



AP-238 Walkthrough

Fukuoka SC4 Meeting

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- **What is the AIM?**

- **The Backbone: Workpiece and Features**
- **The Backbone: Executables and Operations**
- **Milling Operations and Strategies**
- **Milling Tool Types**
- **Projects and Setups**
- **Advanced Control Flow for Programs**
- **Explicit Toolpaths**

- **AP-238 describes how to implement STEP-NC so that it works with existing STEP APs.**
 - AP-238 maps the ISO 14649 information requirements to the integrated definitions used by all other AP.
 - So you can use existing CAD systems, viewers, etc.
- **Why?**
 - Lets domain experts describe requirements clearly (ARM)
 - While the database stays extensible and interoperable with the other application protocols (AIM)
 - Each AP can describe one or two aspects of a product.
 - All APs can be put together to describe everything about a product.

- **We will cover each part of the STEP-NC model**
 - The information requirements (ARM)
 - The database representation (AIM)
- **If you are creating new data**
 - You will populate the database representation, so that you can hook it into existing data properly.
- **If you are browsing existing data**
 - You may traverse the database representation yourself, or
 - You may write EXPRESS-X views to do some of that for you.

- **One STEP-NC AIM will cover all technologies**
 - First edition covers milling.
 - Second edition will extend with turning and EDM.
 - Amendments can add others as needed.

Measures
Project
Workpiece
Features

Executable
Operation
Toolpath

Based on Part 10

Milling Process Operations
Milling Cutting Tools

Based on Part 11
Based on Part 11-1

Turning Process Operations
EDM Process Operations

Based on Part 12
Based on Part 13

**First
Edition**

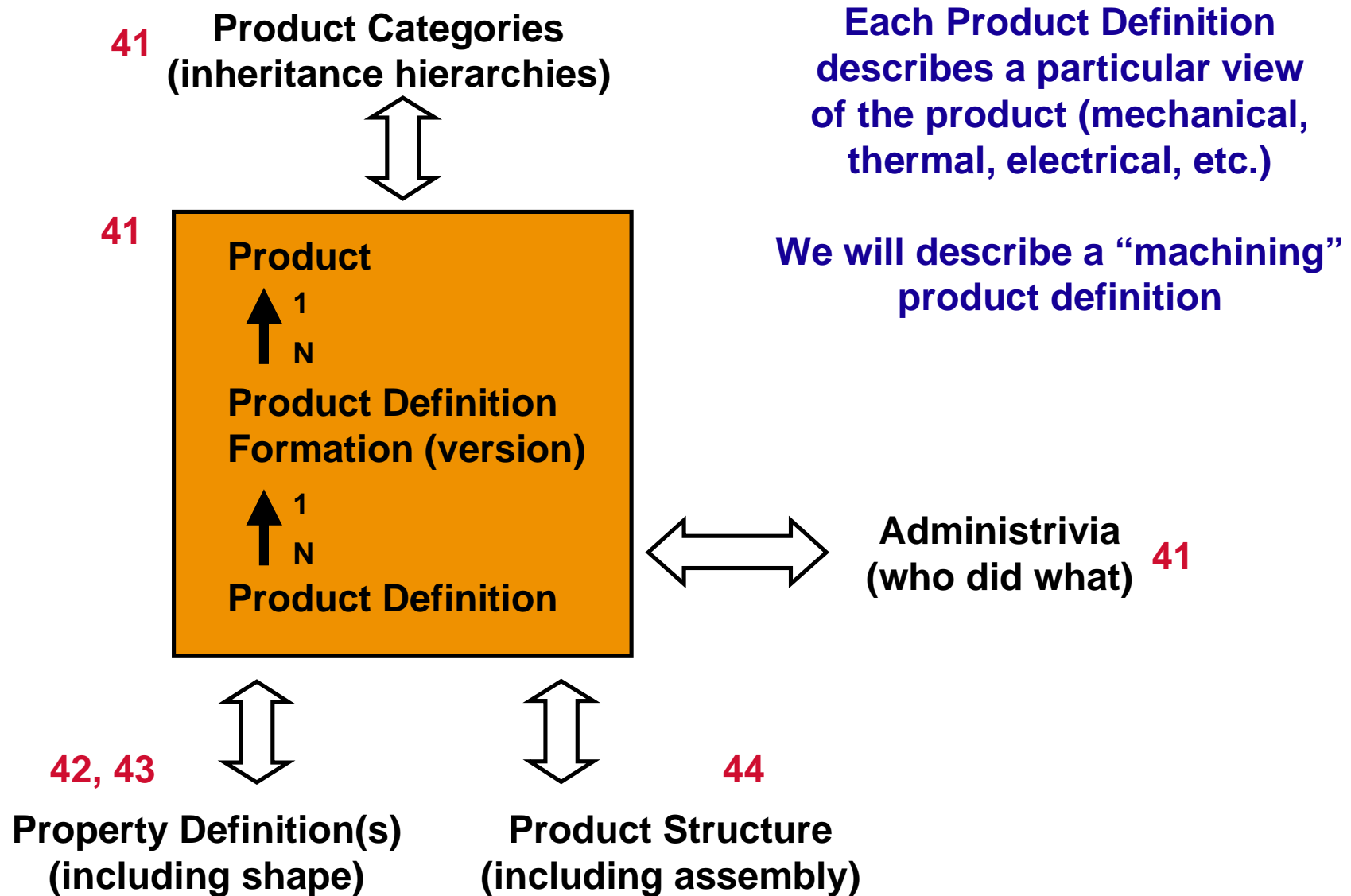
**Second
Edition**

- **All APs contain tables describing how the integrated definitions are used to represent the information requirements**
 - Called mapping tables
- **For each object and attribute in the information requirements, the mapping table shows:**
 - What integrated resource object represents it, and which IR document defines it.
 - A reference path through the database to get to it, including required values in some of the objects (where name = xyz)
 - Any global EXPRESS rules that apply to it.

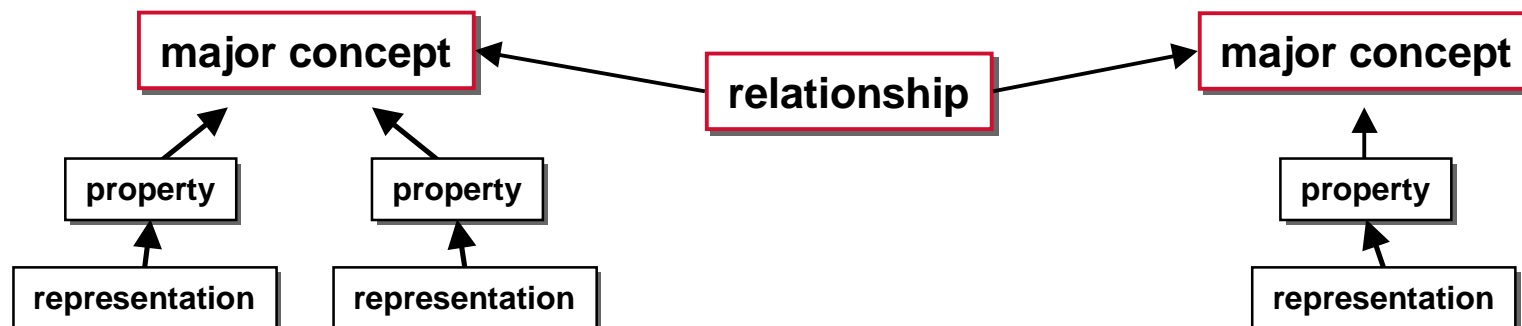
- **Information requirements are represented using the definitions in the Integrated Resources**
 - Part 41 - Product versions, dates, times, people
 - Part 42 - Representation geometric shapes
 - Part 43 - Representation of other properties
 - Part 44 - Relationships between products
 - Part 49 - Actions
- **IRs have very general definitions, so we might create some subtypes to make it clearer.**
 - STEP-NC is primarily about actions, so we will create subtypes of things from Part 49.
- **Write EXPRESS rules for any extra requirements on the information.**

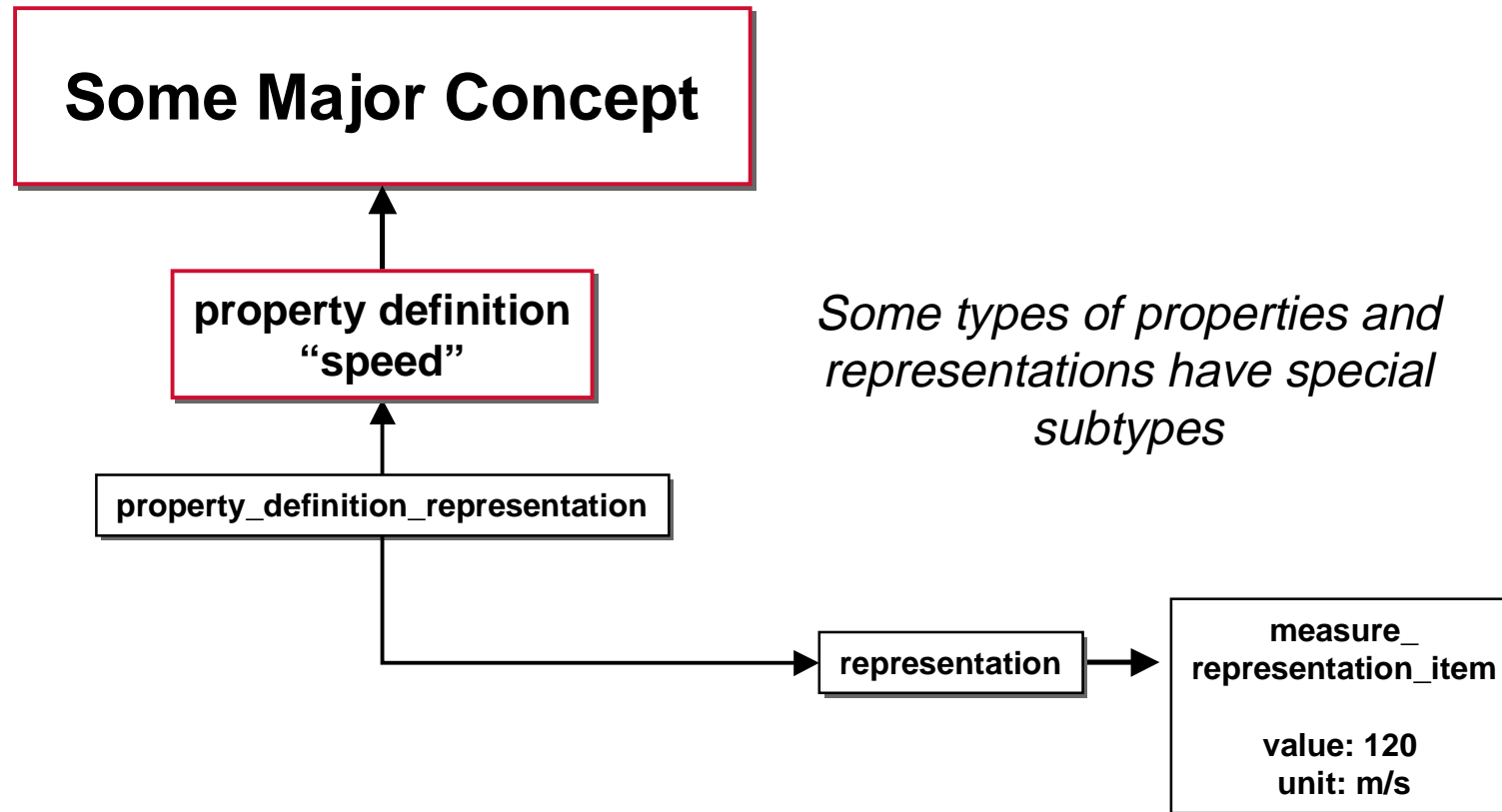
STEP Part Identification Backbone **STEP Tools, Inc.**

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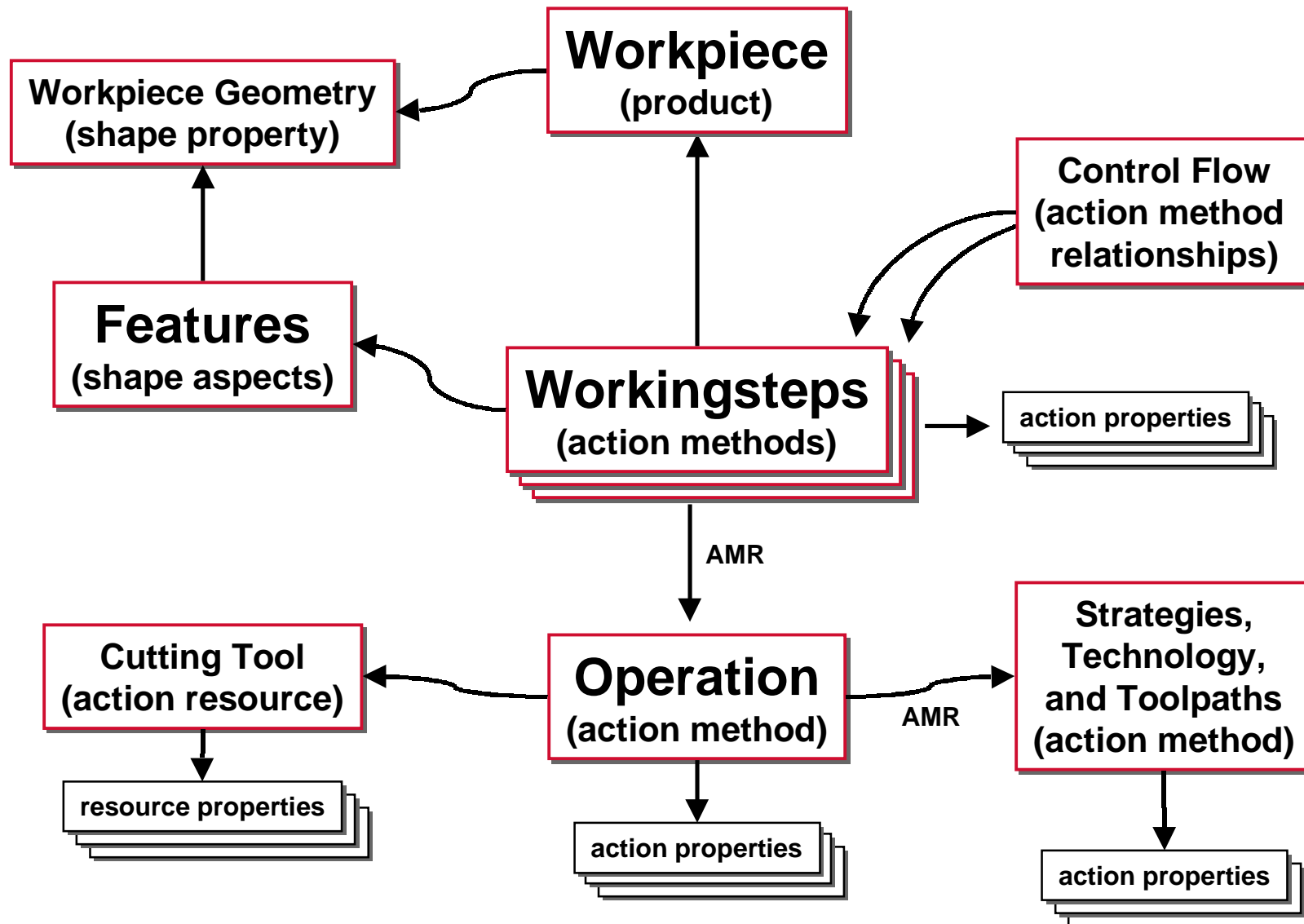


- **Major Concepts**
 - Represented as product, action_method, action_resource.
- **Relationship between major concepts**
 - Represented as relationship object (product definition relationship, action method relationship)
- **Properties**
 - Represented as property object with associated representation.
 - Representations can be simple (scalar value) or complex (multiple scalar values, geometry, expressions)

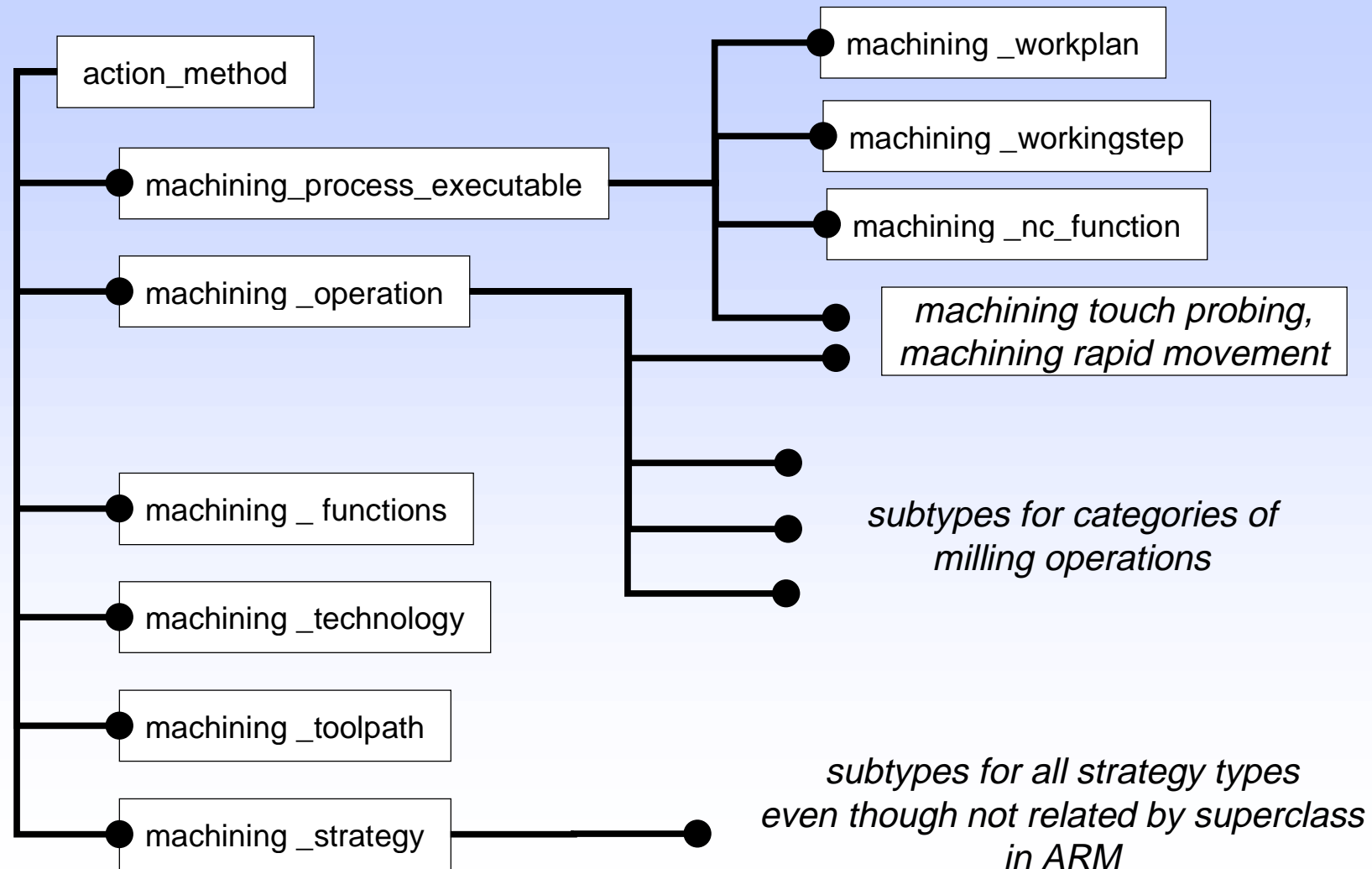




Why so much indirection?
So a property can have multiple representations,
and a representation (like shape) can be reused



- **In the AIM, many things may be mapped to the same IR definition.**
 - For example, strategy, workingstep, operation are all action methods.
 - ARM concepts often distinguished by special strings in name or description fields.
- **Use subtypes of the integrated resources to simplify constraints and make the model clearer**
 - Just for identification, never adds new attributes.
 - Can write local (where) rules rather than global rules.
 - Use prefix “machining” where possible to avoid name conflict with other concepts in other APs.
 - Use the same name where concept is the same in other APs, such as the manufacturing features.

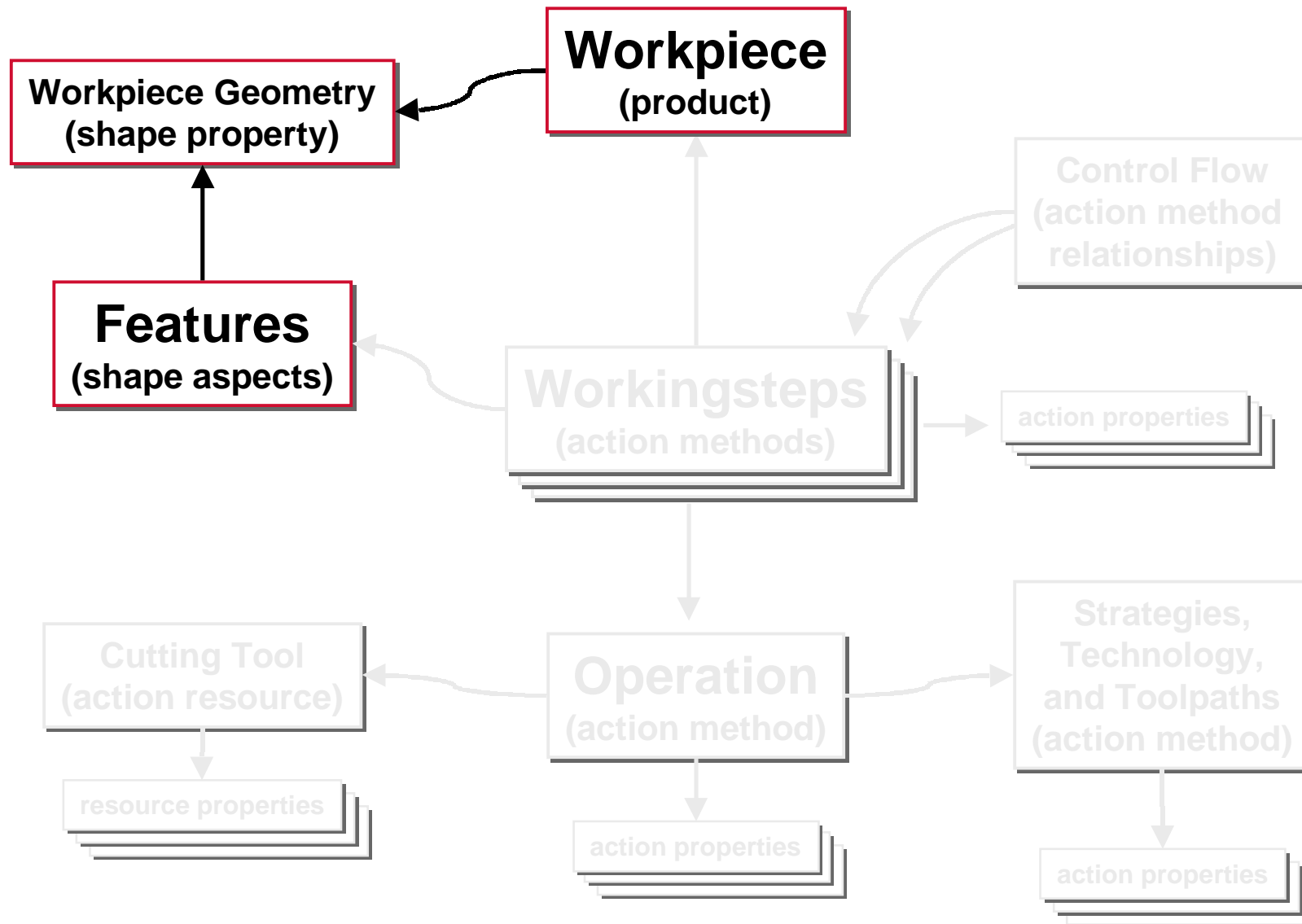


- **Mapping of STEP-NC process data harmonized with other APs.**
 - Process data harmonized with AP-214 and AP-213.
- **Mapping of STEP-NC feature data harmonized with other APs.**
 - Process data harmonized with AP-224 and AP-214.
- **Mapping of STEP-NC product identification harmonized with all other APs.**

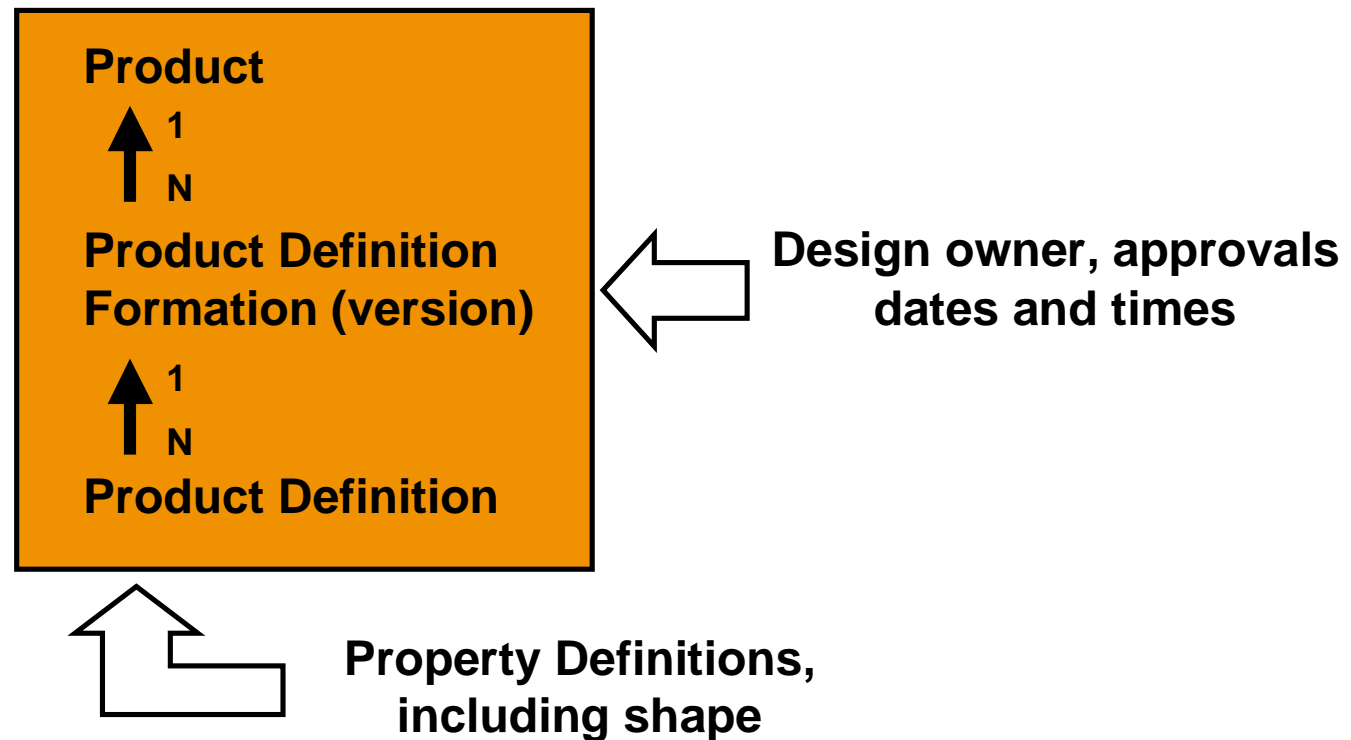
- **What is the AIM?**

- **The Backbone: Workpiece and Features**

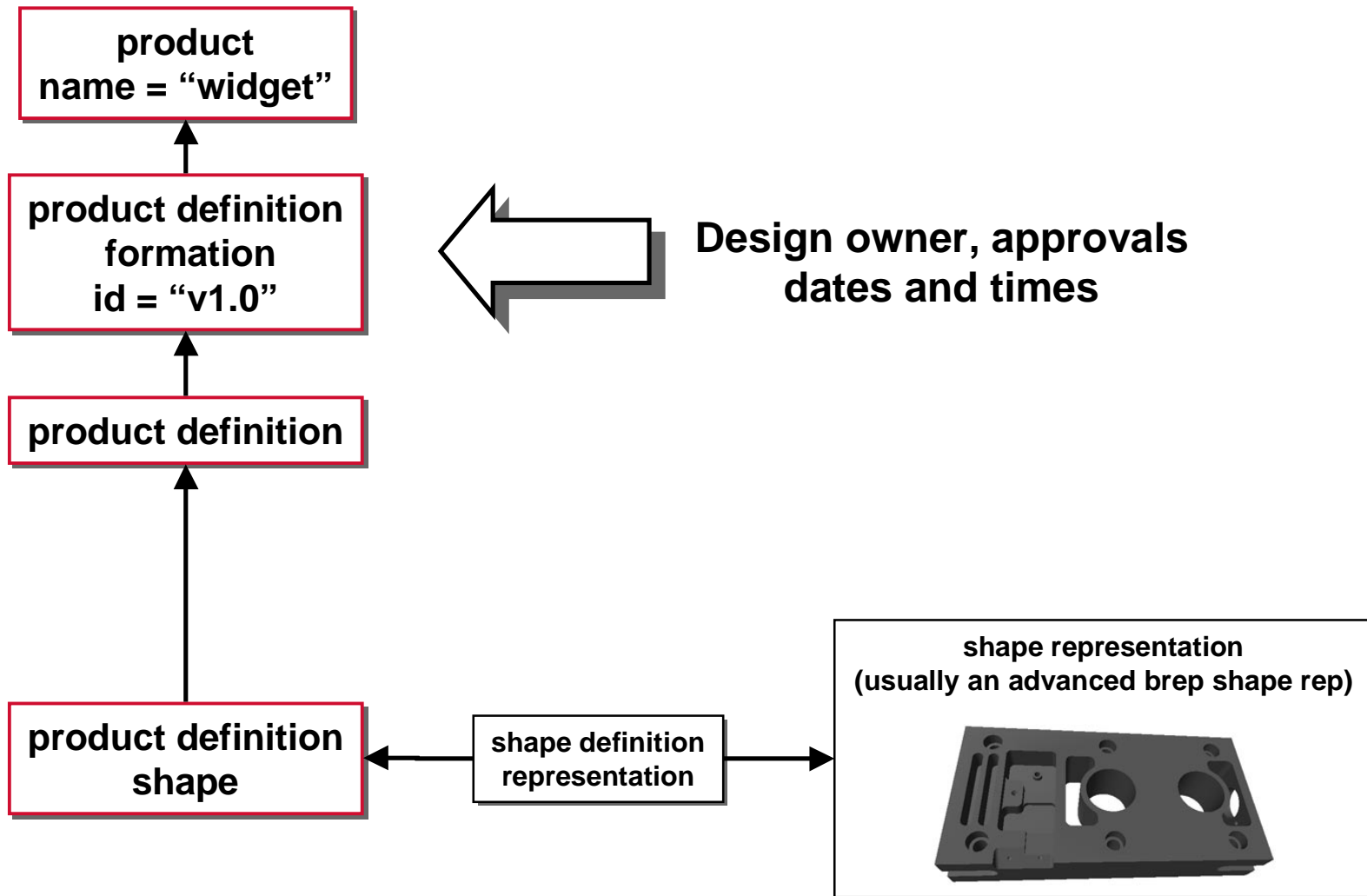
- **The Backbone: Executables and Operations**
- **Milling Operations and Strategies**
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- **Workpiece describes the final output of a manufacturing process**
- **Workpiece is represented as a product**
 - The shape of the workpiece is a property of the product



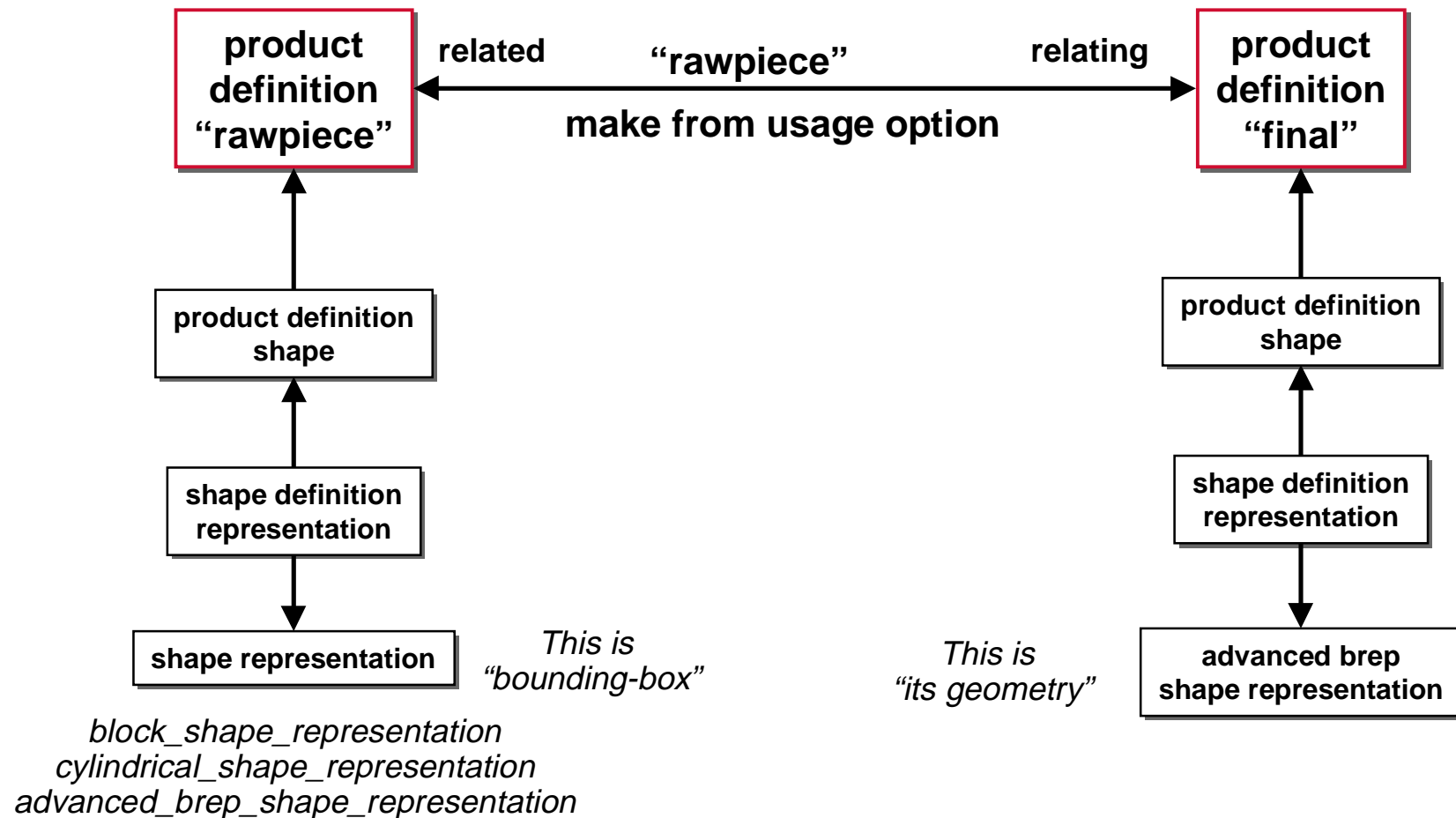
The Workpiece



- **ISO 14649 defines “rawpiece” and “bounding box” as attributes of a workpiece.**
- **In the AIM:**
 - “rawpiece” is a separate product definition
 - “bounding box” is the shape of that product
 - “material” is a material designation on that product

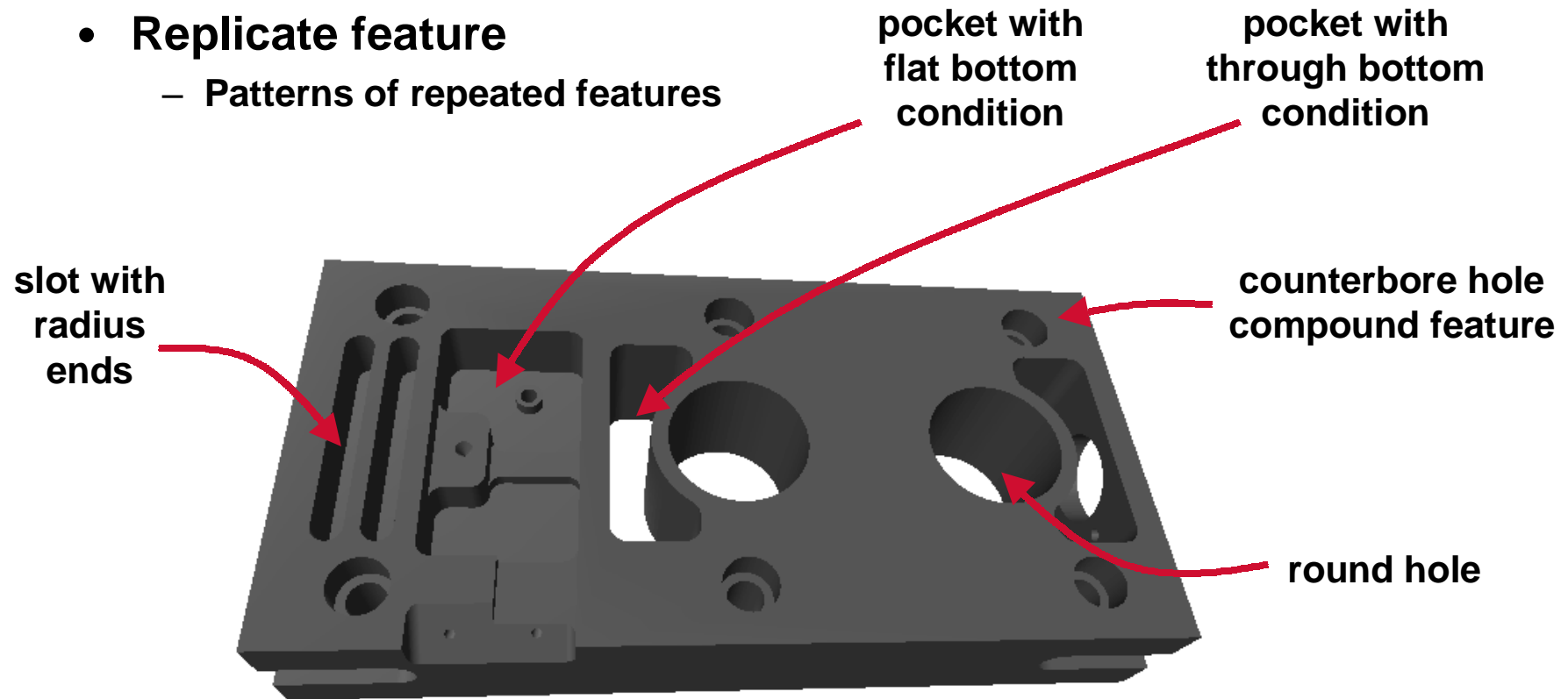
How Stock is Attached

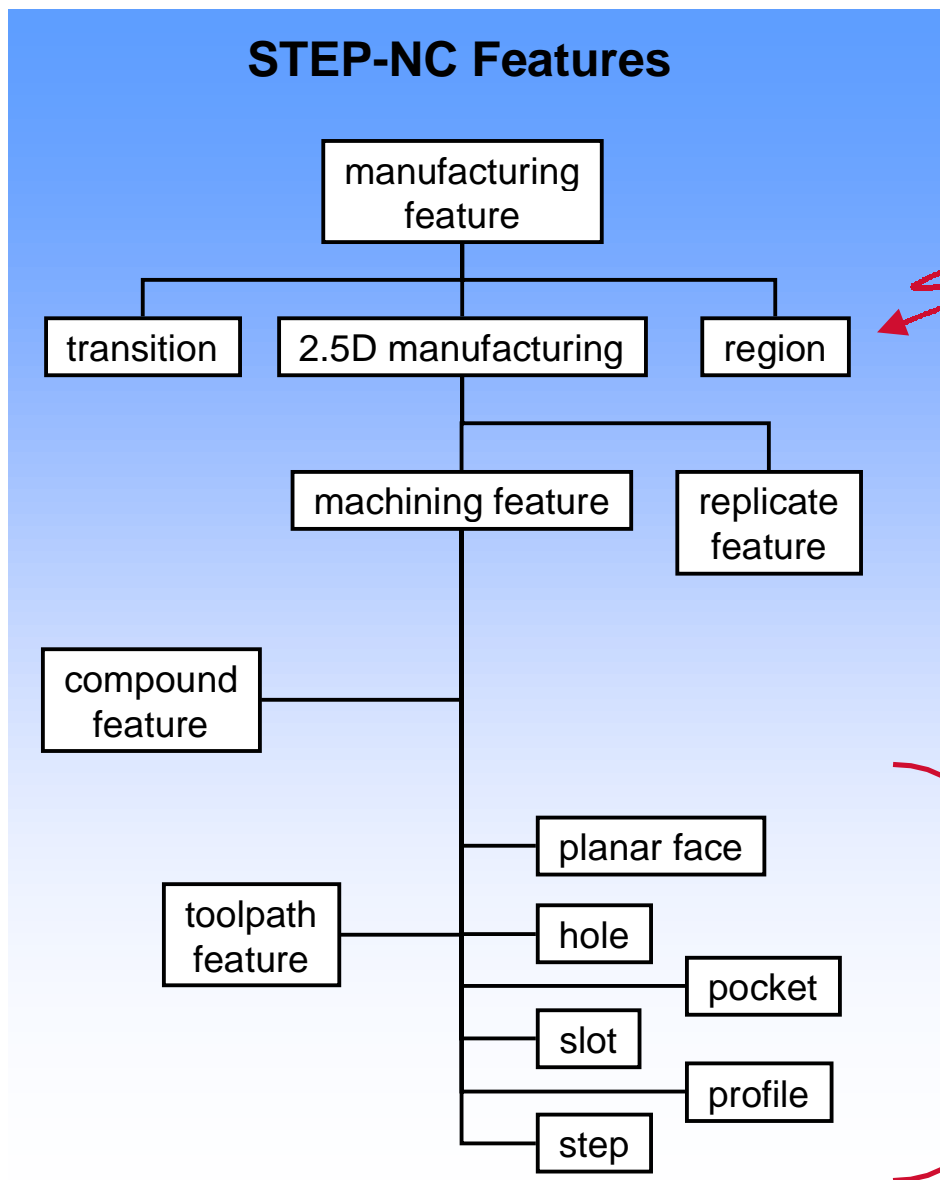
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*for the parameterized ones, you need a placement
check 224 to see if it requires this already (or if it defines an origin)*

- **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

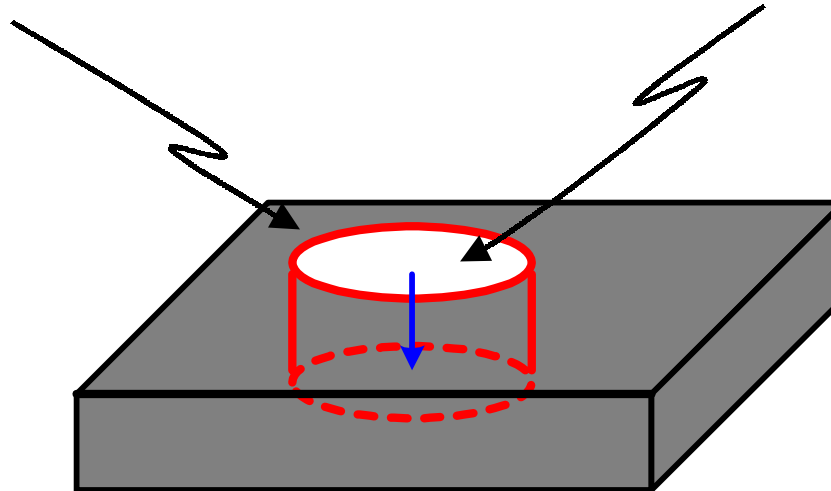




Explicit geometry, points out a surface for freeform milling (5 axis and such)

Implicitly described using profile and path parameters, not explicit geometry

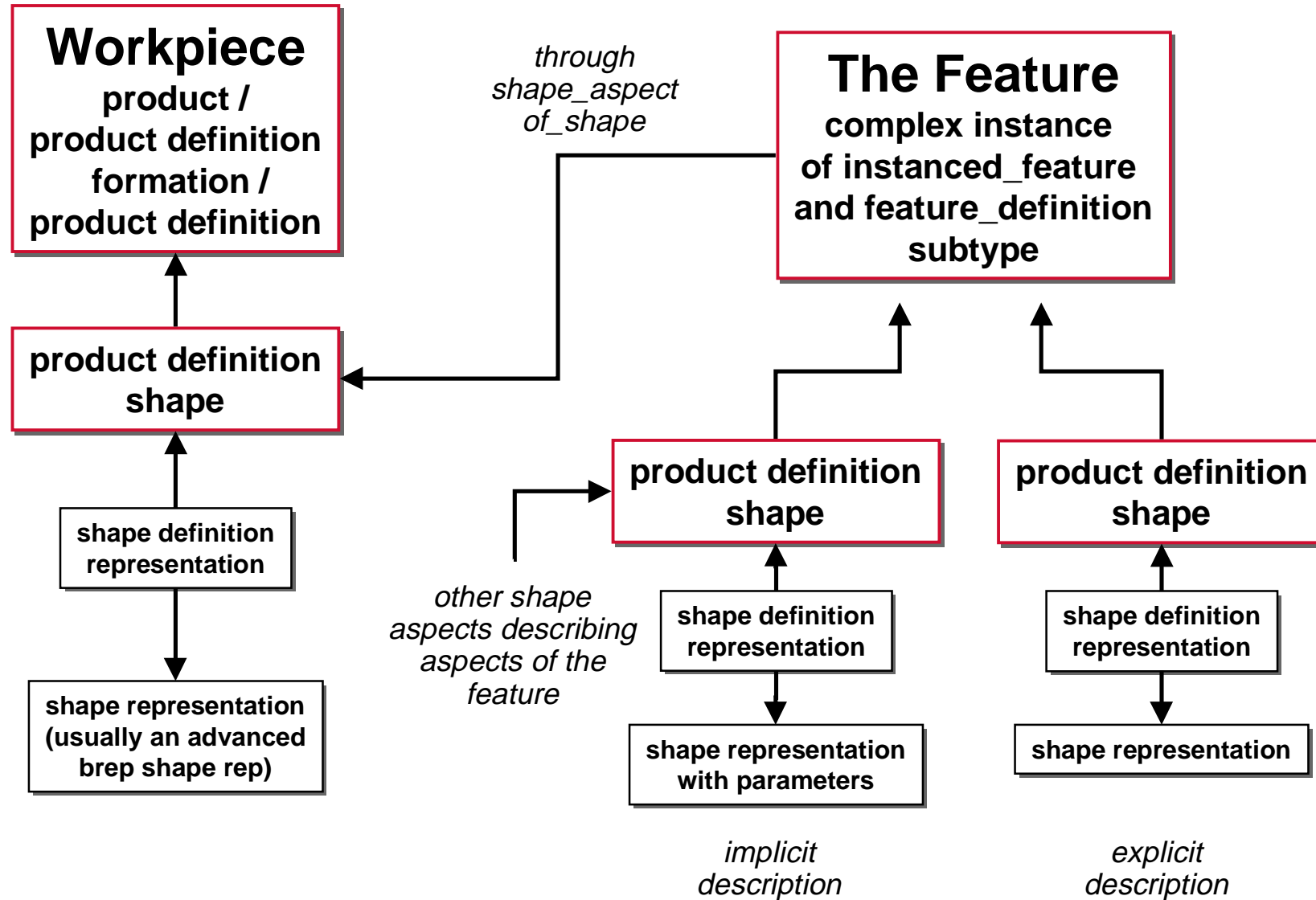
- **Features are described parametrically using a combination of Profiles and Paths**
 - A Profile is swept over the entire length of a Path
 - Profiles described by key parameters, like length, radius.
- **For example, a round_hole is defined by a Complete_circular_profile and a Linear_path**



- **Features describe material removal areas**
- **Features are represented as shape aspects on the workpiece shape**
 - **Implicitly defined features are described by a profile moving along a path.**
 - **Explicitly defined features are described by surfaces from the workpiece shape.**
 - **Profiles, paths and other conditions are defined as shape aspects associated with the feature.**

How Features are Attached

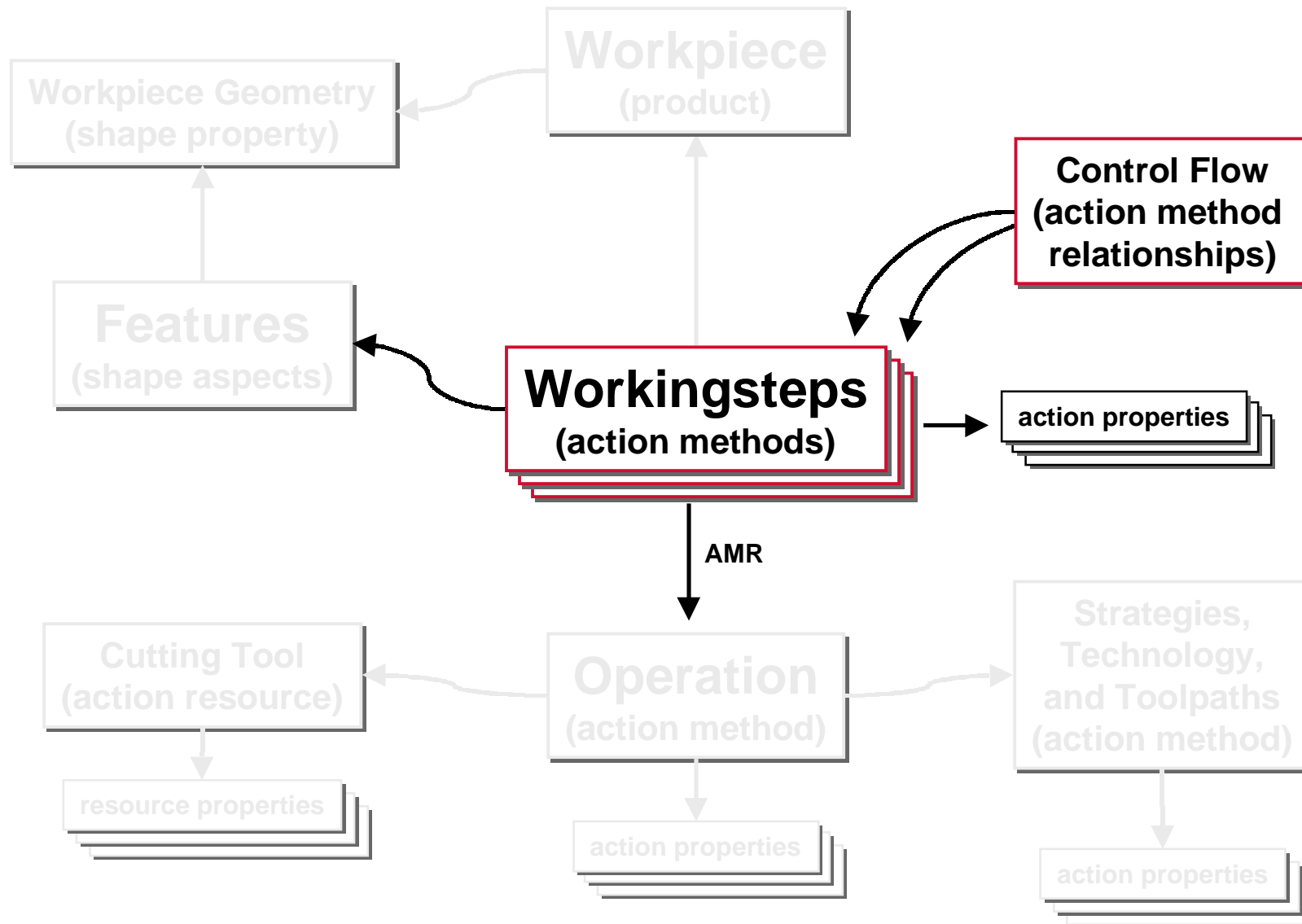
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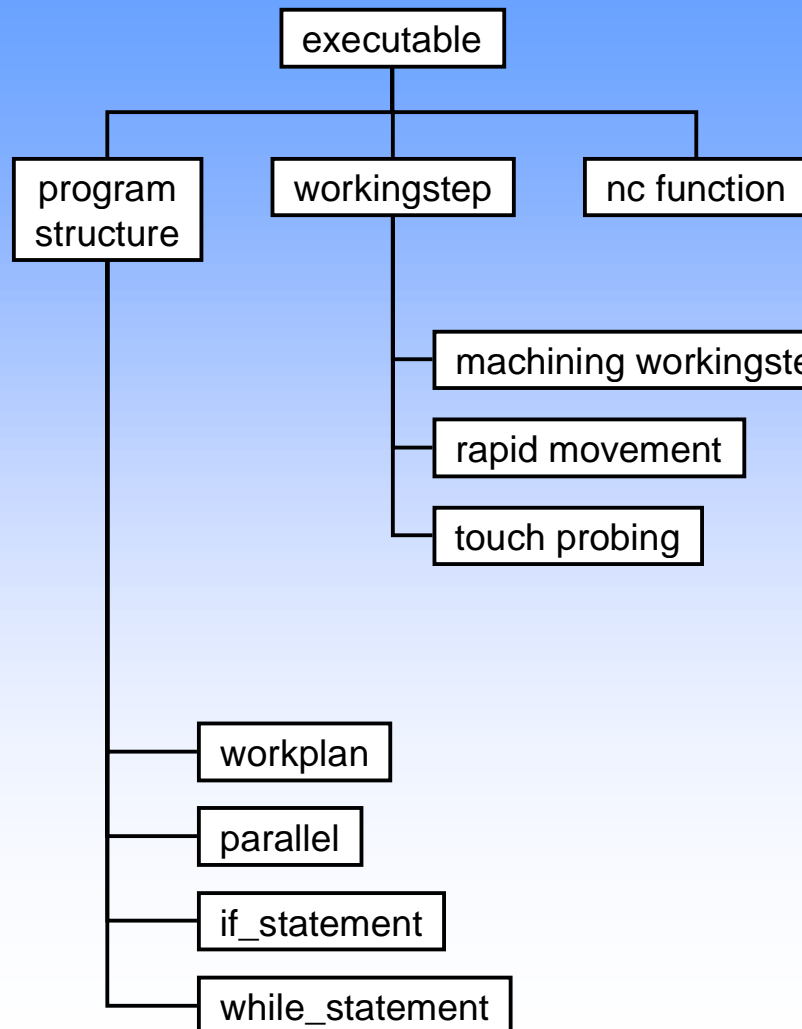
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- **Heart of the STEP-NC model**
- **Executables**
 - Describes control flow and sequencing.
 - Workingstep associates an operation and a feature.
 - Technology independent
- **Operations**
 - Describes what to do within the feature context given by a workingstep — 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.

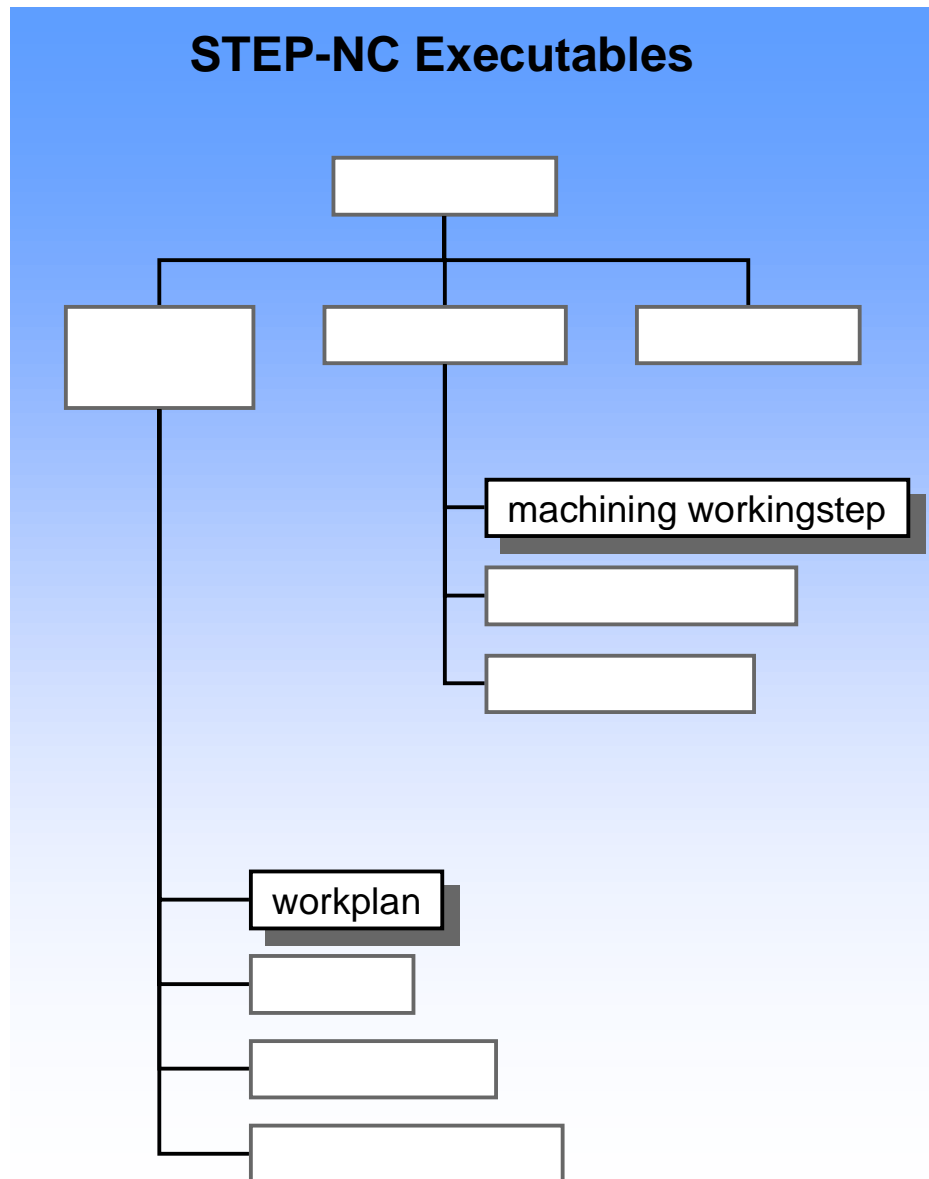
STEP-NC Executables



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

Program steps that move the machine axes

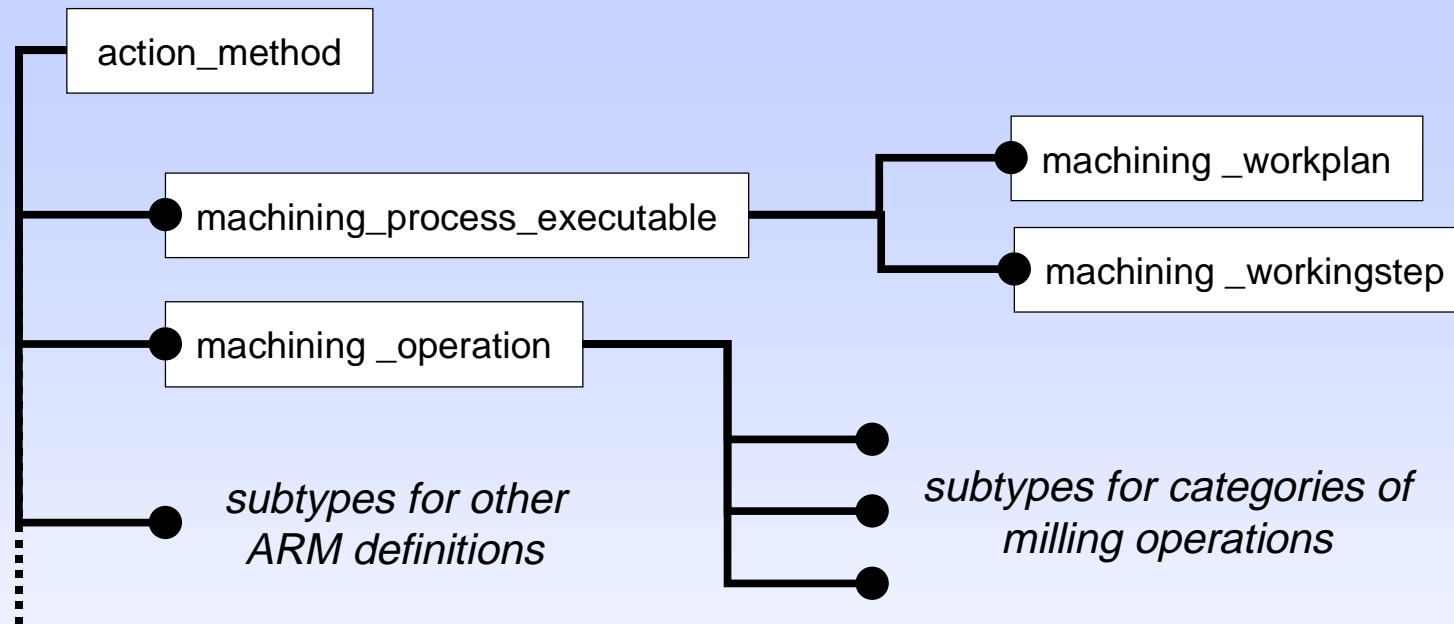
Control flow for the machining program



Focus on a simple machining program

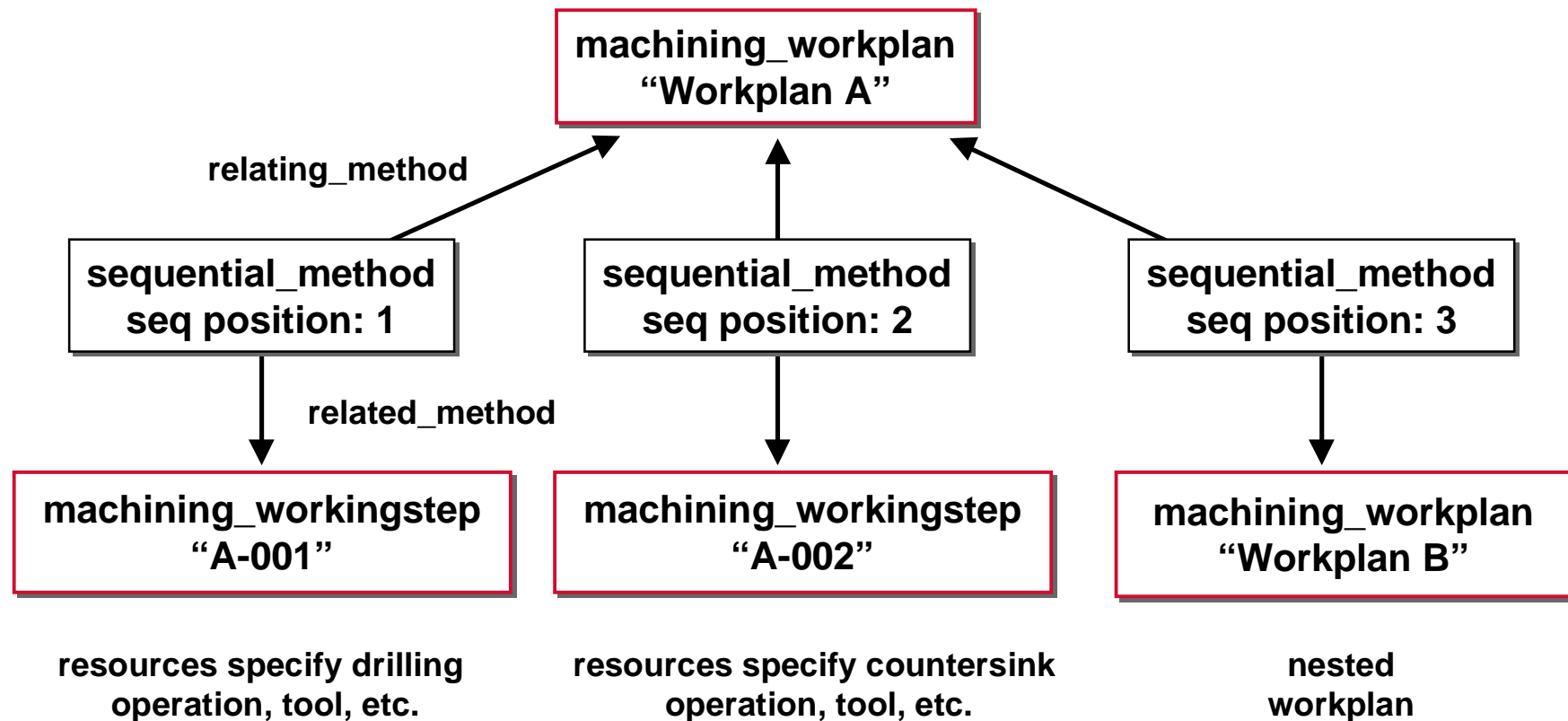
A Workplan containing a sequence of Workingsteps

- **A Workplan**
 - Has a list of workingsteps to be executed
- **A Workingstep**
 - Refers to an operation that describes what to do.
 - Refers to a feature that describes a location and material removal volume.
 - Has a security plane for moving to/from other steps.
- **All executables (workplans and workingsteps)**
 - Have an id so you can refer to them.



- Executables and operations are represented using action methods
 - Special subtypes for operations, workplan, and workingstep
 - Related to each other using action_method_relationships

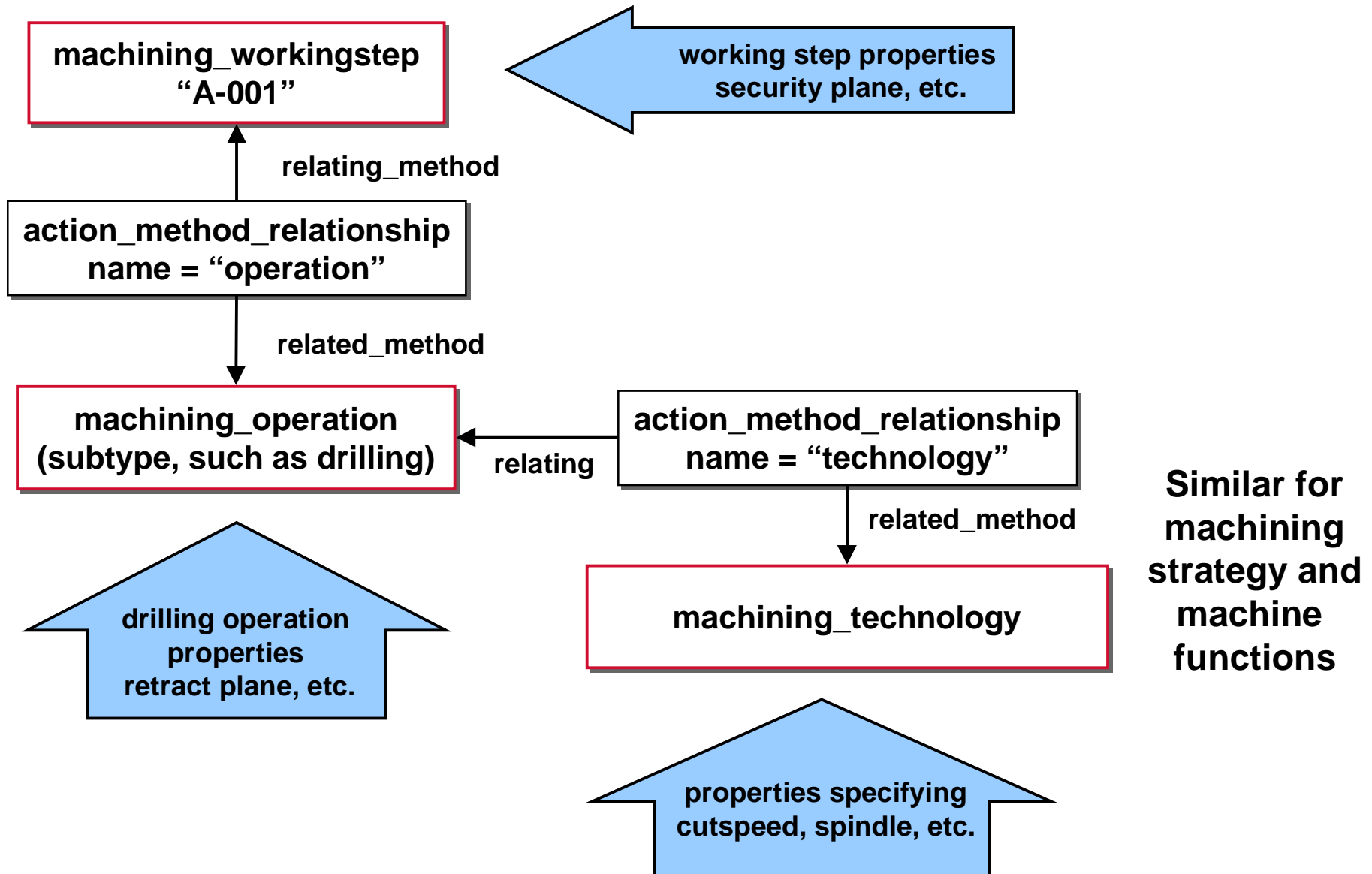
- **Look at how to represent some tangible examples.**
 - How are workingsteps organized into a workplan?
 - How are workingsteps related to an operation?
 - How are workingsteps related to a feature?
 - How are workplans related to a project?



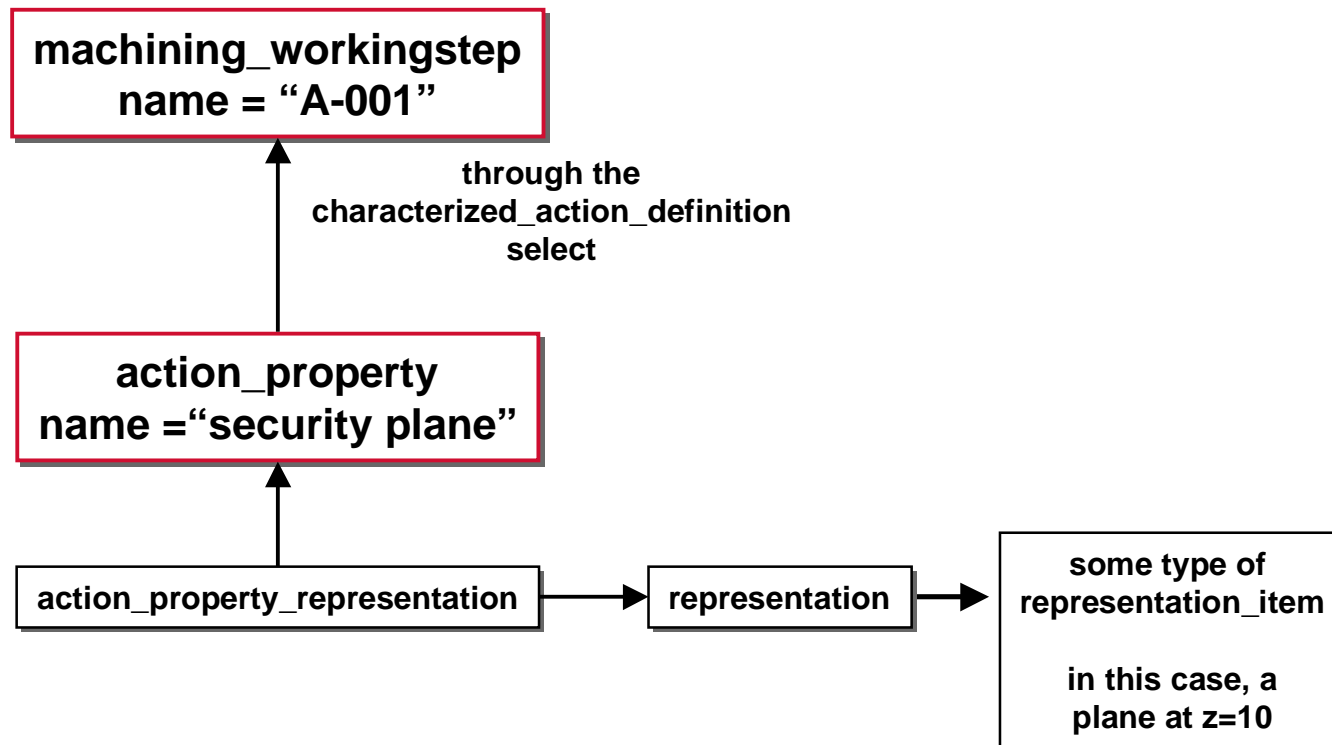
**Sequential method used to establish ordering
(subtype of action method relationship)**

Relating a Workingstep to an Operation

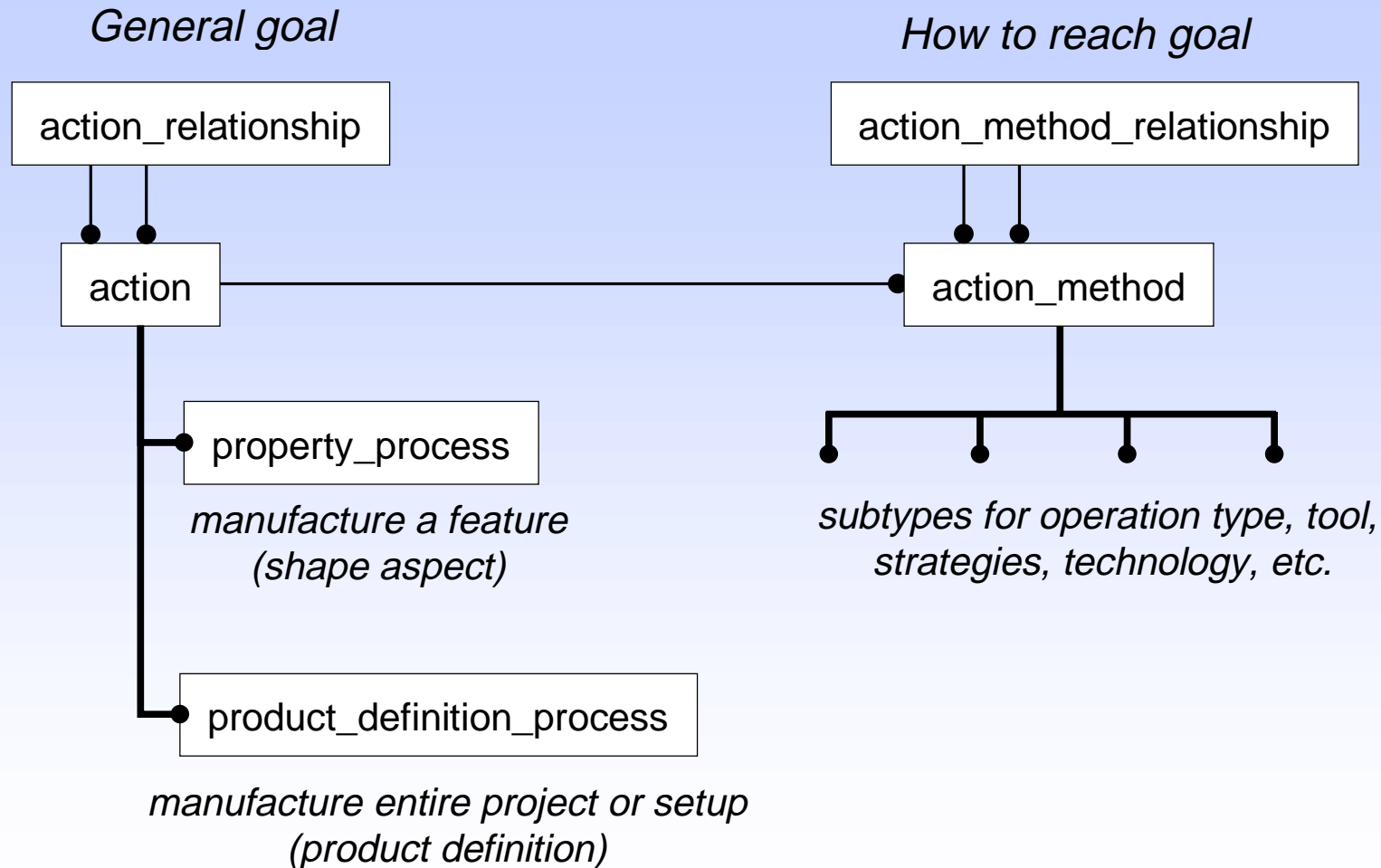
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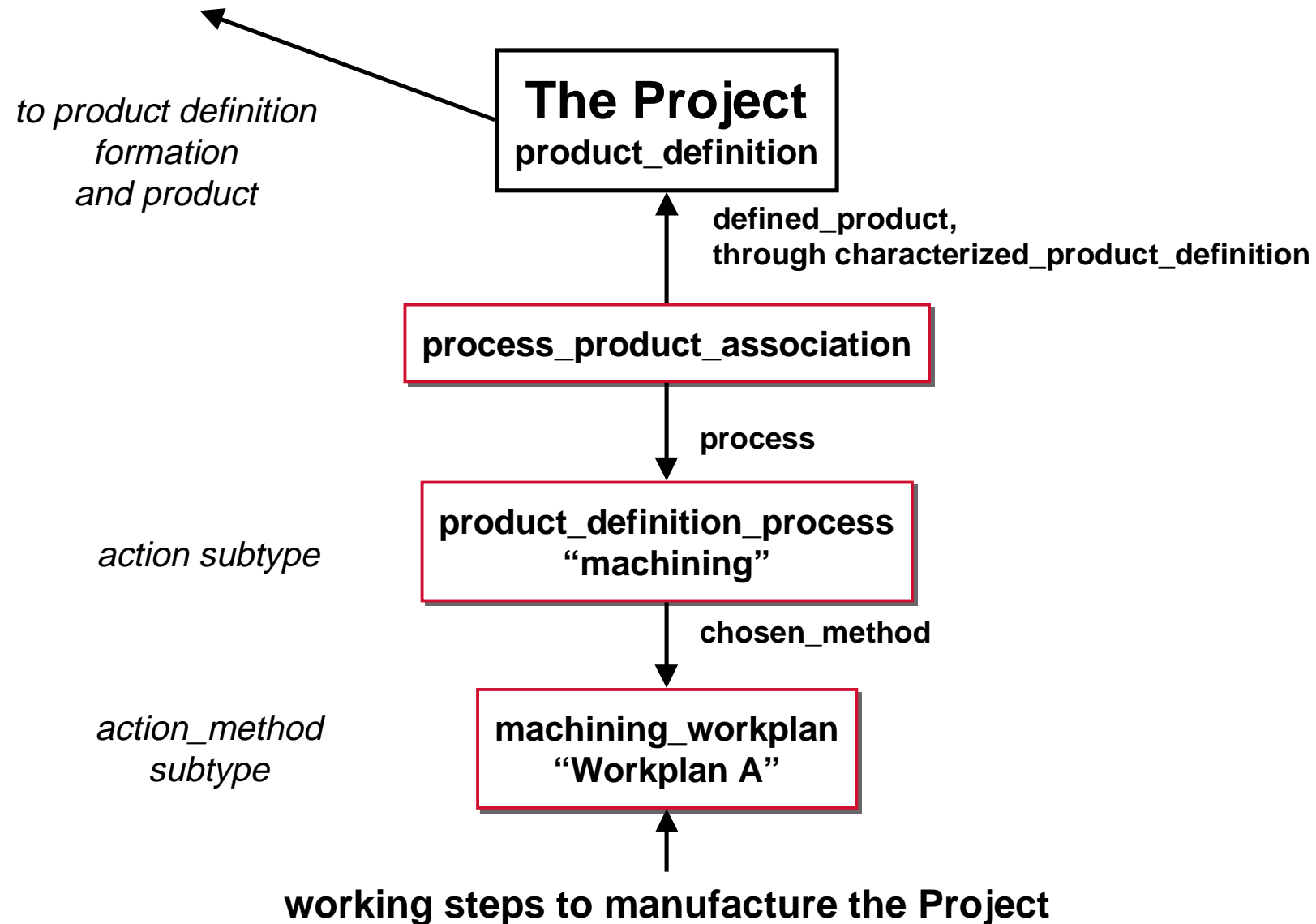


- The required properties for a particular concept are called out by the ARM
 - Workingstep has a security plane



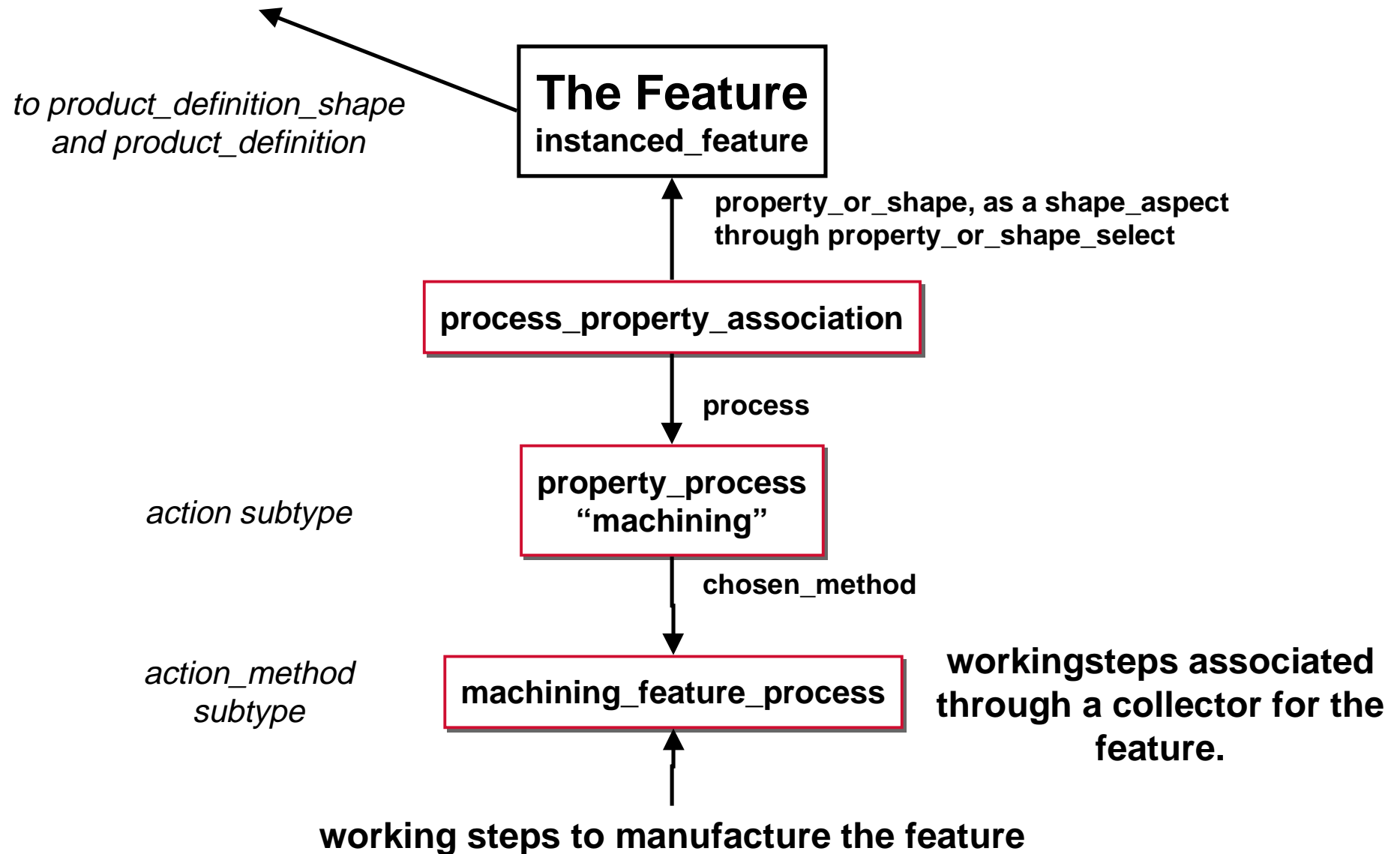
- **STEP process schemas use goals and the methods used to attain them**
 - Workplans, workingsteps are methods.
 - What are the goals?
- **Goals are to manufacture features and the project**
 - action (property_process) related to feature.
 - action (product_definition_process) related to project, which is represented as a product definition.





Associating Workingsteps with a Feature

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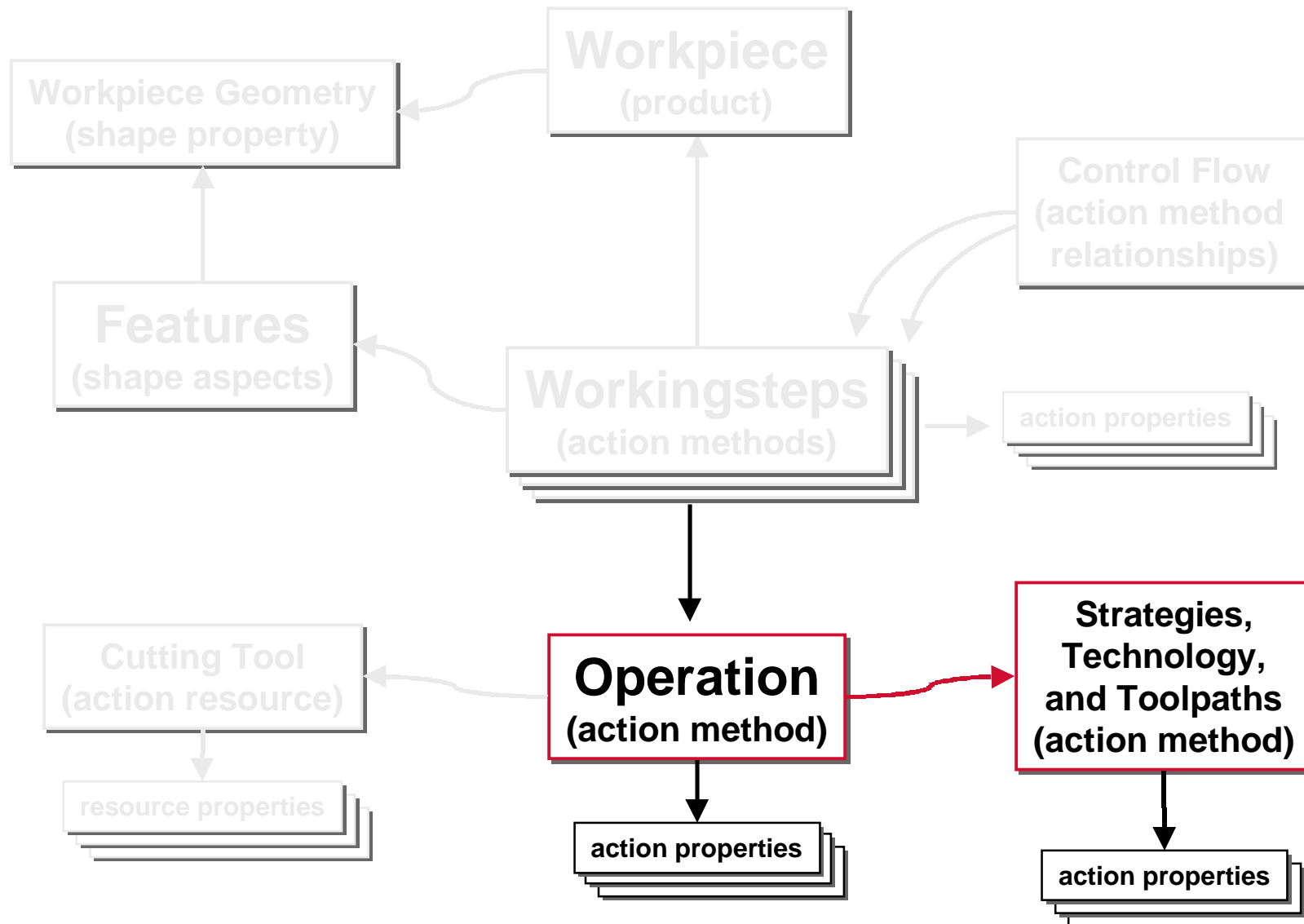


- **Machining Workingsteps**
 - Describe a sequence of material removals, location, and associated parameters
- **Workingsteps are organized into a workplan**
 - Using `sequential_method`, a type of action method relationship, to describe the ordering
- **Have related properties**
 - Which are described by a representation
- **Are related to an operation**
 - Using an action method relationship
- **Are related to features and project**
 - Using action, of which the workplan is the chosen method

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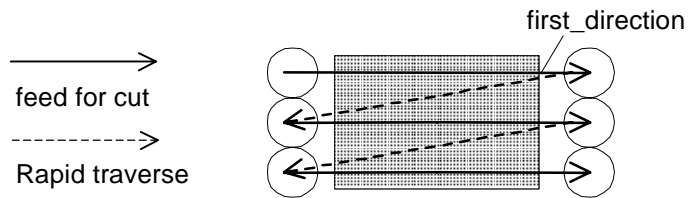
- **2.5D Machining Operations**
 - Plane and side milling.
 - Tool can move in the X-Y plane or along the Z axis, but not at the same time.
 - Set of strategies
- **Freeform Machining Operations**
 - For sculpted surfaces
 - 3, 4, and 5axis motion
 - Set of strategies
- **Drilling Operations**
 - Drilling,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

- **All Machining Operations can have:**
 - A cutting tool requirement
 - A start point and retract plane
 - Technology parameters, which are grouped and shared between operations
 - » Spindle speed, feedrate, feedrate per tooth, etc.
 - Machine settings, which are grouped and can be shared between operations
 - » Coolant, misting, chip removal, etc.
- **Operations can also have strategies**
 - All operations can have an associated machining strategy
 - All milling operations can also have an associated plunge strategy and a retract strategy

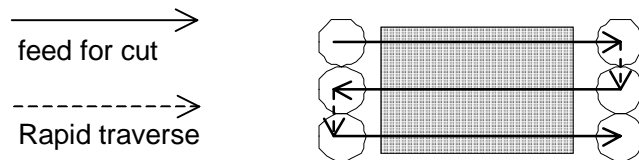
- **2.5D Machining Operations**
 - Plane and side milling.
 - Tool can move in the X-Y plane or along the Z axis, but not at the same time.
 - » `bottom_and_side_milling`
 - » `side_milling`
 - » `plane_milling`
- **All operations have rough and finish versions**
 - Rough milling leaves an allowance of material
 - Finish milling goes right to the feature boundaries

2.5D Milling Strategies

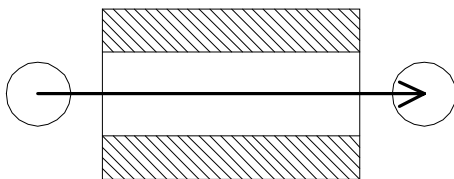
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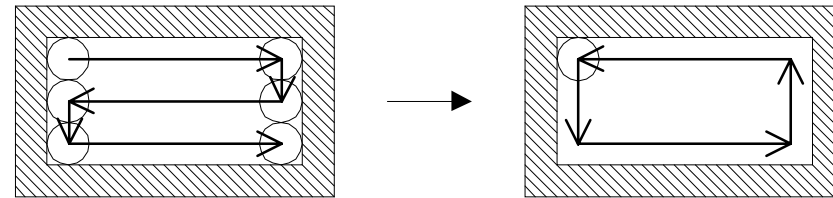
Unidirectional



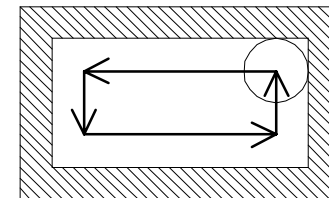
Bidirectional



Center Milling



**Bidirectional Contour &
vice versa**

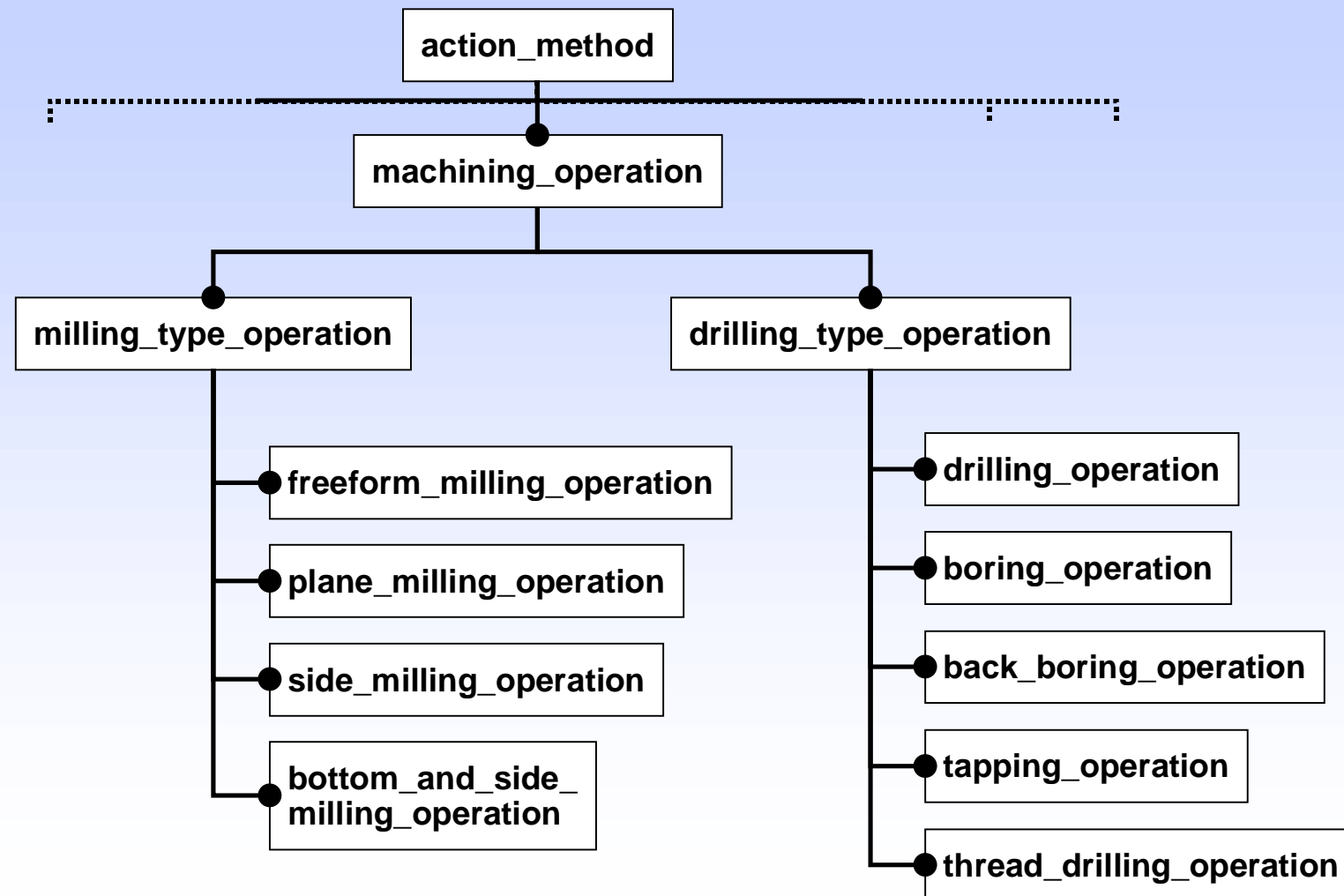


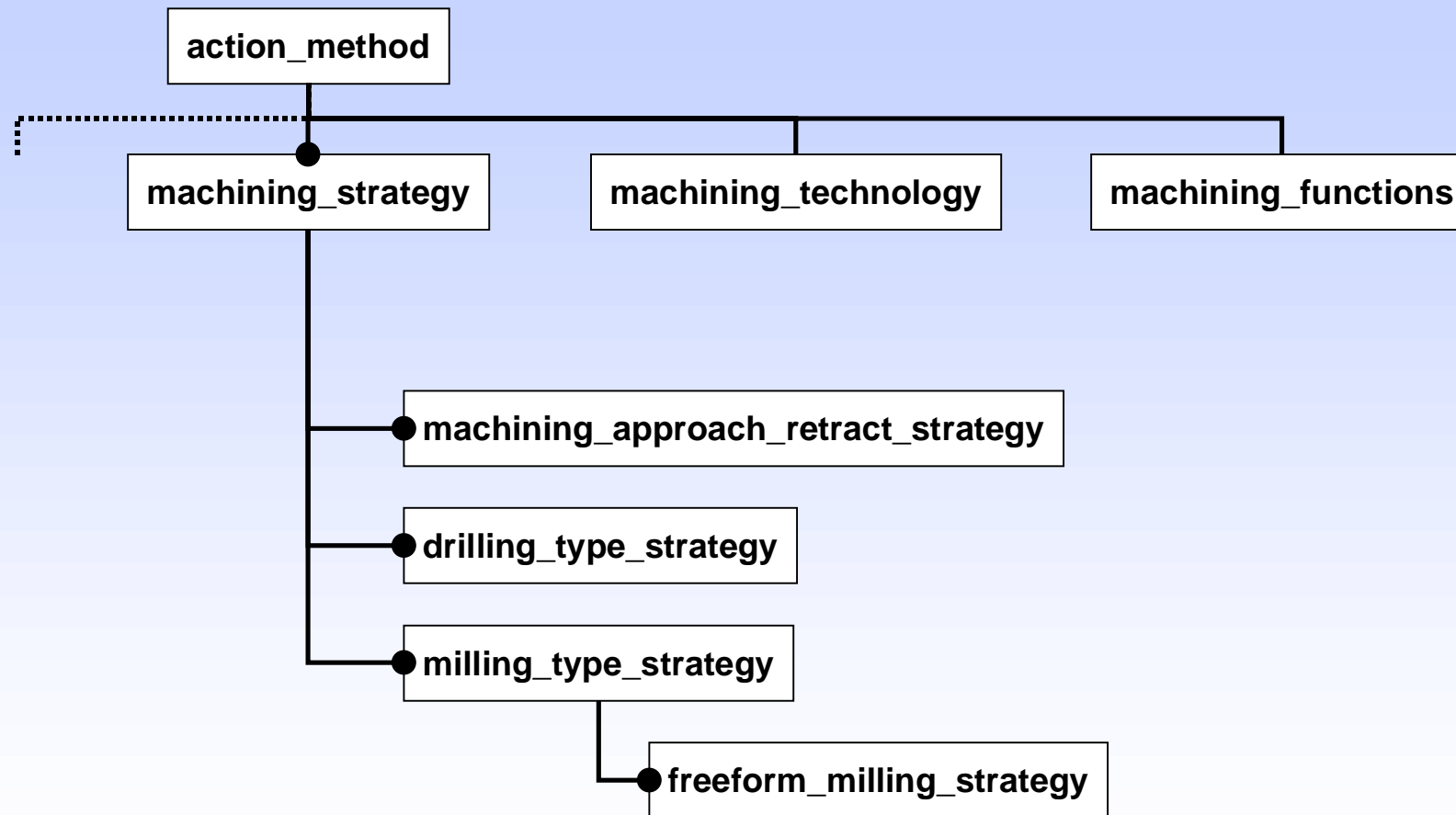
Contour Parallel & Spiral

- **Freeform Machining Operations**
 - For sculpted surfaces
 - 3, 4, and 5axis motion
 - No special subtypes
- **Usually for use with region feature or other explicit surface geometry**
 - Has a scallop height and chord parameters to help controllers decide how to generate toolpaths.
- **Freeform Strategies**
 - Cutter contact, cutter location, UV, leading line

- **Drilling Operations**
 - Drilling, boring, back boring, tapping/threading
 - Tool moves in the Z axis only
 - » **drilling_operation**
 - drilling, center_drilling, counter_sinking, multistep_drilling
 - » **boring_operation**
 - boring, reaming
 - » **back_boring**
 - » **tapping**
 - » **thread_drilling**
- **Only one drilling strategy, but with many parameters**
 - Feed rates for starting, ending, and retract, dwell, depths, etc.

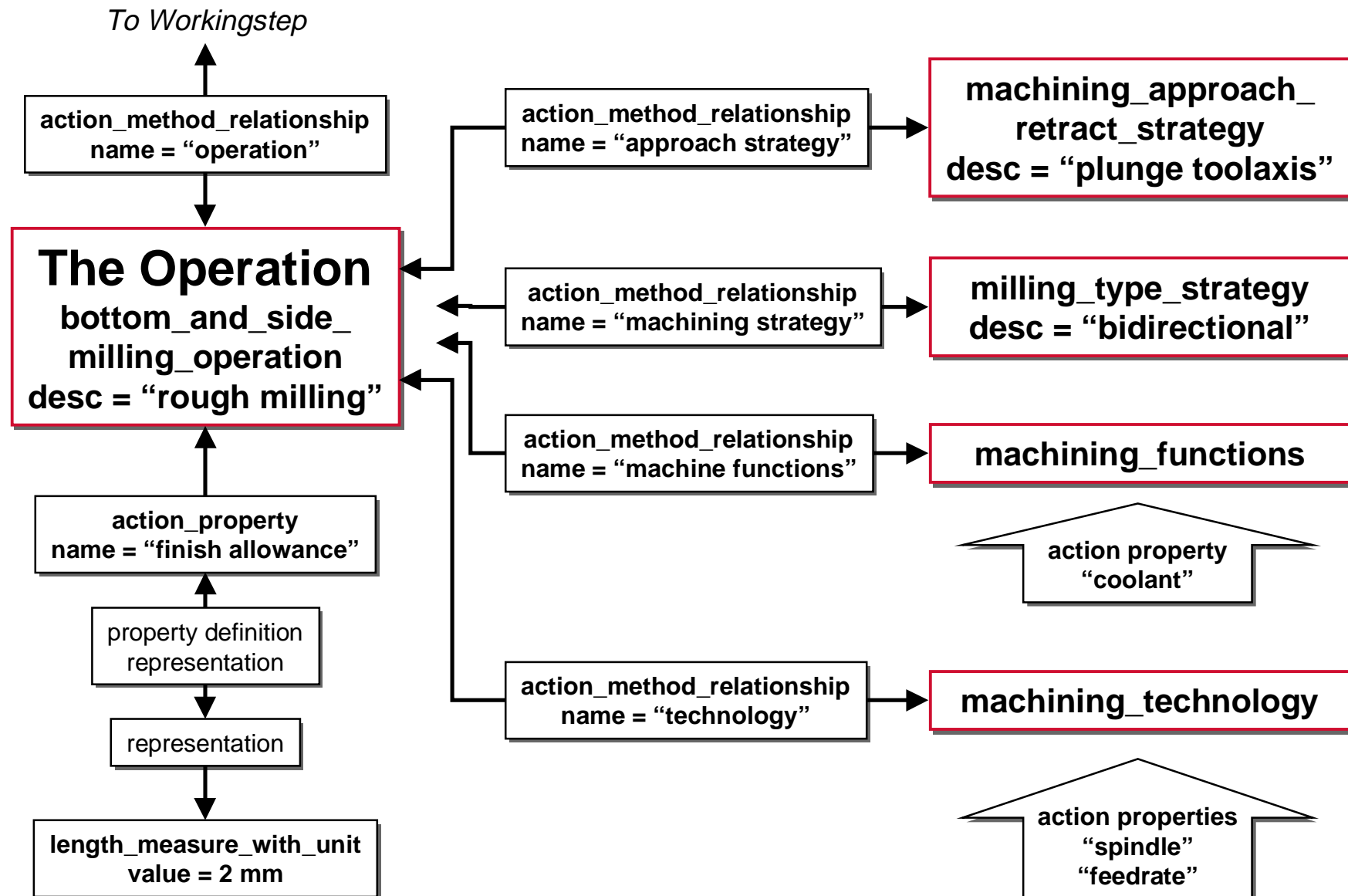
- **Operations are represented as action methods**
- **Strategies and other grouped parameters are also action methods**
 - **Strategies, machine functions, technology**
 - **All are hooked to operation using action method relationships**
 - **Parameters are represented as action properties**
- **Somewhat repetitive, but very straightforward**





Bottom and Side Milling Operation

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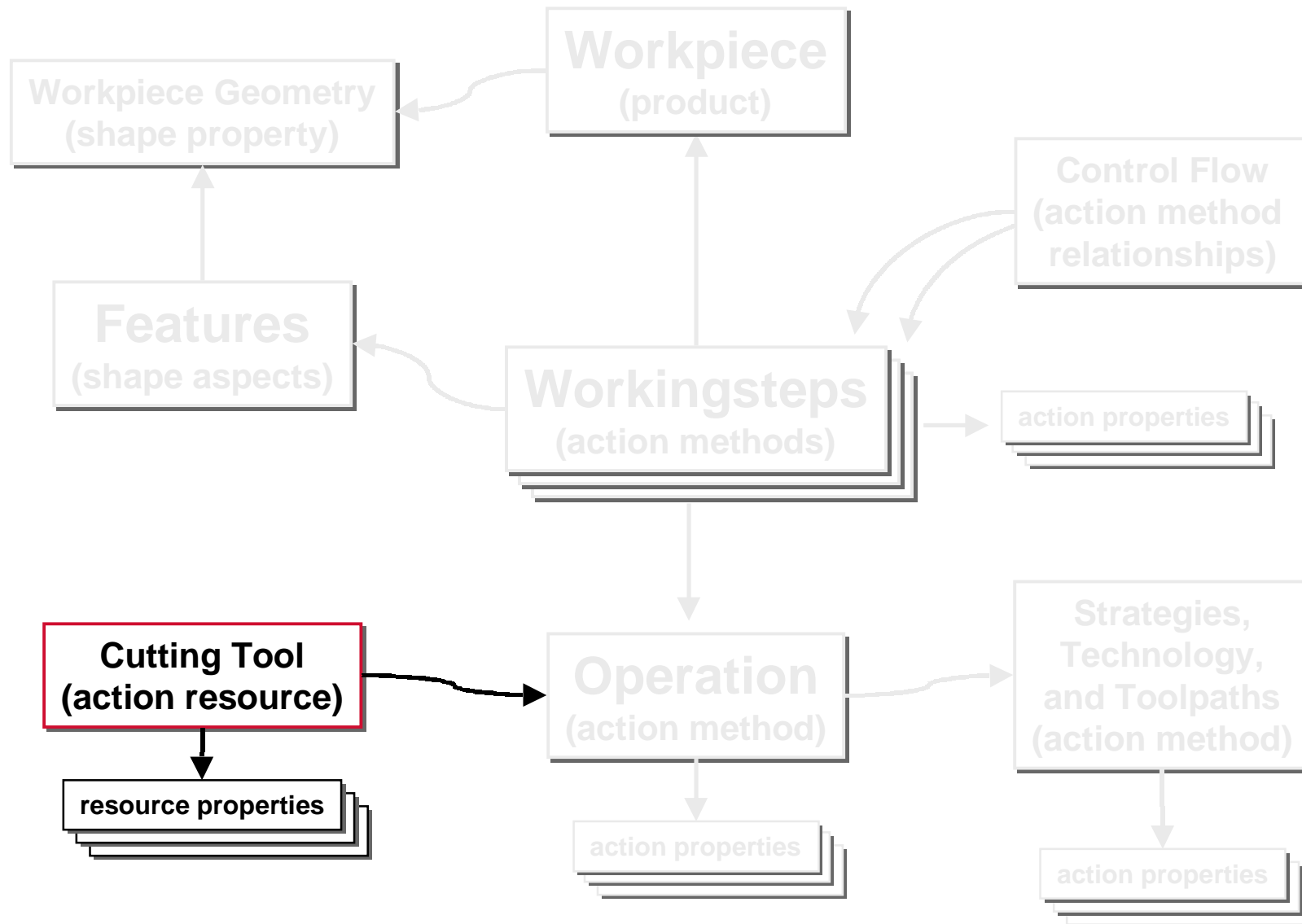


- **Operations**
 - Describe what is to be done.
 - Currently supports 2.5D milling, freeform milling, drilling
 - With many strategies and parameters
- **Future editions will add operations for other machining technologies**
 - Turning
 - Grinding
 - EDM

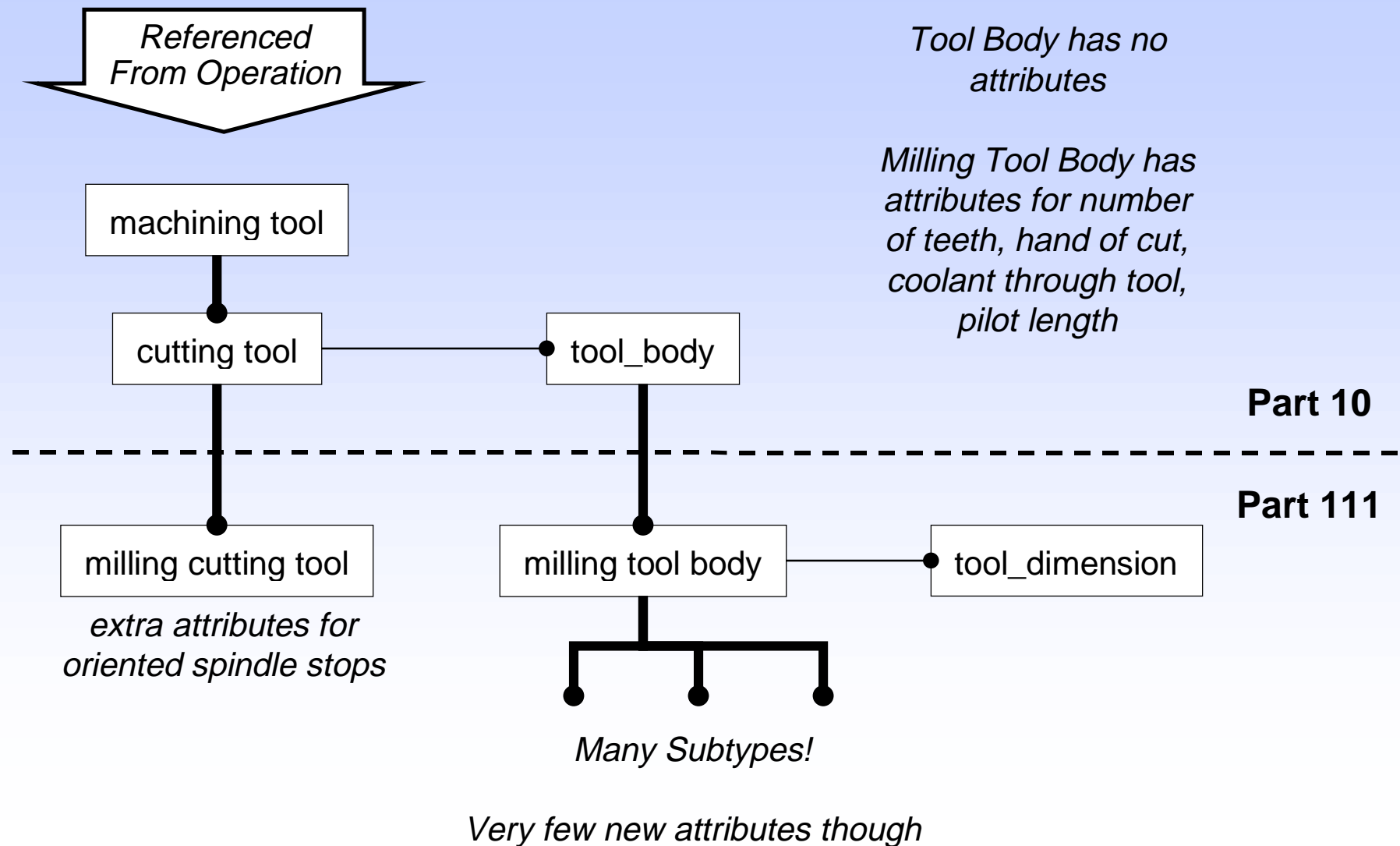
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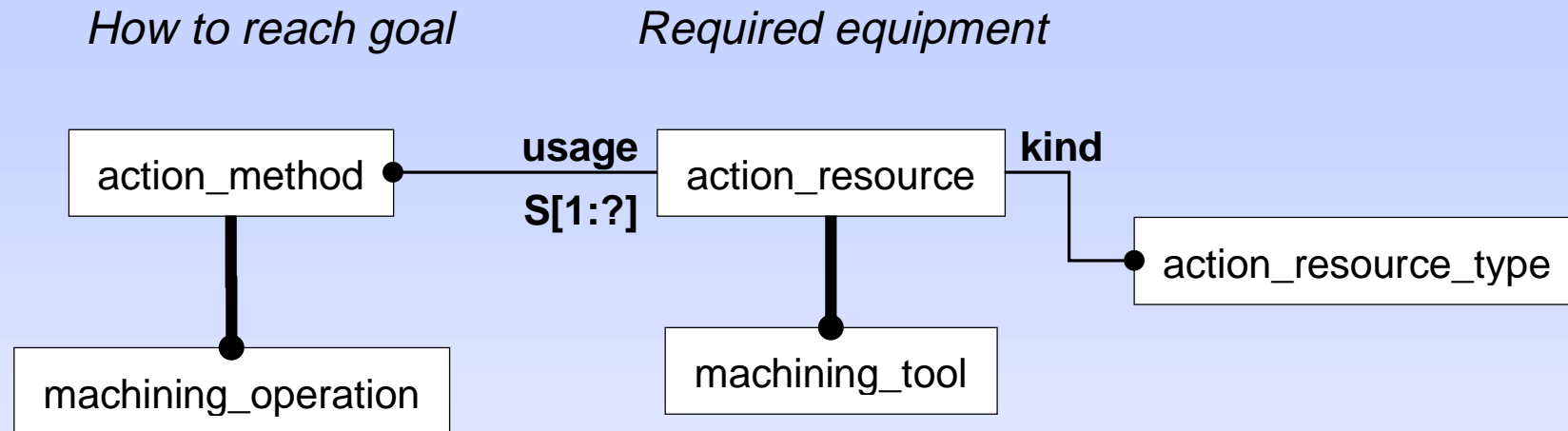
- **Milling Tool Types**

- **Projects and Setups**
- **Advanced Control Flow for Programs**
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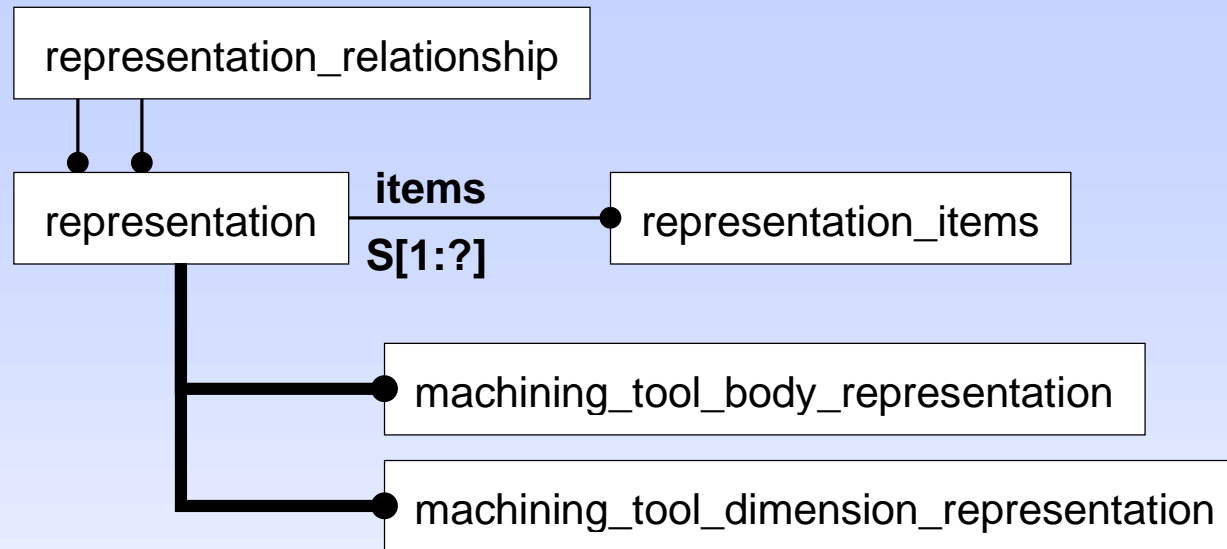


- **Every operation can have a tool associated.**
 - Represents tool requirements, not a physical tool on a machine.
 - Potential for some best-fit optimization by the controller.
 - Only important parameters should be set.
 - » The more constrained the tool is, the less flexibility the controller will have
- **Previously, G&M codes just reference 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.





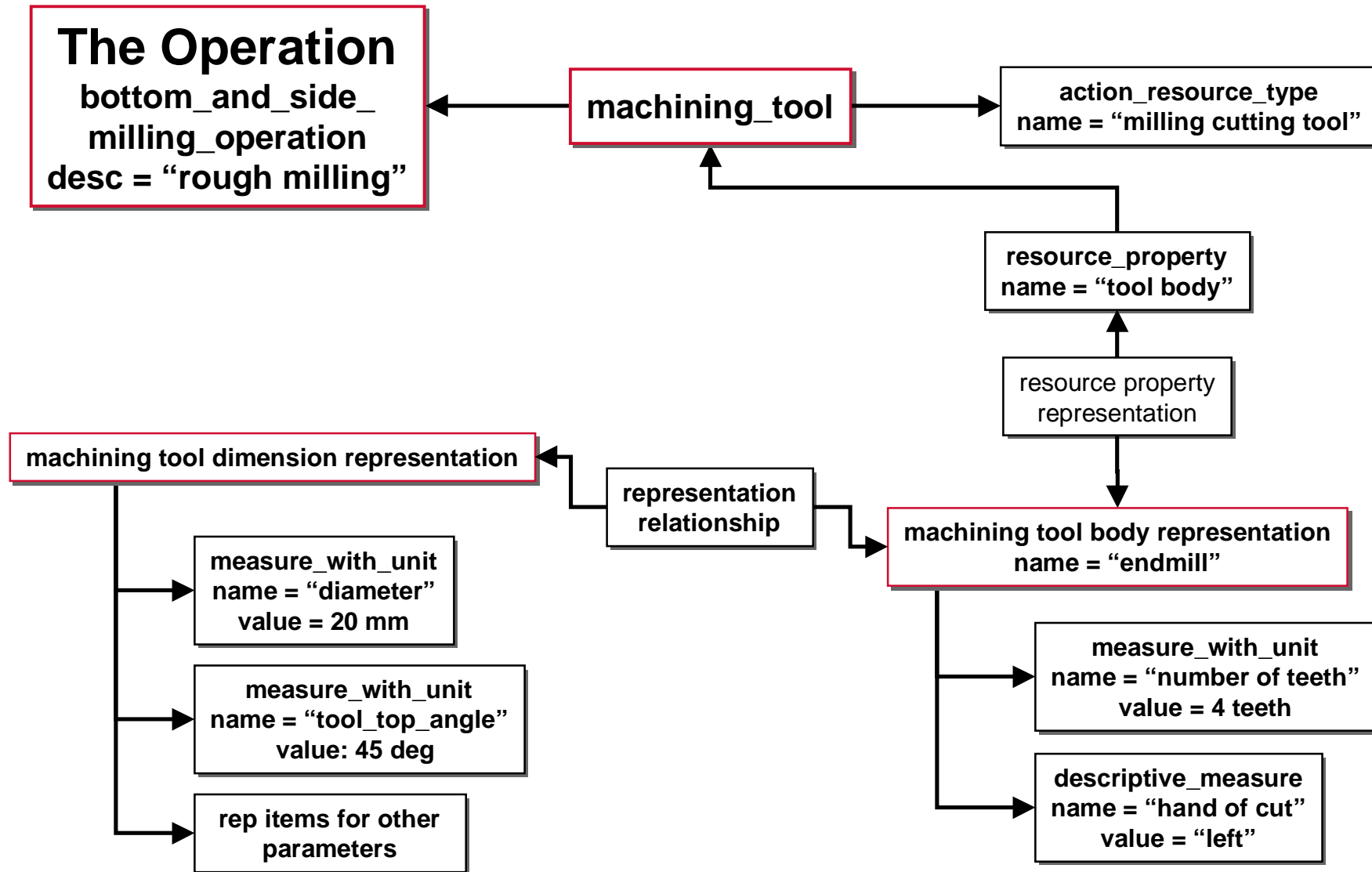
- **Tool is equipment required by the operation**
 - Use action resource subtype machining_tool.
 - action resource refers to all of the action methods that use it through the “usage” attribute.
 - Also has a “kind” attribute that categorizes the resource
 - » A/R Type has value “milling cutting tool”



- **Tool Body and Dimension are complex properties**
 - Mapped as subtypes of representation
 - » Different tool bodies distinguished using the `representation.name` attribute
 - Will contain multiple representation items
 - Tool Dimension related to Tool Body using a representation relationship

20mm Endmill Tool Example

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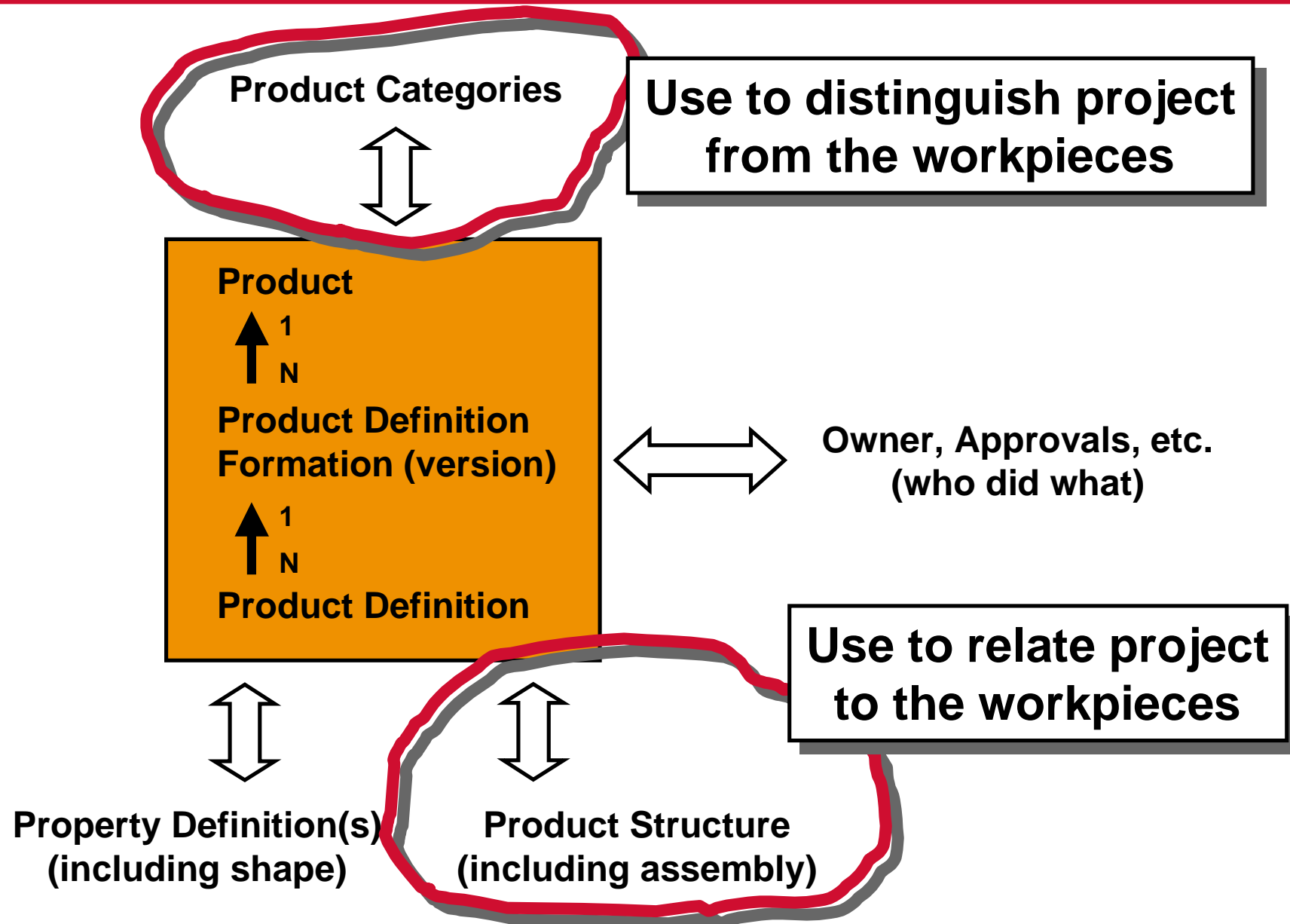
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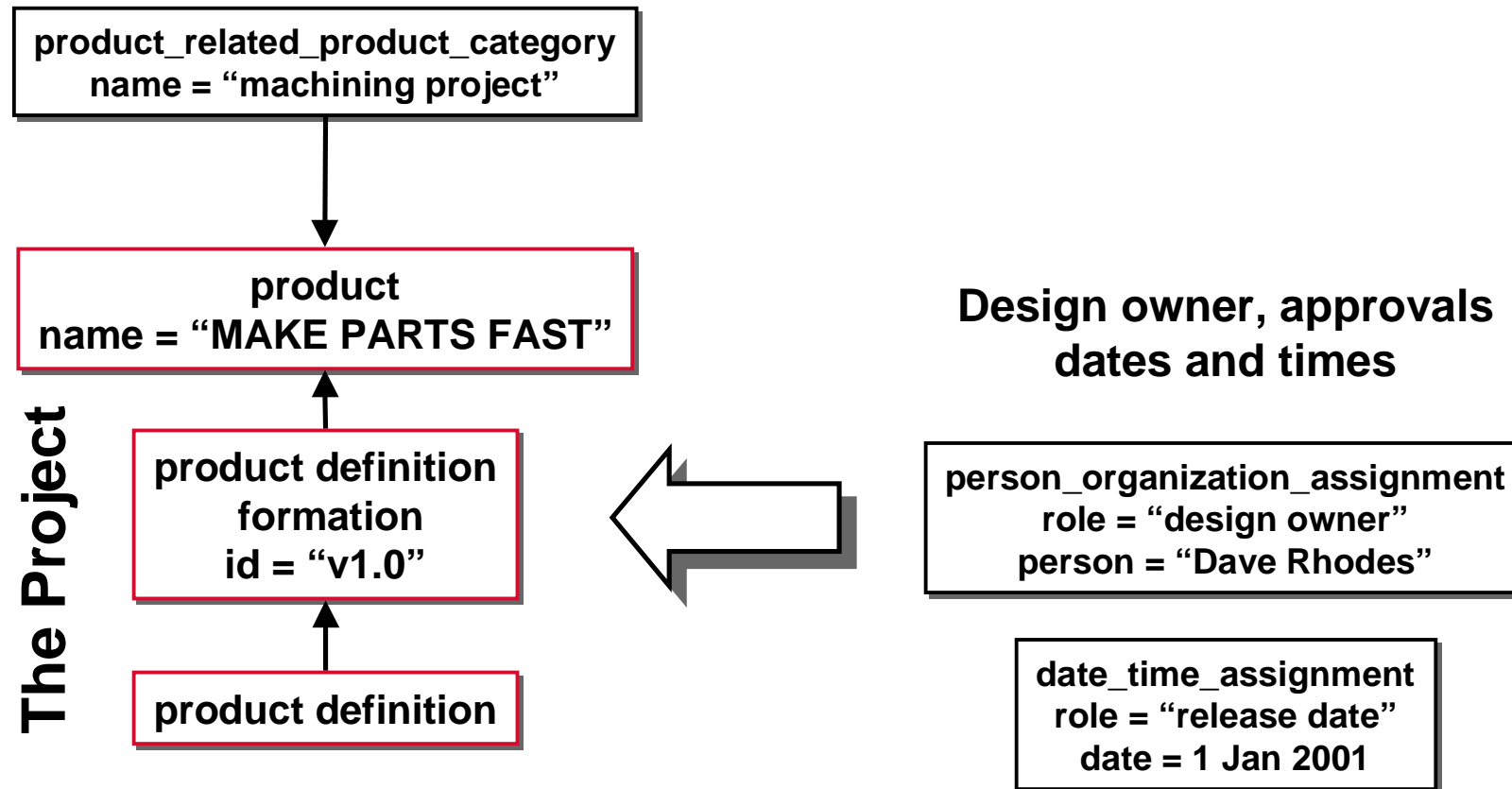
- **Projects and Setups**

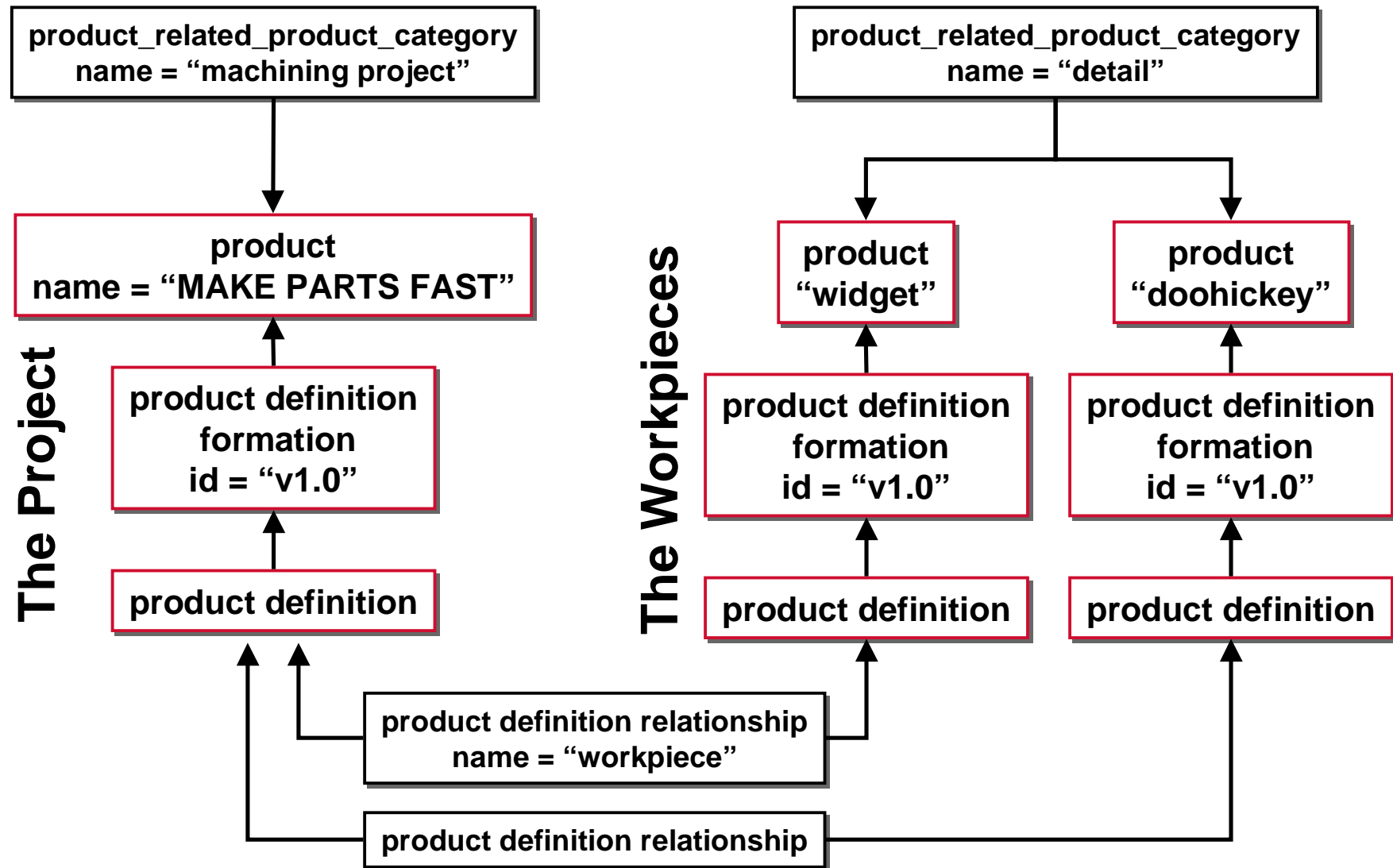
- **Advanced Control Flow for Programs**
- **Explicit Toolpaths**

- **Project is the root of a STEP-NC file**
 - Points to the main workplan
 - Points to one or more workpiece
- **Setups describe how the workpieces are oriented on the machine**
 - A setup may contain many workpieces, or multiple occurrences of one workpiece
- **Questions**
 - How are these represented in the AIM?

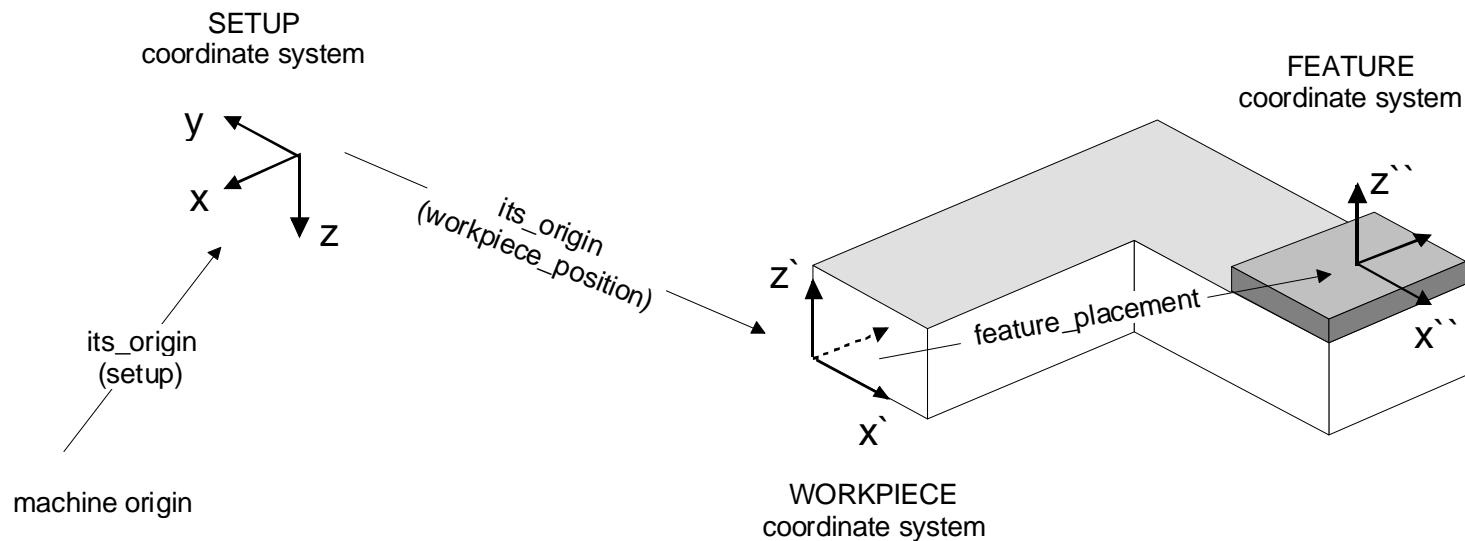
- **Project is represented as a product**
 - We can use all of the PDM information to track the project as well as the workpieces
 - Distinguished by a product category of “machining project”
 - Workpieces have usually have a product category of “detail” but may have others.
 - » represented using product_related_product_category
- **Project has a workplan and set of workpieces**
 - Workplan related as previously described
 - Workpieces are related using product_definition_relationship



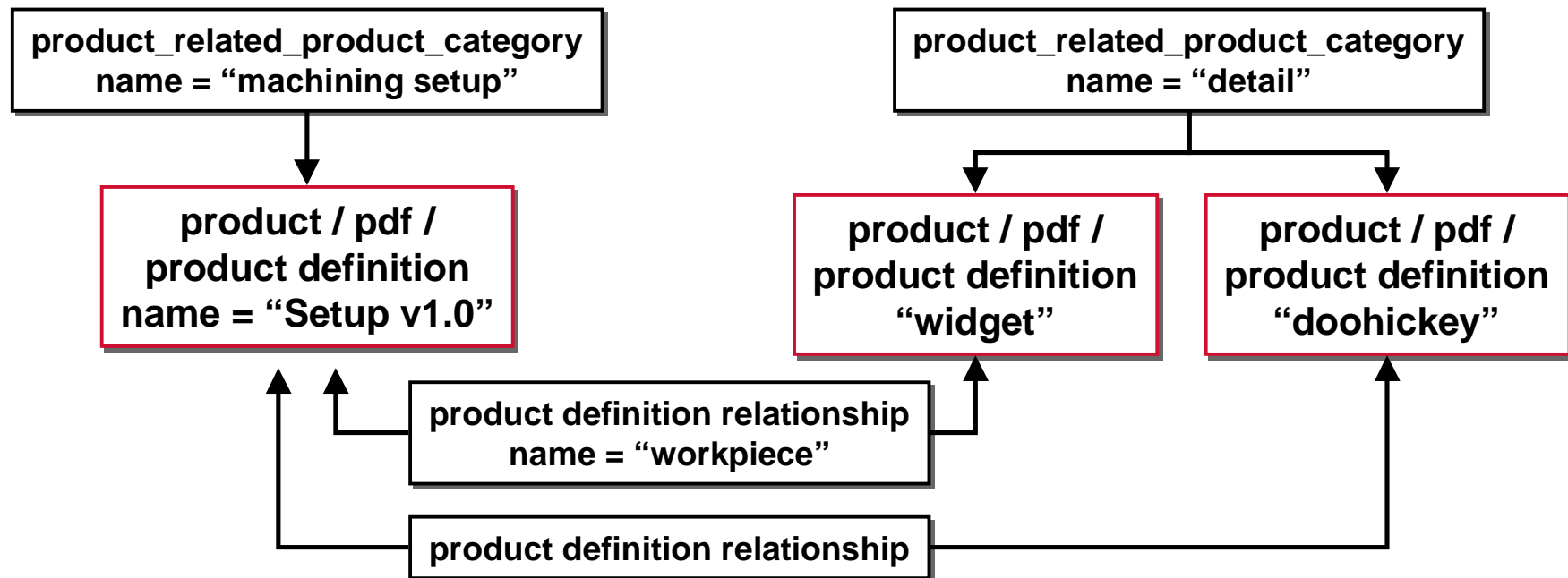




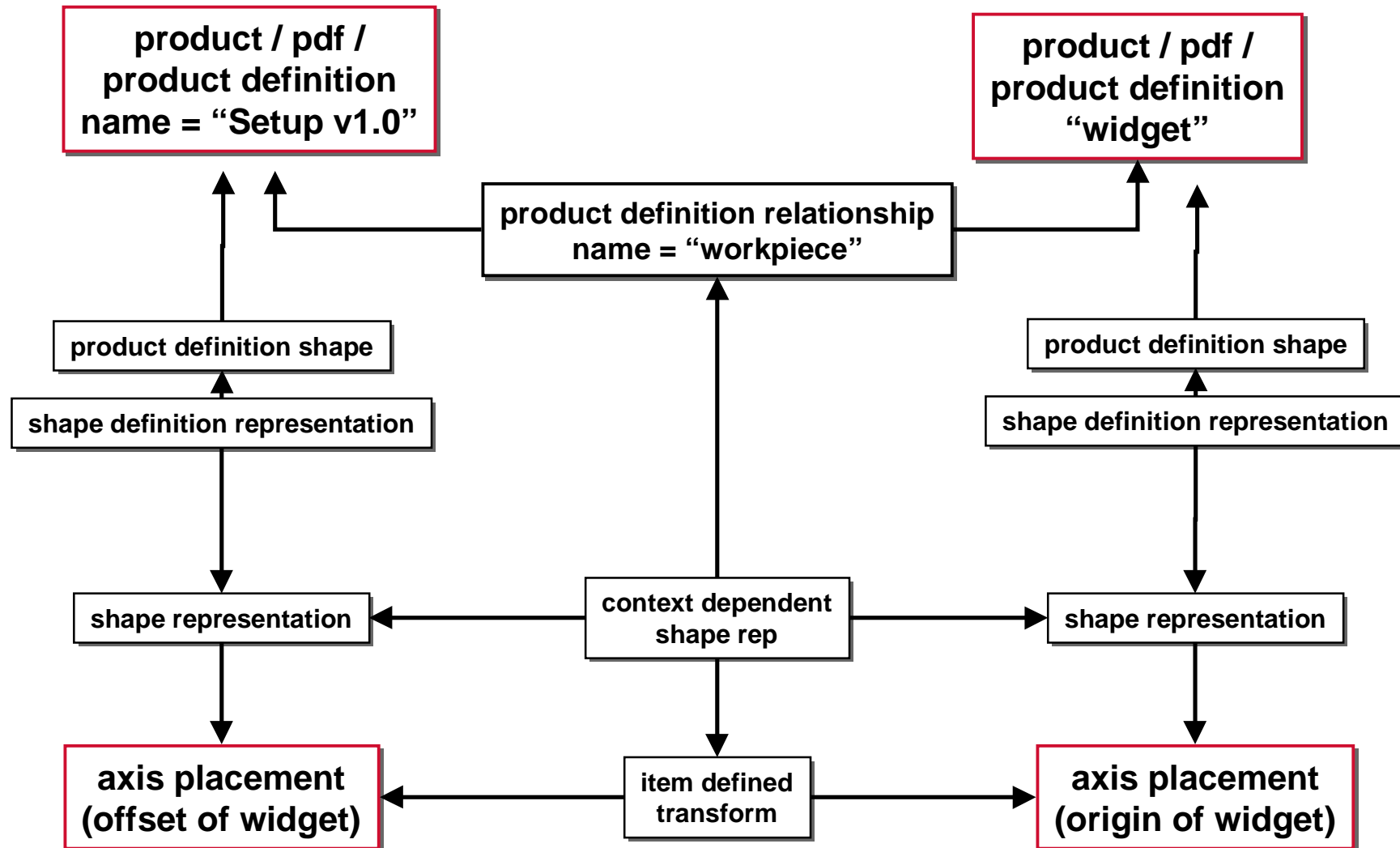
- A setup describes the orientation and locations of workpieces on the machine
 - Referenced by a workplan
 - Conceptually similar to an assembly
 - A setup may have many copies of the same workpiece
 - Also describes “keep out” regions where fixtures may be.

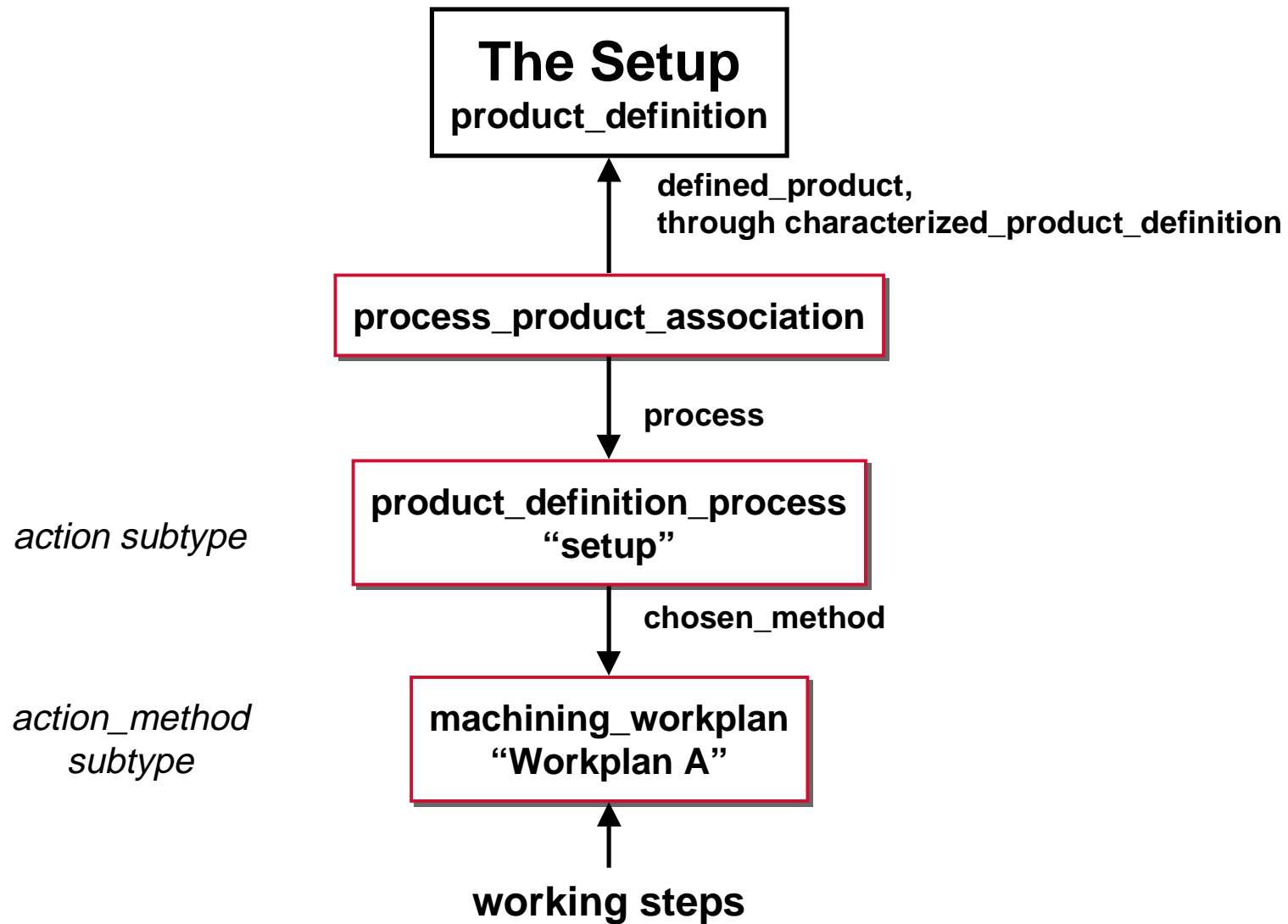


- Handled in the same way as machining projects
 - A product with category “machining setup”
 - Relate to workpiece with product definition relationships.
 - Transform within the setup are handles in the same way as STEP assemblies — with item-defined transforms.



- **The placement of the workpiece within the setup is handled with a context dependent shape rep.**
 - Context-dependent shape representation relates an item defined transform to the relationship.
 - The item-defined transform points to an a2p3d in the setup's product definition shape that gives the workpiece offset.
 - Also points to an a2p3d in the workpiece shape that gives the origin for the workpiece.
- **This is the same technique used for describing the offset of components within an assembly.**
 - Currently used by all AP-203 and AP-214 implementations.





- **Project is the root of a STEP-NC file**
 - Points to the main workplan
 - Points to one or more workpiece
 - Mapped as product, distinguished by product category.
- **Setups describe how the workpieces are oriented on the machine**
 - Referenced by a workplan.
 - Mapped as product, distinguished by product category.
 - Similar to a mechanical assembly, needs a bit more investigation to make sure it is harmonized.

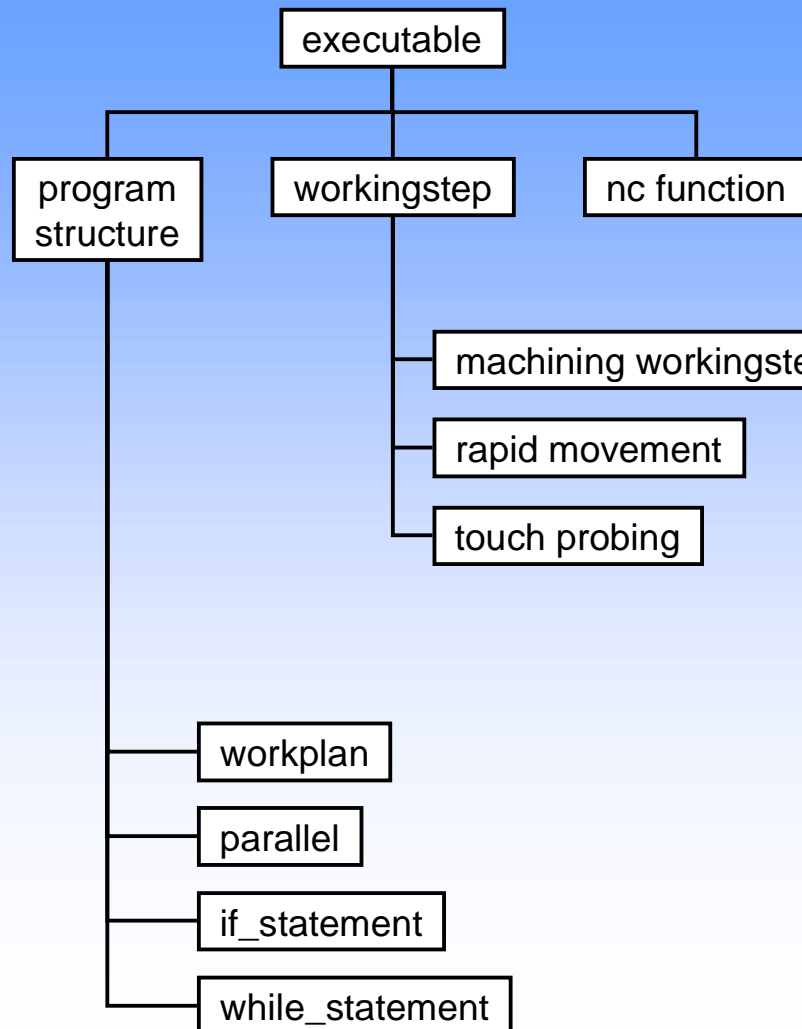
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- **Advanced Control Flow for Programs**

- **Explicit Toolpaths**

- **STEP-NC supports a rich set of control flow for machining workplans**
 - More types of programs than simple linear sequences of machining workingsteps
 - Branches, parallel segments, feedback from probing
 - Room for future intelligent controllers to optimize
- **Questions**
 - What other types of workingstep and functions are available?
 - What control flow options are available?
 - How are controlling expressions represented?

STEP-NC Executables



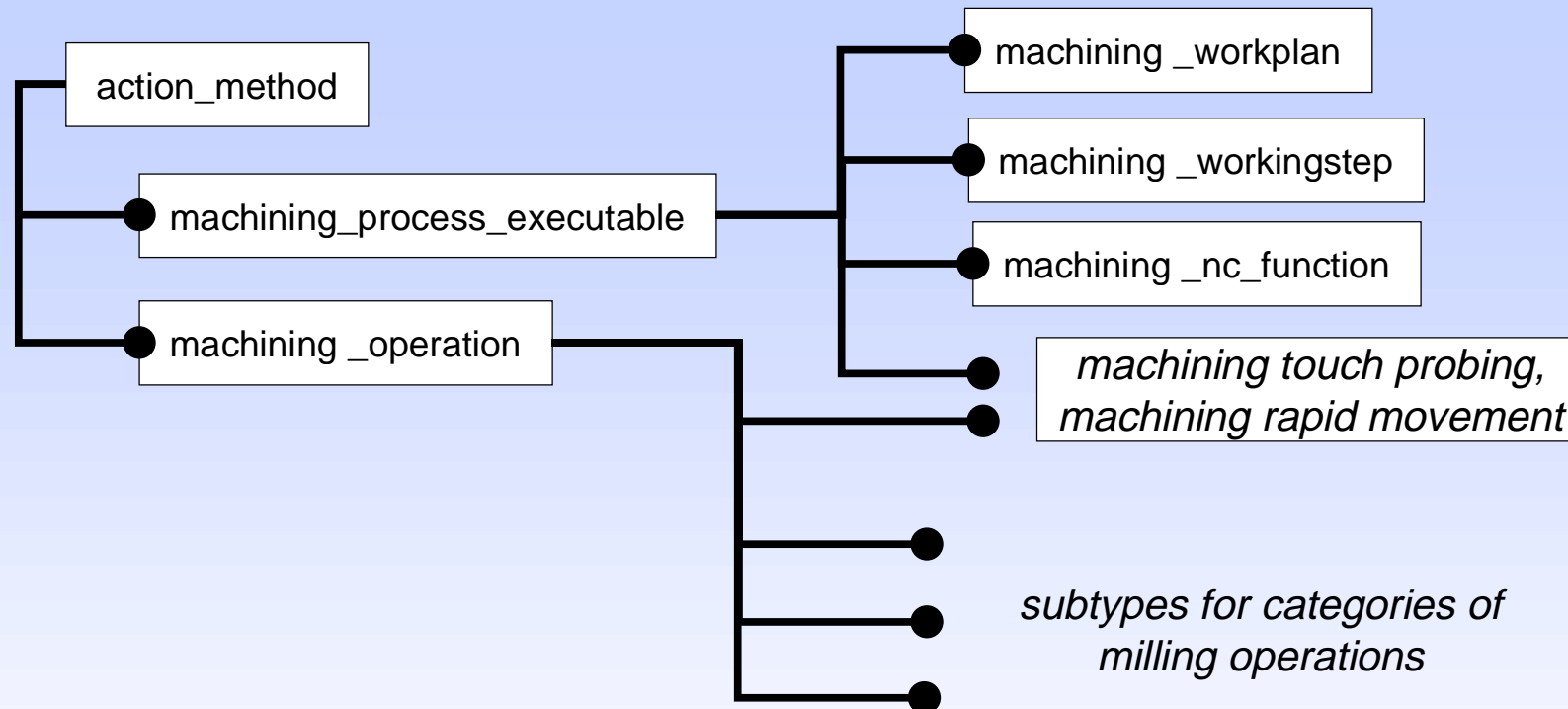
Program steps that do not move any machine axes (display message, etc.)

Program steps that move the machine axes

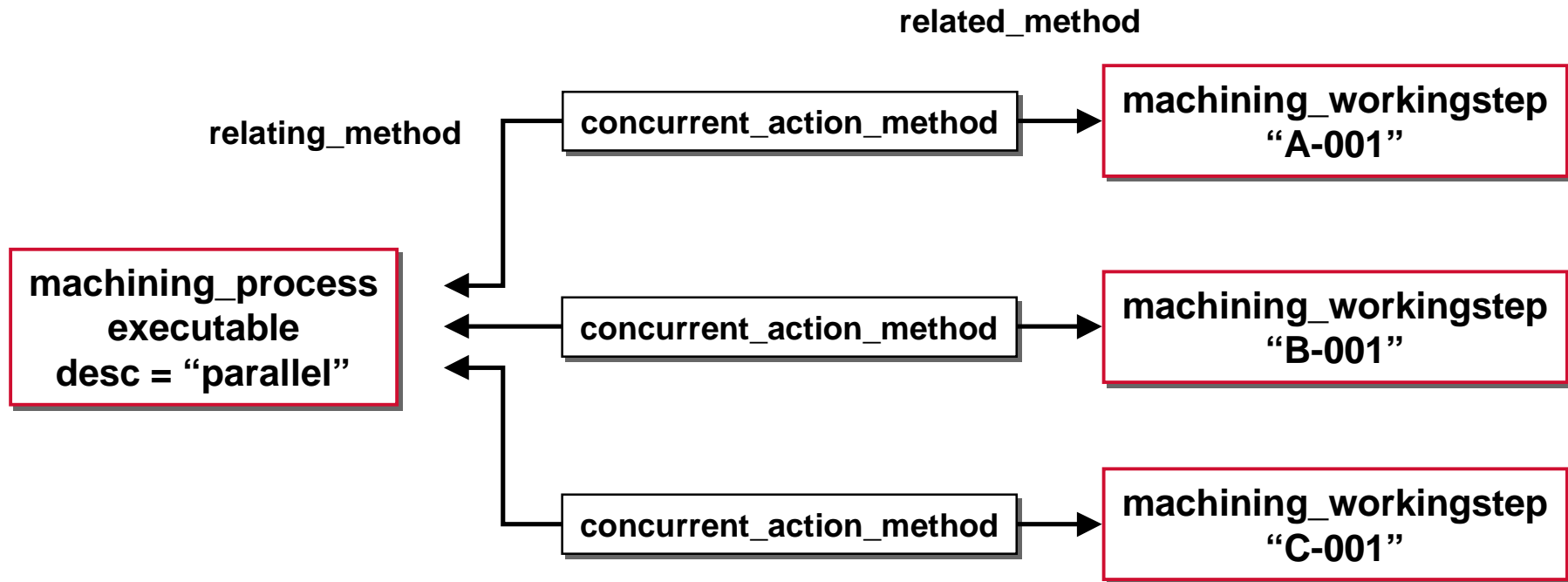
Control flow for the machining program

- **Rapid Movement**
 - return_home
- **Touch Probing**
 - workpiece_probing (offset in one direction)
 - workpiece_complete_probing (x, y, z offsets)
 - tool_probing
 - » tool_length_probing
 - » tool_radius_probing
- **NC Functions**
 - display_message
 - exchange_pallet
 - index_pallet
 - index_table
 - optional_stop
 - program_stop
 - set_mark
 - unload_tool
 - wait_for_mark

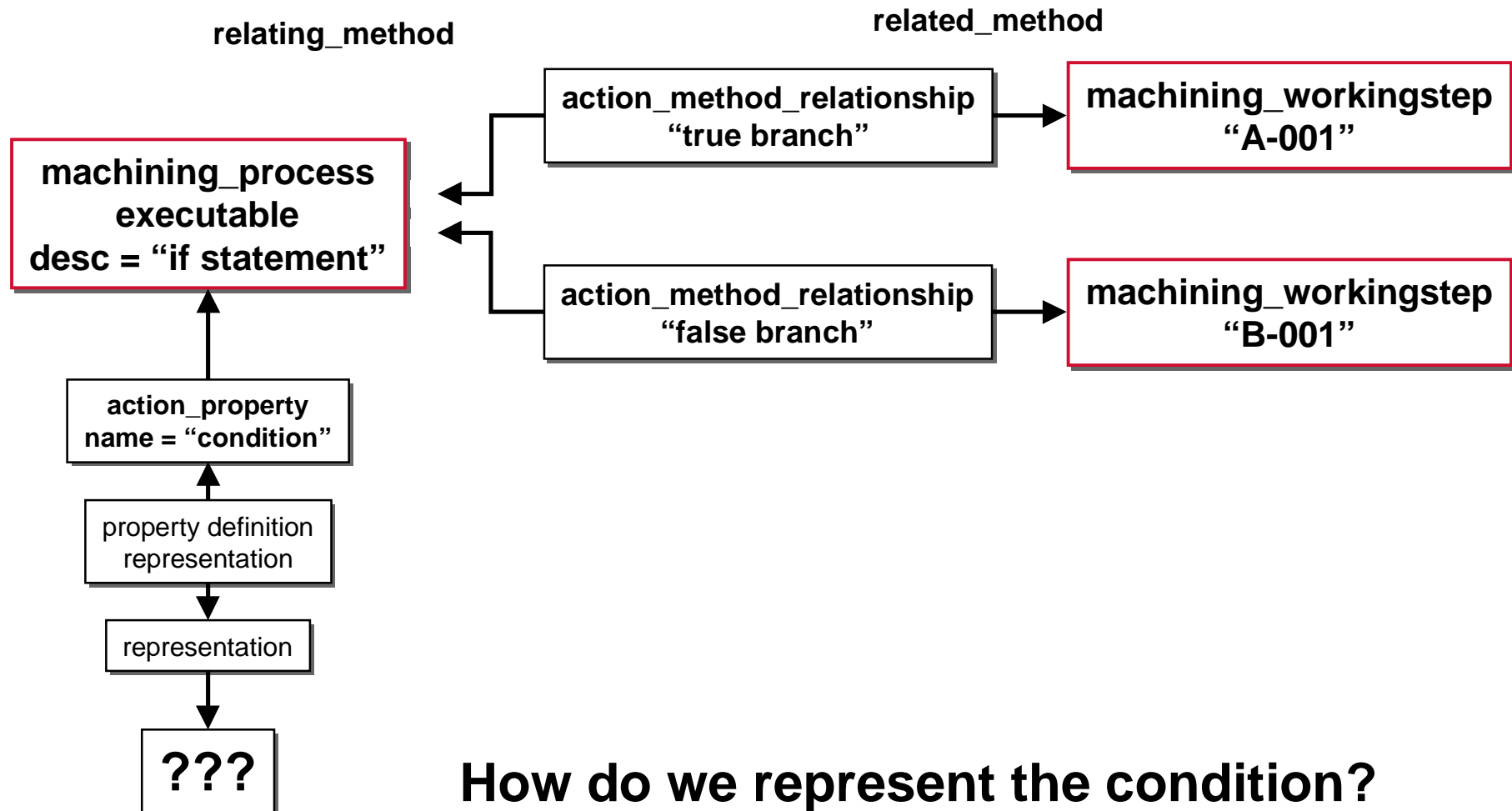
- **STEP-NC supports seven kinds of control flow**
 - **Workplan (Sequential) : execution by a sequence**
 - **Unordered Serial : all executables have to be executed but the order of execution does not matter**
 - **Concurrent : all executables are started at the same time**
 - **Parallel : all executables don't need to be started at the same time**
 - **If Statement : binary choice according to the given condition**
 - **Selective : execute only one among several executables**
 - **While Statement : repetitive execution**



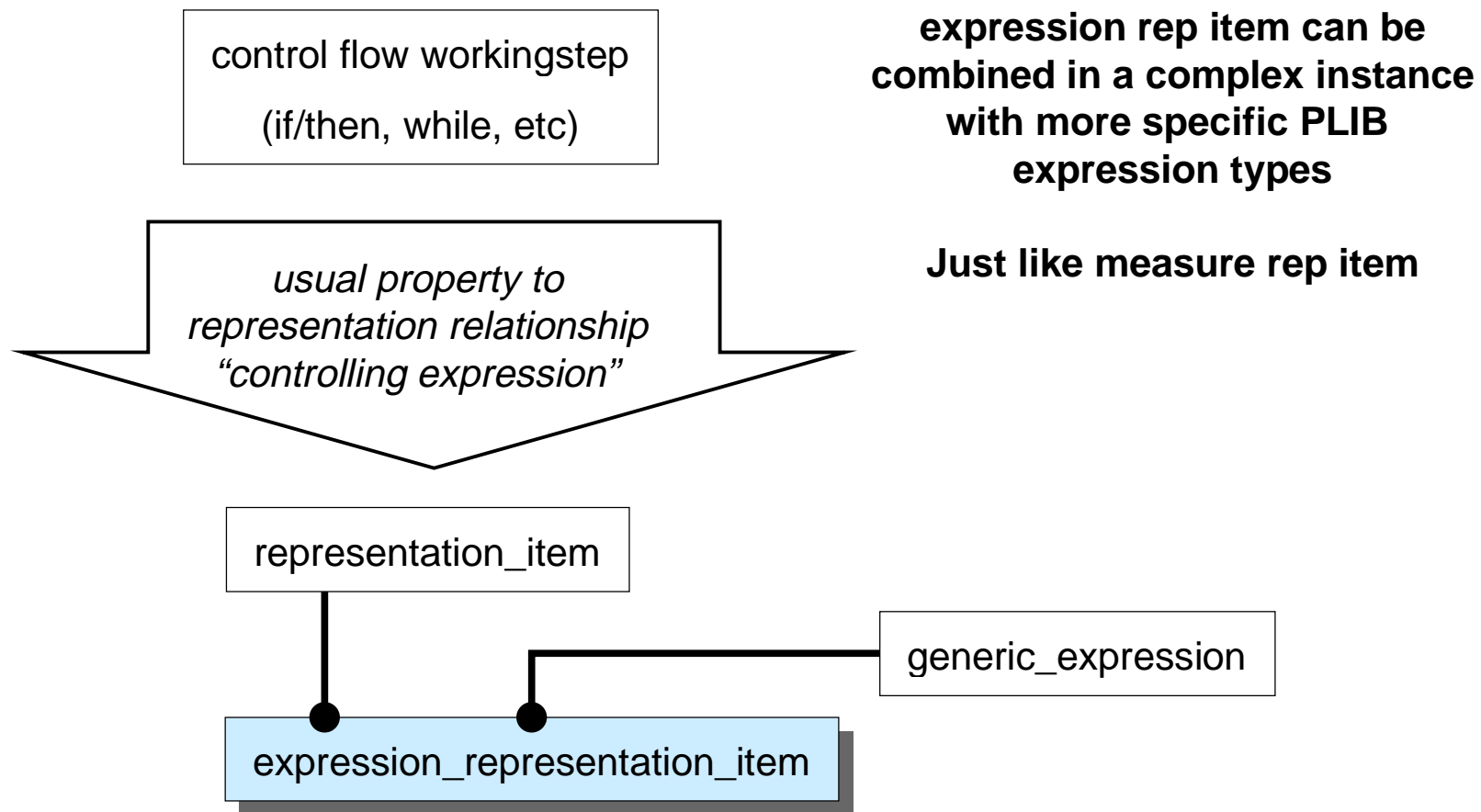
- **Advanced control flow things represented by machining process executable**
 - Use other action method relationship subtypes
 - Not just sequential method

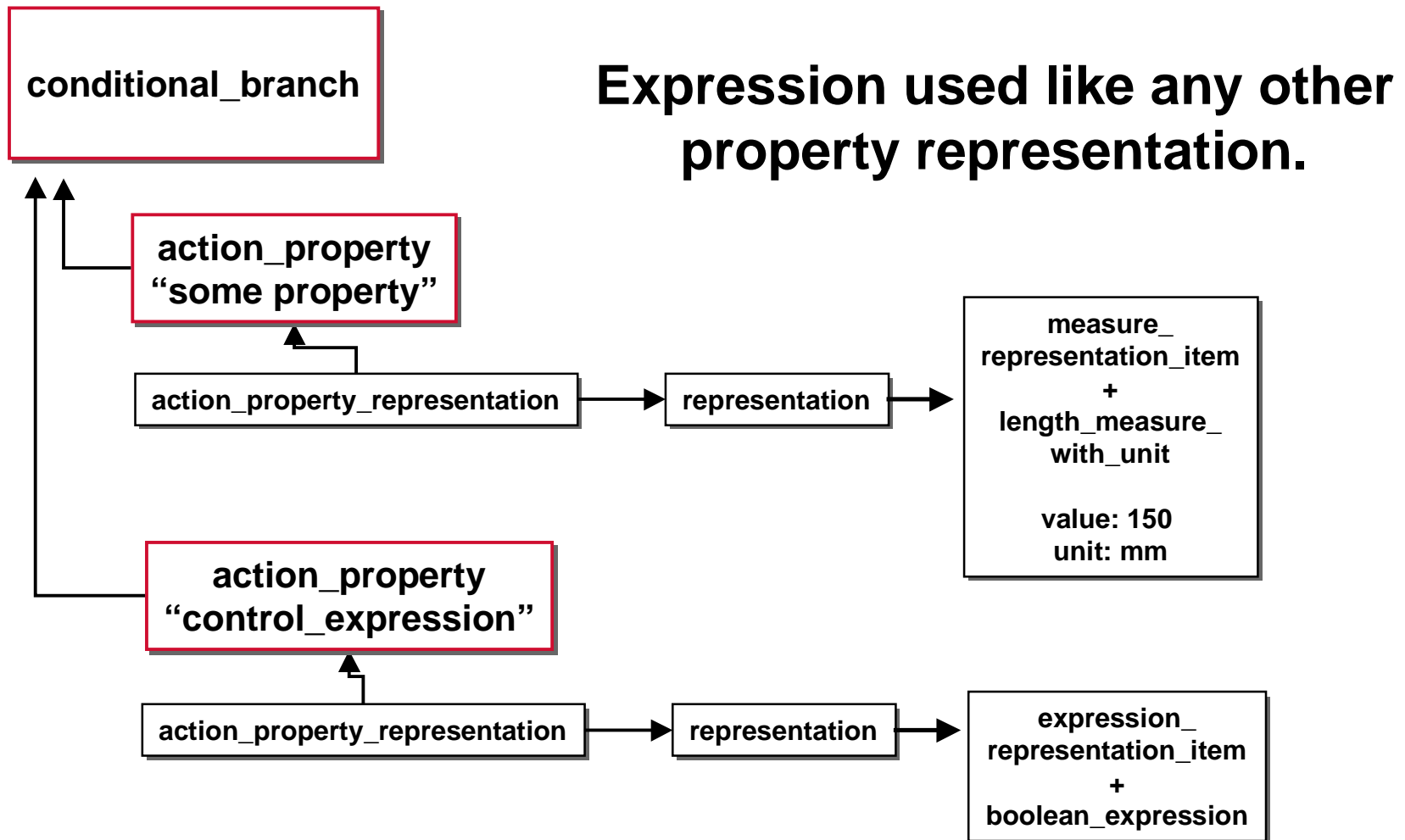


- Use concurrent action method subtype of AMR



- **STEP-NC ARM defines machining control flow (if/then, while, etc) controlled by expressions.**
 - Expressions use literal values and variables that are associated with the result of a measurement operation.
- **Map expressions using PLIB Part 20**
- **Property with expression representation.**
 - The PLIB definitions only references PLIB things.
 - Need some way to relate this to a STEP representation.

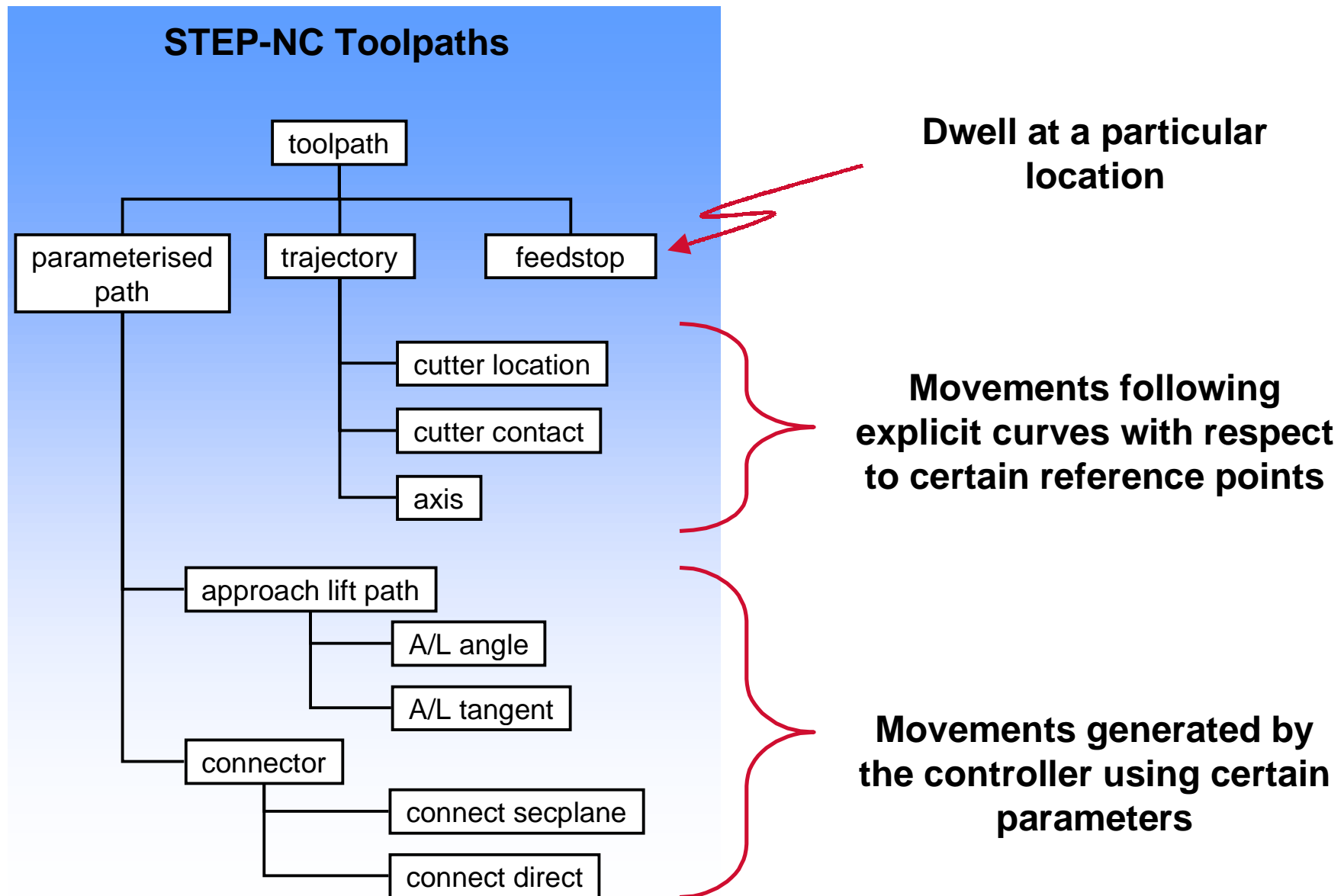


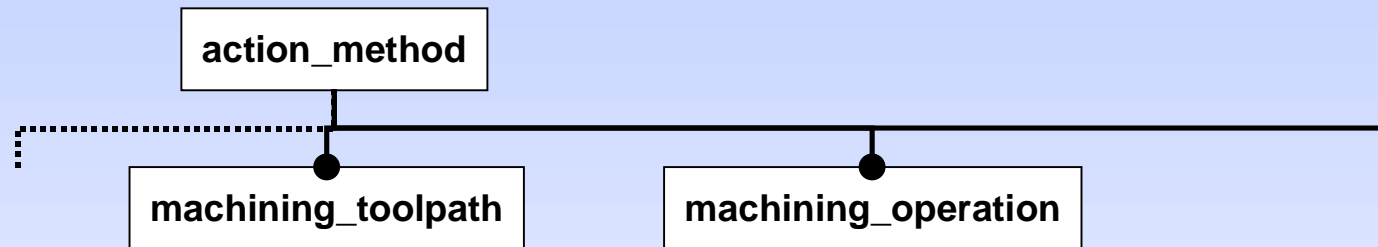


- **What is the AIM?**
- **The Backbone: Workpiece and Features**
- **The Backbone: Executables and Operations**
- **Milling Operations and Strategies**
- **Milling Tool Types**
- **Projects and Setups**
- **Advanced Control Flow for Programs**

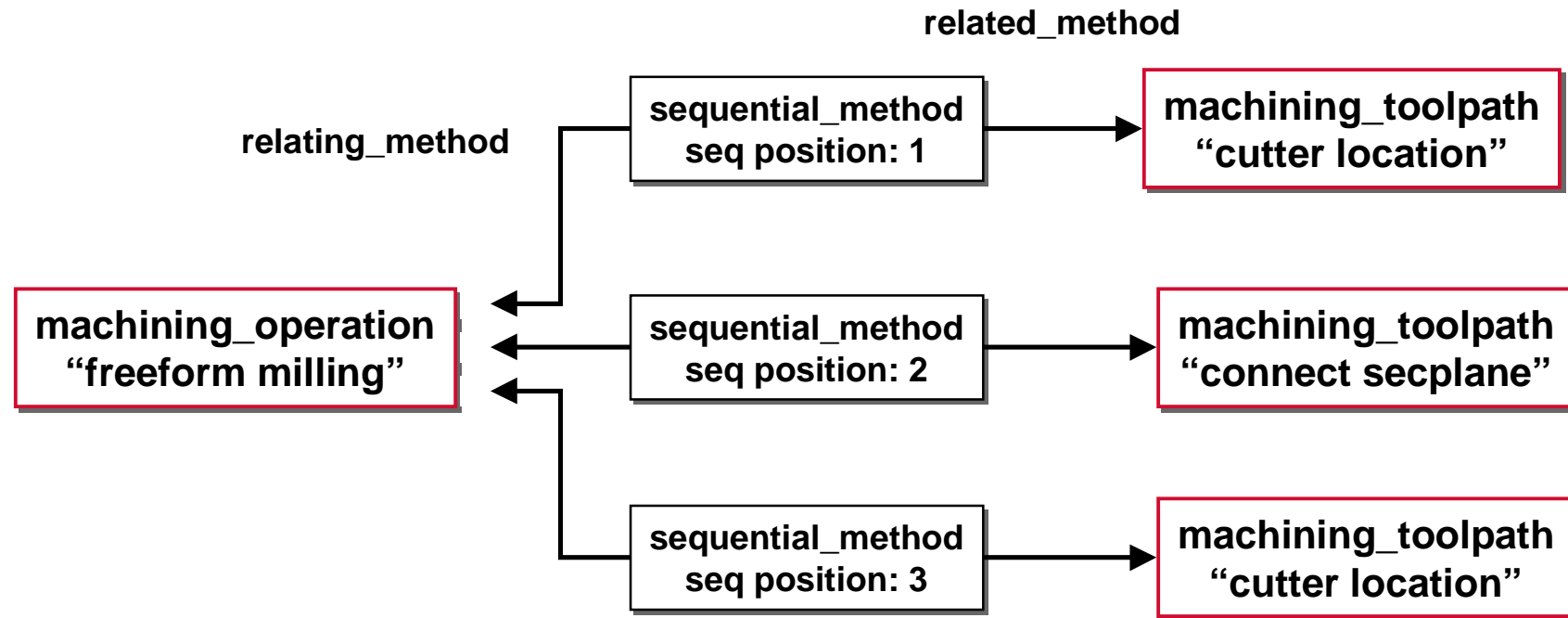
- **Explicit Toolpaths**

- **Toolpaths allow us to capture exact machine axis movements.**
 - Workplan still has “macro” plan with features and operations.
 - Captures a “micro” plan for particular operations.
 - More flexible to give a controller a macro plan and let it generate the micro plan itself.
- **Question**
 - What types of tool paths can we specify?
 - How are they represented in the AIM?
 - How are they attached to an operation?





- Toolpaths represented as action methods
- Related to operation with sequential method
- Curves and parameters related as action properties



- Same technique used to order workingsteps within a workplan

- **AP-238 AIM Document**
 - Updated mapping tables to match latest 14649 specs.
 - Have been updated to include changes from Frankfurt and other reviews.
 - Distributed for review along with supporting materials
 - » http://www.steptools.com/library/stepnc/tech_resources/
 - » AIM Document
 - » AIM Mapping Notes
 - » EXPRESS schema
 - » Complete walkthrough presentations.
 - Distribute for combined NWI/CD ballot after meeting.