

AP-238 DIS Walkthrough

wg3n1543

David Loffredo
loffredo@steptools.com
2004-10-29

STEP Tools, Inc.
14 First Street, Troy, NY 12180
(518) 687-2848 / (518) 687-4420 fax

- **AP-238 pulls together machining process, tool requirement, geometry, tolerances, and PDM.**
 - Start with process and tools described by ISO 14649 parts
 - Add STEP PDM, Geometry, and Tolerances, and integrate so that features and all other data can be shared across APs

Measures Project Workpiece Features	Executable Operation Toolpath	Based on Part 10
Dimensions and Tolerances PDM and Product Geometry		STEP GD&T Common to all APs
Milling Process Operations Milling Cutting Tools		Based on Part 11 Based on Part 111
Turning Process Operations Turning Cutting Tools		Based on Part 12 Based on Part 121

- **Updates include**

- Clarified features in new “fundamental concepts” section, and extended 14649 definitions with necessary
- Added mappings for the turning model (P12, P121)
- Finished toolpath mappings and added enhancements.
- Added ARM description for PDM Information
- Added harmonized GD&T definitions
- Changes to accommodate SC1 concerns about clarity
- Many other smaller fixes.

- **Product Description**
 - Workpiece, PDM and Product Geometry
 - Features
 - Dimensions and Tolerances
 - Measures
- **General Process Description**
 - Project
 - Executable
 - Operation
 - Toolpath
- **Technology Description**
 - Milling Process Operations
 - Milling Cutting Tools
 - Turning Process Operations
 - Turning Cutting Tools

- **Features**

- New “Fundamental Concepts and Assumptions” section addresses remaining feature harmonization issues.
- Worked with Len and Alan in January 2004 to add AIM rule changes to AIC522e2 and ARM changes to AP-224e3.

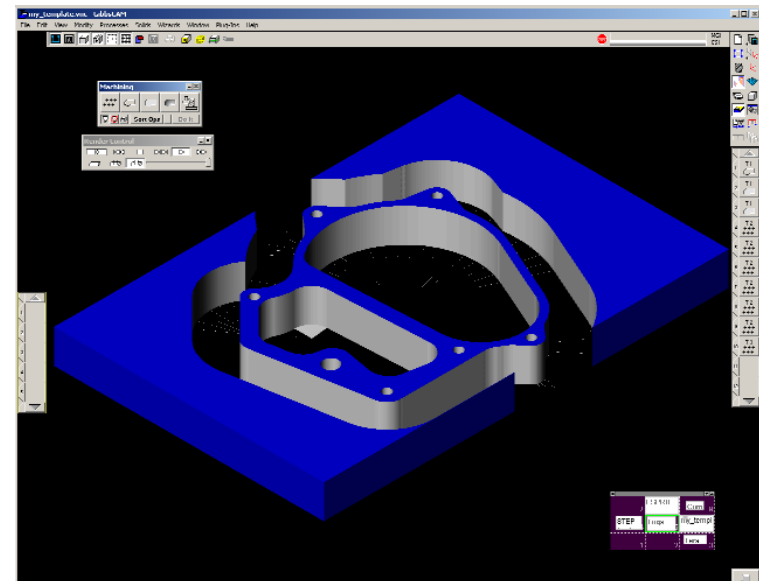
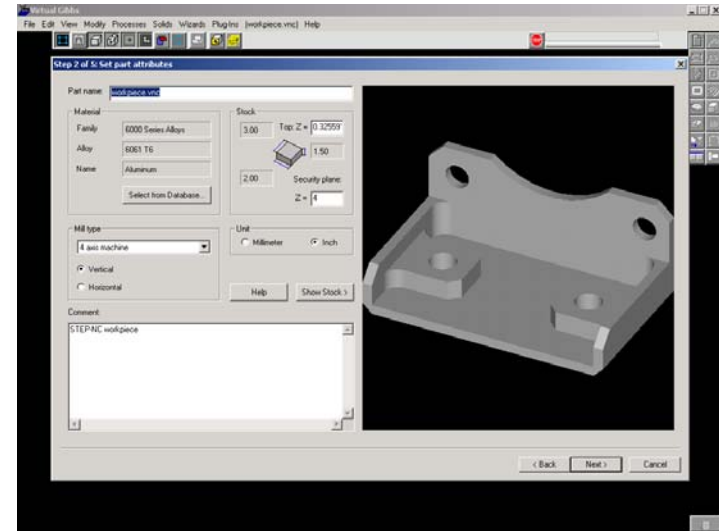
- **PDM Information**

- Added new management UOF and mappings to clarify the handling of approvals and other PDM data. Harmonized with the appropriate modules (ISO 10303-1012, 1015).

- **GD&T**

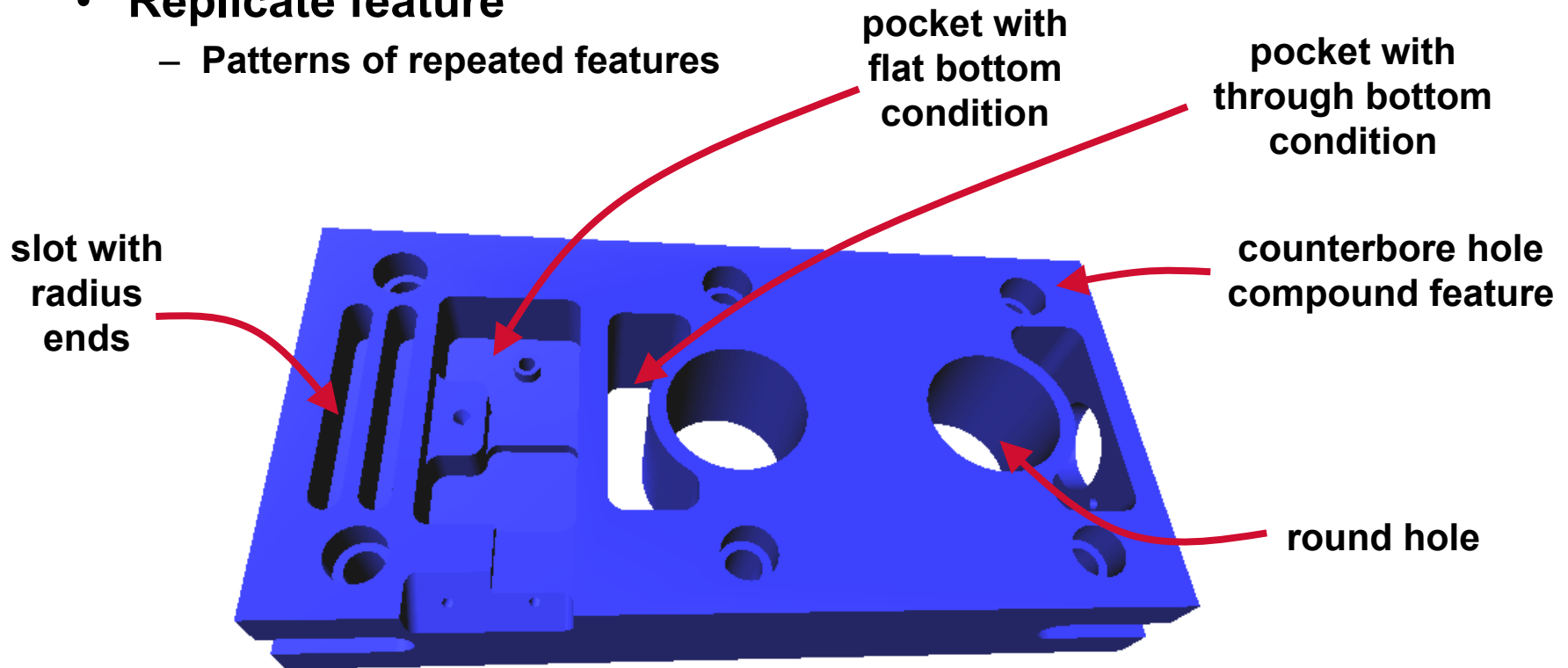
- Resolved all harmonization issues.
- Added ARM and mappings for harmonized definitions
- Extended ARM definitions in “Measure” UOF to explicitly describe units, tolerances on parameters beyond length.

- The workpiece is a STEP product description
 - With all of the owner information, approvals, dates and times.
 - Material and material properties
-
- Shape for workpiece uses advanced B-REP, just like all of the other STEP APs.
 - Produced by any CAD system that supports STEP.

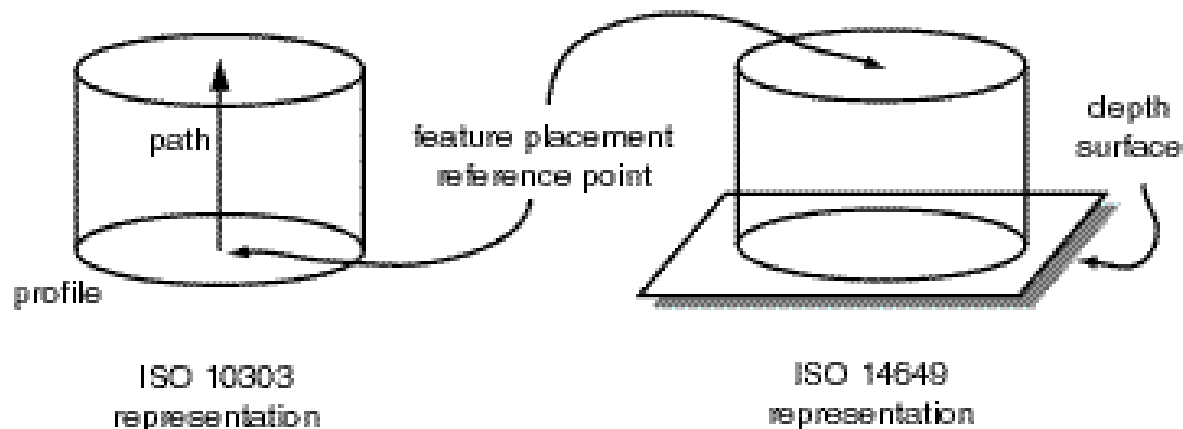


- **Added new management UOF and mappings to clarify the handling of approvals and other PDM data.**
 - Harmonized with module 1012 for approvals and module 1015 for security classifications
 - New application objects for Approval, Approval_relationship, Approval_status, Approving_person_organization, Security_classification, Security_classification_assignment.
 - Person and organization ARM concepts already present in the Project UOF.
- **Added last modified timestamps as per ballot comments**
 - can associate with projects, workpieces, executables, operations, or toolpaths

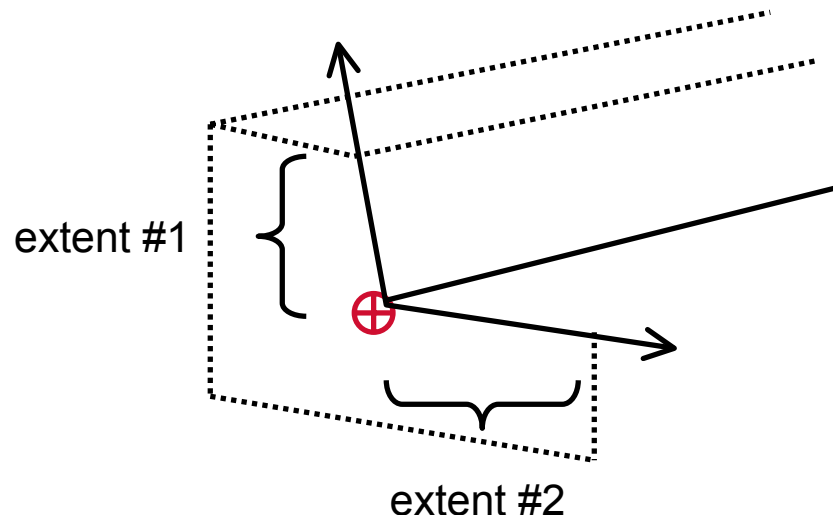
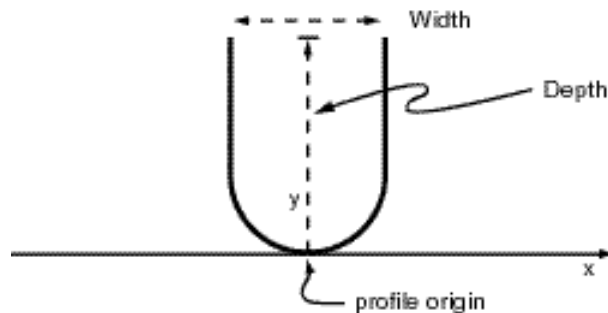
- **2.5D milling features**
 - Hole, pocket, slot, step, etc
- **Transition features**
 - Edge round and chamfer
- **Replicate feature**
 - Patterns of repeated features
- **Region features**
 - Surfaces for freeform milling
- **Turning features**
 - Outer round, knurl, groove



- **Added the new “Fundamental Concepts and Assumptions” section to clarify features**
 - Structural Issues had been harmonized long ago, but some subtle issues remained.
 - Clarify assumptions on how to interpret origin for positioning, calculate feature volume and other things.
 - Explain additional capabilities beyond ISO 14649, such as explicit representation and process vs. final features



- **Additional attributes to bound the volume**
 - Previously, open profiles infinite in extent
 - Added to ARM, mappings to describe how far profile extends
 - Square “U”, Rounded “U”, and “Vee” profiles for slots, steps, and open pockets
 - Removal depth on planar face
 - Pushed back changes to other APs through AIC522e2 and ARM changes to AP-224e3.



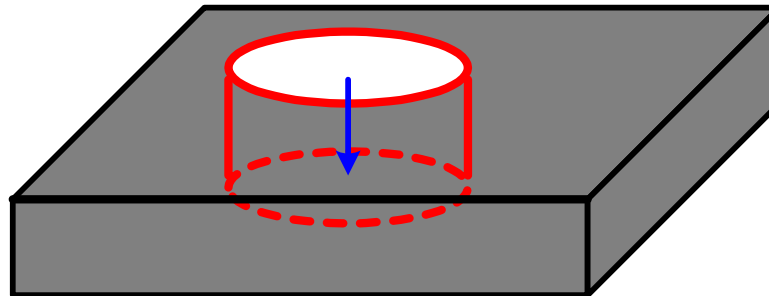
- **Additional attribute to link to explicit shape**
 - ISO 14649 has no way to link feature with part geometry
 - ISO 10303 can provide an explicit description linking geometry
 - Both ISO 14649 and ISO 10303 provide implicit feature description (profiles and paths)

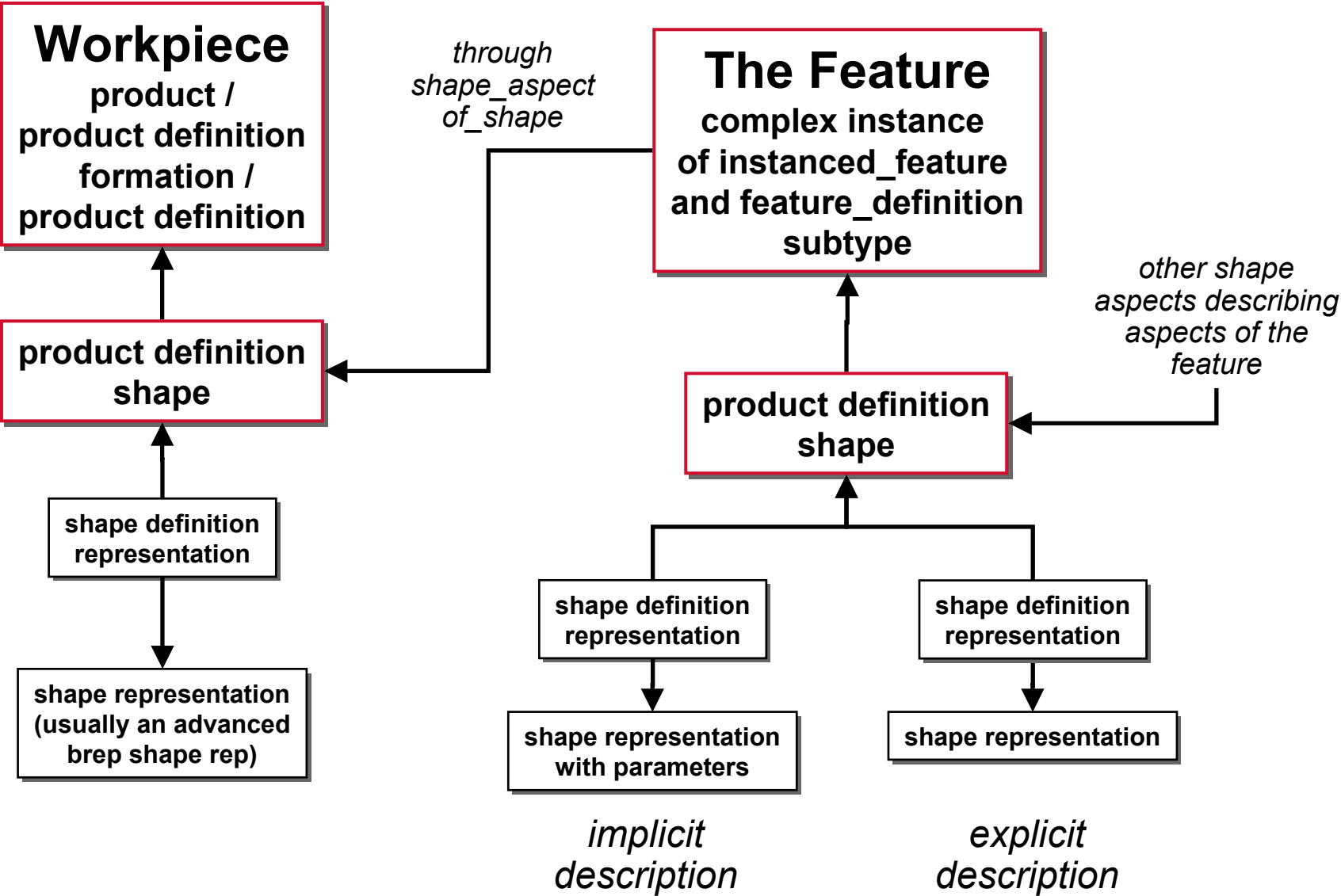
Implicit description

A round_hole is defined by a complete circular profile and a linear path

Explicit description

Refers to the B-REP faces on the geometry that describe the hole





- **An AP-238 model has the notion of both final feature and process feature**
 - Final feature is on final part, from upstream, possibly from an AP-224 or AP-240 application. As such, some features might only define a volume when combined with the stock.
 - Process features are the features pointed to by ISO 14649 workingstep. Specific to a workplan, needs full volume limits.
 - In AP-238 workingstep can also point to one or more final features that it contributes to. (and many workingsteps and process features may contribute to one final feature)

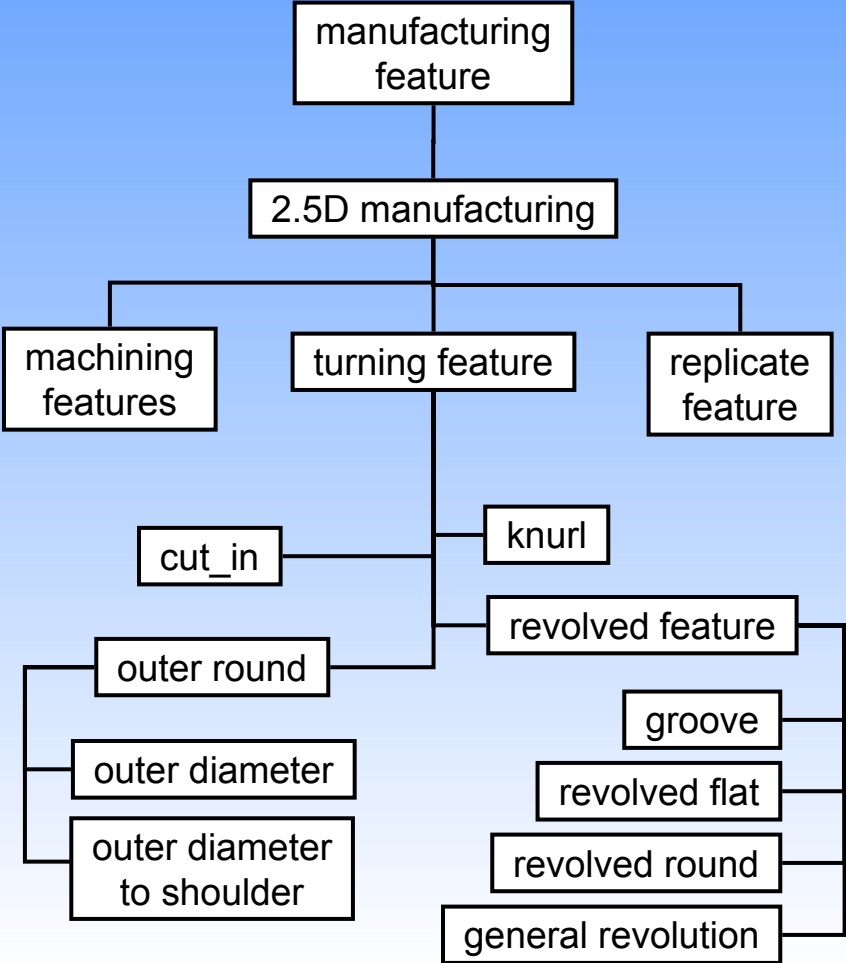


Final feature in red (POCKET)

Process features to:

- Drill the corners (HOLE)
- Mill out center with large tool (POCKET)
- Mill remaining material with smaller tool (FINAL POCKET)

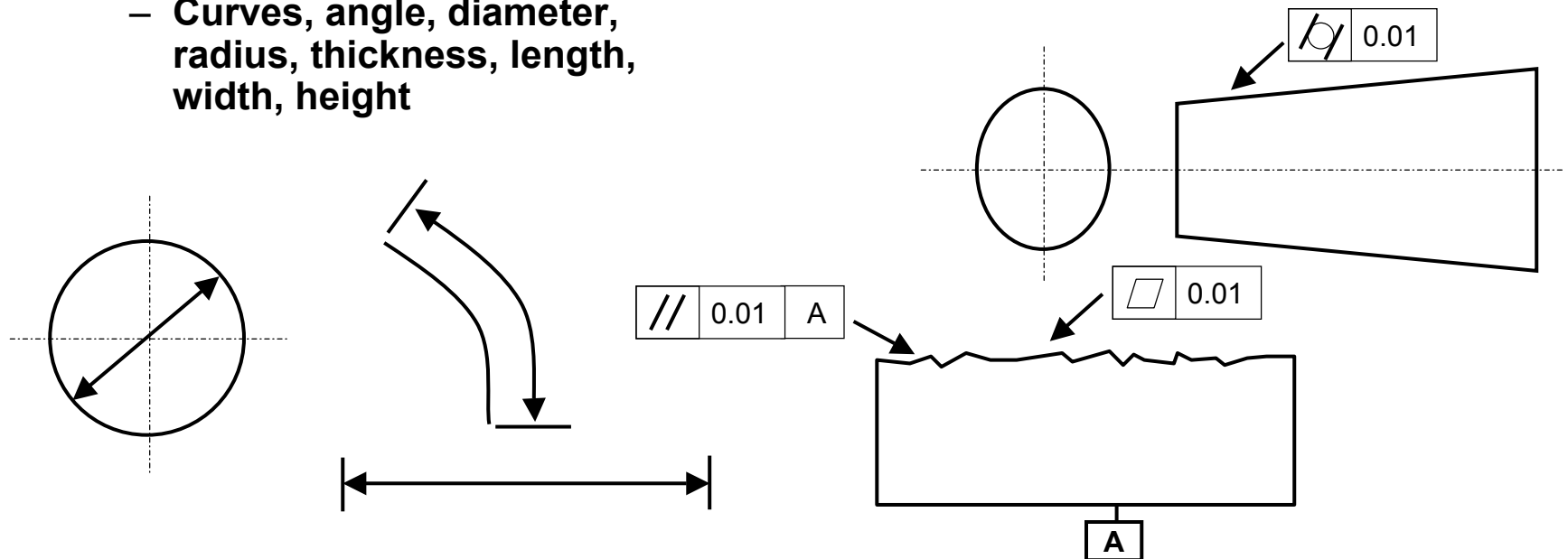
STEP-NC Features



Turning features are now harmonized between Part 12 and AP-224/AP-214

No problems encountered adding the mappings for all turning features.

- **Dimensions defining location**
 - Location defined by a linear distance
 - Location defined by a distance along a curve
 - Location defined by an angle
- **Dimensions defining size**
 - Curves, angle, diameter, radius, thickness, length, width, height
- **Geometric characteristics with datums as needed.**
 - angularity, circular runout, coaxiality, concentricity, cylindricity, flatness, line profile, parallelism, perpendicularity, position, roundness, straightness, surface profile, symmetry, total runout



- **Added GD&T ARM definitions and mappings**
 - 49 new ARM objects, plus things in the measure UOF
- **Before adding to AP, needed to resolve some harmonization issues between APs.**
 - Harmonized across AP-214, AP-224, AP-240, and AP-203e2, which uses Modules 1050 and 1051. Will also be going into AP-219 and other APs.

- **Discussed and Resolved Incompatibilities**
 - Resolved AIM mapping differences on handling of all four value qualifications (range, plus/minus, etc)
 - Agreed on common set of size dimensions
 - » New externally defined size, length, width, height
 - Harmonized mapping of envelope principle
 - Harmonized mapping of angular size full/half angle
 - Extended directed flag to all location dimensions
 - Adopted simplified angular location using axis placement.
 - Added centered/adjoining flag to radial size dimension
- **Issues arising from AP-214 SEDS**
 - Added qualifying notes, including “auxiliary” and “theoretically exact” for dimensions (SEDS 888-891)
 - Added way to specify dimensioning standard for a workpiece (SEDS 892)

- **Discussed Big Picture Strategies for GD&T**
 - Linking of dimensions with the draughting presentation elements of the dimensions.
 - Relationships with TC 10 and TC 213
 - Developed response to TC-213 “expression of concern” about some terminology usages.

- **In Seattle, resolved some issues discovered on Geometric Tolerances**
 - Mapping path for affected_plane attribute (harmonization)
 - Mapping for Common_datum in AP-224 vs AP-214/1051 (harmonization)
 - Distinction between Datum reference and Datum (usage)
 - Link between datums and manufacturing features (usage)

- **The original ISO 14649 measures**
 - Do not allow choice of units. Fixed to mm, deg, m/s
 - Defines plus/minus, limits & fits for length parameters only
- **Enhanced the ARM definitions in AP-238 so that:**
 - All measures can specify their units, as in all other APs.
 - Parameter tolerances can be used for any quantity, not just lengths. Now available for angles, speeds, etc.
 - Allows Max/Min limitation for toleranced parameters.
- **The mappings are harmonized with GD&T**

- **Product Description**
 - Workpiece, PDM and Product Geometry
 - Features
 - Dimensions and Tolerances
 - Measures

- **General Process Description**
 - Project
 - Executable
 - Operation
 - Toolpath

- **Technology Description**
 - Milling Process Operations
 - Milling Cutting Tools
 - Turning Process Operations
 - Turning Cutting Tools

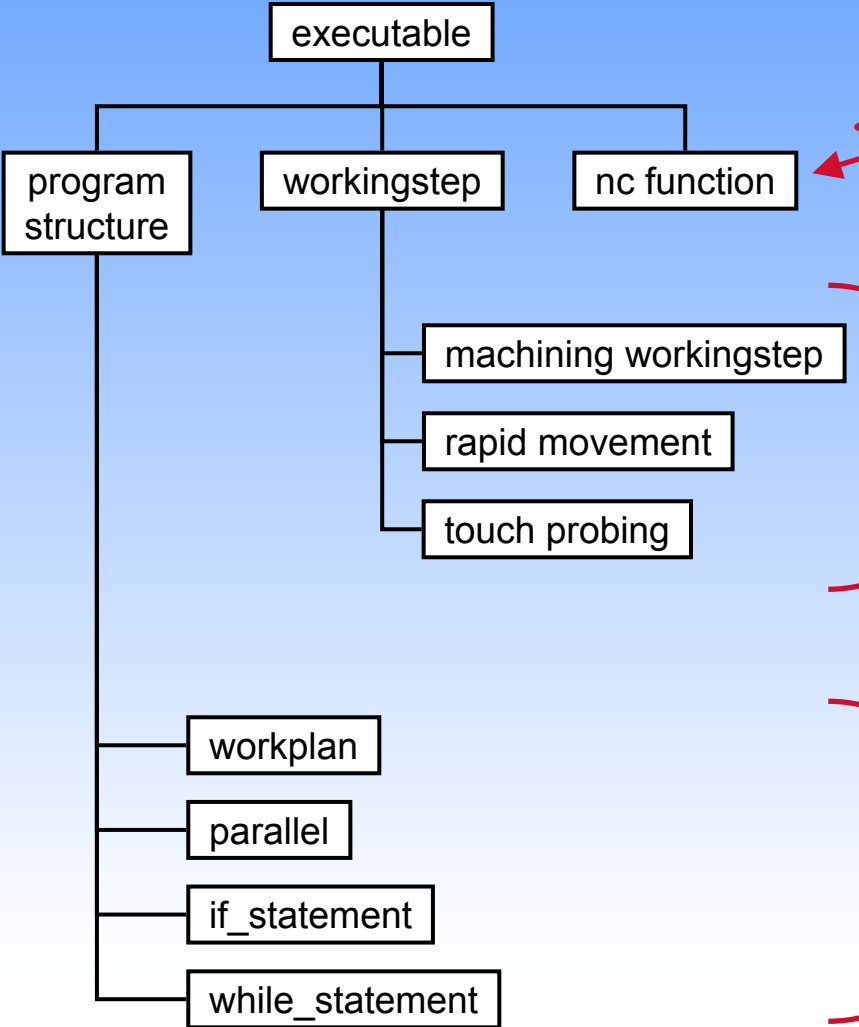
- **Toolpaths**
 - Completed mappings for toolpath subtypes, added all of the matching EXPRESS constraints to the relevant AIM types.
 - Added ARM and mappings for toolpath enhancements determined by 5-axis implementation tests.
- **Relationship with SC1**
 - New relationship subtypes from WG12 meeting.

- **The heart of the STEP-NC model**
 - Workplans containing a sequence of workingsteps.
 - Each workingstep associates an operation with a feature somewhere on the workpiece.
 - Each operation describes what to do and what strategies and parameter settings to use.

- **More information than M and G codes. Linked with geometric and technological information.**
 - Parameters can be grouped and shared, e. g. tools, feeds, etc.
 - Intelligent NC controllers can calculate tool movements for standard features.

- **Project**
 - Starting place, defines setup and main workplan
- **Executables**
 - Describes control flow and sequencing.
 - Workingstep associates an operation and a feature.
 - Technology independent
- **Operations**
 - Describes what a workingstep does to a feature — plane mill, center drill, etc.
 - The basis for all technology-specific extensions.
 - Specifies details like
 - » spindle, feedrate and other technology parameters
 - » coolant & other machine functions
 - » plunge strategies, tool paths, etc.

STEP-NC Executables



Program steps that do not move any machine axes (display message, etc.)

Program steps that move the machine axes

Control flow for the machining program

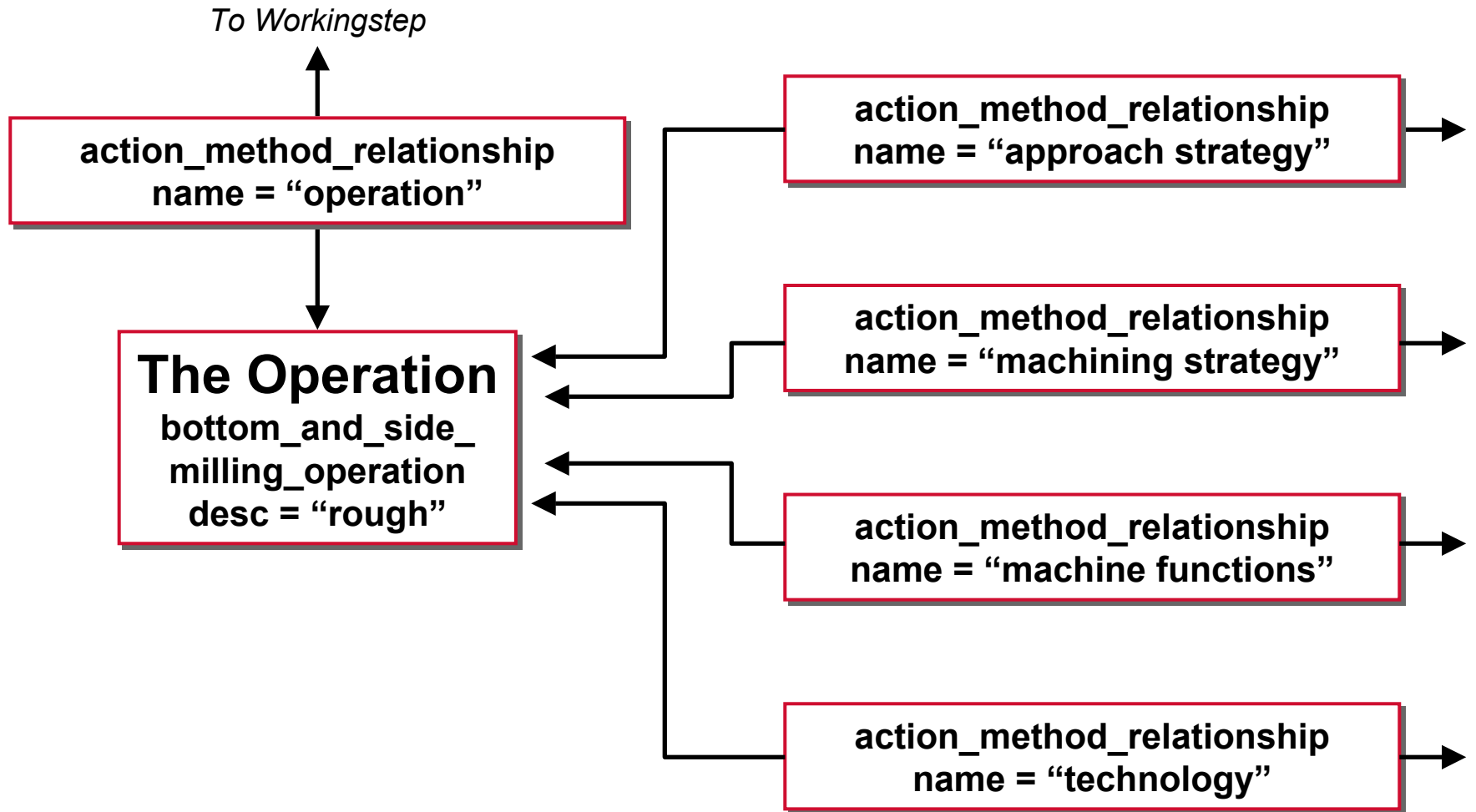
- **In discussions with SC1, agreed to help clarify data by adding AIM subtypes for relationships**
 - Analyzed AP and found 18 distinct relationships
 - Create AMR subtypes and name them based on thing that is being referenced
 - » machining_adaptive_control_relationship
 - » machining_functions_relationship
 - » machining_operation_relationship
 - » machining_operator_instruction_relationship
 - » machining_process_model_relationship
 - » machining_strategy_relationship
 - » machining_technology_relationship
 - » machining_toolpath_sequence_relationship (actually a subtype of sequential_method)

- **Further subtyping helpful for some relationships.**
 - multiple inheritance used when a different subtype is also needed for sequencing.

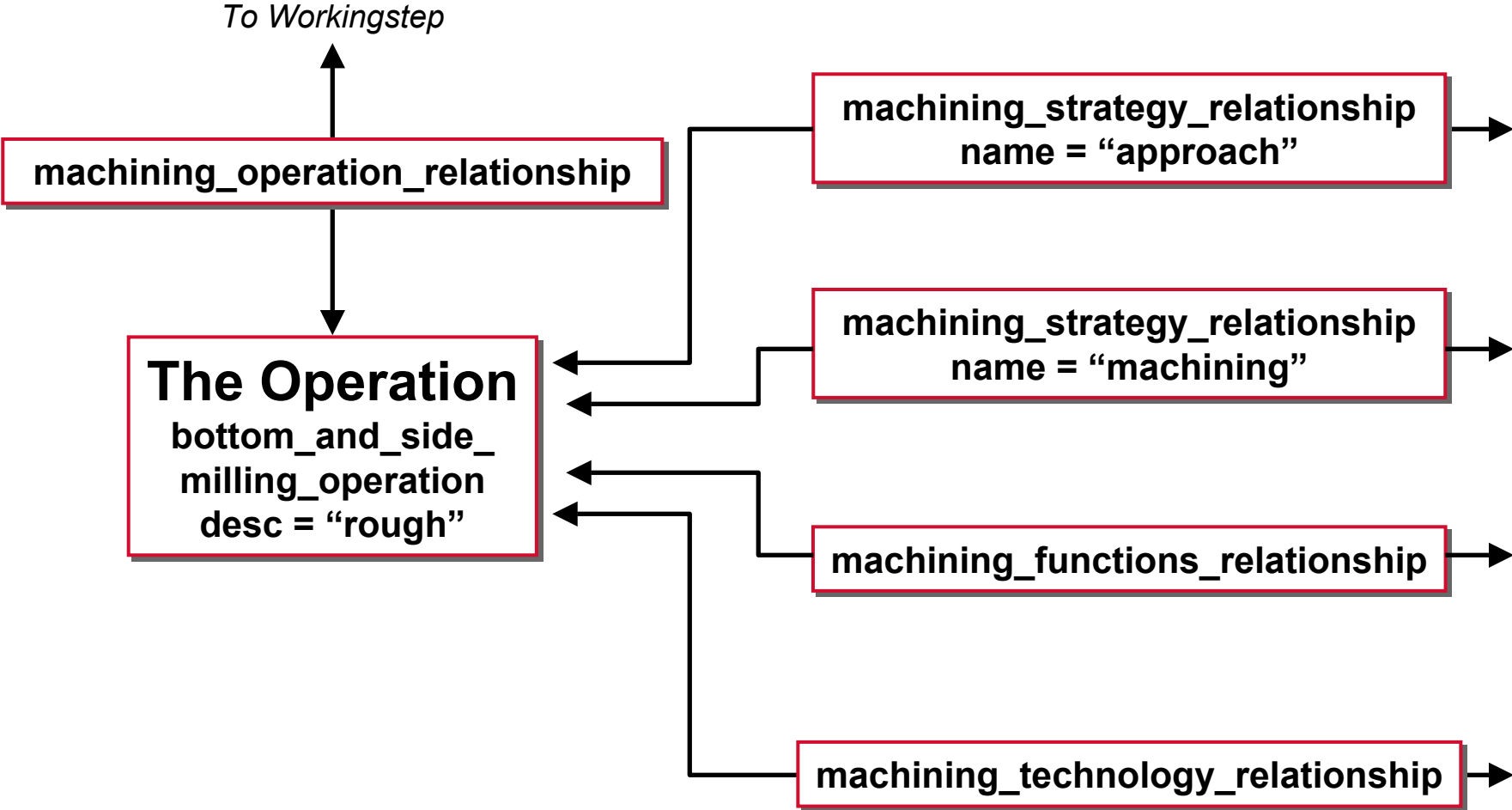
 - **machining_feature_relationship**
 - » **machining_feature_sequence_relationship** (also inherits from **sequential_method**)

 - **machining_final_feature_relationship**

 - **machining_process_body_relationship**
 - » **machining_process_sequence_relationship** (also inherits from **sequential_method**)
 - » **machining_process_concurrent_relationship** (also inherits from **concurrent_action_method**)
 - » **machining_process_branch_relationship**

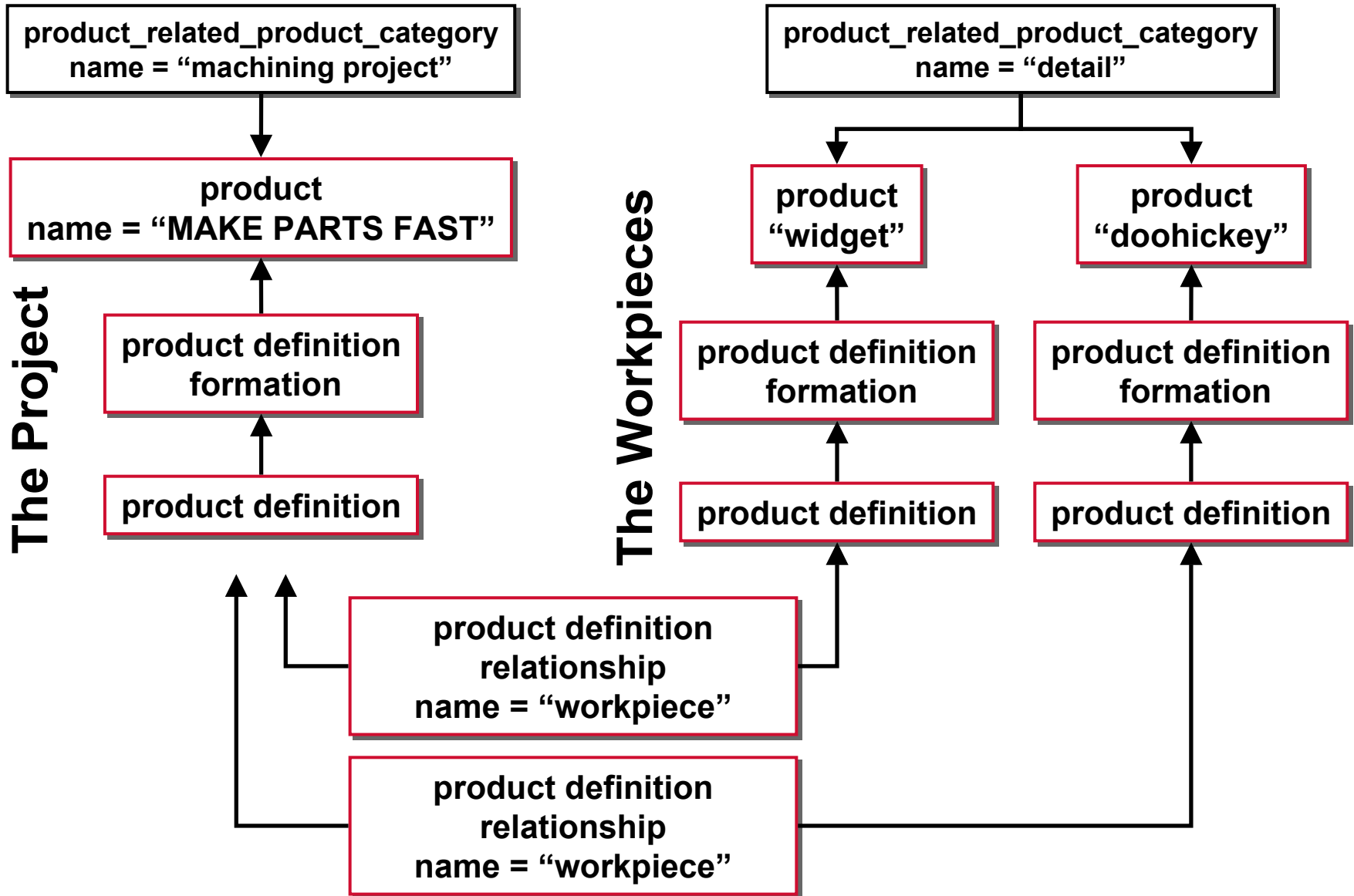


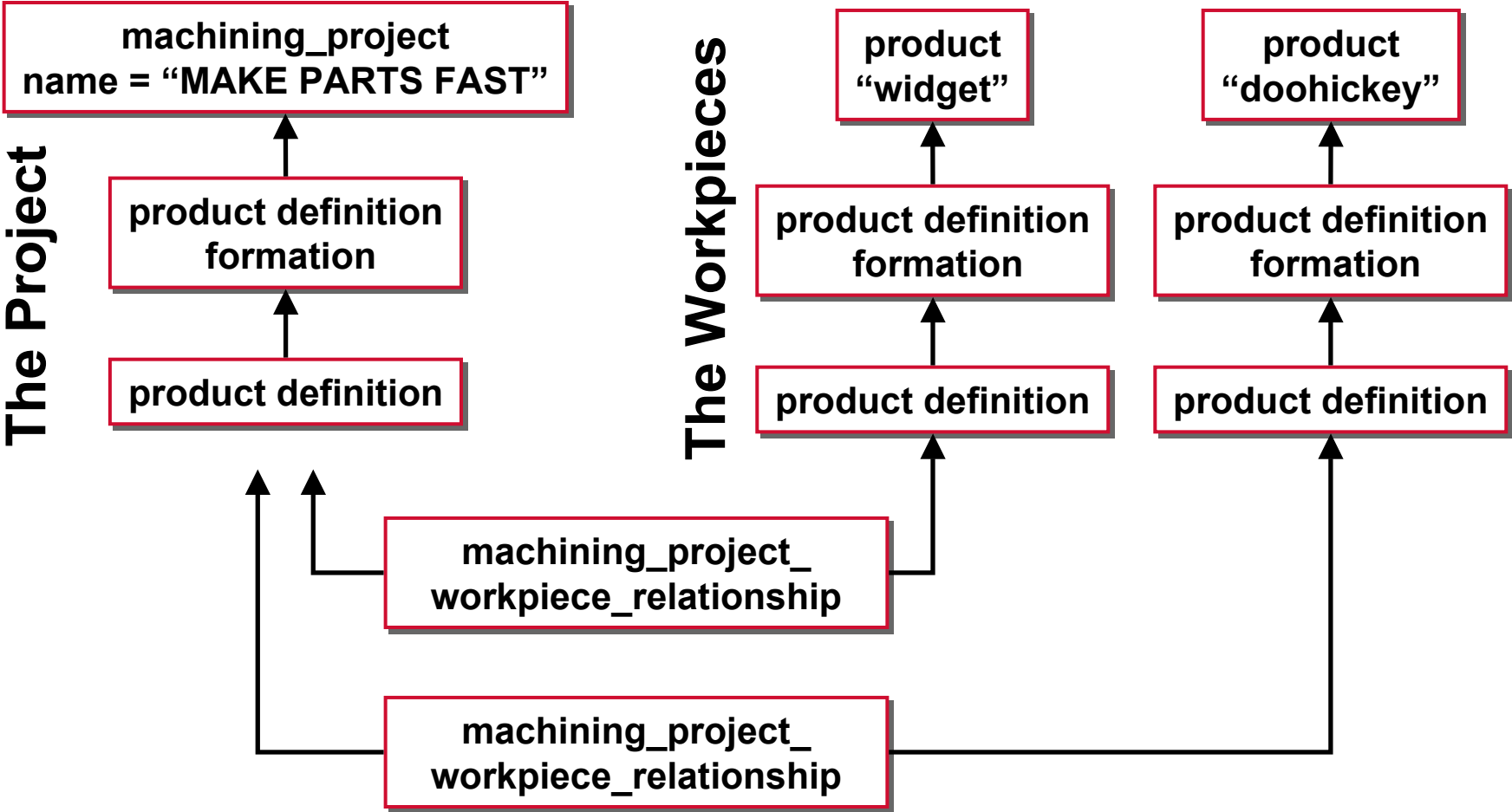
New Way: Milling Operation



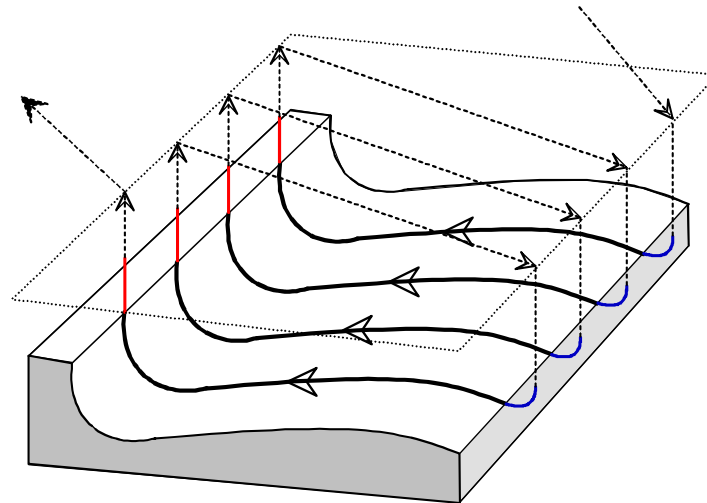
- **Also added subtypes to clarify project and setup**
 - Added product subtypes to identify the project/setup
 - Replaces the use of a product category classification.
 - » machining_project
 - » machining_setup

 - Added product definition relationship subtypes to clarify the linkage between workpieces and the project or setup.
 - Replaces the use of a plain PDR with a name string.
 - » machining_setup_workpiece_relationship
 - » machining_project_workpiece_relationship

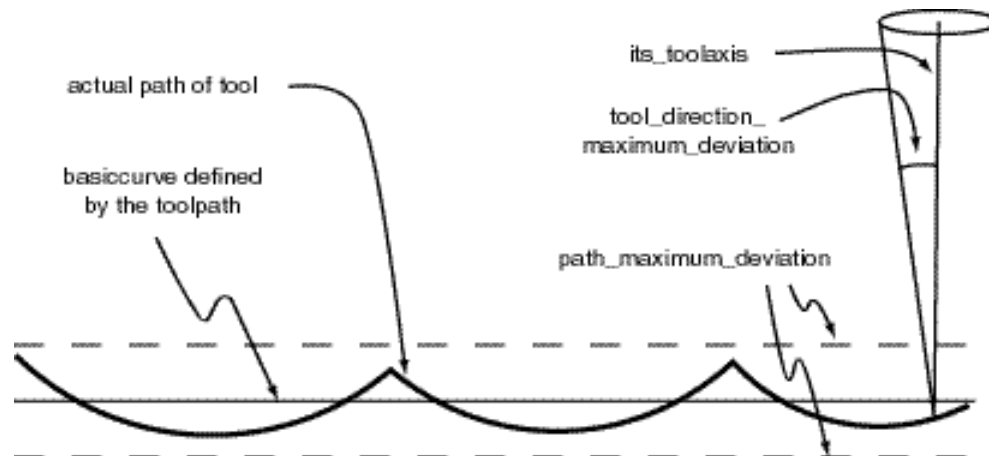


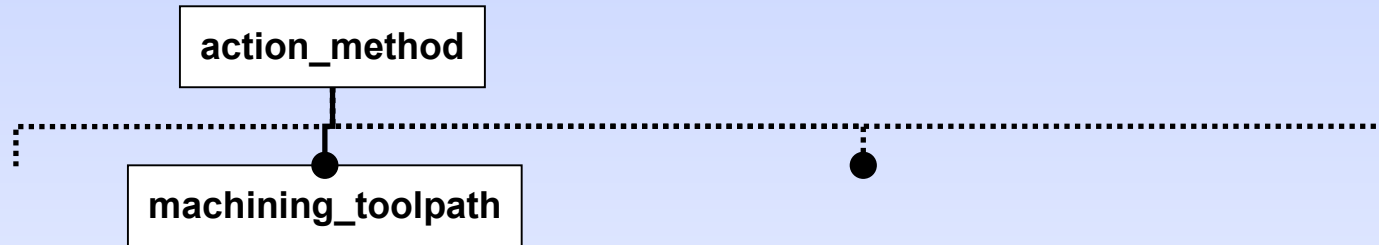


- **Used for explicit control of the tool motion for an operation.**
 - Can use splines or other curves to describe motion and feedrates.
 - Can describe path as machine independent motion of tool center point or tool contact point.
 - Can also describe path using old-style machine dependent motion of individual axis.



- **Added toolpath enhancements for 5-axis work**
 - Maximum deviation for path or tool direction
 - Milling tool holder profile to enable collision checking
 - Relaxed curve constraints on speed profile to allow polylines
 - Machine Axis constraint to limit the range an axis may traverse
 - NC pass through capability to allow legacy codes to be passed through to the underlying controller





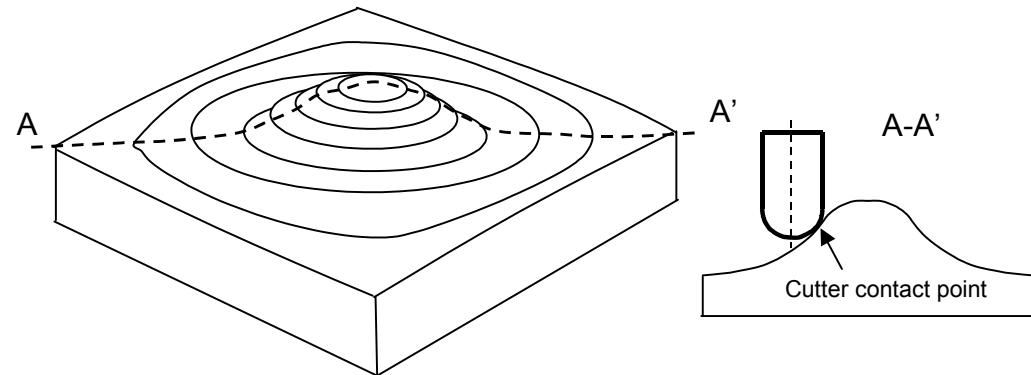
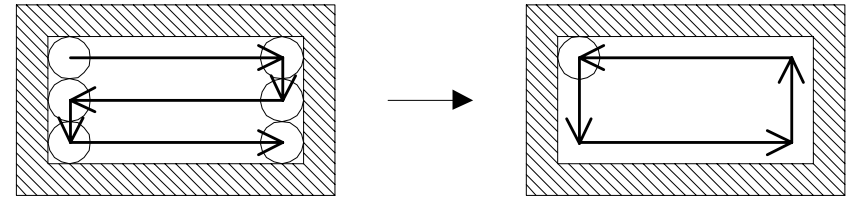
- **ARM Toolpath and subtypes are mapped to AIM machining_toolpath.**
 - Toolpath base class was already completely mapped.
 - Added mapping table entries and corresponding AIM EXPRESS local rules for the subtypes.

- **Product Description**
 - Workpiece, PDM and Product Geometry
 - Features
 - Dimensions and Tolerances
 - Measures
- **General Process Description**
 - Project
 - Executable
 - Operation
 - Toolpath
- **Technology Description**
 - Milling Process Operations
 - Milling Cutting Tools
 - Turning Process Operations
 - Turning Cutting Tools

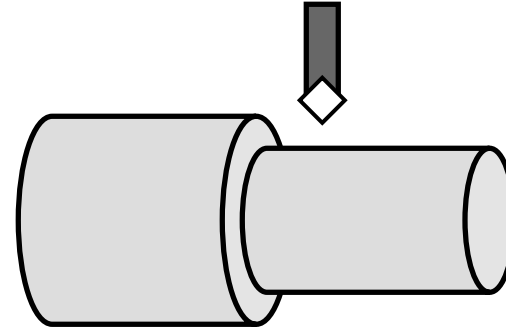
- **Turning Model**

- Added mappings for turning features, operations and tools.
- Reworked mappings for feedrate, spindle speed, and dwell time to unify usage across milling and turning models.

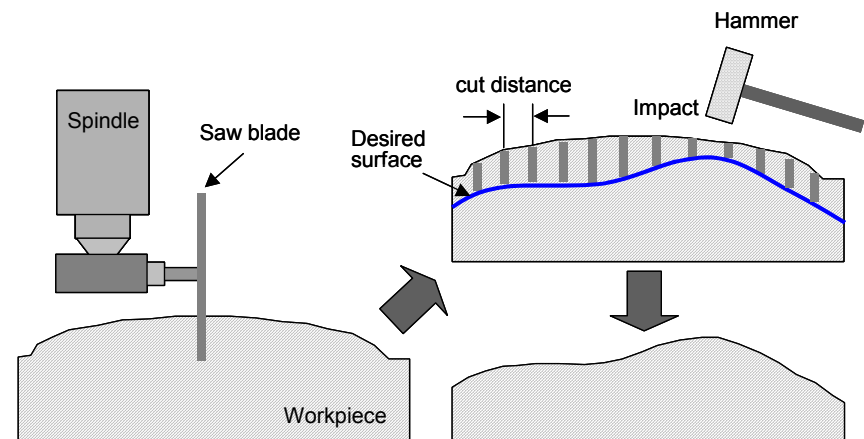
- **Drilling Operations**
 - Drilling, boring, back boring, tapping/threading
 - Tool moves in the Z axis only
 - Many strategy parameters
- **2.5D Machining Operations**
 - Plane and side milling, roughing and finishing
 - Tool can move XY or along Z, but not at the same time.
 - Set of strategies
- **Freeform Machining Operations**
 - For sculpted surfaces
 - 3, 4, and 5axis motion
 - Set of strategies



- **Turning Operations**
 - Contouring, facing, grooving, threading and knurling.
 - Roughing and finishing for each
 - Set of strategies

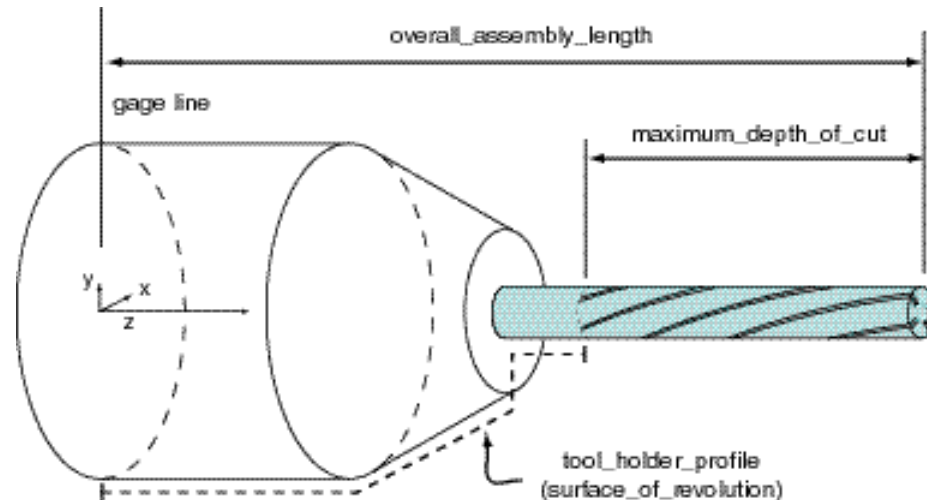


- **Possible Future Operations**
 - Work underway to describe operations for wire and sink EDM, contour cutting of wood and glass, grinding.
 - Efforts in various stages of maturity.
 - Will be added to AP-238 once the information requirements are mature.

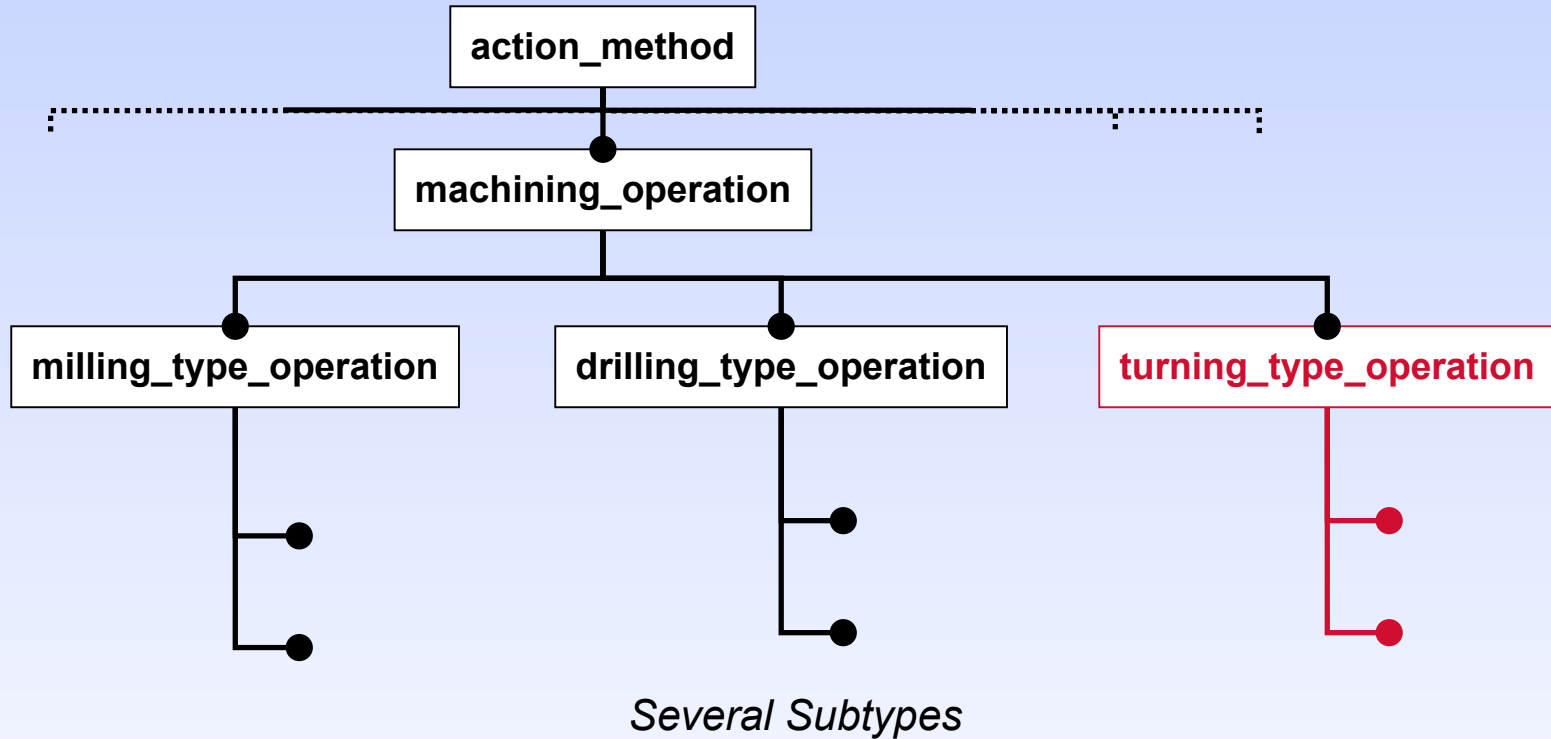


- **Every operation can have a tool associated.**
 - Represents tool requirements, not a physical tool on a machine.
 - Potential for some best-fit optimization by the controller.
- **G&M codes just referenced tool #1, #2, etc.**
 - Human must make sure that #1 corresponds to the right thing.
 - Controller not able to add any value to the process.

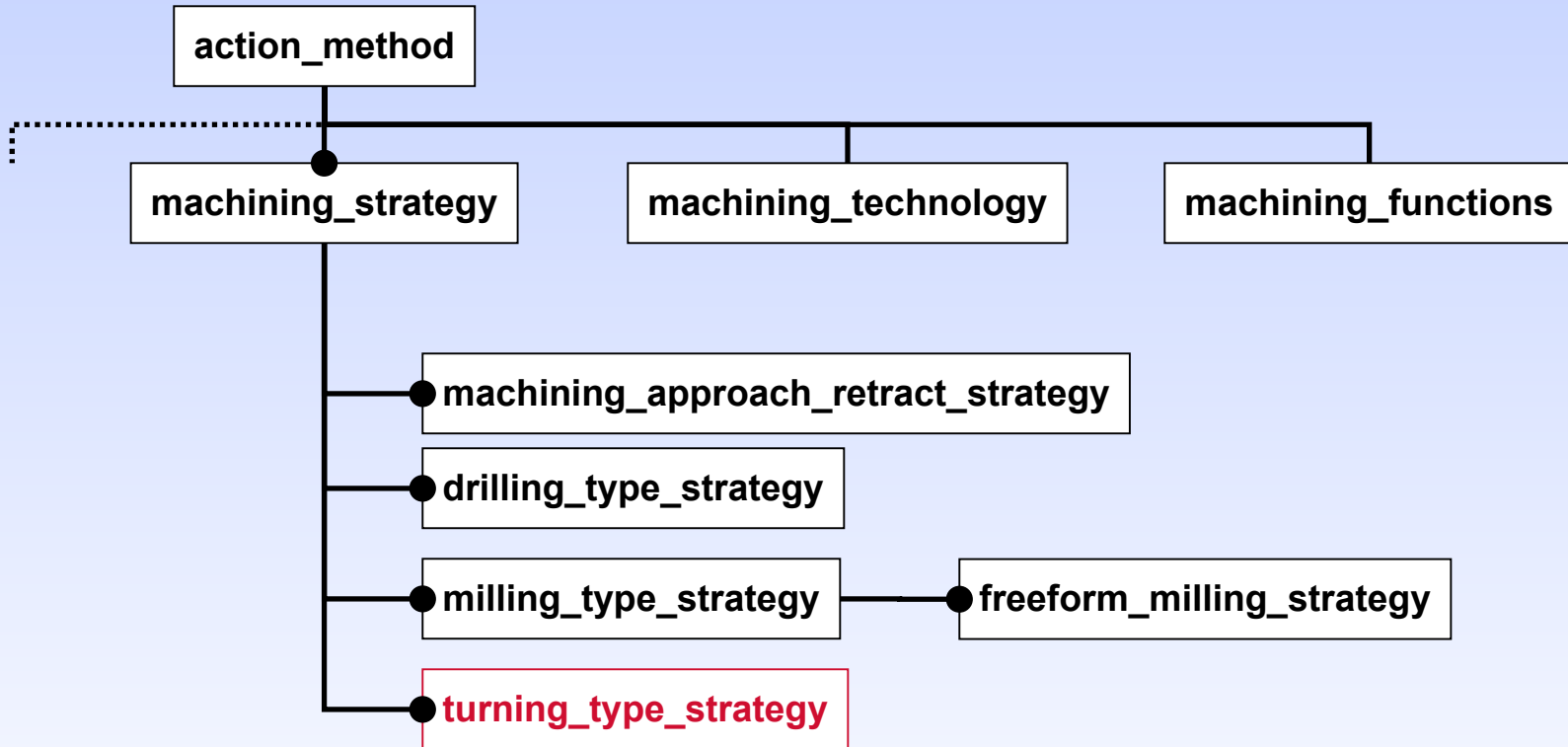
- **Can call out characteristic tool parameters**
 - Endmills, facemill, ball endmill, bullnose endmill, side mill, tslot, tapered, dovetail, threading and woodruff keyseat mills
 - Drills, centerdrill, twist, tapered, or spade drills, combined drill and reamer or tap
 - Boring and reaming tools, tapered reamer, counterbore, countersink, backside counterbore and countersink
 - Turning, grooving and knurling tools, taps and threading tools



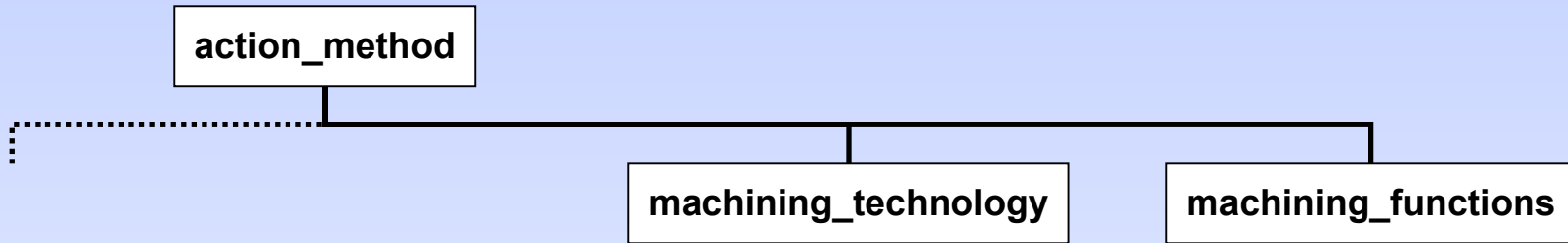
- **Added support for the turning parts**
 - Part 12
 - Part 121
- **Required no major changes**
 - Mappings are straightforward and follow conventions established by the mill/drill mappings.
 - Added UOFs, mappings, and updated AIM constraints.
 - The EXPRESS rules for some of the representation subtypes began to get a bit lengthy, so I abstracted the common idioms into new EXPRESS functions:
 - » `verify_[optional/required]_rep_item`
 - » `verify_[length/angle]_measure_rep_item.`
- **Very encouraging experience for adding other technology parts**



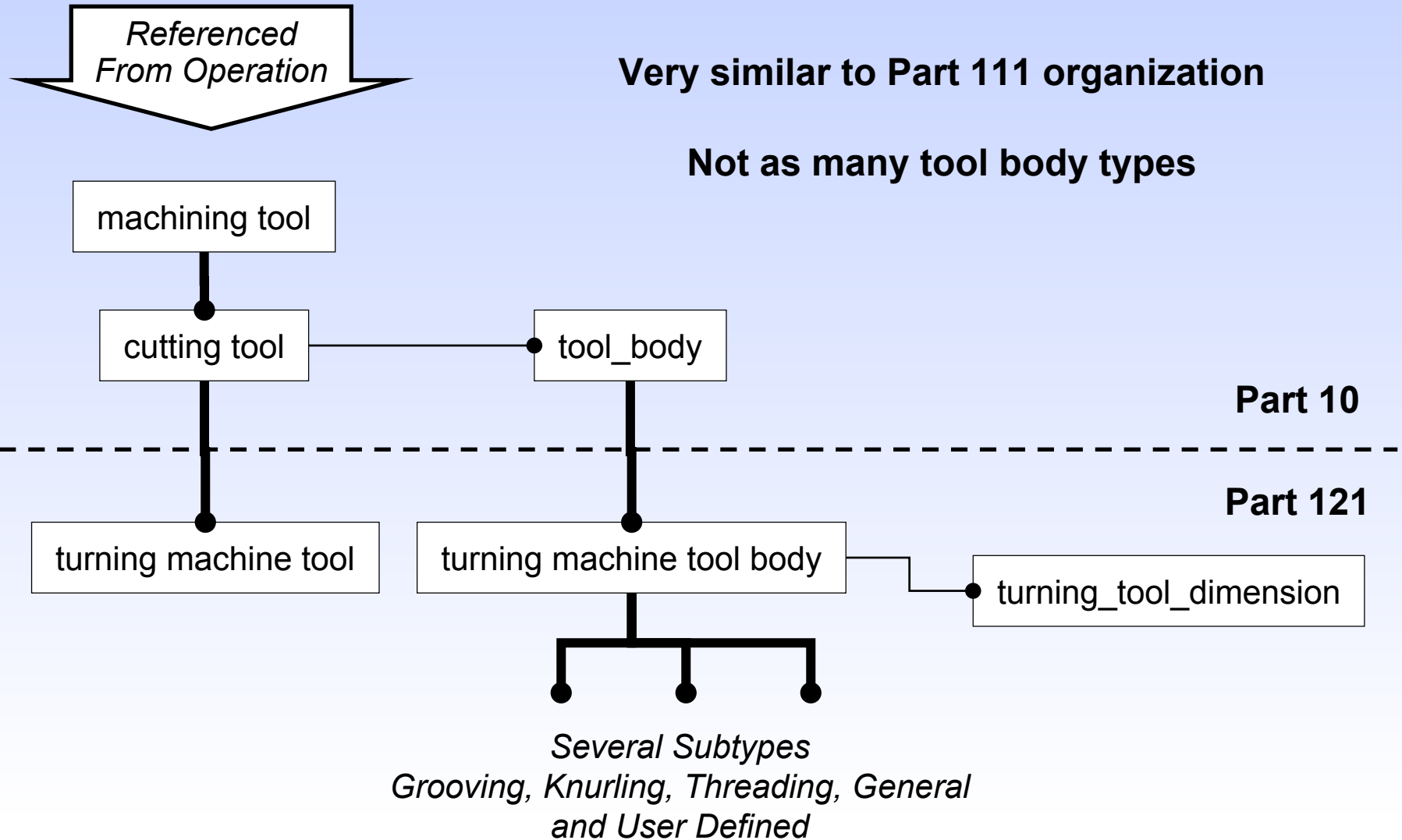
- **Turning operations represented using several new AIM subtypes**
 - As with milling/drilling, attributes represented using a collection of action properties.



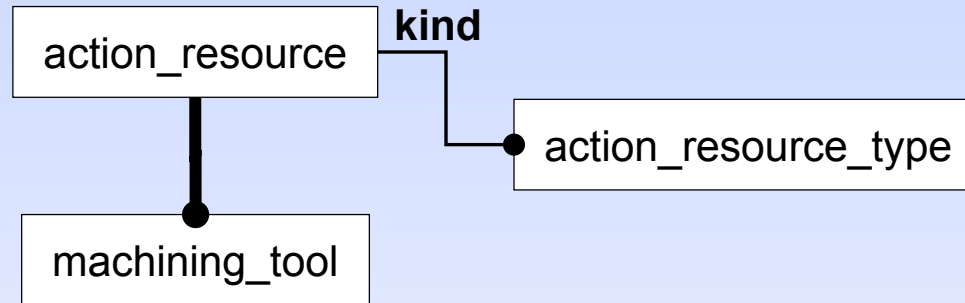
- **Turning strategy represented using a new AIM subtype.**
 - Same techniques as with milling/drilling strategies
 - Part 12 references existing approach/retract strategies



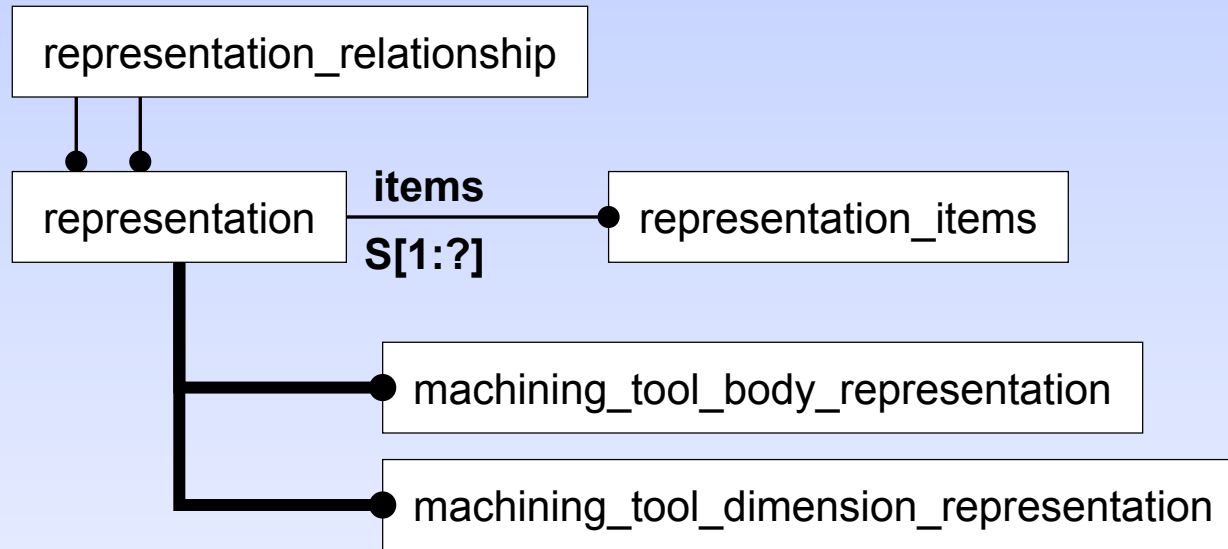
- **Turning technology and machining functions did not require any new AIM types.**
 - Milling technology/functions already distinguished by an `action_method.description` of “milling”.
 - Use `action_method.description` of “turning” to distinguish the turning technology/functions.
 - Many properties are common between milling/turning versions. AIM EXPRESS rules simplified.



Required equipment



- **Turning tools did not require any new AIM types**
 - Use action resource subtype `machining_tool` for the ARM `turning_machine_tool` concept.
 - Has a “kind” attribute that categorizes the resource
 - » We use value “milling cutting tool” for Part 111 data
 - » Now add value “turning cutting tool” for Part 121.



- **No new AIM types needed for body or dimension**
 - Use existing representation subtypes developed for Part 111
 - As with all of our complex types, properties handled as various representation items within.
 - Distinguish tool bodies using the `representation.name`
 - Distinguish milling/turning/other tool dimensions using `representation.name` “milling”, “turning”, etc.

- **Other Improvements**

- Other CD comment resolutions and fixes.
- Many mapping table bugs fixed, discovered during XML work.

- Added four conformance classes as discussed.
- Update ARM & AIM EXPRESS-G diagrams.
- Add informative annex with XML description of mappings