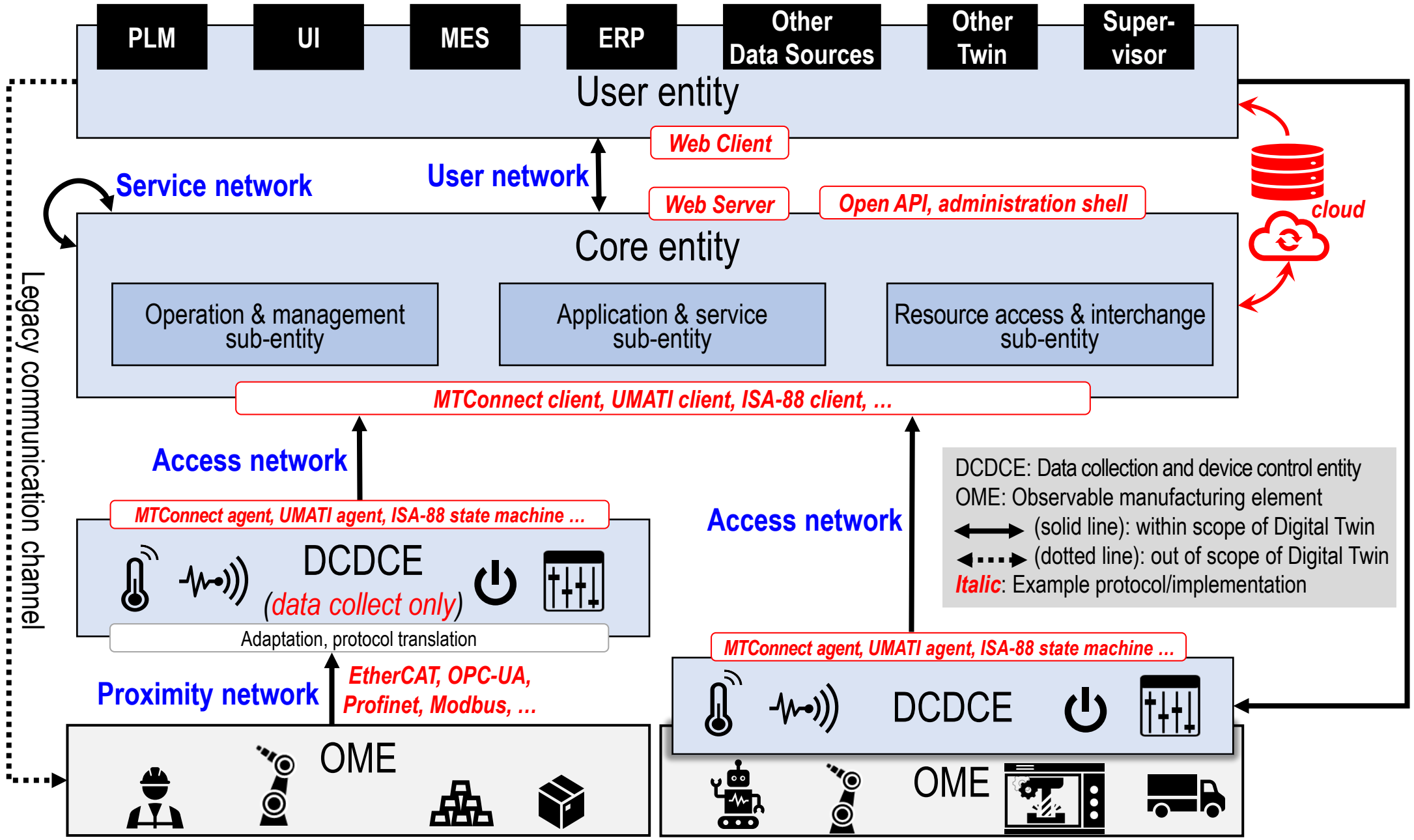
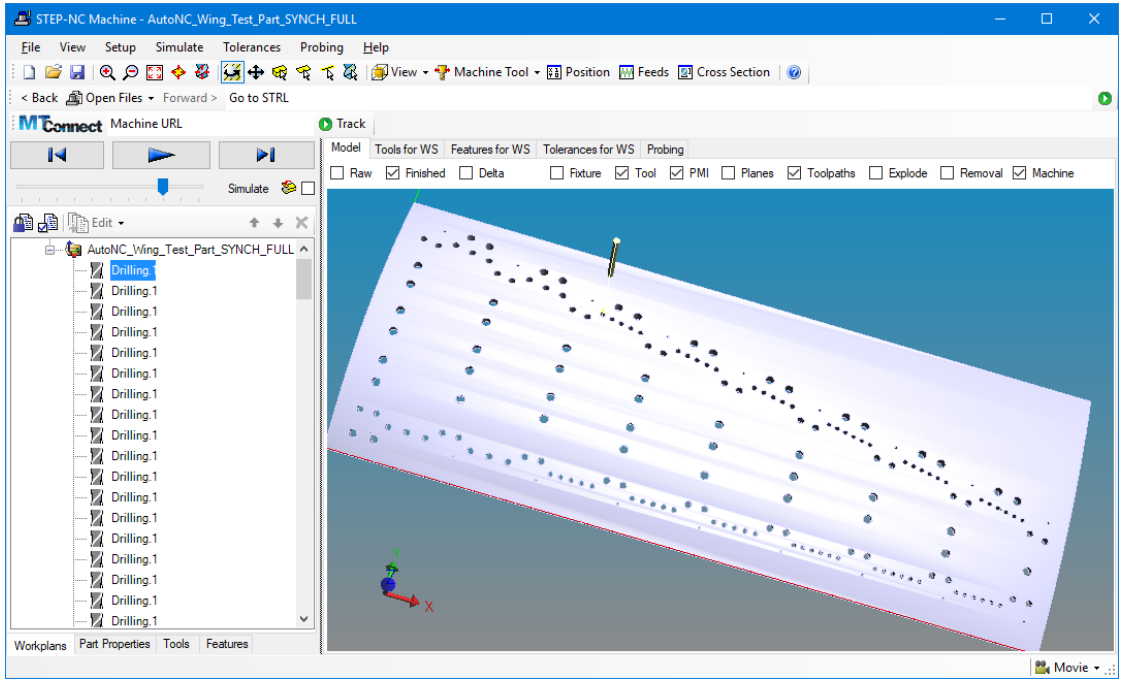
ISO 23247 Digital Twin Use case Testing

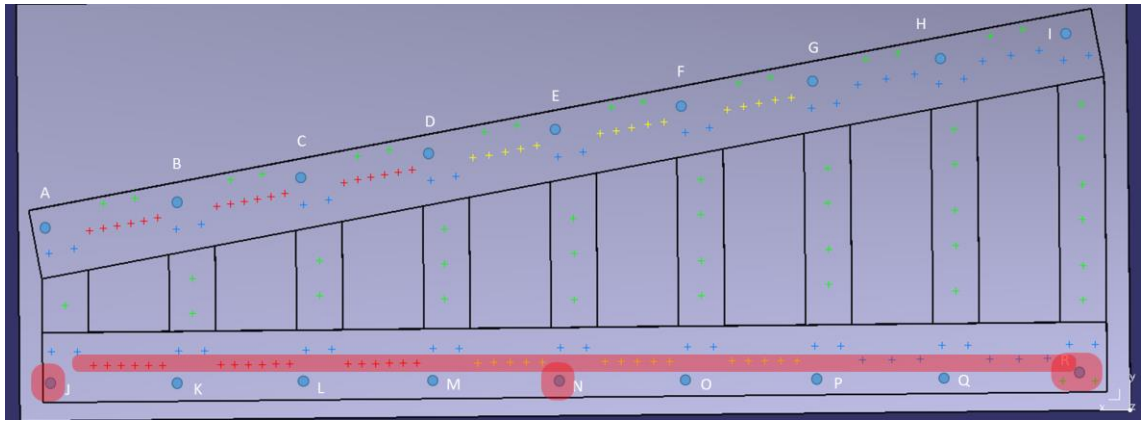
Results of August 25 Conference call

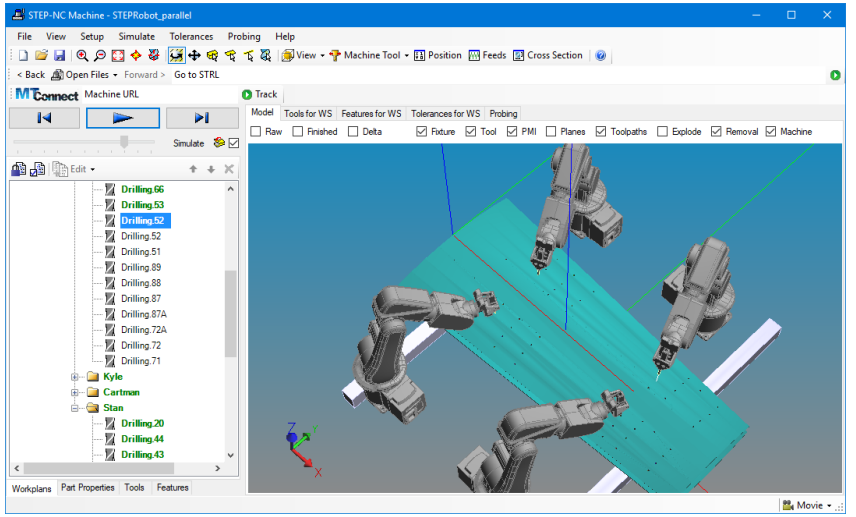
ISO 23247-4 Figure A.1



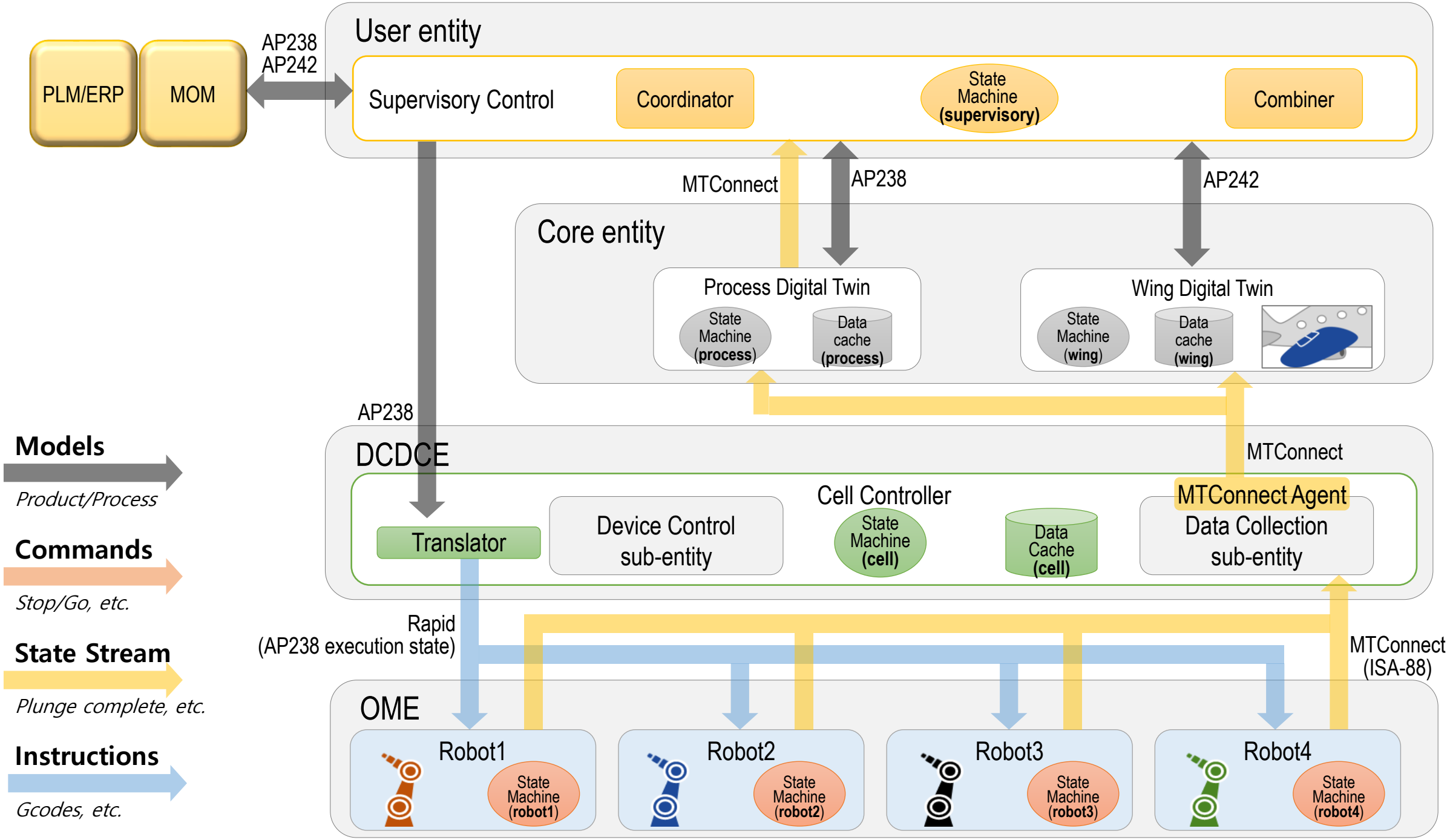
Use Case 1 – flexible schedule for robot drill & fill



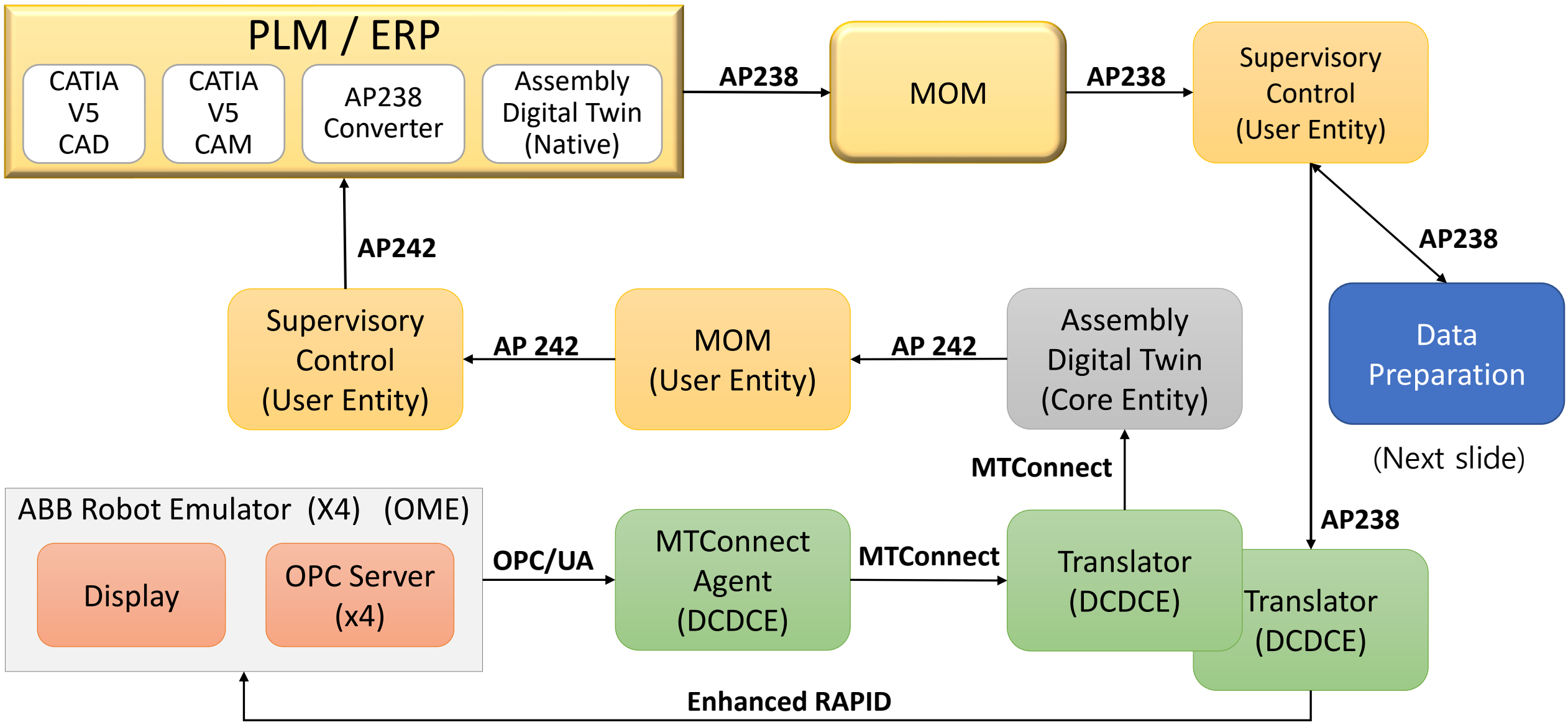




On-shoring can increase by 50%


PLM/ERP
MOM
AP238
AP242
User entity
Supervisory Control
Coordinator
State Machine (supervisory)
Combiner
MTConnect
AP238
AP242
Core entity
Process Digital Twin
State Machine (process)
Data cache (process)
Wing Digital Twin
State Machine (wing)
Data cache (wing)
AP238
DCDCE
MTConnect
Translator
Device Control sub-entity
Cell Controller
State Machine (cell)
Data Cache (cell)
MTConnect Agent
Data Collection sub-entity
Rapid
(AP238 execution state)
MTConnect
(ISA-88)
OME
Robot1
State Machine (robot1)
Robot2
State Machine (robot2)
Robot3
State Machine (robot3)
Robot4
State Machine (robot4)
Models
Product/Process
Commands
Stop/Go, etc.
State Stream
Plunge complete, etc.
Instructions
Gcodes, etc.

Assembly/Process Flow

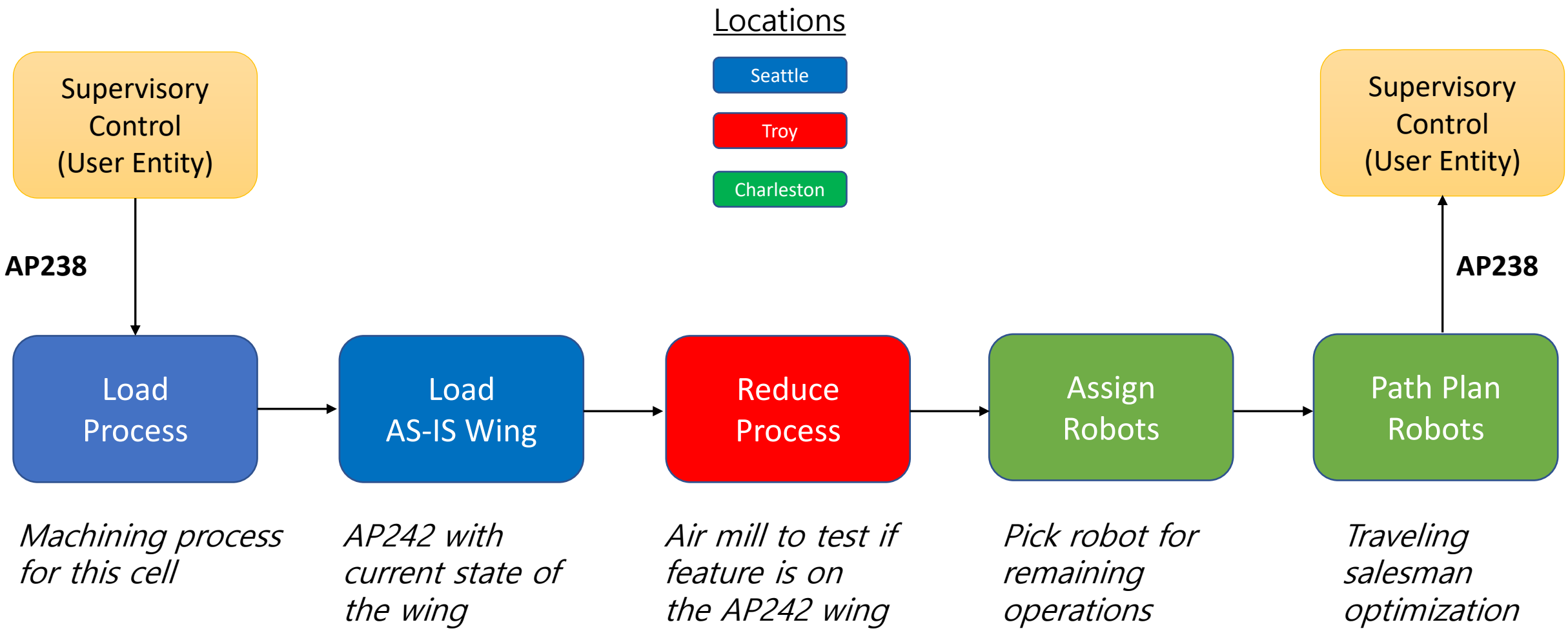


MTConnect

```
<Events>
          <WorkingStepDataSet dataItemId="I22a766e4465"
                    timestamp="2020-07-28T20:27:06.147161Z"
                    name="WorkingStep" sequence="179" count="2">
            <Entry key="NAME">Drilling.2</Entry>
            <Entry key="UUID">b062b09d-c75e-4509-b058-f533fc3121cb</Entry>
          </WorkingStepDataSet>
          <FeatureDataSet dataItemId="I95ded582189"
                    timestamp="2020-07-28T20:27:06.147161Z"
                    name="Feature" sequence="180" count="2">
            <Entry key="NAME">Hole.101</Entry>
            <Entry key="UUID">7ba2387a-5122-471d-9e62-f4dd978dd916</Entry>
          </FeatureDataSet>
</Events>
```

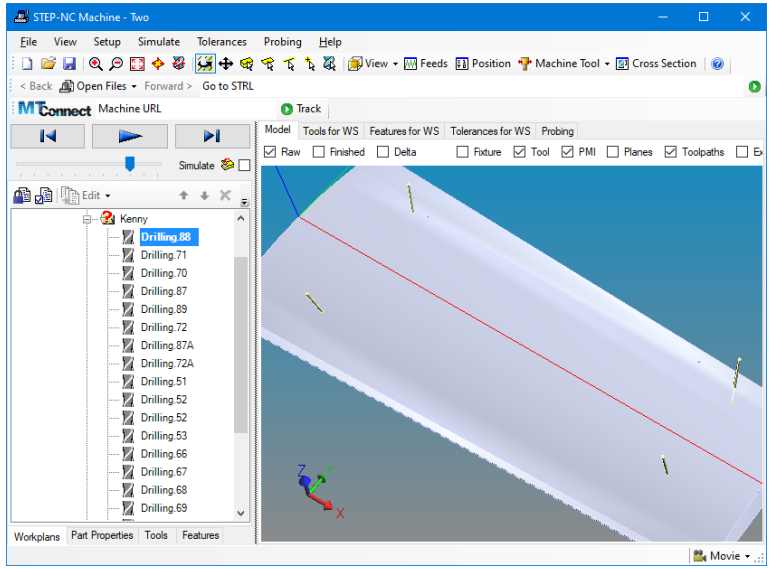
https://github.com/mtconnect/iso_digital_twin_adapter

Data Preparation

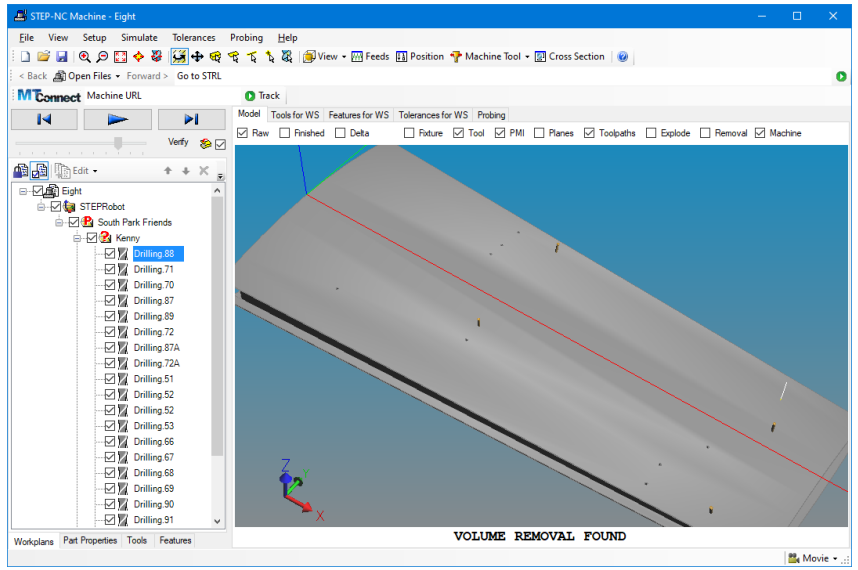


Hole detection using AP242

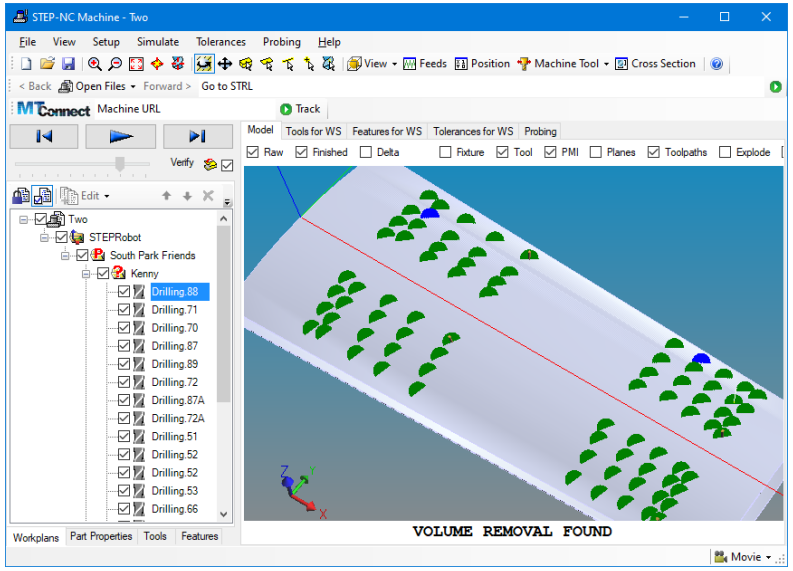
Two holes



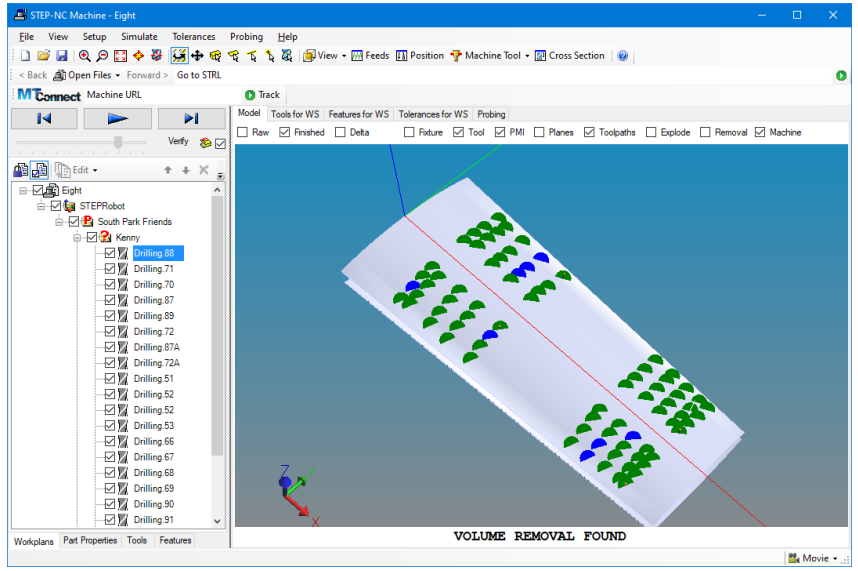
Eight holes



Two holes found

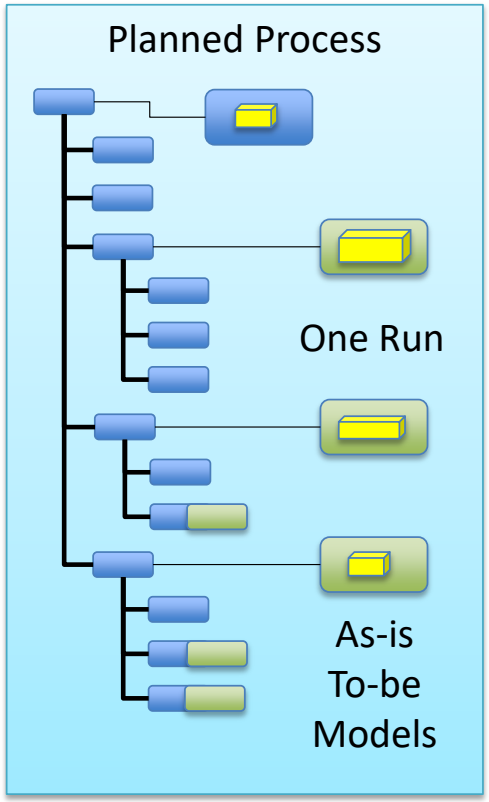


Eight holes found

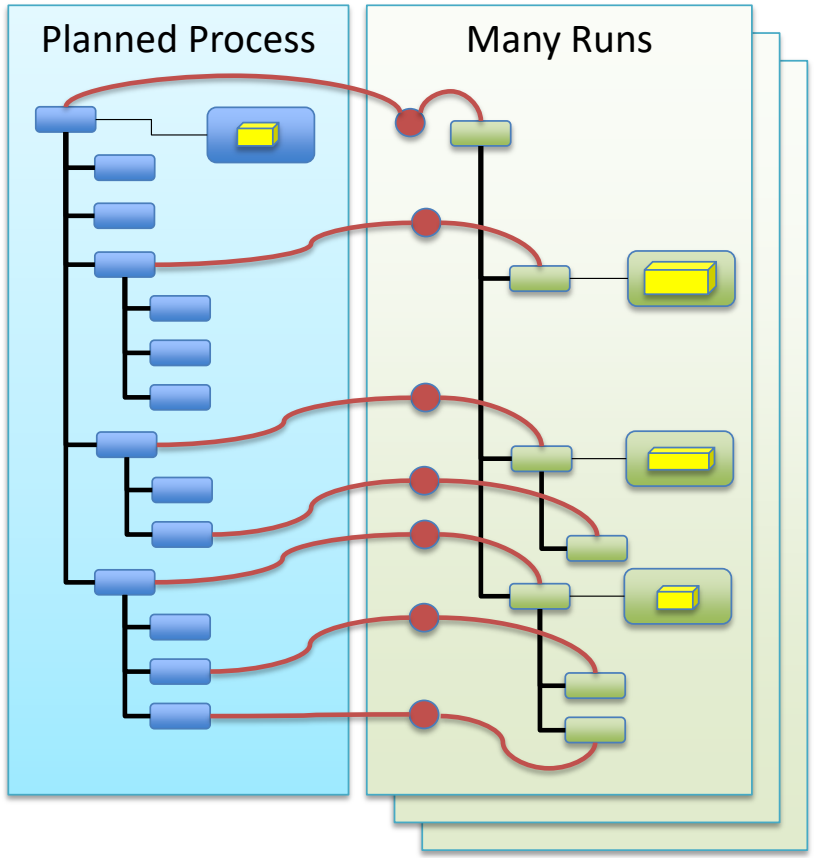


Digital Twin process model

https://stepmfg.github.io/ap238e2/data/clause5.htm#fig-twinmodel



Model process state using new attributes



Link runs using Part 21 Edition 3

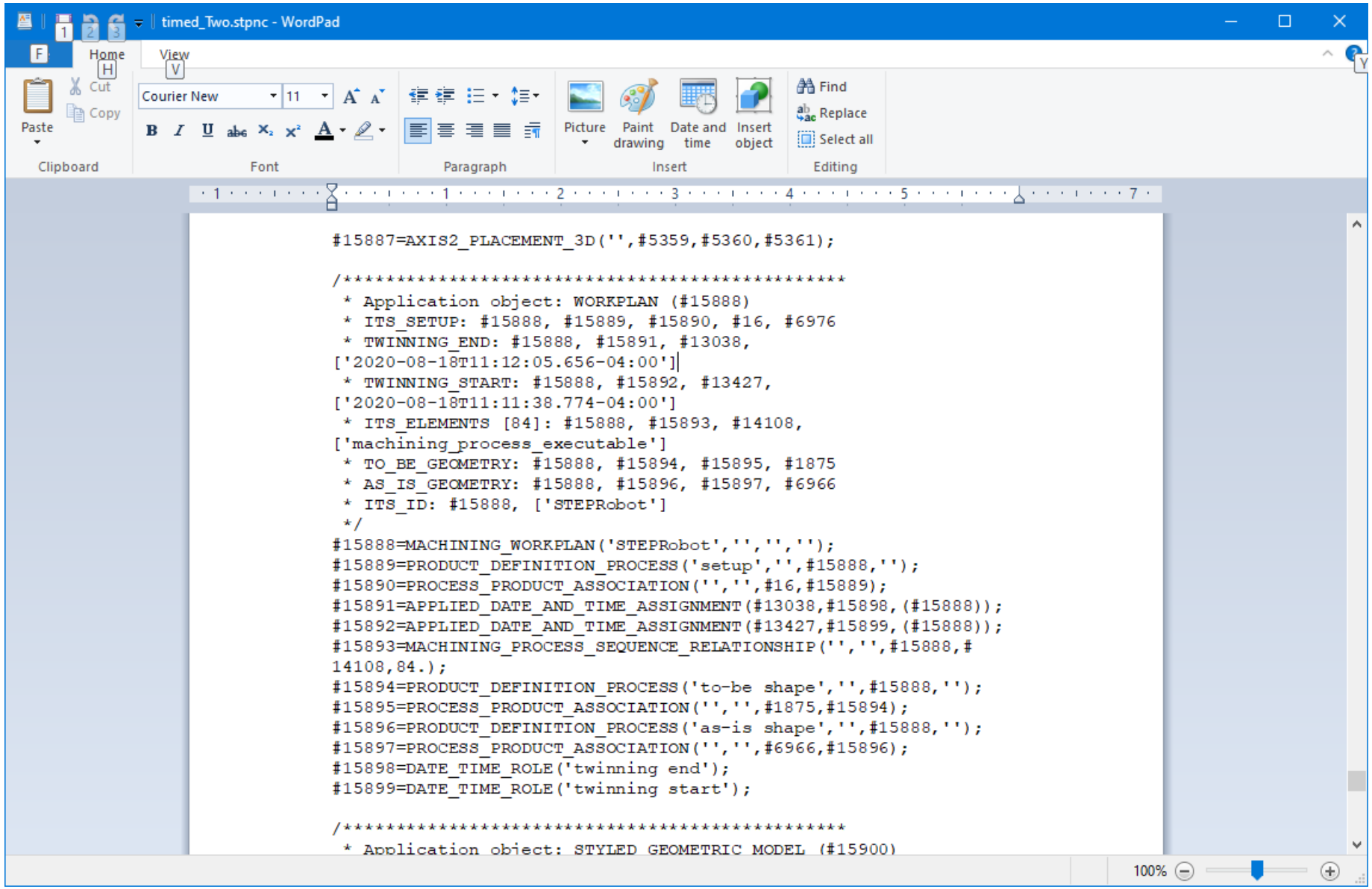
```
ENTITY executable
  [ ... other attributes omitted ... ]
  twin_source: OPTIONAL twin_source_enum;
  twin_plan: OPTIONAL executable;
  twinning_start : OPTIONAL Date_time;
  twining_end :   OPTIONAL Date_time;
  twinning_log : LIST [0:?] log_record;
  in_cut_time : OPTIONAL Duration;
END_ENTITY;

TYPE twin_state_enum = ENUMERATION OF (simulat
ed, machined); END_TYPE;

ENTITY log_record
   description : STRING;
   date_time : Date_time;
END_ENTITY;
```

Executable is supertype of all processes.
Definition above shows new attributes for Edition 2

Sample twin data



STEP-NC Machine - AutoNC_Wing_Test_Part_SYNCH_FULL_With_Probe

File View Setup Simulate Tolerances Probing Help

View Feeds Position Machine Tool Cross Section

< Back Open Files Forward > Go to STRL

MTConnect Machine URL Track

Simulate

- Hole.1 (ROUND_HOLE)
- Hole.2 (ROUND_HOLE)
- Hole.3 (ROUND_HOLE)
- Hole.4 (ROUND_HOLE)
- Hole.5 (ROUND_HOLE)
- Hole.6 (ROUND_HOLE)
  - Depth = 0.39 in
  - Diameter = 0.19 in
  - Position = (11.354, 1.149, 0.34) in
  - Bottom type = CONICAL_HOLE_BOTTOM
  - Tools
    - Tool - T6, D=0.19, L=1.96850393700787
  - Workingsteps
    - Drilling.6
  - Entiity = 17463 Started = 2020-07-21T09:16:29.701-04:00
  - Ended =
  - Elaped time =
- Hole.7 (ROUND_HOLE)
- Hole.8 (ROUND_HOLE)
- Hole.9 (ROUND_HOLE)
- Hole.10 (ROUND_HOLE)
- Hole.11 (ROUND_HOLE)
- Hole.12 (ROUND_HOLE)
- Hole.13 (ROUND_HOLE)
- Hole.14 (ROUND_HOLE)
  - Depth = 0.387 in
  - Diameter = 0.19 in
  - Position = (7.554, 1.139, 0.372) in
  - Bottom type = CONICAL_HOLE_BOTTOM
  - Tools
    - Tool - T6, D=0.19, L=1.96850393700787
  - Workingsteps
    - Drilling.14
  - Entiity = 17391 Started = 2020-07-21T09:16:01.341-04:00
  - Ended = 2020-07-21T09:16:25.616-04:00
  - Elapsed = 24 seconds, 275 milliseconds
- Hole.15 (ROUND_HOLE)
- Hole.16 (ROUND_HOLE)
- Hole.17 (ROUND_HOLE)
- Hole.18 (ROUND_HOLE)

Workplans Part Properties Tools Features

Model Tools for WS Features for WS Tolerances for WS Probing

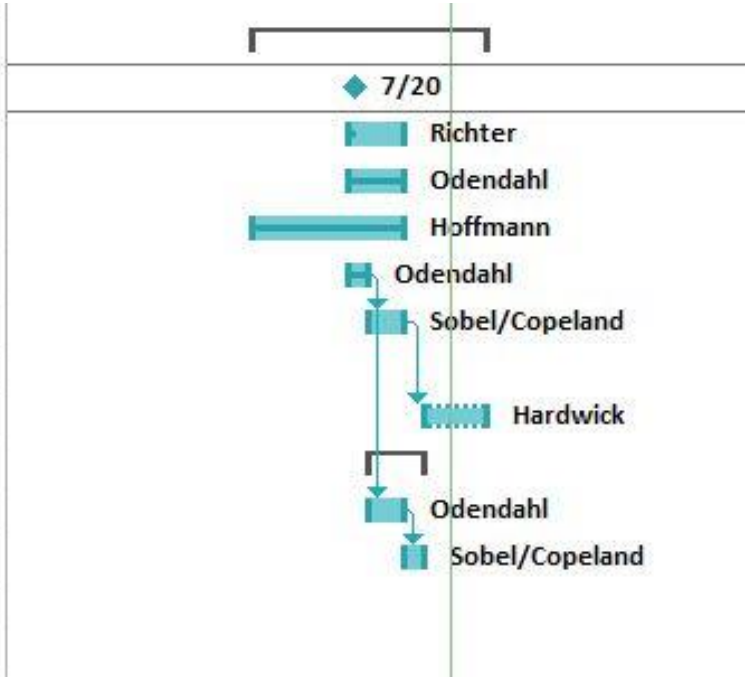
Raw Finished Delta Fixture Tool PMI Planes Toolpaths Explode Removal Machine

White (ready) Green (complete) Orange (in process) Red (error) Pink (missing data)

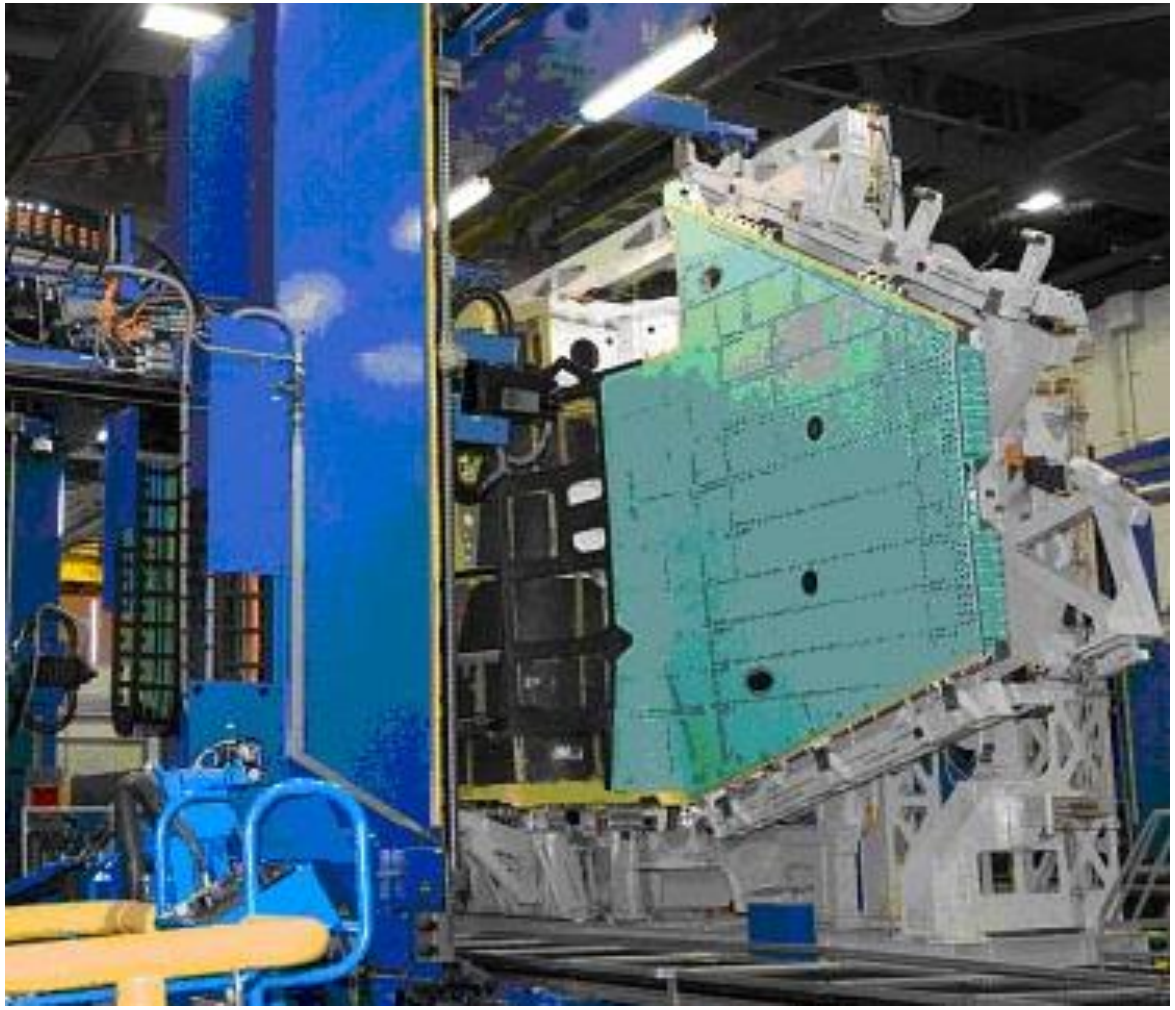
Movie

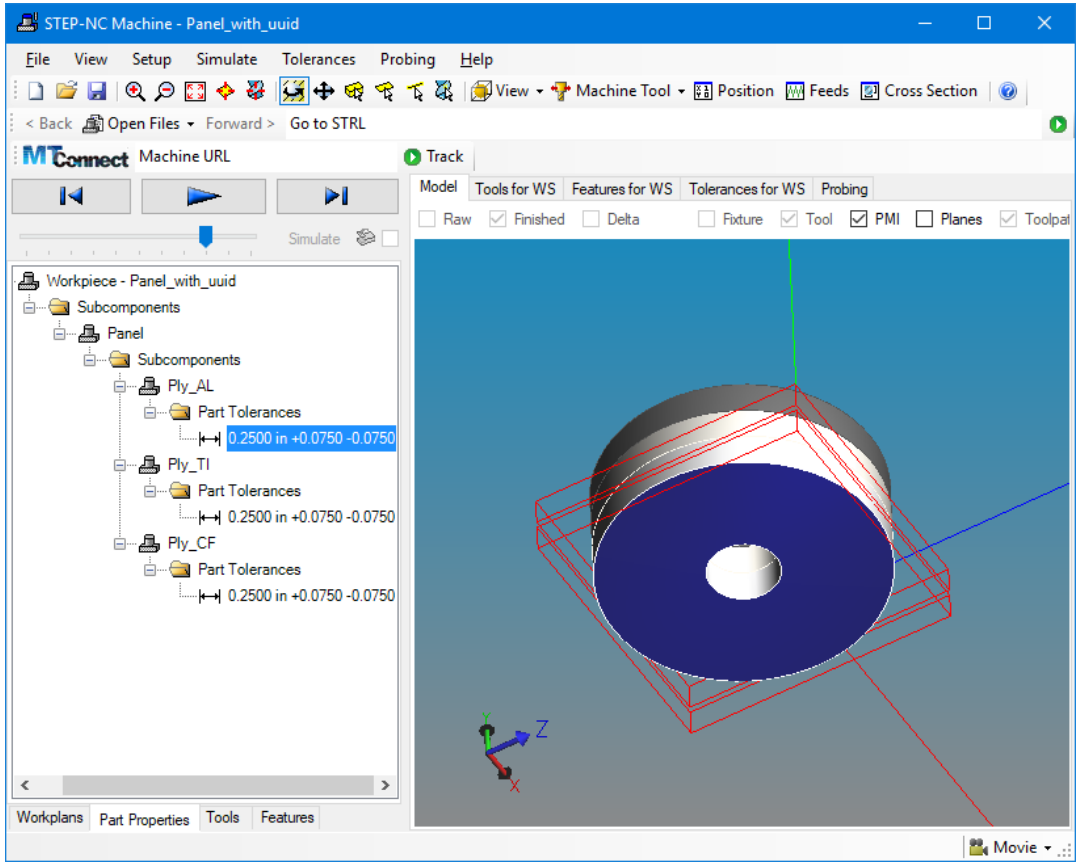
Schedule

		CAD /CAM	**25 days**	**Mon 7/6/20**	**Sat 8/8/20**	
✓		CATIA V5 -> AP238	0 days	Mon 7/20/20	Mon 7/20/20	
		Supervisory Control	6 days	Mon 7/20/20	Mon 7/27/20	
✓		AP238 -> Rapid	6 days	Mon 7/20/20	Mon 7/27/20	
✓		Setup OPC/UA Server	16 days	Mon 7/6/20	Mon 7/27/20	
✓		Define OPC/UA Tags	3 days	Mon 7/20/20	Wed 7/22/20	
		Define MTConnect Tags	3 days	Thu 7/23/20	Mon 7/27/20	30
		Setup MTConnect Adapter/Agent				
		MTConnect -> Digital Twin	7 days	Fri 7/31/20	Sat 8/8/20	31
		State Machine	**6 days?**	**Thu 7/23/20**	**Thu 7/30/20**	
		Define OPC/UA Tags	3 days	Thu 7/23/20	Mon 7/27/20	30
		Define MTConnect Tags	3 days	Tue 7/28/20	Thu 7/30/20	35
		Map MTConnect to PackML				
		PackML Client				

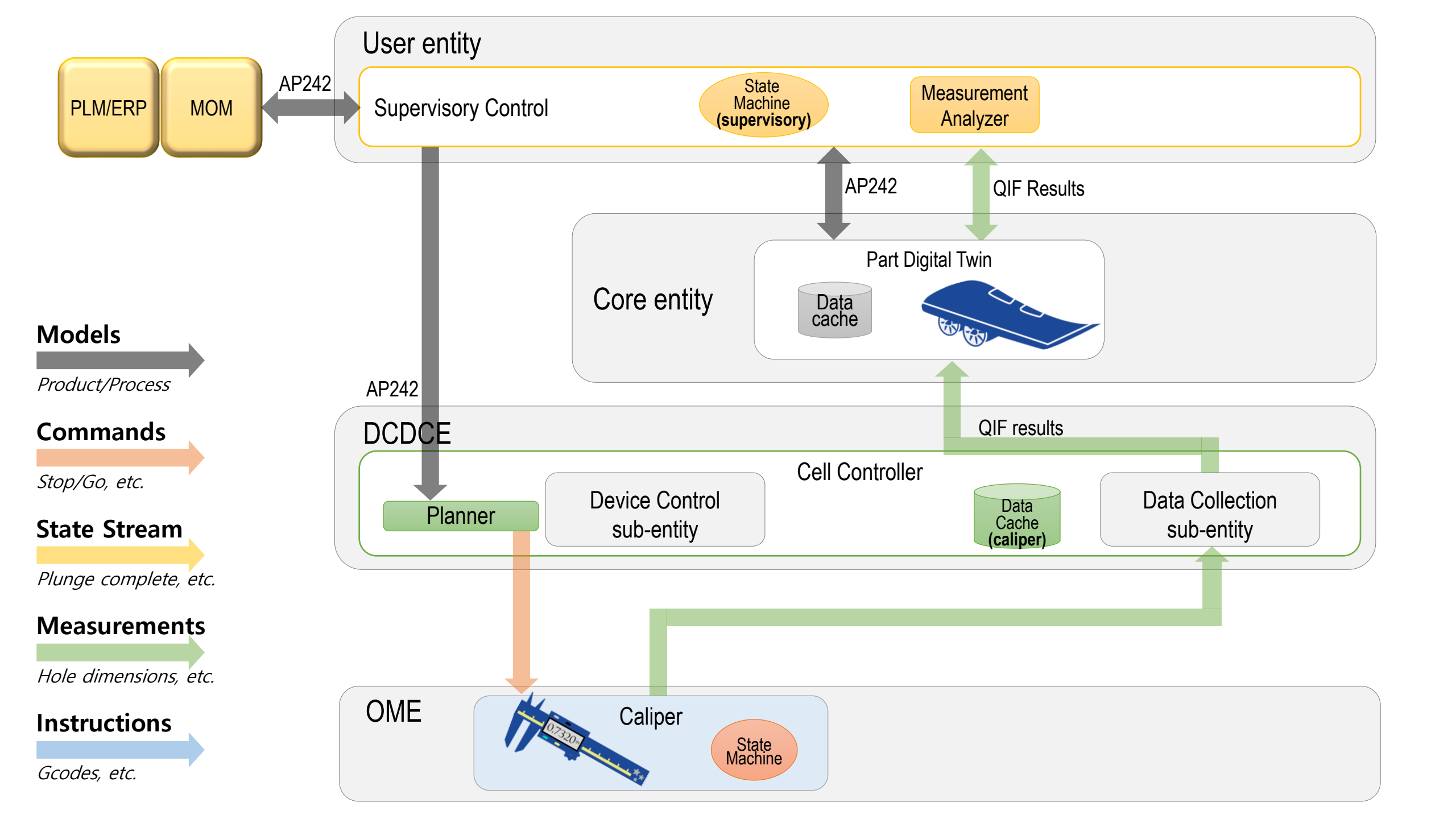


Use Case 2 – weight reduction

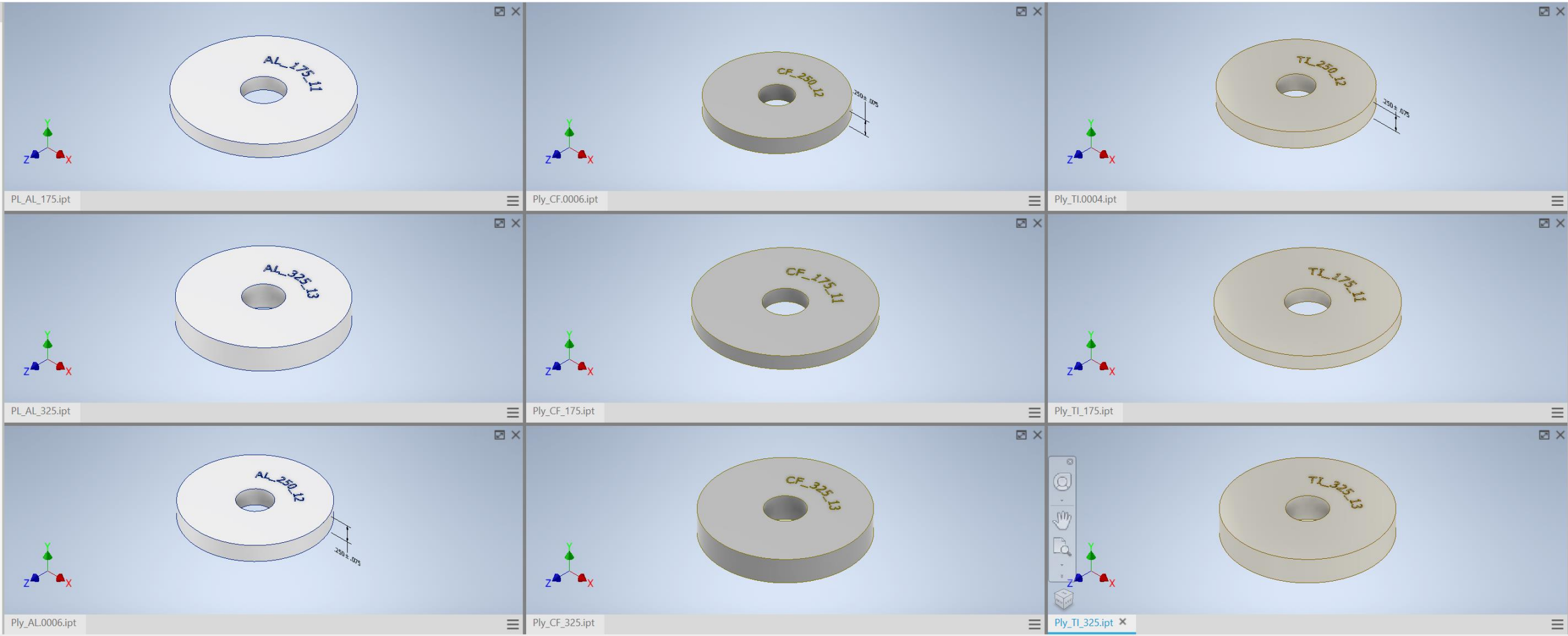




Exact match of fastener to hole depth can reduce weight by 500lb


User entity
PLM/ERP
MOM
AP242
Supervisory Control
State Machine (supervisory)
Measurement Analyzer
AP242
QIF Results
Core entity
Part Digital Twin
Data cache
AP242
DCDCE
QIF results
Cell Controller
Planner
Device Control sub-entity
Data Cache (caliper)
Data Collection sub-entity
OME
Caliper
State Machine
Models
Product/Process
Commands
Stop/Go, etc.
State Stream
Plunge complete, etc.
Measurements
Hole dimensions, etc.
Instructions
Gcodes, etc.

Measurement samples



AL_250_Results.qif

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<MeasurementResults id="13">
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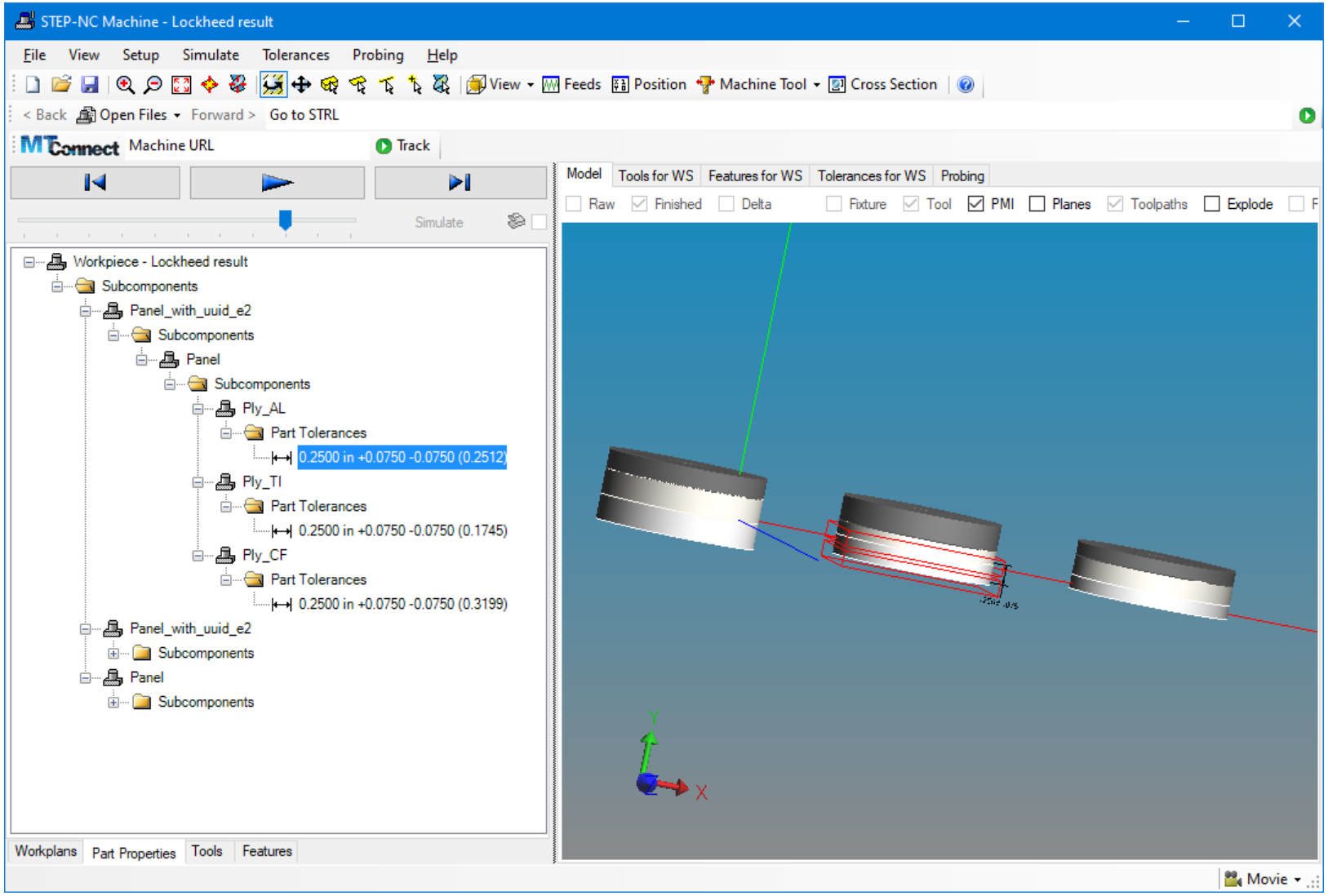
      <CharacteristicMeasurements n="1">
        <DistanceBetweenCharacteristicMeasurement id="14">
          <Status>
            <CharacteristicStatusEnum>PASS</CharacteristicStatusEnum>
          </Status>
          <CharacteristicItemId>6</CharacteristicItemId>
          <TimeStamp>2020-08-14T11:02:48.9811824-05:00</TimeStamp>
          <Value>0.3191</Value>
        </DistanceBetweenCharacteristicMeasurement>
      </CharacteristicMeasurements>
    </MeasuredCharacteristics>
    <InspectionStatus>
      <InspectionStatusEnum>PASS</InspectionStatusEnum>
    </InspectionStatus>
    <ActualComponentIds n="1">
      <Id>15</Id>
    </ActualComponentIds>
  </MeasurementResults>
```

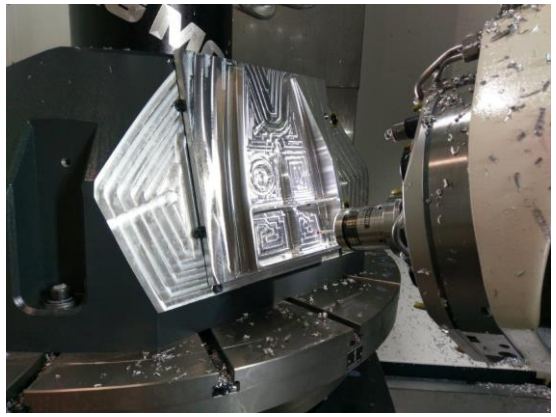
```
<CharacteristicItems n="1">
    <DistanceBetweenCharacteristicItem id="6">
      <Description>AL_250.Thickness</Description>
      <Name>Thickness</Name>
      <CharacteristicDesignator>
        <Designator>25</Designator>
        <UUID>6a45ec6c-3b4e-4b17-ae85-aada5131a8ec</UUID>
      </CharacteristicDesignator>
      <CharacteristicNominalId>4</CharacteristicNominalId>
    </DistanceBetweenCharacteristicItem>
  </CharacteristicItems>
```

Twin model stackup

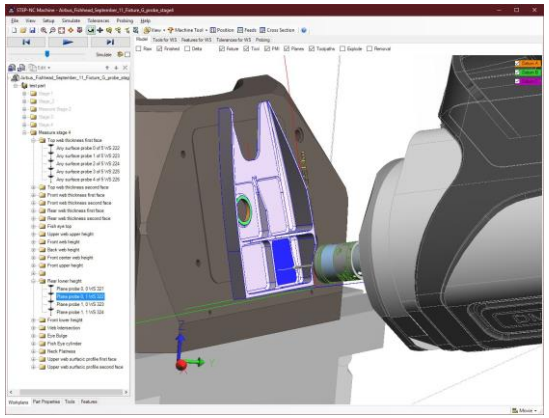


Task	23247 Use Case Reference	Completion Date	Completion %	Status
Define Use Case		16-Mar-20	100%	Complete
Document Use Case		22-Apr-20	100%	Complete
Author MBDs	PLM/ERP	14-May-20	100%	Complete
Export AP242 Nominals	User Entity	14-May-20	100%	Complete
Export QIF Plan	DCDCE	14-May-20	100%	Complete
Measure Parts (key-in)	OME	14-May-20	100%	Complete
Export QIF Measured Results	DCDCE	15-May-20	100%	Complete
Import QIF Measured Results	Core Entity	20-May-20	100%	Complete
Assemble AP242 Digital Twin	User Entity	20-May-20	100%	Complete
Revise Use Case	OME	30-Jun-20	100%	Complete
Receive Fabricated Parts		5-Aug-20		
Measure Parts (as-built)	OME	5-Aug-20		
Internal Rehearsal	OME	7-Aug-20		
Export QIF Measured Results	DCDCE	7-Aug-20		
Import QIF Measured Results	Core Entity	10-Aug-20		
Assemble AP242 Digital Twin	User Entity	14-Aug-20		
Evaluate As-built Digital Twin	PLM/ERP	28-Aug-20		Rehearsal

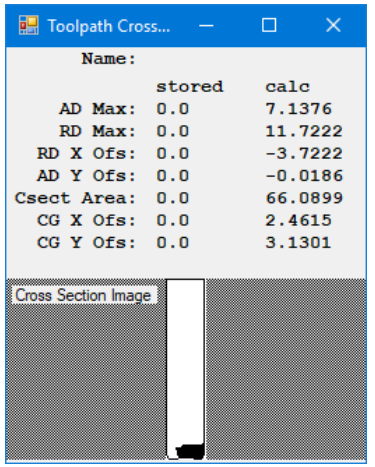
Use Case 3 – tool life optimization



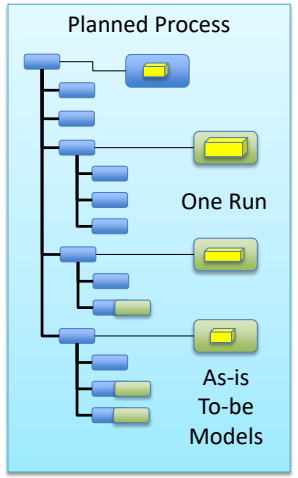
Machine parts

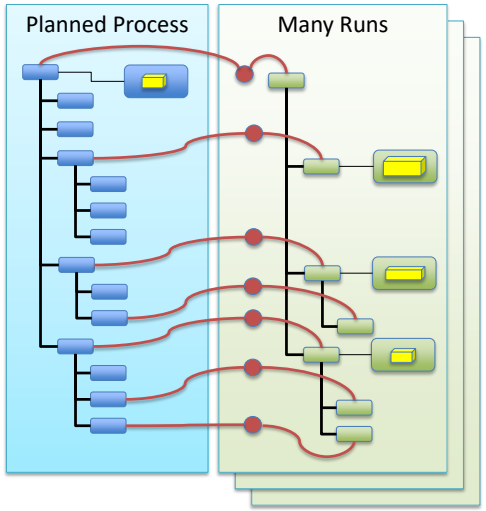


Monitor tool diameter



Compute tool engagement





Store linked data

OMAC

Machining Context Macros

Gcode ops

ANSI

MTConnect

Stream results

STEP Tools

STEP Agent

Apply Results

ISO

STEP-NC

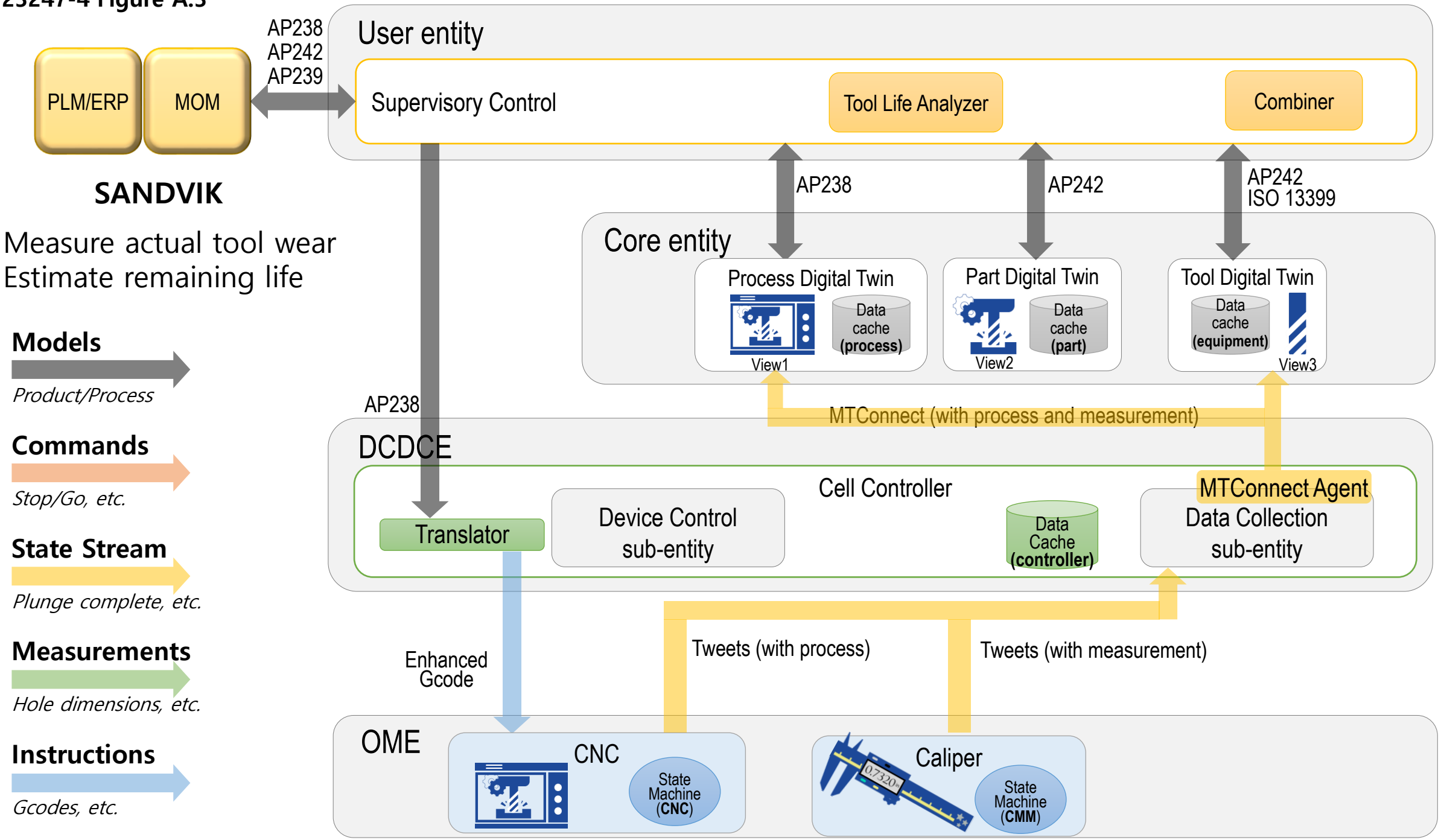
Twin model

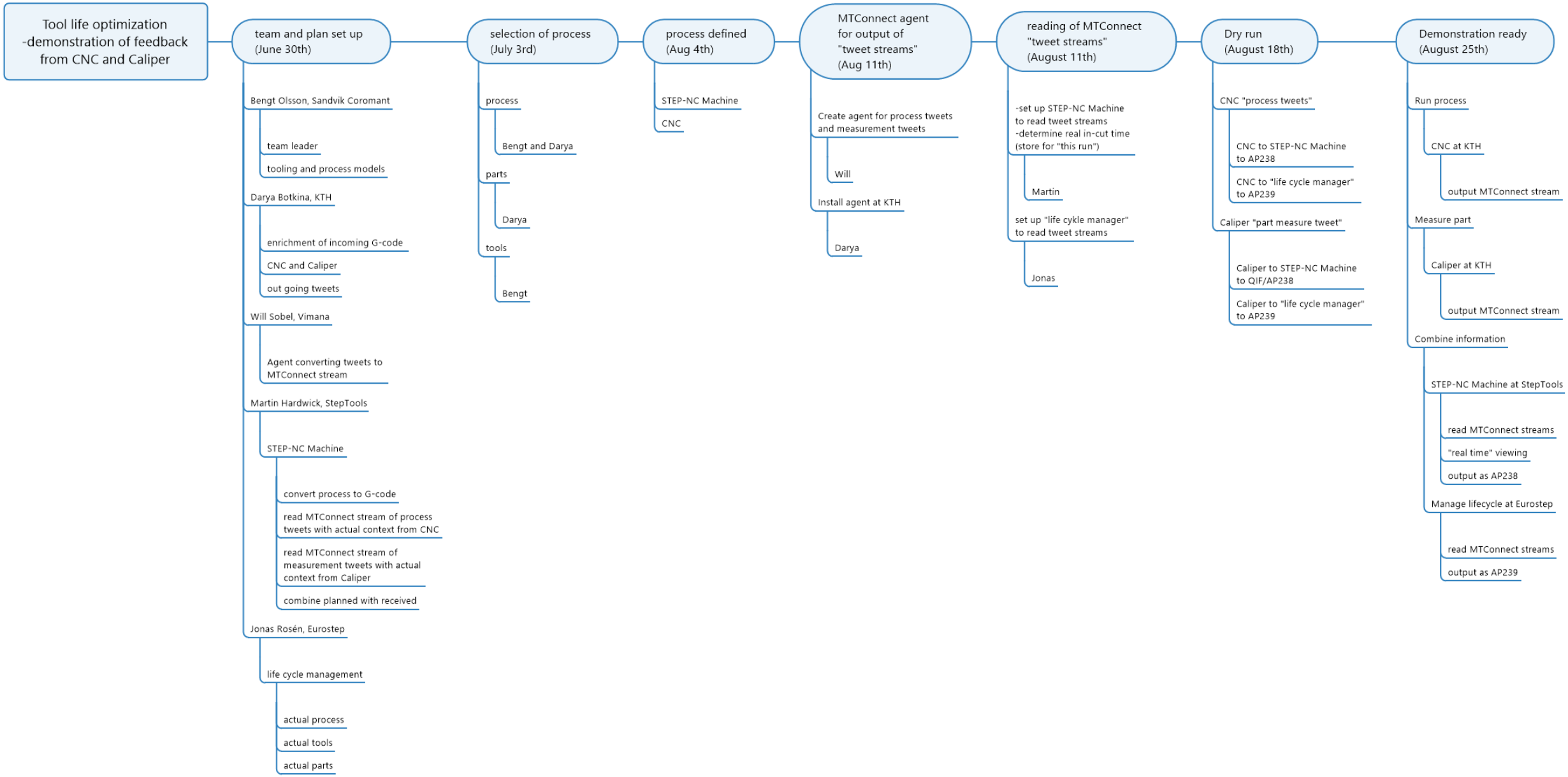
Tool life can increase by 15%

MQTT data

test_data = {"projectRelease":"empty","productID": "Boxy_3-Axis", "featureName":"empty","toolClass":"empty", "workingStepName":"OP 3 Fine Milling Datum D, E, F and G", "workingStepDescription":"empty", "programVersion":"empty","endofcycle":"empty","projectStatus":"empty", "workingStepType":"empty", "toolID":"a410aecc-cdd0-4cc4-890e-cdbbca53ee40", "productVersion":"empty","toolDescription":"empty","featureType":"empty", "workingStepID":"empty","operationID":"empty","operationType":"empty", "startofcycle":"2019-04-04 08:46:02.896","projectID":"empty", "programID":"Boxy_3-Axis_Machining_Setup_1.stpnc", "featureID":"empty","toolName":"empty"}

ISO 23247-4 Figure A.3




Tool life optimization
-demonstration of feedback
from CNC and Caliper
team and plan set up
(June 30th)
Bengt Olsson, Sandvik Coromant
team leader
tooling and process models
Darya Botkina, KTH
enrichment of incoming G-code
CNC and Caliper
out going tweets
Will Sobel, Vimana
Agent converting tweets to
MTConnect stream
Martin Hardwick, StepTools
STEP-NC Machine
convert process to G-code
read MTConnect stream of process
tweets with actual context from CNC
read MTConnect stream of
measurement tweets with actual
context from Caliper
combine planned with received
Jonas Rosén, Eurostep
life cycle management
actual process
actual tools
actual parts
selection of process
(July 3rd)
process
Bengt and Darya
parts
Darya
tools
Bengt
process defined
(Aug 4th)
STEP-NC Machine
CNC
MTConnect agent
for output of
"tweet streams"
(Aug 11th)
Create agent for process tweets
and measurement tweets
Will
Install agent at KTH
Darya
reading of MTConnect
"tweet streams"
(August 11th)
-set up STEP-NC Machine
to read tweet streams
-determine real in-cut time
(store for "this run")
Martin
set up "life cykle manager"
to read tweet streams
Jonas
Dry run
(August 18th)
CNC "process tweets"
CNC to STEP-NC Machine
to AP238
CNC to "life cycle manager"
to AP239
Caliper "part measure tweet"
Caliper to STEP-NC Machine
to QIF/AP238
Caliper to "life cycle manager"
to AP239
Demonstration ready
(August 25th)
Run process
CNC at KTH
output MTConnect stream
Measure part
Caliper at KTH
output MTConnect stream
Combine information
STEP-NC Machine at StepTools
read MTConnect streams
"real time" viewing
output as AP238
Manage lifecycle at Eurostep
read MTConnect streams
output as AP239

Proposed Demonstration Schedule

- September 1 – Dress rehearsal for Use Case 2 - **confirmed**
- September 8 – Dress rehearsal for Use Case 3
- September 15 – Dress rehearsal for Use Case 1
- September 22 – Final planning for public demonstration
- September 29 – One hour demonstration of the three use cases

Action items for next week

- Use Case 1
  - Test connections between from OME to DCDCE, and from DCDCE to CE using MTConnect Adapter and MTConnect Agent
  - Install software systems at University of Washington
- Use Case 2
  - Prepare for September 1 demonstration
- Use Case 3
  - Implement MTConnect Adapter for KTH Boxy machining data