

Crustal Deformation Modeling Tutorial

Introduction to CUBIT

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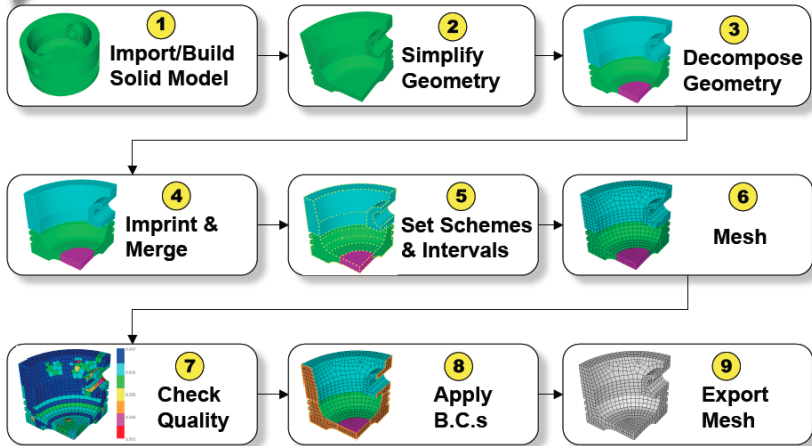


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- Developed by Sandia National Laboratory
 - GUI interface reduces learning curve
 - Inexpensive, \$300 acquisition fee for 5 years of updates/support
 - Scripting via Python and journal files
 - Trial version available from www.csimsoft.com
- Geometry engine
 - Construct domain geometry using simple, yet powerful tools
 - Spline surfaces and curves
 - Some support for mesh surfaces (e.g., triangular facets)
- 2-D and 3-D structured and unstructured meshes
 - Triangular cells
 - Quadrilateral cells
 - Tetrahedral cells
 - Hexahedral cells



The Basic CUBIT Process



Generating a Mesh

General workflow for using CUBIT with PyLith

- 1 Create the geometry
 - Build geometry from bottom-up (points-curves-surfaces-volumes)
 - Import geometry from other geologic models
- 2 Set the discretization size meshing scheme
- 3 Mesh the geometry
- 4 Specify the boundary conditions and materials
- 5 Export the mesh

- GUI
 - Interactive mesh construction
 - Constructing journal files and Python scripts
- Command line
 - Can be run in batch mode and with or without graphics
 - Useful for generating large and/or complex meshes
- Journal files and APREPRO
 - Enables scripting with variables and units
 - Limited to CUBIT commands and a few simple functions
- Python scripts
 - Generate CUBIT commands
 - Full capabilities of Python programming language
 - Restricted to Python interpreter distributed with CUBIT



Entity Types in CUBIT

Geometry Entities in CUBIT



Vertex



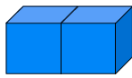
Curve



Surface



Volume



Body

Mesh Entities, which approximate geometry entities of same dimension



Node



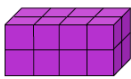
Edge



Face



Hex



Hex



Tri



Tet

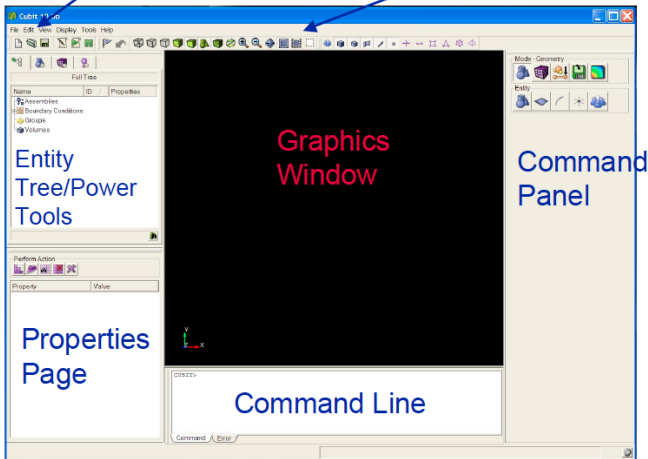
CUBIT Meshes **Vertices** First, Then **Curves**, Then **Surfaces**, Then **Volumes**
(Advancing Front Paradigm)





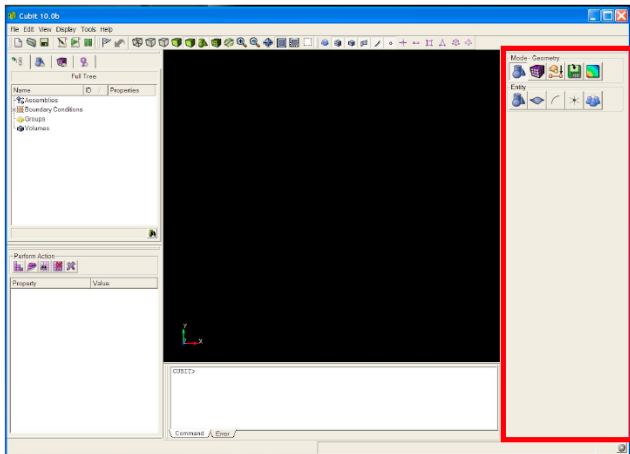
Drop Down Menu Commands

Toolbar
Commands



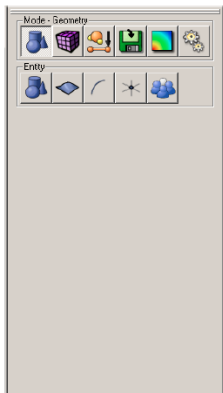


The Command Panel










Operation Mode Buttons



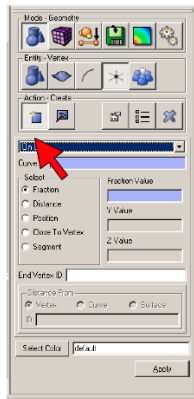
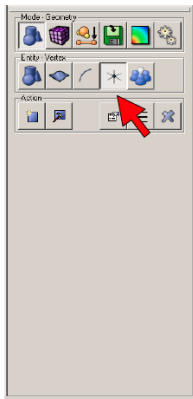
Press an Icon to enter a new mode

-  - Geometry: Create, modify, cleanup...
-  - Mesh: Intervals, schemes, smoothing...
-  - Properties: Nodesets, sidesets, blocks
-  - Analysis Setup: Export mesh
-  - Post Processing: Customizable shortcut



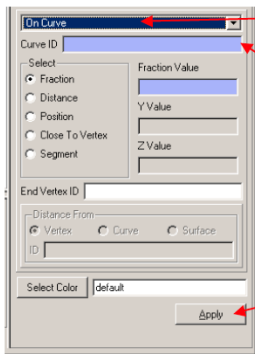
Operation Mode Buttons

Each Button press takes you to a lower level





Typical Dialog Layout



- **Drop Down Menu**

- Select the type of operation (sub-action).

- **ID Input Field**

- You can type IDs here, or fill the box by picking

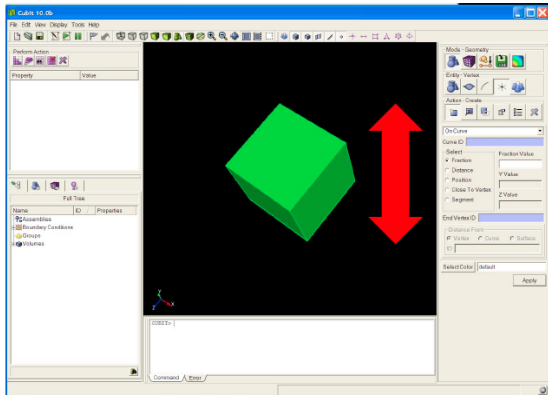
- **Command Options Input**

- **Execute Button**

- Click button or hit alt-a to execute the command.



Zooming

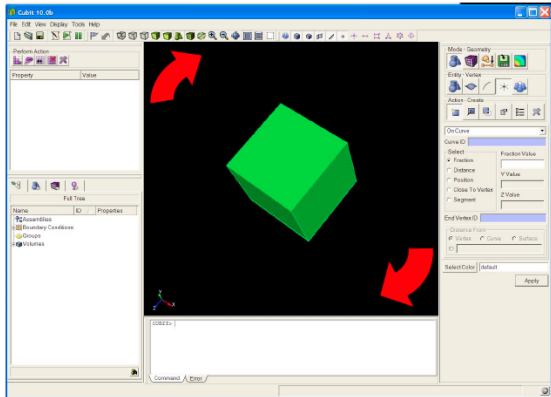


To zoom in and out, move the mouse into the graphics window, hold the right mouse button down, and move the mouse pointer vertically.





Rotate

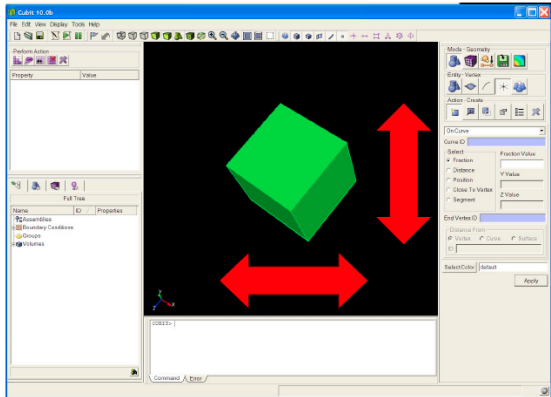


To rotate the model about an axis normal to the screen, move the mouse near the edge of the graphics window, hold the middle mouse button down, and move the mouse pointer along the edge of the window





Panning

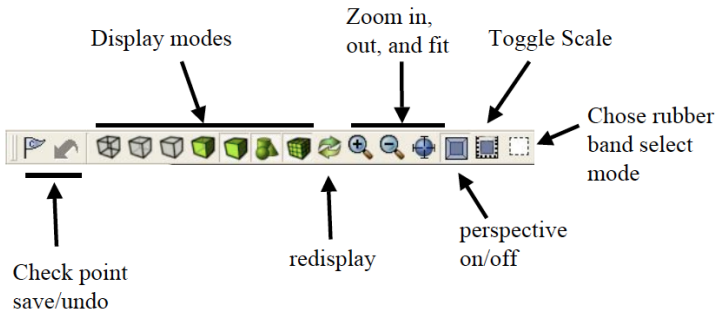


To pan, move the mouse into the graphics window, hold the left mouse button down, and move the mouse pointer horizontally or vertically.





Display Tool Bar





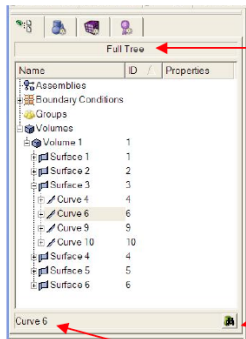
Entity Selection Filter



- **Toolbar buttons toggle entity types that will be included in pre-selection**
- **Default**
 - Volume
 - Surface
 - Curve
 - Vertex
- **Active ID Input field “hijacks” pre-selection so that only the expected entity type is selectable**



Using the Tree View



List Type

List View

Expand tree to show selected entity

Current Selection



Entering Commands

- **All commands can be entered in the command window**
- **Partial words OK**
- **Can use general ID ranges**
 - draw curve 1 to 5 except 4
 - draw curve in volume 2





Basic Aprepro Syntax



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- Aprepro expressions are wrapped in curly braces
- Aprepro evaluated first, results inserted into command:

Brick X {10}

And

Brick X {5*2}

Are Equivalent To

Brick X 10



Types of Functions



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- **Math Functions**

- $\sin(\text{num})$, $\cos(\text{num})$, $\text{asin}(\text{num})$, etc...
- $\text{sqrt}(\text{num})$, $\text{exp}(\text{num})$, $\log(\text{num})$, $\ln(\text{num})$, etc...

- **String Manipulation Functions**

- $\text{Quote}(\text{string})$, $\text{toupper}(\text{string})$, $\text{tolower}(\text{string})$

- **Utility Functions**

- $\text{Print}(\text{string})$, $\text{PrintError}(\text{string})$
- $\text{FileExists}(\text{string})$, $\text{HasFeature}(\text{string})$





Example 7 – Row Of Bricks

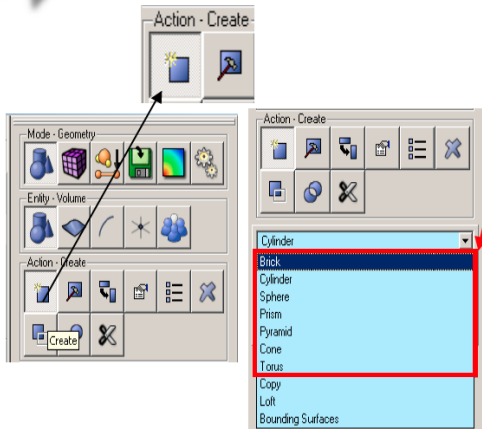


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```
# ***Set parameters***  
# {num_bricks=5}  
# {brick_size=1}  
#  
# ***Create the bricks***  
# {Loop(num_bricks)}  
  Brick Width {brick_size}  
# {EndLoop}  
#  
# ***Scoot them into a line***  
# {cur_brick = 1}  
# {Loop(num_bricks)}  
  Volume {cur_brick} move {(cur_brick-1)*brick_size}  
  #{cur_brick++}  
# {EndLoop}
```



Create Button

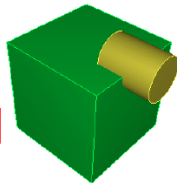
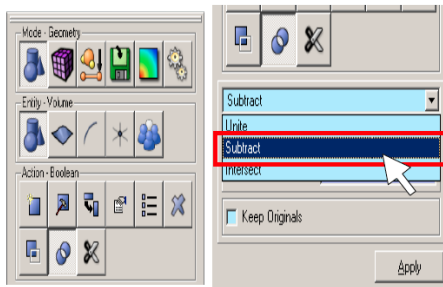


- **Geometry Primitives** are accessed with the **Create** button
- **Seven primitive types** are currently available
- **For command line syntax:**
 - CUBIT> help create

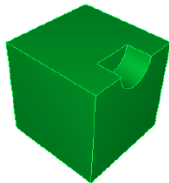


Subtract

- Removes regions that overlap



Before



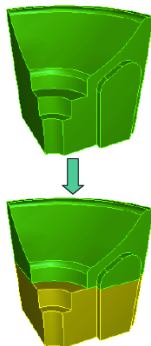
After

```
CUBIT> subtract body 2 from 1
```



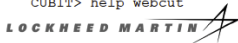
Webcutting

- **Webcutting slices 1 Body into 2 Bodies**
- **Many methods to determine where to make the slice**
 - Plane
 - Cylinder
 - Extended Surface
 - Intersection with "Tool" Body



For command line syntax:

```
CUBIT> help webcut
```





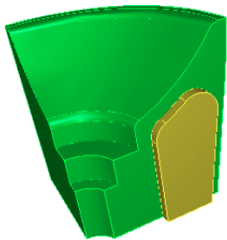
Imprinting

- **Modifies a Body based on what it touches**
- **Splits existing Curves and Surfaces at points of contact**
- **Imprinting is a necessary step to allow adjacent Bodies to share common boundaries**

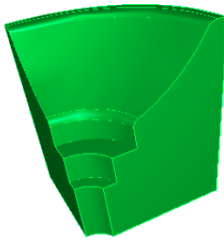




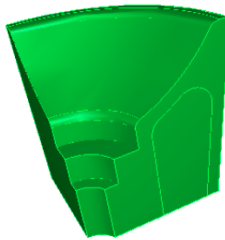
Imprinting



Body 1 and 2



Body 1
before imprinting



Body 1
after imprinting



Surface Meshing Schemes

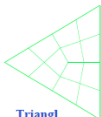


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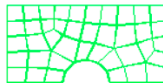
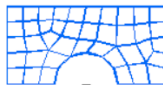
CUBIT Provides a number of different surface mesh schemes. Choosing the best scheme depends on the shape and number of curves in the surface. Your choice also depends on how you plan to mesh the volume.

• Surface Schemes

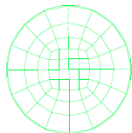
- Map
- SubMap
- Pave
- Triangle Primitive
- Circle Primitive
- Pentagon Primitive
- Morph/Mirror
- TriMesh



Triangle



Copy/Morphing



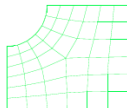
Circle



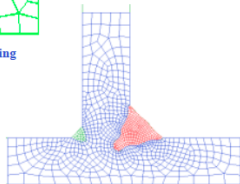
Map



SubMap



Pentagon



Pave





Volume Meshing Schemes

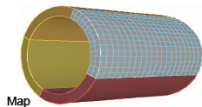


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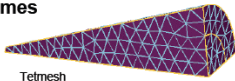
CUBIT Provides a number of different volume mesh schemes. Similar to Surface Scheme Selection, Volume Scheme Selection is based on the shape of the geometry.

Run mesh demo

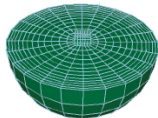
Example Volume Meshing Schemes



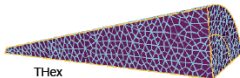
Map



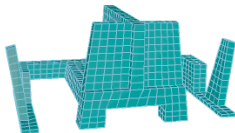
Tetmesh



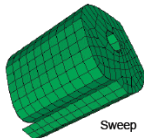
Sphere



THex



Submap



Sweep



Polyhedron



Materials and Boundary Conditions



- Blocks = materials

```
block 1 volume foot_inner
```

```
block 1 volume 1 to 8
```

```
block 1 name "foot_walls"
```

- Nodesets = groups of nodes for boundary conditions and faults

```
group "fault" add node in fault_inner
```

```
nodeset 10 group fault
```

```
nodeset 10 name "fault"
```

- Export mesh

```
export mesh "out.exo" dimension 3 overwrite
```

- In pylithapp.cfg

```
[pylithapp.mesh_generator]  
reader = pylith.meshio.MeshIOCubit  
reader.filename = out.exo
```

- Can select multiple entities at once in many ways
 - draw volume `all with x_coord > 0.0`
 - curve `all in volume 1 to 3 5` visibility off
- Use tree view and info panel (or Python) to find names/numbers/geometry information
- Make sure to
 - “reset” between tests/runs
 - Merge/Imprint all entities before meshing
- Journal files and APREPRO
 - Use journal files to save commands
 - Use APREPRO for units and variables
 - Every command is echoed in the command panel (copy/paste into journal files)

CUBIT Resources

- CUBIT website, cubit.sandia.gov
 - User manual
 - Tutorials (geometry with cones, prisms, spheres, etc)
 - Support via email
- CIG website
 - Slides from past CUBIT tutorials at Crustal Deformation Modeling workshops
www.geodynamics.org
 - Community
 - Working Groups
 - Short-Term Crustal Dynamics
 - Workshops
 - Example files
 - Some support for mesh surfaces (e.g., triangular facets)
- GeoCUBIT developed by Emanuele Casarotti
 - Python scripting of CUBIT for SPEC-FEM3D
 - Available from CIG code repository