(), useAuthorization( token ) - Manage and access a Set of authorization tokens allowing access to locked content. See the section on locking below.

getProperty(key), setProperty(key,value) - Allows for user specified hints. This might allow access to features of a FeatureStore not provided in the GeoAPI interfaces.

getState(key), removeState(key), putState(key,value) - Allows FeatureStores to externalize state under transaction control. Follows the momento design pattern. When the user invokes the setTransaction method on a FeatureCollection, the implementation is expected to call these methods to attach or retrieve state information about the transaction. Then when the transaction is committed, rolled back, or closed, the state objects are enumerated and the corresponding commit or rollback method is called.

6.5.10 Locking

The writers of this specification view the FeatureStore interface as a programming language interface parallel of the WFS web interface. Therefore our design for locking is motivated by the locking functionality given by a WFS. Both transaction-duration locks and WFS-style long-term locks are supported by this API.

This specification provides an attractive middle ground between full versioned Features, and light-weight in-process or file lock based approaches. Locks are maintained for a requested duration. A successful lock operation results in an authorization token that may be used at a later time. A transaction may be assigned such a token allowing it to work on previously locked features. Locks are allowed to be taken out across multiple FeatureCollections (each returning a unique authorization token).

In general, the sequence of events for long-term locking is the following:

- The user retrieves a FeatureCollection.
- The user sets a LockRequest on the FeatureCollection.
- The user invokes lock() on the FeatureCollection to lock all of its features.
- If using a Transaction, the user commits the transaction to get the result of locking. (If not using a Transaction, the lock() method returns the result.)
- Now the features are locked in the database. The result contains an authorization token that is stored for later use.
- At a later time, the user creates a new Transaction and adds the authorization token to it.
The user again retrieves a FeatureCollection with some or all of the locked features in it and sets its transaction to the one with the authorization token.

The user makes changes to the collection and commits the Transaction.

The lock is released.

Locking workflow is described by capabilities of the FeatureCollection.lock() methods, LockRequest, LockResponse, and Transaction.
Figure 32 - Initiating a long term lock while using a Transaction
Figure 33 - Initiating a long term lock without a Transaction

The `LockRequest` class is a wrapper for a lock duration expressed in milliseconds. A static constant on the class, `LockRequest.TRANSACTION_LOCK`, can be used to request a lock lasting until the next commit or rollback. (This follows the Special Case design pattern.) Such locks are often used to ensure access before starting modification.

The `LockResponse` class indicates number of locked features and authorization tokens for each involved `FeatureStore`. The static constant `LockResponse.PENDING` indicates that the lock request is waiting until the next commit to provide authorization tokens and feature counts. The static constant `FeatureResponse.NONE` is used as a return value by `Transaction.commit()` to indicates no lock requests were made. The static constant `LockResponse.TRANSACTION_LOCK_RESPONSE` indicates that acquired locks will expire at the end of the transaction.

The following pseudo-code example demonstrates how locks could be used:

```java
FeatureStore featureStore = ...;
GenericName roads = featureStore.getTypeNames().iterator().next();

// The "bnf" method is unfortunately fictitious
FeatureCollection kaslo = featureStore.getFeatures( roads,
    FilterFactory.bnf( "CITY='kaslo'" )
); 
LockRequest lockRequest = new LockRequest( 45678 );
Transaction t = new DefaultTransaction();
kaslo.setTransaction( t );

// Lock the features
kaslo.setLockRequest( lockRequest );
kaslo.lock(); // returns LockResponse.PENDING
LockResponse lockResults = t.commit();
// kaslo roads are now locked

String token = lockResults.getToken();

// Now try some operations
kaslo.clear();
try {

```
At the end of the above example, the roads in Kaslo are removed and the lock is released since the token has been used.

A couple of important points that prevent deadlock:

- Lock request does not produce an exception, success or failure can be determined by the LockResponse.
- Trying to perform a modification, or trying to lock a previously locked Feature will produce an exception.

6.6 FeatureStore

6.6.1 Model and Rationale

While the Feature and FeatureCollection APIs provide mechanisms for accessing feature data, the model as described thus far does not provide a mechanism for retrieving FeatureCollections from a persistent store of some kind. Thus we introduce FeatureStore.

The FeatureStore interface provides an abstraction for an object that connects to a store of features and provides them to the user. For example, an application may implement the FeatureStore interface to connect to a relational database and provide the contents of the tables as features. (The user of the FeatureStore should not know this implementation detail, and it should only use methods in the FeatureStore interface.)
Note that a FeatureStore implementation need not make any network or database connections to supply features. It may just as easily read a local file and parse all of its contents into memory. In such a case, some methods (such as those that are documented to close any open connections) may do nothing.

6.6.2 Nested Features

As discussed in other sections, Features can be FeatureCollections and thus contain child Feature objects. In such cases, there could be a large containment hierarchy of Features. A FeatureStore that provides such hierarchies of Features can give hints to the user about which types of Features are the "root" Features in such hierarchies by implementing the getRootTypeNames() method, described below.

6.6.3 FeatureStore method detail

- getTypeNames() - Returns a List of GenericName objects that name the types of features provided by this FeatureStore. Although the List interface returns Objects from its accessors, the List returned from this method is guaranteed only to contain instances of GenericName.

- getRootTypeNames() - This method returns a list of names of the types that are the "root" features in nested feature hierarchies. For many FeatureStores, this
method may very well return the same list as returned by `getTypeNames()`. But for all FeatureStores, this list will contain a subset of the names returned by `getTypeNames()`.

- `getFeatureType(GenericName)` - This method returns a `FeatureType` instance that describes the details of the type whose name is given. The `FeatureType` includes information about the attributes of the features, as well as an indication of whether the features of this type are collections.

- `getFeatures(...)` - Each of these methods returns a collection of features from the FeatureStore that passes an optional Filter. Implementors of these methods are free to retrieve all of the features immediately or to defer the retrieval until the FeatureCollection's `iterator()` method is invoked.

- `getDefaultStyle(GenericName)` - Some data providers may also wish to provide the user of the features with a default set of rules for styling their features. This method allows them to do so. It is valid to return `null` from this method if the data provider doesn't know a default style or doesn't care about styling.

- `createType`, `removeType`, `modifyType` - The implementor of a FeatureStore may wish to allow the user to create, remove, and modify the types of features that are available. For example, `createType` for a particular FeatureStore may create a new database table. All three of these methods may throw an exception if the FeatureStore does not support this type of operation.

- `addFeatureStoreListener`, `removeFeatureStoreListener` - For FeatureStores that do support any of the three methods for changing the feature types in the store, they must also implement these methods that allow the user to receive notification when such a change has been made.

### 6.6.4 Filter

The various Filter classes were translated to Java from the XML schemas for Filter [16]:
The meanings of the various members of these classes are identical to the meanings of their corresponding elements in the Filter encoding schema.

The only changes from the OGC Filter specification are the spatial operators. In the Filter specification, the spatial operators are only allowed to compare a Feature's geometry property with a constant geometry. Here both parameters are allowed to be any expression that evaluates to a geometry.

Filter objects cannot be changed after they are created, so they must be created with all of their parameters set. The FilterFactory interface provides methods for creating each type of Filter and these methods accept parameters for all of the pertinent properties.

Included in the filter package is the expression subpackage that provides classes that can evaluate a limited set of mathematical expressions based on the properties of features. These classes are also based on the corresponding classes from the OGC Filter specification and have the same semantics:
6.6.5 FeatureStore Example Usage

The following code demonstrates how one can retrieve some features from a FeatureStore. This simply prints out the feature ID of each feature of the first type offered by the FeatureStore.

```java
FeatureStore featureStore = ...;
List featureTypes = featureStore.getTypeNames();
GenericType typeName = (GenericType) featureTypes.get(0);
System.err.println("Retrieving features of type "+typeName);
FeatureCollection features = featureStore.getFeatures(typeName);
Iterator iterator = features.iterator();
while (iterator.hasNext()) {
    Feature f = (Feature) iterator.next();
    System.err.println(f.getID());
}
System.err.println("Done.");
```

Another usage of FeatureStores is for creation of layers to be displayed in a FeatureCanvas. The following code demonstrates how one might create a Layer and add it to a canvas.
6.6.6 Relationship of FeatureStore to existing OGC standards

The FeatureStore interface does not have a direct counterpart in any of the existing abstract or implementation specifications. However, the FeatureStore Java interface (along with FeatureCollection) does very closely resemble the HTTP interface of a web feature server. Both have operations for describing a given type of feature, for retrieving features, for adding features, and for removing features.

6.7 FeatureCanvas

6.7.1 Model and Rationale

A FeatureCanvas represents a visual component that renders features on a display. The FeatureCanvas can be viewed as a mechanism for converting features plus feature styles into graphics on a GO-1 Canvas. Conceptually, the FeatureCanvas is very similar to a Web Map Server. It maintains a list of layers, and each of these layers has a Z-order hint and a currently active style.

![Figure 37 - FeatureCanvas](image)

6.7.2 FeatureStyle

The style portions of this specification are direct Java bindings of the Styled Layer Descriptor XML encoding specified by OGC. (The names for the various style interfaces were taken from version 1.0.20 of the SLD schemas since they are somewhat more compact than the version 1.0 names. However, the functionality of the interfaces is the same as in version 1.0.)
Style objects can be created from a FeatureStyleFactory instance in two ways. The first way is to parse an OGC SLD XML file from an input stream using one of the parse(...) methods. The second is to call the createStyleObject method, passing in a

**Figure 38 - FeatureStyleFactory Interface**

The following diagrams illustrate the top level classes used by an instance of FeatureStyle. As indicated in the picture, an instance of FeatureStyle contains any number of Rules, which in turn contain any number of Symbols. Symbol is an abstract interface; various subclasses of Symbol exist that correspond to differing types of geometry.

**Figure 39 - Style Interfaces**
6.7.3 FeatureLayers

A FeatureLayer instance is a grouping of features that will be drawn on a display. Every FeatureLayer instance has a FeatureCollection that holds the features to be drawn, a z-ordering value, called its "level", and a FeatureStyle object that indicates how the features will be portrayed.

Additionally, FeatureLayers support an event mechanism that allows the user to receive notification when the style or z-order of the layer has been modified.
6.8 GraphicStore, GraphicStoreFactory

In some end user applications, there will be a need for "pluggable" components that provide Graphic objects to be drawn on a Canvas. The GraphicStore interface (similar in concept to the FeatureStore interface) gives a standard interface for such providers to implement.

![Diagram of GraphicStore and GraphicStoreFactory](image)

#### 6.8.1 GraphicStore

There are only a few methods in the GraphicStore interface:

- **getIcon()** - Returns a URL to a small graphic that can be used to represent this GraphicStore in a user interface. Implementations are encouraged to keep this icon smaller than 32 pixels square.

- **getDisplayName()** - Returns a short text name that can be used to represent this GraphicStore in a user interface. This name should be unique enough to identify this instance, but need not be universally unique.

- **getDescription()** - Returns a longer, plain text description of the contents of this GraphicStore. This can be one or two sentences (or more).

- **getGraphics(...)** - This method is the heart of GraphicStore. The implementation uses the factory that is passed as a parameter to create new graphic instances for display. Implementations must create new Graphics each time this method is called. The caller is responsible for caching Graphics and may need to call this method multiple times with different factories for different displays.

#### 6.8.2 GraphicStoreFactory

To facilitate "pluggable" architectures, the specification also defines a factory interface capable of creating GraphicStores from a set of configuration parameters. These configuration parameters take the form of a URI, which indicates the raw data source, and a Map of parameters that provide other hints to the store for connecting to this raw data source (such as passwords, cache size, etc).
createGraphicStore(...) - The heart of GraphicStoreFactory, this method instantiates a new GraphicStore based on the parameters given.

getIcon(), getDisplayName(), getDescription() - Returns basic metadata that can be displayed to a user about this GraphicStoreFactory.

getParametersInfo() - Returns a list of objects that detail which parameters can be passed in the Map given to the createGraphicStore method.

canProcess(...) - This can be used by application code to determine if the given URL and map of parameters can be parsed and handled by this factory.

isAvailable() - In certain cases, this factory may not be able to create the necessary connections to a back end data source. This could happen, for example, if a network connection is down, or if needed classes are not in the classpath. This method should return true if the necessary resources and libraries appear to be available and false otherwise.

6.8.3 Graphic Store Use Cases

There are four general categories this author can envision where application developers may find it useful to implement GraphicStores.

6.8.3.1 Support for Custom Graphics

A GraphicStore may be written in order to take advantage of support for custom graphics provided by a particular GO-1 implementation. An example might be an extension to an existing Graphic or implementation of a new graphic supporting a 3D geometry. Something like the following code snippet would be used by such a GraphicStore to provide the extended capability, and also default behaviour for standard GO-1 implementations. Note that a well-behaved GraphicStore taking advantage of extended capabilities should wherever possible provide a default behaviour based on standard GO-1 Graphics.
6.8.3.2 Support for GraphicScaledImage

A GraphicStore can be written in order to support imagery that is not supported by the native implementation of the GO-1 GraphicScaledImage. For example, support for JPEG 2000 or MrSID could be achieved by business logic encapsulated in a GraphicStore that produced a GraphicScaledImage for use with the Canvas. The following code snippet illustrates how this could be done.

```
GraphicScaledImage scaledImage = (GraphicScaledImage)displayFactory.createGraphic(GraphicScaledImage.class);
CRSAuthorityFactory crsAuthFactory = commonFactory.getCRSAuthorityFactory();
CoordinateReferenceSystem crs = crsAuthFactory.createCoordinateReferenceSystem("EPSG:4326");
GeometryFactory geometryFactory = commonFactory.getGeometryFactory(crs);

// GraphicScaledImage corners behave as Envelope with lower/upper corners
DirectPosition lowerCorner = geometryFactory.createDirectPosition(new double[]{ -90, -180 });
scaledImage.setLowerCorner(lowerCorner);

DirectPosition upperCorner = geometryFactory.createDirectPosition(new double[]{ 90, 180 });
scaledImage.setUpperCorner(upperCorner);

scaledImage.setTransparency(50);

// Custom image generation code would go here
Image image = new ImageIcon(res.getString("wholeWorldImageFile")).getImage();
BufferedImage bufferedImage = new BufferedImage(image.getWidth(null),
image.getHeight(null),
BufferedImage.TYPE_INT_ARGB
```
6.8.3.3 Data to Feature Mapping Issues

Implementing a GraphicStore may be useful in cases where an existing data source does not map well or at all to Features. For example, attempting to support gridded METOC displays with dynamically updating wind barbs would be a good candidate.

6.8.3.4 SLD Issues

In cases where SLD is insufficient, inefficient, or would be overly complex to implement it may prove a better choice to implement with a GraphicStore. For example, using SLD to support MS2525B with the full set of Tactical Graphics would require a multi-megabyte SLD file and likely require some type of service to serve up images. Business logic for the styling rules would also be complex.

6.9 Layer and LayerSource

In the development of applications using FeatureStores and GraphicStores as data sources, the Layer from ISO_19128 7.2.4.5 came across as an obvious mechanism for organizing data. Using a Layer, data could easily be presented in a Table of Contents or
other data view. The Layer and its configuration helpers LayerSource and LayerSourceFactory were thus created.

The Layer provides an implementation of the ISO_19128 Layer and adds the additional GO-1 objects necessary to fulfill the connection between ISO_19128 and this specification. The Layer itself contains FeatureLayers and Graphics, while its creating LayerSource references the FeatureStores and GraphicStores used to create the GO-1 objects in the Layer.

6.9.2 LayerSource

With the exception of the FeatureLayer and Graphic methods, all methods in the Layer interface directly provide access to ISO_19128 Layer properties. Only accessors are provided as Layers are intended to be easily created or copied.

As a Layer implementing ISO_19128, a Layer may have many Styles. When getting the FeatureLayers and Graphics from a Layer, a GO-1 application may want to get FeatureStyles and GraphicStyles from the same Layer's Styles, or it may want to use some other style altogether.

LayerSource methods:

- `getLayers()`: Returns a List of Layers provided by this LayerSource. This List should not be a live List: modifying the returned List should not modify this LayerSource's Layers.
- `getLayer(String name)`: Returns the named Layer.

6.9.3 LayerSourceFactory

LayerSourceFactory methods:

- `createLayerSource(URI provider, Map<String, Object> params)`: Ask for a LayerSource connecting to the indicated provider or service. The returned LayerSource may have been previously cached. Additional hints or configuration information may be provided according to the metadata indicated by `getParametersInfo()`. This information often includes security information such as username and password.
- `createNewLayerSource(URI provider, Map<String, Object> params)`: Ask for a new LayerSource connecting to the indicated provider or service. Additional hints or configuration information may be provided according to the metadata indicated by `getParametersInfo()`. This information often includes security information such as username and password.
- `canProcess(URI provider)`: Indicates this FeatureStoreFactory communicate with the indicated provider or service. This method should not fail. If a connection needs to be made to parse a GetCapabilities file or negotiate WMS versions, any IO problems indicate the inability to process the URI. This method may be considered the same as:
canProcess(provider, hints) where hints was generated by using all the default values specified by the getParametersInfo() method

6.9.4 Layer Example

The following code demonstrates how one can retrieve GO-1 objects from a Layer for display in a Canvas or FeatureCanvas.

```java
Layer[] layers = getLayers();
Style[] styles = getStyles();
for (int i = 0; i < layers.length; i++) {
    // graphics
    final List<Graphic> graphics = layers[i].getGraphics();
    final List<GraphicStyle> graphicStyles = styles[i].getGraphicStyles();
    for (int j = 0; j < graphics.size(); j++) {
        final Graphic graphic = (Graphic) graphics.get(j);
        for (int k = 0; k < graphicStyles.size(); k++) {
            final GraphicStyle graphicStyle = (GraphicStyle) graphicStyles.get(k);
            graphic.setGraphicStyle(graphicStyle);
            canvas.add(graphic);
        }
        if (graphicStyles.size() == 0) {
            // use whatever style information graphic contains
            canvas.add(graphic);
        }
    }
    // featureLayers
    final List<FeatureLayer> featureLayers = layers[i].getFeatureLayers();
    final List<FeatureStyle> featureStyles = styles[i].getFeatureStyles();
    for (int j = 0; j < featureLayers.size(); j++) {
        final FeatureLayer featureLayer = (FeatureLayer) featureLayers.get(j);
        for (int k = 0; k < featureStyles.size(); k++) {
            final FeatureStyle featureStyle = (FeatureStyle) featureStyles.get(k);
            featureLayer.setStyle(featureStyle);
            featureCanvas.addFeatureLayer(featureLayer);
        }
        if (featureStyles.size() == 0) {
            // use whatever style information featureLayer contains
            featureCanvas.addFeatureLayer(featureLayer);
        }
    }
}
```

7 Behaviours

Here we illustrate a few signature behaviours of an application that uses a GO-1 implementation. We present these behaviours as use cases, some accompanied by sequence or state diagrams.

7.1 Adding a Graphic to a display

Description: Create a graphic and add it to the display.
Precondition: Begin with an application that includes a full implementation of GO-1 Application Objects. All required Factory objects and a Canvas object have been instantiated, and a Graphic is ready to be added to the display.

Flow of events:

1. Application requests a Graphic object from the DisplayFactory.
2. Application sets the geometric attributes of the Graphic
3. Application sets the style attributes of the Graphic via getGraphicStyle()
4. Application adds the Graphic object to the Canvas object.

Postcondition: The Graphic is rendered with requested styling on the display device.

This sequence of operations is depicted below.
7.2 Mouse click selects graphical object.

Description: A user selects a feature for editing in the graphical display.

Preconditions: Begin with an application that includes a full implementation of GO-1 Application Objects. The Canvas has a MouseManagerSupport object to which it delegates mouse event operations. A SelectItemsHandler class exists that implements MouseHandler. The MouseManagerSupport object has been registered as a MouseListener and a MouseMotionListener, and the SelectItemsHandler has been pushed onto the MouseManagerSupport’s (empty) MouseHandler stack. (Even though SelectItemsHandler is a Java Listener, it is not registered with any EventSource. It is used as an event dispatcher.)

Flow of events:

1. User clicks on the Canvas, causing a MouseEvent to be fired.
2. The MouseManagerSupport receives the MouseEvent, and passes the MouseEvent to the first and only item on its MouseHandler stack.

3. The MouseEvent is received and consumed by SelectItemsHandler.

4. SelectItemsHandler acquires GraphicStyle from the selected Graphic and calls GraphicStyle.setEditabilitySelected(true) to set it selected.

Postcondition: The user sees the object displayed with styling indicating it has been selected.

Figure 44 - Selecting a Graphic Object
7.2.1 Editing Graphics

Graphic objects purposefully leave editing up to the implementation. The two existing properties on Graphic base class, ShowingAnchorHandles and ShowingEditHandles, are the only hooks provided in the specification pertaining to editing. Their purpose is to offer a programmatic way of moving a Graphic to and from an editable mode determined by the implementation. An implementation may choose to edit a Graphic as it sees fit, but it is widely assumed that users will have the opportunity to modify a Graphic through gestures, particularly mouse gestures.

Graphic has an autoEdit attribute to support EditabilityDisplay conformance. When this property is true, the Canvas should provide a graphical interface that allows the user to modify the geometry of the graphic. Usually, this will take the form of "handles" (small circles or boxes) at the vertices or control points that the user can modify with mouse gestures.

In order to move a Graphic into editing mode, one or both of the setShowingHandles methods must be called. If setShowingAnchorHandles is called, then the Graphic should display handles suitable for relocating the entire Graphic. Each Graphic should display editing handles for its particular Geometry, so a GraphicLineString would display handles at its vertices while a GraphicIcon would only display a handle for rotating (the handle for relocating the GraphicIcon would be categorized as an anchor handle rather than an editing handle).

Whenever a graphic is modified or deleted, a GraphicChangeEvent must be fired by the implementation. When editing starts, a GraphicChangeEvent with a flag of GraphicChangeEvent.EDITABLE_START is fired. When editing ends, a GraphicChangeEvent with a flag of GraphicChangeEvent.EDITABLE_END is fired.

There are seven event flags in total that must be supported by a GO-1 application. Three of these are specific to compliance with Editable Display Objects; EDITABLE_START, EDITABLE_CHANGED, and EDITABLE_END. The other four event flags are GRAPHIC_CHANGED, GRAPHIC_SELECTED, GRAPHIC_DESELECTED, and GRAPHIC_DISPOSED.

7.3 Graphic object is instantiated from a Geometry and an SLD.

Preconditions: Running application has instantiated a geometry LineString and a compatible StyledLayerDescriptor (SLD) object.

Flow of events:

1. Application creates a new Graphic object with the DisplayFactory. Graphic has default styling.

2. Application gets the reference to the Graphic’s GraphicStyle.
3. Application gets various styling attributes from the SLD.

4. Application sets the GraphicStyle’s styling attributes with those obtained from the SLD.

5. Application sets the geometric attributes of the Graphic using the Geometry.

Postcondition: a styled Graphic has been created, and may be added to a Canvas for display.
Figure 45 - Graphic Object Creation
7.4 Relative Coordinate Use Cases

7.4.1 An image that does not scale with a CRS

A dynamically-constructed Graphic that does not scale with the Canvas objective CRS is to be displayed by the Canvas. The objective CRS of a Canvas happens to be a GeographicCRS. In this example, the particular type of the display CRS of the Canvas does not matter. Also irrelevant to this example is the MathTransform (MTOP) that the Canvas also holds to convert Geometry objects in the Canvas objective CRS (the GeographicCRS) into Geometry objects in the Canvas display CRS.

The Graphic is constructed using a square Geometry that is defined by four DirectPosition objects, which are associated with a single ImageCRS (which in this example is not the Canvas display CRS). A MathTransform (MTI) is selected that associates the ImageCRS with the GeographicCRS in such a way that the Geometry does not translate, rotate, or scale.

For example, the square has pixel coordinates (-4, -4), (4, -4), (4, 4), (-4, 4). This square is always drawn with the top left corner 4 pixels above and to the right of the reference coordinate (e.g., a lat/long point) no matter where that point is on the display, and the square is always 8 pixels wide and 8 pixels high, no matter what the scale of GeographicCRS with respect to the ImageCRS (zoom factor). Note that this implies that the Geometry.transform() for the square Geometry may be called on an as-needed basis: whenever the scale, location, or projection of the GeographicCRS changes with respect to either the ImageCRS, or changes with respect to the Canvas display CRS.

7.4.2 An image that is in a CRS chain and scales with a ProjectedCRS

A registered image is to be displayed in a fixed range and bearing from a fixed location in a Canvas objective CRS, which happens to be a ProjectedCRS.

An EngineeringCRS exists, as does a MathTransform (MTEP) that converts from the EngineeringCRS to the ProjectedCRS. An ImageCRS exists, as does a MathTransform (MTIE) that converts from the ImageCRS to the EngineeringCRS.

The registered image is set with two DirectPositions in the ImageCRS. The ImageCRS scales with the EngineeringCRS. The EngineeringCRS scales with the ProjectedCRS.

The Canvas holds another MathTransform (MTOP) to convert the Geometry object in the Canvas objective CRS (the ProjectedCRS) into Geometry objects in the Canvas display CRS. The sequence of CRS objects (starting with the initial ImageCRS
and ending with the Canvas display CRS) bound by the intervening MathTransform objects, together form a “chain”.

An implementation can either create a new Geometry object at each transform() invocation in the chain, or can call MathTransformFactory.createConcatenatedTransform() in sequence on each MathTransform, and ultimately generate a MathTransform that will convert Geometry objects from the starting CRS (the initial ImageCRS) in the chain to those in the ending CRS (the Canvas display CRS) in the chain.

7.4.3 An EngineeringCRS scaling directly with another EngineeringCRS.

A ship is to be depicted coming into port. The ship is represented by a Geometry having an EngineeringCRS (CRSS). The origin of CRSS is a position within the ship’s Geometry, such as at the centre of buoyancy of the ship or at the forward-most point of the bow at main deck level. The port is depicted by a set of DirectPositions having a different EngineeringCRS (CRSP).

A MathTransform (MTSP) exists that converts from CRSS to CRSP. MTSP has the following qualities: (A) a direct identity scaling from CRSS to CRSP, (B) the behaviour that the origin DirectPosition of CRSS corresponds to a particular DirectPosition in CRSP, which denotes the ship position in CRSP, and (C) an orientation of the CRSS to CRSP, denoting the rotation of the ship with respect to the port.

Note that a mathematically identical case would be if CRSP is a georeferenced CRS, such as a GeographicCRS. Similarly mathematically identical is the case where both CRSS and CRSP are georeferenced CRS types; however, Topic 2 would prohibit time-based changes to CRSS in a canonically correct implementation.

7.5 Symbology Use Cases

For all standard symbologies detailed in this document, tag sets are fully defined in Appendix B, and one or more use cases are presented here. Each selected symbology use case provides sample client side source code that could be used to construct the symbol, and an illustration of how a corresponding symbol might appear on a map.

7.5.1 MIL-STD 2525 Tactical Graphic

MIL-STD 2525B [34] has evolved from North Atlantic Treaty Organization (NATO) Standardization Agreement (STANAG) 2019 (APP 6), "Military Symbols for Land Based Systems," and U.S. Army Field Manual (FM) 101-5-1/Marine Corp Reference Publication (MCRP) 5-2A, Operational Terms and Graphics. It provides common warfighting symbology along with details on its display and plotting to ensure the compatibility, and to the greatest extent possible, the interoperability of DOD Command, Control, Communications, Computer, and Intelligence (C4I) systems development, operations, and training. The standard addresses the efficient transmission of symbology.
information within the infosphere through the use of a standard methodology for symbol hierarchy, information taxonomy, and symbol identifiers. The standard applies to both automated and hand-drawn graphic displays. These symbols are designed to enhance DOD's joint warfighting interoperability by providing a standard set of common C4I symbols.

![MIL-STD 2525 Tactical Graphic](image)

**Figure 46 - MIL-STD 2525 Tactical Graphic**

```java
DisplayFactory displayFactory = commonFactory.getDisplayFactory();
GraphicLineString tacgraph =
    (GraphicLineString)displayFactory.createGraphic(GraphicLineString.class);
CRSAuthorityFactory crsAuthFactory = commonFactory.getCRSAuthorityFactory();
CoordinateReferenceSystem crs =
    crsAuthFactory.createCoordinateReferenceSystem("EPSG:4326");
GeometryFactory geometryFactory = commonFactory.getGeometryFactory(crs);

//anchor 1
DirectPosition anchor = geometryFactory.createDirectPosition(new double[]{30, 20});
tacgraph.addAnchorPoint(anchor);

//anchor 2
anchor = geometryFactory.createDirectPosition(new double[]{30, -20});
tacgraph.addPoint(anchor);

//anchor 3
anchor = geometryFactory.createDirectPosition(new double[]{0, 0});
tacgraph.addPoint(anchor);

SymbologyInfo symInfo = new SymbologyInfo("MIL-STD-2525", "B");
tacgraph.getSymbology().setSymbologyProperty(symInfo, "SymbolID", "G*TPP------****X");
tacgraph.getSymbology().setSymbologyProperty(symInfo, "DirectionOfMovement", new Double(6.281));
tacgraph.getActiveSymbology(symInfo);
canvas.add(tacgraph);
```

### 7.5.2 MIL-STD 2525 Air Track

This example illustrates combining point and line dimensions to form this MIL-STD 2525 Air Track symbol.
Figure 45 - MIL-STD 2525 Air Track

```java
DisplayFactory displayFactory = commonFactory.getDisplayFactory();
GraphicIcon icon =
(GraphicIcon)displayFactory.createGraphic(GraphicIcon.class);

CRSAuthorityFactory crsAuthFactory = commonFactory.getCRSAuthorityFactory();
CoordinateReferenceSystem crs =
crsAuthFactory.createCoordinateReferenceSystem("EPSG:4326");
GeometryFactory geometryFactory = commonFactory.getGeometryFactory(crs);

//anchor point
DirectPosition anchor = geometryFactory.createDirectPosition(new double[] { 30,
20 });
icon.setPosition(anchor);

// note this GraphicIcon doesn’t require a java Icon as the image
// will determined by the MIL-STD-2525 symbology.
SymbologyInfo symInfo = new SymbologyInfo ("MIL-STD-2525", "B");

icon.getSymbology().setSymbologyProperty(symInfo, "SymbolID", "SFAPMF------
USA");
icon.getSymbology().setSymbologyProperty(symInfo, "AdditionalInformation", 
"RAF418");
icon.getSymbology().setSymbologyProperty(symInfo, "Frame", Boolean.TRUE);
icon.getSymbology().setSymbologyProperty(symInfo, "Fill", Boolean.TRUE);
icon.getSymbology().setSymbologyProperty(symInfo, "Icon", Boolean.FALSE);
icon.getSymbology().setSymbologyProperty(symInfo, "Speed", new Double(447.2));
icon.getSymbology().setSymbologyProperty(symInfo, "DirectionOfMovement", new 
Double(6.281));
icon.getActiveSymbology(symInfo);
canvas.add(icon);
```

7.5.3 Surface Weather

Surface weather depictions are commonly found in weather reporting systems. This
symbol is rather detailed, so additional annotations are provided in blue and red. This
Surface weather symbology is based upon the U.S. National Weather Service (NWS)
Meteorology standards [32]. Depiction of such symbology tends to vary slightly across
regions, so implementations may adhere to display standards applicable to their own
geographical regions. A common set of tags for this symbology appears in Appendix B,
Table “SurfaceWeather”.

Copyright © Open Geospatial Consortium, Inc (2005)
Figure 46 - Surface Weather (annotated)
DisplayFactory displayFactory = commonFactory.getDisplayFactory();
GraphicIcon icon =
(GraphicIcon)displayFactory.createGraphic(GraphicIcon.class);

CRSAuthorityFactory crsAuthFactory = commonFactory.getCRSAuthorityFactory();
CoordinateReferenceSystem crs =
crsAuthFactory.createCoordinateReferenceSystem("EPSG:4326");
GeometryFactory geometryFactory = commonFactory.getGeometryFactory(crs);

//anchor point
DirectPosition anchor = geometryFactory.createDirectPosition(new double[] {
    24.2, -112.5 });

icon.setPosition(anchor);
Symbology symInfo = symbol.getSymbology("SurfaceWeather");

icon.getSymbology().setSymbologyProperty(symInfo, "SymbolID", "SFAPMF------USA");
icon.getSymbology().setSymbologyProperty(symInfo, "WindDirection", new Double(10.0));
icon.getSymbology().setSymbologyProperty(symInfo, "WindSpeed", new Double(5.0));
icon.getSymbology().setSymbologyProperty(symInfo, "Temperature", new Integer(34));
icon.getSymbology().setSymbologyProperty(symInfo, "PresentWeather", 71);
icon.getSymbology().setSymbologyProperty(symInfo, "Visibility", new Integer(4));
icon.getSymbology().setSymbologyProperty(symInfo, "Dewpoint", new Integer(32));
icon.getSymbology().setSymbologyProperty(symInfo, "SkyCover", new Integer(6));
icon.getSymbology().setSymbologyProperty(symInfo, "StationIdentifier", "AB1");
icon.getSymbology().setSymbologyProperty(symInfo, "PressureChange", new Integer(28));
icon.getSymbology().setSymbologyProperty(symInfo, "PressureTendency", new Integer(1));
icon.getSymbology().setSymbologyProperty(symInfo, "PastWeather", new Integer(6));
icon.getSymbology().setSymbologyProperty(symInfo, "PastPrecipitation", new Double(0.45));
icon.getSymbology().setSymbologyProperty(symInfo, "HighCloudType", new Integer(2));
icon.getSymbology().setSymbologyProperty(symInfo, "MiddleCloudType", new Integer(4));
icon.getSymbology().setSymbologyProperty(symInfo, "LowCloudType", new Integer(7));
icon.getSymbology().setActiveSymbology(symInfo);
canvas.add(icon);

7.5.4 Homeland Security

The Homeland Security symbology [33] is a work in progress by the Homeland Security Working Group. This standard has yet to be released as of this writing. Only point symbols are currently supported. Each SymbolCode is mapped to a single keystroke character. Those symbol codes are further subdivided into one of four categories: Incidents, Natural Events, Operations, and Infrastructures. Tags for this symbology appear in Appendix B, Table “FGDCHomelandSecurity”.

Figure 47 - Homeland Security Symbol
DisplayFactory displayFactory = commonFactory.getDisplayFactory();
GraphicIcon icon = (GraphicIcon)displayFactory.createGraphic(GraphicIcon.class);
CRSAuthorityFactory crsAuthFactory = commonFactory.getCRSAuthorityFactory();
CoordinateReferenceSystem crs = crsAuthFactory.createCoordinateReferenceSystem("EPSG:4326");
GeometryFactory geometryFactory = commonFactory.getGeometryFactory(crs);

// anchor point
DirectPosition anchor = geometryFactory.createDirectPosition(new double[]{24.2, -112.5});

icon.addAnchorPoint(anchor);
symbol.addAnchorPoint(anchor);
Symbology symInfo = symbol.getSymbology("FGDCHomelandSecurity");

// Criminal Activity Incident (Theme)
Symbology symbology = symbol.getSymbology("FGDCHomelandSecurity");
icon.getSymbology().setSymbologyProperty(symInfo, "SymbolCode", "E");
icon.getSymbology().setSymbologyProperty(symInfo, "SymbolType", "Incident")
icon.getSymbology().setSymbologyProperty(symInfo, "Level", new Integer(0));
icon.getSymbology().setActiveSymbology(symInfo);
canvas.add(icon);

7.6 Z-order Use Case

For the GO-1 reference implementation, we chose to implement z-order in such as way as to assume that graphic elements that had not set the z-order hint were assumed to share the z-order of 0 (zero). Any items we desired to draw below the "standard" z-order of all graphic primitives were set at -1. Any items drawn above all objects at the default z-order were set at 1.

A use case for this would be the algorithmic determination of z-order by altitude. The GO-1 client application could pick any range of z for its objects. Let's assume that the client application picked -100.0 to +100.0 to represent algorithmically determined elevation (and depth) levels.

Assuming this to be the situation, the following would be true:

1) Items set with
    graphic.getGraphicStyle().setViewabilityZOrderHint(101.0)
    would appear "on top" of all items determined algorithmically.
2) Items set with 
   `graphic.getGraphicStyle().setViewabilityZOrderHint(-101.0)` would appear "below" all items determined algorithmically.

3) Items with their z-order hint not set would appear at the level determined by inheritance.

4) Items in case #3 with no inherited z-order hint would be displayed at the GO-1 specification default z-order of 0.0.

There are a number of approaches by which z-order can be set:

1) Z-order can be set using the
   `getGraphicStyle().setViewabilityZOrderHint(double)` method, on each graphic.

2) A graphic can be added to an aggregate, which includes `OrderedAggregateGraphic`. If the graphic's z-order hint is unset, and inheritance is enabled, the graphic will be treated as having the z-order of the aggregate.

3) Using `OrderedAggregateGraphic`, which preserve rendering order within themselves, the client application can guarantee the drawing order of all of its objects without using the z-order hint in the graphic styles at all. Since each `OrderedAggregateGraphic` is guaranteed to render its children in order, from index 0 to n, and `OrderedAggregateGraphic` can be added to others as children, this hierarchy of drawing order can be created.

4) Z-order hints set in the `GraphicStyle` of a `Graphic` object **always** override both the default z-ordering, and the ordering of an object within a `OrderedAggregateGraphic`. Setting the hint, in essence, specifies to the `Canvas` exactly at what z level the user wishes the object to be displayed.

Mixing and matching the aforementioned z-order approaches may lead to interesting and non-deterministic results, according to the implementation. It is our suggestion that, if z-order is used, one approach be applied consistently for all client objects in order to decrease the likelihood of unexpected visual results.
Annex A
(normative)

Application Objects Programming Interface for Java

A.1 General

The detailed specifications for the GO-1 Application Objects programming interface have been made available in Javadoc format. These materials are available under separate cover in 03-064_Annex_A.zip.

The Feature and Spatial Object interface specifications are being developed as a part of the Model Driven Architecture interface and specification development experiments described at various points throughout the text above.
Annex B  
(normative)  
Symbology Property Names

B.1 Surface Weather Symbology

References: How to read weather maps

<table>
<thead>
<tr>
<th>Property Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dewpoint</td>
<td>Double</td>
<td>Degrees Fahrenheit</td>
</tr>
<tr>
<td>HighCloudType</td>
<td>Integer</td>
<td>Code from 1-9</td>
</tr>
<tr>
<td>LowCloudType</td>
<td>Integer</td>
<td>Code from 1-9</td>
</tr>
<tr>
<td>MiddleCloudType</td>
<td>Integer</td>
<td>Code from 1-9</td>
</tr>
<tr>
<td>*PastPrecipitation</td>
<td>Double</td>
<td>Inches in past six hours</td>
</tr>
<tr>
<td>PastWeather</td>
<td>Integer</td>
<td>Code from 0-9, past six hours</td>
</tr>
<tr>
<td>PresentWeather</td>
<td>Integer</td>
<td>Code from 0-99, present</td>
</tr>
<tr>
<td>PressureChange</td>
<td>Double</td>
<td>Millibars to nearest tenth</td>
</tr>
<tr>
<td>PressureTendency</td>
<td>Integer</td>
<td>Code from 0-8</td>
</tr>
<tr>
<td>SeaLevelPressure</td>
<td>Double</td>
<td>Millibars to nearest tenth</td>
</tr>
<tr>
<td>SkyCover</td>
<td>Integer</td>
<td>Code from 0-9, total cloud cover</td>
</tr>
<tr>
<td>*StationIdentifier</td>
<td>String</td>
<td><a href="http://weather.noaa.gov/tg/site.shtml">http://weather.noaa.gov/tg/site.shtml</a></td>
</tr>
<tr>
<td>Temperature</td>
<td>Double</td>
<td>Degrees Fahrenheit</td>
</tr>
<tr>
<td>Visibility</td>
<td>Integer</td>
<td>Miles</td>
</tr>
<tr>
<td>WindDirection</td>
<td>Double</td>
<td>Degrees from 0-360</td>
</tr>
<tr>
<td>WindSpeed</td>
<td>Double</td>
<td>Knots</td>
</tr>
</tbody>
</table>

* Table 3 - SurfaceWeather

* Denotes a property name extension outside the specification used, but found to be in common use.
B.2 Homeland Security

Reference: Homeland Security Working Group

<table>
<thead>
<tr>
<th>Property Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SymbolCode</td>
<td>String</td>
<td>keystroke</td>
</tr>
<tr>
<td>SymbolType</td>
<td>String</td>
<td>“Incident”, “NaturalEvent”,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>“Operation”, “Infrastructure”</td>
</tr>
<tr>
<td>Level</td>
<td>Integer</td>
<td>0-4, 0 is no level or n/a</td>
</tr>
</tbody>
</table>

Table 4 - FGDCHomelandSecurity
B.3 U.S. Military Symbology


<table>
<thead>
<tr>
<th>Property Name</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>AdditionalInformation</td>
<td>String</td>
</tr>
<tr>
<td>AltitudeDepth</td>
<td>String</td>
</tr>
<tr>
<td>AuxiliaryEquipment</td>
<td>Boolean</td>
</tr>
<tr>
<td>CombatEffectiveness</td>
<td>String</td>
</tr>
<tr>
<td>CommonIdentifier</td>
<td>String</td>
</tr>
<tr>
<td>DateTimeGroup</td>
<td>Date</td>
</tr>
<tr>
<td>DateTimeGroupAlt</td>
<td>Date</td>
</tr>
<tr>
<td>DirectionOfMovement</td>
<td>Double</td>
</tr>
<tr>
<td>EchelonIndicatorDescription</td>
<td>String</td>
</tr>
<tr>
<td>EquipmentTeardownTime</td>
<td>Integer</td>
</tr>
<tr>
<td>EvaluationRating</td>
<td>String</td>
</tr>
<tr>
<td>FeintDummy</td>
<td>Boolean</td>
</tr>
<tr>
<td>FrameShapeModifier</td>
<td>String</td>
</tr>
<tr>
<td>Frame</td>
<td>Boolean</td>
</tr>
<tr>
<td>Fill</td>
<td>Boolean</td>
</tr>
<tr>
<td>Headquarters</td>
<td>Boolean</td>
</tr>
<tr>
<td>HigherFormation</td>
<td>String</td>
</tr>
<tr>
<td>Hostile</td>
<td>String</td>
</tr>
<tr>
<td>Icon</td>
<td>Boolean</td>
</tr>
<tr>
<td>IFFSIF</td>
<td>String</td>
</tr>
<tr>
<td>Installation</td>
<td>Boolean</td>
</tr>
<tr>
<td>Location</td>
<td>String</td>
</tr>
<tr>
<td>Mobility</td>
<td>String</td>
</tr>
<tr>
<td>OffsetLocation</td>
<td>Boolean</td>
</tr>
<tr>
<td>PlatformType</td>
<td>String</td>
</tr>
<tr>
<td>Quantity</td>
<td>String</td>
</tr>
<tr>
<td>Reduced</td>
<td>Boolean</td>
</tr>
<tr>
<td>Reinforced</td>
<td>Boolean</td>
</tr>
<tr>
<td>SIGINTMobility</td>
<td>String</td>
</tr>
<tr>
<td>SignatureEquipment</td>
<td>String</td>
</tr>
<tr>
<td>SpecialC2Headquarters</td>
<td>String</td>
</tr>
<tr>
<td>Speed</td>
<td>String</td>
</tr>
<tr>
<td>StaffComments</td>
<td>String</td>
</tr>
<tr>
<td>SymbolID</td>
<td>String</td>
</tr>
<tr>
<td>TaskForce</td>
<td>Boolean</td>
</tr>
<tr>
<td>Type</td>
<td>String</td>
</tr>
<tr>
<td>UniqueDesignation</td>
<td>String</td>
</tr>
</tbody>
</table>

Table 5 - MIL-STD-2525B

* Refer to MIL-STD-2525B for property name description and behaviour.
B.4 Aeronautical Symbology (future)


B.5 Nautical Symbology (future)

The current edition of NOAA Chart No. 1 Nautical Chart Symbols is available from the National Geospatial-Intelligence Agency (NGA) at http://pollux.nss.nima.mil/pubs/pubs_j_show_sections.html?d=ON&dpath=Chart1&ptid=3&rid=16
Annex C
(normative)
Open Source Information

The interfaces described in this document are available in source code form from the GeoAPI project's SourceForge web site:

http://geoapi.sourceforge.net

From this page, download version 1.0.0 to retrieve the version of the source code corresponding to this document.

The source can also be retrieved using anonymous CVS:

cvs -z9 -d :pserver:anonymous@cvs.sourceforge.net:/cvsroot/geoapi
    checkout -P -r Release-1_00_00 src

The GeoAPI working group maintains a mailing list where changes and issues with the API are discussed. To access this mailing list, including archives and subscription information, visit this page:

http://lists.sourceforge.net/lists/listinfo/geoapi-devel

Corresponding to this mailing list is an issue tracking tool allowing the developers to log issues and track progress on those issues. Visit this page for more information:

http://jira.codehaus.org/browse/GEO
Annex D
(non-normative)
FeatureCanvas Sequence Diagram

The following sequence diagram illustrates how a (naive) implementation of FeatureCanvas might use a Layer to construct Graphics and add them to a Canvas.

Figure 50 - One possible implementation of adding a Layer to a FeatureCanvas
Annex E
(non-normative)
Package Dependencies

Package Dependencies for selected GO1 Packages

Figure 51 - Package Dependencies
Annex F
(non-normative)
Architecture Diagrams

Figure 52 - A possible architecture using GO-1 components

Figure illustrates how an application using the GO-1 Architecture obtains data from a WFS and makes it available to the display. On the back end, the WFS use various FeatureStores to obtain feature data (ex. the existing ArcSDE FeatureStore or proposed TBMCS FeatureStore). The WFS FeatureStore allows features to be obtained from the WFS, again through the standardized GO-1 FeatureStore APIs. Application code then styles features and graphics and places them on the canvas.

This architecture is already proven to be viable by the GeoTools and GeoServer projects, although they use interfaces that were predecessors to those present in GO-1.

On the server side, a GO-1 Web Feature Server can easily be designed to only use the published FeatureStore interfaces for retrieving data from back-end data stores. This would allow for plugging in arbitrary FeatureStores to provide new data. Thus when new data is introduced to the system, the server does not change. A new FeatureStore is simply added to the classpath and the server is configured to read its features.

On the client side, the WFSFeatureStore is capable of ingesting arbitrary GML from a WFS, so new data will not affect the application's data retrieval or display. Additionally, the application code can easily be written to only use FeatureStore APIs so that any other FeatureStores could be used locally as well.
Figure 53 - A non-network architecture using GO-1 components

Figure depicts a simpler, non-networked architecture that does not involve a Web Feature Server. Using this configuration, application code can be written in such a way that it only depends on GO-1 FeatureStore interfaces and does not have any dependencies on the characteristics of any particular Data Source.
Annex G
(non-normative)
Implementation Notes

Note that it is possible to implement the FeatureCanvas interface entirely on top of the GO-1 Canvas interfaces. In other words, you could write a FeatureCanvas implementation one time and reuse it for various Canvases.

So suppose a new GIS rendering engine hits the market. To get FeatureCanvas support on this new rendering engine, all you have to do is implement the Canvas interfaces and you would get for very little effort a working FeatureCanvas.
Bibliography

[1] ISO 31 (all parts), Quantities and units.
[2] IEC 60027 (all parts), Letter symbols to be used in electrical technology.
[3] ISO 1000, SI units and recommendations for the use of their multiples and of certain other units.
[4] Guidelines for Successful OGC Interface Specifications, OGC document 00-014r1
Filter Encoding:


[18] Web Coordinate Transformation Service (WCTS), v0.0.4, OGC document 02-061r1. Available at: [http://www.opengeospatial.org/docs/02-061r1.pdf](http://www.opengeospatial.org/docs/02-061r1.pdf)


[29] Recommended XML Encoding of CRS Definitions (XML for CRS), v2.1.0, OGC document 03-010r9. Available at: [http://www.opengeospatial.org/docs/03-010r9.zip](http://www.opengeospatial.org/docs/03-010r9.zip)
[30] CT Definition Data for Coordinate Reference (DD CRS), v1.1.0, OGC document 01-014r5. Available at: http://www.opengeospatial.org/docs/01-014r5.pdf

[31] High-Level Ground Coordinate Transformation Interface (HLG-CT), v0.0.3, OGC document 01-013r1. Available at: http://www.opengeospatial.org/docs/01-013r1.pdf


Open Source Implementation Baselines

GO-1 and GeoAPI:

- http://sourceforge.net/projects/geoapi

Geobject 1.3 and Geobject 2.0a:

- http://geobject.org/umldoc/2.0alpha
- http://sourceforge.net/projects/geobject

Geotools and Geotools2:

- http://modules.geotools.org/core
- http://www.geotools.org