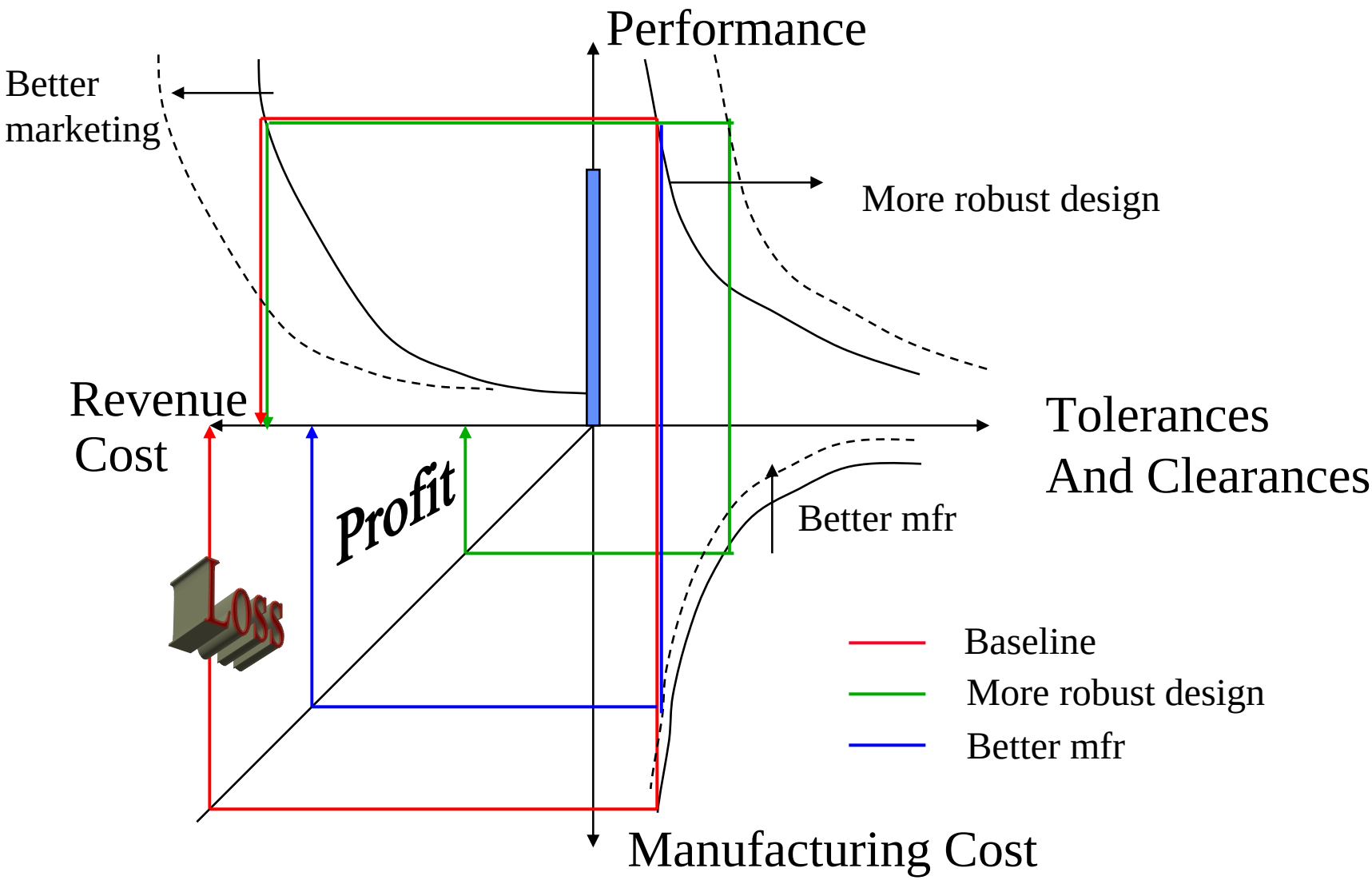
Variation Buildup in Single Parts

- Learn about the history of interchangeable parts
- See how parts are given tolerances
- Learn what geometric dimensioning and tolerancing is all about
- Look ahead to variation buildup in assemblies

The Business Case for Tolerances



Definitions

- Tolerance
  - What is allowed or acceptable, defined by “specification limits”
  - Specification limits are set by engineers, designers, and/or manufacturing people
- Variation
  - What actually happens with real parts and assemblies
  - Variation can be measured
- Clearance
  - Empty space between surfaces on different parts
  - Often confused with “tolerance”
  - Clearances can have tolerances and can vary
- These are typical definitions in the academic and professional literature

History of Interchangeable Parts

- Quest for interchangeability
  - Begins in 1760s as a customer requirement for muskets
- Evolved as a means to systematize manufacturing (1830s)
- Culminates in Ford's moving assembly line
  - Permits rapid assembly and mass production
  - Enables supply chains
  - Avoids coordination
  - The "zeroth" interchange occurs at first assembly
- Enabled supply chains via standards for gaging and tolerancing (1915 to today)

History - 2

- Geometric Dimensioning and Tolerancing (GD&T) replaced ±dimensions (1940s +)
  - Replicated gaging procedures on paper
- Solid modeling CAD forced reconsideration of GD&T on a more mathematical basis
- Parts tolerancing seems OK but assemblies are still something of a mystery
- Coordination makes a comeback as demand for quality exceeds capability

Taniguchi's Diagram

Image removed for copyright reasons.
Source:
Figure 5-1 in [Whitney 2004] Whitney, D. E. *Mechanical Assemblies: Their Design, Manufacture, and Role in Product Development*. New York, NY: Oxford University Press, 2004. ISBN: 0195157826.

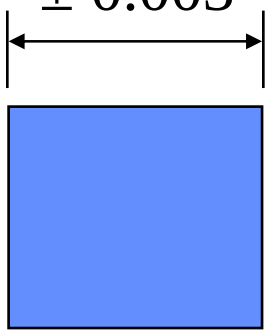
Geometric Dimensioning and Tolerancing

- Seeks to deal with solid objects rather than lines on paper
- The result is definition of “zones” where surfaces should lie
- This is good from the point of view of being realistic about solid objects
- It does not shed light on what the tolerances should be in order to achieve any particular function

How Big is a Cube?

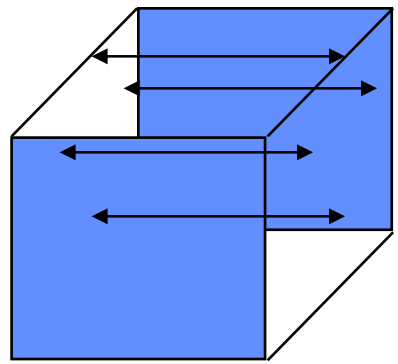
Conventional drawing showing one face

1.000
± 0.003



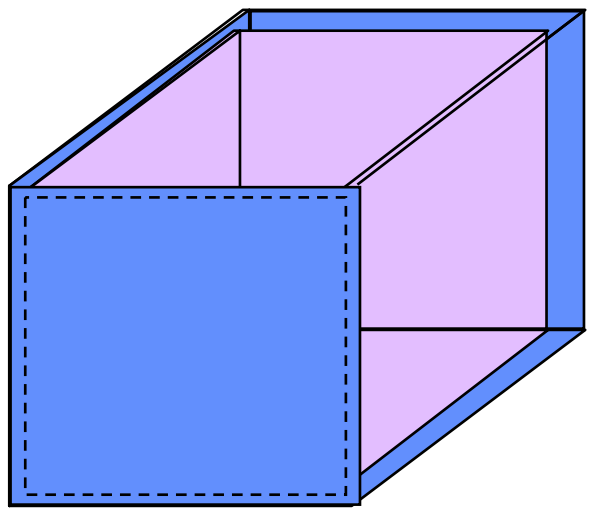
This arrow really sets the distance between two lines. This means nothing.

A more realistic view of the cube



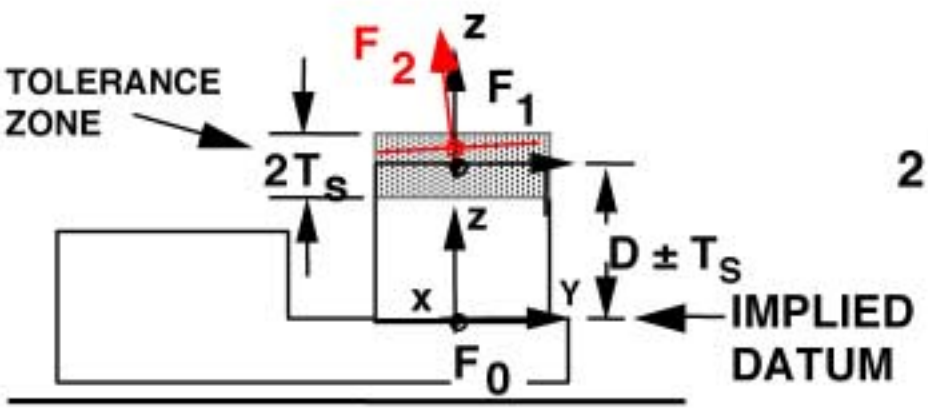
How many arrows are needed to say how far apart the two surfaces are???

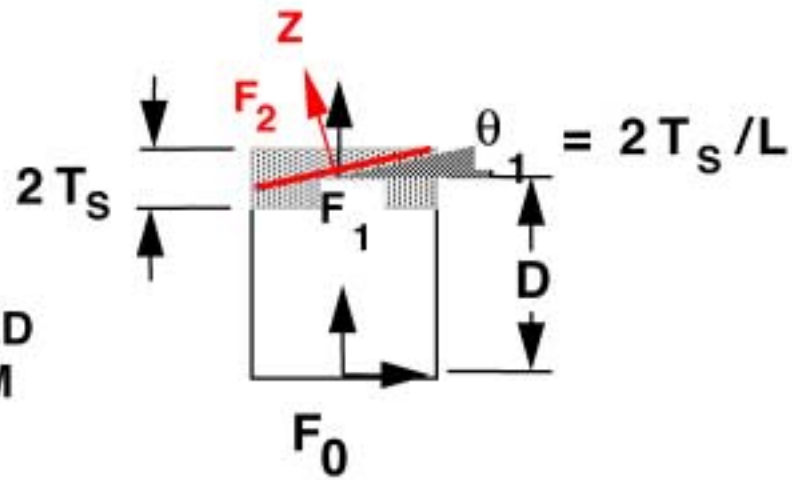
All Acceptable Cubes Lie Between Two Perfect Nested Cubes



The Actual Surface Must Lie Inside the Zone

Rule #1: The surface must be correct at max material condition.



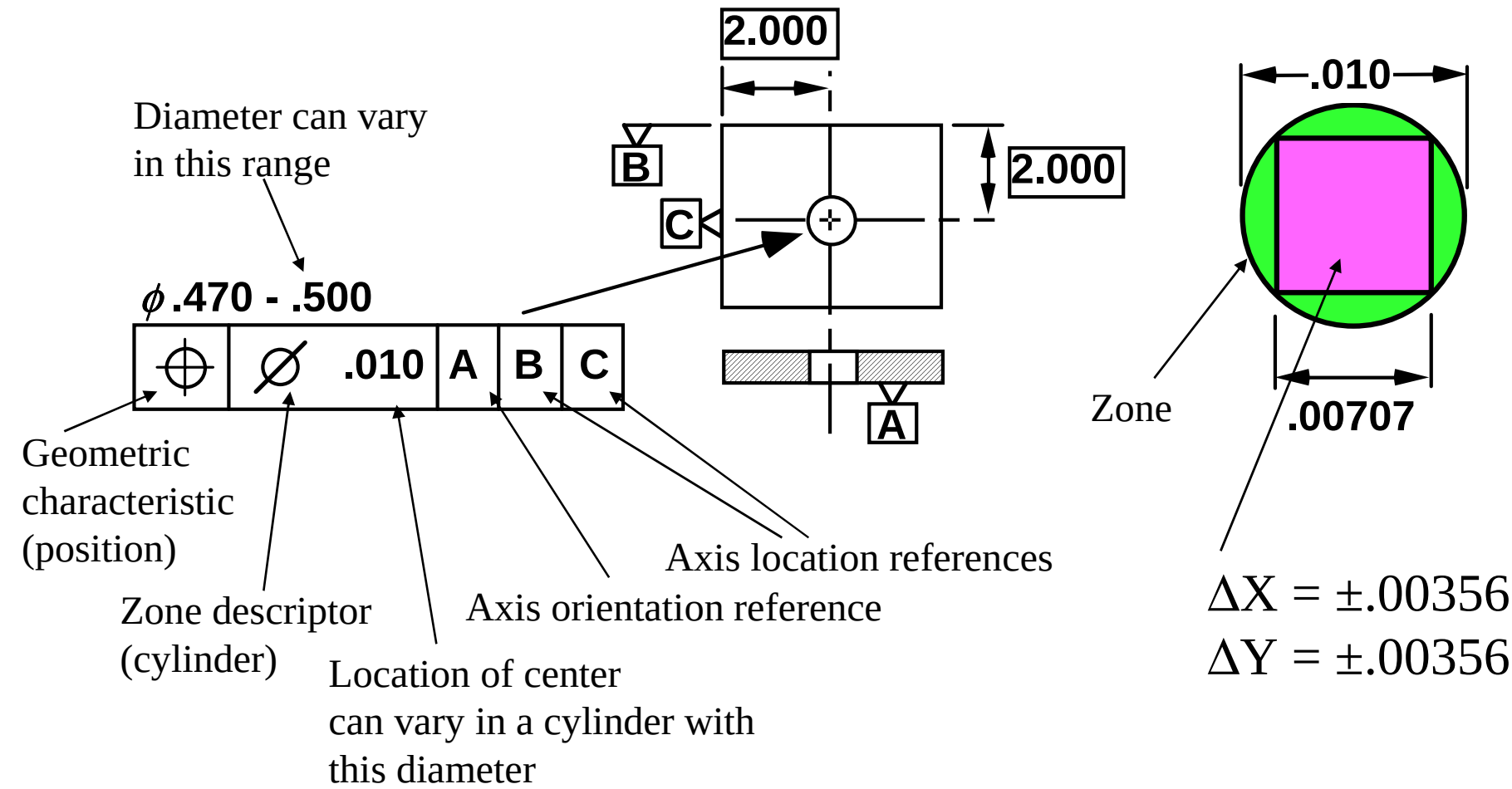


This, too, is allowed unless flatness is specified

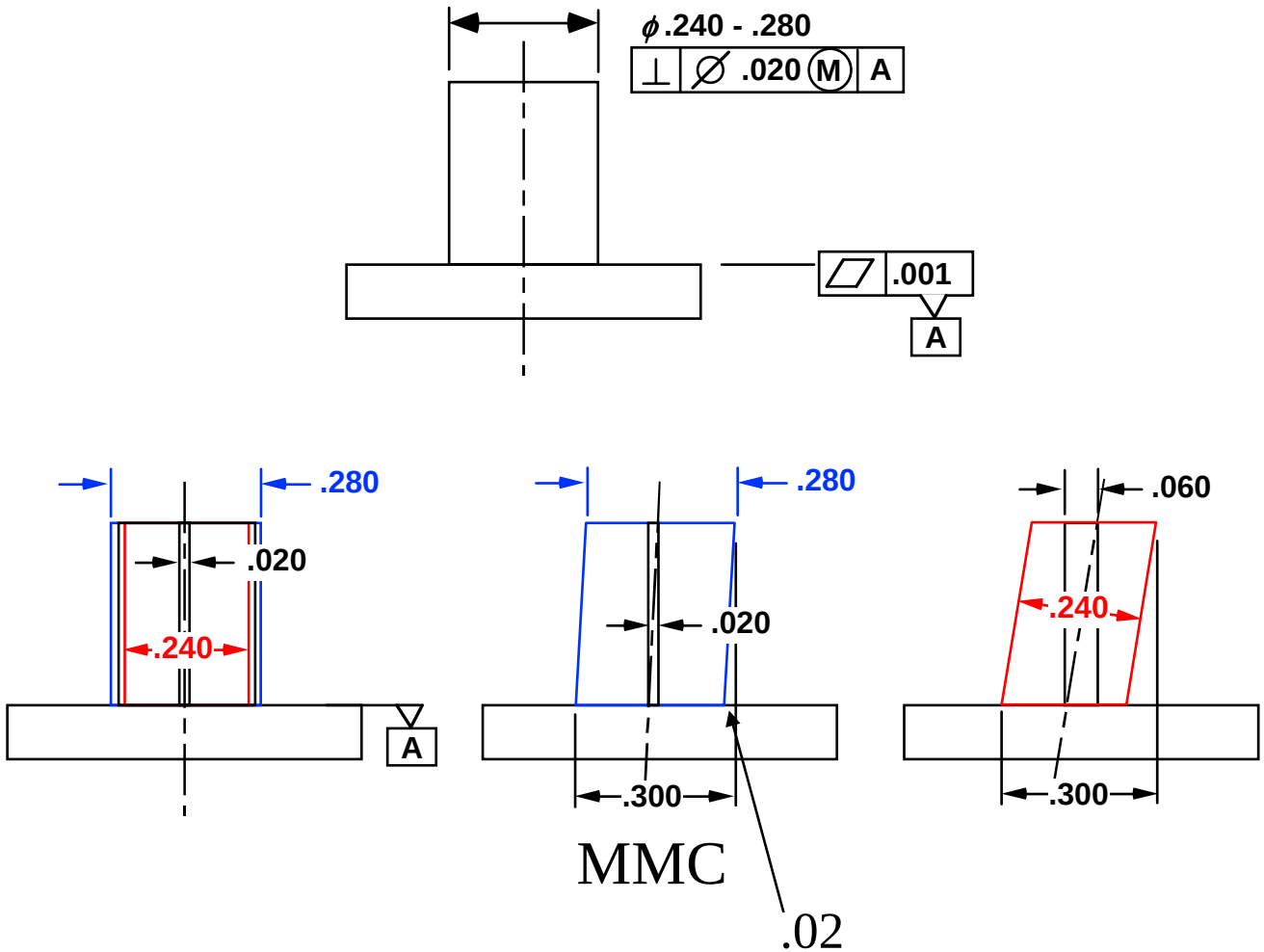
Goals of Geometric Dimensioning and Tolerancing

- Account for 3D Geometry of Parts
- Define Datum Hierarchy
  - A, B, C
  - Corresponds to 3,2,1 of Constraint
  - Standardizes machining, fixturing, and gaging
  - Make the A surface wide, stable, 3 points separated
- Guarantee that any randomly selected pair of parts will assemble (i.e., “worst case” tolerancing)
- Has become an international standard
- Does not apply to assemblies

GD&T Control Frame for Locating and Sizing a Feature

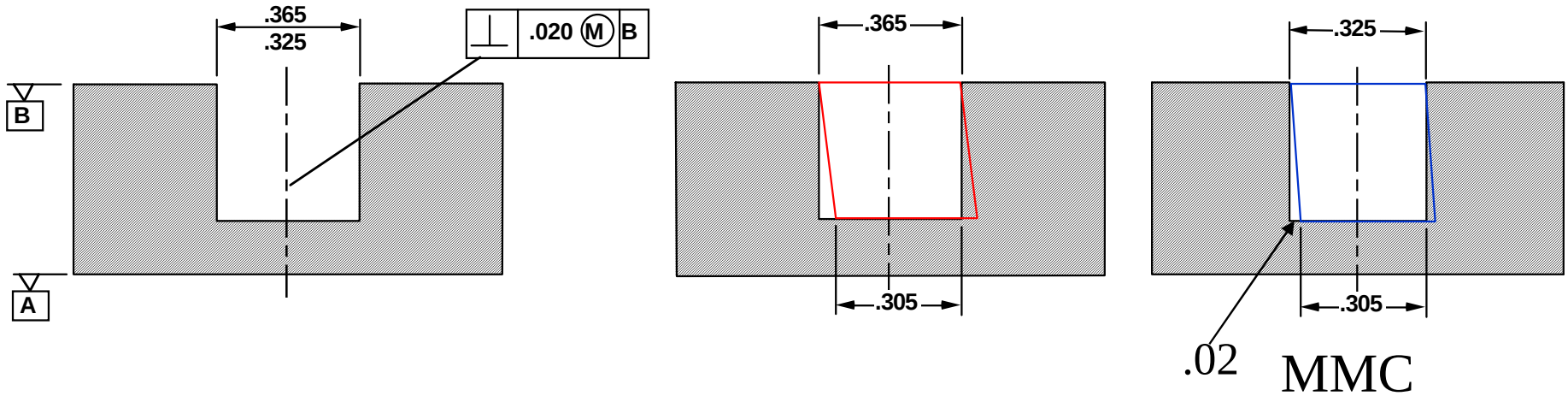


Virtual Condition Guarantees Assembly



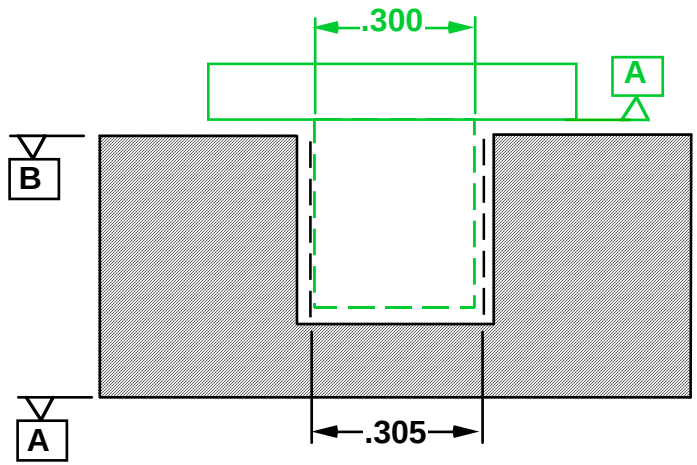
The virtual condition is a perfect round perpendicular pin .300 diam

Virtual Condition Guarantees Assembly - 2



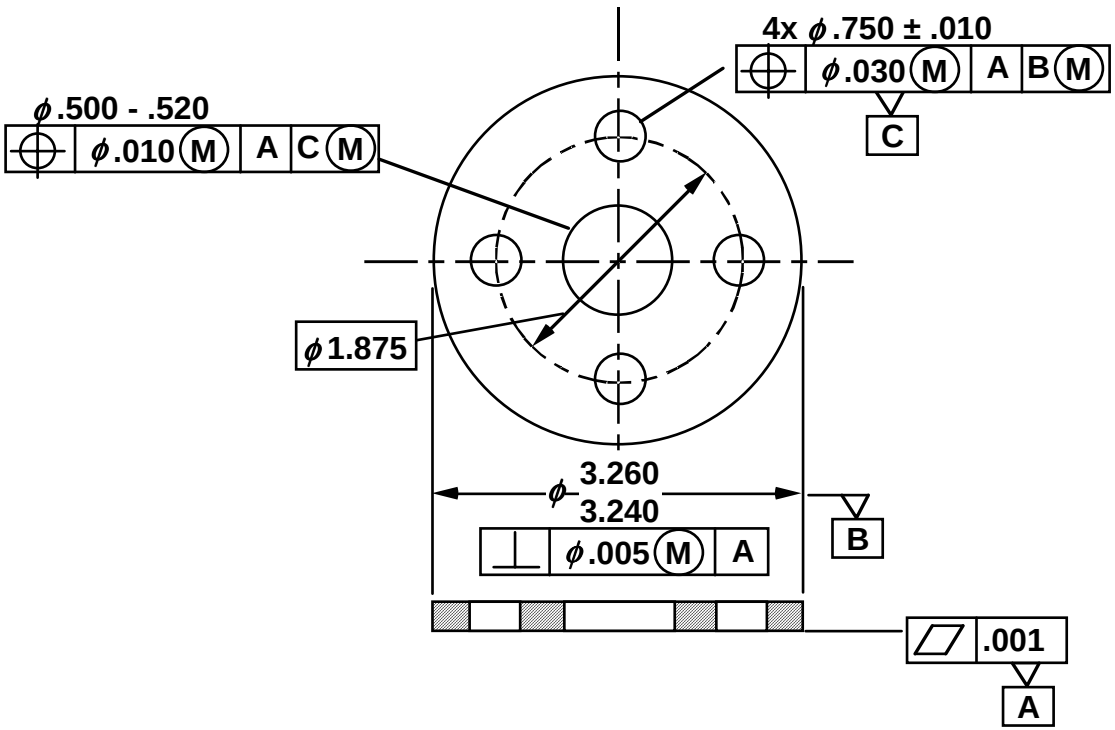
The virtual condition is a perfect round perpendicular hole .305 diam

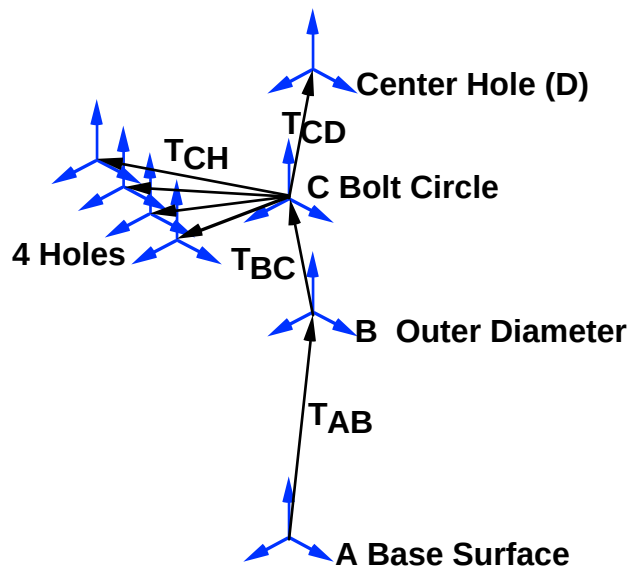
At worst, the hole occupies a region no narrower than .305



At worst, the peg occupies a region no wider than .300

GD&T is ~Equivalent to Chain of Frames Inside a Part





Summary

- The goal of interchangeable parts is over 250 years old
- Parts can be toleranced by international standard methods in ways that
  - Respect our notions of constraint
  - Locate features with respect to datum surfaces
  - Can ~be represented by chains of frames similar to the way assemblies can
  - Impose worst-case tolerances
- No standard exists for tolerancing assemblies
- No clear path exists in standard methods for linking assembly goals to part tolerancing