

Technology for on-machine measurement using the Digital Thread

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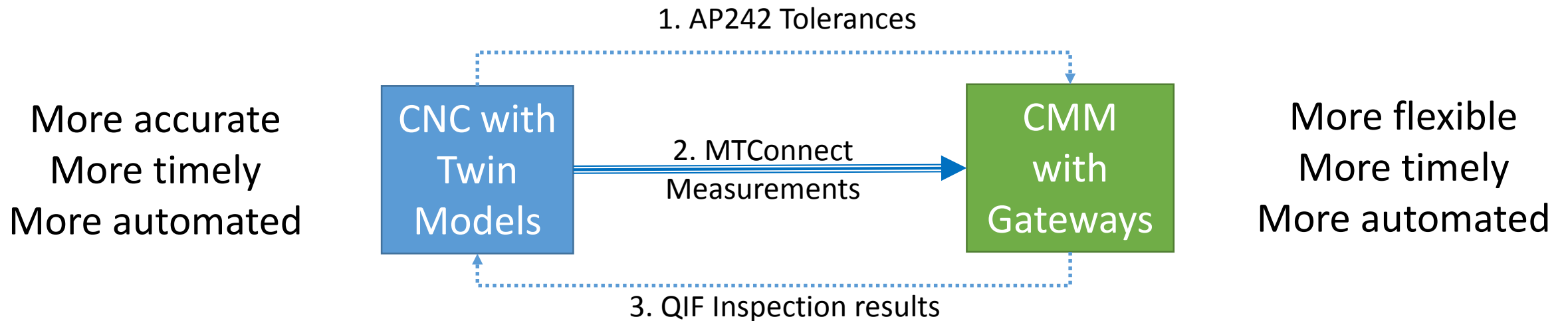
DMDII Project O3 – Operate, Orchestrate, and Originate – 14-06-05

Why the Digital Thread

- The digital thread increases productivity by delivering model data to the shop floor
 - More flexibility to make last minute optimizations
 - More automated detection and correction of anomalies and errors
 - More efficient communication between systems using standards
 - Visual traceability and compliance to LOTAR requirements
 - Automated measurement with minimal operator intervention

Technology Demonstration

- <http://www.steptools.com/demos/mtc/>



1. Tolerances that need to be measured
2. The measurements as they are made
3. The result of evaluating the measurements

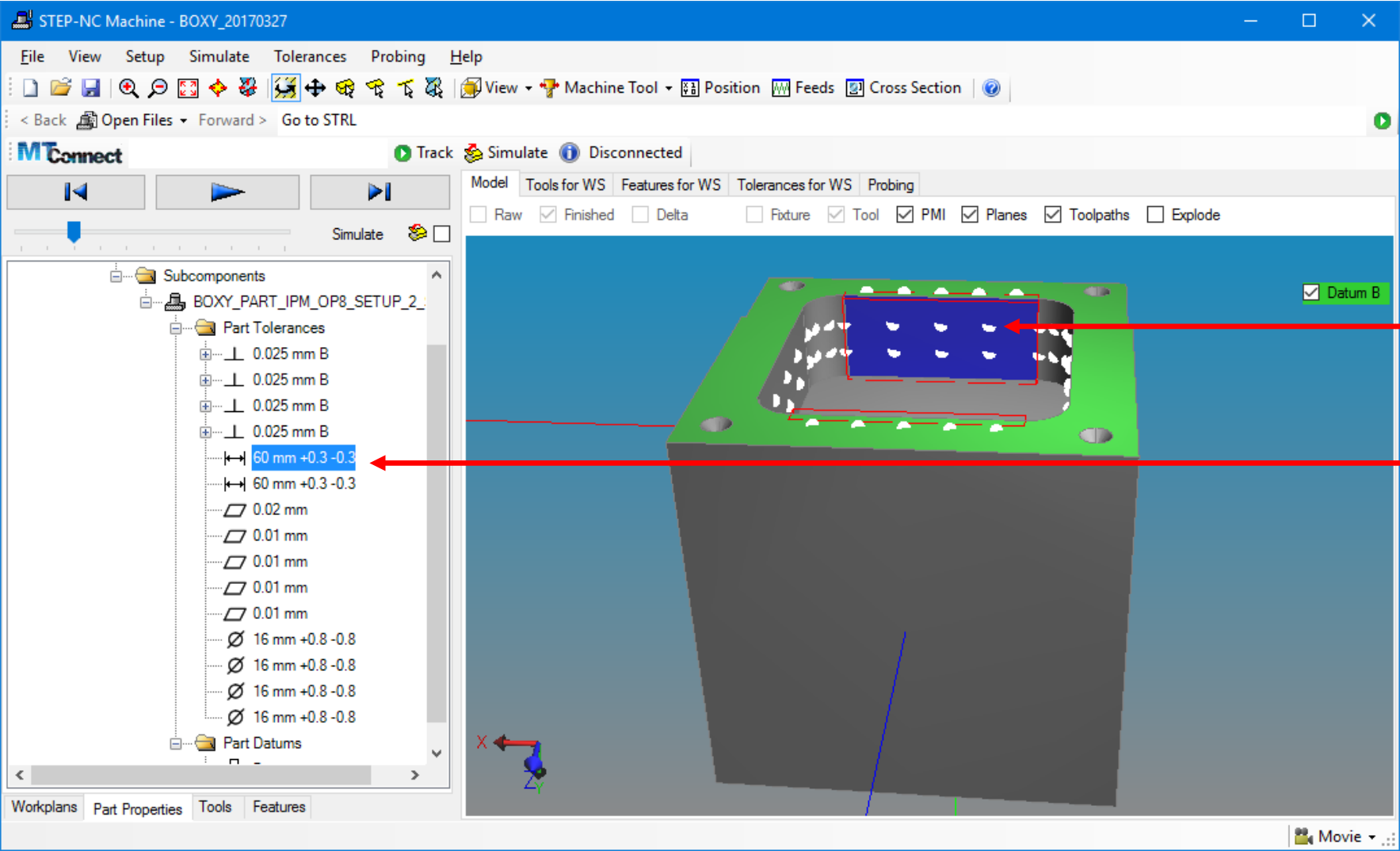
Virtual model of a part machined in Mukilteo

http://swim.steptools.com:8081

Are the features in tolerance?

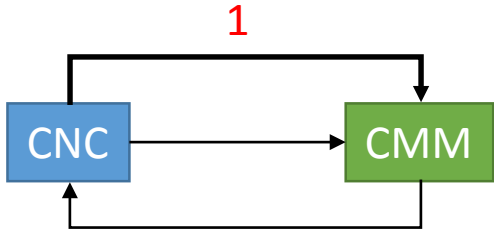
Detailed machining simulation using an MTConnect recording
See video at: <https://www.youtube.com/watch?v=Mjzg5nku5Lg>

1. Tolerances and probe points in AP242



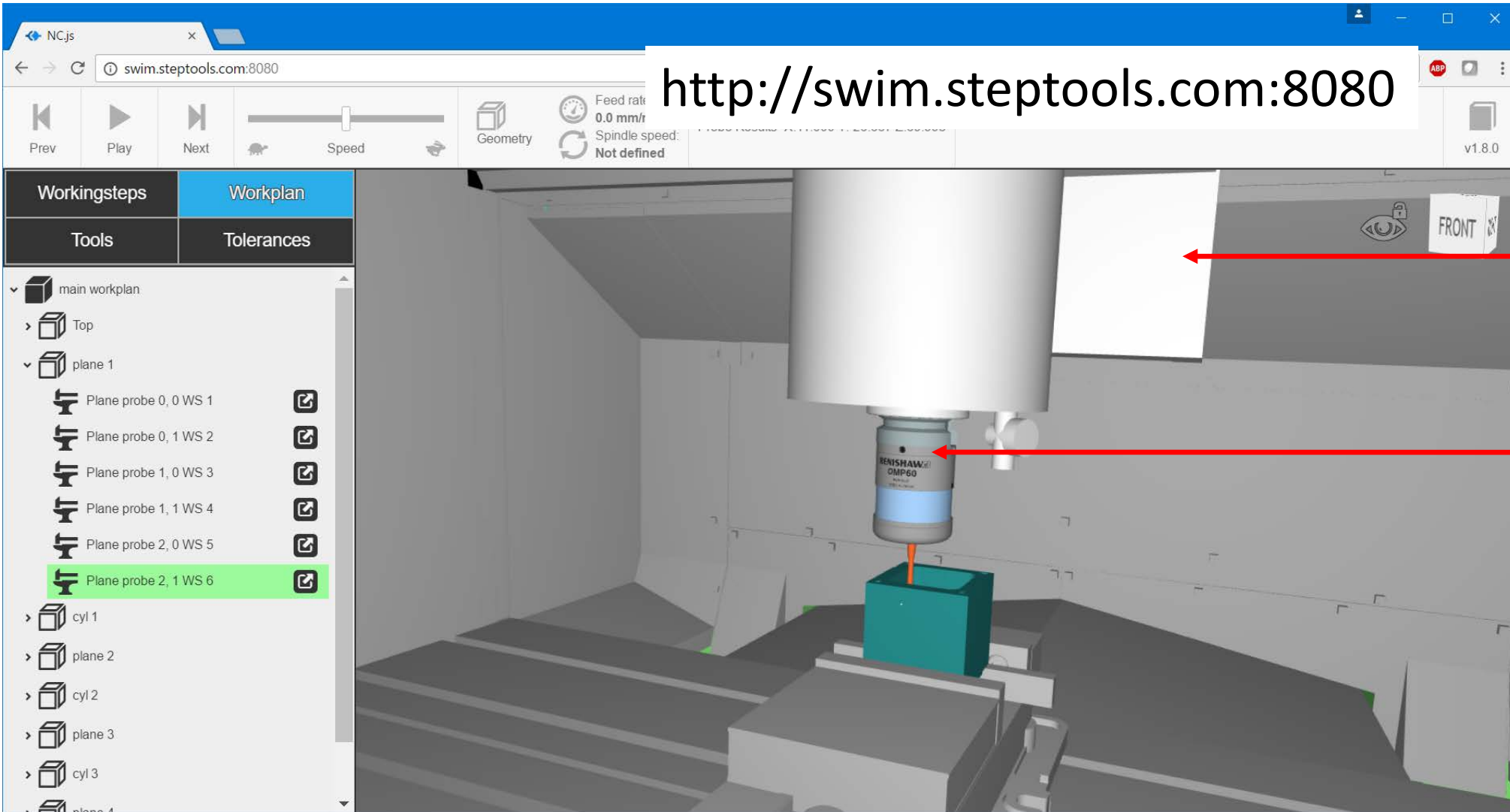
Measurement point

Semantic Tolerance



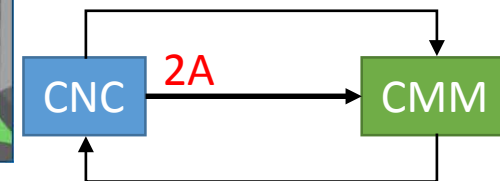
2A. Measurement points on the CNC

<http://swim.steptools.com:8080>



← Machining Twin

← Touch Probe



2B. Measurement points in MTConnect agent

swim.steptools.com:5000/current

2017-02-20T18:41:49.443571Z	Unavailable		system	Msystem	49	
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Path : path

Samples

Timestamp	Type	Sub Type	Name	Id	Sequence	Value
2017-02-20T18:41:49.443571Z	AccumulatedTime	x:CUTTING_TIME	p1CuttingTime	Mp1CuttingTime	27	UNAVAILABLE
2017-02-20T18:41:49.443571Z	PathFeedrate	ACTUAL	p1Fact	Mp1Fact	28	UNAVAILABLE
2017-02-20T18:41:49.443571Z	PathFeedrate	PROGRAMMED	p1Fcmd	Mp1Fcmd	29	UNAVAILABLE
2017-02-20T18:41:49.443571Z	PathPosition		p1LPathPos	Mp1LPathPos	30	UNAVAILABLE
2017-02-20T18:41:49.443571Z	AccumulatedTime	x:OPERATING_TIME	p1OperatingTime	Mp1OperatingTime	34	UNAVAILABLE
2017-02-20T18:41:49.443571Z	AccumulatedTime	x:RUNNING_TIME	p1RunningTime	Mp1RunningTime	35	UNAVAILABLE
2017-02-20T18:41:49.443571Z	AccumulatedTime	x:SPINDLE_RUN_TIME	p1SpindleRunTime	Mp1SpindleRunTime	36	UNAVAILABLE
2017-02-20T18:41:49.443571Z	AccumulatedTime	x:TOTAL_CUTTING_TIME	p1TotalCuttingTime	Mp1TotalCuttingTime	38	UNAVAILABLE
2017-02-20T18:41:49.443571Z	AccumulatedTime	x:TOTAL_OPERATING_TIME	p1TotalOperatingTime	Mp1TotalOperatingTime	39	UNAVAILABLE
2017-02-20T18:41:49.443571Z	AccumulatedTime	x:TOTAL_RUNNING_TIME	p1TotalRunningTime	Mp1TotalRunningTime	40	UNAVAILABLE
2017-02-20T18:41:49.443571Z	AccumulatedTime	x:TOTAL_SPINDLE_RUN_TIME	p1TotalSpindleRunTime	Mp1TotalSpindleRunTime	41	UNAVAILABLE

Events

Timestamp	Type	Sub Type	Name	Id	Sequence	Value
2017-02-20T18:41:49.443571Z	e:BlockNumber		p1BlockNumber	Mp1BlockNumber	24	UNAVAILABLE
2017-02-20T18:41:49.443571Z	e:Variables	x:COMMON	p1CommonVariable	Mp1CommonVariable	25	UNAVAILABLE
2017-02-20T18:41:49.443571Z	ToolNumber		p1CurrentTool	Mp1CurrentTool	26	UNAVAILABLE
2017-02-20T18:41:49.443571Z	e:Macman	x:PANEL_HISTORY	p1MacManPanelHistory	Mp1MacManPanelHistory	31	UNAVAILABLE
2017-02-20T18:41:49.443571Z	e:OutputSignal	x:DRY_RUN	p1MachineOperationPanelOutputDryRun	Mp1MachineOperationPanelOutputDryRun	32	UNAVAILABLE
2017-02-20T18:41:49.443571Z	e:OutputSignal	x:MACHINE_LOCK	p1MachineOperationPanelOutputMachineLock	Mp1MachineOperationPanelOutputMachineLock	33	UNAVAILABLE
2017-02-20T18:41:49.443571Z	ToolAssetId		p1ToolAssetId	Mp1ToolAssetId	37	UNAVAILABLE
2017-02-20T18:41:49.443571Z	Block		p1block	Mp1block	42	UNAVAILABLE
2017-02-20T18:41:49.443571Z	Line		p1line	Mp1line	43	UNAVAILABLE
2017-02-20T18:41:49.443571Z	PathFeedrateOverride	PROGRAMMED	pFovr	MpFovr	44	UNAVAILABLE
2017-02-20T18:41:49.443571Z	Execution		pexecution	Mpexecution	45	UNAVAILABLE
2017-02-20T18:41:49.443571Z	ControllerMode		pmode	Mpmode	46	UNAVAILABLE
2017-02-20T18:41:49.443571Z	PartCount		ppartcount	Mppartcount	47	UNAVAILABLE
2017-02-21T18:54:35.271Z	Program		pprogram	Mpprogram	346	UNAVAILABLE
2017-02-21T14:00:32.526-05:00	Measurement		measure	p1_85	365	feature:"9ffd7cbf-25bd-4be9-ab37-90b7ee855c69" order:1 count:6 id:"FACE27463" characteristic:"3DLocation" x:-11.000000 y:-33.333333 z:10.002639

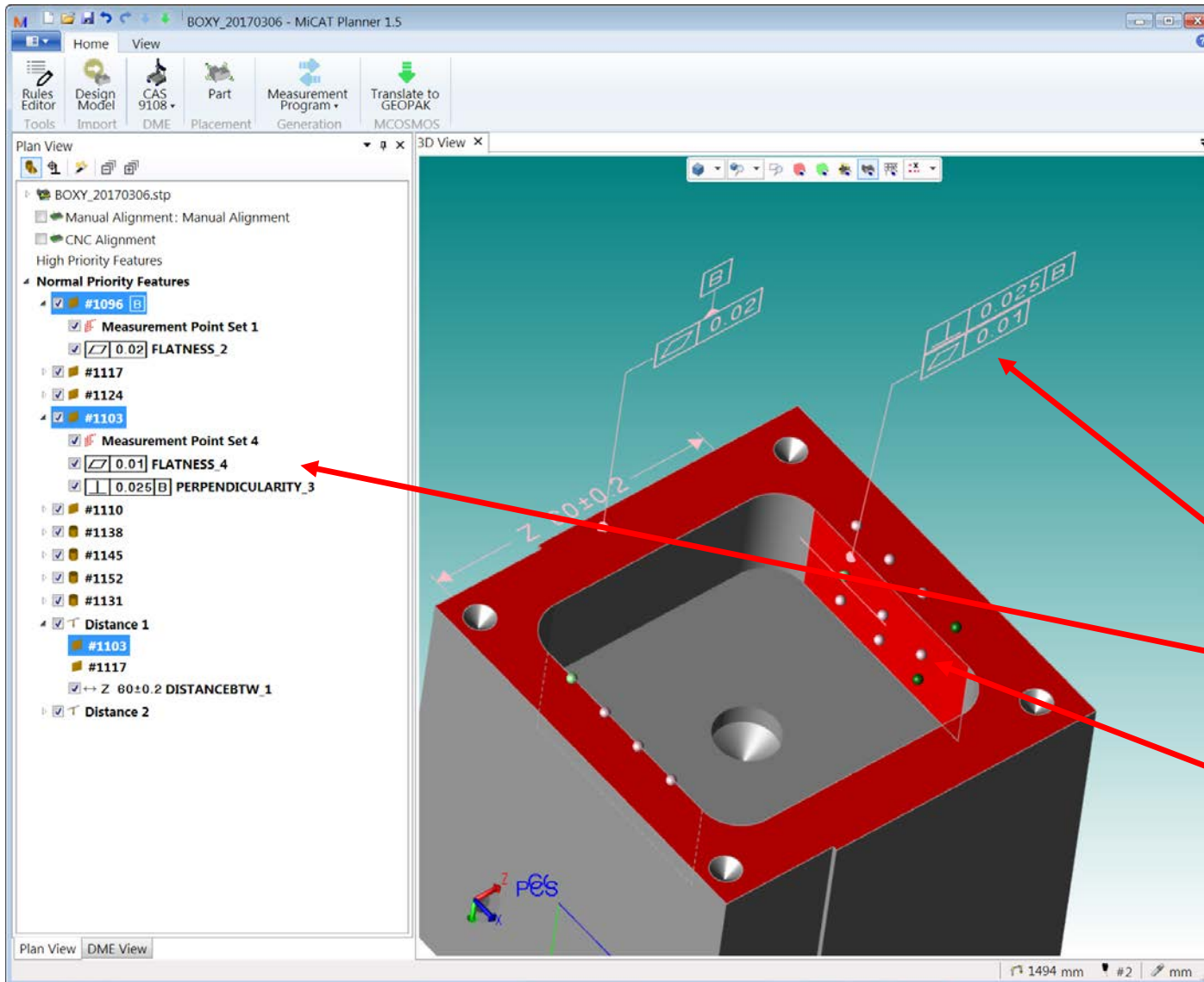
Linear : X

Samples

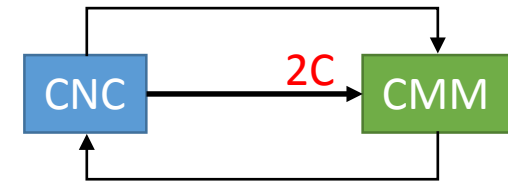


<http://swim.steptools.com:5000/current>

2C. Planner*: CMM evaluation of measurements



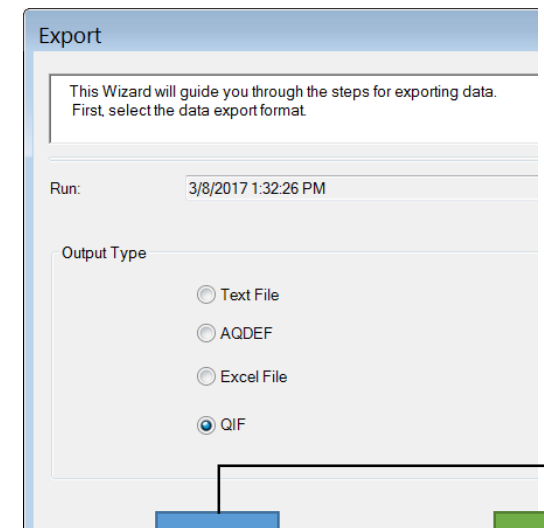
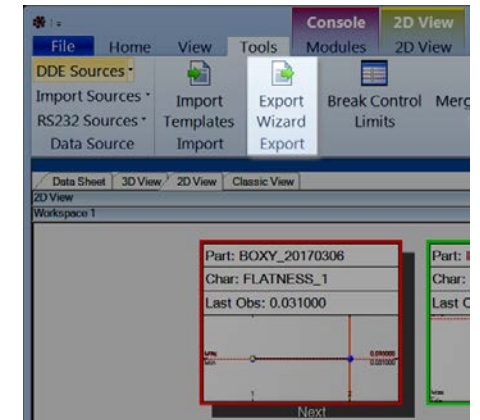
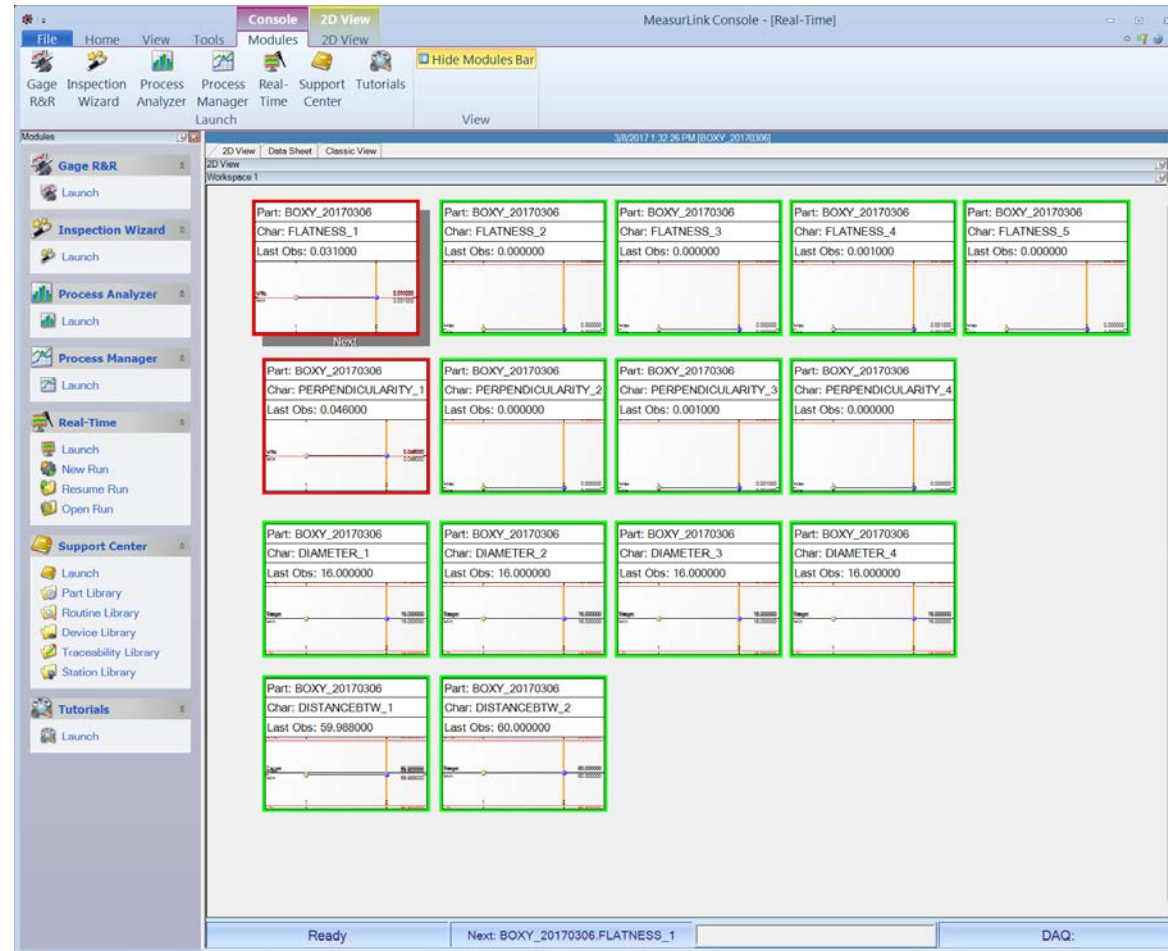
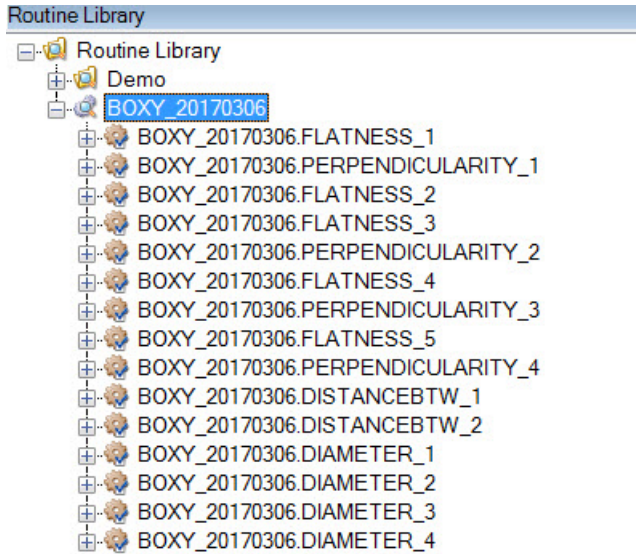
* MiCAT Planner 1.5 special version for DMDII O3 Investigation Only



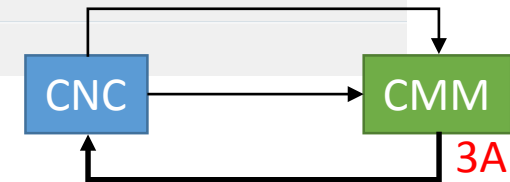
Semantic Tolerance

Measurement point

3A. MeasurLink* generating QIF Results



* MeasurLink v8.2.1
(released Dec 2016) and
newer



3B. ITI adds QIF Results to AP242

The screenshot shows a Windows command prompt window titled 'qif2step.bat - Shortcut' and a Notepad window titled 'BOXY_20170323_C_RES - Notepad'. The command prompt shows the execution of 'qif2step.exe' which processes a QIF file and generates a new STEP file. The Notepad window displays the content of the generated QIF file, which is a STEP file with various features and their attributes.

```
C:\DMDII\ITI\bin>cd c:\dmdii
c:\DMDII>set filename=BOXY_20170323_C
c:\DMDII>del BOXY_20170323_C_RES.stp
c:\DMDII>del BOXY_20170323_C_RES.log
c:\DMDII>set path=C:\Windows\system32;C:\Windows;C:\Windows\System32\Wbem;C:\Win
dows\System32\WindowsPowerShell\1.0\;C:\Program Files\node.js\;%;%cd%\.
c:\DMDII>qif2step.exe -l BOXY_20170323_C_RES.log c:\dmdii\gateway\measurements\B
OXY_20170323_C_RES.qif c:\dmdii\gateway\measurements\BOXY_20170323_C.stp BOXY_20
170323_C_RES.stp
0.2017.0322.1624
0 percent complete
25 percent complete
50 percent complete
75 percent complete
100 percent complete
c:\DMDII>node.exe c:\dmdii\gateway\bin\post.js BOXY_20170323_C_RES.stp
Sending file BOXY_20170323_C_RES.stp with uuid BOXY_20170323_C_RES.stp
File read...
Status: 200
Headers: {"content-length": "10", "content-type": "text/xml"}
result: <success/>
c:\DMDII>notepad BOXY_20170323_C_RES.log
```

BOXY_20170323_C_RES - Notepad

```
qIF2STEP version 0.2017.0322.1624, Copyright (c) 2016 ITI (www.iti-global.com)

Parsing QIF file c:\dmdii\gateway\measurements\BOXY_20170323_C_RES.qif...

Parsing original STEP file c:\dmdii\gateway\measurements\BOXY_20170323_C.stp...

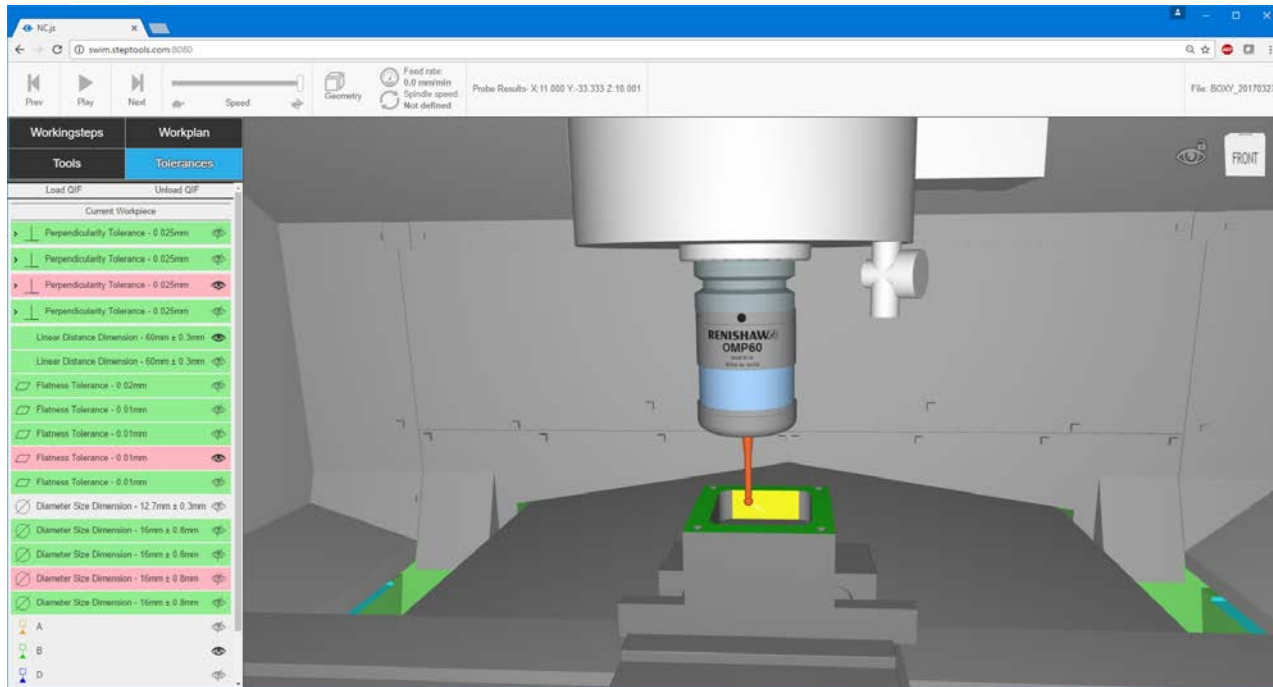
Mapping QIF to STEP...
id=5, name=FLATNESS_1, uuid=b301f89d-dc96-456b-9346-0257c2a399c3, value=0.031, status=FAIL
id=8, name=PERPENDICULARITY_1, uuid=2b35a115-8c94-4790-827a-cf57558507d3, value=0.046, status=FAIL
id=11, name=FLATNESS_2, uuid=dce95a04-4079-42c3-93ea-5d0363c53eb8, value=0, status=PASS
id=14, name=FLATNESS_3, uuid=9d49b7b6-5738-417c-bc4b-6f98cbc727e, value=0.004, status=PASS
id=17, name=PERPENDICULARITY_2, uuid=c1ac3ed7-6a67-4880-b2be-fa5ca5174e19, value=0.004, status=PASS
id=20, name=FLATNESS_4, uuid=ad750c09-4736-49a8-904c-5a12f4d12214, value=0.001, status=PASS
id=23, name=PERPENDICULARITY_3, uuid=2b6c80e3-8e89-4328-9f27-e9153df4dd99, value=0.001, status=PASS
id=26, name=FLATNESS_5, uuid=1327a9eb-4cde-4d56-bb88-ba766e15c6bf, value=0.004, status=PASS
id=29, name=PERPENDICULARITY_4, uuid=b0efac89-131f-4571-9f34-1e537ae37ee0, value=0.004, status=PASS
id=32, name=DISTANCEBTW_1, uuid=66e6d151-14f3-4fd4-a658-5250974550dc, value=59.988, status=PASS
id=35, name=DISTANCEBTW_2, uuid=700d0784-9b57-4cc7-9c18-cd4ac4d58ea1, value=59.996, status=PASS
id=38, name=DIAMETER_1, uuid=f8a056f6-2f52-4e31-8cf5-444dabced8b9, value=16, status=PASS
id=41, name=DIAMETER_2, uuid=8daaf164-c82e-493c-8d48-7fd87b07f141, value=16.247, status=PASS
id=44, name=DIAMETER_3, uuid=84789e75-a2a9-4601-8a23-767f3fb5ab97, value=16.976, status=FAIL
id=47, name=DIAMETER_4, uuid=ff624cca-c0d1-4409-ab34-d42b595e7042, value=16.7, status=PASS

Formatting new STEP file BOXY_20170323_C_RES.stp...

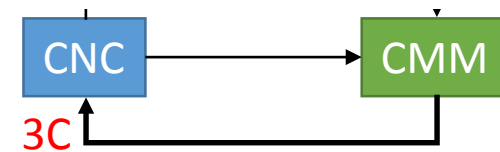
Completed with error code 0
```



3C. QIF Results back to CNC



```
<FlatnessCharacteristicItem id="5">
  <Attributes n="1">
    <AttributeQPIId name="QPIId">
      <Value>27ff0490-e32a-4736-8a30-42da346e1450</Value>
    </AttributeQPIId>
  </Attributes>
  <Description>BOXY_20170306.FLATNESS_1</Description>
  <Name>FLATNESS_1</Name>
  <CharacteristicNominalId>3</CharacteristicNominalId>
</FlatnessCharacteristicItem>
...
<FlatnessCharacteristicDefinition id="2">
  <Name>FLATNESS_1</Name>
  <ToleranceValue>0.01</ToleranceValue>
</FlatnessCharacteristicDefinition>
...
<FlatnessCharacteristicActual id="49">
  <Status>
    <CharacteristicStatusEnum>FAIL</CharacteristicStatusEnum>
  </Status>
  <CharacteristicItemId>5</CharacteristicItemId>
  <Value>0.031</Value>
</FlatnessCharacteristicActual>
```



Internal: UUID's that relate all the data

STEP Data

QIF Data

```
STEP File Browser - BOXY_20170306.stp [page 1/1]
File View Navigate Help
FILE_SCHEMA (('AP242_MANAGED_MODEL_BASED_3D_ENGINEERING_MIM_LF { 1 0 10
ENDSEC;
ANCHOR;
<4210ed32-a599-43d1-9e84-96120d5ece42>=#983; /* perpendicularity_toler
<767be10a-4d9a-49d8-9fd5-205adcd7ad82>=#987; /* perpendicularity_toler
<459f7ee4-fced-4c3d-be7d-ca20f28e1855>=#991; /* perpendicularity_toler
<a584e6fc-b7cc-4904-b41e-81c97383b15f>=#995; /* perpendicularity_toler
<dc13594f-b8d5-4b23-bb38-ca86d96552e1>=#1094; /* datum_feature */
<9ce00c74-b207-4cb5-98fc-734ce92a60b0>=#1101; /* shape_aspect */
<9ffd7cbf-25bd-4be9-ab37-90b7ee855c69>=#1115; /* shape_aspect */
<754a586f-3593-4c1a-b0a9-a36f7c886540>=#1108; /* shape_aspect */
```

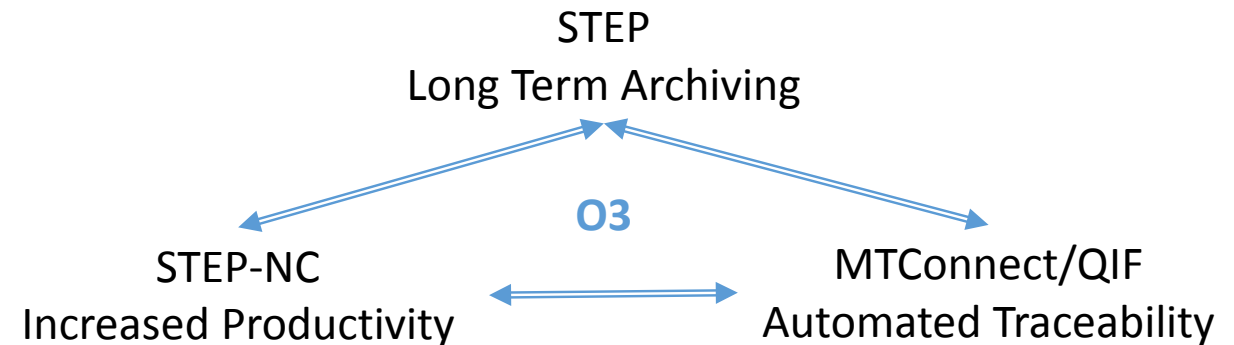
```
BOXY_20170306_Results.xml - Notepad
File Edit Format View Help
<CharacteristicNominalId>19</CharacteristicNominalId>
</FlatnessCharacteristicItem>
<PerpendicularityCharacteristicItem id="23">
  <Attributes n="1">
    <AttributeQPid name="QPId">
      <Value>4210ed32-a599-43d1-9e84-96120d5ece42</Value>
    </AttributeQPid>
  </Attributes>
  <Description>BOXY_20170306.PERPENDICULARITY_3</Description>
  <Name>PERPENDICULARITY_3</Name>
  <CharacteristicNominalId>22</CharacteristicNominalId>
</PerpendicularityCharacteristicItem>
<FlatnessCharacteristicItem id="26">
  <Attributes n="1">
    <AttributeQPid name="QPId">
      <Value>c3fe4af3-8e4a-4345-af0f-d6d62d0b5001</Value>
    </AttributeQPid>
  </Attributes>
```

MTConnect Adapter Data

```
BOXY_20170306.log.txt - Notepad
File Edit Format View Help
2017-03-02T18:53:41.080Z|pprogram|BOXY_20170306
2017-03-02T13:53:49.104-05:00|measure|feature:"dc13594f-b8d5-4b23-bb38-ca86d96552e1" order:1 count:8 id:"FACE32373" characteristic:"3DLocation" x:-14.166667 y:-40.000000 z:9.166667
2017-03-02T13:53:50.306-05:00|measure|feature:"dc13594f-b8d5-4b23-bb38-ca86d96552e1" order:2 count:8 id:"FACE32373" characteristic:"3DLocation" x:-4.722222 y:-40.000000 z:9.166667
2017-03-02T13:53:51.507-05:00|measure|feature:"dc13594f-b8d5-4b23-bb38-ca86d96552e1" order:3 count:8 id:"FACE32373" characteristic:"3DLocation" x:4.722222 y:-40.000000 z:9.166667
2017-03-02T13:53:52.712-05:00|measure|feature:"dc13594f-b8d5-4b23-bb38-ca86d96552e1" order:4 count:8 id:"FACE32373" characteristic:"3DLocation" x:14.166667 y:-40.000000 z:9.166667
2017-03-02T13:53:53.913-05:00|measure|feature:"dc13594f-b8d5-4b23-bb38-ca86d96552e1" order:5 count:8 id:"FACE32373" characteristic:"3DLocation" x:-14.166667 y:-40.000000 z:73.333333
2017-03-02T13:53:55.117-05:00|measure|feature:"dc13594f-b8d5-4b23-bb38-ca86d96552e1" order:6 count:8 id:"FACE32373" characteristic:"3DLocation" x:-4.722222 y:-40.000002 z:73.333333
```

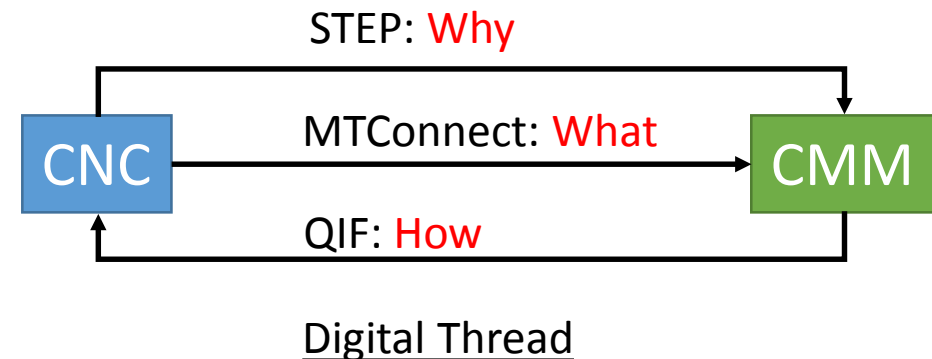
Result - Increased Productivity

- Feedback between suppliers and OEM's
 - Automated detection and correction of anomalies
 - Automated adjustments to meet the tolerances
- Integration of CNC and CMM functions
 - Single setup
 - On demand measurement
- Enabling tooling optimization
 - Feed speed optimization
 - Adaptive programming
 - 15% more efficient manufacturing



Summary

- We automated measurement using semantic tolerances
 - Requirements sent using STEP
 - Measurements streamed using MTConnect
 - Results returned using QIF
- We used the CNC as a CMM
 - One setup
 - On-demand or as-planned
 - Same CMM algorithms



What next?

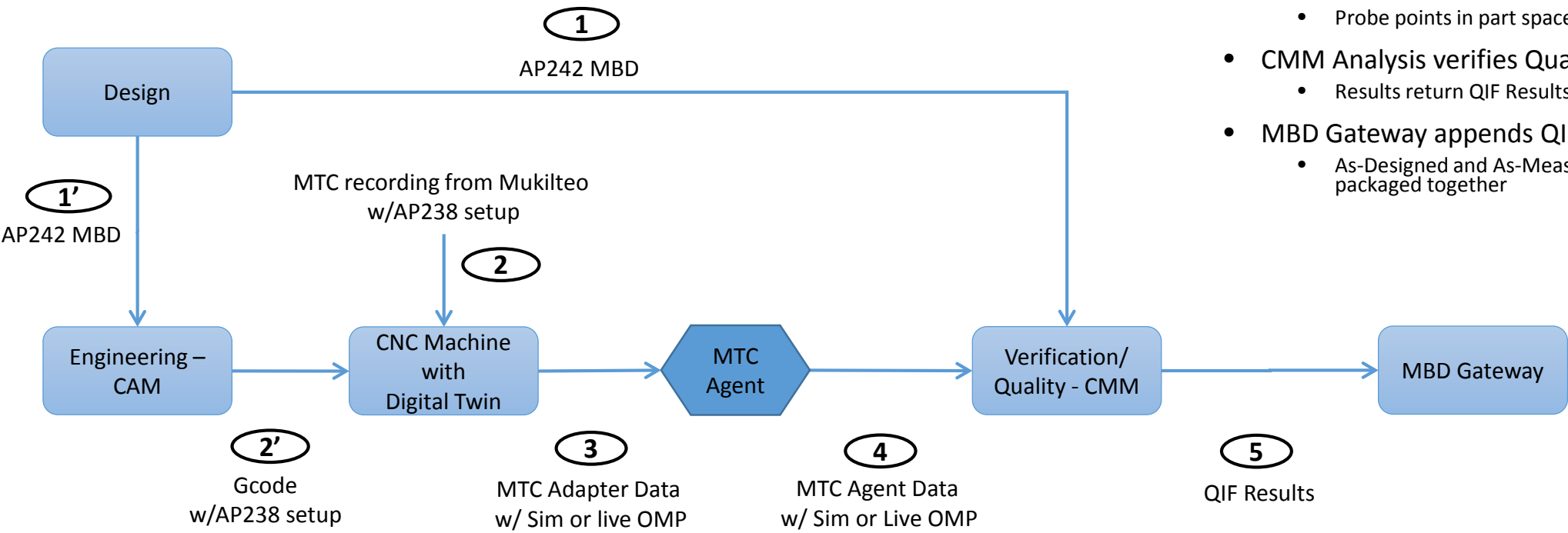
- Live machining at DMDII on May 23rd
 - Machining using a 5-axis Hyundai with Siemens 840D
 - Touch probing using Renishaw macros
 - Tolerance evaluation on a Mitutoyo Metrology server
 - Interoperability testing on a DMG and Okuma
- Pilot production in aerospace in the Fall
 - Demonstration planned for Korea ISO meeting

Backup

Standards used in the thread

	STEP AP242	STEP AP238	MTConnect	QIF
Normal source	CAD systems	CAM systems	CNC systems	CMM systems
Role in thread	Define design tolerances and nominal touch probe points	Translate as-measured touch probe points into part space	Communicate measured points from CNC to CMM	Communicate tolerance quality back to CNC

All the process steps



- Design to CAM/CMM
 - via AP242 MBD
- CAM to CNC Machine with Digital Twin
 - Playback via MTConnect and AP238 for setup
- OMP streams through MTC to CMM
 - Probe points in part space
- CMM Analysis verifies Quality
 - Results return QIF Results
- MBD Gateway appends QIF Results to AP242
 - As-Designed and As-Measured PMI (Characteristics) packaged together

1' **2'** Performed at Mukilteo (see <https://www.youtube.com/watch?v=Mjzg5nku5Lg>)

1 **2** **3** **4** **5** Performed live today with a virtual CNC in NY and a virtual CMM in Chicago