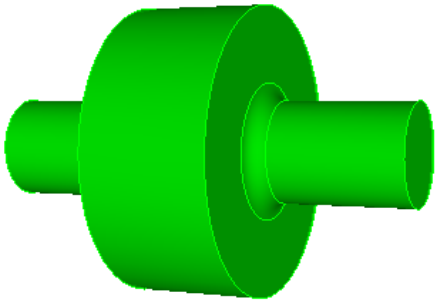
Modeling and Meshing with CUBIT

CUBIT full documentation and code access instructions at http://cubit.sandia.gov.

Simulation Workflow

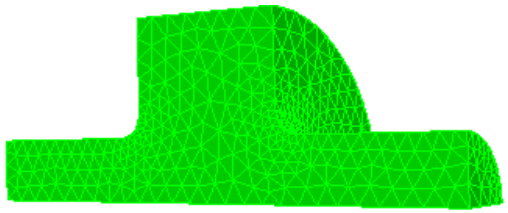
1) Model generation and meshing with CUBIT

Build model



Use symmetry to reduce

Mesh geometry

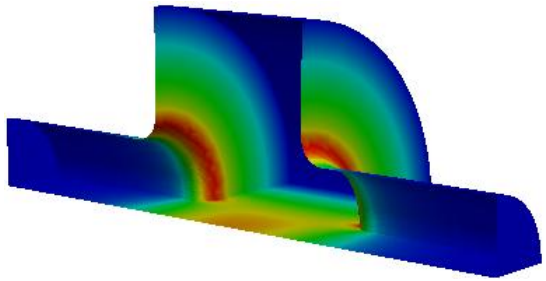


2) Apply ACE3P solver

Run Omega3P

```
  3642 Jul 22 09:32 logfile.output
233544 Sep  3 11:59 mode.10.1.191206E+09.m0
233544 Sep  3 11:59 mode.10.2.064482E+09.m1
388212 Sep  3 10:41 model1.ncdf
   450 Jul 10 08:47 o3p.in
  7511 Sep  3 11:59 output
  5285 Jul 22 09:26 sample.input
   512 Sep  3 11:59 vector1/
```

3) Visualize with ParaView

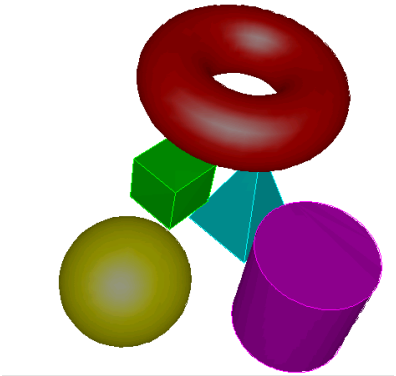


- **CUBIT** basics
- Model generation - Pillbox cavity
  - Model generation and meshing with journal files
- Meshing
  - Mesh quality checking

Creating Geometry in **CUBIT**

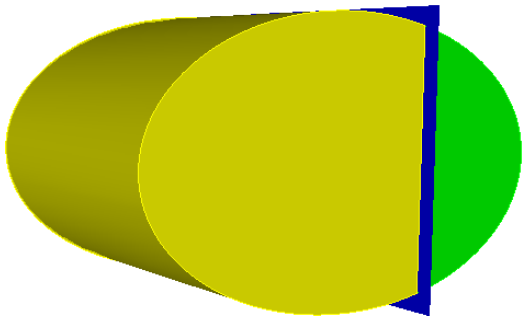
- **CUBIT** can create many analytic geometries from scratch and in decomposition
- Seven geometry primitives types are available and accessed with the **Create button**
- **CUBIT** creates the geometry with the **GUI**

or with command line syntax: *CUBIT> help create*

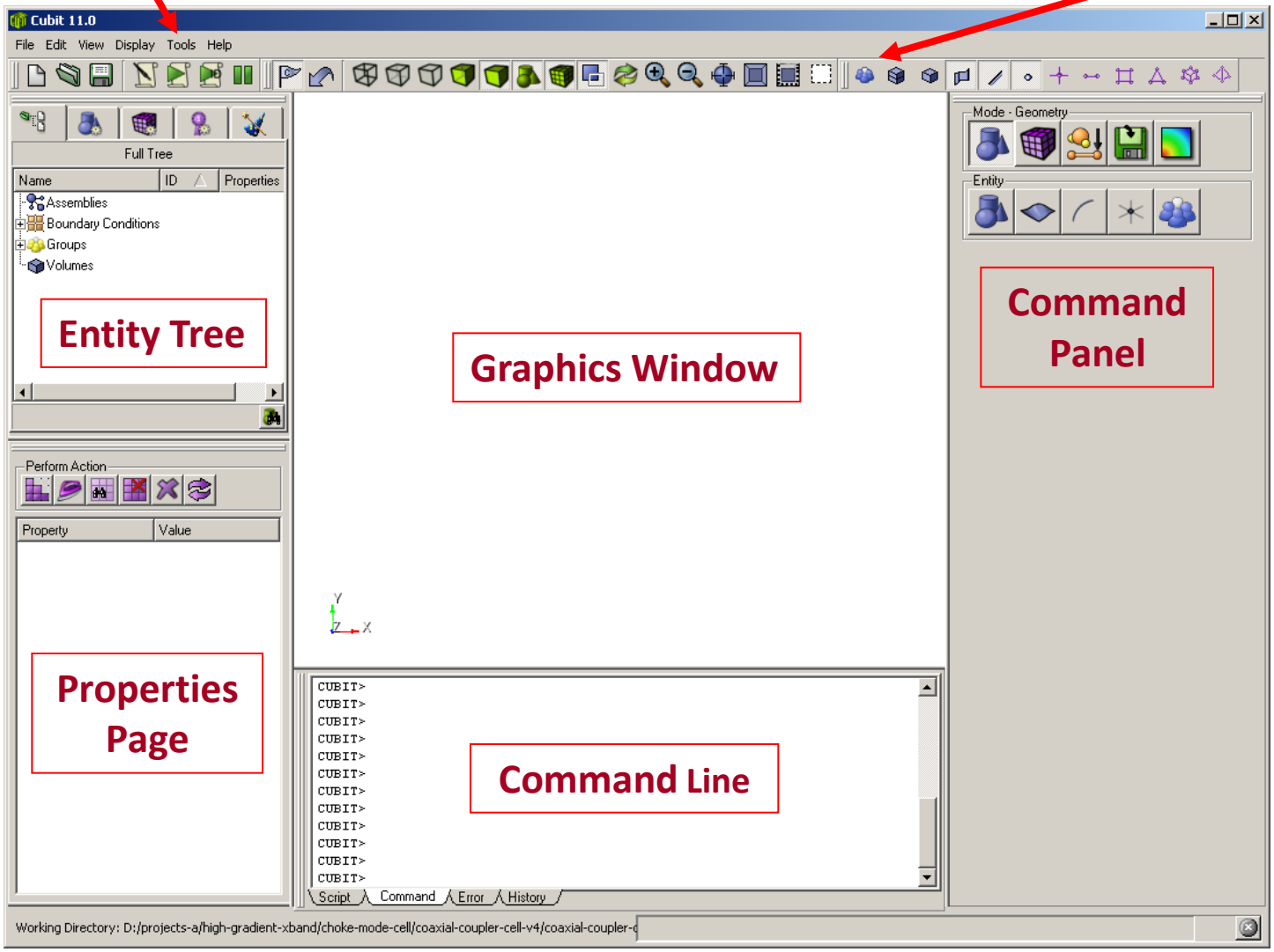


Geometry Booleans & Webcutting

- Geometry Booleans define the shape of a Body based on overlapping regions
  - Subtract - Remove regions of overlap
  - Intersect - Delete all except regions of overlap
  - Unite - Combine all regions
- Webcutting slices 1 Body into 2 Bodies
  - Plane
  - Cylinder
  - Extended Surface
  - Intersection with “Tool”



Working with the **CUBIT** GUI



Tool Bar Commands & Command Panel

Tool Bar Commands

Display modes

Zoom in, out, and fit

Toggle scale

Chose rubber band select mode

Check point save/undo

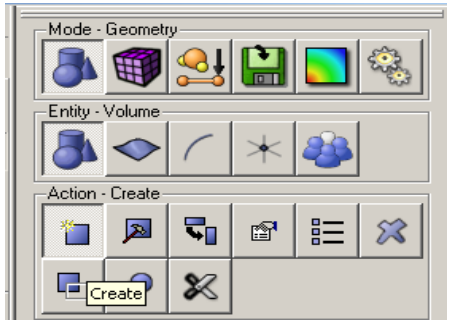
Redraw

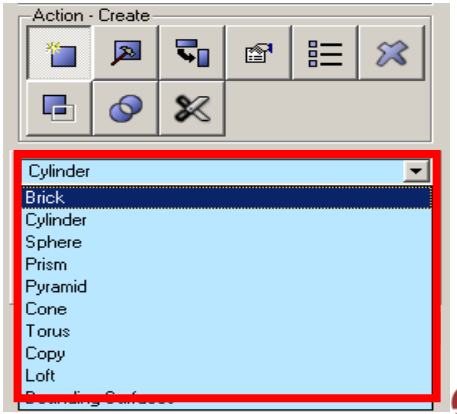
Perspective on/off

Entity Selection Filter

Volume, Surface, Curve, Vertex

Command Panel





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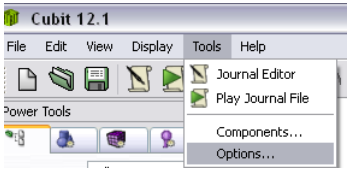
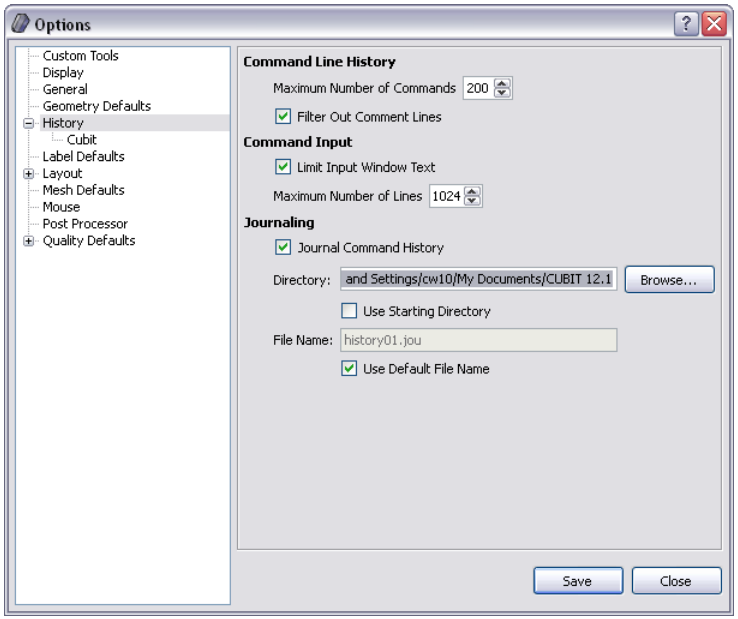
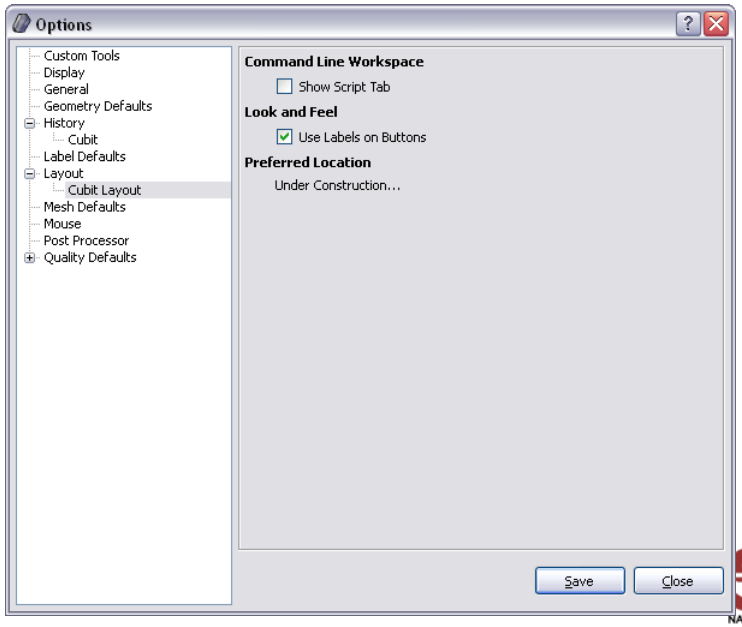
Configuration Options

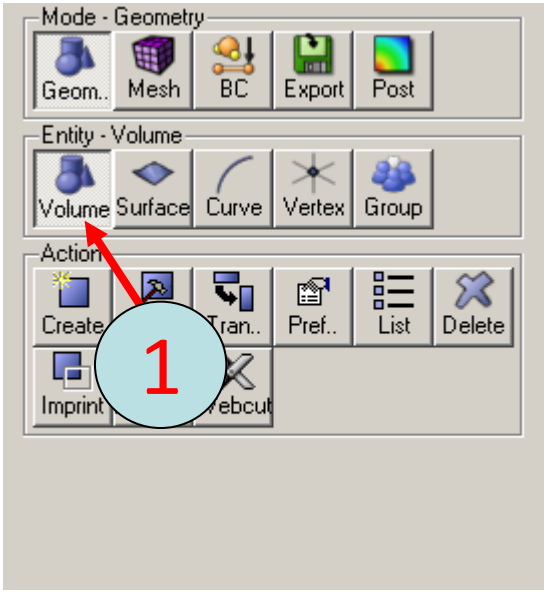
- Tools->Options
- History
  - Uncheck “Use Starting Directory”
  - Change to work directory
- Layout->Cubit Layout
  - Check “Use Labels on Buttons”

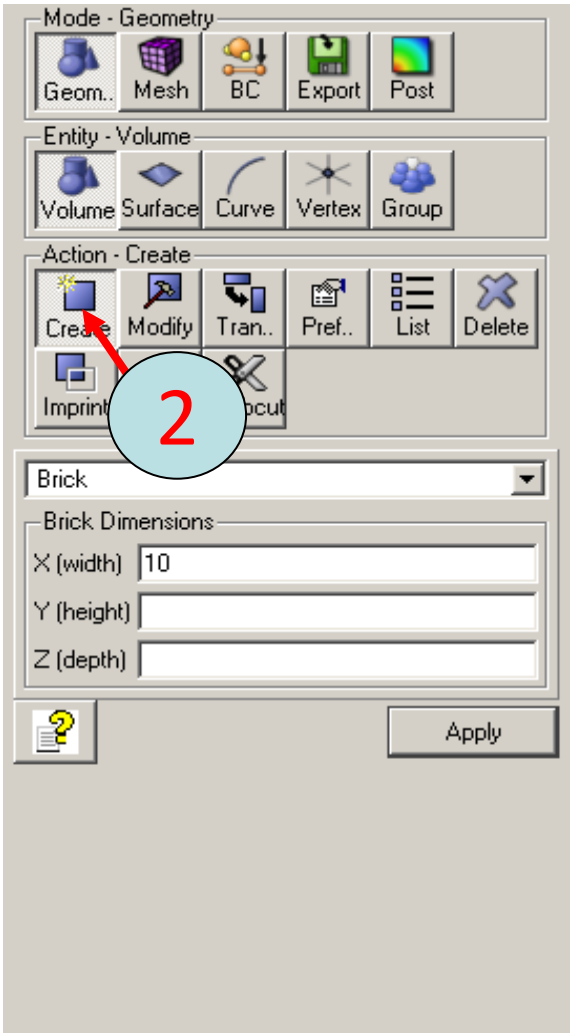


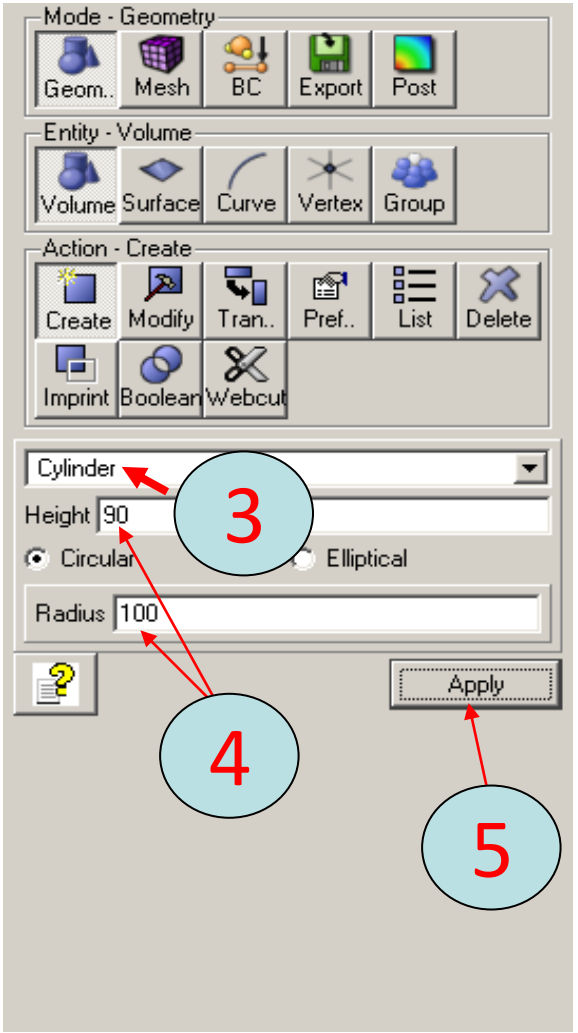




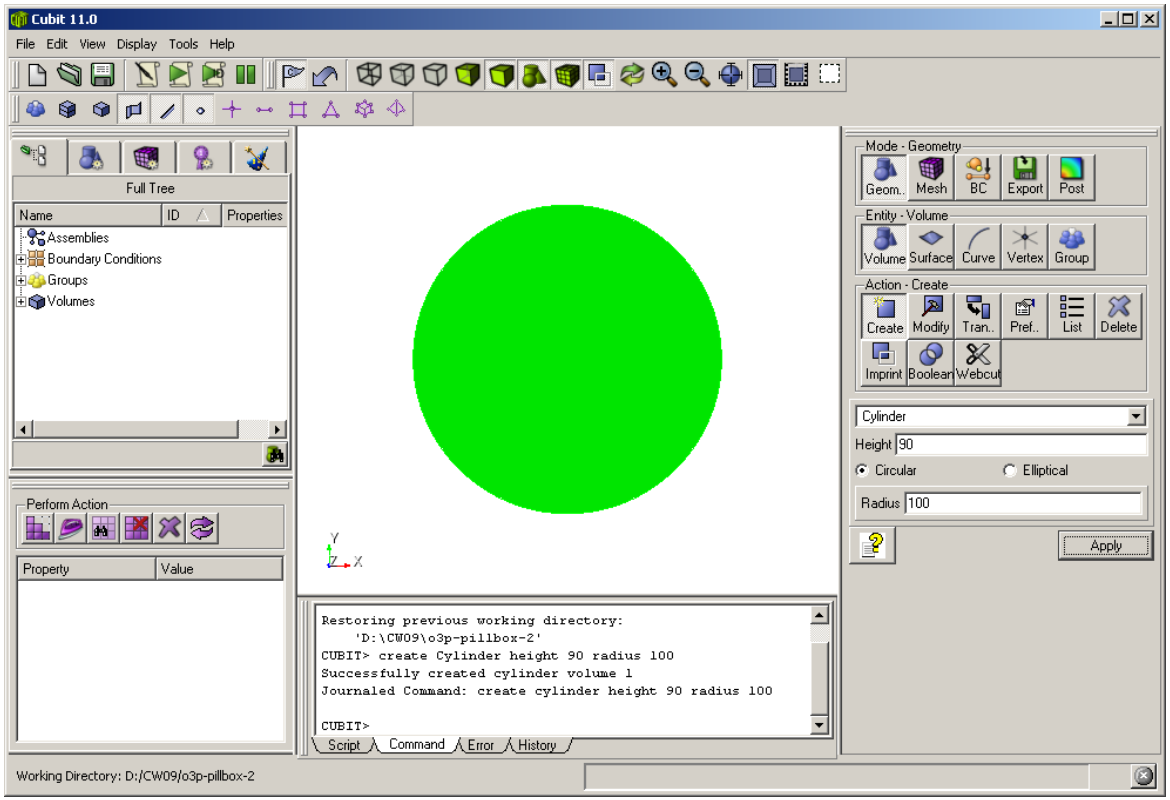
Create **CUBIT** Model for a pillbox cavity with **GUI**

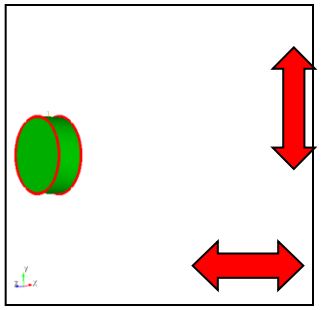


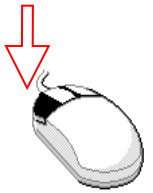




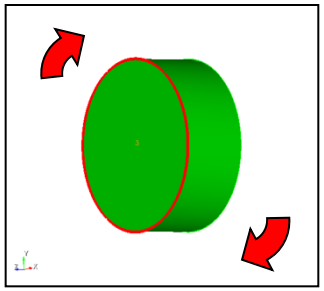
Using the 3 button Mouse

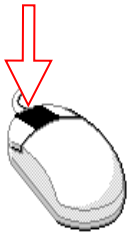




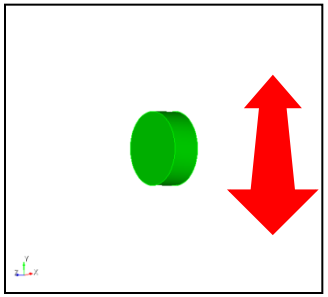


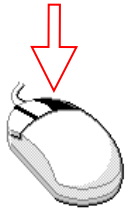
Left-button to Pan





Mid-button to Rotate





Right-button to Zoom

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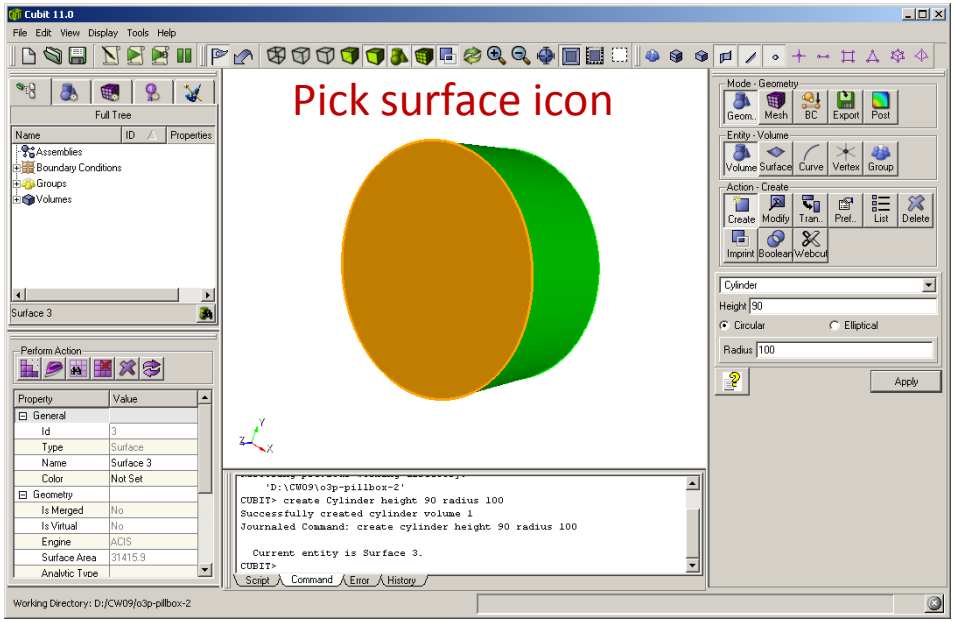
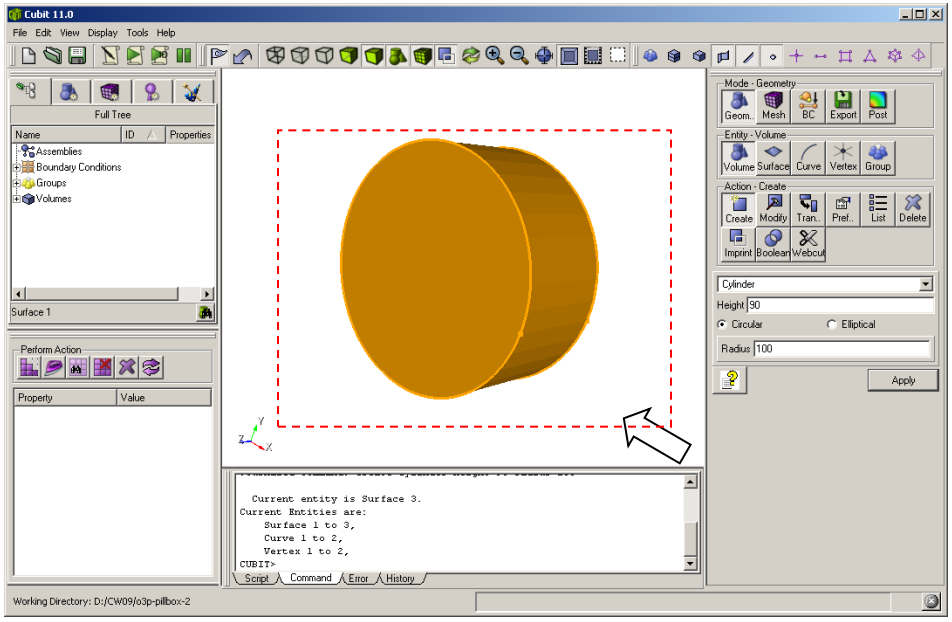
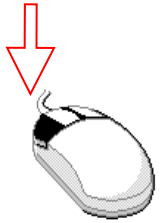
Select One or a Group of Surfaces



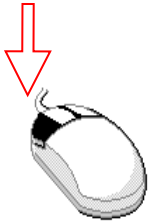


Put curser on surface

Left button click to pick



Ctrl +



Similarly for selecting a curve

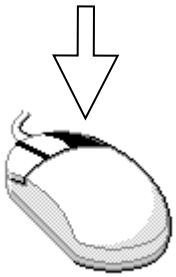
1. A selection box appears when move the mouse
2. Fully cover the surfaces to be selected
3. (curves and vertexes also selected if the curve and vertex icons on top selected)

ID Input Fields

These options only apply when something is selected in the graphics window

Mostly use
"Visibility off"
"All visible"

Right Click



Right clicking in the input field will display an additional command menu

Done Selecting – Move to next field in dialog

Select Other – Used when picking from graphics window. Cycles through nearby entities

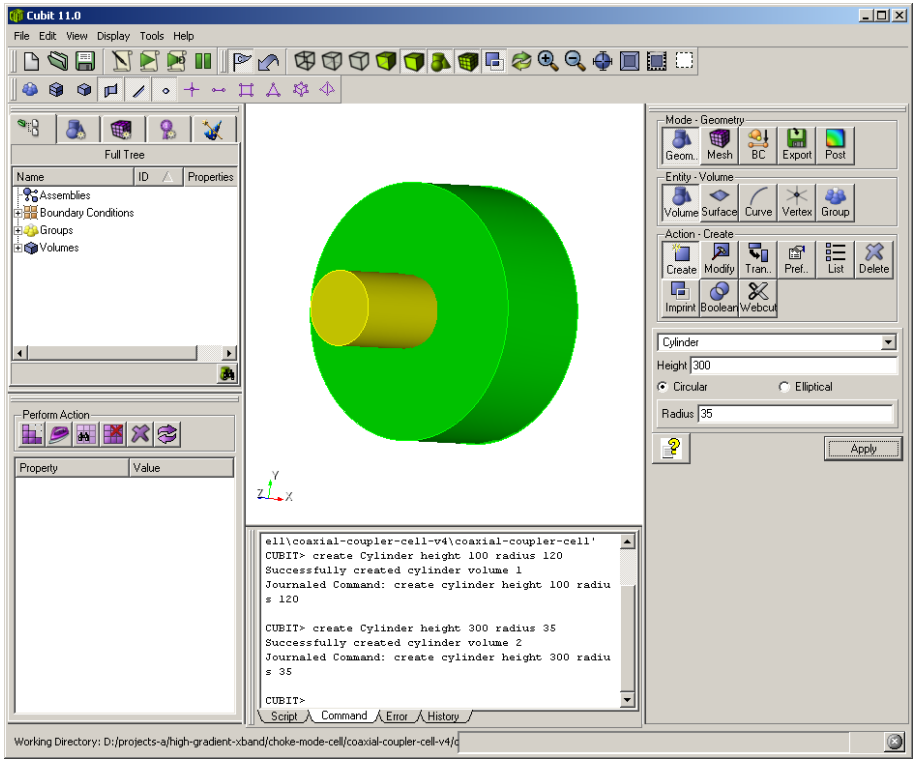
Insert Selection - Add a new selection without changing existing selection

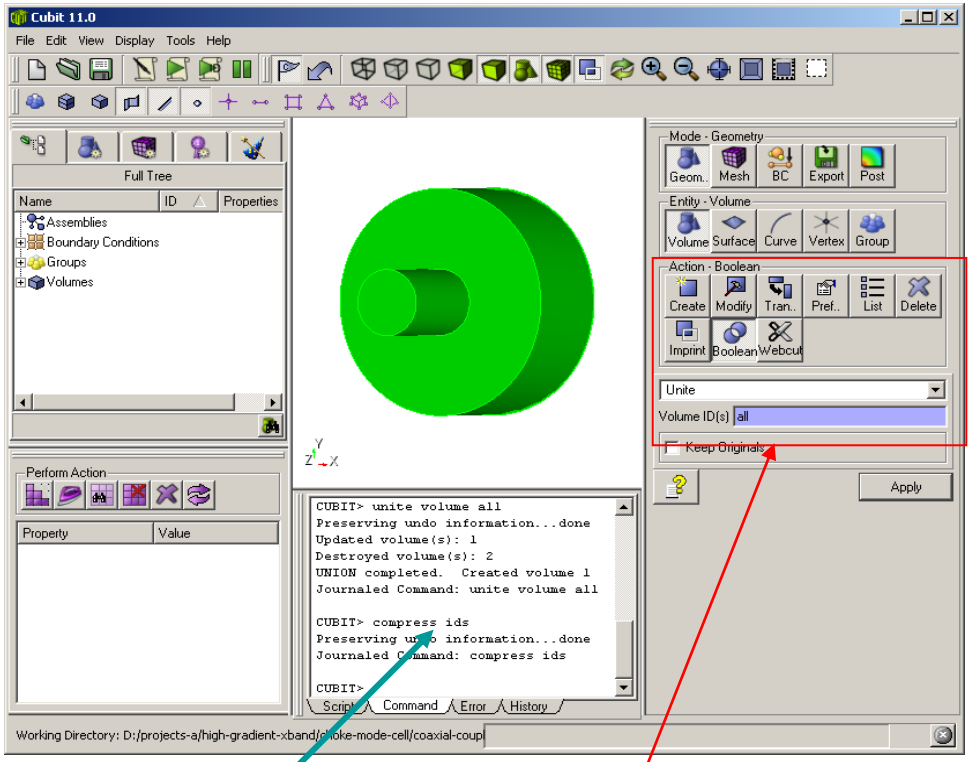
Reject Selection – Removes most recently added id

Select All – Select all input type entities

Clear Selections – Remove all ids from input field

Adding beam pipe to pillbox cavity

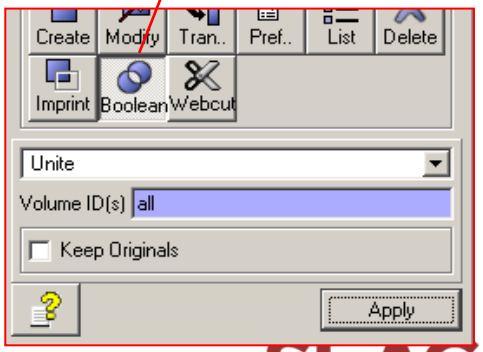




Pill box:
Height = 90
Radius = 100

New cylinder:
Height = 300,
Radius = 35

- Use "Boolean" to "Unite" "all"
- Then type "compress ids" In command window



Good to compress ids after "unite" or "delete" entries

CW10

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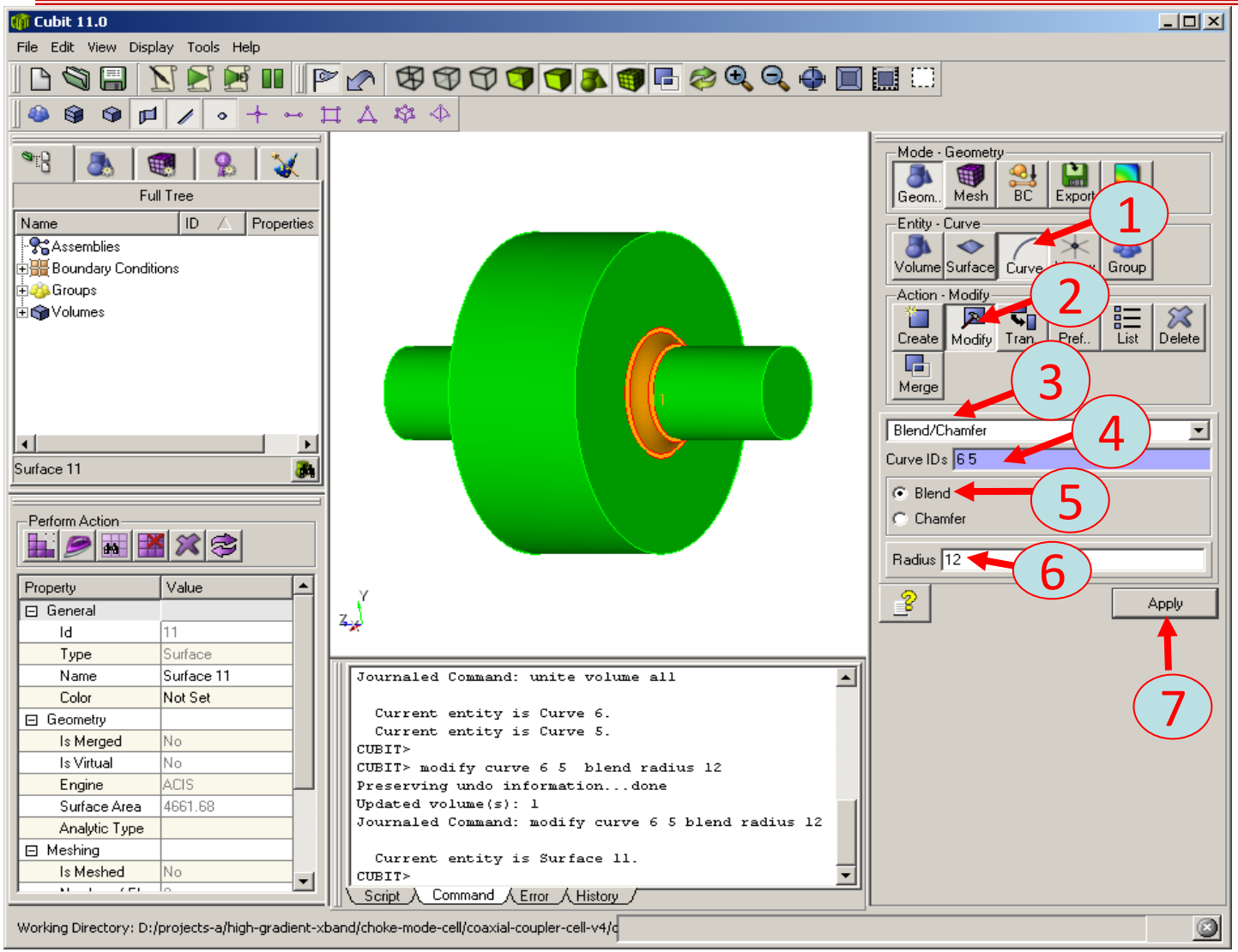
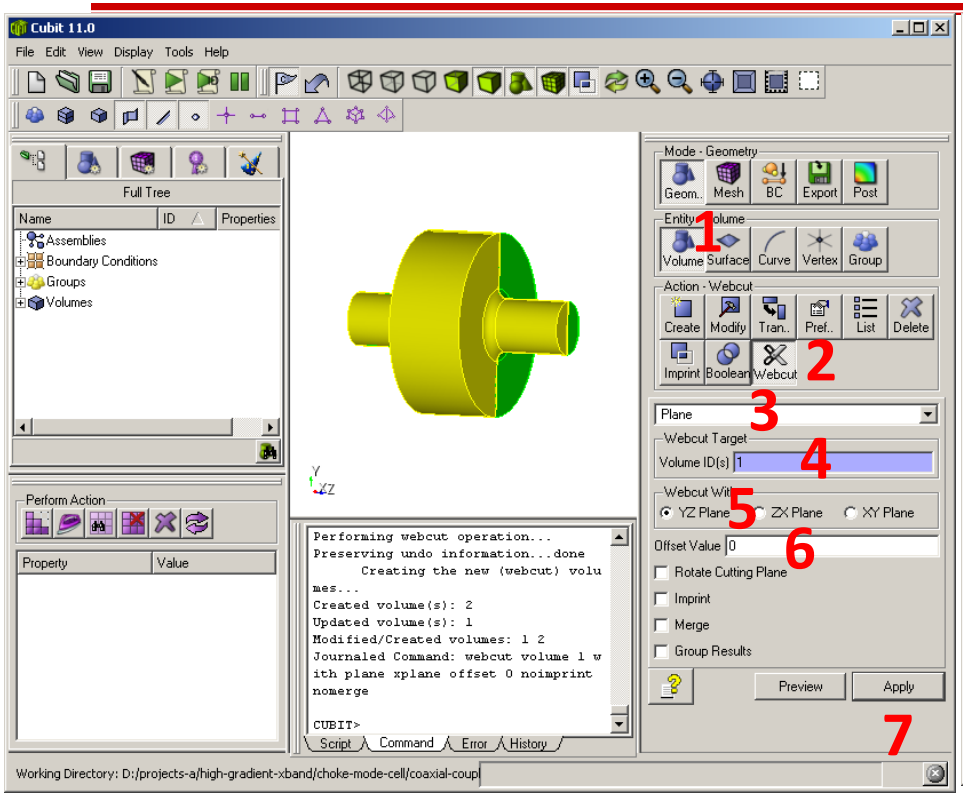
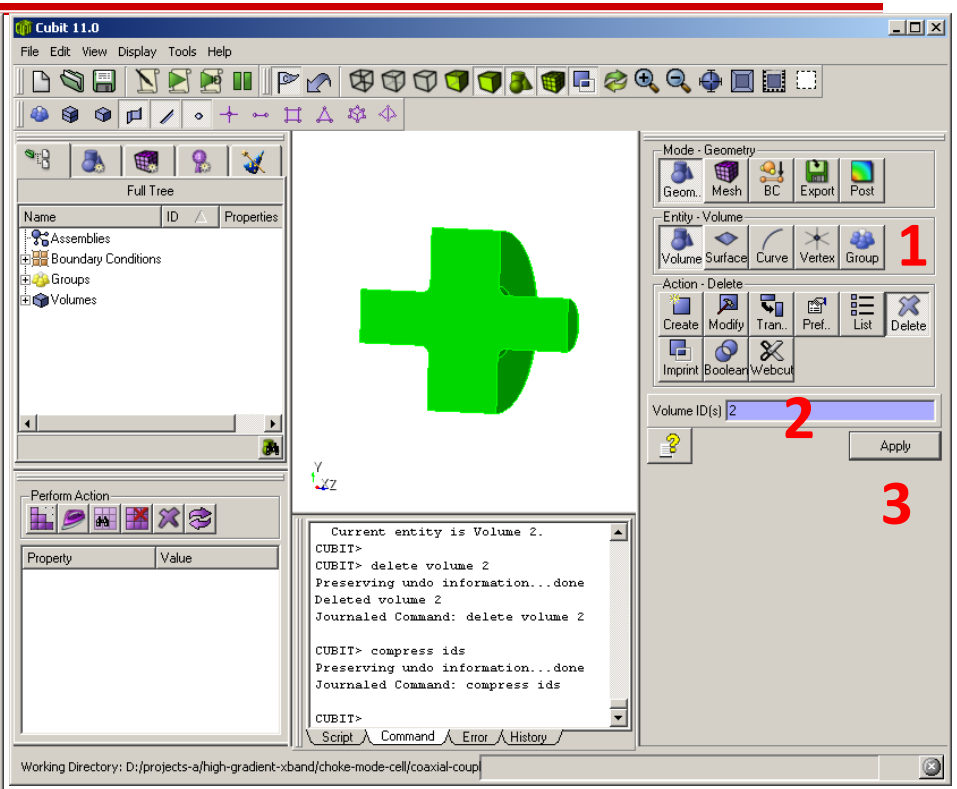
Rounding the Iris of the pillbox with beampipe



1. Curve
2. Modify
3. Blend/Chamfer
4. Curve IDs [5 6]
5. Blend
6. Radius
7. Apply

Use symmetry to reduce ½ of the cavity





1. Volume
2. Webcut
3. Plane
4. Volume IDs [1]
5. YZ Plane
6. Offset Value [0]
7. Apply

1. Delete
2. Volume ID [2]
3. Apply

"compress ids" in command window

CW10

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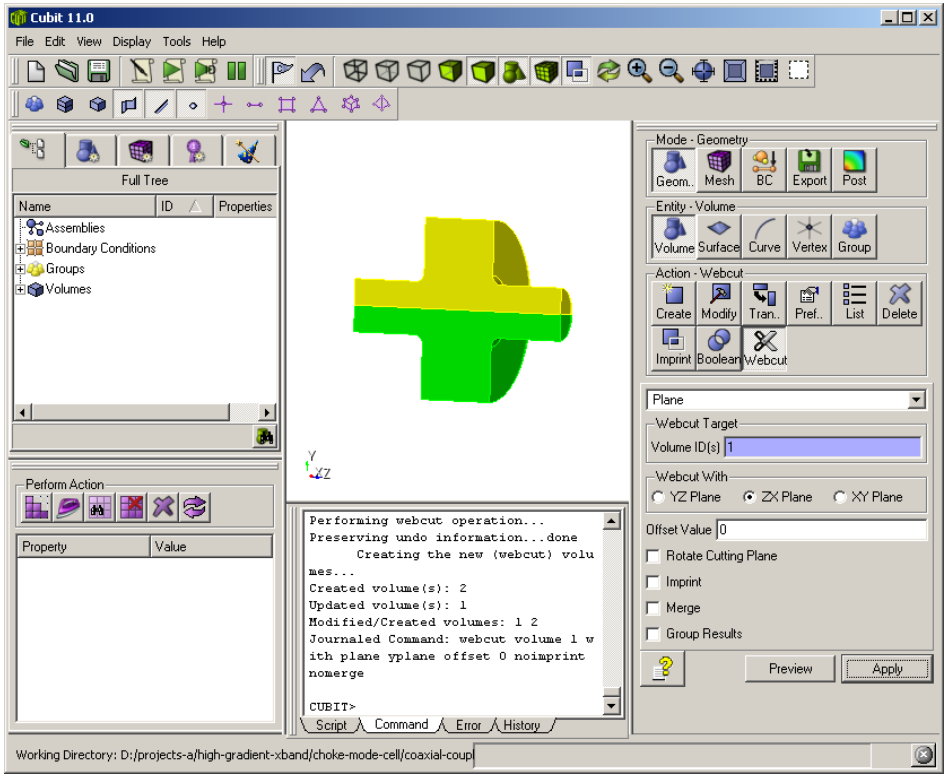
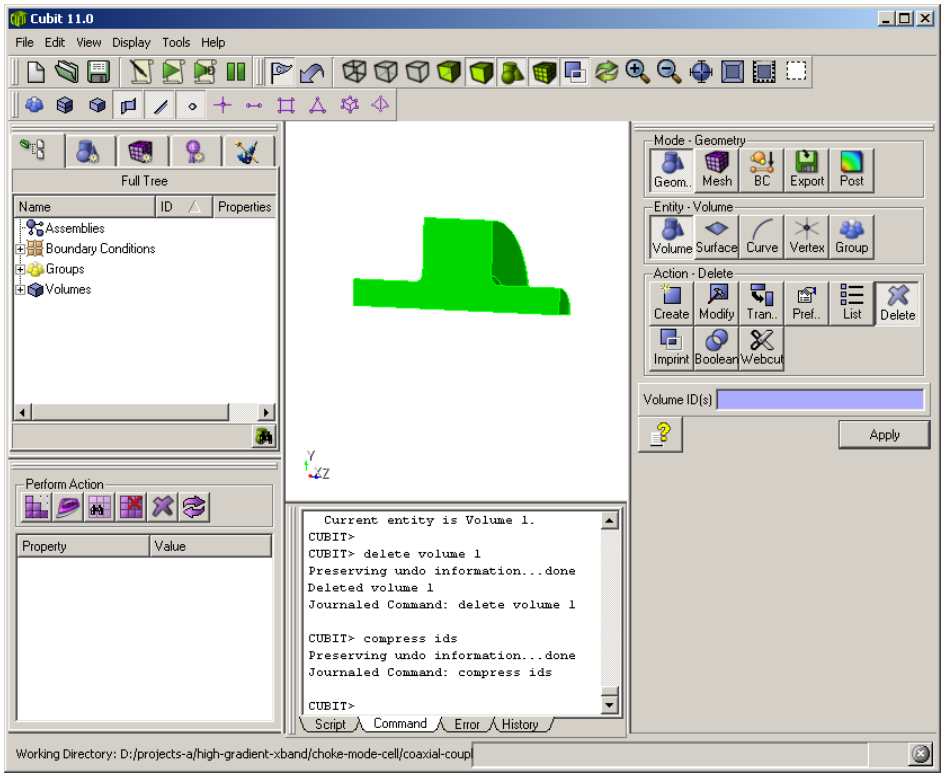
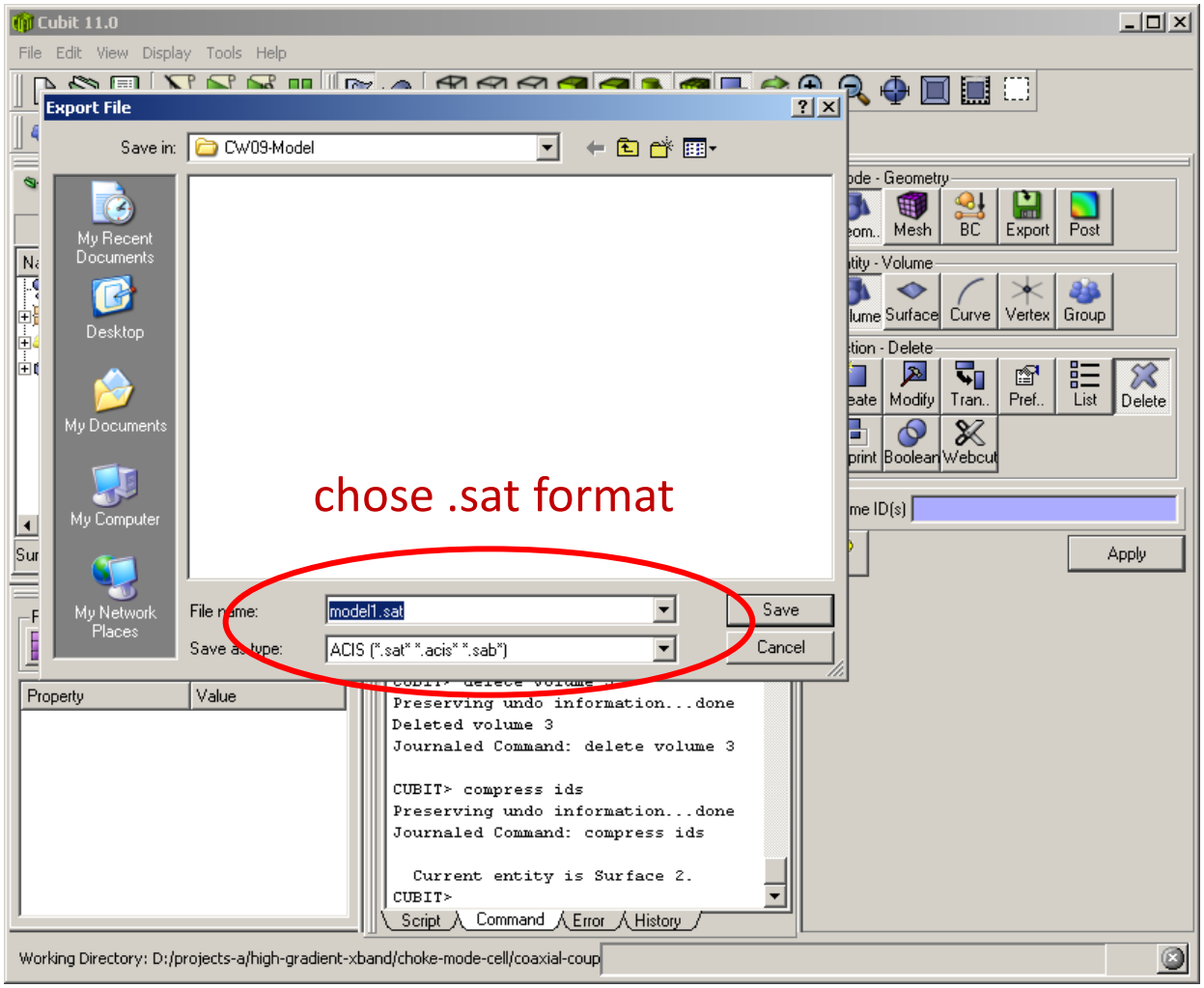
Reduce to ¼ with Webcut, XZ Plane and Delete





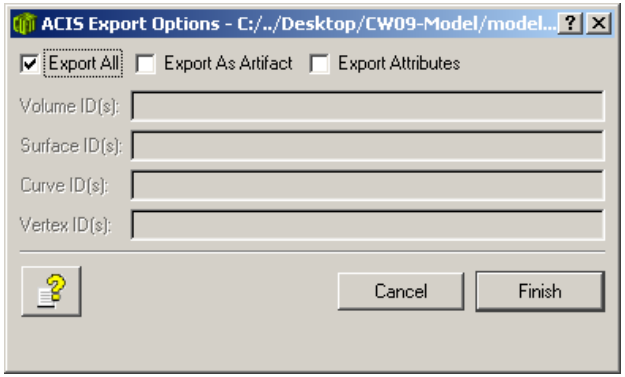
"compress ids"

Save the Model in ACIS (.sat) Format

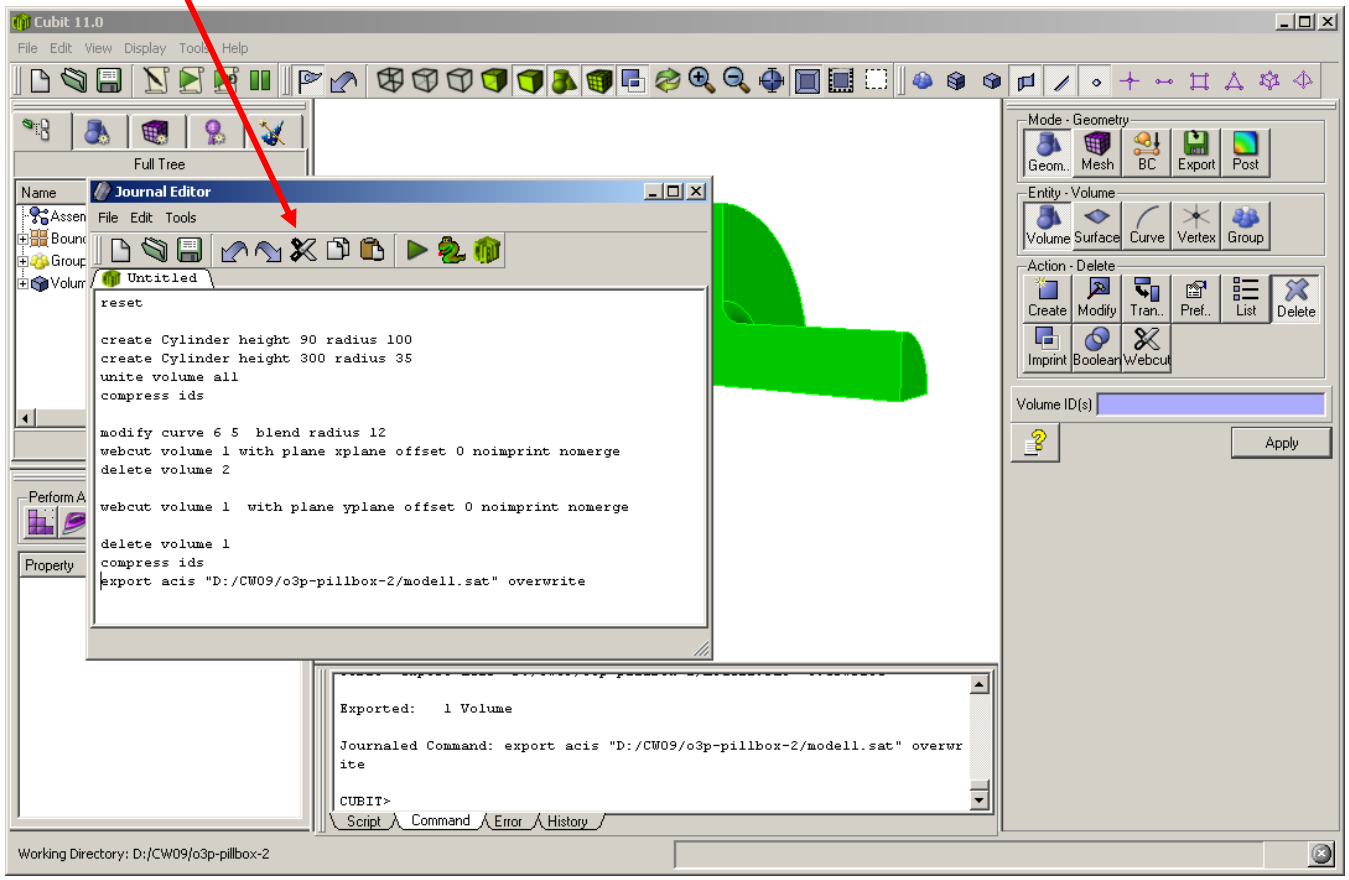


1. File
2. Export
3. Save

4. Finish



Journal Files



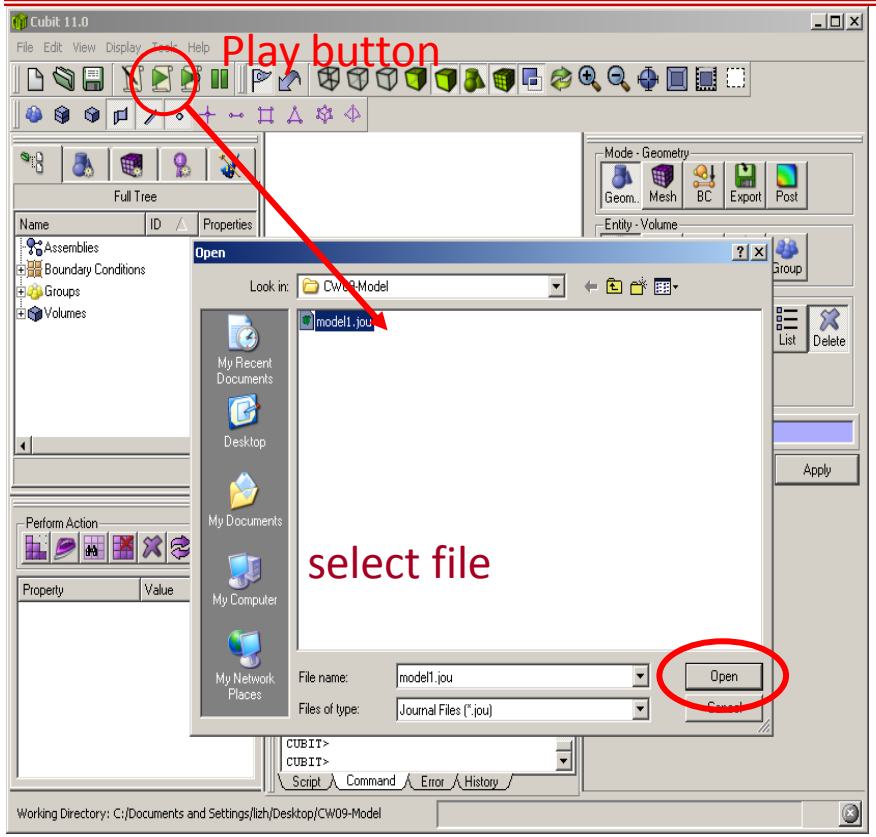
Tools
->Journal Editor

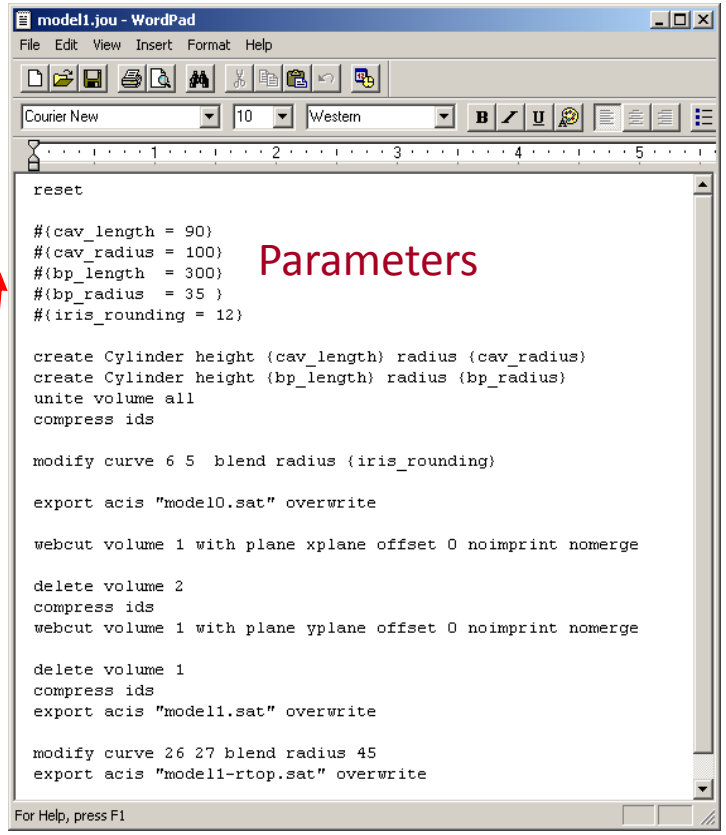
In Journal Editor window
-> File
-> Import
-> From "Command Tab"

Then save to a file (.jou)

"reset" at top is added to clean up the workspace when "play" the .jou file (see next page)

Same **CUBIT** Model with Parameterized **Journal File**





1. Have model1.jou saved
2. Click the “play” button
3. Select the .jou file
4. Open -> will run through commands in .jou file, model generated

Define Variables #{cav_length = 90} #{cav_radius = 100}
Create Cylinder height {cav_length} radius {cav_radius}

Replace numbers with variables in { } brackets

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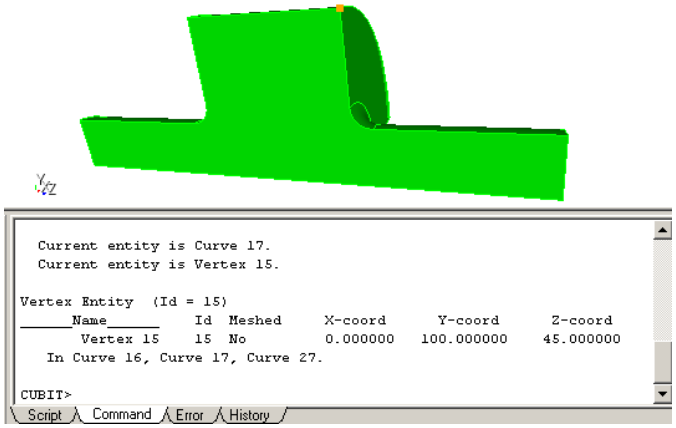
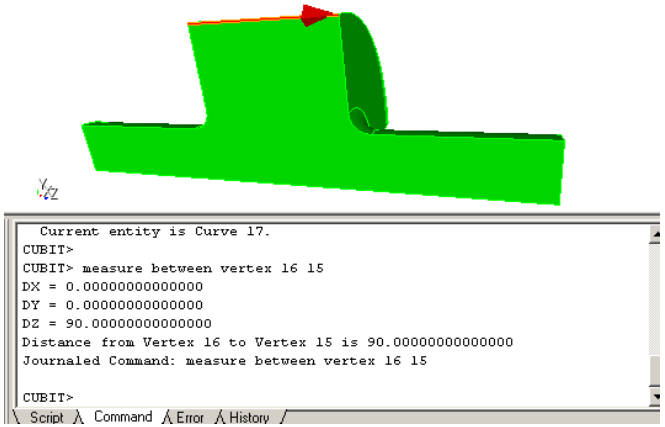
Checking Model Dimensions

- Find coordinate of a vertex
  - Select Vertex Filter
  - Pick a vertex
  - In command window: type “list vertex <#>”
    - Lists the coordinate



- Measure distance
  - Pick two vertices
  - Right click window area and chose “measure”
  - Distance is shown in command window



- Measure length of line segment
  - Select Line Filter
  - Pick a line
  - Right click window area and chose “measure”

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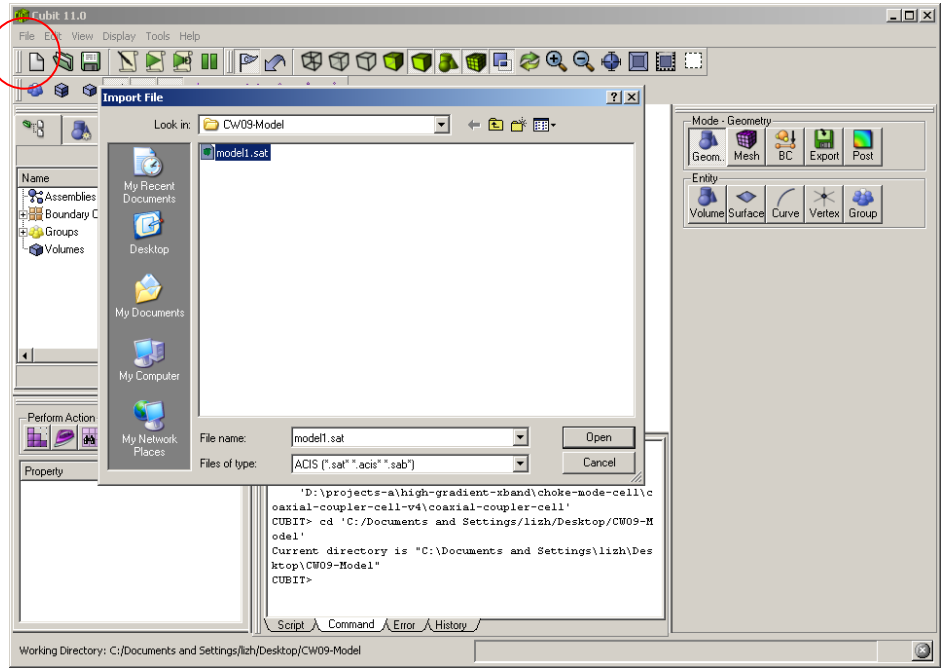
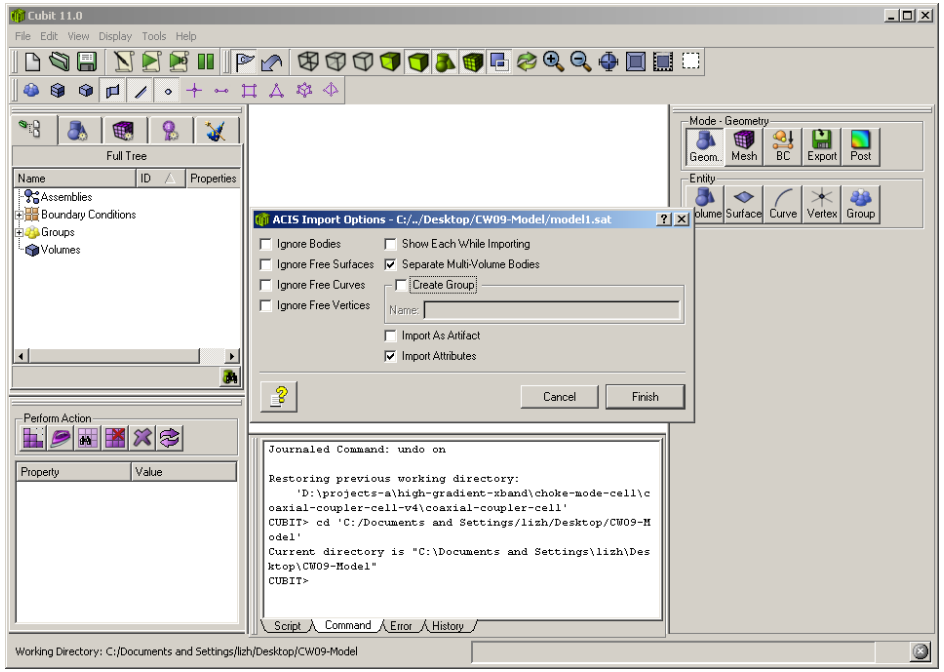
Meshing with **CUBIT** GUI

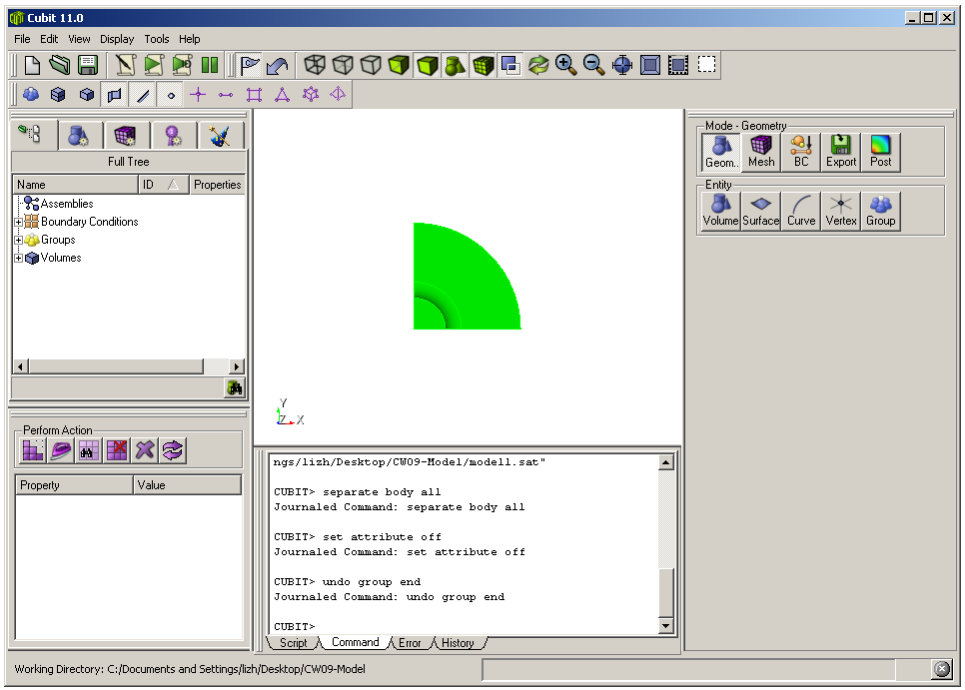


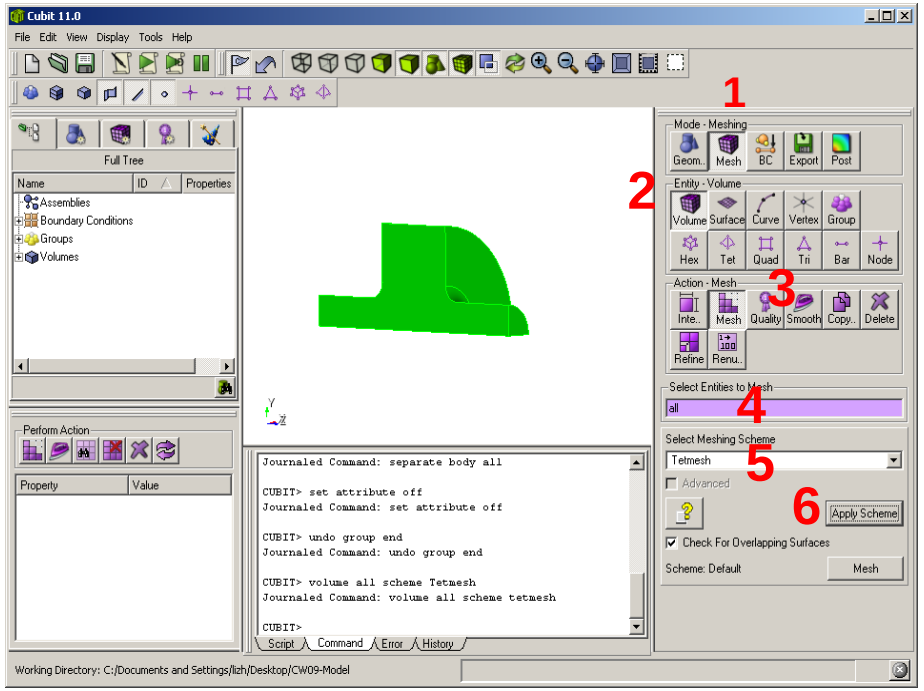


- Import solid model (model1.sat, e.g.)
- File
  - -> Import
  - -> click the file name (in default directory)
  - -> Open

Select “Separate Multi-Volume Bodies”

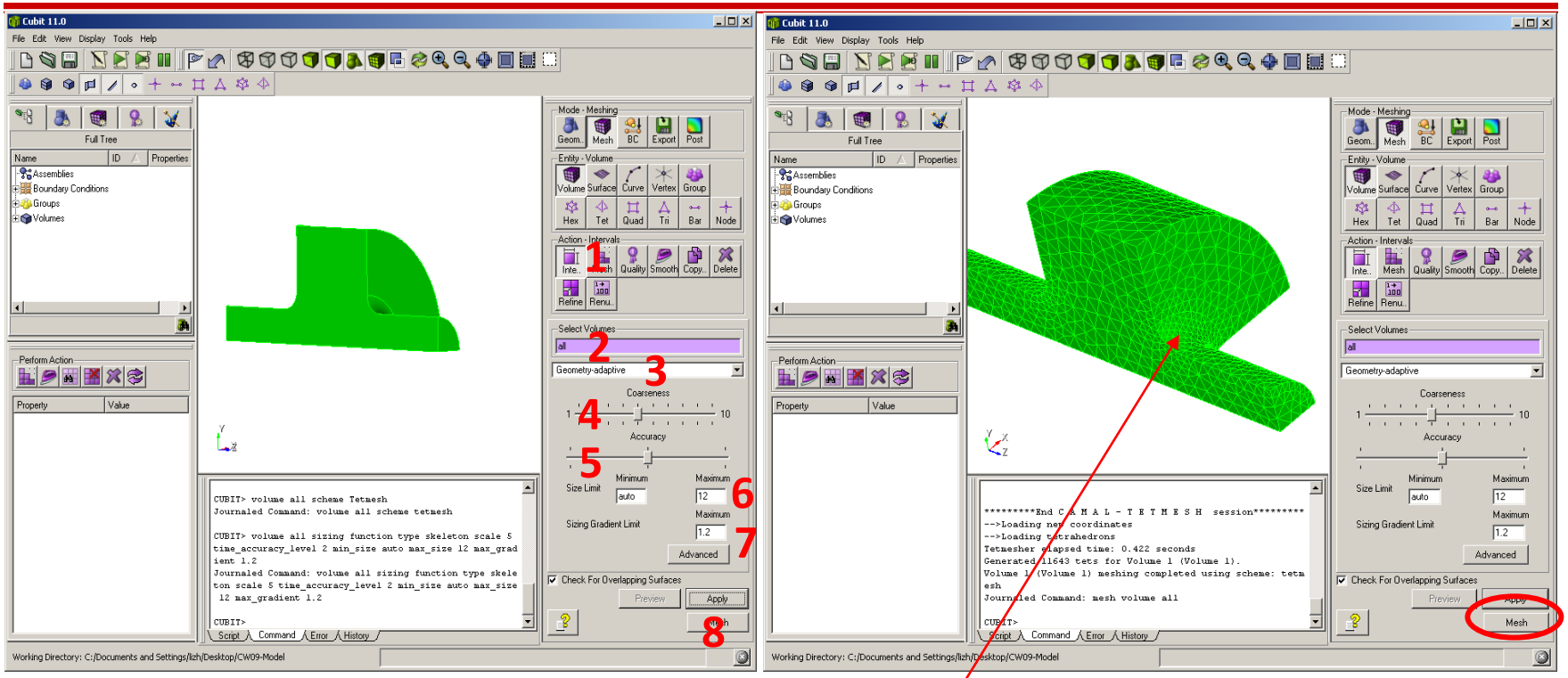
Import Solid Model & Choose Tetmesh





1. Mesh
2. Volume
3. Mesh
4. Select Entries to Mesh {all}
5. Select Meshing Scheme {Tetmesh}
6. Apply Scheme

Set Element Size & Generate Mesh



1. Intervals
2. Select Volume {all}
3. Select {Geometry-adaptive}
4. Coarseness {5}
5. Accuracy – middle {=2}
6. Advanced:
7. Size Limit – Maximum->12
8. Sizing Gradient Limit {1.2}
9. Apply

Smaller mesh size around curved surfaces {adaptive}

Click "Mesh" to mesh

CW10

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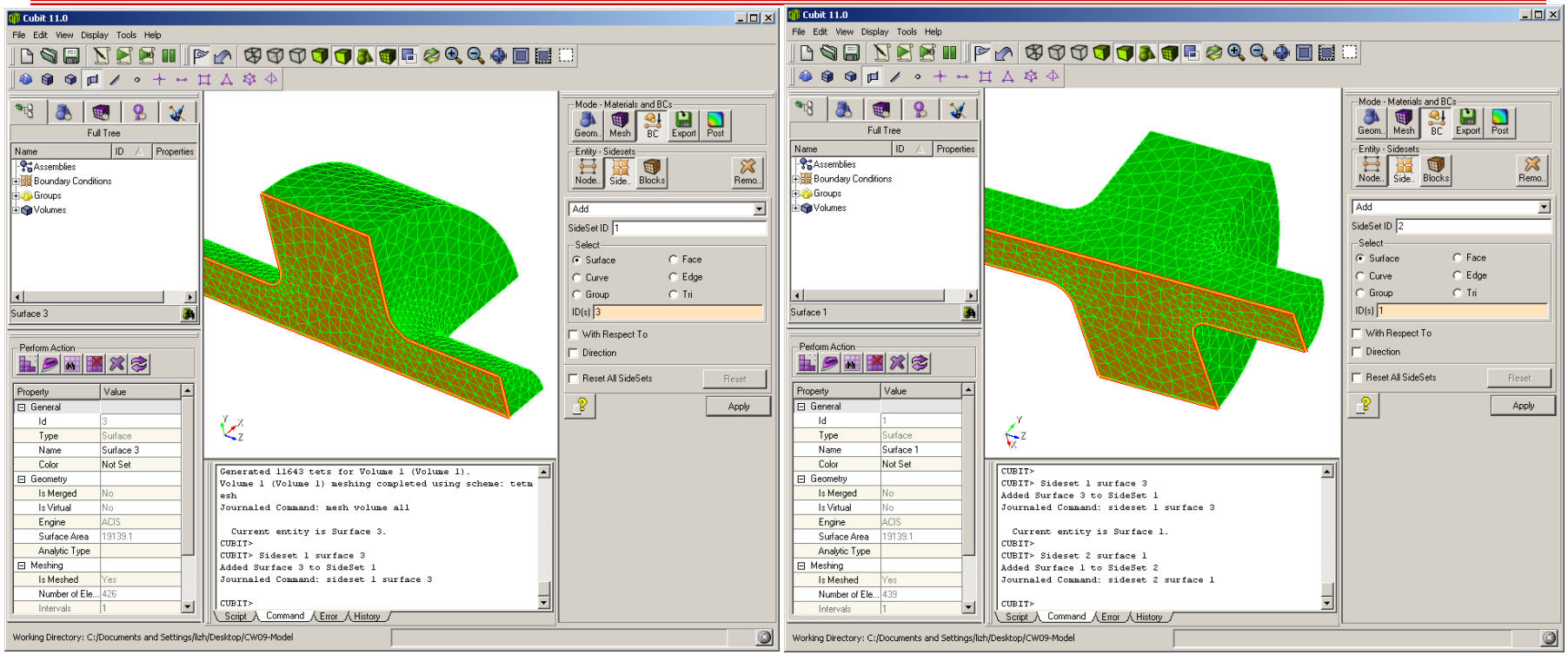
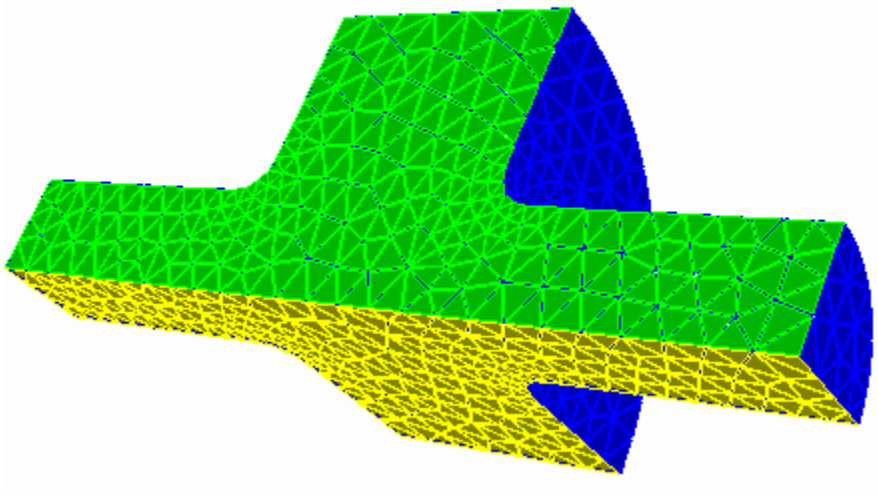
Apply BC at Interior & Exterior Surfaces

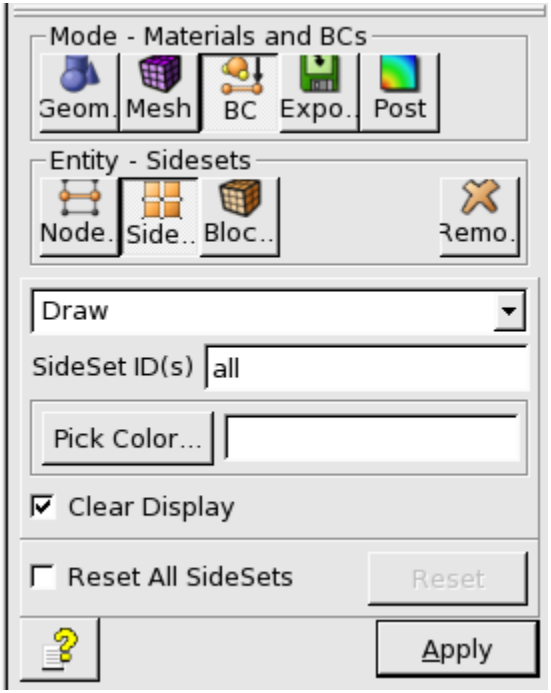


1. Add
2. SideSet ID {1}
3. Surface
4. IDs {all except 1 7}
   (all the surfaces except the two symmetry planes)
5. Apply

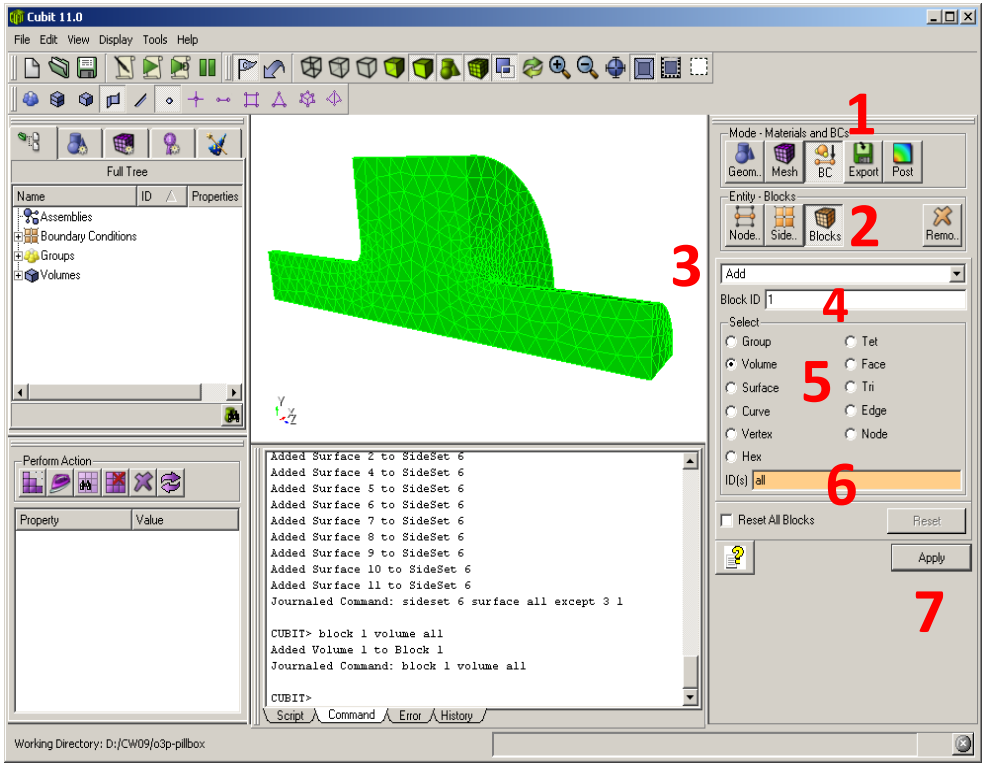
Check Boundary IDs

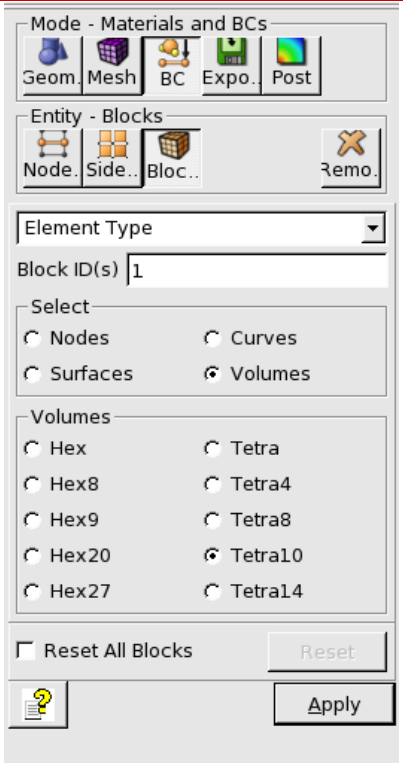
- Add surface 1 to sideset 2
- Add surface 7 to sideset 3
- Draw sidesets





Set “Block ID” for Material Attributes





Use 10-point Tet for curved elements

1. BC
2. Blocks
3. Add
4. 1
5. Volume
6. all
7. Apply

1. BC
2. Blocks
3. Element Type
4. Block ID(s): 1
5. Volumes
6. Tetra10
7. Apply

Tips

- One should set the BC sideset and material IDs (blocks) and “Element type” before the meshing command (enables mesh quality checking during meshing).

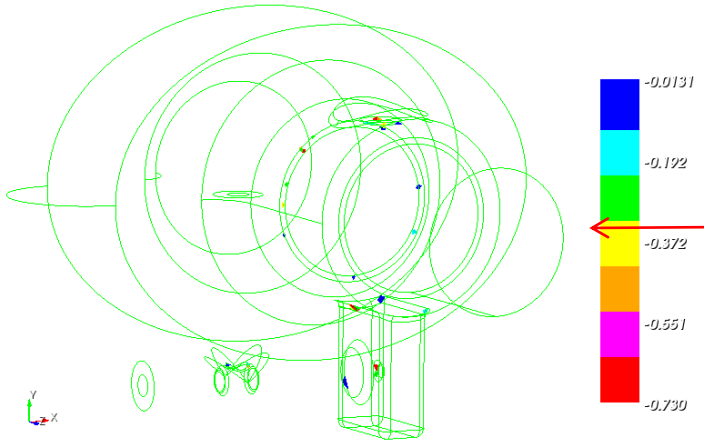
- But you can only “draw” the sideset “colors” after the mesh is generated.

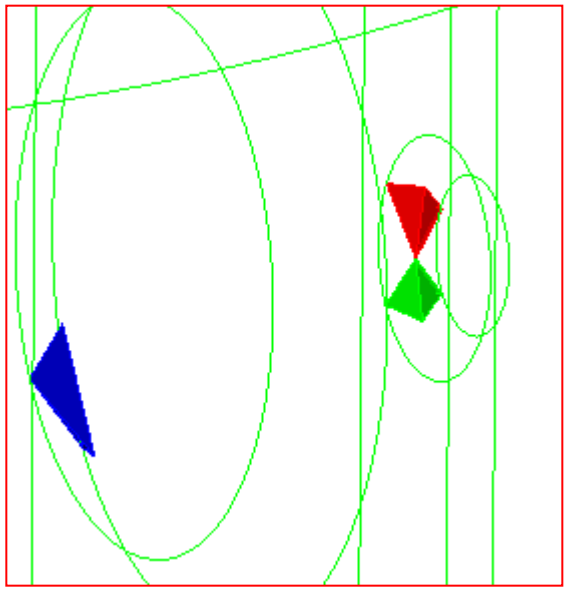
Check Mesh Quality

- Command (type in command window)

  quality vol all distortion

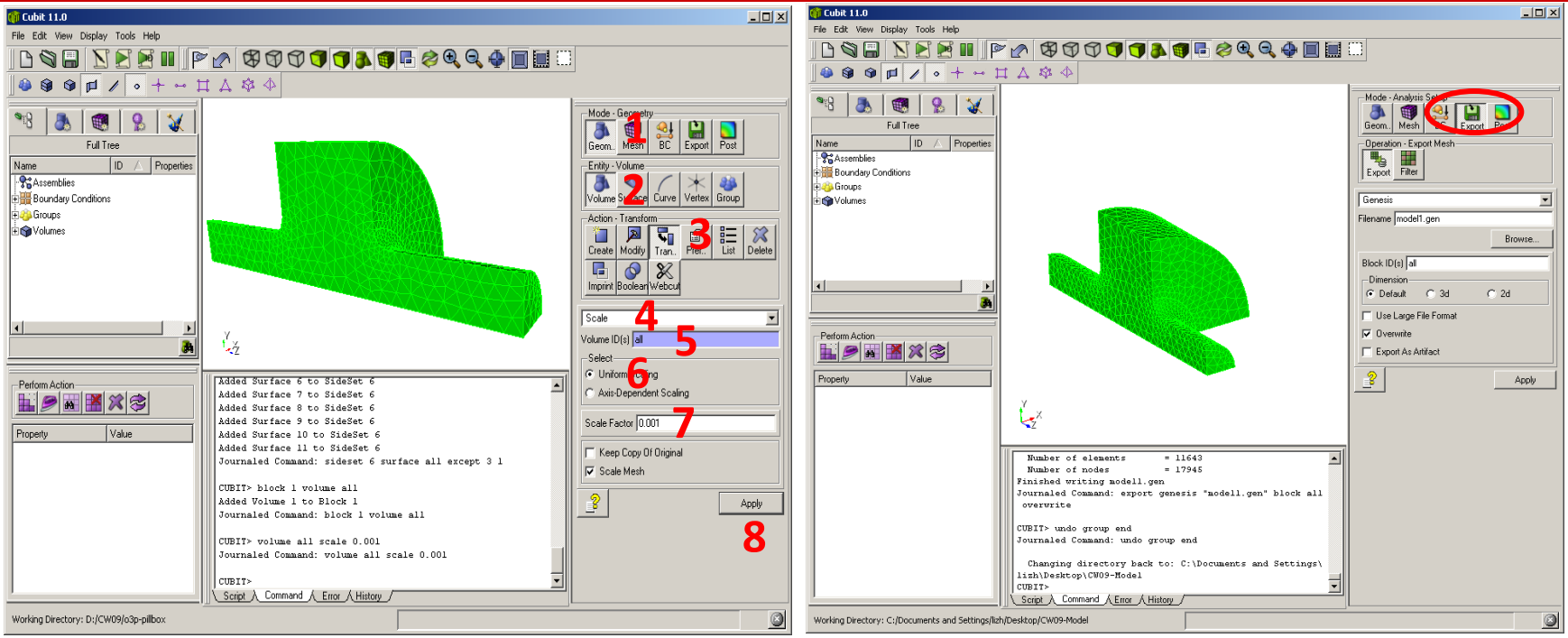
  quality vol all distortion high 0.0 draw mesh





```
CUBIT> quality vol all distortion

Volume 1 Tet quality, 162924 elements:
-------------------------------------
   Function Name    Average      Std Dev      Minimum   (id)    Maximum   (id)
 ----------------  ---------    ---------    -------------    -------------
      Distortion   9.867e-001   4.992e-002  -7.301e-001 (13379)   1.000e+000 (6234)
-------------------------------------

Journaled Command: quality volume all distortion

CUBIT> quality vol all distortion high 0.0 draw mesh

Volume 1 Tet quality, 31 elements:
   Distortion ranges from -7.301e-001 to -1.305e-002 (31 entities)
       Red ranges from -7.301e-001 to -6.277e-001 (4 entities)
    Magenta ranges from -6.277e-001 to -5.252e-001 (0 entities)
   DkYellow ranges from -5.252e-001 to -4.228e-001 (3 entities)
     Yellow ranges from -4.228e-001 to -3.204e-001 (4 entities)
      Green ranges from -3.204e-001 to -2.179e-001 (5 entities)
       Cyan ranges from -2.179e-001 to -1.155e-001 (6 entities)
       Blue ranges from -1.155e-001 to -1.305e-002 (9 entities)

Journaled Command: quality volume all distortion high 0 draw mesh
```

Scale Units



1. Geometry
2. Volume
3. Transform
4. Scale
5. “all”
6. Uniform Scaling
7. “0.001”
8. Apply

Use smaller units when creating the model and meshing, e.g. mm

Scale to meters for calculation - ACE3P uses standard units

CW10

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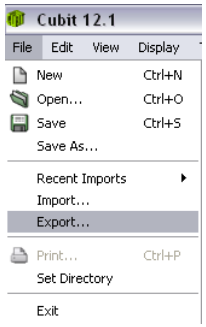
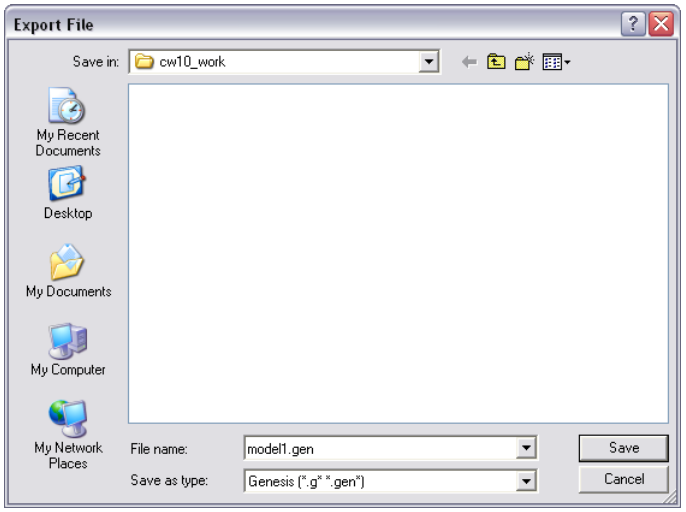
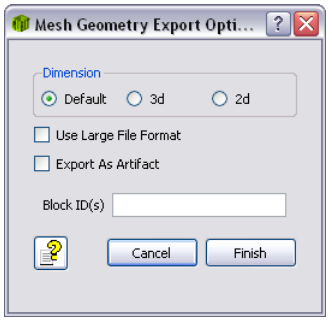
Export the Mesh

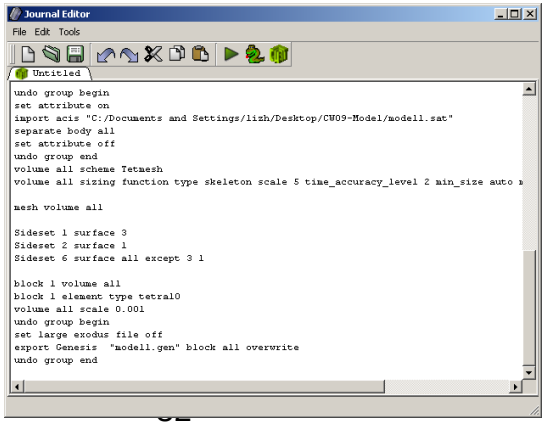
- File->Export
- Save as type: Genesis (*.g* *.gen*)
- Finish







- Import “Command tab” into Journal Editor



Convert and Check the Mesh

- In a terminal:
  - Convert Genesis file to NetCDF format for **ACE3P**

    acdtool meshconvert cubitq netcdf in.gen out.ncdf
  - Check mesh connectivity and quality

    acdtool mesh stats out.ncdf
  - Check for inverted tetrahedra (if Tetra10)

    acdtool mesh check out.ncdf
  - Straighten inverted tetrahedra (if Tetra10)

    acdtool mesh fix mesh.ncdf mesh_fixed.ncdf

acdtool mesh stats Output

TOTALS:
elements: 7530
coordinates: 1728

ASPECT RATIO:
min = 1.07028
max = 2.32866
average = 1.55955
std dev = 0.196946

SHAPE MEASURE:
min = 0.351915
max = 0.996323
average = 0.820372
std dev = 0.100069

ELEMENT VOLUME:
min = 7.59101e-09
max = 5.57899e-07
average = 1.20845e-07
std dev = 7.88559e-08

BOUNDING BOX:
min = (0, 0, -0.15)
max = (0.1, 0.1, 0.15)

EDGE LENGTH:
min = 0.00357312
max = 0.0227063
average = 0.0102788
std dev = 0.00300348

Euler Characteristic:
Surf Euler Char = 2
Vol Euler Char = 1
Euler Char is OK.

acdtool mesh check Output

```
**********************************************************************
Reading the mesh and midpoints ...
**********************************************************************

**********************************************************************
Check whether there are invalid quadratic tetrahedral elements...
**********************************************************************

**********************************************************************
Total Volume is 0.00133192
Total Number of invalid second order tetrahedral elements (ISOTE) is: 0
**********************************************************************
```

Mesh Verification & Convergence

- Smooth transition from coarse to dense regions
- Small feathers have good mesh representation
- Use “Draw sideset #” to check boundary setup
- **Do not** start with very dense mesh
- Start with a reasonable coarse mesh
  - Element size ~ 1/10 - 1/15 of wavelength
  - Smooth mesh on curved surfaces
- Refine the mesh to check accuracy
- Check mesh quality every time