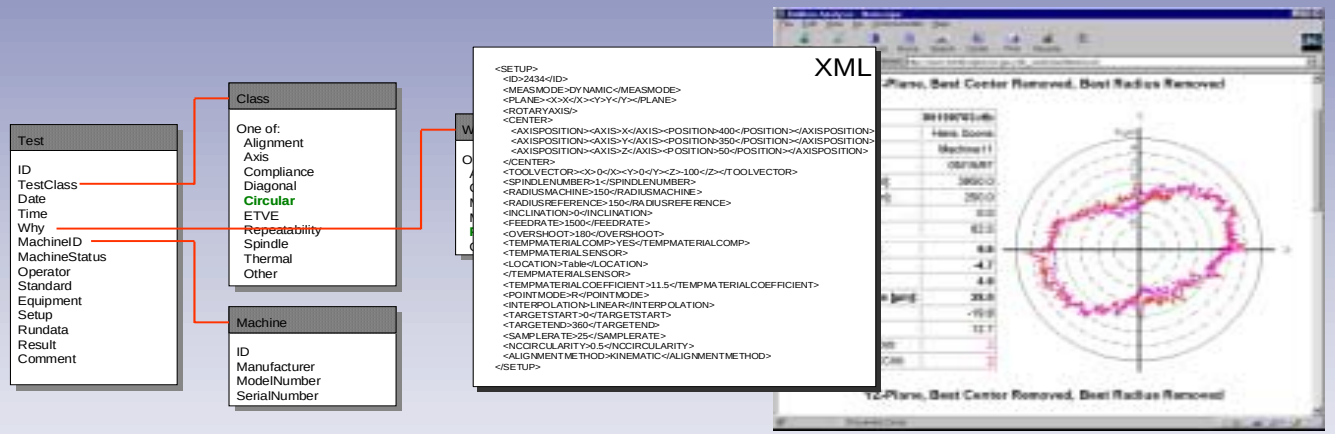
Information Technology
for Engineering & Manufacturing

Characterization of Machine Tools using XML



Hans Soons

Manufacturing Engineering Laboratory

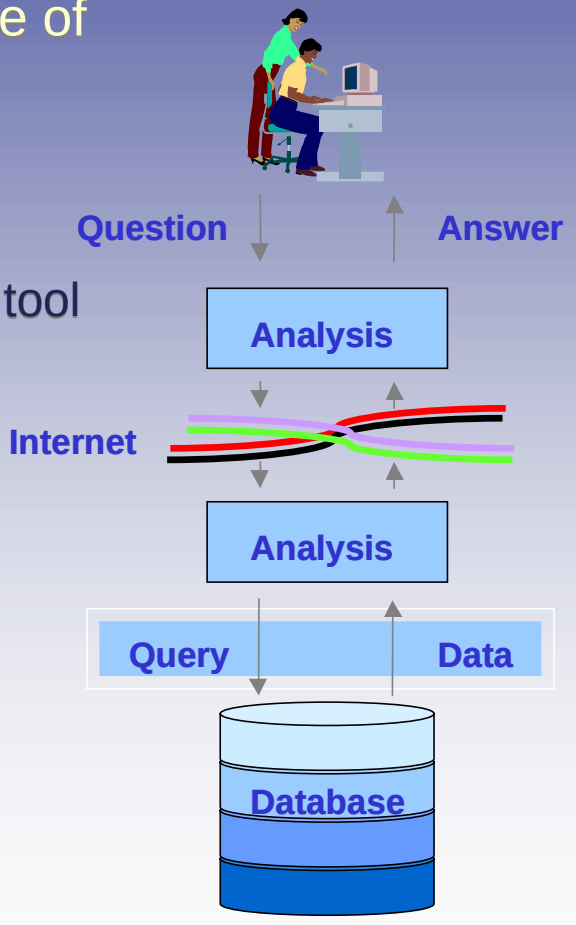
Goal

Standardized representation of machine tool performance data that allows for efficient archiving and exchange of machine information throughout its life-cycle

- Why:

  Provide information to ensure that the right machine tool (supplier) is used to manufacture a part

- Applications:
  - E-commerce
  - Resource allocation / virtual machining
  - Maintenance / quality control
  - Performance verification / comparison



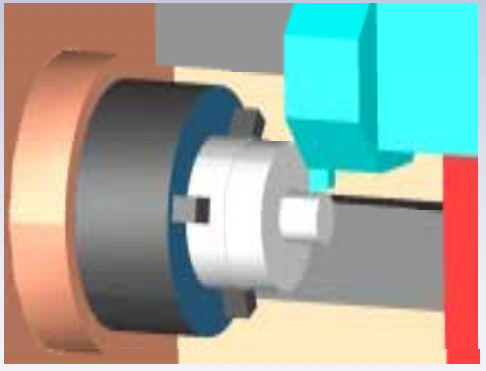
Virtual machining

Cutting Bits

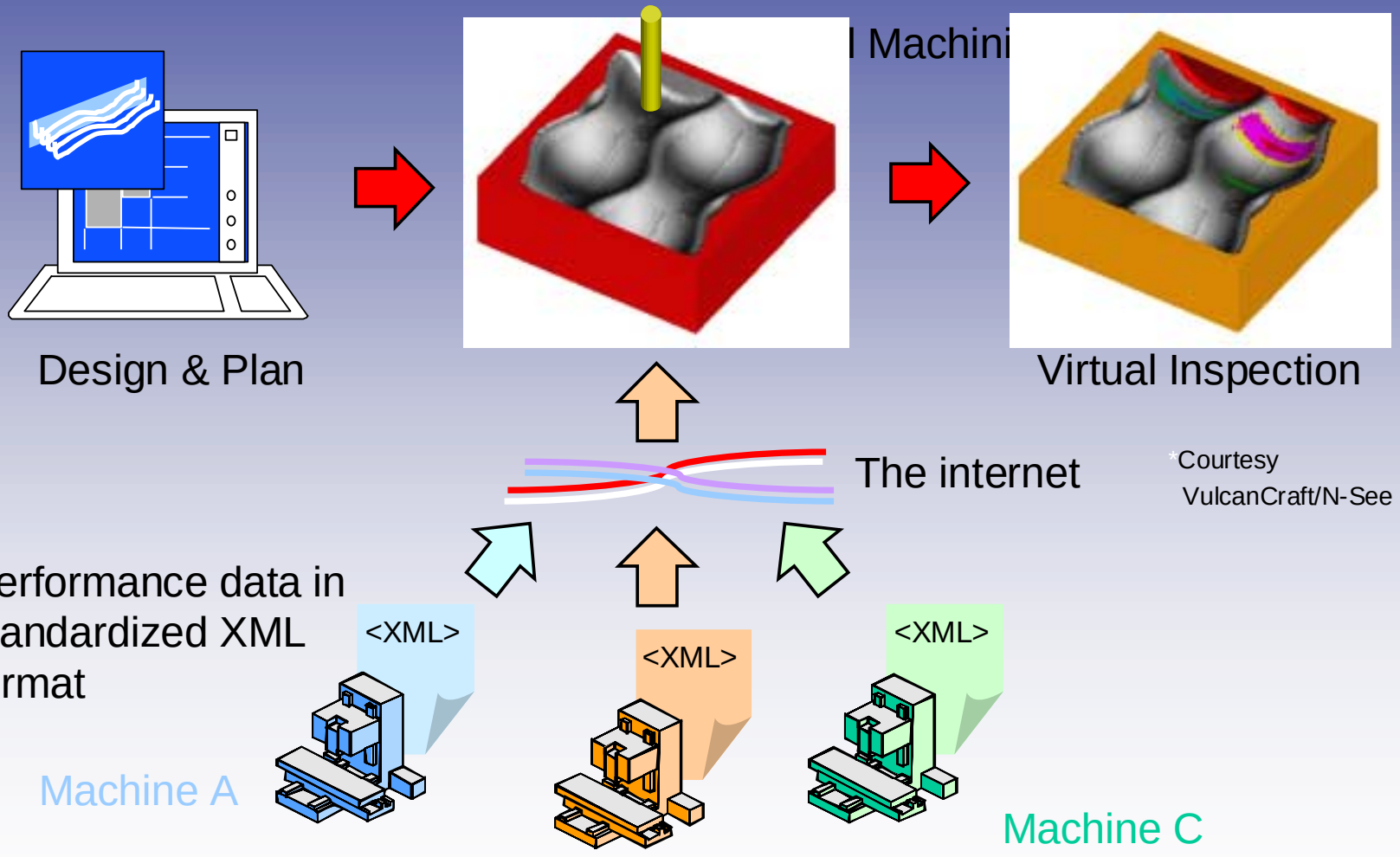
- Virtual machine tool:

  A model that predicts an output of the machining process by simulating the actions of the machine tool in response to the part program and the environment.

- Output:
  - Verification part program
  - Time required to make the part
  - Tolerances part
  - Tool life
  - ……



Virtual machining



Virtual machining

Cutting Bits

- Critical enabler is efficient access to relevant data:
  - The part (geometry, tolerances, material)
  - The process plan (part program, setup and fixturing)
  - The machine tool(s)
  - The tool(s)
  - The machine environment
- Machine tool information:
  - Data that applies to a machine model:

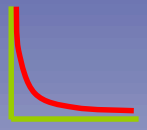
    Classification, number of axes, workspace, feedrate, controller, tool holder standard, coolant management, ….
  - Data that applies to a specific machine:

    Performance test data

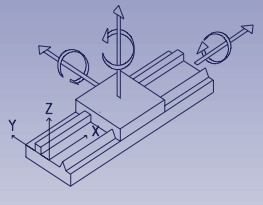
Machine tool information

Machine specific

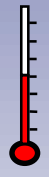
Noise



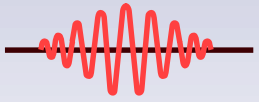
Contouring Errors



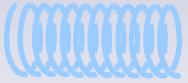
Geometric Errors



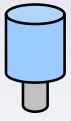
Thermal Errors



Machine Dynamics

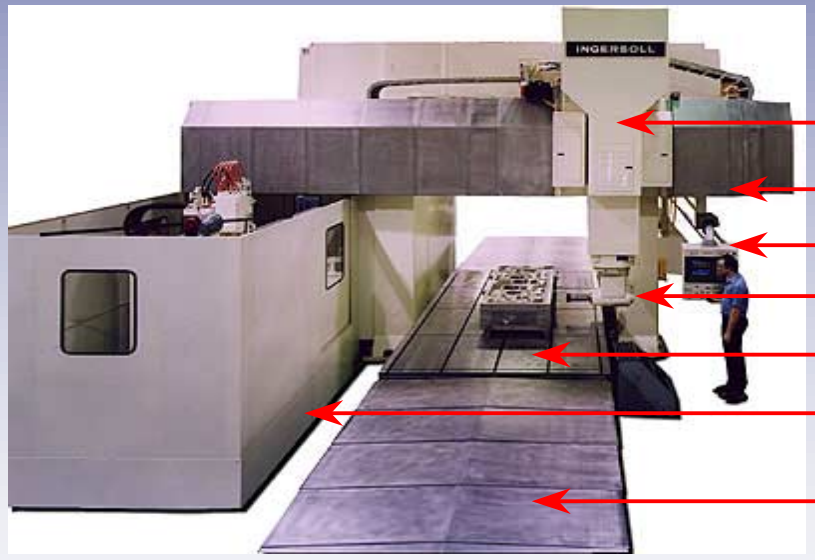


Stiffness



Spindle axis of rotation

Model specific



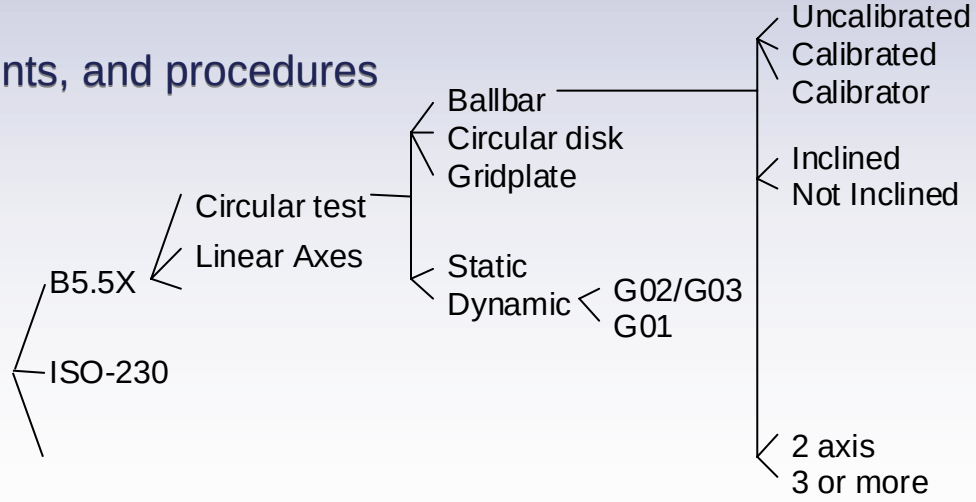
- Axis configuration
- Axis range, speeds, ...
- Controller capabilities
- Spindle speeds, torque, ..
- Table size, loads, ...
- Tool changer, coolant, ...
- Footprint

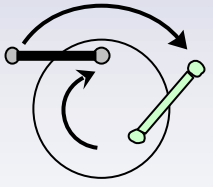
Needs to be tested (periodically)

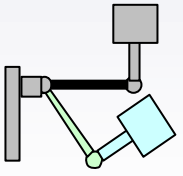
"Catalog" data

Performance tests

- Currently:
  - Many vendor specific formats
  - Not all relevant information is stored (e.g., for error modeling)
  - File based storage
- Unified information model and data format:
  - Straightforward interchange of test data
  - Communication and storage of all relevant information
  - *Facilitates development third-party tools for data analysis and archiving*
- Problem:
  - Many tests, instruments, and procedures







Information standards

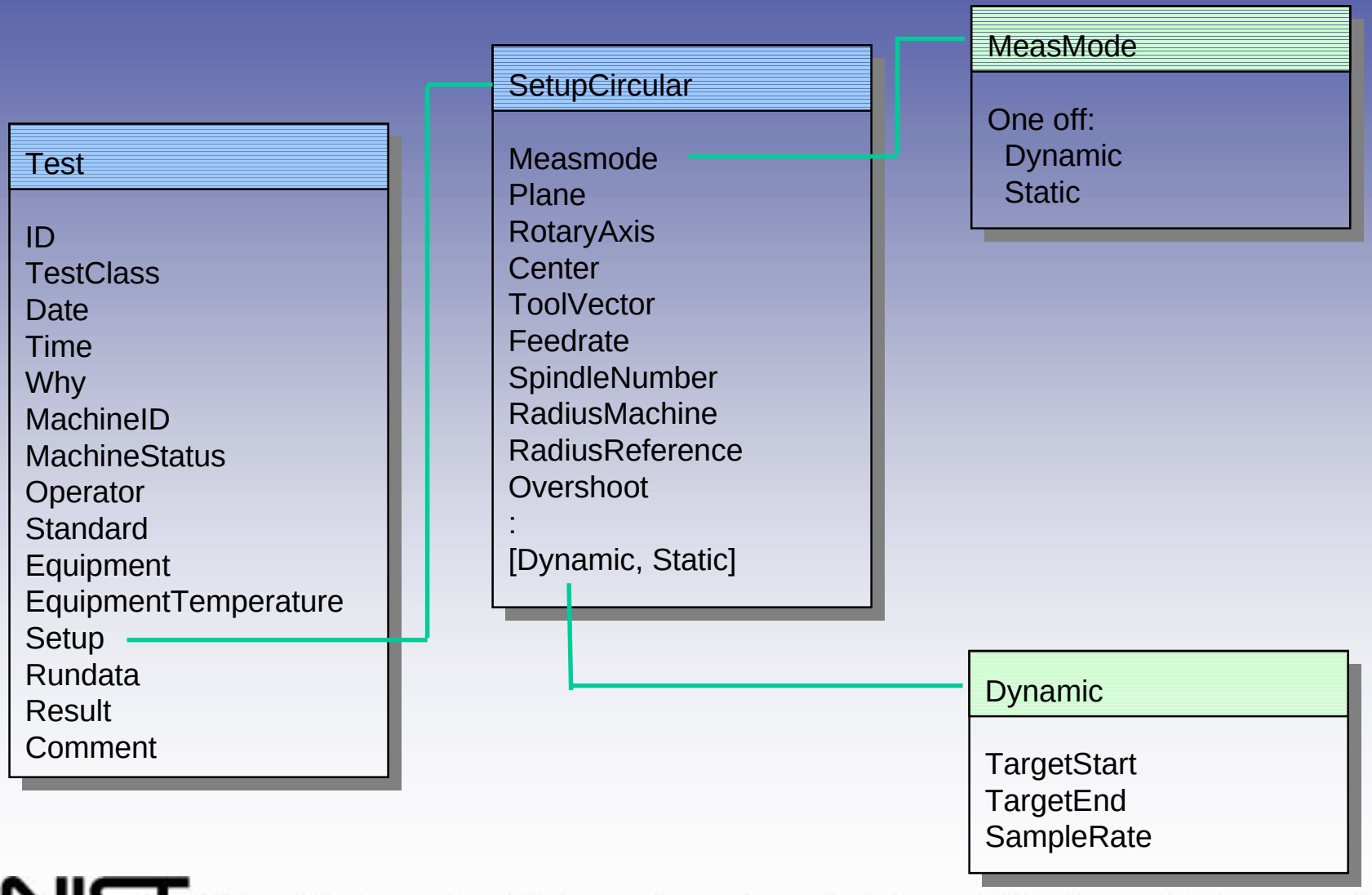
- What:
  - Classification data (applies to a machine model):
    - Classification, number of axes, workspace, feeds & speeds, controller, tool holder standard, ….
  - Performance test data (machine specific):
    - Results and description performance tests
    - Higher order performance test data
      - Performance parameters (nominal, actual over time)
      - Error model parameters (compensation, virtual machining)

}

- How:
  - Information model
  - Data format specification (XML)
  - SQL calls to generate database schema
  - Prototype web-site for data upload and analysis

EXPRESS

Information Model / Data Dictionary



Information model - XML

Test

- ID
- TestClass
- Date
- Time
- Why
- MachineID
- MachineStatus
- Operator
- Standard
- Equipment
- EquipmentTemperature
- Setup
- Rundata
- Result
- Comment

XML


```
<SETUP>
  <ID>2434</ID>
  <MEASMODE>DYNAMIC</MEASMODE>
  <PLANE><X>X</X><Y>Y</Y></PLANE>
  <ROTARYAXIS/>
  <CENTER>
    <AXISPOSITION><AXIS>X</AXIS><POSITION>400</POSITION></AXISPOSITION>
    <AXISPOSITION><AXIS>Y</AXIS><POSITION>350</POSITION></AXISPOSITION>
    <AXISPOSITION><AXIS>Z</AXIS><POSITION>50</POSITION></AXISPOSITION>
  </CENTER>
  <TOOLVECTOR><X>0</X><Y>0</Y><Z>-100</Z></TOOLVECTOR>
  <SPINDLENUMBER>1</SPINDLENUMBER>
  <RADIUSMACHINE>150</RADIUSMACHINE>
  <RADIUSREFERENCE>150</RADIUSREFERENCE>
  <INCLINATION>0</INCLINATION>
  <FEEDRATE>1500</FEEDRATE>
  <OVERSHOOT>180</OVERSHOOT>
  <TEMPMATERIALCOMP>YES</TEMPMATERIALCOMP>
  <TEMPMATERIALSENSOR>
  <LOCATION>Table</LOCATION>
  </TEMPMATERIALSENSOR>
  <TEMPMATERIALCOEFFICIENT>11.5</TEMPMATERIALCOEFFICIENT>
  <POINTMODE>R</POINTMODE>
  <INTERPOLATION>LINEAR</INTERPOLATION>
  <TARGETSTART>0</TARGETSTART>
  <TARGETEND>360</TARGETEND>
  <SAMPLERATE>25</SAMPLERATE>
  <NCCIRCULARITY>0.5</NCCIRCULARITY>
  <ALIGNMENTMETHOD>KINEMATIC</ALIGNMENTMETHOD>
</SETUP>
```

XML → Database

```
<Test>
<Id>BB0699a.rtb</Id>
<TestClass>Circular</TestClass>
<Date>1999-06-22</Date>
<Time>10:06:00</Time>
<Why>Periodic</Why>
<Machine>
   <Id>2434</Id>
   <Manufacturer>XYZ</Manufacturer>
   <Model>ABC</Model>
   <SerialNumber>123</SerialNumber>
   <Location>Shops</Location>
</Machine>
<Conditions>
   <Compensation>Yes</Compensation>

<TempEnvironment>22.5</TempEnvironment>
</Conditions>
```

testdef

testdef_id	id	testclass	date	time	why	machine_id	conditions_id
253	BB0699a.rtb	Circular	1999-06-22	10:06:00	Periodic	254	255

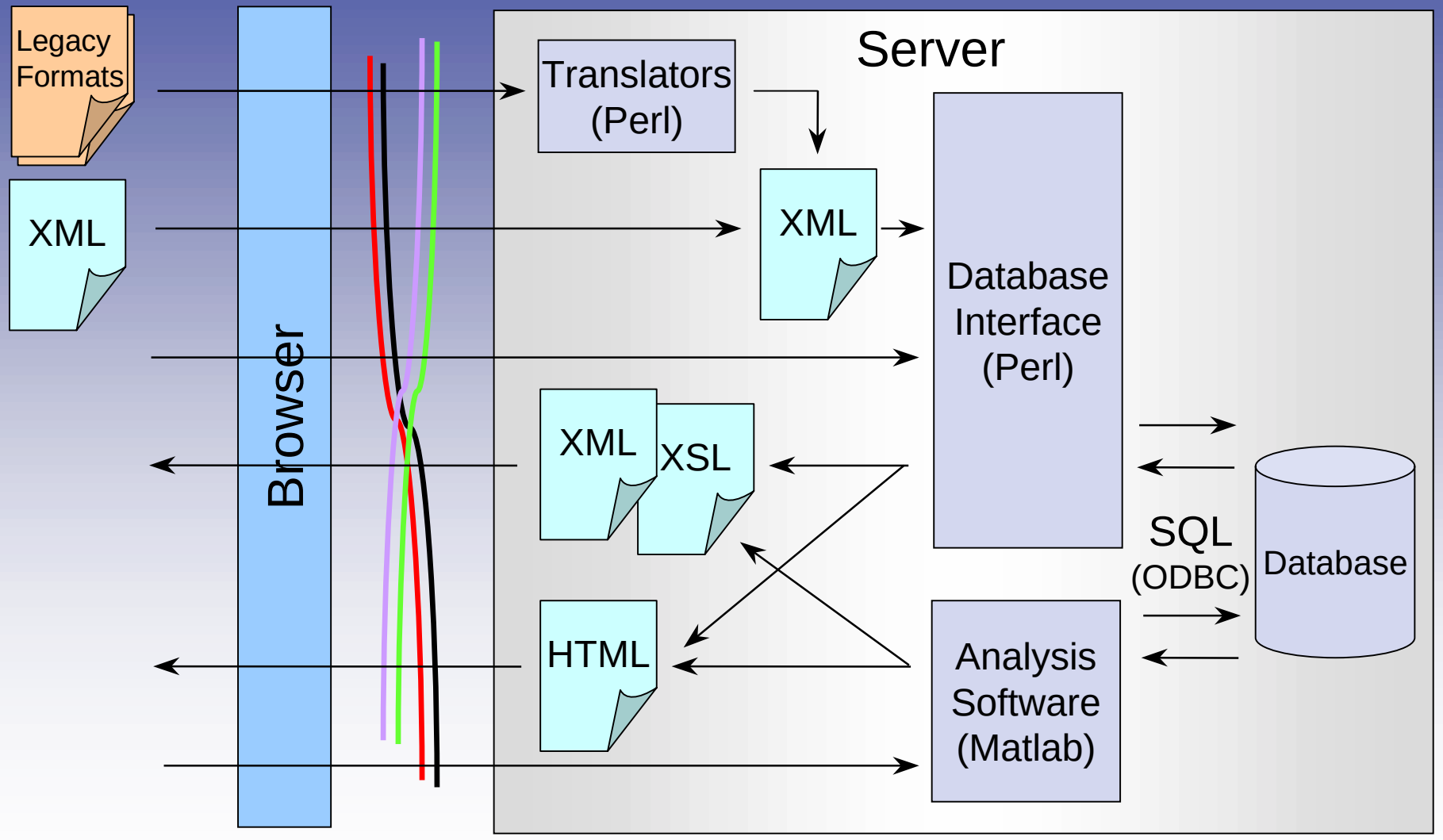
machinedef

machinedef_id	id	manufacturer	model	serialnumber	location
254	2434	XYZ	ABC	123	Shops

conditionsdef

conditionsdef_id	compensation	tempenvironment
255	yes	22.5

Prototype repository web-site



Repository

Select Machine Performance Test

Test Class	Submit Data	Analyze Data	Test Class	Submit Data	Analyze Data
Environmental tests			**Accuracy rotary axes**		
ETVE	●	●	Positioning and repeatability	●	●
Relative vibration	●	●	Periodic error	●	●
Electrical	●	●	Axis of rotation	●	●
Utility air	●	●	**Spindle axis of rotation**	●	●
Accuracy linear axes			**Thermal tests**		
Positioning and repeatability	●	●	Spindle thermal stability	●	●
Periodic error	●	●	Spindle thermal stability	●	●
Angular error motions	●	●	Moving axes	●	●
Straightness	●	●	Composite	●	●
Subsystems repeatability	●	●	**Critical alignments**	●	●
CNC performance tests	●	●	**Circular contouring performance**	●	●
Multi-function cycle test	●	●	**Cutting tests**	●	●

Return To Turning Centers Page
Return To Machining Centers Page

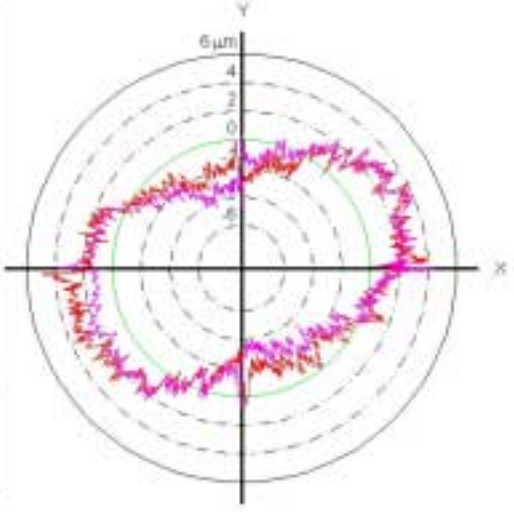
3 Tests match your criteria.

Please select the test(s) that you want to analyze

lect	Filename	Machine	Date	Operator	Plane	Radius	Feedrate	Direction
	05159703.rtb	Machine11	05/15/97	Hans Soons	XY	250.0	3950.0	CW & CCW
	05159708.rtb	Machine11	05/15/97	Hans Soons	YZ	250.0	4000.0	CW & CCW
	05159711.rtb	Machine11	05/15/97	Hans Soons	ZX	250.0	4000.0	CW & CCW

XY-Plane, Best Center Removed, Best Radius Removed

Test:	05159703.rtb
or:	Hans Soons
e:	Machine11
	05/15/97
e [mm/min]:	3950.0
length [mm]:	250.0
on [deg]:	0.0
rate [Hz]:	62.5
Circularity [µm]:	**9.6**
Min Error [µm]:	**-4.7**
Max Error [µm]:	**4.9**
Error best radius [µm]:	**28.0**
X-offset [µm]:	-19.8
Y-offset [µm]:	12.7
Averaged Runs CW:	2
Averaged Runs CCW:	2



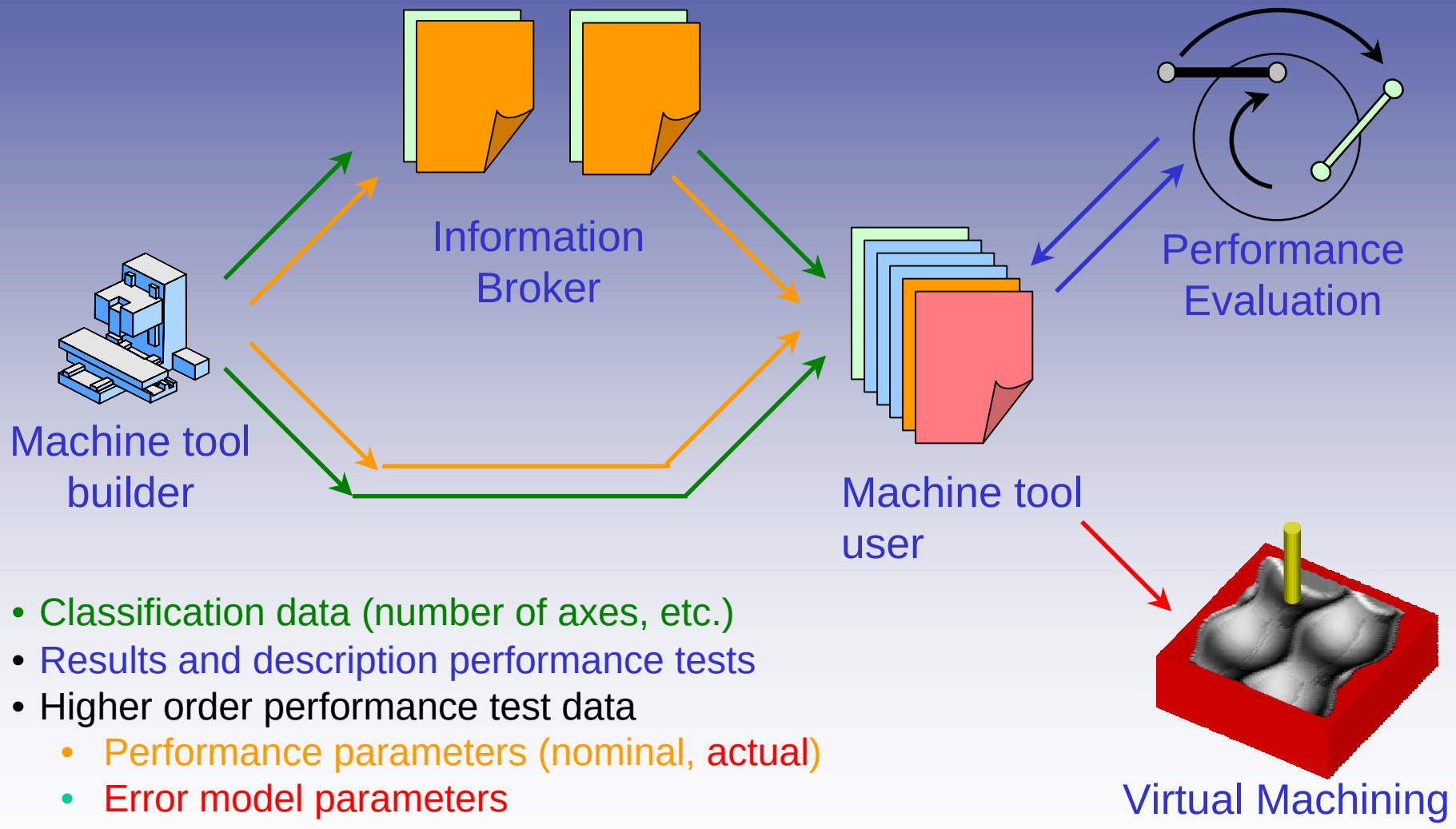
YZ-Plane, Best Center Removed, Best Radius Removed

Select Which Circular Test System Was Use
To Gather The Performance Data of the Machin
Then Pick the 'NEXT' Button.

- API Format
- Heidenhain Format
- Renishaw Format

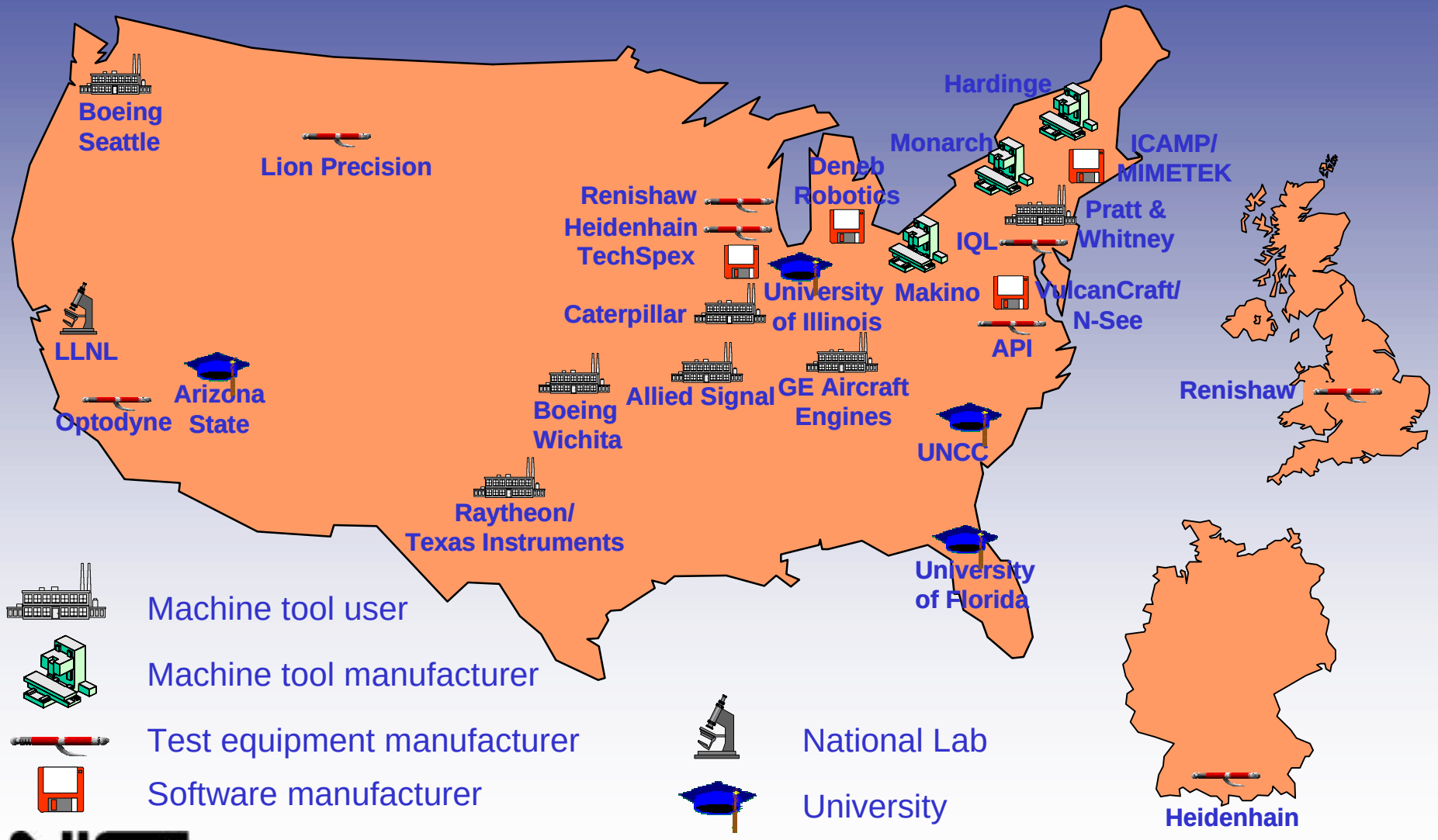
NEXT

Example: Internal repository



- Classification data (number of axes, etc.)
- Results and description performance tests
- Higher order performance test data
  - Performance parameters (nominal, actual)
  - Error model parameters

Project partners



Status

Accomplished:

- 4 workshops and monthly tele-conference meetings
- Draft specification for performance test data and respective XML format
  - (e.g., positioning accuracy, geometric errors, compliance, circular contouring, diagonal positioning, thermal errors, spindle axis of rotation, critical alignments, etc.)
- Information model, database, and prototype web-based repository
- Unification effort for classification data
- ASME B5-TC56 Committee “Information Technology for Machine Tools” established with NIST leadership