

THE VALUE OF PERFORMANCE.
NORTHROP GRUMMAN

Transfer, Edit and View PMI Annotated Models Across Enterprises

October 26, 2016

Robb McCord

Northrop Grumman Mission Systems Overview

- Background
- Status of Model Based Design (MBD) Rollout to suppliers
- Goals of the supplier survey
- Distribution formats
- Product Manufacturing Information (PMI) mapping to the formats
- Results of the survey
- Conclusion and future actions needed

Northrop Grumman Missions Systems

- Mission Systems: recent merger of Electronic Systems and parts of Information Technology



AN/TPS-80 G/ATOR

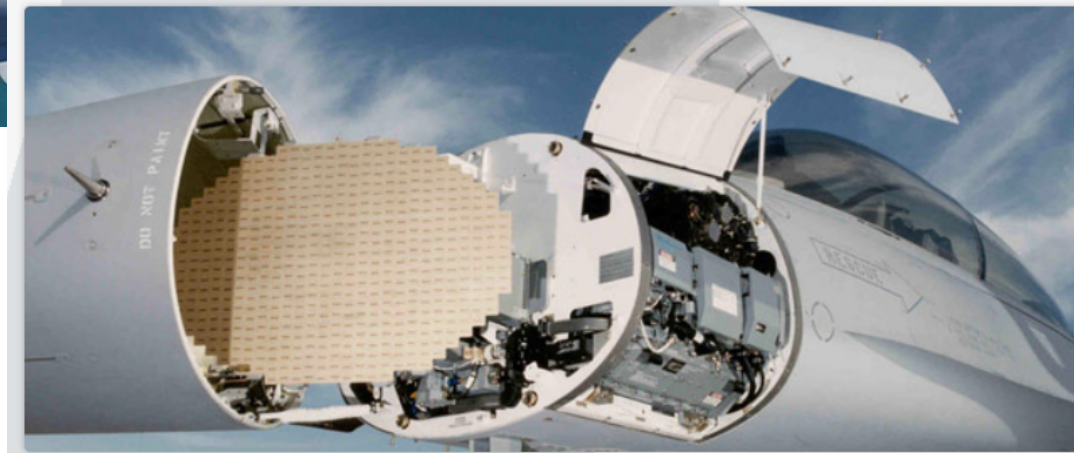


AN/APG-81 for the F-35

Multi-Role Electronically Scanned Array (MESA) Surveillance Radar

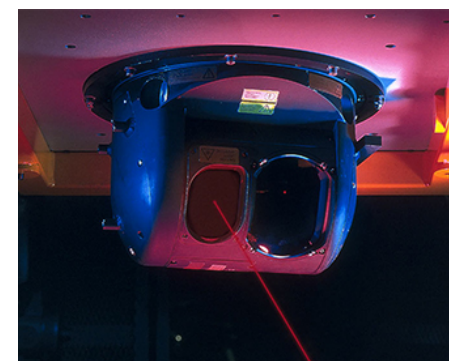


AN/APG-68(V)9 Multimode Fire Control Radar



Mission Systems Sector Today

- Leading global provider of secure software-defined, hardware-enabled mission systems
- \$10.7* billion sales in 2015
- 26,000 employees
- In all 50 U.S. states and 21 countries
- Pioneering capabilities in:
 - Full-Spectrum Cyber
 - End-to-End & Integrated C4ISR
 - Innovative Integrated Solutions
 - Mission Effectiveness from Undersea to Space and Cyberspace



US Air Force Photos

Mission-Enabling Solutions

Mission Systems

From Undersea to Outer space

Advanced Concepts & Technologies

Airborne C4ISR Systems Division

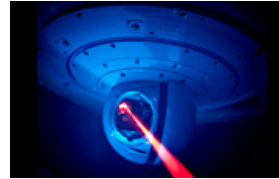
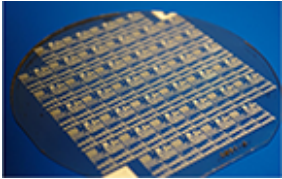
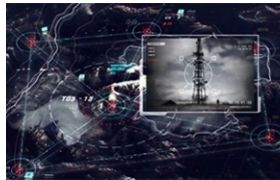
Cyber and Intelligence Mission Solutions Division

Land & Avionics C4ISR Division

Missile Defense and Protective Systems Division

Navigation and Maritime Systems Division

Space ISR Systems Division



- Cyber & Advanced Processing
- Surveillance & Targeting Sensors
- Multifunction Systems
- Integrated Solutions
- Transformational Computing
- Advanced Microelectronics

- Fire Control Systems
- Surveillance Systems
- Electro Optical Systems
- Targeting Systems
- Communications
- SIGINT Systems
- Air C2 & Airborne ISR
- Electronic Attack
- Targeting and Weapon Planning

- Intelligence Acquisition & Analytics
- Cyber Resiliency
- Cyber Defense
- Cyber/Non-Kinetic Operations
- Intelligence Enterprise

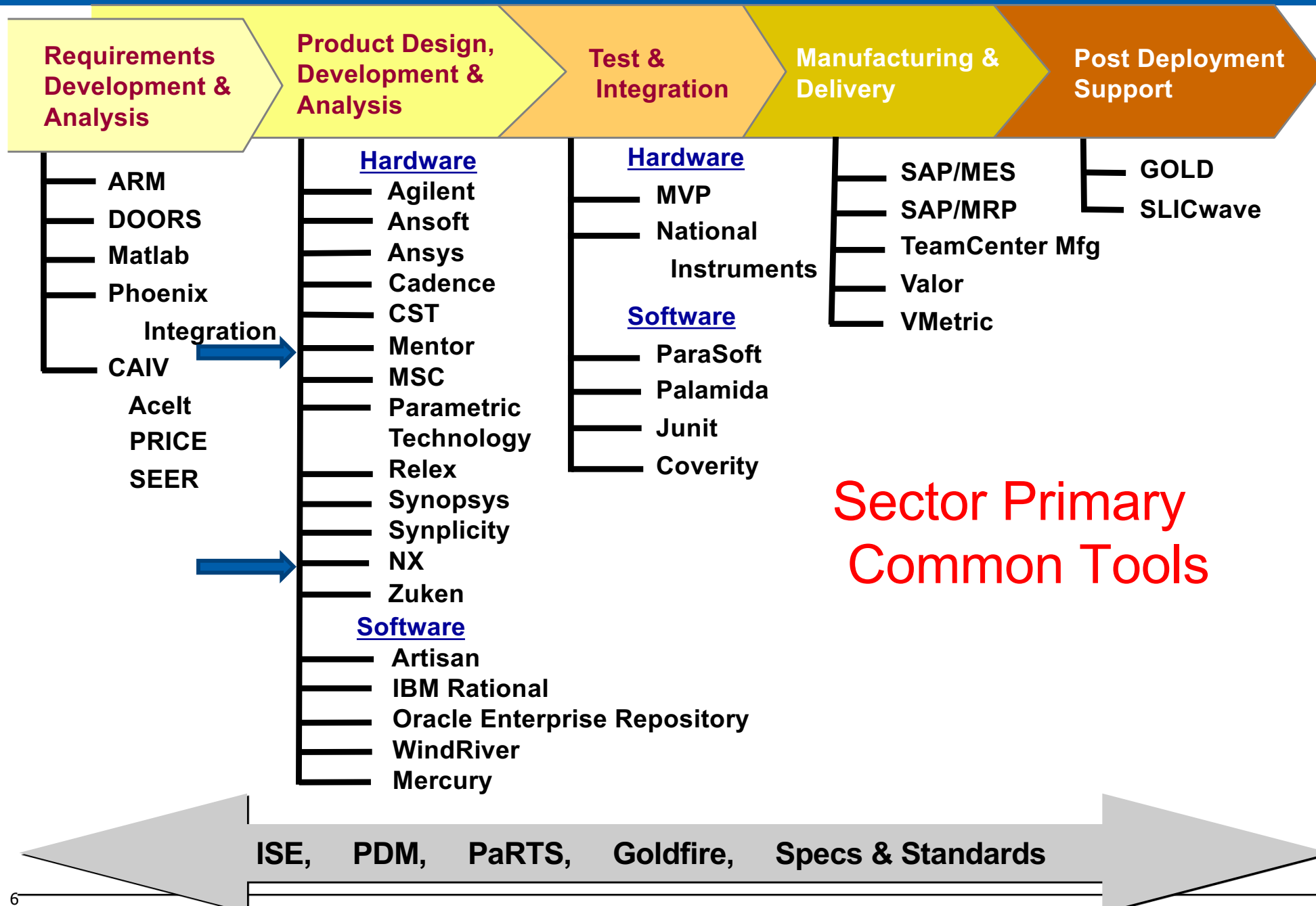
- Integrated Aircraft Survivability Equipment
- Multi-Spectral Electronic Warfare Systems
- Integrated Avionics Suites
- C2 ERP Systems
- Global Mission Solutions

- C2 for Missile Defense, IAMD, Nuclear Systems and Land Forces
- Strategic Ground Systems
- BMDS Integration, Testing Training, and Readiness Support
- Integrated Fires
- Civil Aviation Planning and ATC
- Civil C2 for Emergency Responders

- Propulsion & Power Systems
- Cold Launch
- Maritime Electronic Warfare & Radars
- Maritime C2
- Machinery Control Systems
- Undersea Sensors & Solutions
- Navigation & Positioning Systems
- International Navigation & Pointing Solutions

- Restricted Programs
- RF Systems
- EO/IR Solutions
- Ground Enterprise
- SSA & Space Operations
- Environmental Solutions
- Integrated Solutions
- Space C2
- Exploitation Processing
- OPIR/SIGINT/GEOINT

Missions Systems: Common Tools

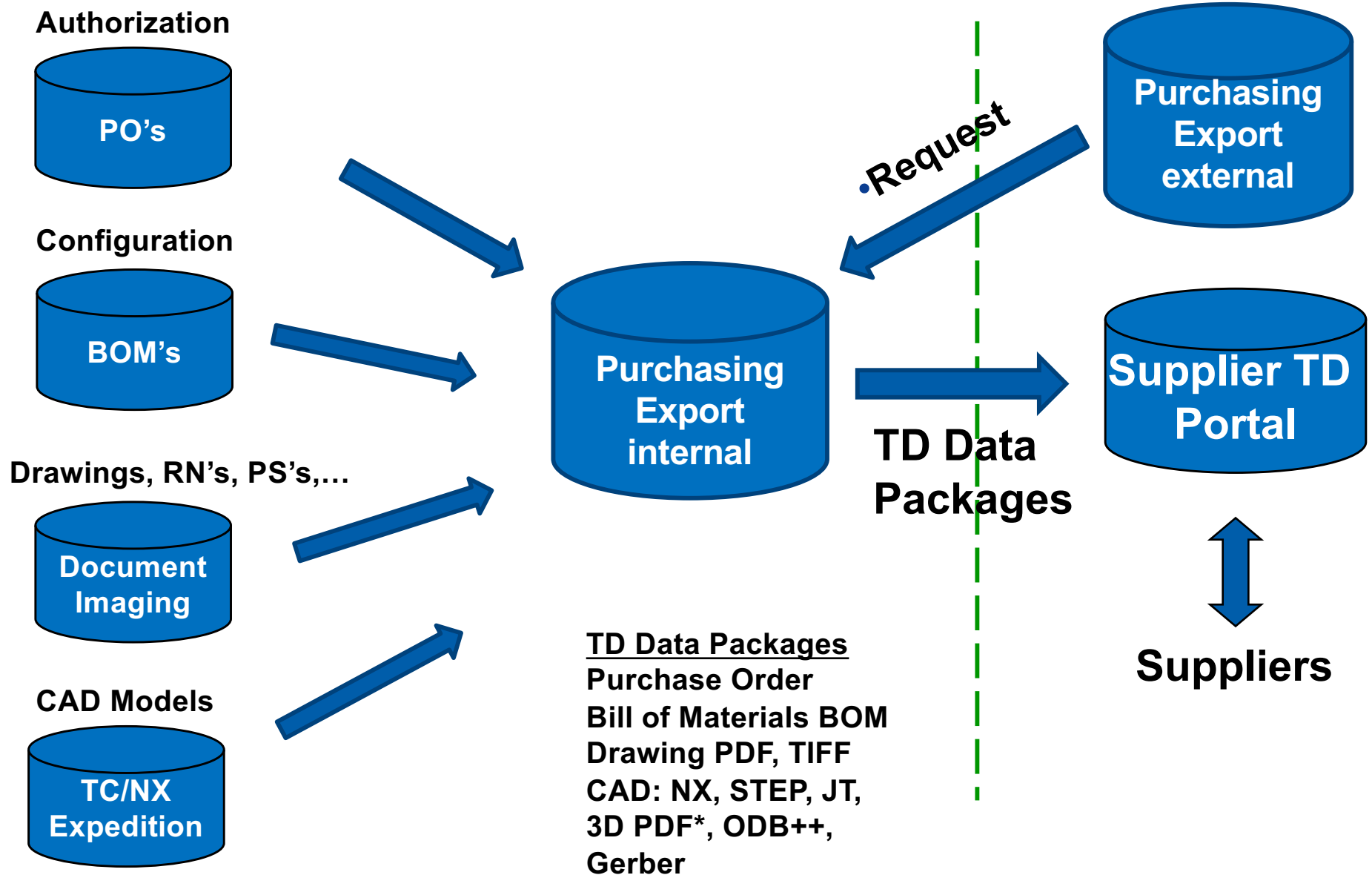


Background

- NGMS utilizes several 100 suppliers to make and assembly mechanical parts
- We have tested MBD and are implementing internally in TC/NX but have only tested with NX based suppliers
- Production Supplier data systems already distributes formats that should convey the PMI
- In this context MBD means:
 - When accompanied with the associated list (parts list), the model shall provide the design, engineering, manufacturing and quality support information necessary to permit a competent manufacturer to produce an interchangeable item which duplicates the physical and performance characteristics of the original design without additional information from design engineering
- PMI Includes : datums, geometric dimensioning and tolerancing, 3D annotations, surface texture specifications, finish requirements, process notes, material specifications, welding symbols and other

- Determine if current production supplier technical data (TD) process conveys PMI data and how well
- Determine quality of the data transfer between design and manufacturing systems and overall supplier readiness to utilize models with PMI
 - Estimating
 - CAD modelling
 - NC programming
 - Inspection
- Focus on non-NX suppliers but include several so group is “representative”
- Baseline for suppliers: “not a test for future work”
- Recommendations for supplier TD process to better transmit MBD data

Current production TD system for suppliers



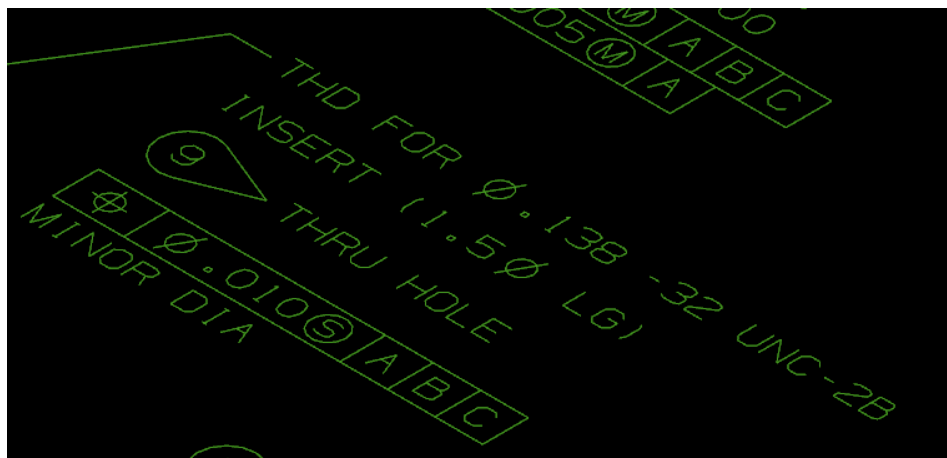
* In process

- Stability of the PMI application within NX – NX10 deployment 9/26 should resolve most
- Create and control JT's upon model release for internal and suppliers – in production
- Outcome of internal Feature Based Manufacturing initiative – pending
- Cultural change
 - Engineering acceptance and adoption – in progress
 - **Supplier acceptance and capability – in progress**
- Broad requirement for Customer TDP deliveries
 - Customers MBD intentions/direction clear
 - Have not filtered down into many actual contract deliverables at this time

Formats Used for Survey

- Siemens NX 10.0.3 native (proprietary) Design Authority
- JT – monolithic for assemblies, with precise geometry, JT V10 (ISO) (Derivative)
- STEP AP203 (ISO) (Derivative)
- 3D PDF - Theorem Solutions PRC (ISO) (Derivative but standalone, ie, no further translation required for viewing)
- Presentation in above generally adheres to ASME Y14.41-2003
- Two methods for displaying PMI in derivative formats
 - Polylines – “Presentation”: suitable for display and human interpretation
 - Semantic - “Representation”: includes annotation structure, associations and definitions, suitable for toolpath and inspection automations

- STEP: polyline only (annotation_occurrence step object with basic smarts such as type and face associativity), NX 11 starts Semantic support.
 - Challenge: STEP definition not fully formed for Semantic (ex: placement plane, leader attachment and jog not supported)
- JT: Combination of polyline and semantic but full semantic for Siemens products read, but read only polyline for JT2Go
- 3D PDF:
 - Solids: PRC format with tessellated (approximate) or precise BREP solid
 - PMI: poly-line representation

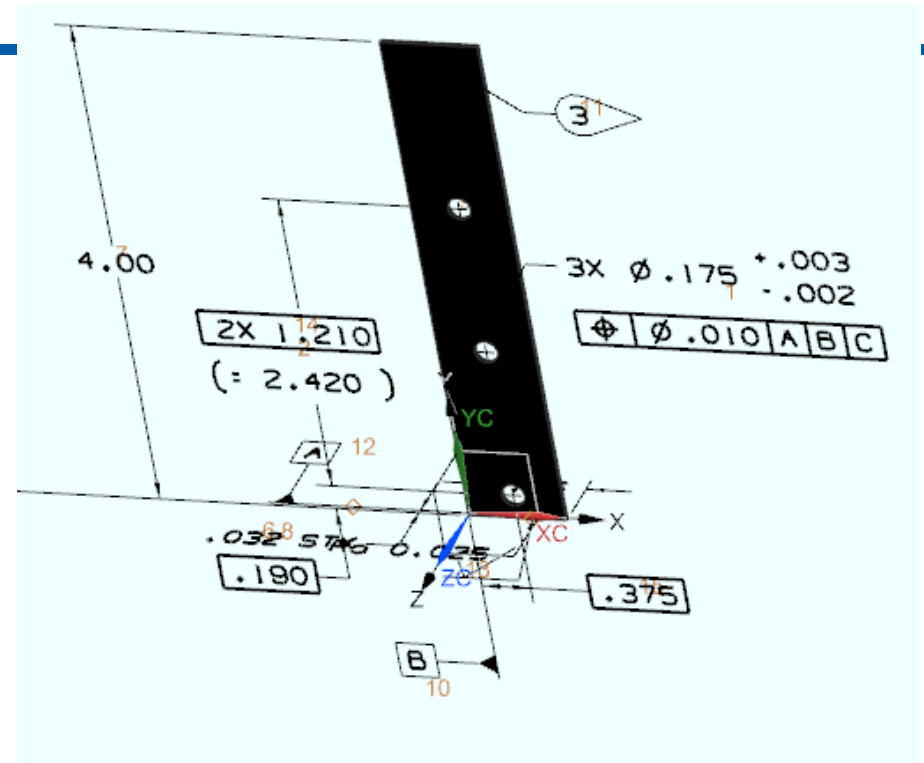


Input: PMI radial dimension, PMI balloon note, PMI feature control frame

Output: Lines, ie, limited automation possible

Sample Model 1

- 8 PMI dimensions
 - 5 PMI linear, 1 simple PMI radial, 2 radial with Control Features Frames (CFF), datums
 - Custom Symbols (teardrop, Datum, center mark)
- Title block view
- Annotation – single and multiline
- Export Control Statement (Not export controlled data)
- Not an assembly



NOTES

1 UNLESS OTHERWISE SPECIFIED:

TOLERANCES APPLY WITH DATUM **A** RESTRAINED AGAINST A FLAT SURFACE.

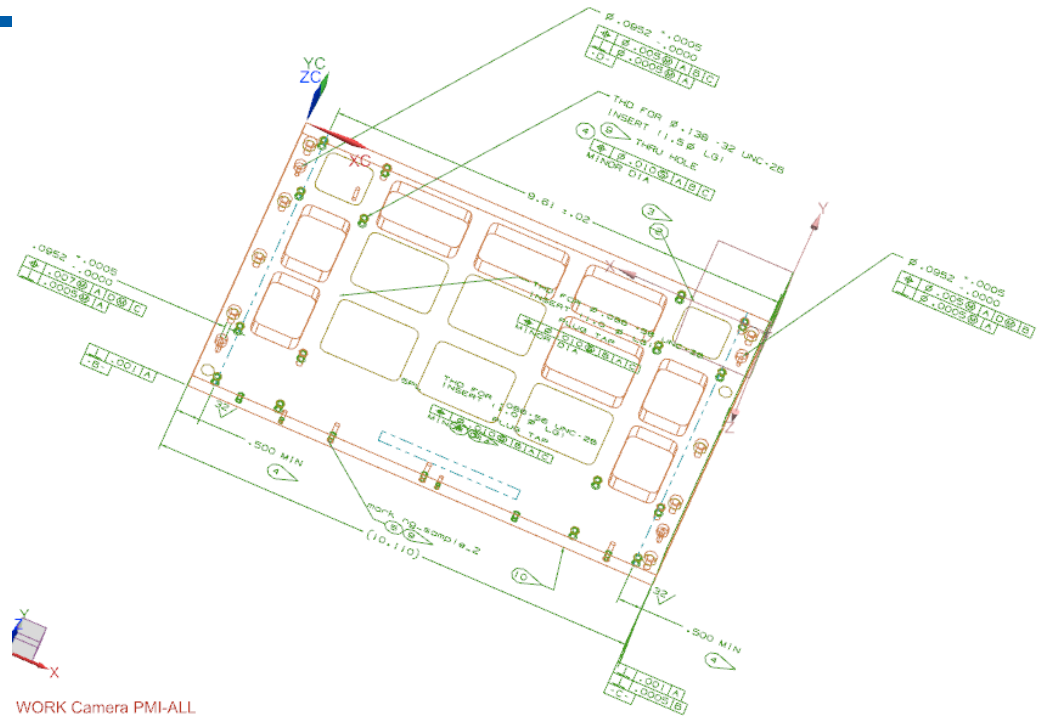
BREAK ALL SHARP CORNERS AND EDGES R.03 MAX OR CHAMFER .02 X .02 MAX.

2 MARK "ng-sample-1, MFR-". WHERE "XXX" IS THE THREE DIGIT NUMBER THAT COMPLETES THE PART NUMBER, ON A LABEL OR TAG WHICH MEETS THE LEGIBILITY AND DURABILITY REQUIREMENTS OF FN 100, AND ATTACH TO THE CONTAINER IN WHICH THE PART IS SHIPPED. MARK MANUFACTURER'S CAGE CODE IN SPACE AFTER "MFR-".

3 PSA LOCATED ON FAR SIDE.

Sample Model 2

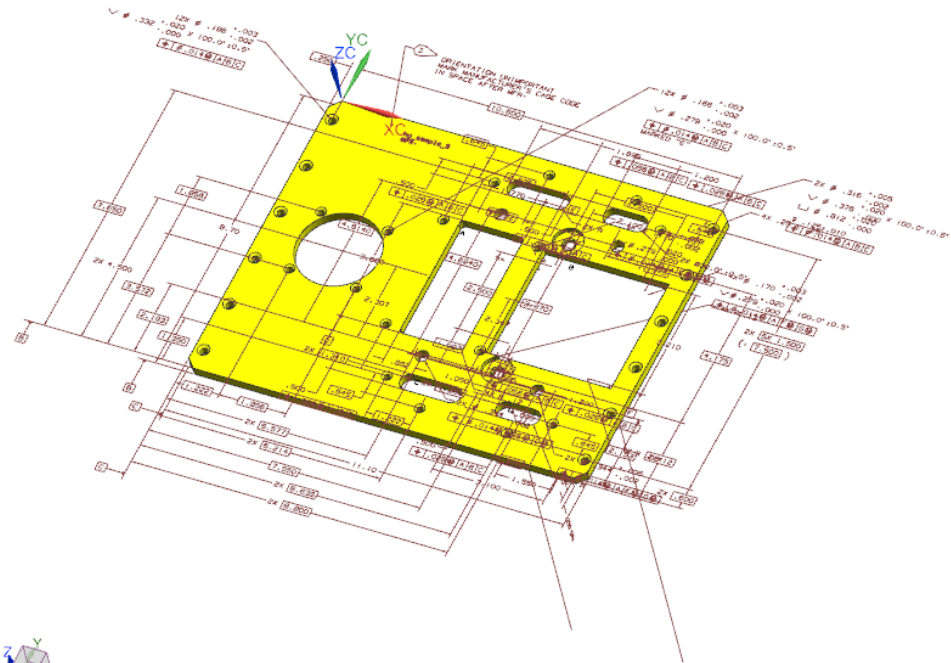
- 11 PMI dimensions
 - 7 PMI linear (1 with control feature frames),
 - 4 PMI radial with CFF, datums
- Custom Symbols (teardrop)
- Title block view
- Annotation – single and multiline
- Export Control Statement (Not export controlled data)



- 1 THIS DRAWING IS TO BE USED IN CONJUNCTION WITH GEOMETRIC DATA OF THE SAME REVISION STORED IN THE RELEASED CAD MODEL: ng-sample-2
- 2 UNLESS OTHERWISE SPECIFIED:
TOLERANCES PER FN 100 PROCEDURE C APPLY.
BREAK SHARP CORNERS AND EDGES R.010 MAX OR CHAMFER .010 X .010 MAX.
- 3 CHROMATE PER FN 109.
- 4 FINISH ENTIRE SURFACES AS INDICATED.
- 5 FOR G01 ONLY:
WELD FN 3 TO FN 1 PER FN 102 CLASS C USING FN 112.
- 6 MACHINE PER FN 103.
- 7 FOR G03 ONLY:
SOLUTION HEAT TREAT AND AGE TREAT PER FN 104. IF ALTERNATE METHOD OF HEAT TREATMENT IS USED, ONLY A WATER OR WATER/GLYCOL QUENCH IS ALLOWED AND 6061-T6 PROPERTIES ARE REQUIRED.
- 8 STRESS RELIEF PER FN 105. MAY BE USED TO STABILIZE ASSEMBLY DURING MACHINING.
- 9 INSTALL HELICAL COIL PER FN 107.
- 10 MARK PER FN 101, APPROXIMATELY AS SHOWN.
- 11 VACUUM BRAZE FN 8 TO FN 7. BRAZE PER FN 110. CLASS C, USING FN 111. THE USE OF FLUX IS NOT PERMITTED AND THE ATMOSPHERE SHALL BE A VACUUM AT 9 X 10 MM HG OR LESS AT BRAZING TEMPERATURE.
- 12 TEST COMPLETED ASSEMBLY PER FN 113.
- 13 PRIOR TO BRAZING, CLEAN FN 7 AND FN 8 PER FN 114.
- 14 SEAL OFF THE COOLANT PASSAGES TO PREVENT SOLUTION ENTRANCE PRIOR TO NOTE 3.

Sample Model 3

- 74 PMI dimensions
 - 60 PMI linear, 14 PMI radial with CFF
- Custom Symbols (teardrop, Datum, Center Mark)
- Title block view
- Annotation – single and multiline
- Export Control Statement (Not export controlled data)



MBD-ALL WORK Camera MBD-ALLS3

NOTES

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TOLERANCES APPLY WITH \boxed{A} RESTRAINED AGAINST A FLAT SURFACE.

BREAK ALL SHARP CORNERS AND EDGES R.03 MAX OR CHAMFER .02 X .02 MAX.

INTERNAL CORNERS SHOWN SHARP SHALL HAVE A RADIUS OF .005 MAX.

MACHINED SURFACES SHALL HAVE A ROUGHNESS AVERAGE OF $\sqrt{.03}$.

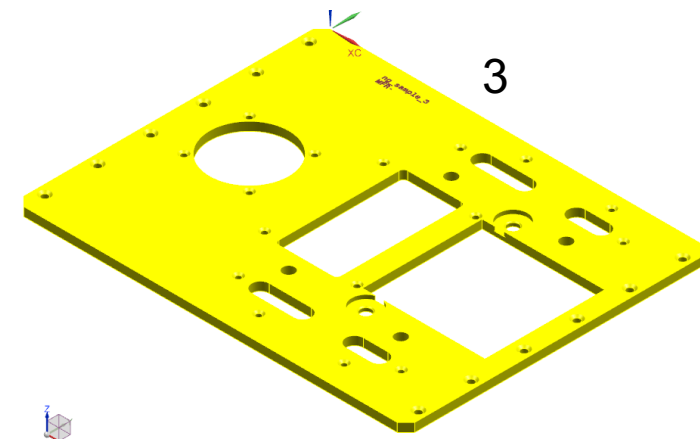
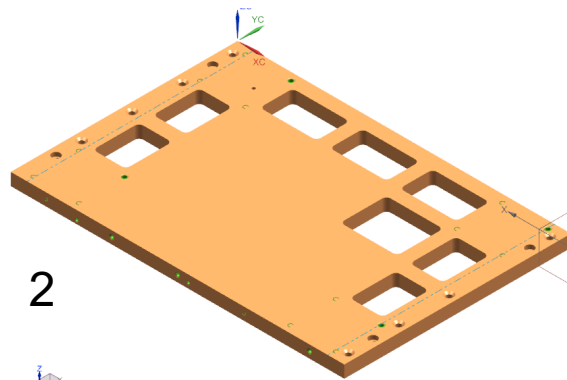
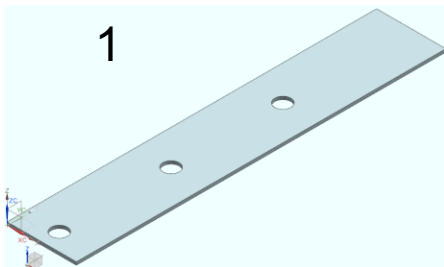
2 CHROMATE COAT PER FN 201.

3 MARK PER FN 200 APPROX AS SHOWN. USE OF A LABEL IN

D-NOTES WORK Camera MBD-ALLS3

Sample Models and Survey Format

- Modelled in NX10
- Based on NG design but not “real” data (removes protection burden)
- 3 samples – simple, medium, complex
- Provided in 4 formats
 - NX10 proprietary and the 3 ISO formats discussed
 - Provided thru the production Purchasing Export system with 3d PDF added
- Survey for each of 3 datasets:
 - 1 thru 5 conversion quality and usefulness section
 - Key functionality section
 - Not “rigorously scientific”



Translation Quality Section

How well do the test data sets translate into the target systems

Translation

Rate how well each format translated into systems listed below. Use a scale of 5 (translated perfectly) to 1 (did not translate at all). Example: If the STEP file translated well into your CAD system you would put a 5 under CAD system for the STEP file. If the JT file was not viewable on any Office system then you would rate that a 1. If some of the PMI translated but not all or if the appearance has been changed on a significant amount of the annotation you might rate that a 3 (judgement call).

	Office Systems	CAD system	CAM system	Inspection system
JT	___ 2 ___	___ 3 ___	___ 3 ___	___ 1 ___
3D PDF	___ 5 ___	___ 1 ___	___ 1 ___	___ 1 ___
STEP	___ 1 ___	___ 5 ___	___ 5 ___	___ 2 ___
NX	___ 1 ___	___ 5 ___	___ 5 ___	___ 1 ___

Key functionality section

How well do the test data sets this function or process

- Can you navigate to PMI model views
- Did you have to acknowledge export warning
- Develop N/C
- Inspection process
- Develop work instructions
- Pricing/Office use
- Future N/C Automation use
- Preferred future format

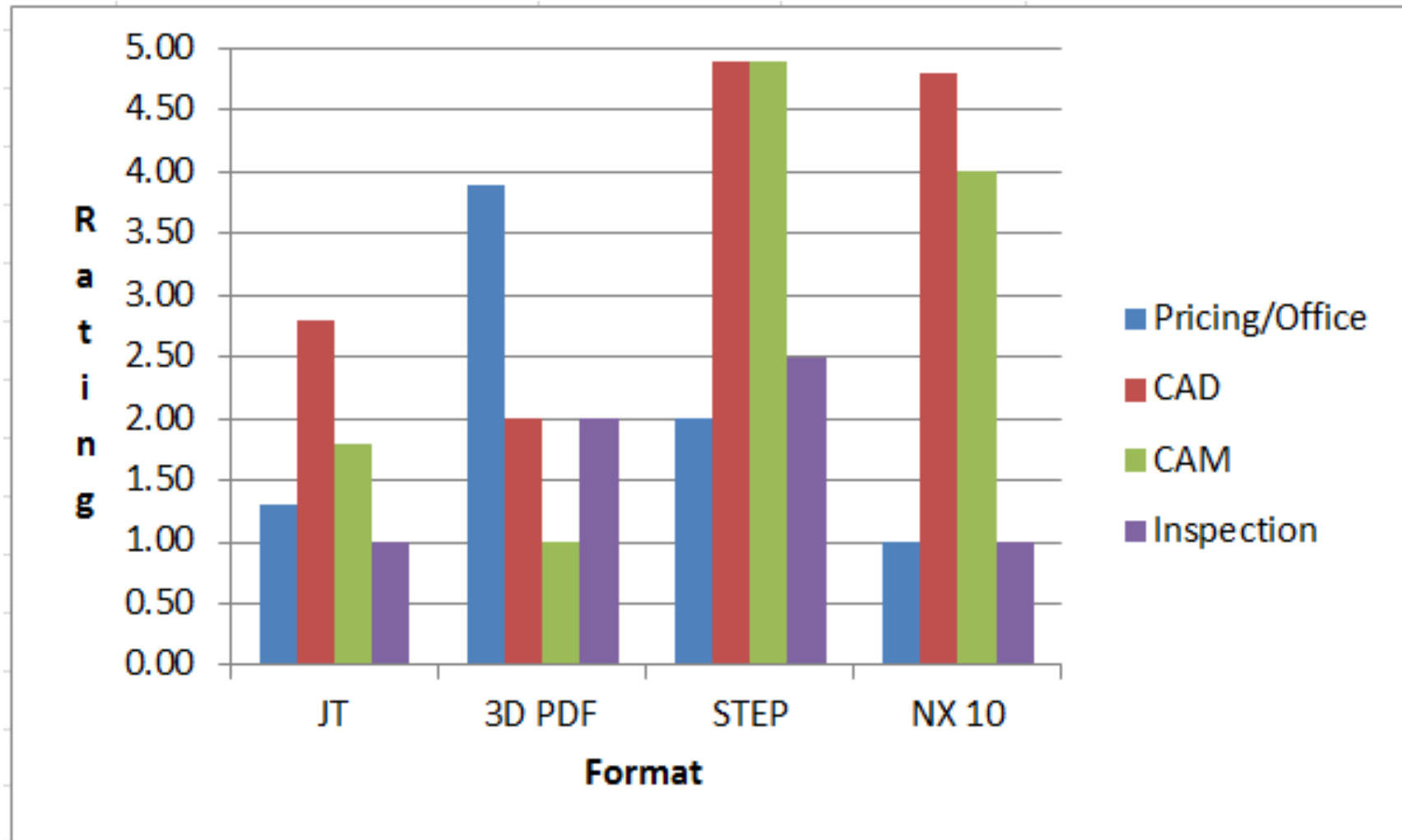
PMI model views

Model Views	
✓	"Back"
✓	"Bottom"
✓	"Front"
✓	"Isometric"
✓	"Left"
+ ✓	"MBD-ALL"
+ ✓	"MBD-BLOCK TOLERANCES"
+ ✓	"MBD-Front"
+ ✓	"MBD-LEGAL"
+ ✓	"MBD-NOTES"
+ ✓	"MBD-TITLE BLOCK" (Work)
+ ✓	"MBD-Top"
✓	"Right"
✓	"Top"
✓	"Trimetric"

Software in Conversion Test

- Office: MS Office, Adobe , Jt2go, Epicor V9, Autovue, E2 7.2
- CAD: Mastercam X9, NX9, NX10,
- CAM: Mastercam X9, NX10
- Inspection: PCDMIS V16, Calypso V2015, MCOSMOS

Survey Results Conversion Quality 1



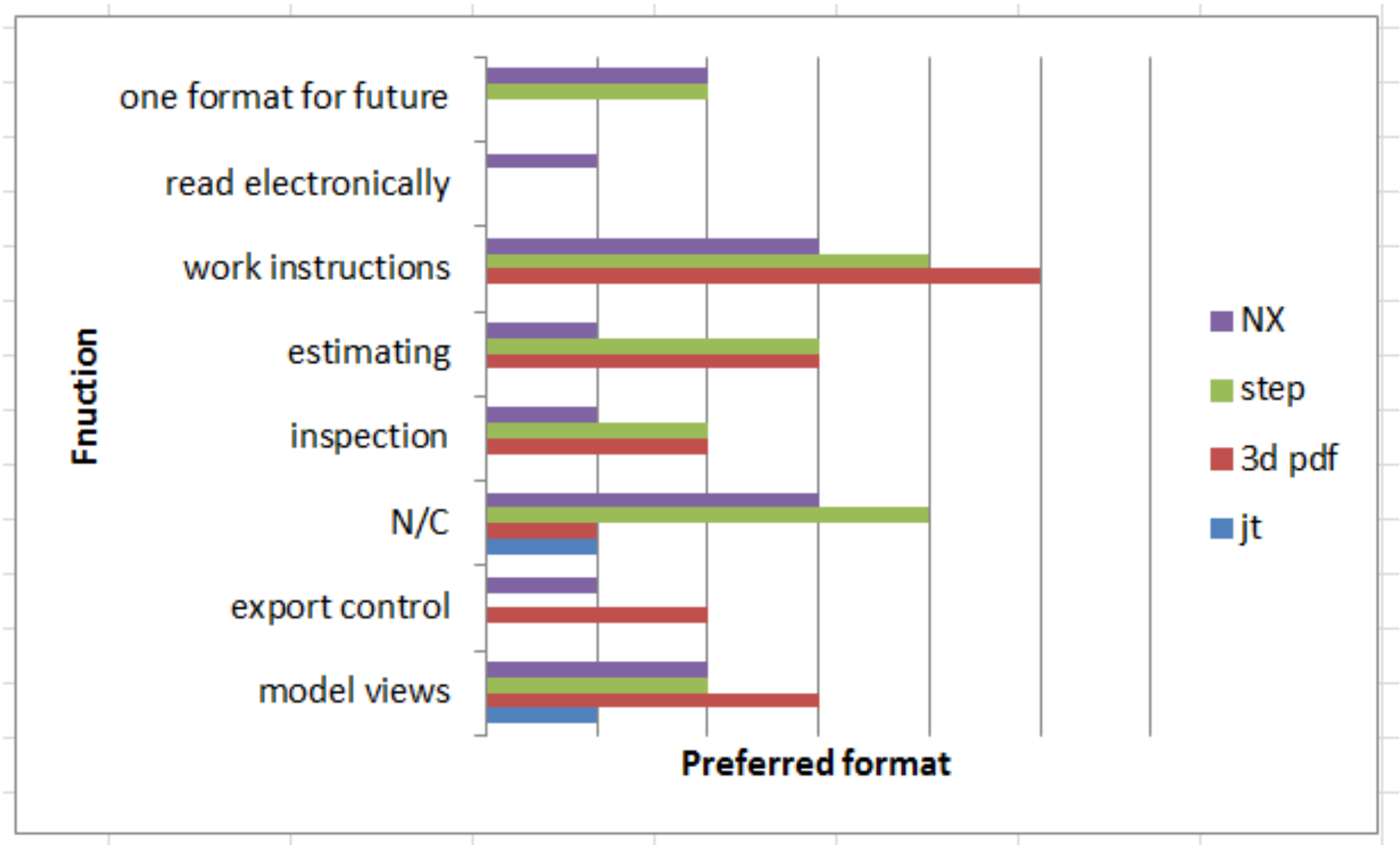
Ratings Key: 1 = no use / bad conversion
5 = most useful / best conversion

Survey Results Conversion Quality 2

FUNCTION	JT	3D PDF	STEP	NX 10
Pricing/Office	1.30	3.90	2.00	1.00
CAD	2.80	2.00	4.90	4.80
CAM	1.80	1.00	4.90	4.00
Inspection	1.00	2.00	2.50	1.00

- STEP AP 203 was the best overall translatable format for the suppliers, followed by NX
- JT was the worst format for conversions to the suppliers systems
- As projected, 3D PDF was rated high for Office and non-CAD users
- STEP and NX were rated highest for CAD modelling and CAM N/C functions.
- Inspection systems saw the worst conversions

Survey Results Key Functionality

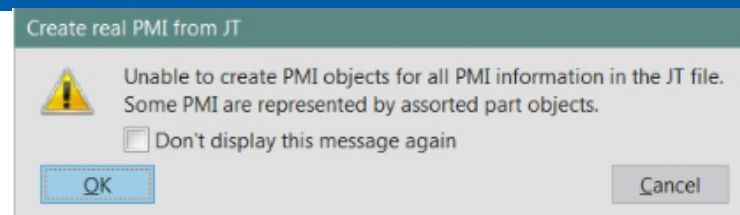


No formats conveyed functionality well enough to be preferred over others
In only 2 of 8 functions were all formats even listed as being partially usable

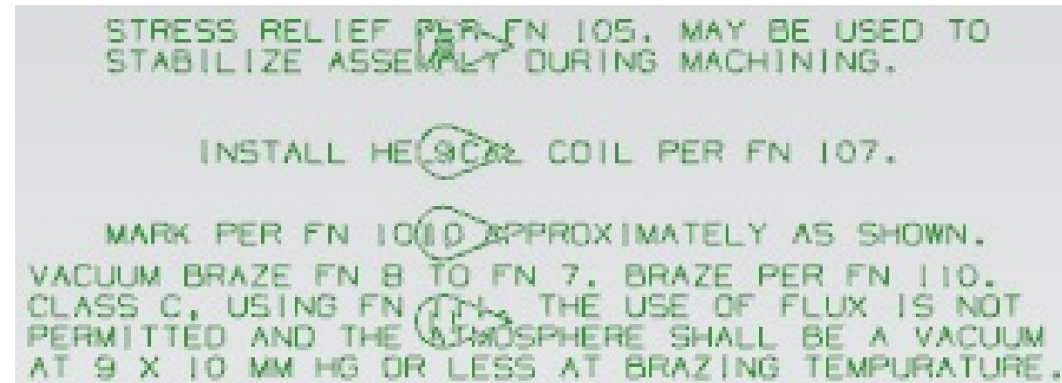
Typical Issues

- Surprise
 - JT to NX issues
 - NX10 to NX10 issues
- 3rd Party NX to XX direct converters (Mastercam)
 - Mostly choked on PMI objects
- All PMI objects reduced to polylines in the receiving system (except NX to NX)
- Some illegibility's in STEP and NX to Mastercam X9 (retested in 2017 with same results)

Jt to NX



NX to NX



Step to Mastercam X9 typical notes

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NX

3 PSA LOCATED

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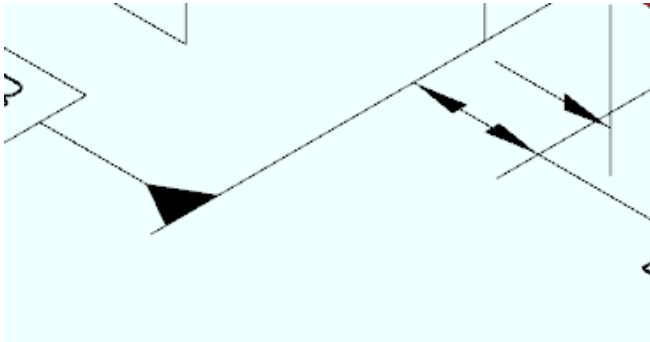
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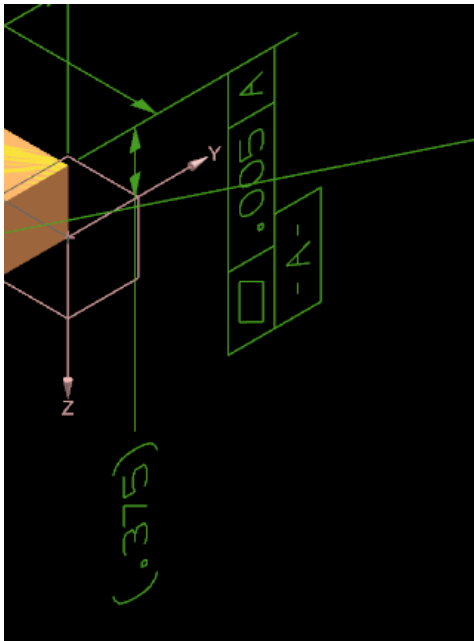
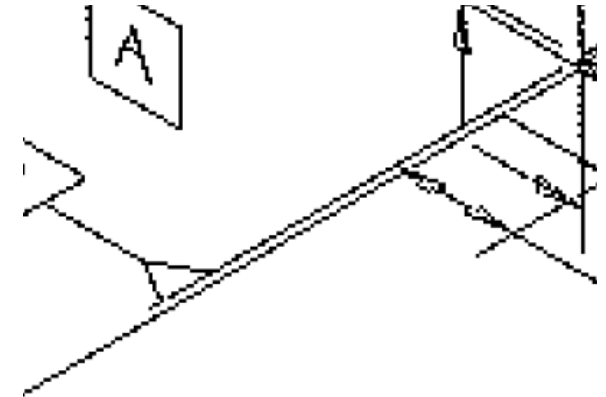
Mastercam X9

Ng_sample_1

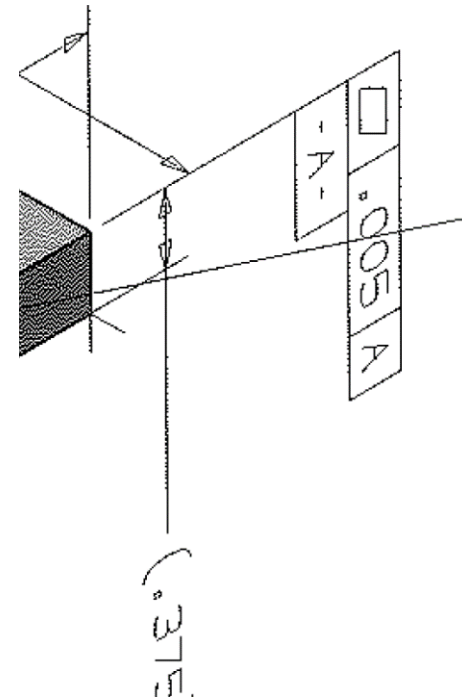
STEP to Mastercam and Autovue typical



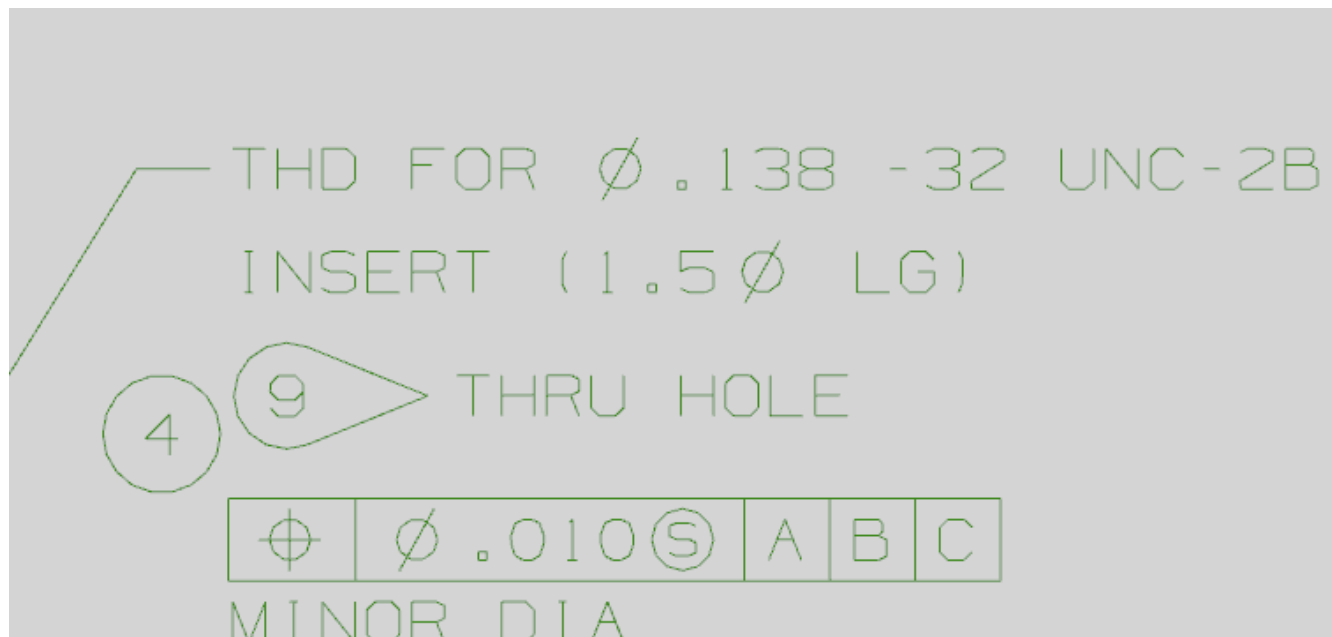
NX or STEP to Mastercam and Autovue. Lose datum and dimension shape fill



STEP to Mastercam 2017. Some CFF's mirrored

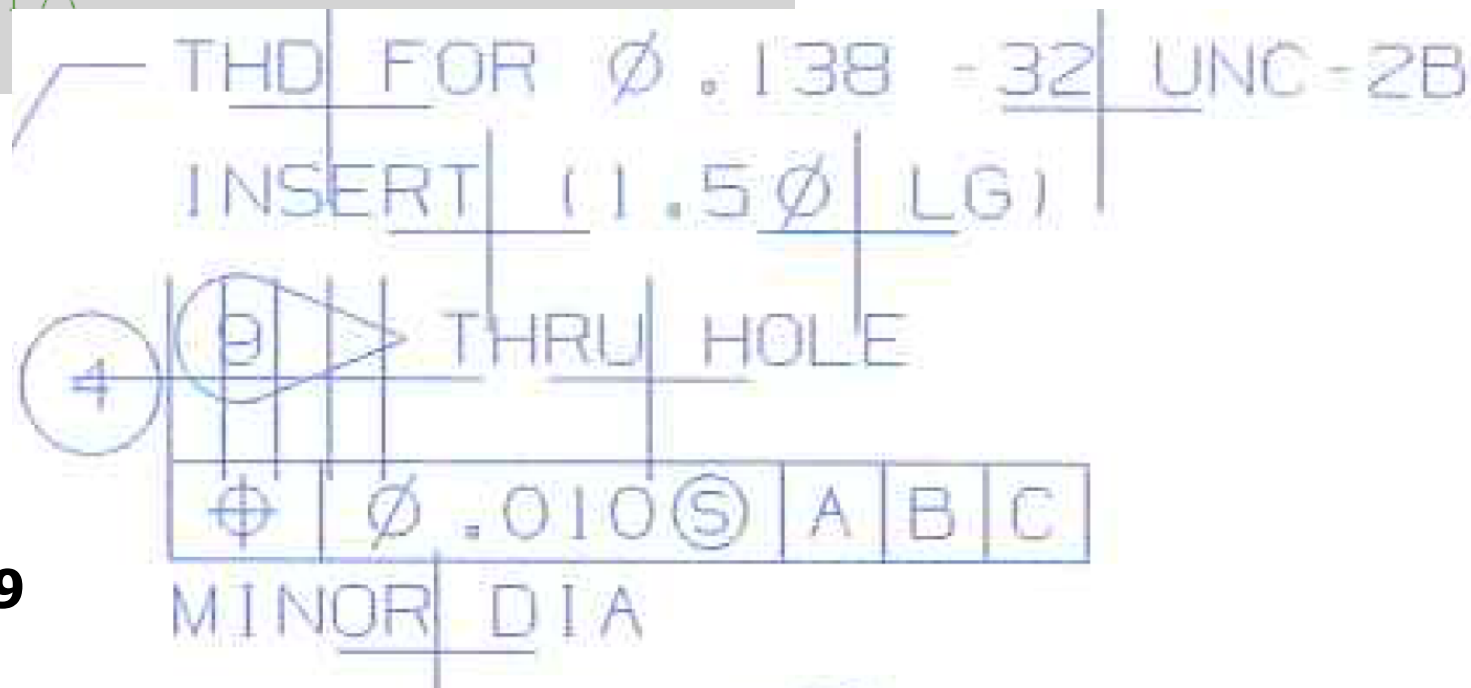


Step to Mastercam Labels and CFF's



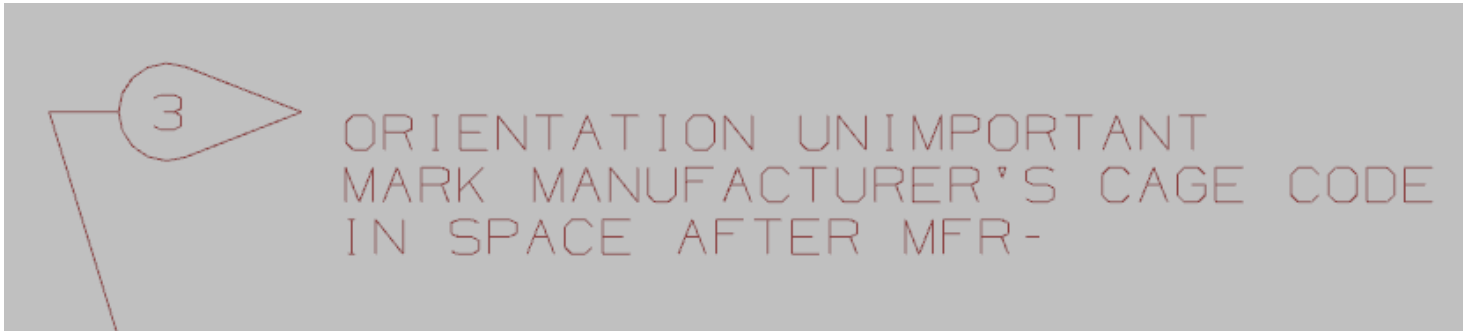
NX

Ng_sample_2



Mastercam X9

NX Native to Mastercam – numerous illegibility's (fixable with some editing)



NX



Mastercam X9

- STEP and NX convey the most complete and accurate PMI depiction to the suppliers of the translatable formats.
- Suppliers are generally familiar with STEP and NX but not with JT or 3D PDF
- Mastercam is a huge partner of ours and we didn't even know it.
- 3D PDF is unique in that it is non-translatable and non-editable but can be viewed at all supplier process levels with tools they already have
- Presentation vs. Representation:
 - Key components of PMI Representation are lost in the translation to the Presentation mode that the step translation reduces it to, such as: annotation structure, geometry associations, etc.
- Edit ability of translated PMI generally available but crude (except native NX)

Conclusions

- Current production supplier technical data (TD) process does convey PMI data with the CAD models that converts with variable quality into suppliers systems.
 - All polyline representations only with considerable quality issues
 - Only NX retains intelligence of the PMI and even with NX to NX there were presentation issues
- Majority of suppliers could estimate and manufacture the 3 sample parts but all agreed more complex parts may present unforeseen problems
- Inspection systems in use generally do not convert any of the formats (except 3d PDF as noted) so operate in an “inspect to print” mode.
- The only two CAM systems in use by suppliers polled are NX CAM and Mastercam X9 and 2017
- Many suppliers are using Mastercam direct NX conversion capability and non-Siemens translation of NX has historically been error prone.
- Limited, if any, automation possible based on the stroked representation of the PMI in the formats other than NX

Future Actions Needed

- Full Mastercam 2017 translators evaluation (STEP and direct NX conversions)
 - Engage with CNC Software Inc. through NIST/PDES Inc. CaX Implementor initiatives to improve and move towards semantic translations
- Inspection – better translation of PMI objects to PCDMIS V16, Zeiss Calypso V2015 and MCOSMOS to facilitate automation
- Further future – semantic conversions (after required standards development and vendor implementation in software)
- Implement 3d PDF in production supplier data packages
 - Most intact human consumable format across suppliers processes
- Assessment: STEP standard and software development required for full assembly level semantic PMI interoperability is in its infancy and will be years before full functionality is achieved – CAD vendors are on board but CAM and niche vendors are lagging.

- One Sentence Summary: PMI annotation required to support MBD practices can be transferred between systems in an enterprise in either the Design Authority or derivative formats but the current state of the art of the translation of the derivatives only yield cosmetically flawed polyline presentations good for human consumption and not useful for MBD automation.
- Robb McCord robb.mccord@ngc.com