Recommended Practices

for

Supplemental Geometry

Release 1.3

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Document History

Revision	Date	Change
1.0	2010-11-01	Public Release of Version 1.0
1.1	2019-08-23	General update for AP242 Added sections on Presentation (5.5) and Properties (5.6)
1.2	2021-07-09	Added section 5.4 on Supplemental Geometry Subsets
1.3	2025-08-01	Added section on Tessellated Supplemental Geometry

1   Introduction

When designing a part in a CAD system, geometrical elements are often created that do not be-long to the actual, i.e. manufactured, shape of the part or assembly, but are used to either create other geometric shapes, or to carry additional information about the part or assembly.

Depending on the application context and the CAD system used, there are many terms for these elements, such as:

- supplemental geometry
- construction (constructive) geometry
- auxiliary geometry
- design geometry
- support geometry
- cosmetics
- reference geometry

It has been agreed to use the term "supplemental geometry" to relate to this capability. It is less ambiguous than the initially used "construction geometry" and is also the term defined by international standards such as ASME Y14.41 and ISO 16792.


Definition of the term "supplemental geometry" according to ASME Y14.41:

"Geometric elements included in product definition data to communicate design requirements but not intended to represent a portion of the manufactured product."

Supplemental Geometry elements typically are faces (e.g. cutting planes), curves (e.g. center lines) and points and coordinate system (e.g. tool targets). CAD systems may handle these in different ways, i.e. bound or unbound.

The main business needs for this capability today are:

- The transfer of supplemental geometry elements that can be referred to by product manufacturing information (PMI), such as Geometric Dimensions & Tolerances (GD&T).
- The transfer of named axis placements as tool targets for downstream processes, such as NC programming, and coordinate measuring.
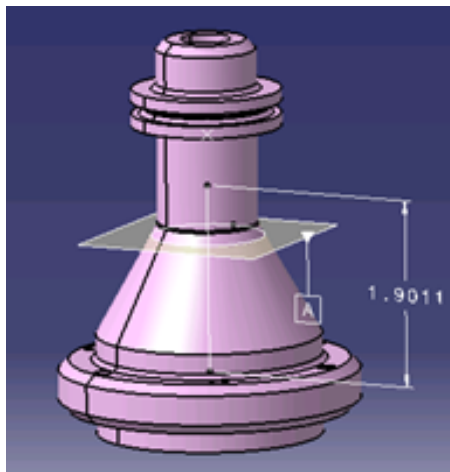
Figure 1: A reference plane for a Datum as example for Supplemental Geometry

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2 Scope

The following are within scope of this document:

- Transfer of geometric elements that are clearly identified as not being part of the man-ufactured shape of the part, including

  o bound and unbound faces and curves

  o cartesian points

  o axis placements

  o closed and open shells

  o wireframe models

  o tessellated geometry

The following are outside of the scope of this document:

- Definition of any properties attached to the supplemental geometry elements beyond the element name

- Styling and presentation of supplemental geometry

3 Document Identification

For validation purposes, STEP processors shall state which Recommended Practice document and version have been used in the creation of the STEP file. This will not only indicate what information a consumer or target system can expect to find in the file, but even more important where to find it in the file.

This shall be done by adding a pre-defined ID string to the `description` attribute of the `file_description` entity in the STEP file header, which is a list of strings. The ID string consists of four values delimitated by a triple dash ('---'). The values are:

```
Document Type---Document Name---Document Version---Publication Date
```

The string corresponding to this version of this document is:

> **CAx-IF Rec.Pracs.---Supplemental Geometry---1.3---2025-08-01**

It will appear in a STEP file as follows:

```
FILE_DESCRIPTION(('...','CAx-IF Rec.Pracs.---Supplemental Geometry---1.3---
2025-08-01'),'2;1');
```

4 Fundamental Concepts

The subtype of `shape_representation` used to gather supplemental geometry elements (`constructive_shape_representation`) has been available since AP214 and AP203e2. It limits the types of allowed geometry elements and carries by itself the information that all enclosed elements are of a supplemental nature.

The following types of geometric element are allowed as the items of a `constructive_-geometry_representation`:

- `placement`
- `curve`
- `edge`
- `face`
- `surface`
- `point`
- `vertex_point`
- `connected_face_set` *
- `connected_edge_set` *

* = new in AP242 Edition 2

Two additions were made with AP242 Edition 2 to allow the definition of wireframe models (e.g. for symbolic threads) as well as closed and open shells as supplemental geometry. The latter enables combining the two halves of a cylinder into a single referable object.

AP242 Edition 4 adds the subtype `tessellated_constructive_geometry_representation` to the data model, which allows the use of tessellated geometry as supplemental geometry. It is defined as a subtype of `tessellated_shape_representation` and allows the use of the following tessellated geometry elements:

- `placement`
- `tessellated_curve_set`
- `tessellated_edge`
- `tessellated_face`
- `tessellated_surface_set`
- `tessellated_vertex`

Unless otherwise noted, the concepts described for Supplemental Geometry in this document apply to exact geometry and tessellated geometry in the same way, by using the respective subtypes of `shape_representation`.

There can be more than one set of supplemental geometry elements, i.e. several instances of `(tessellated_)constructive_shape_representation` in a STEP file. This approach is recommended for the organization of supplemental geometry created to support PMI elements (e.g. to indicate a restricted area). See sections 5.4 and 5.5 below for details.

Acronyms

For better readability, the following acronyms will be used throughout the document:

- CGR = `constructive_geometry_representation`
- TCGR = `tessellated_constructive_geometry_representation`

5 Supplemental Geometry

The basic idea behind the definition of supplemental geometry is to handle it not as a portion of the part shape, but as a separate "shape", which is intended to provide additional information related to the part shape.

The definition of the supplemental geometry itself follows the usual pattern, with the notable difference that unbound geometric elements (such as an infinite planes) are allowed.

5.1 Linking the Supplemental Geometry to the file structure

The diagram given in Figure 2 below describes the structure to define supplemental geometry in relation to the actual part shape.
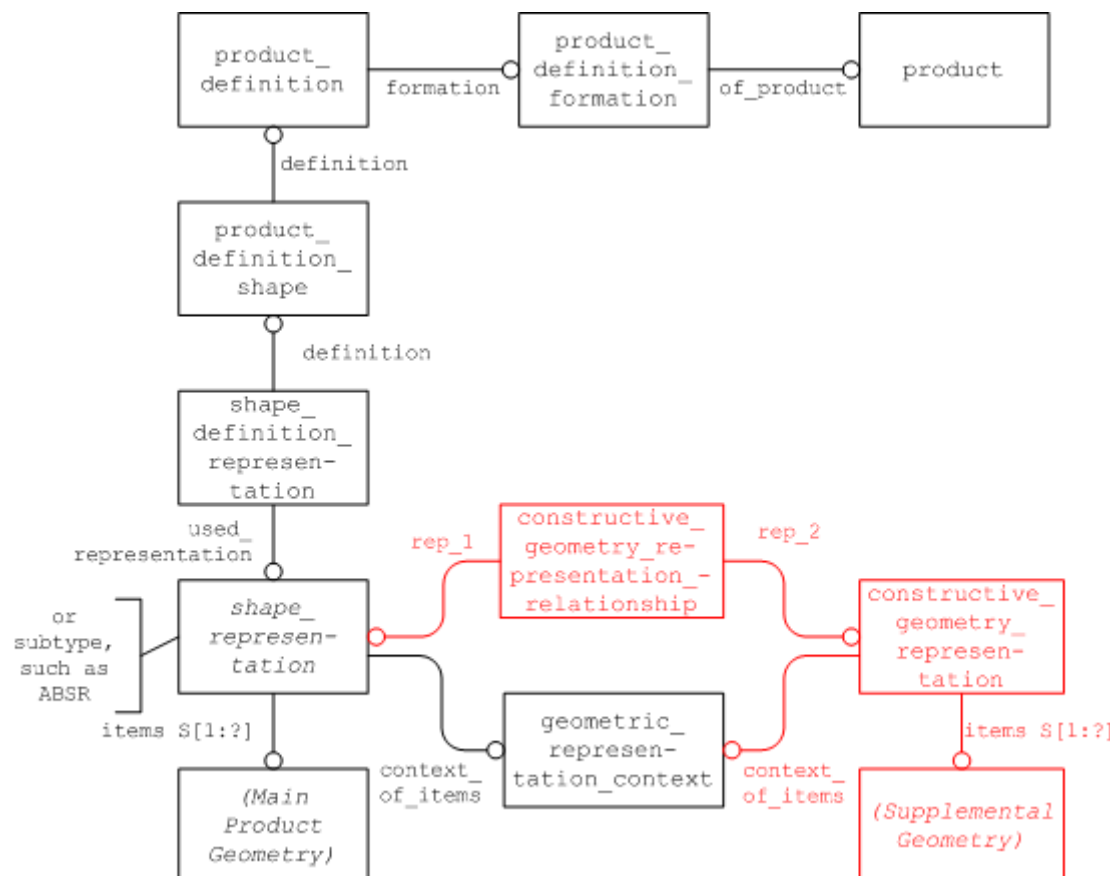

Figure 2: Supplemental Geometry related to the Part Shape

Part 21 Example:

```
#28=(GEOMETRIC_REPRESENTATION_CONTEXT(3)GLOBAL_UNCERTAINTY_ASSIGNED_CONTEXT
((#26))GLOBAL_UNIT_ASSIGNED_CONTEXT((#16,#20,#24))REPRESENTATION_CONTEXT(''
,'3D'));
#32=PRODUCT('sg1','','None',(#31));
#34=PRODUCT_DEFINITION_FORMATION('','None',#32);
#36=PRODUCT_DEFINITION('None','None',#34,#35);
#37=PRODUCT_DEFINITION_SHAPE('None','None',#36);
#38=ADVANCED_BREP_SHAPE_REPRESENTATION('',(#492),#28);
#39=SHAPE_DEFINITION_REPRESENTATION(#37,#38);
#564=CONSTRUCTIVE_GEOMETRY_REPRESENTATION('coordinate
systems',(#494,#498,#502,#506),#28);
#565=CONSTRUCTIVE_GEOMETRY_REPRESENTATION_RELATIONSHIP('coordinate
systems',$,#38,#564);
```

The specific subtype of `shape_representation` used to collect the supplemental geometry elements, `constructive_geometry_representation`, is characterized as follows:

"A `constructive_geometry_representation` is a type of `representation` that is a collection of non-shape geometry that is used to support the definition of the geometry that is representing the shape of the part."

The associated rules require that it shares the same geometric context as the shape of the part, and it needs to be related to the part's `shape_representation` via a `constructive_geometry_representation_relationship`.

Similarly, a `tessellated_constructive_geometry_representation` is a type of `tessellated_shape_representation` that contains a collection of geometric elements used to support the definition of a geometric model.

Each `TCGR` shall be associated with at least a `shape_representation` for the part shape, or another `TCGR`, through an instance of `tessellated_constructive_geometry_-representation_relationship`.

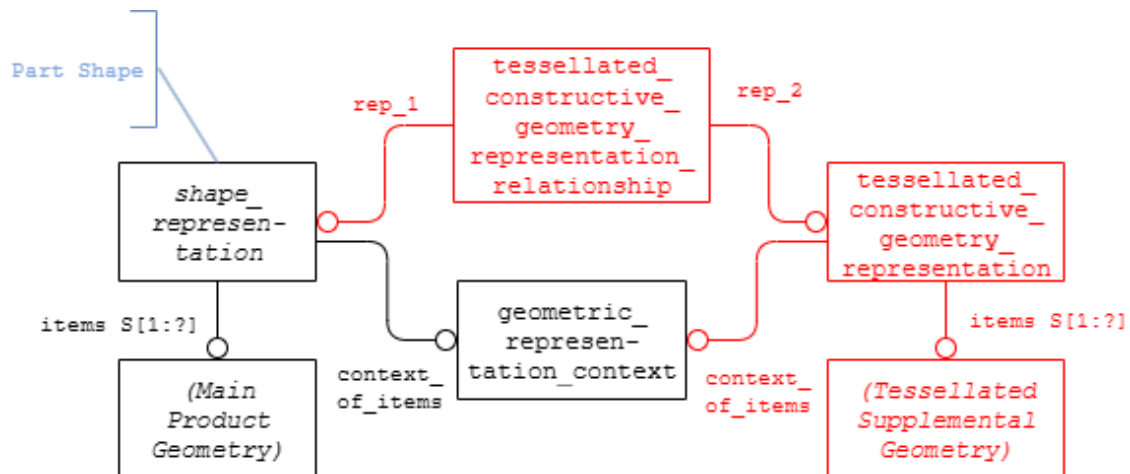Figure 3 shows that this follows the exact same implementation structure as for exact supplemental geometry:

Figure 3: Tessellated Supplemental Geometry

5.2   Definition of exact Supplemental Geometry

The supplemental geometry is defined in the same way as the usual geometry defining the manufactured part shape. All elements are collected in the set of items of the `constructive_geometry_representation` and shall be of type `placement`, `curve`, `edge`, `face`, `point`, `surface`, `face_surface` or `vertex_point`.

AP242 Edition 2 extends this list with `connected_edge_set`, `connected_edge_sub_set`, `connected_face_set`, and `conneceted_face_sub_set`.

Depending on how the supplemental geometry is internally defined in the exporting CAD system, there are two significantly different ways how the detailed definition may look:

Unbound Supplemental Elements

In some systems, e.g., Siemens NX, supplemental elements such as reference planes or center lines are defined as unbound elements, i.e., planes or lines with infinite extent. The corresponding STEP entities to be used are `plane` (defined by point and face normal) and `line` (defined by point and direction).

Bound Supplemental Elements

Other CAD systems, e.g., CATIA V5, define supplemental elements with a default, limited size. A reference plane for instance is displayed as a rectangle with given width and height. The transfer of this information requires the full topological definition with `plane`, `edge_curve`, `edge_loop` and `face_surface`.

Handling of Bound vs. Unbound Supplemental Elements

Each CAD system shall export the Supplemental Elements in the way that it treats them internally. This guarantees an unambiguous data exchange for similar systems. When importing supplemental geometry into a CAD system that handles those elements in a different way than the exporting system, the recommendations are as follows:

- When importing bound elements into a system that usually handles them unbound, it is straightforward to use the underlying, unbound base elements (e.g., the `plane` for a `face_surface`), and omit the boundary definitions.

- In the opposite case, it is recommended that the importing system automatically creates and adds boundaries in a default size (e.g., dynamically derived from the model dimensions), which can later be adopted by the user, should a smaller or larger extent be desired.

- If these supplemental elements have a specific name, it shall be applied to the basic, unbound elements (i.e., `plane` or `line`) to guarantee it can be found by the importing system.

In addition to the geometric definition, supplemental geometry is also handled differently from a model structure point of view. Some CAD systems have designated containers or structural nodes where these elements are linked, other handled thus by assigning the supplemental elements to specific layers.

It was agreed that even while STEP supports layers (see Recommended Practices for Model Styling and Organization), these shall not be used to identify supplemental geometry, but the exporting system shall always map it to the structure defined in section 5.1 of this document.

Points and Axis Placements

Since points and axis placements by definition have no extent, they are always transferred in the same way, as elements in the set of items of the `constructive_geometry_representation` defining the supplemental geometry.

On import, axis placements shall be mapped to (empty) coordinate systems with the name as given in the STEP file by the target system (see Figure 4).
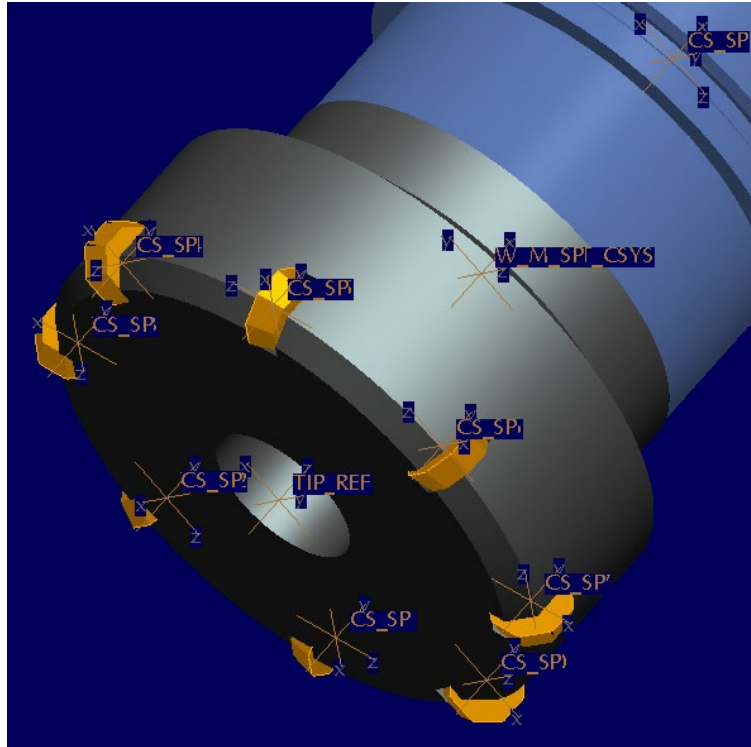
Figure 4: Axis placements as Supplemental Geometry defining tool targets

5.3 Definition of Tessellated Supplemental Geometry

Tessellated supplemental geometry is defined in the same way as tessellated geometry for other purposes. The `tessellated_constructive_element_select` type used for the set of items of the `TCGR` allows for the designation of the data types `placement`, `tessellated_curve_set`, `tessellated_edge`, `tessellated_face`, `tessellated_-surface_set`, and `tessellated_vertex`.

As there is no unbound tessellated geometry, the distinction made in section 5.2 above is not required here.

The same remarks concerning the mapping of axis placements to coordinate systems apply.

5.4   Linking PMI Data to Supplemental Geometry

One of the main usage scenarios for the transfer of supplemental geometry is that it is used as reference elements for PMI data, such as datums or dimensions.

This is also the main use case for tessellated supplemental geometry, as it can be used to illustrate restricted areas that certain PMI apply to. For this use case, the same implementation structure applies as shown below, with the use of `TCGR` and the appropriate relationship types instead of `CGR`.

The basic structure to define the PMI elements themselves and their linkage to the geometry stays the same as when defining PMI elements for the manufactured part shape, only the elements referenced by the `geometric_item_specific_usage` are now (tessellated) supplemental geometry elements, as show in Figure 5 below.
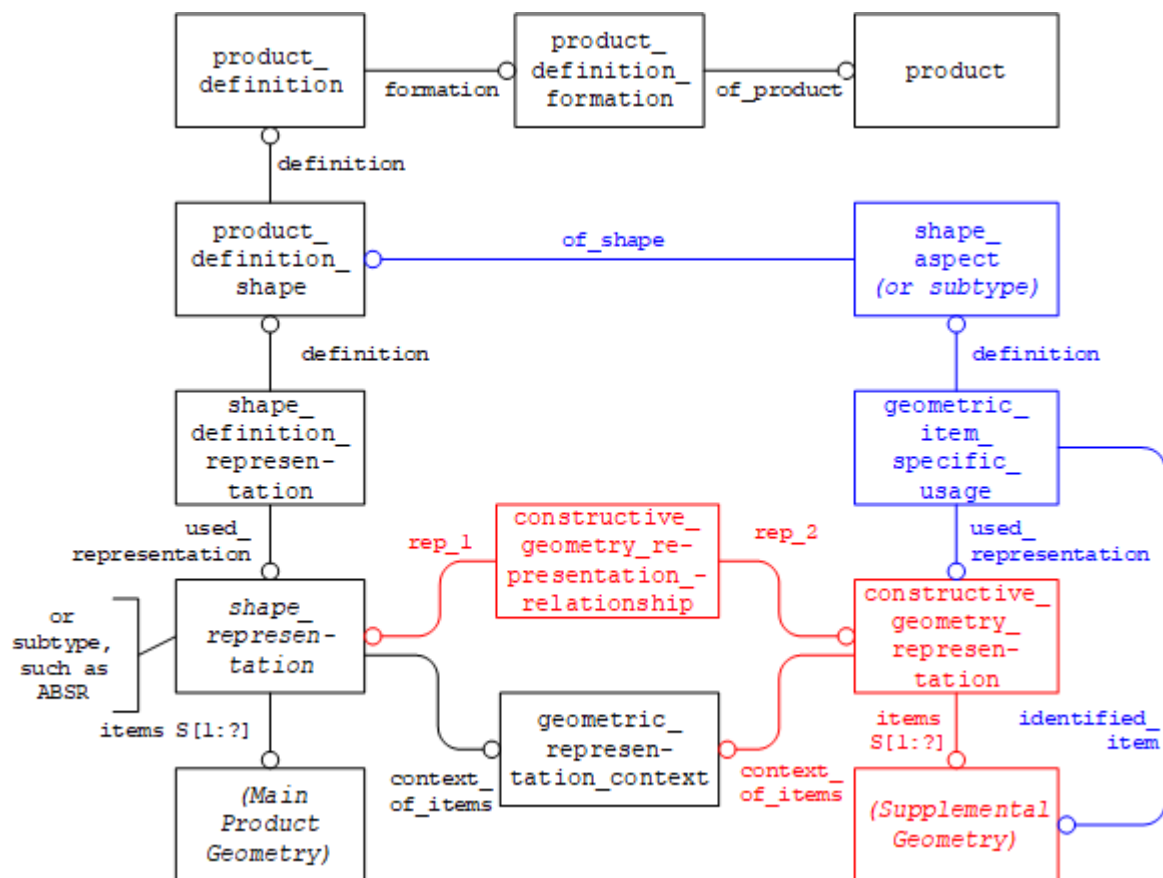

Figure 5: PMI element referencing Supplemental Geometry

Note that the `shape_representation` (or subtype) which contains the main product geometry, the `constructive_geometry_representation` for the supplemental geometry and any `draughting_model` for presentation all must share the same `geometric_representation_context`.
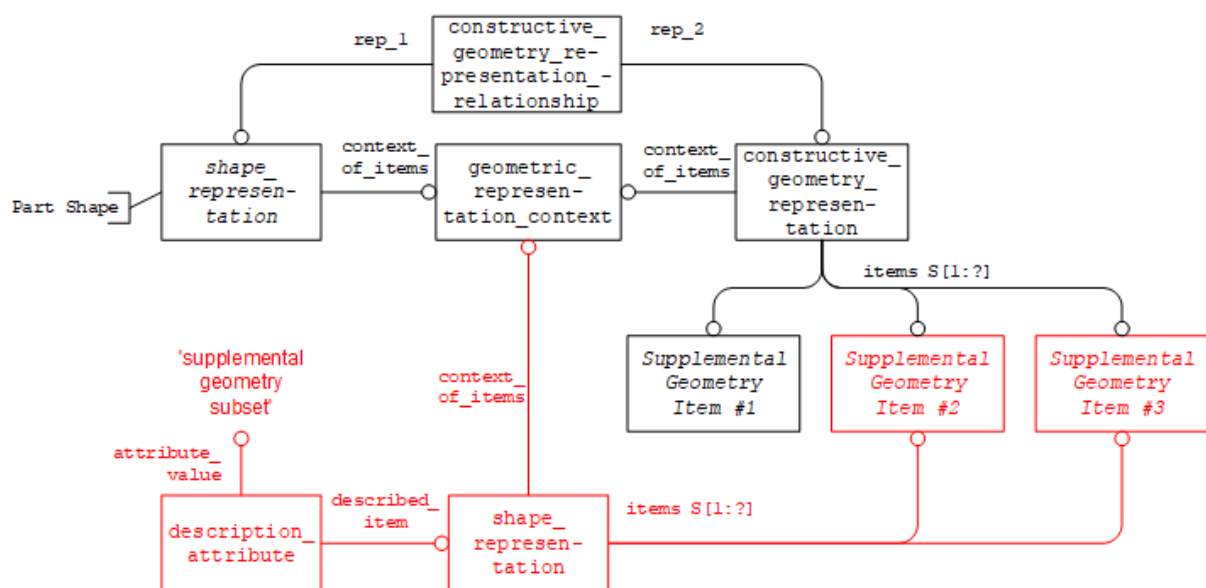
5.5 Definition of Supplemental Geometry Subsets

There are use cases that require referencing subsets of supplemental geometry, for example for display in a Saved View. Since a model may have a large number of supplemental elements of which only few might be applicable for the purpose at hand, the use of invisibility would be impractical. Thus, splitting the representation collecting the supplemental geometry elements is a practical approach.

However, legacy implementations depend on a single container for all supplemental geometry elements as introduced in section 5.1 above.

Hence the agreed solution is to create additional `representations` representing the desired subsets of supplemental geometry. These will use the generic `shape_representation` type instead of the dedicated `constructive_geometry_representation`, since the latter requires establishing a relationship to the part shape. This would again cause issues (duplication of elements) with legacy implementations.

All representations must share the same `geometric_representation_context`, though. In order to easily identify the subsets, the respective `shape_representations` shall have an instance of `description_attribute` linked to them, carrying the magic string 'supplemental geometry subset'.

Figure 6: Defining a Supplemental Geometry Subset

This works in exactly the same way for Tessellated Supplemental Geometry.

5.6 Presentation of Supplemental Geometry

Supplemental geometry elements can be styled in the same way as any geometry defining the part shape. Refer to the "Recommended Practices for Model Styling & Organization" for details.

It is a challenge to ensure the correct visibility of supplemental geometry elements in any Saved View defined in the model. Elements such as the indication of what is the restricted area in an annotation, is vital for a correct understanding of the model. Section 9.4.2.2 of the "Recommended Practices for the Representation and Presentation of Product Manufacturing Information (PMI)", version 4.1 or later, defines the recommended approach.

5.7 Defining Properties on Supplemental Geometry

Properties can be defined on supplemental geometry in the same way as they can be defined on the part shape. The definition of such properties is not in the scope of this document but can be taken from the respective Recommended Practices referenced below.

Note that as shown in Figure 5, any `geometric_item_spedific_usage` or `item_identified_representation_usage` used to identify supplemental geometric elements must refer the corresponding `constructive_geometry_representation` as the `used_representation`.

5.7.1 Supplemental Geometry Validation Properties

As pointed out in section 5.2, supplemental geometry elements may change their definitions when being transferred from one CAD system to another. Hence, supplemental geometry shall not be included in any part-level geometric validation properties.

It is, however, possible to define geometric validation properties for individual supplemental geometric elements. Refer to sections 4.5 through 4.10 of the "Recommended Practices for Geometric & Assembly Validation Properties" for details.

5.7.2 User Defined Attributes on Supplemental Geometry

The STEP data model allows for associating user-defined attributes with supplemental geometry. Refer to sections 6.3 and 7 of the "Recommended Practices for User Defined Attributes" for details.

Annex A   Availability of Implementation Schemas

A.1   AP214

The long form EXPRESS schema for the third edition of AP214 (2010) can be retrieved from:

- https://www.mbx-if.org/home/wp-content/uploads/2024/07/AP214E3_2010.zip

A.2   AP203 2nd Edition

The long form EXPRESS schema for the second edition of AP203 (2011) can be retrieved from:

- https://www.mbx-if.org/home/wp-content/up-loads/2024/07/part403ts_wg3n2635mim_lf.zip

A.3   AP242 Edition 1

The long form EXPRESS schema for the first edition of AP242 (2014) can be retrieved from:

- https://www.mbx-if.org/home/wp-content/uploads/2024/07/ap242_is_mim_lf_v1.36.zip

A.4   AP242 Edition 2

The long form EXPRESS schema for the first edition of AP242 (2019) can be retrieved from:

- https://www.mbx-if.org/home/wp-content/up-loads/2024/07/ap242ed2_mim_lf_v1.101.zip

A.5   AP242 Edition 3

The long form EXPRESS schema for the third edition of AP242 (2022) can be retrieved from:

- https://www.mbx-if.org/home/wp-content/up-loads/2024/07/ap242ed3_mim_lf_v1.152.zip

A.6   AP242 Edition 4

The long form EXPRESS schema for the fourth edition of AP242 (2025) can be retrieved from:

- https

Note that this is the minimum version required for Tessellated Supplemental Geometry.