GLOBAL PRODUCT DATA INTEROPERABILITY SUMMIT 2019

Integrating Semantic Quality Information with the Digital Thread

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Introduction

Brian Nielsen

- **Boeing employee of 24 years**
  - **17 years in manufacturing including assembly and fabrication**
  - **7 years as a Geometric Dimensioning and Tolerancing (GD&T) and Producibility focal**
  - **Boeing Designated Expert (BDE) of GD&T**
- **ASME certified GDTP S09-8143**
- **ASME subcommittee volunteer**
  - **Member of Y14.5.2, Y14.39, AED & AED ALT subcommittees**
  - **Participant in Y14.5**

- **Outside of work I enjoy spending time with my family, hiking and nature photography**

Introduction

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Agenda

- **Potential benefits from having a digital thread for tolerancing information with examples**
- **Potential benefits from having a digital thread for inspection data**
- **Obstacles to realizing these potentials**
- **Ideas on how to overcome those obstacles**

The Potential. What if…

- **Tolerance requirements were linked to the actual design geometry and computer readable instead of flag notes?**
  - **Some CAD systems have this capability to some extent (e.g. CATIA FT&A, NX PMI to name a couple)**
- **Semantic tolerance requirements were available throughout the value stream, including manufacturing?**
  - **Some inspection programs include import tools to utilize CAD specific semantic tolerancing information**

Example: Importing CATIA FT&A into Polyworks

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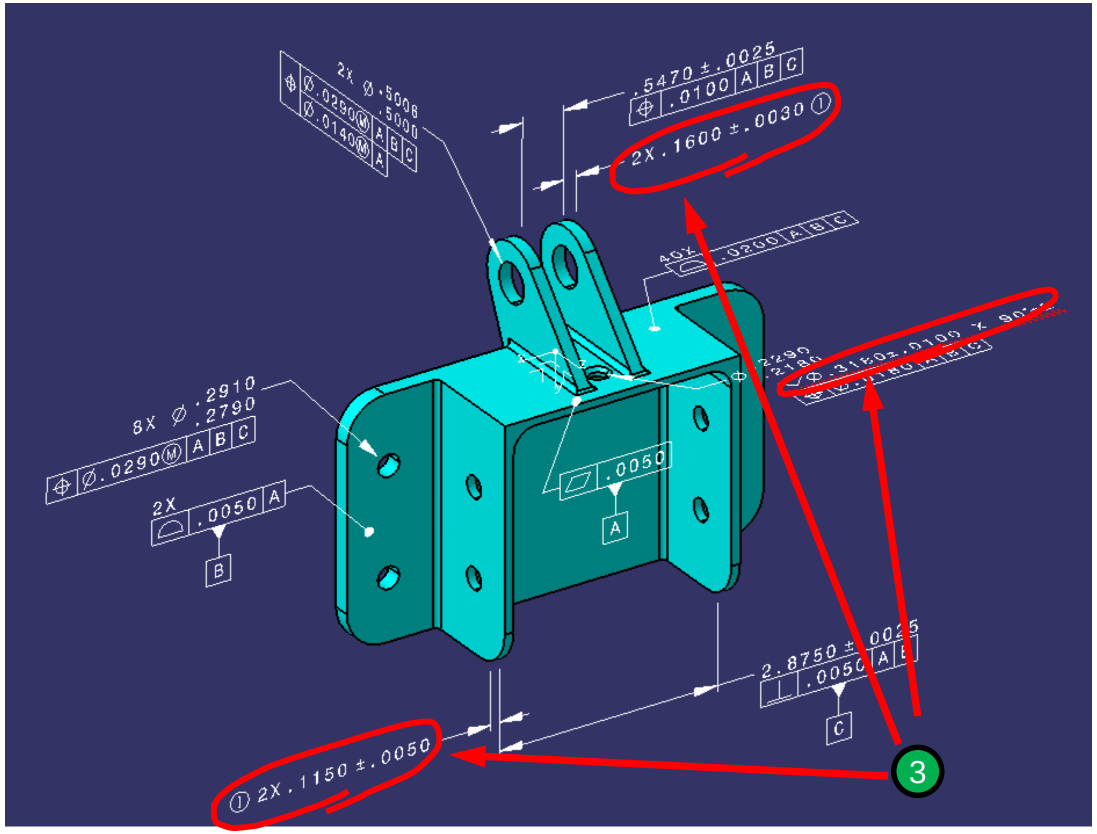
CATIA FT&A



Results in Polyworks

Name	Control	Nom	Tol
Pad.2 (2)	▱ 0.005		0.005
Hole.1	Ø 0.224±0.005 mating	0.224	±0.005
	⌖ Ø 0.018 A B C		0.018
	Diameter	0.224	±0.005
Pocket.1	Ø 0.500+0.001/+0.000 mating	0.500	+0.001/0.000
	Diameter	0.500	+0.001/0.000
Pocket.1 (2)	Ø 0.500+0.001/+0.000 mating	0.500	+0.001/0.000
	Diameter	0.500	+0.001/0.000
EdgeFillet.2	⌓ 0.020 A B C		0.020
Pad.2 (7)	⌓ 0.005 A		0.005
Pocket.1 (3)	Ø 0.500±0.002 mating	0.500	±0.002
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
Pocket.1 (4)	Ø 0.500±0.002 mating	0.500	±0.002
	⌖ Ø 0.014 Ⓜ A		0.014 (B: 0.000)
datum slab C	Thickness	2.875	±0.003
pattern 1	8X Ø 0.285±0.006 mating	0.285	±0.006
	8X Ø 0.285±0.006 mating	0.285	±0.006
	8X Ø 0.285±0.006 mating	0.285	±0.006
	8X Ø 0.285±0.006 mating	0.285	±0.006
	8X Ø 0.285±0.006 mating	0.285	±0.006
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	8X Ø 0.285±0.006 mating	0.285	±0.006
	8X Ø 0.285±0.006 mating	0.285	±0.006
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
slab 2	⊥ 0.005 A B		0.005
slab 3	⌖ 0.010 A B C		0.010
	Thickness	0.547	±0.003

Short list of issues

1. Rounding
2. 40X profile may have lost association to some features
3. Did not import those items circled in red

Example: Importing NX PMI into Polyworks

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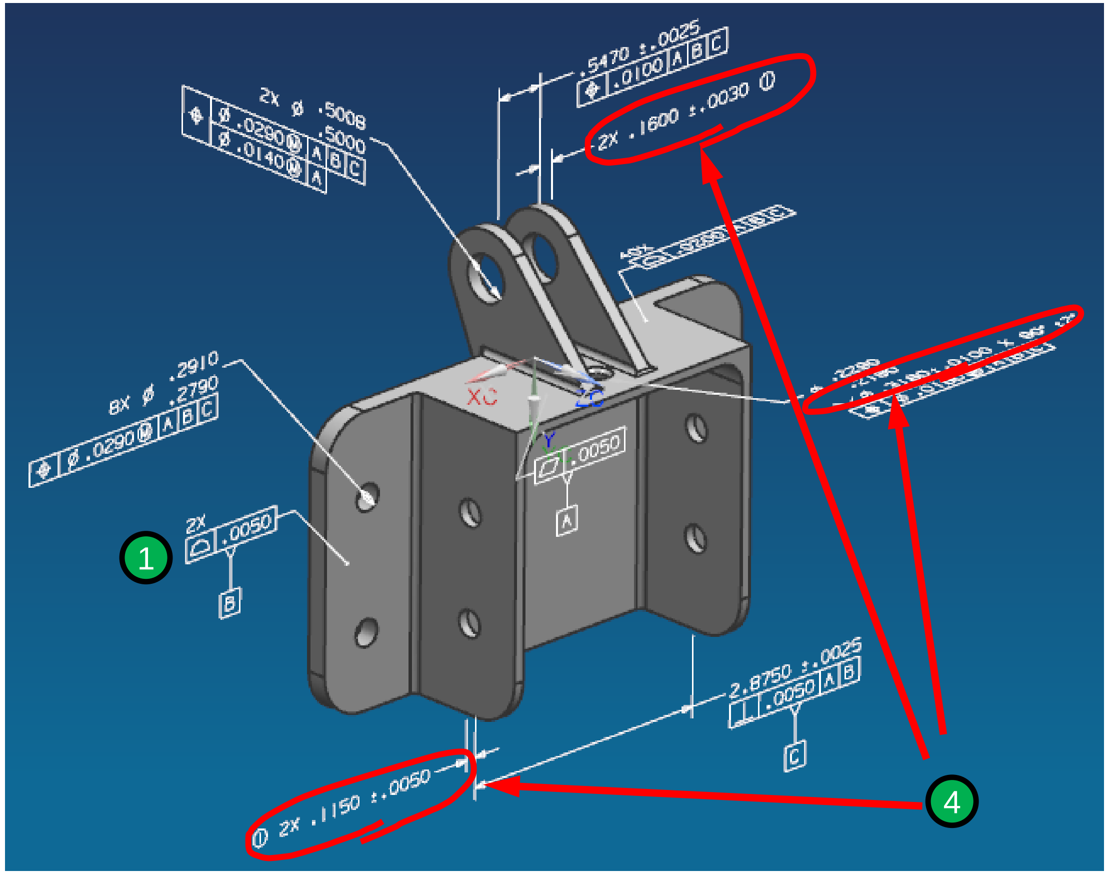
NX PMI



Results in Polyworks

Name	Control	Nom	Tol
PARTBODY (2)	▱ 0.005		0.005
cylinder 3	Ø 0.224±0.006 mating	0.224	±0.006
	⌖ Ø 0.018 Ⓜ A B C		0.018 (B: 0.000)
	Diameter	0.224	±0.006
cylinder 12	Ø 0.500+0.000/0.000 mating	0.500	+0.000/0.000
	Diameter	0.500	+0.000/0.000
cylinder 13	Ø 0.500+0.000/0.000 mating	0.500	+0.000/0.000
	Diameter	0.500	+0.000/0.000
PARTBODY (12)	⌓ 0.020 A B C		0.020
PARTBODY (13)	⌓ 0.005		0.005
cylinder 14	Ø 0.500±0.002 mating	0.500	±0.002
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
cylinder 15	Ø 0.500±0.002 mating	0.500	±0.002
	⌖ Ø 0.014 Ⓜ A		0.014 (B: 0.000)
datum slab C	Thickness	2.875	±0.003
pattern 2	8X Ø 0.285±0.006 mating	0.285	±0.006
	8X Ø 0.285±0.006 mating	0.285	±0.006
	8X Ø 0.285±0.006 mating	0.285	±0.006
	8X Ø 0.285±0.006 mating	0.285	±0.006
	8X Ø 0.285±0.006 mating	0.285	±0.006
	8X Ø 0.285±0.006 mating	0.285	±0.006
	8X Ø 0.285±0.006 mating	0.285	±0.006
	8X Ø 0.285±0.006 mating	0.285	±0.006
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
	⌖ Ø 0.029 Ⓜ A B C		0.029 (B: 0.000)
slab 6	⊥ 0.005 A B		0.005
slab 7	⌖ 0.010 A B C		0.010
	Thickness	0.547	±0.003

3

2

Short list of issues

1. Human error copying to NX model. Omitted datum reference A on profile tolerance
2. Rounding.
3. 40X profile may have lost association to some features
4. Did not import those items circled in red

Increased potential. What if…

- **Tolerance requirements were linked in a standard, non-proprietary format that could be understood and analyzed by multiple systems?**
  - **Using STEP 242.**
- **Semantic tolerance requirements were available throughout the value stream, including manufacturing?**
  - **Using STEP 242.**
- **Semantic GDT Inspection results were available throughout the value stream, including design?**
  - **Quality Information Framework (QIF)**
- **Semantic GD&T Inspection results were easily available, without requiring special tools?**
  - **QIF**

The demonstration

1. **GD&T defined by Mitutoyo using native CATIA V5 FT&A Workbench**
2. **Machining process defined using CATIA V5 Machining Workbench**
3. **Machining process exported to STEP 238 using CATIA V5 and Boeing add-ons**
4. **GD&T exported to STEP 242 using CATIA V5 and Boeing add-ons**
5. **Multiple parts machined by different CNC suppliers**
6. **Parts inspected on Mitutoyo CMM using STEP 242 GD&T**
7. **Mitutoyo CMM produces QIF results file for multiple parts**
8. **QIF results linked back to original CATIA V5 design using Boeing add-ons**

Processing tolerance requirements

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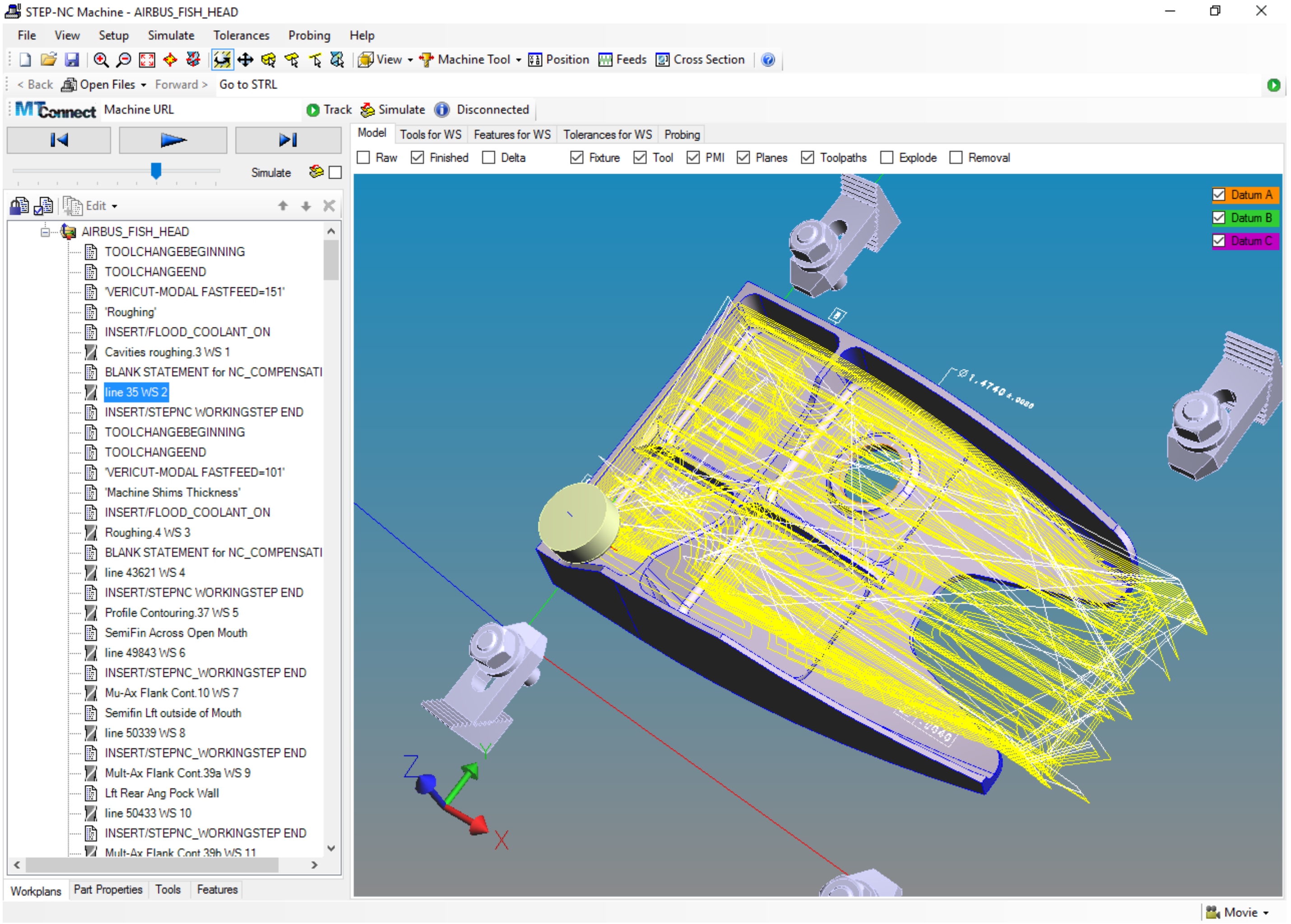
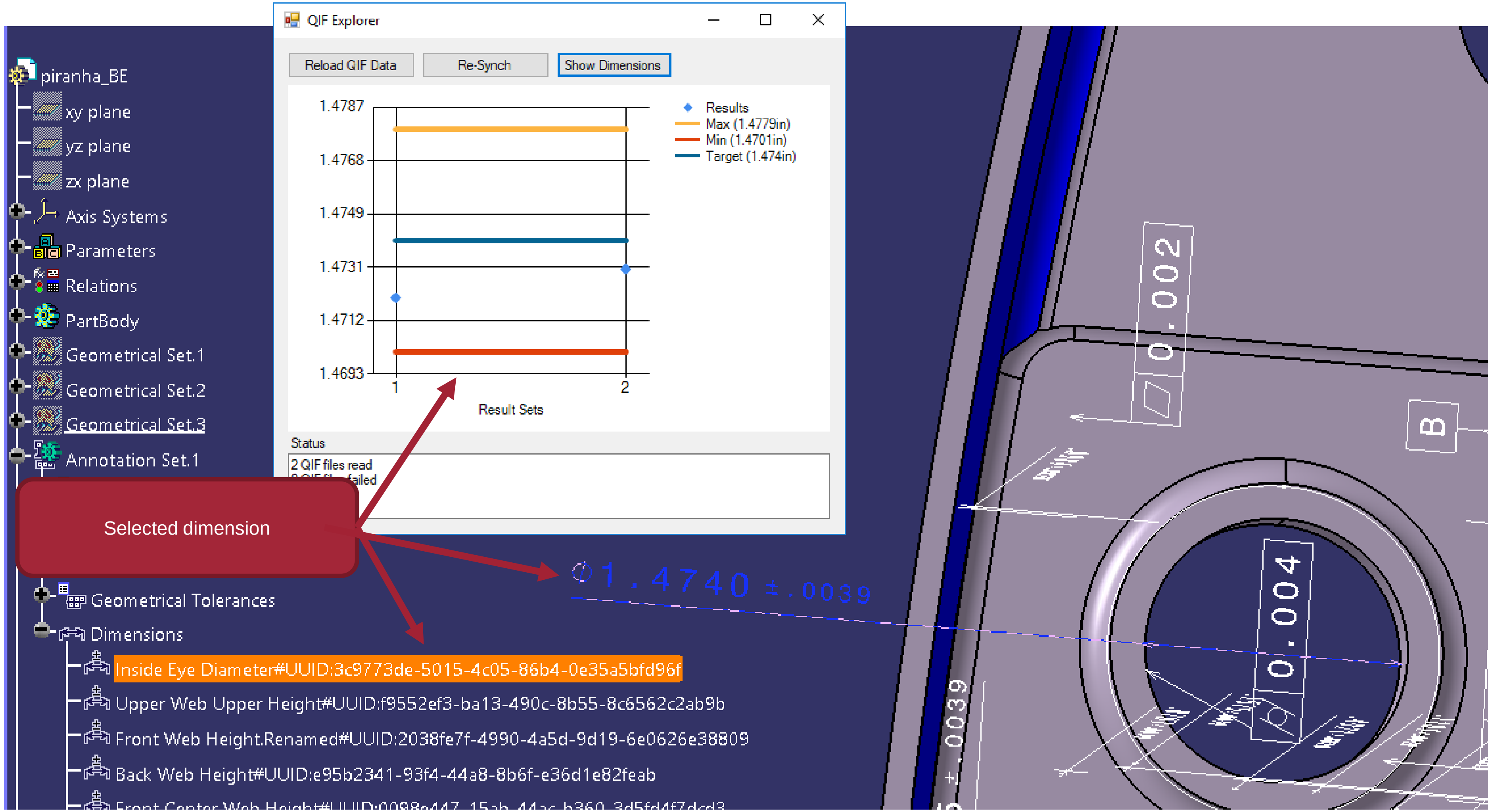
- **Exported to STEP 242**
- **Inspection plan defined by Mitutoyo directly using STEP-242 data**
- **Inspection data saved using the QIF**



Contextual Integration

- **Historical inspection data retrieved by linking to QIF and viewed in context with design part**



About UUIDs

- **Universal Unique Identifiers**
- **Unique Hex strings ex: 3c9773de-5015-4c05-86b4-0e35a5bfd96f**
- **Ubiquitous services provide them**
- **Used to track GD&T elements through the thread**
- **For now, embedded in GD&T element names**

About STEP (ISO 10303)

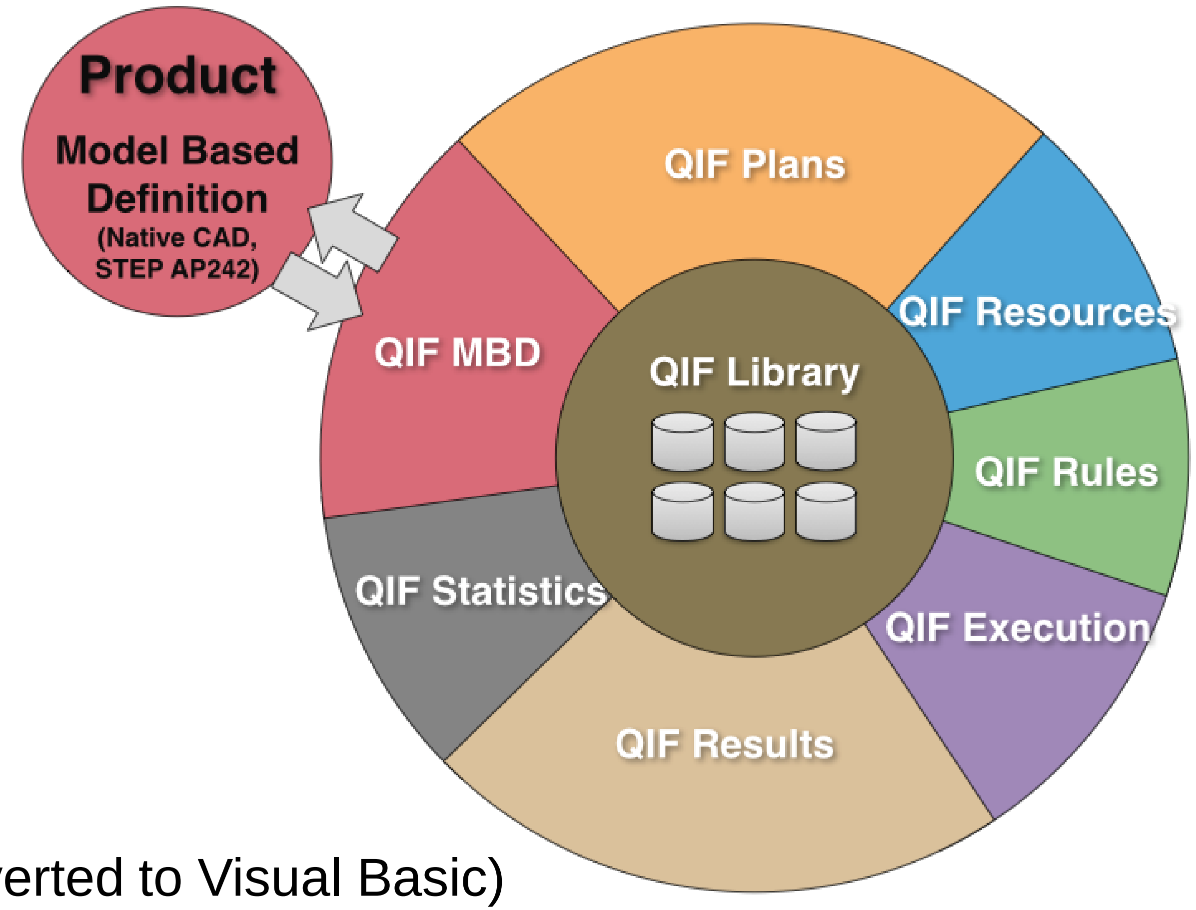
- Different Application Protocols that share the same schemas

- AP-242
  - Replaces AP203 and AP214
  - Includes GD&T and Kinematics
  - Tessellated or Breps
  - Edition 2 finalized in 2019

- AP-238
  - “STEP-NC”
  - Includes process planning
  - Includes AP242
  - Edition 2 finalized in 2019

About QIF

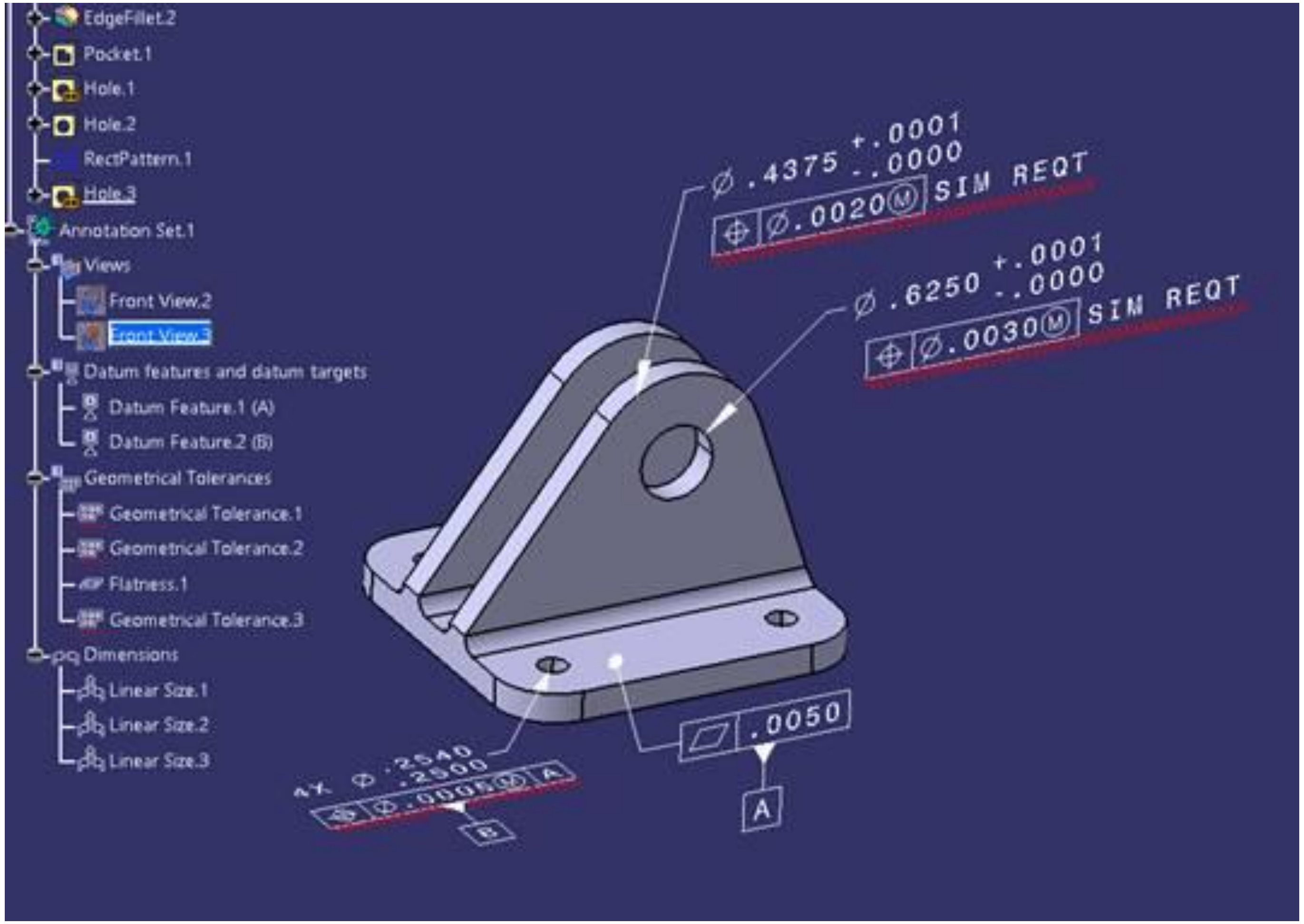
- “Quality Information Framework”
- Developed by DMSC (Developers of DMIS)
  - http://www.dmsc-inc.org/
- ANSI standard being harvested by ISO
- Modern, XML based
- Includes Planning, Inspection, Evaluation
- Development kits available:
  - Python, C#, C++, (For the demo it was converted to Visual Basic)



- **Tolerancing with notes**
  - **Endless loop of specifications that apply unless otherwise specified (UOS)**
    - **Conflict resolution**
    - **Lack of associativity**
    - **Encourages unconscious tolerancing; undervalues tolerancing with purpose**
  - **What qualifies as otherwise specified?**

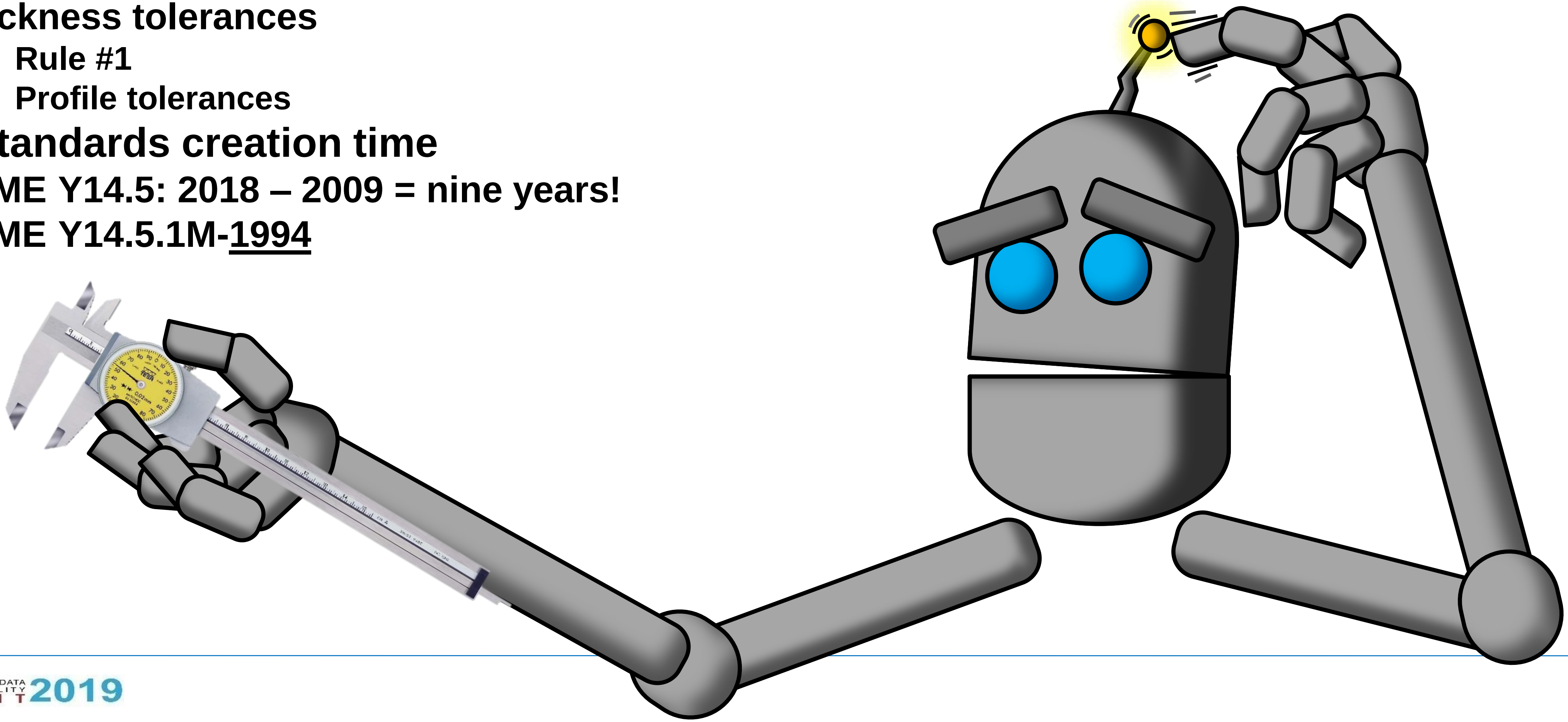
Obstacles

- **Confidence in the tools**
  - **Доверяй, но проверяй - trust but verify**
- **Tool capability**
  - **E.g. semantic tolerancing tools that do not allow all available tolerancing methods**



Obstacles

- **Ambiguous or non-existent tolerancing tools**
  - **Simultaneous requirements for datum-less tolerances**
  - **Thickness tolerances**
    - **Rule #1**
    - **Profile tolerances**
- **Slow standards creation time**
  - **ASME Y14.5: 2018 – 2009 = nine years!**
  - **ASME Y14.5.1M-1994**



Solutions

- **Stop using notes, use semantic tolerancing as a standard practice**

- **Confidence in the tools will come with time and familiarity**
  - **Work to fix the problems as they are encountered**

- **Encourage participation in the development of standards**
  - **Make your needs known to the standards committees**
  - **Try to anticipate the ways in which tolerancing standards will advance**

Characteristics of Tolerances

Identifying the characteristics that describe the tolerances can help with covering all possible current methods and in some ways reveal what might be added in the future.

Tolerance Type	Degree of Freedom Constraints Related to Datum Reference Frame						Feature to Feature Related (Pattern)					
	x	y	z	u	v	w	x	y	z	u	v	w
▱ — ○ ⌭	n/a	n/a	n/a	n/a	n/a	n/a	n/a (Individual)					
∠ // ⊥	n/a	n/a	n/a	Yes	Yes	Yes	n/a (Individual)					
⌖ ⌓ ⌒	Yes	Yes	Yes	Yes	Yes	Yes	Yes					
FRTZF ⌖ ⌓ ⌒	n/a	n/a	n/a	Yes	Yes	Yes	Yes					
Future tool?	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	Yes	Yes	Yes

Yes on this table means capable of, not that it is in all situations

Characteristics of Tolerances

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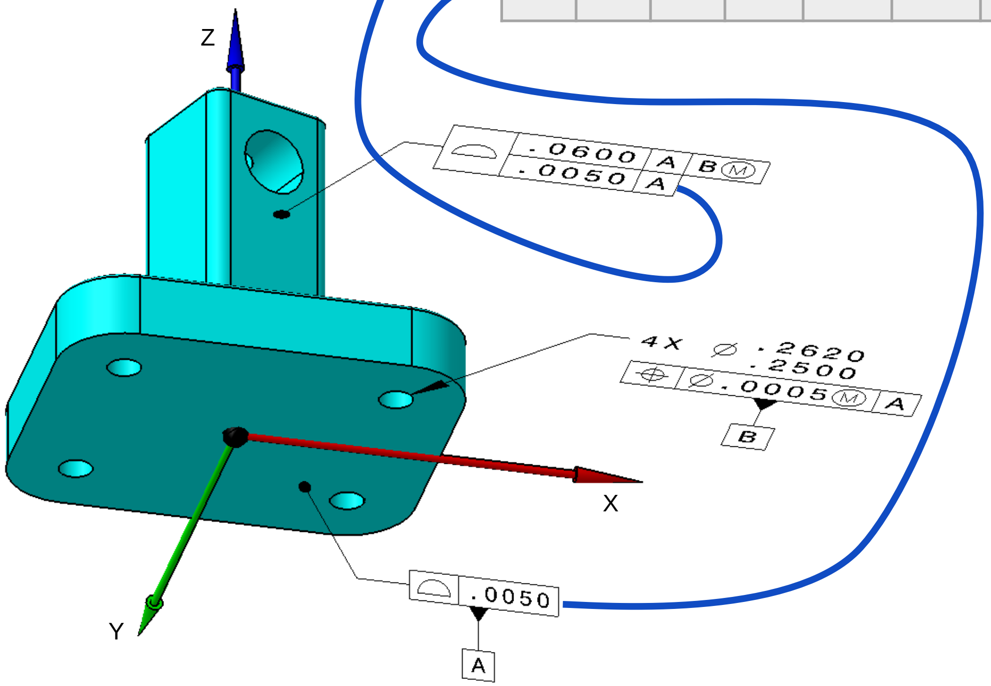
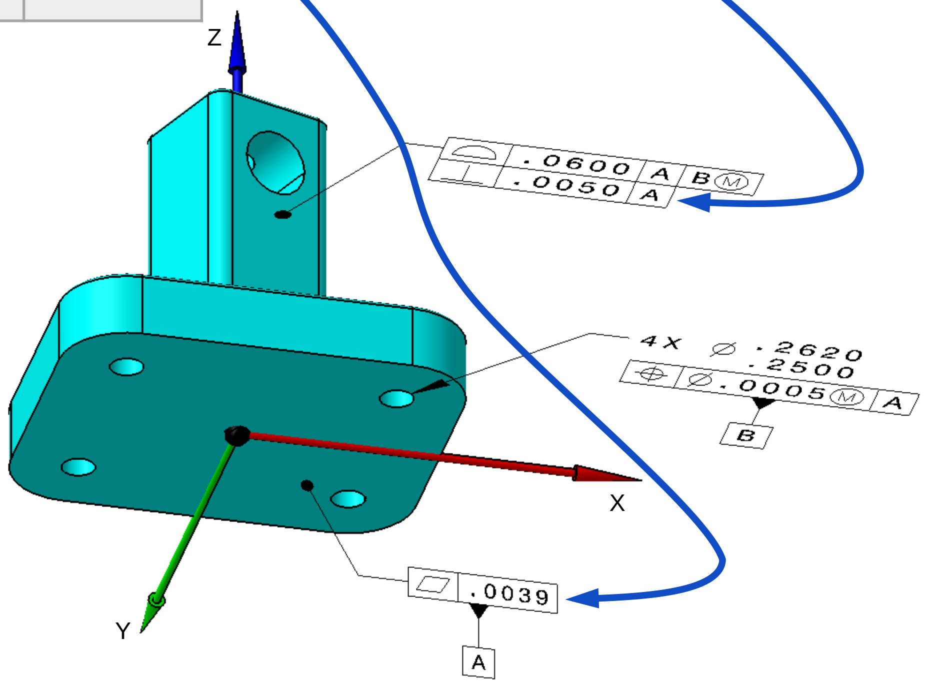
Constrained Relative to a Datum Reference Frame						Feature to Feature Related (Pattern)	Number of Features in Pattern	Type of Feature
x	y	z	u	v	w	x, y, z, u, v, w		
No	No	No	Yes	Yes	No	Yes, but only 1→	1	Planar
No	No	No	No	No	No	Yes, but only 1→	1	Planar





Characteristics of Tolerances

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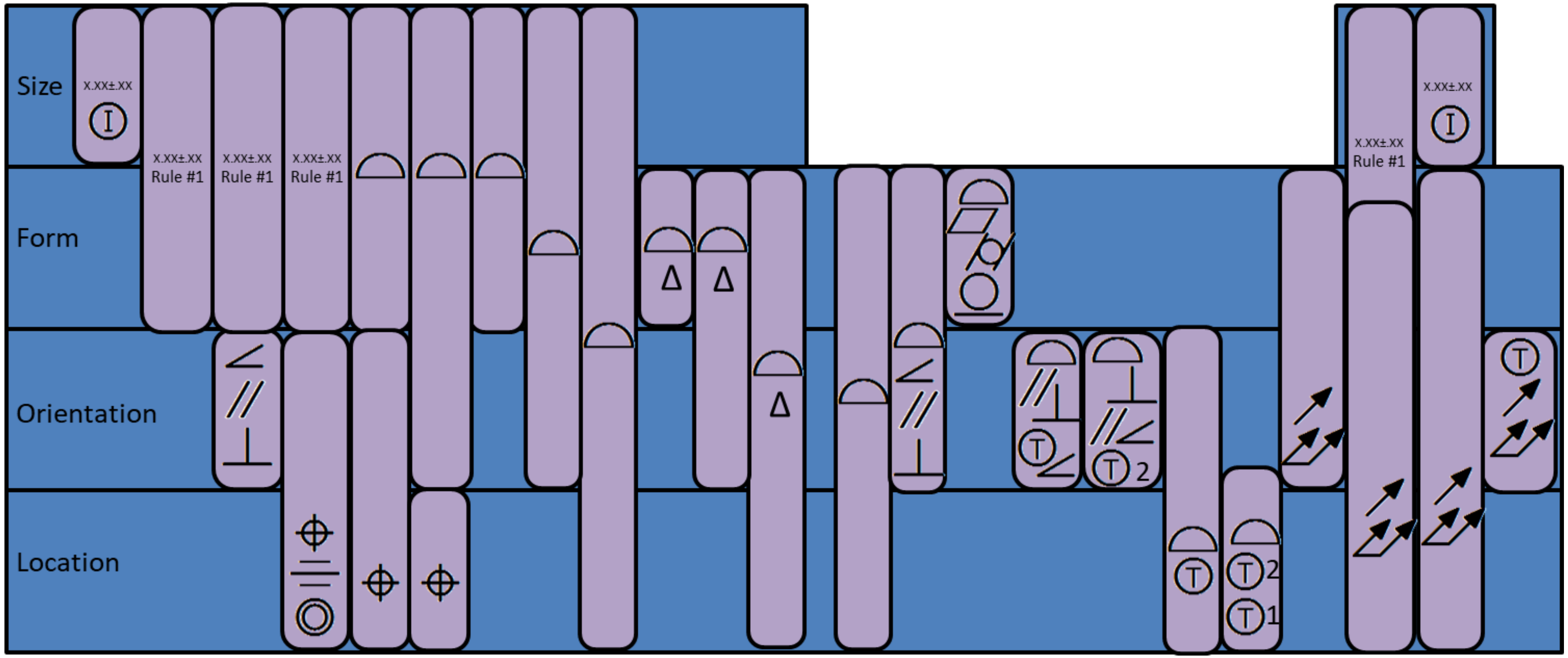
Identifying the characteristics that describe the tolerances can help with covering all possible current methods and in some ways reveal what might be added in the future.



Conclusion

- **Digital thread has great potential to**
  - **Improve efficiencies**
  - **Facilitate automation**
- **QIF stretches the digital thread and can close the loop**
  - **Improve data driven decisions**
- **Obstacles can be overcome by**
  - **Cultural changes (no more notes and conscious tolerancing)**
  - **Getting ahead of changes and identifying tolerance characteristics**
- **Special thanks to:**
  - **David Odendahl**
  - **Craig Farniok**
  - **Jason Emmons**
  - **John Scheibel**

Questions?