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- *XMILE: An XML Interchange Language for System Dynamics*. 7 June 2013. Karim Chichakly. http://www.iseesystems.com/community/support/XMILEv4.pdf.

This specification is related to:

- *SMILE: A Common Language for System Dynamics*. 7 June 2013. Karim Chichakly. http://www.iseesystems.com/community/support/SMILEv4.pdf.

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- http://docs.oasis-open.org/xmile/ns/XMILE/v1.0

Abstract:

The content of this OASIS Standard is unchanged. This Errata corrects a typographical error for the "report_interval" attribute in xmile.xsd schema.

The XML Interchange Language (XMILE) for System Dynamics (SD) defines an open XML protocol for the sharing, interoperability, and reuse of SD models and simulations. This document describes the XMILE language and format anyone who wishes to use SD models or embed them in their applications, such as vendors of SD software, Big Data, cloud, mobile, and social media solutions, as well as end users and consultants in the SD field.

Status:

This document was last revised or approved by the OASIS XML Interchange Language (XMILE) for System Dynamics TC on the above date. The level of approval is also listed above. Check the "Latest version" location noted above for possible later revisions of this document. Any other numbered Versions and other technical work produced by the Technical Committee (TC) are listed at https://www.oasis-open.org/committees/tc_home.php?wg_abbrev=xmile #technical.

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1 Introduction

This document defines a specification for both a core system dynamics (SD) language and its representation in XML and thus provides a common structure for describing SD models.

In the Spring 2003 System Dynamics Society newsletter, Jim Hines proposed that there be a common interchange format for system dynamics models. Magne Myrtveit originally proposed such an idea at the 1995 International System Dynamics Conference (ISDC), but Jim hoped to revive interest in the idea and chose the name SMILE (Simulation Model Interchange LanguagE) to keep people lighthearted. The benefits Jim proposed at the time were:

- Sharing of models can lead to greater increases of knowledge and sharing of ideas.
- On-line repositories could be built to facilitate learning.
- Open standards lead to better acceptance in larger corporations as it minimizes their risk with specific vendors.
- It spurs innovation by allowing non-vendors to develop add-ons.

To this formidable list, the following can be added:

- It allows the creation of a historical record of important works that everyone has access to.
- It allows vendors to expand their market base because suddenly their unique features (and let's be honest – each of the three major players has unique competencies) are available to all system dynamics modelers.

Vedat Diker and Robert Allen later presented a poster at the 2005 ISDC that proposed a working group be formed and that XML be the working language for the standard, leading to the name XMILE (XML Modeling Interchange LanguagE). During the first meeting of the Information Systems Special Interest Group (SIG) at the 2006 ISDC, Karim Chichakly volunteered to develop the draft XMILE specification, which he presented at the 2007 ISDC. Several drafts later, the OASIS XMILE Technical Committee (TC) was formed in June 2013 to standardize the specification across all industries. This document is the result of that TC's work.

This specification defines the XMILE specification version 1.0.

1.1 Terminology

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in **[RFC2119]**.

1.1.1 Definitions

File or **XMILE File**

An XML file that is conforms to this specification.

Model or **XMILE Model**

The model section of a XMILE file.

Root Model

The top-level model of a whole-model. This is the unnamed model within the XMILE file.

Simulator or **XMILE Simulator**

An implementation that simulates XMILE whole-models per this specification.

Whole-model or **XMILE Whole-model**

An XML file that conforms to this specification plus all XMILE files included through either the includes section of the header or through the resource attribute of a XMILE model or a module.

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1.2 Normative References

[RFC2119] Bradner, S., “Key words for use in RFCs to Indicate Requirement Levels”, BCP 14, RFC 2119, March 1997. http://www.ietf.org/rfc/rfc2119.txt.

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2 Overall Structure

A XMILE file contains information about a whole-model, with a well-specified structure. The file MUST be encoded in UTF-8. The entire XMILE file is enclosed within a <xmile> tag as follows:

```
<xmile version="1.0"
      xmlns="http://docs.oasis-open.org/xmile/ns/XMILE/v1.0">
   ...
</xmile>
```

The version number MUST refer to the version of XMILE used (presently 1.0). The XML namespace refers to tags and attributes used in this specification. Both of these attributes are REQUIRED. Inside of the <xmile> tag are a number of top-level tags, listed below. These tags are marked req (a single instance is REQUIRED), opt (a single instance is OPTIONAL), * (zero or more tags MAY occur) and + (one or more tags MAY occur). Top level tags MAY occur in any order, but are RECOMMENDED to occur in the following order:

- <header> (req) - information about the origin of the file and required capabilities.
- <sim_specs> (opt) - default simulation specifications for this file.
- <model_units> (opt) - definitions of model units used in this file.
- <dimensions> (opt) - definitions of array dimensions specific to this file.
- <behavior> (opt) - simulation style definitions that are inherited/cascaded through all models defined in this XMILE file.
- <style> (opt) - display style definitions that are inherited/cascaded through all views defined in this XMILE file.
- <data> (opt) - definitions of persistent data import/export connections..
- <model>+ - definition of model equations and (optionally) diagrams.
- <macro>* - definition of macros that can be used in model equations.

These tags are specified in the subsequent sections of this chapter, after XMILE namespaces are discussed.

When an XMILE file includes references to models contained in separate files or at a specific URL, each such file may contain overlapping information, most commonly in sim_specs, model_units and dimensions. When such overlap is consistent, combining parts is done by taking the union of the different component files. When an inconsistency is found, (for example, a dimension with two distinct definitions) software reading the files MUST resolve the inconsistency and SHOULD provide user feedback in doing so. Some inconsistencies, such as conflicting Macro or Model names MUST be resolved as detailed in section 2.11.3.

2.1 Namespaces

There are four categories of namespaces in play in a XMILE whole-model - XML tag namespaces, Variable namespace, Function namespace and Unit namespaces. XML tag namespaces and Unit namespaces are independent, but Variable and Function namespaces interact.

XML tag namespaces are global. Unadorned tags are described in detail in the various sections of this document and provision for vendor specific additions are also detailed.

Each XMILE whole-model has a single Unit namespace against which all Unit Definitions and Equation Units are resolved. The Unit namespace is separate from any other namespaces and this means that the variables of units and variable or function names can overlap (for example someone might use Ounce/Min and define Min as an alias of Minute even though MIN is a reserved function name). Because

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this namespace crosses models Unit Definitions contained in separate files must be combined into this namespace.

The Function namespace combines global definitions (all functions defined here along with vendor specified functions) with whole-model specific definitions through Macros. In every case, however, the names MUST be uniquely resolvable within a whole-file independent of the file in which they appear. It is not possible, for example, to give the same macro name two different definitions in separate files. Dimension names, though conceptually part of the Variable namespace, behave the same way and MUST be unique across a whole-model.

Variable names are resolved within models, but in the same context as functions and therefore can't overlap. It is not, for example, possible to have a variable named MIN as this is a reserved function name. Similarly, if the macro BIGGEST has been defined, no variable may be given the name BIGGEST. It is, however, possible, to have the same variable name appear in different models. For example if you have a project with one model MyCompany and another model Competitors, both could contain the variable profit (with MyCompany.profit and Competitors.profit the way to refer to that variable from different models).

One final subtlety in namespaces is that Dimension names, in turn, define their own Element namespace. Thus, even though Array Dimension names must be unique, they can have overlapping Element names and the Element names can be the same as Variable names. Element names are resolved by context when they appear inside square brackets of a variable and can be used in context by prefixing them with the array dimension name (as in Location.Boston, where Location is a Dimension name with element Boston).

2.2 Header Section

The XML tag for the file header is `<header>`. The REQUIRED sub-tags are:

- Vendor name: `<vendor>` w/company name
- Product name: `<product version="…" lang="…">` w/product name – the product version number is REQUIRED. The language code is optional (default: English) and describes the language used for variable names and comments. Language codes are described by ISO 639-1 unless the language is not there, in which case the ISO 639-2 code should be used (e.g., for Hawaiian).

OPTIONAL sub-tags include:

- XMILE options: `<options>` (defined below)
- Model name: `<name>` w/name
- Model version: `<version>` w/version information
- Model caption: `<caption>` w/caption
- Picture of the model in JPG, GIF, TIF, or PNG format: `<image resource=””>`. The `resource` attribute is optional and may specify a relative file path, an absolute file path, or an URL. The picture data may also be embedded inside the `<image>` tag in Data URI format, using base64 encoding.
- Author name: `<author>` w/author name
- Company name: `<affiliation>` w/company name
- Client name: `<client>` w/client name
- Copyright notice: `<copyright>` w/copyright information
- Contact information (e-mail, phone, mailing address, web site):
  `<contact>` block w/contact information broken into `<address>`, `<phone>`, `<fax>`, `<email>`, and `<website>`, all optional
- Date created: `<created>` whose contents MUST be in ISO 8601 format, e.g. “ 2014-08-10”.

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- Date modified: `<modified>` whose contents MUST be in ISO 8601 format, as well
- Model universally unique ID: `<uuid>` where the ID MUST be in IETF RFC4122 format (84-4-4-12 hex digits with the dashes)
- Includes: `<includes>` section with a list of included files or URLs. This is specified in more detail in Section 2.11.

2.2.1 XMILE Options

The XMILE options appear under the tag `<options>`. This is a list of functionality that is used in the file that may not be included in all implementations. If a file makes use of any of the following functionality[1], it MUST be listed under the `<options>` tag. The available options are:

```
<uses_conveyor/>
<uses_queue/>
<uses_arrays/>
<uses_submodels/>
<uses_macros/>
<uses_event_posters/>
<has_model_view/>
<uses_outputs/>
<uses_inputs/>
<uses_annotation/>
```

There is one OPTIONAL attribute for the `<options>` tag:

- Namespace: `namespace="…"` with XMILE namespaces, separated by commas. For example, `namespace="std, isee"` means try to resolve unrecognized identifiers against the `std` namespace first, and then against the `isee` namespace. (default: `std`)

The `<uses_arrays>` tag has one REQUIRED attribute and OPTIONAL attribute:

- Required: Specify the maximum dimensions used by any variable in the whole-model: `maximum_dimensions`.
- Optional: Specify the value returned when an index is invalid: `invalid_index_value="…"` with NaN/0 (default: 0)

The `<uses_macros>` tag has two REQUIRED attributes:

- Has macros which are recursive (directly or indirectly): `recursive_macros="…"` with true/false.
- Defines option filters: `option_filters="…"` with true/false.

The `<uses_conveyor>` tag has two OPTIONAL attributes:

- Has conveyors that arrest: `arrest="…"` with true/false (default: false)
- Has conveyor leakages: `leak="…"` with true/false (default: false)

The `<uses_queue>` tag has one OPTIONAL attribute:

- Has queue overflows: `overflow="…"` with true/false (default: false)

[1] In the case of included macro files, only the features from macros actually used is required. The intent is that vendors will provide library files containing macros for all of their specific functions. If a file does not use a macro built on optional features, it SHOULD NOT be restricted to simulators that support those optional features.

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The <uses_event_posters> tag has one OPTIONAL attribute:

- Has messages: messages="…" with true/false (default: false)

The <has_model_view> tag notes whether the XMILE file contains one or more <view> sections containing a visual representation of one or more models. Note that any software which supports XMILE should be able to simulate all whole-models, even those without diagrams.

The <uses_outputs> tag implies both time-series graphs and tables are included. It has three OPTIONAL attributes:

- Has numeric display: numeric_display="…" with true/false (default: false)
- Has lamp: lamp="…" with true/false (default: false)
- Has gauge: gauge="…" with true/false (default: false)

The <uses_inputs> tag implies sliders, knobs, switches, and option groups are included. It has three OPTIONAL attributes:

- Has numeric input: numeric_input="…" with true/false (default: false)
- Has list input: list="…" with true/false (default: false)
- Has graphical input: graphical_input="…" with true/false (default: false)

The <uses_annotation> tag implies text boxes, graphics frames, and buttons are included.

A sample options block appears below:

```
<options namespace="std, isee">
   <uses_conveyors leak="true"/>          <!-- has conveyors, some
leak -->
   <uses_arrays maximum_dimensions=”2”/>   <!-- has 2D arrays -->
   <has_model_view/>                      <!-- has diagram of model -
->
</options>
```

2.3 Model Simulation Specification Section

Every XMILE file MUST contain at least one set of simulation specifications, either as a top-level tag under <xmile> or as a child of the root model. Note that simulation specifications can recur in each Model section to override specific global defaults. Great care should be taken in these situations to avoid nonsensical results.

The simulation specifications block is defined with the tag <sim_specs>. The following properties are REQUIRED:

- Start time: <start> w/time
- Stop time: <stop> w/time (after start time)

There are several additional OPTIONAL attributes and properties with appropriate defaults:

- Step size: <dt> w/value (default: 1)
  Optionally specified as the integer reciprocal of DT (for DT <= 1 only) with an attribute of <dt>: reciprocal="…" with true/false (default: false)
- Integration method: method="…" w/XMILE name (default: euler)
- Unit of time: time_units="…" w/Name (empty default)
- Pause interval: pause="…" w/interval (default: infinity – can be ignored)

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- Run selected groups or modules: `<run by="…">` with run type either: `all`, `group`, or `module` (default: all, i.e., run whole-model). Which groups or modules to run are identified by `run` attributes on the group or model.

2.4 Model Units Section

All user-specified model unit definitions are specified in the `<model_units>` tag as shown below:

```
<model_units>
   <unit name="models_per_person_per_year">
      <eqn>models/person/year</eqn> <!-- name, equation -->
   </unit>
   <unit name="Rabbits">
      <alias>Rabbit</alias>    <!-- name, alias -->
   </unit>
   <unit name="models_per_year">
      <eqn>models/year</eqn>        <!-- name, eqn, alias -->
      <alias>model_per_year</alias>
      <alias>mpy</alias>
   </unit>
   <unit name="Joules" disabled="true"> <!-- disabled unit -->
      <alias>J</alias>
   </unit>
</model_units>
```

All unit definitions MUST contain a name, possibly an equation, and 0 or more aliases (Including a unit definition with only a name is valid but discouraged). Unit equations (`<eqn>` tag) are defined with XMILE unit expressions. One `<alias>` tag with the name of the alias appears for each distinct unit alias. A unit with the attribute disabled set to true MUST NOT be included in the unit substitution process. It is included to override a Unit Definition that may be built into the software or specified as a preference by the user.

Vendor-provided unit definitions not used in a model are NOT REQUIRED to appear in the file, but SHOULD be made available in this same format in a vendor-specific library.

2.5 Dimensions Section

When the `<uses_arrays>` XMILE option is set, a list of dimension names is REQUIRED. These dimension names must be consistent across the whole-model. The set of dimension names appear within a `<dimensions>` block as shown in the example below.

```
<dimensions>
   <dim name="N" size="5"/>    <!-- numbered indices -->
   <dim name="Location">       <!-- named indices -->
      <elem name="Boston"/>    <!-- name of 1st index -->
      <elem name="Chicago"/>   <!-- name of 2nd index -->
      <elem name="LA"/>        <!-- name of 3rd index -->
   </dim>
</dimensions>
```

Each dimension name is identified with a `<dim>` tag and a REQUIRED name. If the elements are not named, a size attribute greater or equal to one MUST be given. If the elements have names, they appear in order in `<elem>` nodes. The dimension size MUST NOT appear when elements have names as the number of element names always determines the size of such dimensions.

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2.6 Behavior Section

Every XMILE file MAY include behavior information to set default options that affect the simulation of model entities. Support for behaviors is REQUIRED. This is usually used in combination with macros to change some aspect of a given type of entity's performance, for example, setting all stocks to be non-negative.

The behavior information cascades across four levels from the entity outwards, with the actual entity behavior defined by the first occurrence of a behavior definition for that behavior property:

1. Behaviors for a given entity
2. Behaviors for all entities in a model (affects only that Model section)
3. Behaviors for all entities in all models in the file (affects all Model sections)
4. Default XMILE-defined behaviors when a default appears in this specification

The behavior block begins with the `<behavior>` tag. Within this block, any known object can have its attributes set globally (but overridden locally) using its own modifier tags. Global settings that apply to everything are specified directly on the `<behavior>` tag or in nodes below it. This is true for `<behavior>` tags that appear within the `<model>` tag as well. For example, all entities (particularly stocks and flows) can be set to be non-negative by default:

```
<behavior>
   <non_negative/>
</behavior>
```

Only stocks or only flows can also be set to non-negative by default (flows in this example):

```
<behavior>
   <flow>
      <non_negative/>
   </flow>
</behavior>
```

2.7 Style Section

Every XMILE file MAY include style information to set default options for display objects. When `<has_model_view>` is set in the `<options>` block, support for styles is REQUIRED. Being style information, this mostly belongs to the Presentation section (5.3), which describes the display and layout of XMILE files.

The style information is cascading across five levels from the entity outwards, with the actual entity style defined by the first occurrence of a style definition for that style property:

1. Styles for the given entity
2. Styles for all entities in a specific view
3. Styles for all entities in a collection of views
4. Styles for all entities in the XMILE file
5. Default XMILE-defined styles when a default appears in this specification

The style information usually includes program defaults when they differ from the standard, though it can also be used for file-specific file-wide settings. Whenever possible, style information uses standard CSS syntax and keywords recast into XML attributes and nodes.

The style block begins with the `<style>` tag. Within this block, any known object can have its attributes set globally (but overridden locally) using its own modifier tags. Global settings that apply to everything are specified directly on the `<style>` tag or in nodes below it; this is true for `<style>` tags that appear within the `<views>` tag as well. For example, the following sets the color of objects within all views in the file to blue and the background to white:

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```
<style color="blue" background="white"/>
```

Unless otherwise indicated or specified, style information appears in XML attributes. For example, `font_family` would be an attribute.

These changes can also be applied directly to objects (again as a child to a `<style>` tag), e.g.,

```
<style color="blue" background="white">
   <connector color="magenta">
</style>
```

Note that when style information applies to a specific object, that style cannot be overridden at a lower level (e.g., within a view) by a change to the overall style (i.e., by the options on the `<style>` tag). Using the example above, to override the color of connectors at a lower level (e.g., the Display), the `<connector>` tag must explicitly appear in that level's style block. If it does not appear there, connectors will be magenta at that level by default, even if the style block at that level sets the default color of all objects to green. In other words, object-specific styles at any level above an object take precedence over an overall style defined at any lower level.

2.8 Data Section

Persistent data import/export connections are defined within the OPTIONAL `<data>` tag, which contains one `<import>` tag for each data import connection and one `<export>` tag for each data export connection. Both tags include the following properties (the first four are optional):

- Type: `type="…"` with "CSV", "Excel", or "XML" (default: CSV)
- Enabled state: `enabled="…"` with true/false (default: true)
- How often: `frequency="…"` with either "on_demand" or "automatic" (default: automatic, i.e., whenever the data changes)
- Data orientation: `orientation="…"` with either "horizontal" or "vertical" (default: vertical)
- Source (import) or destination (export) location: `resource="…"`. A resource can be a relative file path, an absolute file path, or an URL.
- For Excel only, worksheet name: `worksheet="…"` with worksheet name

The `<export>` also specifies both the optional export interval and one of two sources of the data:

- Export interval: `interval="…"` specifying how often, in model time, to export values during the simulation; use `"DT"` to export every DT (default: 0, meaning only once)
- `<all/>` to export all variables in the whole-model or `<table uid="…"/>` to just export the variables named in the table (note that any array element in the table will export the entire array when interval is set to zero). The `<table>` tag has an optional attribute `use_settings="…"` with a true/false value (default: false), which when true causes the table settings for orientation, interval, and number formatting to be used (thus, when it is set, neither orientation nor interval are meaningful, so should not appear). The uid used for the table must be qualified by the name of the module in which the table appears. If in the root a '.' is prefixed to the name, same as module qualified variable names.

2.9 Model Section

Model tags define models that can either be simulated directly, or instantiated inside of other models as a module. Chapter 4 contains the specification for `<model>` tags.

2.10 Macro Section

Macro tags define macros that can be used in model entity equations. Chapter 4 contains the specification for `<macro>` tags.

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2.11 Includes

XMILE files MAY link to other XMILE files by using includes. Support for includes is REQUIRED. This serves the following use cases:

(1) A whole-model can be split across multiple files, allowing submodels and other components to be individually edited or versioned.
(2) A modeler may create a common library of submodels or macros and use them for multiple whole-models.
(3) A modeler may create a common style for models and include a common file for such style in different whole-models.
(4) A vendor may create a common library of macros with specific functionality used by all whole-models produced by that vendor's software.

Included files are specified with an <includes> tag which goes inside of <header>

```
<header>
   ...
   <includes>
      <include resource="http://systemdynamics.org/xmile/macros/standard-1.0.xml" />
      <include resource="http://systemdynamics.org/xmile/macros/extra-1.0.xml" />
   </includes>
</header>
```

The included resource can be specified in multiple ways. Specifically, the resource attribute can be specified with:

(1) URLs. By convention, a file retrieved from a URL is assumed to be an unchanging resource and may be cached. The file may also be provided automatically by the simulation software.

    Example:

    ```
    <include resource="http://systemdynamics.org/xmile/macros/standard-1.0.xml" />
    ```

(2) Relative file paths. Search relative to the location of the XMILE file. This allows modelers to distribute their whole-models as a folder of related files. This is a machine-independent path specification using "/" to separate directories. The "*" indicates a wildcard. Files are not cached.

    ```
    <include resource="my-macro-library.xml" />
    <include resource="macros/my-macro-library.xml" />
    <include resource="macros/*" />
    <include resource="macros/supplychain-*.xml" />
    ```

(3) Absolute file paths. Similar to relative file paths except that the resource starts with "/" or "file://". In such cases, the file path is loaded from an absolute location on the local machine. Application programs may choose to limit file access or base the root directory in a particular location (e.g. a home directory) for security reasons. A platform-specific volume name (e.g. "D:") may not be specified.

    ```
    <include resource="/library/my-macro-library.xml" />
    <include resource="file://library/my-macro-library.xml" />
    ```

    If an absolute file path does not resolve to a file, as a fallback, the final filename in the path should be stripped off and that name used for a search relative to the XMILE file itself.

2.11.1 Versioning

By convention, files included from URLs are assumed to be standard libraries provided by a vendor, organization or modeler, and MUST never change once public. Such files should be versioned in the form LIBRARY-MAJOR.MINOR.xml, e.g. "standard-1.0.xml". Changes to the content of such libraries will require the major or minor version number to be incremented. The full URL, e.g. “http://systemdynamics.org/xmile/macros/standard-1.0.xml” represents a unique identifier for the content

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of this file. Consequently, software packages MAY cache such libraries or come pre-bundled with libraries for particular vendors or organizations. Downloading the libraries each time the file is discouraged.

As a contrast, files specified with a file path (particularly a relative file path) are assumed to be part of the whole-model distribution and SHOULD be reloaded each time the file is loaded. Version numbers in the file name are allowed but not required.

2.11.2 Format of Included Files

The format of the included files is a simplified version of the format of the full XMILE file. The <header> tag is OPTIONAL, and if included can omit required header attributes. The <options> tag is optional.

```
<xmile version="1.0"
   xmlns=" http://docs.oasis-open.org/xmile/ns/XMILE/v1.0">
   <header>
   </header>
   <macro name="LOG">
      ...
   </macro>
   <macro name="LOG10">
      ...
   </macro>
</xmile>

<xmile version="1.0" level="2"
   xmlns="http://www.systemdynamics.org/XMILE">
   <style>
      ...
   </style>
</xmile>

<xmile version="1.0" level="2"
   xmlns="http://www.systemdynamics.org/XMILE">
   <model>
      ...
   </model>
</xmile>
```

2.11.3 Merging Included Files

Software packages MUST process included files before simulation is started, and the content of included files MUST be merged into the whole-model environment before simulation. Specifically:

- The <options> tag options will be merged with the <options> from the primary model. This means that if an included file specifies an option such as <uses_conveyor/>, then the simulation SHOULD assume the whole-model has the <uses_conveyor/> option specified. When merging XMILE <options> the most specific of each option will take priority.
- When an included file only contains <behavior> and/or <style> options[2], those <behavior> and <style> options in the included file will be merged into the default styles of

[2] This separation is necessary because an included file can contain behavior and style options specific to the models and macros in that file – and which should not override or be merged with those in the file that includes those models and macros, as they're unrelated. Furthermore, the intent of including behavior

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the file including them. This allows behaviors and styles to be included from other files. When merging <behavior> and <style> options, any behaviors and styles specified in the file that included them will take priority. (This allows the file that included them to override styles specified in the included file).

- <model> and <macro> tags in the included file will be merged into the file that includes them at the start of that file, in the order in which they appear in the list of included files. If there are name conflicts between <model> and <macro> tags in the included file and the primary model, the primary model will take priority. (This allows the primary model to overwrite submodels or macros specified in the included file).

and style information is so that vendors can create, and include in all their models, a file with all of their defaults when they differ from the XMILE defaults.

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3 Model Equation Structure

At their heart, system dynamics models are systems of integral (or differential) equations. We start from that perspective in defining the basic structure of the simulation language. Using this frame, a model is composed of stocks, flows, and other equations necessary to compute the flows or initialize the stocks which we will call inclusively auxiliaries. Stocks are also often called levels or states, and flows are often called rates or derivatives. All other computations can include constants, initialization computations, data constructs, and other items that will be distinguished by their defining equations - all will be referred to as auxiliaries. Stocks, flows, and auxiliaries will be collectively referred to as variables.

We also base our computational definition on the assumption that a model starts from some well-defined initial condition and then computations progress forward in time. Other approaches, such as mixed initial and terminal conditions or simulating backwards in time, can be applied to the models specified in this document but will require extensions of the specification to accommodate these differences.

We will refer to the computation used to determine the values of variables over time as "the simulation." In later sections, we will discuss solution techniques for integral equations, but for discussion purposes we will use the notion that time is broken up into finite intervals during this computation. We will call the time between these intervals DT, corresponding the denominator in the $\frac{d}{dt}$ notation often used in introductory calculus courses. DT is directly analogous to Δt in the Riemann sum. This discrete time terminology is often used for pedagogical purposes and is also important in defining computation, especially with some of the added constructs such as queues now common in many system dynamics models.

As a final note, all variables in XMILE models are floating point numbers. It is recommended that software supporting XMILE use double-precision floating point numbers as specified by IEEE 754. At a minimum, such software should maintain at least single-precision floating point numbers.

3.1 Basic Functionality

The following sections define the core system dynamics language that is REQUIRED to be XMILE-compliant.

3.1.1 Stocks

Stocks accumulate. To simulate, their value at the start of the simulation MUST be set as either a constant or with an initial equation. The initial equation is evaluated only once, at the beginning of the simulation.

During the course of the simulation, the value of a stock is increased by its inflows and decreased by its outflows. Using the discrete time interval *dt* and subscripted text to represent a value at given time, we can write

$$stock_t = stock_{t-dt} + dt \cdot (inflows_{t-dt} - outflows_{t-dt})$$

The above computation is notional, though it is used in one of the specified integration techniques (Euler).

In specifying a stock, we list its inflows and outflows separately as in:

stock: Population
  inflows: births, immigration
  outflows: deaths, emigration
  eqn: 100
  units: people

3.1.2 Flows

Flows represent rates of change of the stocks. To simulate, they MUST be defined using any algebraic expression as described in Section 3.3 or by using a graphical function as described in Section 3.1.4.

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During the course of a simulation, a flow's value is computed and used in the computation of levels as described. An example flow:

flow: births
eqn: Population*birth_rate
units: people/year

3.1.3 Auxiliaries

Auxiliaries allow the isolation of any algebraic function that is used. They can both clarify a model and factor out important or repeated calculations. To simulate, they MUST be defined using any algebraic expression (including a constant value), optionally in conjunction with a graphical function.

An example auxiliary:

aux: birth_rate
eqn: normal_birth_rate*food_availability_multiplier
units: people/person/year

Auxiliaries can also represent constants:

aux: normal_birth_rate
eqn: 0.04
units: people/person/year

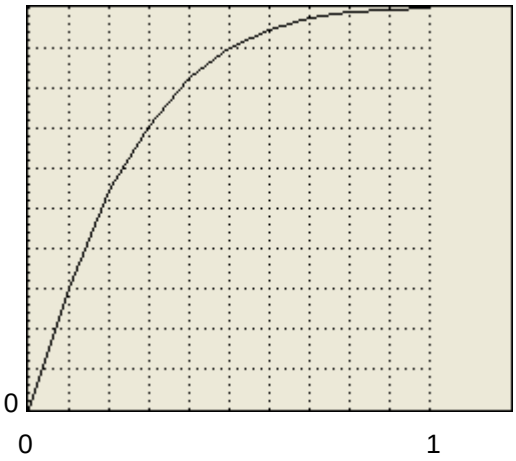
3.1.4 Graphical Functions

Graphical functions are alternately called lookup functions and table functions. They are used to describe an arbitrary relationship between one input variable and one output variable. The domain of these functions is consistently referred to as *x* and the range is consistently referred to as *y*.

A graphical function MUST be defined either with an x-axis scale and a set of *y*-values (evenly spaced across the given *x*-axis scale) or with a set of *x*-*y* pairs. An example of a graphical function using an *x*-axis scale with a set of *y*-values:

Graphical Function: food_availability_multiplier_function
x scale: 0 to 1
y values: 0, 0.3, 0.55, 0.7, 0.83, 0.9, 0.95, 0.98, 0.99, 0.995, 1

As there are 11 *y* values, the *x*-axis also must be divided into 11 values from zero to one, leading to an *x*-axis interval of 0.1. The graph of this function appears below.



Distinct *x*-*y* pairs are intended for use when the function cannot be properly represented by using a fixed interval along the *x*-axis. Although not desired for the above graphical function, it can be represented using a set of *x*-*y* pairs as follows:

Graphical Function: food_availability_multiplier_function
x values: 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1
y values: 0, 0.3, 0.55, 0.7, 0.83, 0.9, 0.95, 0.98, 0.99, 0.995, 1

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The example graphical function above is continuous. There are three types of graphical functions supported, with these names, which define how intermediate and out-of-range values are calculated:

Name	Description
continuous	Intermediate values are calculated with linear interpolation between the intermediate points. Out-of-range values are the same as the closest endpoint (i.e, no extrapolation is performed).
extrapolate	Intermediate values are calculated with linear interpolation between the intermediate points. Out-of-range values are calculated with linear extrapolation from the last two values at either end.
discrete	Intermediate values take on the value associated with the next lower *x*-coordinate (also called a step-wise function). The last two points of a discrete graphical function must have the same *y* value. Out-of-range values are the same as the closest endpoint (i.e, no extrapolation is performed).

Graphical functions can stand alone, as shown above, or be embedded within a flow or auxiliary. In the latter case, the graphical function name is OPTIONAL, for example:

aux: food_availability_multiplier
eqn: Food
gf:
xscale: 0.0-1.0
ypts: 0, 0.3, 0.55, 0.7, 0.83, 0.9, 0.95, 0.98, 0.99, 0.995, 1

3.1.5 Model Decomposition

Larger models are typically organized into smaller parts, often called, groups, sectors or views, in order to make them easier to understand. In XMILE, this can be accomplished by arranging or tagging variables for inclusion in groups, breaking up the displays for a model into different views, nesting models, or creating separate models that exchange inputs and outputs with one another.

Groups represent the simplest of these organizational concepts. Groups allow related model variables to be collected in one physical place on the diagram. Any subset of groups MAY be independently simulated if the application software supports that, though no explicit restrictions on how such computational closure is obtained are required by the standard. Every group has a unique name and its own documentation. The names of variables of IDs of drawing objects within that group are listed in the group:

group: Fleet Size
entities: Fleet, buy_planes, sell_planes
display: UID 7, UID 8

Groups do not have any direct effect on computation, except when simulated independently. Groups can also be used to control the visual display of models as discussed in later sections on this specification and can be used by documentation and other tools to organize equations and variable definitions.

Submodels are more formal than groups. These are extensions of the basic modeling language and so may not be supported by all implementations. They are described in a later section of this specification.

3.2 General Conventions

All statements and numeric constants follow US English conventions. Thus, built-in function names are in English, operators are based on the Roman character set, and numeric constants are expressed using US English delimiters (that is, a period is used for a decimal point).

Variable names, model names, group names, unit names, comments, and embedded text MAY be localized.

3.2.1 Numeric Constants

As mentioned, numeric constants MUST follow US English conventions and are expressed as floating point numbers in decimal. They begin with either a digit or a decimal point and contain any number of digits on either side of the OPTIONAL decimal point. They MUST contain at least one digit, but a decimal

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point is OPTIONAL. The number can be OPTIONALLY followed by an “E” (or “e”) and a signed integer constant. The “E” is used as shorthand for scientific notation and represents “times ten to the power of”.

In BNF,

number ::= { [*digit*]+[**.**[*digit*]*] | [*digit*]***.**[*digit*]+ }[{**E** | **e**} [{**+** | **–**}] [*digit*]+]

digit ::= { **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** }

Note that negative numbers are entered using the unary minus sign which is included in expressions (Section 3.3).

Sample numeric constants: 0 -1 .375 14. 6E5 +8.123e-10

3.2.2 Identifiers

Identifiers are used throughout a model to give variables, namespaces, units, subscripts, groups, macros, and models names. Most of these identifiers will appear in equations, and as such need to follow certain rules to allow for well-formed expressions.

The form of identifiers in XMILE is relatively restrictive, but arbitrary UTF8 strings MAY be included by surrounding the names in double quotes (") and appropriately escaping certain special characters. This will mean that some variable names may require quotes, even when they would not be required in their vendor-specific implementation.

Note the underscore (_) is often used in variables that appear in diagrammatic representations with a space. For example *birth_rate* might appear as simply *birth rate* in the diagram. One consequence of this is that *birth_rate*, *"birth_rate"*, and *"birth rate"* are all considered to be the same name. Typically, only one of these forms (*birth_rate*) SHOULD be used.

3.2.2.1 Identifier Form

Identifiers are formed by a sequence of one or more characters that include roman letters (A-Z or a-z), underscore (_), dollar sign ($), digits (0-9), and Unicode characters above 127. Identifiers SHALL NOT begin with a digit or a dollar sign (with exceptions as noted for units of measure), and SHALL NOT begin or end with an underscore.

Any identifier MAY be enclosed in quotation marks, which are not part of the identifier itself. An identifier MUST be enclosed within quotation marks if it violates any of the above rules. Within quotation marks, a few characters MUST be specified with an escape sequence that starts with a backslash. All other characters are taken literally. The only valid escape sequences appear below. No other character SHALL appear after a backslash. If any character other than those specified below appears after a backslash, the identifier is invalid.

Escape sequence	Character
\"	quotation mark (")
\n	newline
\\	backslash

Sample identifiers:

Cash_Balance draining2 "wom multiplier" "revenue\ngap"

Control characters (those below U+0020) SHOULD never appear in an identifier, even one surrounded by quotation marks but MAY be treated as a space if encountered when reading a file.

3.2.2.2 Identifier Equivalences

Case-insensitive: Identifiers MAY use any mixture of uppercase and lowercase letters, but identifiers that differ only by case will be considered the same. Thus, Cash_Balance, cash_balance, and CASH_BALANCE are all the same identifier. For Unicode characters, case-insensitivity SHALL be defined by the Unicode Collation Algorithm (UCA – http://www.unicode.org/unicode/reports/tr10/), which is compliant with ISO 14651. For C, C++, and Java, this algorithm is implemented in the International Components for Unicode (ICU – http://site.icu-project.org/).

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Whitespace: Whitespace characters SHALL include the space ( ), non-breaking space (U+00A0), newline (\n), and underscore (_). Within an identifier, whitespace characters SHALL be considered equivalent. Thus, wom_multiplier is the same identifier as "wom multiplier" and "wom\nmultiplier".

Additionally, groups of whitespace characters SHALL always be treated as *one* whitespace character for the purposes of distinguishing between identifiers. Thus, wom_multiplier is the same identifier as wom_____multiplier.

Unicode equivalences: There are several Unicode spaces, e.g., the en-space (U+2002) and the em-space (U+2003). These SHALL not treated as whitespace within XMILE. If they are supposed to be treated as whitespace, be certain to map them to a valid XMILE whitespace character when entered by the user. Likewise, the roman characters, including letters, digits, and punctuation, are duplicated at full width from U+FF00 to U+FF5E. These SHALL NOT be recognized in XMILE as valid operators, symbols, or digits, nor do the letters match with the normal roman letters. It is strongly RECOMMENDED that these be mapped to the appropriate roman characters when entered by the user.

3.2.2.3 Namespaces

To avoid conflicts between identifiers in different libraries of functions, each library, whether vendor-specific or user-defined, SHOULD exist within its own namespace.[3] Note that identifiers within macros and submodels, by definition, appear in their own local namespace (see Sections 3.6.1 and 3.7.4). Array dimension names also receive special treatment as described below and in section 3.7.1.

A namespace SHALL be specified with an identifier. An identifier from a namespace other than the local one is only accessible by qualifying it with its namespace, a period (.), and the identifier itself, with no intervening spaces. For example, the identifier *find* within the namespace *funcs* would be accessed as *funcs.find* (and not as *funcs . find*). Such a compound identifier is known as a *qualified name*; those without the namespace are known as *unqualified*.

Namespace identifiers MUST be unique across a whole-model and cannot conflict with any other identifier. XMILE predefines its own namespace and a number of namespaces for vendors:

Name	Purpose
std	All XMILE statement and function identifiers[4]
user	User-defined function and macro names
anylogic	All Anylogic identifiers
forio	All Forio Simulations identifiers
insightmaker	All Insight Maker identifiers
isee	All isee systems identifiers
powersim	All Powersim Software identifiers
simanticssd	All Simantics System Dynamics Tool identifiers
simile	All Simulistics identifiers
sysdea	All Strategy Dynamics identifiers
vensim	All Ventana Systems identifiers

It is RECOMMENDED that user defined functions and macros be included in a child namespace of the global `user` namespace.

Namespaces MAY be nested within other namespaces. For example, `isee.utils.find` would refer to a function named `find` in the `utils` namespace of the `isee` namespace.

Unqualified names are normally only resolved within the containing model (along with the implicit array namespace or, in a macro definition, strictly inside the macro), i.e., they are assumed local to their model.

---

[3] Note that when the actual encoding of models in XML is done there will be additional identifiers (tags and descriptors) that are part of the XML specification. These are treated separately from the namespaces and identifiers that are part of a model, and follow the conventions of XML which are somewhat different (more restrictive identifiers, a colon instead of period for separators and so on).

[4] Note that both units has its own separate, unnamed namespace. Unit names always appear separately from equations so there is never any overlap.

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However, an entire XMILE file, or individual models within an XMILE file, can avoid the use of qualified names from other namespaces, especially for function names in equations, by specifying that the given file or model uses one or more namespaces. In this case, unqualified names MUST first be resolved locally, within the containing model. If no match is found, the specified namespaces MUST then be searched in order, from left to right as specified, until a match is found. By obeying the specified namespace order, XMILE allows user to control how conflicting identifiers are resolved. However, it is strongly RECOMMENDED that a warning be generated for such conflicts. It is also RECOMMENDED that vendors provide an option to treat these as errors.

Note this namespace resolution capability is only available for explicitly defined namespaces and not for the implicit namespaces of submodels (see Section 3.7.4). Any identifiers other than array dimensions that are accessed across models MUST be qualified.[5]

By default, all XMILE files are in the `std` namespace, but this MAY be overridden by explicitly setting one or more namespaces. It is intended that most XMILE files SHALL specify that they use the `std` namespace, thus obviating the need to include `std.` in front of all XMILE identifiers.

The same identifier can be used in different namespaces, but identifiers in the `std` namespace SHOULD be reserved to prevent confusion. Similarly, identifiers in any libraries of functions or macros (whether vendor-supplied or user-defined) SHOULD be avoided. It is strongly RECOMMENDED that implementations do not allow the addition of model variables that are the same as function or macro names and that when a new library is added to the whole-model, a check for conflicting symbols be performed.

3.2.2.4 Identifier Conventions

Identifiers defined by XMILE, including registered vendor namespaces (see Section 3.2.2.3), should be chosen so that they do not require quotation marks. Note that the registered vendor names are all in lowercase; this is intentional. It is also preferred that vendors choose the identifiers within their namespaces such that they do not require quotation marks.

3.2.2.5 Reserved Identifiers

The operator names `AND`, `OR`, and `NOT`, the statement keywords `IF`, `THEN`, and `ELSE`, the names of all built-in functions, and the XMILE namespace `std`, are reserved identifiers. They cannot be used as vendor- or user-defined namespaces, macros, or functions. Any conflict with these names that is found when reading user- or vendor-supplied definitions SHOULD be flagged as an error to the end user.

3.2.3 Data Types

There is only one data type in XMILE: real numbers. Although some parts of the language require integers, e.g., array indices, these are still represented as real numbers.

3.2.4 Containers

All containers in XMILE are lists of numbers. As much as possible, the syntax and operation of these containers are consistent. Only one container is inherent to XMILE: graphical functions. Three containers are optional in XMILE: arrays, conveyors, and queues.

Neither a graphical function nor an array SHALL change its size during a simulation. However, the size of a conveyor (its length) MAY change and the size of a queue changes as a matter of course during a simulation.

Since all four containers are lists of numbers we may wish to operate on (for example, find their mean or examine an element), they are uniformly accessed with square bracket notation as defined in Section

[5] As explained in Section 3.7.1, array dimensions must be visible and identical across an entire model.

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3.7.1, Arrays. There are also a number of built-in functions that apply to all of them. These features are OPTIONAL and are only guaranteed to be present if arrays are supported.

3.3 Expressions

Equations are defined using expressions. The simplest expression is simply a constant, e.g., 3.14.

Expressions are infix (e.g., algebraic), following the general rules of algebraic precedence (parenthesis, exponents, multiplication and division, and addition and subtraction – in that order). Since our set of operators is much richer than basic algebra, we have to account for functions, unary operators, and relational operators. In general, the rules for precedence and associativity (the order of computation when operators have the same precedence) follow the established rules of the C-derived languages.

Expressions in an XMILE document MUST follow the rules or assertions expressed in this section and sub-sections, even when these are not worded using RFC2119 keywords.

3.3.1 Operators

The following table lists the supported operators in precedence order. All but exponentiation and the unary operators have left-to-right associativity (right-to-left is the only thing that makes sense for unary operators).

Operators	Precedence Group (in decreasing order)
[ ]	Subscripts
( )	Parentheses
^	Exponentiation (right to left)
+ – NOT	Unary operators positive, negative, and logical not
* / MOD	Multiplication, division, modulo
+ –	Addition, subtraction
< <= > >=	Relational operators
= <>	Equality operators[6]
AND	Logical and
OR	Logical or

Note the logical, relational, and equality operators are all defined to return zero (0) if the result is false and one (1) if the result is true.

Modulo is defined to return the floored modulus proposed by Knuth. In this form, the sign of the result always follows the sign of the divisor, as one would expect.[7]

Sample expressions: `a*b` `(x < 5) and (y >= 3)` `(-3)^x`

3.3.2 Function Calls

Parentheses are also used to provide parameters to function calls, e.g., `ABS(x)`. In this case, they take precedence over all operators (as do the commas separating parameters). Note that functions that do not take parameters do not include parentheses when used in an equation, e.g., `TIME`. There are several cases where variable names MAY be (syntactically) used like a function in equations:

- Named graphical function: The graphical function is evaluated at the passed valued, e.g., given the graphical function named `cost_f`, `cost_f(2003)` evaluates the graphical function at *x* = 2003.

[6] Although mathematics classifies <> as relational, computer languages typically lump it with equality.

[7] Note the standard C modulo operator uses the truncated modulus which gives a sign consistent with the dividend. The choice of modulus method affects integer division, which does not exist in XMILE, as well as the `INT` function, which must return the floor of the number. By definition, a = INT(a/b)*b + a MOD b.

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- Named model: A model that has a name, defined submodel inputs, and one submodel output can be treated as a function in an equation, e.g., given the model named `maximum` with one submodel input and one submodel output that gives the maximum value of the input over this run, `maximum(Balance)` evaluates to the maximum value of `Balance` during this run. When there is more than one submodel input, the order of the parameters must be defined as they are for a macro definition. For more information, see Sections 3.6.1 (macros) and 3.7.4 (submodels).
- Array name: An array name can be passed the flat index (i.e., the linear row-major index) of an element to access that element. Since functions can only return one value, this can be useful when a function must identify an element across a multidimensional array (e.g., the `RANK` built-in). For example, given the three-dimensional array `A` with bounds `[2, 3, 4]`, `A(10)` refers to the tenth element in row-major order, i.e., element `A[1, 3, 2]`. See Section 3.7.1 for more information about arrays.

3.3.3 Structured Statements

One control structure statement MUST be supported:

`IF` *condition* `THEN` *expression* `ELSE` *expression*

where *condition* is an expression that evaluates to true or false. We follow the convention of C that all non-zero values are true, while zero is false. Generally, *condition* is an expression involving the logical, relational, and equality operators.

Note that some vendors implement this as a built-in function:

`if_then_else`(*condition*, *then-expression*, *else-expression*)

While the statement form is preferred, this OPTIONAL alterative, if used, should be implemented by the vendor using an XMILE macro (Section 3.6).

3.3.4 In-line Comments

Comments are provided to include explanatory text that is ignored by the computer and MUST be supported. Comment are delimited by braces { } and MAY be included anywhere within an expression. This functionality allows the modeler to temporarily turn off parts of an equation or to comment the separate parts of a complex formulation.

Sample comments: `a*b { take product of a and b } + c { then add c }`

3.3.5 Documentation

Each variable OPTIONALLY has its own documentation, which is a block of unrestricted text unrelated to the equation. This MAY be stored in either plain text or in rich text (HTML).

3.3.6 Units

Each variable OPTIONALLY has its own units of measure, which are specified by combining other units defined in the `units` namespace as described below.

Units of measure are specified with XMILE expressions, called the *unit equation*, restricted to the operators ^ (exponentiation), - or * (multiplication), and / (division) with parentheses as needed to group units in the numerator or denominator. Exponents MUST be integers. When there are no named units in the numerator (e.g., units of “per second”), the integer one (1), or one of its aliases as described below, MUST be used as a placeholder for the numerator (e.g., 1/seconds). The integer one (1) MAY be used at any time to represent the identity element for units and both Dimensionless and Dmnl are RECOMMENDED as built-in aliases for this.

Units appearing in the *unit equation* MAY also be defined in terms of other units. For example, Square Miles would have the equation Miles^2. When a unit is defined in this way, any use of it is the equivalent of using its defining equation. Units with no defining equation are called primary units. Every *unit equation* can be reduced to an expression involving only primary units by the process of substitution.

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Unit aliases allow multiple names to have the same meaning. For example, People, Person, and Persons could all be considered to be the same. When a unit has an alias, that unit's name or any of its aliases MAY be used interchangeably for the purpose of specifying the *units equation*. Aliases are actually a special case of units being defined by other units, but allowing multiple aliases simplifies the way that information about units is kept. Unit aliases may be chained by specifying the name of an existing unit (or one of its aliases) as the equation. This allows the addition of user-defined aliases for built-in units in a straightforward manner.

A unit is thus specified by a name, an equation, and a sequence of aliases. The name and equation are standard XMILE identifiers except that $ is allowed as the first (and often only) character in the name of a unit without surrounding quotes. Also, the single digit 1 is used as the unit identity. Like variables names, unit names are stored with underscores (_) but generally presented to users with spaces. A unit with no equation is a primary unit. A unit with an equation SHOULD, when possible, be presented to the user with its name rather than its equation

There is a separate unnamed namespace for units. All units, regardless of which model they are contained in, are resolved against that single namespace.

The following baseline unit definitions are RECOMMENDED. 1 is REQUIRED.

Name	Equation	Aliases
1		Dimensionless, Unitless, Dmnl
nanoseconds		ns, nanosecond
microseconds		us, microsecond
milliseconds		ms, milliseconds
seconds		s, second
per_second	1/seconds	
minutes		min, minute
per_minute	1/minutes	
hours		hr, hour
per_hour	1/hours	
days		day
per_day	1/days	
weeks		wk, week
per_week	1/weeks	
months		mo, month
per_month	1/months	
quarters		qtr, quarter
per_quarter	1/quarters	
years		yr, year
per_year	1/years	

Each model SHOULD contain a list of unit definitions that are used by that model to resolve *unit equations* for the purpose of checking units. While, when defining a unit, both the equation and the aliases are optional, a unit that has neither SHOULD NOT be separately defined, as such units MUST be recognized implicitly when the *unit equation* is parsed. Since an XMILE file may reference other files with Unit Definitions, there MAY be repetition within these. Repetition MUST be ignored.

Because unit definitions can involve equations, they have the potential to be circular. The unit definitions specified in a whole-model MUST NOT have any circularity either through their equations or aliases. This also means that no alias SHALL appear more than once, or as a name. If a circular definition, name repetition, or alias repetition occurs as a result of combining the specified units with an implementation's built-in units, the implementation SHOULD respect the unit definitions for the model when it is possible to do so. To make that resolution persist, it is also possible to mark unit names, and by implication their associated equation and aliases, as “disabled” in the XMILE file. Disabled definitions MAY be ignored in implementations where the name does not exist in the built-in unit definitions.

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3.4 Simulation Specifications

Every XMILE model MUST specify the start time and the stop time of the simulation. If DT is not specified, it defaults to one (1). For DT <= 1, DT MAY be specified as an integer reciprocal (e.g., 16 for DT = 1/16). Units of time MUST be specified, usually with XMILE predefined time units (Section 3.3.6).

The language also supports an OPTIONAL pause interval. By default, a model runs to completion (from STARTTIME to STOPTIME). However, if the pause interval is specified, the model pauses at all times that match STARTTIME + interval*N; N > 0. Software packages are free to ignore this specification if they do not support this mode of operation.

The simulation specifications MAY also specify whether to only run selected groups (each selected group is marked), only run selected submodels (each selected submodel is marked), or run the whole-model (default).

3.4.1 Integration Methods

By default, the integration method is Euler's, but other methods are supported as follows:

XMILE Name	Integration Method
`euler`	Euler's method (default)
`rk4`	Runge-Kutta 4
`rk2`	Runge-Kutta 2 (OPTIONAL – falls back to RK4)
`rk45`	Runge-Kutta mixed 4th- 5th-order (OPTIONAL)
`gear`	Gear algorithm (OPTIONAL)

The last three integration methods are OPTIONAL. In these cases, a supported fallback method SHOULD also be provided, for example, "`gear, rk4`". This means that Gear should be used if the product supports it. Otherwise, use rk4.

Some vendors do not offer RK2, as it is less useful than it once was when computing power was expensive. XMILE defines RK4 to always be the fallback for RK2, i.e., RK2 implies "`rk2, rk4`."

3.4.2 Simulation Events

Events based on entity values MAY be triggered while the model is being simulated. Any implementation that does not support simulation events is free to ignore them.

Within the simulation, these events are limited to pausing or stopping the simulation. Events are specified as a series of threshold values that, when exceeded, trigger the specified action:

XMILE Name	Action
`pause`	Pause the simulation (default)
`stop`	Stop the simulation
`message`	Issue a message such as a warning but allow the simulation to continue

For each value, thresholds can be exceeded in either of two directions (only):

XMILE Name	Action occurs when entity value becomes:
`increasing`	Larger than the threshold (default)
`decreasing`	Smaller than the threshold

The number of times the event occurs during the simulation (its frequency) can also be controlled:

XMILE Name	Event occurs:
`each`	Each time the threshold is exceeded (default)
`once`	Only the first time the threshold is exceeded each run
`once_ever`	Only the first time the threshold is exceeded this session

When the frequency is set to `each`, an OPTIONAL repetition interval can also be specified which causes the event to be triggered again every so many unit times (at the specified interval) that the variable remains above the threshold.

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Each unique threshold value and direction MAY be given more than one event. In this case, the events are triggered in order based on which instance the threshold has been exceeded since the start of the run. For example, if there are three events assigned to a threshold of 5 (increasing), the first event will be triggered the first time the variable goes above 5, the second event will be triggered the second time it goes above 5, and the third will be triggered the third time it goes above 5. If the variable goes above 5 after that, no further events will be triggered. When multiple events are assigned in this way, the frequency can only be `once` or `once_ever` (i.e., it cannot be `each`).

A range (minimum and maximum) that contains all events MAY also be specified to more readily allow the user to edit the thresholds in context. By default, this range should be initialized to the variable's known range at the time the events are first created (the user then has to modify them if they are no longer appropriate; they do not readjust if the variable's range changes).

3.5 Built-in Functions

Certain built-in functions must be relied upon across all systems. This section strives to define the minimum set of built-in functions that MUST be supported, along with their parameters. The mechanism for defining vendor-specific built-ins is described in Section 3.6.

3.5.1 Mathematical Functions

ABS: absolute value (magnitude) of a number
Parameters: 1: the number to take the absolute value of
Range: $[0, \infty)$
Example: ABS(Balance)

ARCCOS: arccosine of a number
Parameters: 1: the number to take the arccosine of
Range: $(0, \pi)$
Example: ARCCOS(x)

ARCSIN: arcsine of a number
Parameters: 1: the number to take the arcsine of
Range: $(-\pi/2, \pi/2)$
Example: ARCSIN(x)

ARCTAN: arctangent of a number
Parameters: 1: the number to take the arctangent of
Range: $(-\pi/2, \pi/2)$
Example: ARCTAN(x)

COS: cosine of an angle in radians
Parameters: 1: the number to take the cosine of
Range: [-1, 1]
Example: COS(angle)

EXP: value of *e* raised to the given power
Parameters: 1: the power on *e*
Range: $(-\infty, \infty)$
Example: EXP(x)

INF: value of infinity
Parameters: none
Example: INF

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INT: next integer less than or equal to the given number
Parameters: 1: the number to find next lowest integer of
Range: (-∝, ∝); note negative fractional numbers increase in magnitude
Example: INT(x)

LN: natural (base-*e*) logarithm of the given number
Parameters: 1: the number to find the natural logarithm of
Range: [0, ∝); note domain is (0, ∝)
Example: LN(x)

LOG10: base-10 logarithm of the given number
Parameters: 1: the number to find the base-10 logarithm of
Range: [0, ∝); note domain is (0, ∝)
Example: LOG10(x)

MAX: larger of two numbers
Parameters: 2: the numbers to compare
Example: MAX(x, y)

MIN: smaller of two numbers
Parameters: 2: the numbers to compare
Example: MIN(x, y)

PI: value of π, the ratio of a circle's circumference to its diameter
Parameters: none
Example: PI

SIN: sine of an angle in radians
Parameters: 1: the number to take the sine of
Range: [-1, 1]
Example: SIN(angle)

SQRT: square root of a positive number
Parameters: 1: the number to take the square root of
Range: [0, ∝); note domain is the same
Example: SQRT(x)

TAN: tangent of an angle in radians
Parameters: 1: the number to take the tangent of
undefined for odd multiples of π/2
Range: (-∝, ∝)
Example: TAN(angle)

3.5.2 Statistical Functions

EXPRND: Sample a value from an Exponential distribution
Parameters: 1 or 2: (*mean*[, *seed*]); 0 ≤ *seed* < 2^{32}
If *seed* is provided, the sequence of numbers will always be identical
Example: EXPRND(8) samples from an exponential distribution with mean 8

LOGNORMAL: Sample a value from a log-normal distribution
Parameters: 2 or 3: (*mean*, *standard deviation*[, *seed*]); 0 ≤ *seed* < 2^{32}
If *seed* is provided, the sequence of numbers will always be identical
Example: LOGNORMAL(10, 1) samples from a lognormal distribution with mean 10 and standard deviation 1

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NORMAL: Sample a value from a Normal distribution
Parameters: 2 or 3: (*mean*, *standard deviation*[, *seed*]); 0 ≤ *seed* < 2^{32}
If *seed* is provided, the sequence of numbers will always be identical
Example: NORMAL(100, 5) samples from *N*(100, 5)

POISSON: Sample a value from a Poisson distribution
Parameters: 2 or 3: (*mean*[, *seed*]); 0 ≤ *seed* < 2^{32}
If *seed* is provided, the sequence of numbers will always be identical
Example: POISSON(3) samples from a Poisson distribution with a mean arrival rate of 3 arrivals per unit time

RANDOM: Sample a value from a uniform distribution
Parameters: 2 or 3: (*minimum*, *maximum*[, *seed*]); 0 ≤ *seed* < 2^{32}
If *seed* is provided, the sequence of numbers will always be identical
Example: RANDOM(1, 100) picks a random number between 1 and 100

3.5.3 Delay Functions

DELAY: infinite-order material delay of the input for the requested fixed time
Parameters: 2 or 3: (*input*, *delay time*[, *initial value*])
If *initial value* is not provided, the initial value of *input* will be used
Example: DELAY(orders, ship_time)

DELAY1: first-order material delay of the input for the requested fixed time
Parameters: 2 or 3: (*input*, *delay time*[, *initial value*])
If *initial value* is not provided, the initial value of *input* will be used
Example: DELAY1(orders, ship_time)

DELAY3: third-order material delay of the input for the requested fixed time
Parameters: 2 or 3: (*input*, *delay time*[, *initial value*])
If *initial value* is not provided, the initial value of *input* will be used
Example: DELAY3(orders, ship_time)

DELAYN: N^{th}-order material delay of the input for the requested fixed time
Parameters: 3 or 4: (*input*, *delay time, n*[, *initial value*])
If *initial value* is not provided, the initial value of *input* will be used
Example: DELAYN(orders, ship_time, 10) delays orders using a 10^{th} order material delay

FORCST: Perform a trend extrapolation over a time horizon
Parameters: 3 or 4: (*input*, *averaging time*, *horizon*, [, *initial trend*])
If *initial trend* is not provided, zero will be used
Example: FORCST(Quality, 5, 10) calculates value of quality 10 time units in the future

SMTH1: first-order exponential smooth of the input for the requested time
Parameters: 2 or 3: (*input*, *averaging time*[, *initial value*])
If *initial value* is not provided, the initial value of *input* will be used
Example: SMTH1(Quality, perception_time)

SMTH3: third-order exponential smooth of the input for the requested time
Parameters: 2 or 3: (*input*, *averaging time*[, *initial value*])
If *initial value* is not provided, the initial value of *input* will be used
Example: SMTH3(Quality, perception_time)

SMTHN: N^{th}-order exponential smooth of the input for the requested time
Parameters: 3 or 4: (*input*, *averaging time*, *n*[, *initial value*])
If *initial value* is not provided, the initial value of *input* will be used
Example: SMTHN(Quality, perception_time, 10) performs a 10^{th} order smooth

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TREND: Find trend in input over a given time frame
Parameters: 2 or 3: (*input*, *averaging time*, [, *initial value*])
If *initial value* is not provided, zero will be used
Example: TREND(Quality, 5) calculates the fractional change in Quality per unit time

3.5.4 Test Input Functions

PULSE: Generate a one-DT wide pulse at the given time
Parameters: 2 or 3: (*magnitude*, *first time*[, *interval*])
Without *interval* or when *interval* = 0, the PULSE is generated only once
Example: PULSE(20, 12, 5) generates a pulse value of 20/DT at time 12, 17, 22, etc.

RAMP: Generate a linearly increasing value over time with the given slope
Parameters: 2: (*slope*, *start time*); begin in-/de-creasing at *start time*
Example: RAMP(2, 5) generates a ramp of slope 2 beginning at time 5

STEP: Generate a step increase (or decrease) at the given time
Parameters: 2: (*height*, *start time*); step up/down at *start time*
Example: STEP(6, 3) steps from 0 to 6 at time 3 (and stays there)

3.5.5 Time Functions

DT: value of DT, the integration step
Parameters: none
Example: DT

STARTTIME: starting time of the simulation
Parameters: none
Example: STARTTIME

STOPTIME: ending time of the simulation
Parameters: none
Example: STOPTIME

TIME: current time of the simulation
Parameters: none
Example: TIME

3.5.6 Miscellaneous Functions

INIT: initial value (i.e., value at STARTTIME) of a variable
Parameters: 1: the variable to get the initial value of
Example: INIT(Balance)

PREVIOUS: previous value of a variable
Parameters: 2: variable and initial value expression, i.e., (*variable*, *initial value*)
Example: PREVIOUS(price, 0) returns the value of *price* in the last DT, or zero in the first DT

SELF: refers to variable the equation defines. Only valid within the PREVIOUS function and the SIZE function defined in the section on Arrays below.
Parameters: none
Examples: PREVIOUS(SELF, 0) retains our previous value in the next DT

3.6 Extending the Standard Language

XMILE OPTIONALLY provides a way for vendors to specify the operation of both their own functions and the functions of other vendors that their users wish to use. In the latter case, these can map to either their own functions (if available) or to the XMILE functions. As described in Section 3.2.2.3, vendor-specific

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function names SHOULD appear in their own namespace, and thus be prefixed by a vendor identifier to avoid conflicting names between both different vendors and XMILE, e.g., `isee.HISTORY`.

As a simple example, let us say that vendor A does not have a `LOG10` built-in, but has a general (any base) `LOG` built-in. That vendor should then be able to map any `LOG10(x)` function to `LOG(x, 10)` when the file is read in. Conversely, if the vendor wishes to use their general `LOG` function within XMILE, they should be able to provide a translation that maps `LOG(x, y)` to `LN(x)/LN(y)`.[8]

The first kind of translation, from XMILE functions to the vendor's functions, could be handled either by the vendor as the file is read in, or through an XSLT translator. The macro functionality described below could also handle this (by creating a macro for the XMILE function).

The second kind of translation, mapping unsupported functions in the file to XMILE, is the main focus of this section. Every unsupported built-in that a vendor wants to appear within an XMILE file needs to be defined in an XMILE macro. The macros may appear in the same file as the model or in a separate file, perhaps on the Internet. Each vendor is encourages to provide their file of macros to use with their models and to provide that file at a canonical URL.

The exact format used for defining macros is described in Chapter 4.

3.6.1 Macros Implementing Functions

Macro support in XMILE implementations is OPTIONAL. However, if an implementation does not support them, it cannot simulate models that use vendor-specific functions. Macros can use all of the syntax of XMILE to achieve their result. The simplest kind of macro is a single expression using existing functions and operators. In this regard, its value is specified in the same way as an auxiliary. The change of base formula above is a good example:

```
LOG(x, y):
   LN(x)/LN(y)
```

Macros can be recursive, so a slightly more complicate macro would call itself:

```
FACT(x):
   IF x <= 1 THEN 1 ELSE x*FACT(x – 1)
```

More complicated macros can use stocks, flows, and auxiliaries to define their behavior. This would be the approach, for example, to implement a smooth function if one did not already exist:

```
SMOOTH1(input, averaging_time) returns Smooth_of_Input:
    stock: Smooth_of_Input
        inflows:    change_in_smooth
        initial eqn: input
    flow: change_in_smooth
        eqn:        (input – Smooth_of_Input)/averaging_time
```

Macros can also run with their own simulation specifications, which can be calculated from the passed parameters. Such macros are, in fact, independent models that run to completion each time they are invoked. The factorial function, defined recursively above, can also be defined using stocks and flows, provided the simulation specifications are given to run from 1 to *x* with the default DT of one:

```
FACT(x) returns Current_Factorial:
    stock: Current_Factorial
        inflows:    change_in_factorial
        initial eqn: 1
    flow: change_in_factorial
        eqn:        Current_Factorial*TIME
```

In equations, the macro name is used as a function. Variable numbers of arguments are not supported, but the same macro MAY be defined multiple times with a different number of arguments. Finally, the

[8] Change of base formula – `LOG10` works just as well as `LN`.

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names of any variables (including parameter identifiers) defined within a macro are local to that macro alone and will not conflict with any names within either the whole-model or other macros.

Macros OPTIONALLY include text describing their usage format and text describing their purpose, both of which are helpful documentation for the user of the function. They MAY also include display information to allow for graphical editing as described in Chapter 4.

3.6.2 Macros Extending Building Block Behavior

XMILE defines a small subset of building block options that are NOT REQUIRED to be supported (vendors are free to add their own), e.g., non-negativity. These options are included as both documentation and to provide a hook outside the standard to implement them when desired.

One possible way to handle these would be to define built-in macros that are used to envelope an object's equation. Non-negative flows (aka uniflows), for example, could have their equations wrapped in a built-in macro that implements `MAX`(<flow value>, 0). Ideally, though, macros would support these options without having to change any equations. For simple cases, such as non-negative flows, the format can mimic the built-in macros. However, more complicated options require greater support. For example, non-negative stocks implement the non-negative logic in the stock's *outflows*, not in the stock itself. Furthermore, each outflow needs not only its own value, but the stock's value, and the sum of the values of every higher-priority flow (which the stock could find for it).

XMILE therefore supports building block options with macro *filters*, also called *option filters*. The filters run after the object's value has been computed and allow the object's value to be altered (filtered) based on the option setting. If several filters are needed, they SHALL run in the order they appear in the object's list of options. A basic filter would only affect the given object, and so is passed just the object itself and the value of the option setting. More complicated filters affect inflows or outflows of the object and need to be invoked for those inflows or outflows and not for the object. They then need to be passed the affected flow, the given stock, and the sum of the inflows or outflows already evaluated. This is summarized in the table below.

filter type	applied to	Parameters
stock, flow, aux	itself	object value, option value
stock	its inflows	flow value, option value, stock value, inflow sum
stock	its outflows	flow value, option value, stock value, outflow sum
flow	upstream stock	stock value, option value, flow value
flow	downstream stock	stock value, option value, flow value

Option filters give software packages and modelers tremendous control over the behavior of the basic building blocks, including the ability to arbitrarily change the value of stock. However, in general, the stock equation in 3.1.1 SHOULD NOT be violated. If you must violate this equation, it is strongly RECOMMENDED that you visually indicate that to the model user (e.g., by using a different symbol for the stock that does not behave as an XMILE stock is defined to behave).

3.7 Optional Language Extensions

Compliant products MUST implement the language described in Sections 3.1-3.5 in its entirety.

Macros, described in Section 3.6, are OPTIONAL. Vendors may choose to only support a basic macro compatibility, which does not permit macros to refer to other macros (or do recursive calls), and does not support option filters. Models containing macros that refer to other macros, or use option filters should indicate such requirements in the `<uses_macros>` tag under `<options>`. See Section 2.2.1 for more information.

There are also a number of OPTIONAL language extensions, described in this section, which are left to each vendor's discretion as to whether or not to support. These are not intended to be vendor-specific features, but common features that lighter packages may either not support, or support in part. These features include enhanced arrays, conveyors, queues, and submodels.

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3.7.1 Arrays

Arrays add depth to a model in up to *N* dimensions. Products that support arrays are free to offer different values of *N*.

Arrays are defined using dimension names. Each subscript indices of each named dimension SHALL be specified with either a name (an XMILE identifier) or with consecutive numbers that MUST start at one. For example, a two-dimensional array of location vs. product could have a dimension called `Location` with three indices `Boston`, `Chicago`, and `LA`, and another dimension called `Product` with two indices `dresses` and `skirts`. If we are looking at sales, we might have a variable `sales[Location, Product]` which has elements `sales[Boston, dresses]`, `sales[Boston, skirts]`, `sales[Chicago, dresses]`, `sales[Chicago, skirts]`, `sales[LA, dresses]`, and `sales[LA, skirts]`.

Dimension names only ever appear as unqualified identifiers. Because of this, they need to be unique and accessible across a whole-model (including submodels). In addition, they must be distinct from model variables names within the whole-model. Subscript index names, on the other hand, are unique within each dimension name as they typically only appear as a subscript into an array that is defined with that dimension name. Within equations, subscripts are XMILE expressions that appear within square brackets with each index separated by a comma.

Subscript index names MAY be used unambiguously as part of a subscript (i.e., inside the square brackets)[9] once the dimensions assigned to the variable have been specified. To use subscript index names in other parts of equations, they MUST be prefixed with the dimension name as in `Location.Boston`. Such usage will evaluate to the position of the subscript index name in its definition (e.g., 1.0 for `Location.Boston`, 2.0 for `Location.Chicago`, and so on).

If a subscript expression results in an invalid subscript index (i.e., it is out of range), a zero (0) MUST be returned[10] and, optionally, a warning SHOULD be given to the user. The user SHOULD be allowed to treat all subscript indices – even named ones – as numbers, specifically integers. Arrays are assumed to be stored in row-major order, which is important for initialization, in data sets, and when using flat indices (as described in Section 3.3.2).

There are two ways to define equations for arrays in XMILE:

- One equation for the entire array (called *Apply-to-All* arrays): One equation is given for the array and MAY include dimension names. No element equations appear. Graphical functions MUST use this option to define a single equation, but there MAY still be separate graphical functions defined for each element.
- One equation for each element of the array (called *non-Apply-to-All* arrays): Each element of the array appears with its own equation. No equation appears for the entire array.

Within the equations of Apply-to-All arrays only, dimension names MAY be used in subscripts. A dimension name is a placeholder for the subscript index used by the element in which the equation appears. For example, an array `profit[Location, Product]` could have the single equation:

```
revenue[Location, Product] - sales[Location, Product]
```

However, when all indices are dimension names, they can be omitted as usually found in languages that support matrix arithmetic. The following equation is identical to the above equation and is preferred:

```
revenue - sales
```

[9] Note, however, that equations can specify subscripts using equations. In these cases, if a variable name is the same as an element name, the element name prevails (i.e., the variable name is hidden within that subscript).

[10] Note this can be NaN if so specified in the `<uses_arrays>` tag of the header options block.

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When dimension names are used (or omitted when allowed), the equation for each element of the array SHALL have the dimension name bound to (replaced by) their index in that dimension. For example, when the equation for *profit*[*Boston*, *blouses*] is evaluated, it gets bound to the above equation as follows:

```
revenue[Boston, blouses] - sales[Boston, blouses]
```

Clearly, for dimension names to be used in this way, the array containing the equation MUST itself be sized using those dimension names, though not necessarily in the same order (e.g., the same equation could be used for profit defined with dimensions in the opposite order as in `profit[Product, Location]`).

3.7.1.1 Array Operations

As much as possible, arithmetic operators should behave in the expected linear algebra ways. Operations with a scalars fall out using the dimension name syntax. Addition and subtraction of same-sized arrays fall out in the same way. However, for historical reasons, the XMILE operators for multiplication, division, and exponentiation also perform element-by-element operations instead of their linear-algebra analogs (i.e., matrix, or tensor, multiplication and inversion).[11]

There are three ways to transpose arrays:

- Transposition operator: If reversing the dimensions is sufficient (i.e., turning a 1 × *M* array into an *M* × 1 array, transposing a square matrix, or turning an *M* × *N* × *P* array into a *P* × *N* × *M* array), the transposition operator, ' (apostrophe), can be used after the array, e.g., `A'` or `A[M, 1, N]'`. This unary operator has the highest arithmetic precedence (just above exponentiation) and right-to-left associativity.
- Dimension names: If the dimension names being transposed are unique, the dimension names can be used directly. For example, if array `A` has dimensions Dim*M* × Dim*N* × Dim*P* and array `B` has dimensions Dim*P* × Dim*M*, a slice of `A` can be assigned to `B` with the equation (in `B`): `A[DimM, 2, DimP]`. If all the dimensions match, but are in a different order, just the variable name is needed, e.g., to assign an Dim*M* × Dim*N* × Dim*P* array `C` to a Dim*N* × Dim*P* × Dim*M* array `D`, just set `D`'s equation to: `C`.
- Dimension positions: When dimension names are not unique and the desired order is not an exact reversal, neither of the two methods above will work. In this case, the dimension position operator, @ (at-sign), must be used with an absolute dimension position of the dimension in the entity that contains the equation. Given an array `A` with dimensions Dim*M* × Dim*N* × Dim*N* that we wish to assign to an Dim*N* × Dim*N* × Dim*M* array `B` with the first Dim*N* in `A` corresponding to the first Dim*N* in `B`, the equation for `B` will be: `A[DimM, @1, @2]`. Note that `@1` resolves to the first dimension in `B` (i.e., the first Dim*N*) while `@2` resolves to the second dimension in `B` (i.e., the second Dim*N*). Note that the equation `A[DimM, @2, @1]` (or the more obscure but equivalent `A[@3, @2, @1]`) is the same as `A'`, i.e., it just reverses the dimensions.

3.7.1.2 Array Slicing

Within an array built-in function, an array MAY be sliced by using the wildcard * (asterisk) for a dimension name. For example, `A[1, *]` extracts the first row of matrix *A* while `A[*, 3]` extracts the third column.

More complex slicing can be done using ranges with the start and ending indices separated by `:` (colon). For example, `A[1:3]` extracts the first three elements of *A* (even if that dimension has named indices) and `SUM(A[1:3])` finds the sum of those elements. Ranges can be used outside of array built-in functions, but when the specified range does not match the given array in an Apply-to-All equation, they will be truncated or extended (potentially with zeroes) as necessary. Extension is non-standard with the

[11] Note that the linear-algebra analogs are not supported by XMILE 1.0.

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implementation free to handle it by either filling with zeroes or additional elements from the same array. A warning SHOULD be generated whenever a range is truncated or extended.

3.7.1.3 Array Built-in Functions

Arrays both extend the functionality of existing built-in functions and add new built-in functions:

MAX:	largest value in an array (or array slice) – *extends MAX(x, y)*
Parameters:	1: the array to examine 2: any mix of arrays and scalars
Examples:	MAX(A) finds the maximum value in array A MAX(A, 0) finds the maximum value of all the values in array A and zero (i.e., if all values in A are negative, the result is zero)
MEAN:	average of values in an array (or array slice) (i.e., SUM(A)/SIZE(A))
Parameters:	1: the array of values to average
Example:	MEAN(A) find the average value of all elements in array A
MIN:	smallest value in an array (or array slice) – *extends MIN(x, y)*
Parameters:	1: the array to examine 2: any mix of arrays and scalars
Examples:	MIN(A) finds the minimum value in array A MIN(A, 0) finds the minimum value of all the values in array A and zero (i.e., if all values in A are positive, the result is zero)
RANK:	index of element of given rank in 1D array sorted in ascending order *OR* flat index of element of given rank in *N*-D array in ascending order
Parameters:	2 or 3: (*array*, *rank number*[, *secondary sort array*]); breaks ties using second array
Examples:	RANK(A, 1) gives index of MIN value in array A (i.e., first ranked, ascending order) RANK(A, SIZE) gives index of MAX value in array A (i.e., final ranked, ascending order) RANK(A, 3, B) gives index of third smallest value in array A, breaking any ties between same-valued elements in A by comparing the corresponding elements in array B
SIZE:	size of array (or array slice)
Parameters:	1: the array
Example:	SIZE(A[1, *]) gives the size of one row of A (i.e., the size of the first dimension) SIZE(SELF[1, *]) gives the size of one row of ourselves Note the subscript [1, *] refers to row one (1), all columns (*), so it is an entire row.
STDDEV:	standard deviation of values in an array (or array slice)
Parameters:	1: the array of values to find the standard deviation of
Example:	STDDEV(A) find the standard deviation of all elements in array A
SUM:	sum of values in an array (or array slice)
Parameters:	1: the array of values to sum
Example:	SUM(A[M, *]) sums all rows of A, placing each row sum into a separate element of the 1D array of size M that includes this equation

All of these functions MUST work on all container objects. For example, `MIN` should be able to be applied to a graphical function to find the minimum *y*-value, to a queue to find the minimum value in the queue, or to a conveyor to find the minimum value in the conveyor. Additionally, the [] notation used to access array elements MUST also work on all containers. Thus, `var[3]` returns the *y*-value of the third data point in a graphical function or the third element (from the front) of a queue or a conveyor. If any of these objects is arrayed, two sets of subscripts are used, the first for the container's array dimensions and the second for the element within that container. For example, if the array *A* of size *M* x *N* is a queue, `A[2, 3][1]` accesses the front element of queue `A[2, 3]`.

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3.7.2 Conveyors

A conveyor conceptually works like a physical conveyor. Objects get on at one end and some time later (the length of the conveyor), they fall off. Some things can leak out (fall off) of a conveyor partway, so one or more leakage flows MAY also be defined. In addition, the conveyor has a variable speed control, so you can change the length of time something stays on it.

Since the outflows have different purposes, it is necessary to be specific about which outflow does what. While leakage flows can be explicitly marked, it is NOT REQUIRED. When they are not marked, by convention, if there is only one outflow, it SHALL be the stuff coming off the end of the conveyor. If there are two or more outflows, the first SHALL always be the conveyor's output, while the remaining outflows SHALL be the conveyor's leakages.

In addition to the REQUIRED length of a conveyor (in time units), a conveyor has the following OPTIONAL parameters (the first four are defined with XMILE expressions):

- Capacity: Maximum contents of a conveyor (default: `INF`)
- Inflow limit: Maximum amount of material that can flow into the conveyor in each unit time (default: `INF`)
- Sample: When provided, the transit time changes only when this expression is true. (default: 1, i.e., the transit time is updated every DT)
- Arrest: When provided, the conveyor shuts down (stops moving, leaking, etc.) whenever this expression is true. (default: 0, i.e., the conveyor never arrests)
- Discrete: Whether the conveyor is discrete (moving batches of material) or continuous (moving a constant stream, e.g., sand and gravel). When discrete, the initial value is applied to the start of each unit time within the conveyor (rather than evenly distributed) and the inflow limit, while still per unit time, can be fulfilled within one DT (in the continuous case, the per DT limit is DT*inflow limit). This is only meaningful when there is *not* a queue immediately upstream of the conveyor (when there is a queue, the conveyor must be discrete). (default: false)
- Batch integrity: Whether batches from an upstream queue can be split into smaller units to meet the limits on the conveyor (they cannot when this is true). This is only meaningful when there is a queue immediately upstream of the conveyor. (default: false)
- Number of batches: How many batches can be taken from the front of the upstream queue to meet the conveyor limits: restricted to one or as many as possible. This is only meaningful when there is a queue immediately upstream of the conveyor (otherwise, it always takes as much as possible). (default: one)
- Exponential leakage: True if the leakage should be an exponential decay across the conveyor (false if the leakage is linear, expressed as fraction of the inflowing amount to leak by the time it exits the conveyor). This is only meaningful if the conveyor has one or more leakage outflows. (default: false)

Each leakage outflow of the conveyor SHOULD be marked as such and has the following options:

- Leakage zone start: Fraction, in [0, 1], of conveyor length that marks the start of the leakage zone (from the inflowing side), i.e., the fractional length that does not leak on the inflowing side (default: 0)
- Leakage zone end: Fraction, in [0, 1], of conveyor length that marks the end of the leakage zone (from the inflowing side); note (1 – leakage zone end) is the fractional length that does not leak on the outflowing side (default: 1)
- Leak integers: True to leak only integers (default: false)

3.7.3 Queues

Queues are first-in, first-out objects that track individual batches that enter them (otherwise, they'd just be stocks). The first batch to enter is the first batch to leave. Queues are important when it is necessary to track batches or when there are input constraints downstream that force the queue outflow to zero (e.g., a capacity limit on a conveyor).

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The value of a queue outflow is determined by the queue's inflow, the queue's contents, and what is downstream of the queue. A conveyor, in particular, can limit the outflow of a queue based on its inflow and capacity limits. Queues flowing to regular stocks and clouds are not limited in any way, so their outflows will always empty the queue.

Queues MAY have multiple outflows and some of these (other than the first one) MAY be designated overflows, i.e., flows that take excess capacity from the front of a queue only when a higher priority queue outflow has been blocked due to capacity constraints, inflow limit constraints, or the downstream conveyor being arrested. These are the only conditions that redirect queue contents to an overflow. If a queue outflow is blocked for any other reason, e.g., an isee systems oven is cooking, the overflow SHALL not remove anything from the queue. Note that since queue outflows to clouds or regular stocks drain the entire contents of the queue, a queue overflow to a cloud or regular stock will do the same (rather than only removing the front element).

3.7.4 Submodels

The features explained here are general enough for hierarchical models or models made up of separate unrelated pieces. This section supports the idea of independent model pieces interacting with each other in some way (i.e., sharing model inputs and outputs). These pieces MAY have separate (and different) simulation specifications, though having them usually only makes sense when the pieces are arranged hierarchically.

The most relevant issue for XMILE is how these disparate model pieces communicate with each other. Each submodel MUST be uniquely named across the whole-odel and its name must be unique from all variable names within the model where it is defined (i.e., within that model, its name is treated just like variable names). This allows the model name to be used as the local namespace so that objects can be referred to across model boundaries using qualified names. For example, the variable named `expenditures` in the submodel `marketing` can be referenced from any other model as `marketing.expenditures`. Note this single qualifying level forces submodel names to be unique across a whole-model. The top level of a model has no name, so the variable `cost` at the top level is simply `.cost`.[12]

Submodels appear in a distinct container object created by and visible to the user (called a *module*). The XMILE format includes modules for this purpose. Modules are NOT REQUIRED to appear in any view but MUST be defined in the model's variables to be used. The module MUST have the same name as the model it contains except in the case where the module is loaded from an external resource. In that case, the module MAY have the same name as its loaded model, but if the external resource does not contain a model with the same name as the module, the module will then represent the single unnamed (root) model in the external resource.[13] However, if the module has been created and named, but not yet assigned a model, it can (and will) have a name that does not correspond to any model.

A module can also have an icon or picture assigned to it. Depending on the package, this will be shown inside the existing icon, or will replace the module icon.

The scope of variables within a submodel is local to that model; variables in a model are not normally visible from outside the model.[14] It is therefore REQUIRED to explicitly specify the variables that are accessible outside the model, i.e., the *outputs* of the model. Specific variables MUST also be set aside for *inputs* to the model – i.e., to pick up the outputs from other models.

---

[12] Note that display IDs, described in Chapter 5, must also be qualified when referenced across models (particularly in interface objects), e.g., `.12` or `marketing.4`.

[13] Note that using an unnamed (root) model in an external file is extremely useful for team development as it enables separate submodel files to be developed and tested independently from the entire model.

[14] If the scope of variables in a model should be global, the correct mechanism is a *group*, not a submodel.

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The variables that are used for this cross-model communication, the inputs and outputs, are given an additional *access* attribute. The access is restricted to the following values:

XMILE Name	Access Level
`input`	placeholder for input value (acts like an alias)
`output`	public access output (restricted by upward connections)

There is a third access level that is not explicitly represented: an output can have restricted access, available only within the next lower module. These act like function parameters and are typically represented by connections from that entity to the module that represents the model they are being passed to. An entity with input access MAY also have this restricted local (implicit) output access, to act as a pass-through from one module up into the containing model and then down again into the other module (which is only necessary if the variable is also used in the model containing those two modules).

Note there is no option for an input that is also a global output. This requires an intermediate auxiliary. As placeholders, inputs do not have to be assigned to an output from another module. When assigned, an input is also referred to as a cross-level ghost (or alias).

By default, a submodel inherits the simulation specifications of the whole-model. However, each submodel can specify its own simulation specs. In such cases, there are two modes of operation:

XMILE Name	Run mode
`normal`	use the same time base as the whole-model, but a different DT
`independent`	do a complete run for every DT in the containing model

In the first mode (normal), the whole-model's DT must be an integer multiple of the submodel's DT. Note the submodel's start and end are forced to be the same as the whole-model.

In the second mode (independent), the length of the simulation specifies how many times to iterate before returning a value. This performs a simple loop.

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4 Model Equation XML Encoding

This chapter describes the specific structure of XMILE tags appearing within the <model> tag of an XMILE file. Tags specific to displaying the model or creating interfaces to models are restricted to the <views> tag within the model. These are detailed in Chapters 5 and 6.

The overall structure of a <model> tag appears below (sub-tags MUST appear in this order):

```
<model>
   <sim_specs>                <!-- OPTIONAL – see Chapter 2 -->
      ...
   </sim_specs>
   <behavior>             <!-- OPTIONAL – see Chapter 2 -->
      ...
   </behavior>
   <variables>                <!-- REQUIRED -->
      ...
   </variables>
   <views>                <!-- OPTIONAL – see Chapters 5 & 6 -->
      ...
   </views>
</model>
```

An XMILE file MAY define many models, each in its own <model> tag[15]. The primary, or root, model has no name, but all remaining models MUST be named; they represent submodels of the root model. The <model> tag has the following OPTIONAL attributes:

- Name: name="…" with the model name (a valid XMILE identifier). This is REQUIRED for all but the root model (which SHALL be unnamed).
- Run enabled: run="…" with true/false (default: false). This is only in effect when running the model by module.
- Namespace: namespace="…" with XMILE namespaces, separated by commas. For example, namespace="std, isee" means resolve unrecognized identifiers against the std namespace first, and then against the isee namespace. If this setting appears, it overrides the file-level namespace setting in the XMILE options block. (default: same as the file-level namespace)
- Optional reference to a separate model file for the model contents: resource="…". A resource can be a relative file path, an absolute file path, or an URL. Since the <module> tag can also specify a separate model file resource, this is only needed for models that do not use modules. However, when the same module is shared in multiple parts of the file, it is better to create one URL reference in a model block, rather than specifying it in the module block.

The model section can OPTIONALLY include <sim_specs> and <behavior> tags, as described in Chapter 2, to override specific settings. The rest of this chapter focuses on the specific tags that appear within the <variables> tag, which are all entities that either simulate or affect the simulation.

Any individual model with an XMILE file can OPTIONALLY be encrypted. Encrypted models are stored in such a way that the contents of the model are unknown unless the proper password is provided to

[15] When multiple models are defined in an XMILE file, the <uses_submodels> option MUST be set in the XMILE options (see Chapter 2).

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decrypt the model content. In this first version of XMILE, there is only a single supported encryption scheme as described below.

Models that have been encrypted are first emitted in plain-text form (typically in memory). Then the generated UTF-8 string representing the entirety of the model tag is encrypted using the cipher block chaining mode (CBC) of an AES-128 block cipher.

A SHA-256 keyed hash message authentication code (HMAC) is generated to allow implementations to verify whether decryption was successful or not. Because a CBC mode cipher is used, an initialization vector (IV) is required to initialize the cipher and it too MUST be provided to decode the encrypted model (cipher text).

In the encrypted XMILE file, a `<model>` tag is written with the following four REQUIRED attributes allowing it to be decoded in place into a normal `<model>` tag:

- Encryption scheme: `encryption-scheme="…"` with a comma-separated list of the block cipher, the block mode, and the HMAC. The only currently supported value is `AES-128,CBC,SHA256`. The currently supported encryption scheme uses a CBC AES-128 block cipher with a SHA-256 HMAC for verification of the decrypted cipher text.
- IV: `iv="…"` The initialization vector as a base64 encoded string. The decoded (from base64) string is used to initialize the CBC AES-128 block cipher.
- HMAC: `hmac="…"` The HMAC as a base64 encoded string. The decoded (from base64) string is used to verify the decrypted cipher text.
- Cipher text: (contents of the tag). The cipher text as a base64 encoded string. The decoded (from base64) string is the output of the cipher.

The password entered by the user is hashed using the SHA-256 algorithm to generate the encryption key for the cipher allowing the cipher text to be decrypted or the plain-text to be encrypted.

When encrypting a model, the software must first prompt for the password, which it then SHA-256 hashes to generate the encryption key. Then a 128-bit IV needs to be generated to initialize and start the CBC. The cipher can then encrypt the unencrypted model tag. Finally, after encryption is complete, the HMAC is calculated using the same encryption key, the concatenated IV, and unencrypted text as inputs to the HMAC-SHA256 algorithm.

When decrypting a model, the software must first prompt for the password, which it then SHA-256 hashes to generate the encryption key. The IV is then used to initialize the CBC cipher, which then decrypts the cipher text using the generated encryption key. After decryption, the IV (decoded from base64) is concatenated with the decrypted plain-text and the result is used to generate an HMAC using the same process as when encrypted. The new HMAC is then compared to the HMAC from the file (decoded from base64) to verify a successful decryption.

4.1 Common Variable Properties

All variables have the following REQUIRED property:

- Name: `name="…"` attribute w/valid XMILE identifier

All variables that are dimensioned have the following REQUIRED property:

- Dimensions: `<dimensions>` w/`<dim name="…">` for each dim in order (see Arrays in Section 4.1.4) (default: none)

All non-apply-to-all arrayed variables, including non-apply-to-all graphical functions, have the following REQUIRED property:

- Element: `<element>` with a valid subscript attribute (default: none). The `subscript="…"` attribute lists comma-separated indices in dimension order for the array element. This attribute is only valid on the variable type tag for array elements of non-apply-to-all arrays (see Arrays in Section 4.5). There MUST be one `<element>` tag for each array entry and each MUST encapsulate either an `<eqn>` tag (non-graphical functions) or a `<gf>` tag (graphical functions).

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All variables have the following OPTIONAL properties:

- Access: `access="…"` attribute w/valid XMILE access name – see Submodels in Chapter 3 and in Section 4.7 (default: none)
- Access automatically set to output: `autoexport="…"` attribute with true/false – see Submodels in Section 4.7 (default: false)
- Equation: `<eqn>` w/valid XMILE expression, in a CDATA section if needed
- MathML equation: <mathml> block containing content-based MathML representation of the equation[16]
- Units: `<units>` w/valid XMILE units (default: none)
- Documentation: `<doc>` w/block of text, optionally in HTML format (default: none)
- Message Poster: `<event_poster>` as described in Section 4.1.2 (default: none)
- Input range: `<range>` as described in Section 4.1.1 (default: unspecified)
- Output scale: `<scale>` as described in Section 4.1.1 (default: unscaled)
- Number format: `<format>` as described in Section 4.1.1 (default: unspecified)

Of these, the name is REQUIRED for all variables and must be unique across all variables in the containing model. If the intent is to simulate the model, the equation is also required. For a stock, the equation contains the stock's initial value, rather than the stock's integration equation.

The documentation can be plain text or can be HTML. If in plain text, it must use XMILE identifier escape sequences for non-printable characters (i.e., \n for newline, \t for tab, and, necessarily, \\ for backslash), rather than a hexadecimal code such as &#x0A. If in HTML, it must include the proper HTML header. Note this is true for all documentation and user-specified text fields in a XMILE file (i.e., including those in display objects defined in Chapters 5 and 6).

4.1.1 Ranges, Scales, Number Formats

All XMILE objects MAY have explicit ranges and scales that are used by default in input and output devices, respectively. These same properties can appear within the input and output devices to override the entity's setting for that device.

The `<range>` tag is used to specify the default input range for an input device. Without it, any reasonable guess can be used (typically tied to the variable's scale). The `<scale>` tag is used to specify the global scale of a variable. Without it, the scale of variable matches the (output) range of its values. Both tags have two attributes:

- Range/scale minimum: `min="…"` with the minimum value for the range/scale
- Range/scale maximum: `max="…"` with the maximum value for the range/scale

Note that it is REQUIRED that `min` <= `max`. For the `<scale>` tag only, two OPTIONAL attributes exist that can only be used when the `<scale>` tag appears within the definition of an output device (typically graphs):

- Autoscale: `auto="…"` with true/false to override the global scale within that output device; this is mutually exclusive with `min`, `max`, and `group` (default: false)
- Autoscale group: `group="…"` with a unique number identifying the group in that output device; note this implies `auto="true"` and is therefore mutually exclusive with `min`, `max`, and `auto` (default: not in a group)

[16] This is optional for a number of reasons, most notably the size of the representation. All vendors, however, should strive to offer MathML output as a user-option.

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Groups require more than one variable in them and are specifically used to autoscale a group of variables to the same scale starting at the minimum value of all variables in the group and ending at the maximum value of all variables in the group. This is the default scaling for all variables in a comparative plot, so does not need to appear in that case.

The `<format>` tag allows default formatting to be set for values of each variable. Without it, the default settings for each attribute below takes effect:

- Precision: `precision="…"` with value indicating precision of least significant digit, e.g., “0.01” to round to the hundredths place or “0.5” to round to the nearest half (default: best guess based on the scale of the variable)
- Magnitude scale: `scale_by="…"` with the factor to scale all values by before displaying, e.g., “1000” to display thousands (default: no scaling, i.e., 1); note the `precision` applies to the scaled number
- Special symbols: `display_as="…"` with “number”, “currency”, or “percent” (default: `number`)
- Include thousands separator: `delimit_000s="…"` with true/false (default: false)

These can also be overridden, using the same attribute names, in variable definitions of individual input or output devices.

4.1.2 Event Posters

Events based on entity values can be triggered while the model is being simulated. At the simulation level, these events are limited to pausing the simulation (default) or stopping the simulation. The model user can be informed of these events in various ways, as described in Chapter 6.

All events appear in an `event_poster` block with `min` and `max` attributes specifying the lower and upper bounds for all posters (this is a user setting to help them decide where to place events). A series of `threshold` blocks then define the event triggers:

```
<event_poster min="0" max="10">
   <threshold value="5">
      <event>
         ...
      </event>
      ...
   </threshold>
</event_poster>
```

The threshold has these additional OPTIONAL attributes:

- Direction: `direction="…"` w/valid XMILE event direction name – see Chapter 3 (default: `increasing`)
- Frequency: `repeat="…"` w/valid XMILE event frequency name – see Chapter 3 (default: `each`)
- Repetition interval: `interval="…"` w/number of unit times (default: disabled; only enabled if present)

Each threshold block MUST have a unique value and direction (so there can be two threshold blocks at 5 as long as one is increasing and the other is decreasing). Within each threshold block, the actual events are defined, which MAY be either a single event that is used every time the threshold is exceeded (frequency of `each` REQUIRES there be only one event) or a sequence of events that are used one at a time in their specified order each time the threshold is exceeded (i.e., the first event is used the first time the threshold is exceeded, the second is used the second time, etc.). Events appear in an `<event>` tag which has one OPTIONAL attribute:

- Action: `sim_action="…"` w/valid XMILE event action name – see Chapter 3 (default: `pause`)

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4.1.2.1 Interactivity in Event Posters

Posters can also include OPTIONALLY visual and aural components that tell the user what happened. These are defined within the <event> tag using the following tags:

- Text message: <text_box> with text as described in Section 6.5.1
- Image message: <image> as described in Section 6.5.2
- Video message: <video> as described in Section 6.5.2
- Sound attached to message: <sound> as described in Section 6.5.3
- Hyperlink to a place to navigate to: <link>, as described in Section 6.5.3.

Note that only one visual type message (text, image, video) SHALL be allowed per event. While event poster interactivity is an optional part of the standard, it is strongly recommended that all implementations of event posters support text messages.

The following example shows a poster that puts up a text message when 10 is exceeded, but then, when 19 is exceeded, plays a sound and a movie while navigating to an interface:

```
<event_poster min="1" max="20">
   <threshold value="10">
      <event>
         <text_box>Careful!</text_box>
      </event>
   </threshold>
   <threshold value="19">
      <event>
         <sound>bicycle_bell.wav</sound>
         <link target="view" view_type="interface" x="0" y="0"/>
         <video>c:/Movies/uh-oh.mov</video>
      </event>
   </threshold>
</event_poster>
```

4.1.3 Graphical Functions

Graphical functions are defined within a <gf> tag. A graphical function definition MAY stand alone, providing it is named, or it can be embedded within a flow or an auxiliary. As provided in XMILE expressions, named graphical functions MAY also be invoked like built-in functions.

The graphical functions has several properties, as described below. Note that it is REQUIRED to include exactly one of x-axis scale and x-axis points (either, but not both).

- Name: name="…" w/valid XMILE identifier (default: anonymous). The name is REQUIRED if a graphical function is defined outside other variables (flows or auxiliaries). It is OPTIONAL when it is defined inside a variable.
- Type: type="…" w/valid XMILE graphical function type name – see Chapter 3 (default: continuous) OPTIONAL
- *x*-axis scale: <xscale min="…" max="…"/> defines the scale of the *x*-axis (default: smallest and largest values in <xpts>). REQUIRED when no x-axis points.
- *y*-axis scale: <yscale min="…" max="…"/> defines the scale of the *y*-axis (default: smallest and largest values in <ypts>). This only affects the scale of the graph as shown in a user interface; it has no impact on the behavior or interpretation of the graphical function. In general, include it only if the user-desired scale differs from the minimum and maximum *y*-values in <ypts>. OPTIONAL

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- *x*-axis points: <xpts>…</xpts> specifies the exact *x*-values corresponding to the *y*-values given in the <ypts> (default: the *x*-axis scale, <xscale>, evenly divided into the number of points in <ypts> creating a (fixed) increment along the *x*-axis). Note that when this is specified, the number of points given MUST exactly match the number of points in <ypts>, one *x*-value for each and every *y*-value, corresponding positionally, and the values must be sorted in ascending order (from smallest to largest). By default, these values are comma-separated. REQUIRED when no x-axis scale.
- *y*-axis points: <ypts>…</ypts> specifies the *y*-values for the graphical function, starting with the *y*-value for the smallest *x*-value and continuing as *x* increases until ending with the *y*-value corresponding to the largest *x*-value. By default, these values are comma-separated. REQUIRED

The <xpts> and the <ypts> tags have one OPTIONAL attribute to specify the separator between values:

- Value separator: sep="…" w/the single character used as the separator (default: "," – comma)

Only <ypts> are always REQUIRED, but since the default values for other properties depend on properties other than <ypts>, <ypts> alone is never sufficient. In particular, <xpts> defaults to values from <xscale> and <xscale> defaults to values from <xpts>, so one or the other is always REQUIRED.

The smallest possible (named) graphical function definition is therefore:

```
<gf name="rising">
   <xscale min="0" max="1"/>
   <ypts>0,0.1,0.5,0.9,1</ypts>
</gf>
```

This definition implies a corresponding set of *x*-values of (0, 0.25, 0.5, 0.75, 1) and a *y*-scale from 0 to 1.

A named graphical function (whether defined stand alone or within a variable) can then be directly referred to in a variable:

```
<gf name="rising"/>
```

or in a XMILE expression:

```
<eqn>rising(star)</eqn>  <!-- evaluate gf "rising" at star -->
```

The set of defaults given above are specifically designed to avoid redundancies in the definitions that lead to contradictions. Property defaults must be used to reduce the graphical function to its smallest form. For example, the following overspecified graphical function, even though it is self-consistent, is not valid (since it includes both the x-axis scale and the x-axis points):

```
<gf name="overspecified">
   <xscale min="0" max="0.5"/>
   <yscale min="0" max="1"/>
   <xpts>0,0.1,0.2,0.3,0.4,0.5</xpts>
   <ypts>0.05,0.1,0.2,0.25,0.3,0.33</ypts>
</gf>
```

Likewise, the following invalid graphical function shows how overspecification leads to inconsistencies:

```
<gf name="inconsistent">
   <xscale min="0" max="0.5"/>
   <yscale min="0" max="1"/>
   <xpts>0,1,2,3,4,5</xpts>
   <ypts>0.05,0.1,0.2,0.25,0.3,0.33</ypts>
</gf>
```

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Even removing overspecified fields will not prevent errors. When <xpts> are included, the *x*-values MUST be in ascending order and the number of *x*-values MUST match the number of *y*-values. The following graphical function, although not overspecified, violates both of these rules:

```
<gf name="invalid">
   <yscale min="0" max="1"/>
   <xpts>2,1,3,0</xpts>
   <ypts>0.05,0.1,0.2,0.25,0.3,0.33</ypts>
</gf>
```

Flows and auxiliaries (only) can be defined as graphical functions. This is done using a <gf> block within the variable, as shown below.

```
<gf>
   <xscale min="0" max="0.5"/>
   <yscale min="0" max="1"/>
   <ypts>0.05,0.1,0.2,0.25,0.3,0.33</ypts>
</gf>
```

If the x-axis points are evenly spaced, as above, it is strongly RECOMMENDED you use the x-axis scale to define the graphical function. Thus, the above graphical function is preferable to the equivalent valid (but not recommended) definition that uses <xpts> instead of <xscale>:

```
<gf>
   <yscale min="0" max="1"/>
   <xpts>0,0.1,0.2,0.3,0.4,0.5</xpts>
   <ypts>0.05,0.1,0.2,0.25,0.3,0.33</ypts>
</gf>
```

4.1.4 Arrays

Any variable MAY be arrayed (the <uses_arrays> option must also be set in the XMILE header). All arrayed variables MUST include exactly one <dimensions> tag that specifies the array dimensions of the variable. Like its cousin at the top of each XMILE file, this tag includes <dim> tags that define which dimensions are used and in which order. Only the name attribute is used on each <dim> tag. For example, the following definition states that the variable is a two-dimensional array with dimensions X by Y:

```
<dimensions>
   <dim name="X"/>
   <dim name="Y"/>
</dimensions>
```

There are three different kinds of XMILE arrays:

- Apply-to-all arrays, where one variable, the array owner, acts as a surrogate for all array elements
- Non-apply-to-all arrays, where one variable, the array owner, acts as a container for many different array elements (this container necessarily shares some things across all elements, e.g., units)
- Apply-to-all arrays with non-apply-to-all graphical functions, where one variable, the array owner, acts as the surrogate for all properties of the array elements except the graphical function used for each element (which differs by element)

Apply-to-all arrays are the simplest: They are just variables that include a <dimensions> tag. However, unlike non-arrays and arrays that are not apply-to-all, they can use dimension names in their equations.

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The remaining two arrays types, which are at least partially non-apply-to-all, use the <element> tag to define the individual characteristics of each array element. For these types, the variable tag (e.g., <stock> for stocks) acts as a container for both the array elements and the shared properties of all elements. Examples are given (in Section 4.5) after the three basic variable types are introduced below.

4.2 Stocks

All stocks REQUIRE a name. To simulate, a stock also needs an initial value, specified with the <eqn> tag. If the stock's value is to change during the simulation, at least one flow is necessary. Rather than write the stock's equation, XMILE mandates that we classify the flows that affect the stock as either inflows or outflows[17]. The basic stock definition is shown below with sample values.

```
<stock name="Motivation">
   <eqn>100</eqn>
   <inflow>increasing</inflow>
   <outflow>decreasing</outflow>
</stock>
```

Note again that the equation is for the stock's initial value only. If the equation is not constant, the initial values of the included variables will be used to calculate the stock's initial value.

The set of inflows and/or outflows is NOT REQUIRED. If there are multiple inflows, they appear with multiple tags in inflow-priority order (if the order of inflow to the stock is important). For example, if in1 must be treated before in2, the inflows must appear within the <stock> block in this order:

```
<inflow>in1</inflow>
<inflow>in2</inflow>
```

Multiple outflows appear in a similar fashion, i.e., in separate tags. The order in which they appear is their outflow priority, if that is important. I.e., material from the stock is first given to the first outflow listed. If there is still something in the stock, the second outflow gets some of it. Inflow priority is only important for queues and capacity-constrained conveyors. Outflow priority is only important for non-negative stocks (for example, Inventory), queues, and conveyors with multiple leakages.

The stock has three mutually exclusive OPTIONS, all properties, that affect the behavior of the stock when simulated:

- Conveyor: <conveyor>…</conveyor> causes the stock to behave as a conveyor with the given conveyor parameters (see Chapter 3)
- Queue: <queue/> causes the stock to behave as a queue (see Chapter 3)
- Non-negative: <non_negative/> invokes an optional macro that prevents the stock from going negative.

Note that non-negative is not directly supported by XMILE. The option exists partly for documentation, partly to allow a vendor to invoke a macro to implement the functionality. If this property has been set at a higher level (in a <behavior> tag), it can be turned off locally with:

```
<non_negative>false</non_negative>
```

The conveyor options are described in the next section.

Queues do not have any options. However, their outflows have a priority order and MAY have the <overflow/> option set on all but the first outflow (see Section 4.3).

[17] The classification is based on the direction of flow when the flow rate is positive. Negative inflows flow outward while negative outflows flow inward.

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4.2.1 Conveyor Options

To simulate a conveyor, the conveyor MUST have at least one outflow. Since the conveyor can have both its normal outflow (i.e., where the material exits from the conveyor) and any number of leakage outflows (i.e., where material prematurely falls off the conveyor), to simulate a conveyor, at least one of its outflows MUST be its normal outflow. By convention, the first outflow in the conveyor's list of outflows SHALL be the normal outflow and all subsequent outflows are leakage outflows. However, this behavior MAY be explicitly overridden by tagging each leakage flow with the `<leak/>` property (see Section 4.3).

The following conveyor properties are REQUIRED:

- Transit time: `<len>…</len>` specifies the XMILE expression for the length of the conveyor (in time units), i.e., how much time elapses between when material enters the conveyor and when it exits. When it varies, every batch that entered the conveyor stays on the conveyor for the transit time of the conveyor when it entered (i.e., the speed of the conveyor does not change). Thus, the conveyor is extended to accommodate a larger length, but not immediately shortened for smaller lengths (unless no batches exist in the part that would be truncated).

The following conveyor properties and attributes are OPTIONAL:

- Capacity: `<capacity>…</capacity>` specifies the XMILE expression for the maximum amount of material that can be on the conveyor at any given moment (default: INF). When it varies and becomes smaller than the material that is presently on the conveyor, the conveyor's capacity will be exceeded only until enough material exits to bring the conveyor's contents down to the new capacity limit.
- Inflow limit: `<in_limit>…</in_limit>` specifies the XMILE expression for the maximum amount of material that can enter the conveyor each time unit (default: INF). For conveyors that are not discrete, this is converted to a per DT limit by multiplying by DT. For discrete conveyors, the full amount allowed each time unit is allowed to enter in a single DT.
- Sample transit time: `<sample>…</sample>` specifies the XMILE conditional expression used to decide when to sample and update the conveyor's transit time (default: DT). When the specified equation evaluates to true (non-zero), the conveyor's transit time is updated with the transit time equation's value.
- Arrest conveyor: `<arrest>…</arrest>` turns on the ability to arrest the conveyor and specifies the XMILE conditional expression used to decide when to arrest the conveyor (default: conveyor does not arrest). When the specified equation evaluates to true (non-zero), all inflows and outflows to the conveyor stop flowing (are forced to zero) and the conveyor stops moving (i.e., time suspends for all material on the conveyor). The conveyor will not start again until the equation evaluates to false (zero).
- Discrete: `discrete="…"` with true/false (default: false); true if a discrete conveyor (the conveyor MUST be discrete if there is a queue directly upstream)
- Batch integrity: `batch_integrity="…"` with true/false (default: false); true if only entire batches can be taken from the (REQUIRED) upstream queue and false if partial batches are allowed
- Number of batches: `one_at_a_time="…"` with true/false (default: true); true if only the front batch from the (REQUIRED) upstream queue can be taken each DT and false if as many batches as will fit (subject to capacity and inflow limits) can be taken
- Exponential leakage: `exponential_leak="…"` with true/false (default: false); if true, leakage is an exponential decay across the conveyor (rather than linear) – for *all* leakages

For example, a conveyor with a transit time of 4 and a capacity of 1200:

```
<stock name="Students">
```

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```
      <eqn>1000</eqn>
      <inflow>matriculating</inflow>
      <outflow>graduating</outflow>
      <conveyor>
         <len>4</len>
         <capacity>1200</capacity>
      </conveyor>
   </stock>
```

4.3 Flows

All flows REQUIRE a name. To simulate, most flows also require an equation. The only exceptions to requiring an equation for simulation are queue and conveyor outflows, which MUST NOT have an equation as their attached conveyor or queue drives them. The basic flow definition is shown below with sample values.

```
   <flow name="increasing">
      <eqn>rewards*reward_multiplier</eqn>
   </flow>
```

One OPTIONAL property is available to all flows:

- Unit conversion multiplier: `<multiplier>…</multiplier>` specifies the XMILE expression to be used to convert the units of the flow on the downstream side of the flow. This is used to convert units between stocks in a main chain. For example, if the unit conversion multiplier is 3 and the flow's value is 4, 4 units of material will be taken from the upstream stock and 3*4 = 12 units of material will be given to the downstream stock. This does not violate conservation when the units change correctly. Note that when a unit-converted flow appears between two stocks, the downstream stock SHOULD have different units than the upstream stock; the flow units are based on the upstream stock.

Three OPTIONAL flow properties are mutually exclusive and affect the behavior of the flow when simulated:

- Non-negative: `<non_negative/>` invokes an optional macro that prevents the flow from going negative (also called a unidirectional flow, or uniflow – a flow without this property is a bidirectional flow, or biflow, i.e., material can flow in either direction depending on whether the flow value is positive or negative). Note that queue and conveyor inflows MUST be non-negative. In addition, queue outflows and normal, non-leakage conveyor outflows are non-negative by definition so this property MUST NOT appear for them.
- Queue overflow: `<overflow/>` makes a queue outflow an overflow, i.e., if a higher priority queue outflow has been blocked due to capacity restrictions or an arrested conveyor, the overflow becomes active (note that it too might get blocked, allowing a lower priority overflow to become active). This property can only appear in a queue outflow.
- Conveyor leakage fraction: `<leak>` with a valid XMILE expression that defines the leakage fraction for this conveyor outflow, or `<leak/>` to explicitly mark a partially defined conveyor outflow as a leakage outflow (before a leakage fraction is specified). The latter is critical for when the user is editing the model and may have temporarily disconnected or deleted the normal conveyor outflow. This property can only appear in a conveyor outflow.

Note that non-negative is not directly supported by XMILE. The option exists partly for documentation, partly to allow a vendor to invoke a macro to implement the functionality. If this property has been set at a higher level (in a `<behavior>` tag), it can be turned off locally with:

```
   <non_negative>false</non_negative>
```

If a flow is a conveyor leakage, it can have these additional OPTIONAL properties and attributes:

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- Leak integers: `<leak_integers/>` forces a leakage flow to only leak whole numbers (default: leak fractions)
- Leak zone start: `leak_start="…"` with the fractional starting position of the leakage zone within the conveyor (from the inflowing side of the conveyor) (default: 0)
- Leak zone end: `leak_end="…"` with the fractional ending position of the leakage zone within the conveyor (from the inflowing side of the conveyor) (default: 1)

An example conveyor leakage that does not yet simulate:

```
<flow name="shrinking">
   <leak/>                                  <!-- RECOMMENDED -->
</flow>
```

An example conveyor leakage that simulates:

```
<flow name="attriting" leak_end="0.25">  <!-- freshman year only -->
   <leak>0.1</leak>                      <!-- leakage fraction -->
</flow>
```

An example uniflow that simulates:

```
<flow name="increasing">
   <eqn>rewards*reward_multiplier</eqn>
   <non_negative/>
</flow>
```

4.4 Auxiliaries

Auxiliaries, like flows, also REQUIRE a name. To be simulated they must also have an equation. The basic auxiliary definition is shown below with sample values.

```
<aux name="reward_multiplier">
   <eqn>0.15</eqn>
</aux>
```

This particular auxiliary is a constant, i.e., it depends on no other variables and its value does not change.

Auxiliaries have one OPTIONAL attribute:

- Flow concept: `flow_concept="…"` with true/false, which is true if the auxiliary represents a flow concept (default: false). Besides documenting that the variable is conceptually a flow, this affects how values are reported under certain integration methods and in tables.

4.5 Arrays

As discussed on Section 4.1.4, there are three types of arrays. This section gives an example of each, in each case making an array of auxiliaries.

4.5.1 Apply-to-All Array

A two-dimensional (2D) array with dimensions X by Y:

```
<aux name="distance">
```

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```
    <dimensions>
       <dim name="X"/>
       <dim name="Y"/>
    </dimensions>
    <eqn>SQRT(X^2 + Y^2)</eqn>
    <units>kilometers</units>
 </aux>
```

The value of each element of the auxiliary is of the distance on the Cartesian plane from the origin (0, 0) to that (*x*, *y*) coordinate. For example, distance[3, 4] = SQRT(3^2 + 4^2) = 5, the distance from the origin to (3, 4).

4.5.2 Non-Apply-to-All Array

Non-apply-to-all arrays are embedded in the tag associated with the type of variable (e.g., `<stock>` for stocks and `<flow>` for flows). Each array element is represented using the `<element>` tag with only the `subscript` attribute allowed. Each element MAY define its own equation and other simulation attributes (such as event poster and transit time) that are allowed to vary between elements. The documentation, the units, and any variable-type-specific setting (e.g., non-negative, conveyor, or leak) are part of the array block, and MUST be shared for all elements. The event poster MAY also be shared.

A 2D non-apply-to-all array with dimensions X by X, where X is size 2:

```
<aux name="not_apply_to_all">
   <dimensions>
      <dim name="X"/>
      <dim name="X"/>
   </dimensions>
   <element subscript="1,1">
      <eqn>TIME</eqn>
   </element>
   <element subscript="1,2">
      <eqn>2*TIME</eqn>
   </element>
   <element subscript="2,1">
      <eqn>5*TIME</eqn>
   </element>
   <element subscript="2,2">
      <eqn>11*TIME</eqn>
   </element>
   <units>months</units>
</aux>
```

Note that each element has its own equation unrelated to its subscript index.

4.5.3 Apply-to-All Arrays with Non-Apply-to-All Graphical Functions

Arrayed graphical functions are REQUIRED to have one equation, so are technically apply-to-all arrays. Thus, they typically appear in the same way as apply-to-all arrays. However, it is also possible to specify a different graphical function for each array element. In these cases, arrayed graphical functions use an `<element>` tag, just like a non-apply-to-all array. The only information that SHALL appear in each array element is a `<gf>` tag describing the graphical function for that element. All other attributes are associated with the array owner.

A 1D apply-to-all arrayed auxiliary with dimension X, where X is size 2, and non-apply-to-all graphical functions.

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```
<aux name="graphical_not_apply_to_all">
   <dimensions>
      <dim name="X"/>
   </dimensions>
   <element subscript="1">
      <gf>
         <xscale min="1" max="9"/>
         <ypts>0,50,25</ypts>       <!-- implied y scale from 0-50 -
->
      </gf>
   </element>
   <element subscript="2">
      <gf>
         <xscale min="1" max="9"/>
         <yscale min="0" max="100"/>
         <ypts>90,10,50</ypts>
      </gf>
   </element>
   <eqn>TIME</eqn>
   <units>buildings</units>
</aux>
```

Each graphical function is evaluated using the same equation, TIME.

4.6 Groups

Groups, aka sectors, collect related model structure together. Groups REQUIRE a name and MAY have documentation. The group includes the names of all entities in that group using the `<entity>` tag with a `name` attribute. View-only objects within the group appear in their own `<group>` under the `<view>` tag (see Chapter 6).

Groups have the following unique OPTIONAL properties and attributes:

- Entity reference: `<entity name="…"/>` with the name of the entity that is in the group.
- Run enabled: `run="…"` with true/false (default: false). This is only in effect when running the model by group.

A sample group from the `<variables>` section of the model:

```
<group name="Financial Sector">
   <doc>
      The operation of the Finance department is modeled in
      this sector.
   </doc>
   <entity name="Cumulative Revenue"/>
   <entity name="revenue"/>
   ...
</group>
```

4.7 Submodels

Submodels appear within their own `<model>` tag. Within the same file as the root model or other submodels, that tag MUST include the `name` attribute. When the submodel appears alone in its own file, the `name` generally SHOULD NOT be provided, allowing the submodel to be developed and tested as a stand-alone model.

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To be used by any other model, including the root model, submodels MUST be directly represented with an explicit module in the variables section of the model directly above them. This is because the connections between submodels are defined in modules.

4.7.1 Modules

Modules are placeholders in the variables section, and in the stock-flow diagram, for submodels. If present, this must appear in every model that references that submodel. A module appears in a `<module>` block with two possible attributes and one property:

- Name: `name="…"` attribute w/valid XMILE identifier. If the optional `resource` is not specified, the name is required to match the `name` attribute of the submodel. If the optional `resource` is specified, the name will be used to try to match the `name` attribute of any model in the submodel file. If no match is found, the name is required to be ignored for the purposes of locating the submodel and the and the module will then represent the unnamed (root) model in the referenced file. REQUIRED
- OPTIONAL location: `resource="…"` with a reference to the submodel's file. A resource can be a relative file path, an absolute file path, or an URL. This is REQUIRED if the submodel is not in the same file as the model. Likewise, this should not appear if there is a `<model>` block for the submodel that already includes the `resource` attribute (see the beginning of Chapter 4).
- Submodel input assignment: `<connect to="…" from="…"/>` where `to` contains the name of the module input within this submodel or one its submodels (in which case, it is qualified with the submodel's name) that is assigned and `from` contains the qualified name of the submodel output that is being assigned to that submodel input. To support arbitrary re-use of submodels[18], the inputs of a submodel within a submodel must be allowed to appear here as the connections must be specified at the lowest common ancestor (LCA) of the submodel hierarchy (keep in mind also that the module itself always appears one level above the submodel it refers to). OPTIONAL

When a module does exist, connectors from entities to that module automatically denote that those entities are submodel outputs into just that module, so no additional designation is used. Likewise, connectors from the module to entities automatically turn those entities into submodel inputs (inputs are always marked as such in the XMILE).

Below is an example showing the inclusion of a module sharing data with the root model when saved within the same XMILE file:

```
<?xml version="1.0" encoding="utf-8" ?>
<xmile version="1.0" xmlns="http://docs.oasis-
      open.org/xmile/ns/XMILE/v1.0">
   <header>
      <product version=”1.0”>Product</product>
      <vendor>sample</vendor>
      <options>
         <uses_submodels/>
      </options>
   </header>
```

[18] By "re-use", we specifically mean either the re-use of independently developed modules within different models, or the re-use of the same module, stored in a separate file, within the same model. The latter works because nothing precludes separate modules, all with different names, referring to the same model file. Note that within the same model file, each model (and therefore associated module) must have a unique name. However, when using separate files, a separate unnamed (root) model can appear in each file. Each of these separate models do not have a name until they are assigned to named modules in the larger model, allowing multiple modules to refer to the same model [file].

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```
   <sim_specs method="Euler" time_units="Months">
      <start>1</start>
      <stop>13</stop>
      <dt>0.25</dt>
   </sim_specs>
   <model>
      <variables>
         <module name="Sub_Model">
            <connect to="Input" from=".Root_Model_Output"/>
            <connect to=".Root_Model_Input" from="Sub_Model.Output"/>
         </module>
         <aux name="Root_Model_Output" access="output"/>
         <aux name="Root_Model_Input" access="input"/>
      </variables>
   </model>
   <model name="Sub_Model">
      <variables>
         <aux name="Input" access="input"/>
         <aux name="Output" access="output"/>
      </variables>
   </model>
</xmile>
```

If saved in separate files this same model would look like this:

```
<?xml version="1.0" encoding="utf-8" ?>
<xmile version="1.0" xmlns="http://docs.oasis-
      open.org/xmile/ns/XMILE/v1.0">
   <header>
      <product version=”1.0”>Product</product>
      <vendor>sample</vendor>
      <options>
         <uses_submodels/>
      </options>
   </header>
   <sim_specs method="Euler" time_units="Months">
      <start>1</start>
      <stop>13</stop>
      <dt>0.25</dt>
   </sim_specs>
   <model>
      <variables>
         <module name="Sub_Model" resource=”module.xml”>
            <connect to="Input" from=".Root_Model_Output"/>
            <connect to=".Root_Model_Input" from="Sub_Model.Output"/>
         </module>
         <aux name="Root_Model_Output" access="output"/>
         <aux name="Root_Model_Input" access="input"/>
      </variables>
   </model>
</xmile>
```

And in file “module.xml”:

```
<?xml version="1.0" encoding="utf-8" ?>
```

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```
<xmile version="1.0" xmlns="http://docs.oasis-
      open.org/xmile/ns/XMILE/v1.0">
   <header>
      <product version=”1.0”>Product</product>
      <vendor>sample</vendor>
      <options/>
   </header>
   <sim_specs method="Euler" time_units="Months">
      <start>1</start>
      <stop>13</stop>
      <dt>0.25</dt>
   </sim_specs>
   <model>
      <variables>
         <aux name="Input" access="input"/>
         <aux name="Output" access="output"/>
      </variables>
   </model>
</xmile>
```

4.7.2 Submodel Inputs

Submodel inputs are identified by setting the `access` property of the variable to `input`:

```
<aux name="xyz" access="input">
   ...
</aux>
```

Note that variables MAY be designated submodel inputs without assigning them to submodel outputs. In this case, the variable’s equation determines its value (rather than a submodel output).

Submodel inputs MAY simultaneously be implicit submodel outputs (see Section 4.7.3) by having a connector from the submodel input directly into a module. In this case, the variable is called a submodel throughput. This is used, for example, when the output of a module not only wants to be used at the level above it, but also wants to be forwarded on to another module.

4.7.3 Submodel Outputs

Submodel outputs are identified by either having connectors into a module or explicitly setting the `access` property of the variable to `output`:

```
<aux name="abc" access="output">
   ...
</aux>
```

There is a rather large difference between implicit outputs (formed through connectors) and explicit outputs (using `access="output"`, as variable *abc* does above):

- Implicit outputs SHALL only be accessible in the submodel they are directly connected to. These outputs, therefore, have very limited scope.
- Explicit outputs SHALL be accessible in all submodels above or across from the submodel that contains it, where “across” means the modules are connected by a connector and includes any submodels thereof. In this sense, they are exported *upwards* from the submodel they appear within, but due to connectors between modules, they can also be used in all connected modules and those connected modules’ submodels. For example, if a model contains two modules *A* and *D*, and *A* is connected to *D* (with a connector), than any explicit submodel output in *A* can be accessed in *D*. Furthermore, if *D* has its own module named *E* and *E* has its own module named

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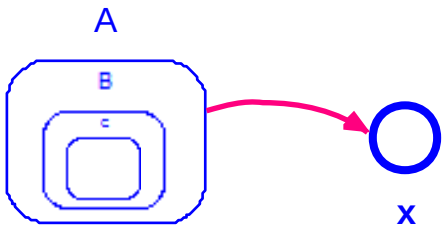
F, any explicit submodel output in *A* can be accessed in *E* and *F* (shown below).

D, *E*, and *F* can access all explicit submodel outputs of *A* and its submodels.

Finally, imagine A has its own module named *B* and *B* has its own module named *C*. If there is a connector from module *A* to a converter *x* (shown below), *x* can be assigned to any submodel output in *A*, *B*, or *C*.



x can be assigned to any explicit submodel output in *A*, *B*, or *C*.

Every variable that is an explicit output may also include the following OPTIONAL attribute:

- Autoexport: `autoexport="…"` with true/false (default: false). This is true when the software (rather than the user) turned an entity into an explicit output, as, for example, when creating aliases across submodels. When this is true, there are likely connections between modules that were automatically made using connectors. This is indicated with the `autocreate` attribute in a connector (see Chapter 6).

4.8 Macros

Macros allow new built-in functions to be defined, which can also be used to translate built-in functions across vendor packages. They also provide a way to implement non-standard simulation behavior for stocks, flows, and auxiliaries.

Macros live outside of all other blocks, at the same level as the `<model>` tag, and MAY be the only thing in a file other than its header. Macros MUST satisfy all the rules and assertions expressed under this section, unless indicated as optional. Macros are defined with a `<macro>` tag, which has these REQUIRED properties and attributes:

- Name: `name="…"` with the macro name (a valid XMILE identifier).
- Equation: `<eqn>` w/valid XMILE expression, in a CDATA section if needed.

Macros also have the following OPTIONAL properties and attributes:

- Parameter: `<parm>` with the name of the formal parameter within the macro (its local name, which must be a valid XMILE identifier) (default: no parameters). There must be one `<parm>` property for each macro parameter and they must appear in the expected calling order (i.e., the order of the actual parameters). Parameters can optionally have default values so they do not always have to be specified when the macro is called. These are specified with the `default="…"` attribute on the `<parm>` tag, using a valid XMILE expression that can refer to any parameter already defined. Every parameter after the first parameter that has a default value specified (i.e., uses `default`) must also have a default value specified (i.e., the first use of `default` makes all succeeding parameters optional as well). Since the macro equation often refers to these parameters, it is strongly recommended that the `<parm>` tag, when used, appears before the `<eqn>` tag.

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- Function format: <format> with text that indicates the proper use of the function, usually with its name and a description of its parameters in order (default: none).
- Function documentation: <doc> with text that describes the purpose of the function, optionally in HTML format (default: none).
- Simulation specifications: <sim_specs> as defined for the model (see Section 2.3) (default: same DT and integration method as model that invokes the macro). This must only appear in conjunction with a <variables> tag. Only <start>, <stop>, <dt>, and method="…" are allowed and all but method are specified with a valid XMILE expression that can include parameters. When <sim_specs> appears, the default DT is one and the default integration method is euler.
- Variables: <variables> as defined for <model> (see Sections 4.1-4.7) (default: no variables).
- View: Exactly one <view> within a <views> tag (see Chapters 5 and 6) (default: no view). This must only appear in conjunction with a <variables> tag and exists only to facilitate editing macros.
- Namespace: namespace="…" with a XMILE namespace, for example, namespace="isee" (default: single namespace specified in the header's <options> tag, or no namespace if either no namespaces or multiple namespaces are specified in the header).

Macros MAY include submodels. OPTIONALLY, they can also be recursive, i.e., they can refer to themselves in their equations. In this case, the recursive_macros option must be set to true in the <uses_macros> tag of the XMILE options (see Section 2.2.1).

4.8.1 Macros without Variables

Macros can be used to implement simple functions that either extend the available built-in functions or translate vendor-specific functions. For example, to define a general logarithm for any base:

```
<macro name="LOG">
   <parm>x</parm>
   <parm>base</parm>
   <eqn>LN(x)/LN(base)</eqn>
   <format>
     <![CDATA[LOG(<value>, <base>)]]>
   </format>
   <doc>
     <![CDATA[Finds the base-<base> logarithm of <value>.]]>
   </doc>
</macro>
```

Within an XMILE expression, this function could be used to, for example, find the base-2 logarithm of 256:

```
LOG(256, 2)
```

Recursion MAY be used to implement simple functions, for example, to calculate the factorial of a number:

```
<macro name="FACT">
   <parm>x</parm>
   <eqn>IF x <= 1 THEN 1 ELSE FACT(x - 1)</eqn>
</macro>
```

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Nested loops – or nested recursion – can be implemented by calling another recursive macro from within a recursive macro. For example, we can use the recursive FACT(*x*) function above to find the sum of the first *x* factorials:

```
<macro name="FACTSUM">
   <parm>x</parm>
   <eqn>IF x <= 1 THEN 1 ELSE FACT(x) + FACTSUM(x - 1)</eqn>
</macro>
```

By using default parameter values to implement optional parameters, more complex operations can be performed, such as finding the index of a value in a 1D-array:

```
<macro name="FIND">
   <parm>A</parm>
   <parm>value</parm>
   <parm default="1">i</parm>
   <eqn>IF i > SIZE(A) THEN 0 ELSE
      IF A[i] = value THEN i ELSE FIND(A, value, i + 1)</eqn>
   <format>FIND(<array>, <value>[, <starting index>])</format>
</macro>
```

Note that these last three examples of recursion all make use of tail recursion, i.e., the recursive call is the last thing that appears in the equation. This is important because implementers are free to map macros into any internal form, especially for the sake of efficiency. The use of tail recursion whenever possible allows implementers to convert the recursion into a simple loop.

4.8.2 Macros with Variables

The above simple forms are useful when functions can be directly represented by existing built-ins. However, sometimes extra variables (stocks, flows, auxiliaries) are also needed. In these cases, the extra variables MUST also be defined using a `<variables>` block, just as in a model. Consider a first-order smooth that we wish to name SMOOTH1. Since XMILE includes a built-in first-order smooth, we could define this function as follows:

```
<macro name="SMOOTH1">
   <parm>input</parm>
   <parm>averaging_time</parm>
   <parm default="input">initial</parm>
   <eqn>SMTH1(input, averaging_time, initial)</eqn>
</macro>
```

Now imagine XMILE does not have a first-order smooth function. In this case, we need to implement it ourselves using stocks and flows:

```
<macro name="SMOOTH1">
```

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```
   <parm>input</parm>
   <parm>averaging_time</parm>
   <parm default="input">initial</parm>
   <eqn>Smooth_of_Input</eqn>
   <variables>
      <stock name="Smooth_of_Input">
         <eqn>initial</eqn>
         <inflow>change_in_smooth</inflow>
      </stock>
      <flow name="change_in_smooth">
         <eqn>(input - Smooth_of_Input)/averaging_time</eqn>
      </flow>
   </variables>
</macro>
```

Note that any stocks that are defined within a macro MUST have their own instances for each use of that macro and these instances MUST persist across the length of the simulation. That is to say, if this SMOOTH1 function is used five times in a model, there must also be five copies of the stock Smooth_of_Input, one for each use. Use of flows and auxiliaries do not require this (auxiliaries, in particular, are useful to simplify the equation into smaller, meaningful pieces).

Recall that when variables appear within the macro, a view may also appear. This facilitates editing of the macro, allowing it to be created and edited as a stock-flow diagram.

4.8.3 Macros with Variables and Simulation Specs

By combining variables with simulation specs, we can explicitly write loops. Instead of using recursion, as in Section 4.8.1, we can write the factorial macro using a loop:

```
<macro name="FACT">
   <parm>x</parm>
   <eqn>Fact</eqn>
   <sim_specs>
      <start>1</start>
      <stop>x</stop>          <!-- note stop time is parameterized -
->
   </sim_specs>          <!-- DT defaults to 1 -->
   <variables>
      <stock name="Fact">
         <eqn>1</eqn>
         <inflow>change_in_fact</inflow>
      </stock>
      <flow name="change_in_fact">
         <eqn>Fact*TIME</eqn>
      </flow>
   </variables>
</macro>
```

This is far more cumbersome than the recursive implementation, but it illustrates the mechanism for iteration. Each time FACT(*x*) is called, this submodel runs from 1 to *x*, accumulating the product of all TIME values (DT = 1, so 1, 2, 3, ..., *x*) into the stock *Fact*, which is also the return value.

The recursive macro to find the first index of a given value in an array that was shown in Section 4.8.1 can also be rewritten as a loop (simplified here to only two parameters):

```
<macro name="FIND">
```

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```
      <parm>A</parm>
      <parm>value</parm>
      <eqn>index</eqn>
      <sim_specs>
         <start>1</start>
         <stop>SIZE(A)</stop>
      </sim_specs>
      <variables>
         <stock name="index">
            <eqn>0</eqn>
            <inflow>find_value</inflow>
         </stock>
         <flow name="find_value">
            <eqn>
               IF (index = 0) AND (A[TIME] = value)
               THEN TIME/DT
               ELSE 0
            </eqn>
         </flow>
      </variables>
   </macro>
```

There is one critical difference between this function and the recursive one (beyond the relative brevity of the recursive version): This version always looks at every element of the array whereas the recursive version stops looking as soon as it finds the solution.

Just as nested recursion was implemented with two recursive macros, one calling the other, nested loops can be implemented by using two iterative macros with one calling the other. For example, to sum all elements in a 2D array of size *X* by *Y*:

```
   <macro name="SUM2D">
      <parm>A</parm>
      <eqn>Total</eqn>
      <sim_specs>
         <start>1</start>
         <stop>SIZE(A[*, 1])</stop>
      </sim_specs>
      <variables>
         <stock name="Total">
            <eqn>0</eqn>
            <inflow>change_in_sum</inflow>
         </stock>
         <flow name="change_in_sum">
            <eqn>SUM1D(A[TIME, *])</eqn>
         </flow>
      </variables>
   </macro>

   <macro name="SUM1D">
```

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```
    <parm>A</parm>
    <eqn>Total</eqn>
    <sim_specs>
       <start>1</start>
       <stop>SIZE(A)</stop>
    </sim_specs>
    <variables>
       <stock name="Total">
          <eqn>0</eqn>
          <inflow>change_in_sum</inflow>
       </stock>
       <flow name="change_in_sum">
          <eqn>A[TIME]></eqn>
       </flow>
    </variables>
</macro>
```

This method takes advantage of array slicing, building up a two-dimensional result by breaking the 2D array into one-dimensional rows. Thus, SUM2D invokes SUM1D to sum each row, passing it, through array slicing, a 1D array.

In the general case, where slicing cannot produce the necessary results, additional information needs to be passed to the macro implementing the inner loop. Although the following is a contrived and inflexible example, SUM2D could instead call a function SUMROW that knows it's getting a 2D array and is given the row number to sum (by changing `change_in_sum`'s equation to `SUMROW(A, TIME)` in SUM2D):

```
<macro name="SUMROW">
    <parm>A</parm>
    <parm>i</parm>
    <eqn>Total</eqn>
    <sim_specs>
       <start>1</start>
       <stop>SIZE(A[i, *])</stop>
    </sim_specs>
    <variables>
       <stock name="Total">
          <eqn>0</eqn>
          <inflow>change_in_sum</inflow>
       </stock>
       <flow name="change_in_sum">
          <eqn>A[i, TIME]></eqn>
       </flow>
    </variables>
</macro>
```

The main difference from the previous example is passing the row number, *i*, and then using it both to specify the stop time and select with row in the flow equation.

4.8.4 Modifying Stock and Flow Behavior

Filters based on options specified with a stock, a flow, or an auxiliary (called "option filters") are used to modify the behavior of stocks, flows, and auxiliaries when they are simulated. Option filters are macros that run whenever a variable with the specified option is evaluated. Since they are macros, they MAY use any of the features already described. For clarity, all of the examples in this section refrain from using variables.

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All option filters are always passed both the value of the variable and the value of the option[19]. They may also be passed other parameters and the order of those parameters will vary as described below.

Option filters add two additional attributes to macros:

- Type filtered: `filter="…"` with `stock`, `flow`, or `aux`. Existence of this attribute signals that the macro is an option filter. REQUIRED
- Redirection: `applyto="…"` with valid values from the table below (default: apply to filtered variable). OPTIONAL

The ability to redirect the filter so that it is applied to a variable (or variables) other than the one specified in the filter allows more sophisticated filters that operate on a stock's flow, or stocks connected to a flow. In these cases, not only does the `applyto` option need to be specified, but additional parameters are also passed to the filter as detailed below:

filter type	applyto value	Parameters
stock	Inflows	flow, option, stock, inflow_sum
stock	Outflows	flow, option, stock, outflow_sum
flow	upstream	stock, option, flow
flow	downstream	stock, option, flow

In the parameter lists above, *flow* refers to the calculated flow value, *stock* refers to the calculated stock value, *option* refers to the value of the option, *inflow_sum* refers to the sum of the stock's inflows that have higher-priority than this flow, and *outflow_sum* refers to the sum of the stock's outflows that have higher-priority than this flow.

An option filter to implement uniflows, i.e., flows with the `<non_negative/>` tag (option), could be implemented as follows:

```
<macro filter="flow" name="non_negative">
   <parm>flow</parm>
   <parm>option</parm>
   <eqn>IF option THEN MAX(flow, 0) ELSE flow</eqn>
</macro>
```

Note this is an option filter for a flow (`filter="flow"`) and it implements the non-negative option (`name="non_negative"` – note this name must exactly match the tag that turns on the option). It is passed the value of the flow as the first parameter and the value of the option (zero if off, one if on) as the second parameter. The implementation is very straightforward, using the MAX function when the option is on.

Non-negative stocks can also be implemented with an option filter, though it's a bit more complicated as non-negative stocks must limit their outflows, not themselves (as mentioned in Chapter 3, it is strongly RECOMMENDED that option filters not be used to directly modify the value of a stock).

```
<macro filter="stock" name="non_negative" applyto="outflows">
   <parm>flow</parm>
   <parm>value</parm>
   <parm>stock</parm>
   <parm>outflow_sum</parm>
```

[19] For options that are only true or false, one (1) is passed for true and zero (0) is passed for false.

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```
      <eqn>
         IF value
         THEN MAX(stock/DT – outflow_sum, flow)
         ELSE flow
      </eqn>
   </macro>
```

The existence of such a macro does not rule out another macro that operates on the stock instead of its outflows. Such a macro would not have the `applyto` option. In fact, any stock or flow option can implement three filters: one for the stock or flow itself and one for each of the two `applyto` options.

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5 Diagram and visual components structure

Each XMILE file has one OPTIONAL child `<views>` tag. The `<views>` tag is REQUIRED to contain a list of one or many `<view>` tags which describes the layout, content and appearance of the user interface and stock and flow diagram. The `<views>` tag can also contain an OPTIONAL `visible_view` attribute specifying the index of the view which the user desires to be active upon loading of the file. The index refers to the full list of views regardless of the view's type.

Simple XMILE display tag hierarchy example:

```
<xmile>
   <model>
      <variables>
         <aux name="Input"/>
      </variables>
      <views>
         <view type="stock_flow".../>
            <aux name="Input"/>
         </view>
         <view type="interface" .../>
            ...
         </view>
      </views>
   </model>
</xmile>
```

Note that all models, even those without the <`views`> section, are RECOMMENDED to be simulatable by any software which supports XMILE.

5.1 Introduction to the XMILE view

An XMILE view contains XMILE display objects. A view can be thought of as a page, or a screen of a model's stock and flow diagram, or its interface. An XMILE view has an OPTIONAL `type` parameter to notify users of the model as to whether or not the view is a part of the stock and flow diagram, or if the view is a part of the user interface. When a type is not specified on a view it is RECOMMENDED that the view be classified as a "stock_flow" view. Other acceptable view types are `popup` (for popup windows) or vendor specific types.

Views which have the type "stock_flow" are assumed to contain display objects which make up the stock and flow diagram. Typical objects appearing in a "stock_flow" view are stocks, flows, auxiliaries, aliases, and connectors. "stock_flow" views can also contain objects which are normally associated with an interface like sliders, graphs, and tables.

Views which have the optional type "interface" are assumed to contain display objects which make up the interactive learning environment or user interface for the model. Any display object can be present in a view with the user interface type with the REQUIRED exception of the canonical representation of a model variable object (see Section 5.1.1). Said another way, model variables cannot be defined in a view marked as being a part of the user interface.

XMILE views also contain an OPTIONAL `order` attribute which represents the order that views should be presented within the application. The `order` attribute is an integer starting from 0 and counting up. The lower the order number the earlier it appears in the list. Views with the type "stock_flow" are ordered

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separately from views with the type “interface”. If any view does not contain an order number it is RECOMMENDED that one is be assigned based on its position within the <views> tag.

XMILE views are also REQUIRED to have a width and a height measured in pixels. These properties describe the size of a view. Views are REQUIRED to be rectangular. Views may also have an OPTIONAL zoom specified as a double where 100 is default, 200 is 2x bigger by a factor of 2 and 50 is smaller by a factor of 2. In addition views can also have OPTIONAL attributes for storing the scroll position called scroll_x and scroll_y. The scroll position is the origin (top left corner) of the screen in model coordinates (that is, when zoom has not been applied). Also, views may contain an OPTIONAL background attribute that may be specified either as a color or as an external image resource using a file://url.

In order for XMILE views to be printed each view is REQUIRED to specify its paging. Therefore the following attributes are REQUIRED:

- page_width<double> - The width of a printed page
- page_height<double> - The height of a printed page
- page_sequence<string> “row|column” – The ordering of page numbers. With sequence type row, numbers are assigned going from left to right, then top to bottom. With the sequence being column pages are ordered from top to bottom then left to right.
- page_orientation<string> “landscape|portrait” – The orientation of the view on the printed page.
- show_pages<bool> - Whether or not the software overlays page breaks and page numbers on the screen.

In order for XMILE views to be more easily navigated views are REQUIRED to specify:

- home_page<int> default: 0- The index of the printed page which is shown when any link with the home_page target is executed
- home_view<bool> default: false – A marker property which is used to determine which view is navigated to when any link with the target home_view is executed. Only one view for each view type is allowed to be marked as the home_view.

5.1.1 Referencing variable objects in an XMILE view

Any object appearing in the <variables> tag (stock, flow, auxiliary, module, and group) is RECOMMENDED to have a related <stock|flow|aux|module|group> tag in at least one of the <view> tags associated with its model in order to be XMILE compatible. A <stock|flow|aux|module|group> tag is linked to its associated model equation object through the use of its REQUIRED "name" attribute (see sample XMILE in beginning of chapter 5). A <stock|flow|aux|module> (note: not group) tag representing a model variable MUST NOT appear more than once in a single <view> tag. A <stock|flow|aux|module> (note: not group) tag representing a model variable may appear in separate <view> tags, but support of this feature is OPTIONAL. It is RECOMMENDED that in the case where this feature is not supported the lowest order view (or first view encountered is order is not specified) containing a <stock|flow|aux|module> tag representing a model variable is treated as the canonical display for that object and that any other encountered <stock|flow|aux|module> tag in any other <view> tag associated with that model representing the same model variable be treated as an alias (described in section 6.1.7).

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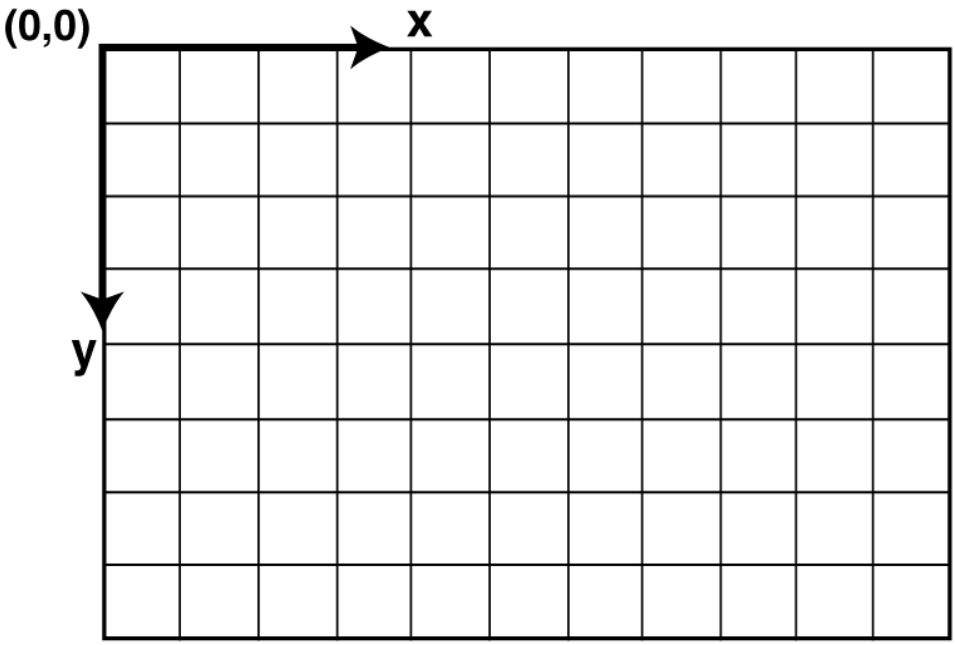
5.1.2 XMILE view assumptions and attributes

All visual objects contained within an XMILE `<view>` are laid out on a 2D Cartesian coordinate space measured in pixels, where 0,0 is the top left of the screen and height runs down while width runs right. An example coordinate space map looks like:



All display objects contained within an XMILE file MUST have the following attributes:

- Position: `x="<double>", y="<double>"`
- Size: arbitrary rectangle or, for specific objects listed below, a `<shape>` tag
  `width="<double>", height="<double>"`

A `<shape>` tag is specified as a child tag of other tags that are themselves child of a `<view>`. Specifically, shape tags allow stock, auxiliary, module, or alias objects to be represented using a different symbol then the RECOMMENDED; rectangle for a stock, circle for an auxiliary and rounded rectangle for a module. It is OPTIONAL for these four object types to specify a `<shape>` tag to change their representation from the defaults specified above to any valid value for a `<shape>` tag described below with the following REQUIRED exceptions:

1. A stock MUST NOT be represented using a circle.
2. An auxiliary or flow MUST NOT be represented using a rectangle except if the equation contains a function or macro which contains a stock.

Shape tags contain a REQUIRED `type` attribute which describes the shape of the object owning the tag. Valid `type` values are: `rectangle`, `circle`, and `name_only`. Shapes of type `rectangle` have two REQUIRED attributes, `width` and `height`, and an OPTIONAL attribute, the corner `radius`, all specified as doubles in pixels. Shapes of type `circle` contain one REQUIRED attribute: `radius`. Shapes of type `name_only` are special: they contain two OPTIONAL attributes `width` and `height` both measured in pixels and represented using a double. The `name_only` shape specifies that the object shall be represented by its name plate only. The optional `width` and `height` attributes are used for line wrapping hints. These hints are only suggestions and may be ignored without consequence.

The position referred to by the `x` and `y` attributes refers to the center of the object when using a `<shape>` tag. When using an arbitrary size, the `x` and `y` attributes refer to the top left corner of the

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object. All locations and sizes of XMILE objects are REQUIRED to be represented using double precision numbers.

5.1.3 Referring to specific XMILE display objects

Display objects do not have names or any other way to specifically refer to individual objects. Therefore any display object which is referred to anywhere else in the XMILE file MUST provide a `uid="<int>"` attribute. This attribute is a unique linearly increasing integer which gives each display object a way to be referred to specifically while reading in an XMILE file. UIDs are NOT REQUIRED to be stable across successive reads and writes. Objects requiring a `uid` are listed in Chapter 6 of this specification. UIDs MUST be unique per XMILE model.

5.2 Common styles associated with all XMILE display objects

All XMILE display objects provide attributes which describe their look and feel or style. Styles applied to visual XMILE objects are composed of attributes of the following core style objects plus any specific attributes available to that specific type of object.

Border

- `border_width="thick | thin |` <double>" –default=1px –thick=3px –thin=1px
- `border_color="`<hex code> | predefined color*"
- `border_style="none | solid"` –default=none

Text Style

- `font_family="`<string>"
- `font_style="normal | italic"` –default=normal
- `font_weight="normal | bold"` –default=normal
- `text_decoration="normal | underline"` –default=normal
- `text_align="left | right | center"`
- `vertical_text_align=”top | bottom | center"`
- `font_color="`<hex code> | predefined color*"
- `text_background="`<hex code> | predefined color*"
- `font_size="`<double>`pt"`
- `padding="`<comma separated list of no more than 4 doubles and no fewer than 1 double>"**
- any attributes of a Border object

All visual XMILE objects allow control over the following style attributes:

- `color="`<hex code> | predefined color*"
- `background="`<hex code> | predefined color*"
- `z_index="`<int>" –default=-1 (-1 is bottom-most, top-most is INT32_MAX ((1 << 31) – 1))
- any attributes of a Text Style object

* The list of predefined colors and their definitions appear in Section 5.2.2

** The specification for the padding attributes appears in Section 5.2.1

5.2.1 Specifications of padding

Padding is specified as the amount of area from an object’s boundary to the start of its content. Padding is broken down into four components: top, left, bottom, right and is measured in pixels. Padding appears as a single attribute on a visual object and can be written in any of the following forms:

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- `padding="2"`
- `padding="2,3"`
- `padding="2,3,1"`
- `padding="2,3,4,5"`

The first form translates into a padding of 2 pixels from all four edges. The second form translates into a padding of 2 pixels from the top and bottom edges and 3 pixels from the left and right edges. The third form translates into a padding of 2 pixels from the top edge, 3 pixels from the left and right edges and 1 pixel from the bottom edge. The fourth form translates into 2 pixels from the top edge, 3 pixels from the left edge, 4 pixels from the bottom edge and 5 pixels from the right edge.

5.2.2 Specification of color

Color is specified using CSS style hex codes or by using a color from the list of predefined colors. When a color is specified using a CSS style hex code it MUST be prefixed by a # followed by up to 6 digits from 0 to F.

List of predefined colors:

Name	Hex Code
aqua	#00FFF
black	#000000
blue	#0000FF
fuchsia	#FF00FF
gray	#808080
green	#008000
lime	#00FF00
maroon	#800000
navy	#000080
olive	#808000
purple	#800080
red	#FF0000
silver	#C0C0C0
teal	#008080
white	#FFFFFF
yellow	#FFFF00

5.3 The cascading style system

A `<style>` tag contains display information and defaults separated into children tags by object type. The style system controls the look and feel of all visual XMILE objects. Attributes on the `<style>` tag itself affect all contained styles of that tag which then go on to affect specific XMILE objects (Section 6.1).

Simple XMILE style tag example:

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```
<style font_color=”blue” font_size=”10”>
   <stock font_weight="bold" font_color="black"/>
   <flow font_size="12"/>
</style>
```

In this example, any related stock objects would have a bold, black, size 10 font and any related flow objects would have a normal weight, blue, size 10 font.

A <style> tag may be placed in any of the following locations which changes the display objects it affects:

- As a child of the root (<xmile>) tag
- As a child of a <views> tag
- As a child of a <view> tag

Simple XMILE style tag hierarchy example:

```
<xmile>
   <style/>
   <model>
      <variables/>
      <views>
         <style/>
         <view>
            <style/>
         </view>
      </views>
   </model>
</xmile>
```

As a child of a <xmile> tag, the <style> tag contains all of the default and highest level styles which apply across all models in the XMILE file. The <style> tag contained within the <views> tag applies to all XMILE views within it. Finally, the <style> tags which are children of the <view> tags override any specifications of the <style> tag associated with the model.

When reading in any XMILE object, any attribute present on that object takes ultimate precedence. For any attribute which is missing, the cascading style system is used; first looking to the nearest <view> tag's child <style> tag then up to the containing <views> tag's child <style>, and finally up to the root <style> tag for that XMILE file. The same principal holds true when writing out style attributes. If the object's attribute contains no difference from the specified cascading style, there is no reason to write out that attribute.

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6 Display and Interface XML Encoding

This chapter describes the specific structure of all XMILE tags appearing within the `<views>` tag of an XMILE file. Section 6.1 describes the display attributes of objects commonly found in a stock and flow diagram and Section 6.2 describes the attributes of common visual objects used to interface with a System Dynamics model.

6.1 Stock and flow diagram objects

Sections 6.1.1 through 6.1.7 describe the attributes commonly associated with objects in a visual representation of a stock and flow diagram. Each section corresponds to a distinct object although many of the attributes are common to multiple objects. These common attributes are listed below with references back to the sections in this document where they are defined and/or specified.

Attributes common to objects described in Sections 6.1.1 through 6.1.7:

- `x,y` – defined in Section 5.1.2
- `color` – defined in Section 5.2 and specified in Section 5.2.2
- `background` – defined in Section 5.2 and specified in Section 5.2.2
- `z_index` – defined in Section 5.2
- `font_family` – defined in Section 5.2
- `font_size` – defined in Section 5.2
- `font_weight` – defined in Section 5.2
- `font_style` – defined in Section 5.2
- `text_decoration` – defined in Section 5.2
- `text_align` – defined in Section 5.2
- `text_background` – defined in Section 5.2
- `vertical_text_align` – defined in Section 5.2
- `text_padding` – same as `padding` as defined in Section 5.2
- `font_color` – defined in Section 5.2
- `text_border_color` – same as `border_color` as defined in Section 5.2
- `text_border_width` – same as `border_width` as defined in Section 5.2
- `text_border_style` – same as `border_style` as defined in Section 5.2

Additional attributes common to objects described in Sections 6.1.1 through 6.1.5:

- `name` – described in Section 5.1.1, but in short it is the local name of the model entity represented by this tag.

Additional attributes common to objects described in Sections 6.1.1 through 6.1.4:

- `width, height` – defined in Section 5.1.2
- `label_side` – This is the side of the symbol that the nameplate appears on. Valid values are top|left|center|bottom|right
- `label_angle` – This is the precise angle (in degrees where 0 is at 3 o'clock, increasing counter-clockwise) of the nameplate on the widget. This is always specified in conjunction with `label_side`.

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`name` is REQUIRED for certain display objects as specified in Section 5.1.1.

`x`, `y`, `width`, and `height` are REQUIRED for certain display objects as specified in Section 5.1.2

All other common attributes listed above are OPTIONAL for all display objects.

6.1.1 Stock

The `<stock>` tag in the context of a `<view>` tag is used to describe the appearance of an XMILE stock equation object. Support is REQUIRED for any implementation supporting views. An example tag is shown below:

```
<stock name="Bathtub" x="50" y="100" width="45" height="35" label_side="top"
color="blue" background="white" z_index="1" font_family="Arial"
font_size="9pt" font_weight="bold" font_style="italic"
text_decoration="underline" text_align="center" vertical_text_align="center"
text_padding="2px" font_color="blue" text_border_color="black"
text_border_width="1px" text_border_style="solid"/>
```

Descriptions of all the display attributes of a stock can be found in Section 6.1.

6.1.2 Flow

The `<flow>` tag in the context of a `<view>` tag is used to describe the appearance of an XMILE flow equation object. Support is REQUIRED for any implementation supporting views. An example tag is shown below:

```
<flow name="faucet" x="50" y="100" width="18" height="18" label_side="top"
color="blue" background="white" z_index="1" font_family="Arial"
font_size="9pt" font_weight="bold" font_style="italic"
text_decoration="underline" text_align="center" vertical_text_align="center"
text_padding="2px" font_color="blue" text_border_color="black"
text_border_width="1px" text_border_style="solid">
      <pts>
            <pt x="0" y="100"/>
            <pt x="150 y="100"/>
      </pts>
</flow>
```

- `pts` REQUIRED – These are the anchor points for the flow specified in model coordinates. Flows can have any arbitrary number of points, but those points MUST form right angles.

Descriptions of all other display attributes of a flow can be found in Section 6.1.

6.1.3 Aux

The `<aux>` tag in the context of a `<view>` tag is used to describe the appearance of an XMILE aux equation object. Support is REQUIRED for any implementation supporting views. An example tag is shown below:

```
<aux name="water flow rate" x="50" y="100" width="45" height="35"
label_side="top" color="blue" background="white" z_index="1"
font_family="Arial" font_size="9pt" font_weight="bold" font_style="italic"
text_decoration="underline" text_align="center" vertical_text_align="center"
text_padding="2px" font_color="blue" text_border_color="black"
text_border_width="1px" text_border_style="solid"/>
```

Descriptions of all the display attributes of an aux can be found in Section 6.1.

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6.1.4 Module

The <module> tag in the context of a <view> tag is used to describe the appearance of an XMILE module equation object. Support is OPTIONAL for any implementation supporting views and modules. An example tag is shown below:

```
<module name="Important_Module" x="50" y="100" width="45" height="35"
label_side="top" color="blue" background="white" z_index="1"
font_family="Arial" font_size="9pt" font_weight="bold" font_style="italic"
text_decoration="underline" text_align="center" vertical_text_align="center"
text_padding="2px" font_color="blue" text_border_color="black"
text_border_width="1px" text_border_style="solid"/>
```

Descriptions of all the display attributes of a module can be found in Section 6.1.

6.1.5 Group

The <group> tag in the context of a <view> tag is used to describe the appearance of an XMILE group object. Support in the view is RECOMMENDED. A <group> display object differs from all other display objects used to represent model section objects in that there is a one-to-one relationship between group objects in the model section and group objects in the display section. This means that you can only have one <group> tag in the <views> tag that represents the <group> tag in the <variables> tag. All XMILE model objects which appear in the group within the model section are implicitly contained within the group object in the display section, but groups can also contain objects which are not present within the model section. Those objects are included within the group using an <item> tag. An example is shown below:

```
<group name="Major_Group" x="50" y="100" color="blue" background="white"
z_index="1" font_family="Arial" font_size="9pt" font_weight="bold"
font_style="italic" text_decoration="underline" text_align="center"
vertical_text_align="center" text_padding="2px" font_color="blue"
text_border_color="black" text_border_width="1px" text_border_style="solid"
locked="true">
      <item uid="1"/>
</group>
```

- <item uid="*"/> OPTIONAL - A tag representing an un-named object which is present inside of this group. The * is a UID for an object in the group's model. These are objects like aliases, tables, graphs, buttons etc. Note: <item> tags representing connector objects are NOT REQUIRED to be present in the tag to be considered a part of the group. Connector objects are automatically considered a part of the group if one end of the connector is contained within the group.
- locked="…" with true/false (default: false) REQUIRED – When a group is locked, all entities in that group move with the group. When not locked, moving the group adjusts the items inside of the group (both model and display section objects).

Descriptions of all other display attributes of a group can be found in Section 6.1.

6.1.6 Connector

The <connector> tag is used to describe the visual appearance of the relationships between XMILE model objects. Support is REQUIRED for any implementation supporting views. A connector is an arrow which only appears between two display objects. An example tag is shown below:

```
<connector uid="1" x="50" y="100" angle="32" line_style="solid"
delay_mark="false" color="blue" background="white" z_index="1"
font_family="Arial" font_size="9pt" font_weight="bold" font_style="italic"
text_decoration="underline" text_align="center" vertical_text_align="center"
text_padding="2px" font_color="blue" text_border_color="black"
text_border_width="1px" text_border_style="solid" polarity="">
```

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```
      <from>
            <alias uid=”2”/>
      </from>
      <to>faucet</to>
      <pts>
            <pt x=”50” y=”50”/>
            <pt x=”100” y=”100”/>
            <pt x=”150” y=”75”/>
      </pts>
</connector>
```

- `polarity` – “+ | - | none” – default option = “`none`” OPTIONAL - The polarity is drawn as a symbol at the end of a connector arrowhead representing the type of the relationship between the variables connected by the connector.
- `from` REQUIRED – The name of (or an alias tag pointing to) the model entity from which this connector starts. The entity needs to be in the same model as the connector.
- `to` REQUIRED – The name of the model entity to which this connector ends, the entity needs to be in the same model as the connector.
- `pts` REQUIRED – These are the anchor points for the connector specified in model coordinates for when there are more than two points (the start and end point). Connectors MAY have any number of points (greater than two) and those points are RECOMMENDED to be connected using an arc when there are two points and Bezier curves if three or more points are present. If a vendor does not support multipoint connectors, this information is ignored and the `angle` attribute is used instead to calculate the connector start and end points.
- `angle` REQUIRED – The angle in degrees of the takeoff point from the center of the start object. 0 is 3 o’clock and angles increase counter-clockwise.
- `line_style` “solid|dashed|vendor specific” – default option=”`solid`” OPTIONAL - Describes whether the connector is dashed or not. For the vendor specific options, SVG line-style types are suggested.
- `delay_mark` ="…" with true/false (default: `false`) OPTIONAL - Describes whether or not this connector is marked with a symbol signifying a delay.

Descriptions of all other display attributes of a connector can be found in Section 6.1.

6.1.7 Alias

The `<alias>` tag is used to describe the visual appearance of an alias of an XMILE model object. Support is REQUIRED for any implementation supporting views. An alias is a symbol representing a “portal” to the display of another XMILE model object in the same view. Aliases are only valid for stocks, flows, and auxiliaries. It is RECOMMENDED for aliases to take on all the same styles as the object they represent with only the differences being written to the `<alias>` tag. Aliases MAY have connectors leaving them but MAY NOT have connectors pointing to them. An example tag is shown below:

```
<alias uid=”1” x=”50” y=”100”>
      <of>faucet</of>
</alias>
```

- `uid` REQUIRED – defined in Section 5.1.3
- `x,y` REQUIRED – defined in Section 5.1.2

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- `of` REQUIRED – The name of the model entity which this alias represents. The model entity must be in the same model as the alias.

The other attributes of an alias are the same as the object to which the alias refers.

6.2 Containers

Containers are used to box up other XMILE display objects into a single unit which can be moved, resized, and displayed together. For this first version of the XMILE draft, there is only one OPTIONAL container - a stacked container which is used to display pages of widgets. In the future, this section of the specification could contain containers used to do auto-layout like horizontal box, vertical box, etc.

Any object within a container does NOT REQUIRE an `x,y` position or a size. It inherits those properties from the container.

6.2.1 Stacked Containers

A stacked container is used to allow XMILE display objects to be stacked on top of one another in flipbook form. Support for this tag is OPTIONAL. This allows model creators to create pages of tables or graphs. Any display object may be placed within a stacked container, but typical objects are graphs and tables. An example tag is shown below:

```
<stacked_container x="92" y="114" height="282" width="492" uid="0"
visible_index=”0”>
</stacked_container>
```

- `visible_index` REQUIRED – Integer 0 based index of which content object to display.

Descriptions of all other display attributes of a stacked container can be found in Section 6.1.

Stacked container objects are REQUIRED to have ONLY the five properties shown above. Any borders, backgrounds etc. are supplied by their contents.

6.3 Input Objects

6.3.1 Sliders and Knobs

Sliders and knobs are used to change the value of a variable in the model from the interface. Support for these tags is OPTIONAL. Stocks can only be manipulated by knobs. Iin this case, knobs can only change the stock’s initial value, i.e., knobs attached to stocks MUST NOT be changed in the middle of a simulation run. Sliders are defined with the `<slider>` tag and knobs are defined with the `<knob>` tag; they are otherwise the same. An example slider tag is shown below:

```
<slider x="172" y="114" color="black" width="197" height="43" min="7" max="9"
background=”white” z_index=”1” font_family=”Arial” font_size=”9pt”
font_weight=”bold” font_style=”italic” text_decoration=”underline”
text_align=”center” vertical_text_align=”center” text_padding=”2px”
font_color=”blue” text_border_color=”black” text_border_width=”1px”
text_border_style=”solid”>
      <entity name="Converter_1" />
      <reset_to after="one_time_unit">7</reset_to>
</slider>
```

- Show name: OPTIONAL `show_name="…"` with true/false (default: `true`)
- Show number: OPTIONAL `show_number="…"` with true/false; when the number is visible it MUST be directly editable (default: `true`)
- Show input range: OPTIONAL `show_min_max="…"` with true/false (default: `true`)
- Input range REQUIRED: `min="…"` and `max="…"`, overriding entity’s input range setting (default: entity’s setting)

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- OPTIONAL reset (slider only): `<reset_to>` with the value to reset the entity to; it has one attribute that define when to reset the entity's value: `after="…"` with either `one_time_unit` or `one_dt`.

Descriptions of all other display attributes of a slider or knob can be found in Section 6.1.

6.3.2 Switches and Radio Buttons (Option Groups)

A switch forces a variable to be evaluated as zero (when the switch is off) or one (when the switch is on). Support for these tags is OPTIONAL. A switch is defined using the `<switch>` tag, which, like the slider, defines which entity to control with the `<entity>` tag and can OPTIONALLY be reset (to either 0 or 1, but usually 0) using the `<reset_to>` tag. In addition, it defines these attributes:

- Show name OPTIONAL: `show_name="…"` with true/false (default: `true`)
- Switch appearance OPTIONAL: `switch_style="…"` with either `toggle` or `push_button` (default: `toggle`)
- Make a sound when clicked OPTIONAL: `clicking_sound="…"` with true/false (default: `false`)

Here is an example switch tag:

```
<switch x="359" y="100" uid="2" label_side="bottom" label_angle="135"
color="black" width="32" height="60" switch_style="toggle"
clicking_sound="true" background=”white” z_index=”1” font_family=”Arial”
font_size=”9pt” font_weight=”bold” font_style=”italic”
text_decoration=”underline” text_align=”center” vertical_text_align=”center”
text_padding=”2px” font_color=”blue” text_border_color=”black”
text_border_width=”1px” text_border_style=”solid”>
      <entity name="Converter_2" value="0" />
      <reset_to after="one_time_unit">0</reset_to>
</switch>
```

Descriptions of all other display attributes of a switch can be found in Section 6.1.

Switches can also OPTIONALLY selectively control the running of groups or modules when the model's simulation specification `run_by` setting is set to `group` or `module`. In these cases, the `<entity>` tag is replaced with either a `<group>` tag or a `<module>` tag, which are otherwise identical to the `<entity>` tag and MUST have both a `name` and a `value`. In these cases, groups or modules without switches run if their `run` property is set to `true` while those with switches only run if the switch is on (set to one).

A group of mutually-exclusive switches (sometimes known as radio buttons or option buttons) is defined using the `<options>` tag with one `<entity>` tag for each entity in the option group. Option groups MUST NOT be automatically reset after an interval (i.e., the `<reset_to>` tag is not allowed). Option groups have these additional REQUIRED attributes:

- Layout: `layout="…"` with vertical/horizontal/grid (default: `vertical`)
- Spacing: `horizontal_spacing="…"` and `vertical_spacing="…"` with CSS spacing amount in pixels (px) by default (default: 2)

A sample options group that selects between three policy options stored in an array:

```
<options x="827" y="146" width="43" height="25">
      <entity name="policy" index="1">
            <value>1</value>
      </entity>
      <entity name="policy" index="2">
            <value>0</value>
      </entity>
```

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```
      <entity name="policy" index="3">
            <value>0</value>
      </entity>
</options>
```

6.3.3 Numeric Inputs and List Input Devices

Numeric inputs allow values to be entered numerically (versus, for example, using a slider). Support for these tags is OPTIONAL. Numeric inputs are defined using the `<numeric_input>` tag, which shares all of the same attributes and properties as the slider (except `show_number`, which is obviously always true for a numeric input, and `show_min_max`, which has no relevance). An example tag is shown below:

```
<numeric_input min="5" max="10" precision="0.01" background=”white”
z_index=”1” font_family=”Arial” font_size=”9pt” font_weight=”bold”
font_style=”italic” text_decoration=”underline” text_align=”center”
vertical_text_align=”center” text_padding=”2px” font_color=”blue”
text_border_color=”black” text_border_width=”1px”
text_border_style=”solid”>
      <entity name="price">
            <value>7</value>
      </entity>
</numeric_input>
```

Descriptions of all other display attributes of a numeric input can be found in Section 6.1.

List inputs provide a way to enter tabular data for a related group of variables. They are RECOMMENDED to be arranged in pages within a stacked container. A list input is defined using the `<list_input>` tag, which can use any of the display properties with their defaults and adds two new REQUIRED attributes:

- Name of the input page REQUIRED: `name="…"` with page name (default: none)
- Numeric column width REQUIRED: `column_width="…"` with width in model coordinates; the name column width is the remaining width of the list input (default: half the width of the list input)

The entries within the list input are defined using the `<numeric_input>` tag. The following sample list input accepts values for prices of three different products:

```
<list_input x="446" y="161" width="230" height="97">
      <numeric_input min="5" max="10" precision="0.01">
            <entity name="price" index="Shirt">
                  <value>7</value>
            </entity>
      </numeric_input>
      <numeric_input min="10" max="20" precision="0.01">
            <entity name="price" index="Pant">
                  <value>15</value>
            </entity>
      </numeric_input>
      <numeric_input min="20" max="60" precision="0.01">
            <entity name="price" index="Shoe">
                  <value>40</value>
            </entity>
      </numeric_input>
</list_input>
```

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6.3.4 Graphical Inputs

Graphical inputs allow graphical functions to be changed from the interface. Support for this tag is OPTIONAL. They are defined using the <graphical_input> tag which shares all the display properties and their defaults. The REQUIRED <entity> tag defines which graphical function entity is controlled. If the graphical input contains a different graphical function than the controlled variable, i.e., the user has edited the graphical input but not restored it, the <entity> tag is REQUIRED to also contain a <gf> tag describing the edited graphical function (otherwise, no <gf> tag appears). The following graphical input has not been edited by the user so does not affect the controlled entity:

```
<graphical_input x="311" y="341" width="100" height="103" background=”white”
z_index=”1” font_family=”Arial” font_size=”9pt” font_weight=”bold”
font_style=”italic” text_decoration=”underline” text_align=”center”
vertical_text_align=”center” text_padding=”2px” font_color=”blue”
text_border_color=”black” text_border_width=”1px” text_border_style=”solid”>
      <entity name="effect of overtime on productivity"/>
</graphical_input>
```

Descriptions of all other display attributes of a graphical input can be found in Section 6.1.

However, this one has been edited by the user and overrides the graphical function in the controlled entity:

```
<graphical_input x="311" y="341" width="100" height="103">
      <entity name="effect of overtime on productivity">
         <gf>
            <xscale min="0" max="1"/>
            <ypts>1,0.9,0.5,0.1,0</ypts>
         </gf>
      </entity>
</graphical_input>
```

6.4 Output Objects

6.4.1 Numeric Displays

The <numeric_display> tag is used to describe the appearance of a widget on the model canvas which shows the instantaneous value of a model entity as text. Support for this tag is OPTIONAL. An example tag is shown below:

```
<numeric_display precision="0.1" delimit_000s="true" color="blue"
show_name="true" retain_ending_value="true" uid="1" x="339" y="261"
width=”100” height=”22” background=”white” z_index=”1” font_family=”Arial”
font_size=”9pt” font_weight=”bold” font_style=”italic”
text_decoration=”underline” text_align=”center” vertical_text_align=”center”
text_padding=”2px” font_color=”blue” text_border_color=”black”
text_border_width=”1px” text_border_style=”solid”>
      <entity name="Converter_2" />
</numeric_display>
```

- Show name: OPTIONAL show_name="…" with true/false (default: true)
- Retain ending value (at end of simulation, rather than show nothing) OPTIONAL: retain_ending_value="…" with true/false (default: true)
- Number formatting properties – Section 4.1.1

Descriptions of all other display attributes of a numeric display can be found in Section 6.1.

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6.4.2 Lamps and Gauges

Lamps and gauges also indicate the current value of a single variable. Support for these tags is OPTIONAL. A lamp is defined with the `<lamp>` tag and looks similar to an LED or LCD indicator. A gauge is defined with the `<gauge>` tag and looks similar to a speedometer. An example tag is shown below:

```
<lamp retain_ending_value="true" x="543" y="104" uid="3">
<entity name="Converter_1" />
       <zones>
            <zone type="panic" min="8" max="8.33" color="red" />
            <zone type="caution" min="8.33" max="8.66" color="yellow" />
            <zone type="normal" min="8.66" max="9" color="green"/>
       </zones>
</lamp>
```

- Show name: OPTIONAL `show_name="…"` with true/false (default: `false` for lamps, `true` for gauges)
- Show number (gauges only): OPTIONAL `show_number="…"` with true/false (default: `true`)
- Retain ending value (at end of simulation, rather than show nothing): OPTIONAL `retain_ending_value="…"` with true/false (default: `true`)
- Flash when in the panic region: `flash_on_panic="…"` with true/false (default: `true`) OPTIONAL

Lamps and gauges REQUIRE a list of zones within a `<zones>` tag, defining non-overlapping value ranges for the variable. Each zone is defined by a `<zone>` with the following attributes:

- Type: `type="…"` with `normal`, `caution`, or `panic` (default: `normal`) REQUIRED
- Color when variable is in range: `color="…"` w/valid CSS color (default: `black`) REQUIRED
- Start of range: `min="…"` with starting value of range REQUIRED
- End of range: `max="…"` with ending value of range REQUIRED
- Sound to play while in range: `sound="…"`. The value should be a resource which is a relative file path, an absolute file path, or an URL. OPTIONAL

Descriptions of all other display attributes of a lamp or gauge can be found in Section 6.1.

6.4.3 Graphs

Support for this tags is REQUIRED if the implementation supports outputs (per the header options, Section 2.2.1). Graphs are defined within the `<graph>` tag, which has the following attributes and properties, beyond the applicable display attributes, e.g., `background`:

- Graph type: REQUIRED `type="…"` with `time_series`, `scatter`, or `bar` (default: `time_series`)
- Title: OPTIONAL `<title>` with graph title (default: none)
- Documentation: OPTIONAL `<doc>` with block of text, optionally in HTML format (default: none)
- Show grid: OPTIONAL `show_grid="…"` with true/false (default: `true`)
- Number of X Grid Lines: OPTIONAL `num_x_grid_lines="…"` with integer (default: `0`)
- Number of Y Grid Lines: OPTIONAL `num_y_grid_lines="…"` with integer (default: `0`)
- Number of X Axis Labels: OPTIONAL `num_x_labels="…"` with integer (default: `0`)

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- Number of Y Axis Labels: OPTIONAL `num_y_labels="…"` with integer (default: `0`)
- X Axis Title: OPTIONAL `x_axis_title="…"` with string (default: `empty`)
- Right Axis Title: OPTIONAL `right_axis_title="…"` with string (default: `empty`)
- Right Axis Auto-scale: OPTIONAL `right_axis_auto_scale="…"` with true/false (default: `true`)
- Right Axis Multi-scale: OPTIONAL `right_axis_multi_scale="…"` with true/false (default: `true`)
- Left Axis Title: OPTIONAL left`_axis_title="…"` with string (default: `empty`)
- Left Axis Auto-scale: OPTIONAL `left_axis_auto_scale="…"` with true/false (default: `true`)
- Left Axis Multi-scale: OPTIONAL `left_axis_multi_scale="…"` with true/false (default: `true`)
- Display numbers: OPTIONAL `plot_numbers="…"` with true/false (default: `false`)
- Comparative plots: REQUIRED `comparative="…"` with true/false (default: `false`).

*Auto-scaling is defined as rounding axis labels to 'pretty' increments.

*Multi-scaling is defined as using a different scale for each plot vs. grouping all plots on that axis to the same set of axis labels.

Time-series graphs can OPTIONALLY include the following additional attributes:

- Starting display time: `from="…"` with the start time (default: STARTTIME)
- Ending display time: `to="…"` with the ending time (default: STOPTIME)

Each graph includes a number of plotted variables. Within the `<graph>` tag, one `<plot>` tag MUST appear for each variable plotted. Each `<plot>` tag has the following attributes:

- Plot index: REQUIRED `index="…"` with sequential index number starting at zero for the first plot; this is important for both the legend and plotting numbers on curves (the plotted number is one greater than the index); for scatter plots, index 0 is the *x*-axis variable, index 1 is the *y*-axis variable, and (if a 3D scatter plot) index 2 is the *z*-axis variable (default: position of plot relative to other plots)
- Line thickness: OPTIONAL `pen_width="…"` with the line thickness in pixels (default: 1)
- Line style: OPTIONAL `pen_style="…"` with `solid`, `dotted`, `dashed`, or `dot_dashed` (default: `solid`)
- Display y-axis scale: OPTIONAL `show_y_axis="…"` with true/false (default: `true`)
- Plot title: REQUIRED `title="…"` with String (default: `entity display name`)
- Which axis the plot is plotted against: OPTIONAL `right_axis="…"` with true/false (default: `false`)

Within the `<plot>` tag, the REQUIRED`<entity>` tag defines which entity to plot, and the OPTIONAL `<scale>` tag defines custom scaling for the entity. The scale settings are overridden by the presence of auto-scaling or non-mutli-scaling on the axis.

The default scale for entities with a globally defined scale is that global scale. When no global scale is defined for an entity, the default scale automatically fills the range of values for the entity (for comparative graphs, this is across all runs of that entity in the graph). The `<scale>` tag allows the user to override these settings.

Graphs plot an entity's data from the current run and any other loaded runs. An example tag is shown below:

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```
<graph background="#FFFFC9" x="132" y="36" width="492" height="282"
title="Cool Graph" comparative="true" type="time_series" show_grid="true"
num_x_grid_lines="5" num_y_grid_lines="5" num_x_labels="5" num_y_labels="3"
left_axis_multi_scale="true" left_axis_auto_scale="true"
right_axis_multi_scale="true" right_axis_auto_scale="true" from="1" to="13">
      <plot precision="1" color="blue" pen_width="1" index="0"
      show_y_axis="true">
            <entity name="Converter_1" />
      </plot>
      <plot precision="1" color="red" pen_width="1" index="0"
      show_y_axis="true" right_axis="true">
            <entity name="Converter_2" />
      </plot>
</graph>
```

6.4.4 Tables

Support for this tags is REQUIRED if outputs are supported (per the header options, Section 2.2.1). Tables are defined within the `<table>` tag, which has the following attributes and properties, beyond the applicable display attributes, e.g., `background` and `font_size` (and their defaults):

- Title: OPTIONAL `<title>` with table title (default: none)
- Documentation: OPTIONAL `<doc>` with block of text, optionally in HTML format (default: none)
- Data orientation: REQUIRED `orientation="…"` with either `horizontal` or `vertical` (default: `vertical`)
- Default column width: REQUIRED `column_width="…"` with width in model coordinates
- Default blank column width: OPTIONAL `blank_column_width="…"` with width in model coordinates
- Report interval: REQUIRED `interval="…"` specifying how often, in model time, to report values during the simulation; use `DT` to export every DT (default: 1)
- Report ending/beginning balances: OPTIONAL `report_balances="…"` with either `beginning` or `ending` (default: `beginning`)
- Sum flows across report interval: OPTIONAL `report_flows="…"` with either `instantaneous` or `summed` (default: `instantaneous`)
- Comparative plots: REQUIRED `comparative="…"` with true/false (default: `false`)
- Wrap text in columns: OPTIONAL `wrap_text="…"` with true/false (default: `false`)
- Header style: OPTIONAL Same attributes from section 5.2 prefixed with "`header_`"

Each table includes a number of variables. Within the `<table>` tag, it is REQUIRED that one `<item>` tag appears for each variable displayed. Each `<item>` tag has the following unique attributes:

- Item type: REQUIRED `type="…"` with either `time`, `variable`, or `blank` (blank line) (default: `variable`). Note that the `time` item only needs to be specified to override the default item settings (e.g., the column width) for the time column/row.

Note that, unlike other display objects, the default `text_align` for table variables is `right`, rather than `left`.

Within the `<item>` tag, the REQUIRED `<entity>` tag defines which entity to plot.

Just as with the graph Tables plot an entity's data from the current run and any other loaded runs. An example tag is shown below:

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```
<table font_size="9pt" column_width="59" x="127" y="355" width="465"
height="286" comparative="true">
      <item precision="0.01" type="time" />
      <item precision="0.01" delimit_000s="true">
            <entity name="Converter_1" />
      </item>
</table>
```

6.5 Annotations

6.5.1 Text Boxes

The `<text_box>` tag is used to describe the appearance of a static label on the model canvas. Support for this tag is OPTIONAL. An example tag is shown below:

```
<text_box x="274" y="119" uid="0" color=”black” background=”white”
z_index=”1” font_family=”Arial” font_size=”9pt” font_weight=”bold”
font_style=”italic” text_decoration=”underline” text_align=”center”
vertical_text_align=”center” text_padding=”2px” font_color=”black”
text_border_color=”black” text_border_width=”1px” text_border_style=”solid”
width="260" height="58" appearance="transparent">
      Some text
</text_box>
```

- `appearance` OPTIONAL – “transparent|normal” – default `normal`. A text box with a transparent appearance has no background and can easily be layered on top of other XMILE objects. A text box with a normal appearance respects its `background` setting.

Descriptions of all display attributes of a text box can be found in Section 6.1.

6.5.2 Graphics Frames

The `<graphics_frame>` tag is used to describe the appearance of an image or video on the model canvas. Support for this tag is OPTIONAL. The content for a graphics frame goes inside of the graphics frame object and is represented using either an `image` or a `video` tag. The `image` tag is capable of representing its data as a string embedded within the XMILE file, or like the `video` tag is capable of referring to an external file using URL syntax. For files hosted on the local file system, the file:// syntax is used. Files can be referred to either absolutely or relatively. If referred to absolutely and if a lookup by absolute path fails, a lookup using just the file name in the same directory as the XMILE file is the RECOMMENDED fallback. An example graphics frame tag is shown below:

```
<graphics_frame x="102" y="301" uid="1" width="400" height="300"
border_color="black" border_style="solid" border_width="thin”>
      <image|video/>
</graphics_frame>
```

Descriptions of all display attributes of a graphics frame can be found in Section 6.1.

Both `<image>` and `<video>` have one OPTIONAL attribute:

- Resize to completely fill the parent container: `size_to_parent="…"` with true/false (default: `false`)

Example `<image>` and `<video>` tags:

```
<image size_to_parent="true" width="2509" height="1932">
      file://C:/Users/xmile/Downloads/Archive/home-screen.png
</image>
```

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```
<video size_to_parent="true" width="2509" height="1932">
      file://C:/Users/xmile/Downloads/Archive/home-screen.png
</video>
```

When an image is embedded directly within the XMILE file, the data is started by using with 'data:' then its MIME type ('image/png'), then a semi-colon (';') then the type of encoding ('base64') (base64 is the only REQUIRED option for this version of the spec) a comma (',') and finally the data (``). An example tag is shown below:

```
<image size_to_parent="true" width="2509" height="1932">
      *
</image>
```

6.5.3 Buttons

Buttons are used to control the program, navigate to a hyperlinked location, or to display an information window (`<popup>` containing text, an image, or a video). Support for this tag is OPTIONAL. All buttons appear within the `<button>` tag, which includes the standard display properties (section 5.2), as well as the following properties:

- Transparency: OPTIONAL `appearance="…"` with either `opaque` or `transparent` (default: `opaque`)
- Button corner style: OPTIONAL `style="…"` with `square`, `rounded`, or `capsule` (default: `square`)
- Label OPTIONAL: `label="…"` with text of label to appear on button; when there is a label, the default text alignment is center (rather than left)
- Image on button (overrides label) OPTIONAL: Image in JPG, GIF, TIF, or PNG format: `<image resource="">`. The `resource` attribute is OPTIONAL and may specify a relative file path, an absolute file path, or an URL. The picture data may also be embedded inside the `<image>` tag in Data URI format, using base64 encoding.
- Make a sound when clicked: OPTIONAL `clicking_sound="…"` with true/false (default: `true`)
- Sound played after click OPTIONAL (played after clicking sound, if any): `<sound>` with URL-format pathname (default protocol is file://)

Buttons that launch an information window contain a `<popup>` tag. The `<popup>` tag uses the same attributes as the other display objects, but its coordinates and size are in *screen* coordinates rather than model coordinates. Its position is relative to the top-left corner of the button (in screen coordinates). If it is off screen, it is RECOMMENDED to be forced on screen when it appears. The `<popup>` tag OPTIONALLY contains one of the following:

- A `<text_box>` tag to display text (described under "Text Boxes" below)
- An `<image>` tag to display an image
- A `<video>` tag to display a movie

Buttons that navigate include a `<link>`. The OPTIONAL `<link>` tag has several attributes:

- Top left position: `x="…"` and `y="…"` (default: 0) REQUIRED
- Zoom level (when `target` is model or interface): REQUIRED `zoom="…"` with percentage zoom (default: 100.0)
- OPTIONAL visual effect (when target is not `URL` or `file`): `effect="…"` with `none` or one of the several predefined visual effects (default: `none`)
  Predefined effect names (all directional names have an implied "from" in front of them, e.g.,

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wipe_left means wipe from the left side [to the right]): dissolve, checkerboard, bars, wipe_left, wipe_right, wipe_top, wipe_bottom, wipe_clockwise, wipe_counterclockwise, iris_in, iris_out, doors_close, doors_open, venetian_left, venetian_right, venetian_top, venetian_bottom, push_bottom, push_top, push_left, push_right

- Effect to black and back (only when an effect is given): OPTIONAL to_black="…" with true/false; it uses the given effect to a black screen and then uses its opposite, if there is one, back out again to show the new location (default: false)
- Link target REQUIRED: target="…" as an attribute as described below

There are several possible link targets:

- An arbitrary XMILE view:
  - Concatenate the view's type (section 5.1) with its order (section 5.1) using a colon. For example: target=stock_flow:0 would specify that this link points to the first stock_flow view. The view's order can either be an integer or home_view. If the order is not specified the order is assumed to be the home_view. For targets like this which do not use a page the x and y attributes of the link are assumed to be in view coordinates (vs. page coordinates)
- An arbitrary XMILE page:
  - First navigate to the view using the above syntax, and then concatenate the page number using a comma. For example: target=stock_flow:0,5 would specify that this link points to the first stock_flow view's fifth page. The page can either be an integer or home_page. If the page number is not specified the home_page is assumed. For targets like this which do use a page in their target the x and y attributes of the link are assumed to be in page coordinates (vs. view coordinates)
- Next page: next_page or previous page: previous_page, or home_page or an integer representing the page number
  - using paging attributes (section 5.1) within the view the button is defined in. The x and y attributes of the link are assumed to be in page coordinates (vs. view coordinates)
- Next view: next_view or previous view: previous_view
  - using order attribute defined in section 5.1, the view's type is assumed to be the same type as the view which contains the button. The x and y attributes of the link are assumed to be in view coordinates (vs. page coordinates)
- Home view: home_view
  - using the home_view attribute defined in section 5.1, the view's type is assumed to be the same type as the view which contains the button. The x and y attributes of the link are assumed to be in view coordinates (vs. page coordinates)
- Last page navigated from: back_page. The x and y attributes of the link are assumed to be in page coordinates (vs. view coordinates)
- Last view navigated from: back_view. The x and y attributes of the link are assumed to be in view coordinates (vs. page coordinates)
- File or web URL: URL (<link> tag contains target URL; protocol is http:// if not specified)

Buttons that control the program contain a <menu_action> tag, which has the menu name as its data. OPTIONAL menu actions are broken into various categories:

- File: open, close, save, save_as, save_as_image, revert
- Printing: print_setup, print, print_screen
- Simulation: run, pause, resume, stop, run_restore (run *only if* restored)

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- Restore objects: `restore_all`, `restore_sliders`, `restore_knobs`, `restore_list_inputs`, `restore_graphical_inputs`, `restore_switches`, `restore_numeric_displays`, `restore_graphs_tables`, `restore_lamps_gauges`
- Data: `data_manager`, `save_data_now`, `import_now`, `export_now`
- Miscellaneous: `exit`, `find`, `run_specs`

In the case of `import_now` and `export_now`, the `<menu_action>` tag has the following REQUIRED attributes:

- Source (import) or destination (export) location: `resource="…"`. The `resource` attribute may specify a relative file path, an absolute file path, or an URL.
- For Excel only, worksheet name: `worksheet="…"` with worksheet name
- Alternatively, if all on-demand links are to be imported or exported: `all="true"` (as a consequence, when `all` does not appear, it is `false`)

In the case of `save_data_now`, the `<menu_action>` tag has the following REQUIRED attributes:

- Name of saved run: `run_name="…"` with name of saved run

Note that buttons that navigate (i.e., use a `<link>` tag) MAY combine other actions with that navigation. In particular, they MAY include both a `<menu_action>` and a `<popup>`. They MAY also behave like a switch if they include a `<switch_action>` tag. The entity being switched on or off is defined within the `<switch_action>` tag in the same way as within a `<switch>` tag, i.e., using an `<entity>` tag, or the identically formatted `<group>` or `<module>` tag. If the value in the tag is 1 then the group or module is included in the simulation, if 0 it is not included. The following button combines several properties to place an image on its face, redefine the clicking sound to a bicycle bell, and, when clicked, navigate to the next page with a visual effect while restoring graphs and tables and turning the bicycle policy group on:

```
<button x="748" y="226" width="294" height="252" clicking_sound="false">
      <image size_to_parent="true" width="960" height="720">
         C:/Images/button_ok.jpg
      </image>
      <sound>bicycle_bell.wav</sound>
      <link target="next_page" to_black="true" effect="iris_in"/>
      <menu_action>restore_graphs_tables</menu_action>
      <switch_action>
         <group name="Bicycle Policy">
            <value>1</value>
         </group>
      </switch_action>
</button>
```

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7 XMILE Implementation Conformance

7.1 ConformanceTargets

XMILE has two conformance targets:

1. XMILE file
2. XMILE simulator

Within each of these targets, XMILE has a base level of conformance with several optional features that create higher levels of conformance in different combinations. In addition, within each conformance level, some features are optional.

7.2 Conformance Clause 1: XMILE File

A file conforms to this specification as an XMILE file if it meets the requirements in the following subsections.

7.2.1 Base-Level Conformance

To conform to the XMILE base level, an implementation:

1. MUST include an `<xmile>` tag that contains both the version of XMILE used and the XMILE XML namespace (Section 2)
2. MUST include a `<header>` tag (Section 2) with sub-tags `<vendor>` and `<product>` with its version number (Section 2.2)
3. MUST include at least one `<model>` tag (Section 2)
4. MUST name models beyond the root model (Section 4)
5. MUST, on read, resolve inconsistencies between multiple files (Section 2)
6. MUST obey the namespace rules (Section 2.1 and 2.2.1)
7. MUST include, when using optional features, the <options> tag with those features specified (Section 2.2.1)
8. MUST contain at least one set of simulation specifications (Section 2.3)
9. MUST support model behaviors (Section 2.6)
10. MUST support include files (Section 2.11)
11. MUST support all base functionality objects (Section 3.1 and all subsections)
12. MUST obey the grammar for numbers, variables, and expressions (Sections 3.2 and 3.3, and all subsections except Sections 3.3.5 and 3.3.6)
13. MUST support the REQUIRED common variable properties, specifically the name and for arrays, dimensions and, when not apply-to-all, elements (Section 4.1)

7.2.2 Optional Conveyor Conformance

To support the optional conveyor features of XMILE, an implementation:

1. MUST include the `<uses_conveyor>` tag in the `<options>` block (Section 2.2.1)
2. MUST support the `<conveyor>` block with all of its options (Sections 4.2 and 4.2.1)
3. MUST support conveyor leakage and its properties (Section 4.3)

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7.2.3 Optional Queue Conformance

To support the optional queue features of XMILE, an implementation:

1. MUST include the <uses_queue> tag in the <options> block (Section 2.2.1)
2. MUST support the <queue/> tag in the stock (Section 1.2)
3. MUST support the queue overflow (Section 4.3)

7.2.4 Optional Array Conformance

To support the optional array features of XMILE, an implementation:

1. MUST include the <uses_array> tag in the <options> block with the correct number of dimensions (Section 2.2.1)
2. MUST include a <dimensions> tag (Section 2.5)
3. MUST support arrays and their syntax (Sections 3.7.1 and all subsections)
4. MUST support the three different types of arrays (Sections 4.1.4 and 4.5)

7.2.5 Optional Submodel Conformance

To support the optional submodel features of XMILE, an implementation:

1. MUST include the <uses_submodels> tag in the <options> block (Section 2.2.1)
2. MUST support features of modules, including submodel inputs, submodel outputs, and qualified entity names (Section 3.7.4)
3. MUST support module entities (Section 4.7.1)
4. MUST include all connections between modules within the proper module entity (Section 4.7.1)
5. MUST properly mark module inputs and outputs and obey access rules (Sections 4.7.2 and 4.7.3)

7.2.6 Optional Macro Conformance

Macros include a base level, a recursive level, and an options filter level.

7.2.6.1 Base Macro Conformance

To support the optional macro features of XMILE, an implementation:

1. MUST include the <uses_macros> tag in the <options> block and MUST specify whether recursive macros and/or option filters are also supported (Section 2.2.1)
2. MUST support the <macro> tag (Section 4.8)

7.2.6.2 Recursive Macro Conformance

To support the optional recursive macro features of XMILE, an implementation:

1. MUST, in the <uses_macros> tag of the <options> block, specify that recursive macros are supported (Section 2.2.1)

7.2.6.3 Option Filter Macro Conformance

To support the optional option-filter macro features of XMILE, an implementation:

1. MUST, the <uses_macros> tag of the <options> block, specify that option filters are supported (Section 2.2.1)
2. MUST support option filter macros (Section 3.6.2 and 4.8.4)

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7.2.7 Optional Event-Poster Conformance

To support the optional event poster features of XMILE, an implementation:

1. MUST include the <uses_event_posters> tag in the <options> block (Section 2.2.1)
2. MUST support simulation events and their options (Sections 3.4.2 and 4.1.2)

7.2.8 Optional Model-View Conformance

To support the optional features of XMILE to represent a model view, an implementation:

1. MUST include the <has_model_view> tag in the <options> block (Section 2.2.1)
2. MUST support styles (Section 2.7)
3. MUST have one <views> tag and at least one <view> tag (Sections 5, 5.1, and subsections of 5.1)
4. MUST support the <stock> tag (Section 6.1.1)
5. MUST support the <flow> tag. Anchor points for the flow MUST be specified (Section 6.1.2)
6. MUST support the <aux> tag (Section 6.1.3)
7. MUST support the <connector> tag. <from>, <to>, <pts>, and <angle> attributes for the connector tag MUST be specified (Section 6.1.6)
8. MUST support the <alias> tag. If they exist, alias objects MUST represent only stock, flow, and aux objects. Alias objects MUST NOT have connectors pointing to them. <uid>, <x>, <y>, and <of> attributes for each alias MUST be specified for an alias object (Section 6.1.7)
9. MUST support the <graph> tag. <type> and <comparative> attributes MUST be specified for each graph .One <plot> tag MUST appear for each variable being plotted. Each <plot> tag MUST specify a value for the <index>, <title>, and <entity> attributes (Section 6.4.3)
10. MUST support a <table> tag. <orientation>, <column_width>, <interval>, and <comparative> attributes for the table MUST be specified .One <item> tag MUST appear for each variable being displayed. Each <item> tag MUST specify a value for the <type> and <entity> attributes (Section 6.4.4)

Additionally,

11. Each <stock|flow|aux|module|group> tag in a view MUST specify a <name> attribute (Section 5.1.1)
12. A model variable object MUST be defined somewhere other than in a view of type “interface”, i.e., a view of type “interface” may not contain the canonical representation of a model variable object (Section 5.1)
13. All views MUST be rectangular and MUST specify a <width> and a <height> (Section 5.1)
14. To print a view, the view MUST specify its paging as described in Section 5.1
15. All views MUST specify a <home_page> and a <home_view> attribute. There MUST be only one <home_view> specified (Section 5.1)
16. A <stock|flow|aux|module> (note: not <group>) tag representing a model variable MUST NOT appear more than once in a single <view> tag (Section 5.1.1)
17. All display objects contained within an XMILE model MUST specify the <x> and <y> position attributes (Section 5.1.2)
18. All display objects contained within an XMILE model MUST specify the <width> and <height> attributes EXCEPT when the following objects contain a <shape> tag: <stock>, <aux>, <module>, or <alias> (Section 5.1.2)
19. A stock MUST NOT be represented using a circle (Section 5.1.2)
20. An auxiliary or a flow MUST NOT be represented using a rectangle except if the equation contains a function or macro which contains a stock (Section 5.1.2)

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21. Display objects containing a <shape> tag MUST specify a <type> attribute with one of the following values: “rectangle”, “circle”, or “name_only” (Section 5.1.2)
22. Display objects of type rectangle MUST specify a <width> and a <height> (Section 5.1.2)
23. Display objects of type circle MUST specify a <radius> (Section 5.1.2)
24. All values for <x>, <y>, <width>, and <height> MUST be double precision numbers (Section 5.1.2)
25. All display objects that are referred to anywhere other than a display view MUST provide a <uid> attribute and the value of each <uid> MUST be unique within the model (Section 5.1.3)
26. When a color is specified for a display object using a CSS style hex code, it MUST be prefixed by a # followed by up to 6 hexadecimal digits from 0 to F (Section 5.2.2)
27. Stacked containers, if supported, MUST have values for <x>, <y>, <height>, <width>, <uid>, and <visible_index> (and only those) attributes specified (Section 6.2.1)

7.2.9 Optional Outputs Conformance

To support the optional simulation output features of XMILE, an implementation:

1. MUST include the <uses_outputs> tag in the <options> block (Section 2.2.1)
2. MUST support the <graph> tag. <type> and <comparative> attributes MUST be specified for each graph .One <plot> tag MUST appear for each variable being plotted. Each <plot> tag MUST specify a value for the <index>, <title>, and <entity> attributes (Section 6.4.3)
3. MUST support the <table> tag. <orientation>, <column_width>, <interval>, and <comparative> attributes for the table MUST be specified .One <item> tag MUST appear for each variable being displayed. Each <item> tag MUST specify a value for the <type> and <entity> attributes (Section 6.4.4)
4. If numeric_display is true in the <uses_outputs> tag, MUST support numeric displays (Section 6.4.1)
5. If lamp is true in the <uses_outputs> tag, MUST support lamps and a list of zones with non-overlapping value ranges for the variable MUST be specified within the <zones> tag (Section 6.4.2)
6. If gauge is true in the <uses_outputs> tag, MUST support gauges and a list of zones with non-overlapping value ranges for the variable MUST be specified within the <zones> tag (Section 6.4.2)

Additionally,

7. Each zone for a lamp or a gauge (in a <zone> tag) MUST specify values for <type>, <color>, <min>, and <max> (Section 6.4.2)

7.2.10 Optional Inputs Conformance

To support the optional user input features of XMILE, an implementation:

1. MUST include the <uses_inputs> tag in the <options> block (Section 2.2.1)
2. MUST support the <slider> and <knob> tags (Section 6.3.1)
3. MUST support the <switch> and <options> tags (Section 6.3.2)
4. If numeric_input is true in the <uses_inputs> tag, MUST support numeric inputs (Section 6.3.3)
5. If list is true in the <uses_inputs> tag, MUST support list inputs (Section 6.3.3)
6. If graphical_input is true in the <uses_inputs> tag, MUST support graphical inputs. If the graphical input contains a different graphical function than the controlled variable, the <entity> tag MUST include a <gf> tag to describe that graphical function (Section 6.3.4)

Additionally,

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7. The input range tags <min> and <max> MUST be specified for sliders and knobs (Section 6.3.1)
8. A switch's <group> or <module> tag MUST specify a <name> and a <value> (Section 6.3.2)
9. Option groups MUST specify values for <layout>, <horizontal_spacing>, and <vertical_spacing> (Section 6.3.2)
10. A list input MUST specify a <name> and <column_width> (Section 6.3.3)
11. A graphical input MUST specify an <entity> tag (Section 6.3.4)

7.2.11 Optional Annotations Conformance

To support the optional model annotation features of XMILE, an implementation:

1. MUST include the <uses_annotations> tag in the <options> block (Section 2.2.1)
2. MUST support the <text_box> tag (Section 6.5.1)
3. MUST support the <graphics_frame> tag (Section 6.5.2)
4. MUST support the <button> tag (Section 6.5.3)

Additionally,

5. When an image is embedded directly within the XMILE file, the type of encoding MUST be "base64" (Section 6.5.2)
6. Buttons that control the program MUST contain a <menu_action> tag
7. Menu actions <import_now>, <export_now>, and <save_data_now> MUST have the required attributes specified (Section 6.5.3)

7.3 Conformance Clause 2: XMILE Simulator

An implementation conforms to this specification as an XMILE simulator if it meets the requirements in the following subsections.

7.3.1 Base-Level Conformance

To conform to the XMILE base level, an implementation:

1. MUST adhere to the model assumptions (Section 3)
2. MUST support the simulation rules of each base functionality object (Section 3.1 and all subsections)
3. MUST support Euler's method and Runge-Kutta 4 (Section 3.4.1)
4. MUST support the full range of built-in functions (Section 3.5 and all subsections)

7.3.2 Optional Conveyor Conformance

To support the optional conveyor features of XMILE, an implementation:

1. MUST implement conveyors as described (Section 3.7.2)
2. MUST support the full list of array built-in functions for conveyors, including the [] operator to access conveyor elements (Section 3.7.1.3)
3. MUST implement all conveyor and leakage properties (Sections 4.2, 4.2.1, and 4.3)

7.3.3 Optional Queue Conformance

To support the optional queue features of XMILE, an implementation:

1. MUST implement queues as described (Section 3.7.3)
2. MUST support the full list of array built-in functions for queues, including the [] operator to access queue elements (Section 3.7.1.3)
3. MUST implement the queue overflow (Section 4.3)

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7.3.4 Optional Array Conformance

To support the optional array features of XMILE, an implementation:

1. MUST support dimensions (Section 2.5)
2. MUST generate one value for each array element (Section 3.7.1)
3. MUST support subscripts and subscript expressions (Section 3.7.1)
4. MUST support array operators (Section 3.7.1.1)
5. MUST support array slicing (Section 3.7.1.2)
6. MUST support the full list of array built-in functions (Section 3.7.1.3)

7.3.5 Optional Submodel Conformance

To support the optional submodel features of XMILE, an implementation:

1. MUST support the basic run behavior, i.e., use the same simulation specifications as the whole-model (Section 3.7.4).

7.3.6 Optional Macro Conformance

Macros include three levels: a base level, a recursive level, and an options-filter level.

7.3.6.1 Base Macro Conformance

To support the optional macro features of XMILE, an implementation:

1. MUST support all macro features but recursive macros and option filters (Section 3.6.1 and Sections 4.8.1-4.8.3)

7.3.6.2 Recursive Macro Conformance

To support the optional recursive macro features of XMILE, an implementation:

1. MUST implement recursive macros (Section 3.6.1 and Sections 4.8.1-4.8.3)

7.3.6.3 Option-Filter Macro Conformance

To support the optional option-filter macro features of XMILE, an implementation:

1. MUST implement option filter macros (Section 3.6.2 and 4.8.4)

7.3.7 Optional Event-Poster Conformance

To support the optional event poster features of XMILE, an implementation:

1. MUST implement simulation events and their options (Sections 3.4.2 and 4.1.2)

7.3.8 Optional Inputs Conformance

To support the optional user input features of XMILE, an implementation:

1. Knobs attached to stocks MUST only adjust the stock's initial value (Section 6.3.1)
2. Option groups MUST NOT support `reset_to` (Section 6.3.2)

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Appendix A. Acknowledgments

The following individuals have participated in the creation of this specification and are gratefully acknowledged:

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Appendix B. Revision History

Revision	Date	Editor	Changes Made
1.0wd01	9/23/13	Karim Chichakly	Created from input documents
1.0wd02	8/26/14	Karim Chichakly	Combined edits from TC editors
1.0wd03	10/21/14	Karim Chichakly and Gary Baxter	Edited in response to public comments by Karim Chichakly, Gary Baxter, and William Schoenberg

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