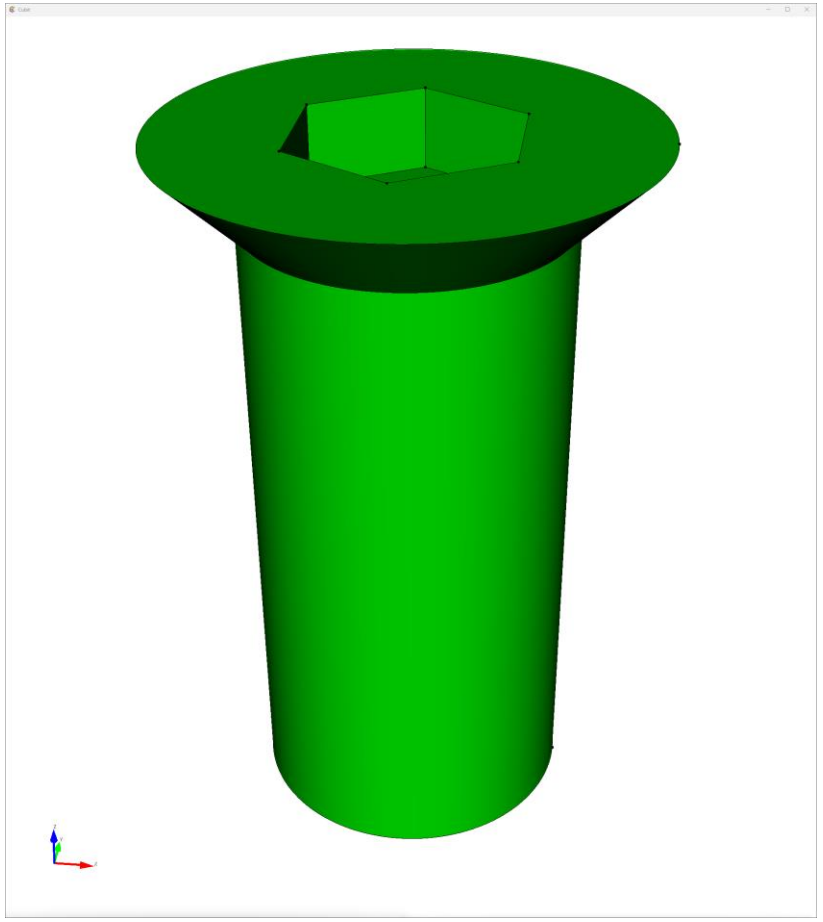
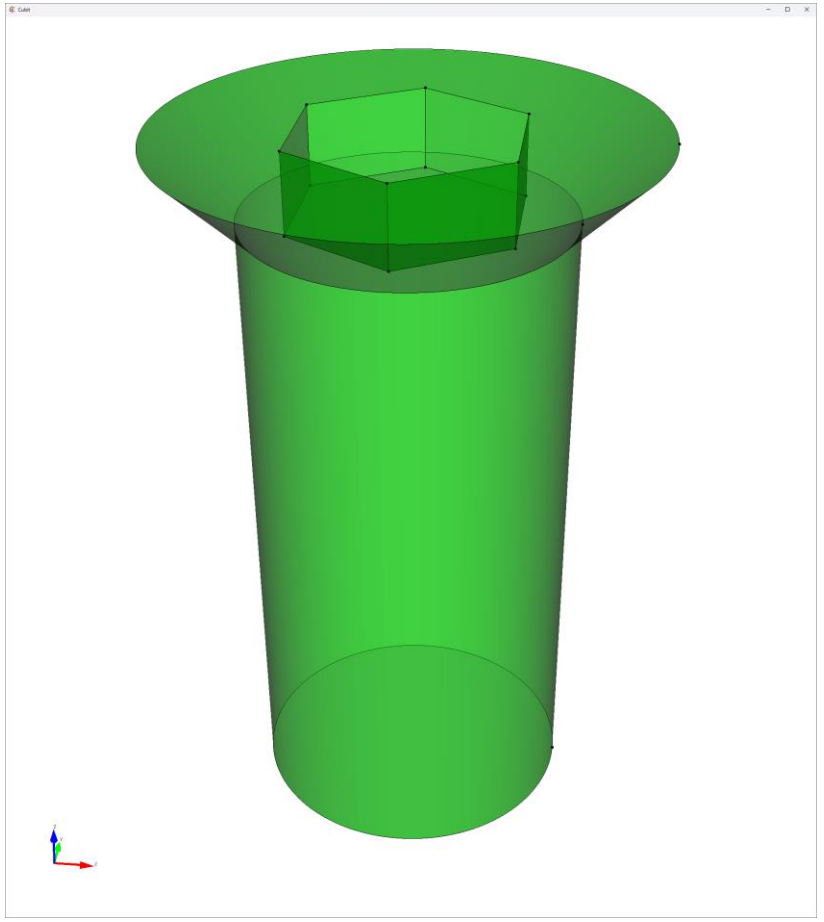
Preparing Tire Tread Models in Coreform Cubit

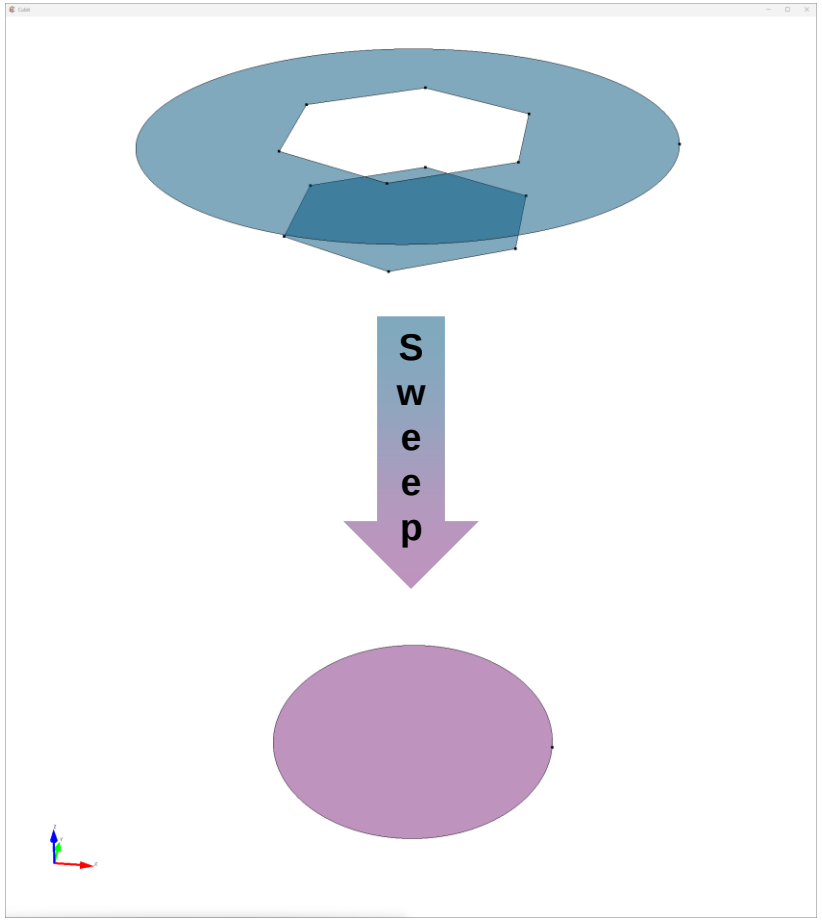
Many-to-one Sweep



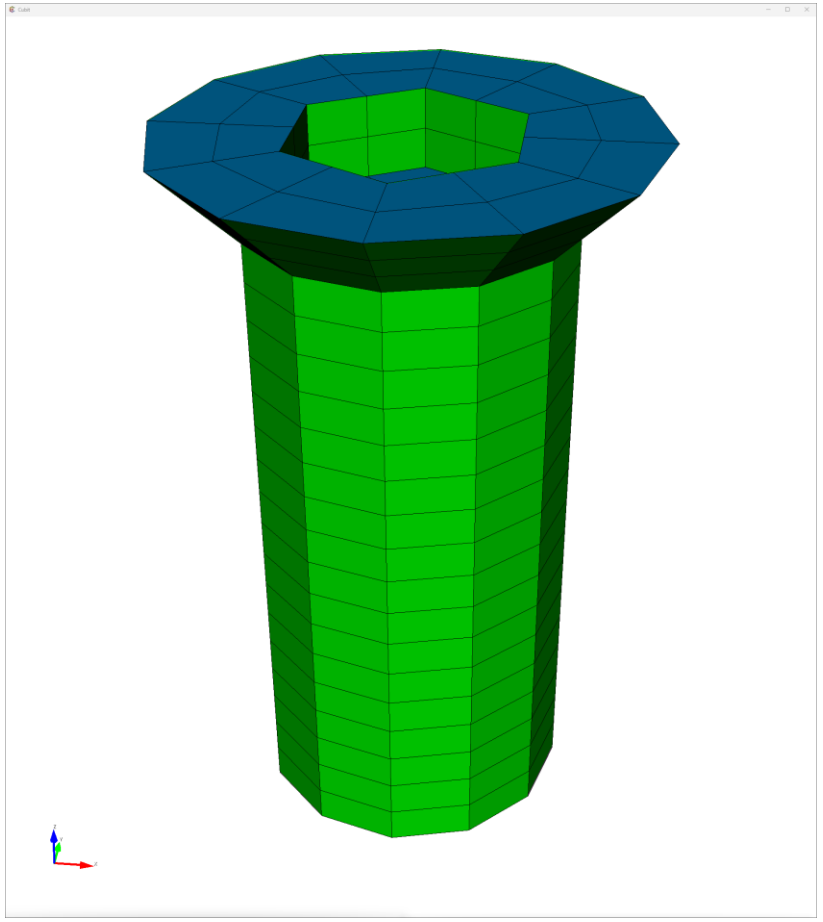


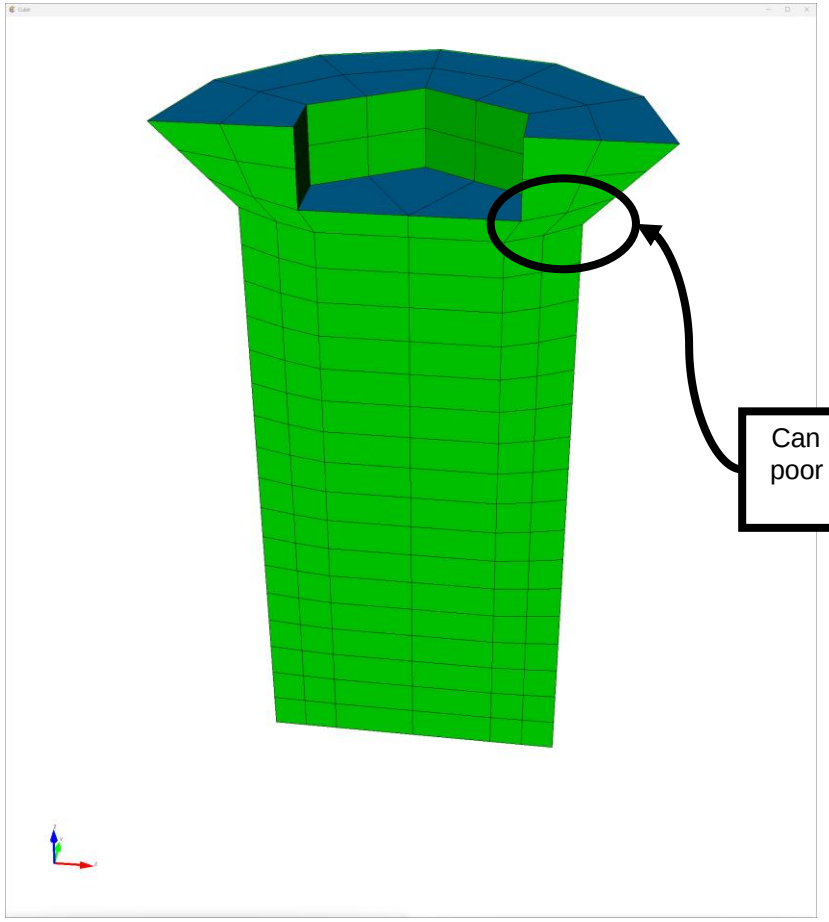
Many-to-one Sweep

- Coreform Cubit is a *semi-automated* hex-mesher
  - Means that Cubit can recognize certain topologies as meshable without further decomposition by the user
- A “many-to-one sweep” (N:1) is one of the techniques that can recognize topologies as meshable
- Importantly, whenever an N:1 sweep is used, you *could* have done additional decompositions to make multiple 1:1 sweeps

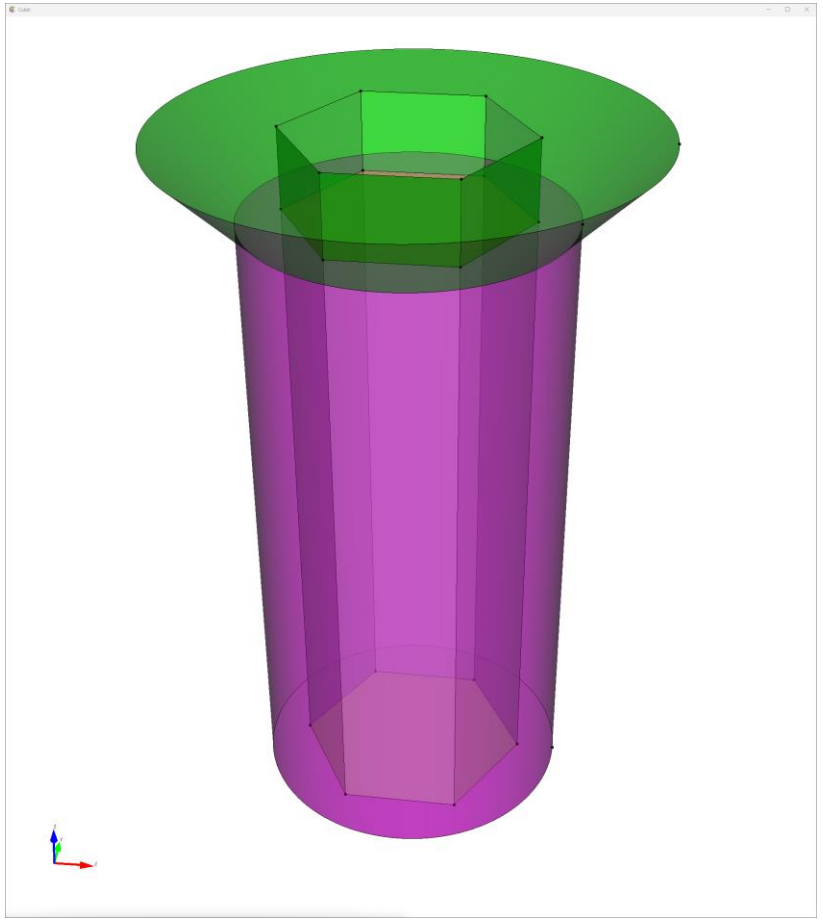


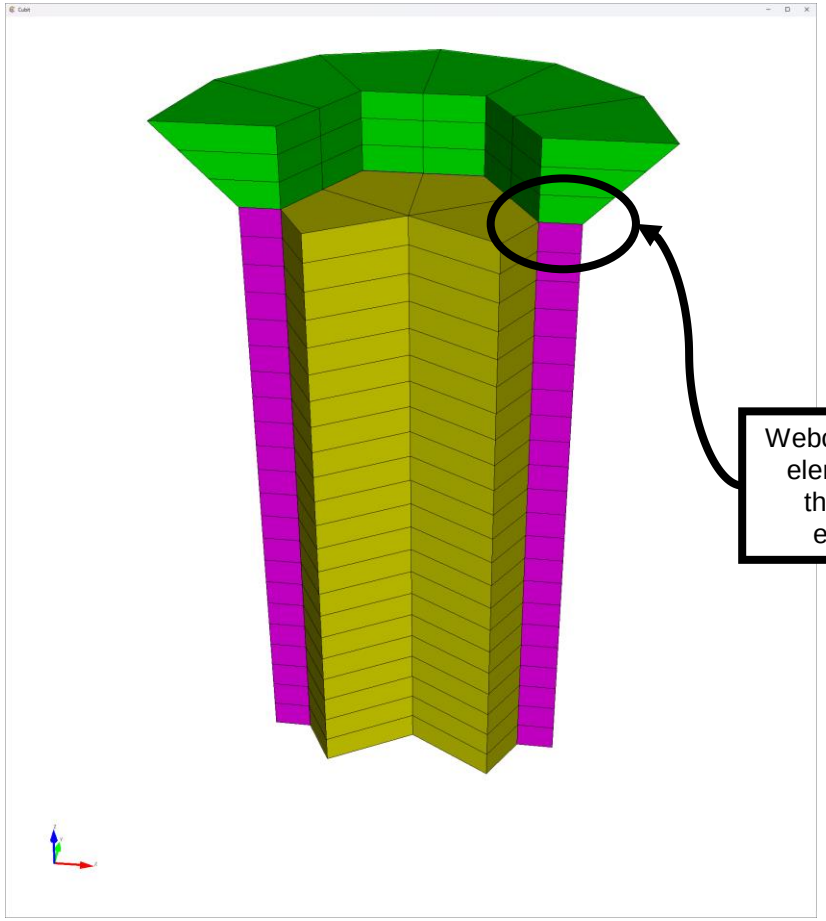
Many-to-one Sweep





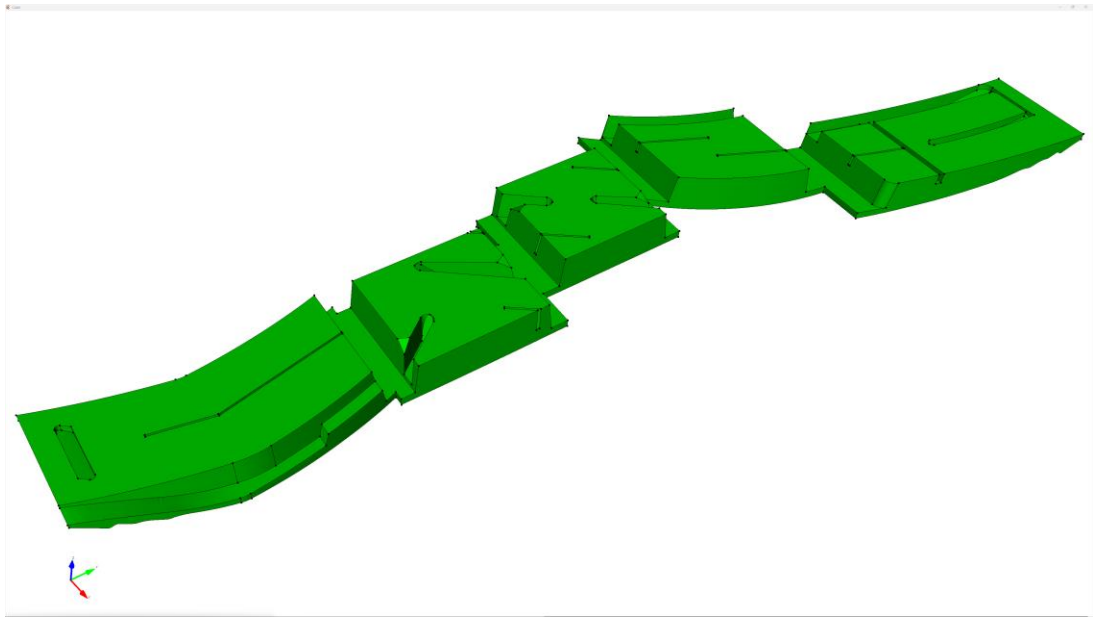
Manual decomposition



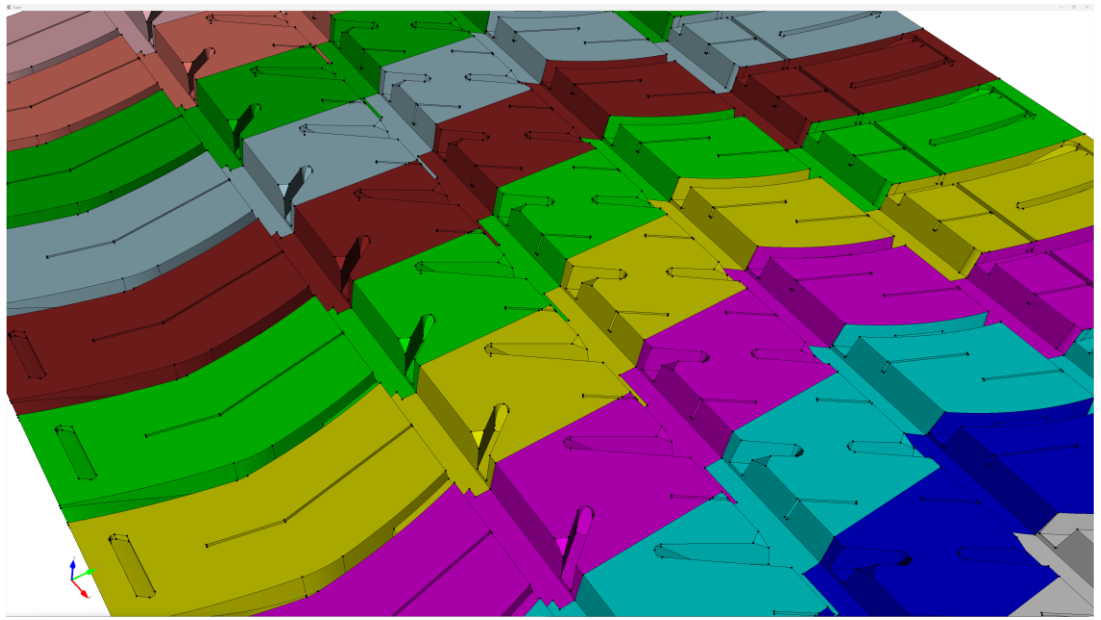


Tire tread geometry

Single “unit” of tread with symmetry

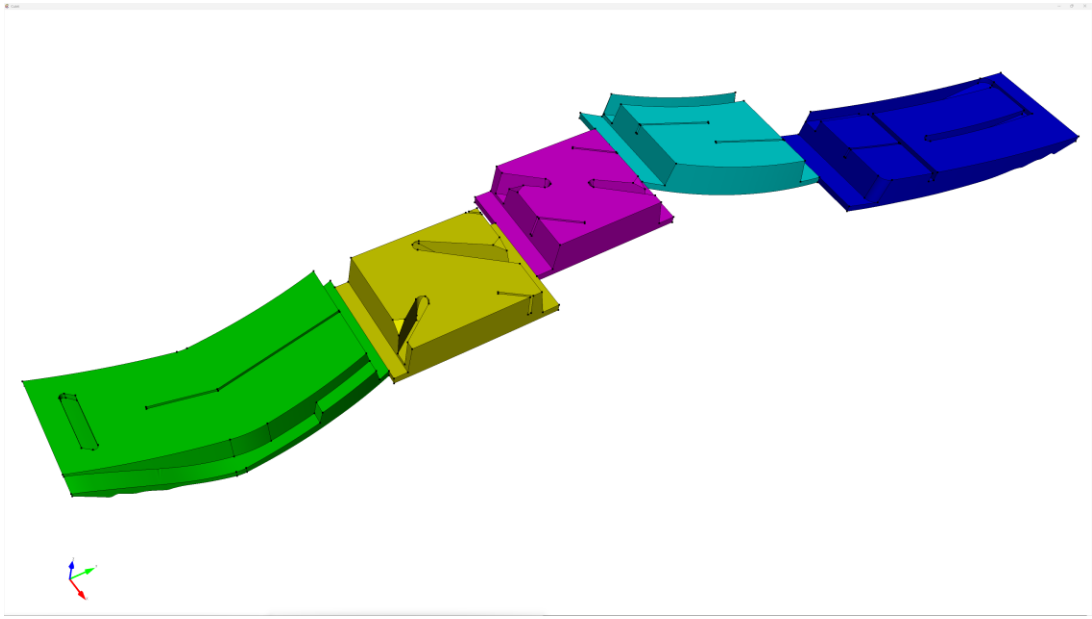


Full tread pattern



Separating into subunits

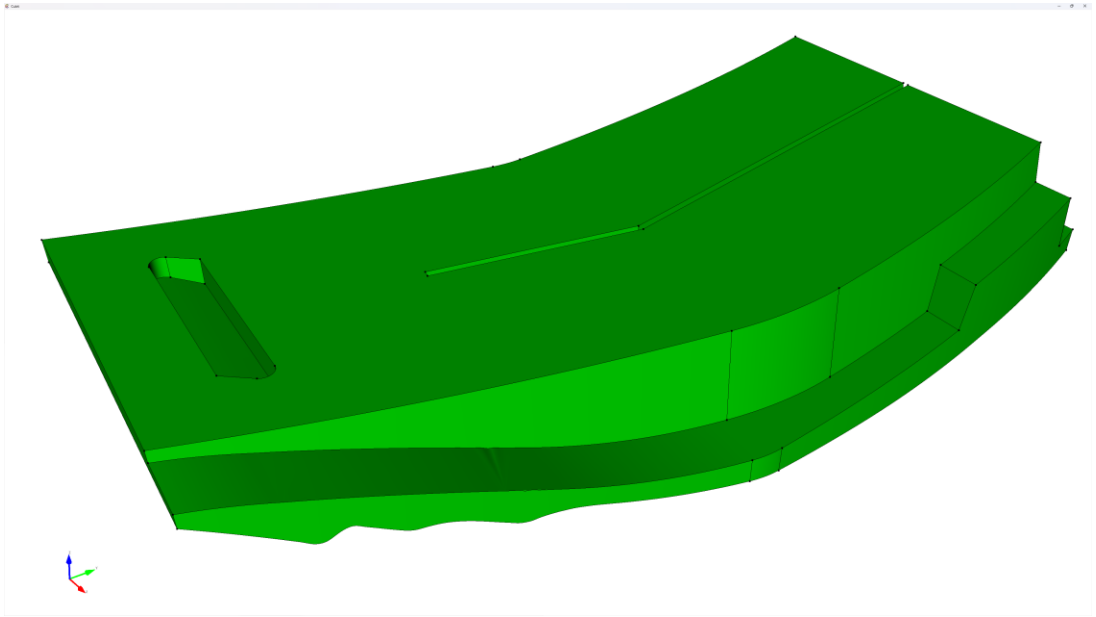
- When dealing with complex models, it's often helpful to cut the model into simpler subunits and process individually
  - Export each subunit to unique ACIS file
  - Process each model to obtain mesh, save as CUB5
  - Import all CUB5 and apply final operations for global meshability



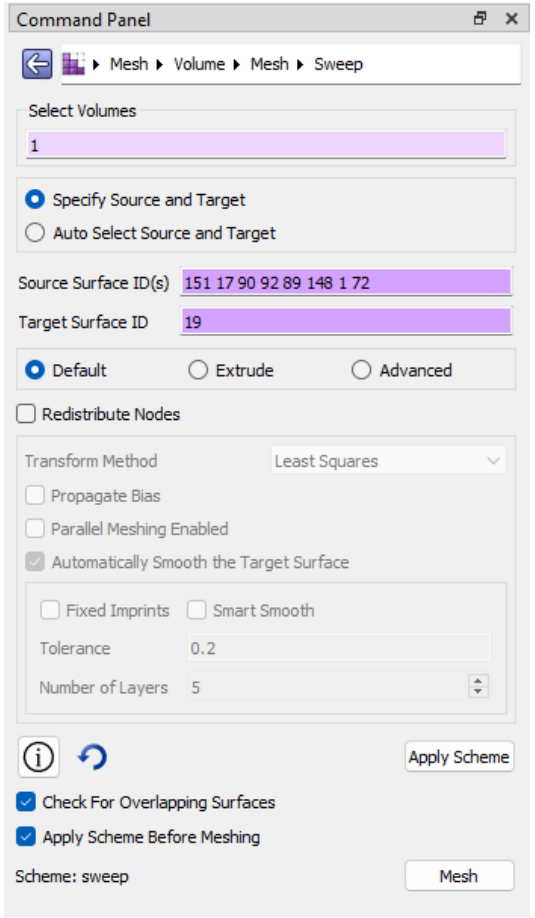
Meshing Section 1

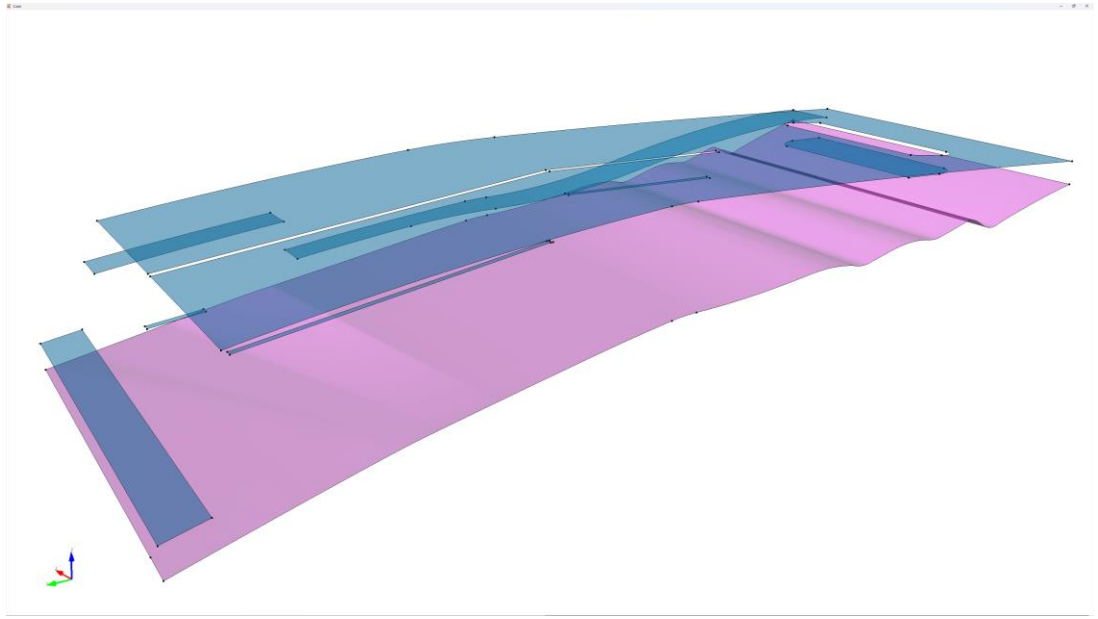
Overview

- This section doesn’t require any cleanup to produce an N:1 mesh

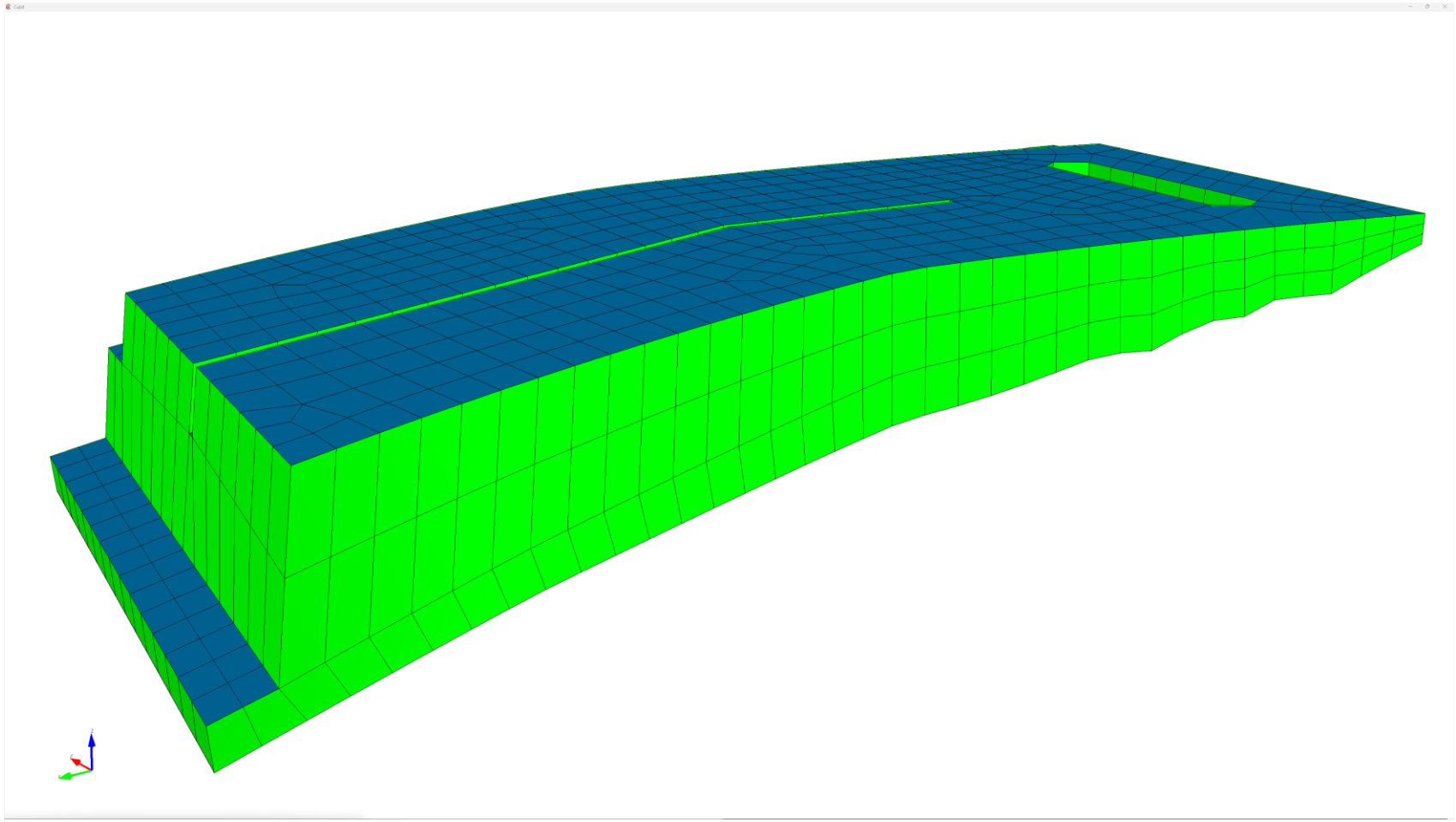


Meshing Section 1

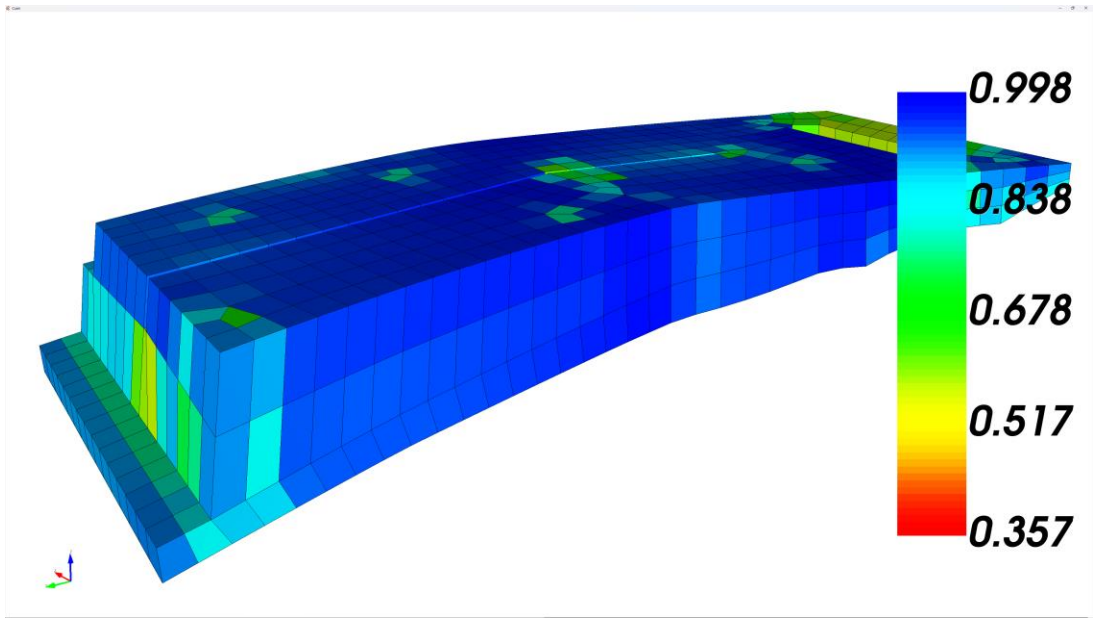




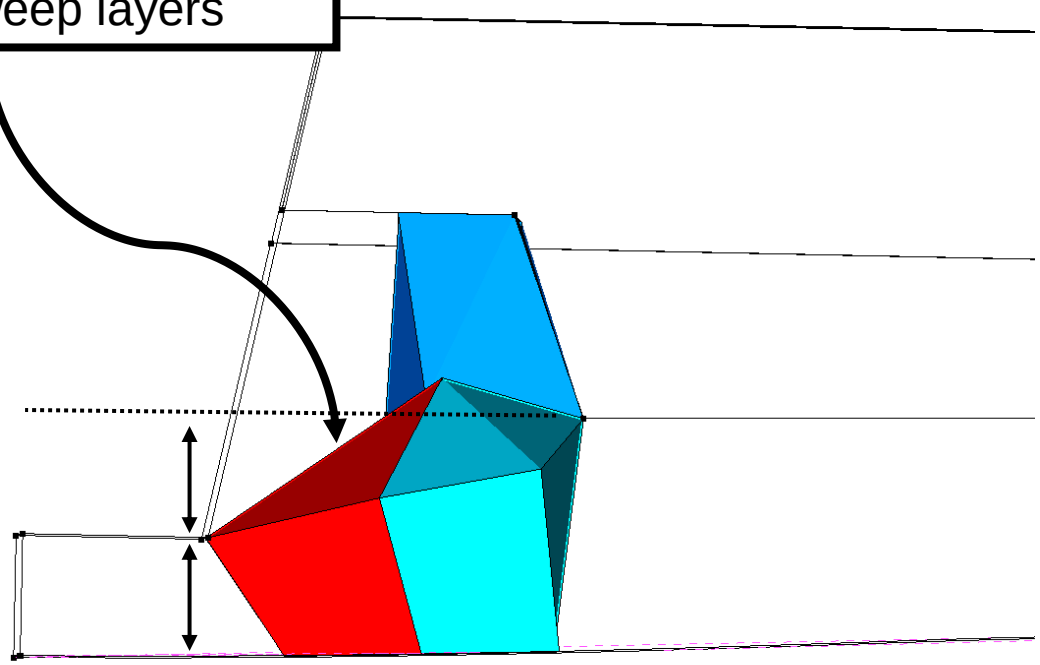
Meshing Section 1



Mesh quality

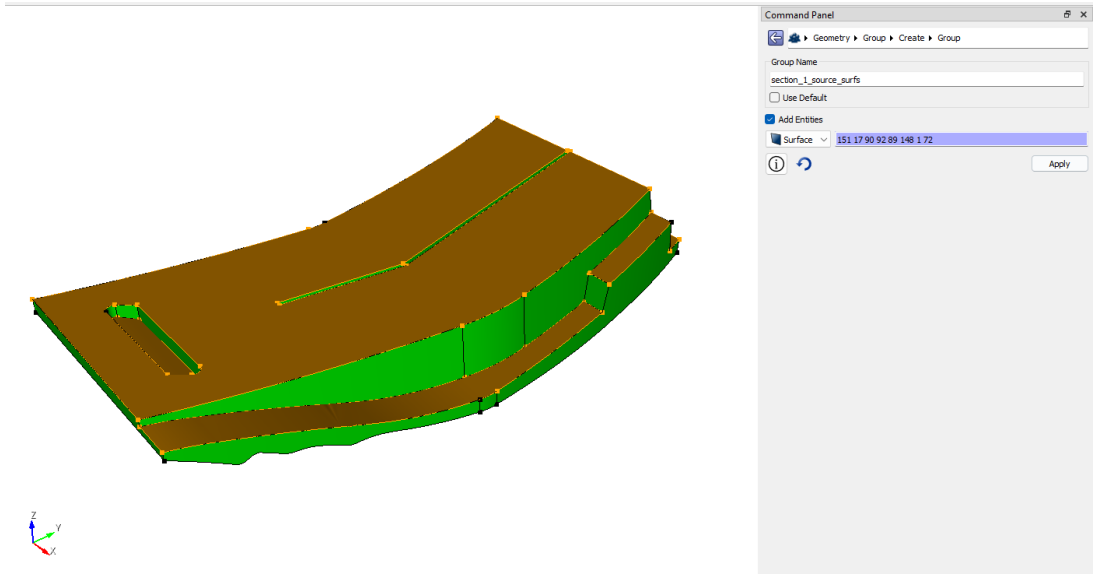


Note that the poor elements tend to be caused by “linking” between sweep layers



Group assingments

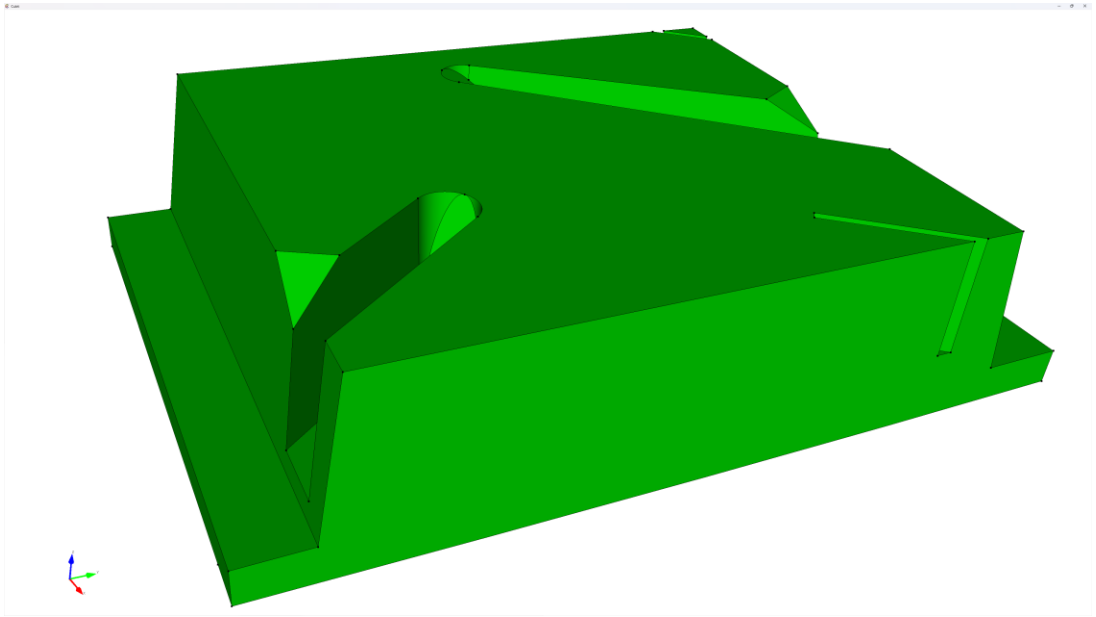
- When meshing using this “by-section” approach, it can be useful to add any sweep assignments to groups
- This will allow for easily reassigning mesh commands when recombining all the sections together
- When finished save as a CUB5
- Do this process for each section



Meshing Section 2

Overview

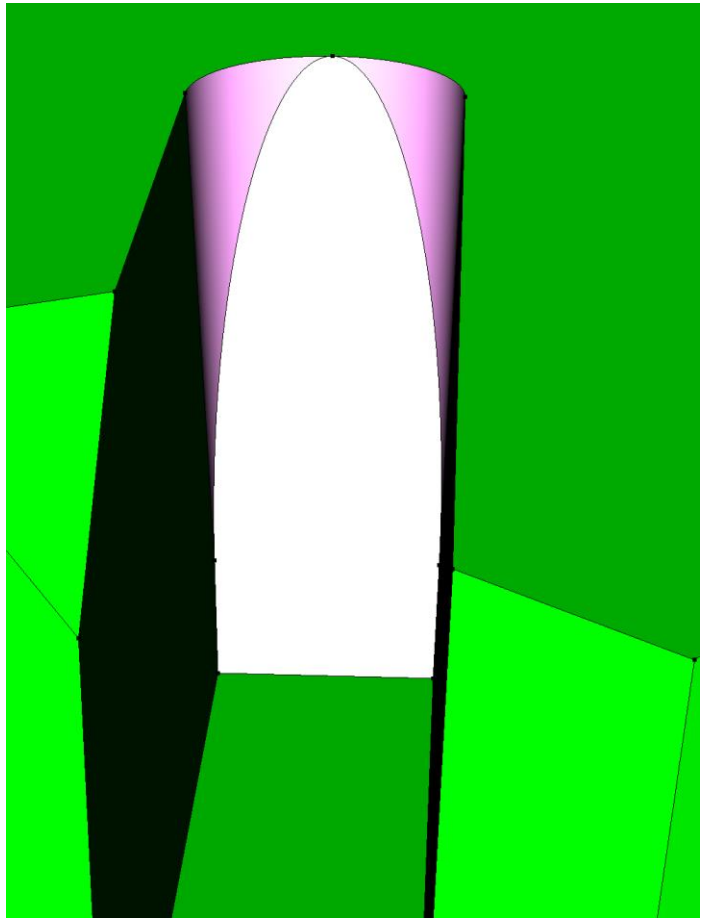
- This section will require a few composite operations, to convert challenging-to-mesh surfaces into simpler topology



Meshing Section 2

- Many sipes have rounded features such as shown on the right

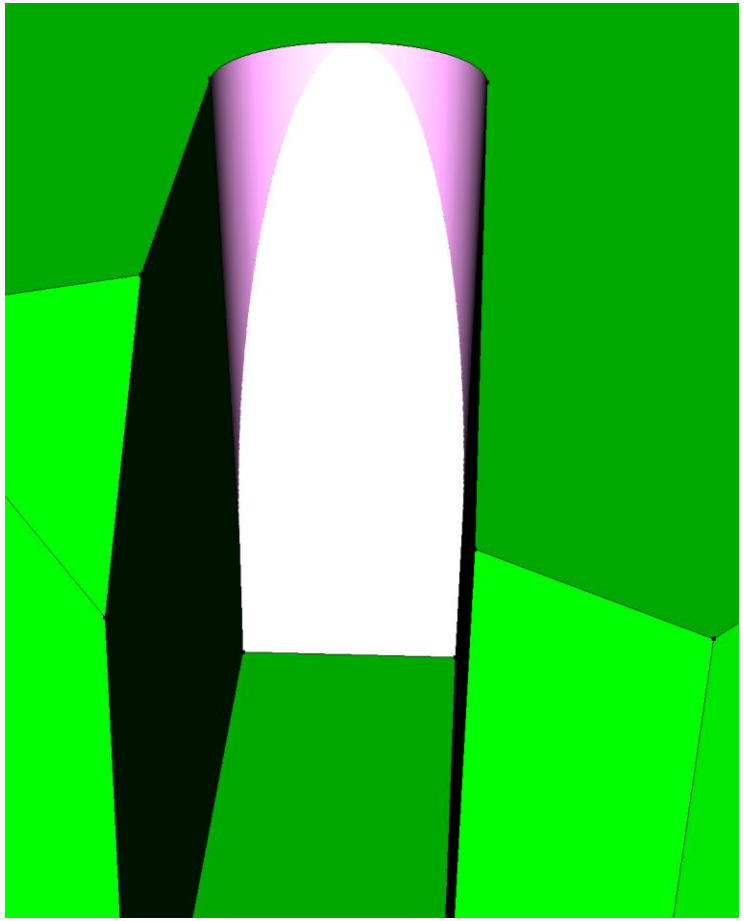
- These pose a challenge for meshing as the linking curves for our eventual sweep become perpendicular to the sweep direction *and* form a singularity between three surfaces



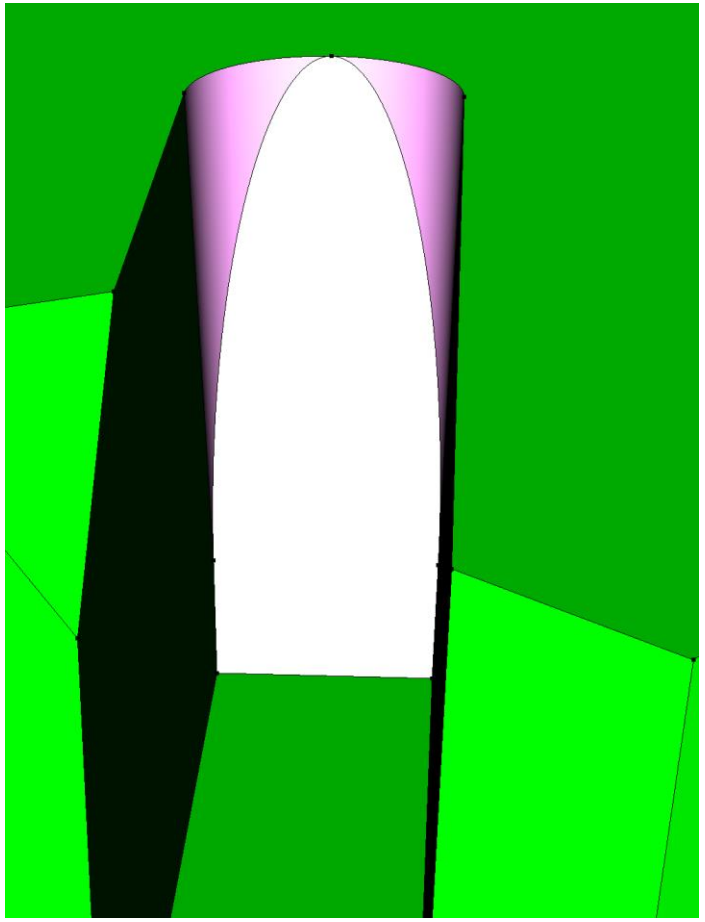
Meshing Section 2

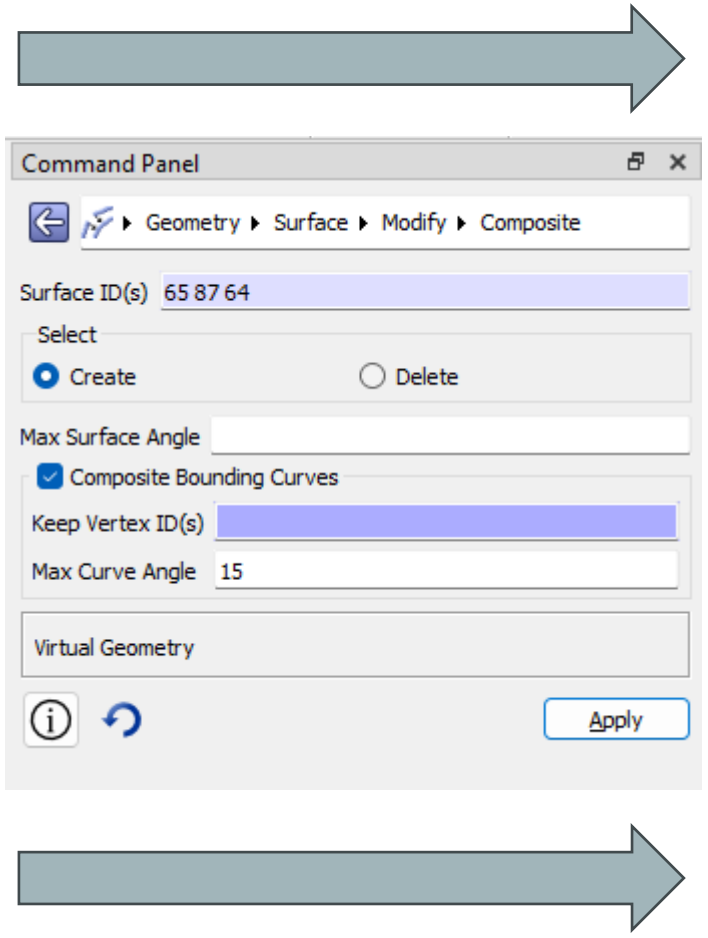
- Compositing the three surfaces into a single curve allows Cubit to ignore the troublesome *topology*.

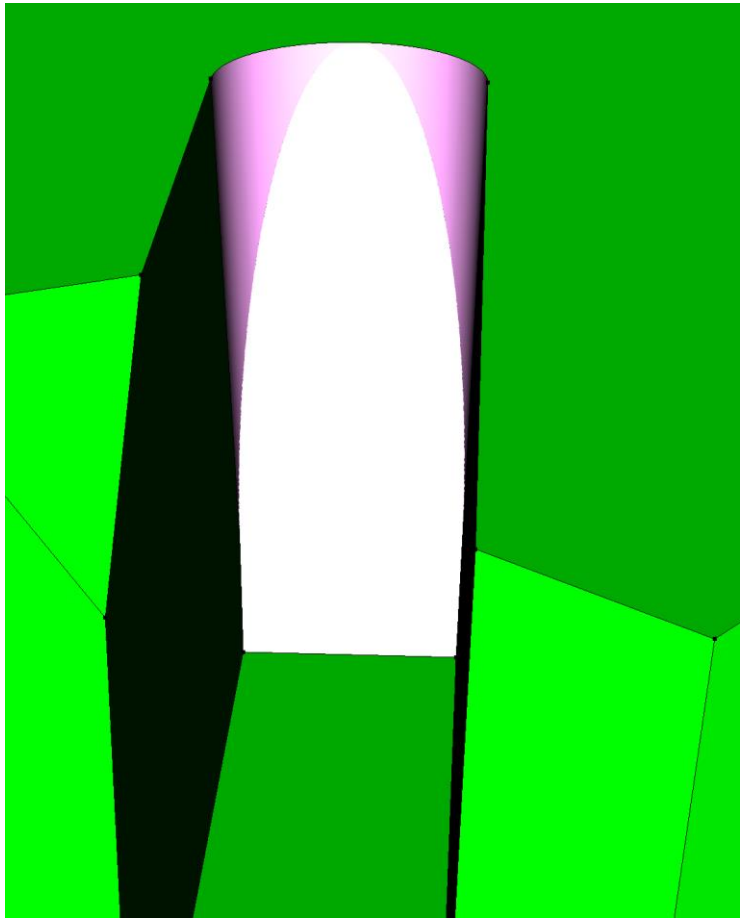
- When placing elements & nodes, Cubit will still evaluate the underlying surface geometries (i.e., shape), just has the freedom to ignore the topology



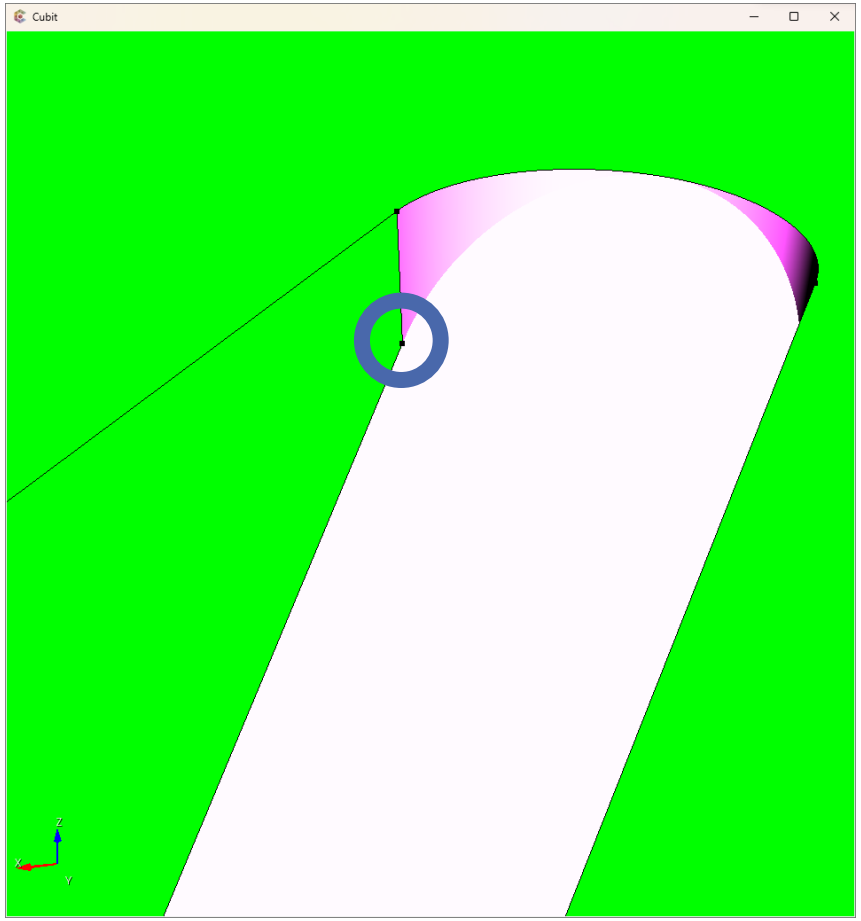
Meshing Section 2

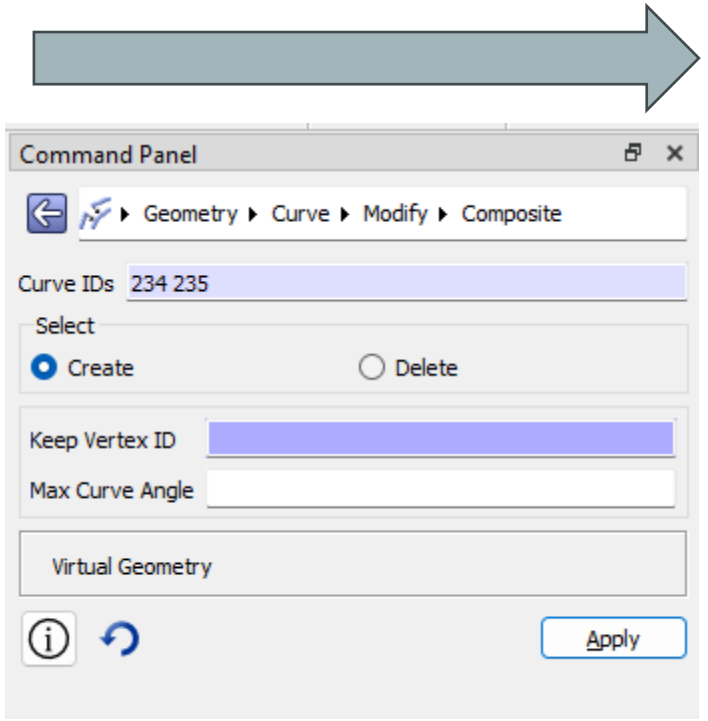


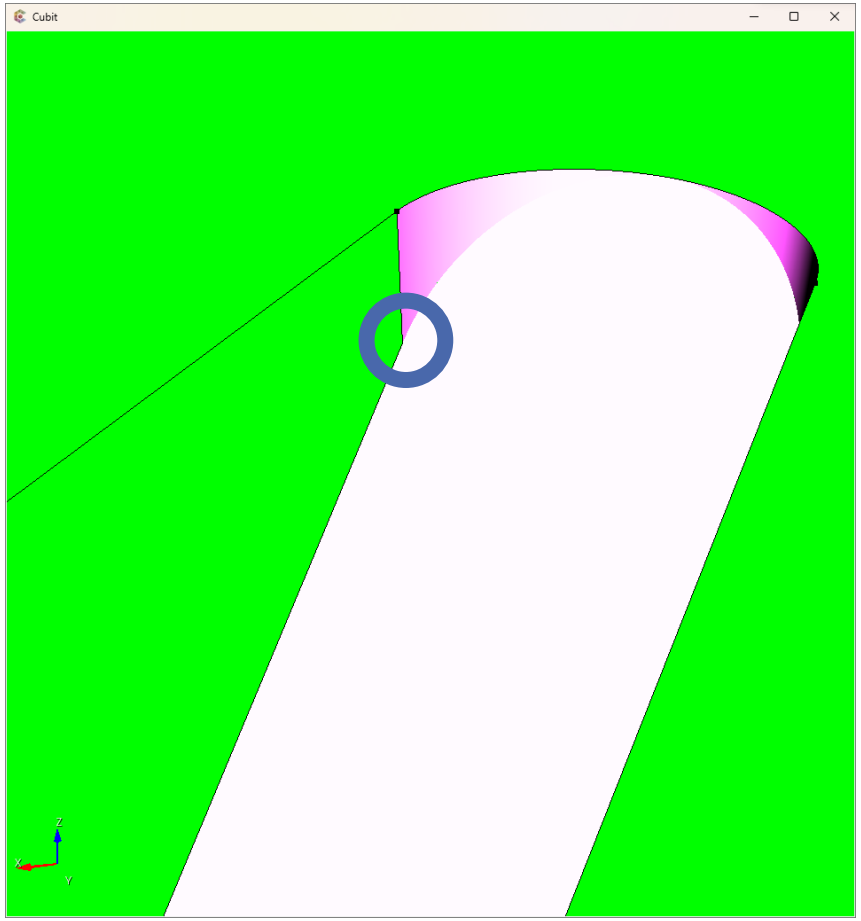


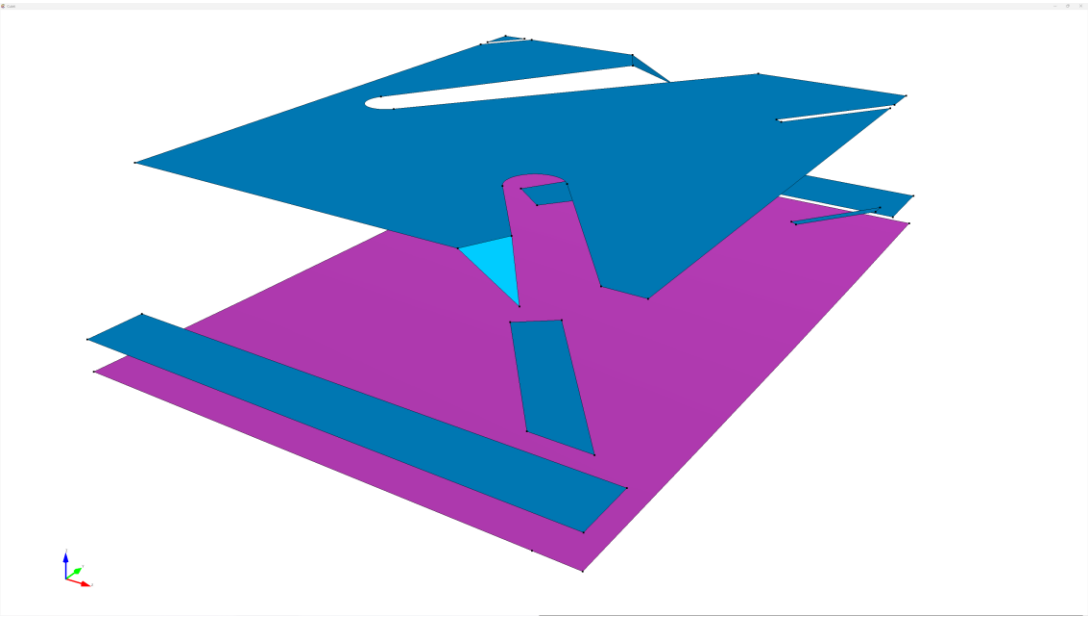


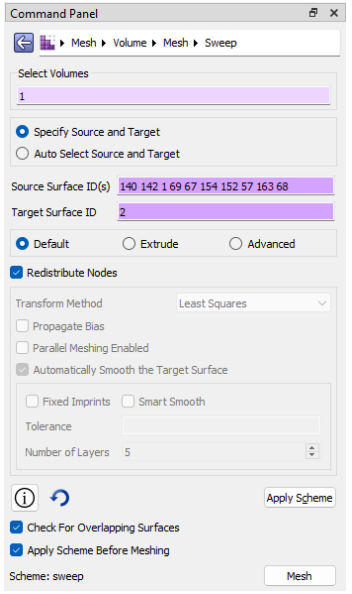
Meshing Section 2

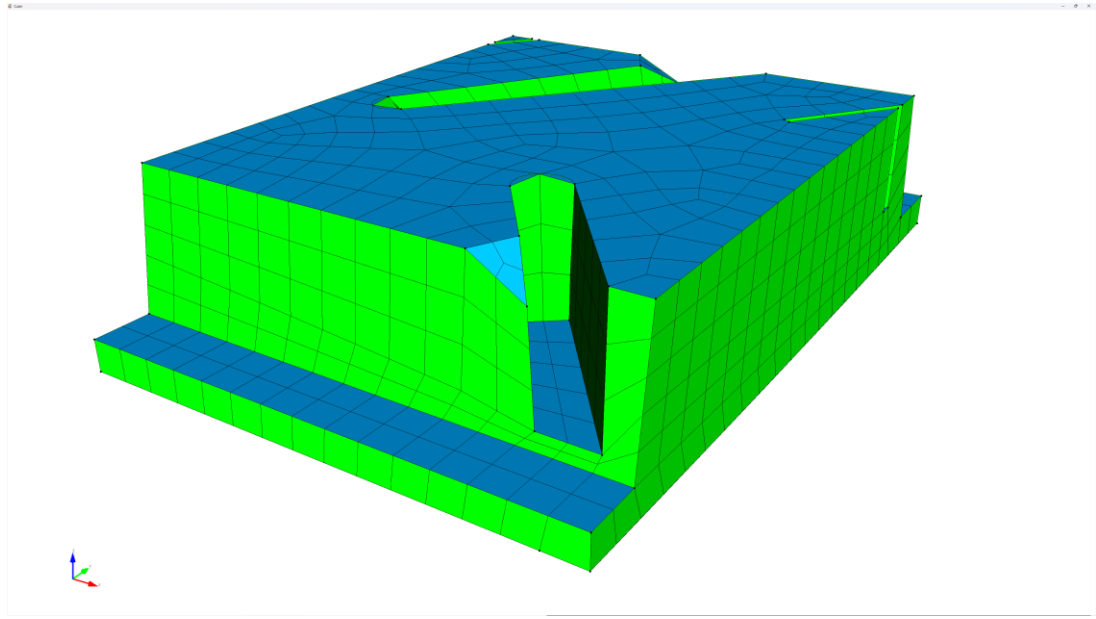




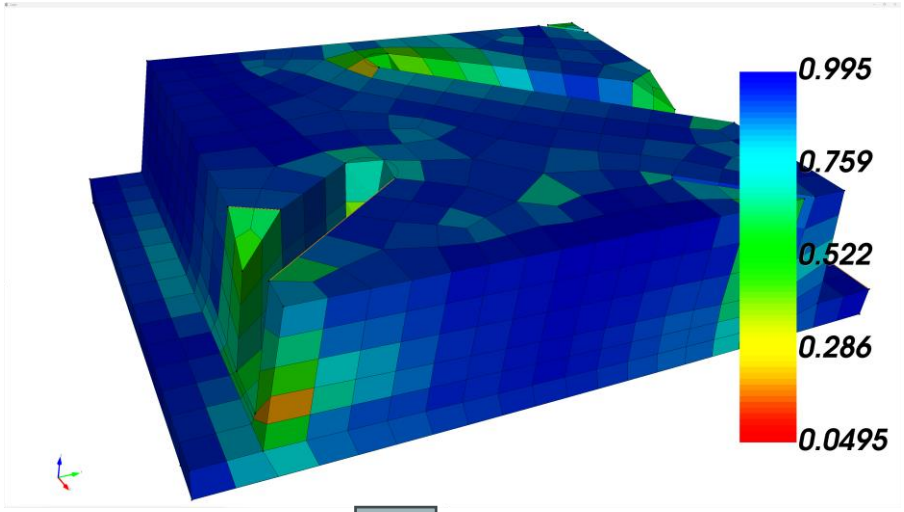


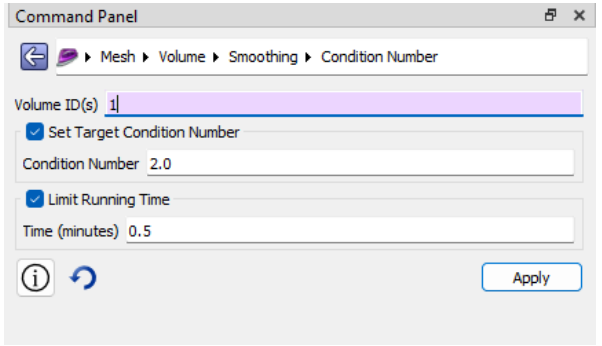


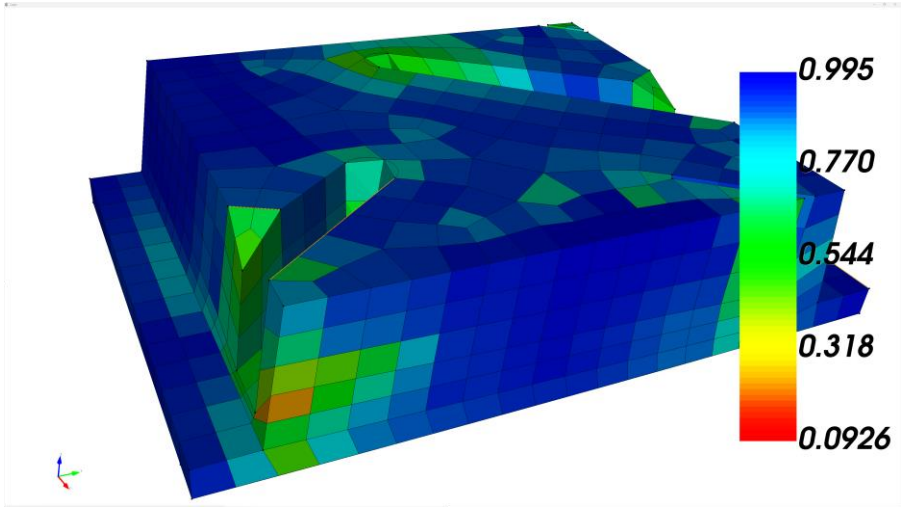

Command Panel
Mesh ▸ Volume ▸ Mesh ▸ Sweep
Select Volumes
1
Specify Source and Target
Auto Select Source and Target
Source Surface ID(s)
140 142 1 69 67 154 152 57 163 68
Target Surface ID
2
Default
Extrude
Advanced
Redistribute Nodes
Transform Method
Least Squares
Propagate Bias
Parallel Meshing Enabled
Automatically Smooth the Target Surface
Fixed Imprints
Smart Smooth
Tolerance
Number of Layers
5
Apply Scheme
Check For Overlapping Surfaces
Apply Scheme Before Meshing
Scheme: sweep
Mesh



Smoothing


0.995
0.759
0.522
0.286
0.0495


Command Panel
Mesh
Volume
Smoothing
Condition Number
Volume ID(s) 1
Set Target Condition Number
Condition Number 2.0
Limit Running Time
Time (minutes) 0.5
Apply


0.995
0.770
0.544
0.318
0.0926

Command Panel

Mesh ▸ Volume ▸ Quality ▸ Quality Metrics

Volume ID(s) 1

Quality Metric Scaled Jacobian

Summary Options

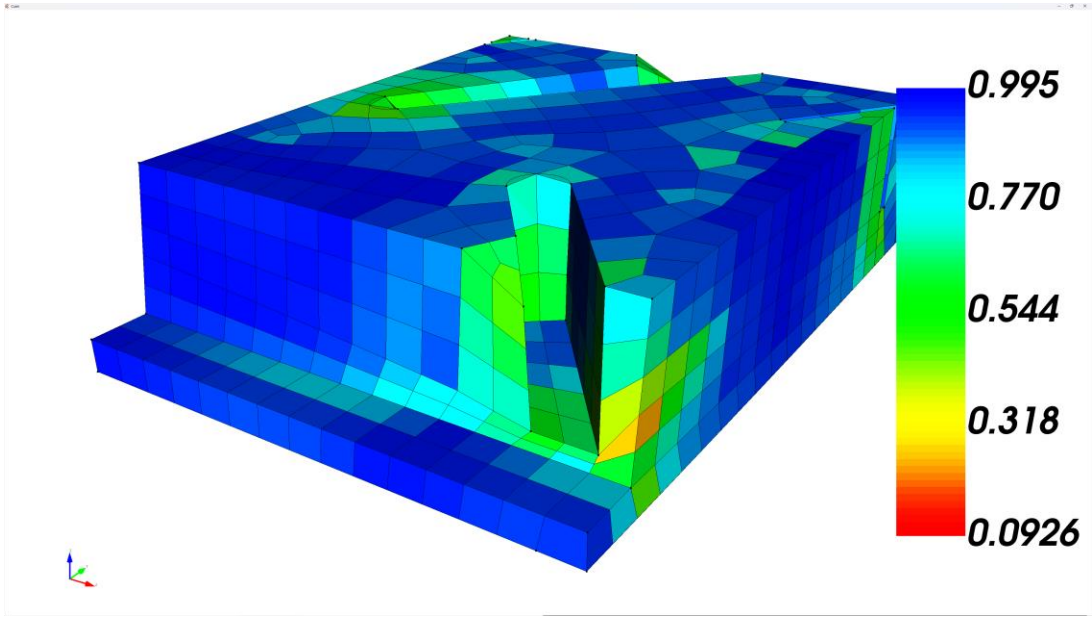
- (•) Combined Summary
- ( ) One Summary Per Entity

- [ ] Filter Element Quality Range
- [ ] Filter Using Element Quality Rank
- [x] Display Graphical Summary

- [x] Draw Mesh Elements
- [ ] Draw Histogram
- [ ] Monochrome
- [x] Clear Display for Mesh

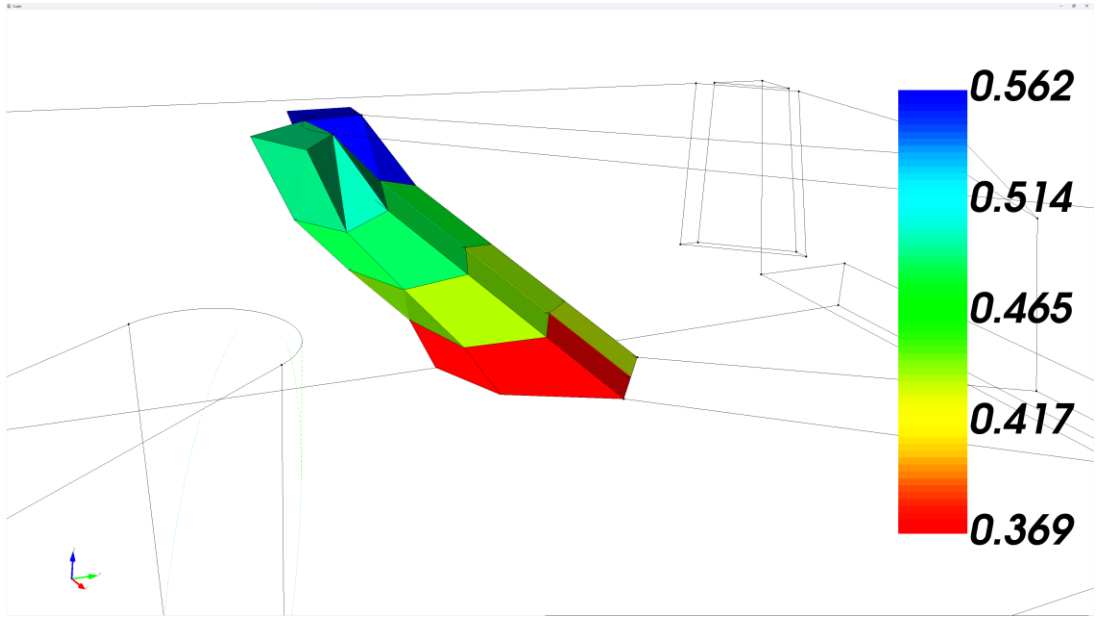
- [ ] Print Text Summary

Apply



- Note that the sloped surface results in relatively poorly shaped elements, but this element quality isn't too bad

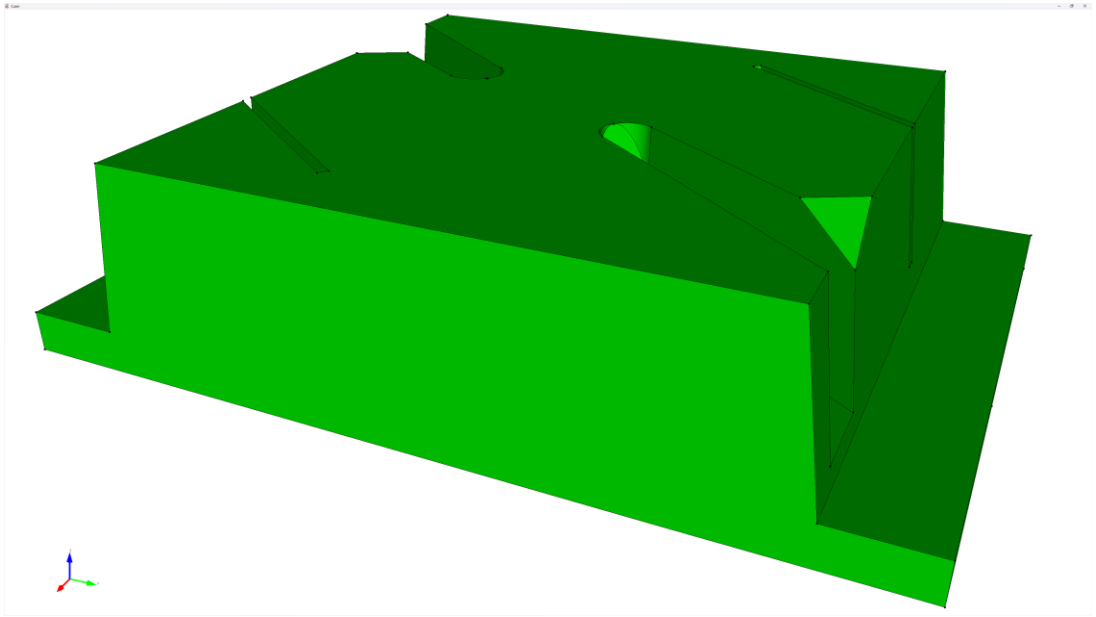
- The less perpendicular the surface, the more elements need to deform to conform, resulting in worse element quality

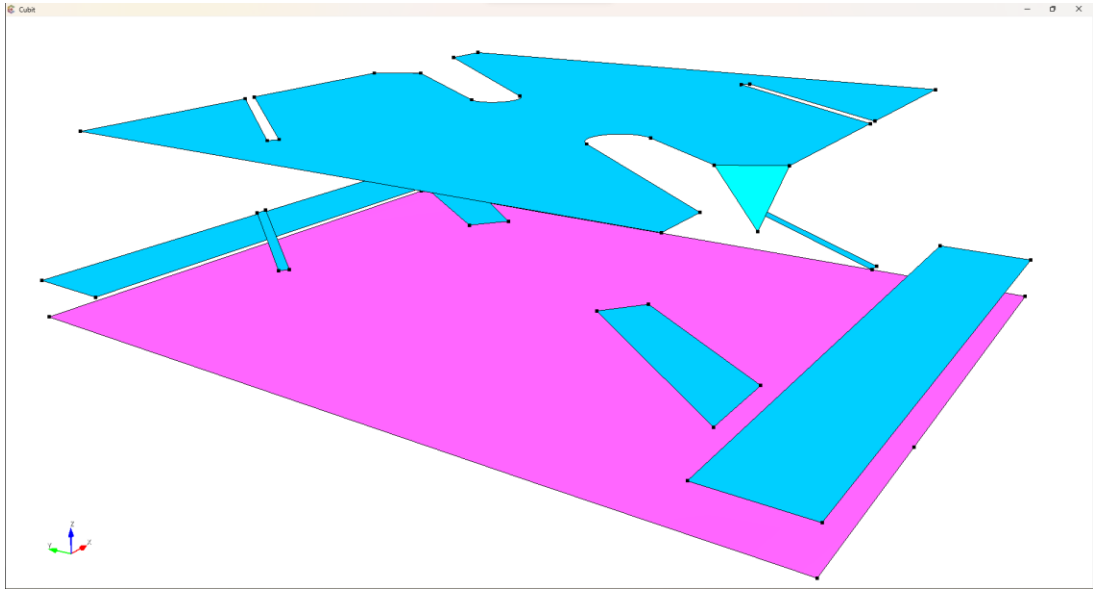


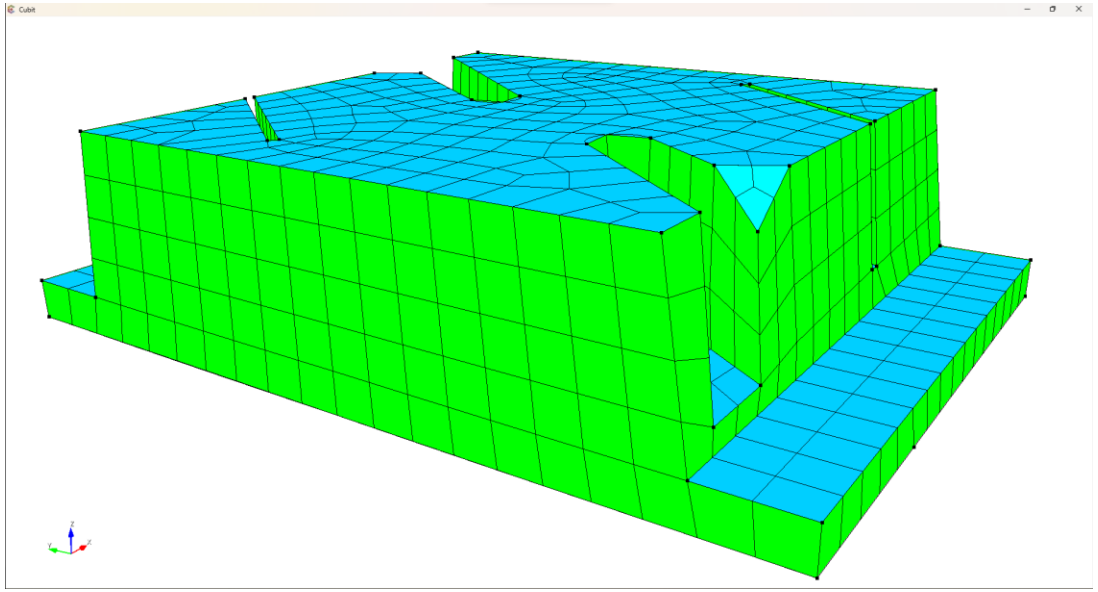
Meshing Section 3

Overview

- This section is nearly identical to the second section, requires similar processing to produce an N:1 mesh



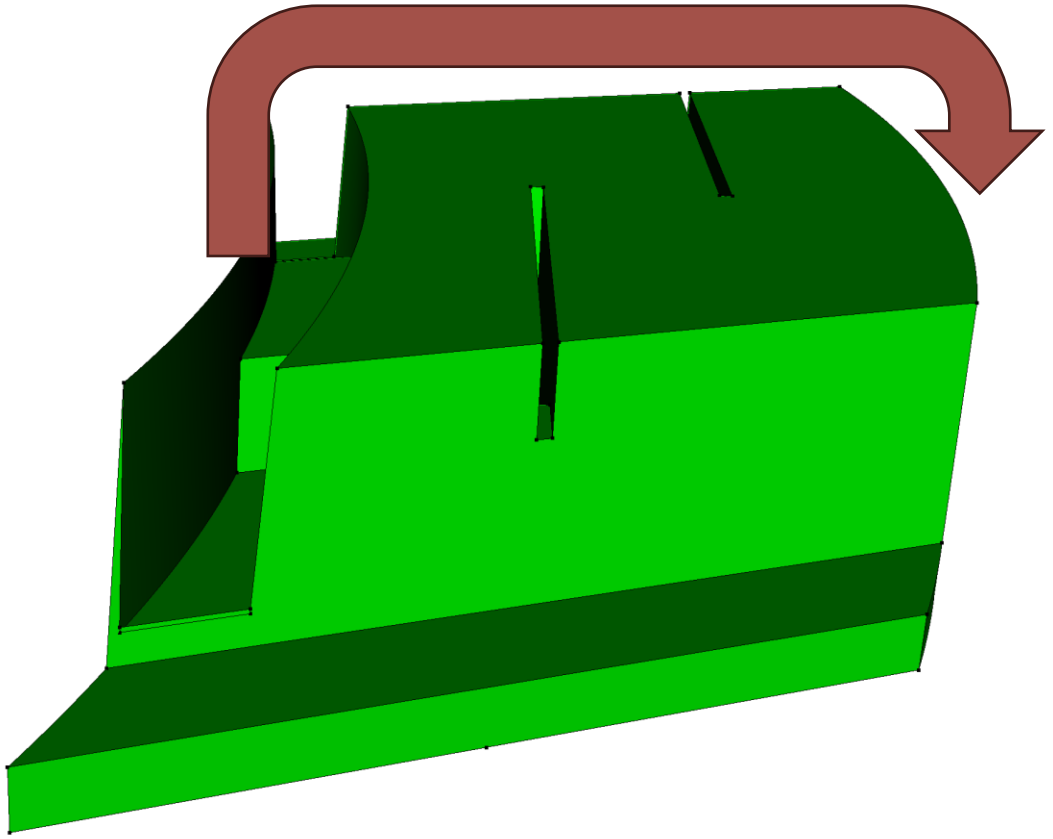




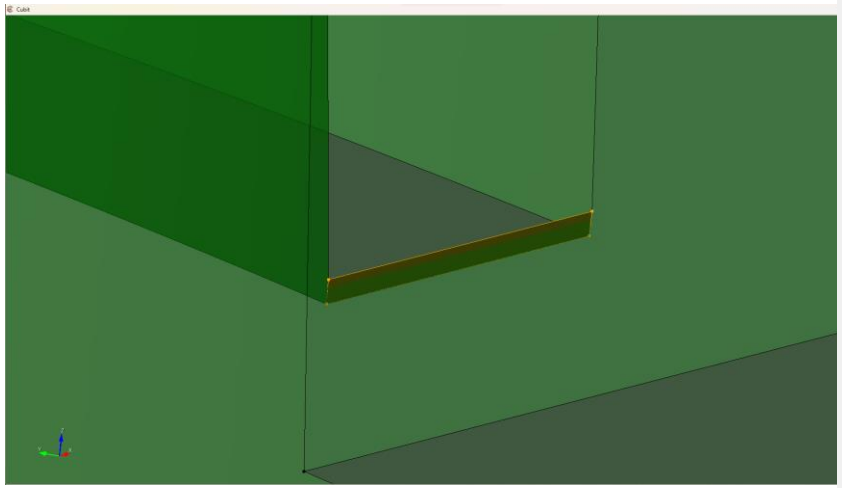
Meshing Section 4

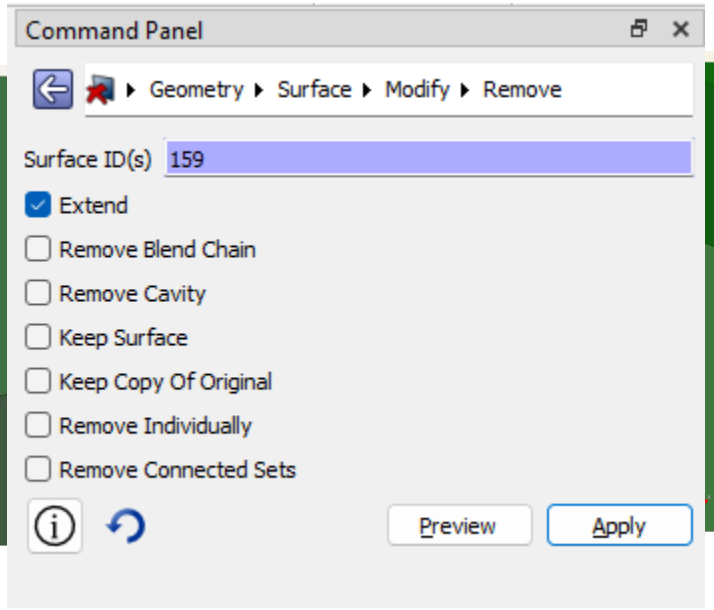
Overview

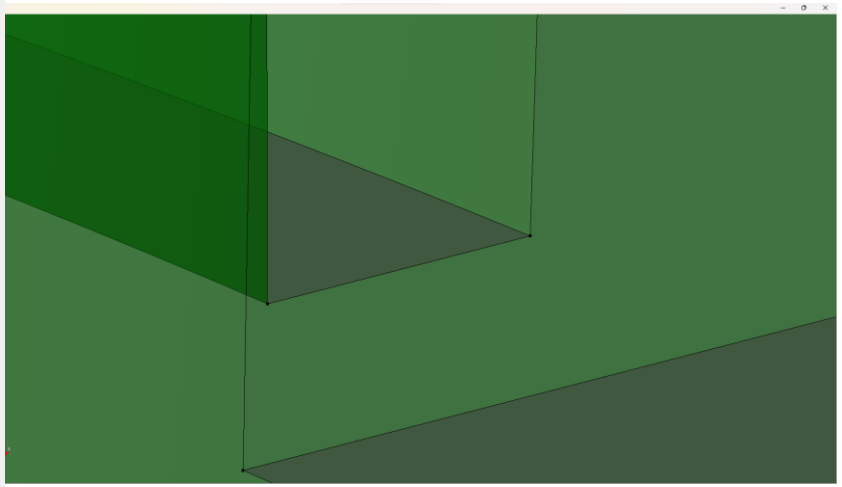
- This model has a sliver that was made to ensure vertical surfaces on the symmetry surfaces
- This sliver would *enforce* poor element quality but we can move the geometry back to the other side and make a better “symmetry cut”
- This, combined with some other cleanup will then allow us to make an N:1 sweep



Initial Cleanup

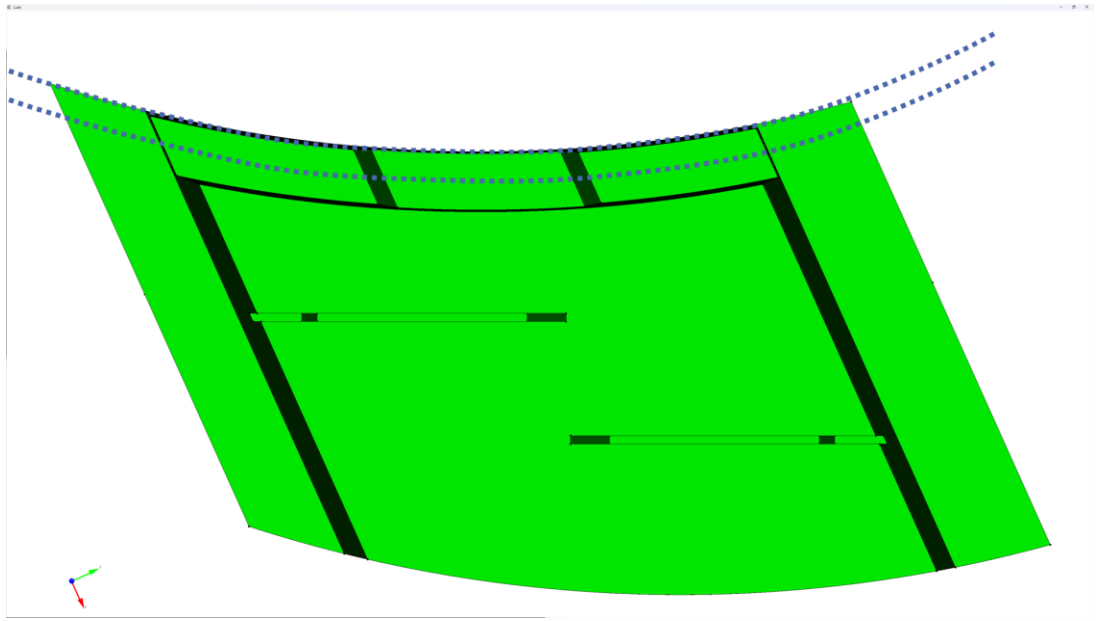






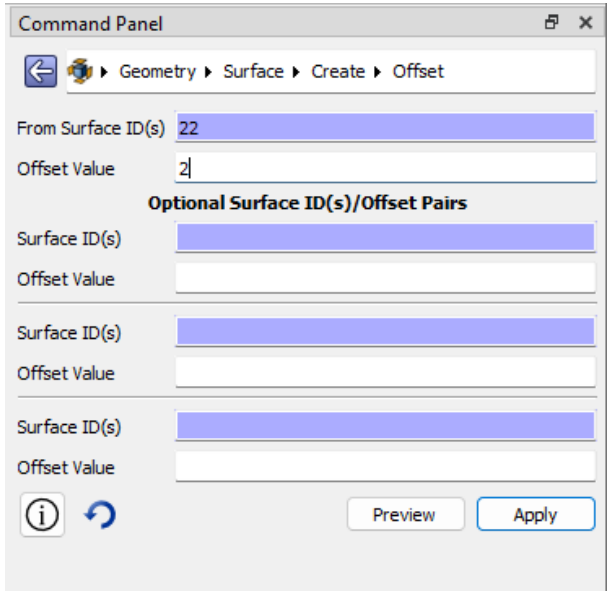
Overview of the new cut

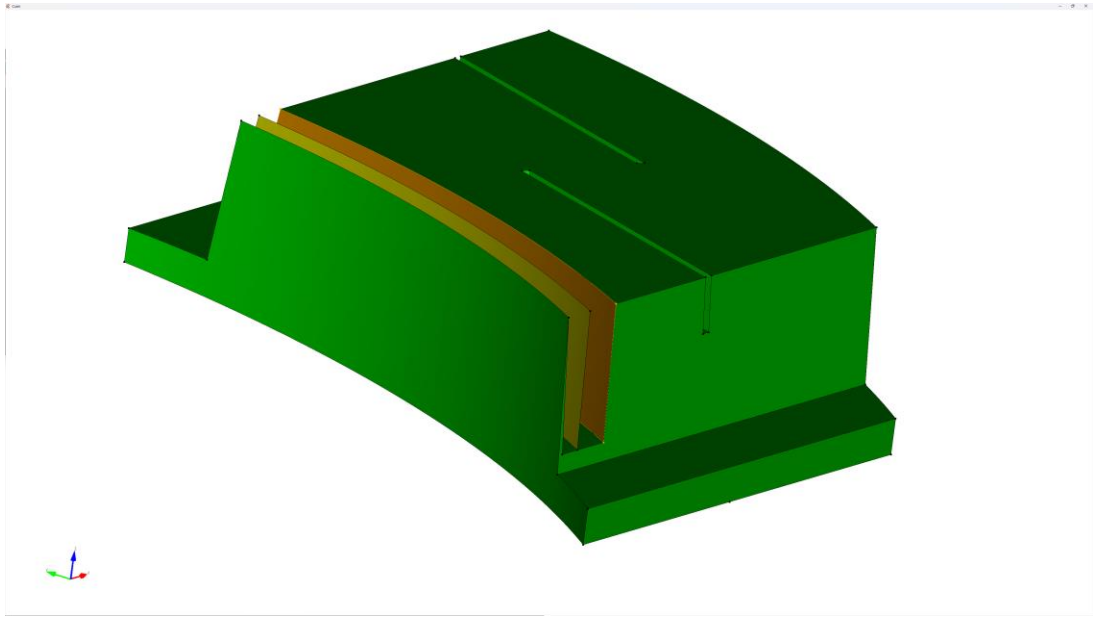
- **Goal:**
  - We want a curve that will allow us to sweep in the –Z direction, approximately in-between the two nearly-vertical surfaces



Create offset surface

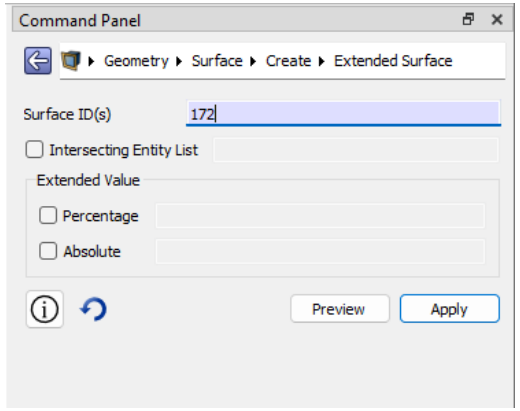
- **Step 1:**
  - Create an offset surface approximately, will retain the general shape of the surface

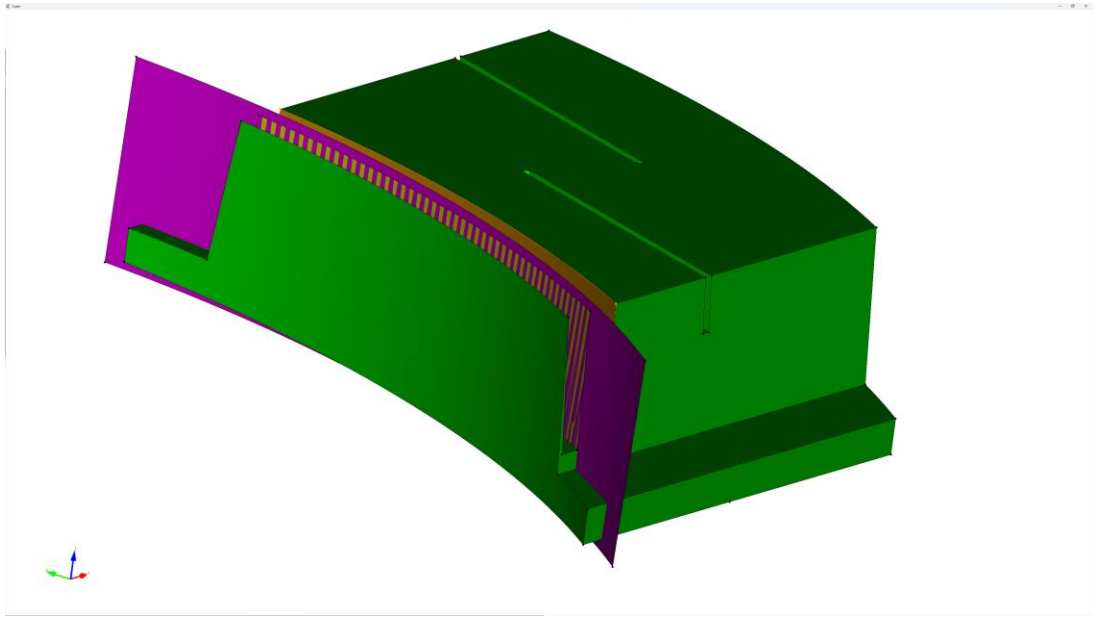




Create extended surface

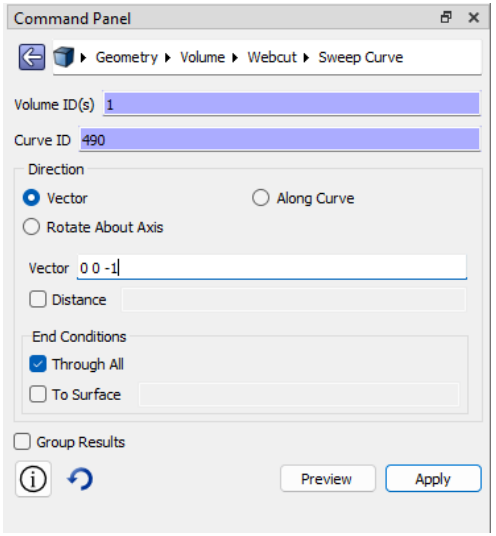
- **Step 2:**
  - Create an extended surface, extended from the offset surface.
  - By default the extended surface extends to extent of total bounding box – which is why it was helpful to split the part into sections

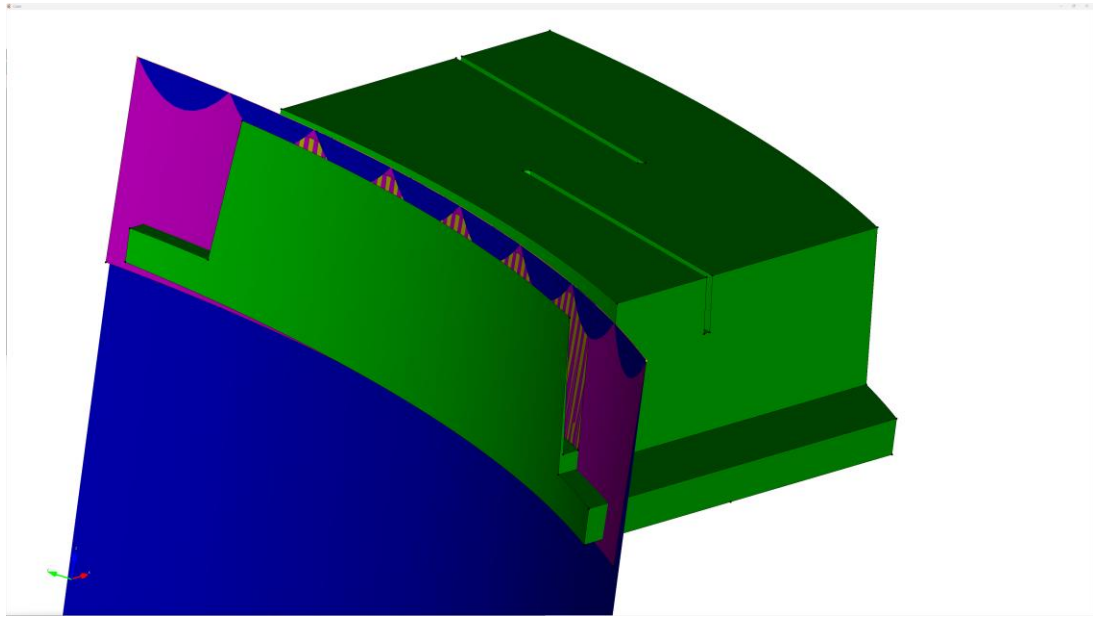




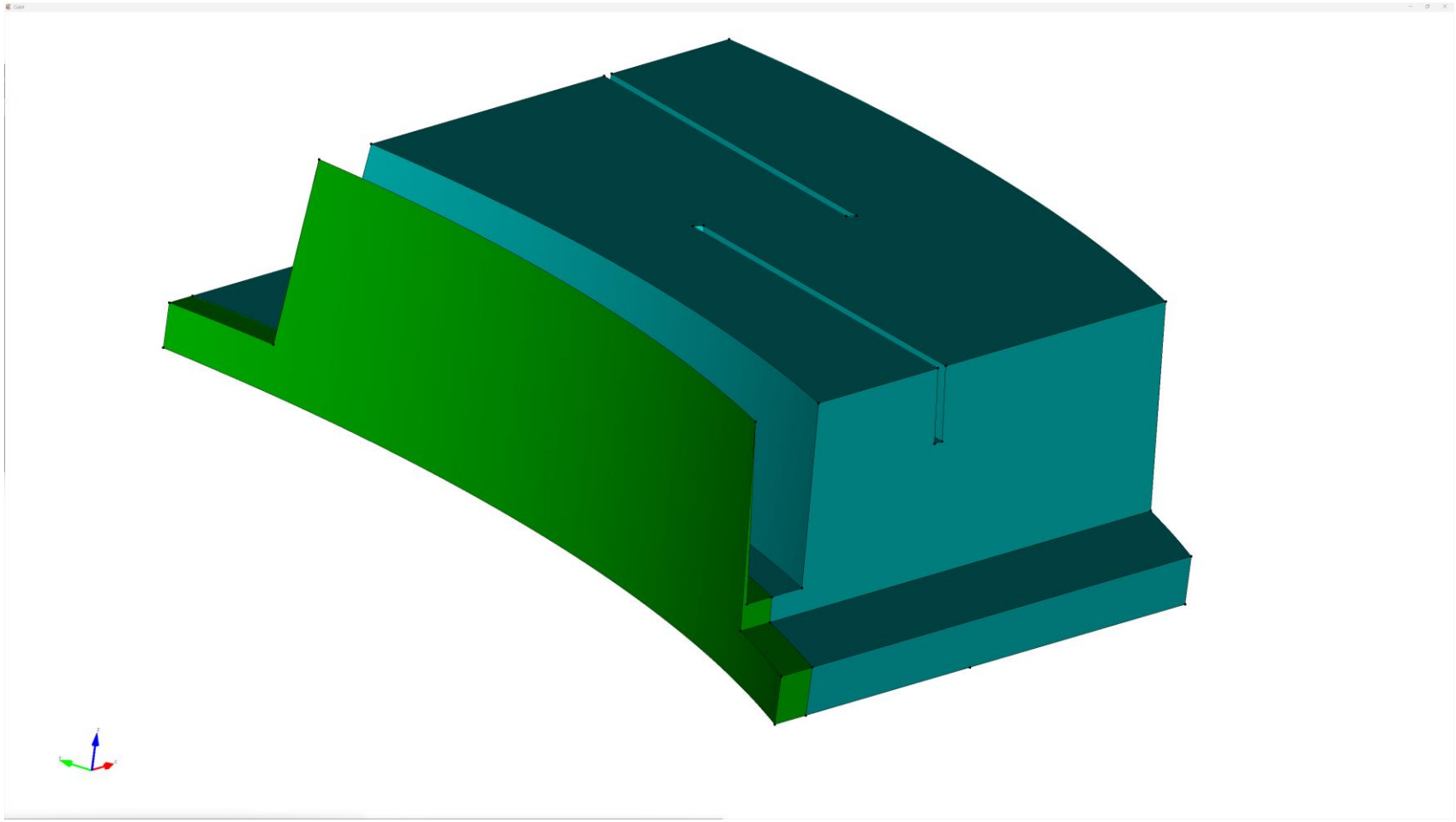
Webcut sweep curve

- **Step 3:**
  - Sweep the top curve of the extended surface, in the –Z direction



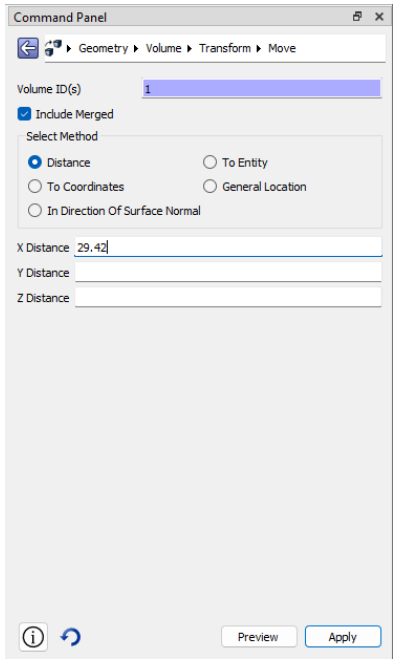


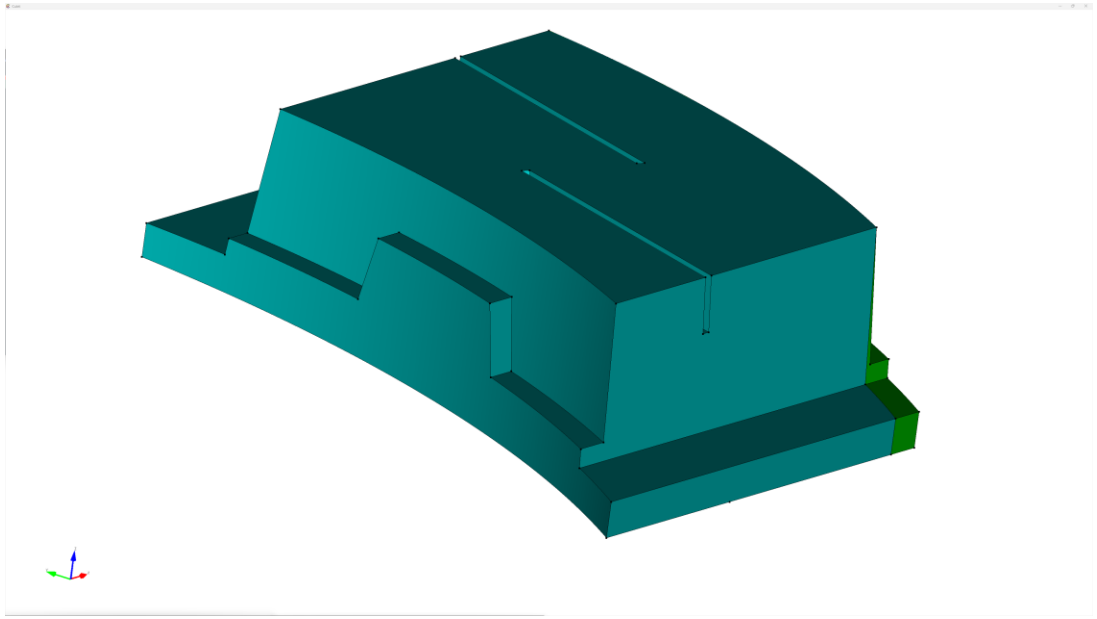
Webcut sweep curve



Move chopped volume

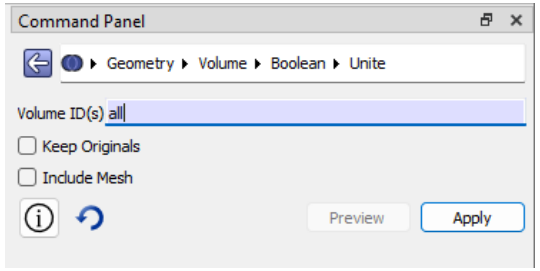
- **Step 4:**
  - Now we want to move the volume to the other side of the volume – a distance 29.42 in the +X direction

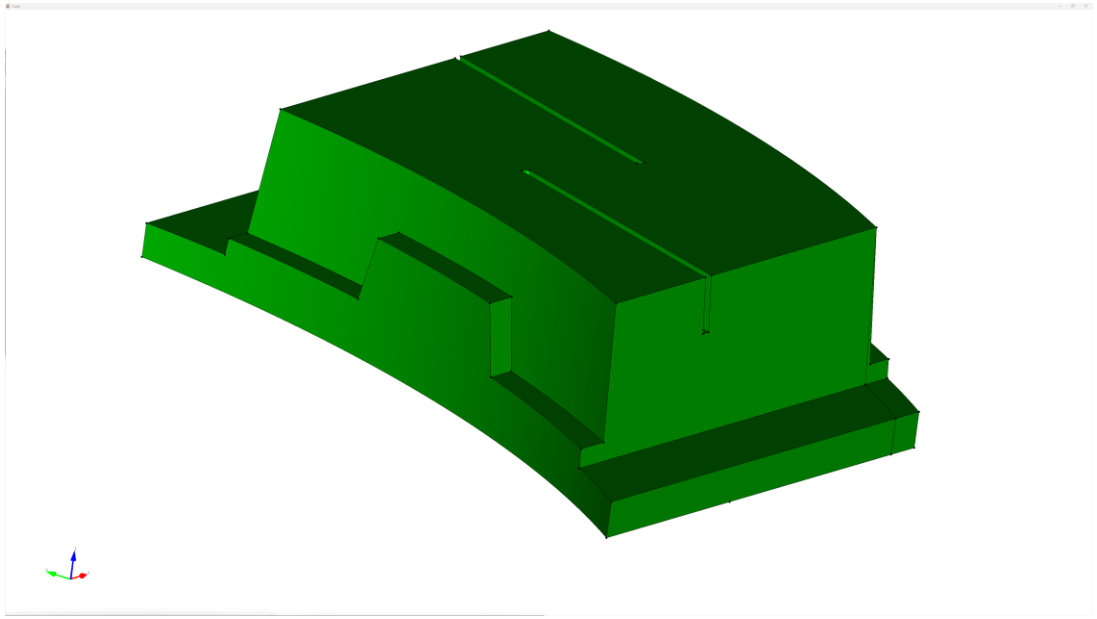




Unite into single volume

- **Step 5:**
  - We can then safely unite the volumes back into a single volume

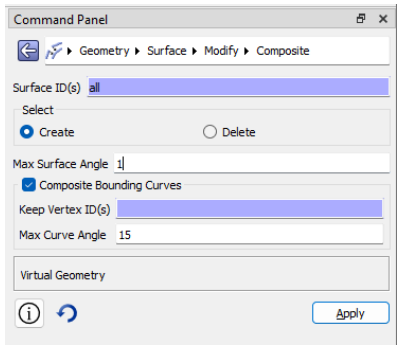


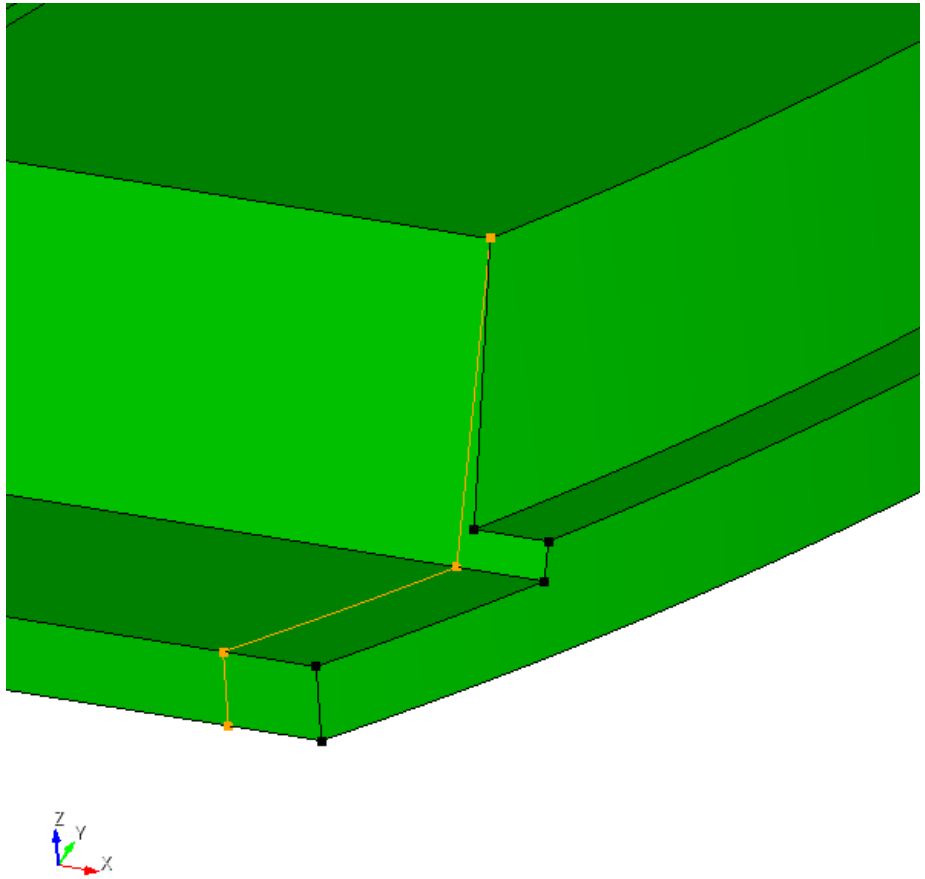


Composite surfaces

- The geometry modification completed, we now composite extraneous surfaces into macro surfaces

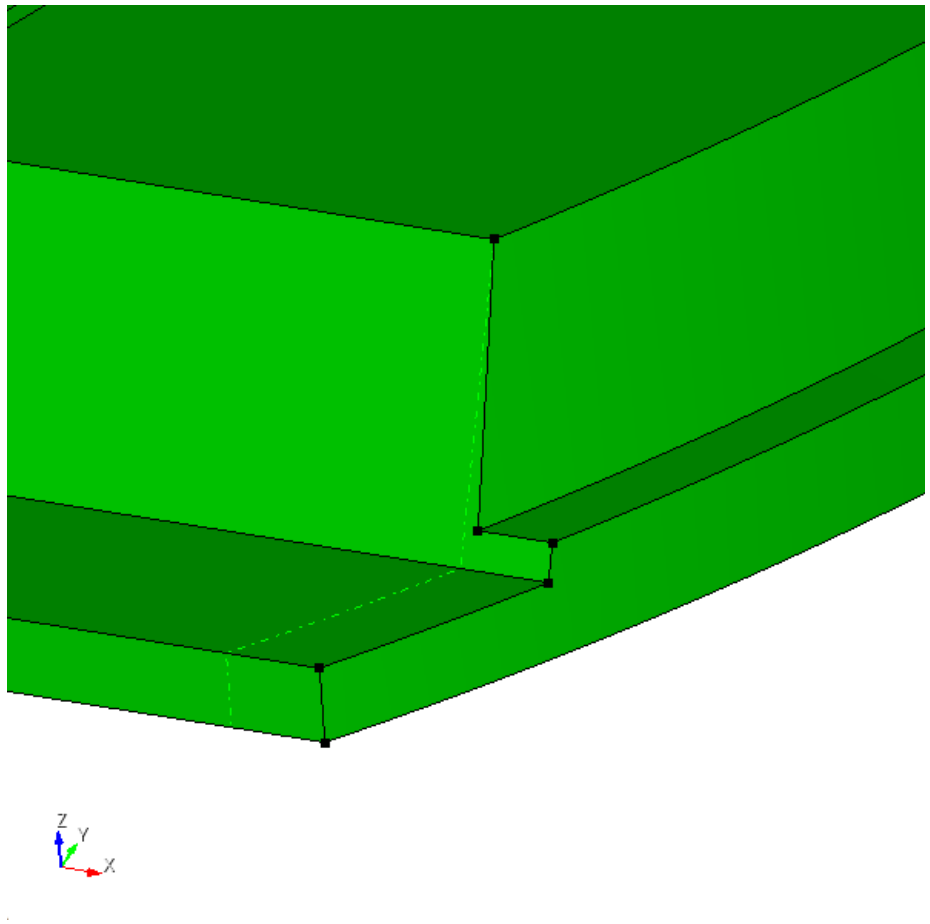
- Sometimes can be done as a single operation on all surfaces



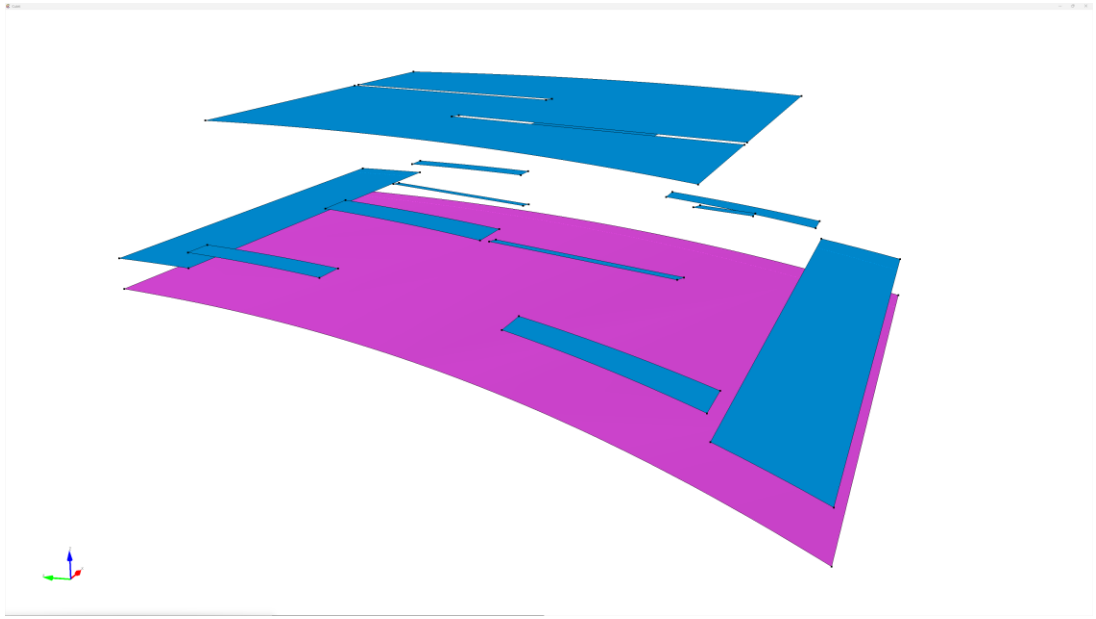


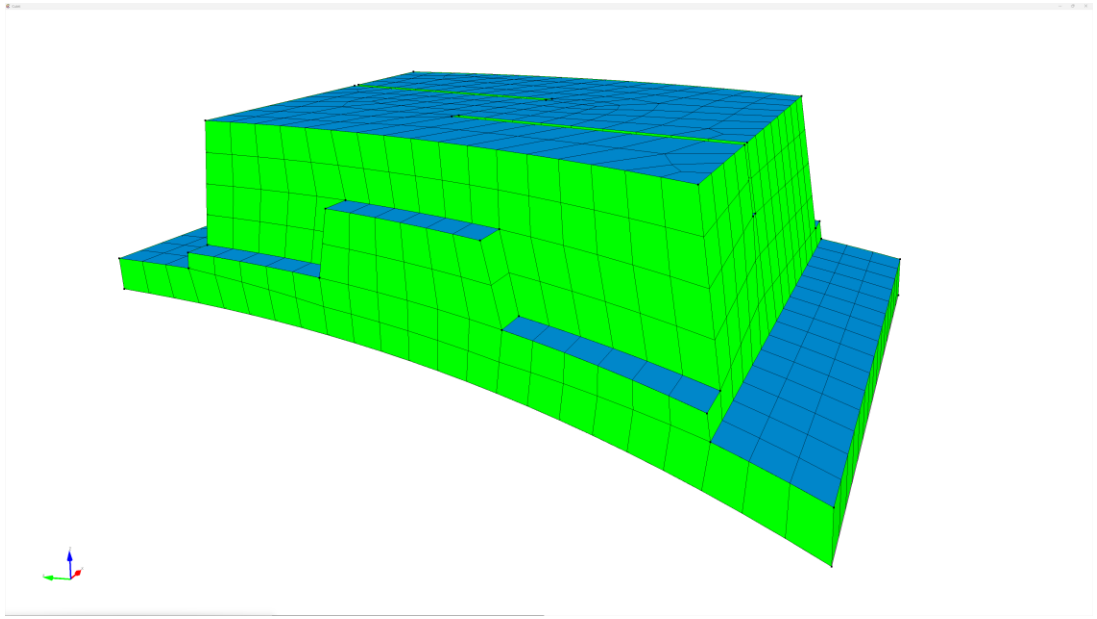
Composite surfaces

- Ignored curves will be shown as a dashed line



Generate many-to-one mesh

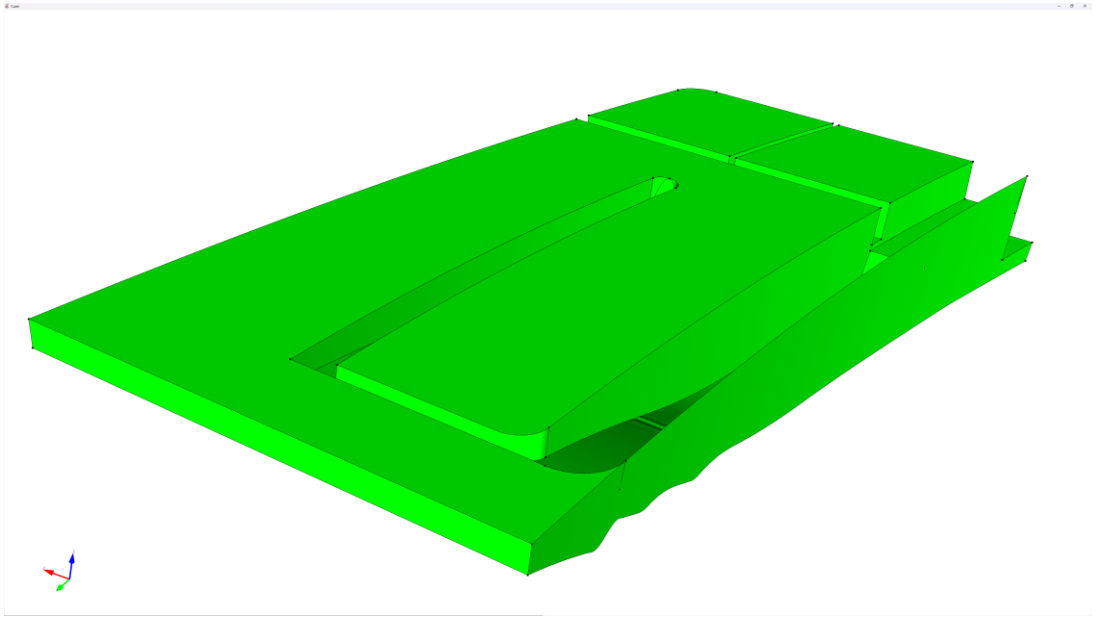




Meshing Section 5

Overview

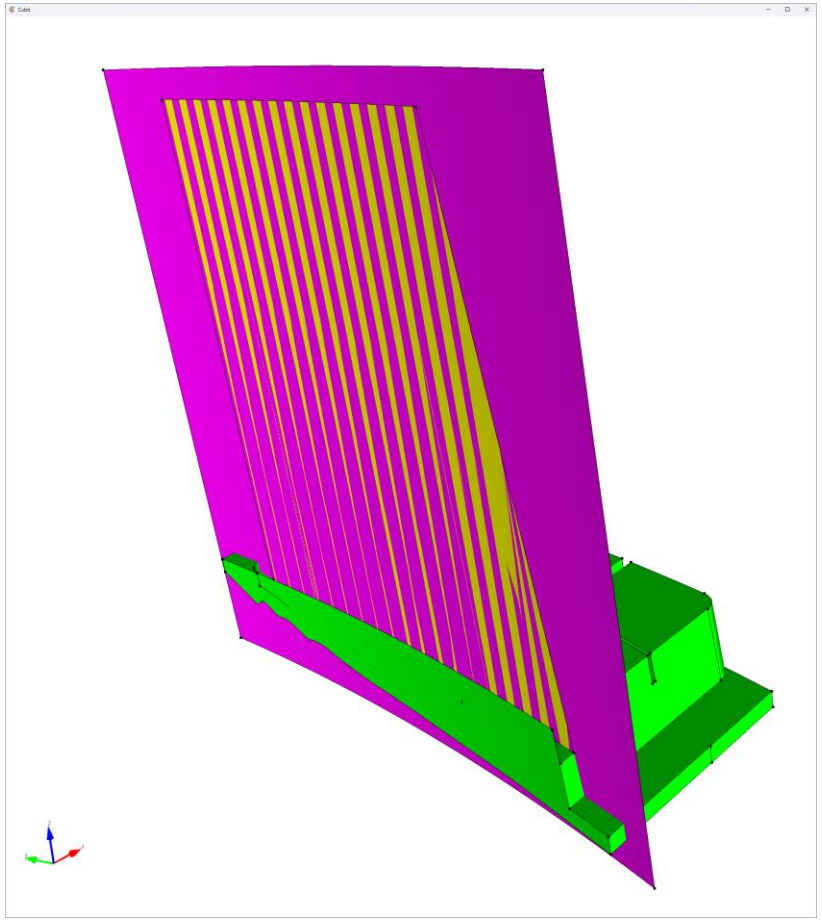
- The most complicated section, we need to use all the tools:
  1. Rechop to remove sliver feature
  2. Geometry cleanup
  3. Virtual topology
  4. N:1 meshing



Chop off the sliver

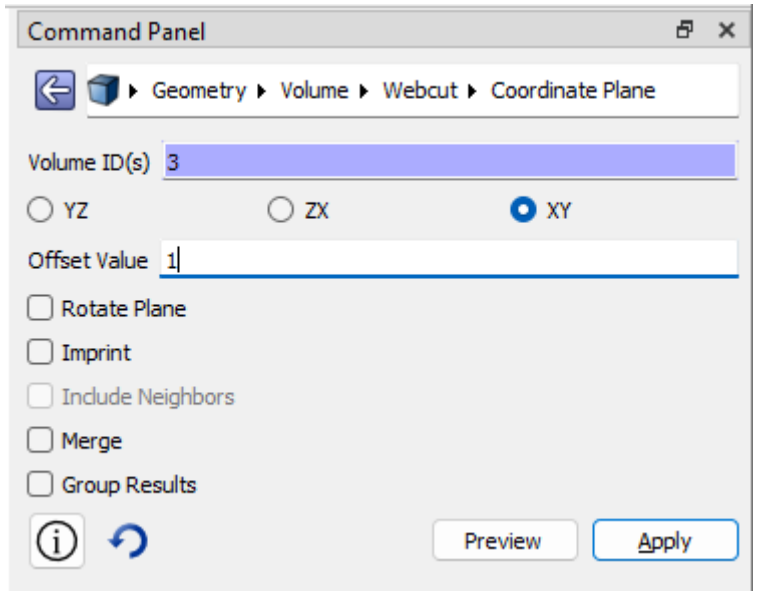
- We use the same approach as for section 4 to chop and recombine the sliver region

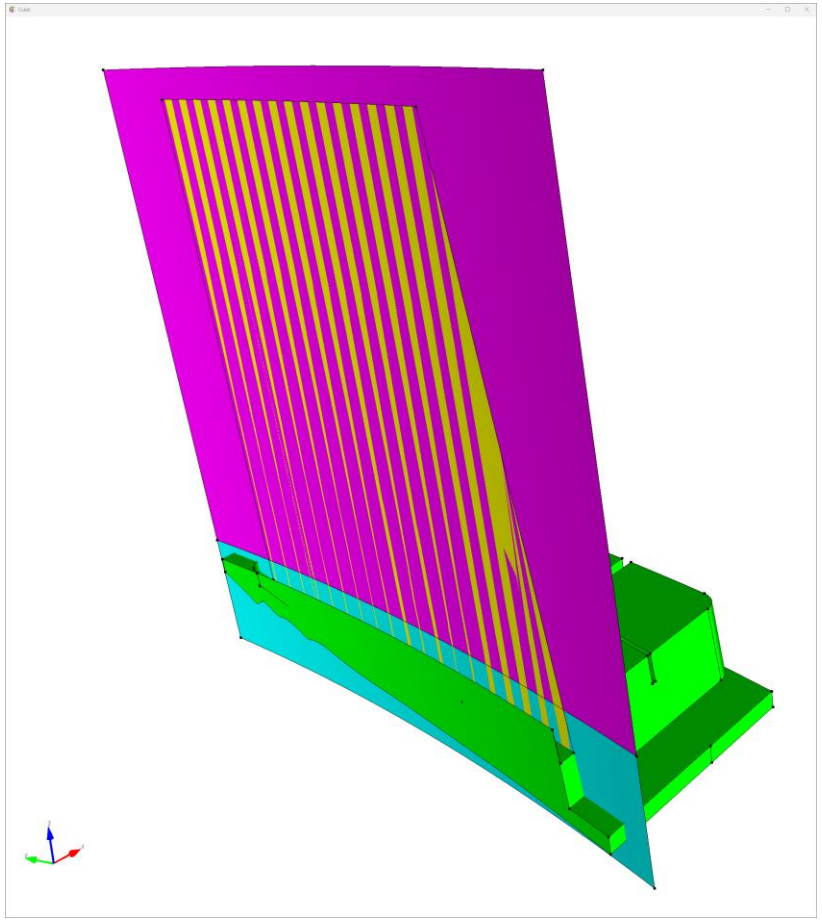
- Note here that the offset and extended surfaces are tall and, due to their angle, the top curve isn’t over the desired cut surface



Chop off the sliver

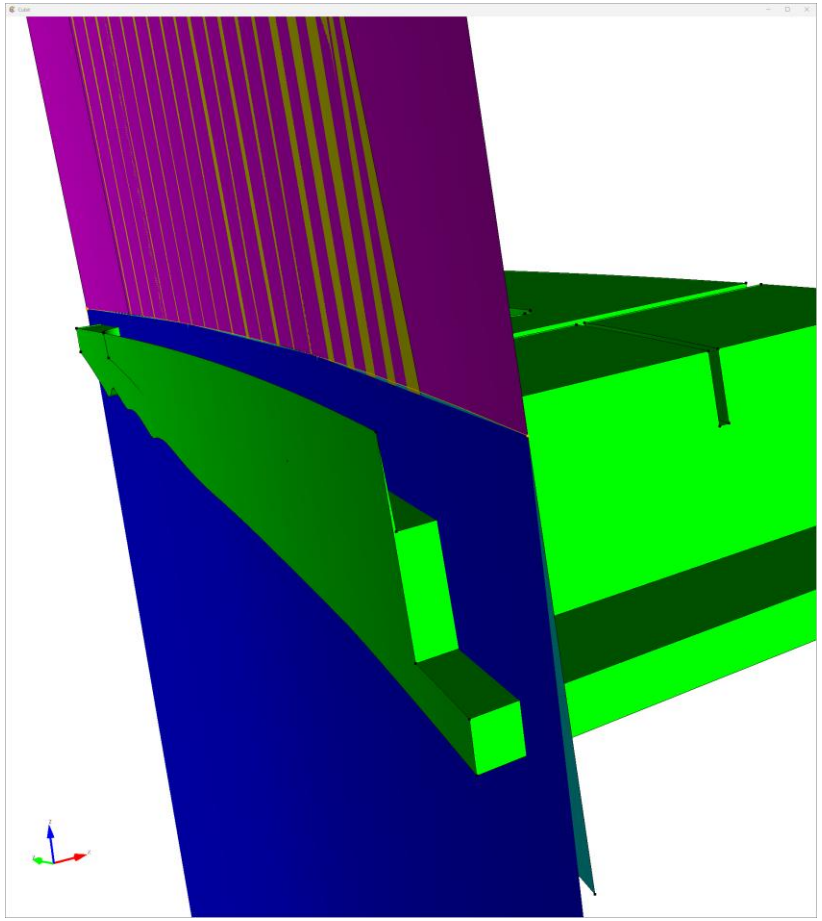
- So we'll trim the extended surface to give ourselves a curve that we *can* use for our cut



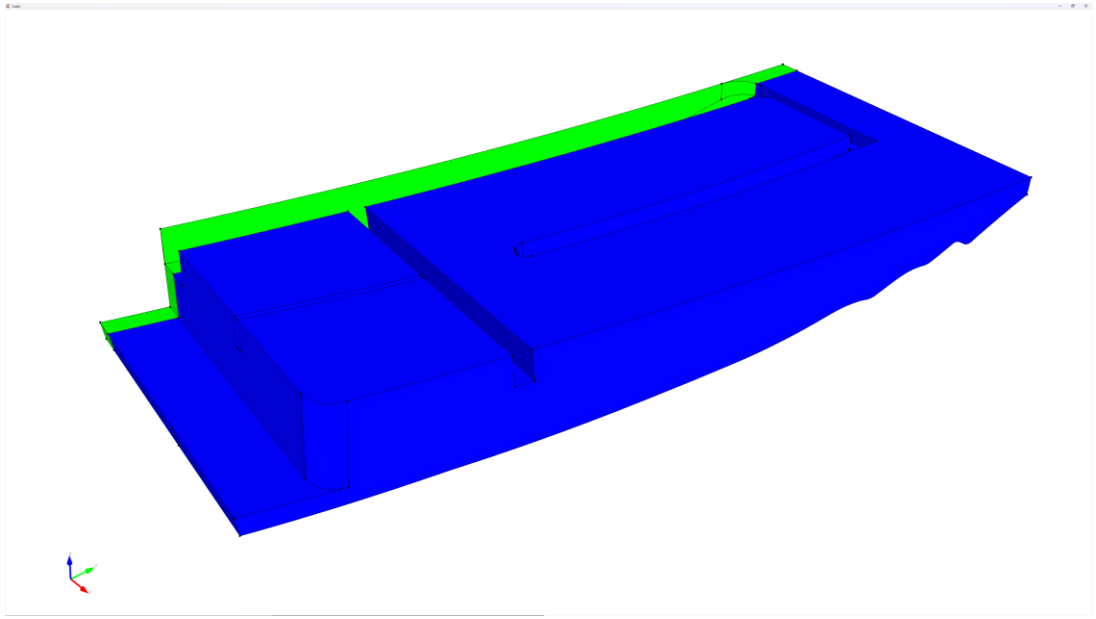


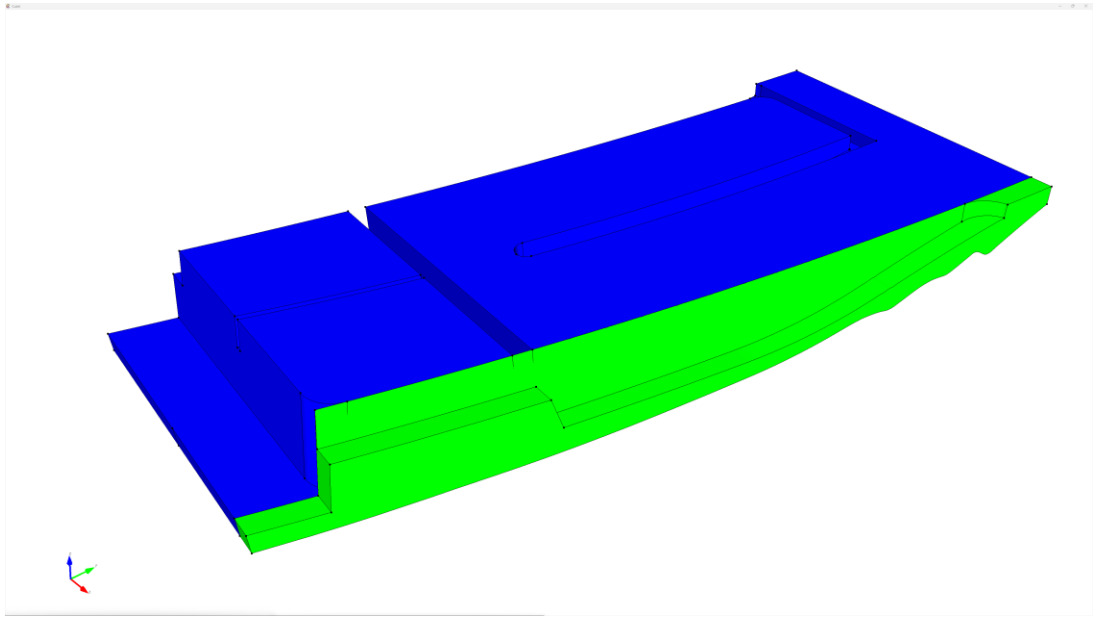
Chop off the sliver

- Then we do our same webcut approach as before



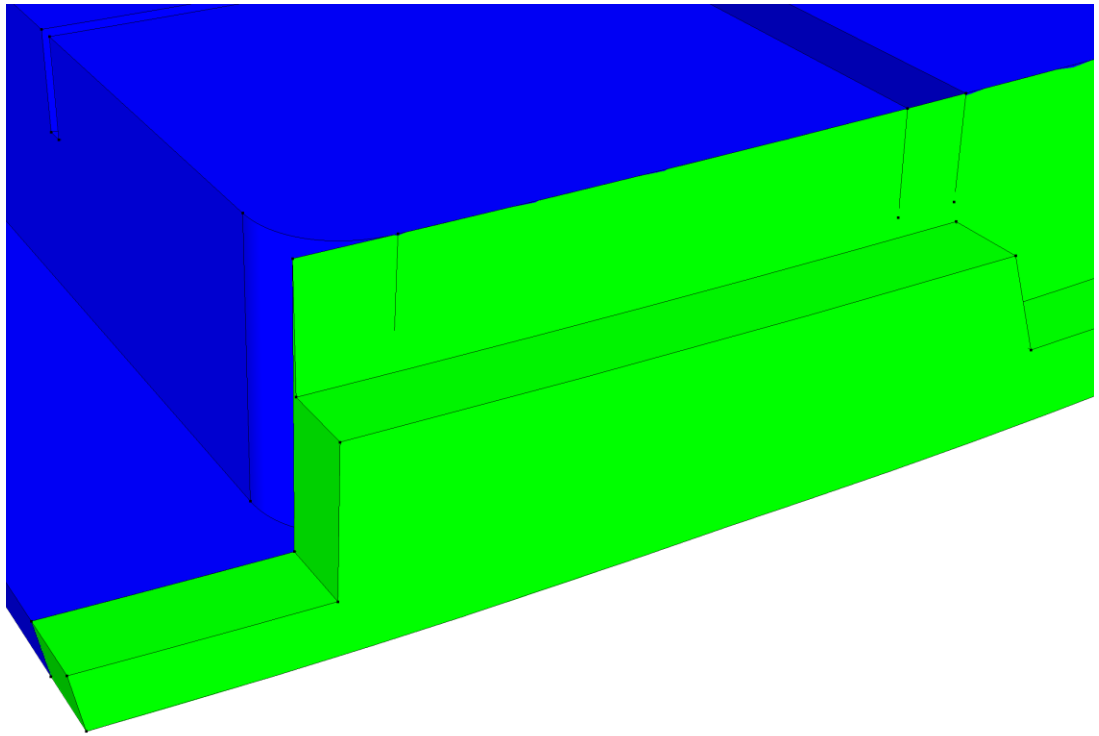
Move the chopped surface





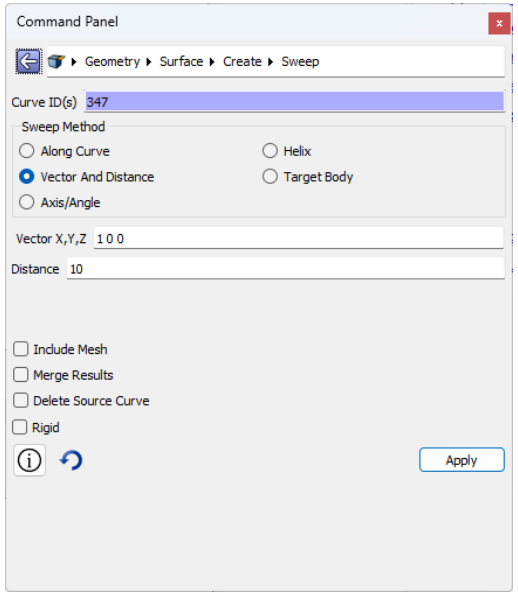
Recombining & cleanup

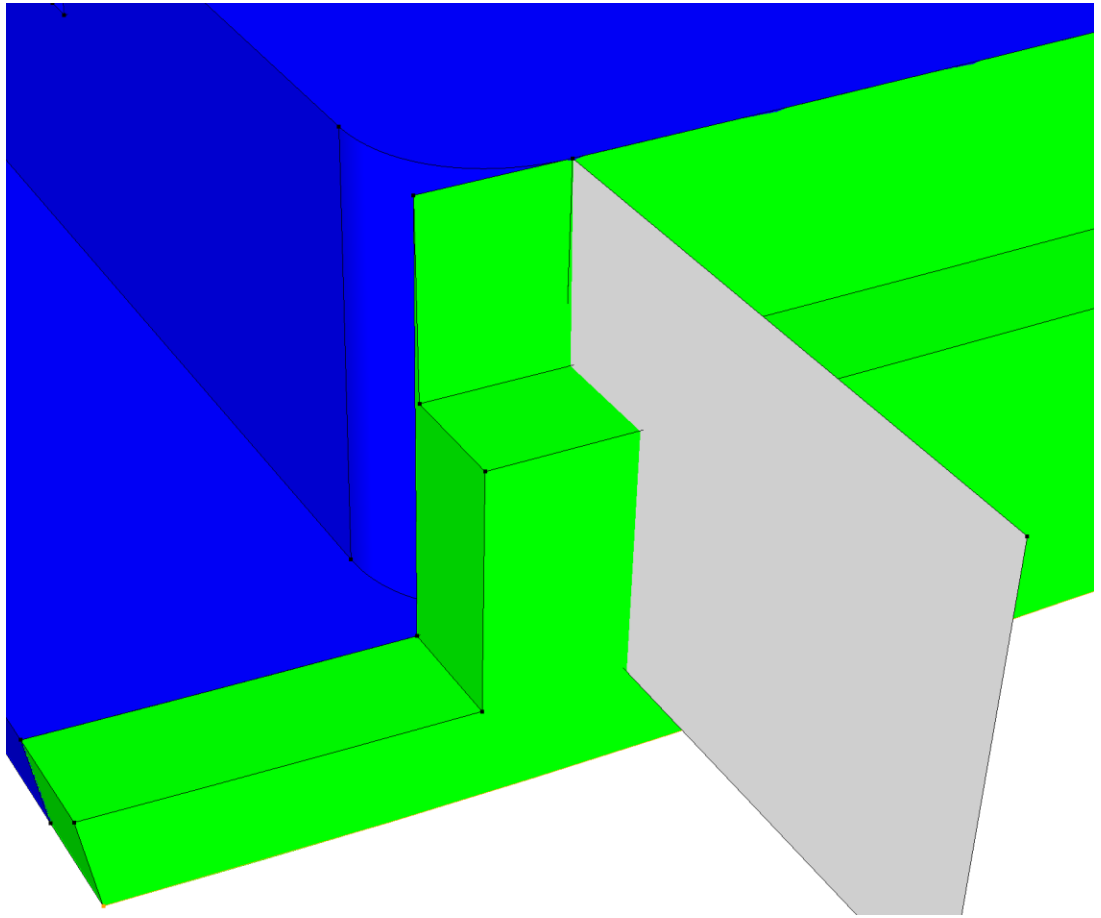
- **Goal:**
  - Some CAD modeling errors can be seen prior to us re-uniting the volumes
  - We want to clean up these mistakes
    - You could ask the CAD designer to fix in native CAD software
    - Or you can fix yourself using Cubit's direct modeling engine



Chop off extra block

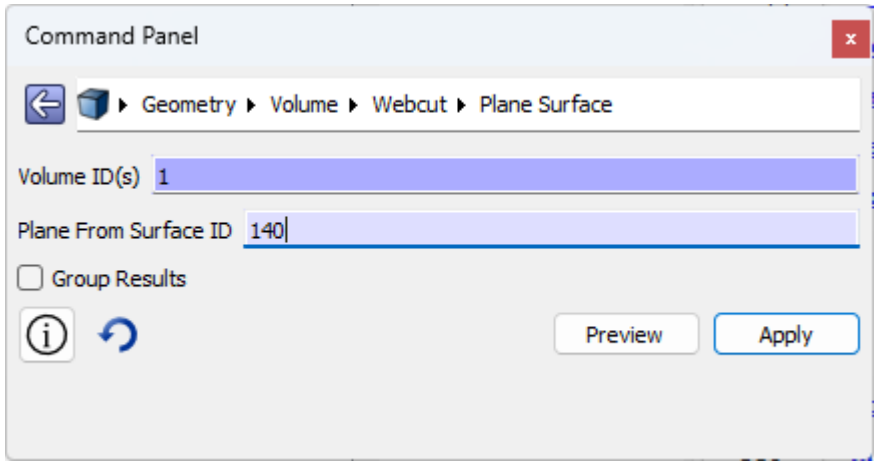
- Create a surface by sweeping the fillet's curve in the +X direction

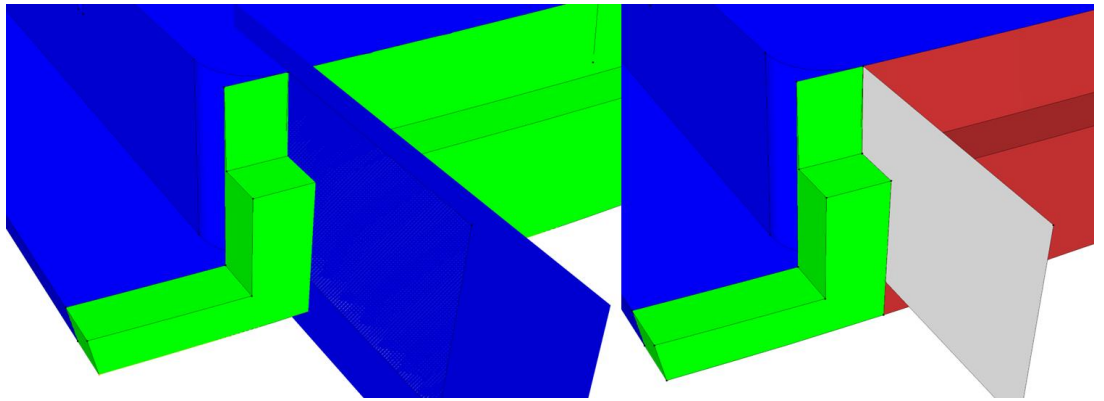




Chop off extra block

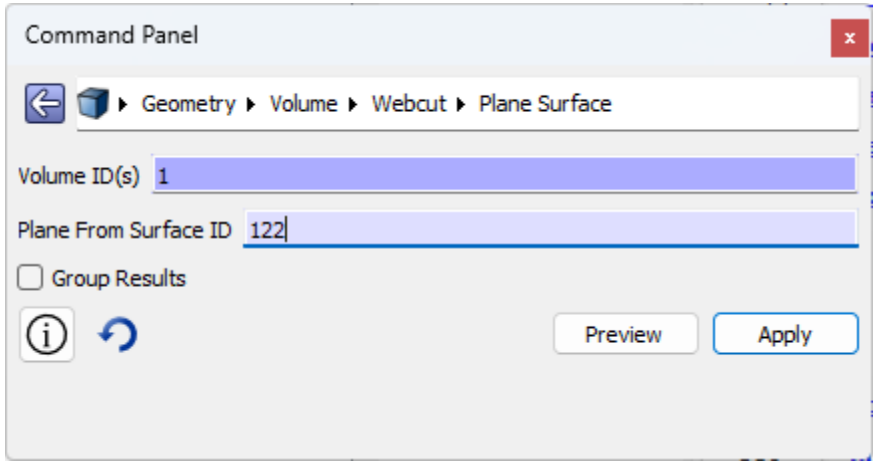
- Then we can use a webcut using the plane of this surface to begin trimming this region away

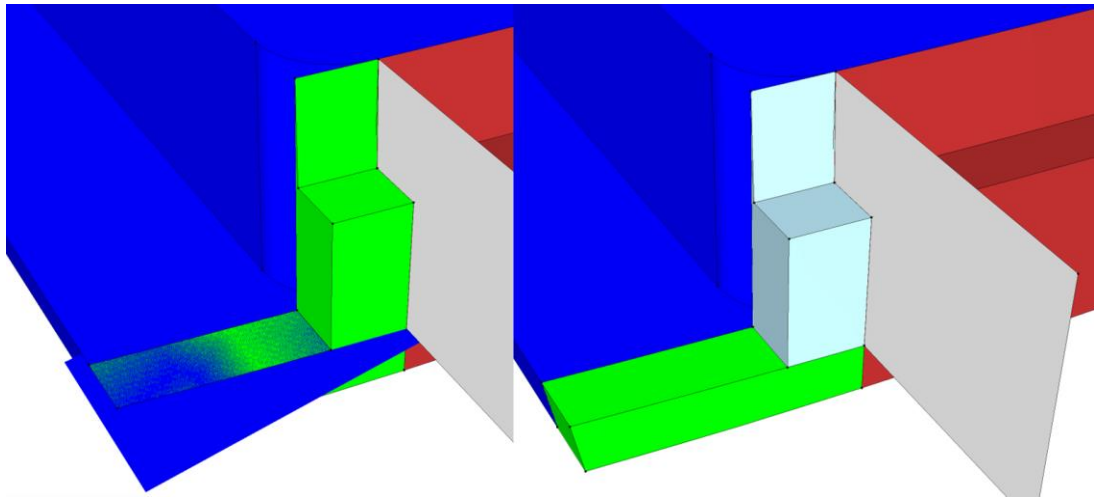




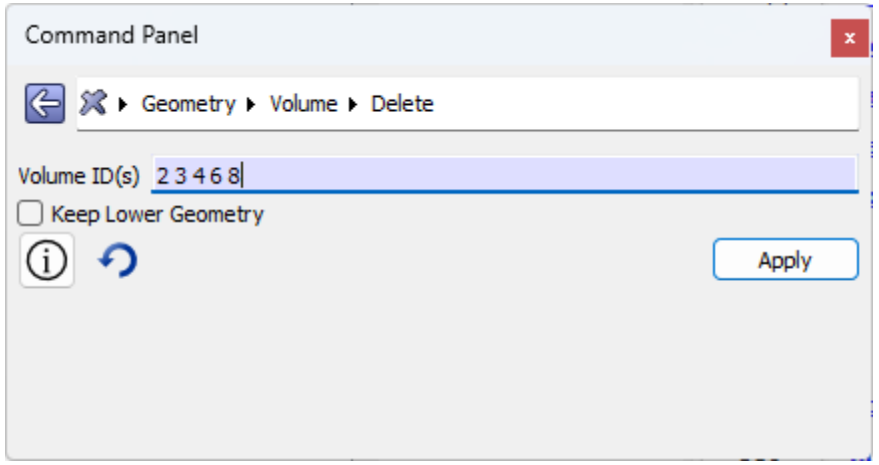
Chop off extra block

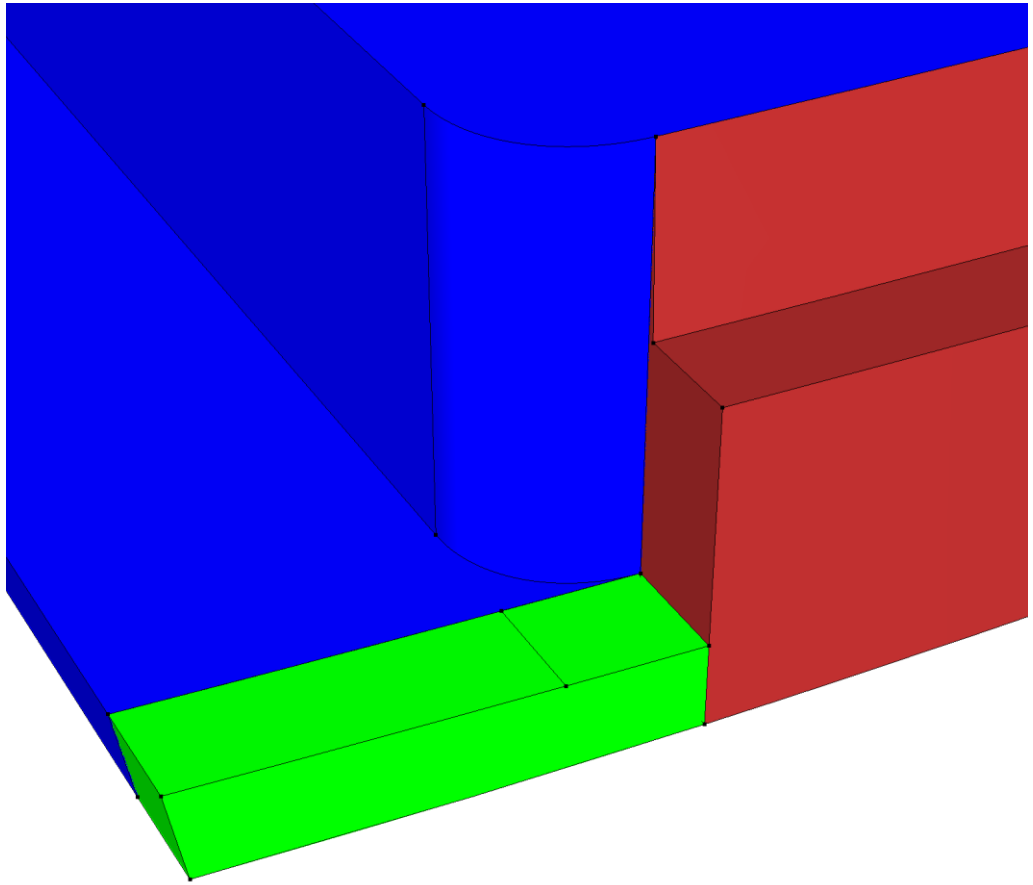
- Next we chop off the “tower” part of the block by the plane defined by the base surface



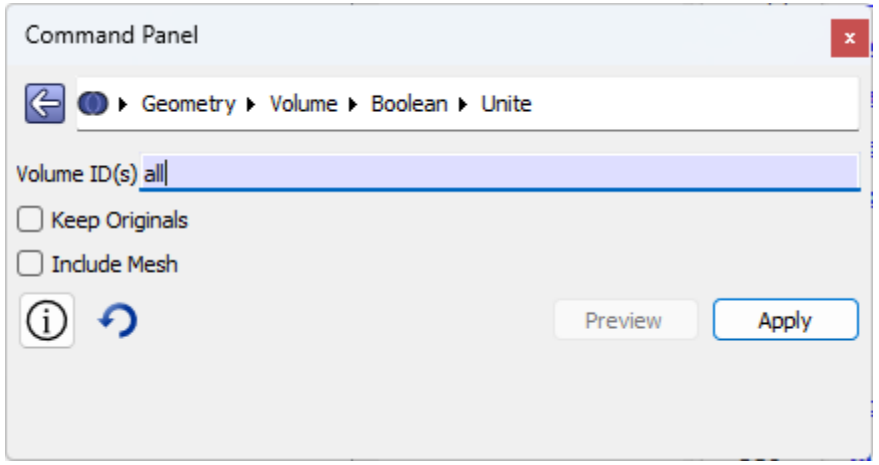


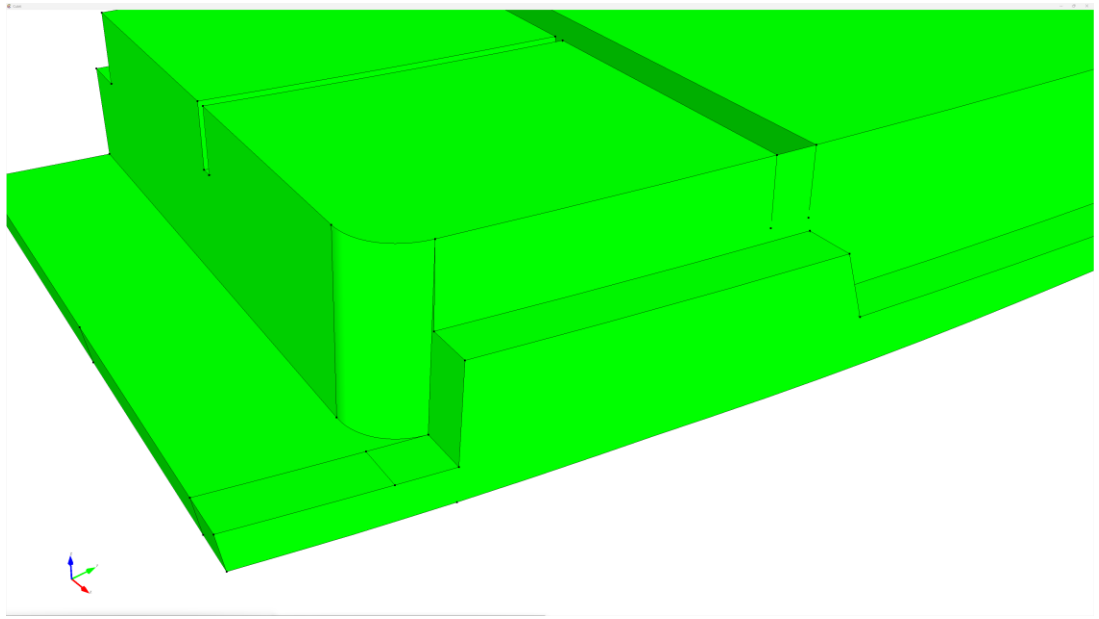
Delete the volume & tools



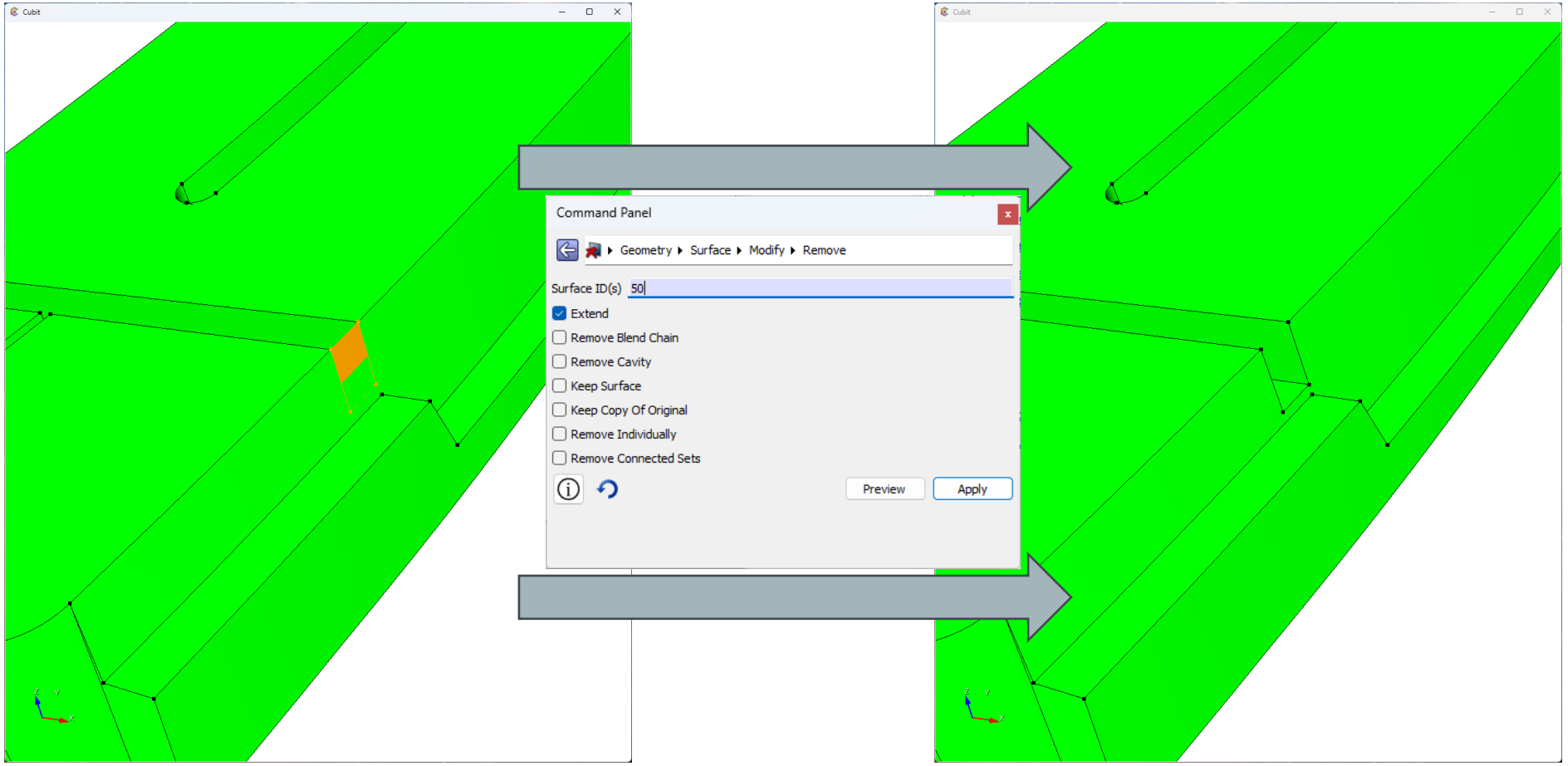


Reunite volumes



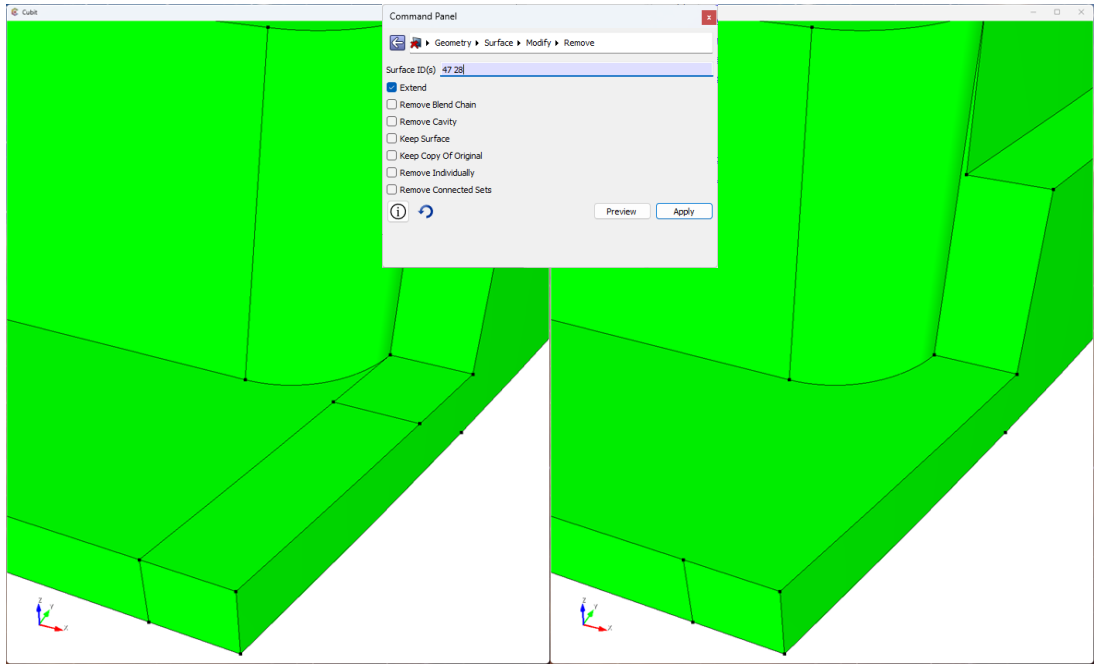


Remove sliver surface



Cleanup extraneous surfaces

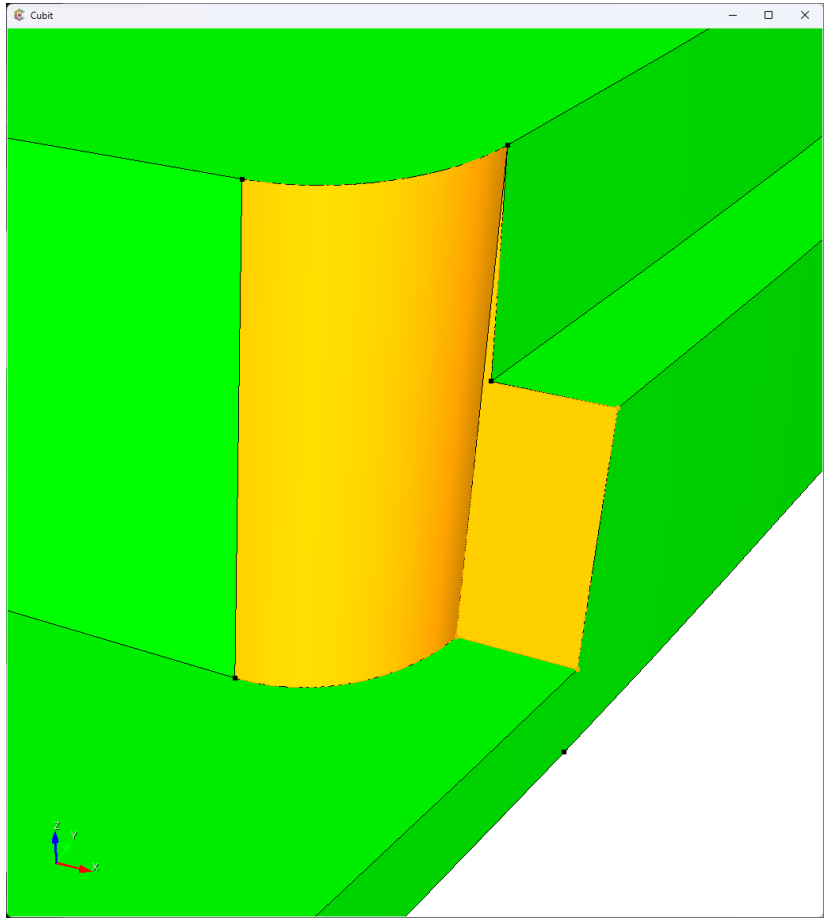
- Sometimes these operations result in nearly-equivalent surfaces that are only different due to numerical noise
  - For example, face normals that are 1e-12 different, so that a “regularize” command won’t clean them
- When these surfaces will eventually be shared between the different model sections, you may choose to use compositing
- When the surfaces won’t be shared, you may wish to use the “remove extend” approach to create *real* geometry changes



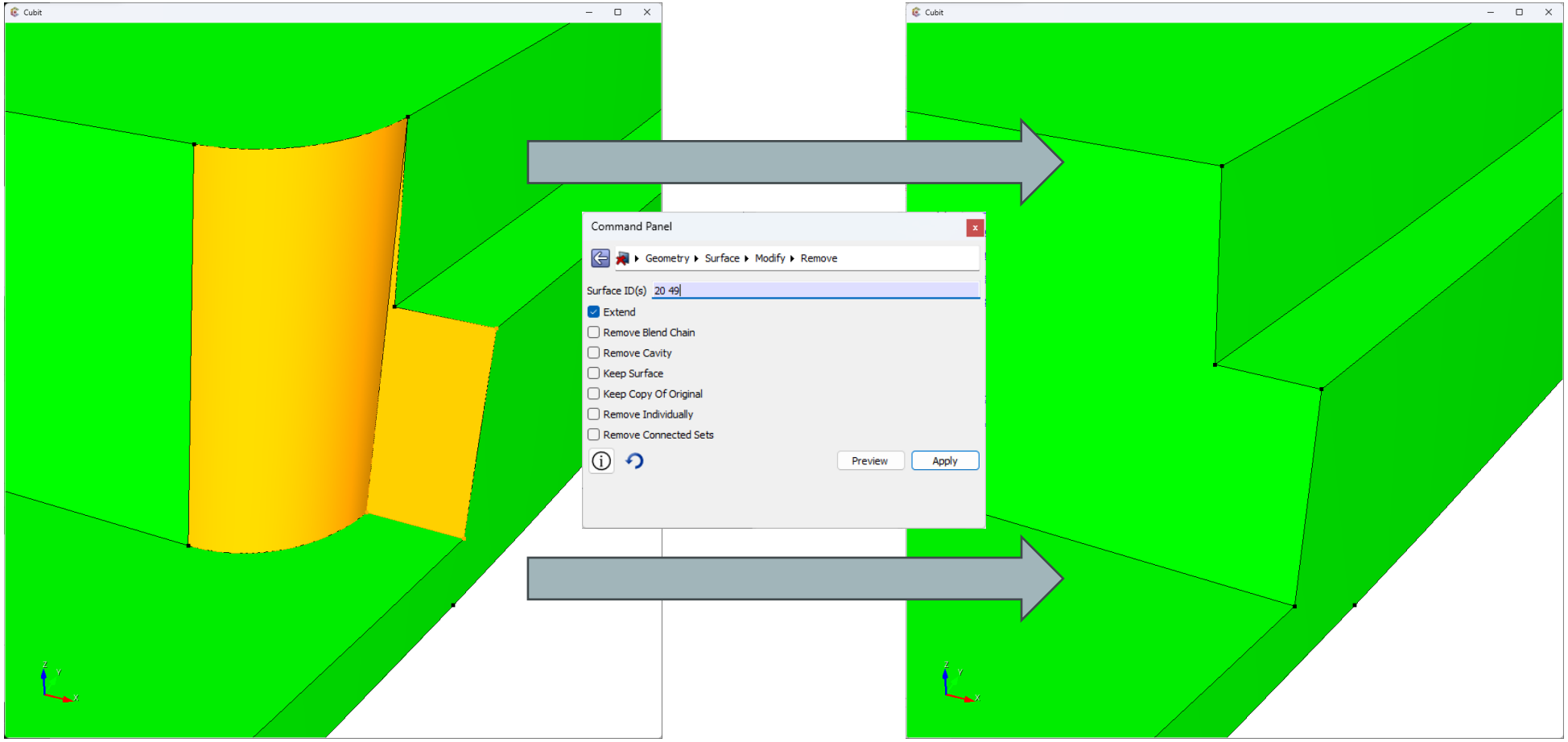
Continuing CAD Cleanup

- It appears that the designer's modifications to create the original repeat unit cell resulted in a few more errors

- We need to remove the sliver surface that is caused by the fillet being cylindrical rather than conical



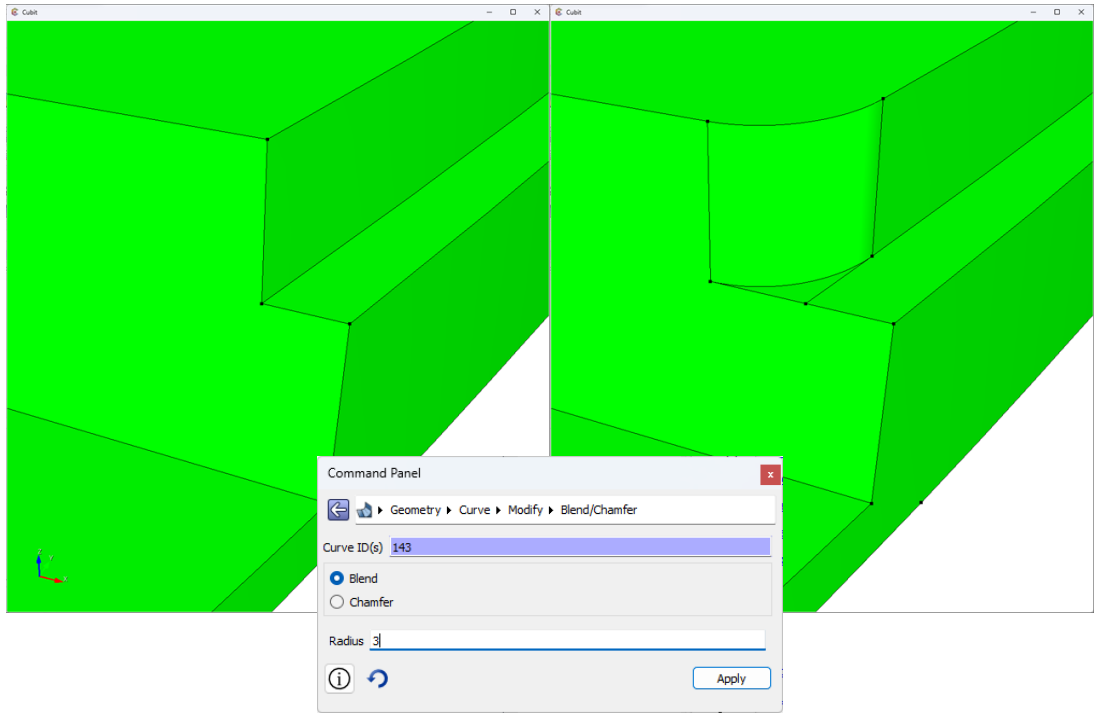
Remove the offending surfaces



Add a new fillet

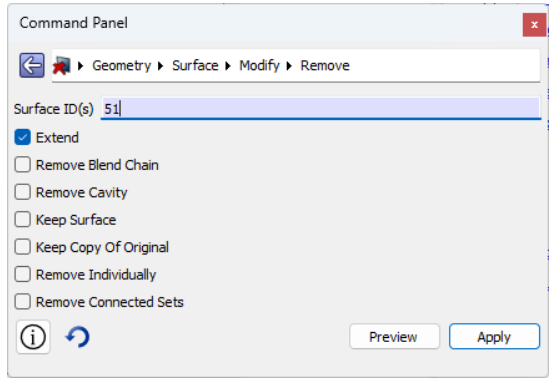
- Since Cubit doesn't have the ability to directly modify the original fillet to match the (nearly) conical shape, we will instead create a new fillet

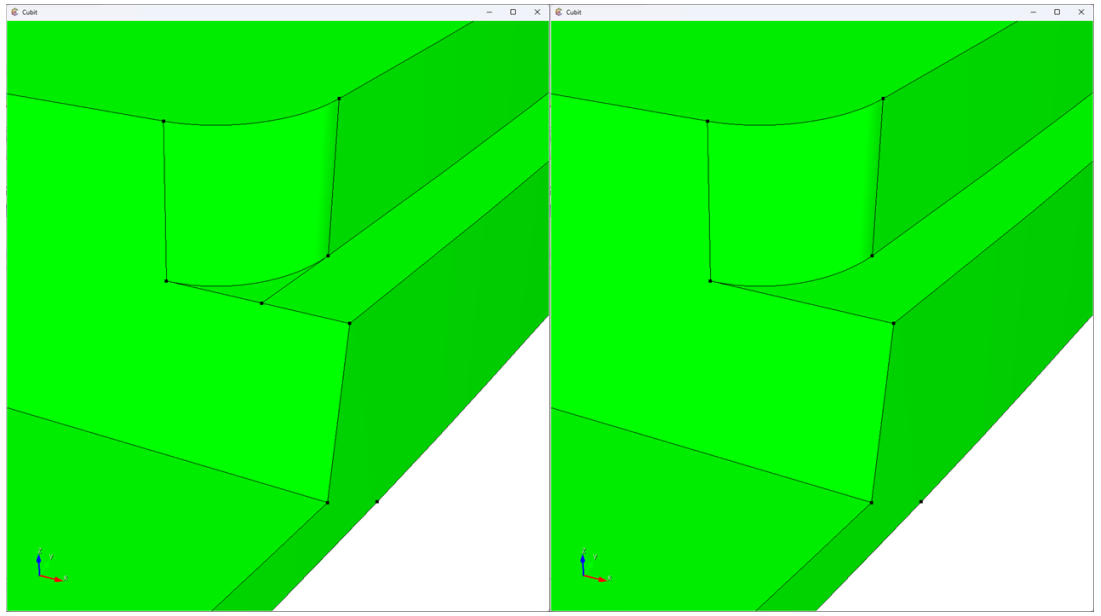
- This **is** changing the geometry, though very slightly
  - The best approach would have been to bring up these modeling issues to the original CAD designer



Remove extraneous surface

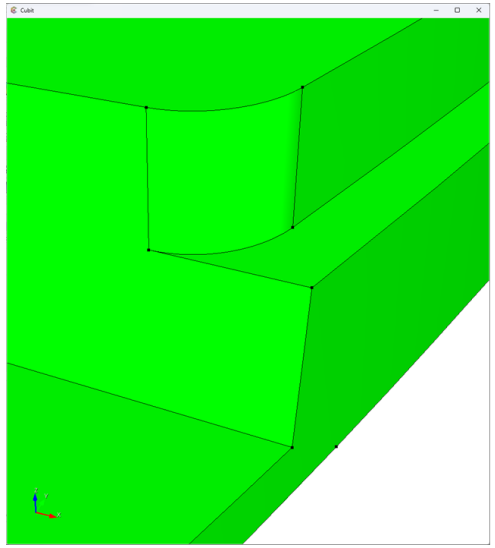
- Again, cleanup extraneous surfaces
  - Even though we will be removing this surface, by cleaning it we will improve the robustness of forthcoming operations

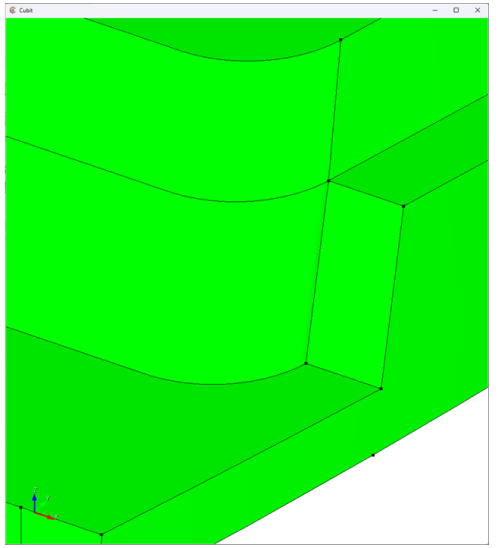




Complete the fillet

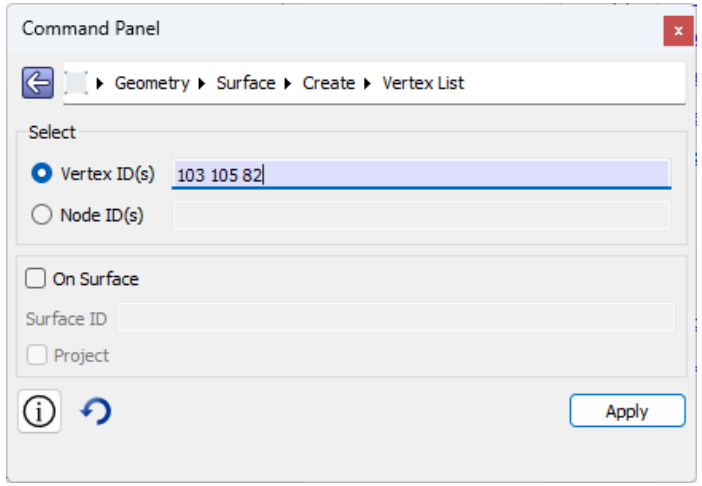
- **Goal:**
  - We want to remove the ledge feature, resulting in a full-length fillet
- **Strategy:**
  - Create a surface that can be swept and Boolean subtracted to leave the fillet

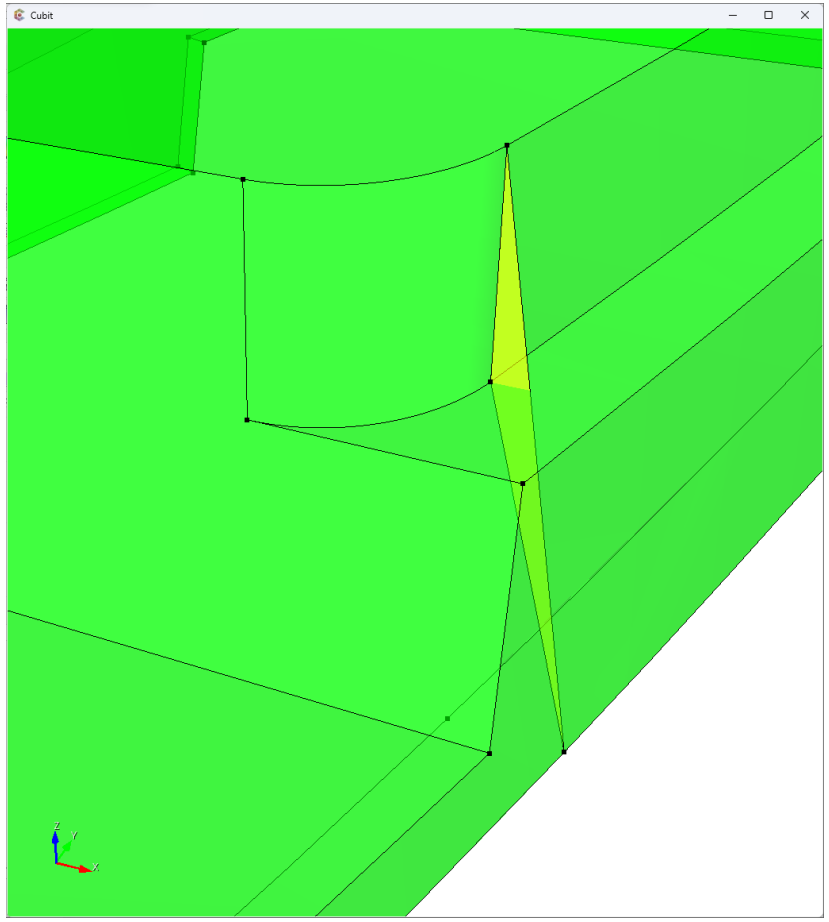




Complete the fillet

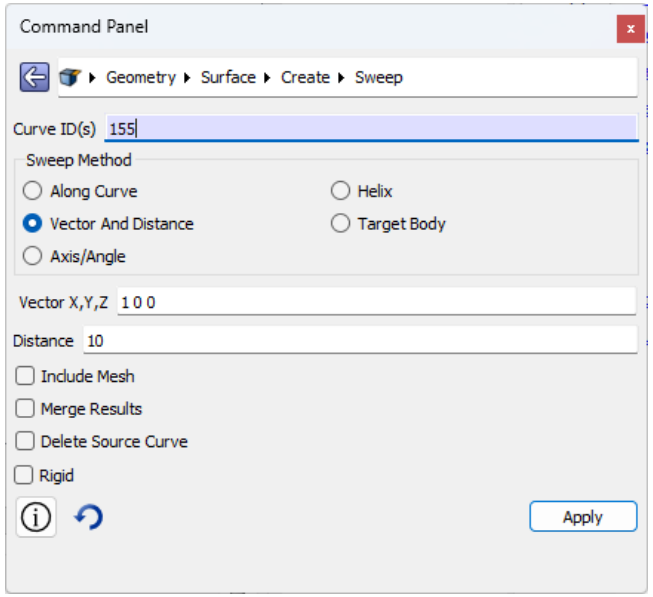
- **Step 1:**
  - Create a minimal plane

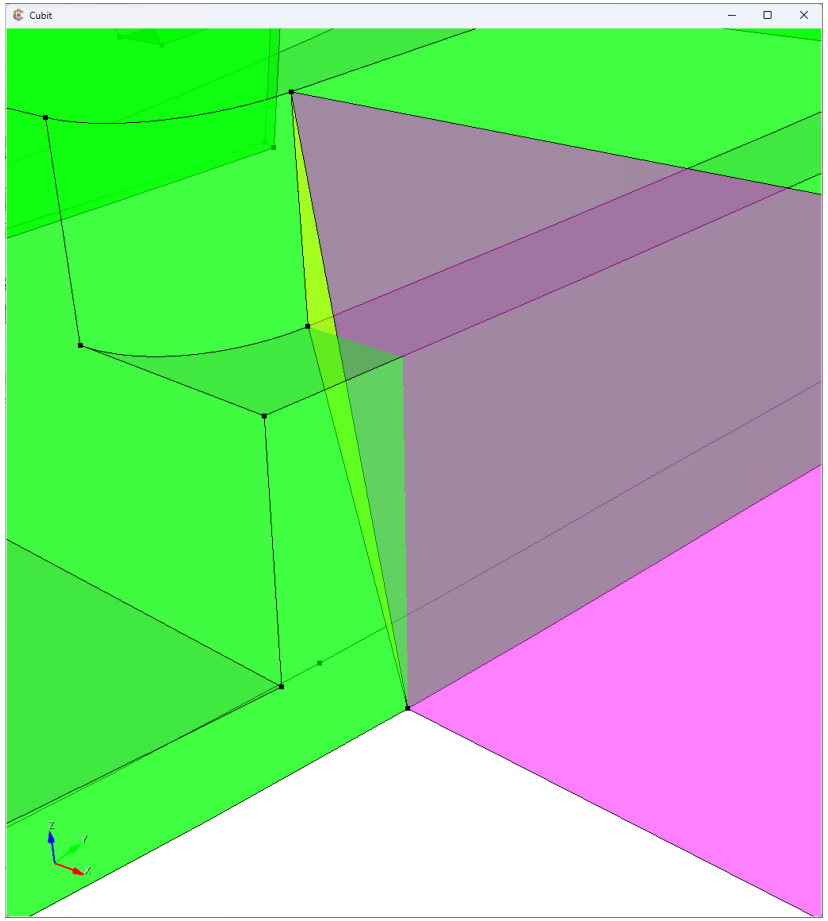




Complete the fillet

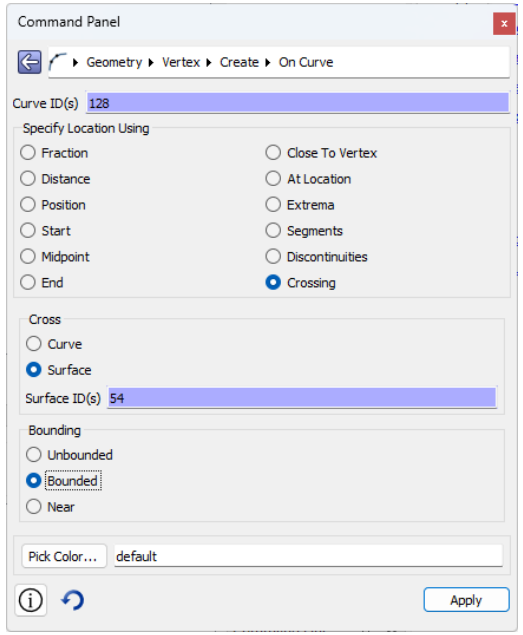
- **Step 2:**
  - Create a plane surface by sweeping the curve so that it extends beyond the outer surface

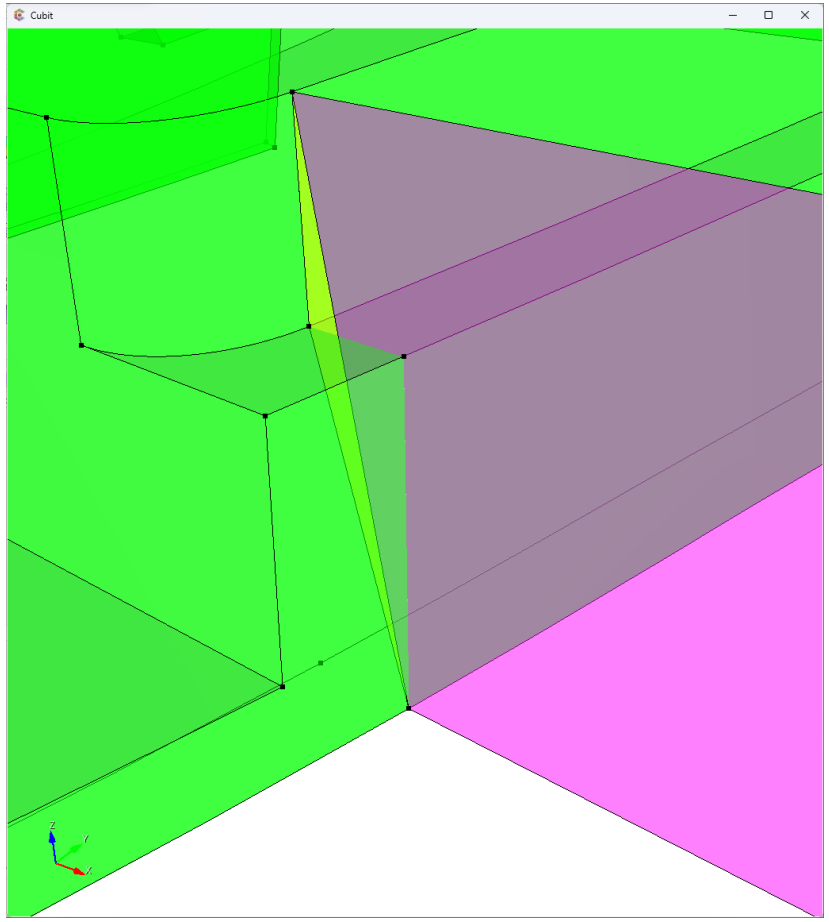




Complete the fillet

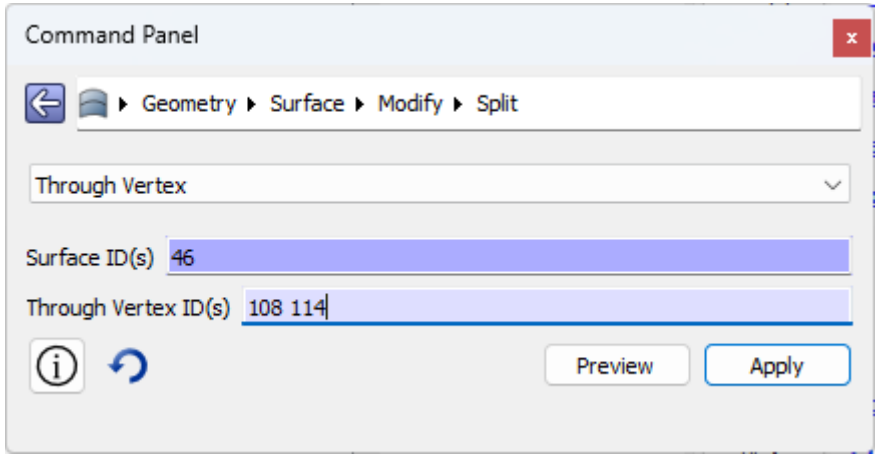
- **Step 3:**
  - Create a vertex on the target surface's outer curve

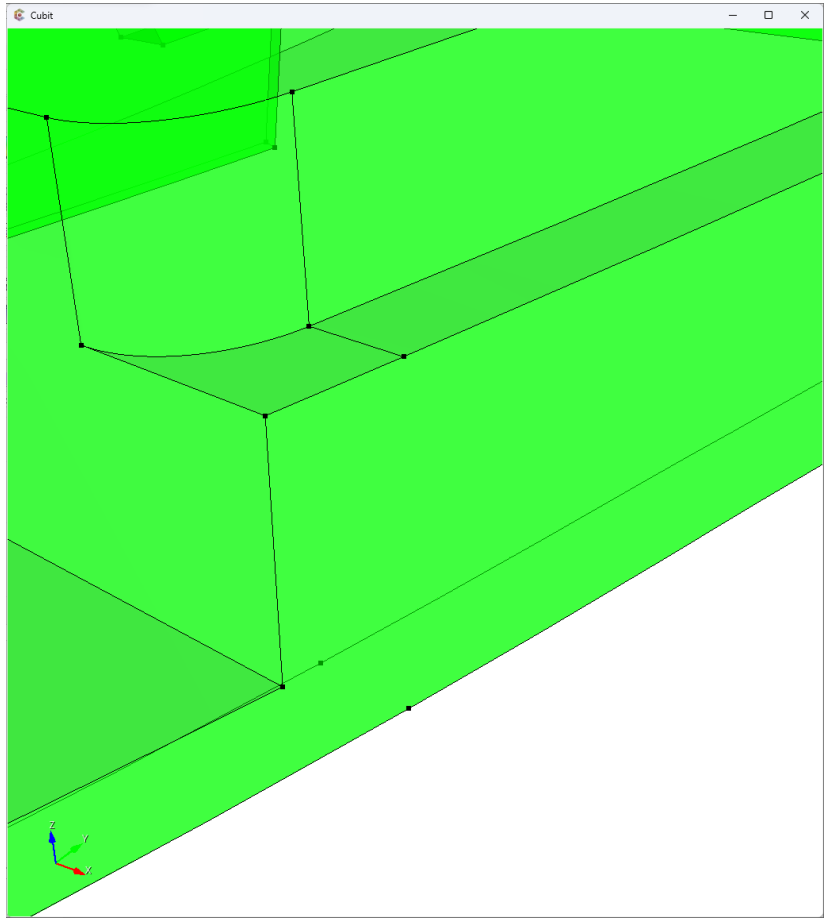




Complete the fillet

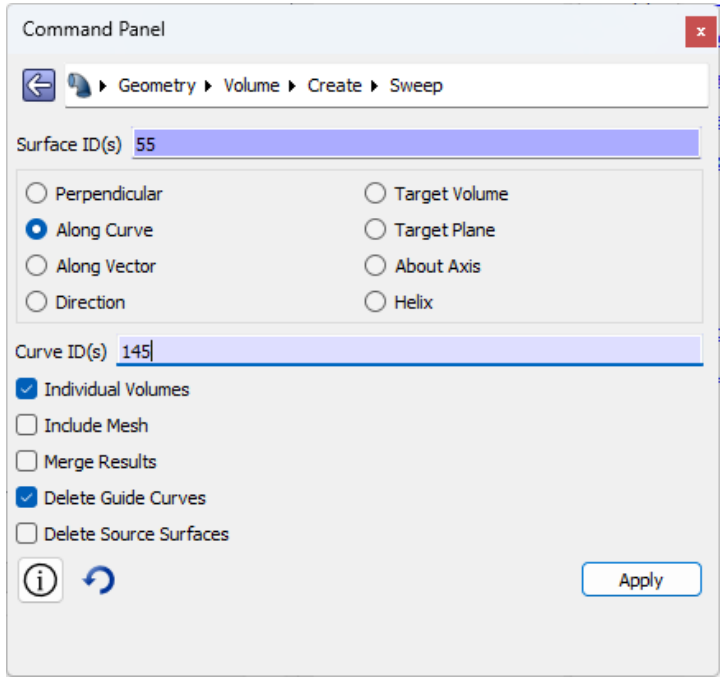
- **Step 4:**
  - Partition the target surface through the two vertices

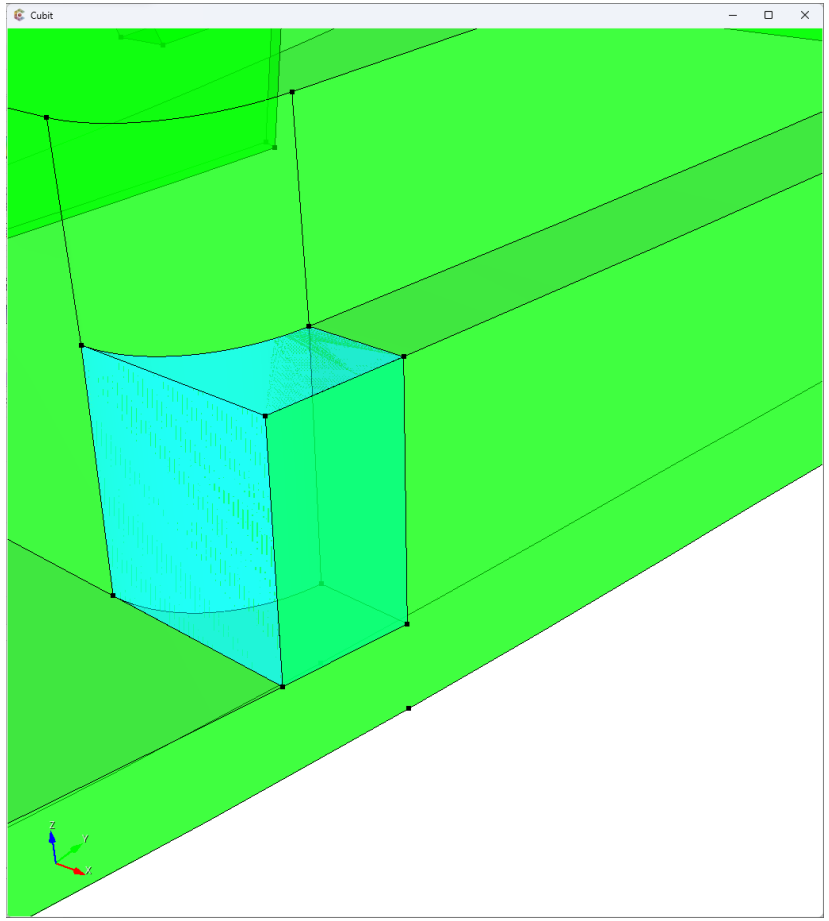




Complete the fillet

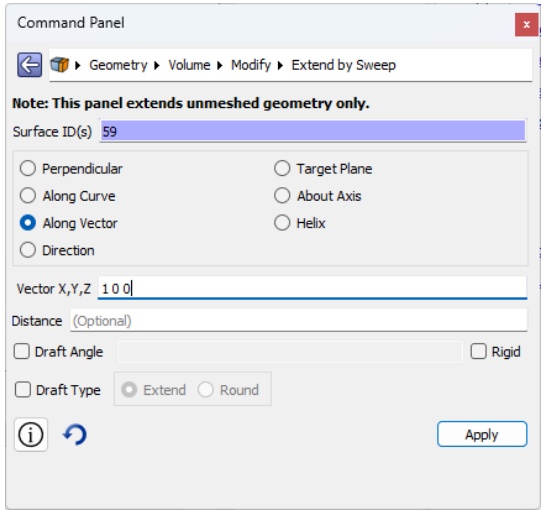
- **Step 5:**
  - Create a volume by sweeping the target surface along the outer curve

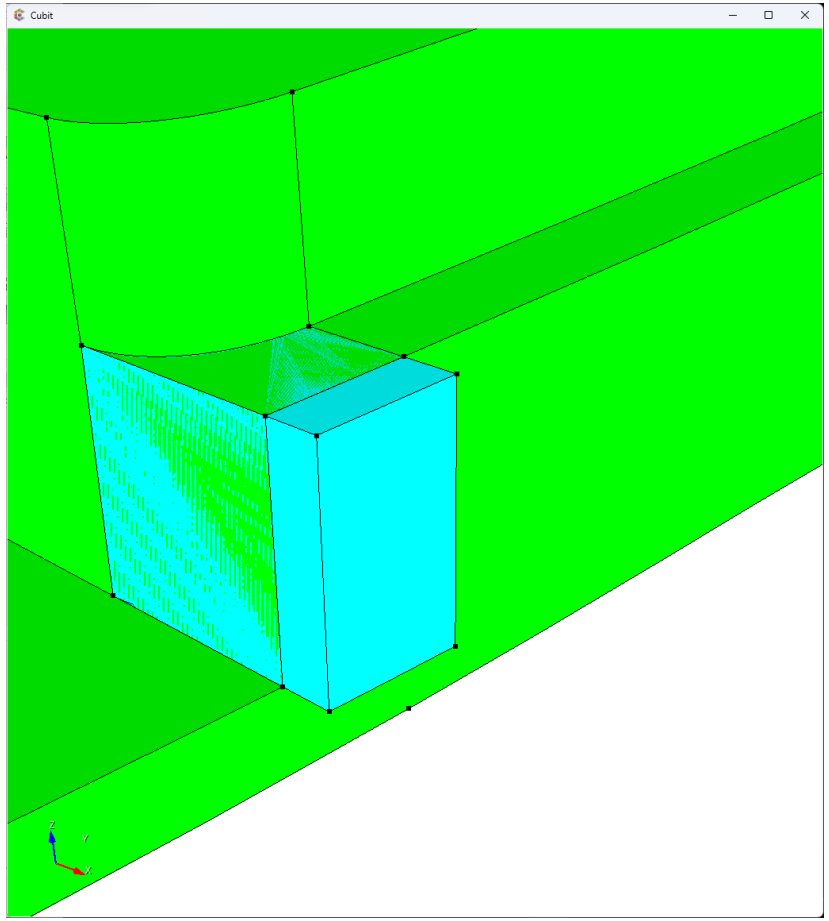




Complete the fillet

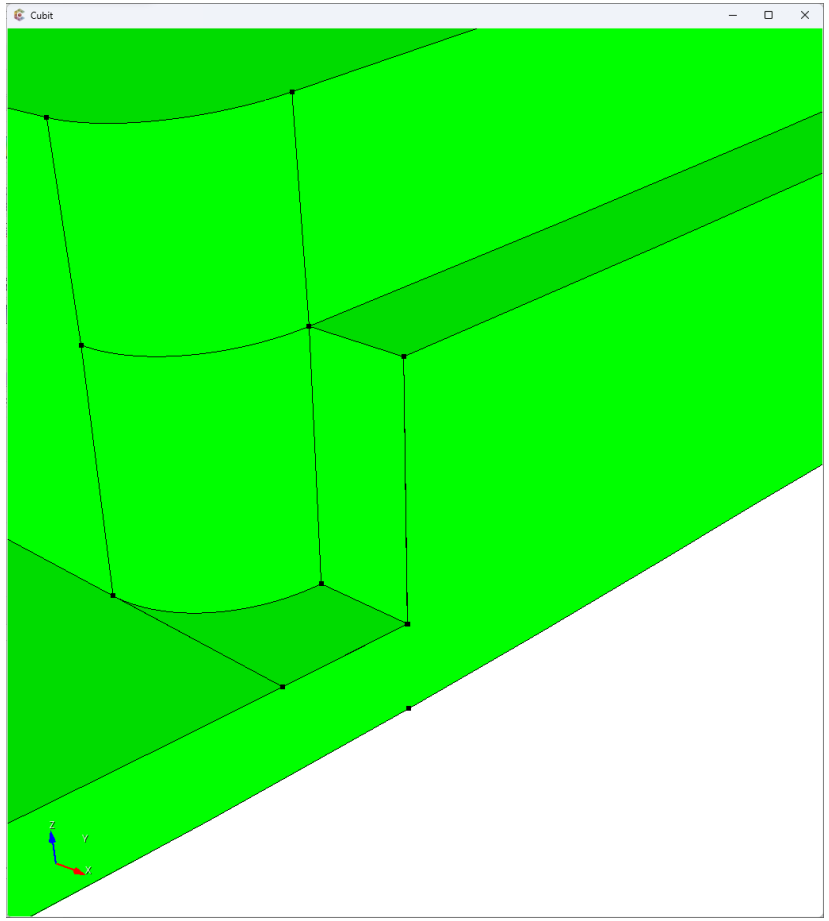
- **Step 6:**
  - We suspect that there will be small CAD features introduced if we were to Boolean subtract, so to minimize we extend the volume to at least remove one potential issue





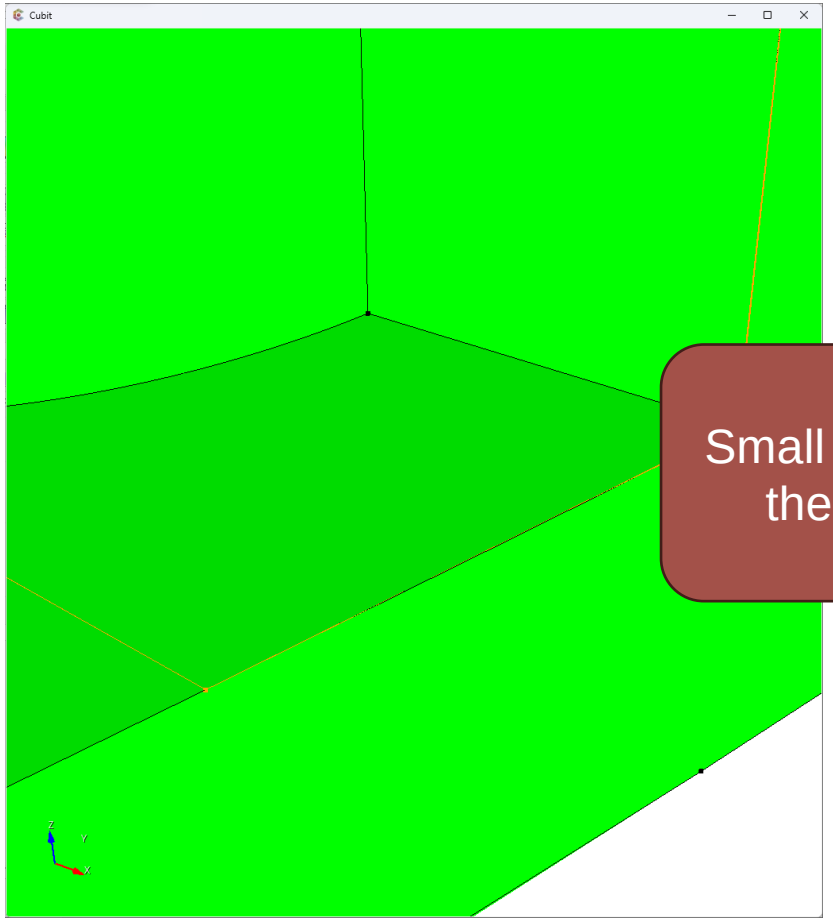
Complete the fillet

- **Step 7:**
  - Subtract the tool volume
  - This leaves a little pocket which we will need to cleanup



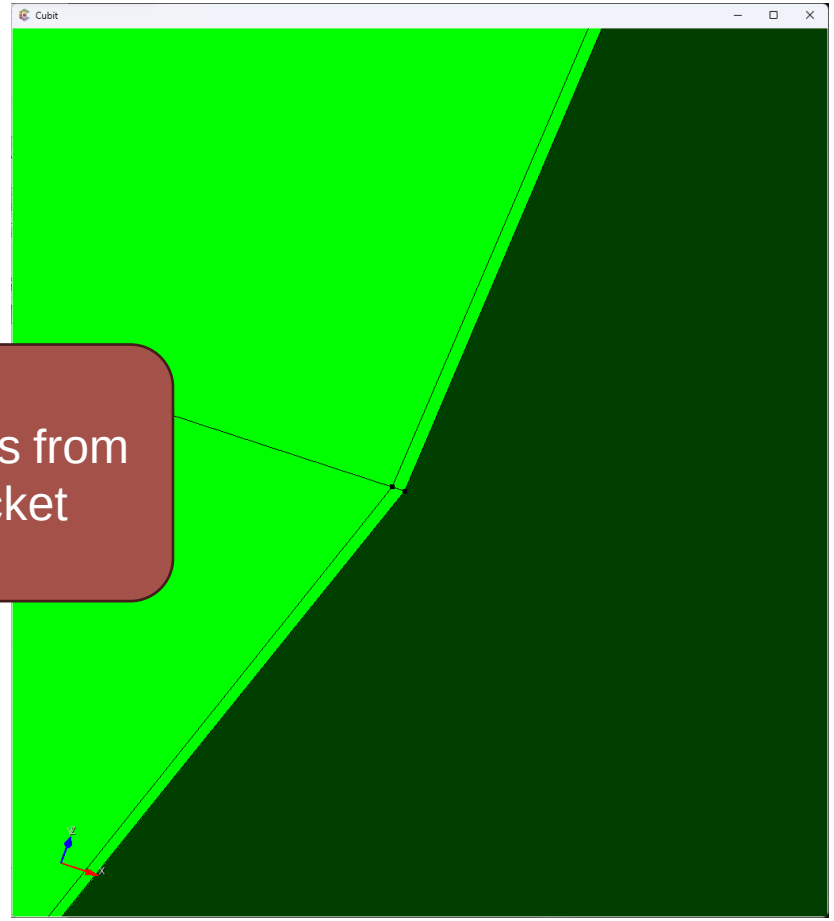
Complete the fillet

Overview of pocket

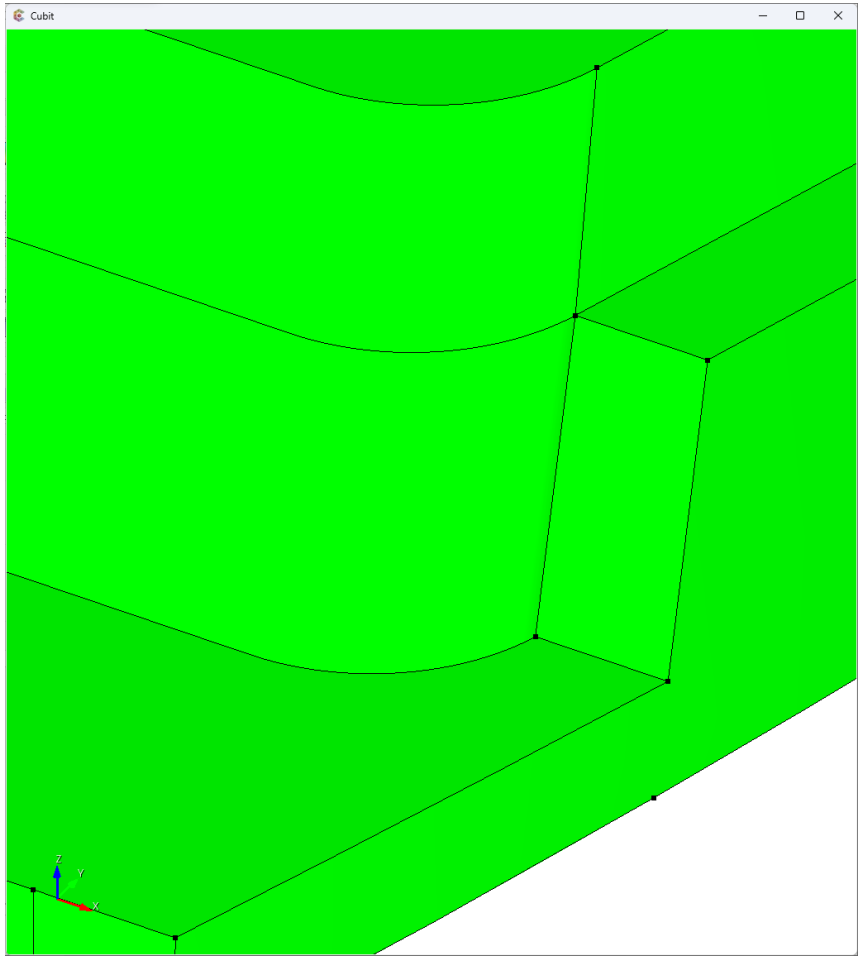


Small CAD surfaces from the resulting pocket

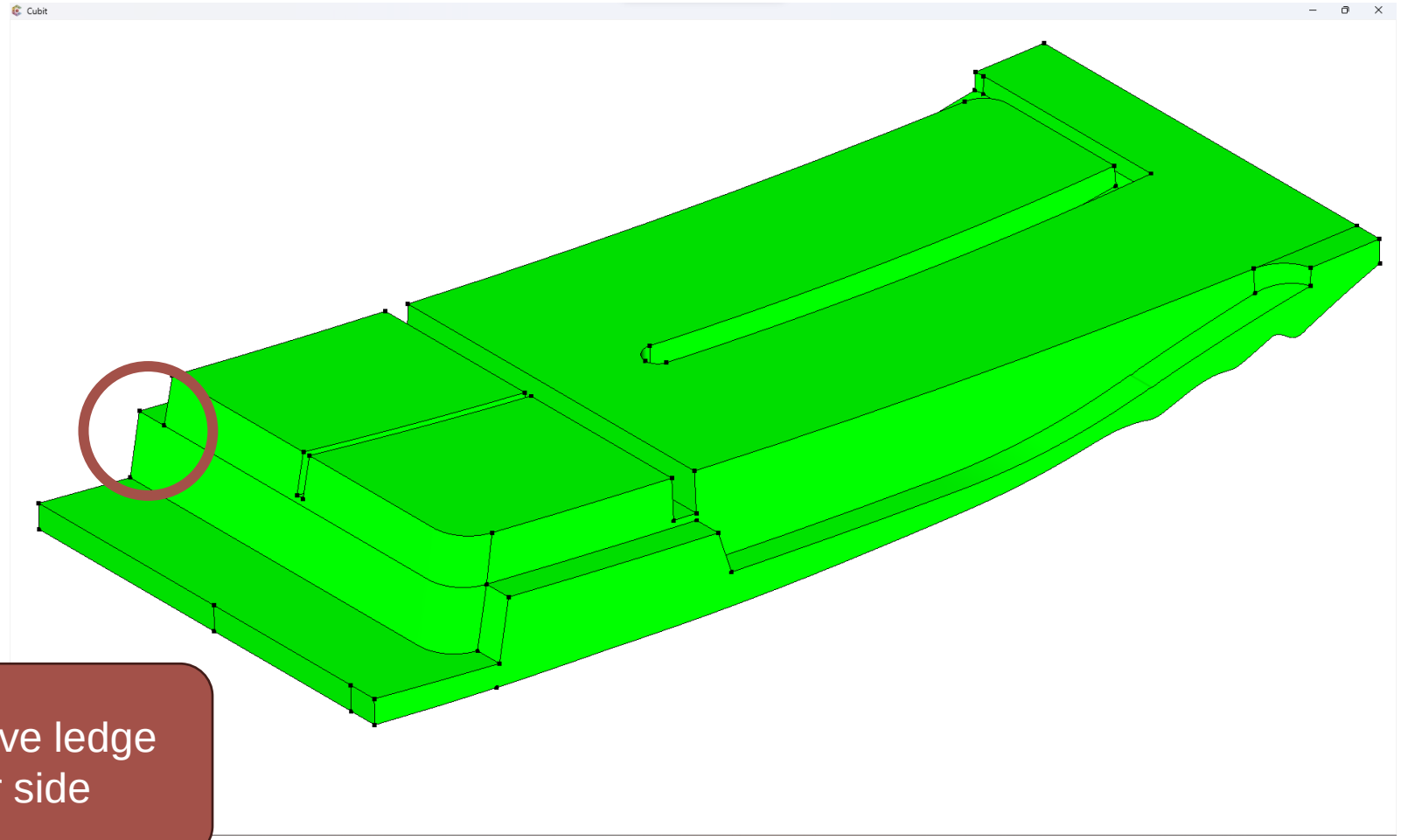
Detail



Complete the fillet



Taking stock of progress

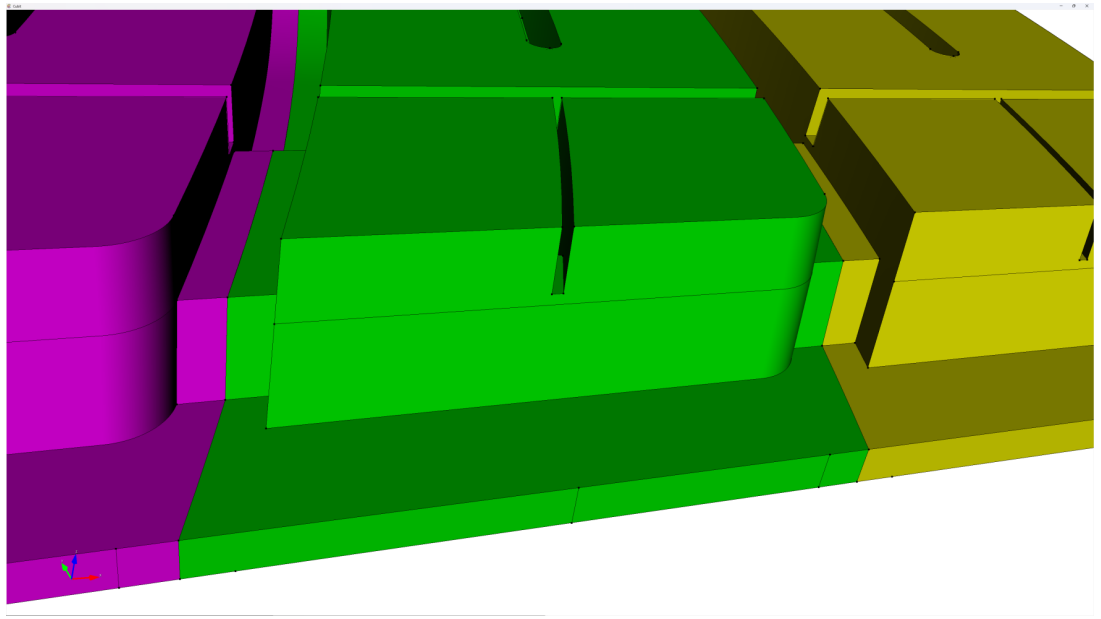


Need to remove ledge from other side

Reviewing symmetry model

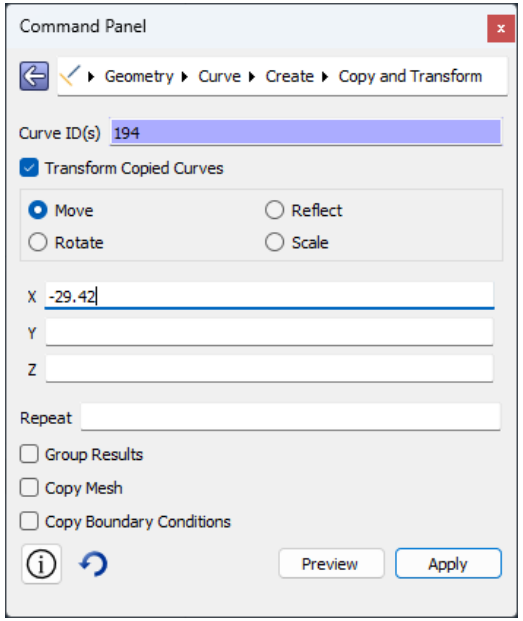
Recovering symmetry

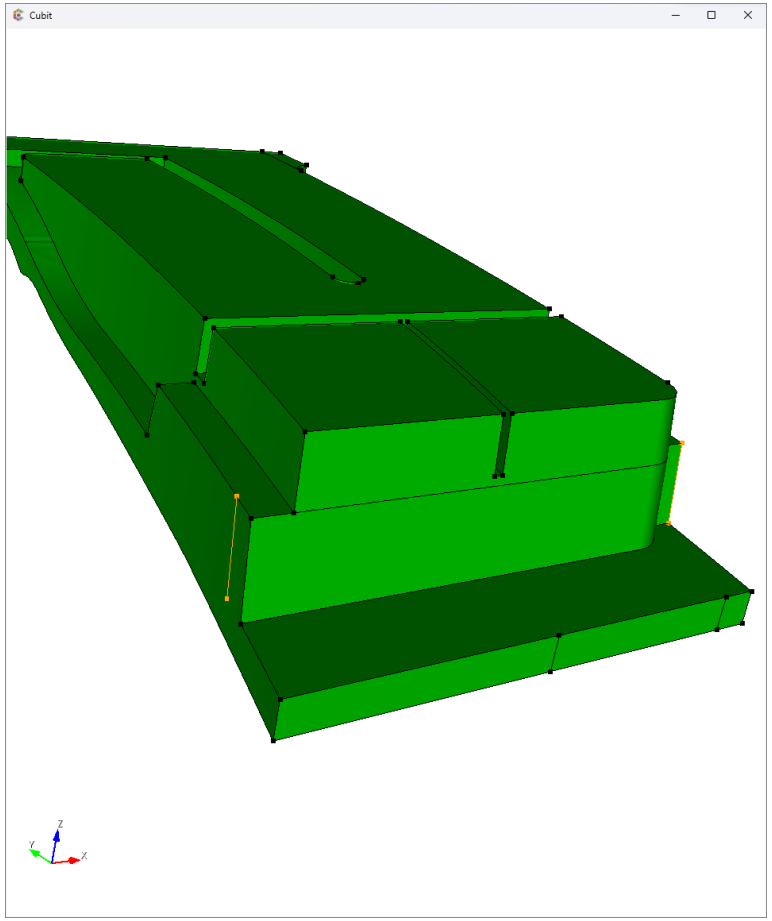
- **Goal:**
  - Recover symmetry by making the ledges on both sides match



Recovering symmetry

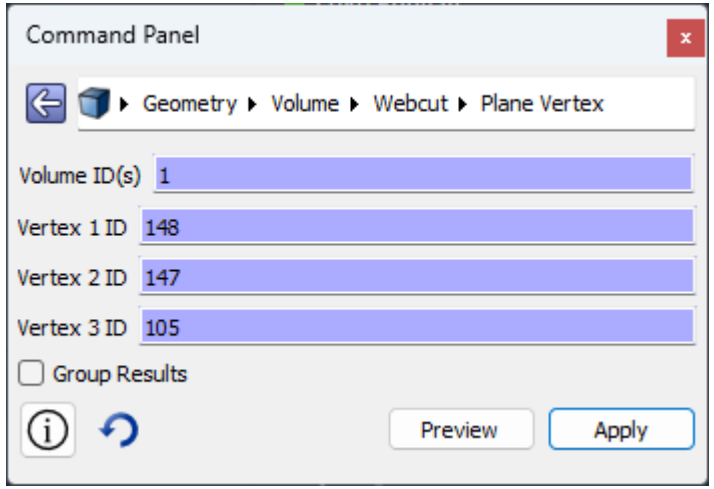
- Step 1:
  - Create copy of the target curve on our current working surface

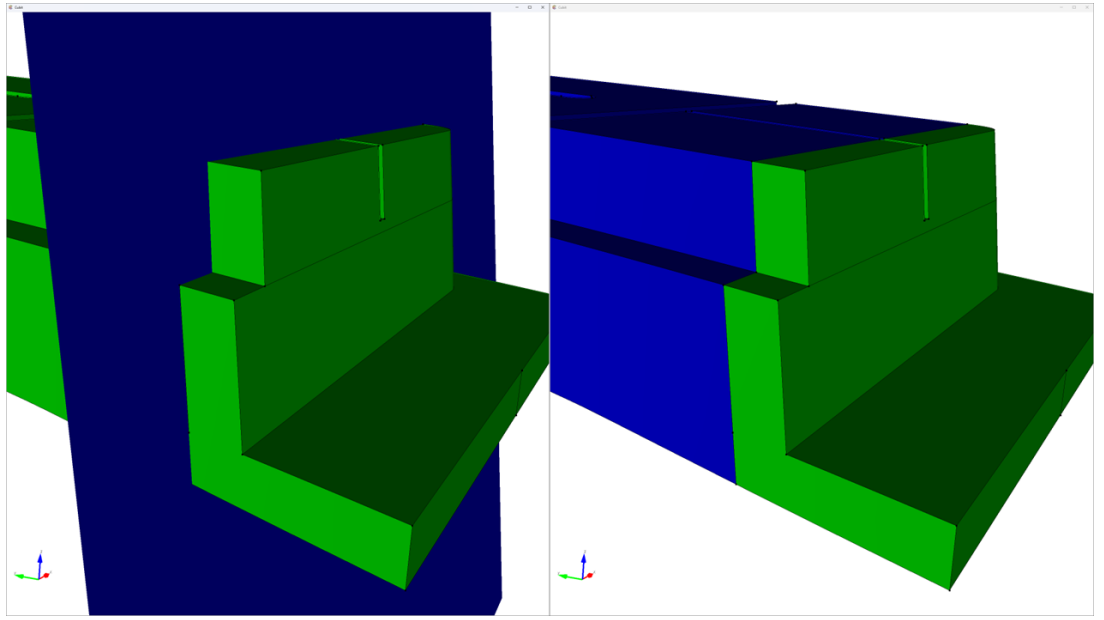




Recovering symmetry

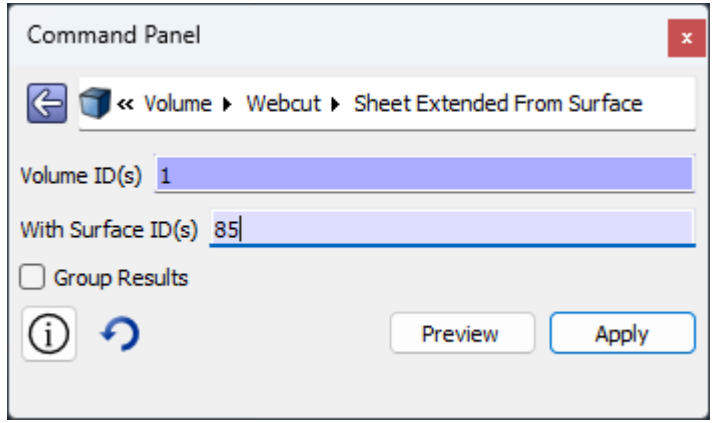
- **Step 2:**
  - Use the two vertices from the new curve and one vertex on the original curve to define a cut plane

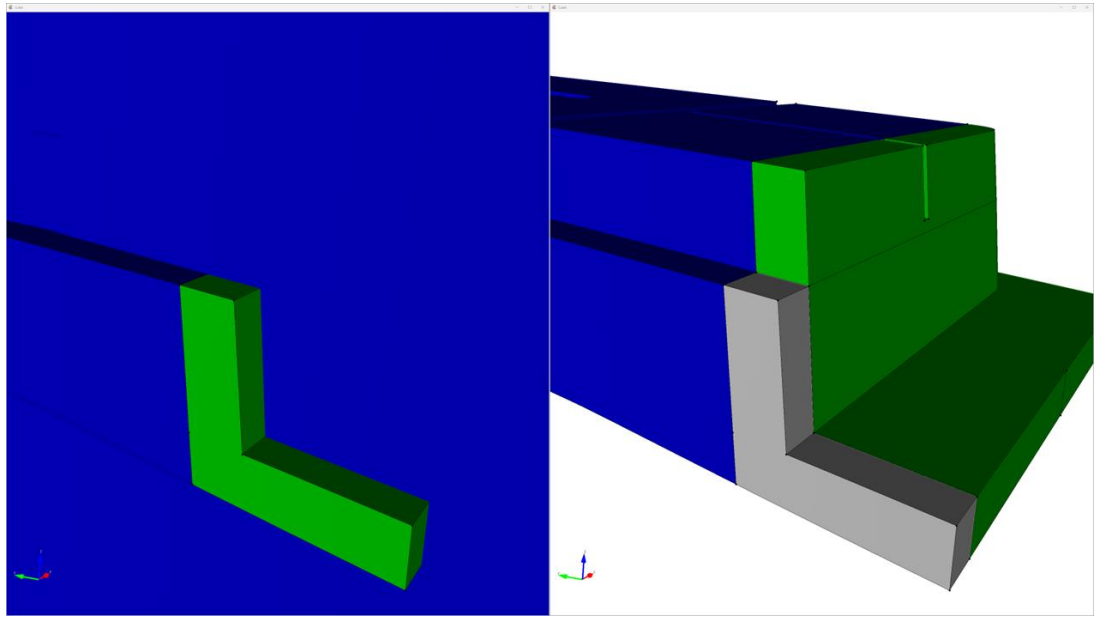




Recovering Symmetry

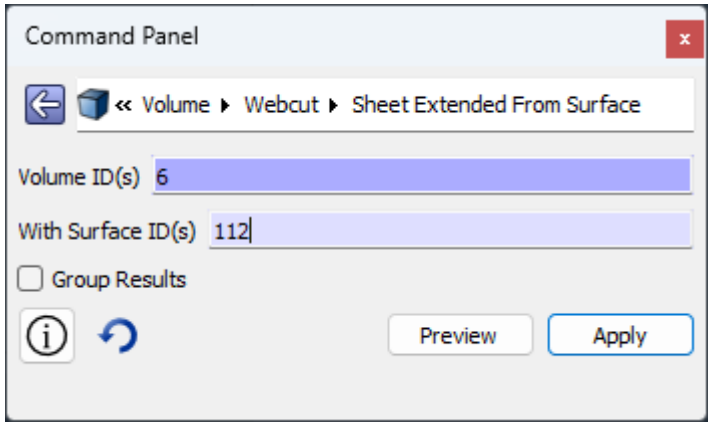
- **Step 3:**
  - Begin chopping off the region to remove, here extending one of the base surfaces

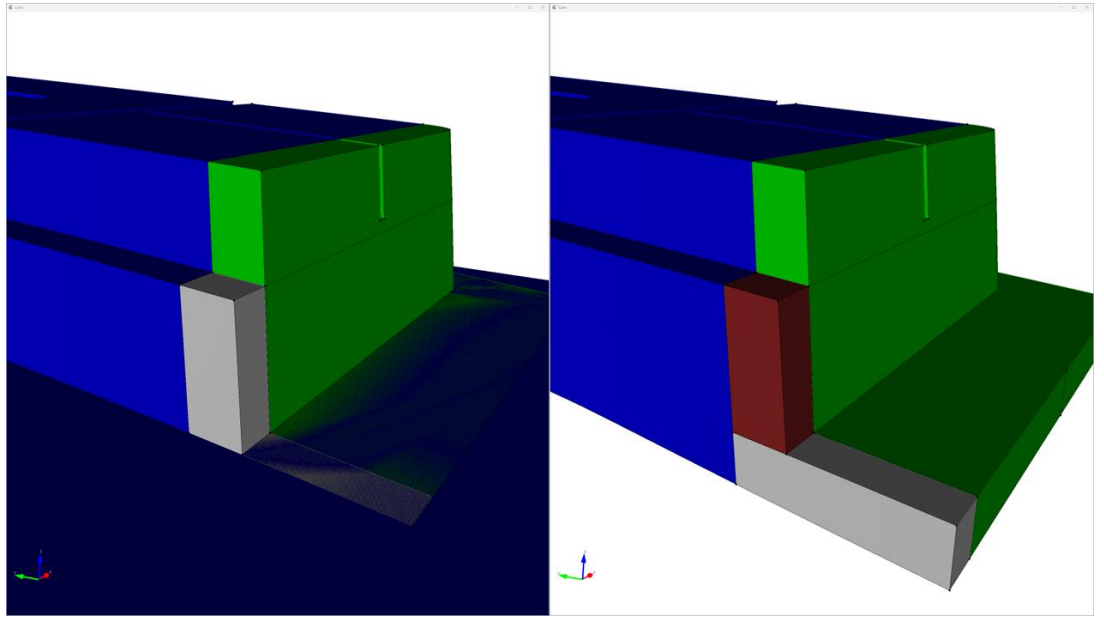




Recovering Symmetry

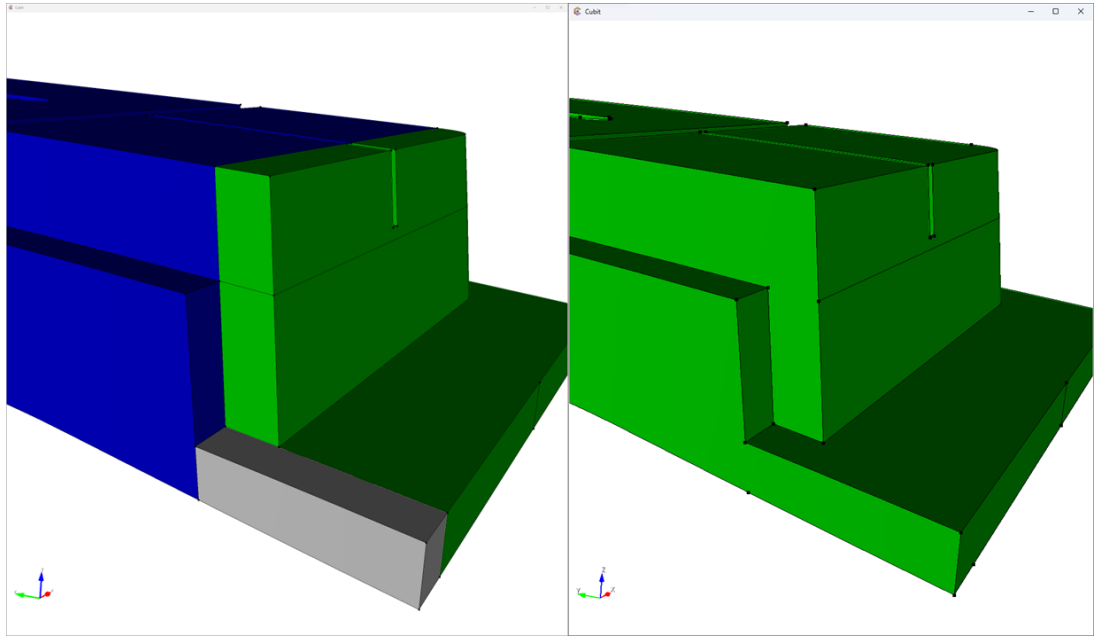
- **Step 4:**
  - Continue chopping off the region to remove, here extending other base surface



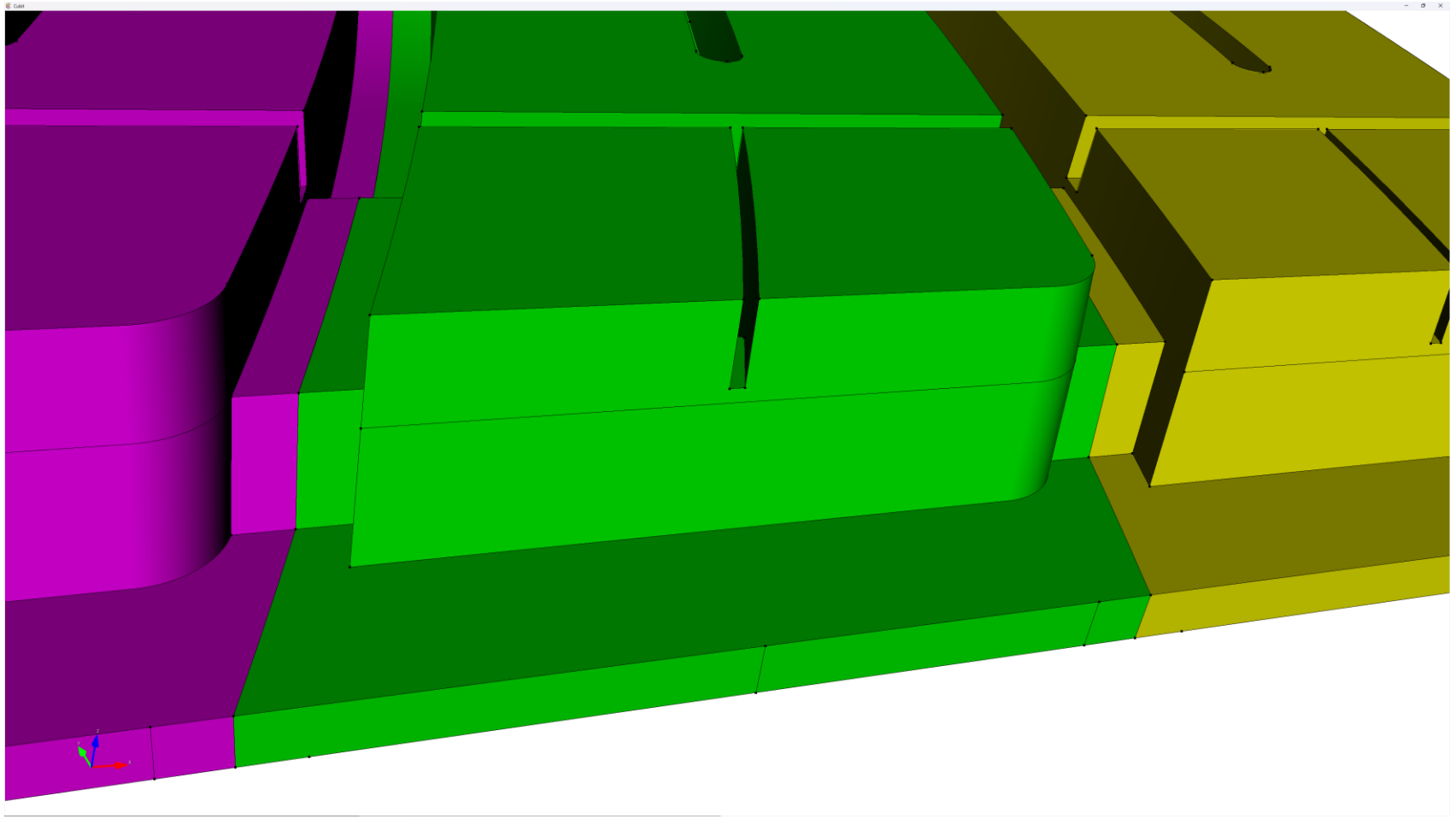


Recovering Symmetry

- **Step 5:**
  - Subtract the extraneous volume
- **Step 6:**
  - Unite the volumes



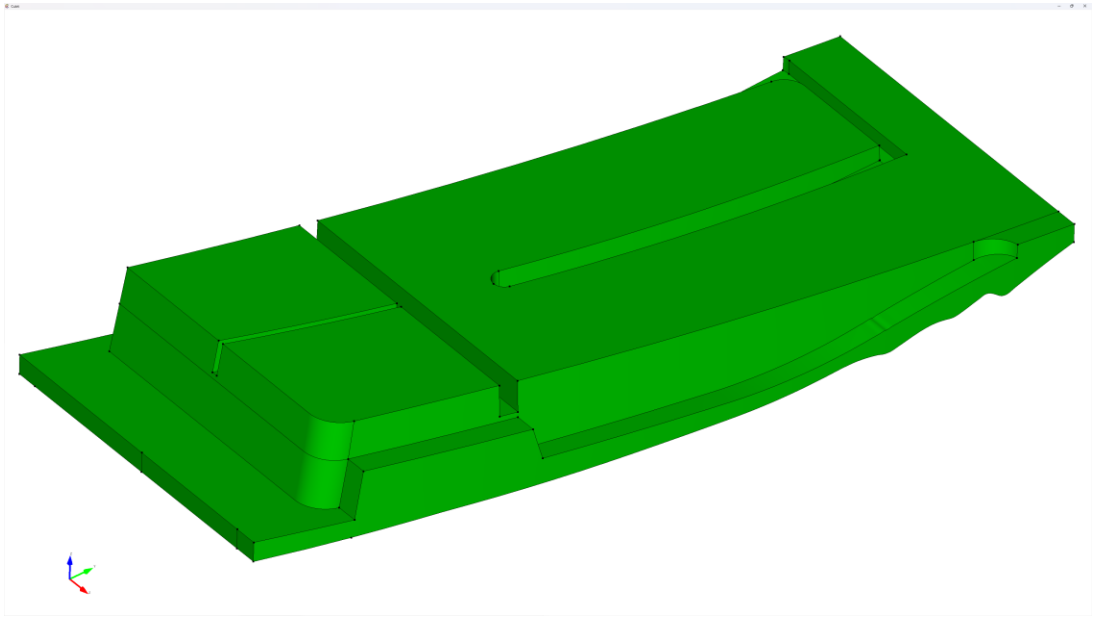
Recovering Symmetry



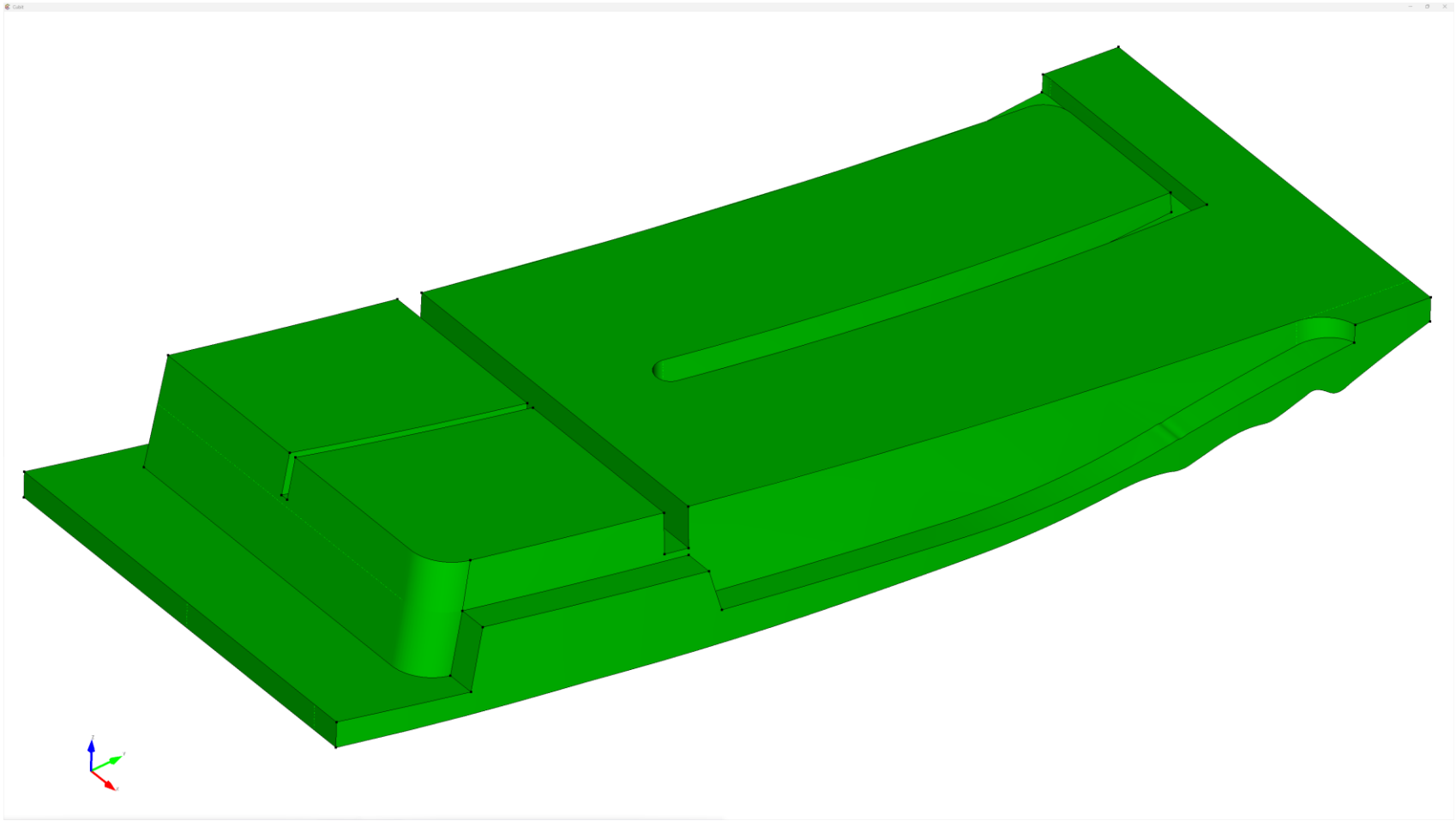
Meshing Section 5

- Now we have finished fixing the geometry

- Next, we will go through the model and composite surfaces to support a quality mesh



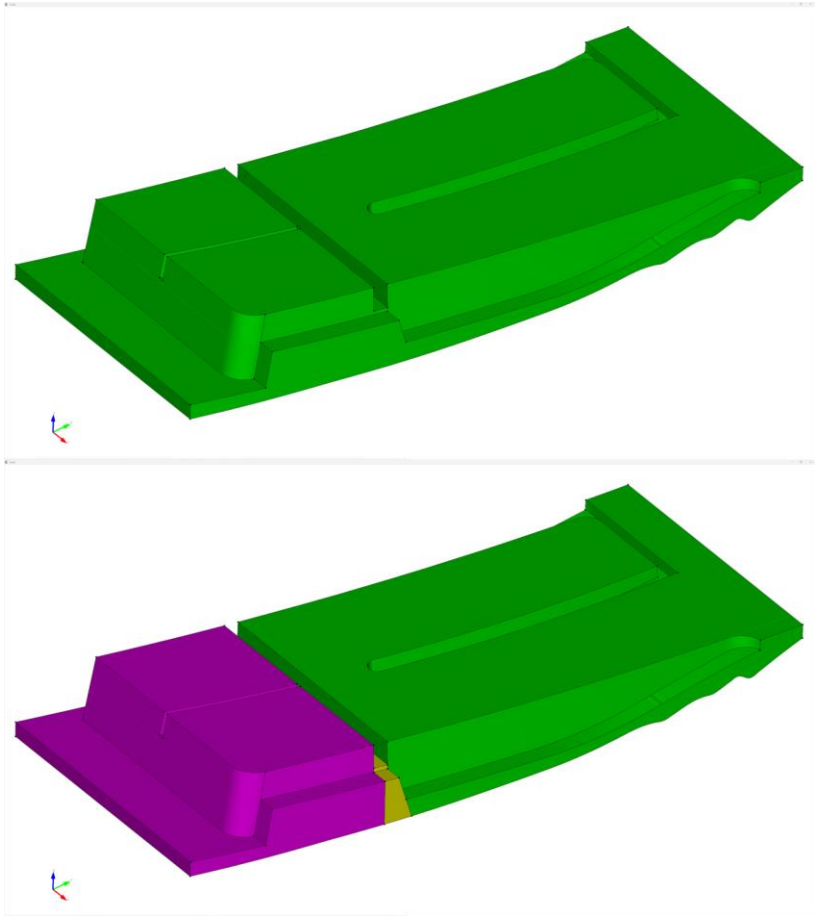
Result of compositing



Meshing Section 5

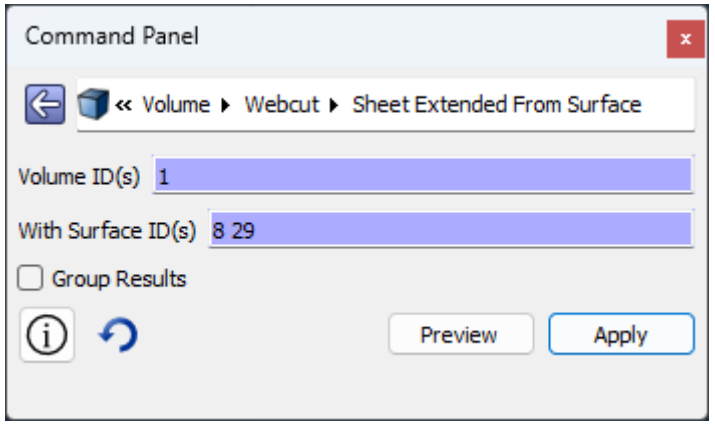
- While we could build an N:1 mesh on the remaining volume, there's enough source surfaces that it makes sense to split into three sections to make things a bit more manageable

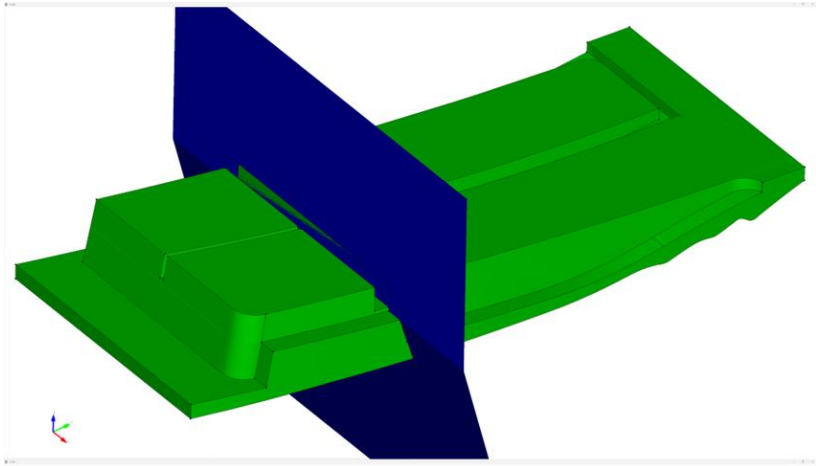
- Also provides a little bit of rigidity to the mesh that helps with robustness and quality

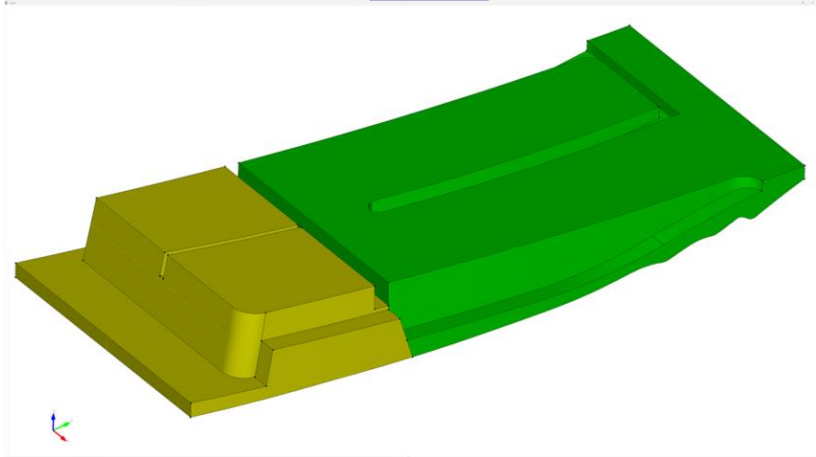


Meshing Section 5

- **Step 1:**
  - Apply “Sheet Extended From Surface” webcut, using ***2*** surfaces
  - The resulting webcut will use the trimmed extensions of these surfaces (note the angle)

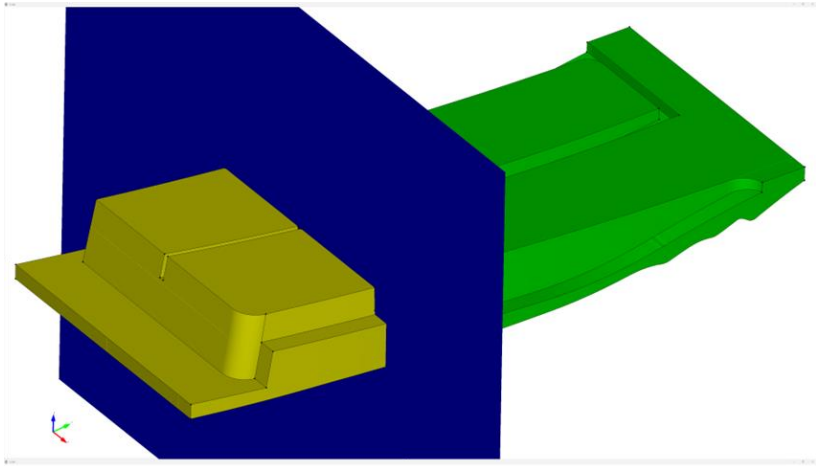


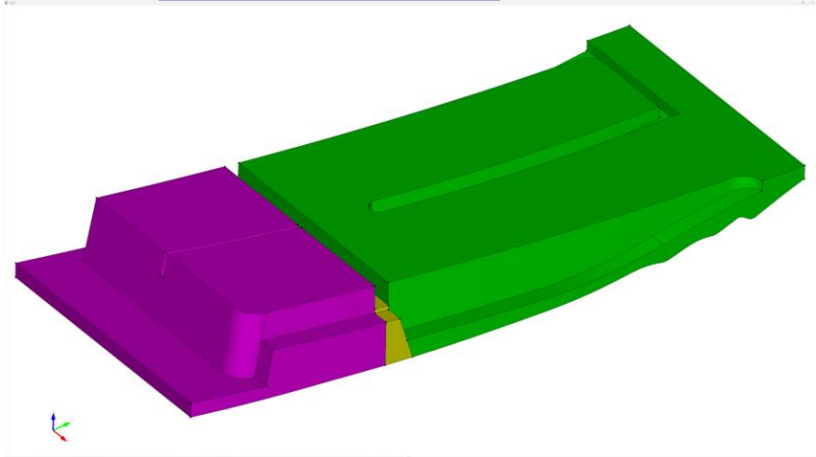




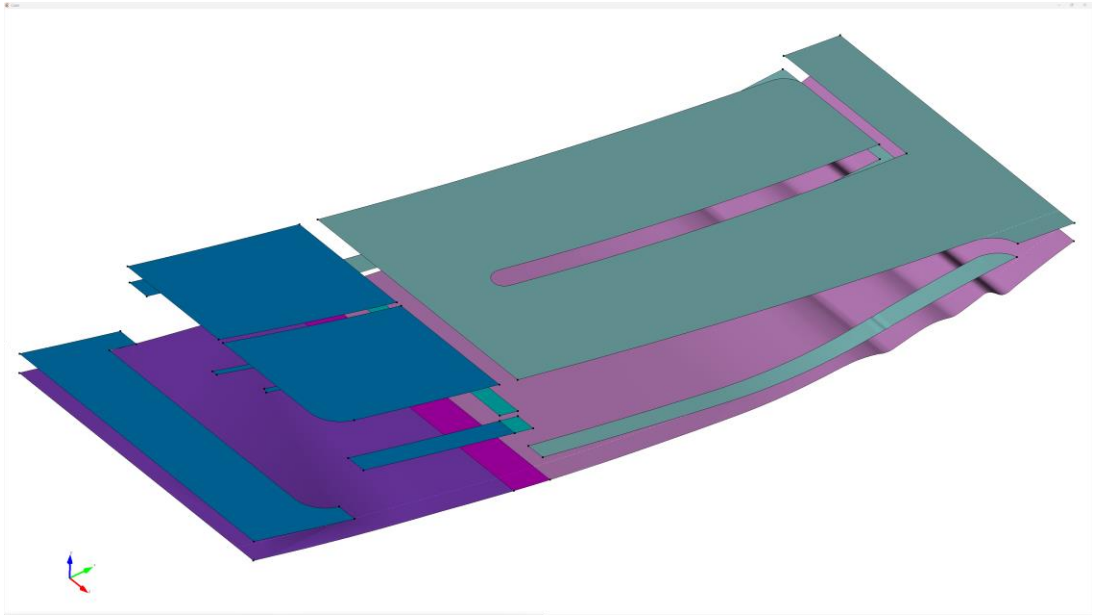
Meshing Section 5

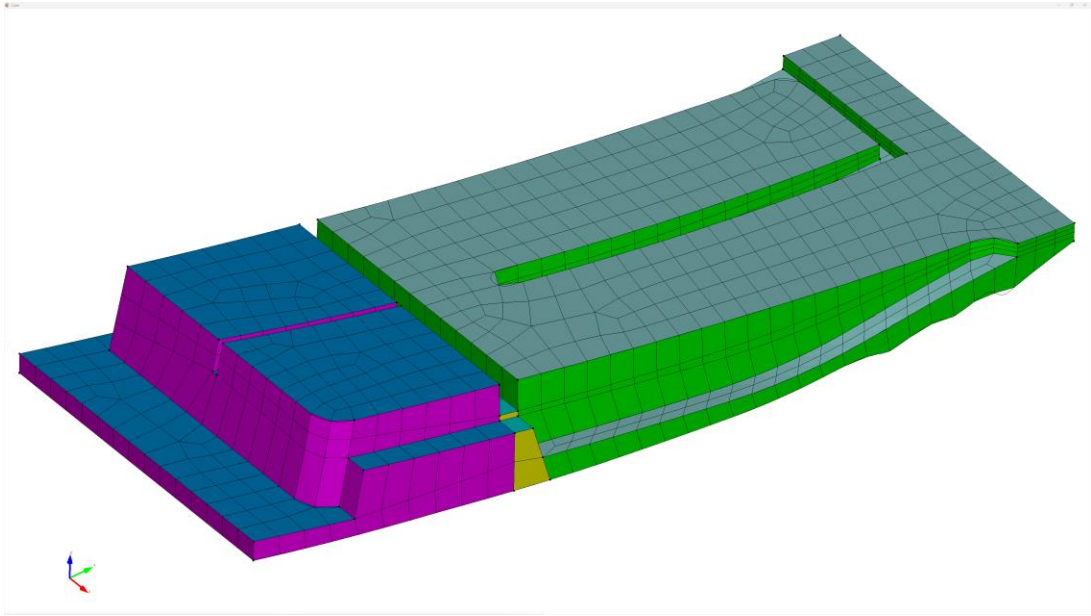
- **Step 1:**
  - Apply “Sheet Extended From Surface” webcut, using ***1*** surface





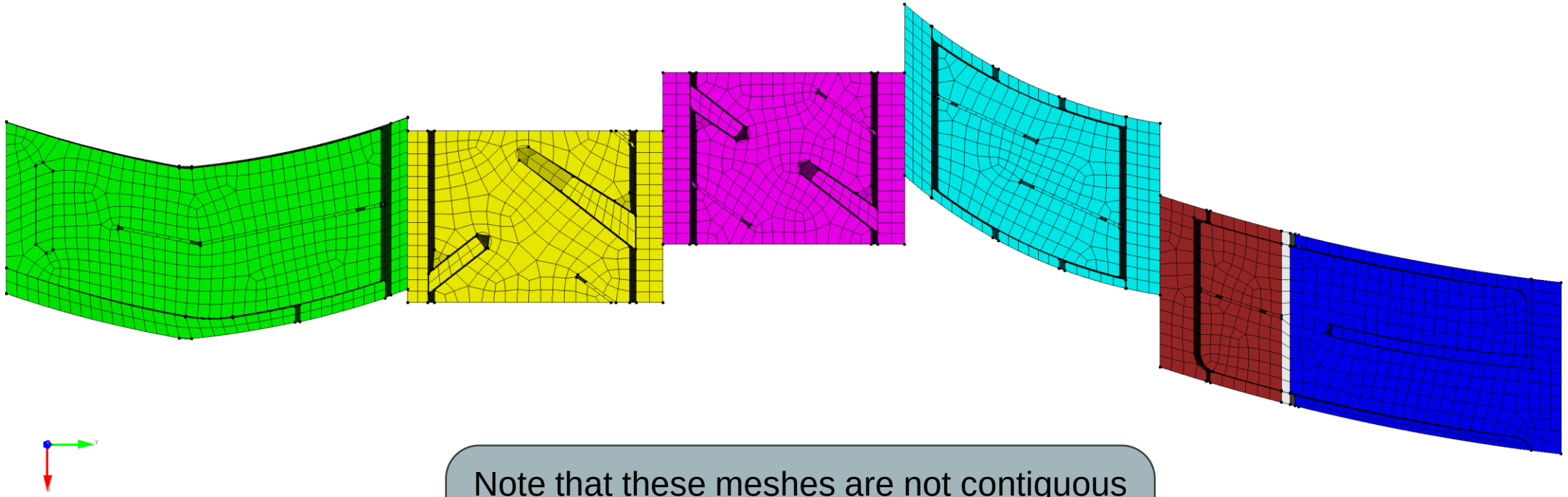
Meshing Section 5





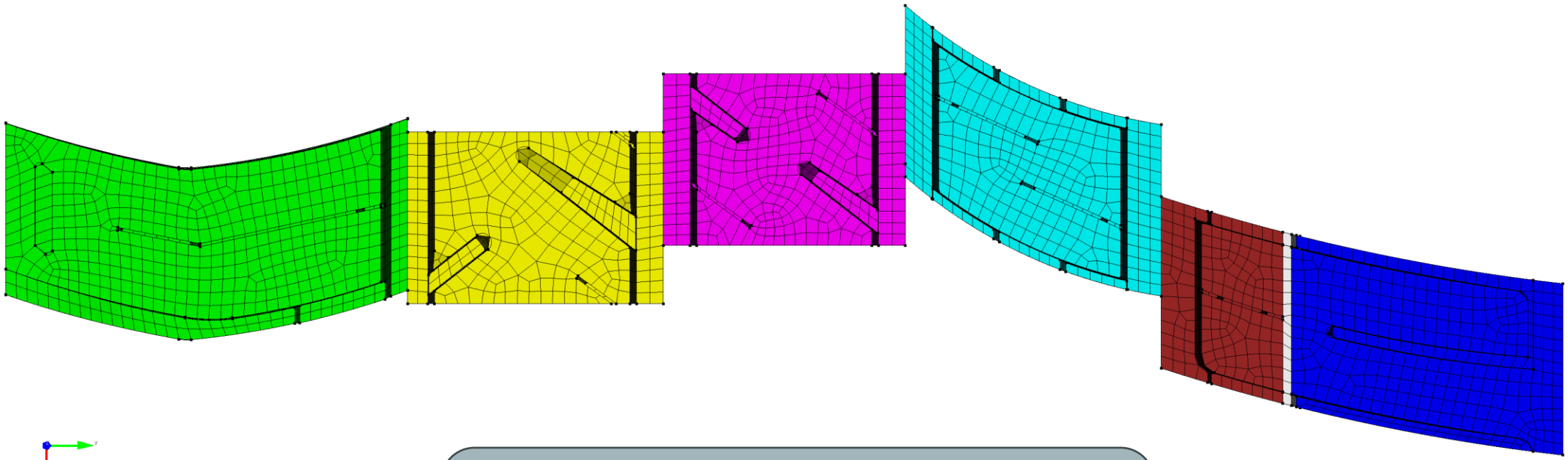
Recombine and Create Unified Mesh

Import each section



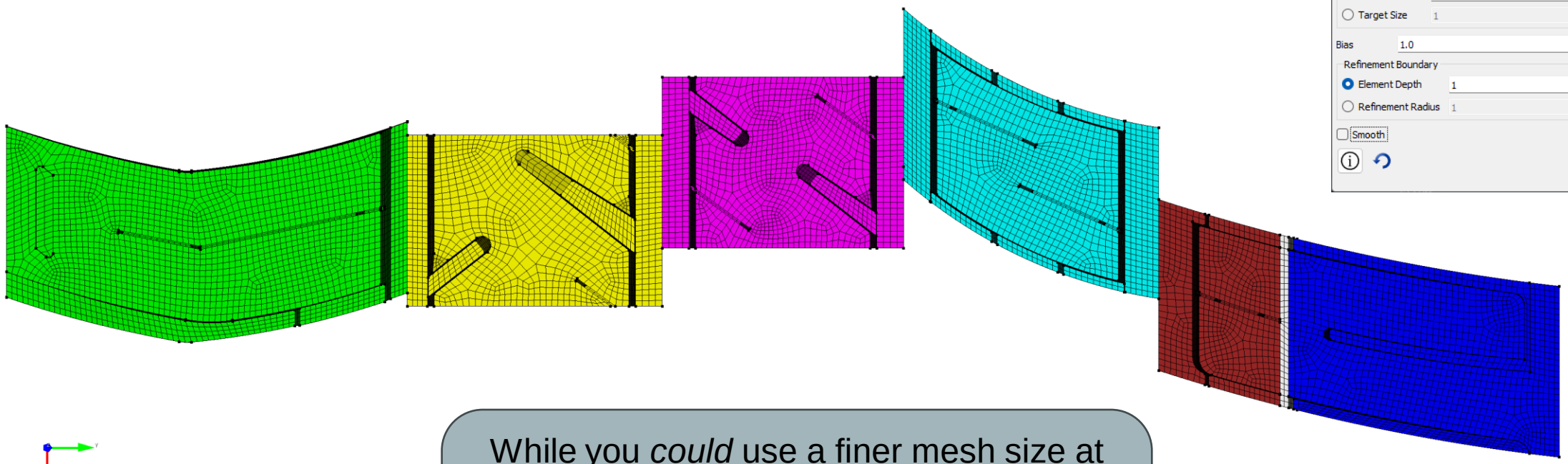
Note that these meshes are not contiguous at their boundaries. We will need to imprint and merge these volumes with each other and remesh!

Create Contiguous Mesh



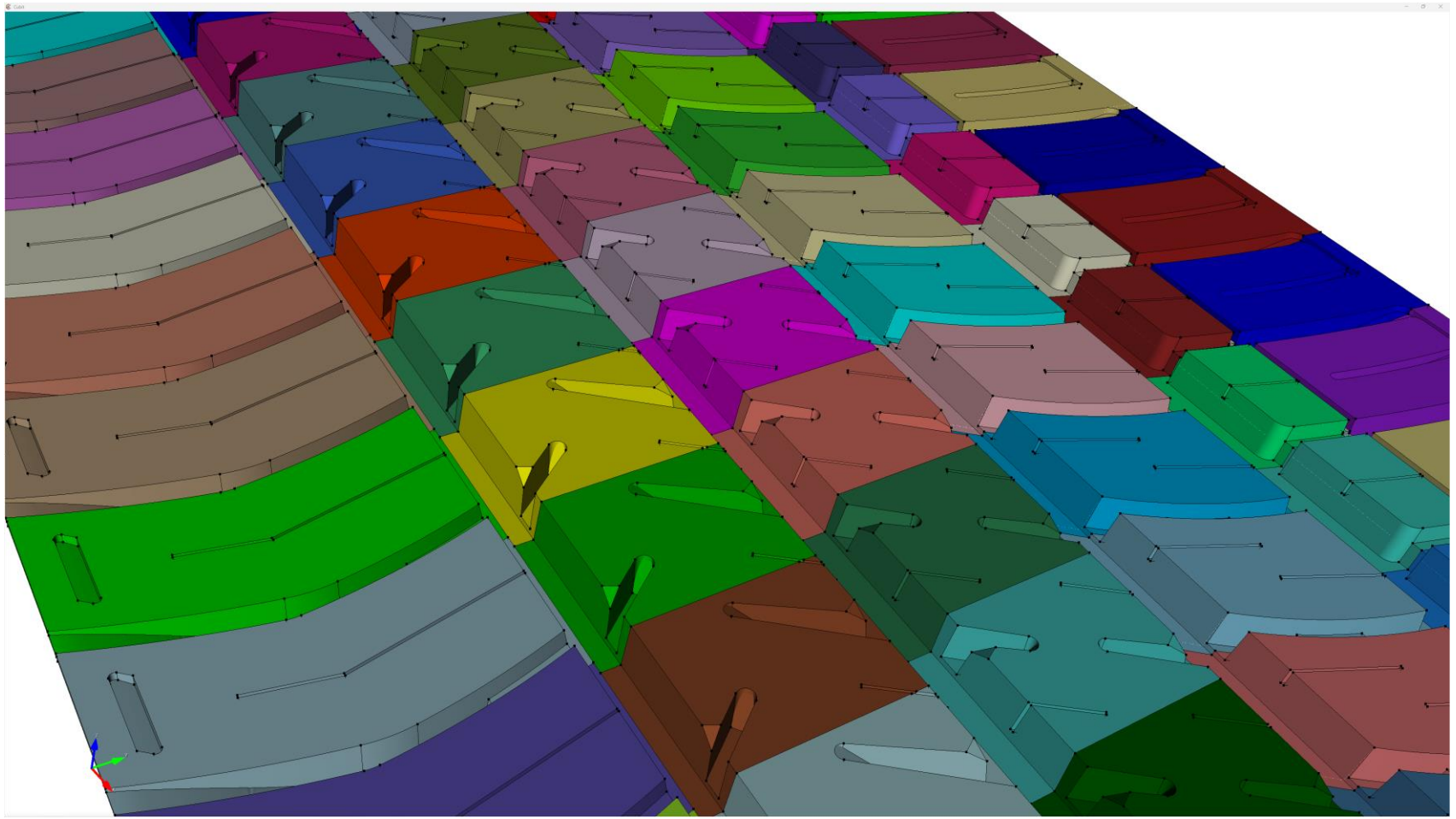
After imprinting and merging, we reapply the sweep schemes using the groups we created along the way.
Now we have a contiguous mesh!

Refining the mesh

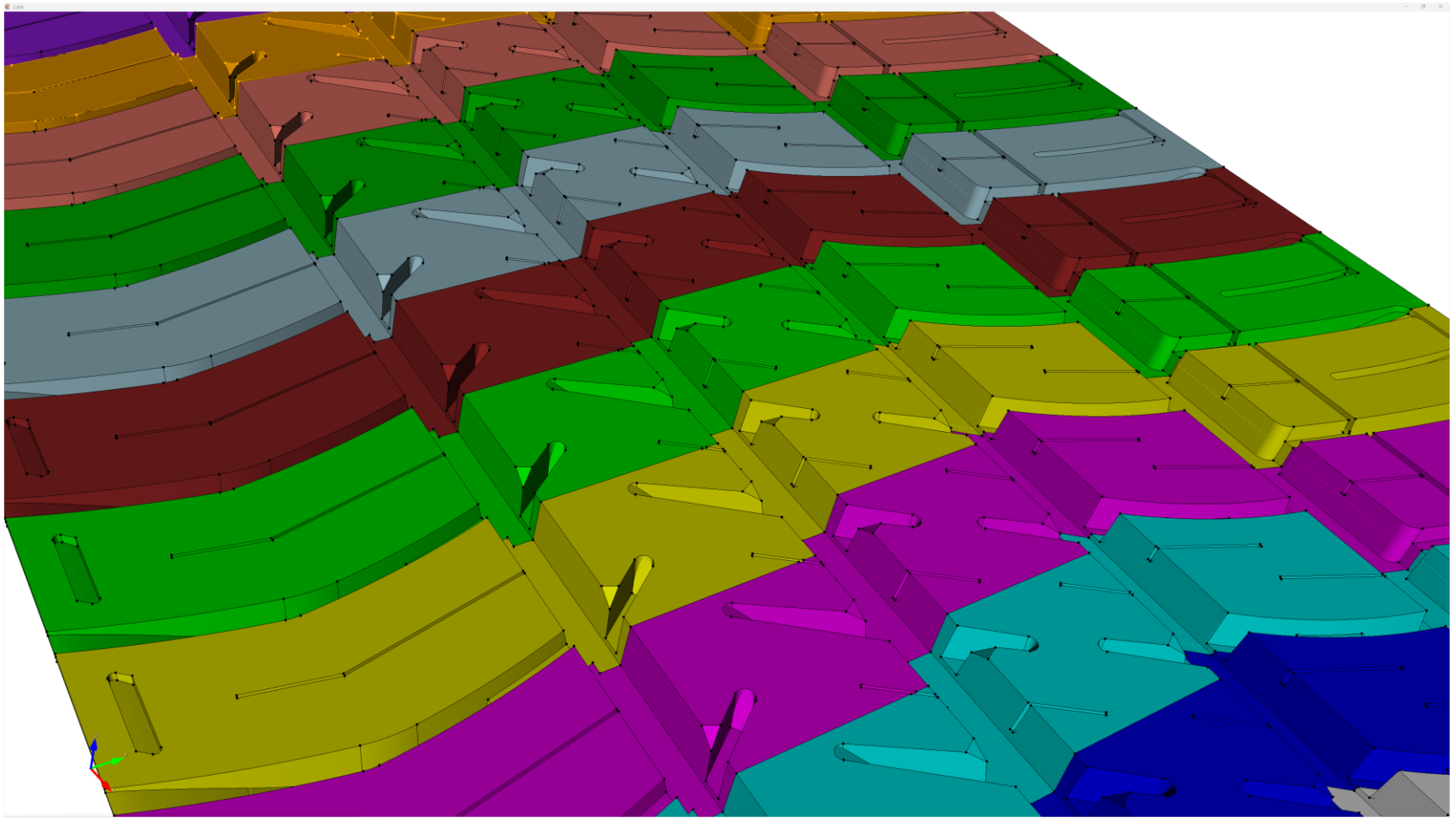


While you *could* use a finer mesh size at the time of creation, I find that sometimes it's faster and more robust to mesh coarse and then refine to the desired size – especially when using N:1 sweeps

Reviewing the model



Reviewing the model



Reviewing the model