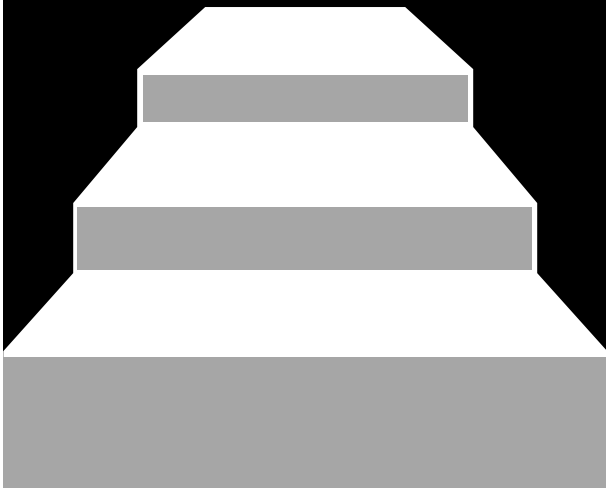# Machining Programs and Tooling

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2004-10-06

STEP Tools, Inc.
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http://www.steptools.com

- **STEP-NC is a new language for CNC control**
  - **Complete, unambiguous model of the part and process**
  - **Brings together machining process, tool requirements, geometry, tolerances, and PDM.**
  - **Makes CNC systems**
    - » **More interoperable**
    - » **Faster to program**
    - » **Safer to operate**

- **STEP-NC can enable million of dollars of savings using lean manufacturing**

Problem is Tool Motions

The standard for 40 years!

machine-specific part program with axis data generated by a postprocessor

vendor-specific extensions of the original standard

only primitive motion and switch commands

no standardized data format for spline processing and sophisticated NC technology
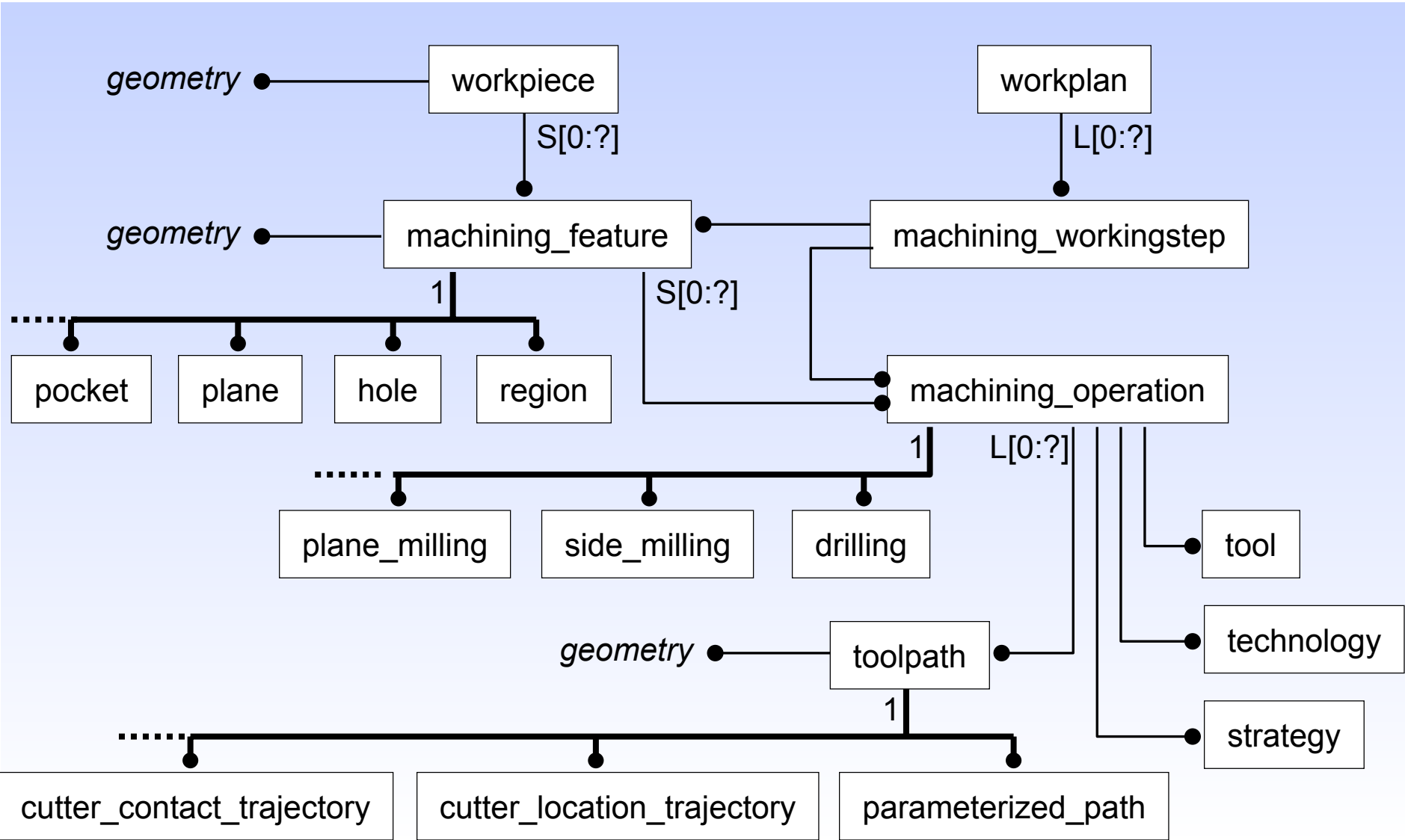
```
%
N05     G54
N10     G00  Z10.000
N15     G91 G0 Z200
N20     T5 D1 WW
N30     G90 M5
N35     G00 X0.000   Y-150.000
N40     G00 Z5.000
N45     M08
N50     S3183.000
N55     M03
N60     F1477.000
N65     G00 X60.000   Y-150.000
N70     G00 Z5.000
N75     G00 X60.000   Y-150.000
N80     G01 Z-0.500
...
```
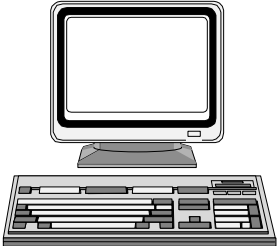
Ideal for Paper Tape!
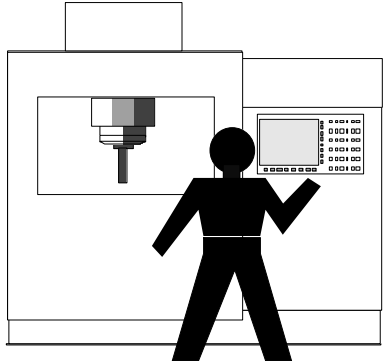
STEP-NC replaces this with a rich, integrated 3D data format

- ## AP-238 describes "what" as well as "how"
  - **Make this geometry from this stock**
  - **By removing these features**
  - **In this order**
  - **With these tolerances**
  - **And tools that meets these requirements**
  - **May even let the controller choose tool motion**

- ## The old standard only described "how"
  - **Move tool to this location**
  - **Move tool to this location**
  - **And so on for millions of commands**

- **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**

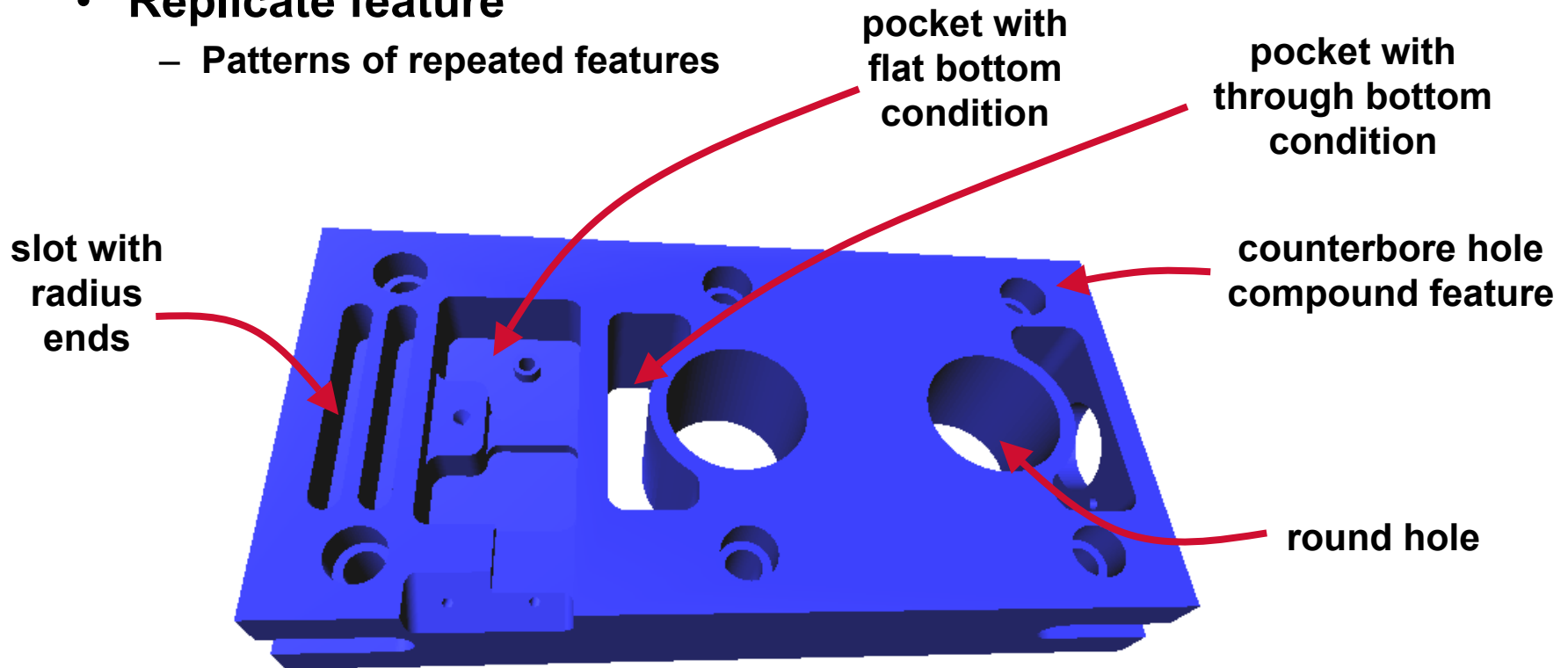|		
Measures **Executable**		
Project **Operation**	**Based on Part 10**	
Workpiece **Toolpath**		
Features		**First** **Edition**
Dimensions and Tolerances	**STEP GD&T**	
PDM and Product Geometry	**Common to all APs**	
		Second **Edition**
Milling Process Operations	**Based on Part 11**	
Milling Cutting Tools	**Based on Part 111**	
Turning Process Operations	**Based on Part 12**	
Turning Cutting Tools	**Based on Part 121**	
EDM Process Operations	**Based on Part 13**	
Other Technology Parts as they reach DIS		

- **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**

Workpiece, Shape, and PDM

STEP **Tools, Inc.**

- **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.**

Machining Features
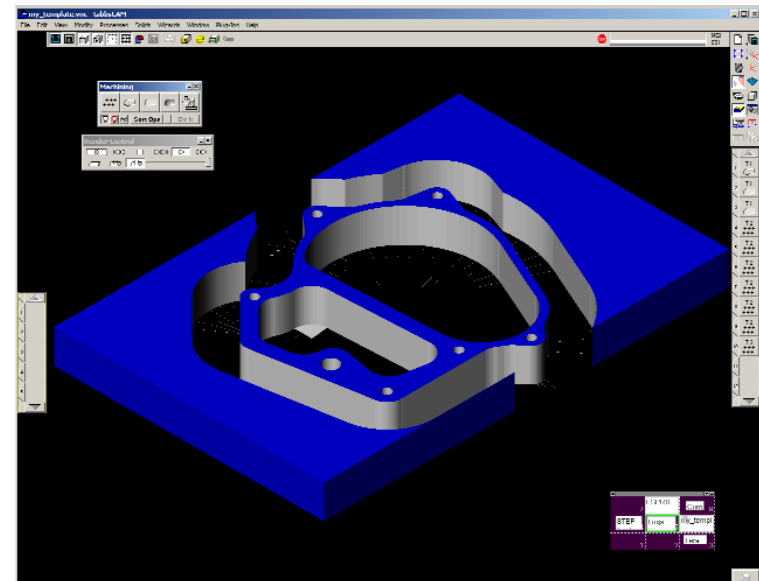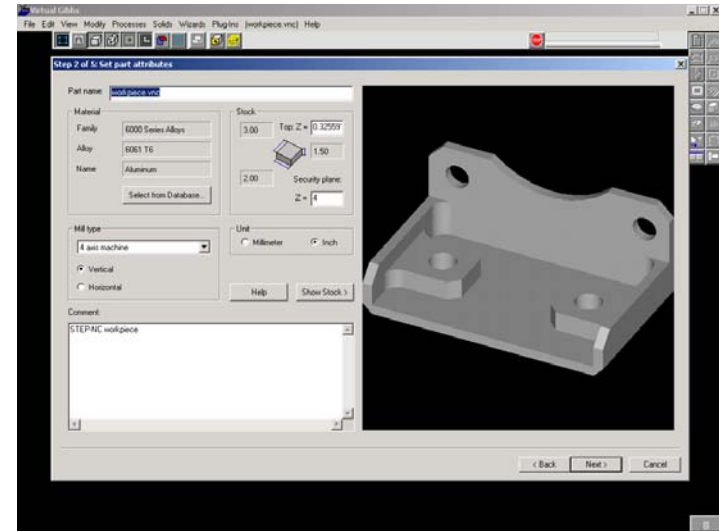
- **2.5D milling features**
  - **Hole, pocket, slot, step, etc**

- **Transition features**
  - **Edge round and chamfer**

- **Replicate feature**
  - **Patterns of repeated features**

- **Region features**
  - **Surfaces for freeform milling**

- **Turning features**
  - **Outer round, knurl, groove**

pocket with flat bottom condition

pocket with through bottom condition

slot with radius ends

counterbore hole compound feature

round hole

- **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**
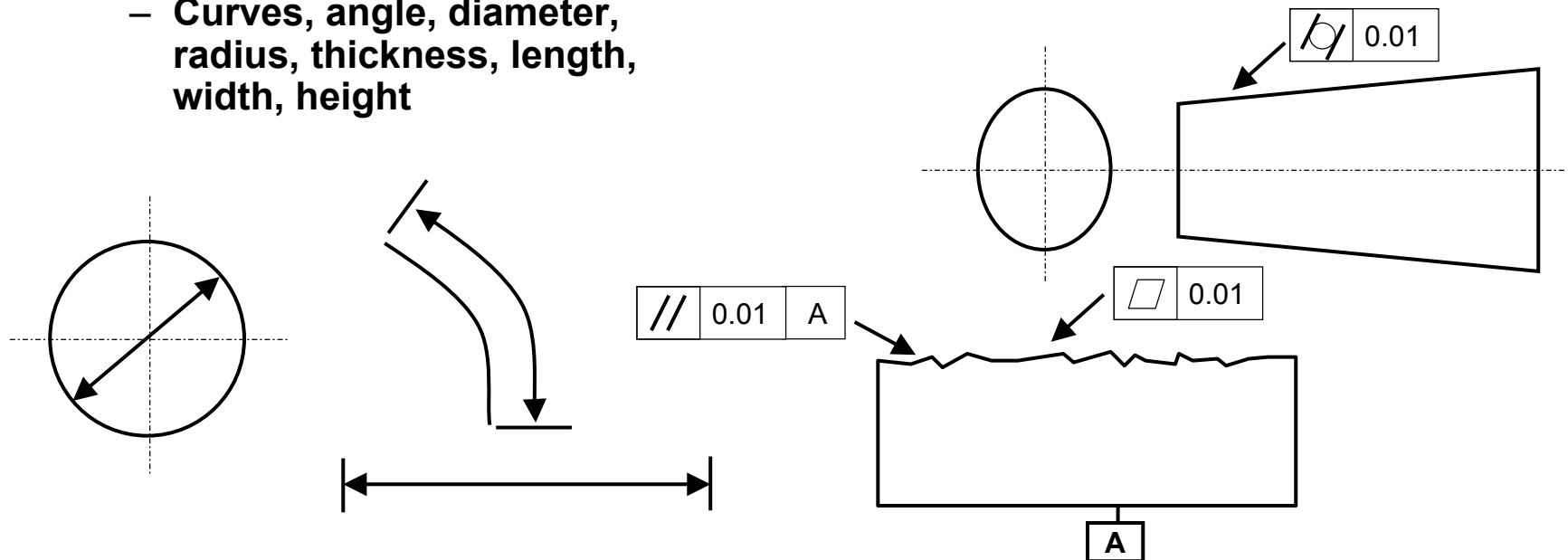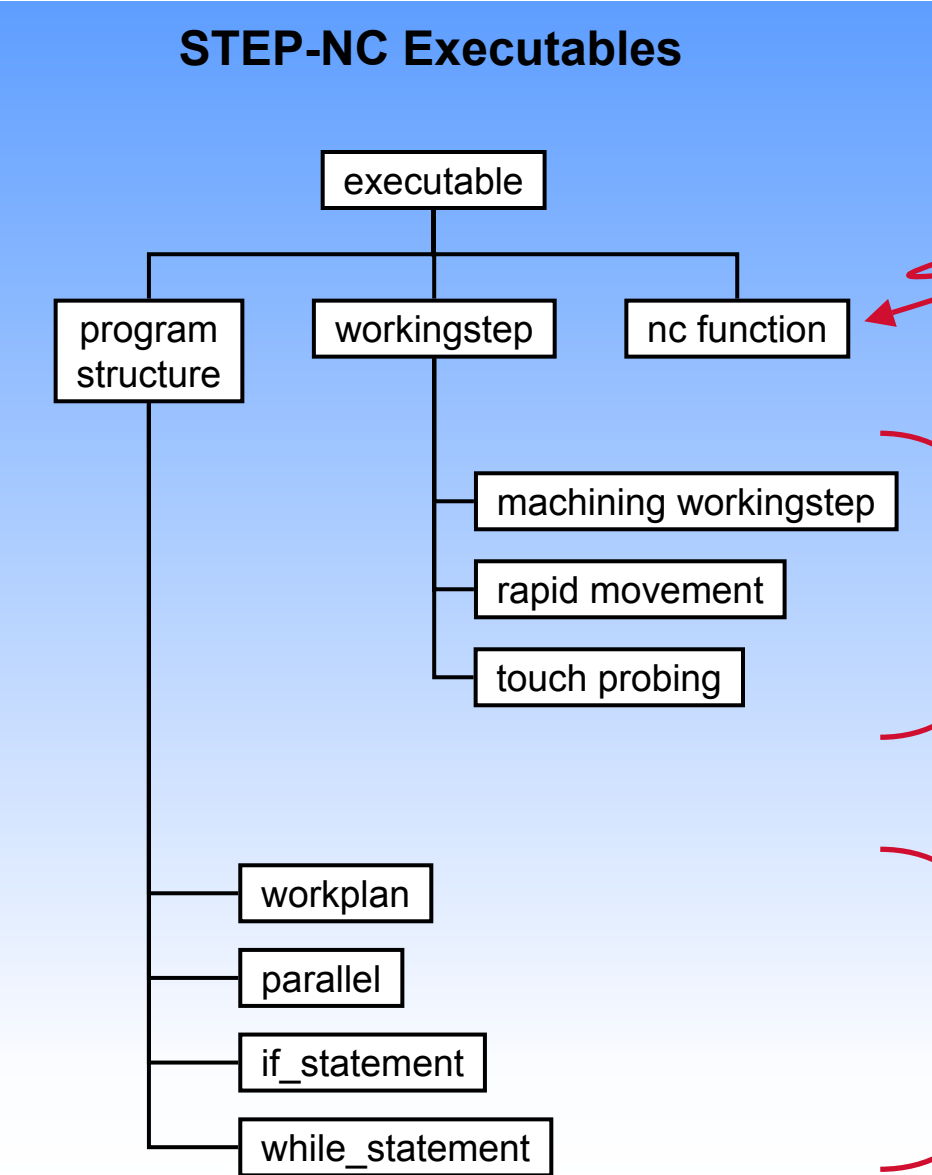
AP-238 Units of Functionality

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

- **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

executable

program structure

workingstep

nc function

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

machining workingstep

rapid movement

touch probing

Program steps that move the machine axes

workplan

parallel

if_statement

while_statement

Control flow for the machining program

- **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.**
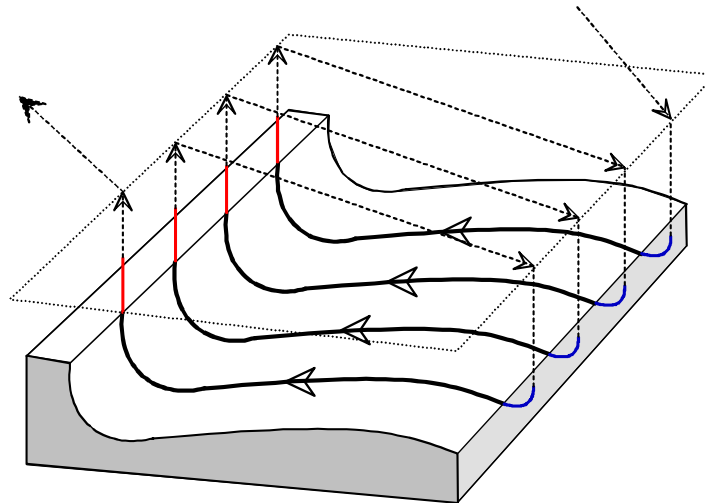

Diagram WZL RWTH Aachen

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

- ## 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**

A   A'   A-A'

Cutter contact point
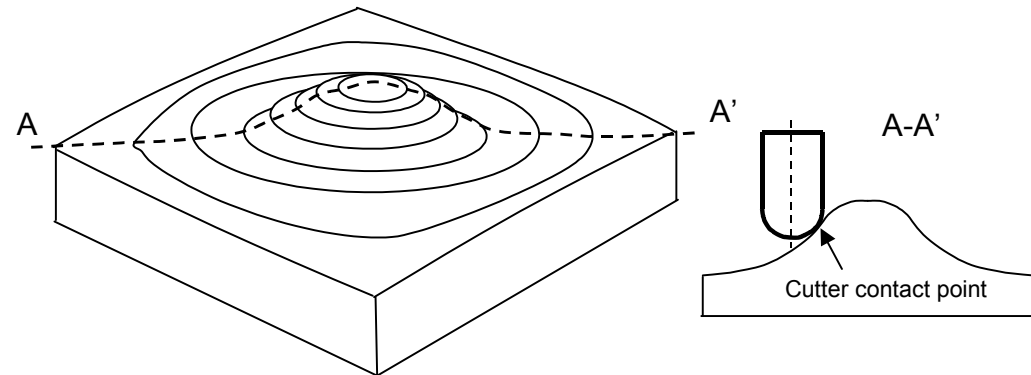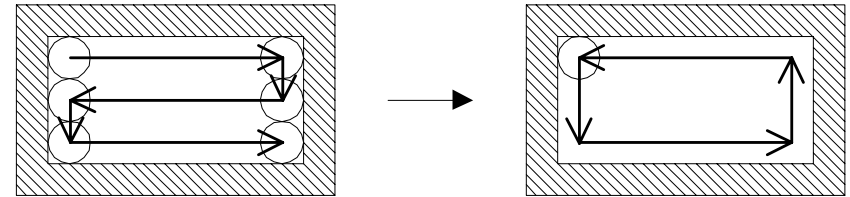
- **Turning Operations**
  - **Contouring, facing, grooving, threading and knurling.**
  - **Roughing and finishing for each**
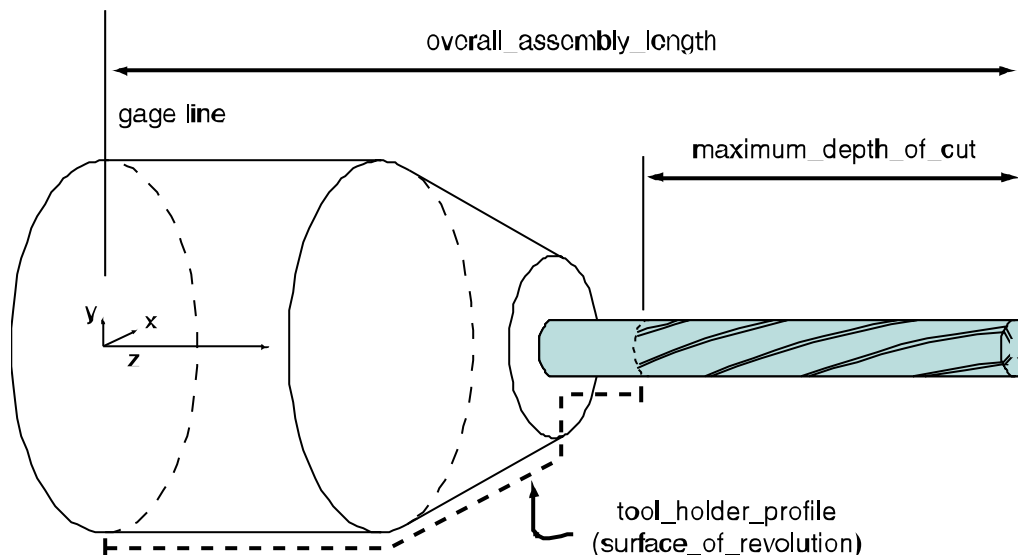 - **Set of strategies**
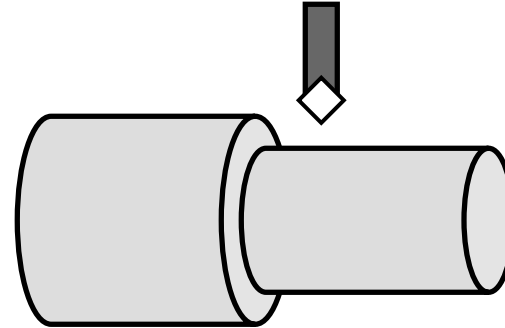
- **Possible Future Operations**
  - **Work underway to describe operations for wire and sink EDM, contour cutting of wood and glass, grinding.**
  - **Efforts in various stages of maturity.**
  - **Will be added to AP-238 once the information requirements are mature.**
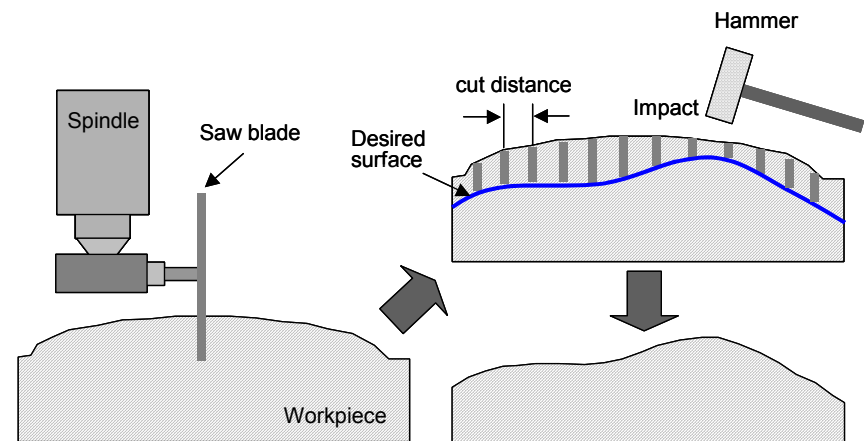
- **Every operation can have a tool associated.**
  - Represents tool requirements, not a physical tool on a machine.
  - Potential for some best-fit optimization by the controller.

- **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**

overall_assembly_length

gage line

maximum_depth_of_cut

y
x
z

tool_holder_profile
(surface_of_revolution)

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  - **Complete, unambiguous model of the part and process**
  - **Integrates machining process, tool requirement, geometry, tolerances, and PDM.**

- **Can enable million of dollars of savings using lean manufacturing by making CNC systems**
  - **More interoperable: portable TCP and no more posts**
  - **Faster to program: task-oriented programming**
  - **Safer to operate: full checking information**