
3MF Boolean Operations Extension

Specification & Reference Guide

Version **0.8.0**

Status Draft

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Preface

About this Specification

This 3MF Boolean Operations Extension is an extension to the core 3MF specification. This document cannot stand alone and only applies as an addendum to the core 3MF specification. Usage of this and any other 3MF extensions follow an a la carte model, defined in the core 3MF specification.

Part I, "3MF Documents," presents the details of the primarily XML-based 3MF Document format. This section describes the XML markup that defines the composition of 3D documents and the appearance of each model within the document.

Part II, "Appendices," contains additional technical details and schemas too extensive to include in the main body of the text as well as convenient reference information.

The information contained in this specification is subject to change. Every effort has been made to ensure its accuracy at the time of publication.

This extension **MUST** be used only with Core specification 1.x.

Document Conventions

See [the 3MF Core Specification conventions](#).

In this extension specification, as an example, the prefix "bo" maps to the xml-namespace "http://schemas.microsoft.com/3dmanufacturing/booleanoperations/2023/06". See [Appendix C. Standard Namespace](#).

Language Notes

See [the 3MF Core Specification language notes](#).

Software Conformance

See [the 3MF Core Specification software conformance](#).

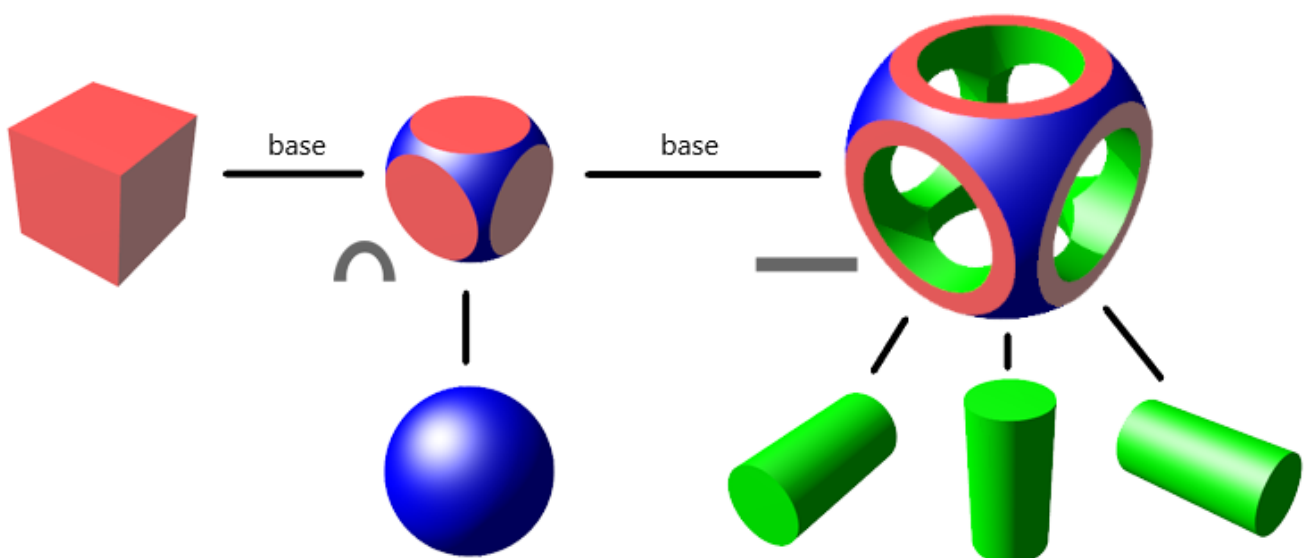
Part I: 3MF Documents

Chapter 1. Overview of Additions

The 3MF Core Specification defines the <components> element in the <object> resource as definition of a tree of different objects to form an assembly, with the intent to allow the reuse of model definitions for an efficient encoding. The resultant shape of a <components> element is the aggregation of each <component> object element.

This extension defines how to combine different objects into a single object. It is based in Constructive Solid Geometry (CSG).

However, to limit complexity in the consumer, this spec reduces the GCG scope to an ordered sequence of boolean operations (left to right in diagram below).

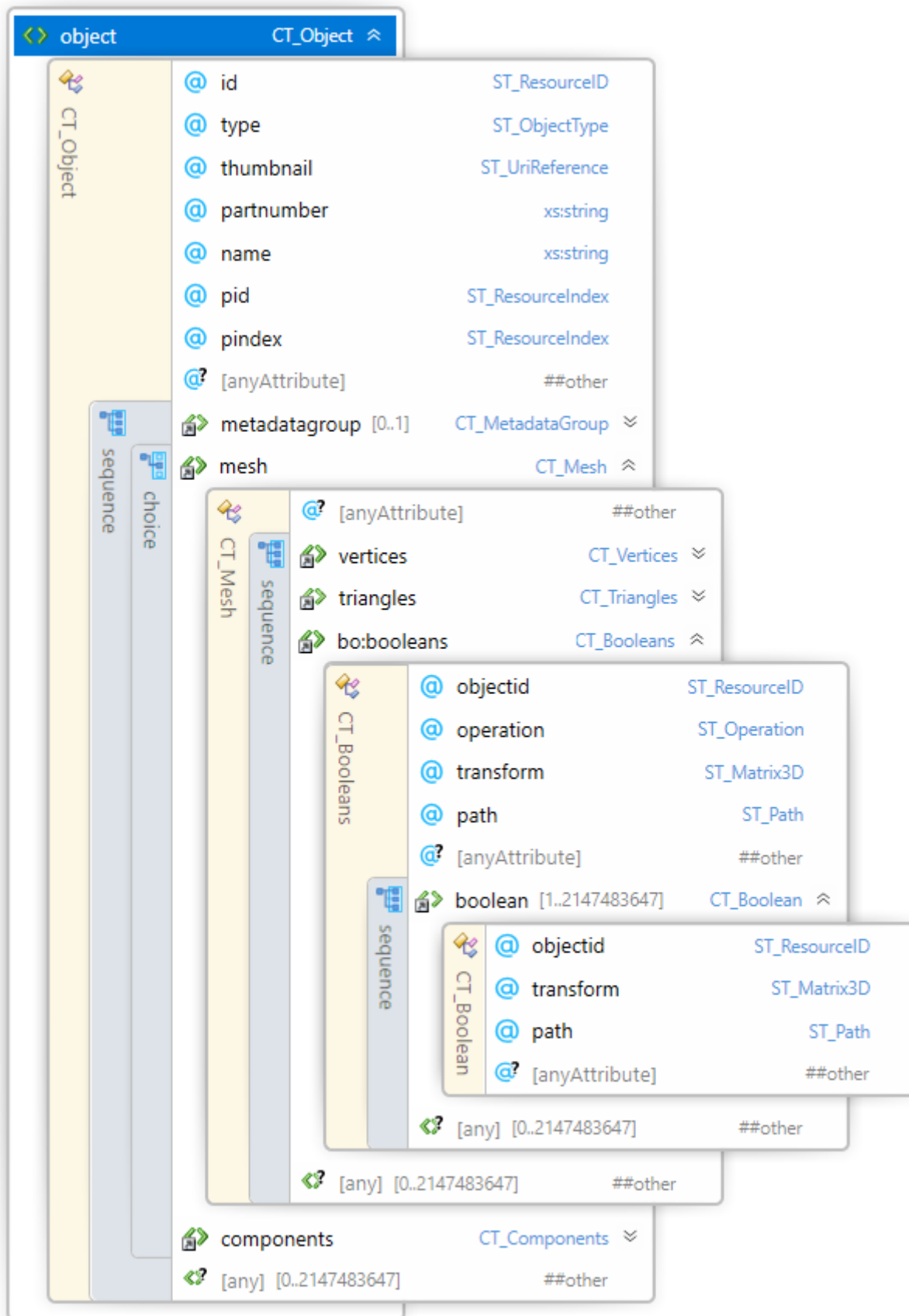


This document describes a new element `<booleans>` in the `<mesh>` elements that specifies a new mesh element type, other than triangle mesh. This element is OPTIONAL for producers but MUST be supported by consumers that specify support for the 3MF Boolean Operations Extension.

The `<booleans>` element defines a sequence of boolean operations to the referenced meshes.

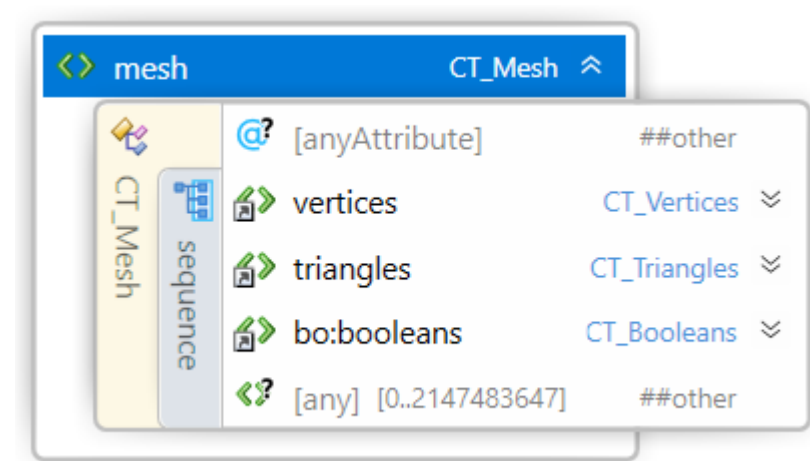
This is a non-backwards compatible change since it declares a different content of the mesh element, with empty vertices and triangles. Therefore, a 3MF package which uses "booleans" meshes MUST enlist the 3MF Boolean Operations Extension as "required extension", as defined in the core specification.

Figure 1-1: Overview of 3MF Boolean Operations Extension XML structure



Chapter 2. Booleans mesh

Element <mesh>

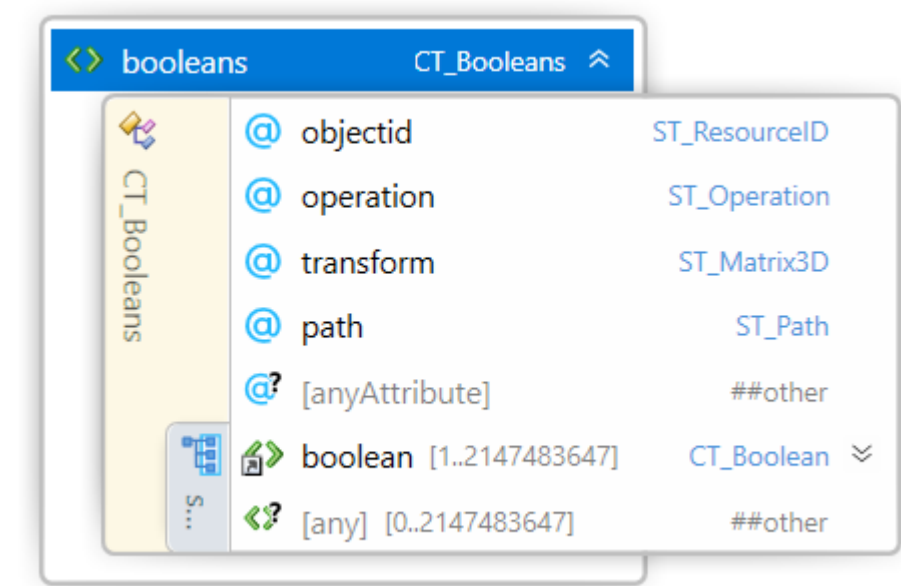


The <mesh> element, defined in [the 3MF Core Specification meshes](#), is enhanced with an optional <booleans> element. When specified, the shape of the object is exclusively defined by a "boolean operation", instead of of being defined by the triangle mesh in the core specification or other 3MF extensions.

The <vertices> and the <triangle> elements MUST be empty, overriding the core spec definition, and MUST NOT contain any shape defined by any other 3MF extension.

2.1. Booleans

Element <booleans>



Name	Type	Use	Default	Annotation
objectid	ST_ResourceID	required		It references the base object id to apply the boolean operation.
operation	ST_Operation		union	The boolean operation: union, difference and intersection.
transform	ST_Matrix3D			A matrix transform (see 3.3. 3D Matrices) applied to the item to be outputted.

Name	Type	Use	Default	Annotation
path	ST_Path			A file path to the base object file being referenced. The path is an absolute path from the root of the 3MF container.

@anyAttribute

The optional <booleans> element, contains one or more <boolean> elements to perform an ordered sequence of boolean operation onto the referenced base object.

objectid - Selects the base object to apply the boolean operation. The object MUST be a mesh object of type "model". It MUST NOT reference a components object.

operation - The boolean operation to perform. The options for the boolean operations are the following:

1. *union*. The resulting object shape is defined as the merger of the shapes. The resulting object surface property is defined by the property of the surface property defining the outer surface, as defined by [the 3MF Core Specification overlapping order](#)

$$\text{union}(\text{base}, a, b, c) = \text{base} \cup (a \cup b \cup c) = ((\text{base} \cup a) \cup b) \cup c$$

2. *difference*. The resulting object shape is defined by the shape in the base object shape that is not in any other object shape. The resulting object surface property, where overlaps, is defined by the object surface property of the subtracting object(s), or no-property is the subtracting object has no property defined in that surface.

$$\text{difference}(\text{base}, a, b, c) = \text{base} - (a \cup b \cup c) = ((\text{base} - a) - b) - c$$

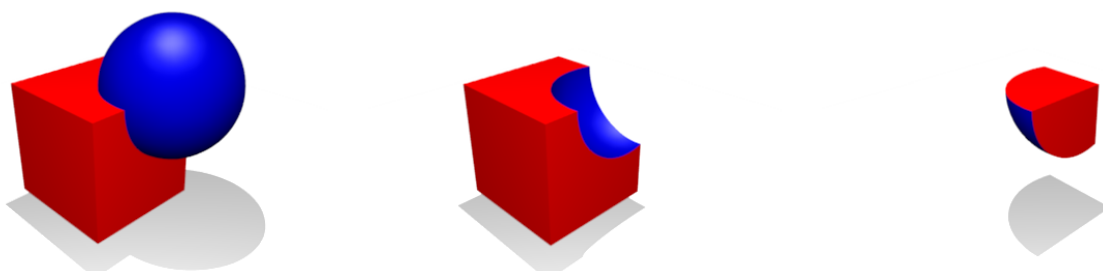
3. *intersection*. The resulting object shape is defined as the common (clipping) shape in all objects. The resulting object surface property is defined as the object surface property of the object defining the new surface, or no-property when that object has no property defined in the new surface.

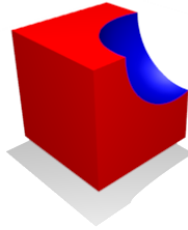
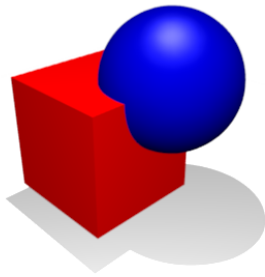
$$\text{intersection}(\text{base}, a, b, c) = \text{base} \cap (a \cup b \cup c) = ((\text{base} \cap a) \cap b) \cap c$$

transform - The transform to apply to the selected base object.

path - When used in conjunction with [the 3MF Production extension](#), the "path" attribute references objects in non-root model files. Path is an absolute path to the target model file inside the 3MF container that contains the target object. The use of the path attribute in a <booleans> element is ONLY valid in the root model file.

The following diagrams, from the **CSG** Wikipedia, show the three operations:





union: Merger of two objects into one

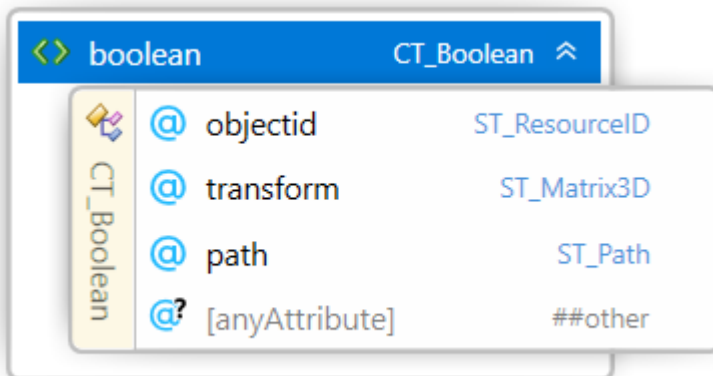
difference: Subtraction of object from another one

intersection: Portion common to objects

Similarly as defined in [the 3MF Core Specification object resources](#), consumers MUST ignore the object type of objects containing a "booleans" mesh, since the type is always overridden by descendant objects. Producers MUST NOT assign pid or pindex attributes to objects that contain a "booleans" mesh. This ensures that an object with no material will not be split into two representations with different materials due to being referenced as a boolean in multiple objects.

2.1.1. Boolean

Element <boolean>



Name	Type	Use	Default	Annotation
objectid	ST_ResourceID	required		It references the object id to perform the boolean operation.
transform	ST_Matrix3D			A matrix transform (see 3.3. 3D Matrices) applied to the item to be outputted.
path	ST_Path			A file path to the model file being referenced. The path is an absolute path from the root of the 3MF container.

@anyAttribute

The <boolean> element selects a pre-defined object resource to perform a boolean operation to the base object referenced in the enclosing <booleans> element. The boolean operation is applied in the sequence order of the <boolean> element.

objectid - Selects the object with the mesh to apply the boolean operation. The object MUST be only a triangle mesh object of type "model".

transform - The transform to apply to the selected object before the boolean operation.

path - When used in conjunction with [the 3MF Production extension](#), the "path" attribute references objects in non-root model files. Path is an absolute path to the target model file inside the 3MF container that contains the target object. The use of the path attribute in a <boolean> element is ONLY valid in the root model file.

The boolean operations are sequentially applied in the order defined by the <boolean> sequence, and they follow the fill rule conversion defined by [the 3MF Core Specification fill rule](#).

Part II. Appendices

Appendix A. Glossary

See [the 3MF Core Specification glossary](#).

Appendix B. 3MF XSD Schema

```
<?xml version="1.0" encoding="UTF-8"?>
<xs:schema
  xmlns="http://schemas.microsoft.com/3dmanufacturing/booleanoperations/2023/06"
  xmlns:xs="http://www.w3.org/2001/XMLSchema"

  targetNamespace="http://schemas.microsoft.com/3dmanufacturing/booleanoperations/20
23/06"
  elementFormDefault="unqualified" attributeFormDefault="unqualified"
  blockDefault="#all">
  <xs:import namespace="http://www.w3.org/XML/1998/namespace"
    schemaLocation="http://www.w3.org/2001/xml.xsd"/>
  <xs:annotation>
    <xs:documentation><![CDATA[ Schema notes:

    Items within this schema follow a simple naming convention of appending a prefix
    indicating the type of element for references:

    Unprefixed: Element names
    CT_: Complex types
    ST_: Simple types

  ]]></xs:documentation>
  </xs:annotation>
  <!-- Complex Types -->
  <xs:complexType name="CT_Mesh">
    <xs:sequence>
      <xs:element ref="booleans"/>
      <xs:any namespace="##other" processContents="lax" minOccurs="0"
maxOccurs="2147483647"/>

```



```

    </xs:sequence>
  </xs:complexType>

  <xs:complexType name="CT_Booleans">
    <xs:sequence>
      <xs:element ref="boolean" maxOccurs="2147483647"/>
      <xs:any namespace="##other" processContents="lax" minOccurs="0"
maxOccurs="2147483647"/>
    </xs:sequence>
    <xs:attribute name="objectid" type="ST_ResourceID" use="required"/>
    <xs:attribute name="operation" type="ST_Operation" default="union"/>
    <xs:attribute name="transform" type="ST_Matrix3D"/>
    <xs:attribute name="path" type="ST_Path"/>
    <xs:anyAttribute namespace="##other" processContents="lax"/>
  </xs:complexType>

  <xs:complexType name="CT_Boolean">
    <xs:attribute name="objectid" type="ST_ResourceID" use="required"/>
    <xs:attribute name="transform" type="ST_Matrix3D"/>
    <xs:attribute name="path" type="ST_Path"/>
    <xs:anyAttribute namespace="##other" processContents="lax"/>
  </xs:complexType>

  <!-- Simple Types -->
  <xs:simpleType name="ST_Operation">
    <xs:restriction base="xs:string">
      <xs:enumeration value="union"/>
      <xs:enumeration value="difference"/>
      <xs:enumeration value="intersection"/>
    </xs:restriction>
  </xs:simpleType>

  <xs:simpleType name="ST_Matrix3D">
    <xs:restriction base="xs:string">
      <xs:whiteSpace value="collapse"/>
      <xs:pattern value="((\\-|\\+)?((\\[0-9]+(\\.\\[0-9]+)?)|(\\.\\[0-9]+))((e|E)(\\-|\\+)?
[0-9]+)?)((\\-|\\+)?((\\[0-9]+(\\.\\[0-9]+)?)|(\\.\\[0-9]+))((e|E)(\\-|\\+)?[0-9]+)?)((\\-|\\+)?((\\[0-9]+(\\.\\[0-9]+)?)|(\\.\\[0-9]+))((e|E)(\\-|\\+)?[0-9]+)?)|((\\[0-9]+(\\.\\[0-9]+)?)|(\\.\\[0-9]+))((e|E)(\\-|\\+)?[0-9]+)?)((\\-|\\+)?((\\[0-9]+(\\.\\[0-9]+)?)|(\\.\\[0-9]+))((e|E)(\\-|\\+)?[0-9]+)?)((\\-|\\+)?((\\[0-9]+(\\.\\[0-9]+)?)|(\\.\\[0-9]+))((e|E)(\\-|\\+)?[0-9]+)?)|((\\[0-9]+(\\.\\[0-9]+)?)|(\\.\\[0-9]+))((e|E)(\\-|\\+)?[0-9]+)?)((\\-|\\+)?((\\[0-9]+(\\.\\[0-9]+)?)|(\\.\\[0-9]+))((e|E)(\\-|\\+)?[0-9]+)?)((\\-|\\+)?((\\[0-9]+(\\.\\[0-9]+)?)|(\\.\\[0-9]+))((e|E)(\\-|\\+)?[0-9]+)?)|((\\[0-9]+(\\.\\[0-9]+)?)|(\\.\\[0-9]+))((e|E)(\\-|\\+)?[0-9]+)?)((\\-|\\+)?((\\[0-9]+(\\.\\[0-9]+)?)|(\\.\\[0-9]+))((e|E)(\\-|\\+)?[0-9]+)?)((\\-|\\+)?((\\[0-9]+(\\.\\[0-9]+)?)|(\\.\\[0-9]+))((e|E)(\\-|\\+)?[0-9]+)?)|((\\[0-9]+(\\.\\[0-9]+)?)|(\\.\\[0-9]+))((e|E)(\\-|\\+)?[0-9]+)?)" />
    </xs:restriction>
  </xs:simpleType>

  <xs:simpleType name="ST_ResourceID">
    <xs:restriction base="xs:positiveInteger">
      <xs:maxExclusive value="2147483648"/>
    </xs:restriction>
  </xs:simpleType>

```

```

<xs:simpleType name="ST_Path">
  <xs:restriction base="xs:string"> </xs:restriction>
</xs:simpleType>

<!-- Elements -->
<xs:element name="booleans" type="CT_Booleans"/>
<xs:element name="boolean" type="CT_Boolean"/>
</xs:schema>

```

Appendix C. Standard Namespace

BooleanOperation <http://schemas.microsoft.com/3dmanufacturing/booleanoperations/2023/06>

Appendix D: Example file

3D model

```

<?xml version="1.0" encoding="utf-8" standalone="no"?>
<model xmlns="http://schemas.microsoft.com/3dmanufacturing/core/2015/02"
  xmlns:bo="http://schemas.microsoft.com/3dmanufacturing/booleanoperations/2023/
06"
  requiredextensions="bo" unit="millimeter" xml:lang="en-US">
  <resources>
    <basematerials id="2">
      <base name="Red" displaycolor="#FF0000" />
      <base name="Green" displaycolor="#00FF00" />
      <base name="Blue" displaycolor="#0000FF" />
    </basematerials>
    <object id="3" type="model" name="Cube" pid="2" pindex="0">
      <mesh>
        <vertices>...</vertices>
        <triangles>...</triangles>
      </mesh>
    </object>
    <object id="4" type="model" name="Sphere" pid="2" pindex="2">
      <mesh>
        <vertices>...</vertices>
        <triangles>...</triangles>
      </mesh>
    </object>
    <object id="5" type="model" name="Cylinder" pid="2" pindex="1">
      <mesh>
        <vertices>...</vertices>
        <triangles>...</triangles>
      </mesh>
    </object>
    <object id="6" type="model" name="Intersected">

```

```

    <mesh>
      <vertices/>
      <triangles/>
      <bo:booleans objectid="3" operation="intersection" transform="0.0741111
0 0 0 0.0741111 0 0 0 0.0741111 2.91124 -0.400453 1.60607">
        <bo:boolean objectid="4" transform="0.0741111 0 0 0 0.0741111 0 0 0
0.0741111 2.91124 -0.400453 1.60607"/>
      </bo:booleans>
    </mesh>
  </object>
  <object id="10" type="model" name="Full part">
    <mesh>
      <vertices/>
      <triangles/>
      <bo:booleans objectid="6" operation="difference">
        <bo:boolean objectid="5" transform="0.0271726 0 0 0 0.0271726 0
-0.0680034 0 4.15442 3.58836 5.23705" />
        <bo:boolean objectid="5" transform="0.0272014 0 0 0 0.0272012 0 0 0
0.0680035 4.05357 6.33412 3.71548" />
        <bo:boolean objectid="5" transform="0 0 -0.0272013 0 0.0272013 0
0.0680032 0 0 5.05103 6.32914 3.35287" />
      </bo:booleans>
    </mesh>
  </object>
  <object id="10" type="model" name="Full part">
    <mesh>
      <vertices/>
      <triangles/>
      <bo:booleans objectid="10" operation="difference">
        <bo:boolean objectid="5" transform="0.0271726 0 0 0 0.0271726 0
-0.0680034 0 4.15442 3.58836 5.23705" />
        <bo:boolean objectid="5" transform="0.0272014 0 0 0 0.0272012 0 0 0
0.0680035 4.05357 6.33412 3.71548" />
        <bo:boolean objectid="5" transform="0 0 -0.0272013 0 0.0272013 0
0.0680032 0 0 5.05103 6.32914 3.35287" />
      </bo:booleans>
    </mesh>
  </object>
</resources>
<build>
  <item objectid="10" transform="25.4 0 0 0 25.4 0 0 0 25.4 0 0 0" />
</build>
</model>

```

References

CSG Wikipedia, the free encyclopedia: [Constructive solid geometry](#)

See the [3MF Core Specification references](#) for additional references.