Manufacturing Models

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This tutorial is an examination of a simple manufacturing model. A manufacturing model is the precise layout of a structural system with the associated details needed for fabrication. It begins as a refinement of a design model.

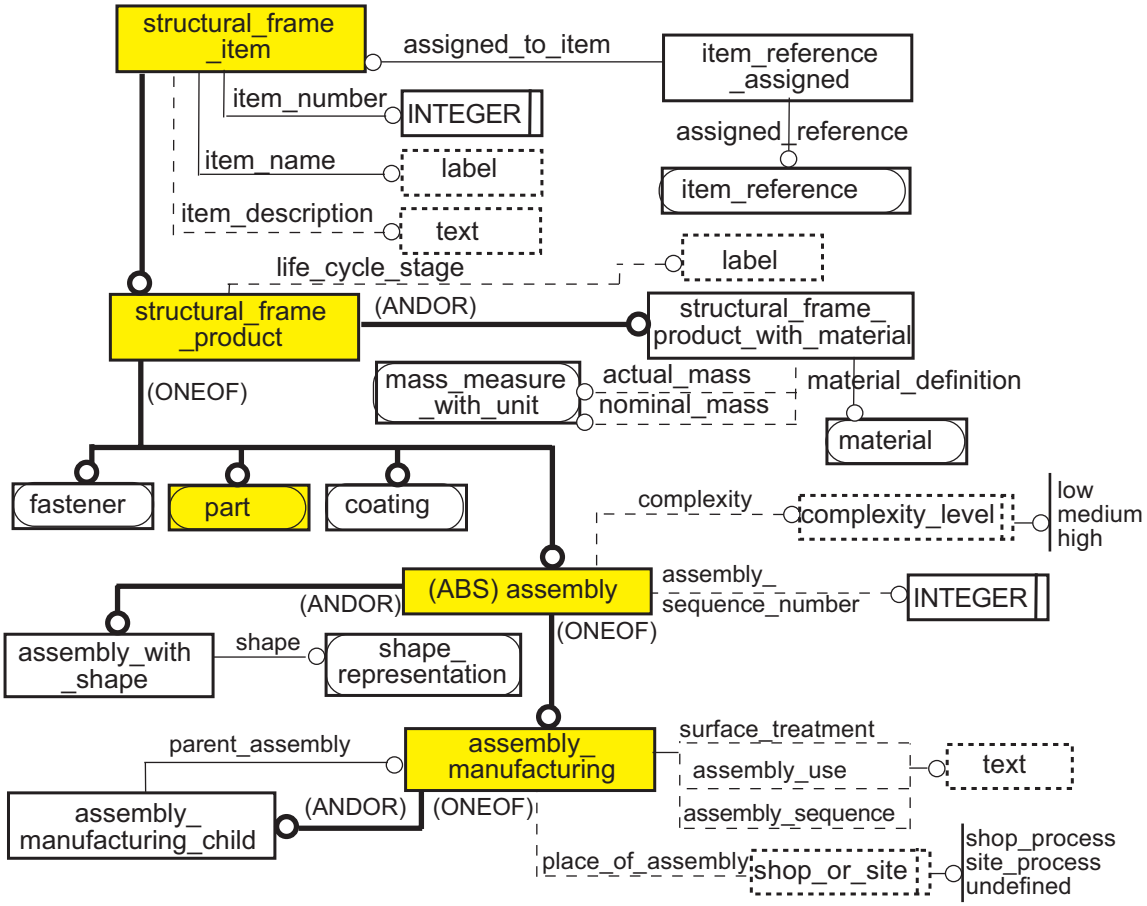

Figure One: The tope level structure representing assmebly_manufacturing.

The Fabrication Model Structure.

The top level instantiated Entity in a Design Model is an assembly_manufacturing. Like assembly_design, it may inherit different optional attributes from assembly, structural_frame_item and structural_frame. Assembly_manufacturing may be defined hierarchically, with child manufacturing assemblies. If all the supertypes are flattened into assembly_manufacturing, the result is:

```
ENTITY assembly_manufacturing
SUPERTYPE OF (assembly_manufacturing_child)
        (assembly:
                (structural_frame_product:
                        (structural_frame_item:
                        item_number : INTEGER;
                        item_name : label;
```

```
                    item_description : OPTIONAL text;
                    );
                life_cycle_stage : OPTIONAL label;
                );
        assembly_sequence_number : OPTIONAL INTEGER;
        complexity : OPTIONAL complexity_level;
        );
        surface_treatment : OPTIONAL text;
        assembly_sequence : OPTIONAL text;
        assembly_use : OPTIONAL text;
        place_of_assembly : OPTIONAL shop_or_site;
END_ENTITY;
```

The result is that manufacturing_assembly carriers ten attributes, eight of which are optional.

A Part 021 file of assembly_manufacturing might be:

```
#11= ASSEMBLY_MANUFACTURING(10,'B2','Column',$,$,.MEDIUM.,$,$,$,
.SHOP_PROCESS.);
```

Assembly_manufacturing is referenced by one or more located_assembly. A located_assembly is a defined subsystem of the assembly, made up of instances, each of which is a located_part. Both located_assemblys and located_parts have their own coordinate system.

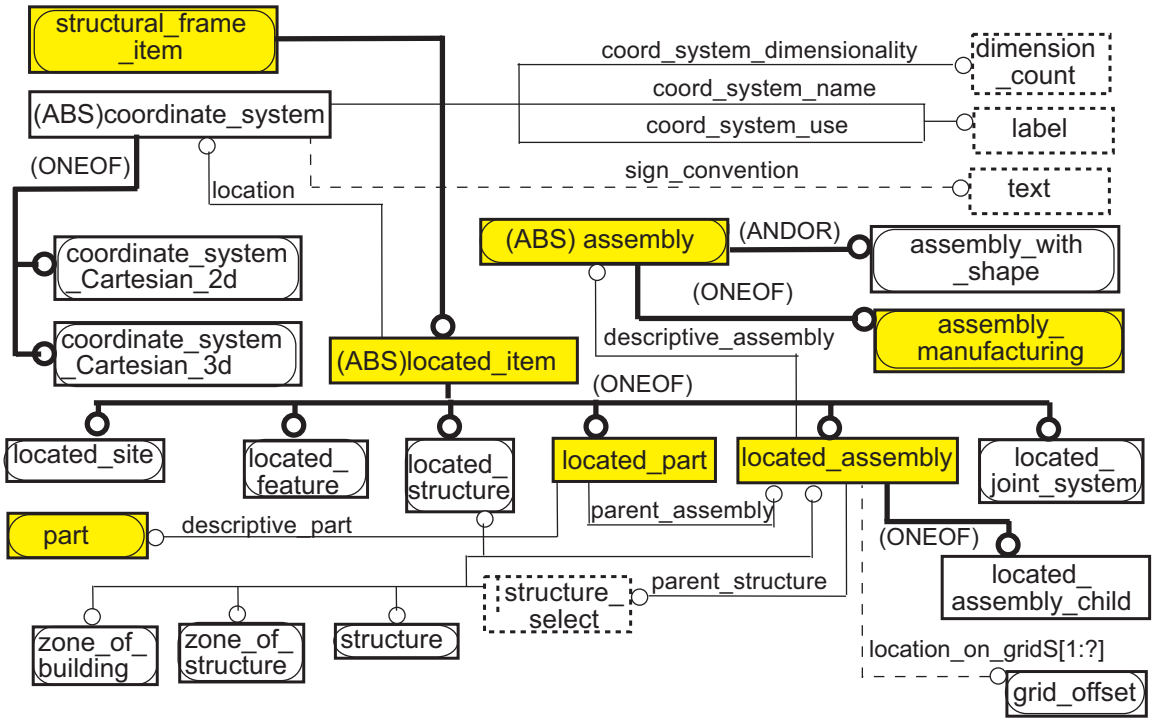

Figure Two: the structure of located_assembly and located_part.

Located_assembly inherits attributes from located_item and structural_frame_item. The flattened definition of located_assembly is:

```
ENTITY located_assembly
SUPERTYPE OF (located_assembly_child)
        (located_item:
```

```
                (structural_frame_item:
                item_number : INTEGER;
                item_name : label;
                item_description : OPTIONAL text;
                );
        location : coord_system;
        );
        location_on_grid : OPTIONAL SET [1:?] OF grid_offset;
        descriptive_assembly : assembly;
        parent_structure : structure_select;
UNIQUE
        URL2 : SELF\located_item.location, descriptive_assembly, parent_structure;
WHERE
        WRL22 : SELF\located_item.location.coord_system_use = 'Assembly Coordinate
System';
        WRL46 : parent_structure :<>: (SELF);
END_ENTITY;
```

A constraint is asserted for each located_assembly that the located_item.location be unique for its descriptive_assembly and partent_structure. Also, the coordinate_system_use attribute of the coordinate system must carry 'Assembly_Coordinate_System' value. (Notice that this WHERE rule checks the value of a string (not an enumerated set of values). Capitalization must be matched and will be checked at runtime.) Also, the located_assembly cannot have itself as a parent structure.

An example Part 021 file entry might be:

```
#123= LOCATED_ASSEMBLY(123,'ASSEMBLY2',$,#3,$,#11,#1);
```

In the Part 021 file entry, there is a reference to a location (#3), a descriptive_assembly, (#11) and a parent_structure (#1), which a WHERE clause does not allow to be a self reference.

Fabrication Parts

A located_part is an individual structural member. Typical or template members can be defined as a part and be referenced by one or more located_parts (in the same way as design_parts). We will consider part first (part is also defined in the Design Model tutorial.)

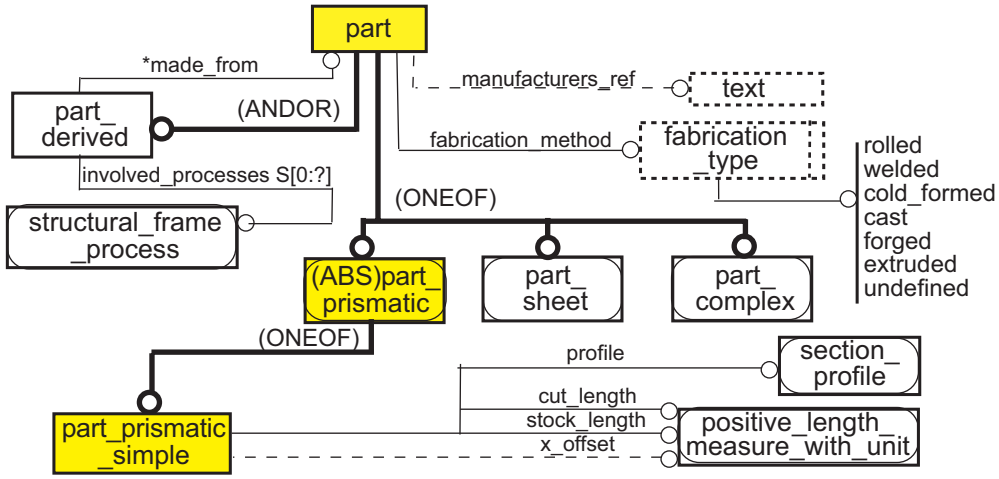

Figure 3: Express-G definition of part.

A part may be of several subclasses. At the top level, a distinction is made whether the part is prismatic (linear) sheet (plate) or complex (has four or more connections). These each have further subclasses. For this tutorial, we only consider prismatic parts. The standard member defined by a section profile and length is part_prismatic_simple.

The Express-G is shown in Figure Three. part_prismatic_simple inherits attributes from part, from structural_frame_item and structural_frame_product (like assembly).

The flattened EXPRESS code is:

```
ENTITY part_prismatic_simple
        (part :
                (structural_frame_product :
                        (structural_frame_item:
                        item_number : INTEGER;
                        item_name : label;
                        item_description : OPTIONAL text;
                        );
                life_cycle_stage : OPTIONAL label;

        fabrication_method : fabrication_type;
        manufacturers_ref : OPTIONAL text;
        );
        profile : section_profile;
        cut_length : positive_length_measure_with_unit;
        stock_length : OPTIONAL positive_length_measure_with_unit;
        x_offset : OPTIONAL positive_length_measure_with_unit;
END_ENTITY;
```

Part_prismatic_simple has nine attributes. A Part 021 file is shown below as an example. It includes a cut_length that references a length_measure and also a section_profile. Section_profiles are reviewed in a separate tutorial.

```
#4321=PART_PRISMATIC_SIMPLE(234,'BEAM21','test','detailing',
.ROLLED.,$,#1324,#1325,$,$ );
#1325 = LENGTH_MEASURE_WITH_UNIT (240.0, #111);
#111=CONTEXT_DEPENDENT_UNIT((LENGTH_UNIT()#10,'INCH',));
#10= DIMENSIONAL_EXPONENTS(1.0,0.0,0.0,0.0,0.0,0.0,0.0);
```

Located_parts reference a part, as defined above. The additional structure of a located_part is shown in Figure Four below. It consists of three attributes: a coordinate_system (inherited from located_item), a reference to the part that is the design reference and the located_assembly it is part of.

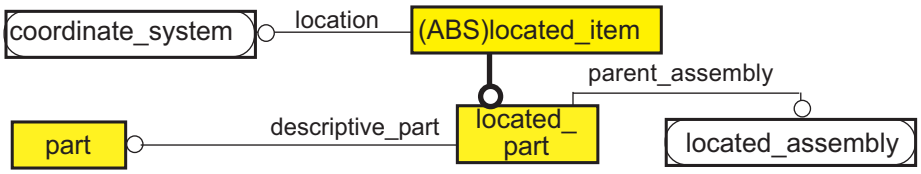

Figure 4: Express-G of a located_part.

The flattened EXPRESS code is:

```
ENTITY located_part
        (located_item:
                (structural_frame_item:
                item_number : INTEGER;
                item_name : label;
                item_description : OPTIONAL text;
                );
        location : coord_system;
        );
        descriptive_part : part;
        parent_assembly : located_assembly;
UNIQUE
        URL9 : SELF\located_item.location, descriptive_part, parent_assembly;
WHERE
        WRL32 : SELF\located_item.location.coord_system_use =
                 'Part Coordinate System';
        WRL33 : 'STRUCTURAL_FRAME_SCHEMA.COORD_SYSTEM_CHILD' IN
                TYPEOF (SELF\located_item.location);
        WRL34 : 'STRUCTURAL_FRAME_SCHEMA.ASSEMBLY_MANUFACTURING'
                IN TYPEOF (parent_assembly.descriptive_assembly);
        WRL35 : SELF\located_item.location.parent_coord_system
                 :=: parent_assembly\located_assembly\located_item.location;
END_ENTITY;
```

Located_part fixes the location of the member described in part and allows it to be detailed using features. They have constraints that require the located_item.location to be unique, that the associated coordinate system be labeled 'Part Coordinate System' (WRL32), that the location of STRUCTURAl_FRAME_SCHEMA be 'COORD_SYSTEM_CHILD' (WRL33), that the type of assembly this located_part is associated with is ASSEMBLY_MANUFACTURING (WRL34) and the parent coordinate system of this part is the same as the located_item_location.

An example Part 021 file for a located_part might be:

```
#346= LOCATED_PART(125,'example',$,#338,#4321,#123);
#338= COORD_SYSTEM_CARTESIAN_3D( 3.0,4.0,5.0,$,$,'Part Coordinate
System','example',$,z,3);
```

#338 refers to a coordinate system. #4321 refers to a part desribed earlier and #123 refers to a located_assembly also defined earlier.

Summary

This basic structure, referring to various parts allows features and other refinements to be appended, resulting in a complete shop model of the steel members and assemblies. The part instances referenced in assembly_manufacturing may be the same part instances referenced in the corresponding design model, or they may be different ones, as revised during detailing.