Status of CAD/MCNP 3-D Analysis

THE UNIVERSITY
of
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MADISON

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3-D Geometry Capability
Enhancements

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Overview

- Code history & status

- Feature assessment

- Experience with ITER Benchmark

- ARIES-CS neutronics

- Issues in solid modeling

MCNP(X)-CGM History

- 2001 – began implementation of CGM in MCNPX v2.1.5

- 6/2004 – Proof-of-principle complete

   (50-100x performance penalty)

- 3/2005 – Oriented bounding box technology with faceted surface intersections implemented (3-12x performance penalty)

- 4/2005 – Analysis of ARIES-CS neutron transport on complex surfaces

MCNP(X)-CGM Development Plan & Progress

- Upgrade to newest versions of MCNP(X)

- Upgrade to MCNPX **v2.5.0** complete
  - MCNP compatibility enhancement
    - Forced collision variance reduction
    - Reflecting boundary conditions
    - Surface flux tally
  - Features added
    - Elimination of fatal errors from cell and surface definitions
    - Elimination of surface definitions entirely
    - Ability to define reflecting boundary conditions in CAD geometry file

MCNP(X) Compatibility

- Geometry
    - Cell volume/Surface areas – functional
    - Boundary conditions
        - Specular reflection – functional
        - White reflection – functional
        - Periodic – near term
    - Lattice/universe – long term
- Source
    - Fixed source – functional
    - Fission source – *testing*
    - Surface source write/read – long term

MCNP(X) Compatibility

- Variance Reduction
  - Cell importance – functional
  - Exponential transform – functional
  - Forced collision – functional
  - Weight windows (cell-based) – *testing*
  - Weight windows (mesh-based) – functional
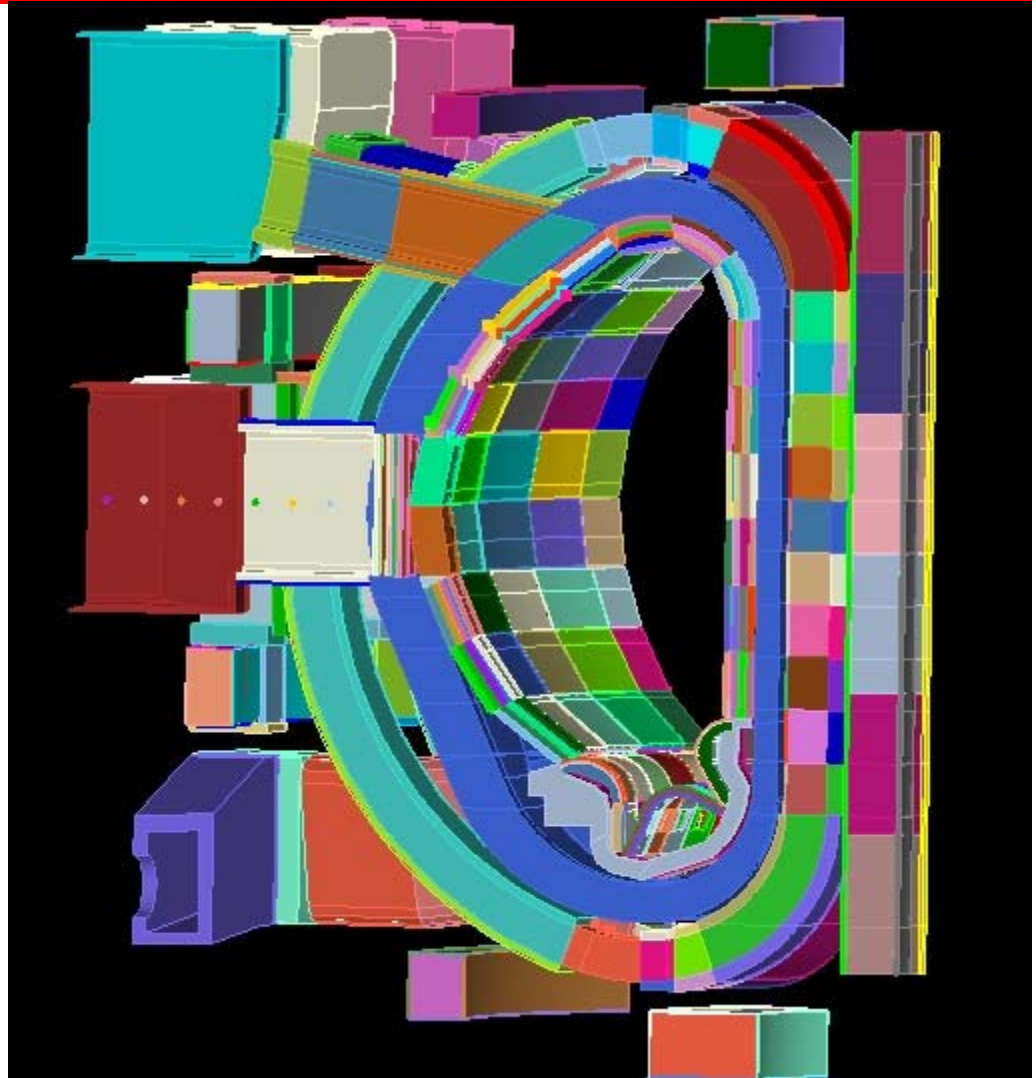 - Detector tallies - functional

MCNP(X) Compatibility

- Tallies
  - Surface current (type 1) – functional
    - Cosine bins – functional (directional ambiguity)
  - Surface flux (type 2) – functional
  - Cell flux (type 4,6,7) – functional
  - Pulse height (type 8) – testing
  - Point detector (type 5) – functional
  - Mesh tallies – functional in MCNPX
    - Note: MCNP and MCNPX have different mesh tally implementations
  - Cell flagging – functional
  - Surface flagging – functional
  - Multipliers – functional
  - Segmenting – long term ??

CGM-related Enhancements
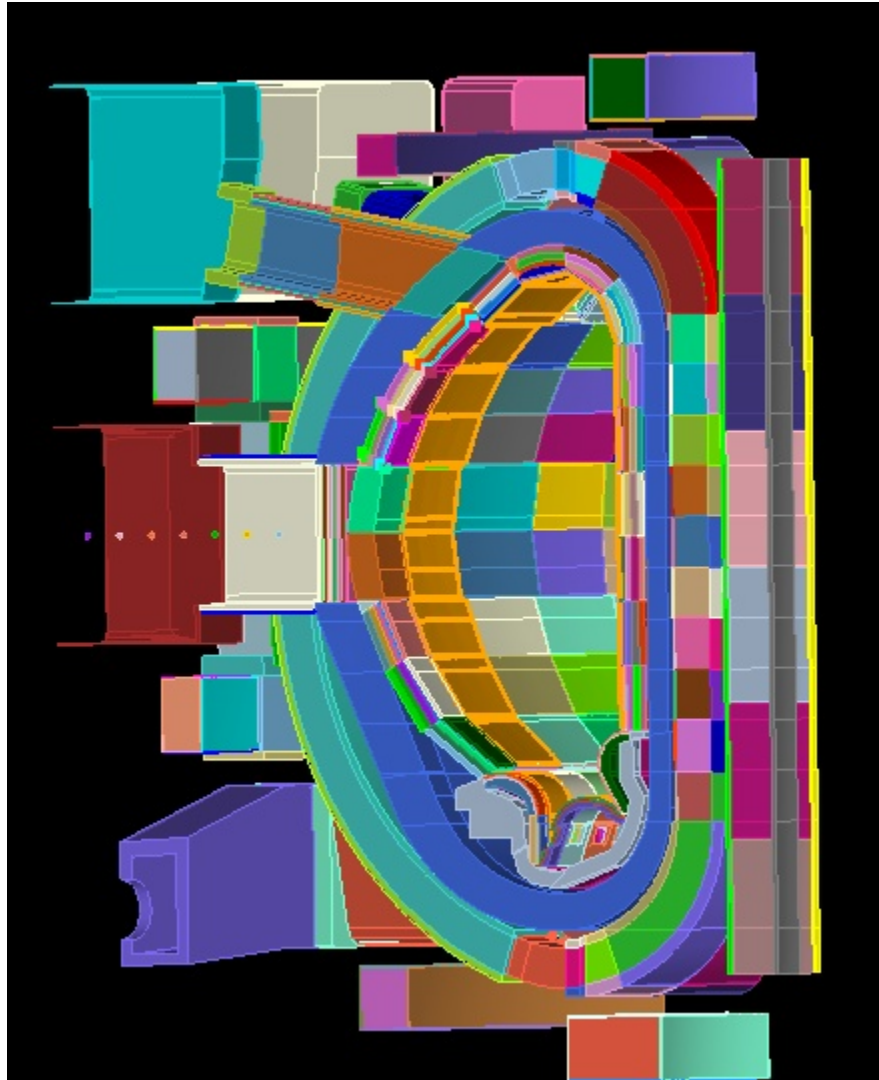
- CAD/Cubit definition of materials – near term

- CAD/Cubit definition of tallies – long term
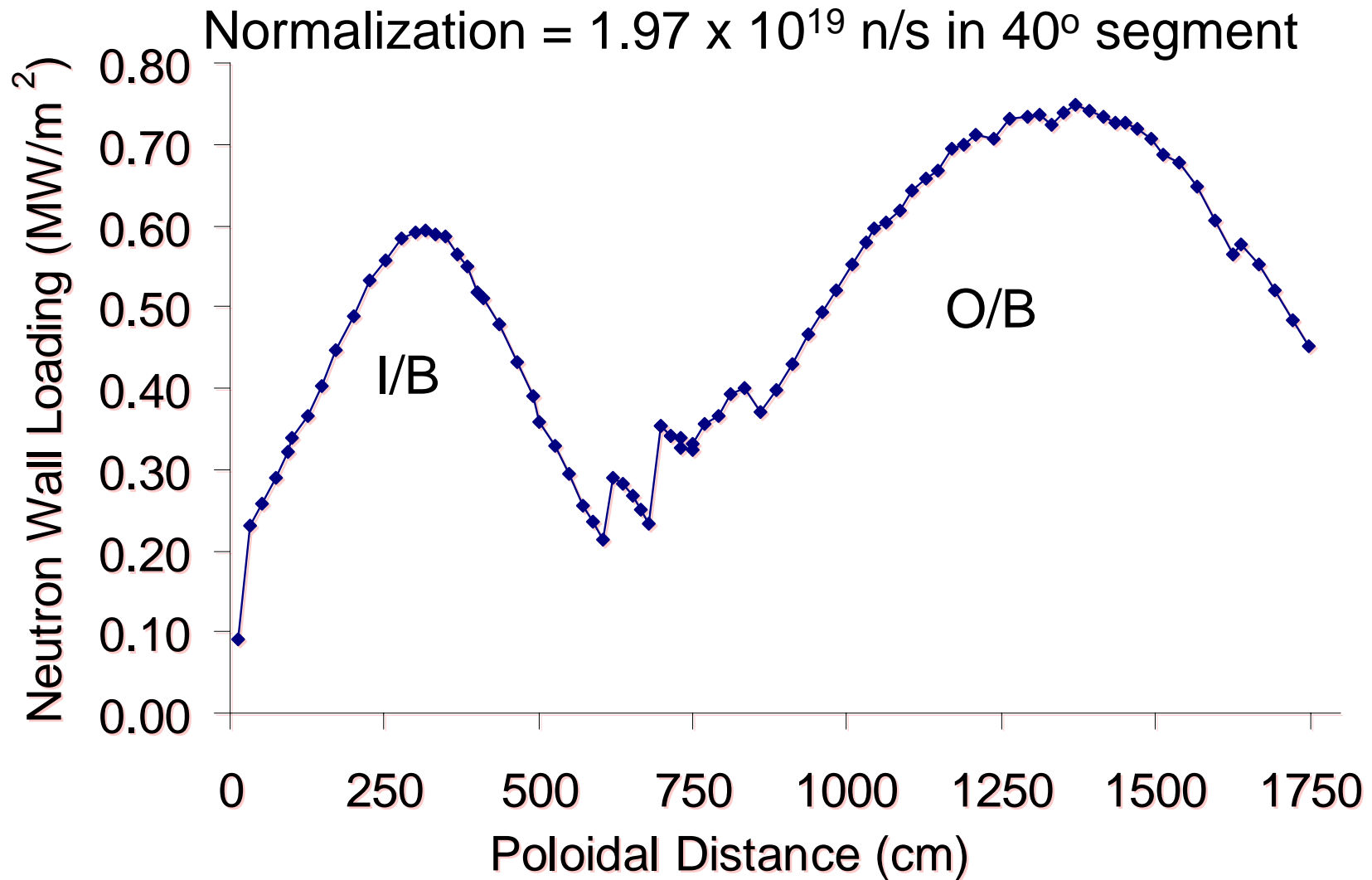
- Further geometry-based performance enhancements

ITER Model

- 40° toroidal segment
- Source defined on 40x40 R-Z grid
- 774 volumes
- 18116 surfaces

Neutron Wall Loading

Neutron Wall Loading

Normalization = 1.97×10^{19} n/s in 40° segment

Neutron Wall Loading (MW/m²) vs Poloidal Distance (cm)

I/B

O/B
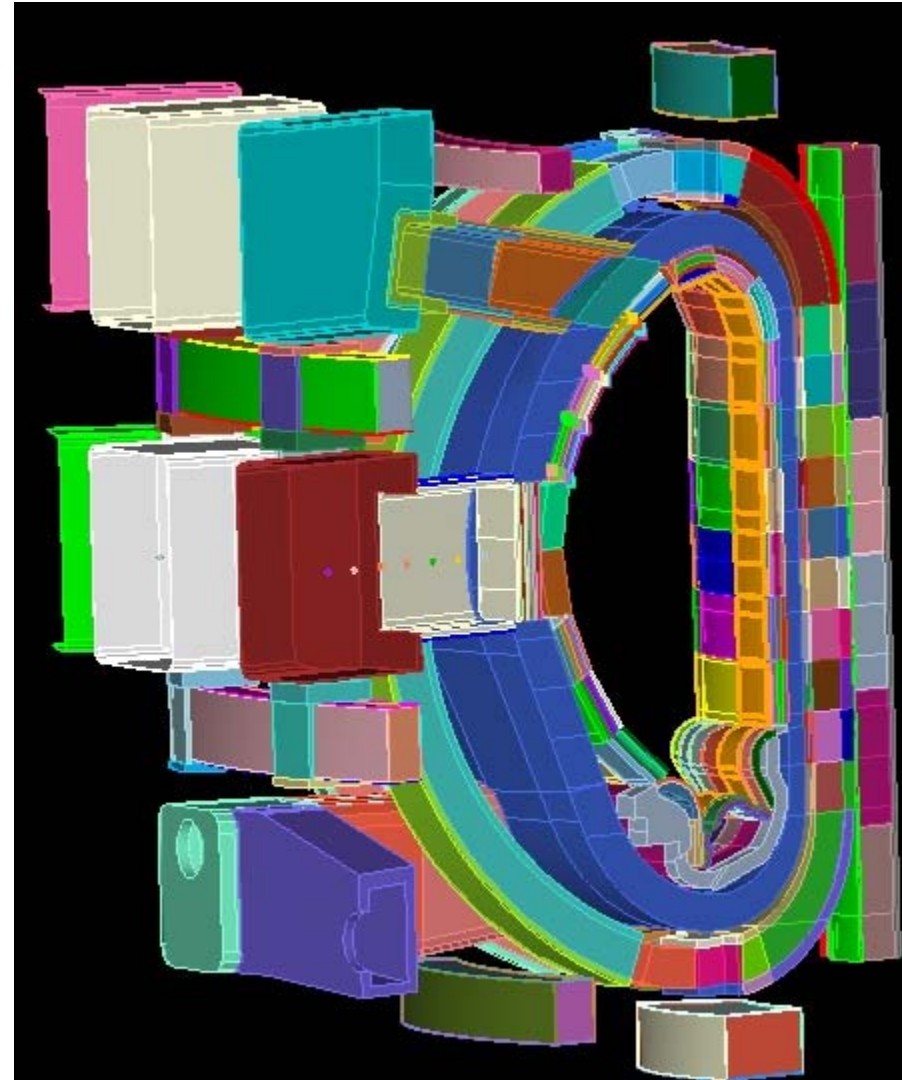
3D Neutronics for ARIES-CS

- Neutron wall loading
  - Previous work demonstrated capability BUT
    - Used incorrect interpretation of n-source distribution
    - Enhanced geometry capability drives enhanced n-source definition
  - NWL will be calculated on surfaces offset from plasma surface by 5 cm and 20 cm

3D Neutronics for ARIES-CS

- Nuclear analysis of 3-D ARIES-CS design
  - Including standard fusion power plant components
  - Important to properly develop CAD models
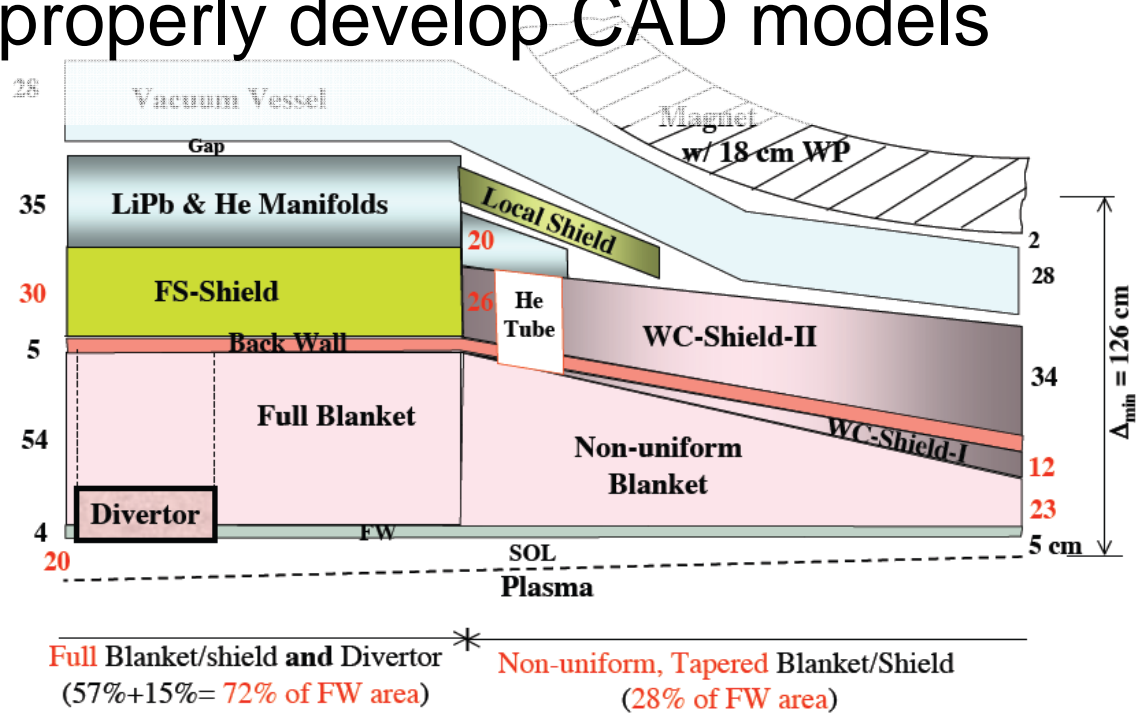
CAD Issues Requiring "Repair"

Human effort shifts from traditional MCNP model creation to CAD/Solid Model repair

- Overlapping Volumes (i.e.: clashes)
- Mating surfaces not contacting
- Slight "Misalignment"
  - Imprint generates ultra thin surfaces
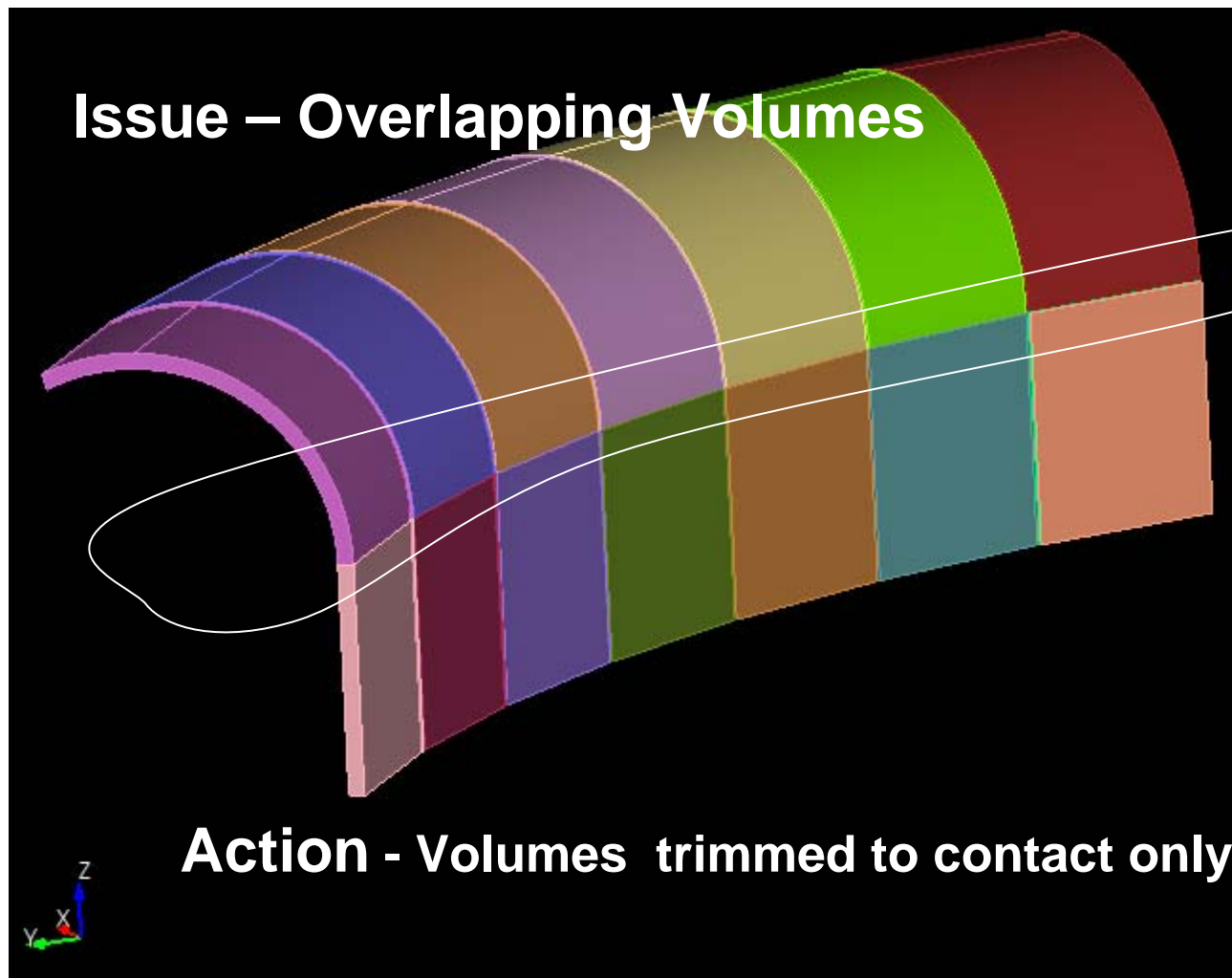 - Doesn't always require repair

- Complex Surface Definition

Examples of Typical CAD Issues and Typical Repairs

Overlapping Volumes

Issue – Overlapping Volumes

Action - Volumes trimmed to contact only

Mating Surfaces Not Contacting

Issue – No Contact

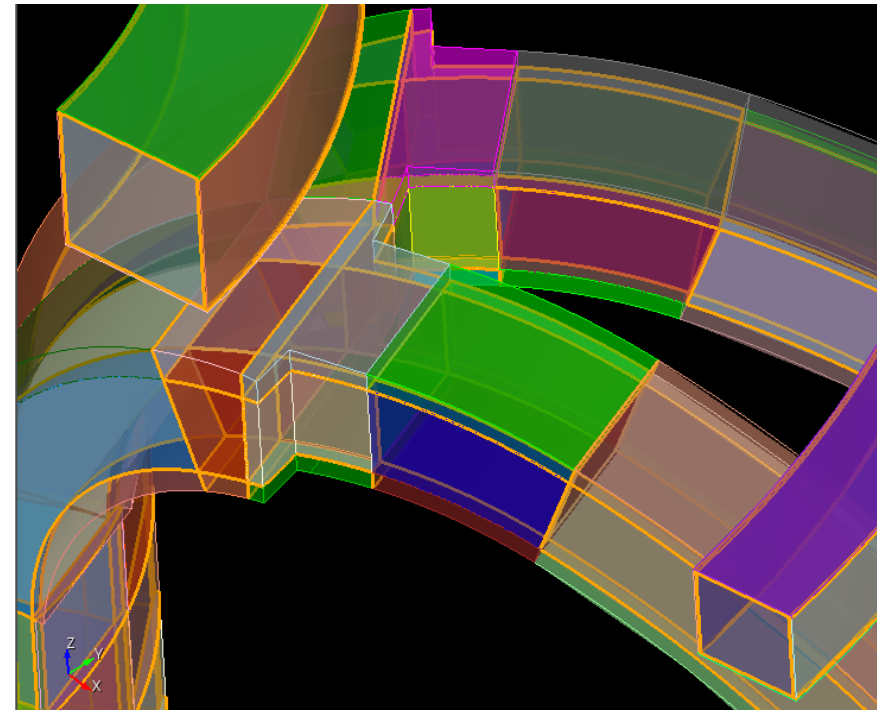**Action – Edit geometry to establish proper contact**
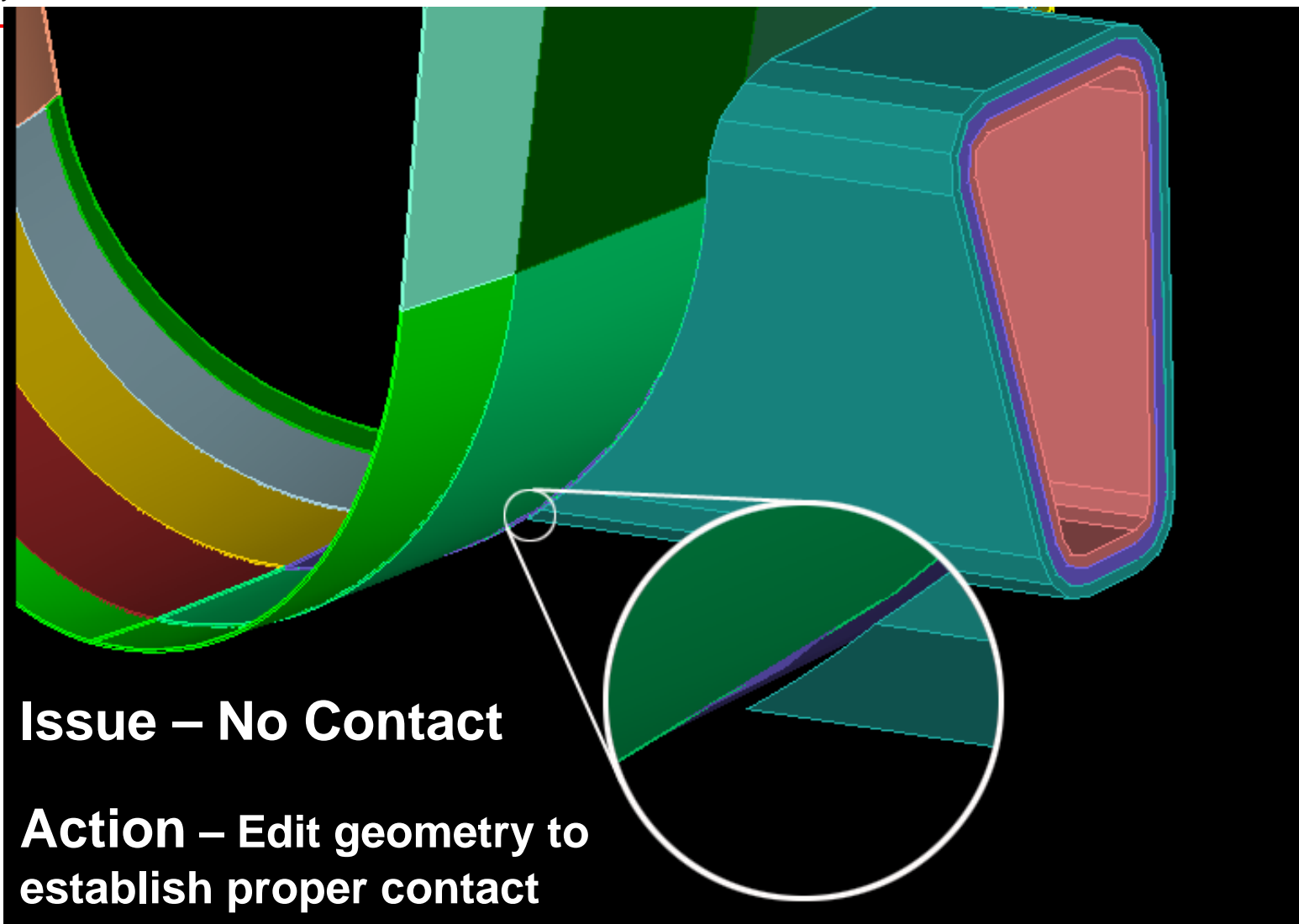
Misalignment
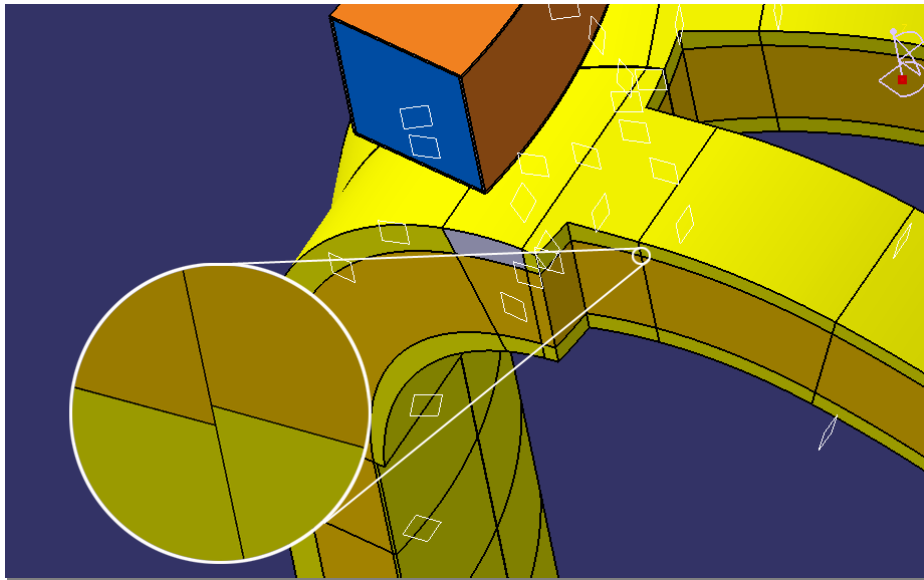
Issue – misalignment …   **… causes imprint difficulty and therefore no merge**

Misalignment
Issue – Slight Edge Misalignment
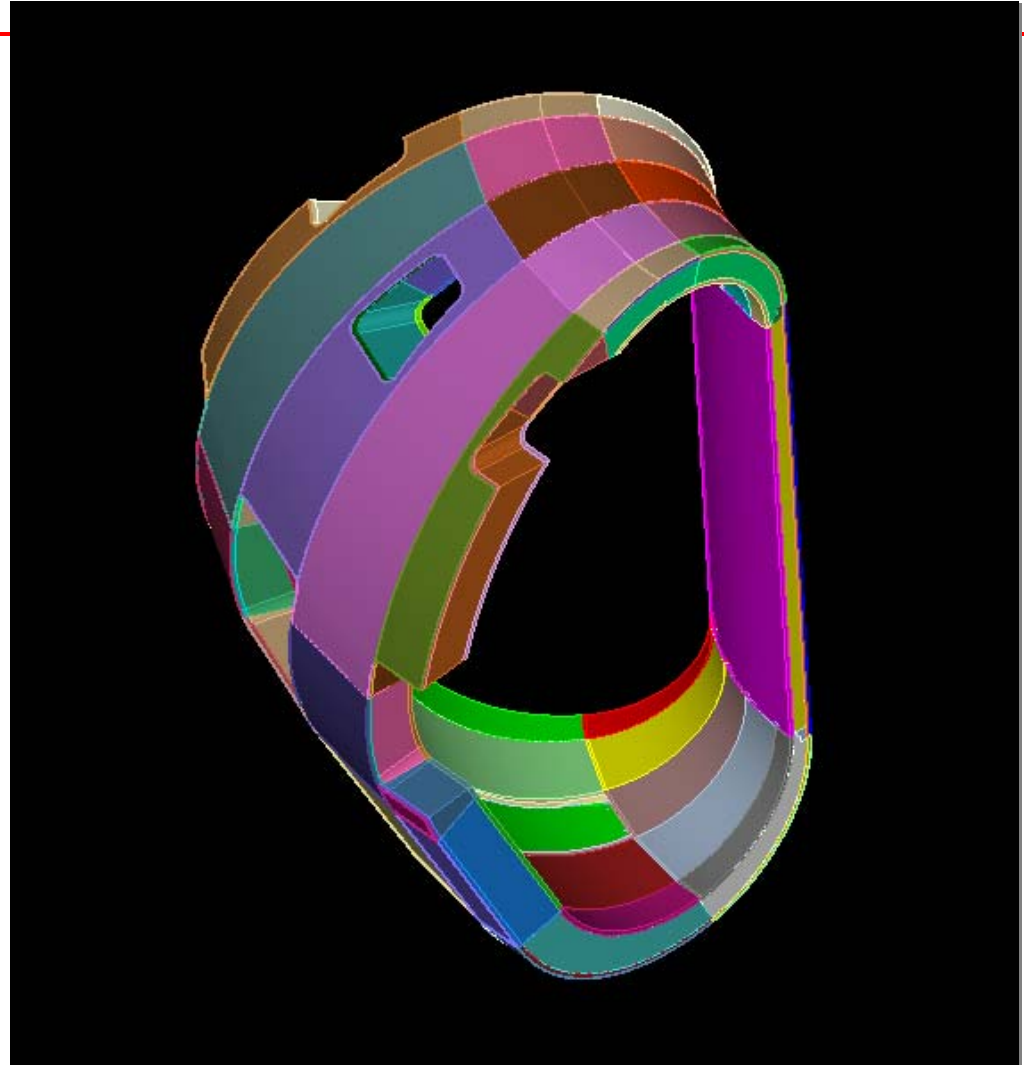

Edges cross at this point
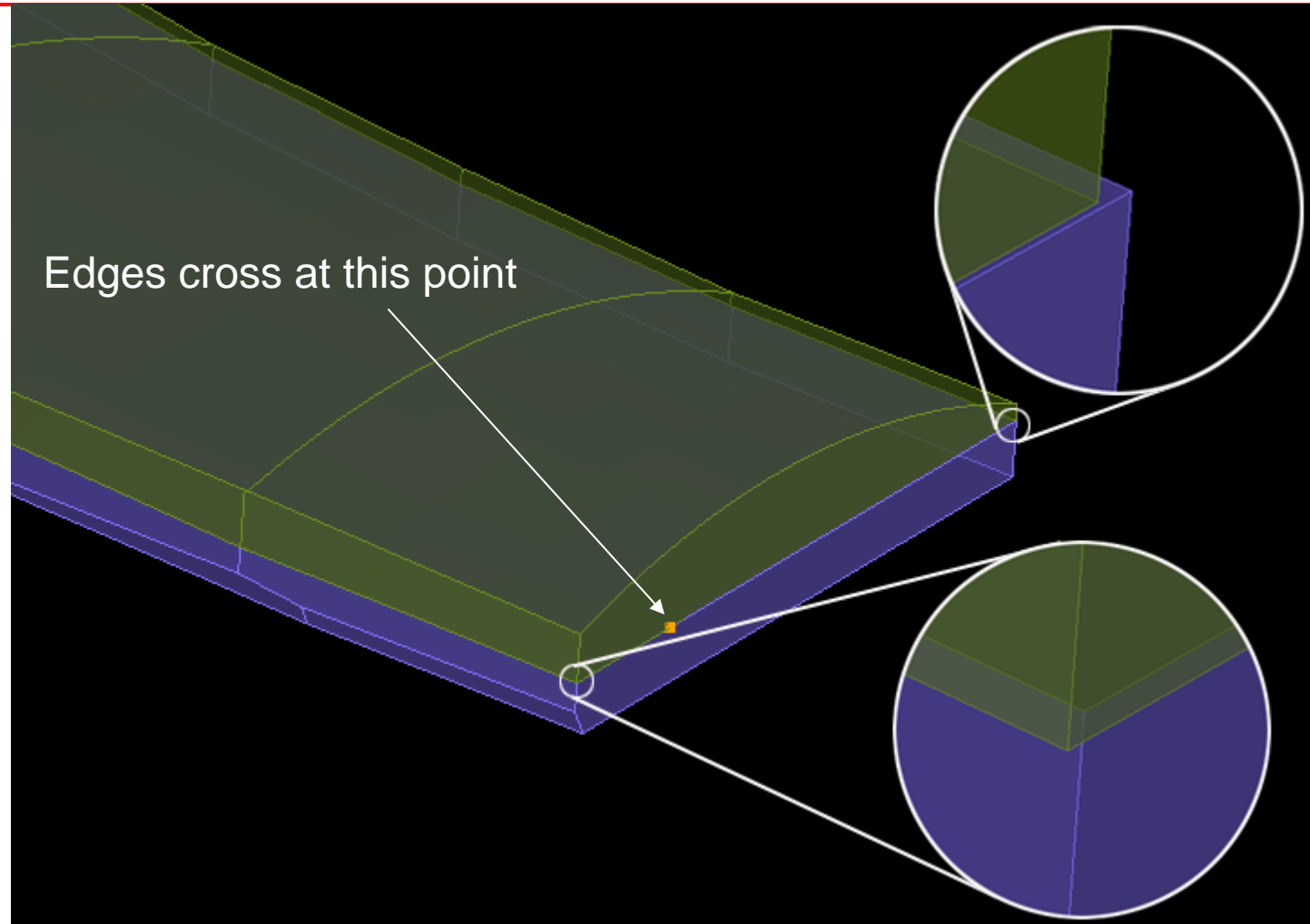
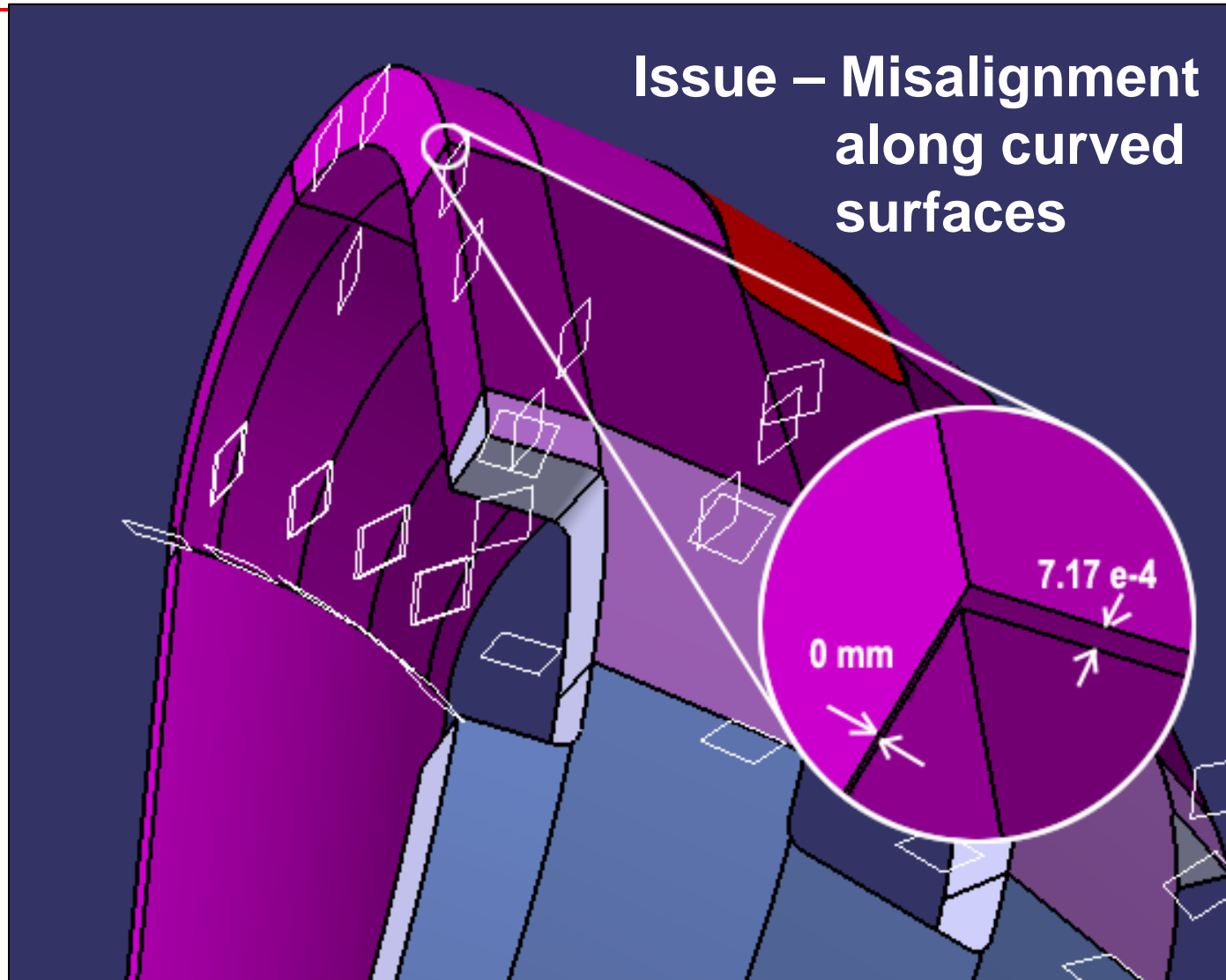**Action – MAY require recreating volume**

Complex Surface Definition

Issue – definition of neighboring complex surfaces differ slightly, preventing surfaces from merging
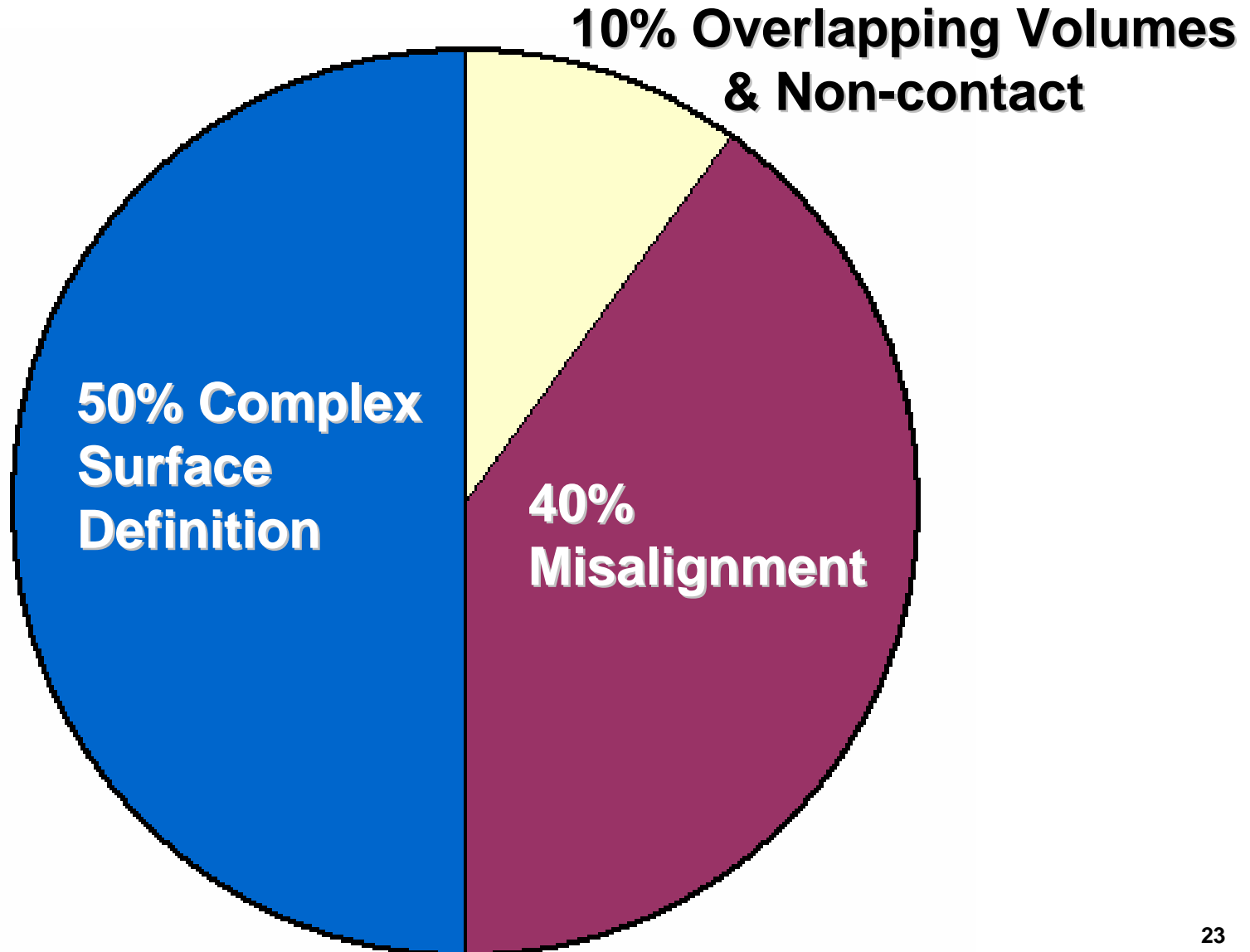
Action – Recreate geometry and/or "Unify" neighboring volumes into a single volume.

Complex Surfaces & Misalignment

Issue – Misalignment along curved surfaces

7.17 e-4

0 mm

Distribution of Repair Efforts

10% Overlapping Volumes & Non-contact

50% Complex Surface Definition

40% Misalignment

Improving the Process

- **Direct Link to CATIA (or appropriate modeler) data – eliminating possible translation issues.**

- ***Work with original ITER data – simplification process may have introduced errors***

- **Tighten design process to minimize "designer-introduced" issues**

- **Leverage prior work via configuration control - allowing future model revisions to address only those area that have changed.**

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