International Institute of GD&T

Implications of Complex Surface Geometries and Tight Tolerances on Manufacturing & Metrology

Presented at "NACMA"

September 17, 2009

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Abstract:

Complex surface geometries and decreasing feature tolerances are driving the need for unprecedented precision in product design definition and identifying Profile Tolerancing as “the” solution for future dimensioning and tolerancing practices for mechanical components and assemblies. This presentation will highlight limitations in common (+/-) tolerancing schemes and will show how Profile Tolerancing provides the basis for precision tolerancing on the engineering drawings and precision measurement in manufacturing and metrology.

Business & Technology Constraints

Technology Challenges & Constraints

- Miniaturization & Tolerance Truncation
- Cycle-time Competing with Precision Requirements

Business Challenges & Constraints

- Decreasing Profit Margins
- Tolerances Decreasing - Bad Decisions Increasing

High-Risk Issues

- Inability for designers to represent functional intent through engineering drawings and specifications.
- Individuals not trained optimally to manufacture and inspect product to engineering drawings and specification (Includes tooling, fixtures and equipment)

Tolerancing Implications

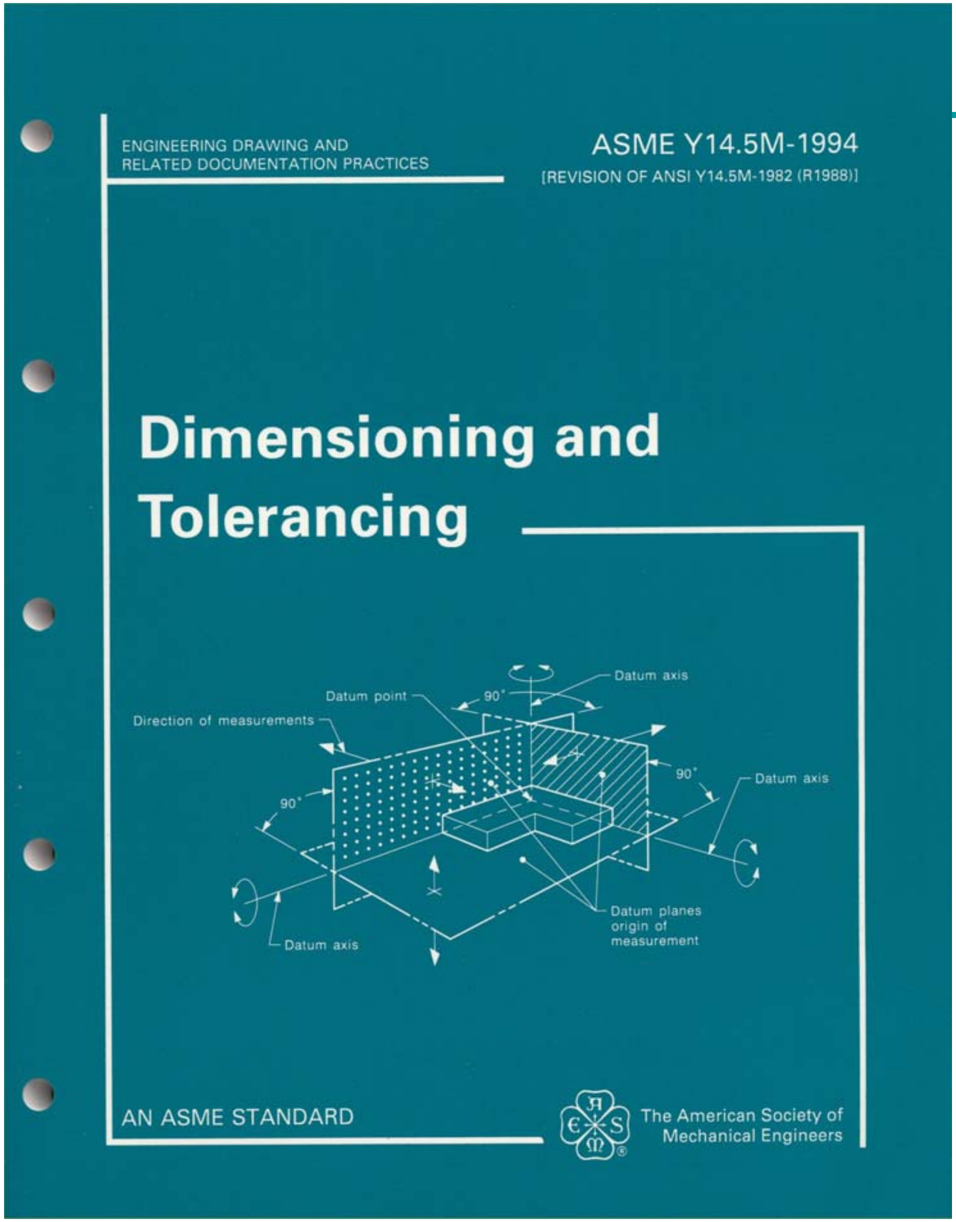
Scenario Based on Design Specification of +/- .001

- +/ - .001000 (1000 µin) = Design Specification
- +/ - .000250 (250 µin) = Manufacturing Requirements at 4:1 Ratio (1 sigma)
- +/ - .000060 (62 µin) = Metrology Requirements at 4:1 Ratio (1 sigma)
- +/ - .000015 (15 µin) = Calibration Requirements at 4:1 Ratio (1 sigma)

Design for 6-Sigma would result in the following

- +/ - .001000 (1000 µin) = Design Specification
- +/ - .000167 (167 µin) = Manufacturing Requirements at **6:1 Ratio** (1 sigma)
- +/ - .000042 (42 µin) = Metrology Requirements at 4:1 Ratio (1 sigma)
- +/ - .000010 (10 µin) = Calibration Requirements at 4:1 Ratio (1 sigma)

Dimensioning & Tolerancing Standards



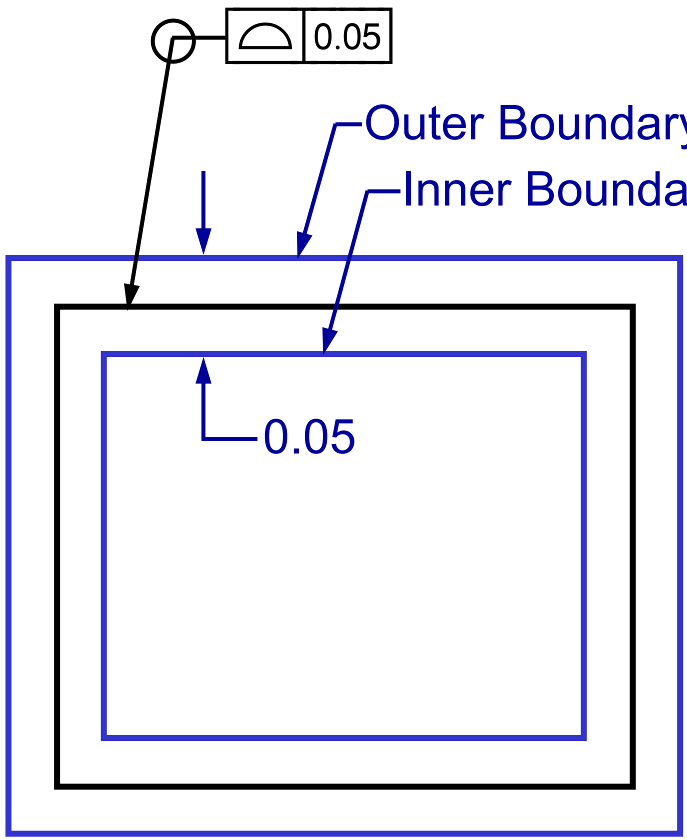
Used by 85% of the companies in the world

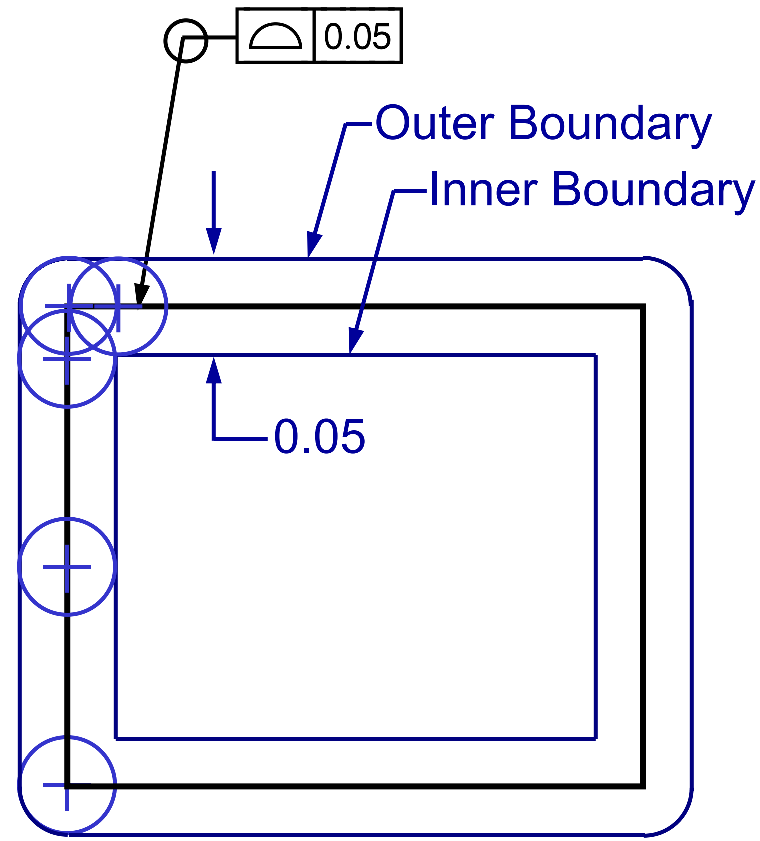
Other National Standards

- **CAN – Canadian Standards**
- **JIS – Japanese Standards**
- **DIN – German Standards**
- **GB – Chinese Standards**
- **UNI - Italian Standards**
- **ISO – ISO Standards**
- **Etc…… the list goes on**

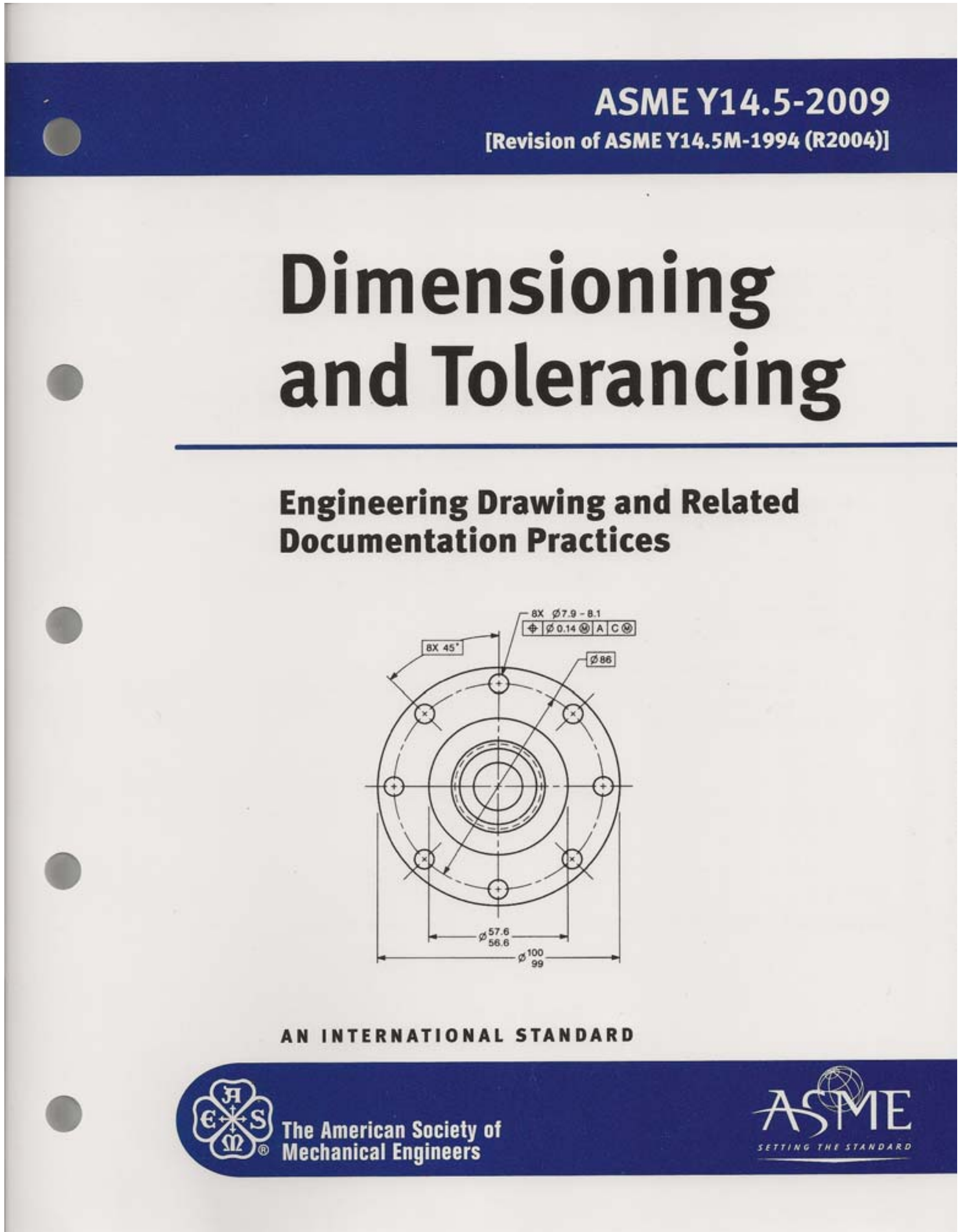
Caution: Other National Standards are not 100% equal to ASME Y14.5M-1994

Profile "ASME Y14.5" -vs- "ISO 1101"





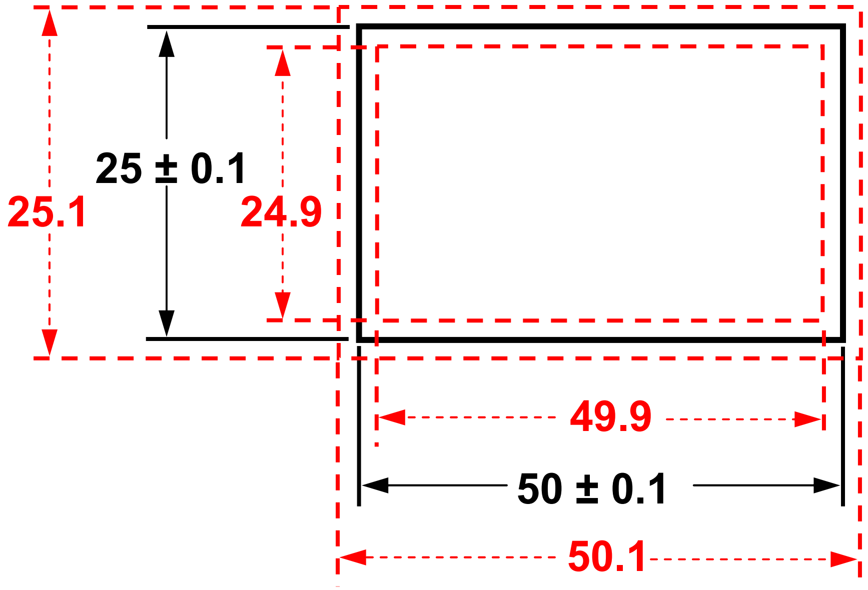
ASME Y14.5-2009



ASME Y14.5 - Rule #1

What are the derived boundaries you envision for the 25 +/- 0.1 & 50 +/- 0.1?

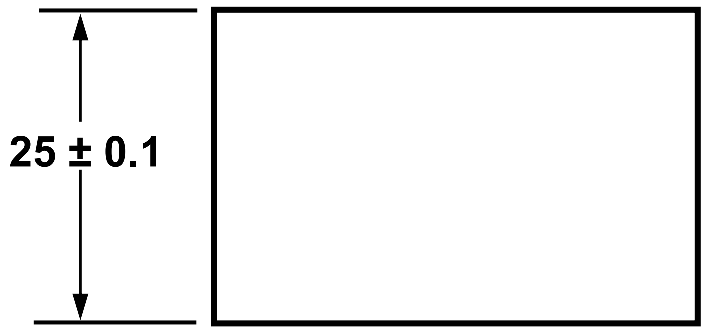
“Perceived” inner and outer boundaries

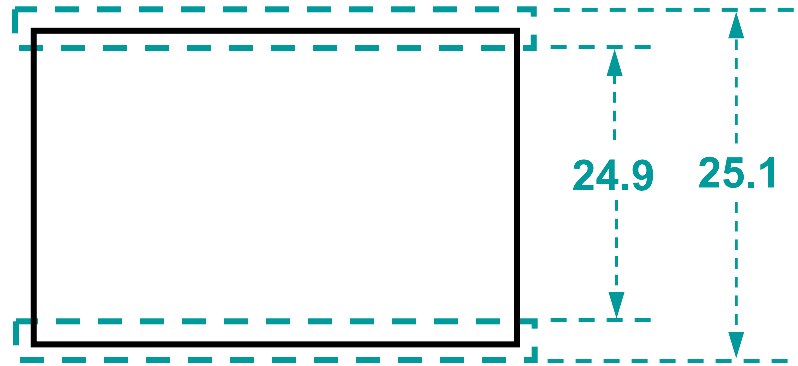


Red boundaries do not represent worst case allowable boundaries

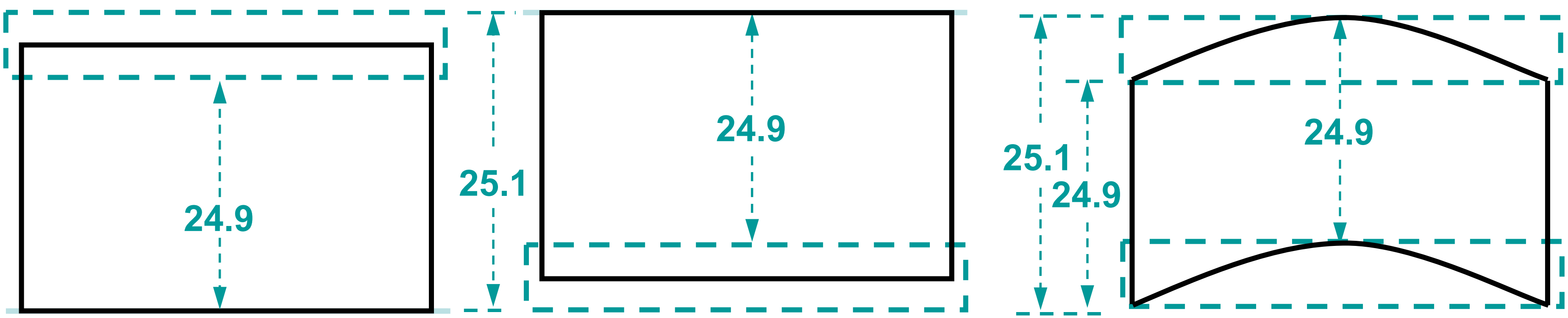
Rule #1

Rule #1 controls the limits of size (actual local size) and the boundary of perfect form at it's Maximum Material Condition (MMC).





Tolerance Boundaries represent allowable variation in form and size



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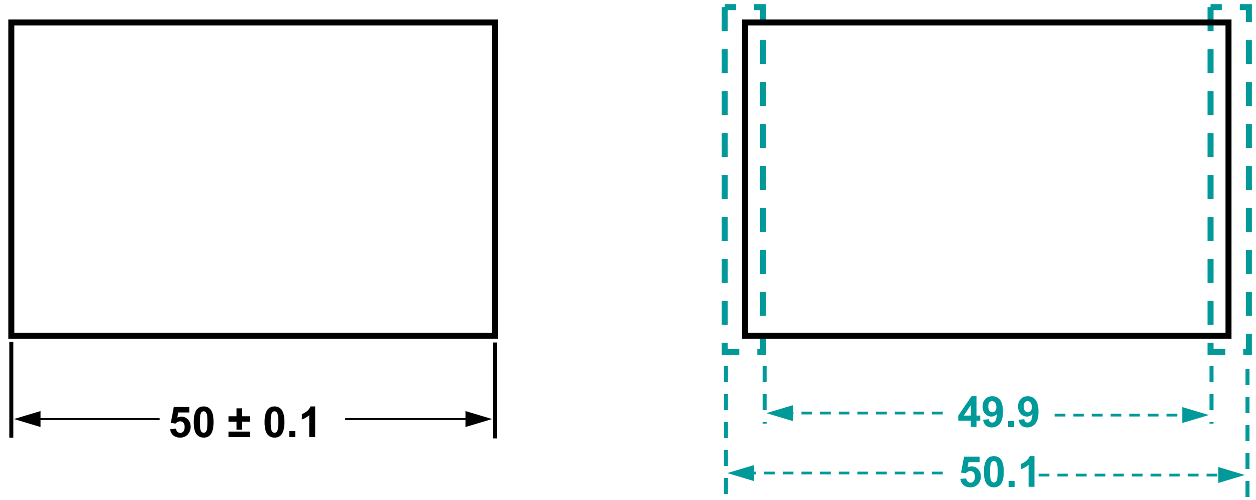

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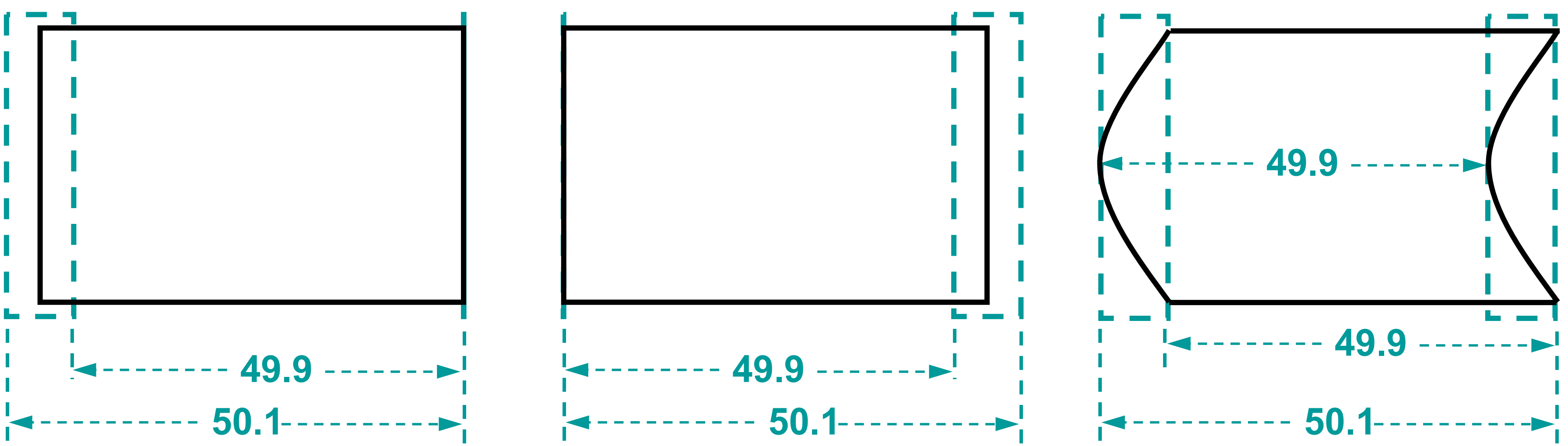
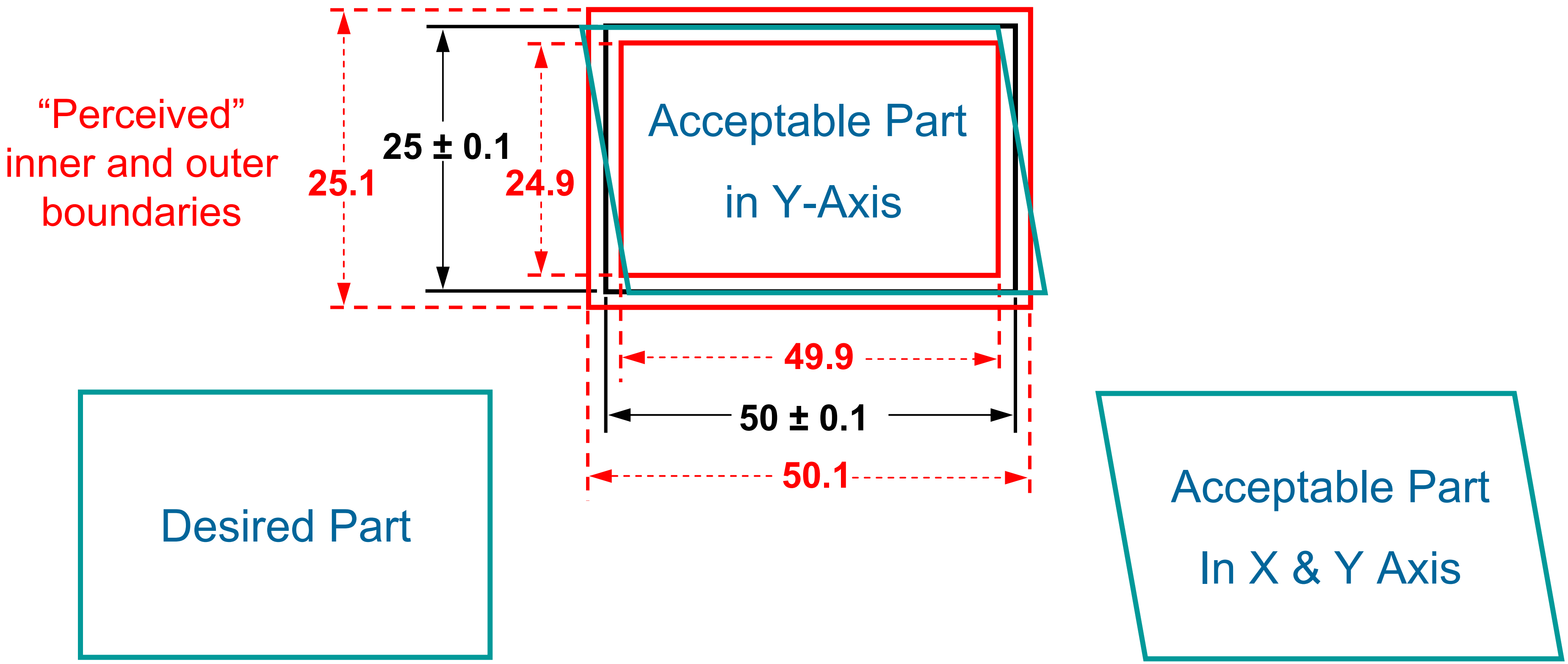


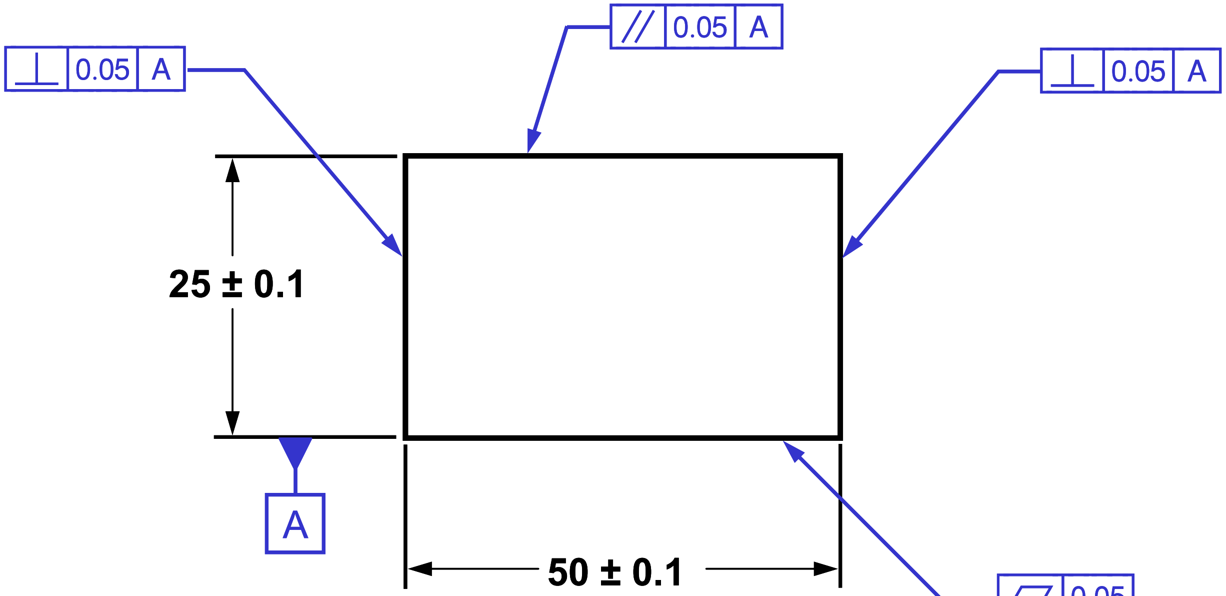
ASME Y14.5 - Rule #1

Rule #1 does not control the interrelationship between features.

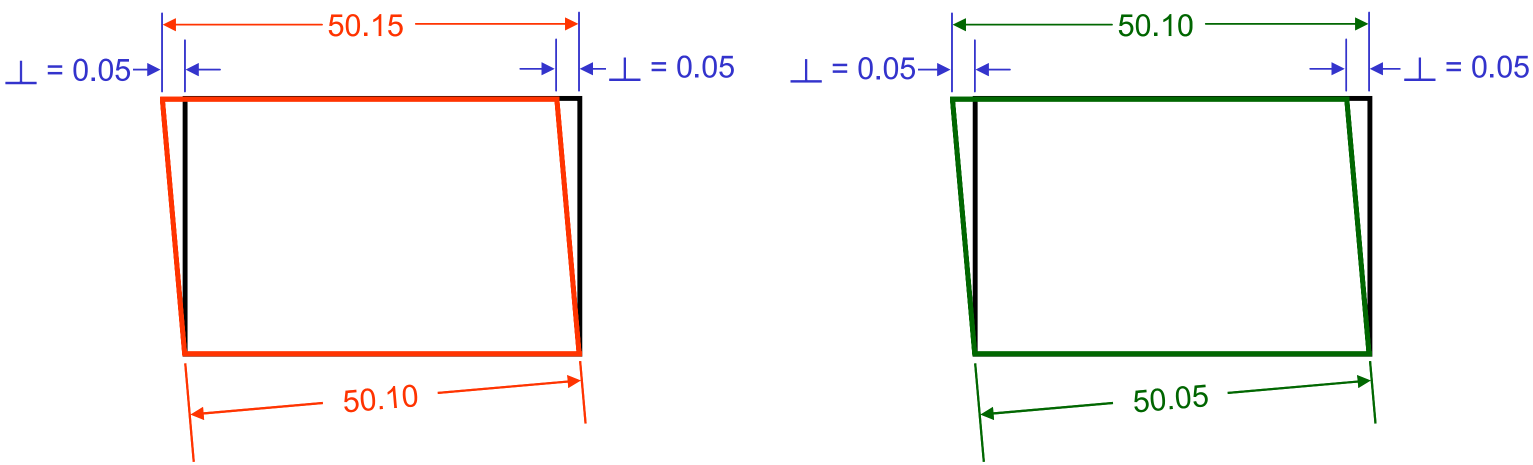


Angular Tolerance Controls Magnitude of the Parallelogram

Less than Optimum Utilization of GD&T Tools



Analysis of X-Axis

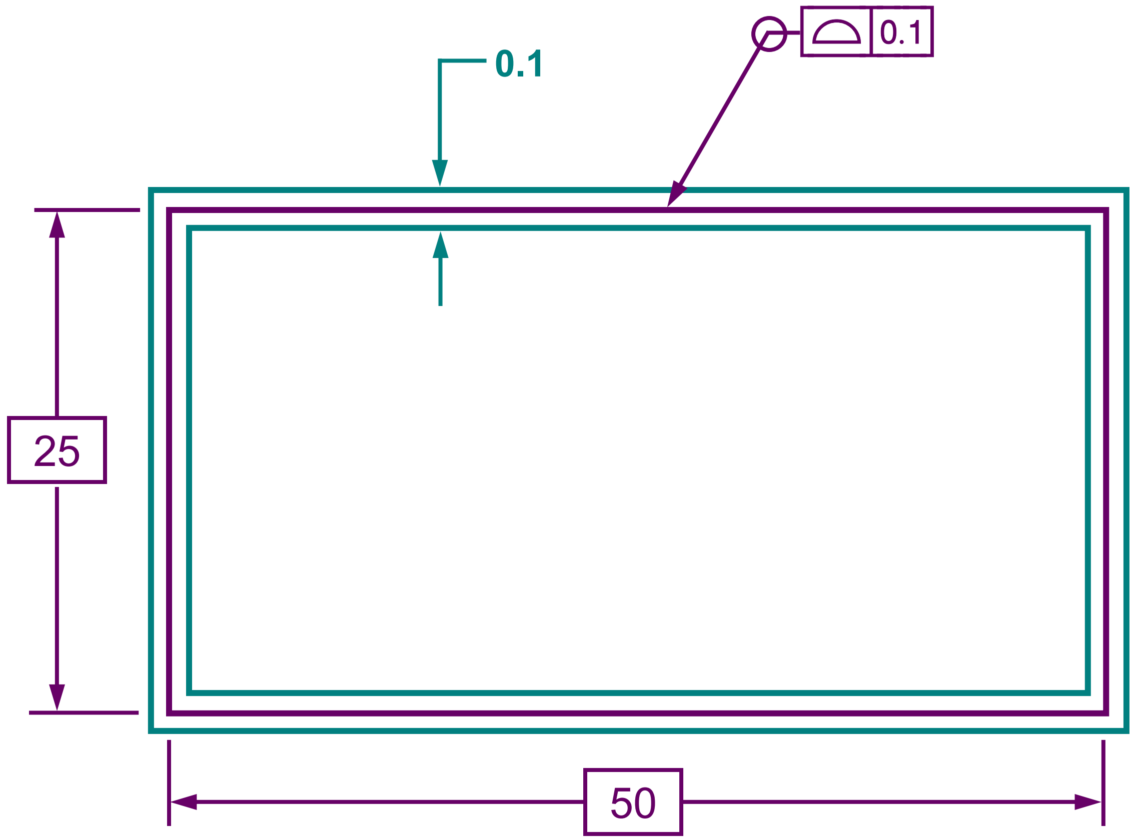


X-Axis @ 50 ± 0.10

X-Axis Dimension Modified to:

50 + 0.05 / - 0.10

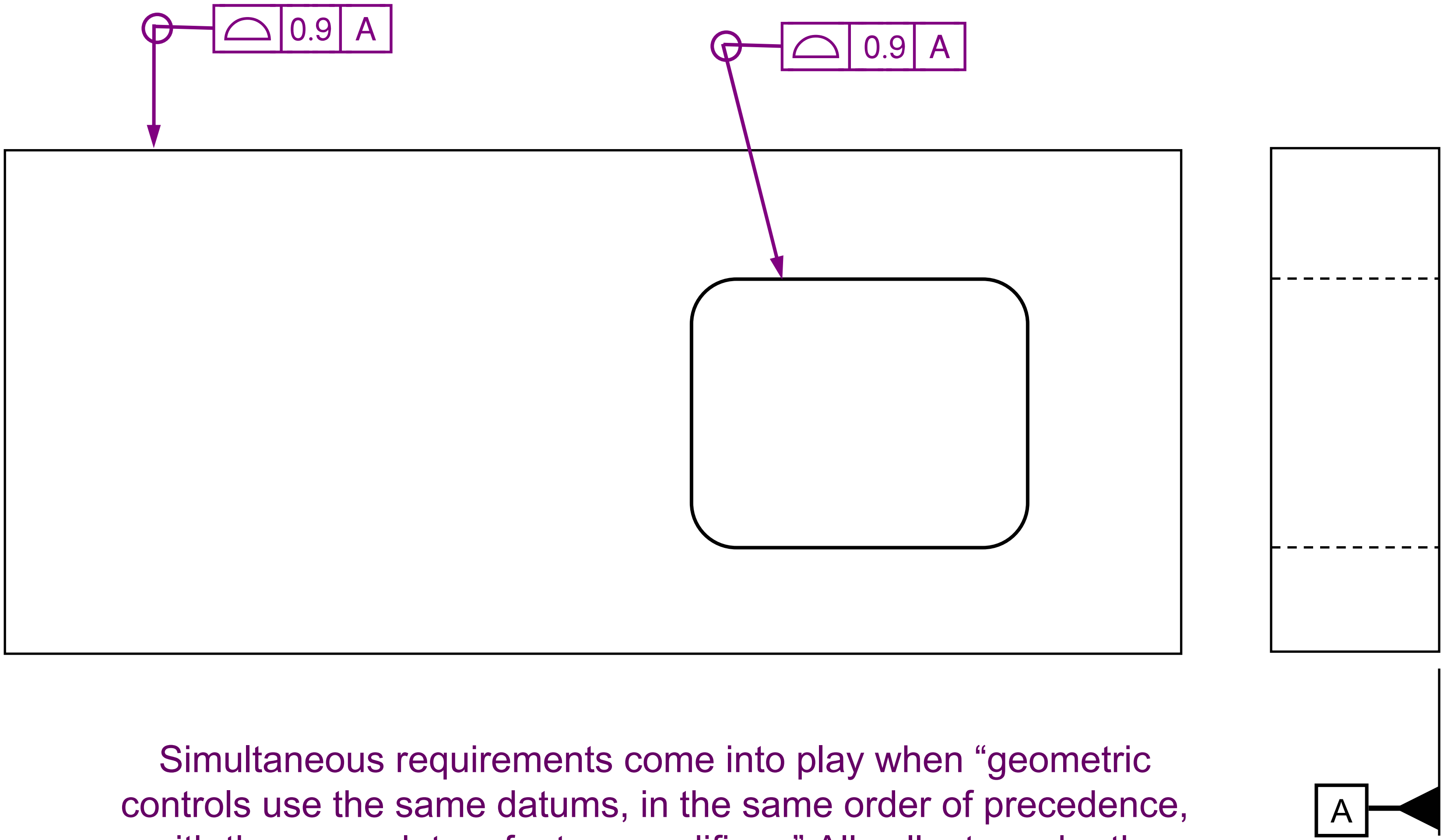
Precision GD&T



“Profile Tolerancing Controls Simple and Complex Geometries”

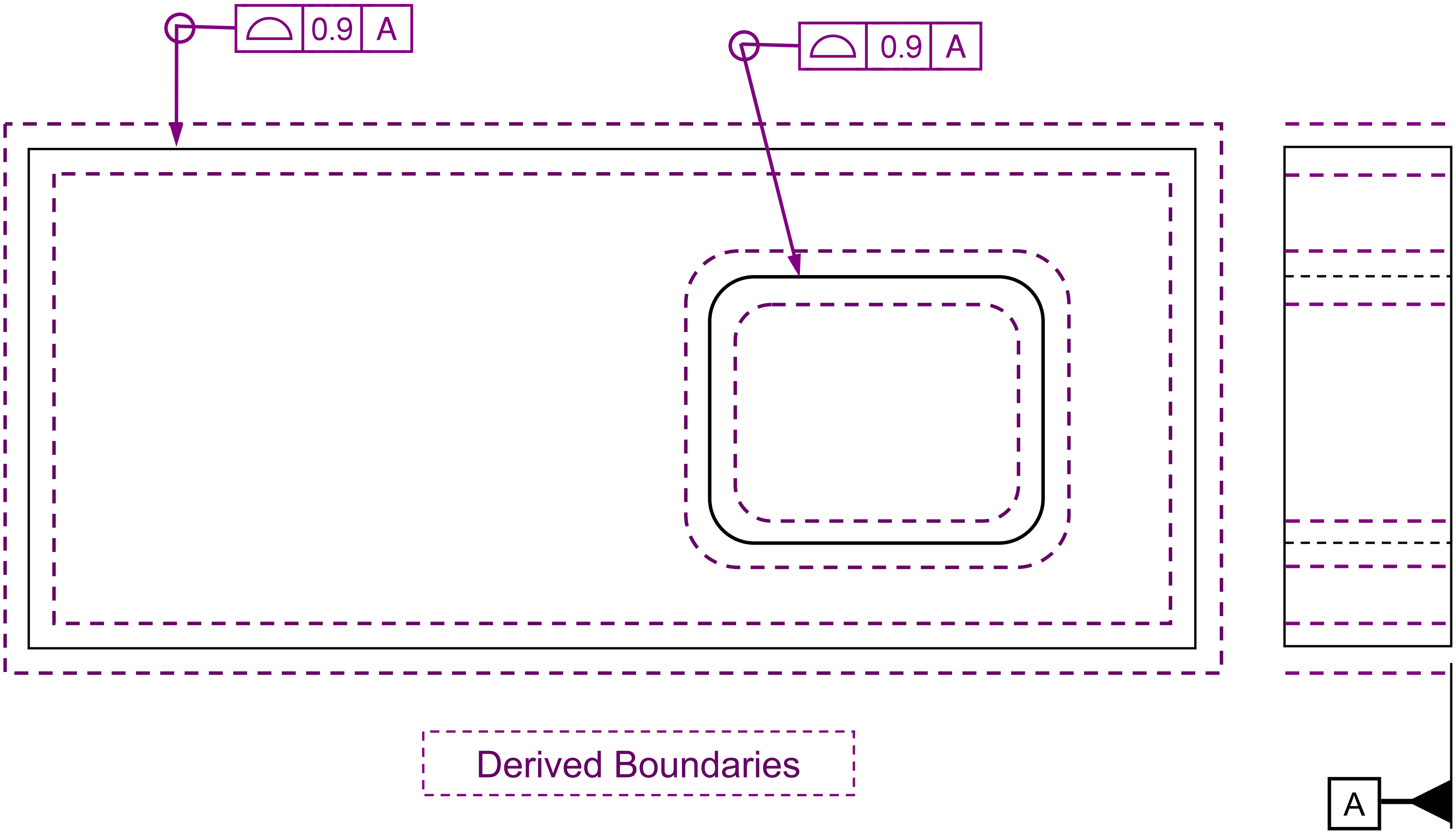
Simultaneous Requirement

Unless Otherwise Specified All Dimensions Controlled by the CAD Model and are Basic

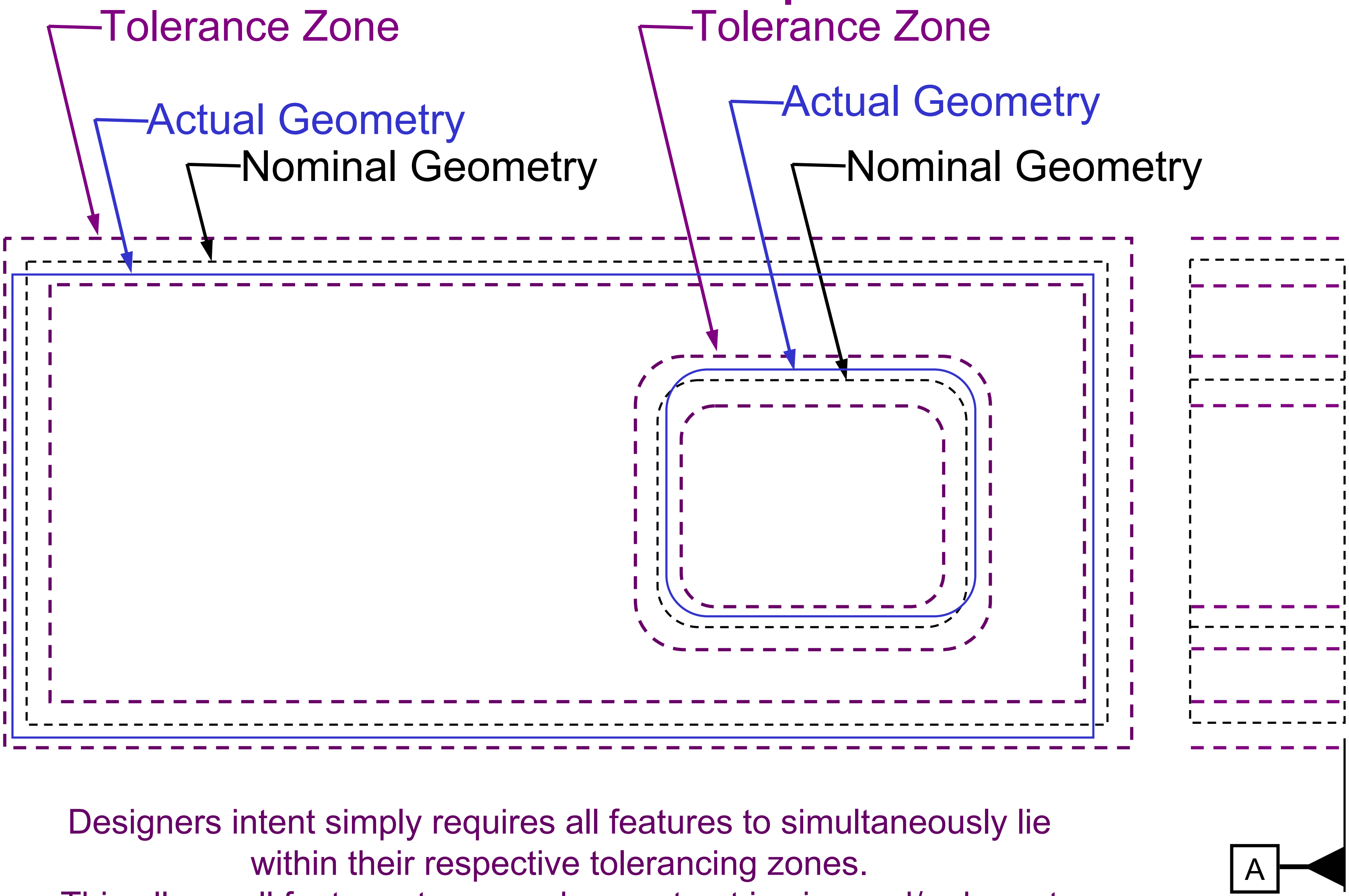


Simultaneous requirements come into play when "geometric controls use the same datums, in the same order of precedence, with the same datum feature modifiers." All callouts under the simultaneous requirement must be evaluated at the same time.

Simultaneous Requirement

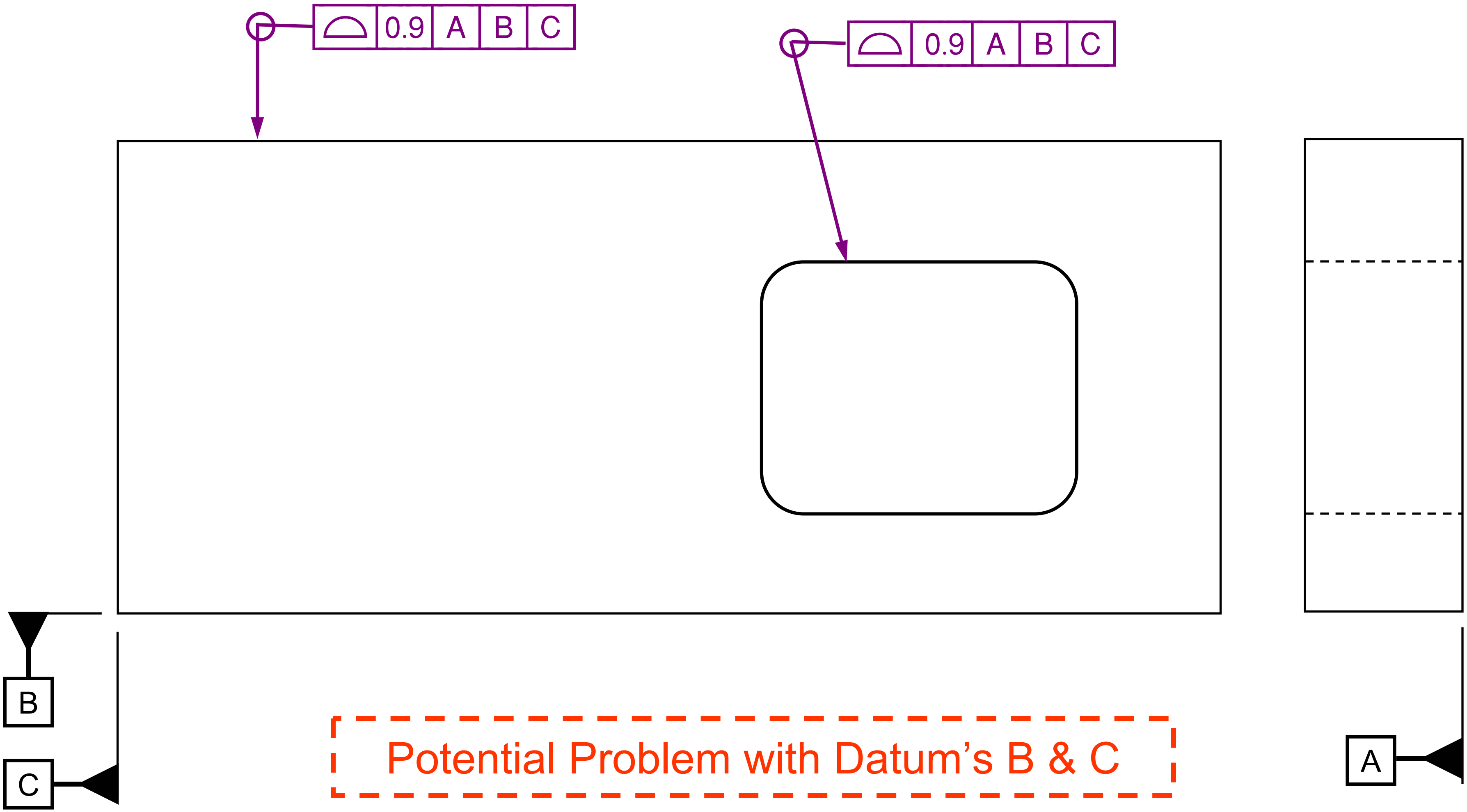


Simultaneous Requirement



Designers intent simply requires all features to simultaneously lie within their respective tolerancing zones.
This allows all features to expand or contract in size and/or be out of square to Datum A and/or be off location to each other as long as they simultaneously lie within their respective tolerance zone.

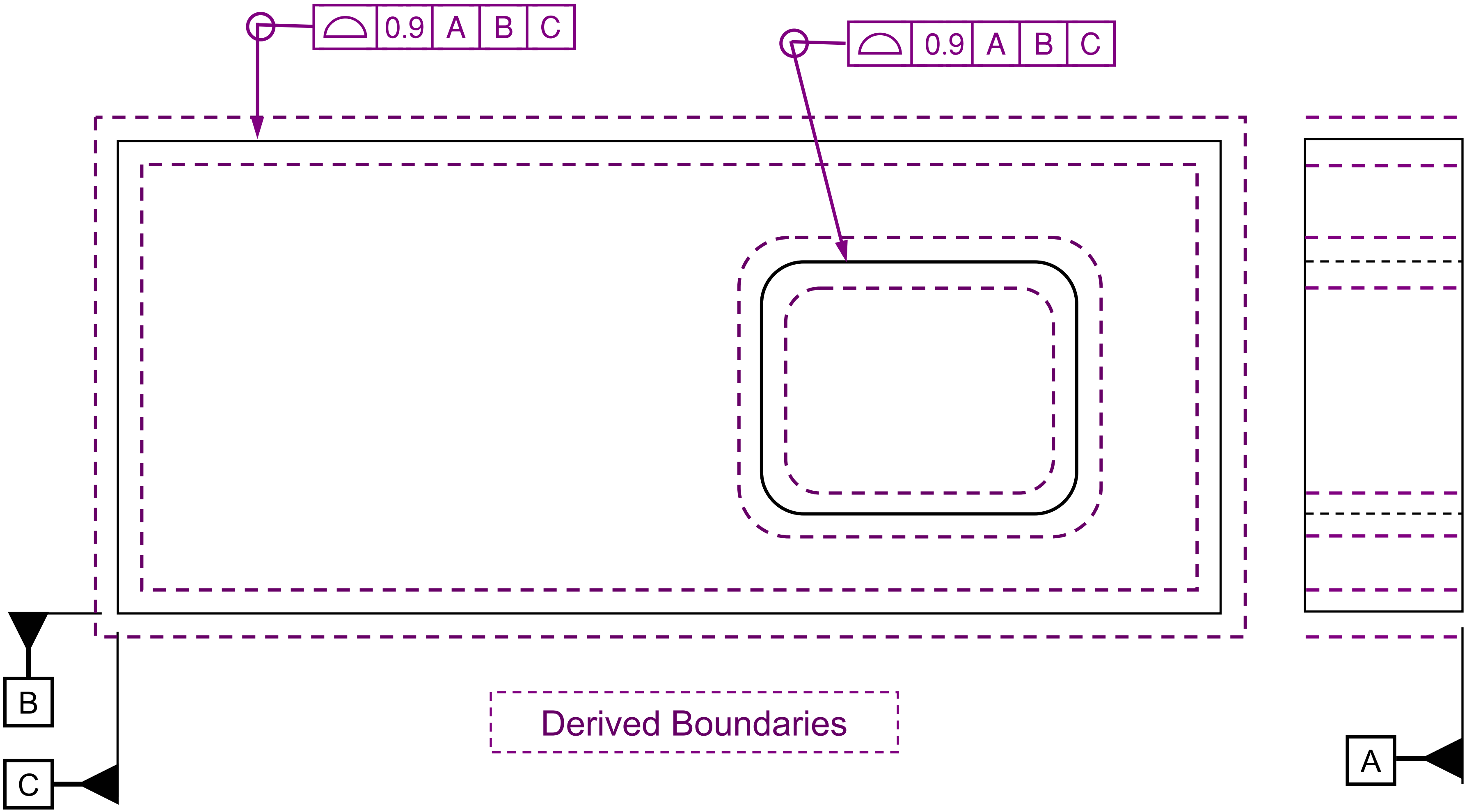
Simultaneous Requirement (Planar Datums)



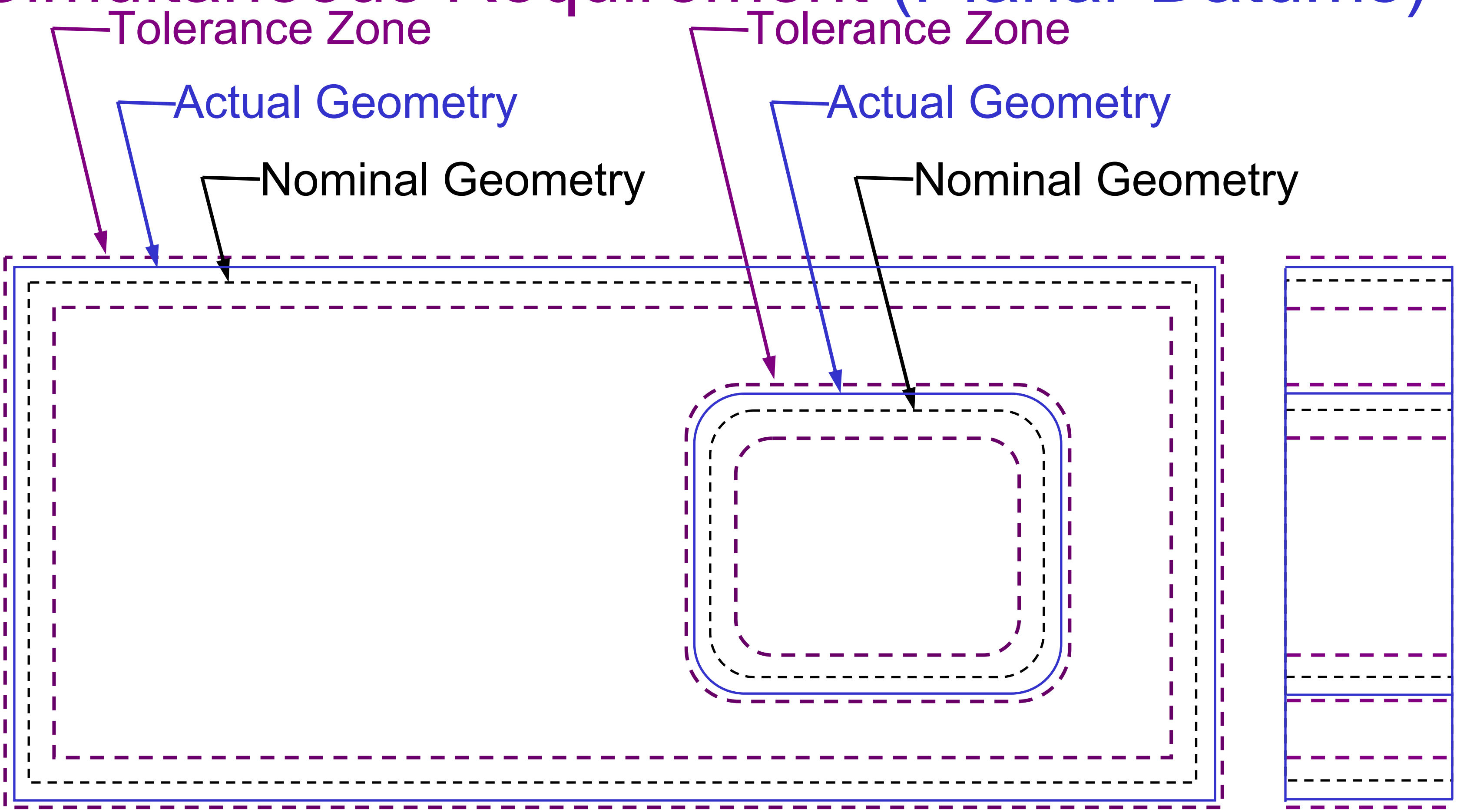
Potential Problem with Datum's B & C

Unless Otherwise Specified All Dimensions Controlled by the CAD Model and are Basic

Simultaneous Requirement (Planar Datums)

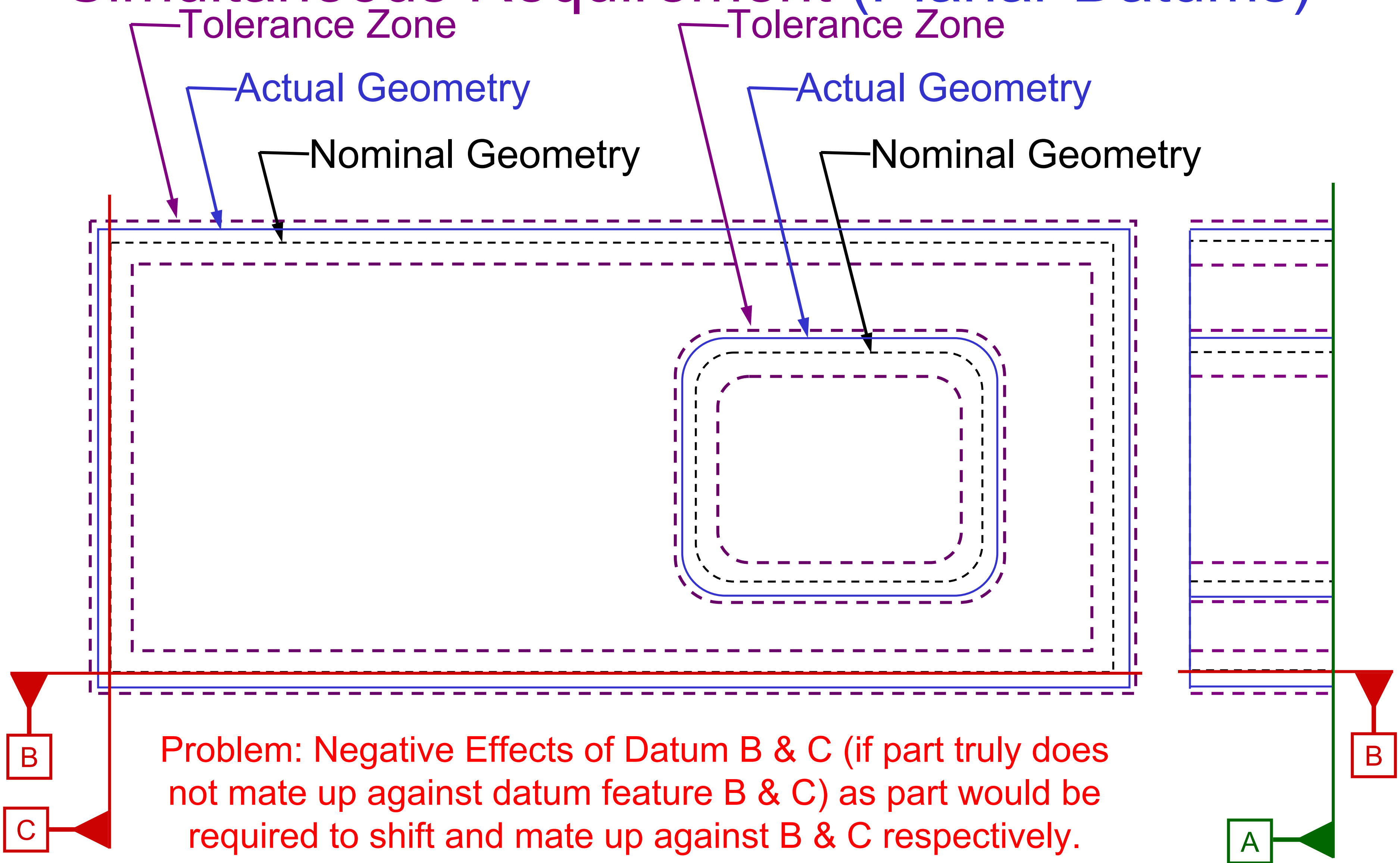


Simultaneous Requirement (Planar Datums)



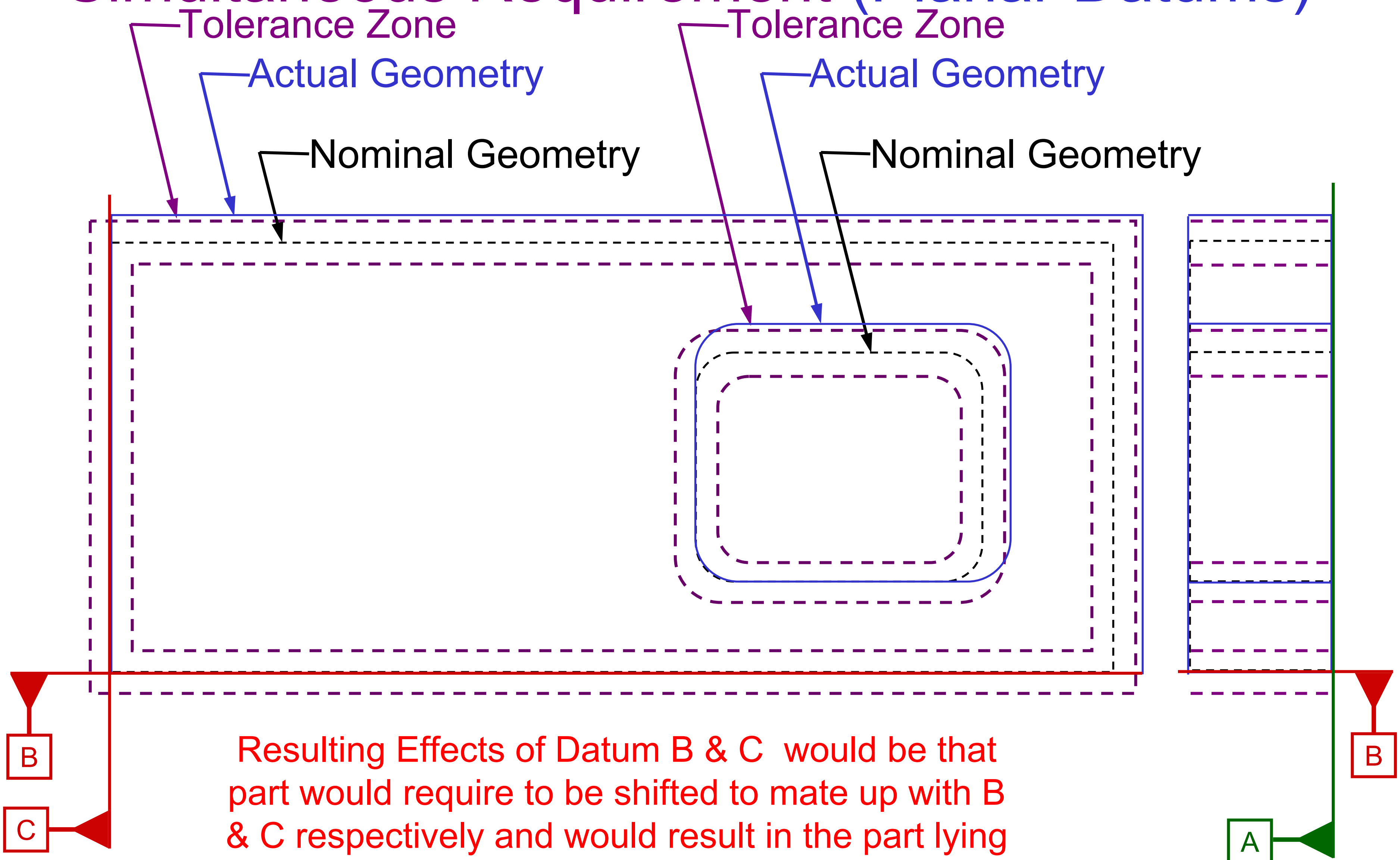
Designers intent simply requires all features to simultaneously lie within their respective tolerancing zones in relationship to respective datum reference frame.
This allows all features to expand or contract in size and/or be out of square to Datum A and/or be off location to datum B & C as long as they simultaneously lie within their respective tolerance zone.

Simultaneous Requirement (Planar Datums)



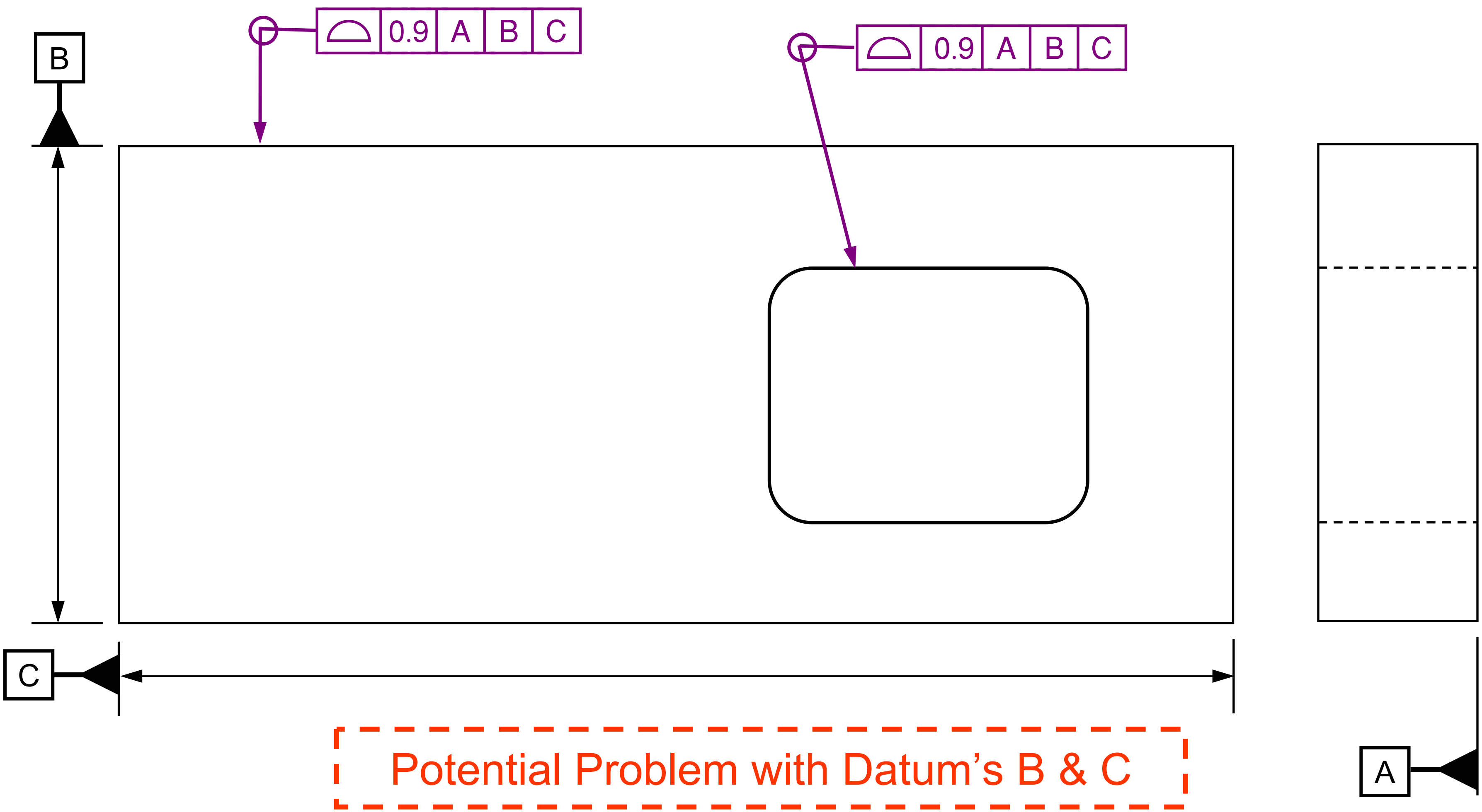
Problem: Negative Effects of Datum B & C (if part truly does not mate up against datum feature B & C) as part would be required to shift and mate up against B & C respectively. The resulting effect would be the part would lie outside the respective Profile Boundaries

Simultaneous Requirement (Planar Datums)



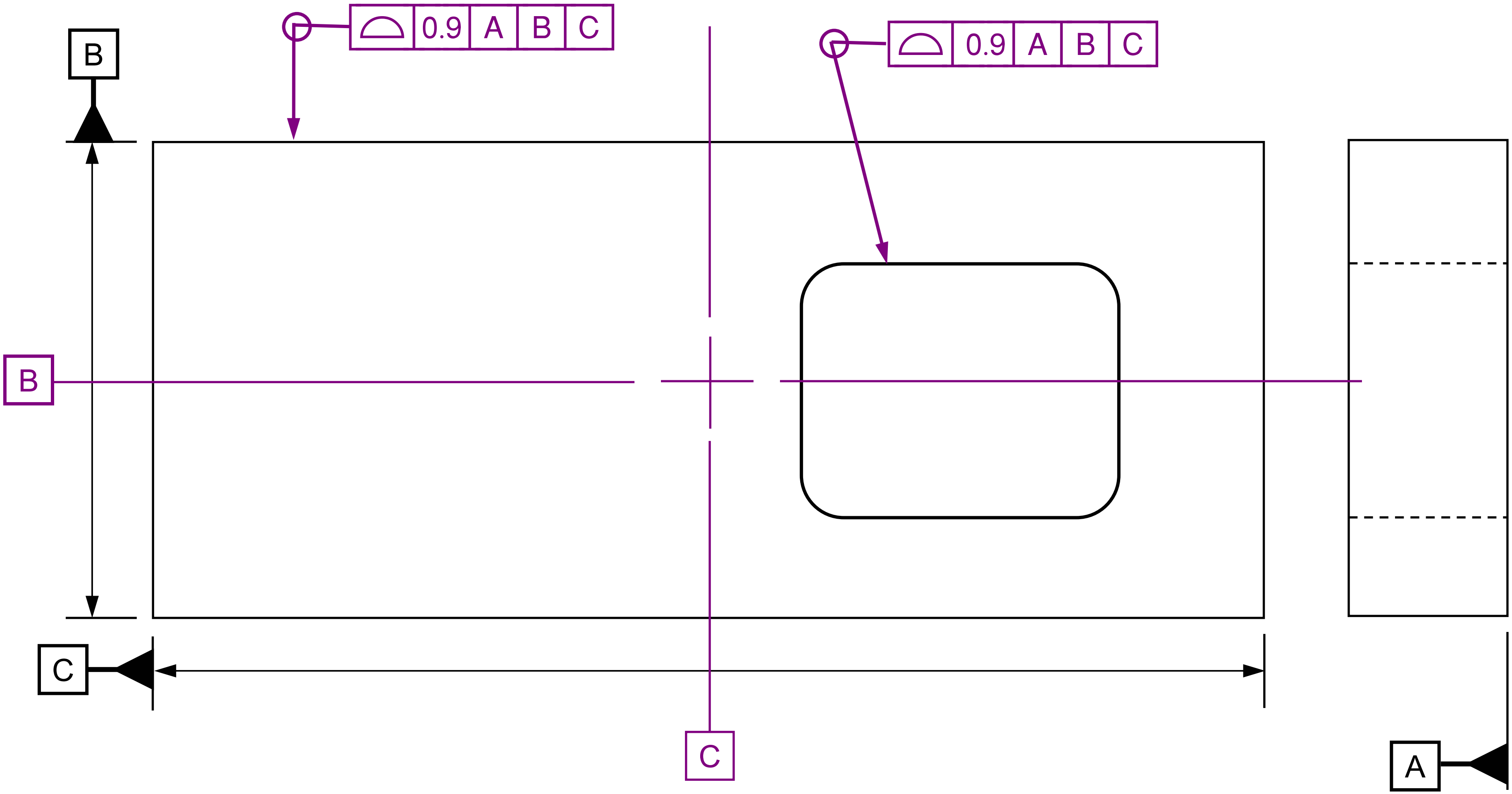
Resulting Effects of Datum B & C would be that part would require to be shifted to mate up with B & C respectively and would result in the part lying outside Profile Boundaries and be Rejected.

Simultaneous Requirement (Mid-Plane Analysis)



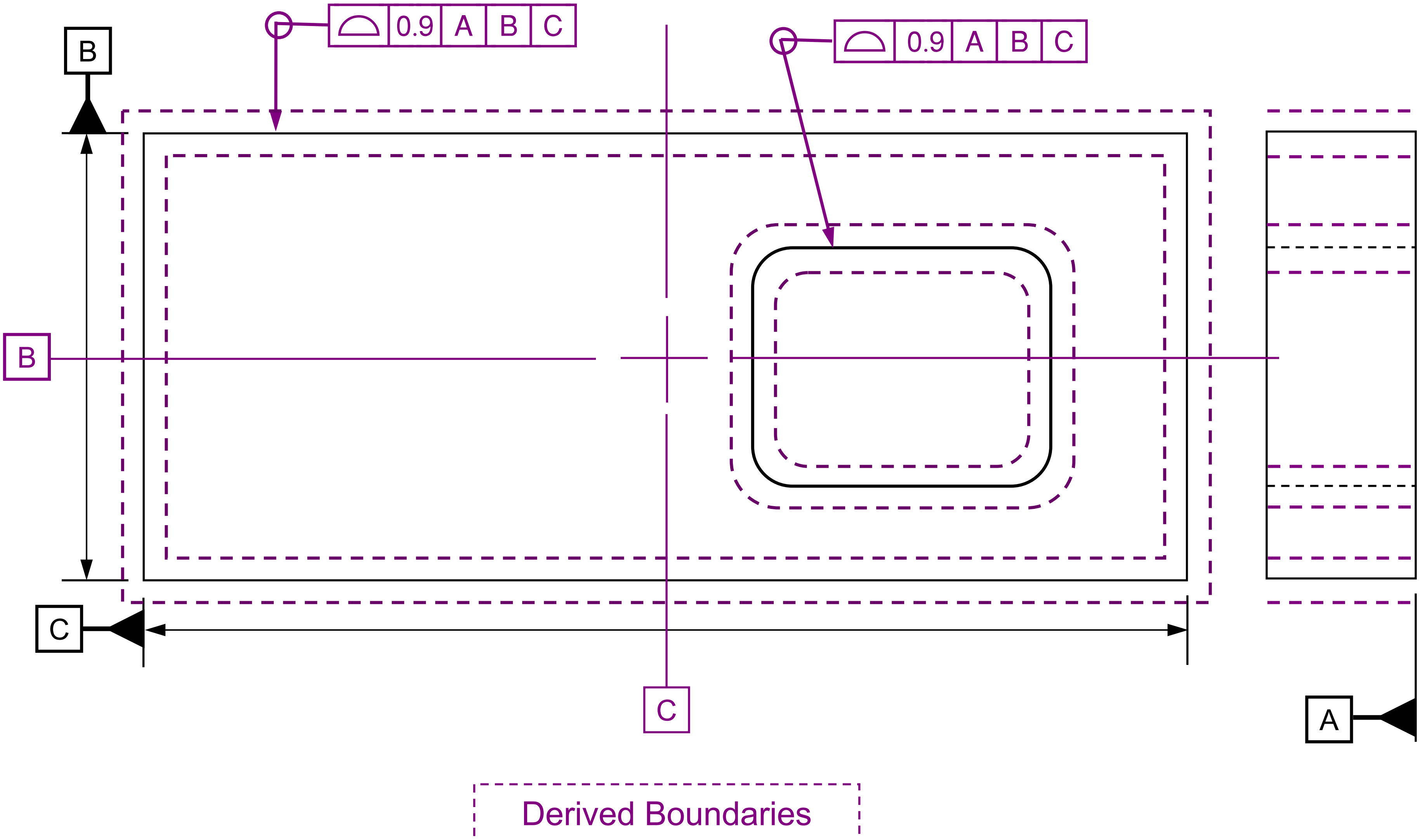
Unless Otherwise Specified All Dimensions Controlled by the CAD Model and are Basic

Simultaneous Requirement (Mid-Plane Analysis)



Datum B and Datum C are the mid-planes between their respective features

Simultaneous Requirement (Mid-Plane Analysis)



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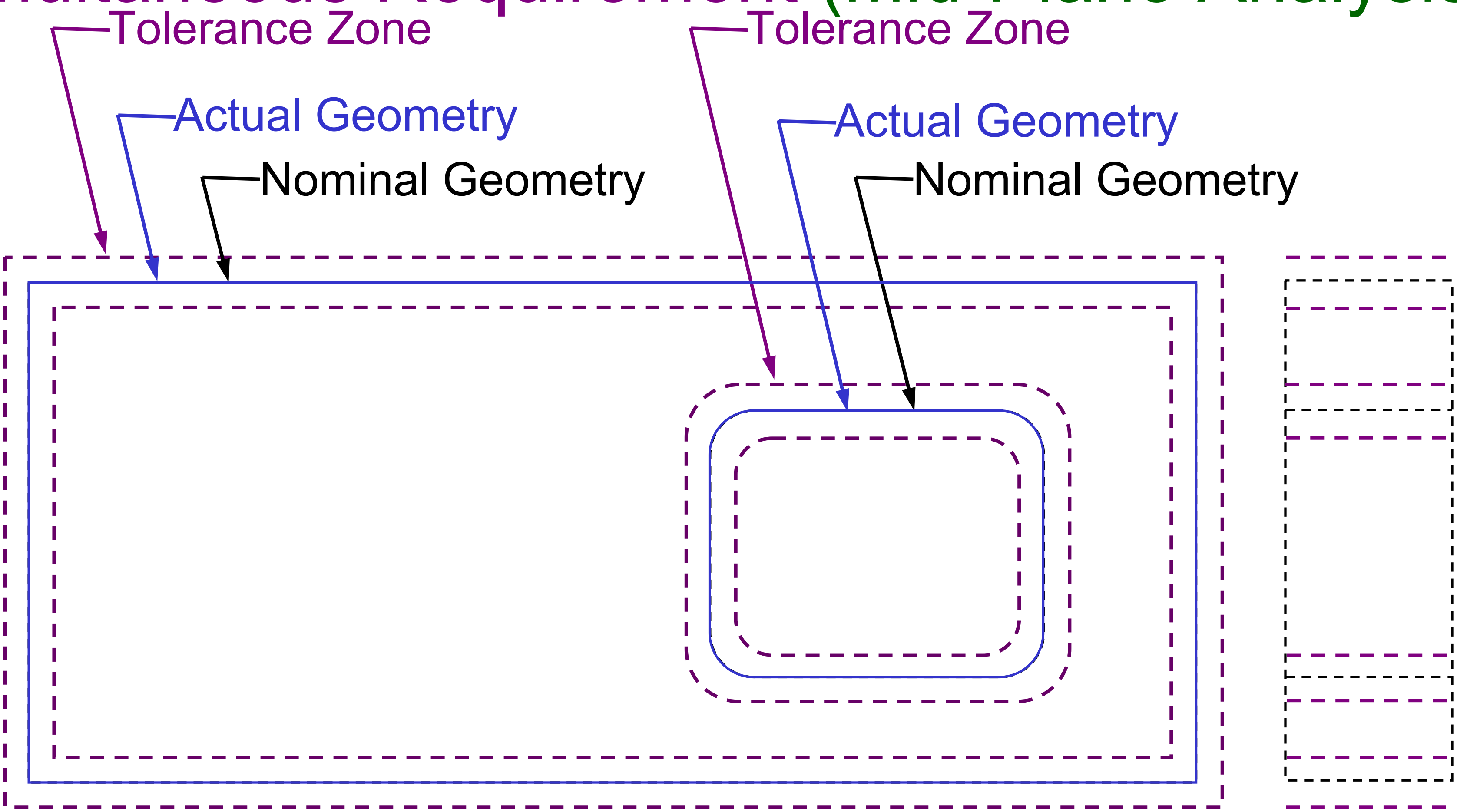
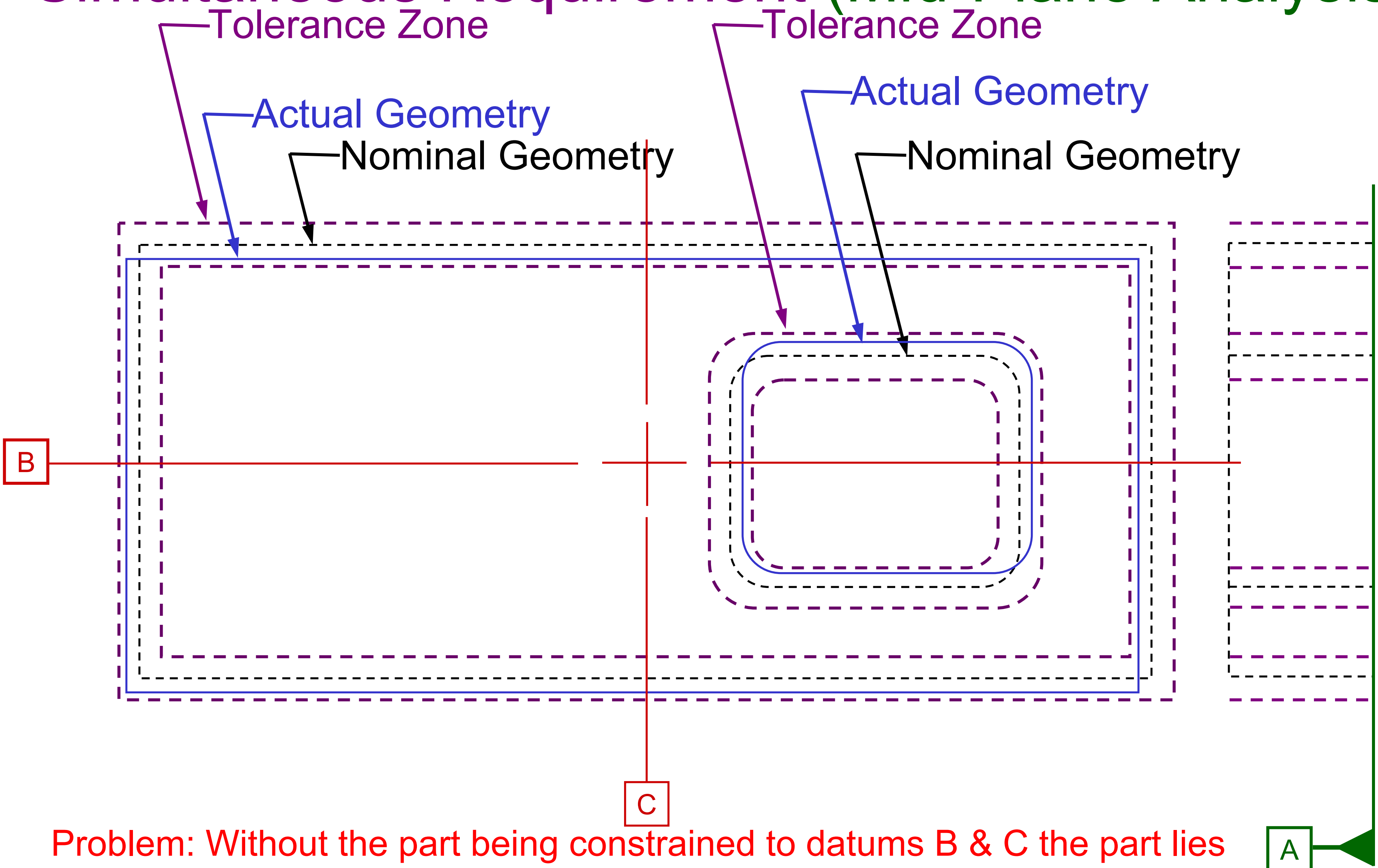


Designers intent simply requires all features to simultaneously lie within their respective tolerancing zones in relationship to respective datum reference frame.

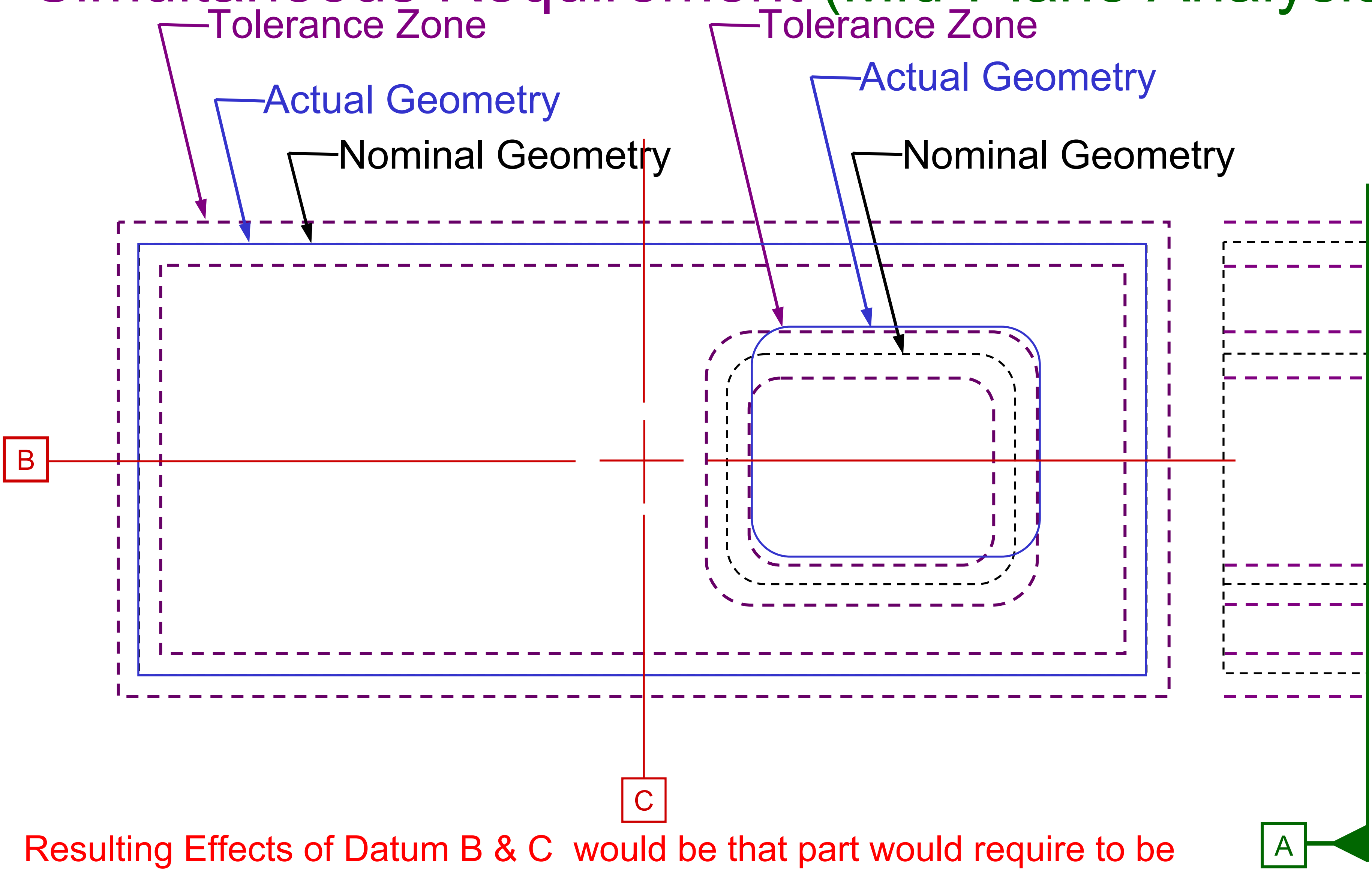
This allows all features to expand or contract in size and/or be out of square to Datum A and/or be off location to datum B & C as long as they simultaneously lie within their respective tolerance zone.

Simultaneous Requirement (Mid-Plane Analysis)



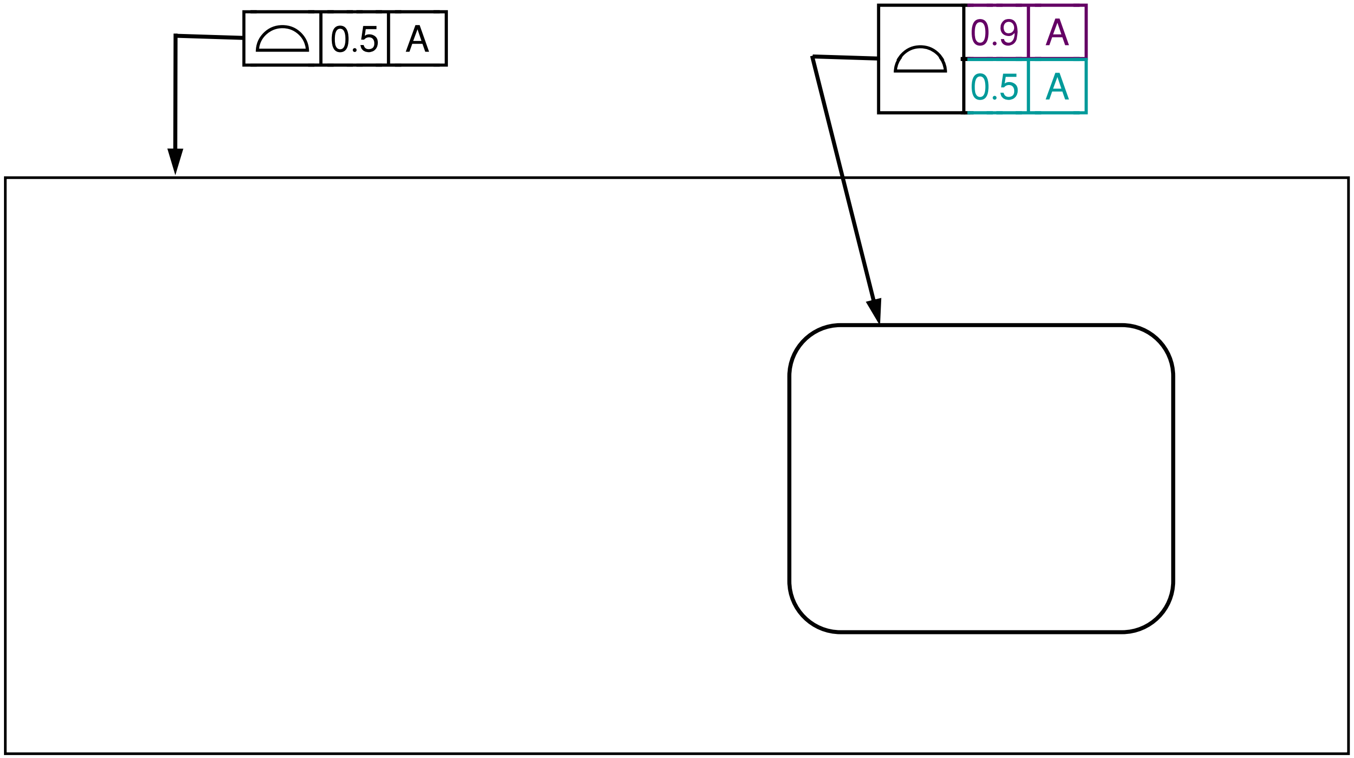
Problem: Without the part being constrained to datums B & C the part lies within its respective tolerance zones. Negative Effects of Datum B & C would be that it would force the part to shift and potentially lie outside the respective Profile Boundaries

Simultaneous Requirement (Mid-Plane Analysis)



Resulting Effects of Datum B & C would be that part would require to be shifted to mate up with B & C respectively and would result in the part lying outside Profile Boundaries and be Rejected.

Simultaneous -vs- Separate Requirement

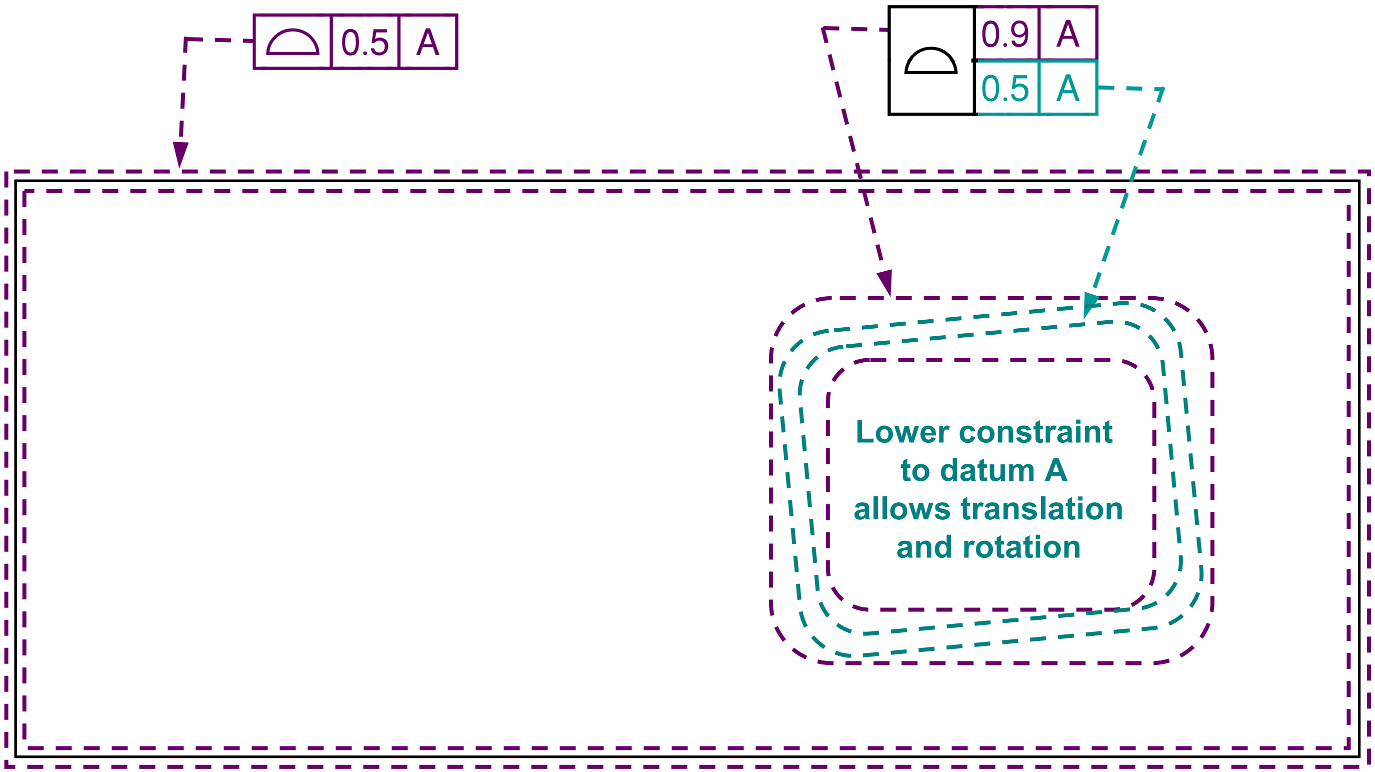


Simultaneous Requirements apply to “all” Single-Segment Feature Control Frames (FCF’s) and to the “Upper Portion” of Composite FCF’s.

Note: Unless otherwise specified on the drawing, lower portions of Composite FCF’s are not constrained by the Simultaneity Rule and are allowed to float within the boundary defined by the upper portion of the Composite FCF.

Unless Otherwise Specified All Dimensions Controlled by the CAD Model and are Basic

Simultaneous -vs- Separate Requirement



Note: Lower portions of Composite FCF's are not constrained by the Simultaneity Rule and are allowed to float within the boundary defined by the upper portion of the Composite FCF.

Unless Otherwise Specified All Dimensions Controlled by the CAD Model and are Basic

Expansion of Profile Tolerancing

- Profile is the most versatile GD&T control and can be used in place all other surface geometry symbols.
- Promotes better definition and understanding of design tolerance boundaries.
- World-wide expansion of the use of Profile

UNLESS OTHERWISE SPECIFIED:

DIMENSIONING & TOLERANCING IN ACCORDANCE WITH ASME Y14.5M-1994

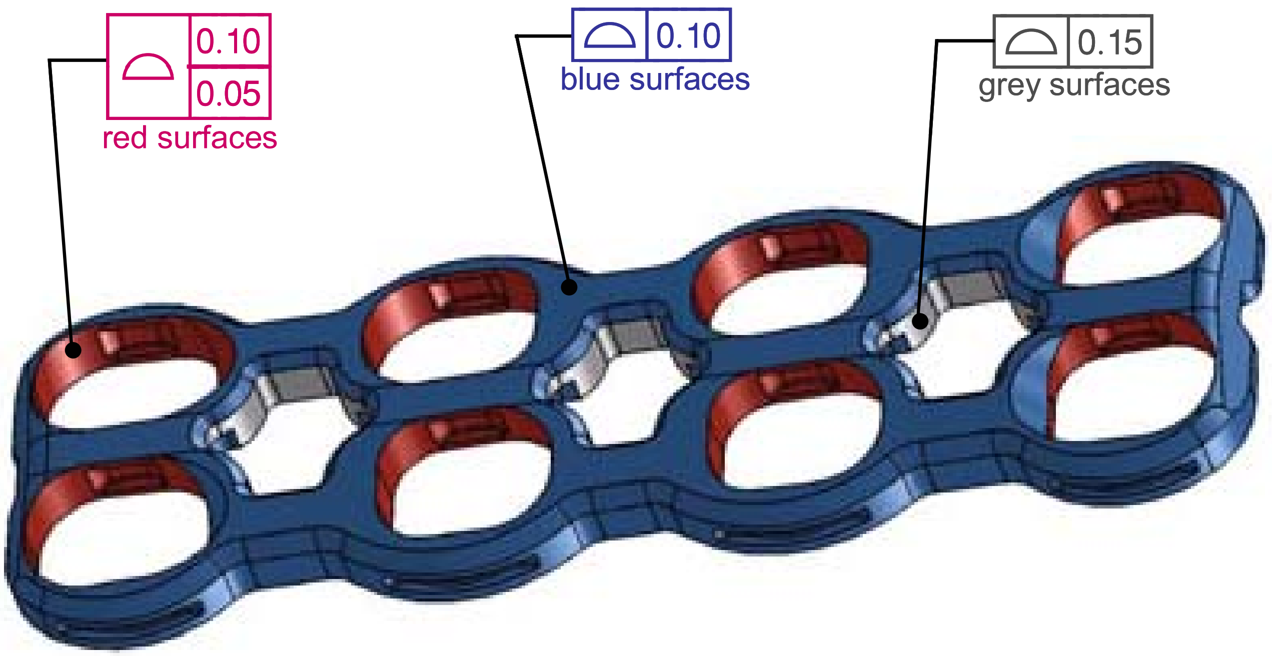
ALL UNTOLERANCED DIMENSIONS ARE BASIC AND CONTROLLED BY THE CAD MODEL

THE FOLLOWING TOLERANCS APPLY:

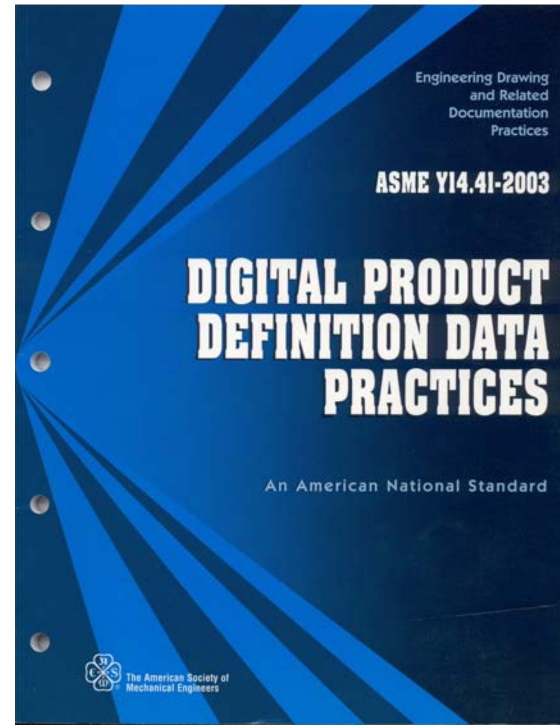
Surfaces = | ⌓ | 0.15 | A |

Hole Locations = | ⌖ | ⌀0,35Ⓜ | A |

3D Profile Definition using ASME Y14.41-2003

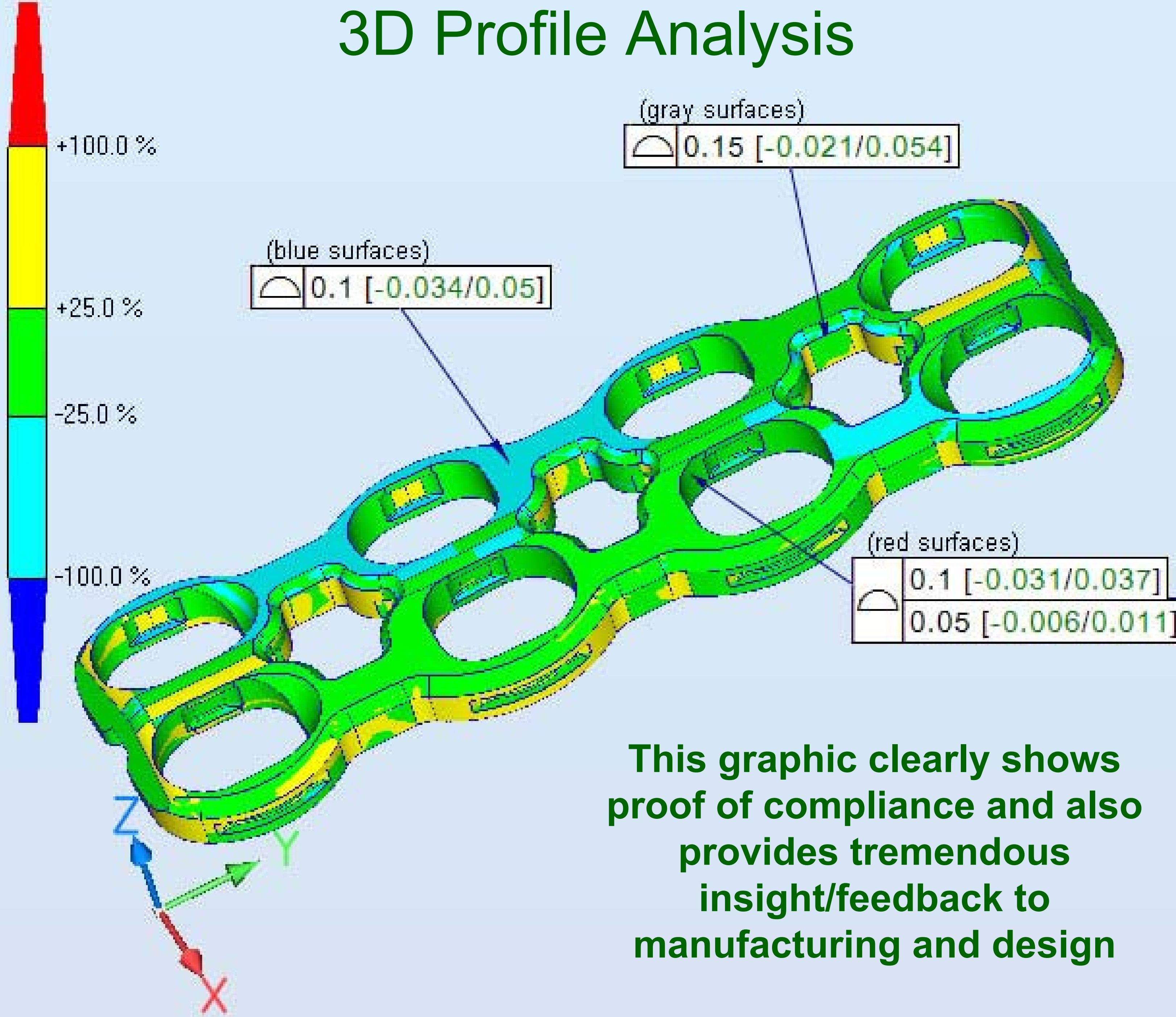


Drawing Note: Unless Otherwise Specified All Dimensions Are Basic and Controlled By The CAD Model



The above engineering drawing example depicts profile tolerancing of all 3D surfaces being fully defined with three explicit profile of a surface callouts per the ASME Y14.41-2003 Standard.

3D Profile Analysis



This graphic clearly shows proof of compliance and also provides tremendous insight/feedback to manufacturing and design

Thank you!