What I will present:

• What is Geometric Dimensioning and Tolerancing (GD&T)
• How GD&T helps Design, Production, Inspection and the Enterprise
• Drawing Previews
• Where the technology is headed
• What Tec-Ease brings to the table
Overview of GD&T

Geometric Dimensioning and Tolerancing (GD&T) is recognized around the world as the only effective way to define and control part geometry.
What Is GD&T?

GD&T is many things including:

- A concise language used on engineering documentation to provide one clear definition of mechanical parts
- Symbols
- Rules
- Vocabulary
- Mathematical definition (ASME Y14.5.1)
- An internationally recognized standard
  - ASME Y14.5-2009
  - International Standards (ISO 1101,........)
Variation

Craftsmen do not need GD&T. If you want it to fit the first time every time, you do need GD&T.

Interchangeability:
Making two or more parts separately and expecting them to fit together and function – even if you are only making one assembly.
The shipping cost is $10,000 a pound.

Houston, it doesn’t fit!
Without GD&T, clear design definition is not possible!

Traditional Engineering Drawing

Desired Part

What the Supplier Can Make and get away with!

Engineering Drawings/3D CAD Data constitute a legal contract between the customer and supplier – Clear design definition is important or we can “eat” bad parts.
Traditional Coordinate Dimensioning and Tolerancing (CD&T)

- Tolerance zones do not reflect geometry.
- Form and shape are not addressed.
- Important features are not identified.
- No clear frame of reference for functional design and inspection.

Does this drawing satisfy design intent?
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN mm
LINEAR TOLERANCE: ±0.2
ANGULAR TOLERANCE: ±2°
If you ignore the tolerance accumulation and angular tolerance, the tolerance zone would look like this:

But, how do you line the part up with the tolerance zone?
Buying?

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN mm
LINEAR TOLERANCE: ±0.2
ANGULAR TOLERANCE: ±0.5°
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN mm
LINEAR TOLERANCE: ±0.2
ANGULAR TOLERANCE: ±2°
With this approach:

- Measurement origins are clear
- Tolerance accumulation is minimized
- Features are tolerated - not points in space
- The tolerance zones are uniform
With new CAD tools we can make decisions earlier in the design process—at the **model stage** before drawings are created.
Caution:

Do not take this next step unless everyone downstream has the technology necessary to interrogate and utilize the CAD file.
ASME Y14.41 establishes rules for the embedding of tolerances on the model.

Tolerances are embedded in the 3-D model.

Those downstream do not need a CAD system—they need a computer. The drawing may be sent in a viewer that they can read but not change.

This will enable automated analysis of parts and assemblies including the tolerance.
Future technology without GD&T will not work. GD&T embedded in solid models will enable:

- Automated tolerance analysis
- Finite element analysis which includes feature variation
- Paperless
- Dimensionless
- But, toleranceless design — NO WAY!!!!!
The problem with this dimension and tolerance is that it isn’t clear what the origin is. Is it the center of the:
- Ø30 Hole?
- Ø50 Hub?
- Ø100 OD?

If you asked Engineering, they would tell you and this is the start of Tribal Knowledge.
Once again, the problem with this dimension and tolerance is that it isn’t clear what the origin is.
What about the 90° angles?
A basic dimension does not use the general tolerance.

UNLESS OTHERWISE SPECIFIED:
LINEAR TOLERANCE: ±0.2
ANGULAR TOLERANCE: ±2°
Once the origin is established using the datum features A, B and C, an indicator may be “zeroed” at the origin and moved 40 mm. When the indicator is moved across the surface, the indicator may not move more than + or - 0.1. The meaning is now clear.
Traditional Coordinate Dimensioning and Tolerancing

If the actual value in the ‘x’ direction for 1.000 dim is 1.005 and the ‘y’ direction is 1.007 with a hole size of Ø.495, do we have a good feature?

Note: The drawings are incomplete intentionally. Dimensions are in inches.

$1.000 \pm .005$

Actual axis located outside of tolerance zone = reject feature!
Actual size is ignored!
(Previous)

Drawing Using GD&T

If the actual value in the ‘x’ direction for 1.000 dim is 1.005 and the ‘y’ direction is 1.007 with a hole size of Ø.495, do we have a good feature?

Note: The drawings are incomplete intentionally. Dimensions are in inches.

Actual Position Tolerance:

\[ = 2 \sqrt{X^2 + Y^2} \]

\[ = 2 \sqrt{0.005^2 + 0.007^2} \]

\[ = 2 \times 0.0086 = \varnothing.0172 \]

Actual axis located outside of tolerance zone = But wait, what is the hole size? Ø.495 = Ø.005 bonus tolerance (=Ø.019 position)! Accept feature!
Tolerance Zone Improvement with GD&T

A round tolerance zone derived from an existing square tolerance zone results in 57% more area. The 57% increase in usable tolerance (shaded areas) derived from geometric tolerancing, would not be acceptable in coordinate tolerancing situations.

The small red crosses represent a few of the infinite number of possible axis locations that would be *unacceptable*, using coordinate tolerancing, but which would be *acceptable* in position tolerancing.

Consequently, geometric position tolerancing—in appropriate applications—has provided significant cost savings.
So, how did we survive all of this time without GD&T?

- Our quality demands are greater today
- Our designs are more complex
- Manufacturing and suppliers took the time to develop tribal knowledge
  - Parts were made in spite of the drawing
  - Much time was required at startup
  - We relied more on gaging and inspecting out the bad parts rather than process control
  - Along the way, time and money were wasted
Problems Resulting from Overly Tight Tolerances, Unclear Geometry and Non-producible Designs Will Manifest

- Requests for engineering changes
- Scrap
- Rework
- “Use as is” decisions
Drawing Previews!
Design: The common thread

Production

Quality
“It’s not like the print, but I think you will like it.”
Ask the right questions up front—document the answers

Find a problem - then fix it - develop tribal knowledge
Reduce Liability

While tribal knowledge is being developed the customer often must accept (and pay for) parts that are unacceptable from suppliers. When the drawing isn’t clear, there is no basis for rejection of these parts.
Applying critical and producible tolerances where needed

As the tolerance gets smaller-the cost goes up.

Where do you find 0?

The first prototype?

Supplier samples?

CAD models?
The best design in the world is worthless if no one can produce it, or produce it cost effectively.

As the tolerance gets smaller, the cost goes up.

Tolerance

The best design in the world is worthless if no one can produce it, or produce it cost effectively.
Who is positively impacted by GD&T?

- Design
- Production
- Quality
- The Entire Enterprise
How Design is helped:

- Clearer design intent
- Shorter cycle time from concept to launch
- Fewer engineering changes
- Less troubleshooting at startup
How Design is helped:

Clearer design intent
Fewer engineering changes:

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How Production is helped:

• Produce parts that will function
  – Reduce Scrap, Rework and “Use as is” decisions

• Reduce the need to develop tribal knowledge

• Make parts according to (rather than “in spite of”) the print

• Startup time for new programs is greatly reduced
How Quality is helped:

• Create clear metrics
  – Provide a means to establish process control indices Cp and Cpk
• Legitimize gages and fixtures
• Meaningfully evaluate suppliers
• Make decisions based on functional requirements
Robust Means:

“Insensitive to variation in the factory and in the hands of the customer”

• A robust design is one that has high Cp’s and high Cpk’s
• Allowable variation in the factory is stated on the drawing by tolerance.
• By properly applying GD&T, Design recognizes process variation and assigns tolerances to minimize the effect of this variation on the product’s performance.
Cp = Design Spec Width
\[
6\sigma
\]
Design

Quality

Production
Responsibilities of the Multi-discipline Team

• Define the ideal geometry on the drawing or CAD file

• Apply critical and producible tolerances where needed

• Maximize production tolerance without sacrificing quality and reliability
In order to properly apply geometric dimensioning and tolerancing, several questions must be answered. These include:

- which features are most critical
- will the effect on the part's performance be altered as a feature’s size varies
- which feature interrelationships are critical
- which features are not critical
- what inspection methods will be used to control the process and are they adequate
• are several processes used to manufacture the part
• are the tolerances reasonable
• or is it producible
• what process or processes will be used
• is the entire feature or only a portion critical
Is the main concern:

- interchangeability
- alignment of multiple parts
- maintaining a minimum wall thickness
- providing minimum material for a subsequent machining or forming operation
- dynamic balance
- feature location, orientation, form or size
- control of a pattern of features
Involving the team in tolerancing:

- increases their awareness of the product’s needs
- causes the right questions to be asked
- is an educational experience for all those involved
- provides two-way communication between departments
- makes those involved feel like a part of the solution - not the problem
- gives everyone a vested interest in making the product work
So, where do tolerances come from?

• Past practice or carryover (legacy)
• Data found in out-dated handbooks based on 3 Sigma quality
• Seat-of-the-pants guesses
• Individual experience of the designer
• Spec Heaven?
Function does not determine the Tolerances!

- Function is what the customer wants
- There are always alternatives to a design
- Some are more robust than others

Tolerances are determined by the design alternative selected.
Consider Design Alternatives

• There are always design alternatives
• Some designs are more robust than others
• The selected design should meet the Quality, Cost and Delivery targets
• The design must be clearly documented using GD&T
Selection of appropriate dimensioning and tolerancing early in the design cycle will result in:

- A more robust design
- Higher quality
- Shorter time to market
- Better product understanding
- Fewer fit and functional problems
- Fewer engineering changes
What we bring to the table:
Our involvement with Standards Committees means you will:

- Be aware of upcoming changes to National and International Standards
- Have a voice at standards meetings
- Have the most authoritative training possible
Free Coaching via Phone, Fax and Email

- Follow on coaching is provided free of charge on specific questions for anyone who has attended our training.
- Responses are, whenever possible, linked to specific references to the appropriate Standard.

We are also available to assist with specific design projects at per diem plus expenses.
Flexibility

- **Training on demand**
  - We will block out days dedicated to you
  - When offering multiple courses, scheduling may be creative to reduce impact on departments’ work loads
Capacity

• Three trainers ready to begin
• Additional Senior Level Certified Trainers are available
• Develop local trainers (Train the Trainer)
• Can assist local colleges with course development
Delivery

• In class presentations
  – PowerPoint ® style presentations
  – Workshops
Delivery

• Student Evaluation
  – Pre-assessment — if desired
  – Post-assessment – if desired
  – On-line testing is included in price
    – Does not take up class time
    – At participants convenience
    – Most cost effective
Delivery

- Computer Based Training development available
Highlights of the Training

• Emphasis on Simultaneous Engineering
• Associate GD&T with Cp and Cpk
• The GD&T Hierarchy
• Economical and Practical Approach
• Tie to Inspection and Manufacturing
• Link to DFA and DFM
• Humor and Uncommon Sense
Tec-Ease Products Include:

- Computer Based Training Software Packages
- Training Texts
- Self Study Courses
- Videos
- Charts
- Pocket Guides
- Premium Membership with access to over 170 GD&T tips.

See our website for more information.
Courses Offered by Tec-Ease, Inc.

- Fundamentals
- Applications
- Inspection
- Tolerance Stack-Ups

- Geometric Dimensioning and Tolerancing
Recommended Course Lengths

• Fundamentals (3 days/24 hours)
• Applications (2 days/16 hours)
• Inspection (2 days/16 hours)
• Tolerance Stack-Ups (2 days/16 hours)
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