Joint Working Group 15
Digital Manufacturing

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Old style machining uses codes

The standard for 40 years!

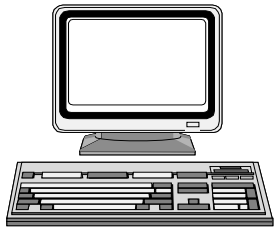
machine-specific part program with axis data generated by a postprocessor

vendor-specific extensions of the original standard

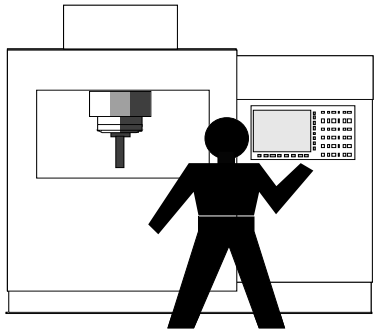
only primitive motion and switch commands

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!

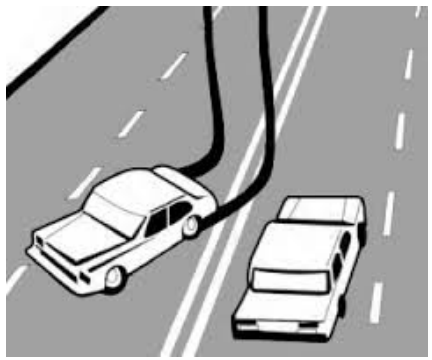


STEP-NC replaces this with a rich, integrated data format

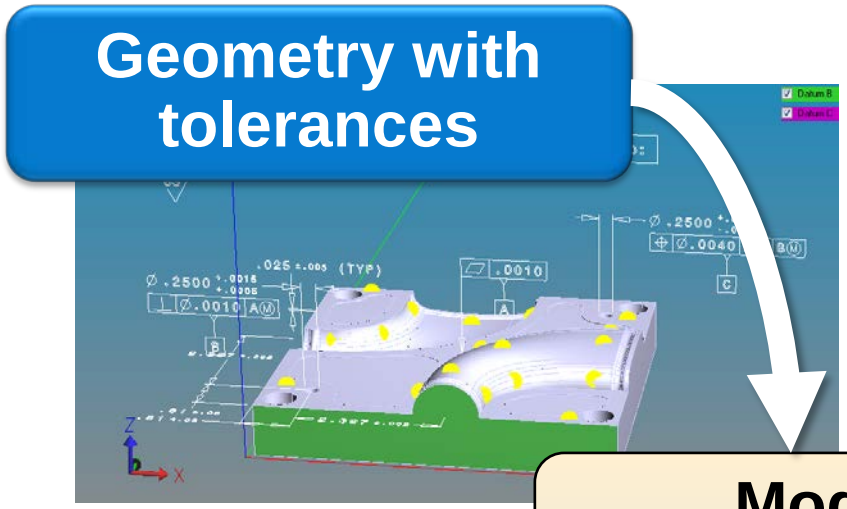
Courtesy WZL RWTH Aachen

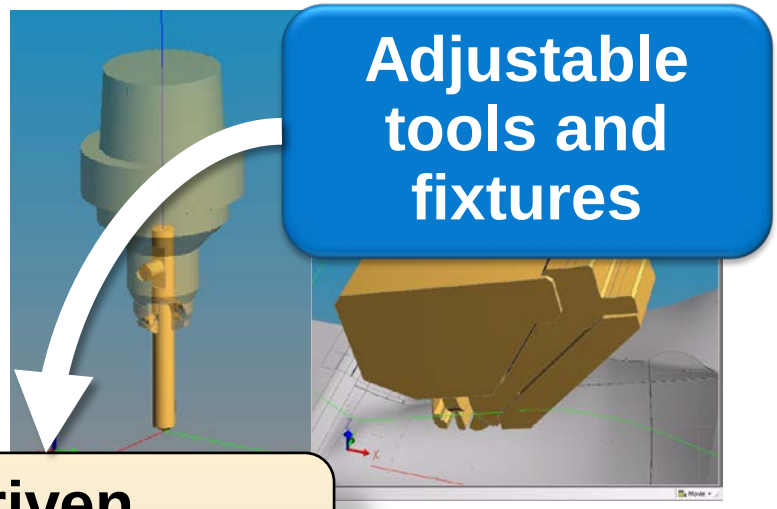
Imagine driving using codes

- **Driving from Albany to Washington DC**
  - **Drive as fast as possible**
  - **Drive again with minimal gas and engine wear**
  - **The two results will be very different!**
- **Now do it with your eyes closed**
  - **Drive for 2 minutes 16 seconds at 69.1 mph**
  - **Turn left by 35 degrees and slow down to 55.4 mph**
  - **Etc. and enjoy! We never make mistakes!**

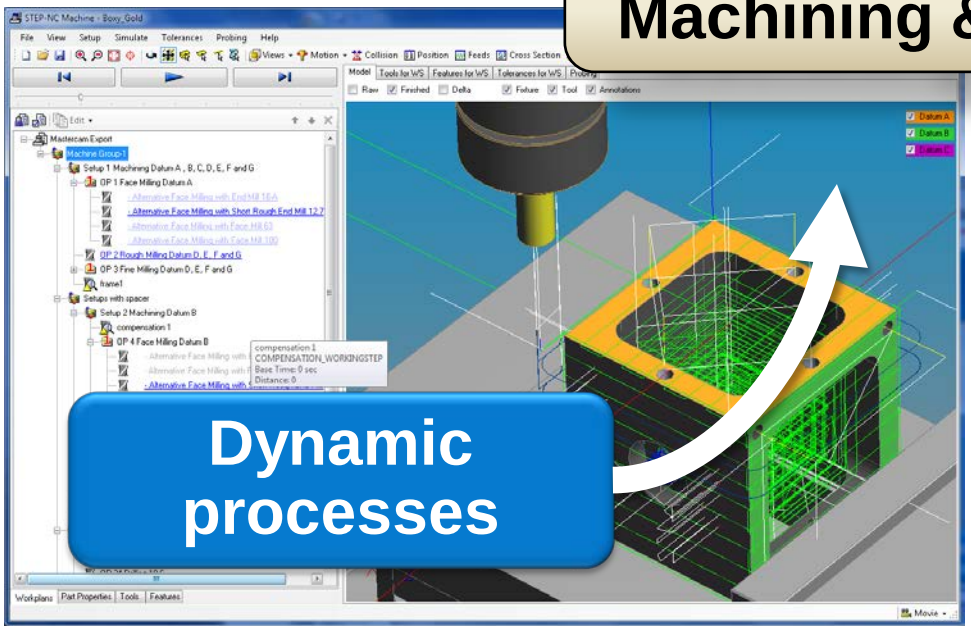


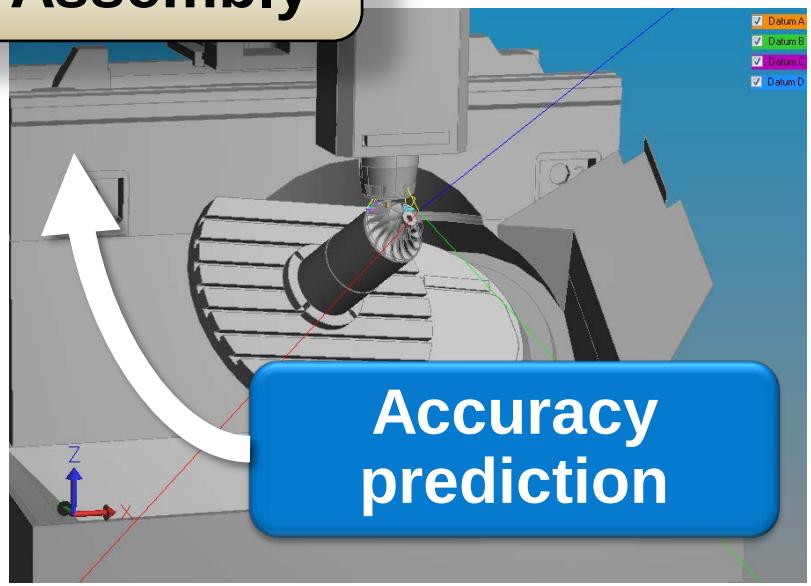
New style machining uses models



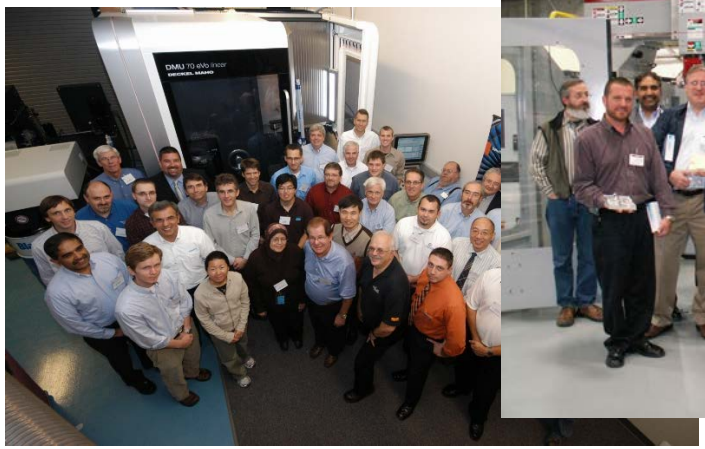


Model Driven Machining & Assembly





10 years of testing shows it works



And produces 15% process savings

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

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

Baltimore meeting October 18-22

- **Technical meetings (Mon, Tues Thurs)**
  - Affirm creation of new working group for digital manufacturing
  - Review requirements for next edition of STEP-NC
  - Define an initial list of technical reports for WG15
  - See these slides for a summary
- **Industry day**
  - See slides made by presenters
  - Additive manufacturing requirements
  - Machine tool requirements
  - Quality assurance requirements
  - Industry 4.0 requirements

Attendees

Technical Days

- Martin Hardwick, STEP Tools, Inc., USA
- Samson Bonafante, STEP Tools, Inc., USA
- Mikael Hedlind, Scania, Sweden
- Bengt Olsson, Sandvik, Sweden
- David Loffredo, STEP Tools, Inc., USA
- Sid Venkatesh, Boeing, USA
- Leon Xu, USA, Boeing, USA
- Rich Morihara, Boeing, USA
- Eujin, Pei, Brunel, UK
- David Odendahl, Boeing, USA
- Magnus Lundgren, KTH, Sweden
- Allisson Bernard Feeney, NIST
- Tom Thurman, USA
- Keith Hunten, USA
- Lothar Klein, LKSoft, Germany
- Professor Suh, POSTECH, Korea
- Sanglin Jeong, ETRI, Korea
- Jumyung Um, Univ Cambridge, UK
- Andy Byrd, Okuma
- Pierre Duchier, CIMPA Airbus

Industry Day

- Martin Hardwick, STEP Tools, Inc., USA
- Graham Hemingway, Vanderbilt University, USA
- Bengt Olsson, Sandvik Coromant, Sweden
- Magnus Lundgren, KTH University, Sweden
- Mikael Hedlind, Scania, Sweden
- Sune Horkeby, Siemens, Sweden
- Lina Larsson, Siemens. Sweden
- Vincent Marchetti, KSHELL, USA
- Scott Lu, Sandvik Coromant, USA
- Professor Suh, POSTECH, Korea
- Jumyung Um, POSTECH, Korea
- Sangjin Jeong, ETRI, Korea
- Dan Finke, Applied Research Lab, Penn State, USA
- Allison Bernard Feeney, NIST, USA
- Andy Byrd, Okuma, USA
- Soonjo Kwon, KAIST, Korea
- Rich Morihara, Boeing, USA
- Sid Venkatesh, Boeing, USA
- Corey Dickman, Penn State University, USA
- Malte Ressin, Brunel University, UK
- Changsoo Lee, GWNU, Korea
- Joe Fritz, STEP Tools, Inc., USA
- Eujin Pei, Brunel University, UK
- Piere Duchier, Airbus, France
- Leon Xu, Boeing, USA
- Alexander Roach, US Army, USA
- Samson Bonfante, STEP Tools, Inc., USA
- David Loffredo, STEP Tools, Inc., USA
- Larry Maggiano, Mitutoyo America, USA
- David Odendahl, Boeing, USA
- Max Ungerer, ProSTEP, Germany

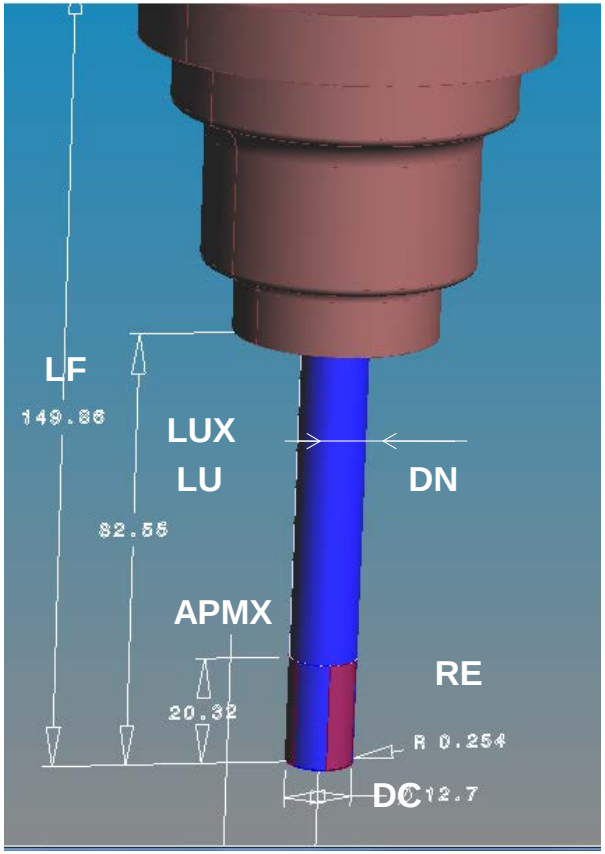
Edition 2 plans

Edition 1

Fixed scope AP

Each parameter mapped to aim by long series of constraints

Definitions for subtractive machining



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Edition 2

Extensible scope AP

Each parameter associated to definition by EXPRESS constant

Modules for manufacturing processes

Enhancements determined during testing

- **Documented**
  - Toolpath Reference Direction
  - Toolpath placement on Workplan
  - Enable/Disable Executable
  - Via points for better High-Speed Machining support.
  - Cross section parameters for Feed Speed optimization.
  - Touch_probe as a real tool.
  - Presentations associated to a workpiece
  - Full workpieces for In-process geometry
  - Improved AP242 compatibility

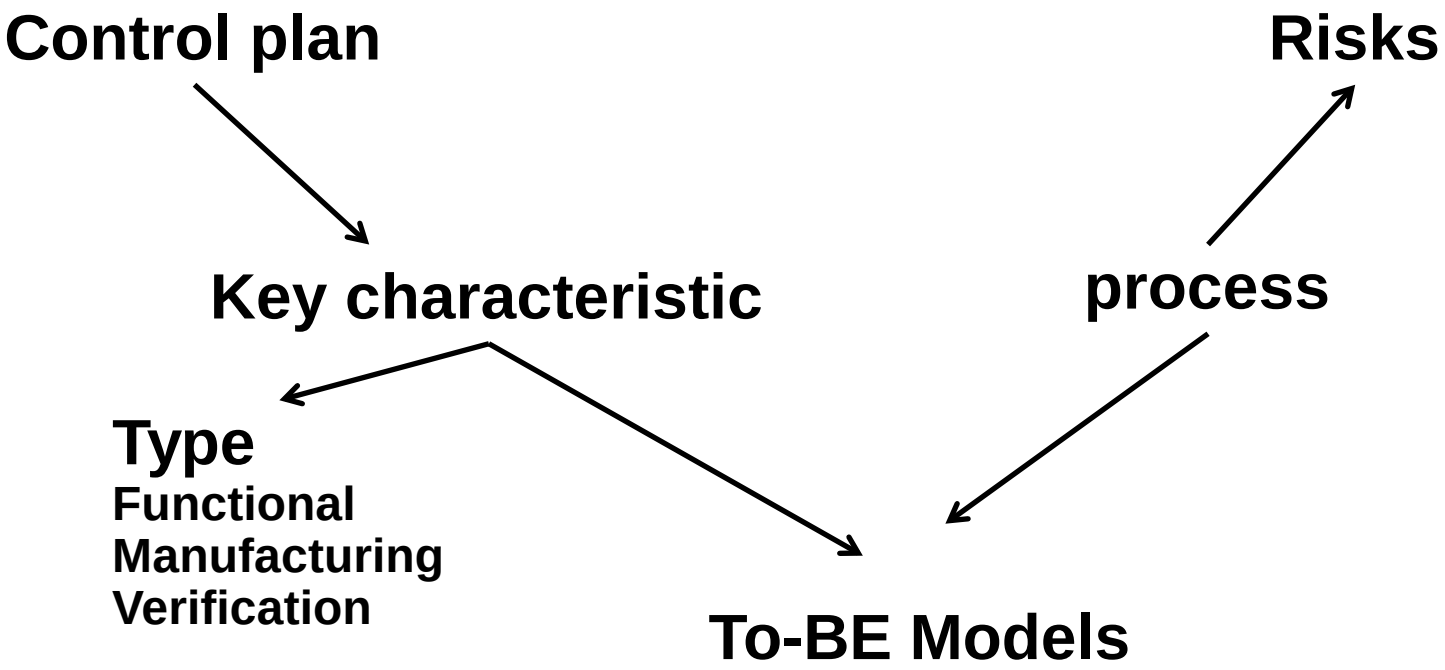
- **Not yet fully documented**
  - APQP quality assurance requirements
    - » key characteristics
    - » risk analysis
  - ISO 13399 tooling harmonization
  - Spindle characteristics
  - Conditional workplans for available tooling and other testable characteristics
  - Machine kinematics
    - » Including key reference points for gauge and fixture

4D Facets for process simulation

APQP New roots

- **Risk analysis**
  - **Level**
  - **Cause**
  - **Effect**
- **Control plan**
  - **List of key characteristics**
    - » **Type of specification**
  - **How they will be measured**
  - **Measurement frequency**

APQP Information dependencies



APQP requirements

- **Functional specifications**
  - **Key characteristics set in a process**
- **Manufacturing specification**
  - **Key characteristics set in a process**
- **Verification specification**
  - **Key characteristics set in a process**

Add to model as “root” items that can then be Used to navigate the data

E.G. Project has 3 Manufacturing specs
Spec A has 4 key characteristics
A1 is a tolerance on the in-process model of WS2

APQP Risk analysis

- **Risk number from**
  - **Occurrence**
  - **Severity**
  - **Detectability**
- **Type - string**
- **Cause - model / explanation**
- **Effect – model / explanation**

Get risk data for a workingstep
Ask project to rank the risk data of a workplan

APQP Control plan

- List of key characteristics
- How they will be measured
- Measurement frequency

ISO 13399 tooling

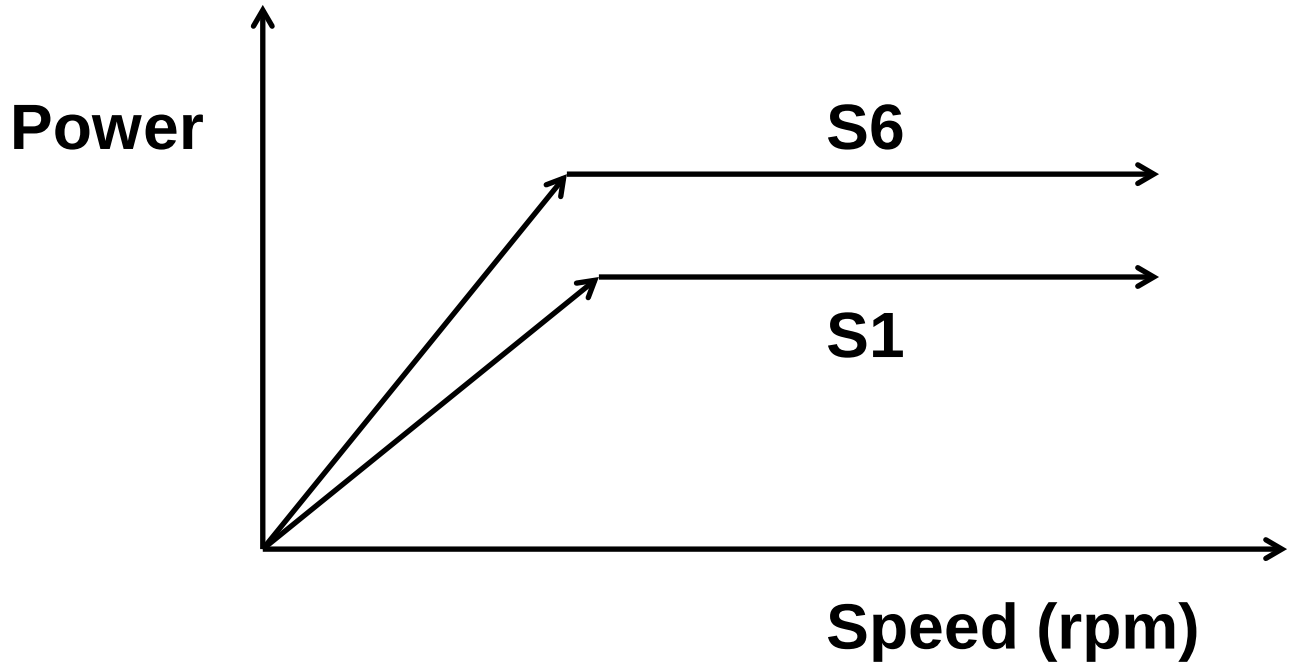
- **Agreement reached between vendors and users**
  - **How to exchange tooling catalogs**
  - **Sandvik has ISO 13399 entries for 53,000 tools**
  - **Sandvik has models for 20,000 of these**
- **Committee has just agreed on how to represent the models**
  - **Coordinate system placement**
  - **Coloring for cutting and non-cutting components**
- **Information packet**
  - **Product data**
  - **3D models**
  - **2D drawings**
  - **Classification hierarchy**
  - **Connection rules**
  - **Icons and pictures**
  - **Time stamps**

Interface to digital manufacturing

- **Cutting tool assembly and 3D model positioning**
  - **Nominal**
  - **Required from process**
  - **As-built**
- **Assembly joint**
  - **Adjustable or fixed**
  - **Type limits and increments**
- **Standardized reference systems**
  - **Mounting on machine (MCS) and process reference (CRP or CIP)**
  - **Cutting reference point (CRP) (CIP for turning)**
- **Operational limits**
  - **Cutting speed, chip thickness, depth of cut, radial/axial engagement, positioning (left or right)**

Spindle characteristics

- **Spindle curves**
  - **Torque**
  - **Power**



Conditional executables

- **Workingstep execution dependent on value of one or more variables**
- **Workplan execution until all values met**

AP238 & Modules

1. **Reason for going modular**
   - To be extensible
   - Take advantage of new resources and definitions
   - Reduce maintenance and integration costs
2. **Use of EXPRESS constants to reduce mapping size**
   - Units example – see P21 Edition 3 Clause K
   - Complete PLIB example
   - Example of AIC 522 machining feature re-organization
   - Reference path includes a constraint that references an EXPRESS constant
3. **4D Facets**
   - Look at PLM incremental update

Action Items for Sapporo meeting

- David Loffredo to define template for WG15 Technical Reports
- Mikael and David O to write implementation guidelines for AP242 machining resource models including definition of kinematics and the interface between the cutting tool and the machine (gauge line, etc.) as a technical report
- Bengt Olsson and Martin Hardwick to write implementation guidelines for requesting tooling solutions and making tooling recommendations in the context of a process
- Mikael and Leon to write AP242 implementation guidelines for the spindle characteristic curves and the tool holder interface.
- Mikael and David O to write AP242 implementation guidelines and schema module for describing the motion error tolerance of a machine tool.
- Mikael Hedlind and Magnus Lundgren to write implementation module and implementation guidelines for key characteristics
  - David O to investigate interest at Boeing
  - Pierre to Duchier to investigate at Airbus
- Mikael Hedlind and David Loffredo to write implementation guidelines for data exchange of non-cnc processes such as painting, washing, hardening
- David Loffredo to update the technical corrigendum documentation
- Martin Hardwick to investigate implementation of conditional workplan
- STEP Tools to develop exemplar modules for toolpath and executable for AP238 Edition 2