Recommended Practices

for

Alternative Shapes

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CAx-IF

Jochen Boy
PROSTEP AG
jochen.boy@prostep.com

Robert Lipman
NIST
robert.lipman@nist.gov

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Document History

Revision	Date	Change
0.1	2016-05-31	Initial creation
0.2	2021-11-23	Update for AP242 Edition 2 Addition of Part 21 Examples Harmonization with Rec. Practices for AP209 and AP242 XML
1.0	2025-10-20	Updates for AP242 Edition 4 Public Release to safeguard results achieved thus far

1 Introduction

This document describes the recommended practices for implementing the ability to exchange information about alternative shapes via the STEP standard.

There are multiple use cases for “alternative shapes”. This document handles four of those use cases. Two of them are at the part level, while the other two are on the assembly level.

Part-level use cases:

- *Alternative Representations for Equivalent Part Shapes* – in this case, there are several different geometric representations for one and the same part shape. Typical scenarios include having a precise B-Rep along with a tessellated representation (or several, for different levels of detail), or a solid model along with a surface model.

- *Alternative Part Shapes* – in this case, there are geometrically different shapes for the same part. A prominent example is defining the folded and unfolded shapes of a sheet metal part (i.e., a “blank” and a finished part).

Assembly-level use cases:

- *Alternative Instance Shapes in an Assembly* – in this case, the shape of a part is modified in the context of an assembly. This can be used to represent assembly-level features which modify the geometry of the constituent parts in a specific way, such as a hole for a rivet or bolt for instance. Another use case is the representation of flexible parts, e.g., the shape of a rubber gasket before and after assembly.

- *Alternative Views on Assembly Structures* – this use case allows for defining different assembly structures for the same version of the product. This could be an “as designed” and an “as manufactured” structure, or an “assembled view” and an “exploded view” of a complex product. The different structures can refer to the same subsequent parts as constituents of the structure.

Upon export, all shapes in scope of the current data exchange are written into the STEP files and identified accordingly. This can be done with all shapes in one STEP file or with in the “nested” case, where each shape is in a separate file with corresponding external references. This document is restricted to the “all in one” scenario.

During import, the choice for the actual shape will in some cases be made interactively by the user (e.g., which state of a sheet metal part to display) and in some cases automatically by the system (e.g., which level of detail to visualize).

Other definitions and use cases for “alternative shapes” are not in scope of this document but may be added in the future.

2 Scope

The following are within the scope of this document:

Implementation recommendations for STEP Part 21 files based on AP242 MIM EXPRESS including one or more of the following:

- The definition of alternative representations for equivalent part shapes
- The definition of alternative part shapes
- The definition of alternative instance shapes in an assembly
- The definition of alternative views on assembly structures

The following are out of scope for this revision of the document but may be added in the future:

- Support for the use cases for “nested” assemblies

The following are out of scope for this document:

- Implementation recommendations for AP242 Domain Model XML
- The definition of part properties and part structure properties
- The definition of assembly structures
- The definition of “alternate parts” and “substitute parts” per sections 4.5.1 / 4.5.2 in the PDM Schema Usage Guide
- The definition of related shapes associated with different products (e.g., mirrored parts or analysis shapes).

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 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.---Alternative Shapes---1.0---2025-10-20`

It will appear in a STEP file as follows:

```
FILE_DESCRIPTION(('...','CAx-IF Rec.Pracs.---Alternative Shapes---1.0---
2025-10-20',),'2;1');
```

4 Fundamentals and Concepts

When looking at the chain of entities leading from the definition of a part down to its shape, there are several links where alternatives can be introduced:

- Each Part can have one or several Part Versions
- Each Part Version can have one or several Views
- Each View can have one or several Shapes

This is shown in Figure 1 below:

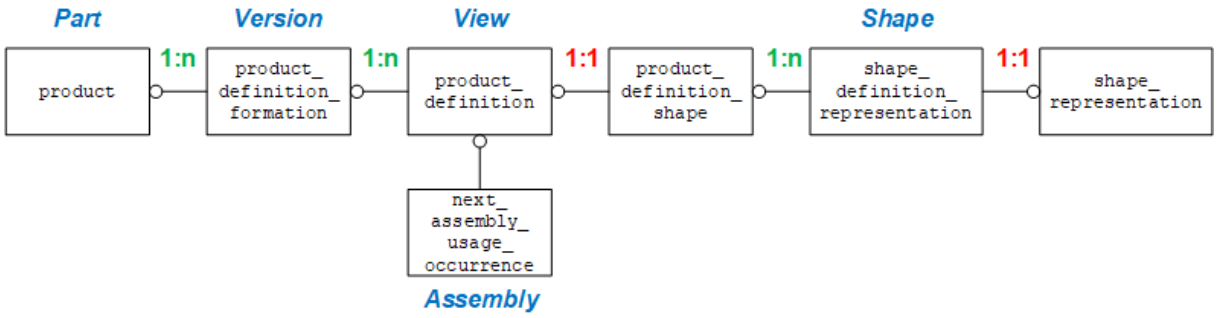

Figure 1: Possible Alternatives from Part to Shape

Depending on which level alternatives are introduced at, they have different meanings as described in the introduction. This also has an impact on how the user will interact with the model. For instance, when defining an assembly, the user must specify which view of a part version will be included in the structure. Note that `next_assembly_usage_occurrence` references the `product_defintion`. However, if several alternative representations are defined for the same shape – for instance varying levels of detail for a tessellated model – it is usually a system decision which shape will be used for interaction.

Most of the concepts described in this document have initially been defined in the PDM Schema Usage Guide, which will be referenced repeatedly throughout this document. The latest version (4.3; January 2002) is publicly available from the MBx-IF homepage under "CAx > Rec. Practices".

The assembly-level use cases, specifically the one covering different views on the assembly structure, are supported by the AP242 Domain Model as well and consequently covered by the Recommended Practices for AP242 XML Product and Assembly Structure. These use cases and the resulting definitions are driven by the PDM Interoperability Forum and reflected here as far as possible. This document can be found on the same Rec. Practices page linked above.

Note that all approaches described in this document aim at representations of the same part (same `product`) in different contexts. Thus, derived parts, e.g., the definition of a mirrored part, are not covered here as this requires additional definitions at the PDM level (the mirrored part will have a different part number and is represented by a different `product`). The relationship between design shapes and analysis shapes as defined in the Recommended Practices for AP209 Edition 2 (section 2.11) is also out of scope, as these shapes are related to different `product` instances as well.

As a reminder from the PDM Schema Usage, section 1.1.1 "Part Master Identification", the relevant entity types, attributes, and recommended values are:

Entity.attribute	Recommended Values
product	
id	Part ID (unique within the organization owning the ID)
name	Part name
descrition	Part description
product_definition_formation	
id	Part Version ID, index (unique for the specified product)
description	Reason for the version
product_definition	
id	Part View ID (unique for the specified version)
description	Part View Name
product_definition_context	
name	Provides a distinction on the type of view on a part version ('part definition') from one of a document version ('digital document definition', 'physical document definition'). This attribute may also indicate other types of definitions: e.g., functional, or spatial and/or zonal.
life_cycle_stage	Contains a description of the particular view-point from which the data may be interpreted. Recommended values include 'design' and 'manufacturing'.

Table 1: Part Master Data attributes

5 Alternative Representations for Equivalent Part Shapes

To avoid confusion, when referring to several shapes linked to the same view on a particular part version, the term “equivalent shapes” is used. This means they have the same geometric and functional specification; however, the shape is represented in different ways. The most common use cases for this are the definition of a precise B-Rep along with one or several tessellated shapes, or the definition of a solid model along with a surface model.

The corresponding ARM element for `shape_definition_representation` is `Shape_description_association`. In AP214 Edition 3, it is defined as “a mechanism to associate the definition of a shape or of a portion of a shape with a geometric representation”. It has a `role` attribute described as “specifies the function performed by the referenced model”. This `role` attribute maps to a `name_attribute` with `shape_definition_representation` (technically, its supertype `property_definition_representation`) as the named item. AP214 recommends the values ‘detailed representation’ and ‘idealized representation’, which goes in the right direction but doesn’t exactly meet the needs of the use cases at hand. It also was never implemented.

For AP242, the definition of the ARM element `Shape_description_association` is given in module 1032. It does no longer include the `role` attribute, but its supertype `Property_definition_representation` has a `name` attribute which maps to the AIM level as described above. In contrast to AP214, AP242 does not provide any recommended values for the name.

Therefore, the following recommendation:

- For the main shape, the `shape_definition_representation` shall have no `name_attribute` attached (no change compared to current files).
- For any additional shape, a `name_attribute` shall be instantiated with the `shape_definition_representation` as the `named_item` and the `attribute_value` given as ‘alternative shape representation’. The subsequent `shape_representation` will carry the user name for the shape, e.g., ‘LOD_1’.

This leaves two scenarios to consider, depending on whether the `shape_representations` share the same geometric context or not.

Note that attributes defined at the part level link to either the `product_definition` (e.g., User Defined Attributes) or the `product_definition_shape` (e.g., Geometric Validation Properties), which means they will be shared by all alternative representations. In particular, the validation properties for all shapes will be accumulated at the part level. To provide properties for a particular shape, it is possible to associate these with the corresponding `shape_representation` (or subtype) for that shape by creating a complex entity with `characterized_representation`. Refer to the Recommended Practices for Geometric Validation Properties, and for 3D Tessellated Geometry, for more details.

5.1 Alternative Representations in same Geometric Context

In the first case, the various `shape_representations` are all defined in the same geometric context. This implies that all alternative shapes are positioned in the same way.

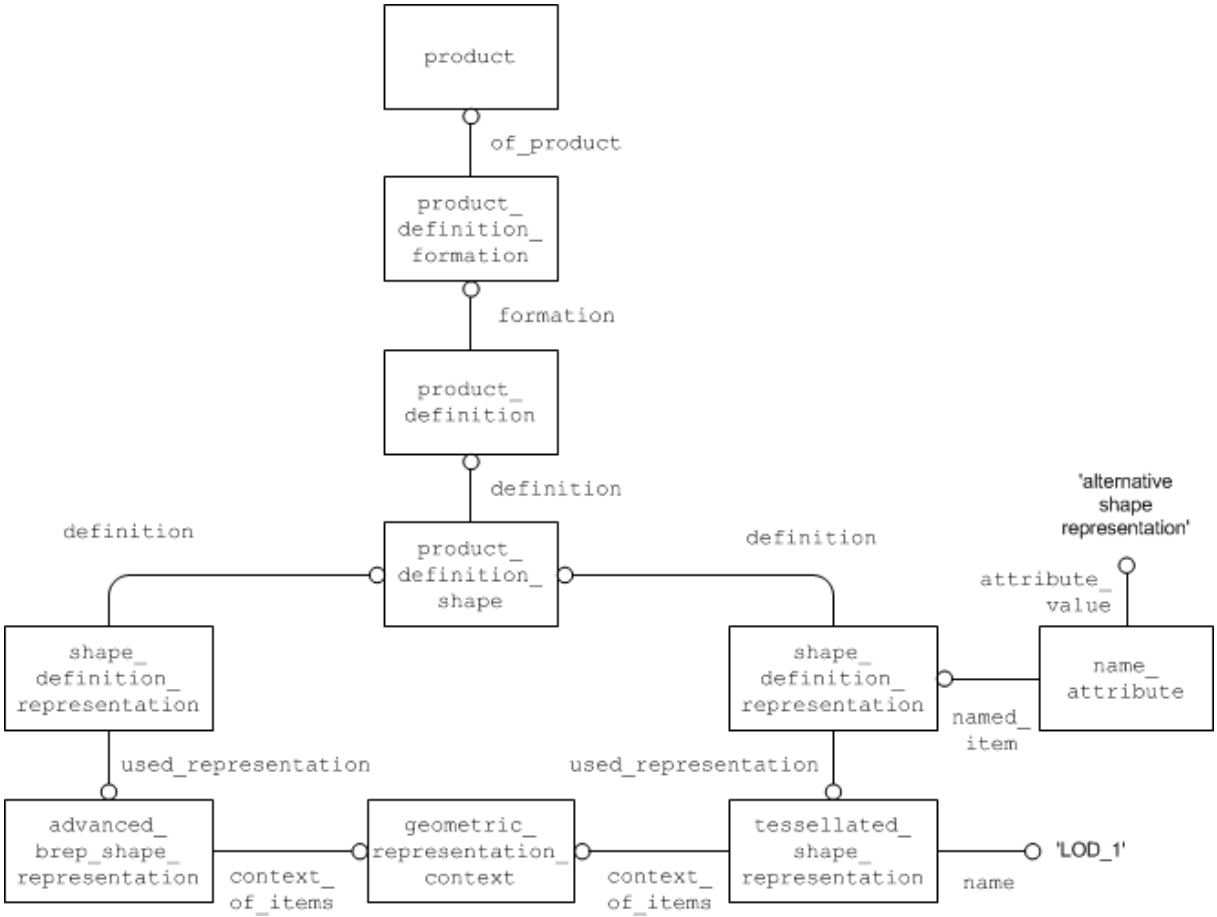

Figure 2: Alternative Representation with same Geometric Context

Part21 Example:

```
#5=( GEOMETRIC_REPRESENTATION_CONTEXT(3)
     GLOBAL_UNCERTAINTY_ASSIGNED_CONTEXT((#6))
     GLOBAL_UNIT_ASSIGNED_CONTEXT((#3,#4))
     REPRESENTATION_CONTEXT('Context #1', '3D Context with UNIT and
UNCERTAINTY'));
#8=PRODUCT('as1','as1','void',(#7));
#9=PRODUCT_DEFINITION_FORMATION('as1','',#8);
#11=PRODUCT_DEFINITION('void','',#9,#10);
#12=PRODUCT_DEFINITION_SHAPE('','',#11);
#2049=ADVANCED_BREP_SHAPE_REPRESENTATION('',(#2048,#1969),#5);
#2050=TESSELLATED_SHAPE_REPRESENTATION('LOD_1',(#2031),#5);
#2053=SHAPE_DEFINITION_REPRESENTATION(#12,#2049);
#2054=SHAPE_DEFINITION_REPRESENTATION(#12,#2050);
#2055=NAME_ATTRIBUTE('alternative shape representation',#2054);
```

5.2 Alternative Representation with separate Geometric Contexts

In the second case, each of the equivalent shapes has its own geometric context. This allows defining the precision of the LODs using the uncertainty measure, but it requires that a `representation_relationship_with_transformation` with a unit transformation is used for every alternative shape, linking it to the main shape. This ensures that all shapes are positioned in the same way.

Note that for use the case of defining several LODs for a tessellated shape, AP242 Edition 2 provides a dedicated subtype of `tessellated_shape_representation` that allows for a more detailed characterization of the LODs. This extension will be described in detail in a future version of the Recommended Practices for 3D Tessellated Geometry.

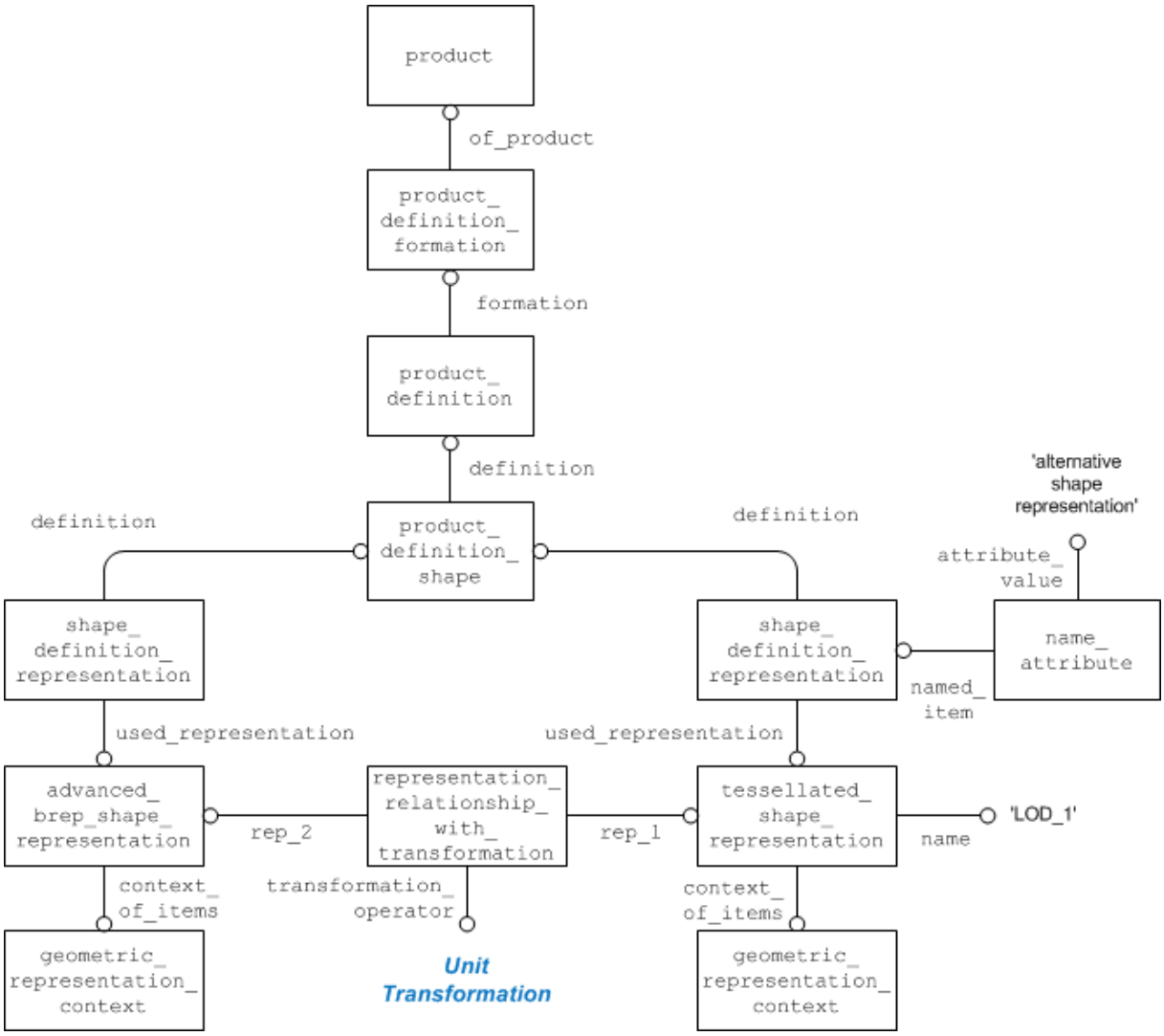

Figure 3: Alternative Representations with separate Geometric Contexts

6 Alternative Part Shapes

The term ‘alternative part shapes’ corresponds to providing different views for the same version of a part. In this case, the shapes are not just represented in a different way; they are either actually geometrically different – in the case of a folded/unfolded sheet metal part – or arranged in a different way, as when providing an exploded view for an assembly. The case of alternative views on assemblies is described in section 8.

The alternative part shapes can also be used to represent various stages in the manufacturing process, for instance a forged or cast part before and after milling, or a part created by additive manufacturing techniques.

As the distinction is made at the `product_definition` level, each of the alternatives also has its own `product_definition_context` with a `life_cycle_stage`. Refer to the PDM Schema Usage Guide, section 1.1.2 “Context Information” for additional details. Also note that this means that each alternative part shape will have its own set of part-level properties, as these are linked to either to the `product_definition` (e.g., for User Defined Attributes) or the `product_definition_shape` (e.g., for Geometric Validation Properties).

As before, there two scenarios, depending on whether the geometric context is shared between the alternative part shapes or not.

6.1 Alternative Part Shapes with same Geometric Context

In the first case, the various `shape_representations` are all defined in the same geometric context. This implies that all alternative shapes are positioned in the same way.

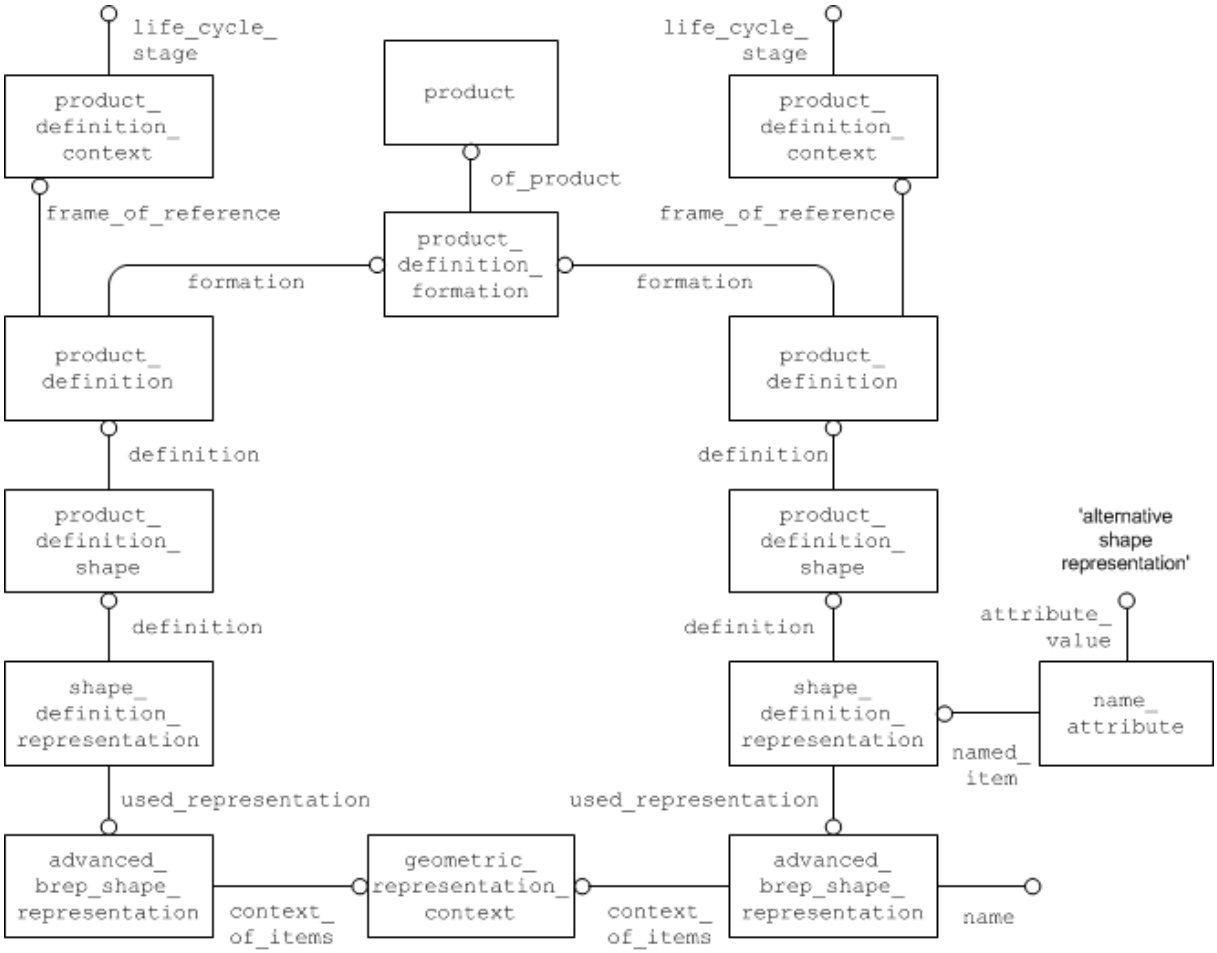

Figure 4: Alternative Part Shapes with same Geometric Context

Part21 Example:

```
#8=( GEOMETRIC_REPRESENTATION_CONTEXT(3)
     GLOBAL_UNCERTAINTY_ASSIGNED_CONTEXT((#9))
     GLOBAL_UNIT_ASSIGNED_CONTEXT((#6,#7))
     REPRESENTATION_CONTEXT('Context #1', '3D Context with UNIT and
UNCERTAINTY') );
#11=PRODUCT('nist_ctc_03_asme1_nx110_rc.prt','','NIST PMI test model
downloaded from http://go.usa.gov/mGVm',(#10));
#12=PRODUCT_DEFINITION_FORMATION('C','',#11);
#13=PRODUCT_DEFINITION_CONTEXT('part definition',#1,'design');
#14=PRODUCT_DEFINITION('design','',#12,#13);
#15=PRODUCT_DEFINITION_SHAPE('','',#14);
#11282=ADVANCED_BREP_SHAPE_REPRESENTATION('',(#11281,#8521),#8);
#11266=SHAPE_REPRESENTATION('',(#11251),#8);
#12770=SHAPE_DEFINITION_REPRESENTATION(#15,#11266);
#12790=PRODUCT_DEFINITION_CONTEXT('part definition',#1,'design');
#12791=PRODUCT_DEFINITION('design','',#12,#12790);
#12792=PRODUCT_DEFINITION_SHAPE('','',#12791);
#12794=SHAPE_DEFINITION_REPRESENTATION(#12792,#11282);
#12795=NAME_ATTRIBUTE('alternative shape representation',#12794);
```

6.2 Alternative Part Shapes with separate Geometric Contexts

In the second case, each of the provided `shape_representations` has its own context. In contrast to the alternative representations for equivalent shapes described in section 5, the alternative shapes at the view level can also be positioned differently. This requires that the respective transformation relative to the main shape is given, as illustrated in Figure 5.

Additionally, it is possible to further classify the relationship between the alternative shapes. For instance, in the case of a folded and unfolded sheet metal part, these can be defined as process steps. The basis for this is the AP242 ARM element `Process_state_relationship` (defined in module 1803), which maps to a `product_defintion_relationship` with its name attribute set to ‘process state relationship’. Concerning the order of the attributes, the following applies, according to the ARM:

A Process_state_relationship is a relationship between two […] objects where the relating […] definition is an in-process-part definition of a particular version of a part. It characterizes a state of the part version that occurs before the state identified by the related […] definition.

In the sheet metal example, from a manufacturing point of view, the unfolded state would be given as `relating_product_definition`, while the folded state would be the `related_product_definition`, as the part is stamped out first, and then bent. This applies even though from a design point of view, usually the folded shape is designed first, and then the unfolded shape is derived from that.

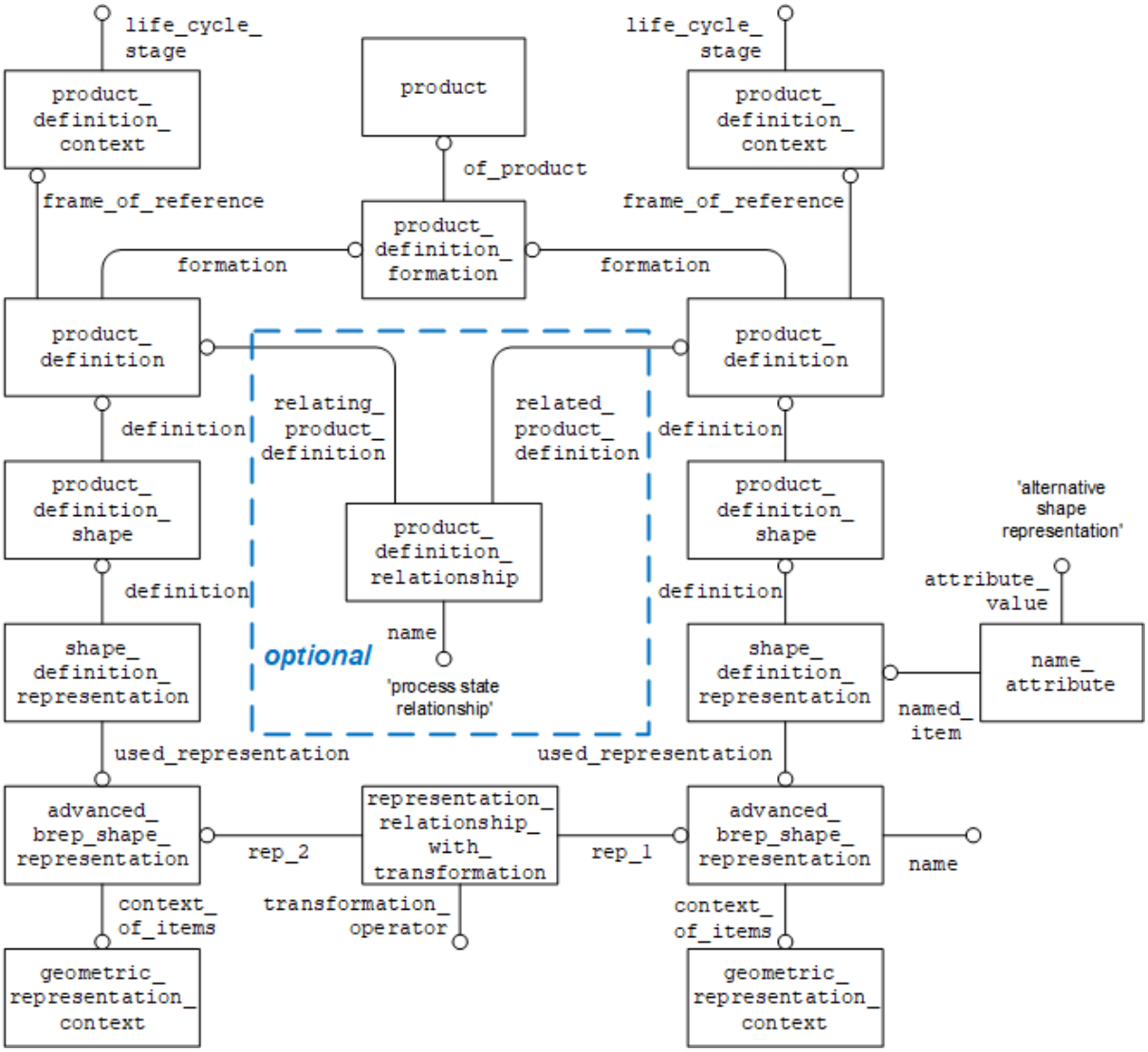

Figure 5: Alternative Part Shapes with separate Geometric Contexts.

7 Alternative Instance Shapes in an Assembly

Note: This capability has not been tested yet in the CAx-IF. It is included for completeness.

There are several use cases where alternative shapes can be defined for a component instance in a product structure. A typical scenario is the definition of flexible parts that are deformed in the assembly process, such as an O-ring or a rubber gasket.

Another scenario is the definition of assembly-level geometrical features which modify the shape of the subsequent parts. A typical example is an assembly of two solid plates with a hole through both of them defined at the assembly level. This means the hole does not exist in the original part definition and it may be in different relative locations on the plate for each of the two usages. A variety of CAD systems support this concept.

This is realized in STEP by associating a new shape for the part with the respective occurrence. While the definition of the product assembly does not change, the definition of the geometric assembly is altered by introducing an intermediate `shape_representation` associated with the `next_assembly_usage_occurrence` that provides the specific shape for this usage. It is linked to the original shape via a `shape_representation_relation-ship` with its name set to 'derived' as illustrated in Figure 6 below. This also means such a part can have a different shape for each usage.

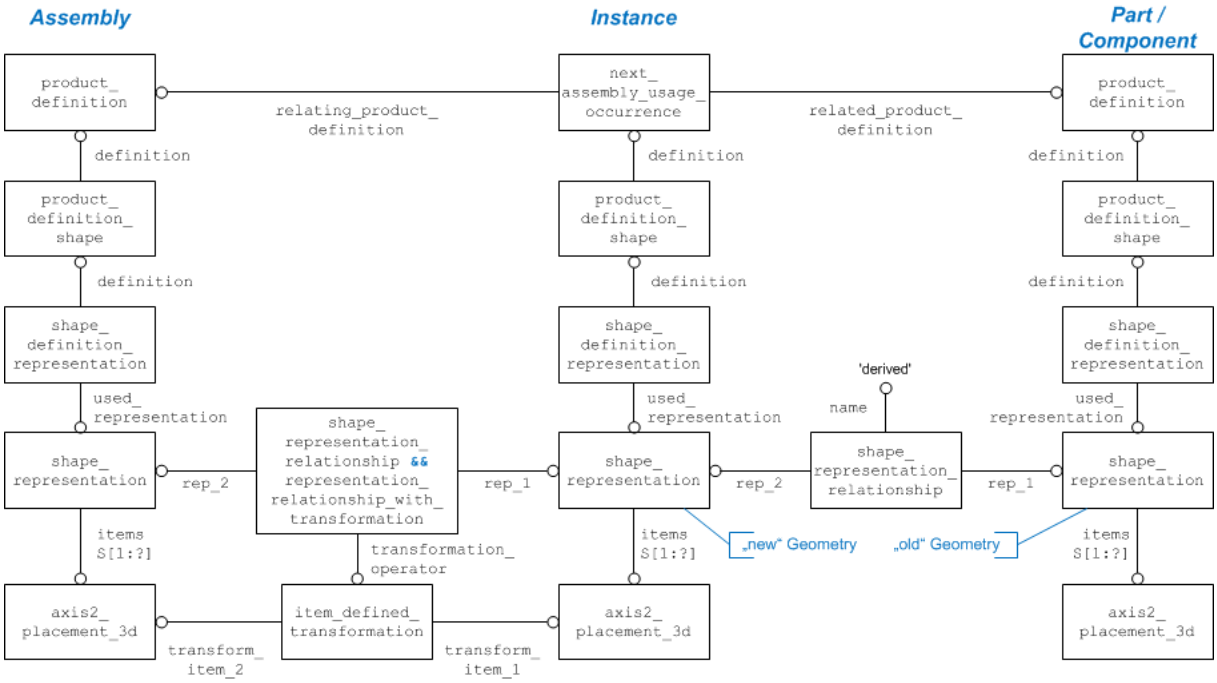

Figure 6: Alternative Shape for an Instance in an Assembly

8 Alternative Views for Assembly Structures

Note: This capability has not been tested yet in the CAx-IF. It is included for completeness.

A specific case of providing alternative views for a part version, as introduced in section 6, is the case where the part in question is an assembly. The alternatives that can be provided at that level go beyond simply exchanging one shape for another; the STEP data model allows for defining an entirely different assembly structure (e.g., nested vs. flattened) or for different placement of the components; for instance, an “as assembled” view and an “exploded” view.

The distinction will be made by defining a new view for the current part version by adding an additional `product_definition` to the `product_definition_formation`. The additional `product_definition` needs to have its own context.

Regarding the subsequent components, the alternative assembly structures can share existing `product_definitions` and `shape_representations` where meaningful, while using different transformations and/or a different organization of the parts.

For additional information, also refer to the PDM Schema Usage Guide; section 4.3 “Different Views on Assembly Structure”.

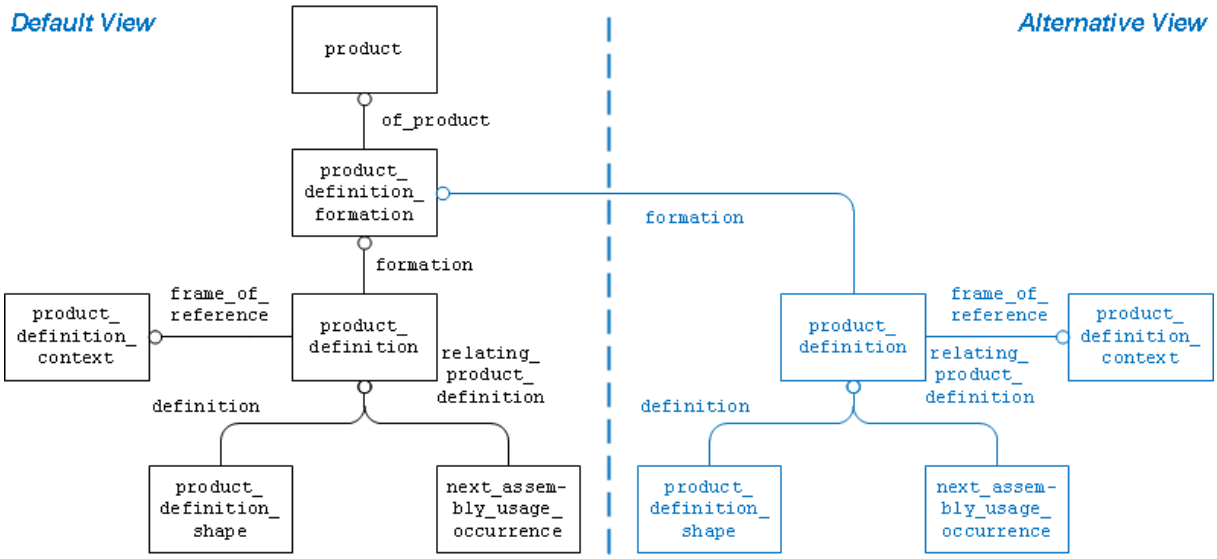

Figure 7: Alternative Views for Assembly Structures

Annex A Availability of Implementation Schemas

A.1 AP242 Edition 4

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

- https://standards.iso.org/iso/ts/10303/-442/ed-7/tech/express/mim_lf.exp

A.2 AP242 Edition 3

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

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

A.3 AP242 Edition 2

The longform EXPRESS schema for the second (2019) edition of AP242 can be retrieved from:

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

A.4 AP242 Edition 1

The longform EXPRESS schema for the first (2014) 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

In general, the capabilities described in this document are also supported the older AP203 and AP214, which have since been succeeded by AP242. The corresponding schemas are listed below. However, the approaches described in this document have not been specifically tested for compatibility with these older standards.

A.5 AP203 Edition 2

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

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

A.6 AP214 Edition 3

The longform 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