Model Quality – Modeling Methods Refinement to Improve Data Consumption

GLOBAL PRODUCT DATA

INTEROPERABILITY

SUMMIT 2025

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RTX Corporation, Technology & Global Engineering (T&GE) Group

Abstract & Presenter Bio

Abstract: In the future state of the MB-DMI process, RTX plans to implement interoperable data standards to connect data flows across all phases of the product lifecycle, thereby building the digital thread. Standards such as ISO 23952 Quality Information Framework (QIF) and ISO 10303 Standard for the Exchange of Product model data (STEP) are essential for integrating CAx applications as the product transitions from engineering to manufacturing for development and production.

This model quality project aims to evaluate the reusability of Geometric Dimensions & Tolerances (GD&T) Product Manufacturing Information (PMI) data in the QIF standard format, translated from native Computer-Aided Design (CAD) formats, to enable automation in Computer-Aided Inspection (CAI) applications. Fundamentally, the translated parametric PMI data in QIF depends on the quality of the source semantic data created in the native CAD model.

Test models were created using major CAD applications and translated into several leading Coordinate Measuring Machine (CMM) applications for QIF parametric data consumption. PMI modeling methods were refined in CAD applications to address the major findings from the initial test results. These improvements in PMI modeling methods led to an increase in MBD data import, which automates the features and characteristics creation in CMM programming process, reducing cycle time significantly today.

Samuel Yang

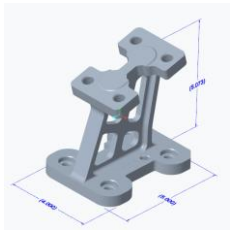
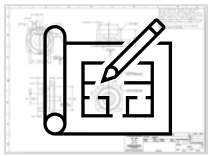
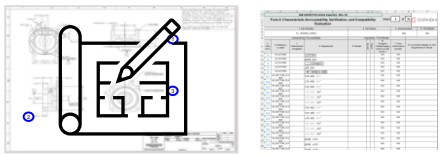
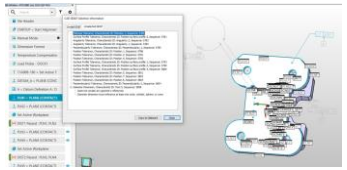
Samuel Yang is a Sr Principal Engineer at Model-Based Digital Thread Process Capability Center (MBDT-PCC) within RTX Corporate Technology & Global Engineering (T&GE) group. He is currently developing digital thread capabilities to enable MB-DMI and to capture insights from existing production data for design producibility assessment. Prior to MBDT-PCC, he has 18 years of design and test engineering experience in space propulsion.

Agenda

- **Motivation & Objective**
- **Development Approach**
- **Initial Test Result & area of improvements**
- **Modeling method improvements**
- **Retest/Validation summary**
- **Enhancement Needs in CAI applications**
- **The take away…**

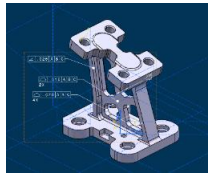
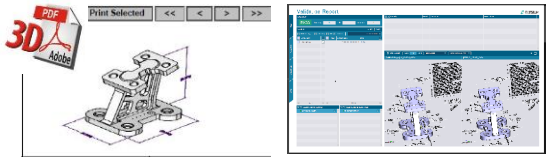
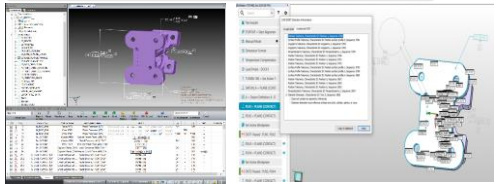
Model Quality: Automation in Inspection Programming

Current State

CAD Modeling	Prepare 2D drawing	Ballon dwg & create FAIR	Import geometry & add characteristics in CAI	Complete probe path program
				
	Drawing as authoritative data	Manually transcribing inspection requirements	Manually recreate part features and characteristics	

Document-based process: Manual transcribing is time consuming and error prone

Future State:

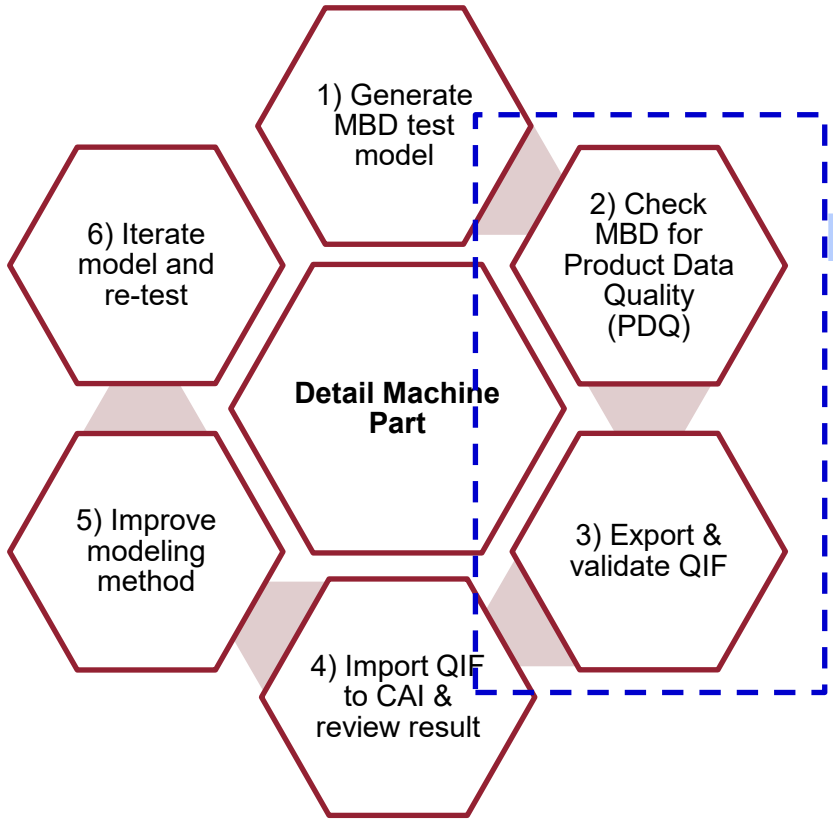
CAD Modeling w/ Annotation	Publish 3D-PDF, QIF, & FAIR + derivative validation	Import QIF derivative w/ characteristics in CAI	Complete probe path program
			
GD&T and notes associated to part features in model ☆ *Method improvement needed*	Auto-publish & validate Derivatives as authoritative data	Import authoritative derivative into CAI to auto-create part feature and characteristics	

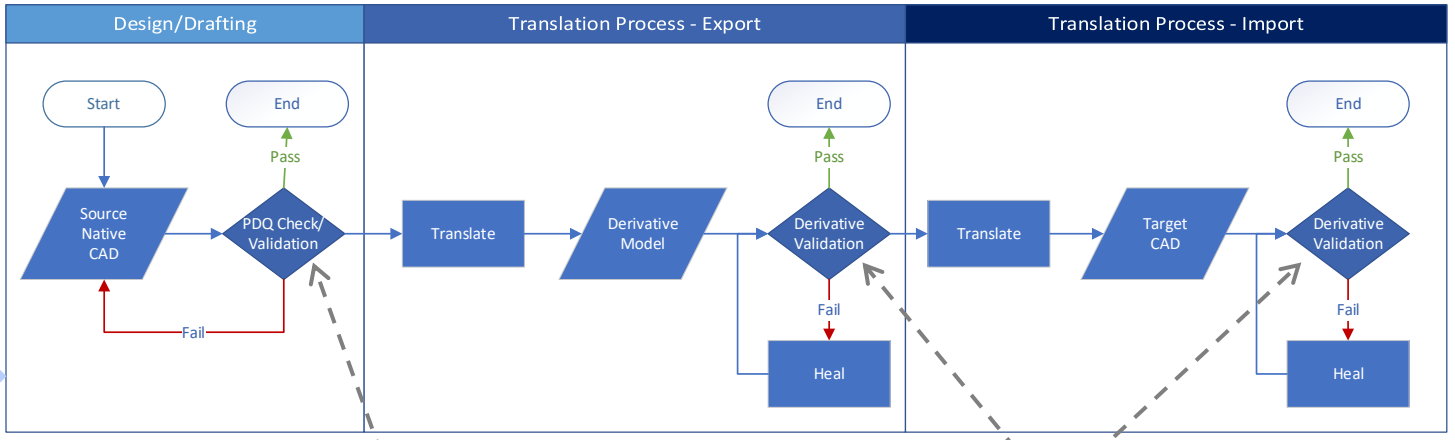
Model-based process: Reuse MBD to enable CAI automation with QIF
Reduces programming cycle-time by 50% and eliminates input errors

CAD: Computer Aided Design
CAI: Computer Aided Inspection
FAIR: First Article Inspection Report
GD&T: Geometric Dimensioning & Tolerancing
QIF: Quality Information Framework

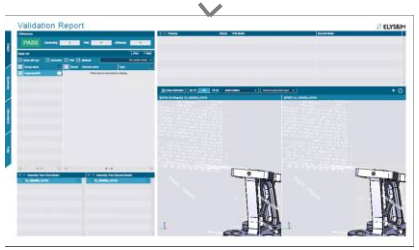
Development Approach:

Test with "future state" process to identify improvement needs, refine methods, and re-test to validate methods





PDQ checking:
To validate the source data is good



Derivative validation:
To validate the translated data is equivalent

Digital data is now a SOURCE OF TRUTH & TRUST of the data is earned

CMM: Coordinate Measurement Machine
GD&T: Geometric Dimensioning & Tolerancing
PMI: Product Manufacturing Information
QIF: Quality Information Framework

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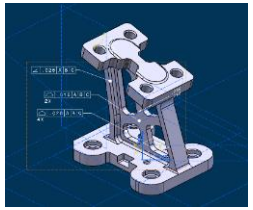
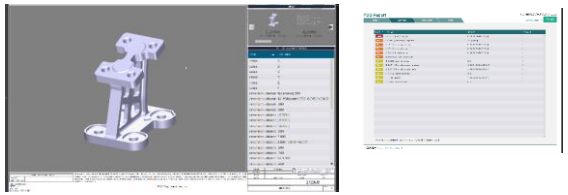
Initial Testing to Establish Baseline

Test model preparation



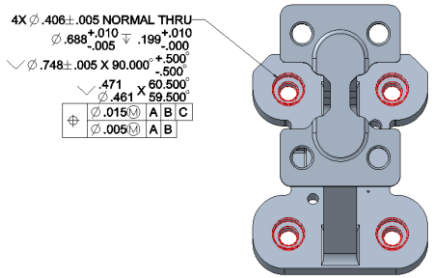
1) Common test model generated in major CAD apps to establish common evaluation criteria



2) Developed PDQ check criteria from MIL-STD-31000A App. C to validate MBD readiness for translation

3) QIF derivative data validated to source CAD, for downstream process application consumption as authoritative

Initial test findings



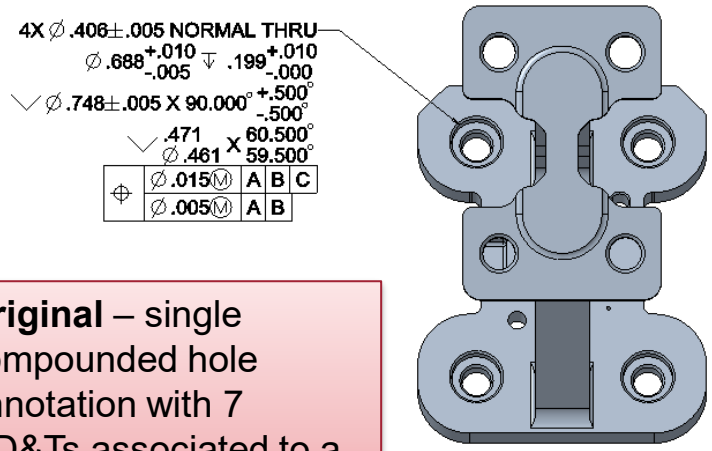
- **30-80% QIF characteristics imported into CMM applications**
  - auto-generate features and characteristics for probe path programming
  - proof of machine interpretability of semantic PMI through quality process consumption

<u>Area for improvement</u> – improve our modeling methods & % imported

- Compounded hole GD&T's not semantically associated to individual surfaces
- Chamfer, complex surface patterns, datum condition not supported

CMM: Coordinate Measurement Machine
GD&T: Geometric Dimensioning & Tolerancing
PMI: Product Manufacturing Information
QIF: Quality Information Framework

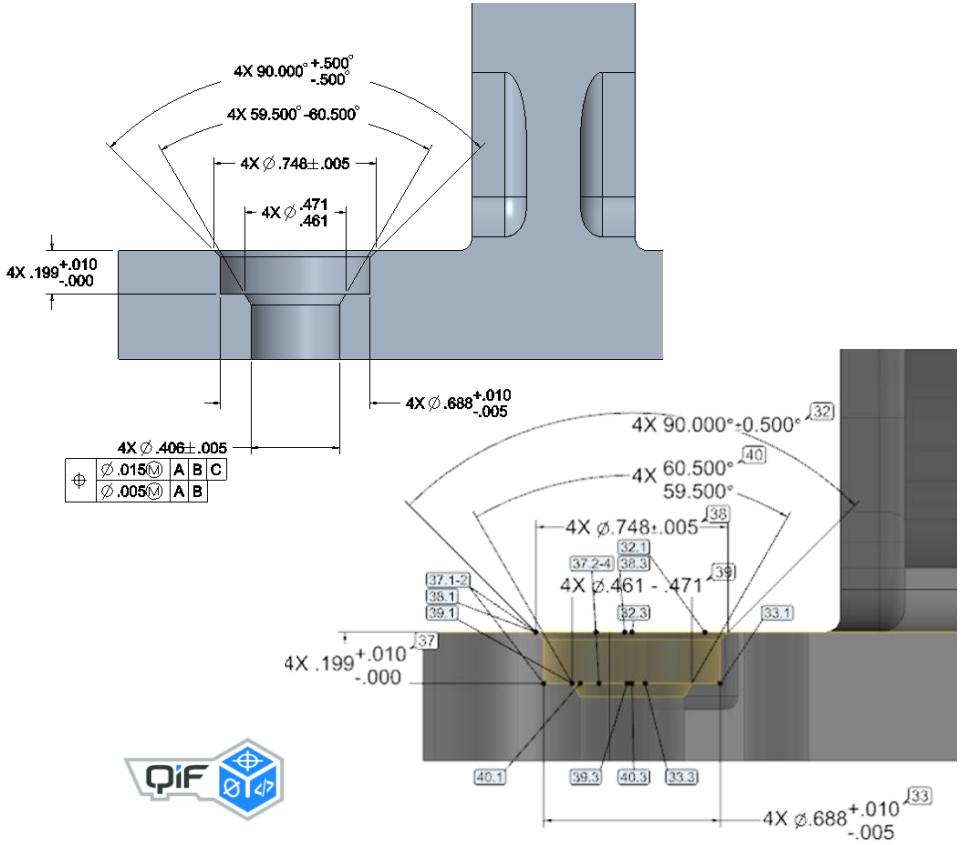
Missing Compounded Hole GD&T Annotation

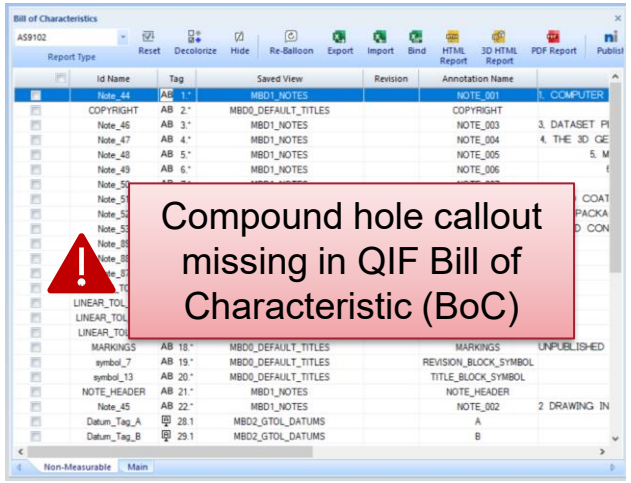


Original – single compounded hole annotation with 7 GD&Ts associated to a group of surfaces

Improvement:

explicit annotation modeling





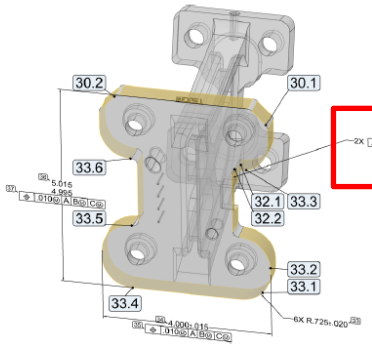
Compound hole callout missing in QIF Bill of Characteristic (BoC)

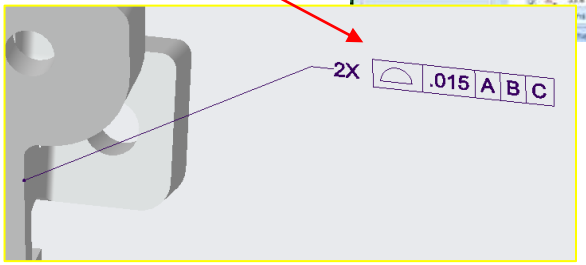
- Seven (7) individual GD&T annotations, individually associated to applicable surfaces.
- Imported into QIF BoC & characteristics ID auto-assigned

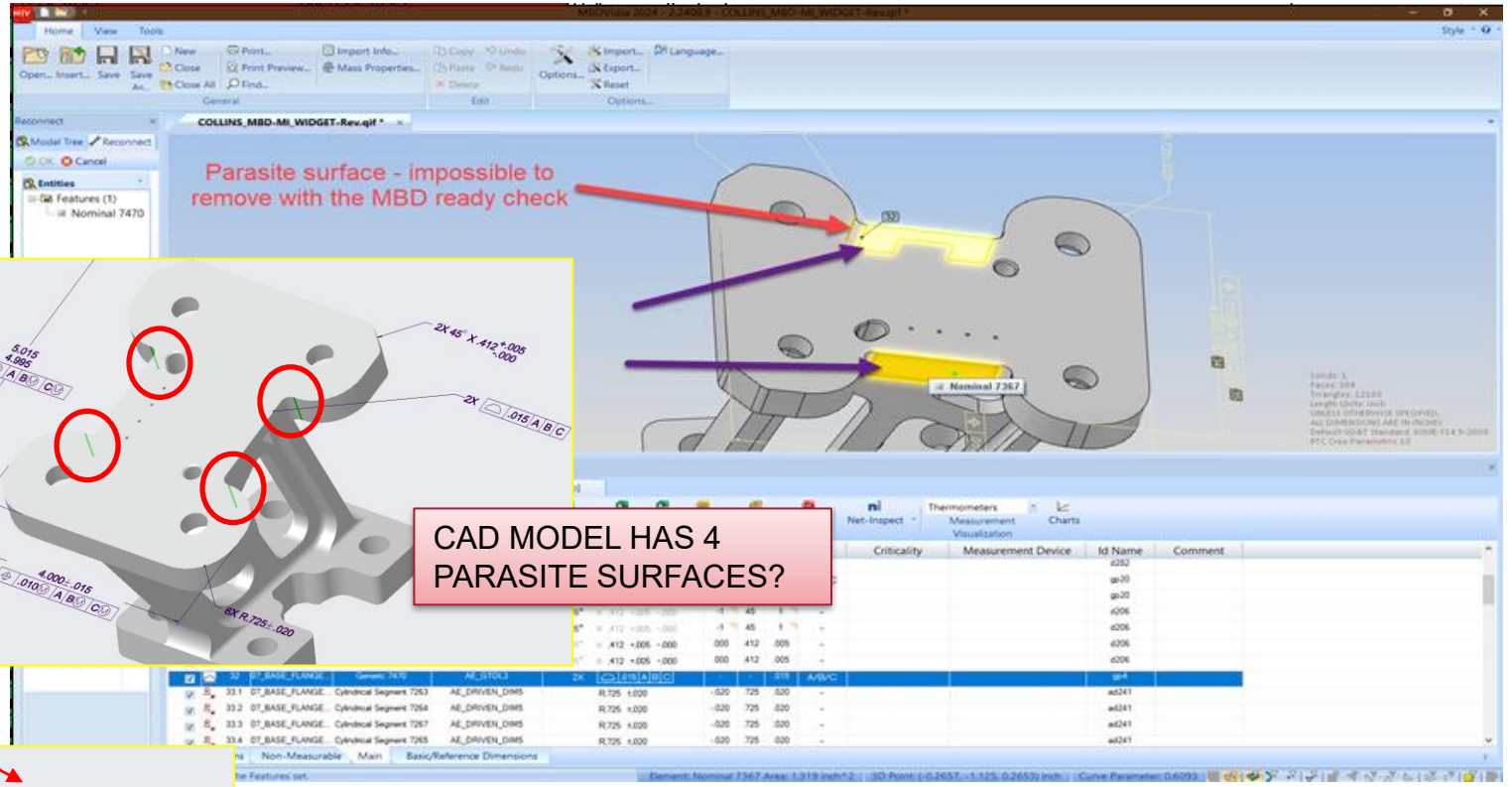
Missing Semantic PMI Association to Parasite Surfaces

CAI import warning: 3 surfaces in QIF instead of 2 (QIF issue, not editable). Should be unsupported but a pattern was created)

Tag	Saved View	Feature Name	Annotation Name	GD&T	(-)	/	(+)	DRF
30.1	07_BASE_FLANGE_PROFI	Plane 7357	DRV_DIM_D206	45° X .412 +.005 -.000	-1	45	1	-
30.2	07_BASE_FLANGE_PROFI	Plane 7358	DRV_DIM_D206	45° X .412 +.005 -.000	-1	45	1	-
32.1	07_BASE_FLANGE_PROFI	Generic 7367	AE_GTOL3	⌓ .015 A B C	-	-	.015	A/B/C
32.2	07_BASE_FLANGE_PROFI	Generic 7470	AE_GTOL3	⌓ .015 A B C	-	-	.015	A/B/C
33.1	07_BASE_FLANGE_PROFI	Cylindrical Segment 7263	AE_DRIVEN_DIM5	R.725 ±.020	-.020	.725	.020	-
33.2	07_BASE_FLANGE_PROFI	Cylindrical Segment 7264	AE_DRIVEN_DIM5	R.725 ±.020	-.020	.725	.020	-
33.3	07_BASE_FLANGE_PROFI	Cylindrical Segment 7267	AE_DRIVEN_DIM5	R.725 ±.020	-.020	.725	.020	-
33.4	07_BASE_FLANGE_PROFI	Cylindrical Segment 7265	AE_DRIVEN_DIM5	R.725 ±.020	-.020	.725	.020	-
33.5	07_BASE_FLANGE_PROFI	Cylindrical Segment 7266	AE_DRIVEN_DIM5	R.725 ±.020	-.020	.725	.020	-
33.6	07_BASE_FLANGE_PROFI	Cylindrical Segment 7268	AE_DRIVEN_DIM5	R.725 ±.020	-.020	.725	.020	-
34	07_BASE_FLANGE_PROFI	Opposite Planes 7259	AE_DRIVEN_DIM4	4.000 ±.015	-.015	4.000	.015	-
35	07_BASE_FLANGE_PROFI	Opposite Planes 7259	AE_GTOL4	⌖ .010Ⓜ A BⓂ CⓂ	-	-	.010	A/BⓂ/CⓂ
36	07_BASE_FLANGE_PROFI	Opposite Planes 7236	AE_DRIVEN_DIM3	5.015-4.995	4.995	-	5.015	-
37	07_BASE_FLANGE_PROFI	Opposite Planes 7236	AE_GTOL2	⌖ .010Ⓜ A BⓂ CⓂ	-	-	.010	A/BⓂ/CⓂ







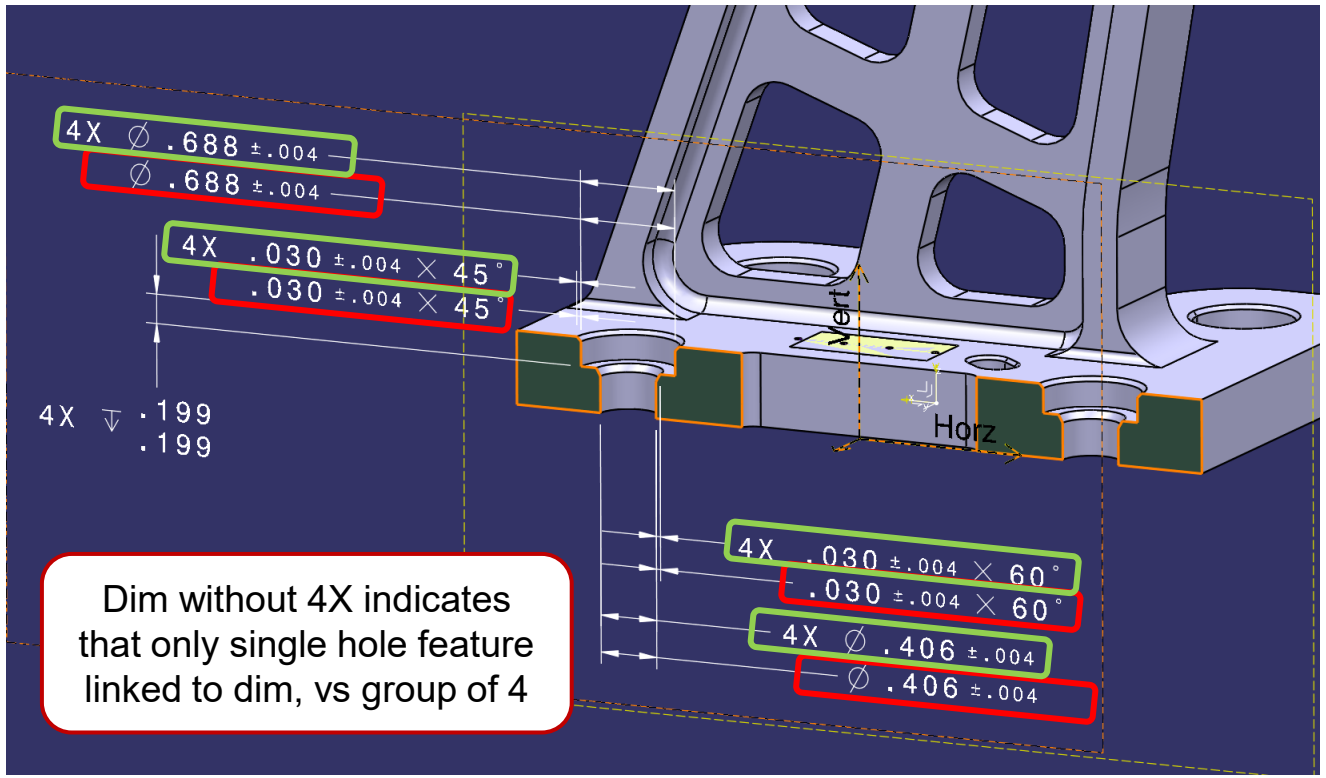
CAD MODEL HAS 4 PARASITE SURFACES?

MBD Product Quality Checking early on!

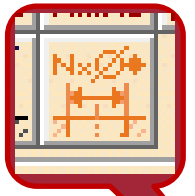
Capture CAD modeling best practice to address test issues

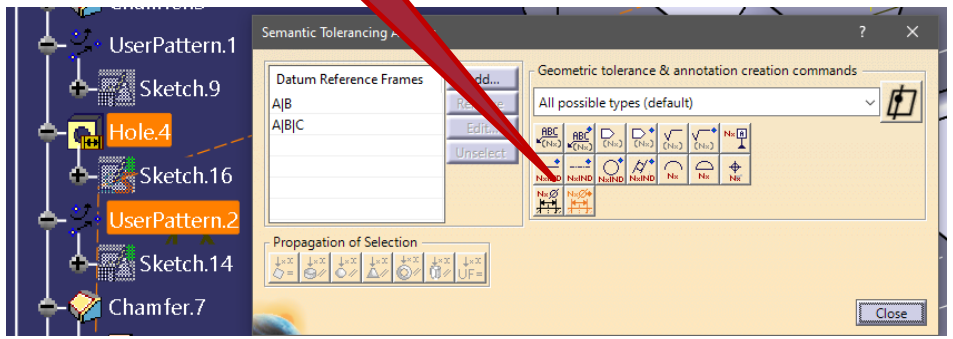
Problem: feature surfaces in ‘pattern/instances/multiple’ failed to associate with dimension control generator

Cause: lack of relationship associativity/continuity between solid modeling and dimensioning tool



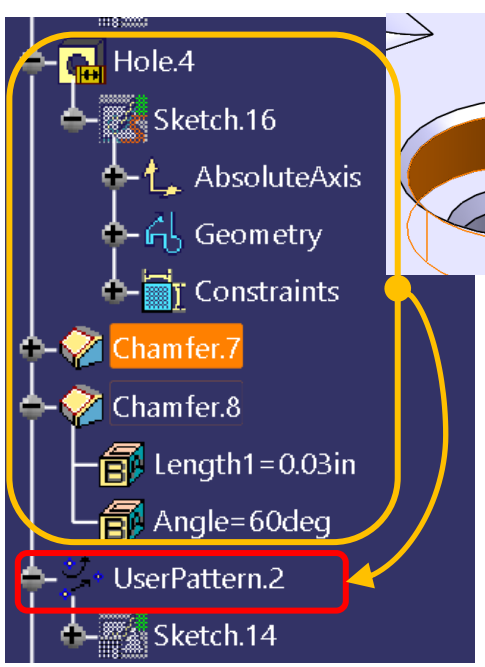
$N_{(of)}X$ = Group
This is critical for “4X” to be semantic

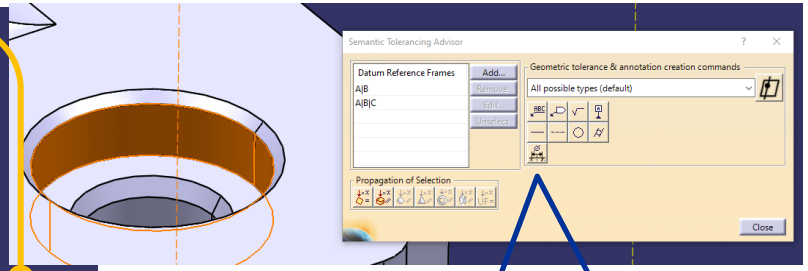




Capture CAD modeling best practice to address test issues

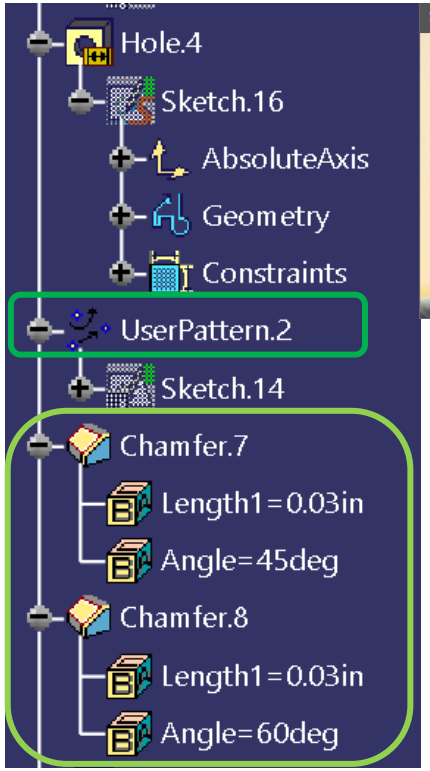
FIX #1: change the Object structure to improve exposure of the element to the Dimensioning module:

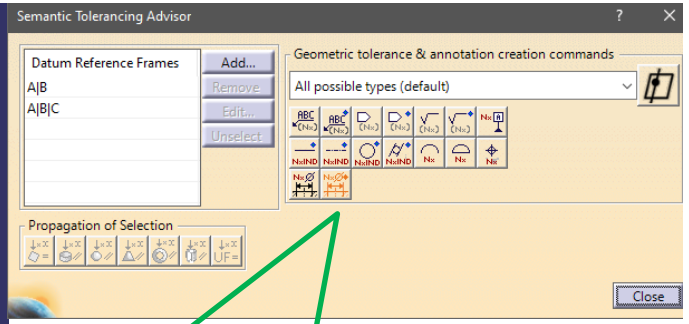




When pattern includes multiple feature, the elements are not available as group

When 'multi' group, root object characteristics are unavailable





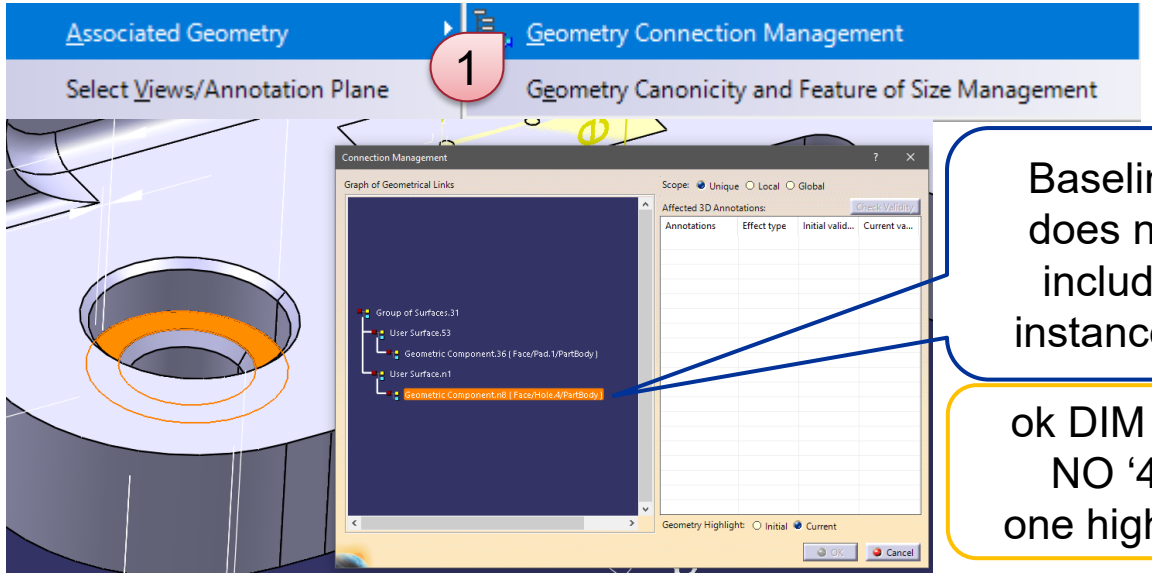
When pattern includes SINGLE feature, Grouped instances becomes available

If object is uniquely exposed, only then it is 'fully' accessible to annotation module?

Order and type of geometry used affects capacity of annotation tool

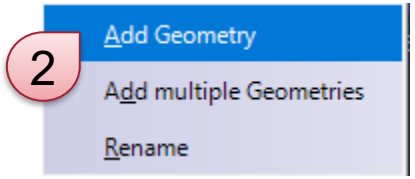
Capture CAD modeling best practice to address test issues

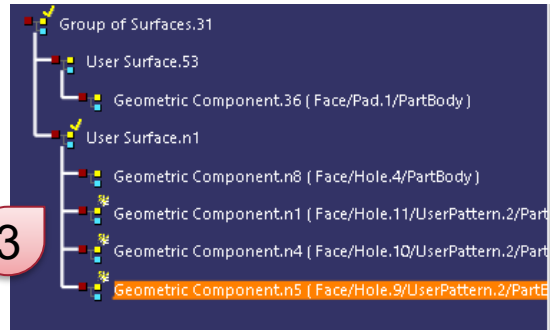
FIX #2: manually adding geometric surfaces to create semantic association

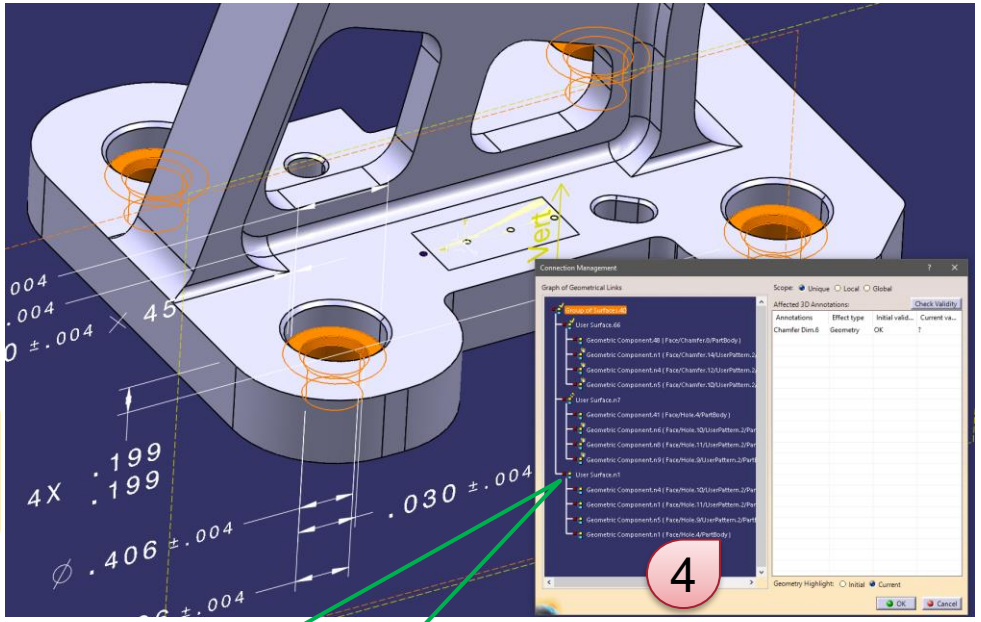


Baseline does not include instances.

ok DIM type
NO '4X'
one highlight







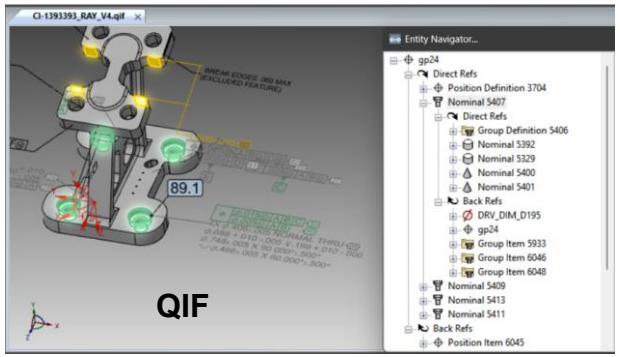
Semantic 'group' expanded to include patterned instances

correct DIM
WITH '4X' & group recognition highlight

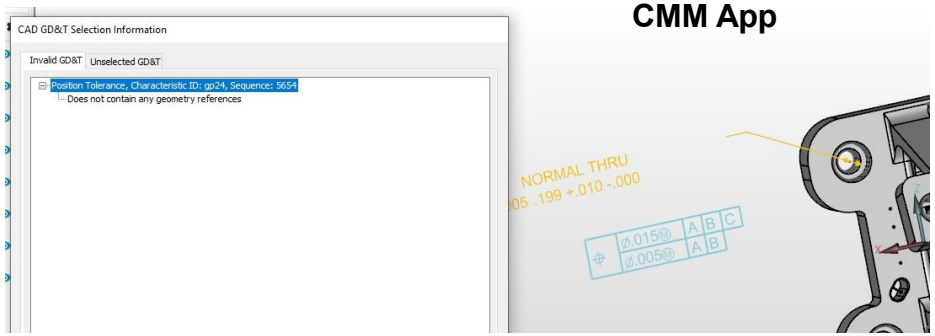
Time-consuming, enhancement needed for FT&A

Enhancement Needs in CAI Applications

QIF implementation needs enhancement by CAI application technology vendors



QIF



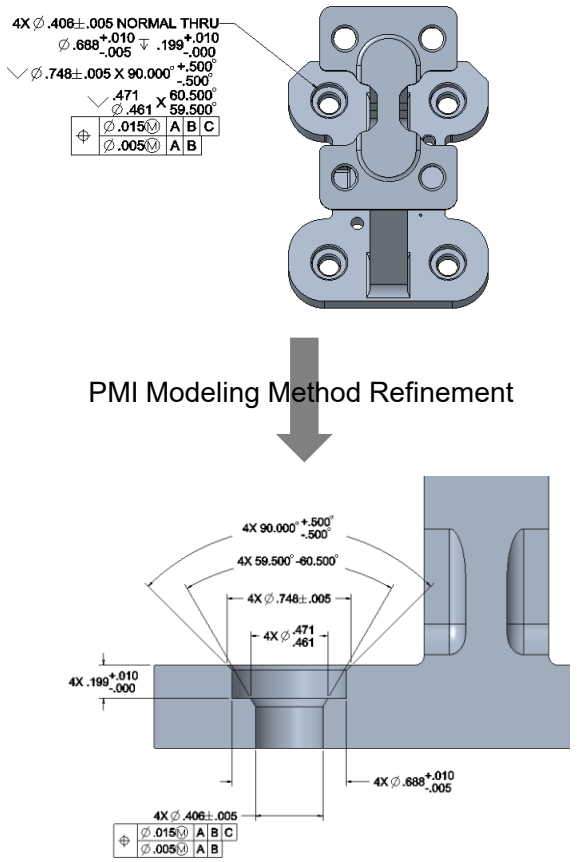
CMM App

Interpretation issue with association to group vs. individual surface?

QIF import/translation into CAI application,

- Import QIF characteristic IDs into to maintain data traceability
- Maintain characteristic types
- Maintain geometry entities associativity to annotations to establish inspection characteristics
- Recognize pattern of freeform surface features, without merged multiple surfaces into one
- Recognize all material condition modifiers (e.g. Ⓣ & Ⓒ)

Improvement & Validation Summary



PMI Modeling Method Improvement & Validation

Method Refinement – improved modeling methods to generate machine-interpretable PMI & % imported into CAI

- Create GD&T annotation with **clear explicit association** to geometry surfaces
- **PDQ checking** prior to translation, need robust checking criteria
- Modeling features & pattern feature position in model tree or via manual association, and double-check for semantic associativity

- **45-90% QIF characteristics imported into CMM applications (vs. 30-70% initial)**
- **Potential to save > 30% of the programming hours today using QIF**

CMM: Coordinate Measurement Machine
GD&T: Geometric Dimensioning & Tolerancing
PMI: Product Manufacturing Information
QIF: Quality Information Framework

Final thoughts

- Capable to add value today by enabling semi-automation in quality inspection programming.
- Feedback to CAD & CAI tech vendors for feature enhancement & continuous improvements.
- Opportunity to work with DMSC QIF testing group, to assess implementation maturity & certify software solutions
- Additional product model types needs to be evaluated and to mature the MBD modeling methods to improve machine interpretability.

Thank you!

Success of this project is attributed to supports provided by RTX Business Units (Pratt & Whitney, Collins Aerospace, and Raytheon) and Connecticut Center for Advance Technology (CCAT).

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