Enabling Model Based Machining with a new Data Standard

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Machining from Codes

The standard for 40 years!

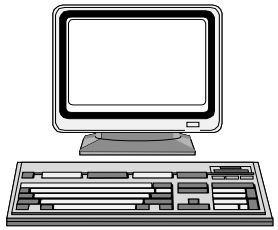
machine-specific part program with axis data generated by a postprocessor

vendor-specific extensions of the original standard

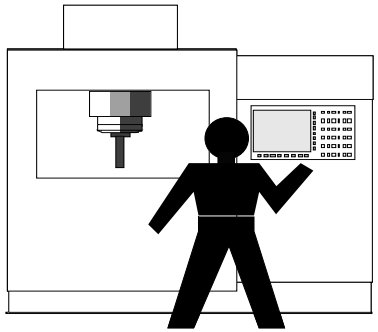
only primitive motion and switch commands

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!



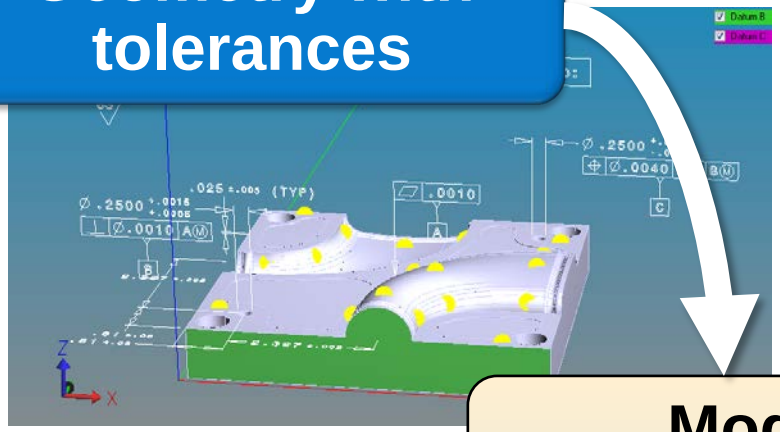
STEP-NC replaces this with a rich, integrated data format

Courtesy WZL RWTH Aachen

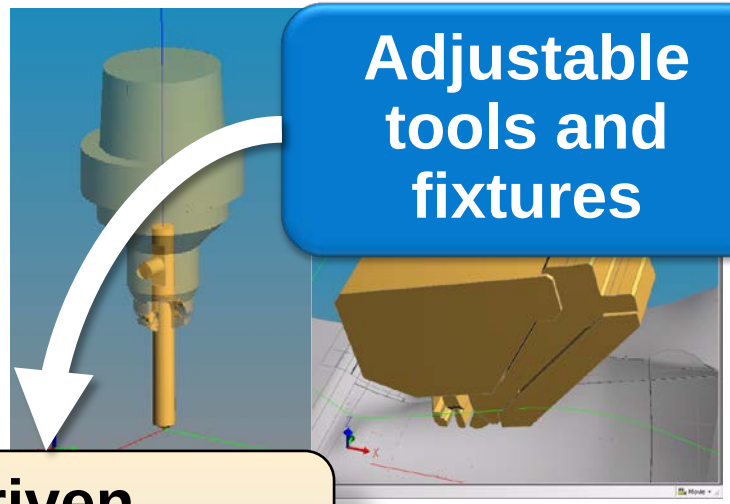
Machining from Models

STEP NC

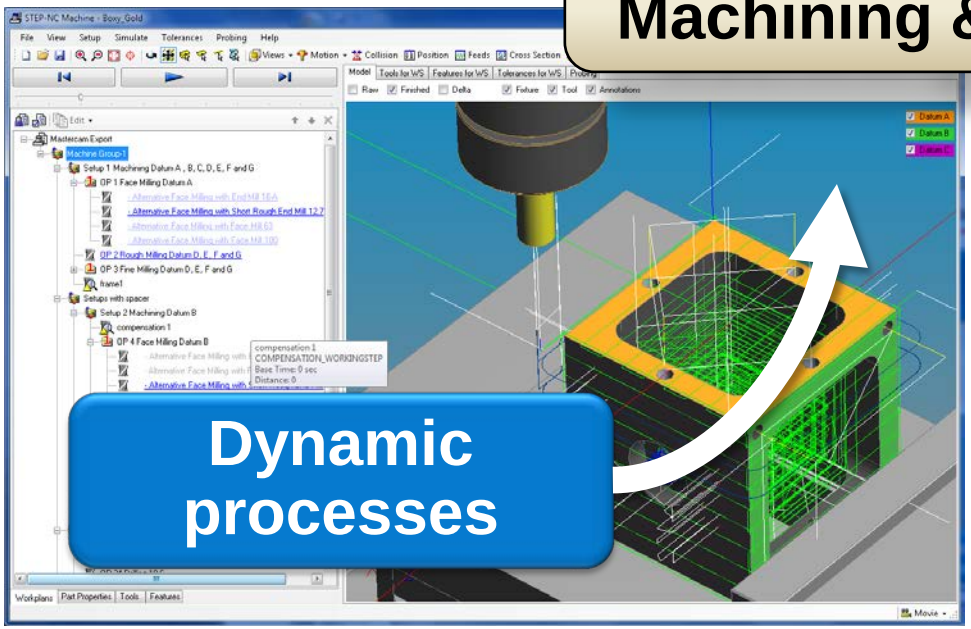
Geometry with tolerances



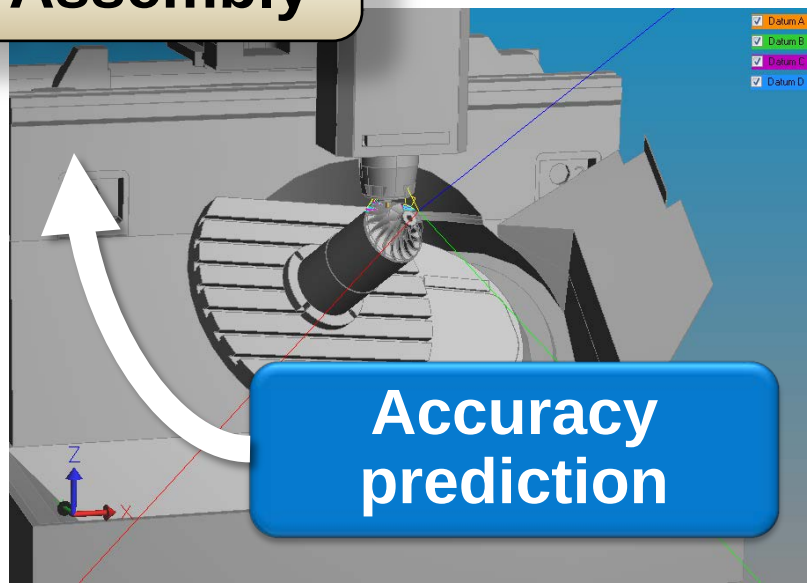
Adjustable tools and fixtures



Model Driven Machining & Assembly



Dynamic processes

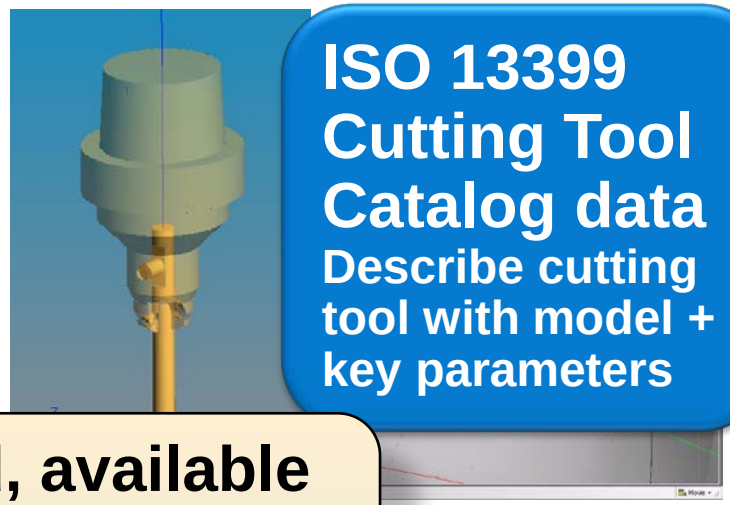


Accuracy prediction

Standards for Model-based Machining

STEP NC

ISO 10303-242 STEP
Describe design requirements including shape and PMI



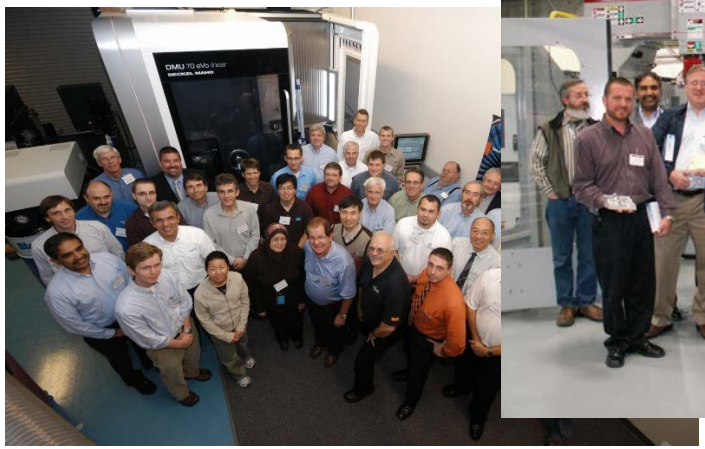
ISO 13399 Cutting Tool Catalog data
Describe cutting tool with model + key parameters

All published, available and tested with enabling software

ISO 10303-238 STEP-NC
Describe rich process with STEP models for stages, fixtures and machine kinematics, and ISO 13399 models for the tools

ISO 10303-242 STEP
Rich machine models with kinematics and ASME B59.2 accuracy data

How do we know - 10 years of testing



Models enable process savings

- We asked Sandvik and Iscar to optimize a Boeing machining program
- We sent them CAM files for selected operations
- They read the files into their systems and selected better tooling
- They returned an optimized process to Boeing

- Tests at Boeing and KTH (Sweden) confirmed our estimates
  - Profiling time 2,680 sec reduced to 859 sec
  - Pocketing time 1,104 sec reduced to 726 sec

How we made the savings

1. Select operation to be optimized

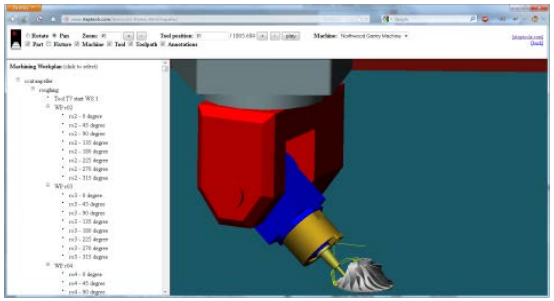
2. Save in-process models As STEP

Boeing
GE
P&W

OEM CAM

STEP File

Catia
Mastercam



Tool Vendor CAM

Sandvik
ISCAR

3. Make tooling recommendations

Job shop

Machine Tool

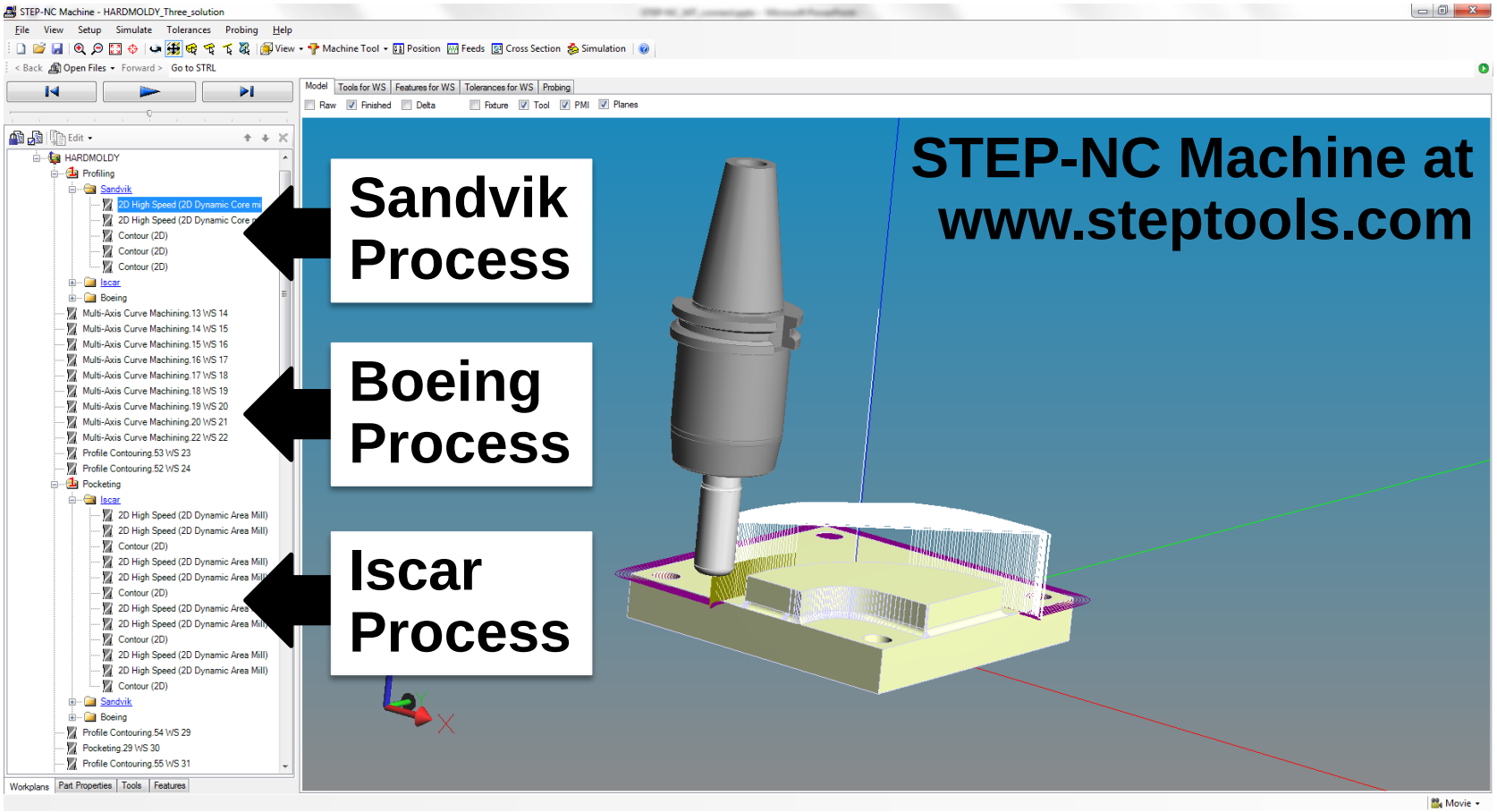
STEP-NC File

4. Export as STEP-NC process

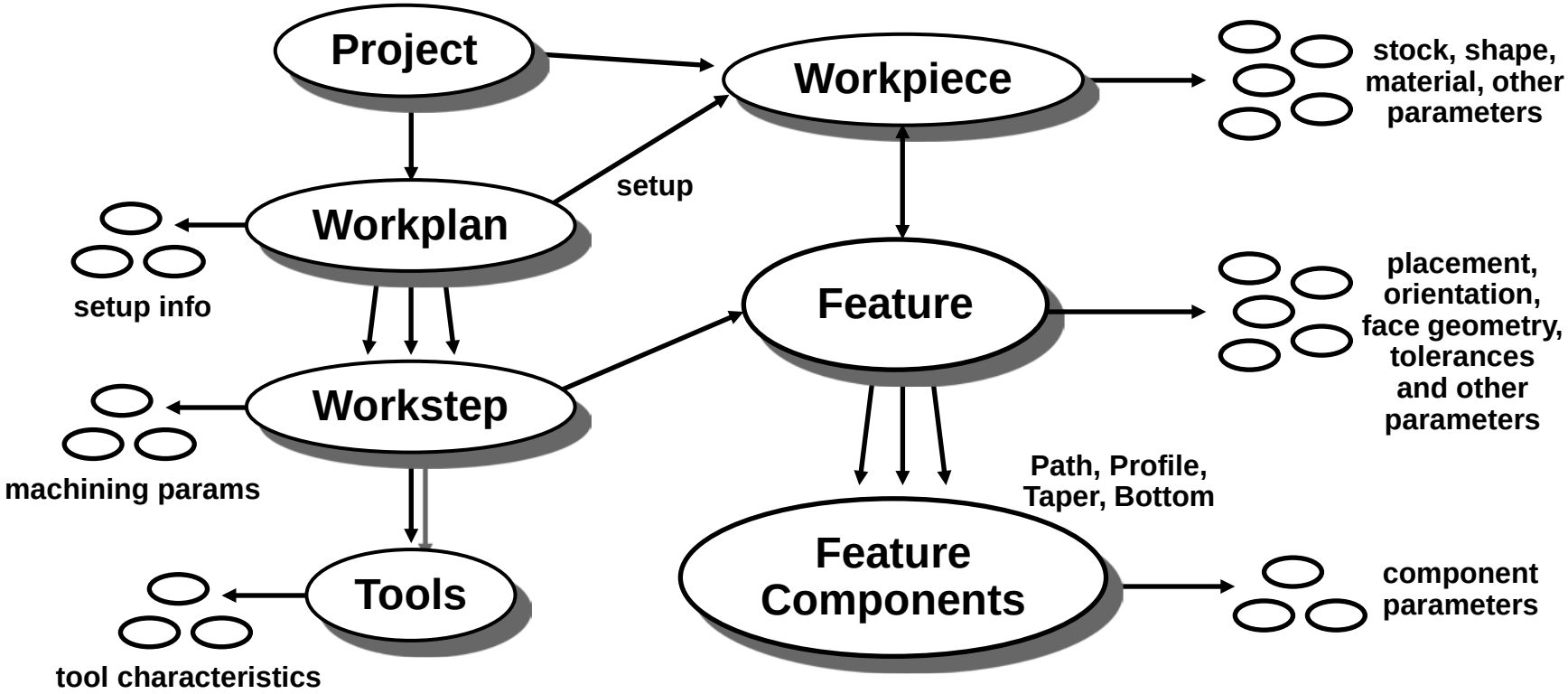
5. 15% to 30% better machining

Model based machining is at least 15% better

- **Get better solutions from your tool vendor!**
  - **Send them a STEP Model, Get a STEP-NC process back**

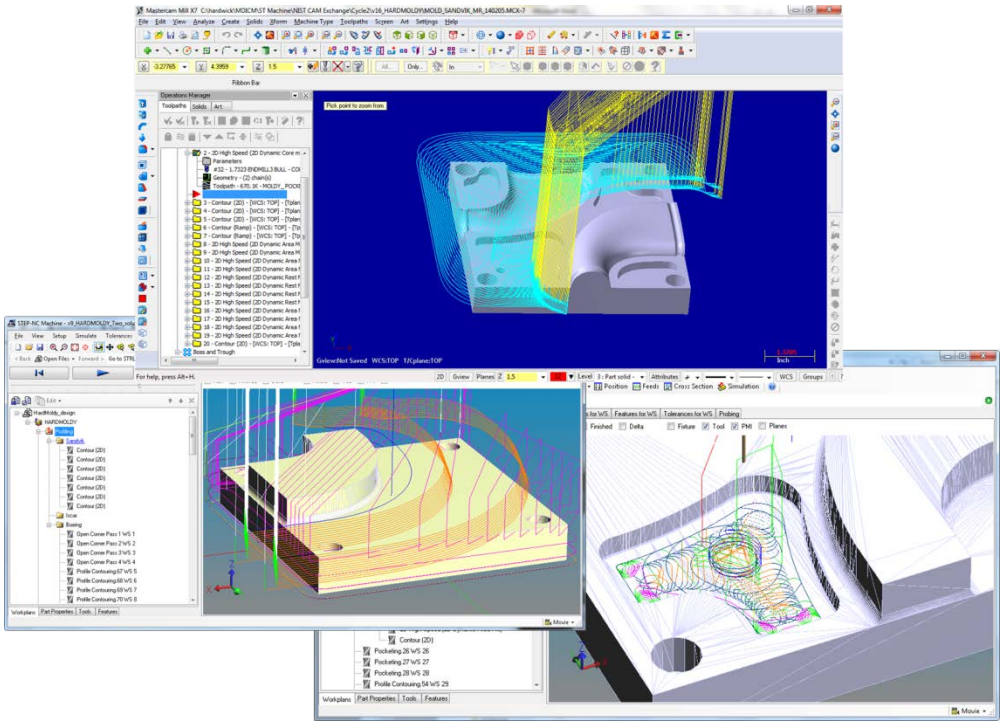


What is in ISO 10303-238 STEP-NC

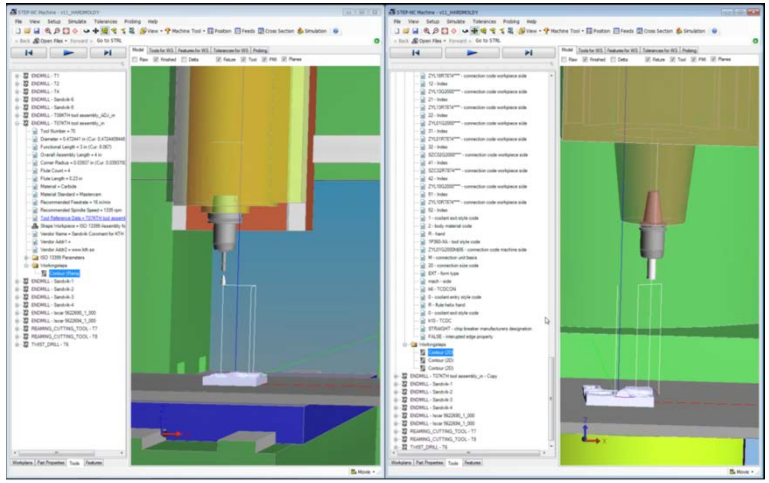


- **Enables CAM to CAM data exchange and cloud services**
- **Enables direct machining from models**
- **Enables high fidelity simulations everywhere**

Other advantages of model based machining



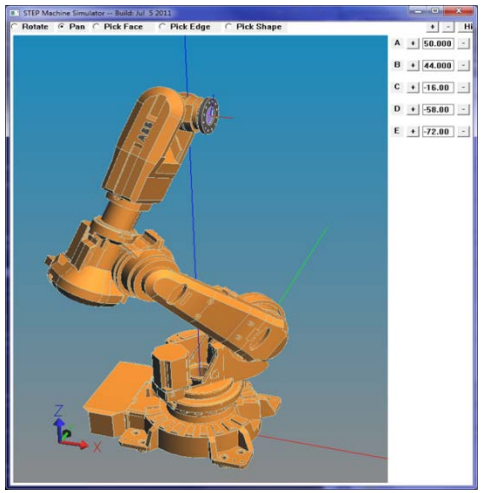
CAM to CAM data exchange



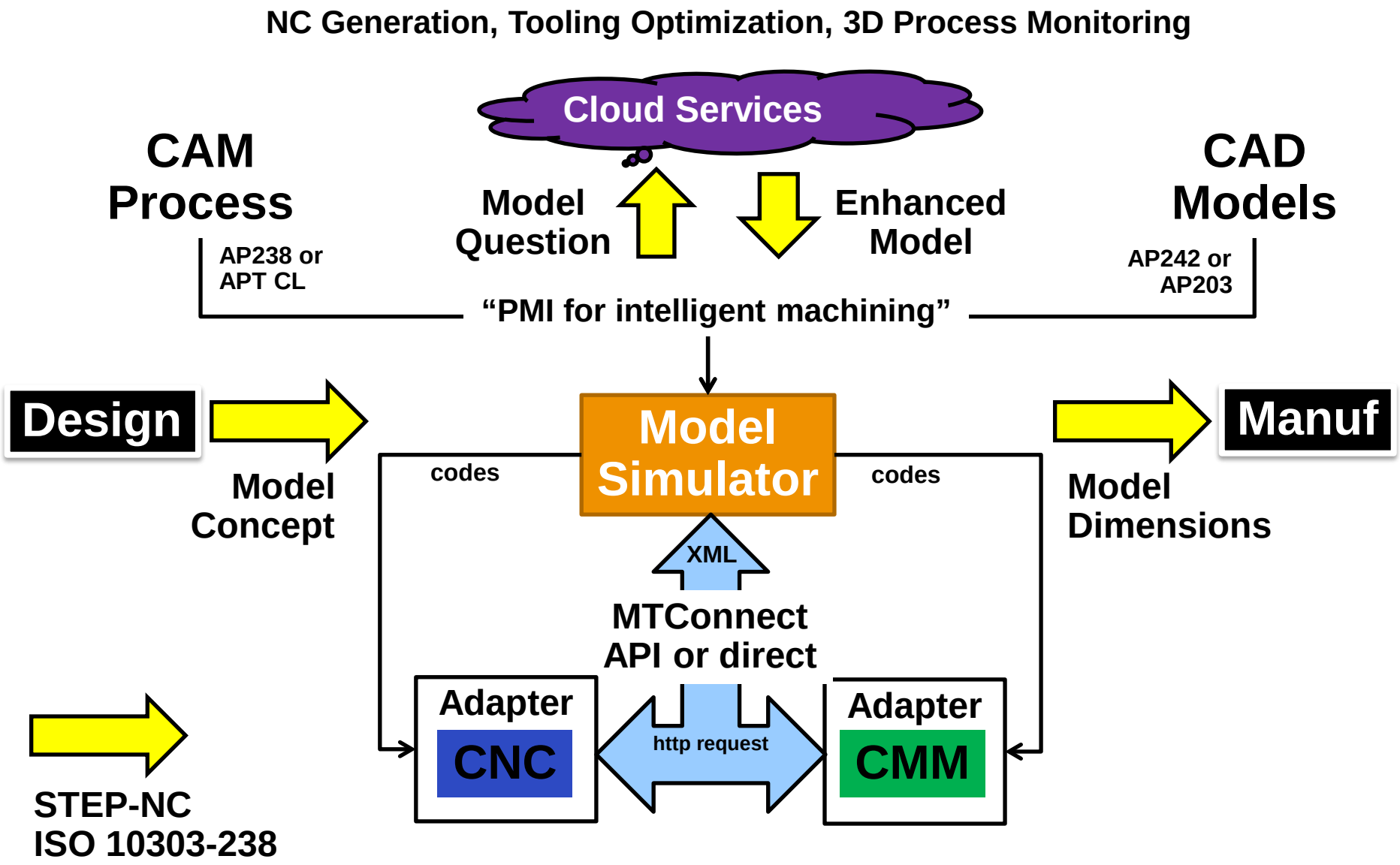
Tooling Substitution

- 5-axis nesting
- Adaptive machining
- Long term archiving

Robot Machining



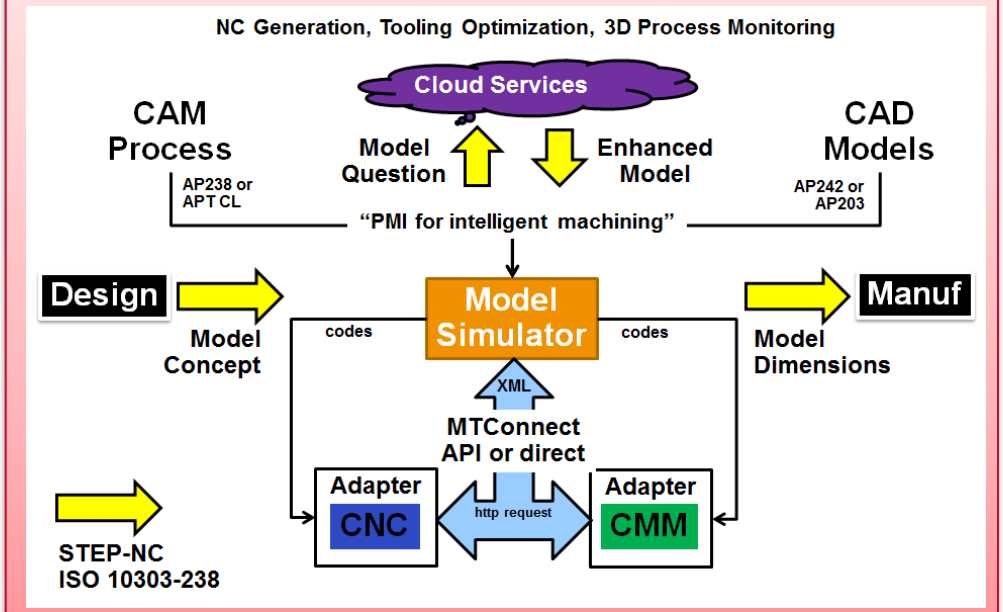
Deployment Architecture



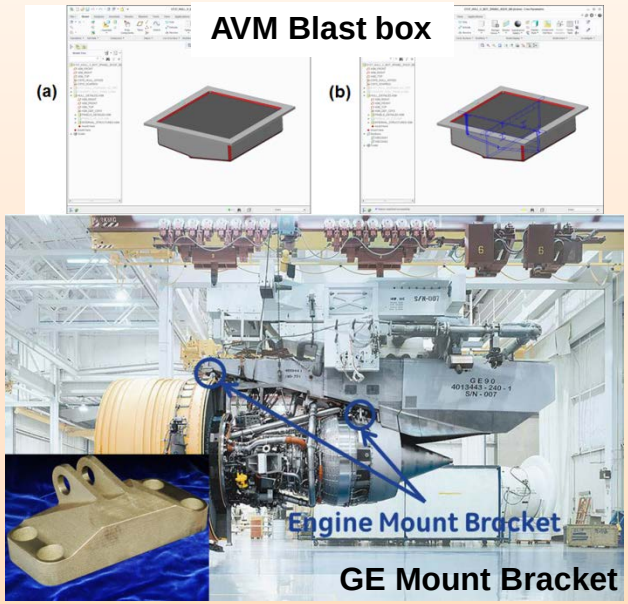
Key points

- **PMI for intelligent machining**
  - The required geometry, dimensions and tolerances
  - Also other PMI such as surface finish
- **MTConnect or API for feedback**
  - Real time simulation of the machining results
  - Software evaluates conformance to PMI requirements
- **Shop receives a model from design**
  - OEM sends a 3D model with PMI
  - No need for a drawing or redundant data entry
- **Cloud services for optimizing the model**
  - Third party software optimizes the solution
  - Models of the product, process and available resources
- **OEM receives a model of the result**
  - Evaluates fit into the assembly
  - Determines if more machining is necessary

Deployment of Model Based Machining



Architecture



Test Cases

Purpose:

- Enable cloud services for manufacturing
- Simplify machine operation

Metrics:

- 15% to 30% faster machining by optimization service
- 35% faster planning by NC generation service
- 50% reduced operator attendance by 3D monitoring

Key Technologies:

- Services to generate NC code for industry stage models
- Services to visualize machining processes in smart phones and web browsers
- STEP Tools, Inc. " National Simulation Service" to evaluate satisfaction of PMI tolerance constraints

Standards deployment

- Stage model machining
- Supply chain enrichment
- PMI Tolerance assessment

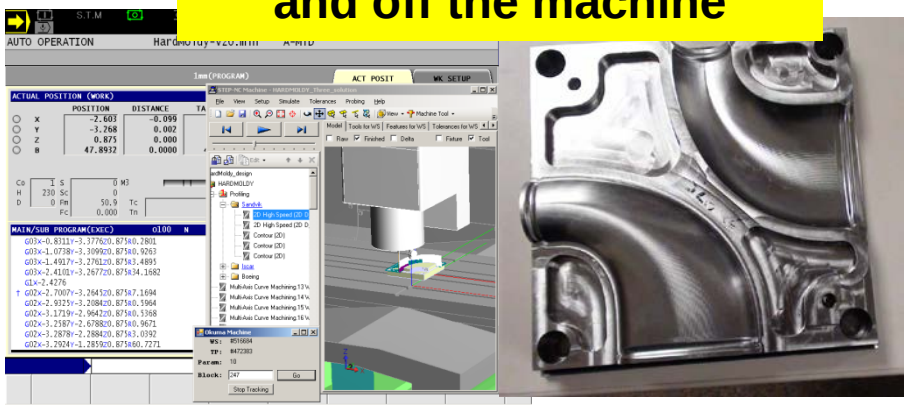
Transition Partners:

- OMAC (end users & vendors)
  - Boeing, GE, Caterpillar, General Dynamics etc
  - Sandvik, Iscar, Okuma, Makino, Mazak, DMG
- Universities
  - RPI, PSU, Vanderbilt
  - Huntsville consortium
- Services
  - TARDEC / RDECOM
  - WVA, NSRP

Three to Five year benefits

- **Easier Machining**
  - Process is graphical
  - System is intelligent
  - Corrections are in the context of the PMI
- **Better Machining**
  - Third party solutions
  - Swap machines when available
  - Less tool wear by “better driving”
  - Curve and surface geometry for greater accuracy
- **More flexibility**
  - Share solutions with suppliers
  - No more post processors
  - Monitor in 3D on smart phones and in browsers
  - Balance machining requirements

Industry can deploy live simulation everywhere on and off the machine



Our Partners

- **End users**
  - Boeing, General Electric, Scania, Pratt & Whitney
  - Make STEP-NC data, Test new cloud services,
  - Machine parts in house and with suppliers
- **Cutter vendors and other solution providers**
  - Sandvik, Iscar
  - Share catalog data
  - Develop cloud services
- **Machine vendors**
  - Okuma, others in negotiation
  - Host STEP-NC simulators,
  - Machine directly or indirectly from STEP-NC
- **CAM vendors**
  - Mastercam, Catia V5
  - Read and write STEP-NC data
  - Enable direct machining of curves and surfaces
- **Software suppliers for the standards**
  - Datakit, ITI, EPM, ProSTEP, LKSoft, STEPCode
  - STEP Tools interfacing toolkit ST-Developer®
  - STEP Tools model based machining simulator STEP-NC Machine®