



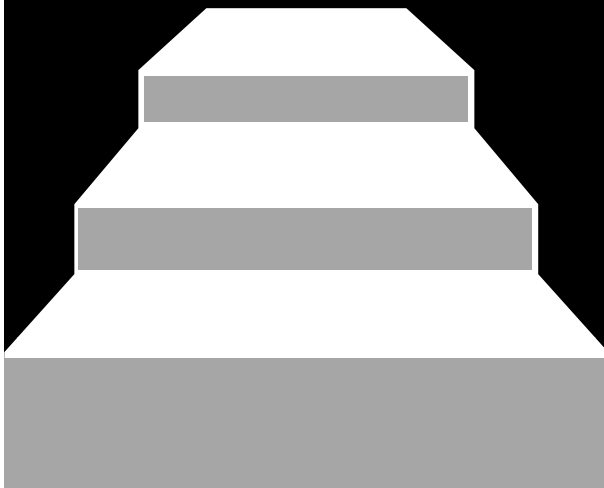
STEP-NC AP238

Summary of Second Edition Enhancements

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- **Collect up all of the corrections and new features from the past several years of implementation and testing.**
 - **Address issues discovered and addressed during testing in Ibusuki, Dallas, Sandviken, Hartford, Renton, Bath, and NIST rounds.**
 - **Originally to be a technical corrigendum (change pages), now enough for a second edition.**
 - **Many changes already formally documented as draft TC.**
 - **Multiple versions circulated since April 2008, last was v1.8**

- **Documented in TC**

- Toolpath Reference Direction
- Gage placement for simulation
- Toolpath placement on Workplan
- Enable/Disable Executable
- Via points for better High-Speed Machining support.
- Cross section parameters for Feed Speed optimization.
- Touch_probe as a real tool.
- Datum and Datum_target reference to workpiece
- Full workpieces for In-process geometry
- Improved AP203 compatibility
- Grammar and wording fixes

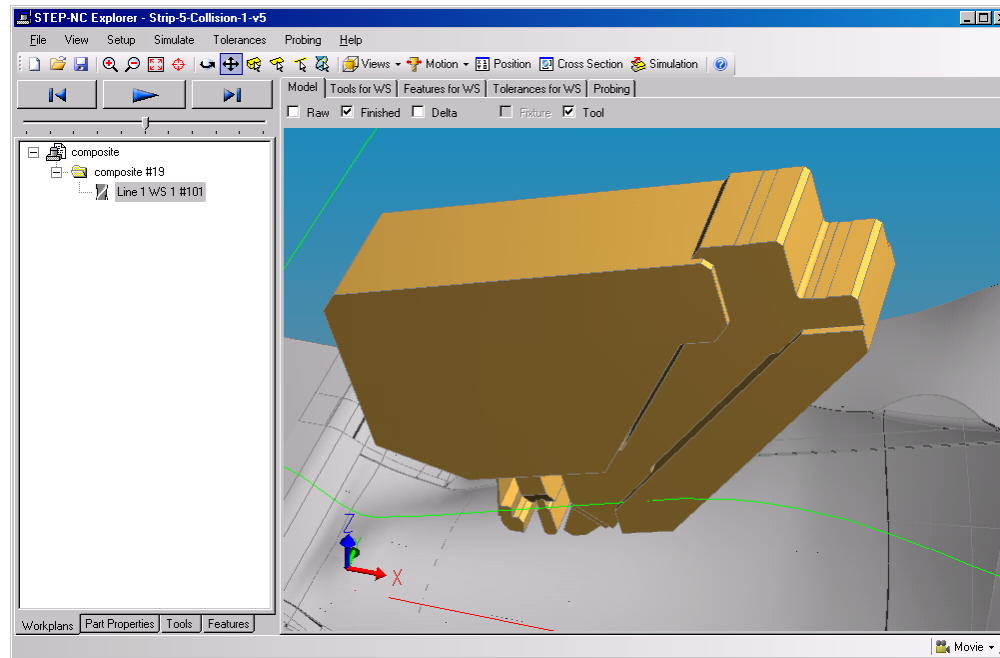
- **Done, but not yet formally documented**

- Ordering of items in pattern features.
- Simplify rawpiece/finished piece
- Adopt presentation UOFs from AP214/AP203e2

- **Open items**

- Curve probing operation
- Enhancements discussed at this meeting.

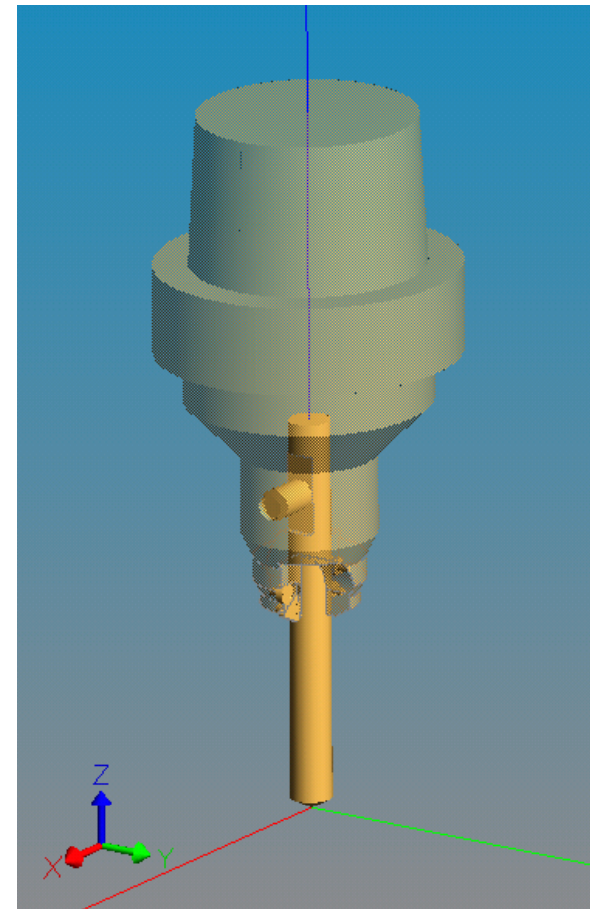
- **Add an optional tool reference direction curve to augment tool axis curves**
 - For use with asymmetric tools, like composite tape laying heads, where two direction vectors are needed to properly align the tool.
 - Bounded curve handled the same way as its_toolaxis



```
ENTITY cutter_location_trajectory
  SUBTYPE OF (trajectory);
  basiccurve:                bounded_curve;
  its_toolaxis:              OPTIONAL bounded_curve;
  its_toolref_direction:     OPTIONAL bounded_curve;
  surface_normal:           OPTIONAL bounded_curve;
  path_maximum_deviation:   OPTIONAL length_measure;
  tool_axis_maximum_deviation:
    OPTIONAL plane_angle_measure;
END_ENTITY;
```

```
ENTITY cutter_contact_trajectory
  SUBTYPE OF (trajectory);
  basiccurve:                curve_with_surface_normal;
  its_toolaxis:              OPTIONAL bounded_curve;
  its_toolref_direction:     OPTIONAL bounded_curve;
  its_contact_type:         OPTIONAL contact_type;
  path_maximum_deviation:   OPTIONAL length_measure;
  tool_axis_maximum_deviation:
    OPTIONAL plane_angle_measure;
END_ENTITY;
```

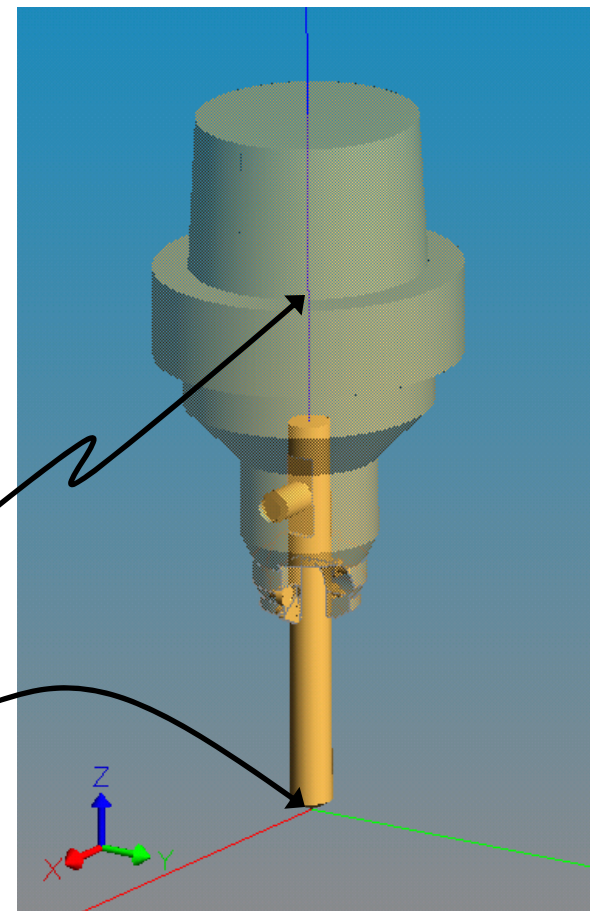
- **For better display and simulation, need way to locate tool product model on machine model**
 - Have been requiring tool product model to have origin at the tool end, subtract the nominal “overall tool length” to find mating point.
 - ISO 13399 calls for a different origin
 - Existing tool geometry CAD files are sometimes modeled with other origin conventions.
 - Extends to allow use of any origin convention



- Add “gage placement” and “tool end placement” to tool_usage to allow any origin convention
 - Explicitly identifies location of the tool end and mounting location on the tool product model.
 - Product model origin can be located anywhere, with any axes.
 - Optional, use existing convention if not present.

gage_placement

tool_end_placement



- **Add as axis placement properties**
 - The axis placement z direction gives the tool axis
 - The axis placement location gives the placement of the gage plane on the tool axis and the tool end point commanded by `cutter_location_trajectory` toolpaths.

```
ENTITY tool_usage;  
  its_id:          label;  
  its_position:    OPTIONAL identifier;  
  its_carousel:    OPTIONAL identifier;  
  its_product:     OPTIONAL workpiece;  
  its_library_reference:  
    OPTIONAL externally defined representation;  
  
  gage_placement:  OPTIONAL axis2_placement_3d;  
  tool_end_placement:  OPTIONAL axis2_placement_3d;  
END_ENTITY;
```


- **With impeller, we reused operations eight times**
 - Transform is already possible on individual workingstep
 - Adding transform to workplan allows more significant reuse.
 - Transform moves toolpaths from all workingsteps or nested workplans at once.

```
ENTITY workplan
  SUBTYPE OF (program structure);
  its_elements: LIST[0:?] OF executable;

  [ . . . ]

  toolpath_orientation: OPTIONAL axis2_placement_3d;
END_ENTITY;
```

- **Add an attribute to store the enabled/disabled state of an executable.**
 - Makes it possible to keep many alternates into the file, as was used heavily with Boxy.
 - Can use to select part of a program for machining.
 - Can use to select an alternative in a selective.

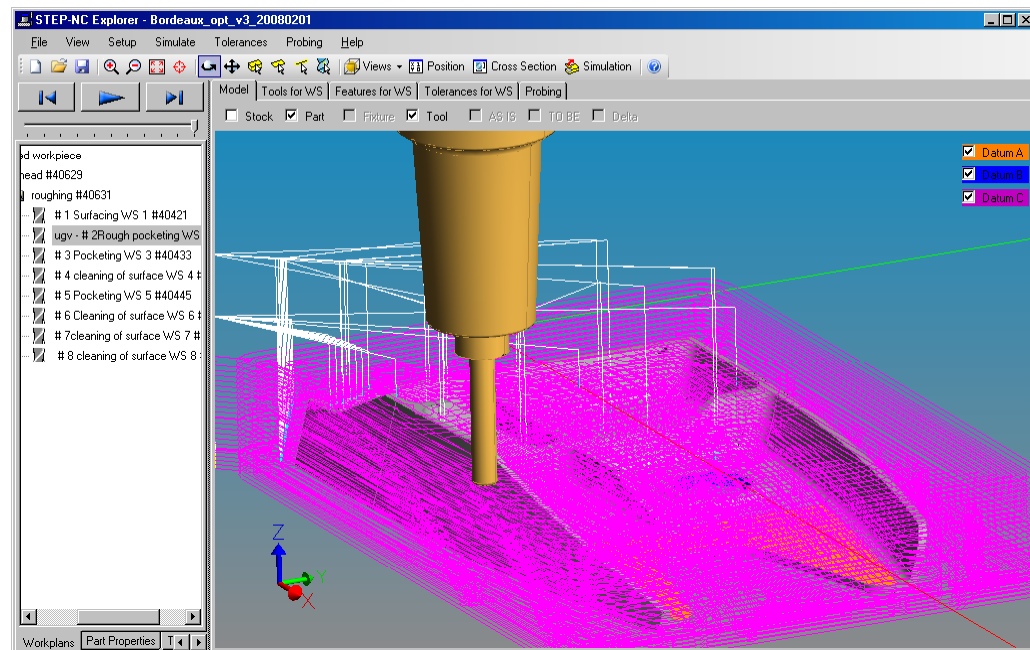
```
ENTITY executable
ABSTRACT SUPERTYPE OF (ONEOF( workingstep, nc_function,
                               program_structure));
    [ . . . ]

    enabled: OPTIONAL BOOLEAN;
END ENTITY;
```

- **High Speed Machining toolpaths use many arcs.**
 - Requires several entities to represent arcs as trimmed curves, (composite curve, composite curve segment, trimmed curve, circle, axis placement, several directions and cartesian points)
 - This is multiplied over several tool curves (basis, tool axis, surface normal, speed profile)
- **Describe using via points following approach used by STEP kinematics model.**
 - Continue to use polylines with addition of cartesian point subtype `via_arc_point`.
 - Subtype for `via_helix_point` also added.
 - Previous method can still be used for other types of curve.

- **Verified by Bordeaux HSM tests in March 2008.**
 - Later rounds clarified how via points behave when too close to each other (within geometric uncertainty)
- **Measurements for Fishhead HSM Program**
 - Contains part geometry, tolerances and tool paths
 - Old: 1.9 MB
 - New: 1 MB

**For comparison:
Mastercam 9 is 3.5 MB
G code is 0.574 MB**

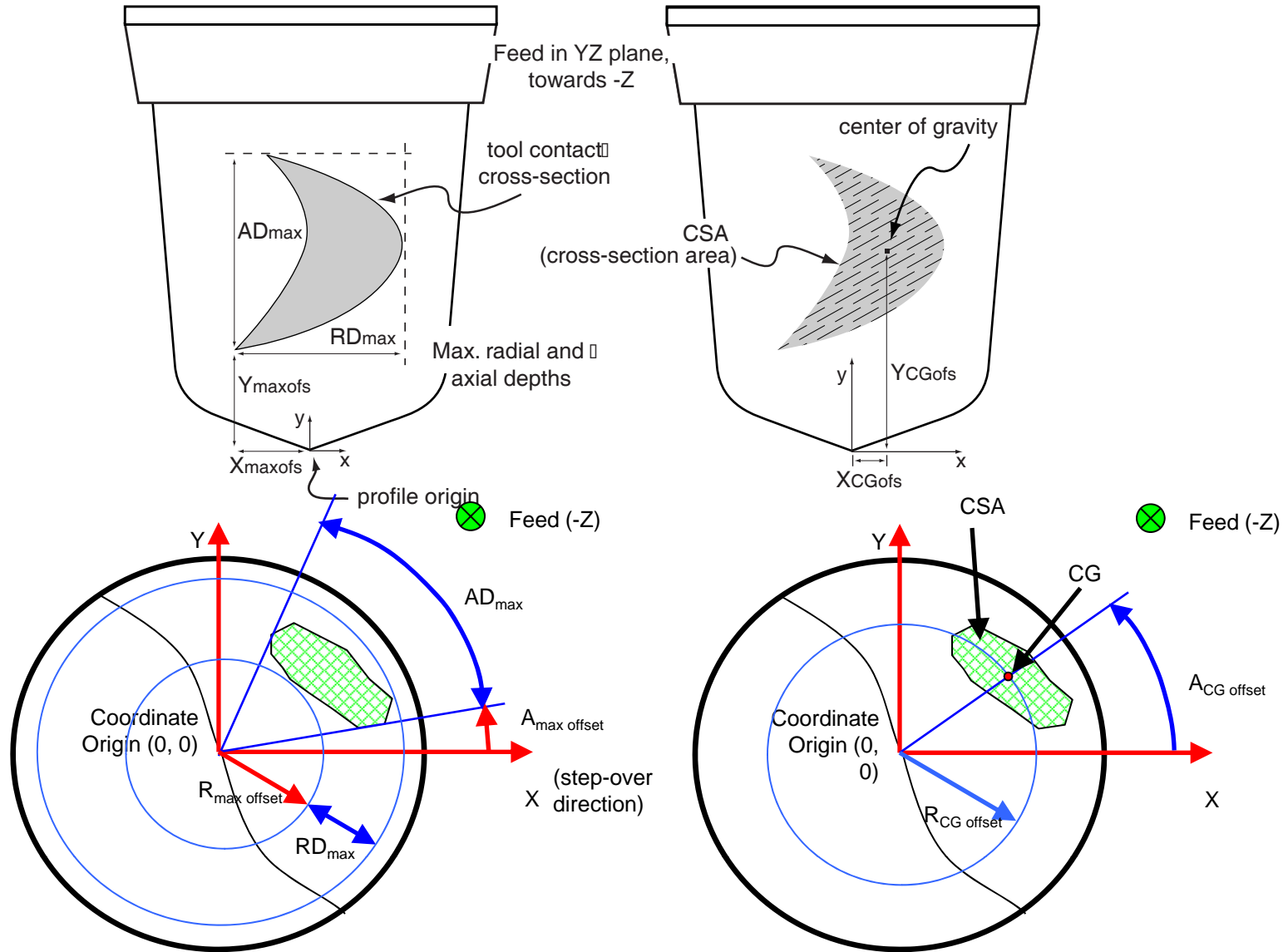


- **Curve that gives a parameterized description of removal cross section along toolpath.**
 - Allows for speed/feed optimization by systems that may not have access to material removal simulator.
 - Tested in several rounds since March 2008
 - Handled like tool position, axis, surface normal curves.
 - Seven dimensions (ADmax, RDmax, Xmaxofs, Ymaxofs, CSArea, XCGofs, YGCofs)

```
ENTITY trajectory
  ABSTRACT
  SUPERTYPE OF (ONEOF(cutter_location_trajectory,
    cutter_contact_trajectory, axis_trajectory))
  SUBTYPE OF (toolpath);
  [ . . . ]
  cross_section_area_flank_parameters: OPTIONAL bounded_curve;
  cross_section_area_plunge_parameters: OPTIONAL bounded_curve;

END_ENTITY;
```

Cross Section Parameters



- **ARM for touch probe changed to make probe a subtype of tool.**
 - Previously was a stand-alone stub. Can now work with probes in the same way as other tools.
 - Enables a connection between a probe and its shape geometry. Previously, there was none.
 - Change requires minor AIM mapping adjustments to touch_probe and probing operations.
 - Some discussions in previous rounds about additional probe characteristics. Open to proposals.

```
ENTITY touch_probe
  SUBTYPE OF (machining_tool);    -- ADDED BY TC
  -- its_id: identifier;  -- now inherited
END ENTITY;
```

- **ARM for Datums and Datum Targets changed to add Workpiece reference**
 - Datums and Datum Targets already link to a workpiece at the AIM level, but there is no reference in the ARM model.
 - Now more in line with features

```
ENTITY Datum
  ABSTRACT SUPERTYPE;
  its_workpiece: Workpiece;      -- ADDED BY TC
END_ENTITY;
```

```
ENTITY Datum_target;
  id : STRING;
  its_workpiece: Workpiece;      -- ADDED BY TC
END_ENTITY;
```


- **Change in-process geometry from just shape_rep reference to full workpiece reference**
 - Simpler, any shape rep made by a CAD system is already part of a workpiece/product.
 - Allows full range of product properties, features, tolerances.
 - Simplify by moving as-is, to-be, and removal links to supertype
 - » Were separate sets of properties on Workplan, Machining_workingstep, and Turning_workingstep.
 - » Move up to Executable so it can be used anywhere.

```
ENTITY executable
```

```
ABSTRACT SUPERTYPE OF (ONEOF( workingstep, nc_function,  
                               program_structure));
```

```
    its_id:      identifier;
```

```
    as_is:      OPTIONAL Workpiece; -- ADDED BY TC
```

```
    fixture:    OPTIONAL Workpiece; -- ADDED BY TC
```

```
    removal:    OPTIONAL Workpiece; -- ADDED BY TC
```

```
    to_be:      OPTIONAL Workpiece; -- ADDED BY TC
```

```
END_ENTITY;
```

- **Improved compatibility for importing AP203 workpieces from existing systems**
 - Extended AIM EXPRESS for security assignment to take assembly nodes. Occasionally seen in AP203 data.
- **Many editorial fixes**
 - Grammar fixes
 - Wording clarifications

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- **Minor AIM issue with the points in a general pattern**
 - In ARM the placements are an ordered list.
 - Mapped to AIM as items within a set, which may not preserve order in some implementations.
 - Discovered in this round while using pattern features to generate drilling and tapping cycles.
- **Change mapping to a list in a compound rep item**
 - Deprecate original mapping

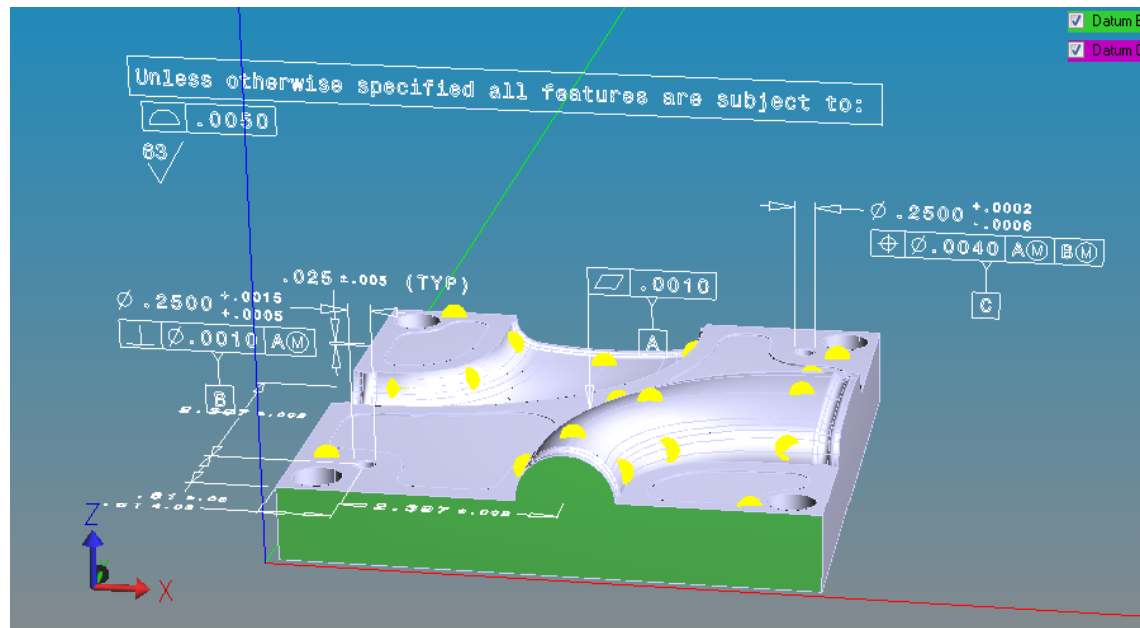
- Improved mapping shown in red.

```
representation
representation.items[i] ->
{representation_item.name = 'base feature placement'}
representation_item =>
    compound_representation_item =>
    compound_representation_item.item_element ->
    compound_item_definition
    compound_item_definition = list_representation_item
    list_representation_item[i] ->
    representation_item =>
geometric_representation_item =>
placement =>
axis2_placement_3d
```

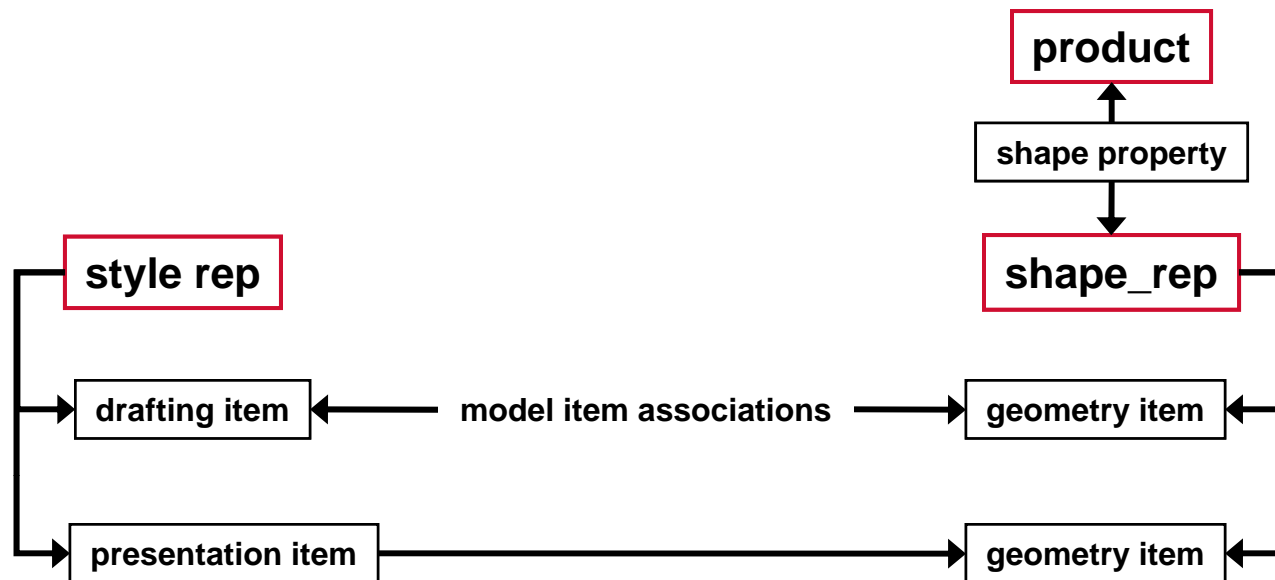
- **With as-is and to-be now full workpieces, we can simplify the handling of raw and finished parts in the model**
 - **Worked out and tested between Renton and Bath cycles, particularly with all of the models in Boxy.**

- **Main workplan**
 - as-is workpiece describes the state of the material at the start of the workplan (what we have been calling stock)
 - to-be workpiece describes the state of the material at the end of the workplan (what we have called “workpiece”, finished part, or often just “part”)
- **Any nested workplans or workingsteps**
 - as-is/to-be can be specified to give additional detail/granularity, and give intermediate forms.
- **Project list of workpieces**
 - Workpieces that the project makes (the final deliverables)
 - May be more than just the to-be of the main workplan because sub workplans may produce finished parts included here.
- **Workpiece “rawpiece” attribute**
 - Initial state of this workpiece before any machining.

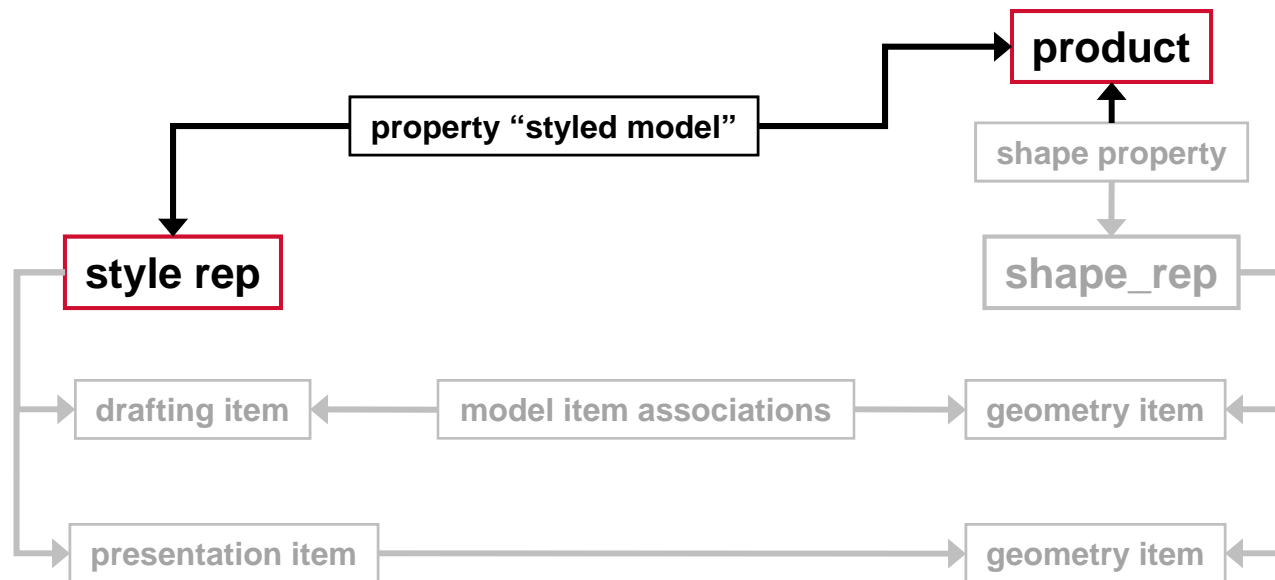
- Adopted Presentation UOFs during Renton cycle to support drawing annotations, colors, and such coming from upstream.
 - Drawing annotations were in AP214 and added as an extension to the original AP203.
 - Reworked a bit in AP203e2 and AP214e3 to add associations for drafting callouts



- AP203/214 files usually have one representation containing all styled_item instances.
 - This “styled model” is not directly related to any product.
 - Callout items may be indirectly related through draughting model item associations shown on previous slides.
 - Colors and other presentation things indirectly related through many layers of rep item links.



- AP238 may include many workpiece products imported from AP203/214 files.
 - Multiple, unowned styled reps make it difficult to identify which callouts/styles belong to which workpieces.
 - Annotate with a property linking the container for callouts and presentation to the workpiece that it was imported with.



- **New its_styled_models property on Workpiece**
 - Mapping shown below

```
product_definition
characterized_product_definition = product_definition
characterized_product_definition
characterized_definition = characterized_product_definition
characterized_definition <-
property_definition.definition
{ property_definition =>
property_definition.name = 'styled model'}
property_definition
represented_definition = property_definition
represented_definition <-
property_definition_representation.definition
property_definition_representation
property_definition_representation.used_representation ->
representation =>
(draughting_model)
(mechanical_design_geometric_presentation_representation)
(mechanical_design_shaded_presentation_representation)
```

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- **Motivation**

- New devices are becoming available that can measure curves
- STEP-NC data contains many bounded curves (tool paths) that can be measured
- Applications like the Impeller can be evaluated using bounded curves on the surface

- **Proposal**

- Add `curve_probing` entity with appropriate parameters
- Add additional parameters to `touch_probe` for accuracy and repeatability

```
ENTITY curve_probing SUBTYPE OF (touch_probing)
  its_probe                : touch_probe;
  start_position           : OPTIONAL axis2_placement_3d;
  start_direction          : OPTIONAL direction;
  start_limit              : OPTIONAL toleranced_length_measure;
  curve_to_be_measured    : bounded_curve;
  curve_surface_normal    : OPTIONAL bounded_curve;
  probe_axis               : OPTIONAL bounded_curve;
  curve_distance           : OPTIONAL length_measure;
  as_measured_curve       : OPTIONAL bounded_curve;
  as_measured_curve_normal : OPTIONAL bounded_curve;
  its_technology           : OPTIONAL technology;
  path_maximum_deviation  : OPTIONAL bounded_curve;
  retract_direction        : OPTIONAL direction;
  retract_distance        : OPTIONAL length_measure;
END_ENTITY;
```

Added curve_surface_normal

Changed curve_axis to probe_axis

- **Grouping or sharing tolerances between in-process shapes.**
- **Tool requirements model**
- **Tool recommendation model**
- **Process monitoring model**
- **Closed loop machining model**
- ***Inspection feature model***
- **Machine tool model**