AISC EDI Technical Workshop,
17-19th Feb 1999, California

Session 1.5

LPM/5:
Part 1: Basic Principles

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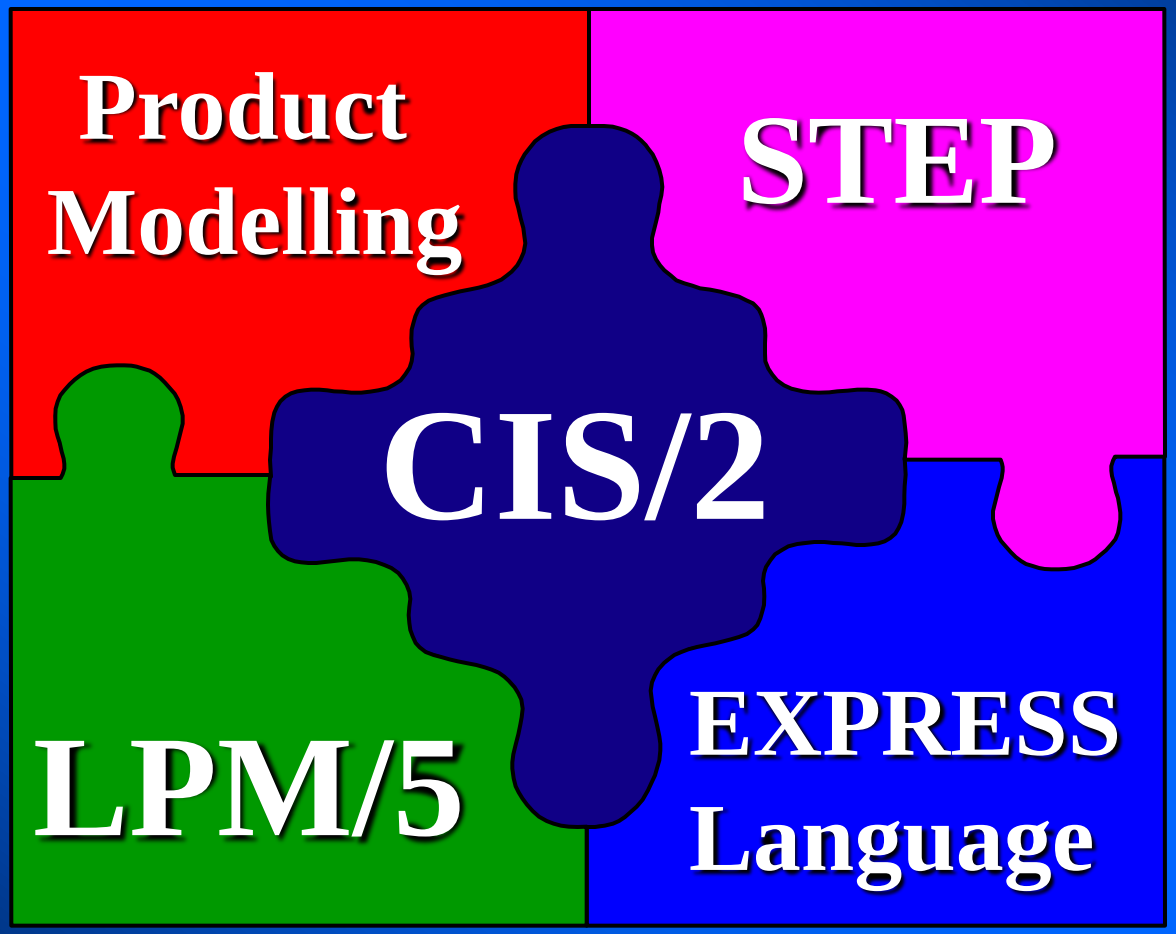
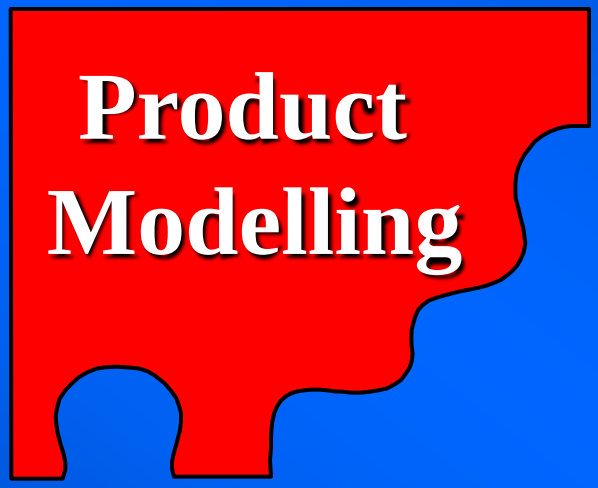
Steel Construction Institute


Product
Modelling
STEP
CIS/2
LPM/5
EXPRESS
Language



- What is a Product Model?
- The Product Model Concept
- Defining a *Lingua Franca*
- Data, Information & Knowledge

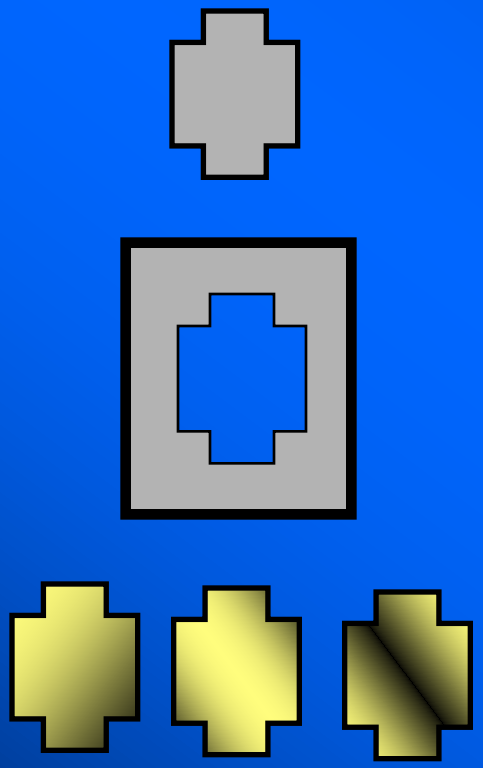
What is a ‘Product Model’?

- 'A Product Model is a formal description of types of ideas and facts,
- with an explicit set of explanatory rules,
- which together form a
  - simplified yet complete,
  - accurate, coherent and unambiguous
  - computer sensible
  - representation of a portion of interest of physically realizable artefacts made by manufacturing processes.'

A Product Model is...

- 'simplified'
  - because there is no need to represent the full complexity of the real world;
- 'complete'
  - for the purposes of communicating information between the human end users (CAE) systems.
- 'computer sensible'
  - as there would be little point in developing a Product Model that cannot be used within CAE systems.
    - The reference to 'types of ideas and facts' emphasises the role the Product Model plays as a 'pattern' or 'template' model as opposed to a populated data model.

The ‘Product Model’ Concept



A “PM” is a pattern ...

... to make a container ...

... to hold information

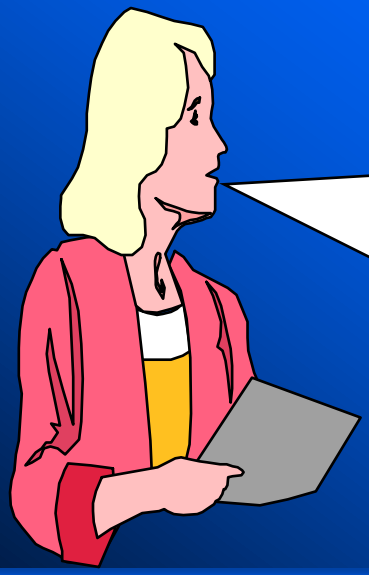
Defining "A lingua franca"

The CIS defines a common language containing:

- a vocabulary of terms
  - a particular set of symbols which are surrogates for an agreed set of objects, concepts or constructs
- the syntax of the language
  - the symbols and rules
- the semantics of the language
  - ascribing meaning to valid combinations of symbols
- a shared context
  - within which relationships between symbols can be interpreted, and the meaning of the message established
- *Compare with a human translator...*

“La construction de ponts de type ‘intégral’ est actuellement en plein essor car elle permet d’éviter les problemes de durabilité liés aux appuis mobiles des ponts á poutres traditonnels.”

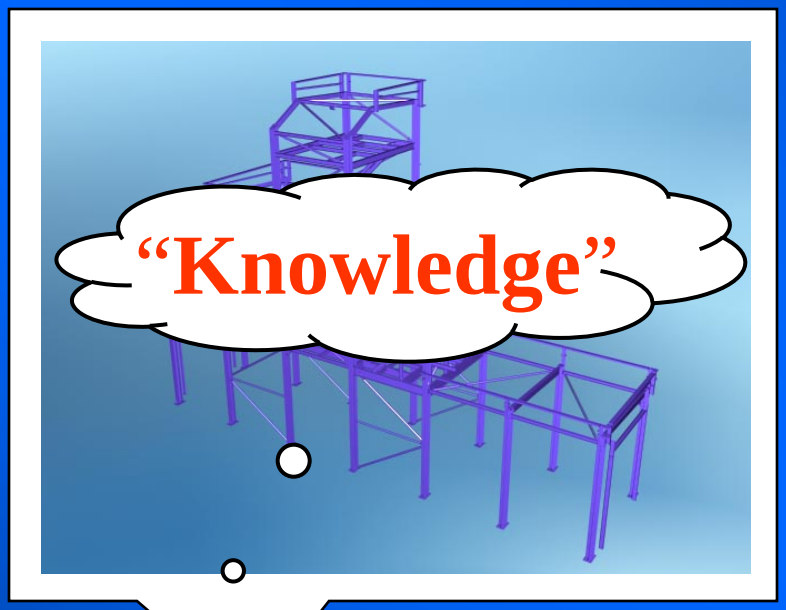
“Actualmente la construccion de puentes integrales se ve favorecida con un intento de evitar los problemas de durabilidad asociados al movimento de las juntas tradicioalmente utilizadas en los puentes de vigas.”

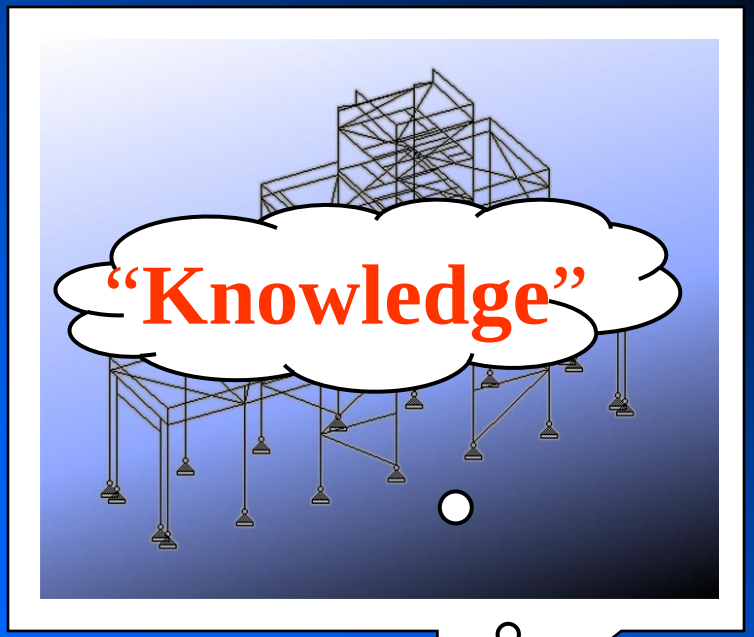


“Integral bridge construction is now being actively pursued as a means to avoid durability problems associated with the movement joints used in traditional beam-type bridges.”

Knowledge structures

- In the absence of any knowledge structure, sentences convey no intrinsic meaning.
- Knowledge structures possessed by humans are extraordinarily rich and complex
- Humans are very good at adapting their interpretations of messages
  - in the light of their own knowledge of the direct context of the message
  - and in the light of their knowledge of the constructs of the sender of the message

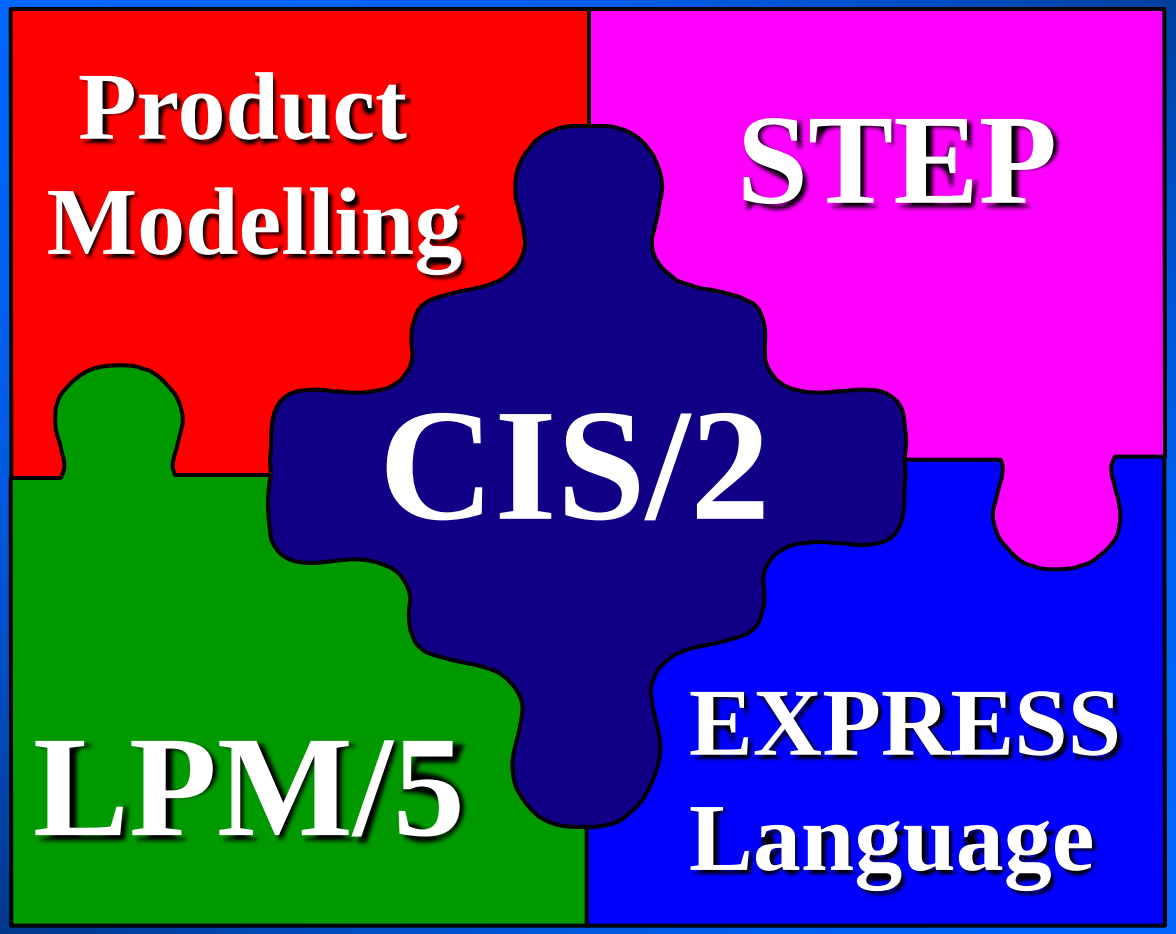




Data

Data, information and knowledge

- ***Computers cannot create knowledge!***
- **Neither can they hold or share knowledge.**
- **Computers can only create, store, or manipulate data.**
- **Knowledge remains with the end-user**


Product
Modelling
STEP
CIS/2
LPM/5
EXPRESS
Language

- The LPM Concept
- Requirements of LPM/5
- Fundamental Principles
- Key Aspects

The LPM Concept

- **Logical**
  - **It exists at the logical level, as opposed to the application or physical level.**
- **Product**
  - **the product we are concerned with is a building-type structural steel frame.**
- **Model**
  - **It is a limited representation of some aspect of the real world.**

The Logical Product Model

- The LPM defines a logical structure for data in terms of:
  - entities (or things),
  - attributes (or characteristics),
  - and relationships between entities.

LPM/5

- A formal definition of how engineering information should be systematically structured for data exchange
  - Intended to cover all types of engineering information associated with a steel frames
- Graphically presented in EXPRESS-G
- Formally specified in EXPRESS
  - Short form (containing definitions of specialized constructs)
  - Long form (implementation schema)
- The key component of the CIS

LPM/5: Short Form

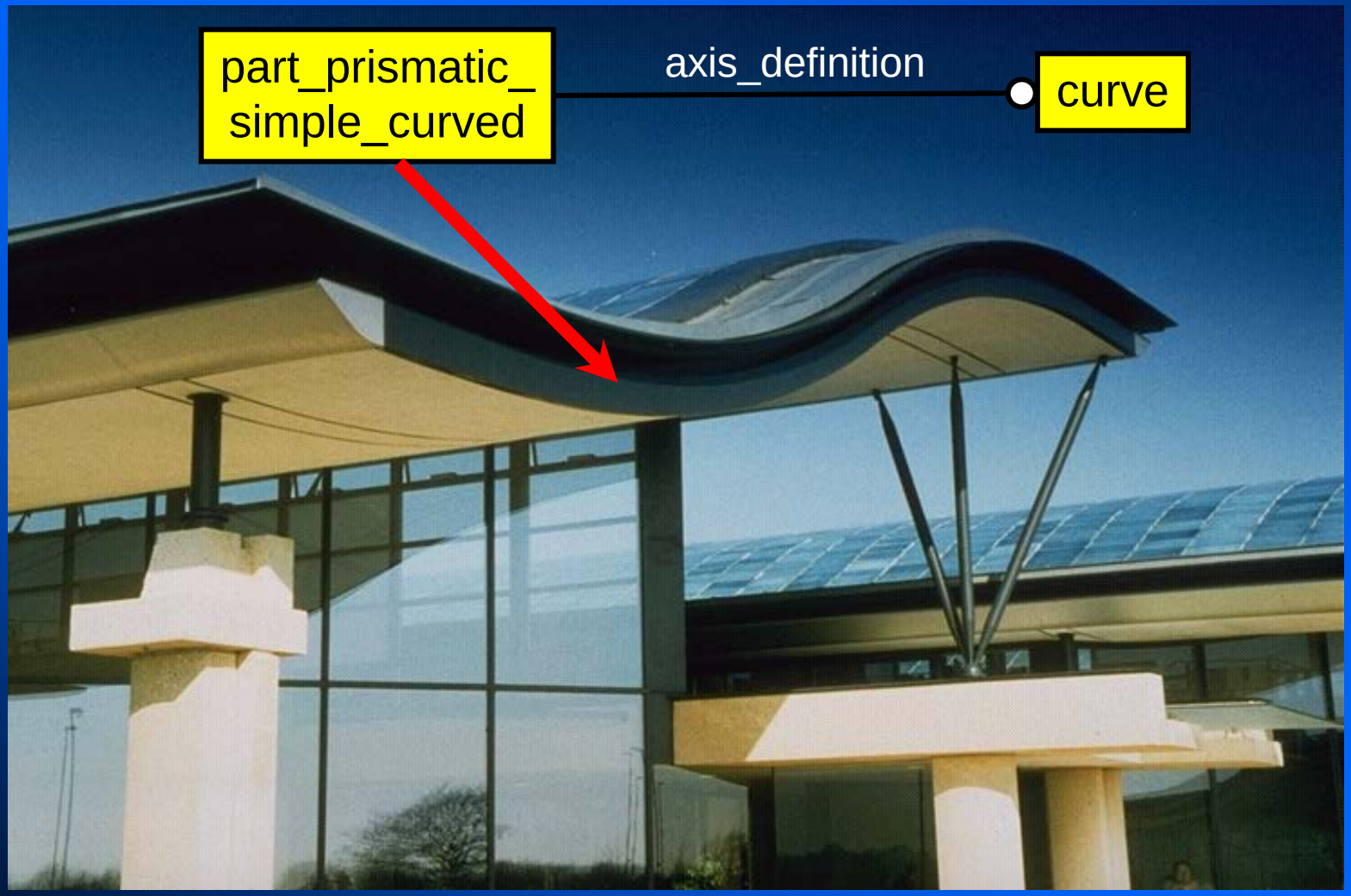
- **LPM/5 EXPRESS Schema 'short form'**
  - **provides illustrated descriptions of LPM/5 entities**
    - **with their attributes & formal propositions (rules & constraints),**
    - **together with references to STEP resources.**
    - ***It does not repeat the definitions of those STEP entities that have been used from the Generic Resources.***
  - **Contains**
    - **Schema Declaration**
    - **Schema Interface Declarations**
    - **Type Declarations - *for Types specific to LPM/5***
    - **Entity Declarations - *for Entities specific to LPM/5***
    - **Rule Declarations**
    - **Function Declarations**

LPM/5 Long Form

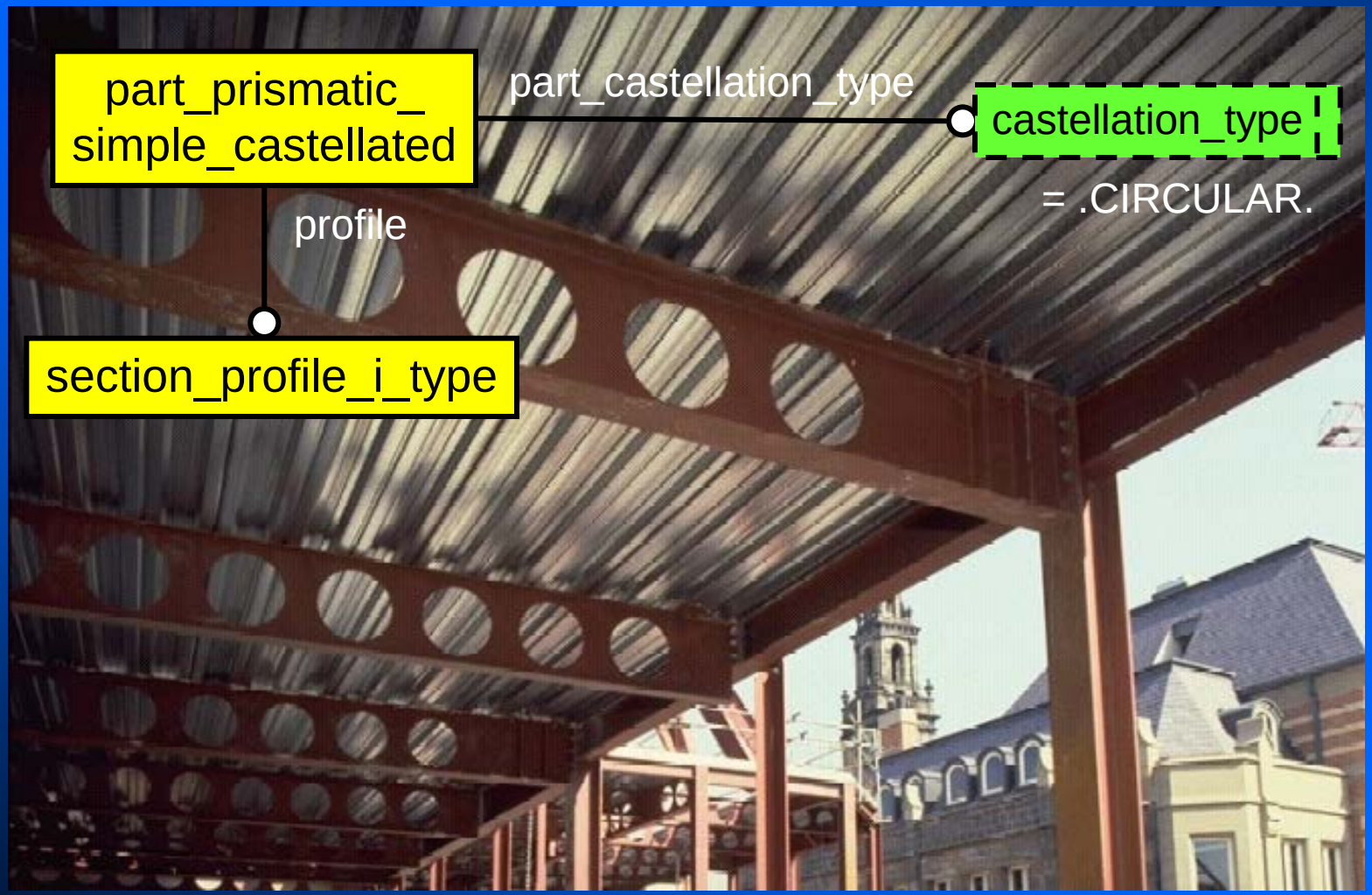
- **LPM/5 EXPRESS Schema 'long form'**
  - one single schema
  - with all the inter-schema references resolved.
  - contains no definitions or explanations,
  - merely an EXPRESS long form listing of the CIS/2 implementation schema.
  - Contains
    - Schema Declaration - STRUCTURAL_FRAME_SCHEMA
    - Type Declarations - *for all (Generic & Specific) Types*
    - Entity Declarations - *for all (Generic & Specific) Entities*
    - Rule Declarations - *for all (imported) Rules*
    - Function Declarations - *for all (imported) Functions*

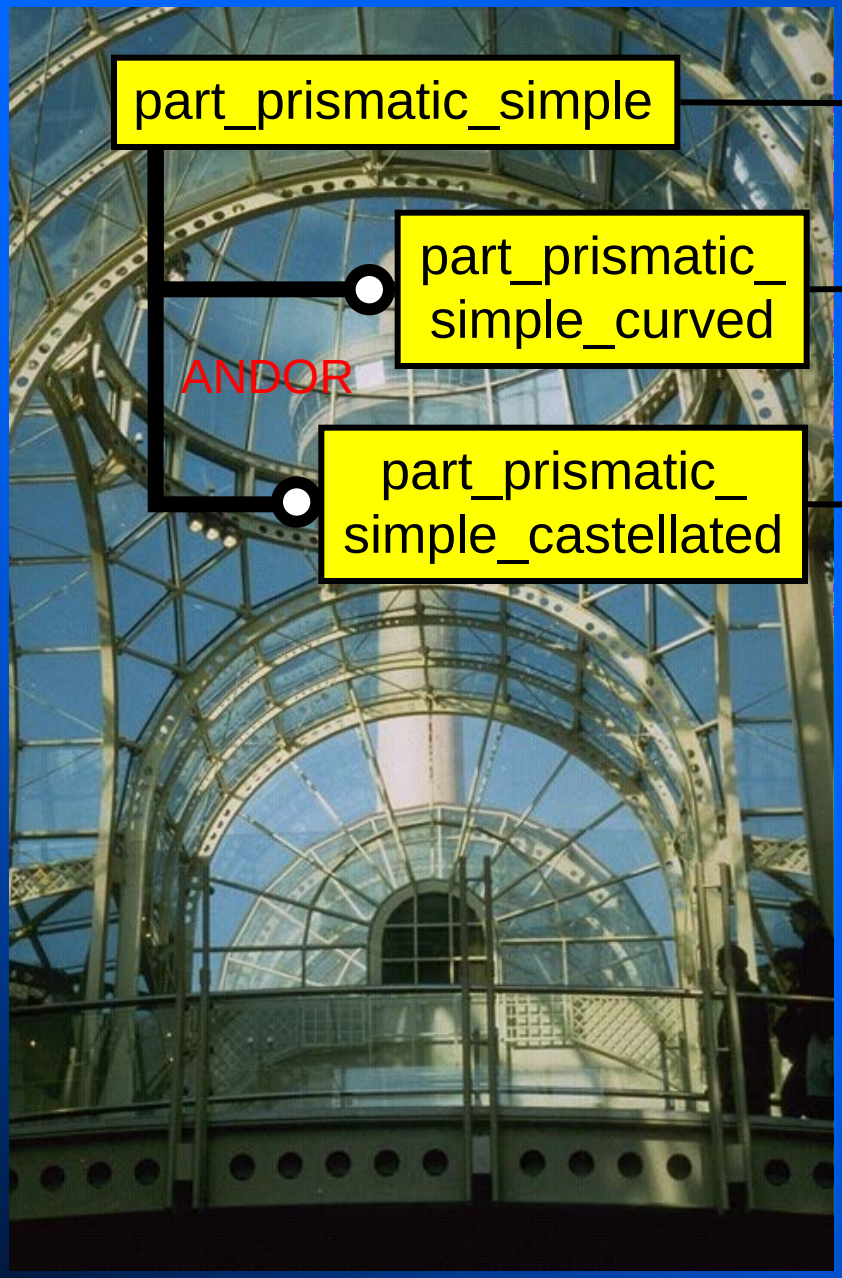
Limitations of CIS/1

Requirements of LPM/5



Requirements of LPM/5





part_prismatic_simple

profile

section_profile_i_type

part_prismatic_
simple_curved

axis_definition

curve

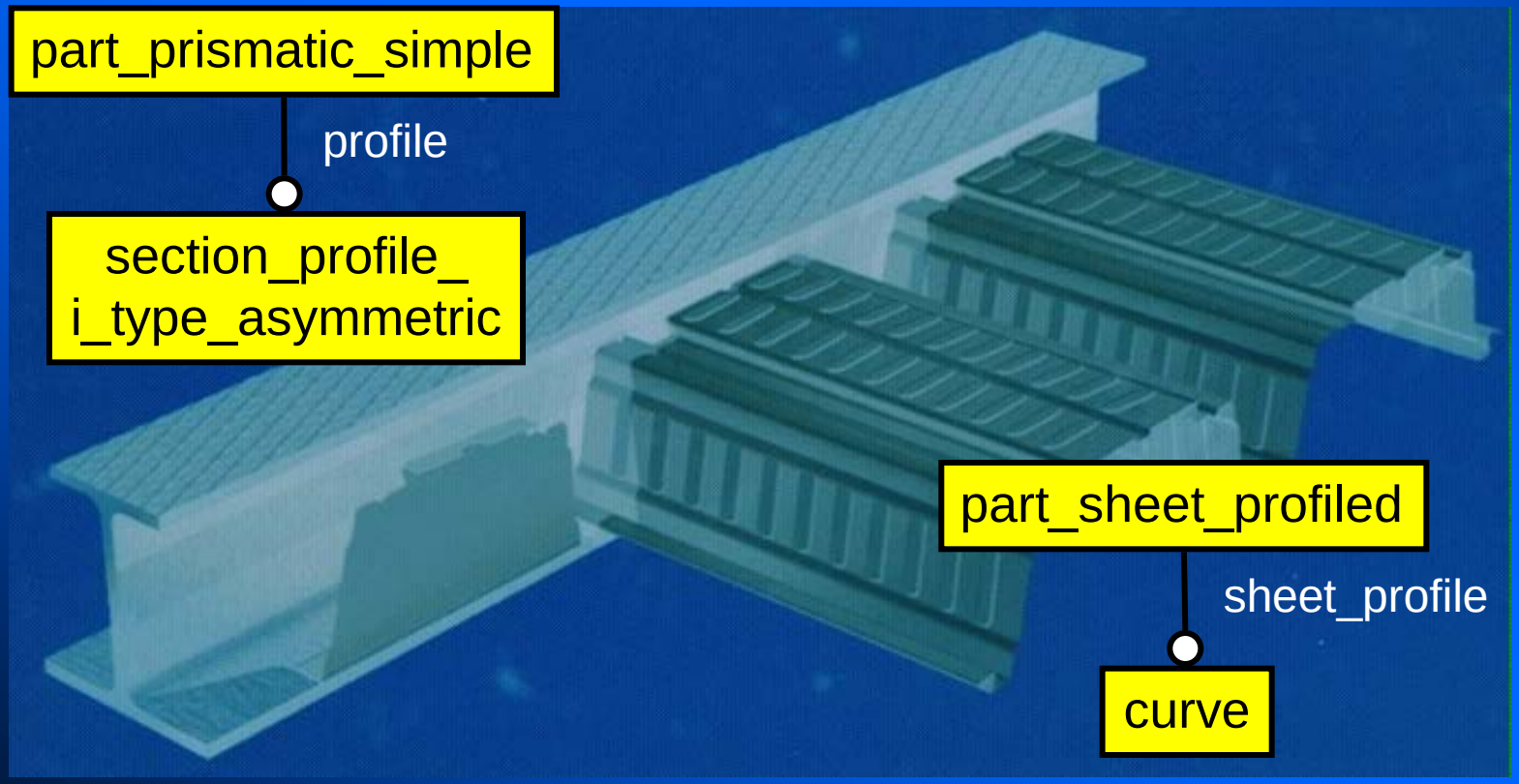
ANDOR

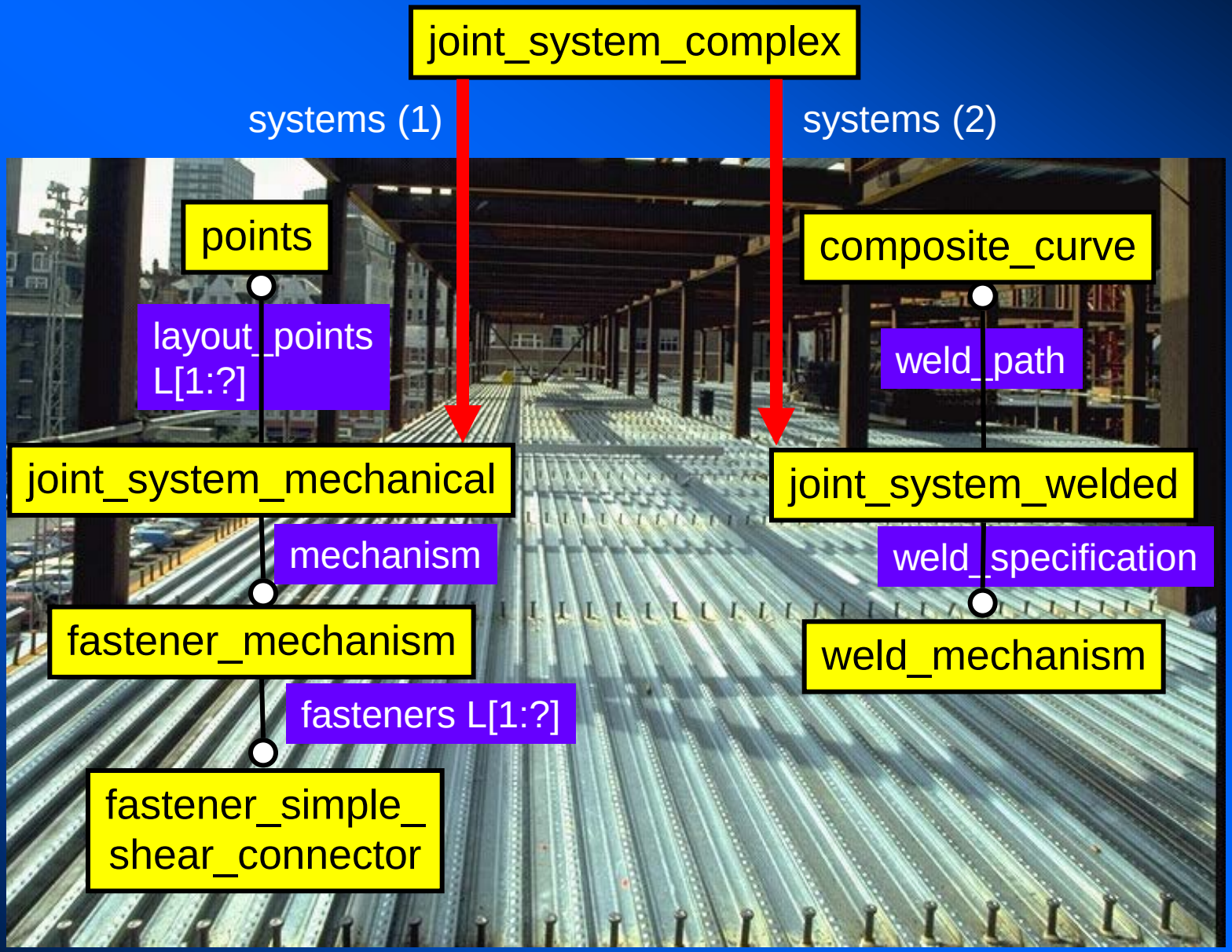
part_prismatic_
simple_castellated

part_castellation_type

castellation_type

= .CIRCULAR.

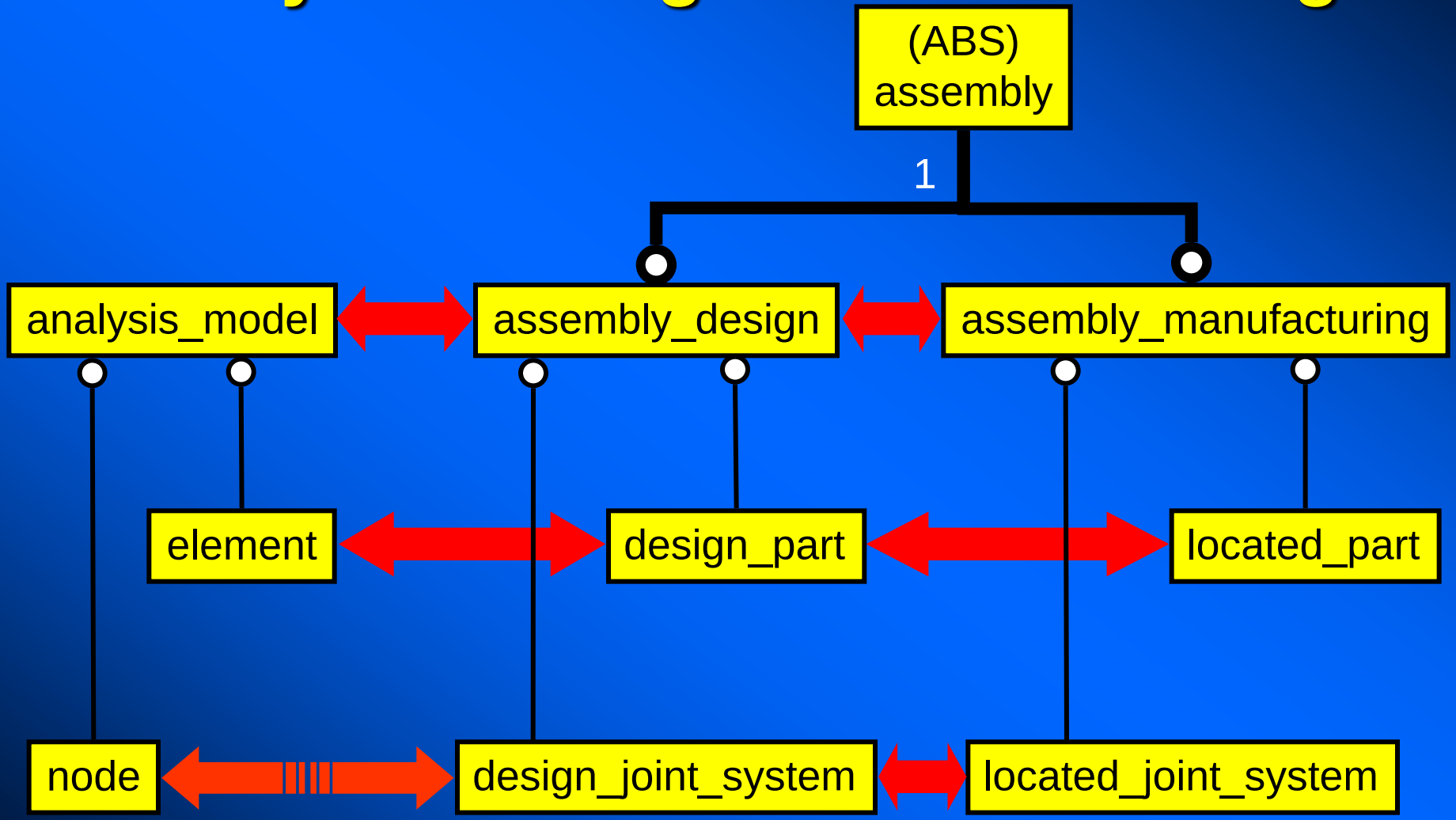

part_prismatic_simple
profile
section_profile_
i_type_asymmetric
part_sheet_profiled
sheet_profile
curve


joint_system_complex
systems (1)
systems (2)
points
layout_points L[1:?]
composite_curve
weld_path
joint_system_mechanical
joint_system_welded
mechanism
weld_specification
fastener_mechanism
weld_mechanism
fasteners L[1:?]
fastener_simple_ shear_connector

Fundamental Principles of LPM/5

- CIS/2 presents LPM/5 as both:
  - Short form EXPRESS schema and
  - Long form EXPRESS schema
- LPM/5 uses STEP 'Generic Resources' wherever possible
  - ISO 10303-41: 1994 - *date, person, measures and units*
  - ISO 10303-42: 1994 - *explicit geometry and topology*
  - ISO 10303-43: 1994
  - ISO 10303-44: 1994
- LPM/5 contains 3 "Views" (models) of structure
  - Analysis, Design, Manufacturing (Physical)

Relationship in LPM/5 between Analysis - Design - Manufacturing



Key Aspects of LPM/5

- Data management constructs
  - separating data from meta-data
- Product item references
  - standard, proprietary, library
- Inclusion of implicit & explicit geometry
  - simple & complex
- Use of ANDOR SUPERTYPEs
- Use of ‘associative entities’
  - the ‘level discriminator’
- Units and measures
  - Global and individual

Naming Convention

- Entities listed in alphabetical order

  ENTITY action;

  ...

  ...

  ENTITY zone_of_structure

- Entities given full names
  - abbreviations avoided
  - name reflects inheritance

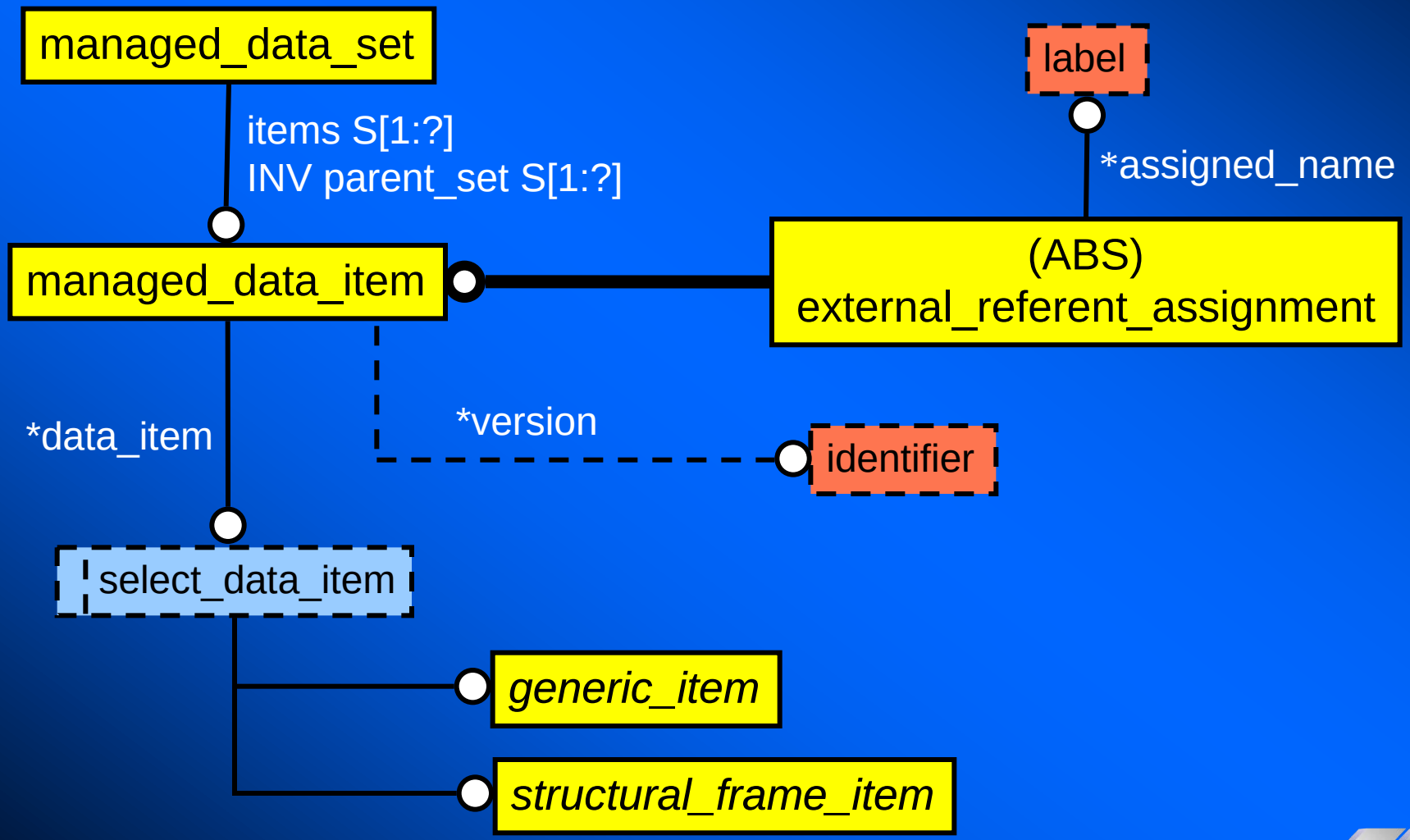
    e.g. assembly_design_structural_member_linear

Data Management in CIS/2

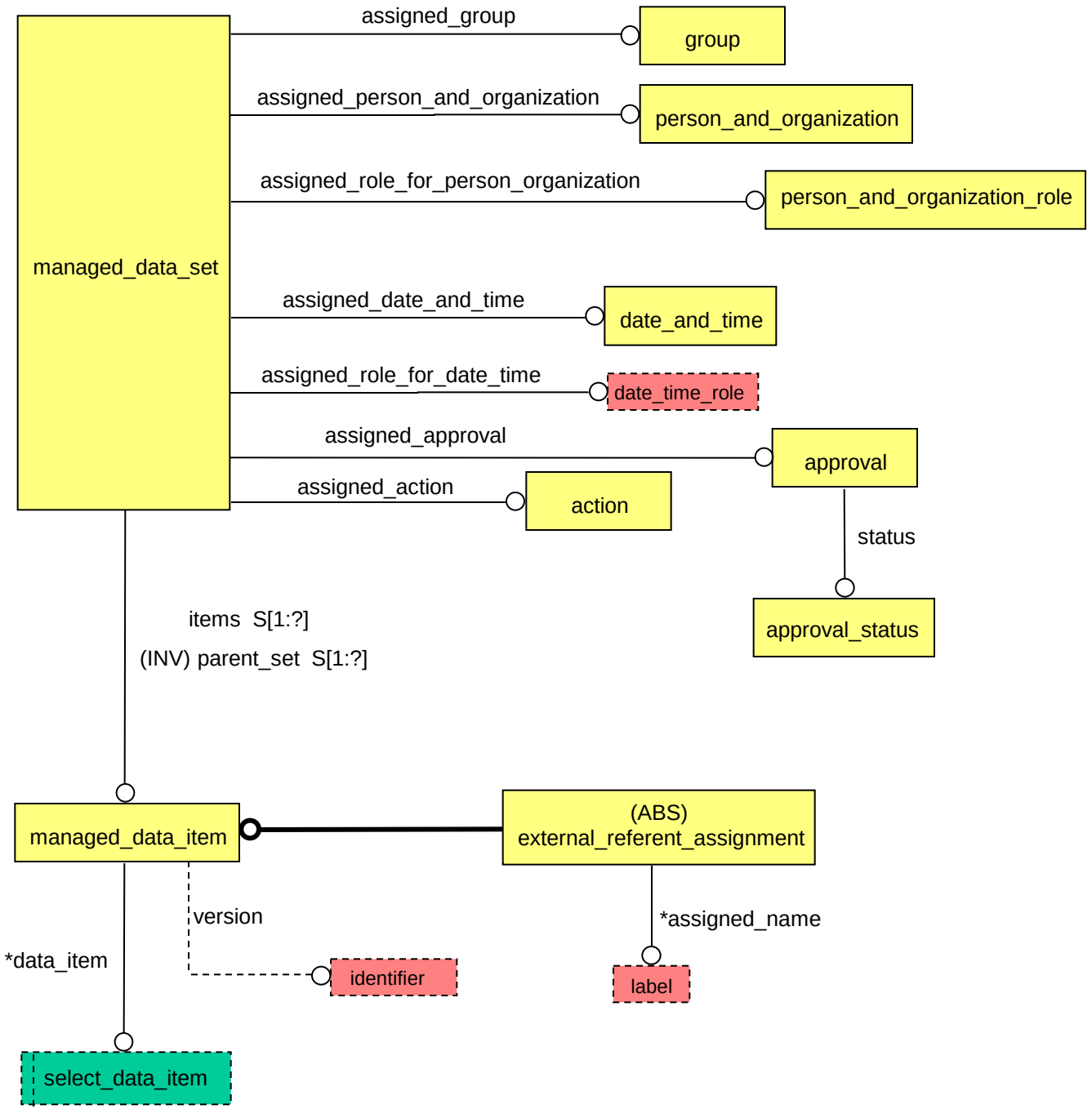
- **LPM/5 separates data from ‘meta-data’,**
  - ***This ‘meta-data’ includes some or all of the following:***
    - **The unique identifier for the item.**
    - **The version of the item.**
    - **The person who created the data.**
    - **The date when it was created.**
    - **Whether the data was new or old data that had been modified.**
    - **The date when it had been modified.**
    - **Whether the data has been approved or not.**

Data Management via CIS/2

- In CIS/2, data management is considered to be the process of assigning meta-data to data.
  - ‘Data Management Conformant’ (DMC) applications produce ‘managed data’
    - Each item of data is given a unique id and placed in a data set
  - ‘Non-DMC applications’ produce ‘unmanaged data’
- Using a DMC application,
  - ‘unmanaged data’ may be mapped onto meta data
  - to become ‘managed data’


managed_data_set
items S[1:?]
INV parent_set S[1:?]
label
*assigned_name
managed_data_item
(ABS)
external_referent_assignment
*data_item
*version
identifier
select_data_item
generic_item
structural_frame_item

EXPRESS-G Diagram

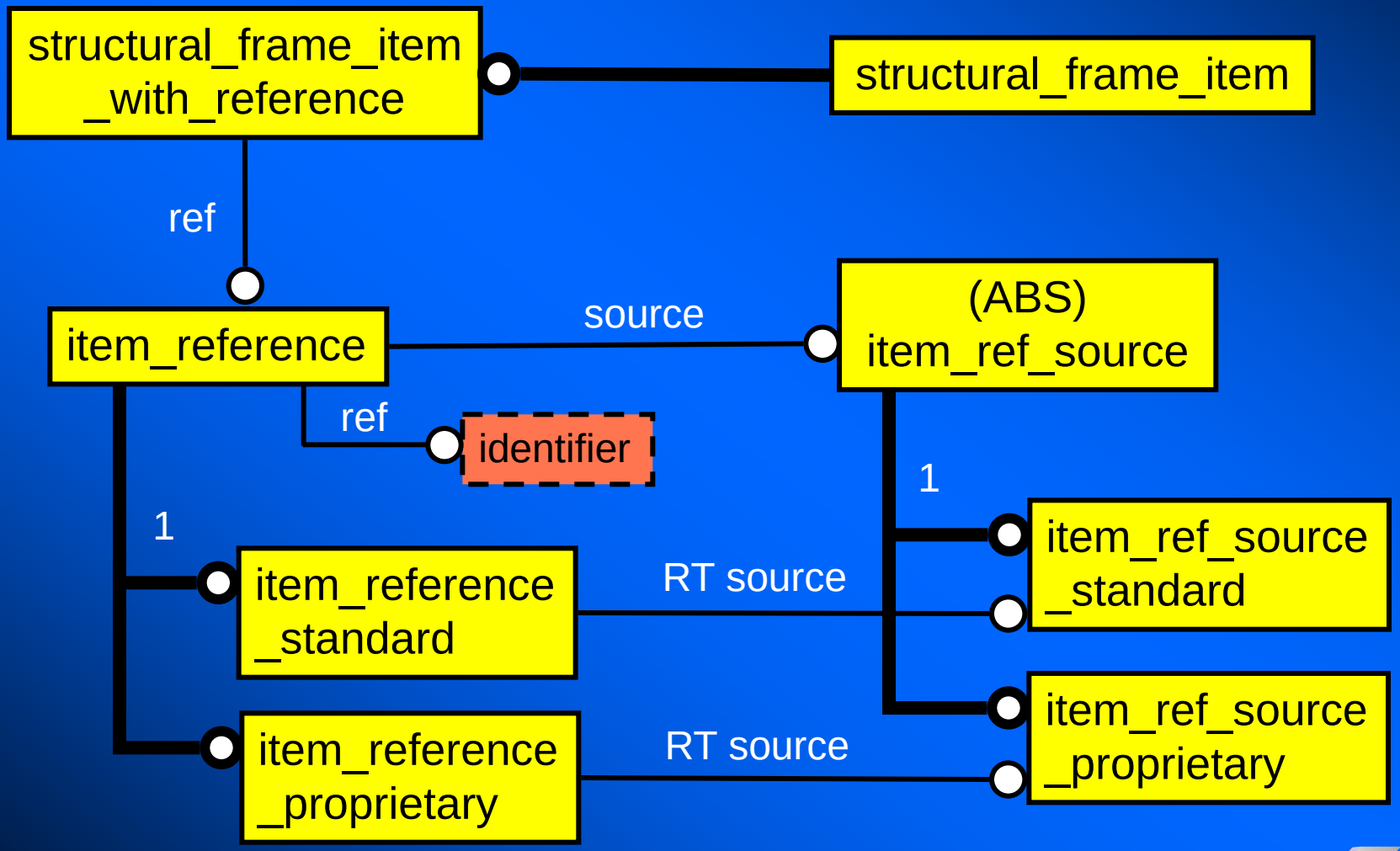


EXPRESS Schema (extract)

```
ENTITY managed_data_set;
        assigned_group : group;
        assigned_person_and_organization : person_and_organization;
        assigned_role_for_person_organization : person_and_organization_role;
        assigned_date_and_time : date_and_time;
        assigned_role_for_date_time : date_time_role;
        assigned_approval : approval;
        assigned_action : action;
        items : SET [1:?] OF managed_data_item;
END_ENTITY;

ENTITY managed_data_item
SUBTYPE OF (external_referent_assignment);
        data_item : select_data_item;
        version : OPTIONAL identifier;
INVERSE
        parent_set : SET [1:?] OF managed_data_set FOR items;
UNIQUE
        UR230 : data_item;
END_ENTITY;
```

Product Identifiers in CIS/2

- 4 classes of product item are defined
  - Standard Items.
  - Proprietary Items
  - Library Items
    - information exchanged by being “passed-by-reference” rather than being “passed by attribute value”.
  - Non-standard Items


structural_frame_item
_with_reference
structural_frame_item
ref
item_reference
source
(ABS)
item_ref_source
ref
identifier
1
1
item_reference
_standard
RT source
item_ref_source
_standard
item_reference
_proprietary
RT source
item_ref_source
_proprietary

EXPRESS Schema (extract)

```
ENTITY structural_frame_item
ABSTRACT SUPERTYPE OF (ONEOF(structural_frame_product,
structural_frame_process) ANDOR structural_frame_item_with_reference);
      item_name : label;
      item_number : INTEGER;
      item_description :OPTIONAL text;
END_ENTITY;

ENTITY structural_frame_item_with_reference
SUBTYPE OF (structural_frame_item);
      ref : item_reference;
END_ENTITY;

ENTITY item_reference
      ref : identifier;
      source : item_ref_source;
END_ENTITY;

ENTITY item_ref_source
ABSTRACT SUPERTYPE OF (ONE OF
      (item_ref_source_standard, item_ref_source_proprietary, item_ref_source_library))
SUBTYPE OF (structural_item);
END_ENTITY;
```

```
ENTITY item_ref_source_standard
SUBTYPE OF (item_ref_source);
      standardization_organization : label;
      name_of_standard : label;
      year_of_standard : year_number;
      version_of_standard : OPTIONAL label;
END_ENTITY;

ENTITY item_ref_source_proprietary
SUBTYPE OF (item_ref_source);
      manufacturers_name : organization;
      manufacturers_range : label;
      year_of_range : year_number;
      version_of_range : OPTIONAL label;
END_ENTITY;

ENTITY item_ref_source_library
SUBTYPE OF (item_ref_source);
      library_owner : person_and_organization;
      library_name : label;
      date_of_library : calendar_date;
      version_of_library : OPTIONAL label;
END_ENTITY;
```

Physical File (extract)

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION(('STEP US FLAVOUR'), '1');
FILE_NAME('Step US Flavour', '11-05-1998', ('AMS'), ('CAE Group'),
 'University of Leeds', 'Tel 0113 233 2317', 'e-mail a.s.watson@leeds.ac.uk');
FILE_SCHEMA(('STRUCTURAL_FRAME_SCHEMA'));
ENDSEC;

DATA;
#3000=GROUP('US Flavour list', 'List of item references in accordance with
ASTM standards');
#3001=FLAVOUR(#3000, (#1, #3, ….. , #2354, #2355)):

#1 = ITEM_REFERENCE_STANDARD('W1100X424', #2);
#2 = ITEM_REF_SOURCE_STANDARD('ASTM', 'ASTM_A6M', 1994, $);
#3 = ITEM_REFERENCE_STANDARD('W1100X369', #2);
#4 = ITEM_REFERENCE_STANDARD('W1100X333', #2);
#5 = ITEM_REFERENCE_STANDARD('W1100X295', #2);

#2354 = ITEM_REFERENCE_STANDARD('M30_TYPE1', #2349);
#2355 = ITEM_REFERENCE_STANDARD('M36_TYPE1', #2349);
ENDSEC;
END-ISO-10303-21;
```

Implicit and Explicit Geometry

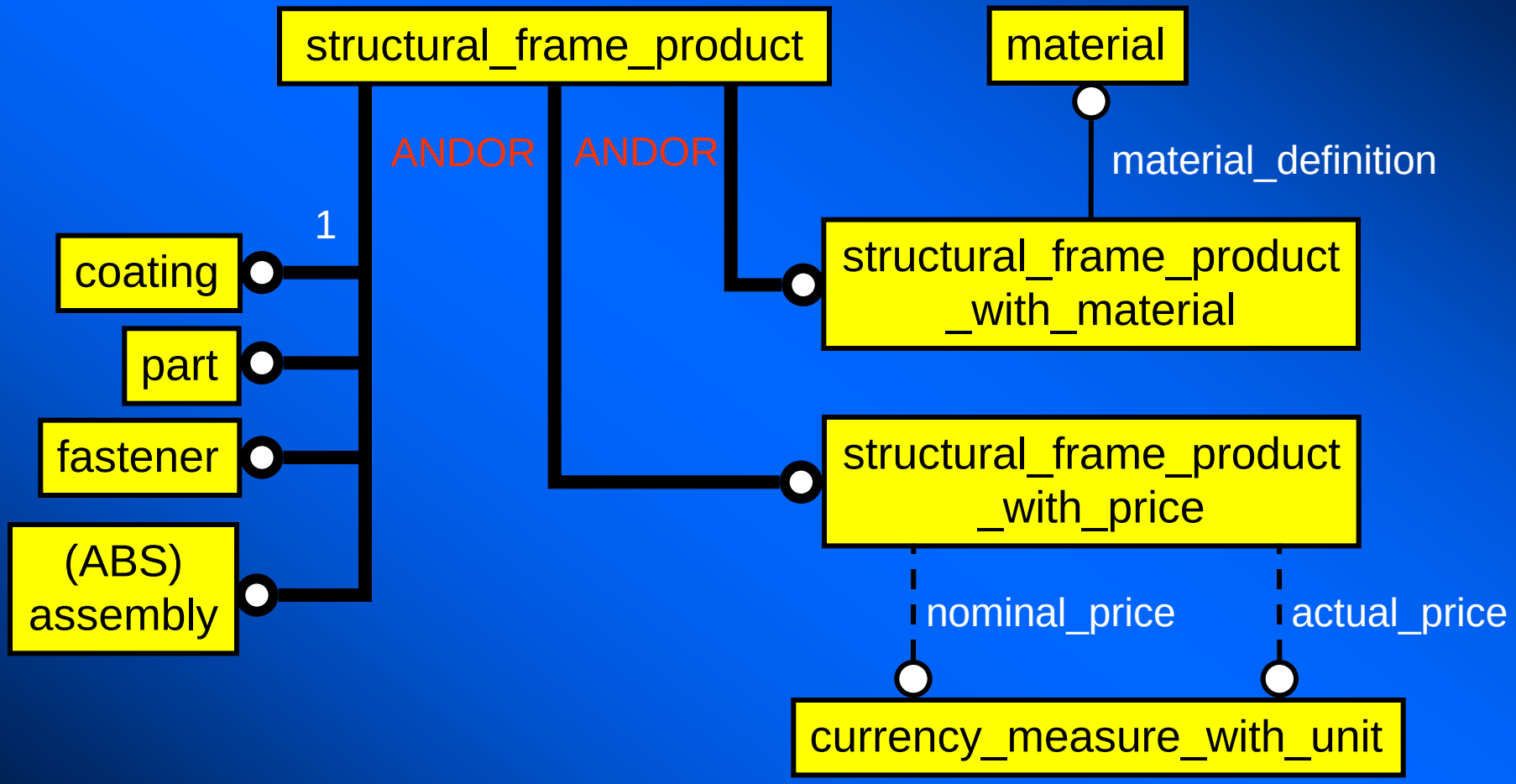
- CIS/1 contained no provision for explicit geometry
  - all geometry defined implicitly using parameters
- CIS/2 incorporates the whole of STEP Part 42
  - all the EXPRESS constructs for geometry and topology included in LPM/5
  - used as resources as required

Simple & Complex Objects

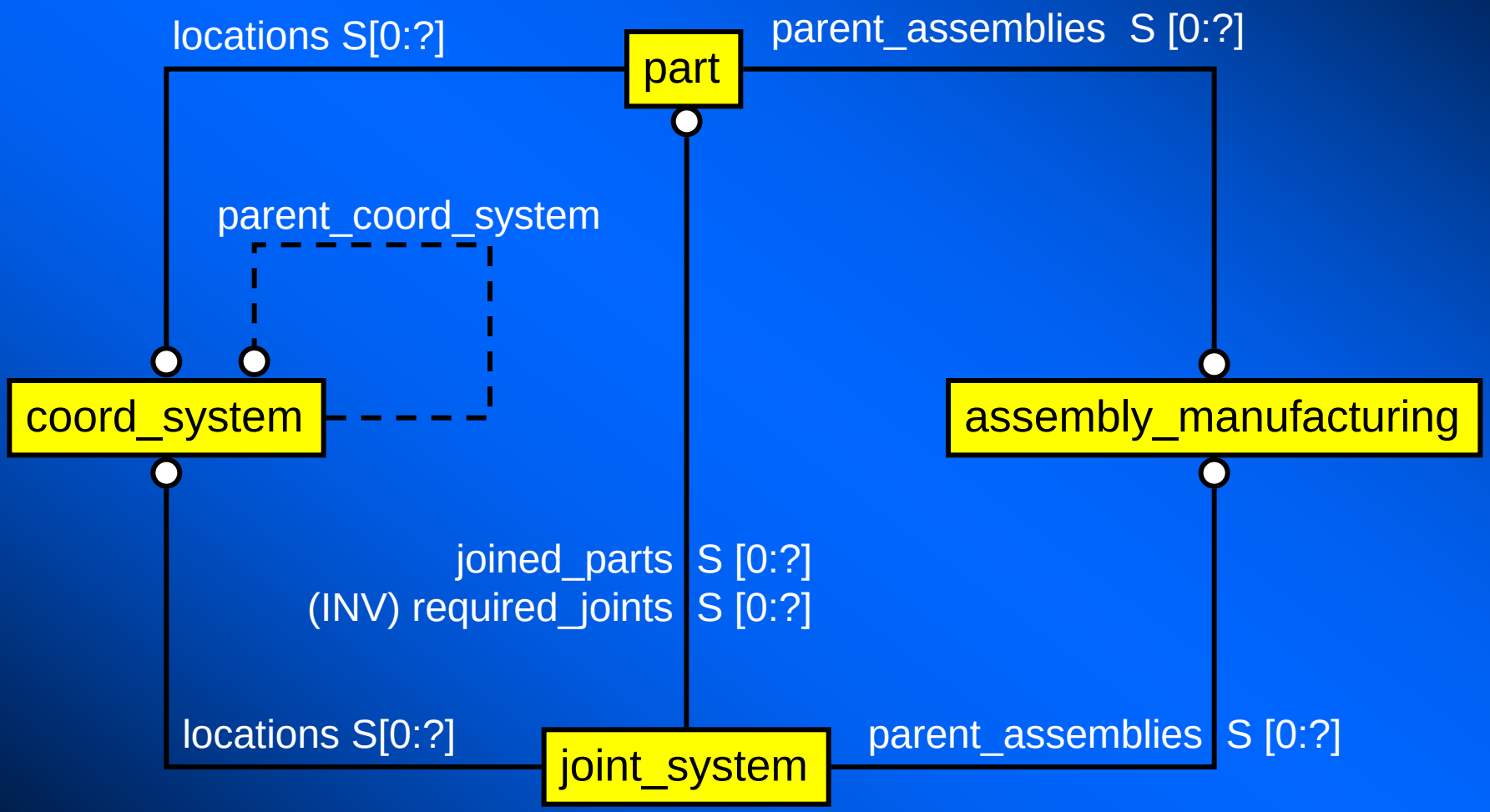
- In LPM/5 Objects are categorized (through subtyping) as either simple or complex
  - depending on the definition of the shape of object
- Simple Objects
  - have their shape defined implicitly through parameters
- Complex Objects
  - have their shape defined explicitly using constructs from STEP Part 42

```
ENTITY object
    SUPERTYPE OF (ONE OF(object_simple, object_complex));
END_ENTITY;

ENTITY object_simple
    SUBTYPE OF (object);
        length : length_measure_with_unit;
        depth : length_measure_with_unit;
        width : length_measure_with_unit;
END_ENTITY;

ENTITY object_complex
    SUBTYPE OF (object);
        shape : shape_representation;
END_ENTITY;
```

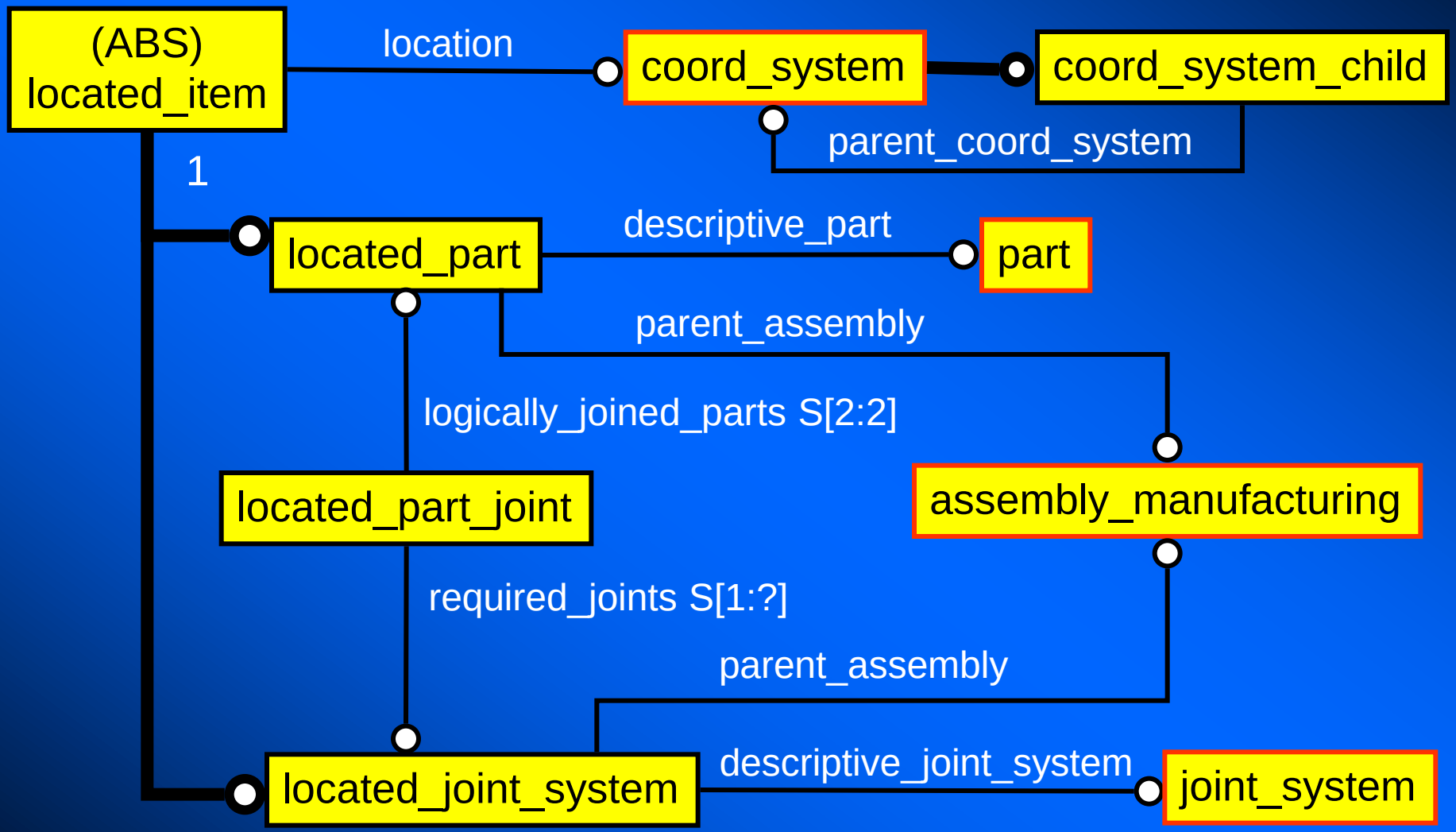
ANDOR SUPERTYPEs



‘Associative entities’



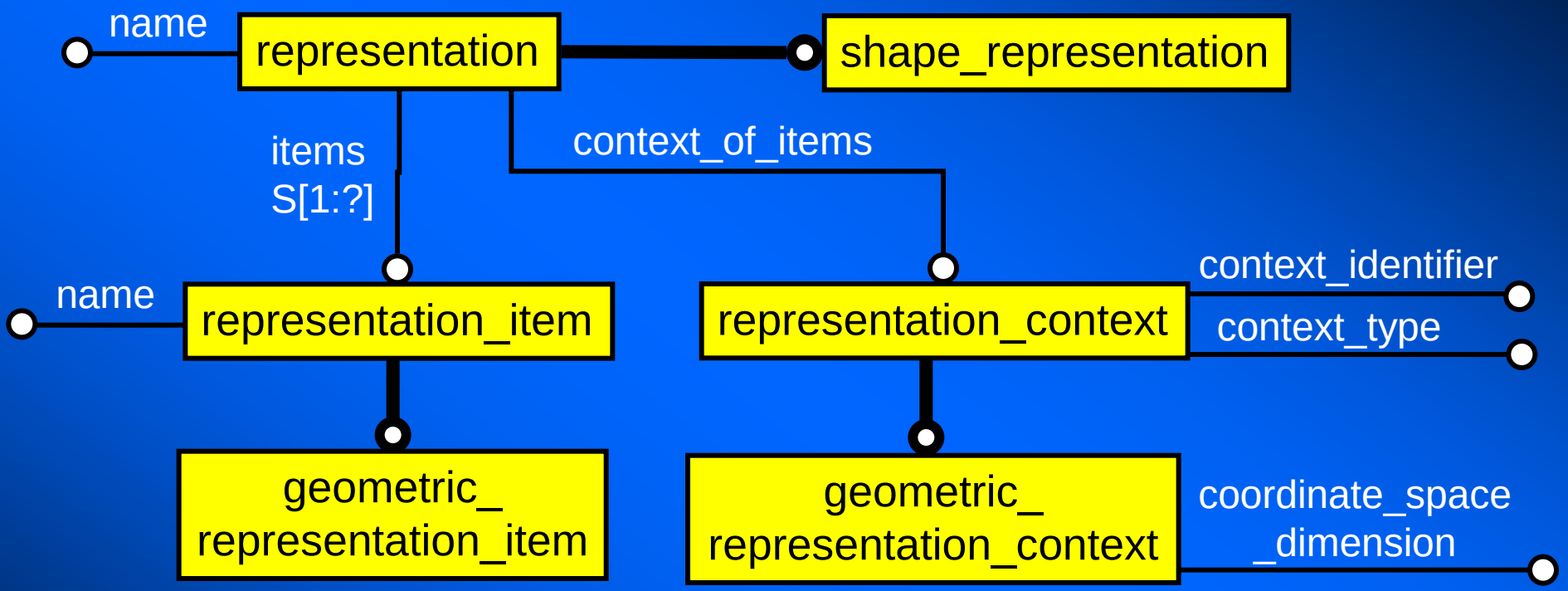
‘The Level Discriminator’



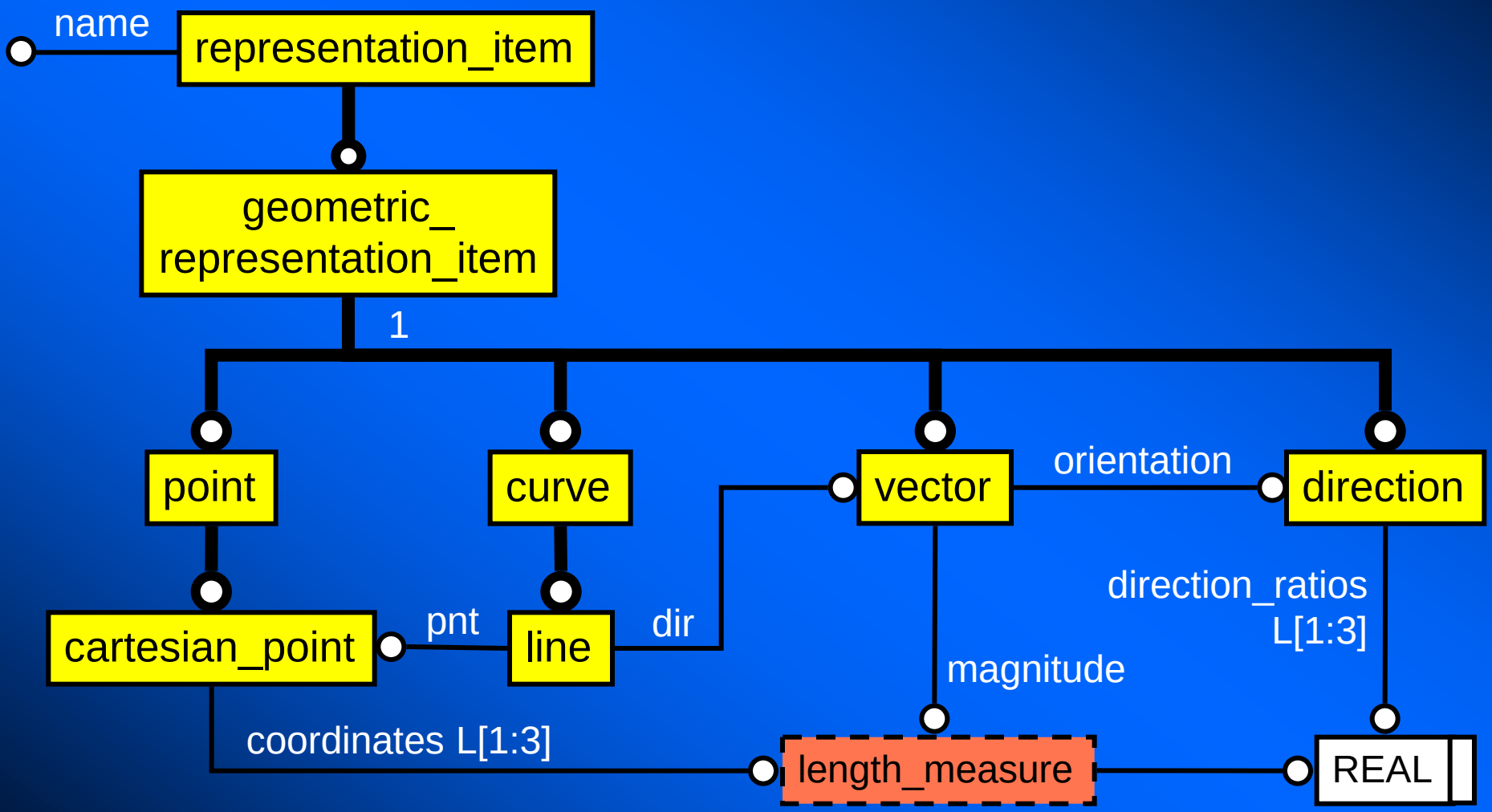
Units & Measures

- Constructs for units and measures have been taken from STEP Part 41
  - Using the ‘interpreted route’
- Units are specified either Globally or individually
  - In general, constructs taken from STEP have their units assigned globally
  - Constructs developed for LPM/5 have their units assigned individually

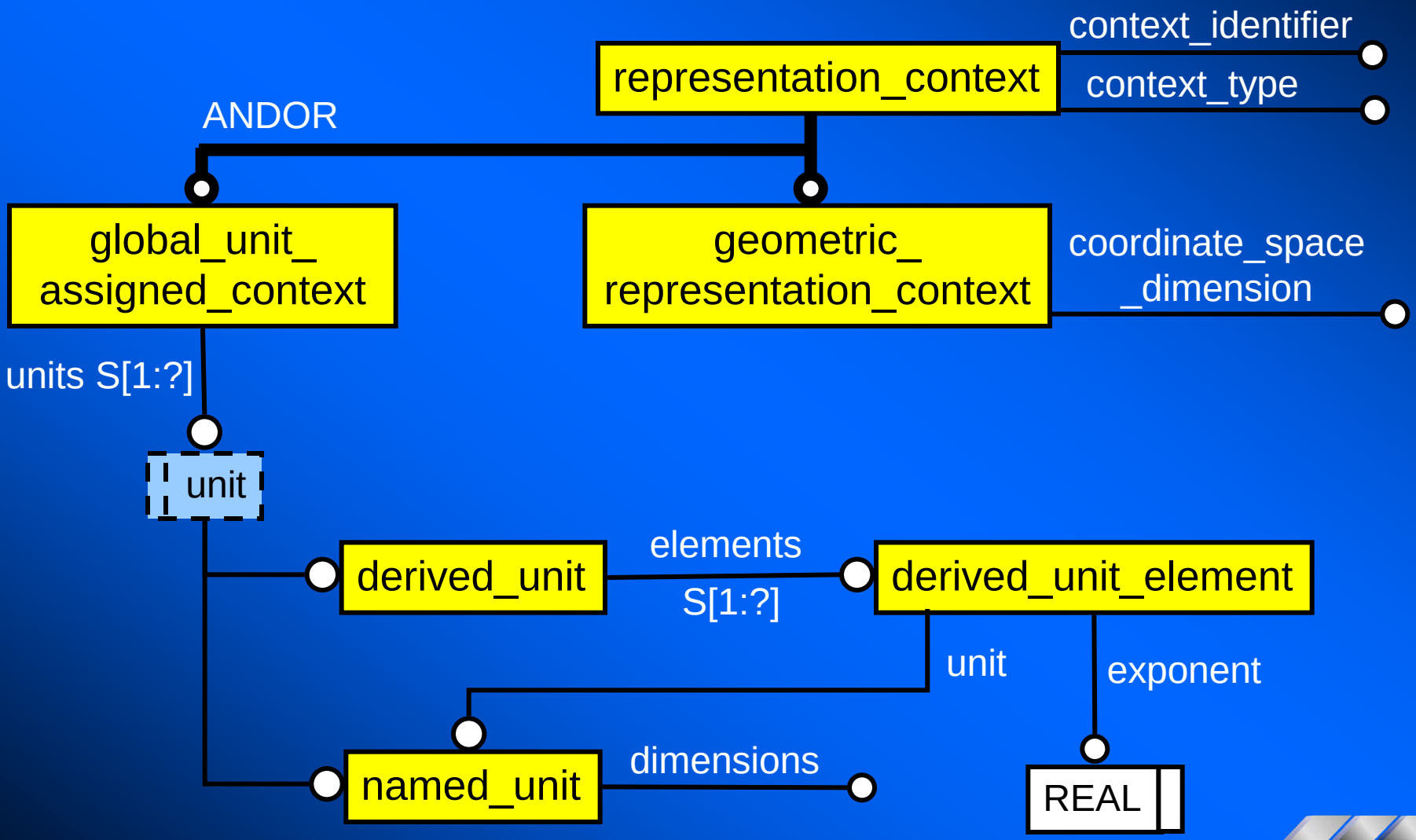
Representation of shape



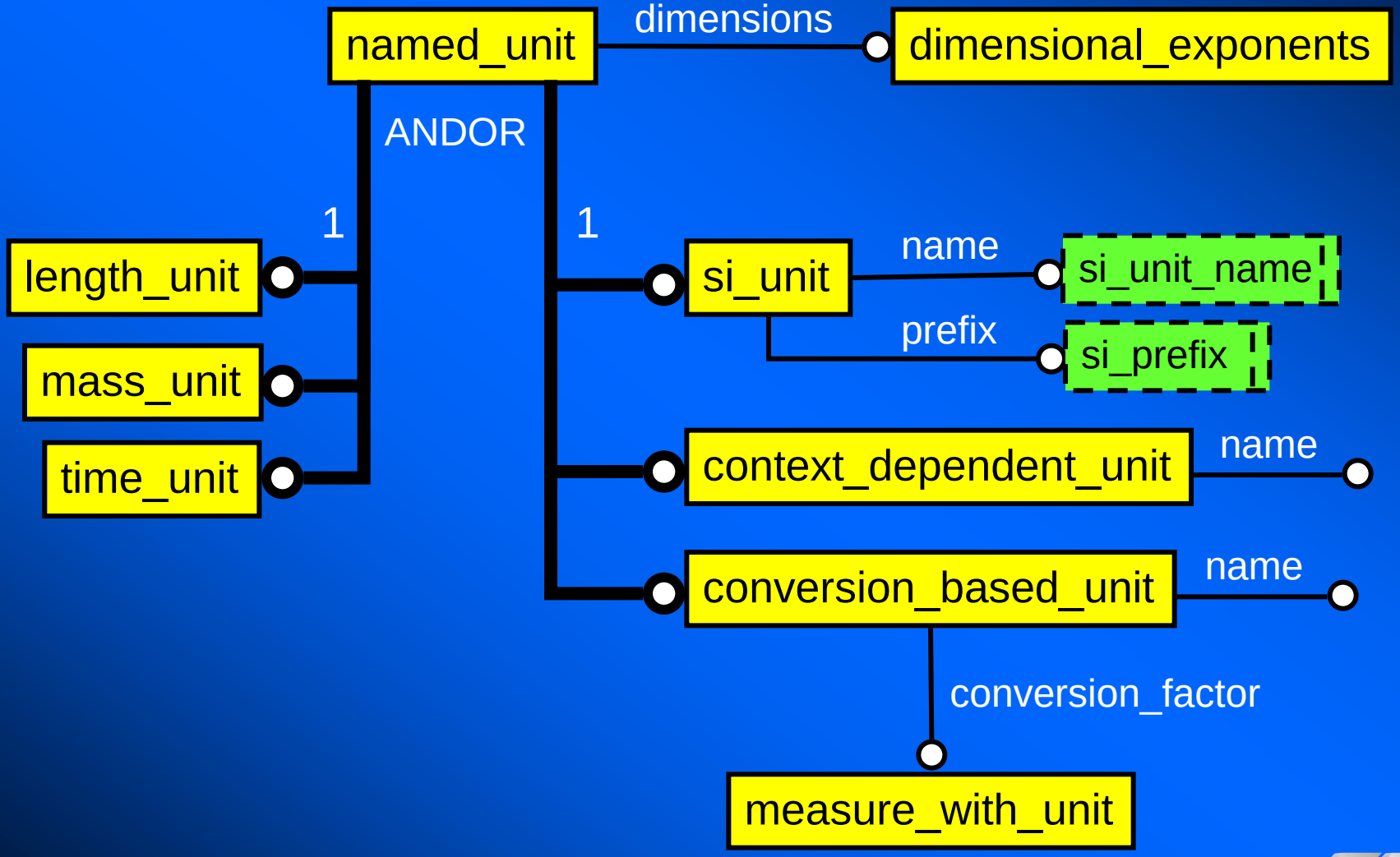
Geometric representation items



Globally assigned units



Named units


named_unit
dimensions
dimensional_exponents
ANDOR
1
length_unit
mass_unit
time_unit
1
si_unit
name
si_unit_name
prefix
si_prefix
context_dependent_unit
name
conversion_based_unit
name
conversion_factor
measure_with_unit

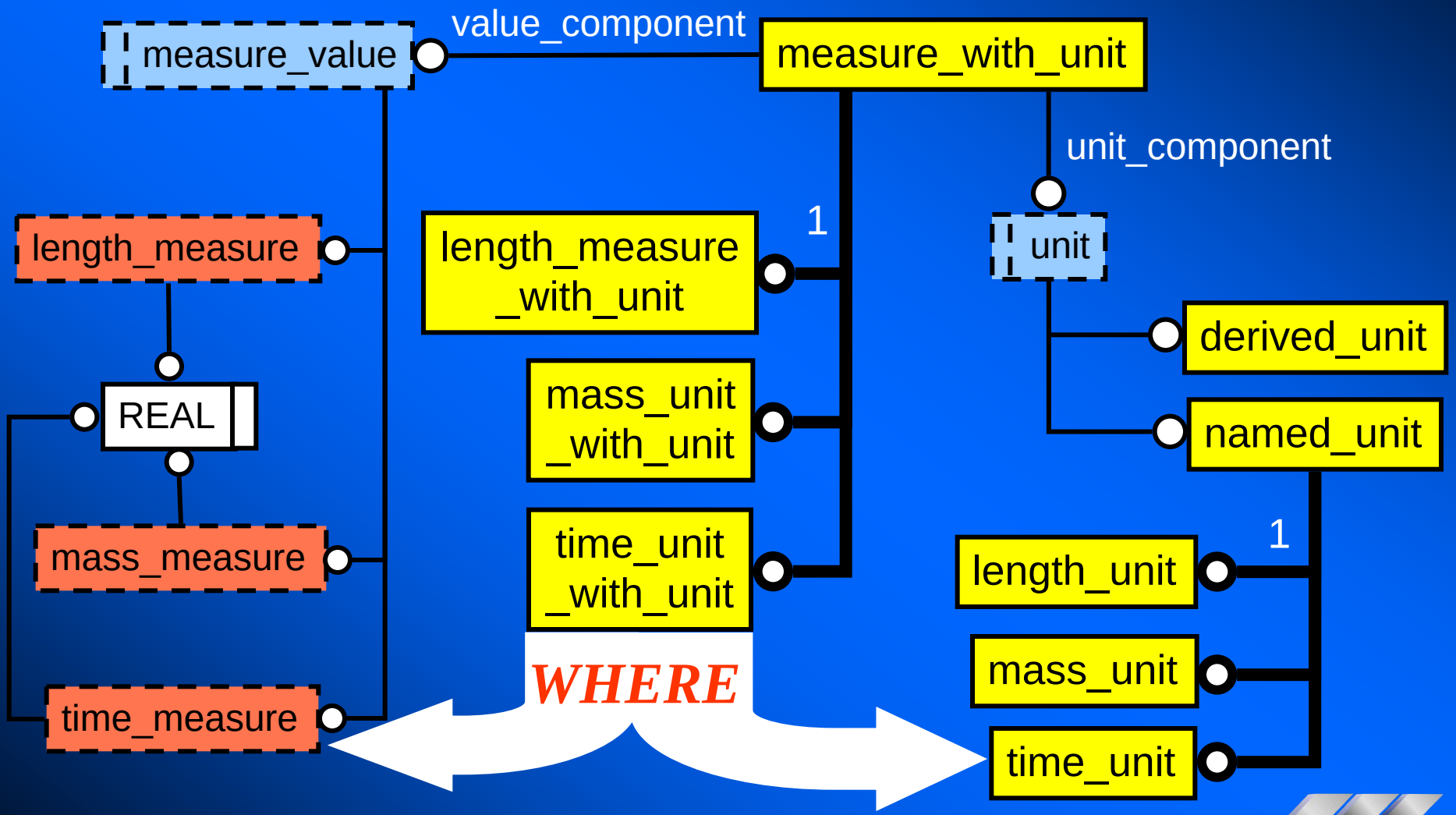
Sample physical file

```
#1 = CARTESIAN_POINT ('node point 1', (0.0, 0.0, 0.0));
#2 = CARTESIAN_POINT ('node point 2', (0.0, 0.0, 5000.0));
...
#501 = REPRESENTATION ('nodal points', (#1, #2, #3, #4, #5, #6), #502);
#502 = (GEOMETRIC_REPRESENTATION_CONTEXT(3)
        GLOBAL_UNIT_ASSIGNED_CONTEXT((#1021))
        REPRESENTATION_CONTEXT('context for nodal points', 'units for
        coordinates'));
...
/* Length Unit (mm) */
#1021 = (LENGTH_UNIT()NAMED_UNIT(*)SI_UNIT(.MILLI.,.METRE.));

/* Force Unit (KN) */
#1031 = (FORCE_UNIT()NAMED_UNIT(*)SI_UNIT(.KILO.,.NEWTON.));

/* Plane Angle Unit (radian) */
#1033 = (NAMED_UNIT(*)PLANE_ANGLE_UNIT()SI_UNIT($,.RADIAN.));
```

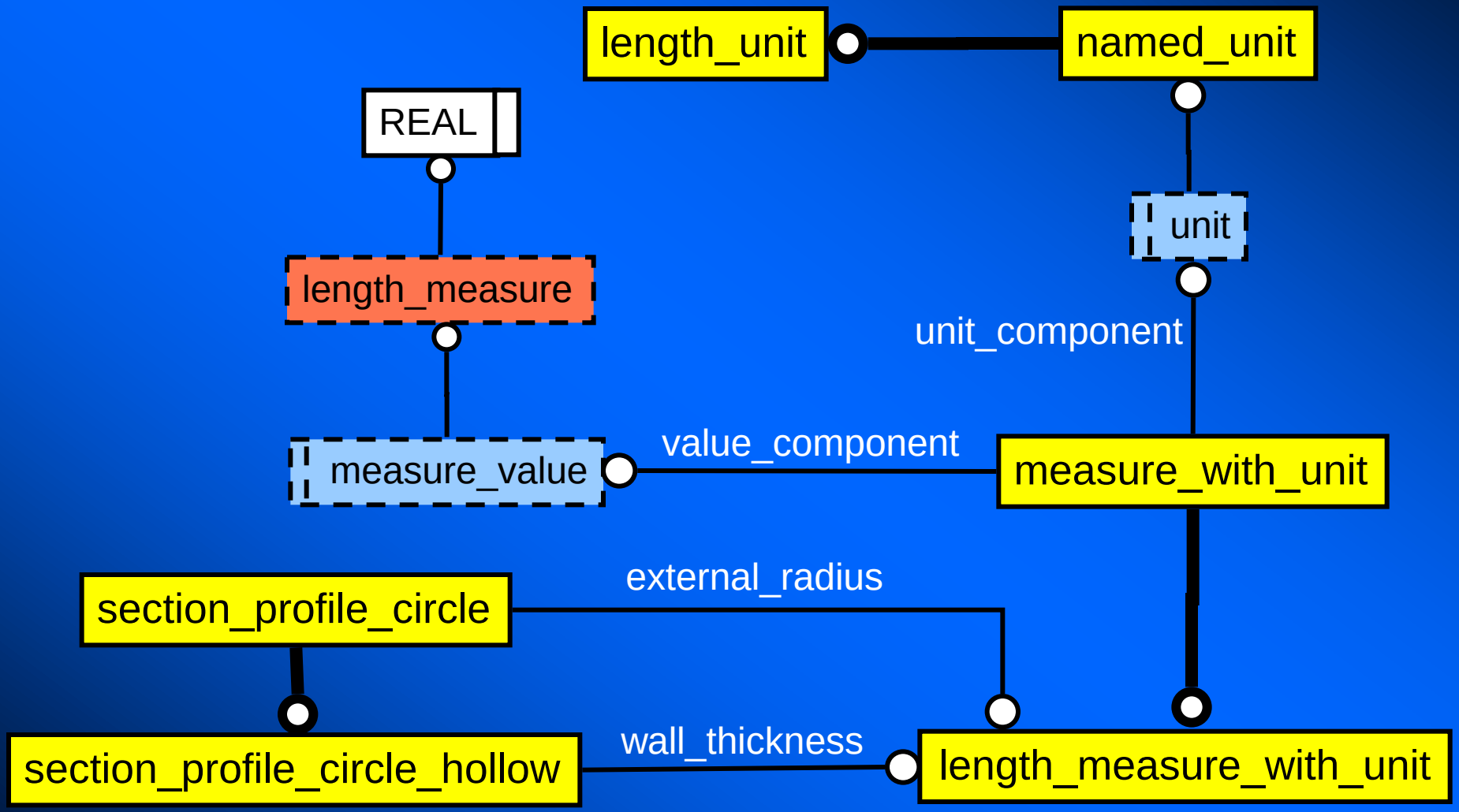
Derived units

```
/* Inertia Unit (cm4) */
#1149 = (LENGTH_UNIT()NAMED_UNIT(*)SI_UNIT(.CENTI.,.METRE.));
#1150 = DERIVED_UNIT_ELEMENT (#1149, 4.0);
#1151 = INERTIA_UNIT ((#1150));

/* Modulus Unit (cm3) */
#1156 = DERIVED_UNIT_ELEMENT (#1149, 3.0);
#1157 = MODULUS_UNIT ((#1156));

/* Area Unit (cm2) */
#1161 = (AREA_UNIT()CONVERSION_BASED_UNIT('square centimetre',
          #1162)NAMED_UNIT (#1165));
#1162 = MEASURE_WITH_UNIT (1.0, #1163);
#1163 = DERIVED_UNIT ((#1164));
#1164 = DERIVED_UNIT_ELEMENT (#1149, 2.0);
#1165 = DIMENSIONAL_EXPONENTS (2.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0);
```

Explicit units

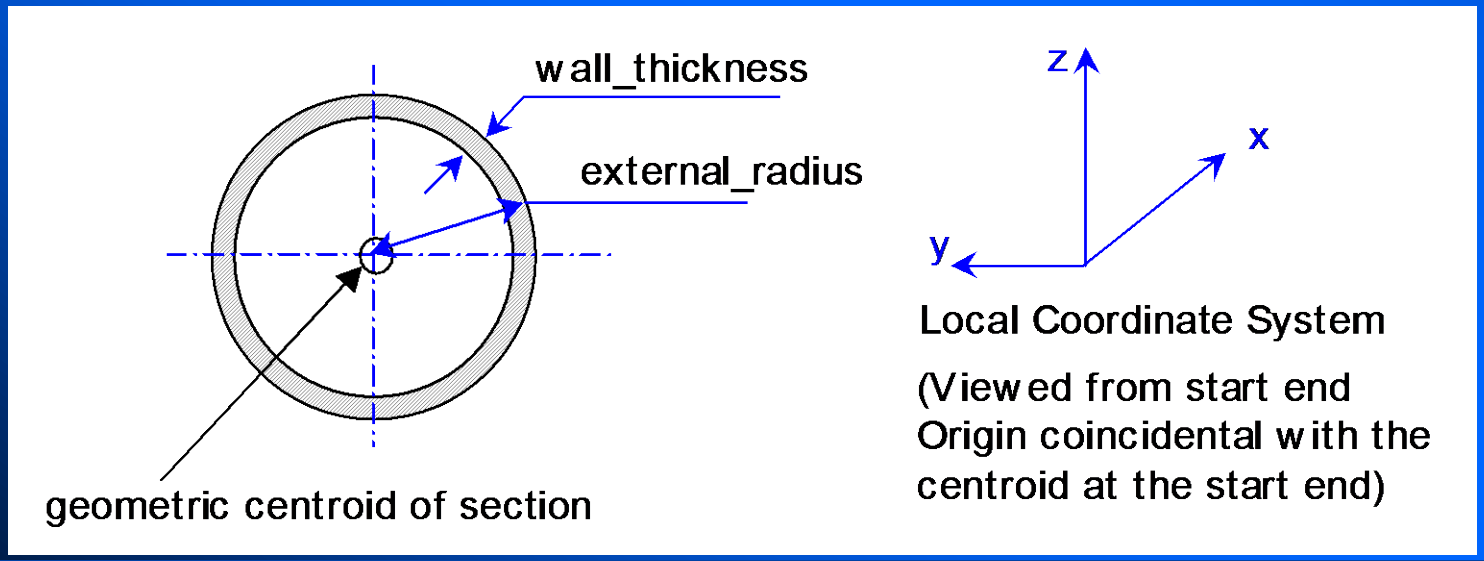


Explicit units

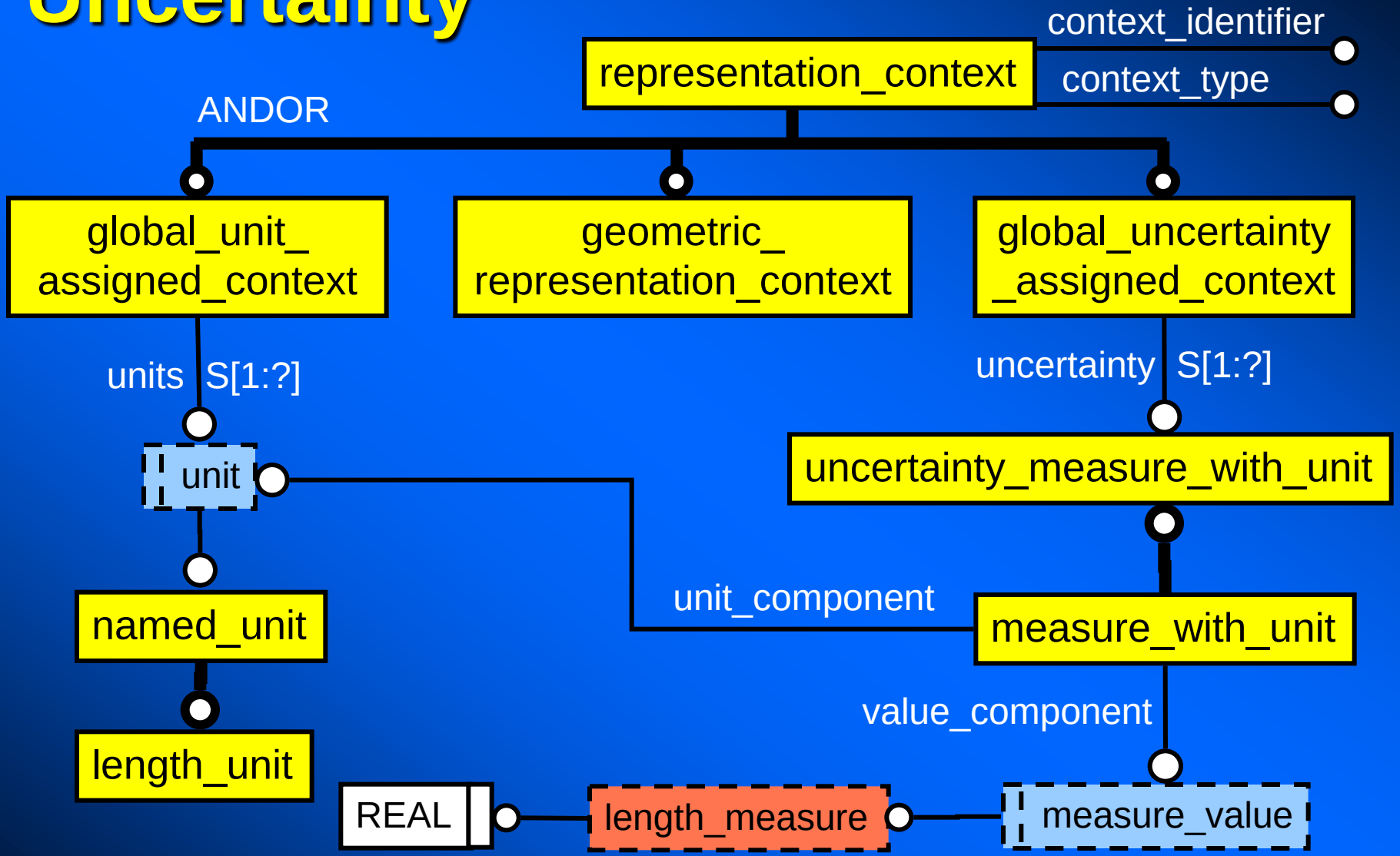


Sample physical file

```
#201 = SECTION_PROFILE_CIRCLE_HOLLOW ('CHS273x10', 1, 'Circular
       Hollow Section beam to EN10210, 'Plastic', $, #202, #203);
#202 = LENGTH_MEASURE_WITH_UNIT (LENGTH_MEASURE(136.5), #1021);
#203 = LENGTH_MEASURE_WITH_UNIT (LENGTH_MEASURE(10.0), #1021);

...
/* Length Unit (mm) */
#1021 = (LENGTH_UNIT()NAMED_UNIT(*)SI_UNIT(.MILLI.,.METRE.));
```



Uncertainty



The Steel Construction Institute