

# Units Markup Language (UnitsML)

Presentation for

**SCC-20 TII/TAD Working Group**

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# Outline

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- Vision
- Introduction
- Background information on units and quantities
- Units Markup Language
- Units Database
- Usage of UnitsML & UnitsDB

# Vision

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- UnitsML schema for encoding scientific units of measure – useful for unit dictionaries and incorporating within other markup languages
- Units Database (UnitsDB) containing extensive information on units, prefixes, quantities, & dimensions
- Guidelines and tools for use of UnitsML & UnitsDB
  - Web Services
  - Unit conversions

# Introduction

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- Units Markup Language (UnitsML) is a proposed method of representing scientific units of measure in XML.
- Original motivation for this project came from initial effort by Frank Olken and John McCarthy of the Lawrence Berkeley National Laboratory (LBNL).
- Initial Collaborators:
  - Barry Taylor (NIST-PL,emeritus)
  - Michael McLay (NIST-EEEL)
  - Frank Olken (LBNL)
  - Peter Murray-Rust (CML - Chemical Markup Language)

# Introduction

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- NIST UnitsML Committee

- Bob Dragoset (PL)
- Simon Frechette (MEL)
- Mark Carlisle (MEL)
- Peter Linstrom (CSTL)
- Gary Kramer (CSTL)
- Martin Weber (PL – NIST Associate)
- Kent Reed (BFRL)
- Evan Wallace (MEL)
- Karen Olsen (PL)
- Several NIST Associates (CSTL, PL, BFRL)

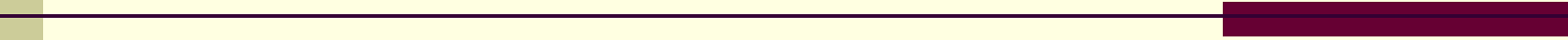
- Funded in part by NIST's Systems Integration for Manufacturing Applications (SIMA) program.

- <http://www.nist.gov/sima>

# Introduction

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- UnitsML OASIS Technical Committee formed on July 12, 2006
- Deliverables due by July 2007:
  - UnitsML Working Draft identifying the requirements and data-model for units of measure
  - UnitsML Proposed Standard for the representation of units information in XML
  - Guidelines for implementation of UnitsML
- Participants from NIST, Granta Design, LSC Group Ltd, IBM, NPL, Univ. of North Florida, IEM
- Soliciting additional non-NIST participants



# Background Information on Units and Quantities

# 7 SI Base Units & Quantities

Unit Name	Unit Symbol	Quantity	Quantity Symbol	Dimension Symbol
meter	m	length	$l$	<b>L</b>
kilogram	kg	mass	$m$	<b>M</b>
second	s	time	$t$	<b>T</b>
ampere	A	electric current	$I$	<b>I</b>
kelvin	K	thermodynamic temperature	$T$	<b>Θ</b>
mole	mol	amount of substance	$n$	<b>N</b>
candela	cd	luminous intensity	$I_v$	<b>J</b>

**Examples:**

$$l = 7.24 \text{ m}$$

$$m = 1.53 \text{ kg}$$

$$v = 6.32 \text{ m/s}$$

$$\dim v = \mathbf{L T^{-1}}$$



# 22 SI Special Derived Units

Derived quantity	Special name	Special symbol	Expression in terms of	
			other SI units	SI base units
plane angle	radian	rad	1	$\text{m} \cdot \text{m}^{-1}$
solid angle	steradian	sr	1	$\text{m}^2 \cdot \text{m}^{-2}$
frequency	hertz	Hz		$\text{s}^{-1}$
force	newton	N		$\text{m} \cdot \text{kg} \cdot \text{s}^{-2}$
pressure, stress	pascal	Pa	$\text{N}/\text{m}^2$	$\text{m}^{-1} \cdot \text{kg} \cdot \text{s}^{-2}$
energy, work, quantity of heat	joule	J	$\text{N} \cdot \text{m}$	$\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-2}$
power, radiant flux	watt	W	$\text{J}/\text{s}$	$\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-3}$
electric charge, quantity of electricity	coulomb	C		$\text{s} \cdot \text{A}$
electric potential, potential difference, electromotive force	volt	V	$\text{W}/\text{A}$	$\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-3} \cdot \text{A}^{-1}$
capacitance	farad	F	$\text{C}/\text{V}$	$\text{m}^{-2} \cdot \text{kg}^{-1} \cdot \text{s}^4 \cdot \text{A}^2$
electric resistance	ohm	$\Omega$	$\text{V}/\text{A}$	$\text{m}^2 \cdot \text{kg} \cdot \text{s}^{-3} \cdot \text{A}^{-2}$
electric conductance	siemens	S	$\text{A}/\text{V}$	$\text{m}^{-2} \cdot \text{kg}^{-1} \cdot \text{s}^3 \cdot \text{A}^2$

# 22 SI Special Derived Units

Derived quantity	Special name	Special symbol	Expression in terms of	
			other SI units	SI base units
magnetic flux	weber	Wb	$V \cdot s$	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
magnetic flux density	tesla	T	$Wb/m^2$	$kg \cdot s^{-2} \cdot A^{-1}$
inductance	henry	H	$Wb/A$	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
Celsius temperature	degree Celsius	$^{\circ}C$		K
luminous flux	lumen	lm	$cd \cdot sr$	cd
illuminance	lux	lx	$lm/m^2$	$m^{-2} \cdot cd$
activity (of a radionuclide)	becquerel	Bq		$s^{-1}$
absorbed dose, specific energy (imparted), kerma	gray	Gy	$J/kg$	$m^2 \cdot s^{-2}$
dose equivalent, <i>et al.</i>	sievert	Sv	$J/kg$	$m^2 \cdot s^{-2}$
catalytic activity	katal	kat		$s^{-1} \cdot mol$

There are also many derived quantities with SI units without special names; e.g., the quantity **area** has units of  $m^2$ ; and multiples and submultiples; e.g., km, cm.

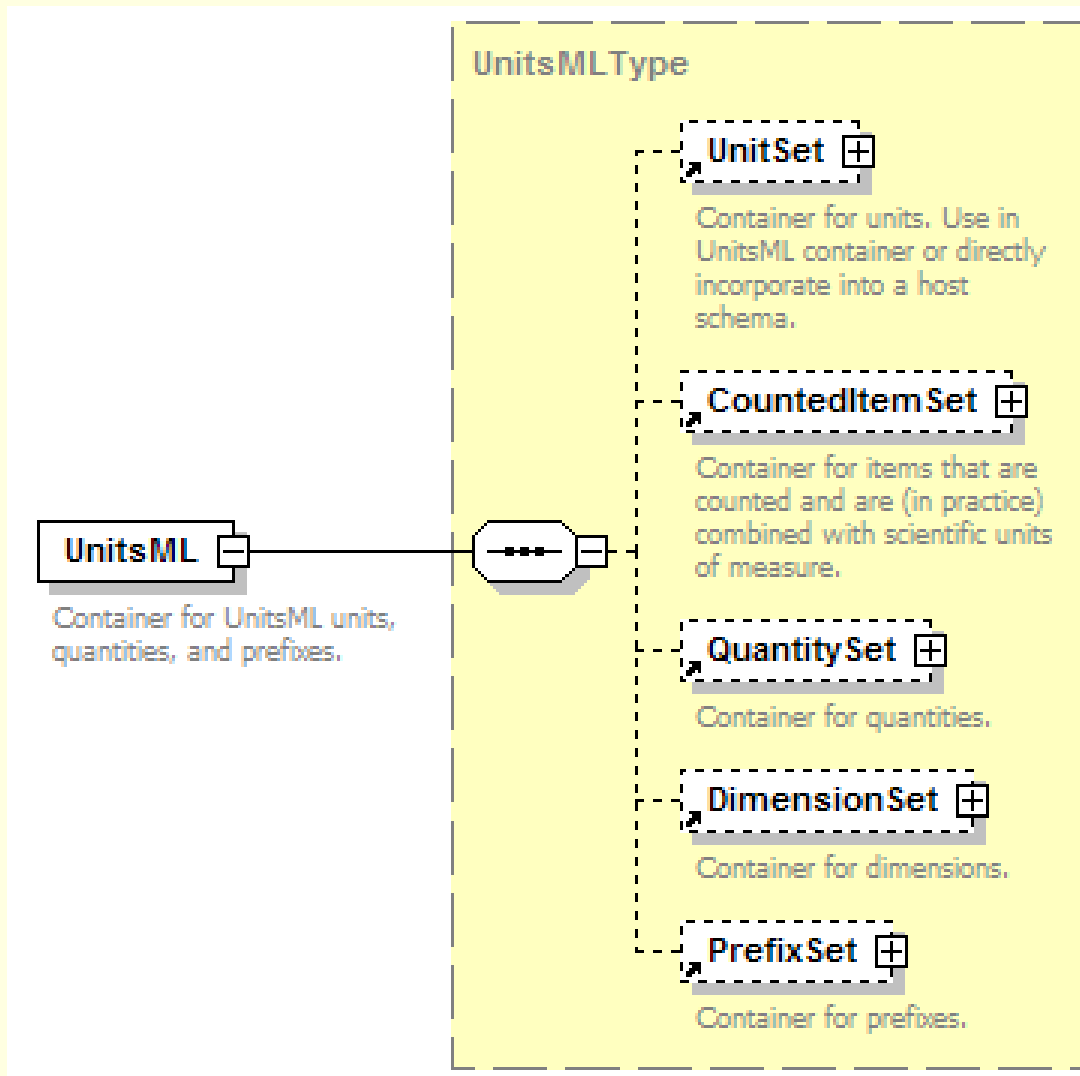
# Non-SI Units

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- According to SP 811, there are 3 categories of non-SI units relating to use within the SI
  - Acceptable
    - Examples: minute, hour, day, liter, metric ton, natural and atomic units
  - Temporarily acceptable
    - Examples: nautical mile, knot, ångström
  - Unacceptable
    - Examples: erg, dyne, fermi, torr, micron

# Units Markup Language (UnitsML)

# UnitsML Root Level



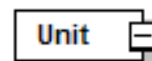
# 'Unit' Element

## ■ Attributes

- xml:id
- dimensionURL

## ■ Elements

- RootUnits
- Conversions
- CodeListValue



Unit  
Element for describing units. Use in containers UnitSet or directly incorporate into a host schema.

## UnitType

### attributes

xml:id

timeStamp

Used to indicate the version of the unit output from the Units Database. Changes in the time-stamp are made if a substantive change has been made to the unit, such as a change in the unit definition or changes in conversion factors.

dimensionURL

URL to a representation of the unit or quantity in terms of the 7 SI base dimensions.

UnitSystem

0..∞

Container for describing the system(s) of units.

UnitName

1..∞

Element containing the unit name.

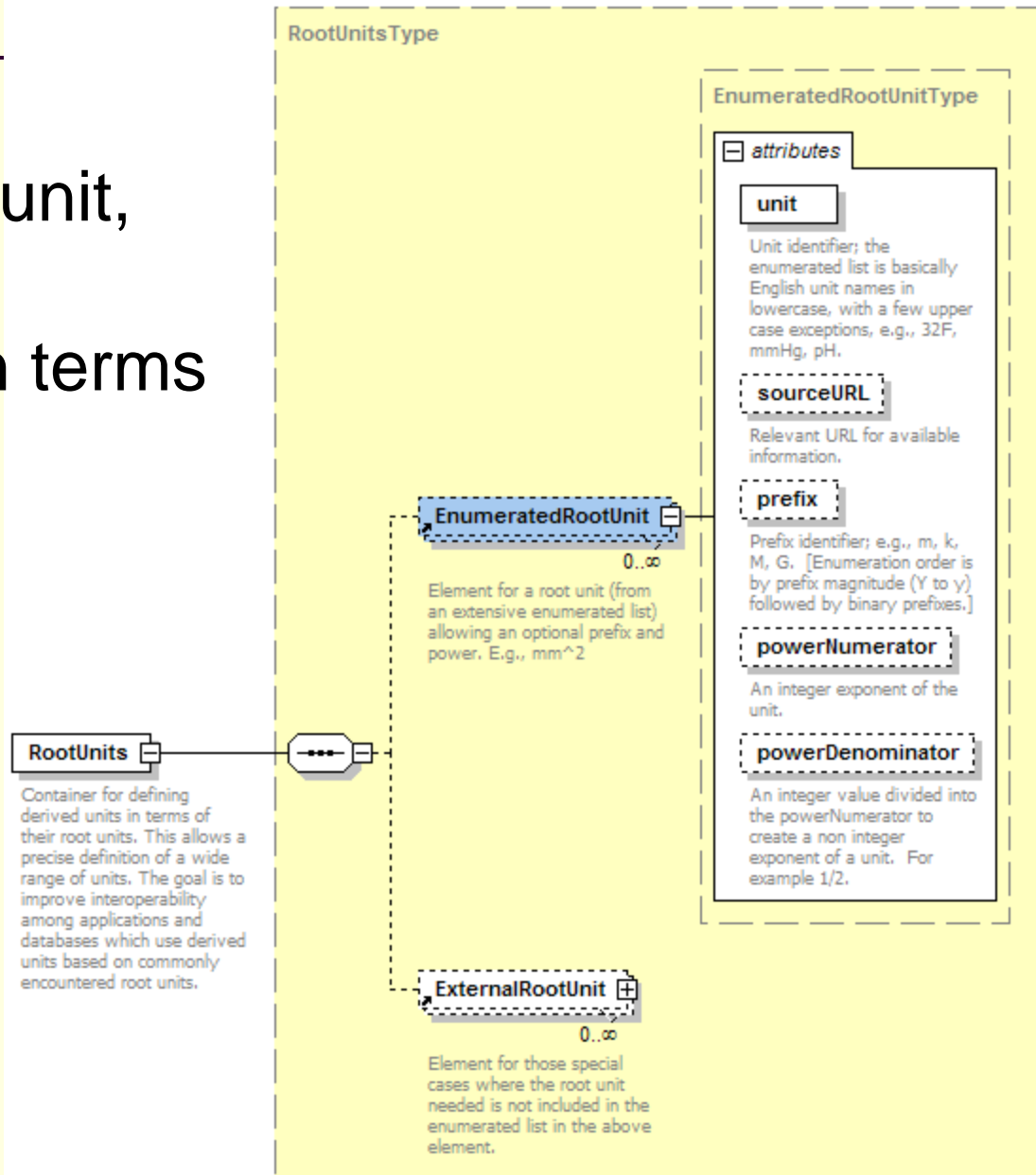
UnitSymbol

0..∞

Element containing various unit symbols. Examples include Aring (ASCII), Å (HTML).

# 'RootUnits' Element

Express a derived unit, e.g., millimeter per second squared, in terms of its components.



# 'Conversions' Element

$$y = d + ((b / c) (x + a))$$

## Attributes

x, initialUnit

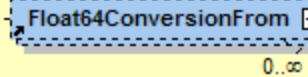
a, initialAddend

b, multiplicand

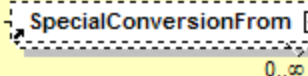
c, divisor

d, finalAddend

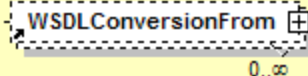
$$x = ((c / b) (y - d)) - a$$



Element for providing factors for a conversion equation from another unit;  $y = d + ((b / c) (x + a))$ .  
Note: The related "conversion to" equation is a simple inversion of the above equation; i.e.,  $x = ((c / b) (y - d)) - a$ .

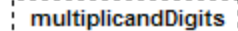


Element for describing a conversion that cannot be described by the linear expression in the element Float64ConversionFrom.



Element for providing conversion based on SOAP/WSDL calls to a remote server.

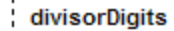
[factor 'b' in equation].



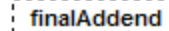
Number of significant digits in the multiplicand value.



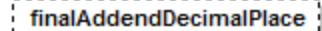
Divisor to be applied to the value at the same time as the multiplicand [factor 'c' in equation].



Number of significant digits in the divisor value.



Number to be added at the end of the conversion [factor 'd' in equation].



Indicates the position of the least significant digit (in decimal) of the finalAddend; the position of this digit is given by ten to additive inverse of this number.



Indicates if the conversion is exact.



Element for descriptive information.

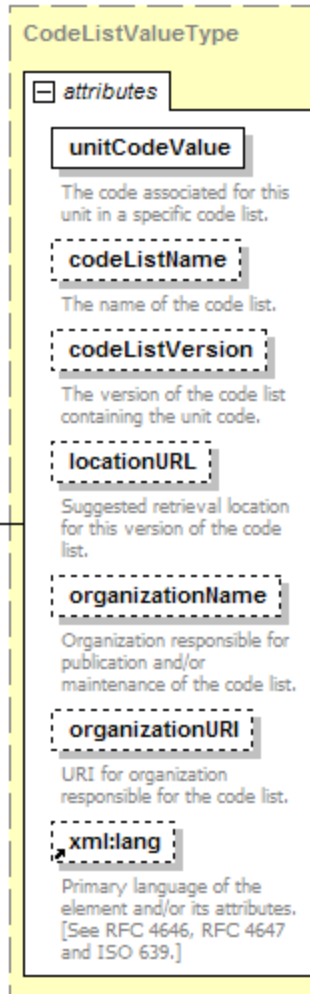


# 'CodeListValue' Element

Equate a unit with a code provided in a specific community's code list.

## CodeListValue

Element for listing the unit code value from a specific code list.



# 'Quantity' Element

- Attributes
  - xml:id
  - dimensionURL
- Elements
  - UnitReference

## Quantity

Element for describing quantities and referencing corresponding units. Use in container or directly incorporate into a host schema.

## QuantityType

### attributes

#### xml:id

#### quantityType

Type of the quantity. For example base or derived.

#### dimensionURL

URL to a representation of the unit or quantity in terms of the 7 SI base dimensions.

### QuantityName

1..∞

Element containing the quantity name.

### QuantitySymbol

0..∞

Element containing various quantity symbols.

### UnitReference

0..∞

Element for specifying particular units associated with the quantity.

### QuantityVersionHistory

0..∞

Element for descriptive information, including version changes to the quantity.

### QuantityDefinition

0..∞

Element to describe the definition of the quantity.

### QuantityHistory

0..∞

Element to describe the historical development of the quantity.



# 'Dimension' Element

Express the dimensionality of a quantity or unit.

## Dimension

Element to express the dimension of a unit or quantity in terms of the SI base quantities length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity.

## DimensionType

### attributes

xml:id

dimensionless

Boolean to designate that a quantity or unit is dimensionless.

### Length

Element containing the dimension of the quantity length.

### Mass

Element containing the dimension of the quantity mass.

### Time

Element containing the dimension of the quantity time.

### ElectricCurrent

Element containing the dimension of the quantity electric current.

### ThermodynamicTemperature

Element containing the dimension of the quantity thermodynamic temperature.

### AmountOfSubstance

Element containing the dimension of the quantity amount of substance.

### LuminousIntensity

Element containing the dimension of the quantity luminous intensity.

### PlaneAngle

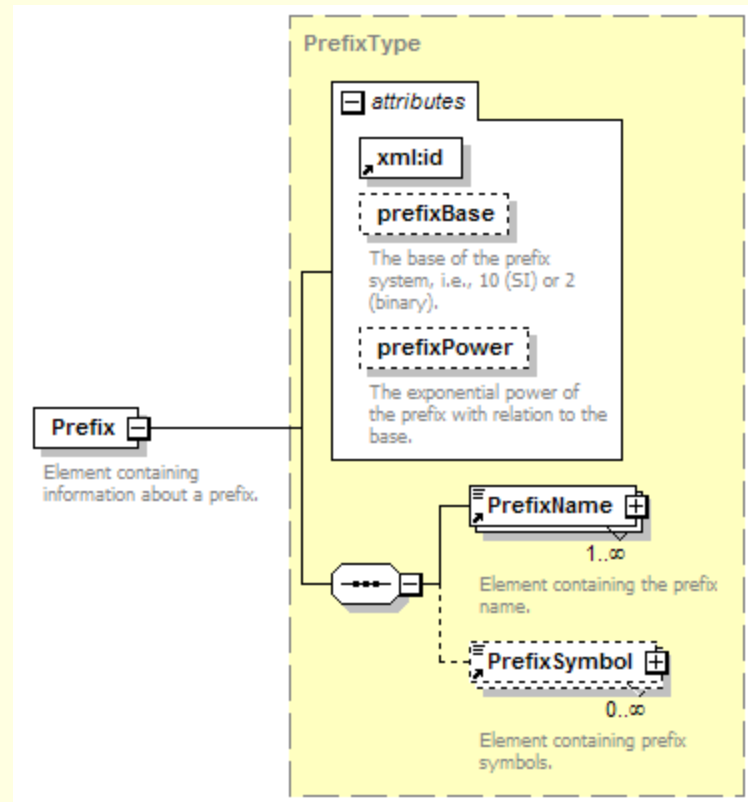
Element containing the dimension of the quantity plane angle.



1..∞

This unbounded sequence allows any order of any number of elements; e.g.,  $L^1 A \cdot L^{-1}$ .

# 'Prefix' Element



# Instance Document Snippets

```
<Unit xml:id="U_mm.s-2" dimensionURL="#D_L.T-2">
  <UnitSystem name="SI" type="SI_derived" xml:lang="en-US"/>
  <UnitName xml:lang="en-US">millimeter per second squared</UnitName>
  <UnitSymbol type="HTML">mm &#183; s<sup>-2</sup></UnitSymbol>
  <RootUnits>
    <EnumeratedRootUnit unit="meter" prefix="m"/>
    <EnumeratedRootUnit unit="second" powerNumerator="-2"/>
  </RootUnits>
  <QuantityReference url="#Q_acceleration"/>
</Unit>
...
<Prefix xml:id="P_m" prefixBase="10" prefixPower="-3">
  <PrefixName xml:lang="en-US">milli</PrefixName>
  <PrefixSymbol type="HTML">m</PrefixSymbol>
</Prefix>
...
<Quantity xml:id="Q_acceleration" dimensionURL="#D_L.T-2" quantityType="derived">
  <QuantityName xml:lang="en-US">acceleration</QuantityName>
  <QuantitySymbol type="HTML"><i>a</i></QuantitySymbol>
</Quantity>
...
<Dimension xml:id="D_L.T-2">
  <Length symbol="L" powerNumerator="1"/>
  <Time symbol="T" powerNumerator="-2"/>
</Dimension>
```

# Units Database (UnitsDB)

# UnitsDB

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- UnitsDB uses JAVA to query a MySQL database
- Human Web interface – possible search methods
  - Scrollable list
  - Specific categories; e.g., SI base, non-SI
  - Name search with partial matches
  - Unit symbol
  - Root units
  - Unique ID – e.g., NISTu1.u3e-1
  - Quantities
  - Prefixes
- Version 1.0 will provide XML & HTML
- Web Services interface planned

# UnitsDB Search: Screen Captures

## Select:

Units

SI / non-SI

Quantities

Prefixes

## Output Format:

XML / HTML

The screenshot displays the 'UnitsML Database Search' web application. At the top, there are four tabs: 'Units/Quantities/Prefixes' (selected), 'Unit Builder', 'Root Units', and 'NIST ID'. Below the tabs, the instruction 'Select from Units, Quantities, or Prefixes' is shown. A 'Select Units' section is active, featuring a '7 selected' indicator and a 'Submit' button. A search filter is set to 'Enter keywords'. The interface is divided into two main sections: 'All SI base units' and 'All SI special derived units'. The 'All SI base units' section contains a list of seven units, each with a checked checkbox: meter [m], kilogram [kg], second [s], ampere [A], kelvin [K], mole [mol], and candela [cd]. The 'All SI special derived units' section contains four units with unchecked checkboxes: becquerel [Bq], coulomb [C], degree Celsius [degC], and farad [F]. To the right of the unit lists, a 'Selected Units:' box contains a bulleted list of the seven selected base units: meter [m], kilogram [kg], second [s], ampere [A], kelvin [K], mole [mol], and candela [cd]. At the bottom of the interface, there are two expandable sections: 'Select Quantities' and 'Select Prefixes'.



# UnitsDB Search: Screen Captures

## Unit Builder

Unit

w/ prefix, power

Add Unit

**Output Format:**  
XML / HTML

UnitsML Database Search

Units/Quantities/Prefixes **Unit Builder** Root Units NIST ID

Build an Expression

Prefixes	Units	Powers	
<input type="text"/>	meter [m]	1	
<input type="text"/>	second [s]	-1	-

Output Format: XML

ASCII:  $m*s^{-1}$

Unit ID: NISTu1.u3e-1/1

# UnitsDB Search: Screen Captures

## Root Units

Select from  
enumerated list

**Output Format:**  
XML / HTML

The screenshot displays the 'UnitsML Database Search' interface. At the top, there are four tabs: 'Units/Quantities/Prefixes', 'Unit Builder', 'Root Units' (which is selected), and 'NIST ID'. Below the tabs, the heading 'Select Enumerated Root Units' is visible. A blue bar indicates '4 selected' units. A search filter is present with the text 'Enter keywords'. To the right of the filter are buttons for 'Check all' and 'Uncheck all'. A list of units is shown with checkboxes: 'light\_year' (unchecked), 'liter' (checked), 'long\_ton' (unchecked), 'lumen' (unchecked), 'lux' (checked), 'maxwell' (unchecked), 'mean\_btu' (unchecked), 'meter' (checked), 'metric\_horsepower' (unchecked), 'metric\_ton' (unchecked), 'mile' (checked), 'minute' (unchecked), and 'mm\_Hg' (unchecked). A 'Submit' button is located to the right of the list. On the far right, a box titled 'Selected Units:' contains a bulleted list of the four selected units: 'liter', 'lux', 'meter', and 'mile'.

# Usage of UnitsML & UnitsDB

# Usage of UnitsML & UnitsDB

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- Methods of using UnitsML & UnitsDB with other markup languages
  - Incorporating part or all of the UnitsML schema:
    - Reference a unique unit ID
    - Refer to the UnitsML schema
    - `<include>` the UnitsML schema
    - `<import>` the UnitsML schema
    - `<redefine>` the UnitsML schema

# Reference a Unique Unit ID

## 'Simple' language instance document

```
<?xml version="1.0" encoding="UTF-8"?>
<SimpleSchemaRoot xsi:noNamespaceSchemaLocation="SimpleSchema0.xsd"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <Text>The width of the room is: </Text>
  <Measurement>
    <NumericValue>3.14159</NumericValue>
  </Measurement>
  <Text>meters. The width has been obtained by ...</Text>
</SimpleSchemaRoot>
```

## Sample instance document: referencing a unique ID

```
<?xml version="1.0" encoding="UTF-8"?>
<SimpleSchemaRoot xsi:noNamespaceSchemaLocation="SimpleSchema1.xsd"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <Text>The width of the room is: </Text>
  <Measurement unit="http://authorative.source/Units#u1">
    <NumericValue>3.14159</NumericValue>
  </Measurement>
  <Text>. The width has been obtained by ...</Text>
</SimpleSchemaRoot>
```

# Refer to the UnitsML Schema

## Sample instance document: referring to UnitsML

```
<?xml version="1.0" encoding="UTF-8"?>
<simple:SimpleSchemaRoot
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:simple="http://unitsml.nist.gov/simple"
  xmlns:unitsml="urn:oasis:names:tc:unitsml:schema:xsd:UnitsMLSchema"
  xsi:schemaLocation="http://unitsml.nist.gov/simple SimpleSchema2.x
  urn:oasis:names:tc:unitsml:schema:xsd:UnitsMLSchema-1.0 UnitsML-1.
  <simple:Text>The width of the room is: </simple:Text>
  <simple:Measurement>
    <simple:NumericValue>3.14159</simple:NumericValue>
    <unitsml:Unit xml:id="u42">
      <unitsml:UnitName xml:lang="en-US">meter</unitsml:UnitName>
      <unitsml:UnitSymbol type="ASCII">m</unitsml:UnitSymbol>
    </unitsml:Unit>
  </simple:Measurement>
  <simple:Text>. The width has been obtained by ...</simple:Text>
</simple:SimpleSchemaRoot>
```

Uses `<xsd: any>` in the simple schema.

The value of `@xml:id` must be unique within a document.

# Combination of Reference & Refer

Sample instance document: referencing a local units database

```
<?xml version="1.0" encoding="UTF-8"?>
<SimpleSchemaRoot
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
  xmlns:unitsml="urn:oasis:names:tc:unitsml:schema:xsd:UnitsMLSchemas
  xsi:schemaLocation="urn:oasis:names:tc:unitsml:schema:xsd:UnitsMLS
    unitsmlSchema-1.0.xsd"
  xsi:noNamespaceSchemaLocation="SimpleSchema6.xsd">
  <Text>The width of the room is: </Text>
  <Measurement unit="#u42">
    <NumericValue>3.14159</NumericValue>
  </Measurement>
  <Text>. The width has been obtained by ...</Text>
  <unitsml:Unit xml:id="u42">
    <unitsml:UnitName xml:lang="en-US">meter</unitsml:UnitName>
    <unitsml:UnitSymbol type="ASCII">m</unitsml:UnitSymbol>
  </unitsml:Unit>
</SimpleSchemaRoot>
```

Uses `<xsd: any>` in the simple schema.

# <import> the UnitsML Schema

Sample instance document: importing UnitsML

```
<?xml version="1.0" encoding="UTF-8"?>
<simple:SimpleSchemaRoot
  xsi:schemaLocation="http://unitsml.nist.gov/simple SimpleSchema7.x
  xmlns:simple="http://unitsml.nist.gov/simple"
  xmlns:unitsml="urn:oasis:names:tc:unitsml:schema:xsd:UnitsMLSchema
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <simple:Text>The width of the room is: </simple:Text>
  <simple:Measurement unit="#u42">
    <simple:NumericValue>3.14159</simple:NumericValue>
  </simple:Measurement>
  <simple:Text>. The width has been obtained by ...</simple:Text>
  <unitsml:UnitSet>
    <unitsml:Unit xml:id="u42">
      <unitsml:UnitName xml:lang="en-US">meter</unitsml:UnitName>
      <unitsml:UnitSymbol type="ASCII">m</unitsml:UnitSymbol>
    </unitsml:Unit>
  </unitsml:UnitSet>
</simple:SimpleSchemaRoot>
```

Uses `<xsd: import>` in the simple schema.



# <include> the UnitsML Schema

Sample instance document: including UnitsML

```
<?xml version="1.0" encoding="UTF-8"?>
<SimpleSchemaRoot xsi:noNamespaceSchemaLocation="SimpleSchema3.xsd"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <Text>The width of the room is: </Text>
  <Measurement>
    <NumericValue>3.14159</NumericValue>
    <Unit xml:id="u42">
      <UnitName xml:lang="en-US">meter</UnitName>
      <UnitSymbol type="ASCII">m</UnitSymbol>
    </Unit>
  </Measurement>
  <Text>. The width has been obtained by ...</Text>
</SimpleSchemaRoot>
```

Uses `<xsd: include>` in the simple schema.

The UnitsML schema must be modified to have either no namespace or that of the simple schema.

# <redefine> the UnitsML Schema

Sample instance document: redefining UnitsML

```
<?xml version="1.0" encoding="UTF-8"?>
<SimpleSchemaRoot xsi:noNamespaceSchemaLocation="SimpleSchema5.xsd"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
  <Text>The width of the room is: </Text>
  <Measurement>
    <NumericValue>3.14159</NumericValue>
    <Unit xml:id="u42">
      <UnitName xml:lang="en-US">meter</UnitName>
      <UnitSymbol type="ASCII">m</UnitSymbol>
      <MyText>This is sample text in an added element.</MyText>
    </Unit>
  </Measurement>
  <Text>. The width has been obtained by ...</Text>
</SimpleSchemaRoot>
```

Uses **<xsd: redefine>** in the simple schema.

The UnitsML schema must be modified to have either no namespace or that of the simple schema.

In addition, the UnitsML schema can be extended.

# Usage of UnitsML & UnitsDB

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- We are working with members from other Markup Languages to implement using UnitsML
  - AnIML – Analytical Information Markup Language
  - MatML – Materials Property Data Markup Language
  - AMDML – Atomic and Molecular Data Markup Language

# Resources

For the most recent UnitsML schema, documentation with images, and *Guidelines for the Use of UnitsML*:  
<http://unitsml.nist.gov>

For information about SI units and non-SI units for the U.S: <http://physics.nist.gov/sp811>

Thank you for your attention.

Questions/Comments?