GD&T Encoding and Decoding with SpaceClaim

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Biography

- **Draftsman aerospace industry 1978 - 1980**
- **B.S. Material Science Michigan State University 1982**
- **Nuclear Power Industry 1982 - 1986**
- **M.S. Engineering Mechanics Mich. State Univ. 1988**
- **Industrial Food Equipment Industry 1988 - 1990**
- **24 years CAD Industry Experience 1990 – Present**
- **SpaceClaim 2011 – Present**
  - **Manage the online help**
  - **Project Manager for GD&T**

Introduction

All CAD systems provide some level of GD&T support

- **“Decorative” symbols**
- **Semantic symbols**
- **Extended online help**
- **Tutorials**
- **Etc.**

SpaceClaim, with its partner SmartGD&T™ , is researching how to advance this to a new level

Variations are inevitable in manufacturing processes

The goal is to manage the variations and produce acceptable parts

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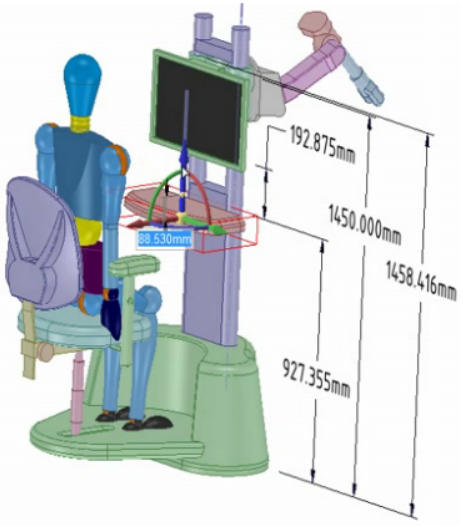
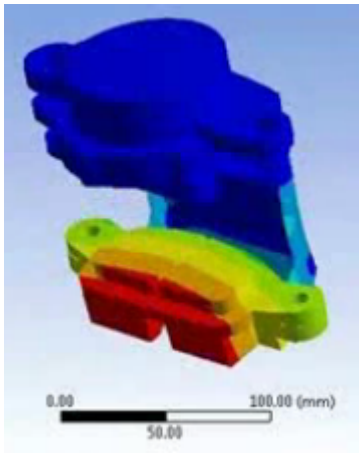
CAD's mission - address issues like this and create efficiencies in product development

- **Virtual prototypes**
- **Simulations**
- **CNC software**
- **CMM**

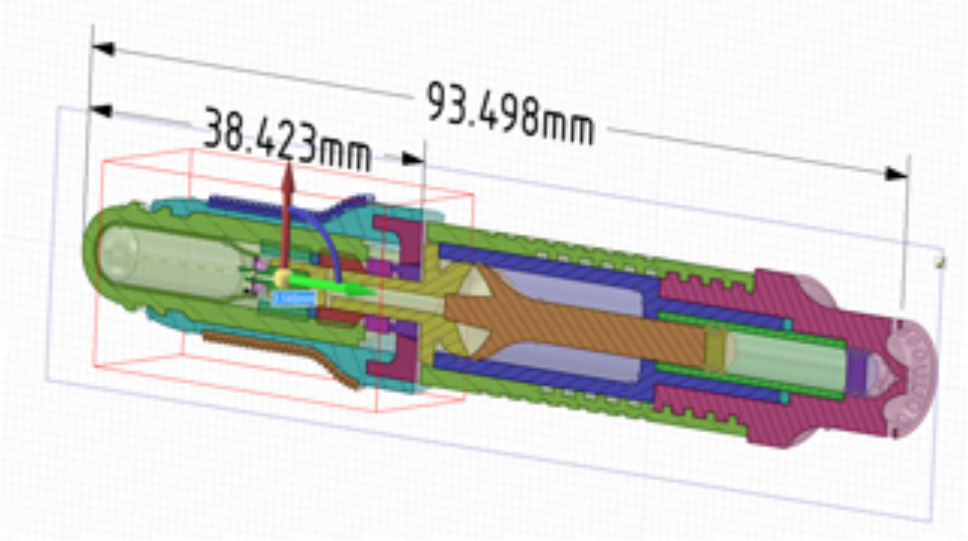




Can CAD address the huge number of possible "imperfections" that *can* be introduced into MFG processes?

CAD models live in a perfect virtual world

- **Made of precise, computer-generated geometry**
- **All dimensions are nominal**
- **Use theoretical, ideal coordinate systems**
- **No material defects**
- **Etc.**



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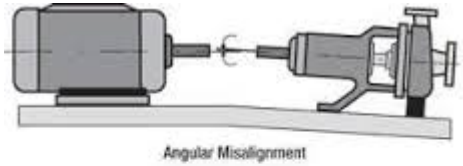
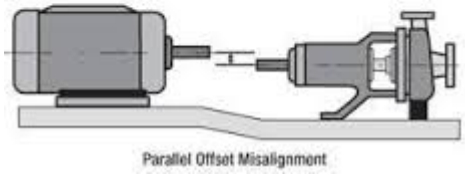
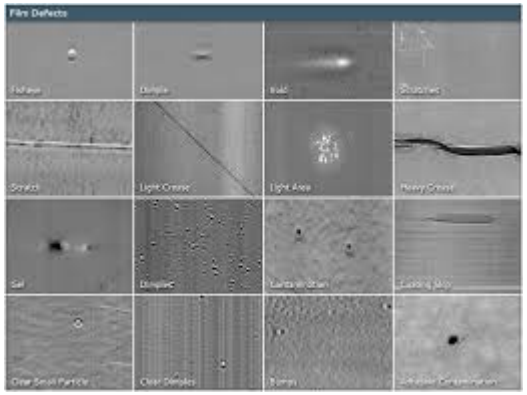
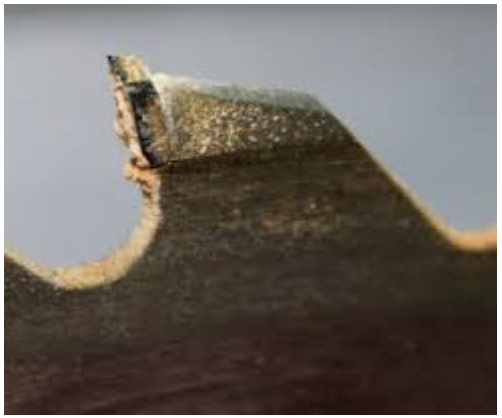
Manufacturing processes live in the real world

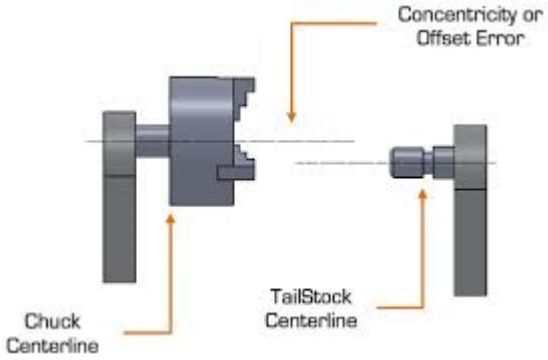
- **Worn tools**
- **Misalignments**
- **Material defects**
- **Etc.**











The perfect virtual world of the CAD model

And the reality-based imperfect world of manufacturing

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The perfect virtual world of the CAD model

And the reality-based imperfect world of manufacturing

Can collide with unpleasant results

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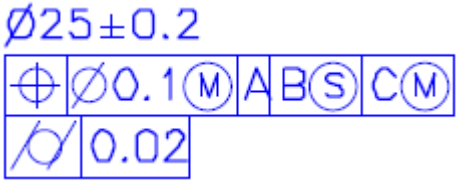
To the rescue is GD&T, which is a:

- **Rule-based**
- **Unambiguous**
- **Symbolic language**
- **Designed to communicate the limits of imperfections in the manufacturing world**



GD&T + ASME Y14.5 2009 = PMI

- **messenger of design intent and assembly instructions**

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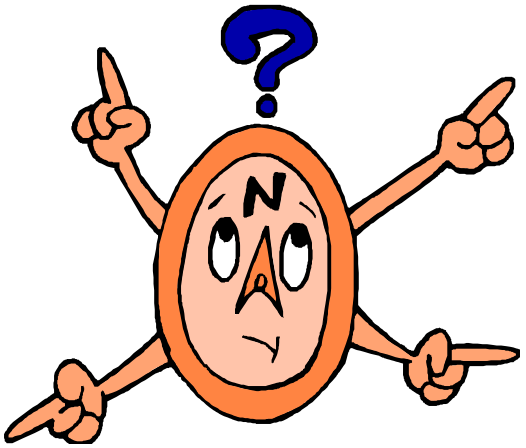
If you read anything about GD&T (ASME Y14.5 2009 standard excluded), you will see words like:

- **Misinterpret**
- **Misunderstood**
- **Confusing**
- **Complicated**
- **Costly**



These words mean GD&T benefits are not generally realized

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Somewhere, something is getting lost in translation

The message is not getting through …

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And worlds keep colliding

GD&T Encoding and Decoding with SpaceClaim

Somewhere, something is getting lost in translation

The message is not getting through …

And worlds keep colliding

But …

All is not lost

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Research is being conducted on new ways of applying GD&T PMI

Other GD&T tools offer:

- **Assistance in applying GD&T symbols**
- **Status highlighting to indicate completeness**
- **Wizard UI**
- **Online help**

GD&T is applied by attaching symbols to surfaces

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The market is in need of new functionality to:

- **Evaluate the perfect CAD geometry**
- **Supply feedback to guide and/or validate GD&T decisions**
- **Encode GD&T into the model based on feature geometry**
- **Graphically display Tolerance Zones to visually decode the GD&T**
- **Decode GD&T with textual descriptions**
- **Provide many other possibilities as we will see**

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CAD systems do a good job stepping you through the GD&T process

They give needed feedback along the way

None go the extra step of evaluating and recommending features for Datum Feature status

Choosing the Datum Features is the first step in the chain of events for applying GD&T

If the first link is off, well, the collision is set in motion

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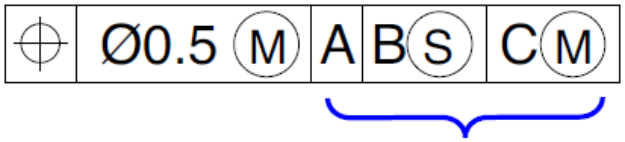
Datum Features form the Datum Reference Frame (DRF)

- **Locates the features for tolerancing**
- **Determines how tolerances stack up**



CAD leaves the choice of Datum Features up to the user

- **Different experience levels – different choices**
- **Different skills (Eng., MFG, QA, …) – different choices**

There needs to be an equalizer

To find one, we look at (yikes!) the standard …

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1.3.17.2 Datum Feature Simulator (Physical). *datum feature simulator (physical)*: the physical boundary used to establish a simulated datum from a specified datum feature.

NOTE: For example, a gage, fixture element, or digital data (such as machine tables, surface plates, a mandrel, or mathematical simulation) —although not true planes — are of sufficient quality that the planes derived from them are used to establish simulated datums. **Physical datum feature simulators are used as the physical embodiment of the theoretical datum feature simulators during manufacturing and inspection**. See ASME Y14.43.

(Emphasis added)

So, DRF's map to gages and fixtures

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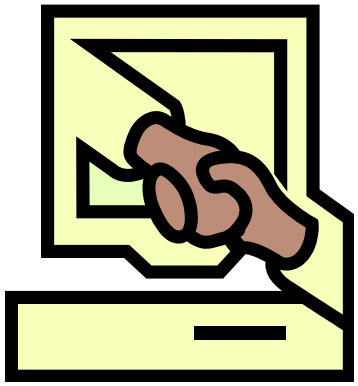
CAD model meet MFG



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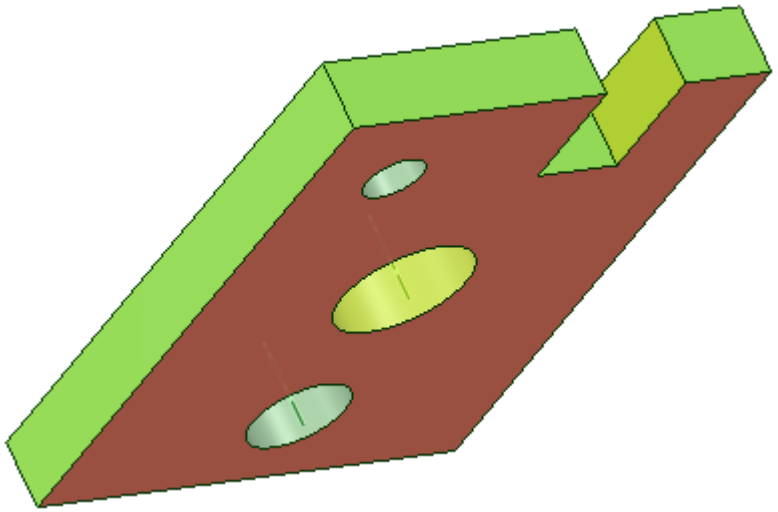
GD&T applies to the functions of *Design Features*

We allow you to "Featurize" the model

NOT *geometry construction features*

Function features

SpaceClaim classifies them as Slot, Bore, All Around, etc.



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Feature geometry should be analyzed to determine ability to constrain degrees of freedom in the model

The result is a ranking of each feature

Balance the rankings with functional, MFG, Assembly, and other considerations

Primary

	DF	Type	Orienting Relativ...	Constraints
☑	A	Planar Surface	90/120	Rx,Ry,Tz
☐	C	Planar Surface	13.39/90	Rx,Ry,Tz
☐		Slot	13.39/26	Rx,Ry,Tz
☐	B	Bore	6.64	Rx,Ry,Tx,...

Secondary

	DF	Type	Locating/Alignin...	Constraints
☑	B	Bore	1/6.64	Tx,Ty
☐	C	Planar Surface	13.39	Rz,Tx
☐		Slot	6.896	Rz,Tx

Tertiary

	DF	Type	Clocking/Alignin...	Constraints
☑	C	Planar Surface	75	Rz,Tx

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No substitute for knowledge and experience but the rankings will:

- **Supplement knowledge and experience**
- **Validate, or call into question, earlier choices**

Rankings allow creation of the SmartGD&T™ Degrees of Constraint Matrix

	Rx	Ry	Rz	Tx	Ty	Tz	Residual Mobility
A	●	●	—	—	—	●	ΔRx ΔRy
B Ⓢ	●	●	—	●	●	—	Stable
C Ⓜ	—	●	●	—	●	—	ΔRz

Use it to find competing Constraints (e.g. slot needed)

With a functionally sound DRF in place, the rest of encoding is guided by SpaceClaim

- Feature geometry filters out geometry control tools
- Geometry control tools determine modifiers
- DRF determines the datum references
- Datum References determine Basic Dimensions

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Encoded GD&T needs to be Decoded for communication

Decoding provides textual and graphical explanations of the encoded GD&T symbols

- **Selected tolerances are described in textual messages**
- **Tolerance zones are shown graphically**
- **Modifier-based TZ expandability and mobility shown graphically**

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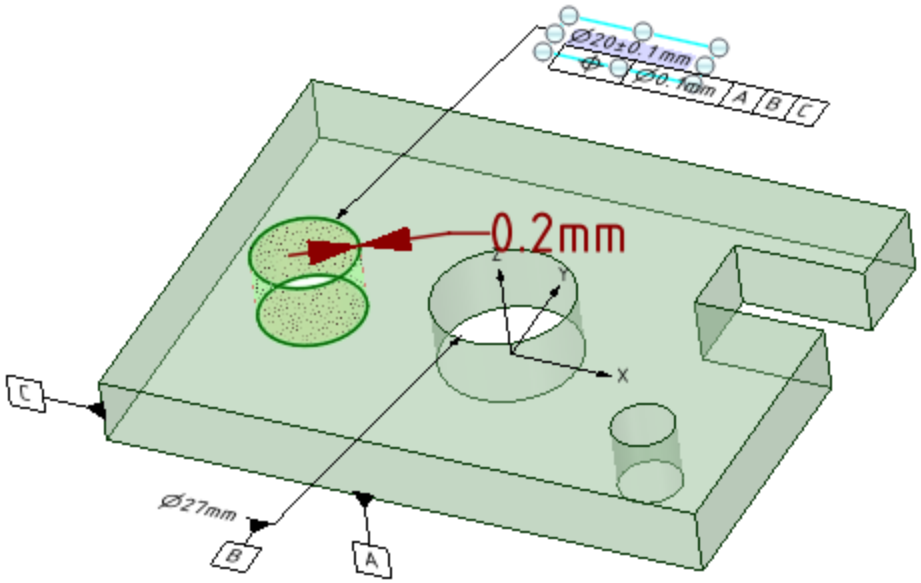
Under the influence of the Envelope Rule, the Diameter tool
requires all points on the surface of the Considered Bore
to lie within a tube-like Tolerance Zone of wall thickness
varying between 0 and 0.2mm, having an In-Space Boundary of perfect form of 20.1mm



Decoding also includes verification

- **Features are assessed for completeness**
- **Existing GD&T is assessed for accuracy**
- **Feature and symbol assessment status is saved to prevent double checking**

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SpaceClaim works well with geometry imported from other CAD systems

This goes for GD&T too

- **Imported directly from another system**
- **Transferred manually from a 2D drawing**
- **All can be evaluated, assessed, and decoded**

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The industry is nearly there:

- **First to link GD&T PMI with manufacturing and inspection by taking a geometry-centric approach**
- **Proprietary methods allow objective evaluations of features' abilities to constrain the model**
- **Datum features established in this way map better to manufacturing and inspection processes**

But there is more we can do

Imagine

- **Partially automated gage and fixture**
- **Assembly constraints intelligently drive automatic Datum Feature selection**
- **Partial automation of the mating part tolerancing process**
- **Expand and contract models to their virtual LMB and MMB**
  - **Nice worst-case and average visual tolerance stack up analysis**

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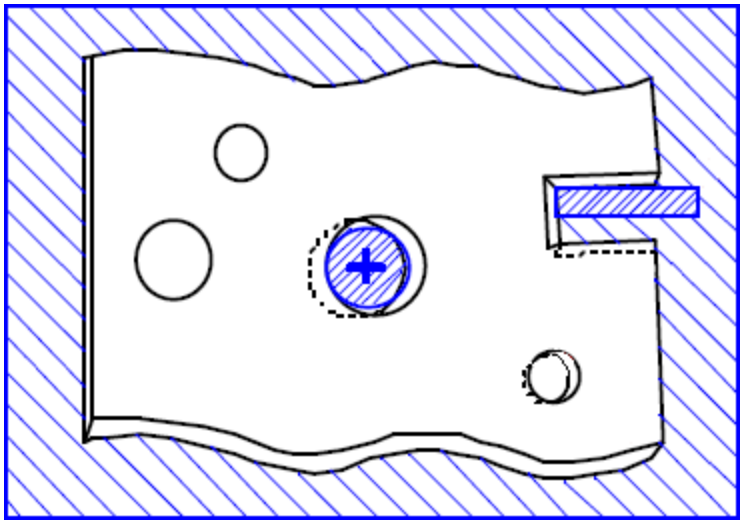
- **Visualize assembly with tolerance zone expandability and mobility**



Simulates assembly

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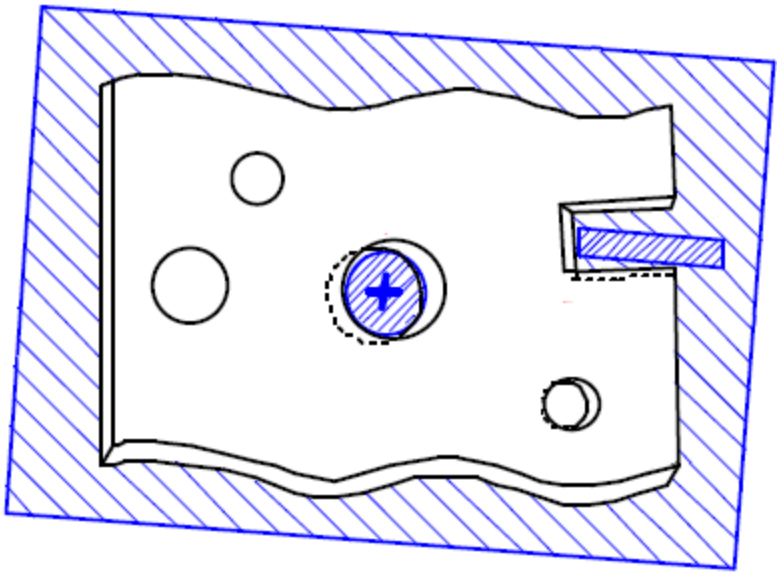
- **Visualize assembly with tolerance zone expandability and mobility**



Simulates assembly

Acknowledgments

Bill Tandler, founded Multi Metrics and serves as the CEO and CTO. He is the inventor of SmartGD&T™ and the author of many GD&T course manuals.

SpaceClaim has partnered with Bill to be an expert consultant on GD&T in SpaceClaim. Aside from SmartGD&T references in this presentation, his input is reflected in the content overall.

Thank you

Q & A