Extensions to the recommended practices for GD&T in STEP-AP210 in the context of packaged electronic components

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Introduction

The purpose of this document is to extend the recommended practices for the representation of GD&T in STEP (ISO-10303) within the context of packaged electronic component models represented in AP210 (ISO-10303:210). The recommendations in this document are intended to be consistent with the current GD&T accepted practice in STEP. Please refer to the document entitled "Recommended Practices for Dimensions, Dimensional and Geometric Tolerances" dated December 6, 2006 by David Briggs, Tom Hendrix, and Steve Yates for current practice recommendations for GD&T in STEP. This document is available on the website of the CAx Implementor Forum (http://www.cax-if.org/) under the Recommended Practices link. The ARM application objects, relationships, attributes, and mapping to the corresponding MIM entities, relationships, and attributes have been updated to the IS version of the 2nd Edition of AP-210.

The largest family of standards for packaged electronic components are those published by JEDEC. The JEDEC standards are freely and publicly available, and contain detailed dimensioned and toleranced specifications for physical package configurations. JEDEC Publication 95 is a series of documents containing specifications for many common physical package configurations. The JEDEC Publication 95 documents can be accessed on-line at: http://www.jedec.org/DOWNLOAD/pub95/default.cfm. In this document, in addition to general guidelines for the representation of tolerances in a packaged electronic component, a set of STEP mappings for a typical toleranced JEDEC package model will be discussed. These examples are intended to be representative of many of the common tolerances encountered in the JEDEC standards.

The GD&T standard referenced by both JEDEC and the 2006 STEP recommended practice is ASME Y14.5 (1994). The recommendations in this document are intended to be consistent with both the 1994 as well as recent 2009 publication of Y14.5.

Notation

ARM AOs will be denoted with a leading uppercase letter in Courier font (i.e. `Datum`) while a MIM entity will be displayed in all lowercase notation (i.e. `datum`).

Assembly vs. Single-Solid representation of a packaged component model

There are two primary alternatives for the representation of the three-dimensional geometric representation of a packaged component model. The preferred representation is one in which each of the physical package features (body, mounting features, terminals, etc.) have an explicit three-dimensional geometric model. In the case of a replicated
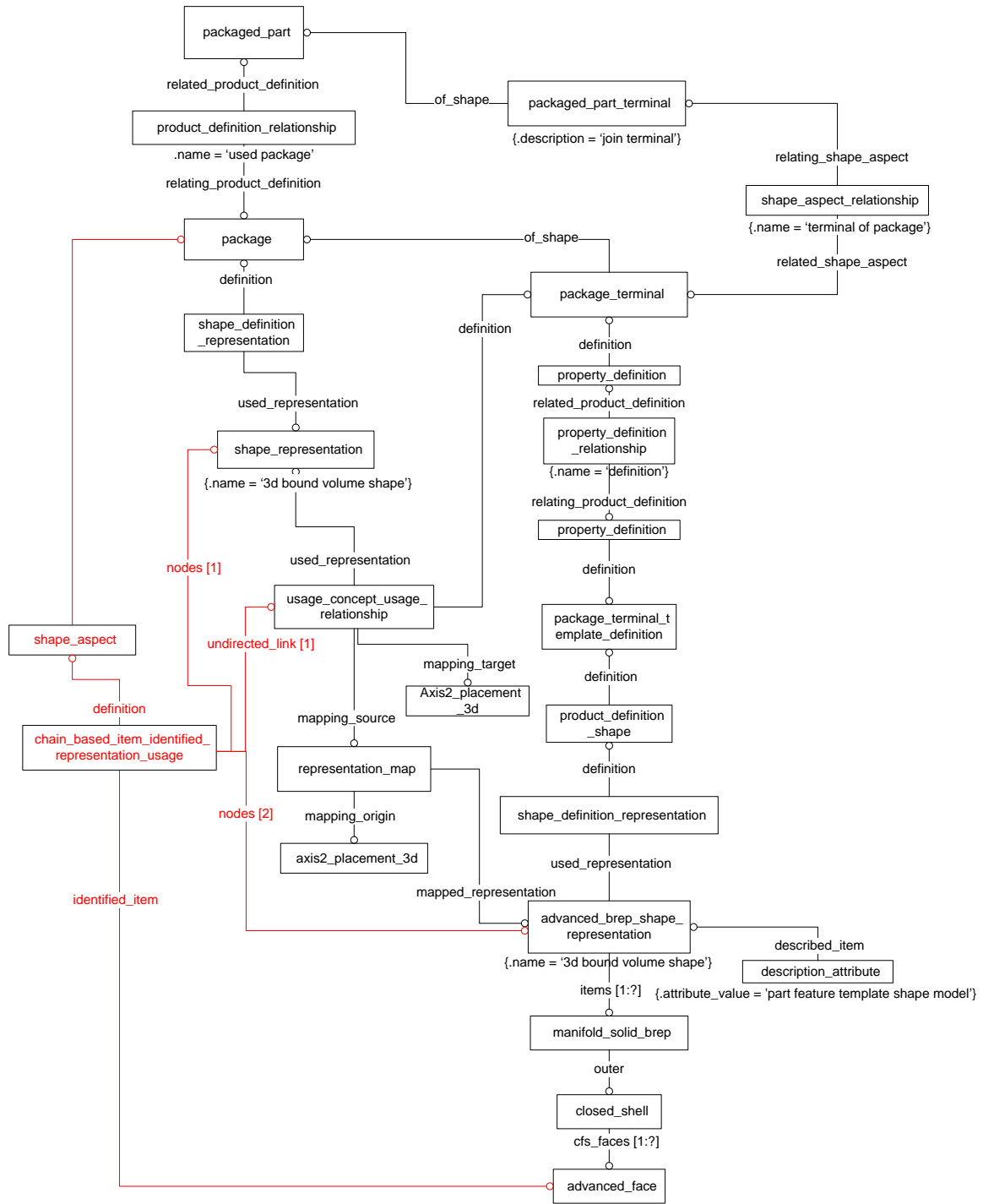
Figure 1. Defining a shape_aspect based on a surface of a terminal in a package model.

feature, such as a terminal, many terminal instances will share a common template (`package_terminal_template_definition`). Figure 1 through Figure 3 illustrate the preferred representation of the geometric model for a `package_terminal`, `package_body`, and `seating_plane`, respectively. As may be seen in the figures, each of the package features has a distinct `shape_representation`, typically an
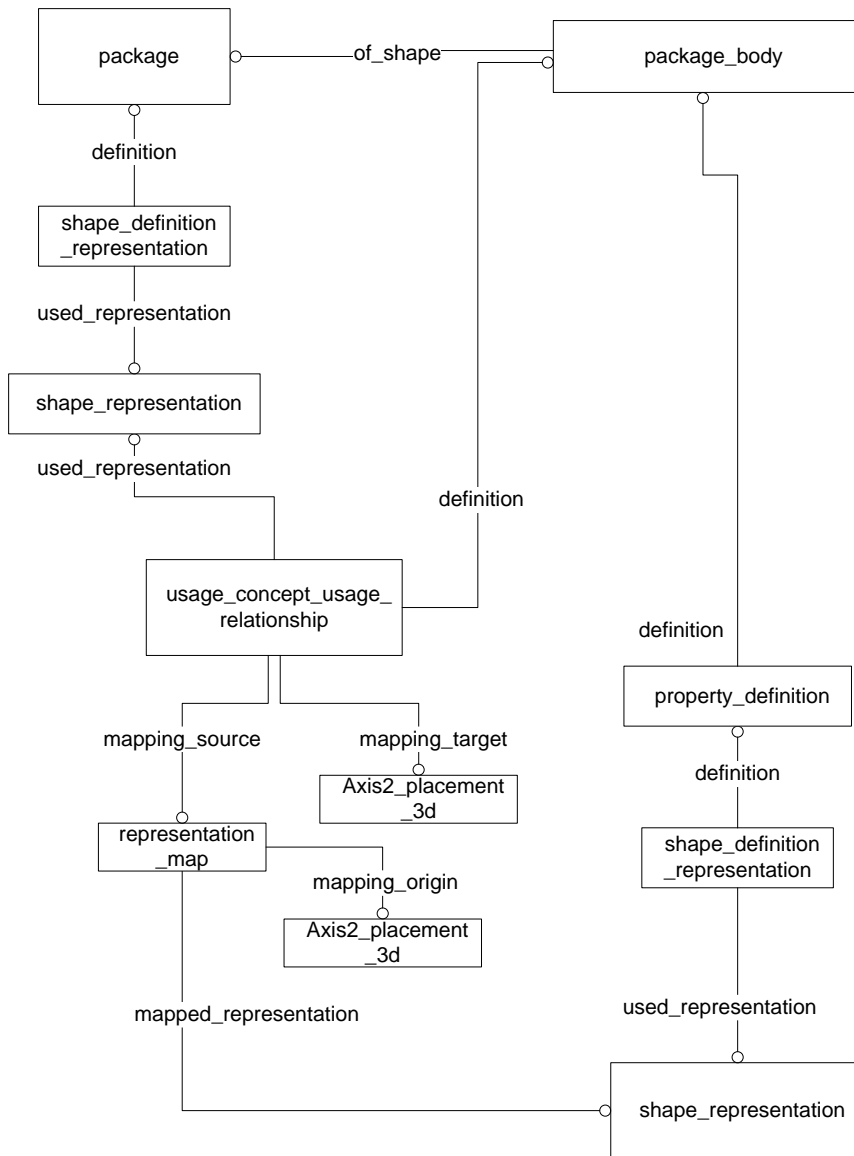
Figure 2. Relationship of the shape model of a package_body to that of the package.

`advanced_brep_shape_representation`. The package features are `shape_aspects` of the package, and the `shape_representation` of the feature is placed with respect to the `shape_representation` of the package with a `usage_concept_usage_relationship`. Explicit representation of the geometric models for distinct package features significantly enhances the ability to perform detailed domain-specific reasoning and functional analysis in contexts such as manufacturability, ECAD-MCAD integration, etc. This preferred representation is analogous to that a mechanical assembly, and the expression of tolerances and dimensions requires representation mechanisms similar to that of mechanical assemblies.
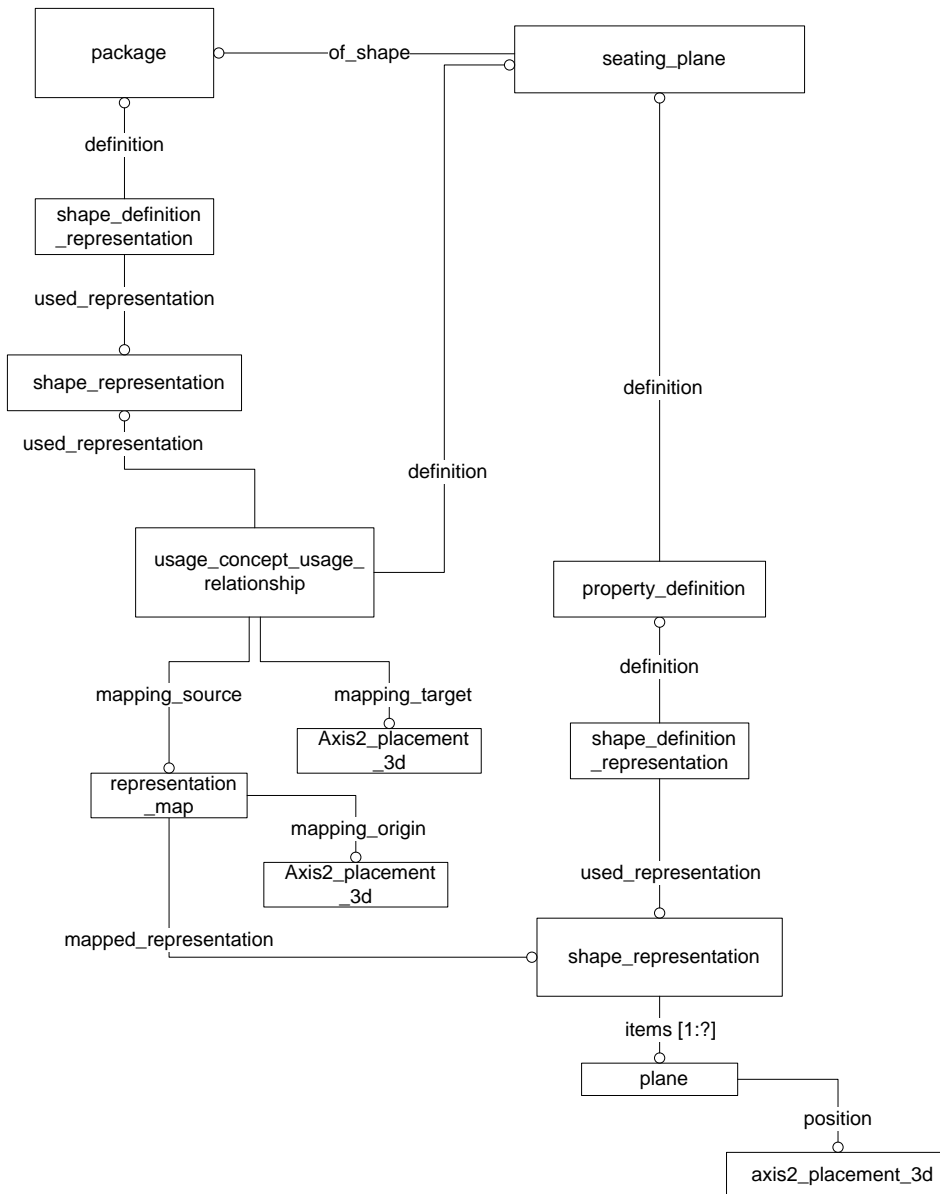
Figure 3. Representation of the seating_plane in a package model.

The alternative is to have a single `shape_representation` that contains the detailed geometric model for the package. In this case, dimensioning and tolerancing can be achieved through mechanisms applicable to a single-solid part.

Shape_elements

Features of the model relevant for GD&T are represented by the `Shape_element` AO. Figure 4 shows several of the important subtypes of `Shape_element`. A surface of a part can be modeled directly as a `Shape_element`. In the MIM mapping, the feature will most likely be associated with an `advanced_face`. When it is desired to treat multiple disjoint regions as a single feature, a `Composite_shape_element` may be employed. A `Composite_shape_element` has two important subtypes – the

`Composite_group_shape_element` and the `Composite_unit_shape_element`. A `Composite_unit_shape_element` is used to aggregate multiple `Shape_elements` that are to be treated as a unit. For example, multiple surfaces of a single feature-of-size.
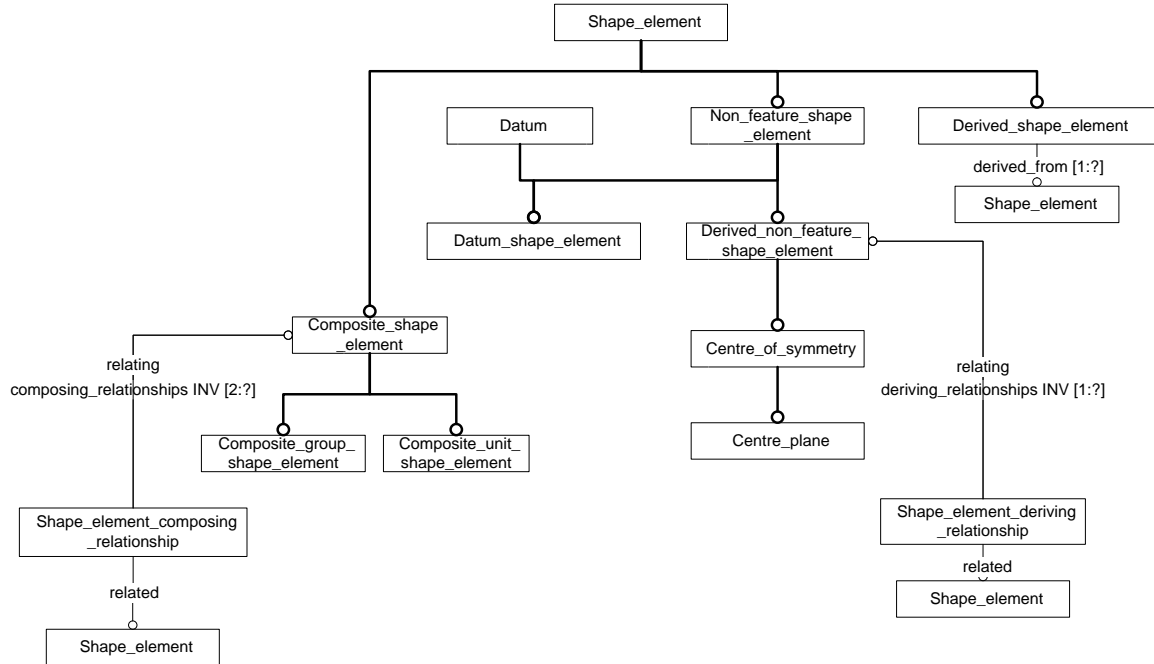

Figure 4. Several relevant subtypes of the Shape_element AO

A `Composite_group_shape_element` is used when it is desired to apply a property to each of the constituent elements individually. Figure 5 contains the MIM mapping of the `Composite_shape_element` (either `composite_group_shape_aspect` or `composite_unit_shape_aspect`) and the relationships to its constitutive elements.

It is often common to require a reference to derived geometry, such as a center plane of a feature. Such a feature would be modeled through the appropriate subtype of `Derived_non_feature_shape_element` (a `Shape_element` that is not on the physical boundary of the part). Figure 6 contains the MIM mapping of the `Centre_plane` AO for the common case in which the derived center-plane is defined by two faces of the model.
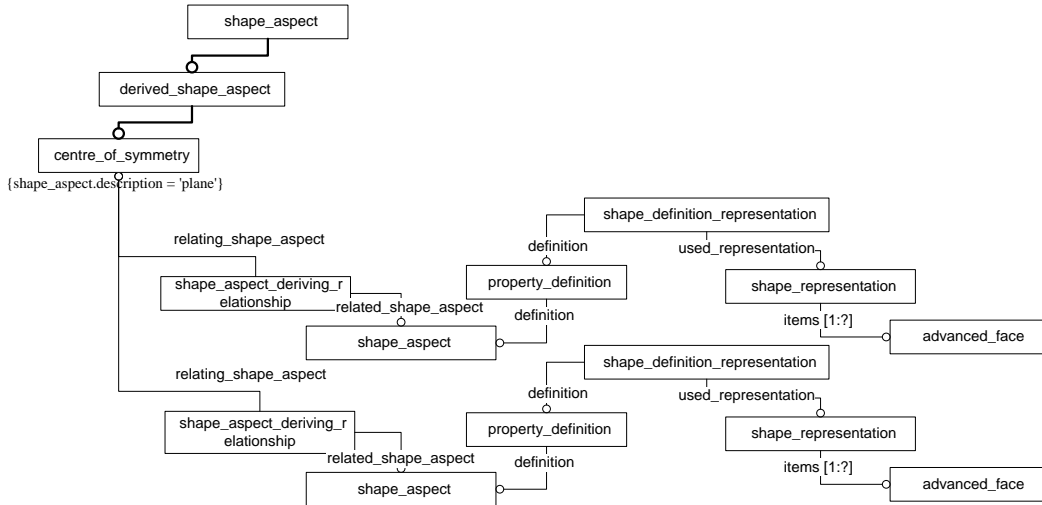

Figure 6. MIM representation of a Centre_plane (a Derived_non_feature_shape_element).

In the context of GD&T for AP210 package models, it is often necessary to reference surfaces of individual terminals as well as groups of terminals for the purposes of
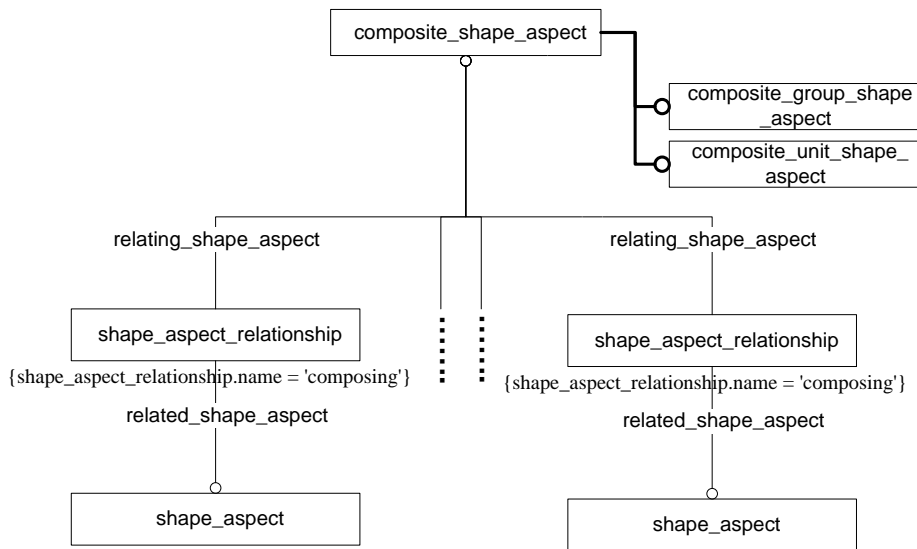

Figure 5. MIM representation of a Composite_shape_element

defining datum and geometric tolerances. As discussed previously, in an AP210 package model, it will often be necessary to individually reference instances of faces used in a common template (for example, assigning a dimension between the outer-faces of two specific terminals instances). Individual instances of the terminal will typically be placed with respect to the shape model of the package using a `usage_concept_usage_relationship`. This case is analogous to a common issue in assembly-level tolerance representation. A mechanism for specifying the required association between a `shape_aspect` and a specific face of an individual terminal instance has recently been established through the MIM entity `chain_based_item_identified_reprsentation_usage`, a subtype of `item_identified_representation_usage`, defined in Technical corrigendum 2 to International Standard ISO 10303-41:2005. As the name implies, the new subtype supports a hierarchically linked chain of representations so as to allow unambiguous reference to a `representation_item` in a lower level of the hierarchy. The MIM mapping for a `Shape_element` needed to identify an individual face on a individual terminal using the `chain_based_item_identified_reprsentation_usage` is detailed in Figure 1, where the associated entities, attributes, and relationships are highlighted in red.

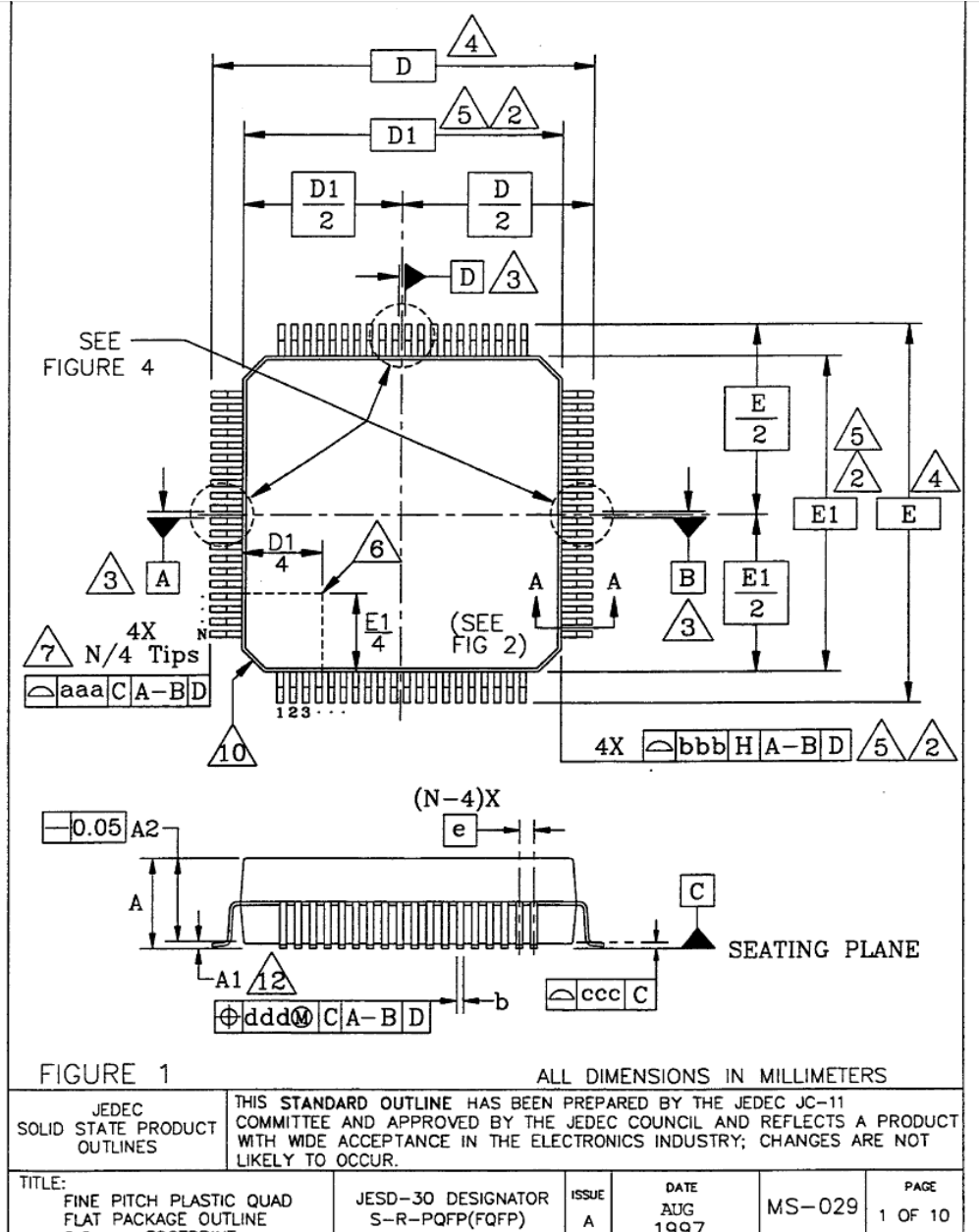### *Representation of dimensional tolerances*

Figure 7. JEDEC Pub. 95 toleranced specification of the QFP package family (MS-029, Figure 1).

The JEDEC Publication 95 standards employ a combination of dimensional tolerances and geometric tolerances. Figure 7 and Figure 8 contains a representative dimensioned and toleranced drawing of a typical JEDEC component package. As may be seen in the figure, there are a number of basic dimensions (D, D1, e, etc.) as well as a number of dimensional tolerances (A, A1, A2), and 5 geometric tolerances specified in control frames.

The toleranced dimensions are all undirected, and are both dimensional and size tolerances. Dimensions A2 and b are size dimensions (height of the body of the package,
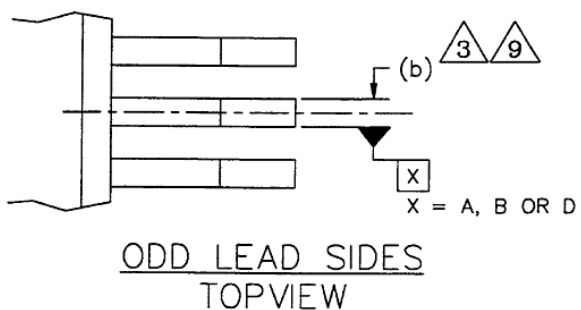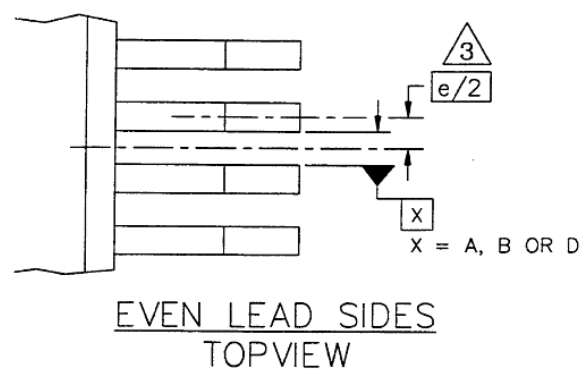
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EVEN LEAD SIDES
TOPVIEW

ODD LEAD SIDES
TOPVIEW

Figure 8. A dimension and datum specified by a feature of size (from JEDEC Pub. 95, MS-029 Figure 4).

width of a terminal, respectively). In each case, the size dimension applies to a regular feature of size (two opposed parallel surfaces). In the case of dimension A2, there is a single package body, whereas dimension b must apply to each of the terminals in the package.

The top-level ARM application objects and attributes used in the representation of a dimensional tolerance are contained in Figure 9 and Figure 10. Dimensions A2 and b would be represented as the `Height_size_dimension` and `Width_size_dimension` subtypes of `Size_dimension`. Each would refer to a single Shape_element. In the event that the geometric model of the terminal was contained within the `package_terminal_template _definition`, a single dimension would intrinsically apply to all terminals in the package. In the event that a single solid was used to represent the complete package

model, it would be necessary to use a `Composite_group_shape_element` which would explicitly contain a shape element for each of the terminal instances in the package. Each of these shape elements would need to reference the two opposing faces (`advanced_face`) of the terminal within the `advanced_brep_shape_representation`. For the majority of the JEDEC dimensions, either a minimum / maximum range, or minimum / nominal / maximum values are provided explicitly. The `dimensional_value` attribute would therefore reference either a `Tolerance_range` or a `Dimension_value_with_limitation`. In certain cases, only a minimum or maximum value is provided. In this case, a `Value_limit` would be used for the representation. The MIM mapping for these ARM concepts for dimensional tolerances are contained in Figure 11 and Figure 12.

Dimensions A and A1 would be represented as instances of the `Linear_distance_dimension`, subtype of `Location_dimension`. Neither of these dimensions relates to a feature of size, and would require two distinct Shape_element, each of which would be associated with a particular surface, or group of surfaces in the model. In both cases, the dimension relates the bottom surfaces of the terminals to a face on the body (either top or bottom surface). The bottom surfaces of the terminals could be referenced through a single `Shape_element` in the case where all terminals are

instances of the same `package_terminal_template_definition`. In the event that a single solid was used to represent the entire package, all bottom terminal surfaces should be aggregated together as a `Composite_unit_shape_element`.
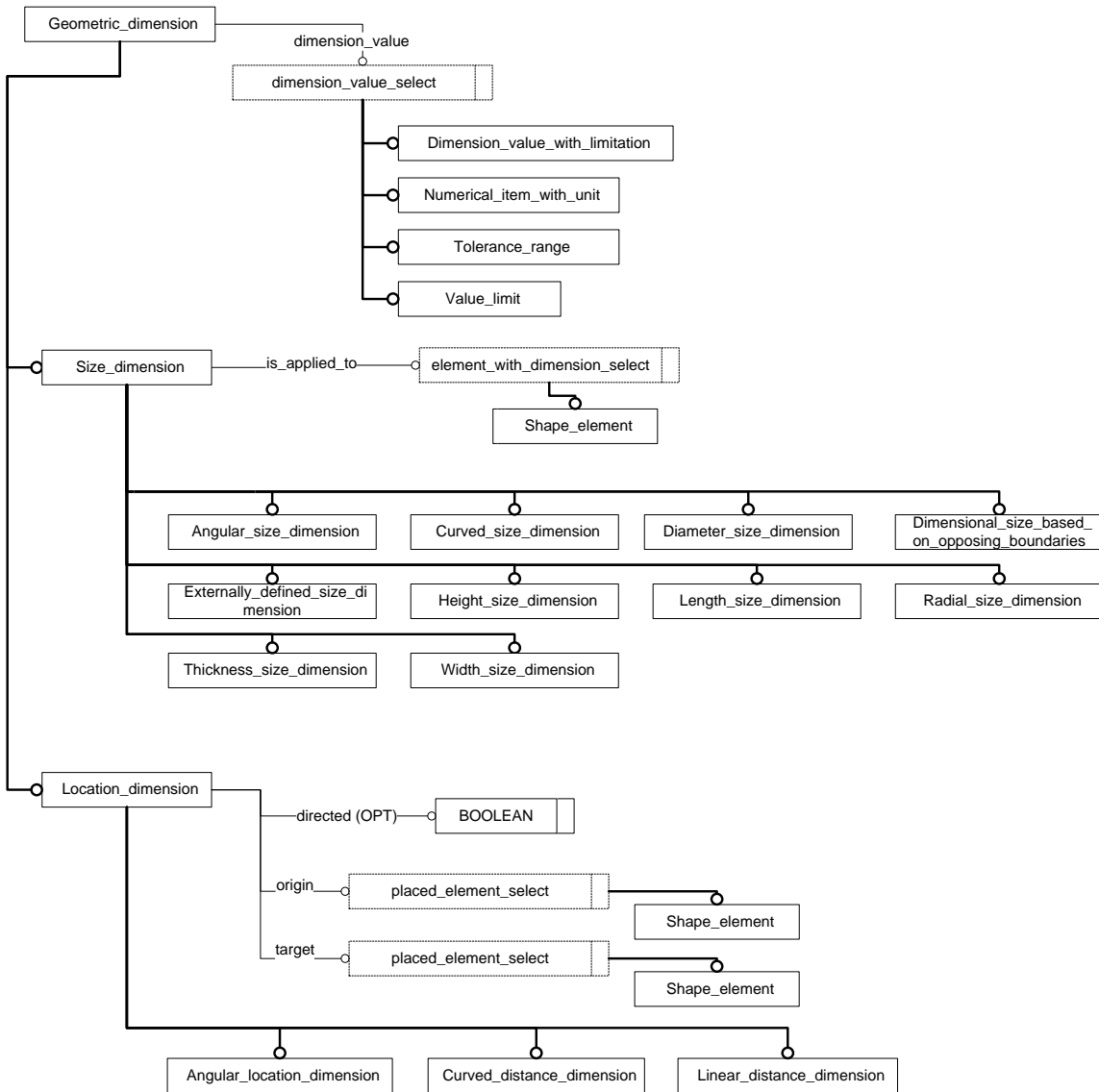

Figure 9. The top-level subtypes and key entities of the Geometric_dimension AO.

Representation of datum

In this document, we consider three common means of defining a datum plane in the JEDEC Publication 95 specification. Per ASME Y14.5 (1994), a datum is a theoretically exact point, line or plane derived from geometric counterpart(s) on the physical model. The geometric counterpart is known as a datum feature. The AP210 ARM supports a family of application objects (AOs) that are subtypes of `Datum`. Several of the commonly used subtypes that are most relevant for the domain of packaged electronic components are documented in Figure 13.
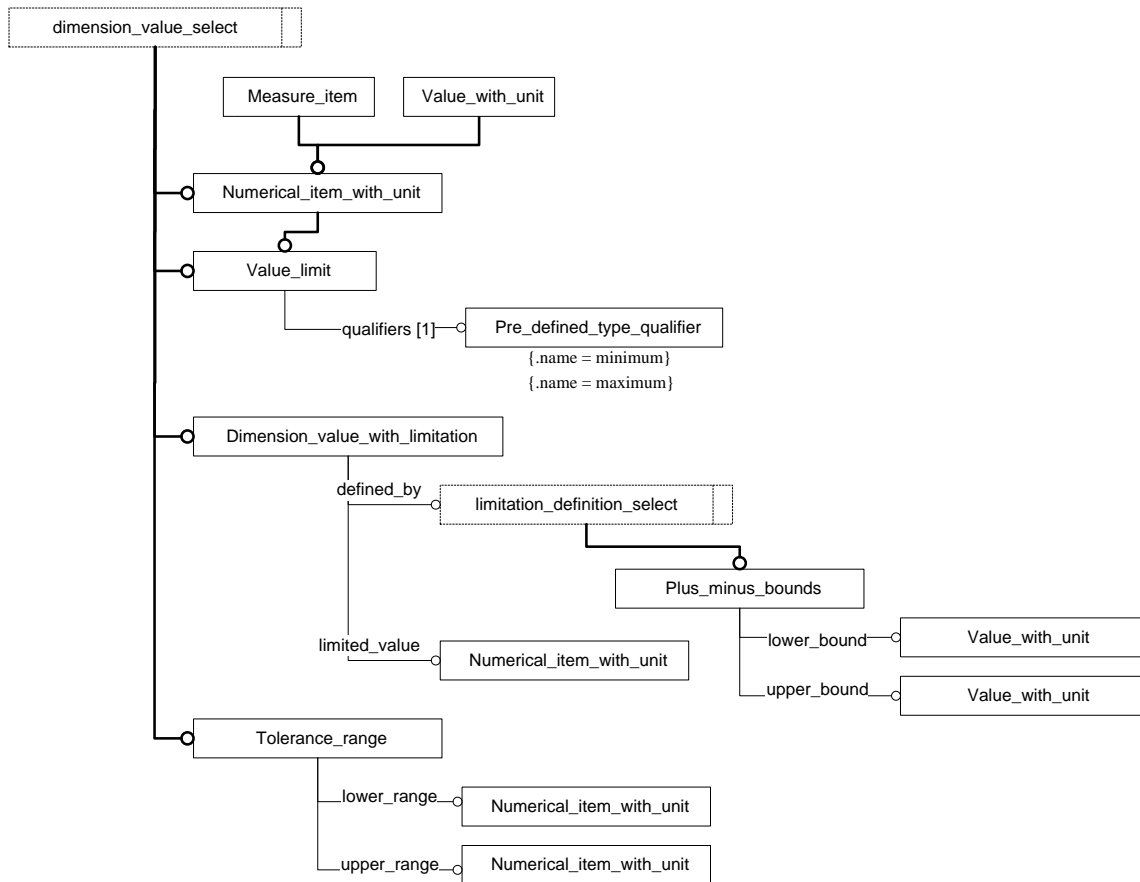
dimension_value_select

Measure_item   Value_with_unit

Numerical_item_with_unit

Value_limit

qualifiers [1]   Pre_defined_type_qualifier
{.name = minimum}
{.name = maximum}

Dimension_value_with_limitation

defined_by   limitation_definition_select

Plus_minus_bounds

limited_value   Numerical_item_with_unit

lower_bound   Value_with_unit

upper_bound   Value_with_unit

Tolerance_range

lower_range   Numerical_item_with_unit

upper_range   Numerical_item_with_unit

Figure 10. ARM AOs for expressing a value of a Geometric_dimension.

In many cases, a datum feature will correspond to either a surface feature of a part or a "feature of size" of a part. When it is required that a specific region of a surface be used to determine the datum, a datum target may be used. A "feature of size" must contain opposed points, and have a reproducible derived median point, axis, or center plane. An example of an internal feature of size would be a slot. A pin or a shaft would be an example of an external feature of size. Many times, a feature of size is used as a datum feature in defining a datum.

A common example in the context of JEDEC Publication 95 would be the use of a package terminal as a feature of size to define a datum plane. Figure 8 outlines how either an internal or an external feature of size would be called out as a datum feature, depending on whether a particular package had an even or odd number of leads on a particular side. In the case of an odd number of leads per side, an external feature of size may be associated with the opposing sides of the lead exiting the body of the component at its center plane. In the case of an even number of leads per side, an internal feature of size may be associated with the opposing (inner) sides of the two center-most leads.

The boxed x, in conjunction with the filled triangle constitutes the datum feature symbol [Y14.5-1994 3.3.2]. In the example of Figure 8, datum features A, B, and D are all defined equivalently.

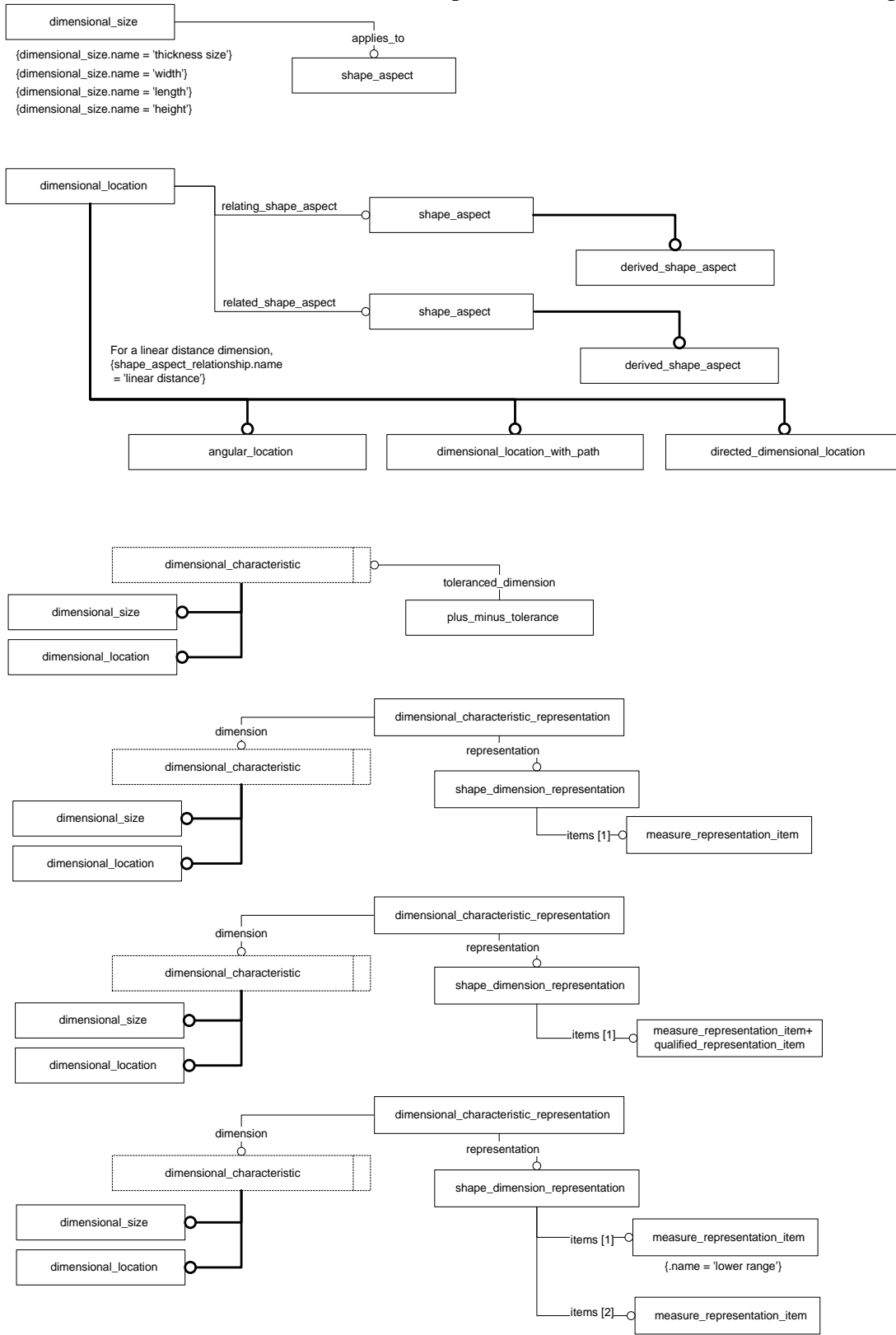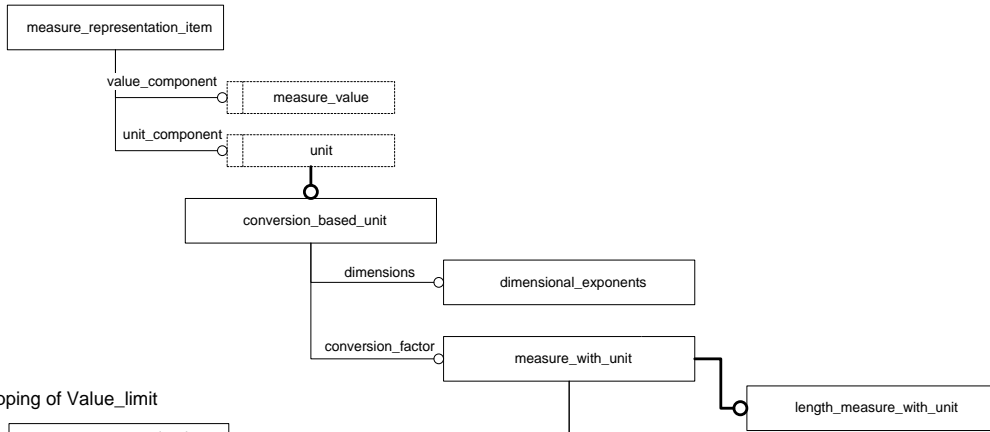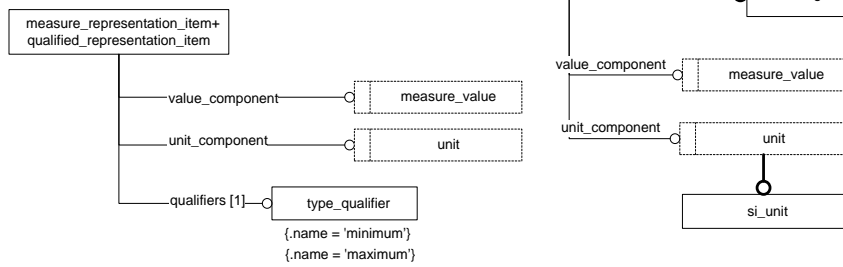Datum features A, B, and D represent a derived datum center plane.

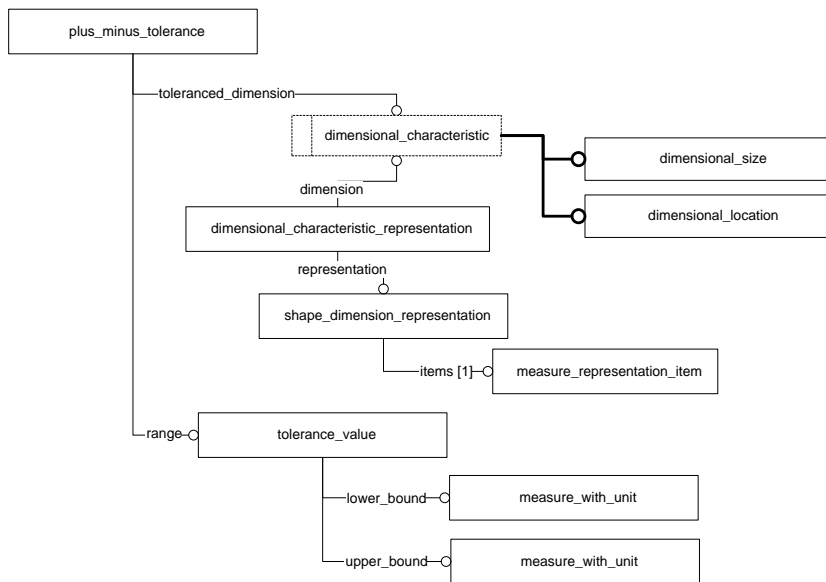**Figure 11. MIM mappings of the Geometric_dimension AO.**

MIM mapping of Numerical_item_with_unit

MIM mapping of Value_limit

{.name = 'minimum'}
{.name = 'maximum'}

MIM mapping of Dimension_value_with_limitation

MIM mapping of Tolerance_range

{.name = 'lower range'}

{.name = 'upper range'}

Figure 12. MIM mappings of the alternate representations for a dimension value.
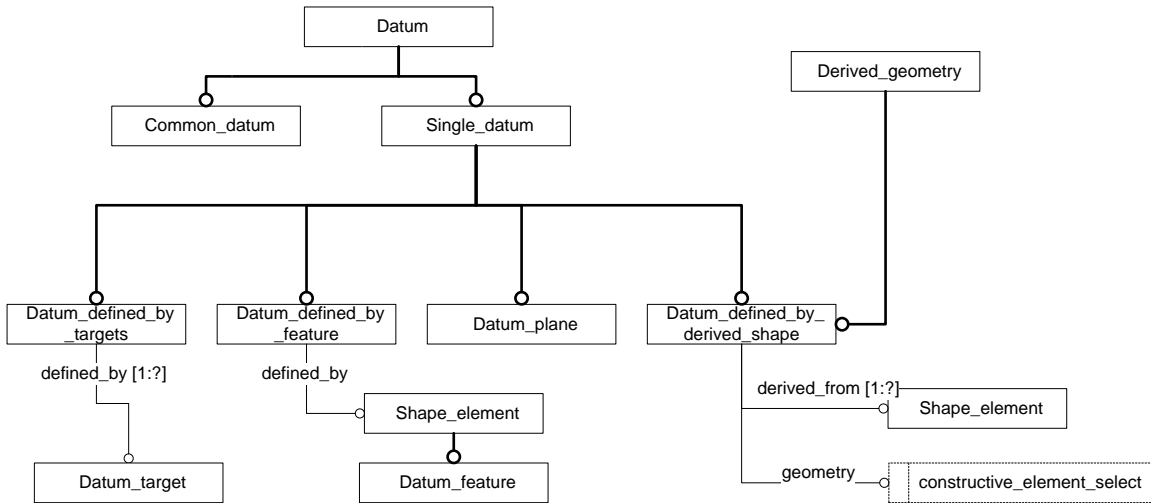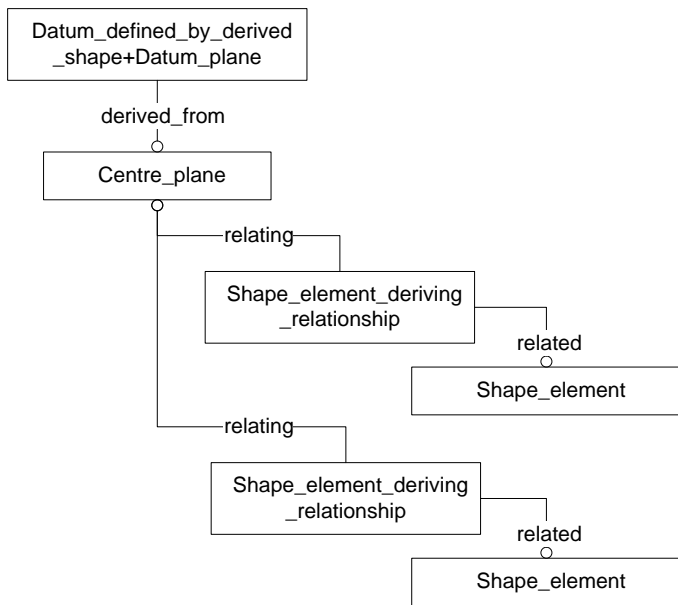
Figure 13. Selected subtypes of the Datum application object

The suggested recommended practice is to use the ARM application object `Datum_defined_by_derived_shape` where the derived shape is a `Centre_plane`. The center plane must reference the two surfaces of the internal or external datum feature. These two surfaces are a `Shape_element` of the model. The relationships between these AOs are depicted in Figure 14 below. The use of the complex entity `Datum_defined_by_derived_shape+Datum_plane` conveys the information that this is a datum plane as well as a datum defined by derived geometry (i.e. a center plane).

The MIM mapping of the AOs in Figure 14 is contained in Figure 15. The `Datum_defined_by_derived_shape` maps to the `datum` entity, and the `Centre_plane` maps to the `centre_of_symmetry` entity, both subtypes of `shape_aspect`. In both cases, the inherited attribute `shape_aspect.description` is set to the value `'plane'` in order to appropriately specialize the two entities. As may be seen in Figure 15, the `centre_of_symmetry` is defined by two entities of type `shape_aspect`, each of which has an `advanced_face` as its `shape_representation`.

There are four datum planes defined in the JEDEC Pub. 95 specification of the QFP package family (see Figure 7). Datum features A, B, C, and D are used to define four datum planes, A-B, C, and D which

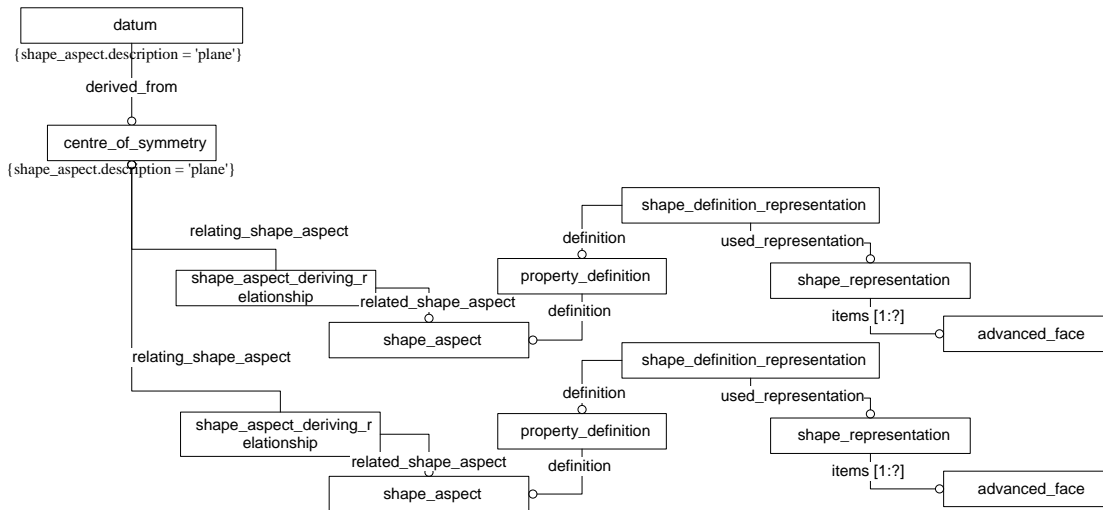**Figure 14. A datum defined by a derived center plane.**

Figure 15. MIM mapping of a derived center plane (and a datum defined by derived center plane).

together constitute a datum reference frame.

Datum features A, B, and D would be modeled as discussed previously (see Figure 14 and Figure 15). Datum A-B would be modeled as a common datum (composed of datums A and B).

The ARM AO Common_datum is composed of a minimum of two Single_datum AOs. Both Datum_plane and Datum_defined_by_derived_shape are subtypes of Single_datum (see Figure 13). The MIM mapping for the A-B Common_datum AO and its relationship with the two individual datum planes is detailed in Figure 16.

Datum C represents the seating plane. As specified in Design Guide 4.4a of JEDEC Pub. 95, the seating plane is the "plane established by three or more leads that support the device when it is placed on top of a horizontal planar surface…. The feet of the leads are datum features that … establish the datum plane."

In order to associate a single datum plane with the feet of the leads as datum features, a complex instance of the ARM AOs `Composite_unit_shape_element` and `Datum_feature` may be employed, as it is intended that the collection of all of the lead feet be treated as a single unit, as opposed to a group (see also `Composite_group_shape_element`). If choosing to model the collection of datum features through a `Composite_unit_shape_element`, the datum itself can be modeled as a `Datum_defined_by_feature+Datum_plane`. The top-level ARM AOs and corresponding MIM mapping for the seating plane datum are detailed in Figure 17.
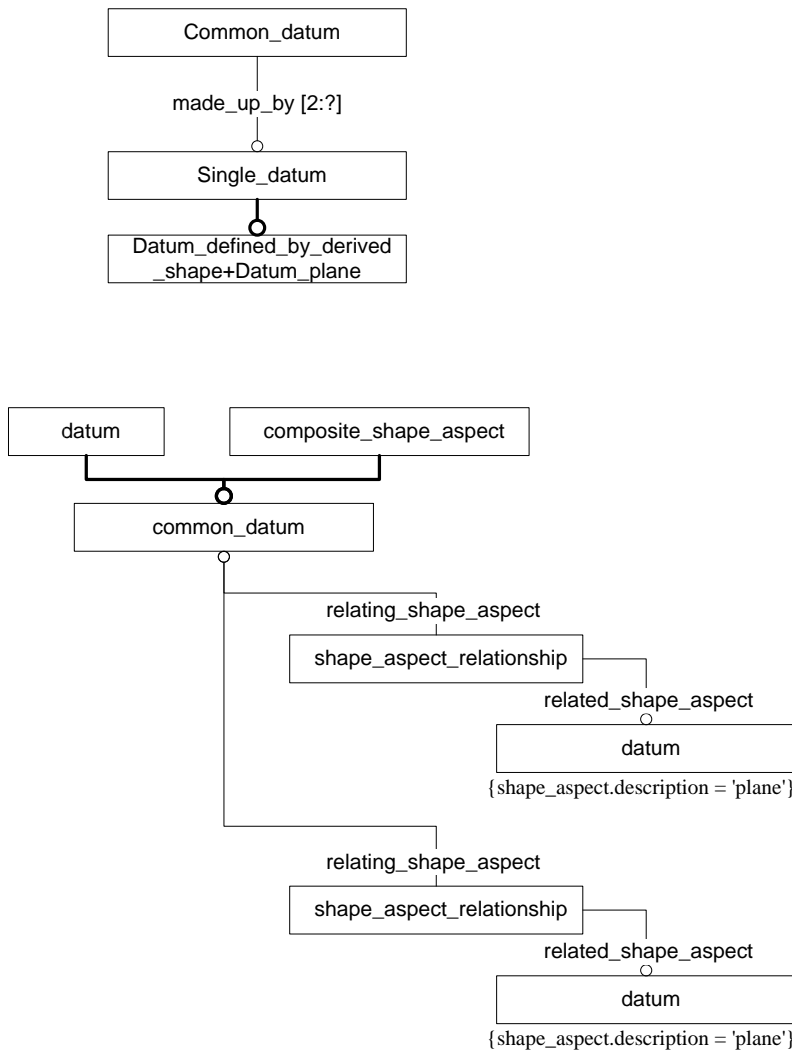

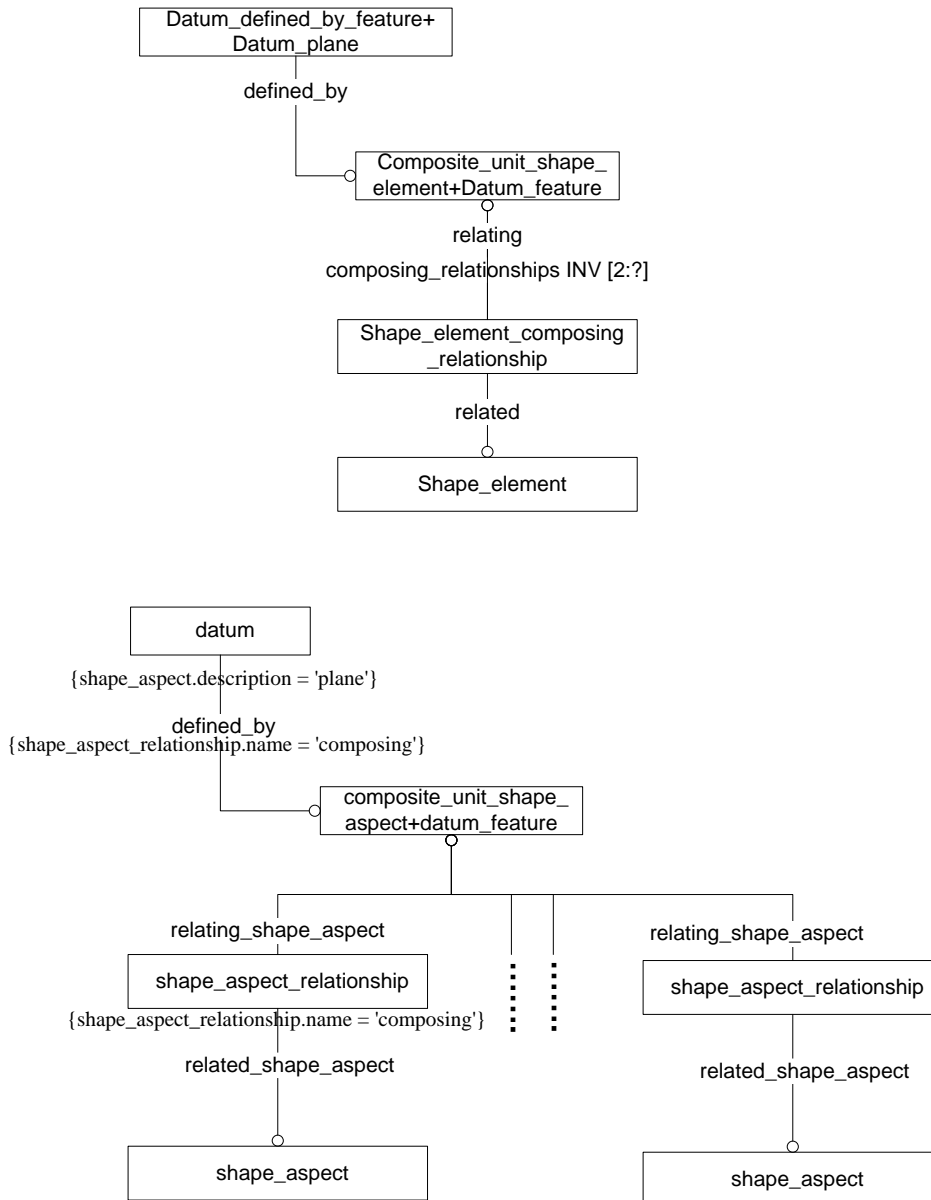**Figure 16. The ARM Common_datum AO and MIM mapping of the A-B datum plane.**

Figure 17. The top-level ARM AOs to be used in the representation of the seating plane (datum C) and their corresponding MIM mappings.

Representation of Geometric Tolerances

In addition to several dimensional tolerances, a number of geometric tolerances are contained in Figure 7. The top-level ARM application objects used to represent geometric tolerances are contained in Figure 18. Figure 19 contains the MIM mapping for the `geometric_tolerance` hierarchy, as well as a number of the key attributes. Tolerances aaa, bbb, and ccc all represent surface profile tolerances. All three have datum references (optional for a surface profile tolerance), and none contain a material condition modifier. For this reason, each would be represented as a complex instance of `geometric_tolerance_with_datum_reference+surface_profile_toleranc`
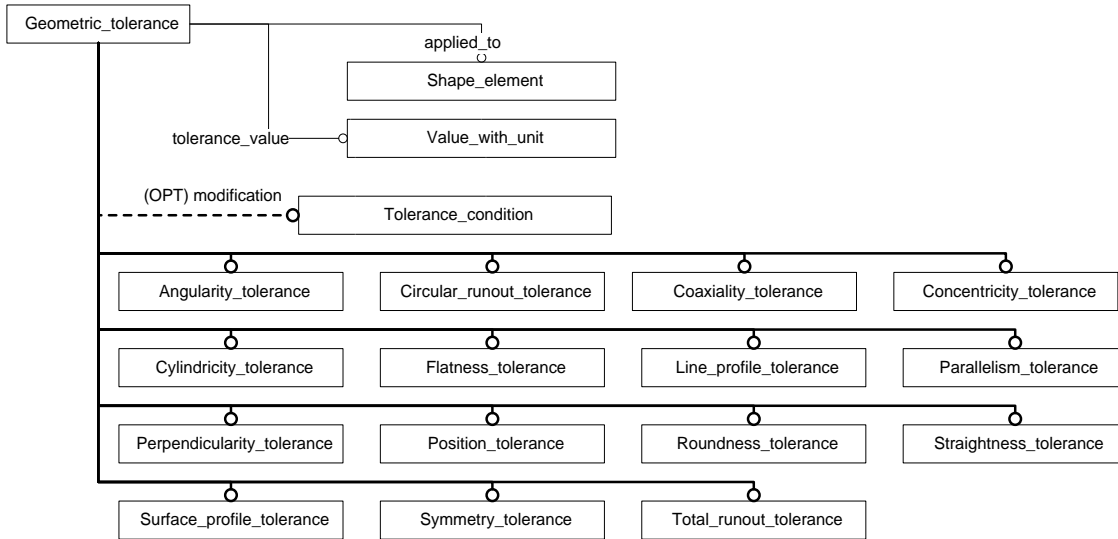
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Figure 18. The top-level subtypes of the Geometric_tolerance AO.

e (see Figure 20). The magnitude of the tolerance would be represented as a `length_measure_with_unit`. In order to communicate the datum references, and their sequence within the datum reference frame, the `geometric_tolerance_with_datum_reference.datum_system` attribute will contain an aggregate of `datum_reference`. As shown in Figure 20, each of the `datum_reference` entities contains an integral `precedence` value, as well as a reference to an individual `datum`. Finally, the tolerance must reference a `shape_aspect`. In the case of surface profile tolerance bbb, there are four instances of the package body side surface that are controlled by the tolerance. These four surfaces (each represented with a `shape_aspect` associated with an `advanced_face`) would be grouped together through a `composite_group_shape_element`. In the case of tolerance aaa, either a single `shape_aspect`, or an aggregation of `shape_aspect` will be used, depending on the representation of the underlying package model.

Positional tolerance ddd is the only positional tolerance called out in Figure 7. This tolerance has a maximum material condition (MMC) modifier, in addition to the datum references. A positional tolerance only controls position of features of size. In this case, tolerance ddd controls the positional accuracy of the center plane of the package terminals. When the MMC condition is applied to modify the location tolerance of a size feature, the tolerance applies at the maximum material condition of the feature. If a material condition modifier is not present, RFS (regardless of feature size) applies automatically.
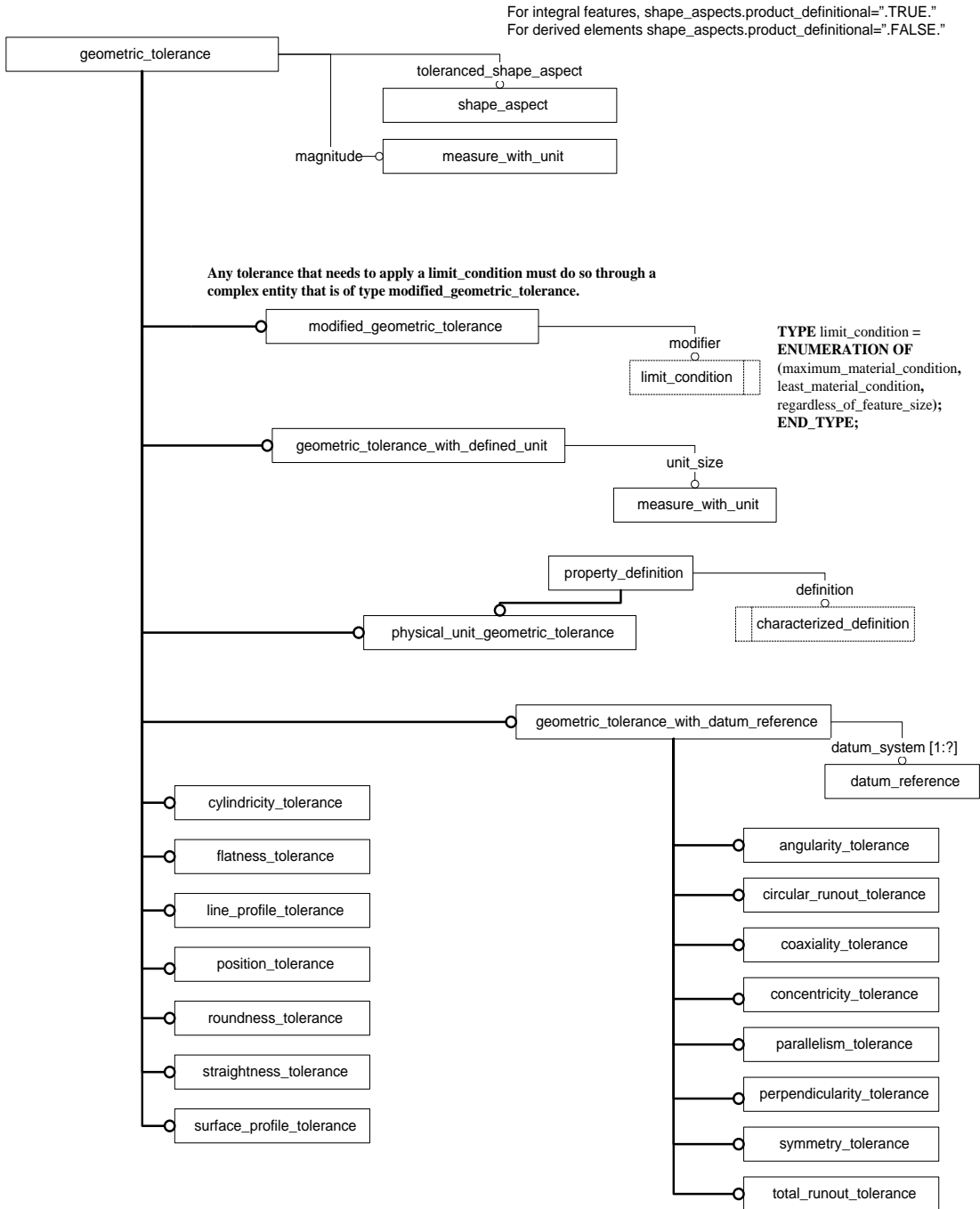
Figure 19. The geometric_tolerance entity hierarchy and certain key attributes.

The two opposing parallel side faces of the terminal constitute an external feature of size. This `shape_aspect` will always be shared between the positional tolerance and a size dimension (the terminal width b). To represent tolerance ddd, we require a complex of `position_tolerance+modified_geometric_tolerance+geometric_tolerance_with_datum_reference` as detailed in Figure 21.
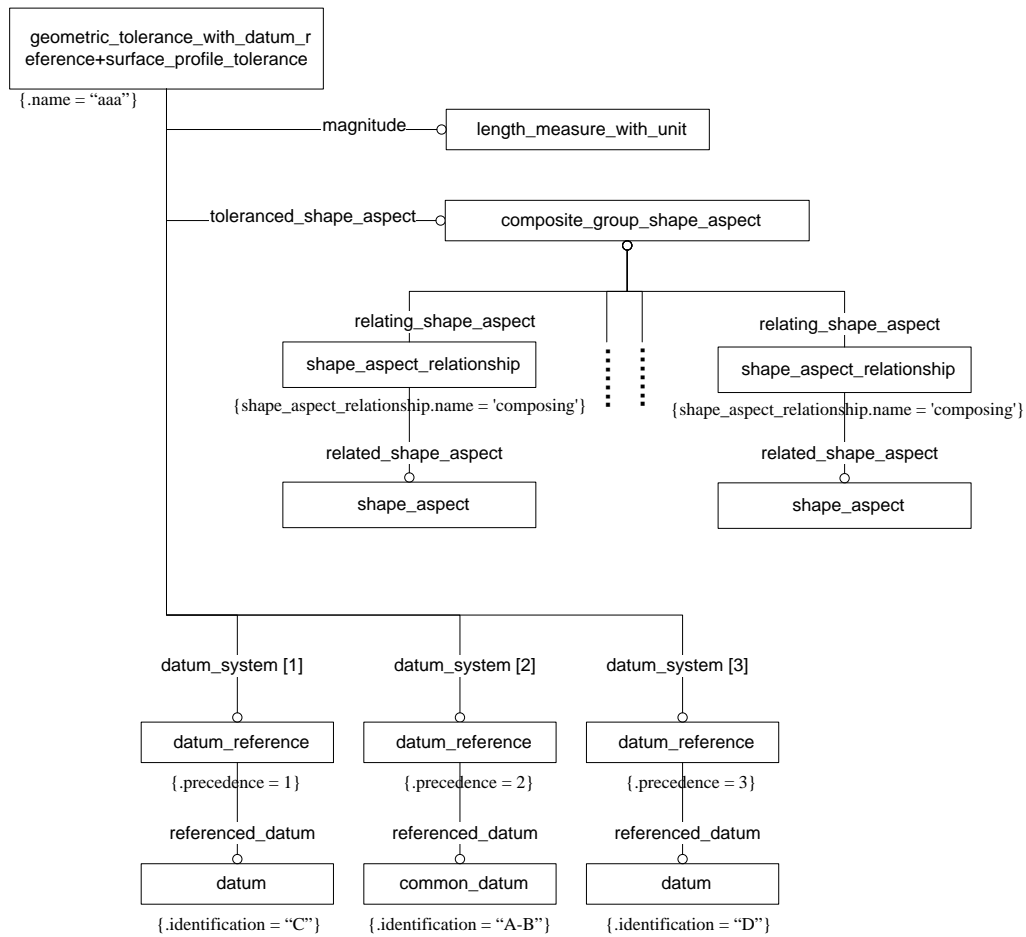
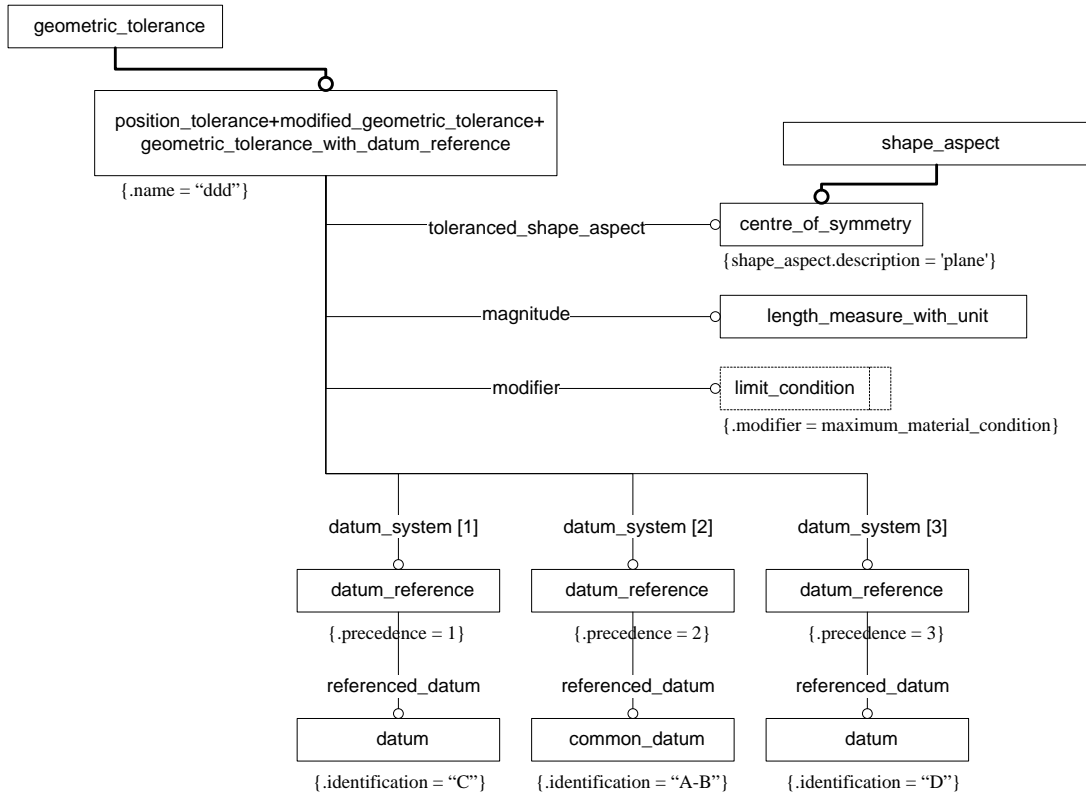**Figure 20. MIM mappings of surface profile tolerance aaa (bbb and ccc similar).**

Figure 21. MIM mapping of tolerance ddd.