# XCEDE 2.0 - A Manual

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# Introduction

This is a manual for version 2 of XCEDE (XML-based Clinical and Experimental Data Exchange). XCEDE 2 is an extensible schema designed to enable the transfer and storage of several types of scientific data and metadata including (but not limited to) clinical, demographic, behavioral, physiological and image data. The target audience for this manual is anyone who is interested in using or learning more about XCEDE 2. This manual will serve as both a tutorial and as a reference.

Though the schema was designed in the context of neuroscientific projects, the structure of the schema is quite generic and can be applied as is to a wide variety of scientific disciplines.

## 1. Manual structure

This manual has two parts. Part I describes the various components of XCEDE 2 and describes the specification in some detail. Part II is a more practical guide to the use of XCEDE 2, providing guidance to those users who wish to extend the schema to represent project-specific metadata, or integrate XCEDE 2 into software applications and services.

## 2. Development

XCEDE 2 development started as an effort to "harmonize" the uses of XML within the BIRN (Biomedical Informatics Research Network) [BIRN] testbeds and collaborators within the neuroscientific community. The feedback from these discussion sessions led to an initial prototype (based on XCEDE 1.0) of a next-generation schema. Over the course of four months of daily teleconferences, the first public release of XCEDE 2 took form.

XCEDE 2 has its origins in various XML schemas developed for collaborative neuroinformatics projects, including:

fMRI Data Center schema
: a general scientific metadata storage framework.

XNAT (Extensible Neuroimaging Toolkit)
: database and web service designed to facilitate management and exploration of neuroimaging and related data.

BIAC XML Header schema
: provides a format-agnostic interface to image data and is the basis for the *binary data resource* in XCEDE 2.0.

BIRN Data Provenance schema
: records the history of processing steps and is the basis for the `<provenance>` element in the schema.

XCEDE (1.0) SPM Toolbox
: provides a general framework (and MATLAB interface) for storage and retrieval of thresholded statistical parametric maps and associated anatomical labels.

The primary developers of XCEDE 2 are (in alphabetical order): Syam Gadde (Duke University), Jeff Grethe (University of California, San Diego), Dave Keator (University of California, Irvine), and Dan Marcus (Washington University, St. Louis), all of whom have received support for this project through various BIRN testbeds.

# 3. For More Information

XXX Contacts XXX

The latest schema and related information can be found on the project's web page at http://www.xcede.org/.

# Part I. XCEDE 2 Core Specification

This section of the XCEDE 2.0 manual focuses on the high-level structure and major components of the XCEDE 2 Core schema. Each chapter contains a description of the component and provides examples of usage. The examples in this section are largely drawn from neuroscientific metadata, as this data served as the driving force behind development. However, these examples are by no means comprehensive; the schema was designed to be generally applicable (and extensible) to many types of scientific data, and this manual by necessity focuses on only a few.

# Chapter 1. Structure and Conventions

## 1.1. The XCEDE 2 Dataset

An XCEDE 2 Dataset is a data repository (stored in files, databases, or using other storage mechanisms) that can be represented as a collection of one or more XML documents, each of which validates against the XCEDE 2 XML schema (Appendix A). The XCEDE 2 specification does not prescribe any particular mechanism by which these documents are located, stored, grouped, or linked, though XCEDE 2 allows certain XML elements to link to other target elements and to optionally specify URLs as hints as to the location of the documents containing these targets.

For example, a given XCEDE 2 dataset may be stored as a single XML document, or a collection of files in a single directory on a file system, or may be distributed within a hierarchical directory structure (which may or may not reflect the structure of the data within), or may be stored within a database accessible by query through a web interface. The semantics of the dataset should be fully reflected in the XML representation, and should not be dependent on how the dataset is stored.

A schema-compliant XCEDE 2 document must be a valid XML 1.0 document [XML10], and must have one root element, `<XCEDE>`, which (like all other XCEDE 2 elements) is in the XML namespace `http://www.xcede.org/xcede-2`.

Several major components of the XCEDE 2 dataset are represented as children of the XCEDE root element. These components include:

- **Experiment hierarchy.** The components in the experiment hierarchy are represented by elements `<project>`, `<subject>`, `<visit>`, `<study>`, `<episode>`, `<acquisition>`. These are described in more detail in Chapter 2.
- **Analyses.** The `<analysis>` element encapsulates metadata about data that is derived from one or more inputs, whose data is represented by other XCEDE elements. See Chapter 9.
- **Protocols.** Structures to describe the expected course of an experimental paradigm are provided by the `<protocol>` element. See Chapter 8.
- **Data resources.** Represented by the element `<resource>`, these point to external files which store actual data. See Chapter 3.
- **Data.** The element `<data>` is used to store actual data within the XML document. Examples include *events* (Chapter 6) and *assessments* (Chapter 7).

Other XCEDE components appear as subcomponents of other XCEDE structures:

- **Data provenance.** The `<provenance>` element appears in the types `analysis_t` (on which the `<analysis>` element is based) and `dataResource_t` (one of the available data models for the top-level `<resource>` element). See Chapter 5.
- **Comments and annotations.** The `<commentList>` and `<annotationList>` provide a mechanism to store descriptive text regarding the real-world entities or concepts represented by the associated XML element, or about the stored XML element itself. These are available in all elements based on `abstract_container_t`, which includes all the hierarchy elements and `<analysis>`.
- **Informational resources.** These point to documentation that may illuminate aspects of the data, data collection, protocol, etc. -- these might include peer-reviewed publications, equipment manuals, and others. Informational resources are represented in the type `informationResource_t` which is

used in the `<resourceList>` element in `abstract_container_t` (as with the comments and annotations).

- **Terminology.** Various elements in XCEDE 2 include the attribute group `terminology_ag` or use the type `terminologyString`, which allow the user to associate them with terms from particular nomenclatures/ontologies. For example, a subject's `<species>` may refer to a standard term listed in a well-known public nomenclature.

# 1.2. XCEDE 2 Schema conventions

The XCEDE XML document structure is defined using W3C XML Schema language [XMLSchema10]. With a few exceptions, the XCEDE 2 XML schema subscribes to the following conventions and best practices.

**Naming and capitalization.**

- Element and attribute names are alphanumeric (`<project>`). All letters are lowercase, with the exception of acronyms, which are uppercase (`<XCEDE>`, `projectID`), and, in multi-word names, the initial letters of the second and following words which are capitalized (`<dataResourceRef>`). For the purposes of this rule, `ID` (for "identifier") is considered an acronym.
- Schema type names (which do not appear in XML instance documents except in `xsi:type` attributes) follow the same naming conventions as element and attribute names, but have the `_t` suffix (`analysis_t`). If the type is "abstract", then it has an `abstract_` prefix (`abstract_container_t`).
- Attribute group names (which do not appear in XML instance documents) follow the same naming conventions as element and attribute names, but have the `_ag` suffix (`allLevelExternalIDs_ag`).

**Schema best practices.**

- Follow the schema versioning best practices recommended by Roger Costello in [CostelloSchemaVersioning]. Some of the implications are listed below:
  - The XCEDE namespace will change for major versions, but not minor versions. So, the namespace is as follows: `http://www.xcede.org/xcede-major_version`. For example: `http://www.xcede.org/xcede-2`
  - XSD files will be named `xcede-`*`version-domain`*. For example: `xcede-2.0-core.xsd`
  - All elements should have a corresponding named `complexType`. For example: `<project>` is of type `project_t`.
  - The schema prescribes a particular document order for some elements -- document creators should follow this strictly. However, applications should be written without expecting a particular element order, in case later versions of the schema change the order of elements. That is, be conservative in what you write, but liberal in what you accept.

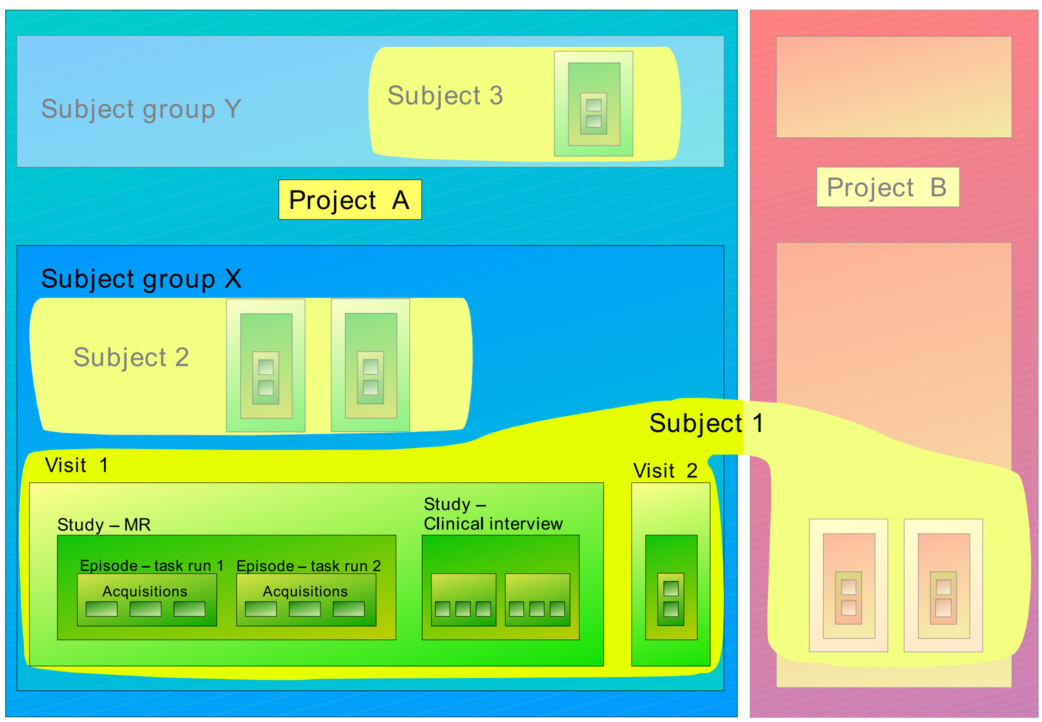
Content within XCEDE documents is expected to be validated using other content-based schema languages, such as Schematron [Schematron].

# Chapter 2. Experiment Hierarchy

## 2.1. Overview

As illustrated in Figure 2.1, the XCEDE experiment hierarchy consists of several *levels* representing divisions of experiment data at various granularities. Elements at each level contain level-specific "info" elements, whose schema types may be derived to store experiment-specific or data modality-specific metadata. The linking mechanism between levels is flexible enough to support the omission of levels if the schema user finds them unnecessary.

**Figure 2.1. XCEDE hierarchy**



## 2.1.1. Hierarchy Levels

In the typical intended usage, a *project* is the top-level division of experiment data, and represents a research project which collects and analyzes data from one or more *subjects* which are divided (within the project) into *subject groups*. A subject may be a member of multiple research projects, and it is the subject group that maintains and distinguishes the mappings between subjects and research projects.

A *visit* may represent a subject's appearance at an experiment "site" (for collaborative projects, this could be the institution or lab at which the data is being collected or analyzed). A visit, may be further subdivided into one or more *studies*, each of would consist of one or more data collection *episodes*.

Visit and study are more or less arbitrary divisions of the data that exist for convenience, and do not in themselves have any inherent meaning as far as the schema is concerned. However, an episode is intended to represent a unit of data collection over a given time interval, and should contain one or more data *acquisitions*, which should be understood to occur simultaneously over the duration of the episode. So, for example, an episode in an fMRI study may encapsulate the acquisition of a time-series of volume images from an MR scanner, as well as other acquisitions of behavioral or physiological data; all these (simultaneous) acquisitions would be stored as part of the same episode.

It would be natural to represent the experiment hierarchy as described as a traditional XML hierarchy, where higher-level elements encapsulate lower-level elements as child elements. However, in XCEDE, all level elements (`<project>`, `<visit>`, etc.) are stored as children of the root `<XCEDE>` element. Links between levels are implicit in the level IDs assigned to each element and propagated to elements in lower levels. One advantage of this approach is to allow users of the schema to omit levels merely by omitting the unnecessary elements and IDs/links. Applications are also easier to write because all major elements are stored in the same place (under the XCEDE root element).

## 2.1.2. IDs and Linking

Any level element can be the target of a link from another element. In addition, most level elements are implicitly linked to "ancestor" level elements. Both these types of links are created by specifying one or more *level IDs* that together uniquely describe a target level element.

Every level element has a set of these level IDs, composed of the element's own `ID` attribute, plus its "ancestor" ID attributes, indicating which higher-level elements have this element in their scope. For example, the `<visit>` element contains `subjectGroupID`, `subjectID`, and `projectID` attributes.

For example, a link to a visit element may specify `visitID`, `subjectID`, `subjectGroupID`, and `projectID` attributes, and a `level` attribute with the value `visit`, indicating that this link is to a visit element. An application resolving this link will search for a visit element in the XCEDE 2 dataset whose attributes match those specified in the link (the `visitID` attribute is matched against the `ID` attribute in the visit element). Level ID attributes not specified in the link should match any value, but a link must specify enough of these IDs match at most one level element.

The elements that can link to any level element are `<catalog>`, `<resource>`, and `<data>` (children of the `<XCEDE>` root element), `<inputRef>` and `<outputRef>` (children of the `<analysis>` element). Level elements (except for `<project>` and `<subject>`, which are at the top of the experiment hierarchy) can be implicitly linked to ancestor elements using the attributes provided.

# 2.2. Examples

## 2.2.1. Metadata hierarchy

The metadata hierarchy illustrated in Figure 2.1 can be represented in XCEDE as shown in Figure 2.2 (only those elements/attributes relevant to linking are shown; the actual metadata contents of the elements are omitted for space).

### Figure 2.2. Metadata hierarchy instance

```
<XCEDE -xmlns="http://www.xcede.org/xcede-2">
 - -<project -ID="A">
 - - - -<projectInfo>
 - - - - - -<subjectGroupList>
 - - - - - - - -<subjectGroup -ID="X">
 - - - - - - - - - -<subjectID>1</subjectID>
 - - - - - - - - - -<subjectID>2</subjectID>
 - - - - - - - -</subjectGroup>
 - - - - - -</subjectGroupList>
 - - - -</projectInfo>
 - -</project>
 - -<project -ID="B">
 - - - -<projectInfo>
 - - - - - -<subjectGroupList>
 - - - - - - - -<subjectGroup -ID="Z">
 - - - - - - - - - -<subjectID>3</subjectID>
 - - - - - - - -</subjectGroup>
 - - - - - -</subjectGroupList>
 - - - -</projectInfo>
 - -</project>
 - -<subject -ID="1" -/>
 - -<subject -ID="2" -/>
 - -<subject -ID="3" -/>
 - -<visit -ID="1"
 - - - - - - - - -projectID="A" -subjectID="1" -subjectGroupID="X" -/>
 - -<study -ID="MR -scan"
 - - - - - - - - -projectID="A" -subjectID="1" -subjectGroupID="X" -visitID="1" -/>
 - -<episode -ID="task -run -1"
 - - - - - - - - -projectID="A" -subjectID="1" -subjectGroupID="X" -visitID="1" -studyID="MR" -/>
 - -<acquisition -ID="MR -image"
 - - - - - - - - -projectID="A" -subjectID="1" -subjectGroupID="X" -visitID="1" -studyID="MR"
 - - - - - - - - -episodeID="task -run -1" -/>
 - -<acquisition -ID="behavioral -data"
 - - - - - - - - -projectID="A" -subjectID="1" -subjectGroupID="X" -visitID="1" -studyID="MR"
 - - - - - - - - -episodeID="task -run -1" -/>
 - -<acquisition -ID="heart -rate"
 - - - - - - - - -projectID="A" -subjectID="1" -subjectGroupID="X" -visitID="1" -studyID="MR"
 - - - - - - - - -episodeID="task -run -1" -/>
 - -<study -ID="Clinical -interview"
 - - - - - - - - -projectID="A" -subjectID="1" -subjectGroupID="X" -visitID="2" -/>
 - -<!-- -... -etc. -... --->
</XCEDE>
```

# Chapter 3. Binary Data Resources

## 3.1. Overview

The XCEDE 2 *Binary Data Resource* component is used to provide a generic interface to a binary data stream stored in one or more external files. Any of the binary data resource types described in this chapter can be used anywhere an `abstract_resource_t` is called for (with the appropriate `xsi:type` attribute); in the current XCEDE schema, these locations are the top-level `<resource>` element and the `<dataResource>` child element of `<acquisition>`.

XCEDE provides multiple layers of derived types to store more specialized information about the binary data. The base type and each of the derived types are described in turn.

**abstract_resource_t.** The abstract base type `abstract_resource_t` provides a few elements and attributes that are especially important for binary data resources. In particular, the `<uri>` element and its `offset` and `size` attributes point to a “chunk” of data stored in an external file. A series of `<uri>` elements define a stream of data that may be described in greater detail by the data types described below.

**binaryDataResource_t.** This type derives from `abstract_resource_t` and allows an application to interpret the data stream as a sequence of data items with a given data type (`<elementType>`) and byte order (`<byteOrder>`).

**dimensionedBinaryDataResource_t.** The data stream, until now, could only be interpreted as a one-dimensional sequence. This type provides `<dimension>` elements that allow the data stream to be interpreted as a multi-dimensional array of data items. Each dimension has a `<size>` and a `<label>`, as well as the ability to discard subsets of the data in the data stream (using the `outputSelect` attribute).

**mappedBinaryDataResource_t.** This type places the multi-dimensional array of data items represented by `dimensionedBinaryDataResource_t` into an arbitrary coordinate system.

## 3.2. Examples

Several examples of binary data are presented here, each showing the use of one of the different binary data types described in this chapter.

### 3.2.1. Basic data stream

The basic binary data resource type describes a sequence of data items. For example, consider a data file (`random_data_file.bin`) containing 2048 random 32-bit floating point numbers, stored in little-endian (least-significant-byte first) order. The `<dataResource>` describing this data is shown in Figure 3.1.

**Figure 3.1. Simple `binaryDataResource_t` example**

```
<dataResource -xsi:type="binaryDataResource_t">
 - -<uri -offset="0" -size="8192">random_data_file.bin</uri>
 - -<elementType>float32</elementType>
 - -<byteOrder>lsbfirst</byteOrder>
</dataResource>
```

Note the `xsi:type` specifying that this `<dataResource>` element is of type `binaryDataResource_t`. (The `xsi:` prefix should have already been declared previously in the XML file using something similar to `xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"`)

The `<elementType>` element is restricted to one of several pre-defined strings (see the schema for details). The `<byteOrder>` element must be `lsbfirst` for little-endian data or `msbfirst` for big-endian data.

If the `<compression>` element is specified, it specifies that the file(s) pointed to by the `<uri>` elements are compressed. The content of the element should specify which type of compression (the only compression method specifically recognized by this specification is `gzip`). The `size` and `offset` attributes in the `<uri>` element always refer to the *uncompressed* data. An example of this is shown in Figure 3.2.

### Figure 3.2. `binaryDataResource_t` with compression

```
<dataResource -xsi:type="binaryDataResource_t">
 - -<uri -offset="0" -size="8192">random_data_file.bin.gz</uri>
 - -<elementType>float32</elementType>
 - -<byteOrder>lsbfirst</byteOrder>
 - -<compression>gzip</compression>
</dataResource>
```

As a special case, if the application does not find the file pointed to by a URI, and the `<compression>` element is *not* present, it may search for the same file with an appended `.gz` suffix, and if it exists, treat it as implicitly gzip-compressed data. Figure 3.3 shows how the same data in Figure 3.2 could be expressed using this alternative method. Pointing to the uncompressed version of the file (even when only the compressed version exists) allows the user to decompress or compress the data file at will, without affecting the ability of the application to read the data using the same `binaryDataResource_t`. Note that the `<uri>` and `<compression>` elements must be internally consistent. It would be an error to reference the uncompressed file `random_data_file.bin` and yet say that it was compressed using `<compression>gzip</compression>`. Likewise, explicit references to the compressed file (especially files that do not have the `.gz` suffix) must specify the compression method explicitly using the `compression` element.

### Figure 3.3. `binaryDataResource_t` with implicit compression

```
<dataResource -xsi:type="binaryDataResource_t">
 - -<uri -offset="0" -size="8192">random_data_file.bin</uri>
 - -<elementType>float32</elementType>
 - -<byteOrder>lsbfirst</byteOrder>
</dataResource>
```

## 3.2.2. Dimensioned data

Consider a camera that acquires an image using a 256x256 matrix of big-endian 32-bit signed integer voxels. This data has two spatial dimensions, which, by convention, we label x, and y (and z if a third spatial dimension is needed, and t if there is a time dimension). Figure 3.4 shows how this data might be represented.

### Figure 3.4. `dimensionedBinaryDataResource_t` example

```
<dataResource -xsi:type="dimensionedBinaryDataResource_t">
 - -<uri -offset="0" -size="262144">rawdata.img</uri>
 - -<elementType>int32</elementType>
 - -<byteOrder>msbfirst</byteOrder>
 - -<dimension -label="x">
 - - - -<size>256</size>
 - -</dimension>
 - -<dimension -label="y">
 - - - -<size>256</size>
 - -</dimension>
</dataResource>
```

Dimensions are ordered from fastest-moving to slowest-moving. So in the above example, the x dimension index changes on each consecutive data item, but the y dimension changes every 256 elements.

# 3.2.3. Mapped data

A “mapped” binary data resource is a (perhaps multidimensional) array of values, the matrix indices of which can be converted into a location in a given coordinate system. The location of the bounding box of the data in this space is given by specifying a location (in target-space coordinates) for the the first data item, and two things for each dimension: a unit-length direction vector (in the target-space coordinate system) and the spacing between successive data items in that dimension. The transformation matrix for a three-dimensional coordinate system has the form shown in Figure 3.5. This transformation matrix converts from matrix indices `(x,y,z)` to a coordinate location `(a,b,c)`. Figure 3.6 shows how the components of a transformation of MR image data into scanner RAS (Right/Anterior/Superior) coordinates are represented in a `mappedBinaryDataResource_t`. The unit vectors for each dimension are ($X_A$ $X_B$ $X_C$) = (1 0 0), ($Y_A$ $Y_B$ $Y_C$) = ( 0 1 0 ), and ($Z_A$ $Z_B$ $Z_C$) = ( 0 0 1 ), and are placed in the `<direction>` elements in each `<dimension>` element. The spacing values ($S_X$ $S_Y$ $S_Z$) = ( 3.75mm 3.75mm 4mm ) are put in the `<spacing>` element in each `<dimension>`. The coordinates of the first voxel in the data are given by ($O_A$ $O_B$ $O_C$) = ( -120 -120 -52 ).

### Figure 3.5. Transformation matrix

$$\begin{pmatrix} X_A & Y_A & Z_A & O_A \\ X_B & Y_B & Z_B & O_A \\ X_C & Y_C & Z_C & O_C \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} S_X & 0 & 0 & 0 \\ 0 & S_Y & 0 & 0 \\ 0 & 0 & S_Z & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} i \\ j \\ k \\ 1 \end{pmatrix} = \begin{pmatrix} a \\ b \\ c \\ 1 \end{pmatrix}$$

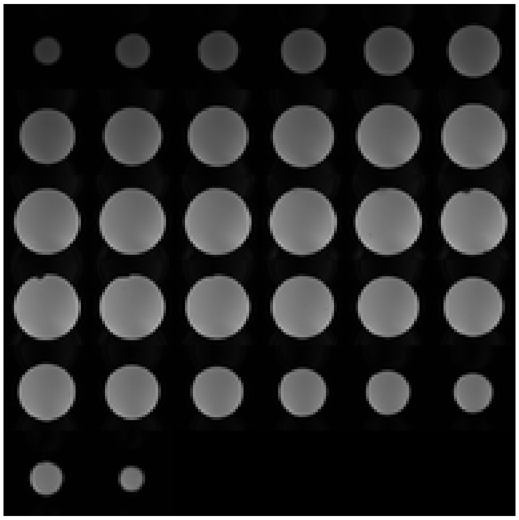
**Figure 3.6. `mappedBinaryDataResource_t` example**

```
<dataResource -xsi:type="mappedBinaryDataResource_t">
 - -<uri -offset="0" -size="442368">V0001.img</uri>
 - -<uri -offset="0" -size="442368">V0002.img</uri>
 - -<uri -offset="0" -size="442368">V0003.img</uri>
 - -<uri -offset="0" -size="442368">V0004.img</uri>
 - -<uri -offset="0" -size="442368">V0005.img</uri>
 - -<!-- -... -135 -more -<uri> -elements -omitted -for -space -... --->
 - -<elementType>int32</elementType>
 - -<byteOrder>msbfirst</byteOrder>
 - -<dimension -label="x">
 - - - -<size>64</size>
 - - - -<spacing>3.75</spacing>
 - - - -<gap>0</gap>
 - - - -<direction>1 -0 -0</direction>
 - - - -<units>mm</units>
 - -</dimension>
 - -<dimension -label="y">
 - - - -<size>64</size>
 - - - -<spacing>3.75</spacing>
 - - - -<gap>0</gap>
 - - - -<direction>0 -1 -0</direction>
 - - - -<units>mm</units>
 - -</dimension>
 - -<dimension -label="z">
 - - - -<size>27</size>
 - - - -<spacing>4</spacing>
 - - - -<gap>1</gap>
 - - - -<direction>0 -0 -1</direction>
 - - - -<units>mm</units>
 - -</dimension>
 - -<dimension -label="t">
 - - - -<size>140</size>
 - - - -<spacing>2</spacing>
 - - - -<gap>0</gap>
 - - - -<datapoints>0 -2 -4 -6 -8</datapoints>
 - - - -<units>sec</units>
 - -</dimension>
 - -<originCoords>-120 --120 --52</originCoords>
</dataResource>
```

## 3.2.4. Advanced topic: split dimensions and outputSelect

A more complicated example is given by data generated by a Siemens MR scanner. In this case, the data represents a three-dimensional 64x64x32 image, stored in DICOM format. However, because the earlier versions of the DICOM format did not support three-dimensional data in one file, Siemens came upon the clever idea to “tile” the 32 two-dimensional slices across an NxN two-dimensional grid (Figure 3.7).

**Figure 3.7. A “tiled”image**



Applications may naturally want to express this data as a three-dimensional block, with columns, rows, and slices. In a conventionally-stored three-dimensional X×Y×Z image, the first X voxels compose the first row in the first slice, and then the next X voxels are the second row in the first slice; likewise the first X*Y voxels are the first slice, and the next X*Y voxels are the second slice, and so on. However, in the “tiled” image, though the first X voxels are again the first row in the first slice, the next X voxels are the first row in the second slice! At first it would seem that the dimension order has merely been switched, and specifying the labels of the dimensions as x, z, and y would fix things. However, we only hit six slices' first rows before hitting going to the second row of the same six slices. Only after going through all the rows in this fashion in the first six slices do we go on to the next six slices.

The end result is that the dimension that we are calling the z dimension has been split in two. The two components of the z dimension are interleaved with the x and y dimensions like so: x, $z_1$, y, $z_2$. The two components of the z dimension are distinguished with the `splitRank` attribute, as shown in Figure 3.8.

**Figure 3.8. Split dimension example**

```
<dataResource -xsi:type="binaryDataResource_t">
 - -<uri -offset="9240" -size="589824">img0001.dcm</uri>
 - -<elementType>uint32</elementType>
 - -<byteOrder>lsbfirst</byteOrder>
 - -<dimension -label="x">
 - - - -<size>64</size>
 - -</dimension>
 - -<dimension -label="z" -splitRank="1">
 - - - -<size>6</size>
 - -</dimension>
 - -<dimension -label="y">
 - - - -<size>64</size>
 - -</dimension>
 - -<dimension -label="z" -splitRank="2">
 - - - -<size>6</size>
 - -</dimension>
</dataResource>
```

Applications should read this data as if it were four dimensions, and then permute the data to bring the two z dimensions together (in the order specified by splitRank) in the position of the highest-ranked split dimension, and the two dimensions can then be merged into one. The size of the new z dimension is the product of the sizes of the component split dimensions, so 6 * 6 = 36.

You may recall that the original data was acquired as a 64x64x32 volume, but the NxN tiling representation requires that the number of tiles be the square of an integer N. One more mechanism has been added to the `<dimension>` element to accomodate the presence of data that should be disregarded: the `outputSelect` attribute (see Figure 3.9).

### Figure 3.9. `outputSelect` example

```
<dataResource -xsi:type="binaryDataResource_t">
 - -<uri -offset="0" -size="589824">img0001.dcm</uri>
 - -<elementType>uint32</elementType>
 - -<byteOrder>lsbfirst</byteOrder>
 - -<dimension -label="x">
 - - - -<size>64</size>
 - -</dimension>
 - -<dimension -label="z" -splitRank="1">
 - - - -<size>6</size>
 - -</dimension>
 - -<dimension -label="y">
 - - - -<size>64</size>
 - -</dimension>
 - -<dimension -label="z" -splitRank="2" -outputSelect="0 -1 -2 -3 -4 -5 -6 -7 -8 -9 -10 -11 -12 -13 -1
 - - - -<size>6</size>
 - -</dimension>
</dataResource>
```

The `outputSelect` attribute specifies a list of indices along the given dimension (or combined dimension if it occurs on the highest-ranked component of a split dimension) that should be regarded as valid data. Data in the other indices should be ignored.

# Chapter 4. Catalogs

## 4.1. Overview

Catalogs in XCEDE 2 are containers of related resources, resource references, and data references. They are recursive in that catalogs can contain a list of catalogs and catalog references.

Catalogs are represented by the catalog_t complex type, derived from abstract_tagged_entity_t. The catalog child element of the root XCEDE element is of type catalog_t. The resources included in the catalog can be pointed to from by resource references in a number of places in XCEDE, including analysis_t and acquisition_t.

Catalogs are useful in a number of contexts. A catalog could be created, for example, to represent all of the acquisition resources associated with an episode. These catalogs could be contained within a parent catalog that represents each of the episodes in an MR study. Catalogs could also be used to represent the various resources generated as part of an analysis or uploaded and tagged by users.

A benefit of using catalogs, as opposed to linking resources directly in analysis and acquisition elements, is that the catalogs can be sent to client applications that choose not to support the full XCEDE specification.

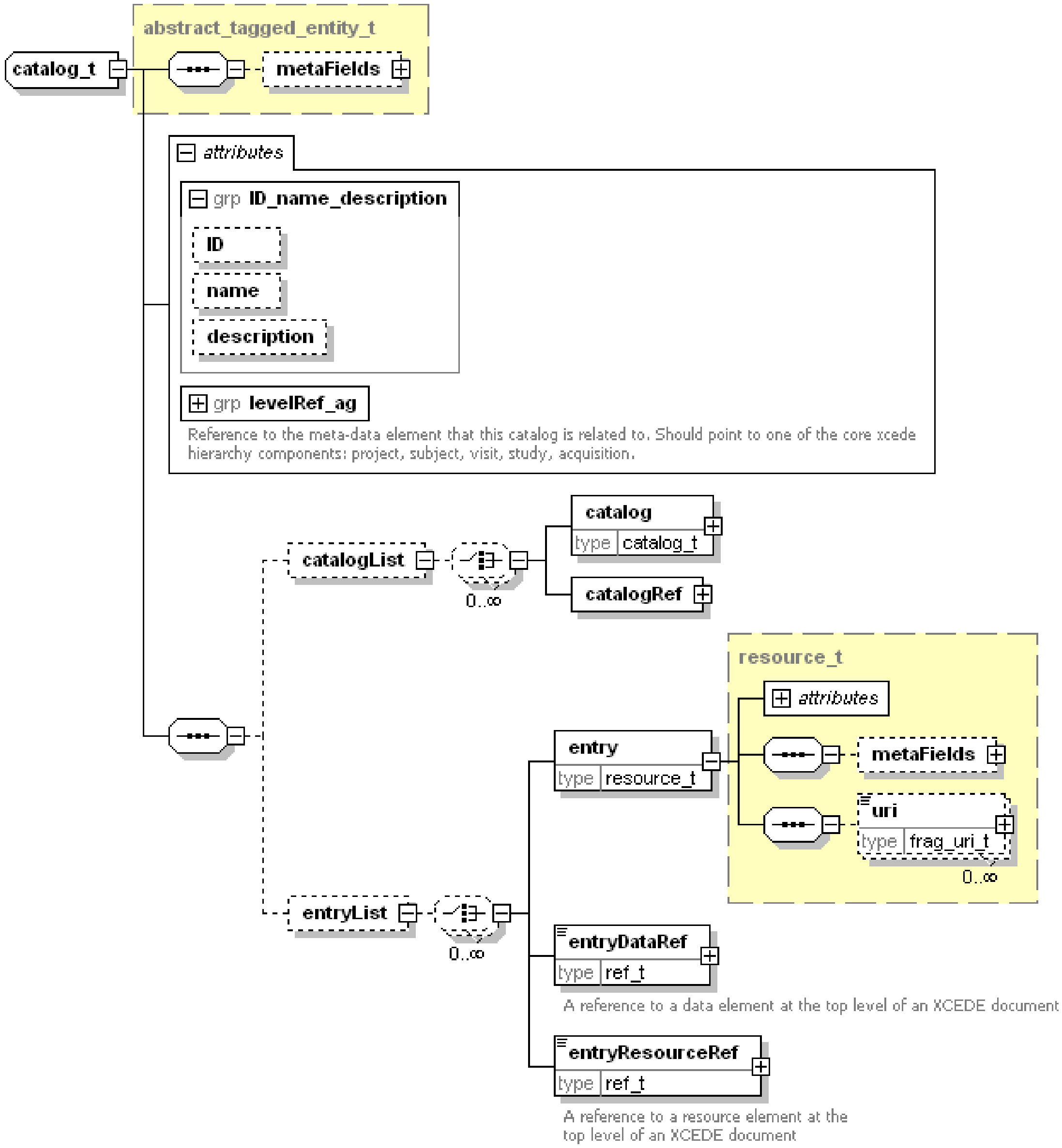
## 4.2. Examples

### Figure 4.1. Catalog instance

```
<XCEDE>
 <catalog -ID="ID0">
  <catalogList>
   <catalog -ID="ID1">
    <entryList>
     <entry -ID="ID2" -name="lh.pial" -description="pial -surface -of -left -hemisphere" -format="FreeS
     <entry -ID="ID3" -name="brain" -description="extracted -brain -mri" -format="FreeSurfer:mgz-1" -co
     <entry -ID="ID4" -name="zstat8" -description="8th -zstatisic -contrast" -format="nifti:nii-1" -con
     <entry -ID="ID5" -name="aparc+aseg" -description="parcellation -and -segmentation -label -map" -fo
    </entryList>
   </catalog>
   <catalog -ID="ID1">
    <entryList>
     <entry -ID="ID2" -name="lh.pial" -description="pial -surface -of -left -hemisphere" -format="FreeS
     <entry -ID="ID3" -name="brain" -description="extracted -brain -mri" -format="FreeSurfer:mgz-1" -co
     <entry -ID="ID4" -name="zstat8" -description="8th -zstatisic -contrast" -format="nifti:nii-1" -con
     <entry -ID="ID5" -name="aparc+aseg" -description="parcellation -and -segmentation -label -map" -fo
    </entryList>
   </catalog>
  </catalogList>
 </catalog>
</XCEDE>
 -
```

# 4.3. Reference

**Figure 4.2. catalog_t**



# Chapter 5. Provenance

Provenance is used to record in detail the sequence of processing and analysis steps that have been executed to create a derived image and/or measures. These details include the name and type of machine on which the executable was run, the name of the executable, and input parameters to the exectuable.

## 5.1. Overview

XCEDE-represented studies will be populated with large numbers of medical image volumes which researchers will wish to access and run various processing tools on in order to obtain derived data. This derived data, such as volumes of various brain structures, cortical thickness etc., will then be placed back into the database, linked to the original volume from which it was produced. If a researcher would like to recreate the processing steps, in order to apply it to a new data set, they will be able to obtain the information needed to download or reconstruct the tools that were used on the original data set. Information about the processing tools needs to be made available by the authors of the tools, is collected at run time by the processing scripts, and written into XCDED.

## 5.2. Examples

## 5.3. Reference

# Chapter 6. Events

## 6.1. Overview

*Events* in XCEDE are merely time intervals annotated with arbitrary metadata. This component can be used to represent several types of behavioral data, statistics calculated on time series data, or any other metadata whose proper interpretation requires that it be associated with a particular time interval.

An XCEDE event consists of the following:

| | |
|---|---|
| onset | The onset (in seconds) of the time interval. |
| duration | The duration (in seconds) of the time interval. |
| type | Usage of this field is user-specified |
| name | Usage of this field is user-specified |
| units | The units of the onset and duration fields. This field is optional, and it is recommended that users of the schema prescribe an implicit unit of measurement and use it consistently. In that case, this field may be considered informational only. |
| values | A *value* adds named metadata to this event. |

The following instance shows how each of these fields may be populated.

```
<event -type="visual" -name="event#1" -units="sec">
 - -<onset>0</onset>
 - -<duration>2</duration>
 - -<value -name="shape">square</value>
 - -<value -name="shapecolor">red</value>
</event>
```

Event elements are stored within the `<data>` element of an `<acquisition>`. The `<data>` element should be of type `events_t` (using `xsi:type` — see examples below).

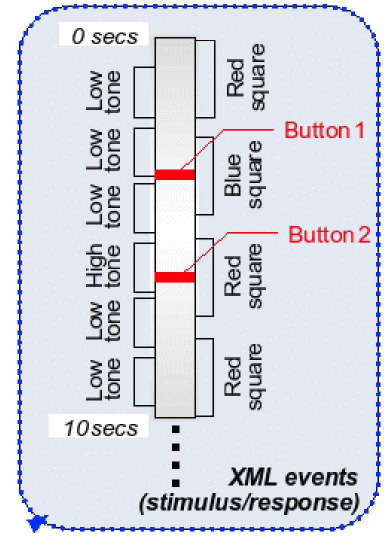
All onsets are relative to an arbitrary time reference. Typically, time 0 (zero) could mean the start of data acquisition. An event list may be interpreted as concurrent with data in other `<acquisition>` elements (which could be other event lists). If so, the same time reference should be used in all concurrent acquisition data.

There is no ordering constraint on events in a list. Applications should depend on using the `<onset>` elements to order the events chronologically if they so desire.

An optional `<params>` element may precede the first event in a list, and this element stores arbitrary metadata (using the same `<value>` element used above) that apply to all events in the list.

# 6.2. Examples

**Figure 6.1. An event timeline**




Consider the timeline shown in Figure 6.1, representing stimuli and responses in a neuroimaging study. We show in Figure 6.2 how the first 5 seconds' worth of the events might be represented in XCEDE.

### Figure 6.2. XCEDE Events example - stimulus/response data

```
<XCEDE -xmlns="http://www.xcede.org/xcede-2"
 - - - - - - -xmlns:xsi='http://www.w3.org/2001/XMLSchema-instance'>
 - -<acquisition -ID="my_stimulus_response_data">
 - - - -<dataRef -ID="my_events" -/>
 - -</acquisition>
 - -<data -ID="my_events" -xsi:type="events_t">
 - - - -<event -type="visual">
 - - - - - -<onset>0</onset>
 - - - - - -<duration>2</duration>
 - - - - - -<value -name="shape">square</value>
 - - - - - -<value -name="shapecolor">red</value>
 - - - -</event>
 - - - -<event -type="visual">
 - - - - - -<onset>2.5</onset>
 - - - - - -<duration>2</duration>
 - - - - - -<value -name="shape">square</value>
 - - - - - -<value -name="shapecolor">blue</value>
 - - - -</event>
 - - - -<event -type="audio">
 - - - - - -<onset>0.3</onset>
 - - - - - -<duration>1.4</onset>
 - - - - - -<value -name="frequency">low</value>
 - - - -</event>
 - - - -<event -type="audio">
 - - - - - -<onset>2.0</onset>
 - - - - - -<duration>1.4</onset>
 - - - - - -<value -name="frequency">low</value>
 - - - -</event>
 - - - -<event -type="audio">
 - - - - - -<onset>3.5</onset>
 - - - - - -<duration>1.4</onset>
 - - - - - -<value -name="frequency">low</value>
 - - - -</event>
 - - - -<event -type="response">
 - - - - - -<onset>3.4</onset>
 - - - - - -<value -name="button">1</value>
 - - - -</event>
 - -</data>
</XCEDE>
```

Each stimulus and each response are stored as separate event elements. Note that all the visual events appear first in the XCEDE file, then the audio events, and then the response event. This ordering is arbitrary, and the events could easily have been presented in chronological (or random!) order. The semantic interpretation of the events within an event list must not depend on their document order.

Stimulus and response data are not the only appropriate content to represent in XCEDE events. Figure 6.3 shows how quality assurance (QA) statistics for each volume/timepoint in an fMRI scan can be stored as events. Note that the time reference for the onsets is arbitrary, but if the `acquisition` containing the event data is contained within the same `episode` as other time-locked data, it should be assumed that the time reference is the same for all `acquisitions` within the `episode`, unless otherwise explicitly specified. So, for example, this QA data might be associated with MR image data in the same `episode`, and time 0 (zero) would by default be assumed to have the same meaning in both sets of data.

## Figure 6.3. XCEDE Events example - QA data

```
<XCEDE -xmlns="http://www.xcede.org/xcede-2"
 - - - - - - -xmlns:xsi='http://www.w3.org/2001/XMLSchema-instance'>
 - -<acquisition -ID="my_stimulus_response_data">
 - - - -<dataRef -ID="my_events" -/>
 - -</acquisition>
 - -<data -ID="my_events" -xsi:type="events_t">
 - - - -<event>
 - - - - - -<onset>0</onset>
 - - - - - -<duration>2</duration>
 - - - - - -<value -name="volmean">759.218</value>
 - - - - - -<value -name="cmassx">106.781</value>
 - - - - - -<value -name="cmassy">118.279</value>
 - - - - - -<value -name="cmassz">66.9694</value>
 - - - -</event>
 - - - -<event>
 - - - - - -<onset>2</onset>
 - - - - - -<duration>2</duration>
 - - - - - -<value -name="volmean">759.218</value>
 - - - - - -<value -name="cmassx">106.801</value>
 - - - - - -<value -name="cmassy">118.242</value>
 - - - - - -<value -name="cmassz">67.1636</value>
 - - - -</event>
 - - - -<!-- -... -etc. -... --->
 - -</data>
</XCEDE>
```

# Chapter 7. Assessments

## 7.1. Overview

Complete data storage and assessment specifications and descriptions are stored in XCEDE using the `assessment_t` and `assessmentDescItem_t` tag structures.

The description of the assessment questions and possible answer choices are specified in the protocol section of the schema whereas the actual assessment data for an acquisition are stored in the `assessment_t` tags

**`assessment_t`.** The `assessment_t` tag extends the `abstract_data_t` tag to include information about the acquired assessment.The *name* element contains the assessment name which is unique within the document and links the acquired listing of assessment data back to the formal assessment definition optionally contained within the protocol descriptionThe *dataInstance* element specifies the state of the acquired data. Specifically whether it is first entry, second entry, validated, unvalidated, etc.

**`assessmentInfo_t`.** The `assessmentInfo_t` tag is derived from the `abstract_info_t` element and is used to store a description of the assessment

**`assessmentItem_t`.** The `assessmentItem_t` tag is used to store the actual data captured by the assessment. The `assessmentItem_t` tag is composed of a `<valueStatus>` element which contains information about whether the subject declined to answer the question or why the data value might be missing. The `<value>` element stores the actual value of the assessment item as captured on the assessment iteself. The `<normValue>` is used to store the normalized value for the element. The `<reconciliationNote>` is used to document whether the values have been reconcilied if this data is part of multiple data entries. The `<annotation>` is used to annotate the assessment item.The `terminology_ag` reference is used to give contextual meaning to the question and link it with known ontologies and concepts.

## 7.2. Examples

The assessment example below shows both a formal assessment description stored in the `<protocol>` block and also the actual acquired assessment data

### 7.2.1. Formal Assessment Description

The formal description of each question for the assessment and possible answer choices

**Figure 7.1.**

```
-<xcede:step -ID="SES" -name="Socio-Economic -Scale" -minOccurences="1" -maxOccurences="1"
- - - - - - - - - - - - - - - -required="true">
- - - - - - - - - - - - - - - - - - - - - -<xcede:items>
- - - - - - - - - - - - - - - - - - - - - - -<xcede:item -ID="ses_education_subject">
- - - - - - - - - - - - - - - - - - - - - - - - - - -<xcede:itemText>
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -<xcede:textLabel -location="leadText"
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -value="What -is -the -highest -level -o
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -that -you -have -achieved?"/>
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -<xcede:textLabel -location="trailText"
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -value="Any -trailing -text -might -go -
- - - - - - - - - - - - - - - - - - - - - - - - - - -</xcede:itemText>
- - - - - - - - - - - - - - - - - - - - - - - - - - -<xcede:itemChoice -itemCode="1"
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -itemValue="professional -or -graduate -training
- - - - - - - - - - - - - - - - - - - - - - - - - - -<xcede:itemChoice -itemCode="2" -itemValue="college -gr
- - - - - - - - - - - - - - - - - - - - - - - - - - -<xcede:itemChoice -itemCode="3" -itemValue="some -colle
- - - - - - - - - - - - - - - - - - - - - - - -</xcede:item>
- - - - - - - - - - - - - - - - - - - - - - - -<xcede:item -ID="ses_education_p_caretaker_prior_18">
- - - - - - - - - - - - - - - - - - - - - - - - - - -<xcede:itemText>
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -<xcede:textLabel -location="leadText"
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -value="What -is -the -highest -level -o
- - - - - - - - - - - - - - - - - - - - - - - - - - -</xcede:itemText>
- - - - - - - - - - - - - - - - - - - - - - - - - - -<xcede:itemChoice -itemCode="1"
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -itemValue="professional -or -graduate -training
- - - - - - - - - - - - - - - - - - - - - - - - - - -<xcede:itemChoice -itemCode="2" -itemValue="college -gr
- - - - - - - - - - - - - - - - - - - - - - - - - - -<xcede:itemChoice -itemCode="3" -itemValue="some -colle
- - - - - - - - - - - - - - - - - - - - - - - -</xcede:item>
- - - - - - - - - - - - - - - - - - -</xcede:items>
- - - - - - - - - - - - - -</xcede:step>
```

## 7.2.2. Actual Acquired Assessment Data

An instance of actual assessment data acquired on a subject during a protocol collection

**Figure 7.2.**

```
<xcede:data -xsi:type="xcede:assessment_t" -subjectID="00301882920">
- - - - - - - -<xcede:name>Socio-Economic -Status</xcede:name>
- - - - - - - -<xcede:dataInstance -validated="true">
- - - - - - - - - - - - -<xcede:assessmentInfo>
- - - - - - - - - - - - - - - - - -<xcede:description>This -is -the -socio-economic -scale. -I'm -sure -th
- - - - - - - - - - - - - - - - - - - - - - -intersting -things -to -say -about -it -but -I -have -no -idea
- - - - - - - - - - - - -</xcede:assessmentInfo>
- - - - - - - - - - - - -<xcede:assessmentItem -ID="ses_education_subject">
- - - - - - - - - - - - - - - - - -<xcede:value>1</xcede:value>
- - - - - - - - - - - - -</xcede:assessmentItem>
- - - - - - - - - - - - -<xcede:assessmentItem -ID="ses_education_p_caretaker_prior_18">
- - - - - - - - - - - - - - - - - -<xcede:value>2</xcede:value>
- - - - - - - - - - - - -</xcede:assessmentItem>
- - - - - - - - - - - - -<xcede:assessmentItem -ID="ses_education_p_caretaker_lifetime">
- - - - - - - - - - - - - - - - - -<xcede:value>2</xcede:value>
- - - - - - - - - - - - -</xcede:assessmentItem>
- - - - - - - - - - - - -<xcede:assessmentItem -ID="ses_education_s_caretaker_prior18">
- - - - - - - - - - - - - - - - - -<xcede:value>1</xcede:value>
- - - - - - - - - - - - -</xcede:assessmentItem>
- - - - - - - -</xcede:dataInstance>
- - - -</xcede:data>
```

# 7.3. Reference

# Chapter 8. Protocols

## 8.1. Overview

## 8.2. Examples

## 8.3. Reference

# Chapter 9. Analysis

This is where the analysis text goes.

## 9.1. Overview

## 9.2. Examples

## 9.3. Reference

# Chapter 10. Terminology

This is where the terminology text goes.

## 10.1. Overview

## 10.2. Examples

## 10.3. Reference

# Part II. Using and Extending XCEDE 2

This section of the XCEDE 2.0 manual provides practical lessons on using the schema, as well as discussions on how to use W3C XML Schema to extend the core XCEDE 2 datatypes and how to integrate it into applications, databases and web services.

# Chapter 11. A Use Case

## 11.1. Overview

## 11.2. Examples

## 11.3. Reference

# Chapter 12. Extending the Schema

## 12.1. Overview

## 12.2. Examples

## 12.3. Reference

# Chapter 13. Integration With Applications and Services

## 13.1. Overview

## 13.2. Examples

## 13.3. Reference

# Appendix A. XML Schema for XCEDE 2.0

```
 - - - -<?xml -version="1.0" -encoding="UTF-8"?>
<!-- -edited -with -XMLSPY -v2004 -rel. -3 -U -(http://www.xmlspy.com) -by -dbk -(UNIV -CA -IRVINE) ---
<xs:schema -xmlns="http://www.xcede.org/xcede-2" -xmlns:xs="http://www.w3.org/2001/XMLSchema" -xmlns:sc
 <xs:import -namespace="http://www.opengis.net/gml" -schemaLocation="http://schemas.opengis.net/gml/3.1
 <xs:annotation>
  <xs:documentation>The -XCEDE -schema -provides -an -extensive -metadata -hierarchy -for -describing -
  <xs:documentation>Each -of -these -sub-schemas -is -composed -of -information -relevant -to -that -as
  <xs:documentation>XCEDE -was -originally -designed -in -the -context -of -neuroimaging -studies -and 
 </xs:annotation>
 <xs:element -name="XCEDE">
  <xs:complexType>
   <xs:choice -minOccurs="0" -maxOccurs="unbounded">
    <xs:element -name="annotationList" -minOccurs="0">
     <xs:complexType>
      <xs:sequence>
       <xs:element -name="annotation" -type="textAnnotation_t" -minOccurs="0" -maxOccurs="unbounded"/>
      </xs:sequence>
     </xs:complexType>
    </xs:element>
    <xs:element -name="revisionList" -minOccurs="0">
     <xs:annotation>
      <xs:documentation>container -for -document -revision -history</xs:documentation>
     </xs:annotation>
     <xs:complexType>
      <xs:sequence>
       <xs:element -name="revision" -type="revision_t" -minOccurs="0" -maxOccurs="unbounded"/>
      </xs:sequence>
     </xs:complexType>
    </xs:element>
    <xs:element -name="project" -type="project_t" -minOccurs="0" -maxOccurs="unbounded"/>
    <xs:element -name="subject" -type="subject_t" -minOccurs="0" -maxOccurs="unbounded"/>
    <xs:element -name="visit" -type="visit_t" -minOccurs="0" -maxOccurs="unbounded"/>
    <xs:element -name="study" -type="study_t" -minOccurs="0" -maxOccurs="unbounded"/>
    <xs:element -name="episode" -type="episode_t" -minOccurs="0" -maxOccurs="unbounded"/>
    <xs:element -name="acquisition" -type="acquisition_t" -minOccurs="0" -maxOccurs="unbounded"/>
    <xs:element -name="catalog" -type="catalog_t" -minOccurs="0" -maxOccurs="unbounded"/>
    <xs:element -name="analysis" -type="analysis_t" -minOccurs="0" -maxOccurs="unbounded"/>
    <xs:element -name="resource" -type="resource_t" -minOccurs="0" -maxOccurs="unbounded"/>
    <xs:element -name="protocol" -type="protocol_t" -minOccurs="0" -maxOccurs="unbounded"/>
    <xs:element -name="data" -type="abstract_data_t" -minOccurs="0" -maxOccurs="unbounded"/>
   </xs:choice>
   <xs:attribute -name="version" -type="xs:string"/>
  </xs:complexType>
 </xs:element>
 <!--********* - - - - - - - - - - - -Top-level -containers - - - - - - - - - - - -*********-->
 <xs:complexType -name="project_t">
  <xs:complexContent>
   <xs:extension -base="abstract_container_t">
    <xs:sequence>
     <xs:element -name="projectInfo" -type="projectInfo_t" -minOccurs="0"/>
     <xs:element -name="contributorList" -minOccurs="0">
      <xs:complexType>
       <xs:sequence>
        <xs:element -name="contributor" -type="person_t" -minOccurs="0" -maxOccurs="unbounded"/>
       </xs:sequence>
      </xs:complexType>
     </xs:element>
     <xs:any -namespace="##other" -minOccurs="0" -maxOccurs="unbounded"/>
    </xs:sequence>
```

```
  </xs:extension>
 </xs:complexContent>
</xs:complexType>
<xs:complexType -name="subjectGroup_t">
 <xs:annotation>
  <xs:documentation>There -should -be -one -of -these -elements -for -each -subject -group -in -this
   project -(e.g. -control, -patient).</xs:documentation>
 </xs:annotation>
 <xs:sequence>
  <xs:element -name="subjectID" -minOccurs="0" -maxOccurs="unbounded"/>
 </xs:sequence>
 <xs:attribute -name="ID"/>
 <xs:anyAttribute -namespace="##other" -processContents="lax"/>
</xs:complexType>
<xs:complexType -name="subject_t">
 <xs:complexContent>
  <xs:extension -base="abstract_container_t">
   <xs:sequence>
    <xs:element -name="subjectInfo" -type="subjectInfo_t" -minOccurs="0"/>
   </xs:sequence>
  </xs:extension>
 </xs:complexContent>
</xs:complexType>
<xs:complexType -name="visit_t">
 <xs:complexContent>
  <xs:extension -base="abstract_container_t">
   <xs:sequence>
    <xs:element -name="visitInfo" -type="visitInfo_t" -minOccurs="0"/>
    <xs:any -namespace="##other" -minOccurs="0" -maxOccurs="unbounded"/>
   </xs:sequence>
   <xs:attributeGroup -ref="visitExternalIDs_ag"/>
   <xs:anyAttribute -namespace="##other" -processContents="lax"/>
  </xs:extension>
 </xs:complexContent>
</xs:complexType>
<xs:complexType -name="study_t">
 <xs:complexContent>
  <xs:extension -base="abstract_container_t">
   <xs:sequence>
    <xs:element -name="studyInfo" -type="studyInfo_t" -minOccurs="0"/>
    <xs:any -namespace="##other" -minOccurs="0" -maxOccurs="unbounded"/>
   </xs:sequence>
   <xs:attributeGroup -ref="studyExternalIDs_ag"/>
   <xs:anyAttribute -namespace="##other" -processContents="lax"/>
  </xs:extension>
 </xs:complexContent>
</xs:complexType>
<xs:complexType -name="studyInfo_t">
 <xs:complexContent>
  <xs:extension -base="abstract_info_t"/>
 </xs:complexContent>
</xs:complexType>
<xs:complexType -name="episode_t">
 <xs:complexContent>
  <xs:extension -base="abstract_container_t">
   <xs:sequence>
    <xs:element -name="episodeInfo" -type="episodeInfo_t" -minOccurs="0"/>
    <xs:any -namespace="##other" -minOccurs="0" -maxOccurs="unbounded"/>
   </xs:sequence>
   <xs:attributeGroup -ref="episodeExternalIDs_ag"/>
   <xs:anyAttribute -namespace="##other" -processContents="lax"/>
  </xs:extension>
 </xs:complexContent>
</xs:complexType>
<xs:complexType -name="acquisition_t">
 <xs:complexContent>
  <xs:extension -base="abstract_container_t">
```

```
    <xs:sequence>
     <xs:element -name="acquisitionInfo" -type="acquisitionInfo_t" -minOccurs="0"/>
     <xs:choice -minOccurs="0">
      <xs:element -name="dataResourceRef" -type="ref_t">
       <xs:annotation>
        <xs:documentation>A -reference -to -a -resource -as -described -above. -The
         resource -could -be -part -of -a -catalog, -a -root -level -resource,
        etc.</xs:documentation>
       </xs:annotation>
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  </xs:annotation>
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   be -extended -to -capture -instance -specific -content -(following -recommendation
  5)</xs:documentation>
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         multiple -projects.</xs:documentation>
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              informant, -clinical -rater, -assessment -date,
             etc</xs:documentation>
```

```
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          <xs:documentation>Indicates -whether -the -instance -has -been
           validated -(e.g. -by -reconciling -double-entry -instances).
           There -should -be -only -one -validated -instance -per
          assessment.</xs:documentation>
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       answer)</xs:documentation>
     </xs:annotation>
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      form</xs:documentation>
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      item</xs:documentation>
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    info</xs:documentation>
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  <xs:annotation>
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    within -the -context -of -their -application -(for -example, -allowing -only
   LSID's)</xs:documentation>
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   referential -links. -The -reason -we -are -not -using -the -native -XML -Schema -ID -attribute -is
   that -enforces -document-wide -uniqueness, -whereas -there -may -be -instances -of -this
   bioterm -schema -that -contain -multiple -namespace-qualified -term -or -ontology -class -sets
   where -IDs -are -unique -within -their -namespace -but -not -across -the -entire -document.
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  </xs:annotation>
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  </xs:annotation>
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 </xs:annotation>
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   </xs:annotation>
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   <xs:annotation>
    <xs:documentation>Software -executable -to -was -run -in -this -step
    </xs:documentation>
   </xs:annotation>
  </xs:element>
  <xs:element -name="programInvocation" -type="mixedType_t">
   <xs:annotation>
    <xs:documentation>Exact -command -line -text -used -to -run -the
    executable</xs:documentation>
   </xs:annotation>
  </xs:element>
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   and -configuration -values</xs:documentation>
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 <xs:annotation>
  <xs:documentation>The -parent -type -(abstract_resource_t) -can -describe -a -stream -of -data.
   The -extensions -in -this -derived -type -(binaryDataResource_t) -tell -you -that -this -data
   stream -is -composed -of -a -sequence -of -units -of -a -given -data -type -and -byte -order. -If
   the -</xs:documentation>
 </xs:annotation>
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  <xs:extension -base="dataResource_t">
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```
      <xs:documentation>This -element -describes -the -type -of -individual -data
       elements -in -the -data -record. -For -numeric -data -types, -this -indicates
       whether -the -element -type -is -a -signed -integer -("int"), -unsigned
       integer -("uint"), -or -floating-point -("float"), -as -well -as -the -number
       of -bits -allocated -to -each -element.</xs:documentation>
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       <xs:enumeration -value="ascii"/>
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     </xs:simpleType>
    </xs:element>
    <xs:element -name="byteOrder" -minOccurs="0">
     <xs:annotation>
      <xs:documentation>This -element -describes -whether -the -individual -data
       elements -in -the -data -record -are -stored -with -the
       most-significant-byte -first -(msbfirst) -or -least-significant-byte
       first -(lsbfirst). -This -element -is -required -if -the -the -data -type
       given -by -the -"elementtype" -element -has -a -size -larger -than -one
      byte.</xs:documentation>
     </xs:annotation>
     <xs:simpleType>
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       <xs:enumeration -value="lsbfirst"/>
       <xs:enumeration -value="msbfirst"/>
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     </xs:simpleType>
    </xs:element>
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     <xs:annotation>
      <xs:documentation>If -this -element -is -present, -the -files -pointed -to -by
       the -uri -elements -are -compressed -data -files. -The -only -compression
       method -specifically -named -by -this -specification -is -"gzip". -As -a
       special -case -for -binaryDataResource_t -and -derived -types, -files
       compressed -with -gzip -and -containing -a -.gz -suffix -can -be -referenced
       in -the -uri -element -without -the -suffix. -If -a -file -pointed -to -by -the
       URI -does -not -exist, -the -application -should -search -for -the -same -file
       with -the -.gz -suffix -appended --- -if -it -exists, -use -that -file -and -act
       as -if -the -compression -element -had -been -specified -with -the -value
       "gzip". -This -allows -the -referenced -files -to -be -compressed -or
       uncompressed -at -will -(as -long -as -the -.gz -suffix -is -appropriately
       added/removed -from -the -filename), -without -needing -to -change -the
       URI's -in -this -element.</xs:documentation>
     </xs:annotation>
    </xs:element>
   </xs:sequence>
  </xs:extension>
 </xs:complexContent>
</xs:complexType>
<xs:complexType -name="dimensionedBinaryDataResource_t">
 <xs:annotation>
  <xs:documentation -xml:lang="en">This -type -adds -multi-dimensionality -to -the
   (uni-dimensional) -data -stream -represented -by
  binaryDataResource_t.</xs:documentation>
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  <xs:extension -base="binaryDataResource_t">
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  <xs:annotation>
   <xs:documentation -xml:lang="en">This -type -places -the -multi-dimensional -data -array -(say -a
    3-dimensional -cube) -into -a -coordinate -space -(say -MR -scanner
   coordinates).</xs:documentation>
  </xs:annotation>
  <xs:complexContent>
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       <xs:documentation -xml:lang="en">This -is -a -coordinate -tuple -giving -the
        location -of -the -first -item -in -the -data. -For -example, -if -this -is -an
        MR -volume, -this -could -be -a -triple -giving -the -location -in -RAS
        coordinates -of -the -first -voxel -in -the -data.</xs:documentation>
      </xs:annotation>
     </xs:element>
    </xs:sequence>
   </xs:extension>
  </xs:complexContent>
 </xs:complexType>
 <xs:complexType -name="binaryDataDimension_t">
  <xs:annotation>
   <xs:documentation -xml:lang="en">This -element -stores -information -about -one -of -the -N
    dimensions -in -the -data -record. -Multiple -instances -of -this -element -are -ordered -from
    fastest-moving -to -slowest-moving. -These -elements -provide -information -to -describe -the
    size -(in -data -elements) -of -the -N-dimensional -bounding -box -for -the -data, -and -in -some
    cases -to -describe -the -mapping -of -indexes -within -this -bounding -box -to -'real-world'
    coordinates.</xs:documentation>
  </xs:annotation>
  <xs:sequence>
   <xs:element -name="size" -type="xs:int">
    <xs:annotation>
     <xs:documentation -xml:lang="en">The -number -of -elements -in -the -data -along -one
      traversal -of -this -dimension.</xs:documentation>
    </xs:annotation>
   </xs:element>
  </xs:sequence>
  <xs:attribute -name="label" -type="xs:string">
   <xs:annotation>
    <xs:documentation -xml:lang="en">This -is -a -label -for -the -dimension. -The -first -three
     spatial -dimensions -(or -however -many -exist) -must -be -labeled, -in -order, -'x', -'y',
     and -'z'. -The -first -temporal -dimension -must -be -labeled -'t'.</xs:documentation>
   </xs:annotation>
  </xs:attribute>
  <xs:attribute -name="splitRank" -type="xs:string">
   <xs:annotation>
    <xs:documentation>If -this -attribute -exists, -this -dimension -is -a -"split" -dimension,
     and -this -dimension -must -be -"merged" -with -one -or -more -other -dimensions -(with -the
     same -label) -before -presenting -the -data -to -the -application. -This -is -useful, -for
     example, -if -the -data -is -stored -in -Siemens' -Mosaic -DICOM -format, -where -slices -of
     a -3-D -volume -are -arranged -to -look -like -they -are -tiled -onto -a -square -2-D -area. -In
     this -case, -what -would -normally -be -called -the -'z' -dimension -has -two -forks, -one
     that -occurs -before -the -'y' -dimension -(the -first -row -in -the -data -covers -the -first
     row -of -several -slices), -and -one -that -occurs -after -the -'y' -dimension. -If, -as -in
     this -case, -there -are -two -or -more -dimensions -that -should -be -merged -into -one, -both
     component -dimensions -should -have -the -label -'z', -but -have -splitRank -attributes
     "1" -and -"2", -which -specifies -the -order -in -which -all -'split' -dimensions -of -the
     same -label -will -be -merged. -After -merging, -the -resultant -'z' -dimension -element
     should -contain -the -same -children -of -the -highest-ranked -split -'z' -dimension,
```

```
    except -for -the -'size' -element, -which -will -be -the -product -of -the -sizes -of -all -'z'
    split -dimensions. -The -position -of -the -resultant -dimension -should -be -the -position
    of -the -highest-ranked -'z' -split -dimension. -The -data -itself -should -also -be
    reordered -to -reflect -the -new -dimension -structure.</xs:documentation>
  </xs:annotation>
 </xs:attribute>
 <xs:attribute -name="outputSelect" -type="xs:string">
  <xs:annotation>
   <xs:documentation -xml:lang="en">In -the -same -way -that -the -'splitRank' -attribute
    allows -you -to -specify -dimensions -that -should -be -merged -before -presenting -the
    data -to -an -application, -this -attribute -specifies -a -data -filter -along -this
    dimension. -If -this -attribute -exists, -it -should -contain -a -whitespace-separated
    list -of -indices -(indexed -starting -at -0). -Only -data -points -along -this -dimension
    that -occur -in -the -index -list -should -be -presented -to -the -application. -Likewise,
    the -'size' -of -the -dimension, -after -selection, -should -be -updated -to -reflect -the
    new -size -of -this -dimension -(which -should -be -the -number -of -indices -in -the -content
    of -this -attribute).</xs:documentation>
  </xs:annotation>
 </xs:attribute>
</xs:complexType>
<xs:complexType -name="mappedBinaryDataDimension_t">
 <xs:complexContent>
  <xs:extension -base="binaryDataDimension_t">
   <xs:sequence>
    <xs:element -name="origin" -type="xs:float" -minOccurs="0">
     <xs:annotation>
      <xs:documentation -xml:lang="en">A -value -assigned -to -the -first -data
       element -along -this -dimension. -For -example, -if -this -dimension
       corresponds -to -"time", -this -element -could -store -the -time
       corresponding -to -the -first -data -element. -If -this -is -a
       two-dimensional -projection -of -the -surface -of -the -Earth, -and -this
       dimension -takes -you -around -the -Earth -parallel -to -the -equator, -this
       value -could -be -the -degrees -longitude. -For -MRI -data, -this -is -the
       single -coordinate -on -the -Left-to-Right, -Posterior-to-Anterior, -or
       Inferior-to-Superior -axis -to -which -this -dimension -most -closely
       matches -(see -'direction' -element -and -'rasOrigin' -element -in
       'mrImageDataResource_t').</xs:documentation>
     </xs:annotation>
    </xs:element>
    <xs:element -name="spacing" -type="xs:float" -minOccurs="0">
     <xs:annotation>
      <xs:documentation -xml:lang="en">This -is -the -average -distance -between
       consecutive -data -elements -in -this -dimension. -If -the -spacing -is -not
       regular, -then -it -may -be -possible -to -calculate -the -actual -distance
       between -any -two -data -elements -in -this -dimension -using -the
       'datapoints' -element.</xs:documentation>
     </xs:annotation>
    </xs:element>
    <xs:element -name="gap" -type="xs:float" -minOccurs="0">
     <xs:annotation>
      <xs:documentation -xml:lang="en">This -is -the -length -of -the -unsampled
       space -between -consecutive -data -elements -in -this -dimension, -i.e. -the
       distance -between -the -end -of -one -data -element -and -the -beginning -of
       the -next. -For -MRI -data, -this -can -be -used -to -specify -the -gap -between
       two -collected -slices -&#x02015; -the -actual -width -of -each -slice
       can -be -calculated -as -'spacing' -minus -'gap'.</xs:documentation>
     </xs:annotation>
    </xs:element>
    <xs:element -name="datapoints" -minOccurs="0">
     <xs:annotation>
      <xs:documentation -xml:lang="en">The -content -of -this -element -is -either
       (1) -a -whitespace-separated -list -of -values, -or -(2) -a -list -of -'value'
       elements, -that -can -be -used -as -a -label -for -each -data -point -along -this
       dimension. -The -values -can -be -numbers -representing -points -on -an -axis
       (this -is -the -typical -case), -text -strings, -coordinate -tuples, -etc.
       Any -datapoint -label -that -includes -whitespace -(coordinate -tuples
       included) -must -be -encapsulated -within -a -child -'value' -element. -If
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          this -element -is -missing, -it -is -assumed -that -labels -can -be -calculated
          using -information -in -other -fields -(such -as -'origin', -'spacing',
          etc.). -This -element -is -particularly -useful -for -dimensions -with
          irregular -spacing.</xs:documentation>
        </xs:annotation>
        <xs:complexType -mixed="true">
         <xs:sequence>
          <xs:element -name="value" -type="xs:string" -minOccurs="0" -maxOccurs="unbounded"/>
         </xs:sequence>
        </xs:complexType>
       </xs:element>
       <xs:element -name="direction" -type="listoffloats_t" -minOccurs="0">
        <xs:annotation>
         <xs:documentation -xml:lang="en">This -element -contains -a -vector
          (represented -as -a -whitespace-separated -list -of -floating-point -values
          in -the -appropriate -coordinate -system) -that -is -parallel -to -this
          dimension's -edge -of -the -bounding -box. -The -vector -starts -at -the -first
          element -in -the -data -and -points -towards -subsequent -elements -along
          this -dimension. -For -MRI -data, -this -should -be -a -unit -vector -in
          (R,A,S) -coordinates -(positive -values -are -Right, -Anterior, -or
          Superior -respectively) -&#x02015; -for -'x' -and -'y' -dimensions,
          this -corresponds -to -the -two -vectors -in -the -ImagePatientOrientation
          field -in -DICOM.</xs:documentation>
        </xs:annotation>
       </xs:element>
       <xs:element -name="units" -type="xs:string" -minOccurs="0">
        <xs:annotation>
         <xs:documentation -xml:lang="en">This -stores -the -units -used -for -all
          numeric -values -in -this -dimension -element. -In -MRI -data, -this -should
          be -'mm' -for -all -spatial -dimensions -('x', -'y', -'z') -and -'ms' -for -the
          temporal -dimension -'t'.</xs:documentation>
        </xs:annotation>
       </xs:element>
       <xs:element -name="measurementframe" -minOccurs="0">
        <xs:annotation>
         <xs:documentation -xml:lang="en">The -mapping -(if -any) -between -the -values
          expressed -in -&lt;datapoints&gt; -and -the -coordinate -system
          used -by -this -datarec. -For -example, -in -DTI -data, -this -is -useful -for
          mapping -gradient -direction -vectors -to -the -RAS -coordinate -space -used
          in -the -&lt;direction&gt; -vectors.</xs:documentation>
        </xs:annotation>
        <xs:complexType>
         <xs:sequence>
          <xs:element -name="vector" -type="listoffloats_t" -minOccurs="0" -maxOccurs="unbounded"/>
         </xs:sequence>
        </xs:complexType>
       </xs:element>
      </xs:sequence>
     </xs:extension>
    </xs:complexContent>
   </xs:complexType>
   <xs:complexType -name="frag_uri_t">
    <xs:annotation>
     <xs:documentation>The -external -data -pointed -to -by -this -uri -is -a -"fragment", -where -a
      "fragment" -is -defined -as -a -stream -of -data -contiguously -stored -in -the -same -file
      offset -by -'offset' -bytes -and -of -'size' -bytes.</xs:documentation>
    </xs:annotation>
    <xs:simpleContent>
     <xs:extension -base="xs:anyURI">
      <xs:attribute -name="offset" -type="xs:unsignedLong">
       <xs:annotation>
        <xs:documentation>The -data -for -this -fragment -will -start -at -this -byte
         position -in -the -resource -specified -by -the -'uri' -element. -If -this
         attribute -does -not -exist -or -is -empty, -it -is -assumed -to -be
        zero.</xs:documentation>
       </xs:annotation>
      </xs:attribute>
```

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   <xs:attribute -name="size" -type="xs:unsignedLong">
    <xs:annotation>
     <xs:documentation>This -specifies -the -size -of -this -block -(in -bytes) -in -the
      resource -specified -by -the -'uri' -element. -If -this -attribute -does -not
      exist -or -is -empty, -it -is -calculated -using -the -dimension -and -elementtype
      element.</xs:documentation>
    </xs:annotation>
   </xs:attribute>
  </xs:extension>
 </xs:simpleContent>
</xs:complexType>
<xs:simpleType -name="listoffloats_t">
 <xs:list -itemType="xs:float"/>
</xs:simpleType>
<xs:complexType -name="format_t">
 <xs:annotation>
  <xs:documentation>Container -for -describing -imaging -formats -and -file -name -extensions
   (currently -underimplemented)</xs:documentation>
 </xs:annotation>
 <xs:sequence>
  <xs:element -name="description" -type="xs:string" -minOccurs="0"/>
  <xs:element -name="documentationList" -minOccurs="0">
   <xs:complexType>
    <xs:sequence>
     <xs:element -name="documentation" -type="informationResource_t" -minOccurs="0" -maxOccurs="unbour
    </xs:sequence>
   </xs:complexType>
  </xs:element>
  <xs:element -name="extensionList" -minOccurs="0">
   <xs:complexType>
    <xs:sequence>
     <xs:element -name="extension" -type="xs:string" -minOccurs="0" -maxOccurs="unbounded"/>
    </xs:sequence>
   </xs:complexType>
  </xs:element>
 </xs:sequence>
 <xs:attribute -name="name"/>
</xs:complexType>
<!--********* - - - - - - - - - - - -Event -types - - - - - - - - - - - -*********-->
<xs:complexType -name="events_t">
 <xs:complexContent>
  <xs:extension -base="abstract_data_t">
   <xs:sequence>
    <xs:element -name="params" -type="eventParams_t" -minOccurs="0"/>
    <xs:element -name="event" -type="event_t" -minOccurs="0" -maxOccurs="unbounded"/>
    <xs:element -name="description" -type="xs:string" -minOccurs="0"/>
    <xs:element -name="annotation" -type="textAnnotation_t" -minOccurs="0" -maxOccurs="unbounded"/>
   </xs:sequence>
  </xs:extension>
 </xs:complexContent>
</xs:complexType>
<xs:complexType -name="event_t">
 <xs:annotation>
  <xs:documentation>This -element -represents -an -interval -of -time, -with -arbitrary -metadata
   (in -the -value -element).</xs:documentation>
 </xs:annotation>
 <xs:sequence>
  <xs:element -name="onset" -type="xs:float" -minOccurs="0"/>
  <xs:element -name="duration" -type="xs:float" -minOccurs="0"/>
  <xs:element -name="value" -type="eventValue_t" -minOccurs="0" -maxOccurs="unbounded"/>
  <xs:element -name="annotation" -type="textAnnotation_t" -minOccurs="0" -maxOccurs="unbounded"/>
 </xs:sequence>
 <xs:attribute -name="type" -type="xs:string" -use="optional"/>
 <xs:attribute -name="units" -type="xs:string" -use="optional">
  <xs:annotation>
   <xs:documentation>This -attribute -is -optional, -but -an -group -using -this -schema -should
    agree -on, -use, -and -enforce -measurement -units -consistently, -to -avoid -the -need -for
```

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    unit -conversion -in -an -application.</xs:documentation>
   </xs:annotation>
  </xs:attribute>
  <xs:attribute -name="name" -type="xs:string" -use="optional"/>
 </xs:complexType>
 <xs:complexType -name="eventValue_t">
  <xs:annotation>
   <xs:documentation>User-specified -metadata -associated -with -an -event.</xs:documentation>
  </xs:annotation>
  <xs:simpleContent>
   <xs:extension -base="xs:string">
    <xs:attribute -name="name" -type="xs:string"/>
    <xs:anyAttribute -processContents="lax"/>
   </xs:extension>
  </xs:simpleContent>
 </xs:complexType>
 <xs:complexType -name="eventParams_t">
  <xs:annotation>
   <xs:documentation>These -value -elements -apply -to -all -events -in -the -parent -event
   list.</xs:documentation>
  </xs:annotation>
  <xs:sequence>
   <xs:element -name="value" -type="eventValue_t" -minOccurs="0" -maxOccurs="unbounded"/>
  </xs:sequence>
 </xs:complexType>
 <xs:complexType -name="abstract_tagged_entity_t">
  <xs:sequence>
   <xs:element -name="metaFields" -minOccurs="0">
    <xs:complexType>
     <xs:sequence -minOccurs="0">
      <xs:element -name="metaField" -minOccurs="0" -maxOccurs="unbounded">
       <xs:complexType>
        <xs:simpleContent>
         <xs:extension -base="xs:string">
          <xs:attribute -name="name" -type="xs:string"/>
         </xs:extension>
        </xs:simpleContent>
       </xs:complexType>
      </xs:element>
     </xs:sequence>
    </xs:complexType>
   </xs:element>
  </xs:sequence>
 </xs:complexType>
</xs:schema>

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```

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