

# Coreform Cubit Decomposition Tutorial

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## Creating Sweepable Volumes Through Webcutting

Most volumes require some measure of decomposition before they can be meshed with a hexahedral meshing scheme. The most common hexahedral meshing tool is the sweeping algorithm. Sweeping is the process of creating a hexahedral mesh by extruding a quadrilateral surface mesh from a source surface onto a topologically similar target surface by way of a linking surface. The surface mesh can be meshed with any surface meshing scheme (i.e. structured or unstructured mesh), but the most common surface meshing scheme for the sweeping algorithm is the pave scheme. In fact, the sweeping algorithm is sometimes called the "pave-sweep" algorithm. Most volumes aren't automatically sweepable, which is why geometry decomposition is so important to the meshing process. Decomposition usually involves a series of webcutting, boolean, and virtual geometry operations that break up a larger model into sweepable regions. Studies have shown that this step in the meshing process is the most time consuming for the analyst.

By completing this tutorial you will learn how to:

1. Recognize sweepable volumes
2. Recognize how to decompose a model into sweepable parts
3. Gain proficiency with webcutting and other decomposition techniques
4. Avoid common pitfalls with decomposition and sweeping

## Why use sweeping?

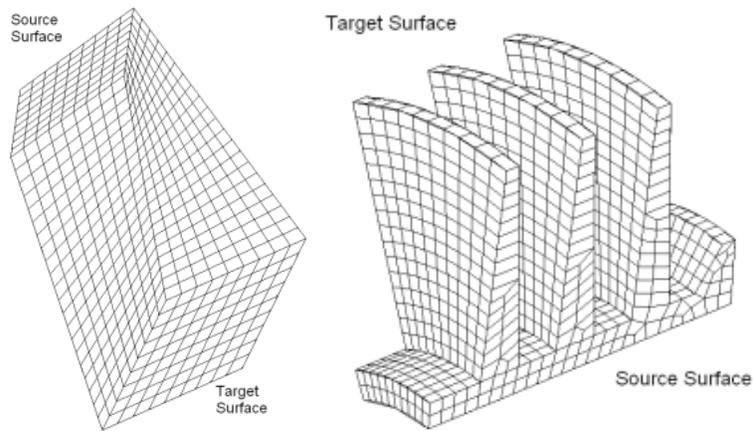
Of all the hexahedral meshing schemes in the Coreform Cubit toolkit, sweeping is considered the most reliable at producing high quality elements. Although decomposing a model into sweepable volumes can be time-consuming, and sometimes falls into the realm of trying to fit a square peg into a round hole, the pave-sweep algorithm has a high rate of success, and it sometimes the only way to get a hexahedral mesh on a model.

## What makes a volume sweepable?

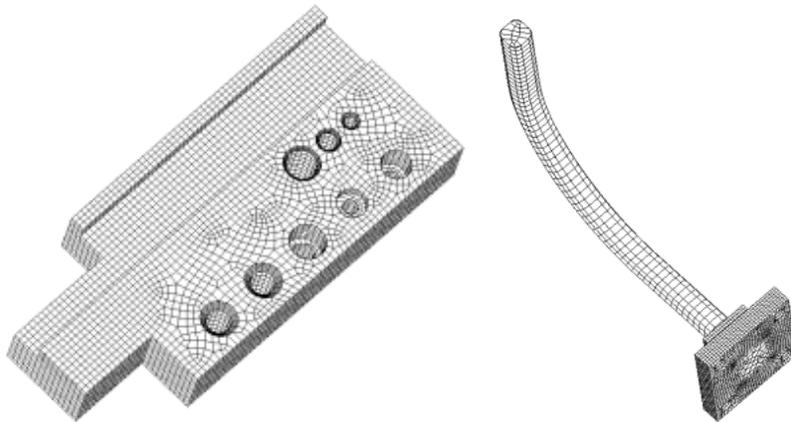
Recognizing sweepable topologies can be an art form. Sweepable volumes can be comprised of many different topologies. We typically classify sweeping problems into three groups, based on the number of source/target surfaces.

## Basic Sweep Groups

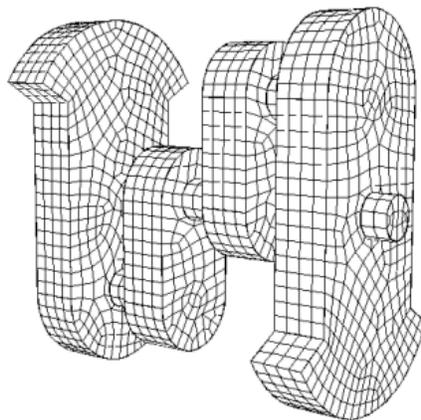
**One-to-one:** A volume with a one source surface and one target surface.



**Many-to-one:** A volume with multiple source surfaces and one target surface



**Multisweep (or Many-to-Many):** A volume with multiple target surfaces

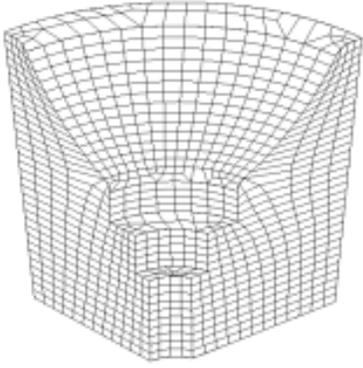
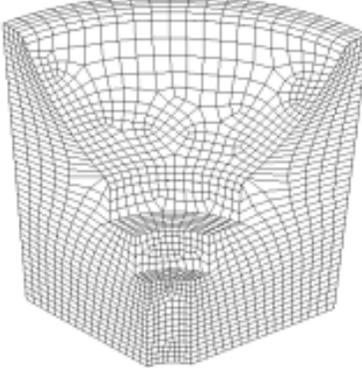
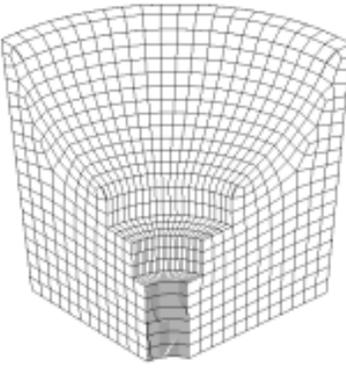


## Points to consider when determining whether a volume is sweepable

- Swept surface meshes can be extruded through a volume which is rotated or translated. However, if the translation/rotation is severe then the quality of the resulting mesh may be poor.
- A volume with multiple target surfaces and a single source surface can sometimes be inverted and handled as a many-to-one sweepable volume. Otherwise, it is treated as a multisweep problem.
- Imprinting introduces new topology onto surfaces. Sweepable volumes may not be sweepable after imprinting and merging adjacent surfaces
- Multisweep is still under development, and has limitations, so if you are having difficulty with the multisweep algorithm, it is usually a good idea to decompose it into many-to-one or one-to-one sweepable regions.
- Coreform Cubit won't always automatically recognize your volume as a sweepable volume, even if it is. Sometimes, you have to give it a list of source/target surfaces explicitly.

## Basic Sweep Paths

In addition to the different topologies, sweepable volumes can be classified by the sweep direction. These include: top-to-bottom, inside-to-outside, and around (rotational). Be sure to consider all the possibilities for sweep directions when you begin decomposing a model. And keep in mind that sweep paths must be compatible with adjacent volumes. To be compatible, overlapping surfaces must have the same scheme (i.e. both must be a linking surface or a paved surface). The volume below is meshed three different times with the three different sweep directions. Notice the difference in element sizes and orientations between the meshes. See if you can pick out the different source and target surfaces in each example. As an exercise, try to mesh this model with each of the different sweep paths.

		
Top-to-Bottom	Inside-to-Outside	Around (Rotational)
Many-to-one	Many-to-one	One-to-one (this is the default sweep direction for this model)

## What are some good strategies for decomposing my model?

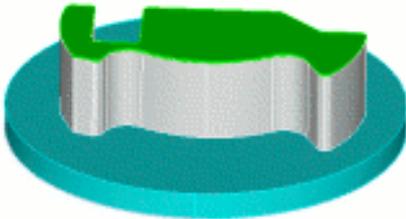
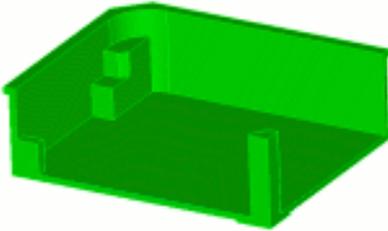
Recognizing when a volume is sweepable is a difficult task, but being able to come up with viable webcutting, compositing, and boolean strategies to make a volume sweepable is even more difficult, and can only be achieved through practice.

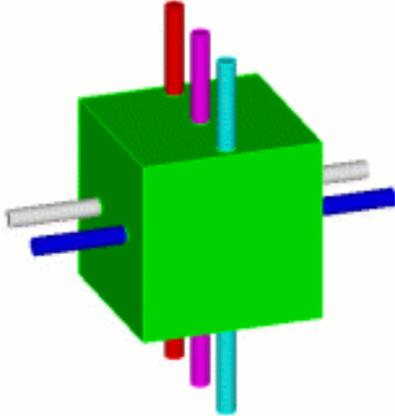
## General Principles to follow when decomposing a mode

- Select your Sweep path
- Use as few webcuts as possible
- Set your own source and target surfaces if Coreform Cubit does not pick them automatically
- If one of your volumes does not mesh, or has an undesirable mesh, try changing the order in which you mesh volumes. This will hard set the intervals on the volumes.
- The Reset Volume command will remove all schemes and interval settings from volumes.
- If changing the mesh order or resetting the volumes does not work and you continue to get “Matching Intervals Failed” errors, set explicit intervals on some or all curves.
- Make additional webcuts if necessary.
- Check for sliver surfaces or curves that may have been introduced during decomposition and remove these through tweaking, collapsing, or compositing.
- Change surface vertex types on mapped or submapped surfaces if you need to force a certain configuration
- Use partitioning to introduce virtual geometry constraints without affecting the underlying geometry.
- Composite surfaces to remove constraints without affecting the underlying geometry
- Save your work often. For a complex model, the meshing process can be very iterative. You may need to start over many times until you find an acceptable solution.

## Decomposition Examples

The following is a compilation of several different decomposition problems of varying difficulty. If you accessed this help from the Coreform Cubitprogram (as opposed to the web documentation), you will need to browse for the geometry files.

Beginner Decomposition Examples		
Example	Image	File
Sweeping through multiple adjacent volumes		example01.sat
Interlocking rings		example02.sat
Webcutting using the "sweep" option		example03.sat

<p>Using the loft command</p>		<p>example04.sat</p>
<p>Multiple sweep directions</p>		<p>example05.sat</p>

## Beginner Decomposition Examples

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### Example 1. Sweeping multiple adjacent volumes

The following model has several interior volumes that share surfaces. This example may at first seem complex, but it actually requires very little decomposition. The key to this example is that each of the interior volumes is already sweepable, oriented along the same sweep axis, and that none of the linking surfaces have additional topology introduced through imprint/merge. In fact, there is only one required webcut to make this model automatically sweepable.

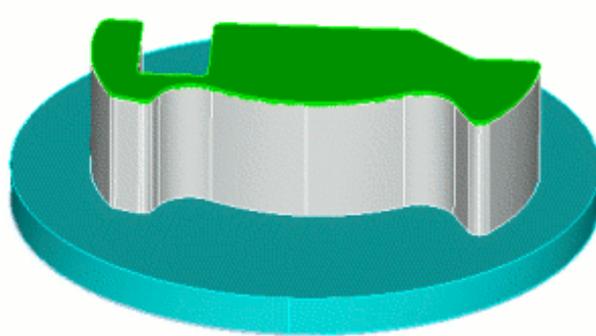


Figure 1. Exterior view

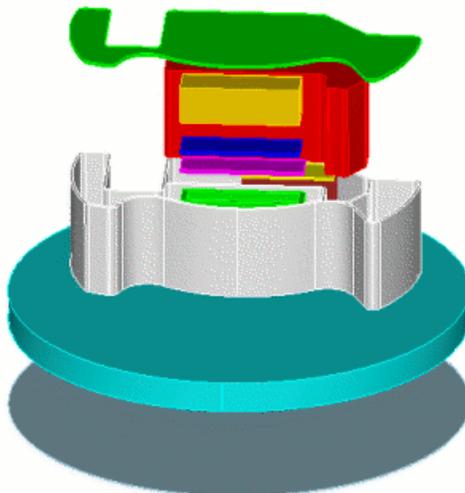
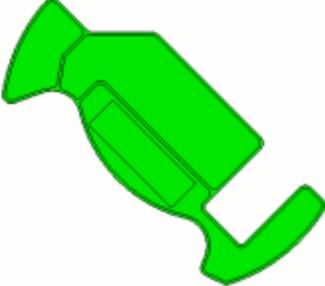
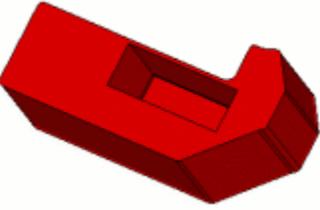
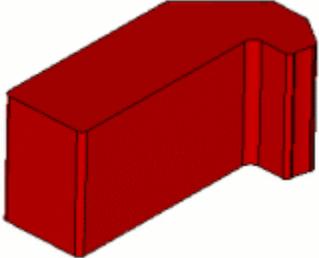
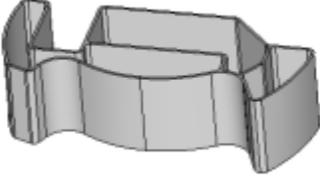
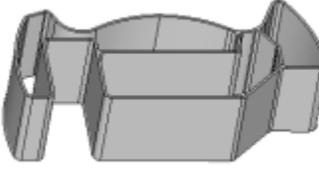
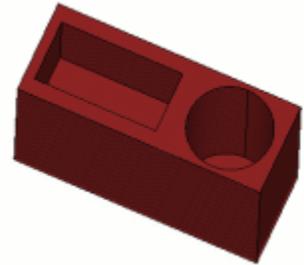
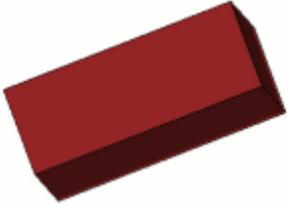
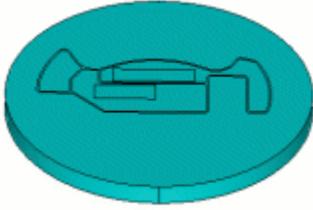
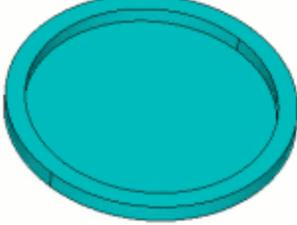


Figure 2. Interior view

We examine several of the volumes below.

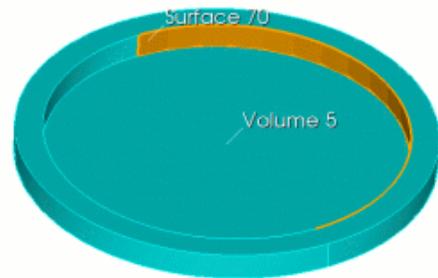
Source Surface(s)	Target Surface(s)	Sweep type
		<p><b>Many-to-one Sweepable</b></p> <p>Imprinting and merging adjacent volumes creates additional partitions on the source surface, but the target surface does not contain imprints.</p>
		<p><b>Many-to-one Sweepable</b></p> <p>Multiple source surfaces due to interior void</p>
		<p><b>One-to-One Sweepable</b></p> <p>Source and target surfaces are single surfaces, and there are no imprints on the linking surfaces</p>
		<p><b>Many-to-one Sweepable</b></p> <p>Interior void causes multiple source surfaces.</p>

		<p><b>Multisweep</b></p> <p>Imprinting causes multiple source surfaces and interior void causes multiple target surfaces. This volume requires decomposition</p>
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### Suggested Webcuts

Begin by Webcutting the Volume

1. On the Command Panel, click on **Geometry** and then **Operation - Decompose Geometry..**
2. Click on the **Volume Entity..**
3. Select **Sheet Extended From Surface** from the drop-down bar.
4. With your cursor in the **Volume ID(s)** field, Click on Volume **5** in the Graphics Window.
5. Enter **70** in the **Surface ID** field.
6. Click **Preview** to preview the webcut.
7. Click **Apply** to cut the volume.



Next Imprint and Merge

1. On the Command Panel, click on the **Geometry** button and then **Operation - Imprint and Merge..**
2. Click on the **Volume Entity..**
3. Select **Imprint/Merge** from the drop-down bar.
4. Enter **all** in the **Volume ID(s)** field.
- 5.
6. Click **Apply**.

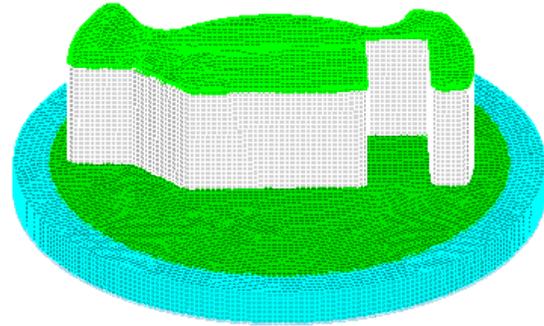
Finish by Meshing the Geometry

1. On the Command Panel, click on **Mesh** and then **Volumes**.
2. Click the **Intervals** action button.
- 3.
4. Select **Approximate Size** from the drop-down menu and enter **0.15** in the **Approximate Size** field.
5. Enter **all** in the **Select Volumes** field.
6. Click **Apply Size**.
7. Click the **Mesh** action button.
8. Select **Automatically Calculate** from the drop-down bar.

9. Enter **all** in the **Select Volumes** field.
- 10.
11. Click **Apply Scheme**.
12. Click **Mesh** to mesh the volume

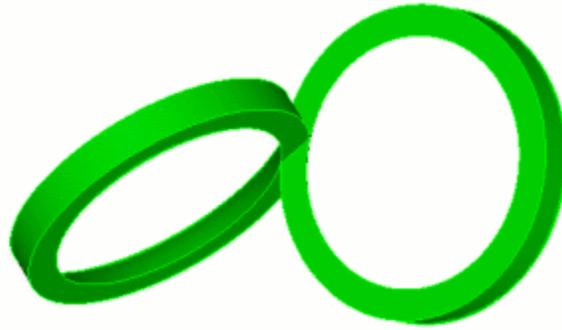
Final mesh

The final mesh is created at a size of 0.15 for all volumes.



## Example 2. Interlocking rings

The following example is composed of two rings of constant cross-section that can be swept along their axes. The problem here is that the rings overlap, forming a tetrahedral shape that cannot be swept. The key to solving this problem is separating out the region of overlap, explicitly setting the source and target surfaces, and using the tetprimitive scheme on the tetrahedral region.



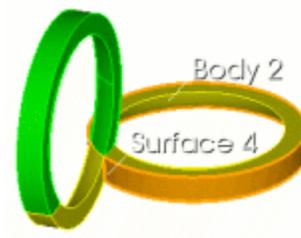
### Suggested webcuts

Begin by performing a series of Webcuts

1. On the Command Panel, click on the **Geometry** button and then **Operation - Decompose Geometry**.
2. Click the Entity - Volumes button.
3. Select **Plane From Surface**, from the drop-down bar.
4. Enter **1** in the **Volume ID(s)** field.
5. Enter **5** in the **Surface ID** field.
6. Click **Preview**
7. Click **Apply**

Second Webcut

1. With the same setting on the Command Panel, select **Sheet Extended From Surface** from the drop-down bar.
2. Enter **2** in the **Volume ID(s)** field.
3. Enter **4** in the **Surface ID** field.
4. Click **Preview**.
5. Click **Apply**.



Third Webcut

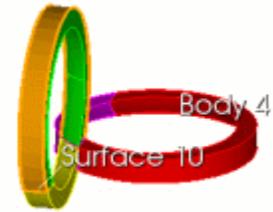
1. With the same setting on the Command Panel, select **Plane From Surface** from the drop-down bar.
2. Enter **3** in the **Volume ID(s)** field.



3. Enter **12** in the **Surface ID** field.
4. Click **Preview**.
5. Click **Apply**.

#### Fourth Webcut

1. With the same setting on the Command Panel, select **Sheet Extended From Surface**.
2. Enter **4** in the **Volume ID(s)** field.
3. Enter **10** in the **Surface ID** field.
4. Click **Preview**.
5. Click **Apply**.



Next, you need to Imprint and Merge the Volumes

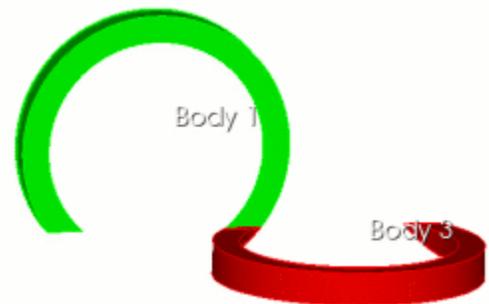
1. On the Command Panel, click on the **Geometry** button and then **Operation - Imprint and Merge**.
2. Click Entity - Volumes.
3. Select **Imprint/Merge** from the drop-down bar.
4. Enter **all** in the **Volume ID(s)** field.
- 5.
6. Click **Apply**.

**Note:** There are five volumes that result from the webcutting. Two of them are automatically sweepable. Two of them must have their schemes set explicitly, and one of them is meshed using the tetprimitive scheme.

Next set schemes and mesh the volumes

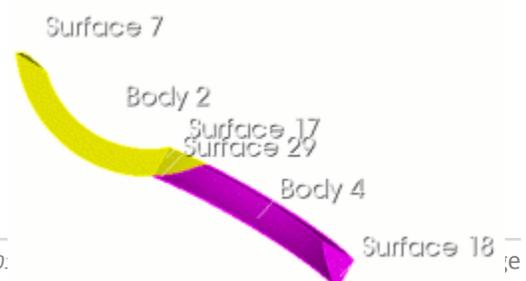
#### One-to-one Sweepable

1. From the Command Panel, select the **Mesh** button and then **Volume**.
2. Click on the **Mesh** action button.
3. Select **Automatically Calculate** from the drop-down bar.
4. Enter **Volume 1** and **3** in the **Select Volumes** field.
- 5.
6. Click **Apply Scheme**



#### One-to-one Sweepable

1. With the same settings on the Command Panel, Select **Sweep** from the drop-down bar and enter **2** in the **Select Volumes** field.
- 2.
3. Enter **17** in the **Source Surface ID(s)** field.



4. Enter **7** in the **Target Surface ID** field.
5. Click **Apply Scheme**.

Next, Specify the Meshing Schemes

1. With the same setting on the Command Panel, enter Volume **4** in the **Select Volumes** field.
- 2.
3. Enter **29** in the **Source Surface ID(s)** field.
4. Enter **18** in the **Target Surface ID** field.
5. Click **Apply Scheme**.

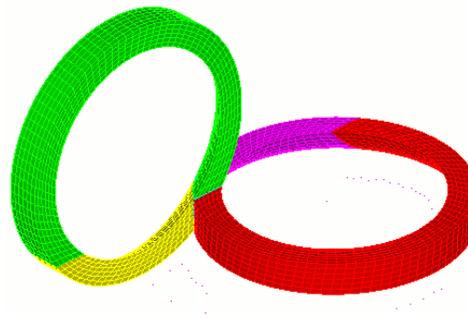
Non-sweepable

1. With the same setting on the Command Panel,lick on the **Intervals** action button.
2. Select **Approximate Interval Count** from the drop-down bar.
3. Enter **5** in the **Select Volumes** field.
- 4.
5. Enter **6** in the Interval field.
6. Click **Apply**
7. With the same setting on the Command Panel, select the **Mesh** action button.
8. Select **Tetprimitive** from the drop-down bar.
9. Enter **5** in the **Select Volumes** field.
- 10.
11. Click **Apply Scheme**.



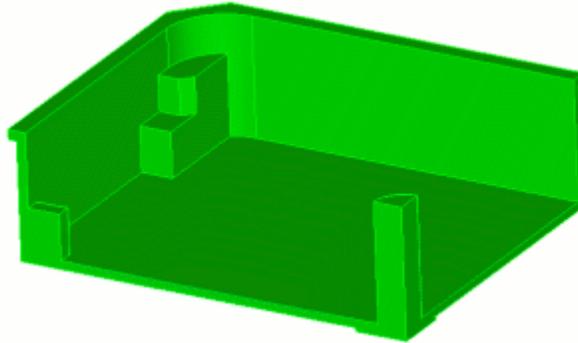
Finish by Meshing the Geometry

1. With the same setting on the Command Panel, select the **Intervals** action button.
2. Select **Approximate Size** from the drop-down bar.
3. Enter **all** in the **Select Volumes** field.
- 4.
5. Enter **0.5** in the **Approximate Size** field. This sets the final mesh to be created at a size of 0.5 for all volumes
6. Click **Apply Size**.
7. Click **Mesh**.



### Example 3. Webcutting using the sweep option

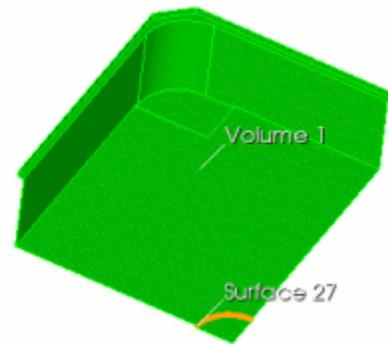
This example introduces additional webcutting options. This example would be a simple many-to-one sweep except for the overhanging lip and the protrusions on the bottom surface. To a beginner user, it may at first seem reasonable to use the bottom surface as a webcutting plane. However, this will not create a many-to-one sweepable volume. Instead, you need to use the protruding surfaces as cutting planes, and extend them through the entire volume.



#### Suggested webcuts

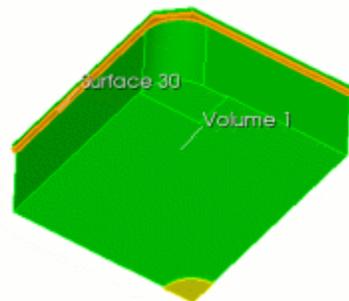
Begin by performing a series of Webcuts

1. On the Command Panel, click on the **Geometry** button and then **Operation - Decompose Geometry**.
2. Click Entity - Volumes.
3. Select **Sheet Extended From Surface** from the drop-down bar.
4. Enter **1** in the **Volume ID(s)** field.
5. Enter **27** in the **Surface ID** field.
6. Click **Preview**.
7. Click **Apply**.



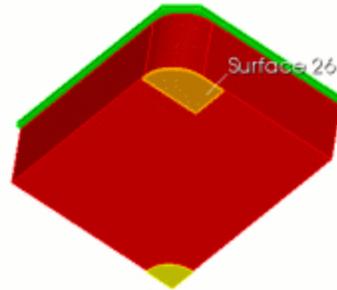
Next

1. With the same settings on the Command Panel, select **Plane From Surface** from the drop-down bar.
2. Enter **1** in the **Volume ID(s)** field.
3. Enter **30** in the **Surface ID** field.
4. Click **Preview**.
5. Click **Apply**



Next

1. With the same setting on the Command Panel, select **Sweep Surface** from the drop-down bar.
2. Enter **all** in the **Volume ID(s)** field.
3. Enter **26** in the **Sweep Surface ID** field.
4. Select **Vector** under the Sweep Direction menu.
5. Enter the **-1** for **X**, enter **0** for **Y** and enter **0** for **Z**.
- 6.
7. Select **Through All**.
8. Click **Preview**.
9. Click **Apply**.

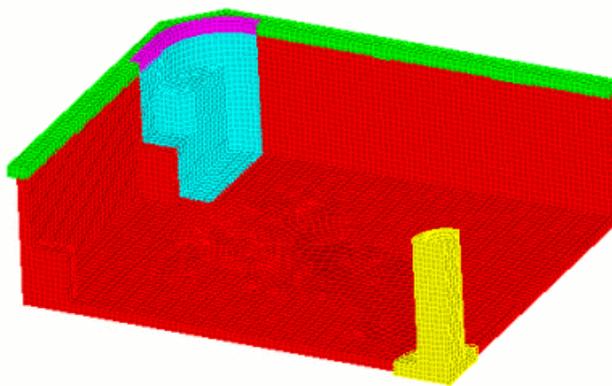


Next, you need to Imprint and Merge the Volumes.

1. With the same setting on the Command Panel, click Operation - Imprint and Merge.
2. Click Entity - Volumes
3. Select **Imprint/Merge** from the drop-down bar.
4. Enter **all** in the **Volume ID(s)** field.
- 5.
6. Click **Apply**.

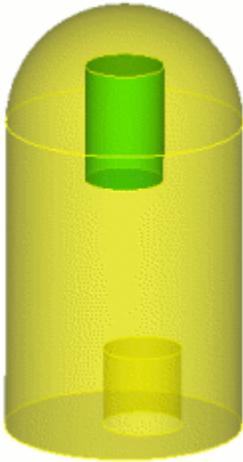
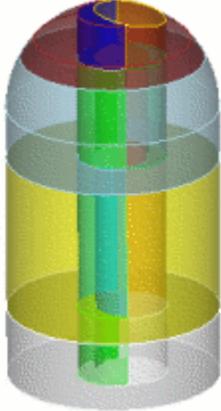
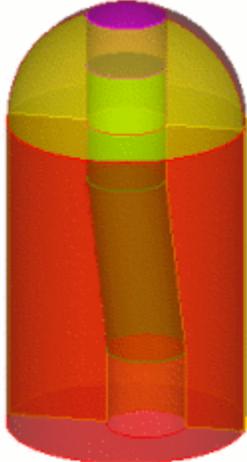
Finish by Meshing the Geometry

1. From the Command Panel, select the **Mesh** button and then **Volume**.
2. Click on the **Intervals** action button.
3. Select **Approximate Size** from the drop-down bar.
4. Enter **all** in the **Select Volumes** field.
- 5.
6. Enter **0.05** in the **Approximate Size** field. This sets the final mesh to be created at a size of 0.05 for all volumes.
7. Click **Apply**.
8. Click **Mesh**.



### Example 4. Using the Loft command

In the next example, the loft command significantly decreases the number of required webcuts. This model also demonstrates using 2 separate sweep paths (top-to-bottom and rotational) on adjacent volumes.

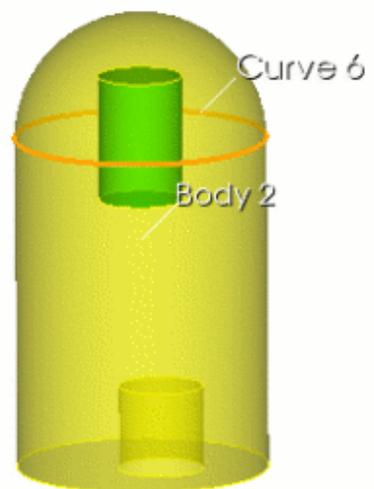
		
Original Volume	Webcuts created from sweeping surfaces (not recommended)	Webcuts using loft command (recommended)

#### Suggested webcuts

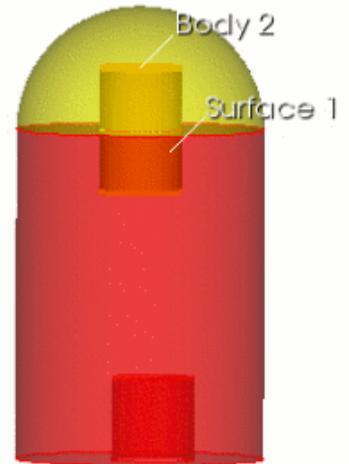
Begin by performing a series of Webcuts

1. On the Command Panel, click on the **Geometry** button and then **Operation - Decompose Geometry**.
2. Click on the **Entity - Volume** button.
3. Select **Loop** from the drop-down bar.
4. With your cursor in the **Volume ID(s)** field, click on **Volume 2** in the graphics window.
5. With your cursor in the **With Curve ID(s)** field, click on **Curve 6** in the graphics window. Click **Preview**.
6. Click **Apply**.

**Note:** Once an ID is selected in the graphics window, you can press the **tab button** to select other identities from that same ID.

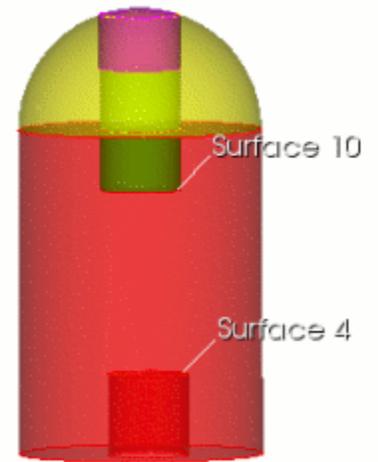


1. With the same settings on the Command Panel, select **Sheet Extended from Surface** from the drop-down bar.
2. With your cursor in the **Volume ID(s)** field, click on **Volume 2** in the graphics window.
3. With your cursor in the **Surface ID(s)** field, click on **Surface 1** in the graphics window.
4. Click **Preview**.
5. Click **Apply**.



Next, you will create surfaces that, in the next step, will help create a volume

1. On the Command panel, click on **Geometry** and then **Operation - Create Geometry**.
2. Click the **Entity - Surfaces** button.
3. Select **Copy and Transform** from the drop-down menu.
4. With your cursor in the **Surface ID(s)** field, click on **Surface 10** and **4** in the graphics window.
5. Uncheck the **Transform Copied Surfaces** box and click **Preview**.
6. Click **Apply**.

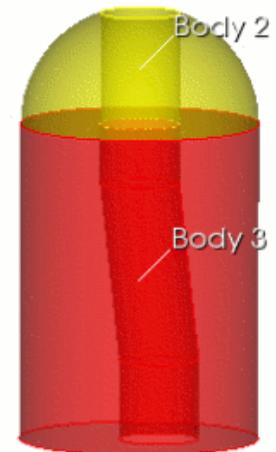


Next, create a lofted volume to connect the two surfaces just created

1. With the same settings on the Command Panel, select **Lofted Volume** from the drop-down bar.
- 2.
3. With your cursor in the **Surface ID(s)** field, click on **Surface 19** and **Surface 20**. These are the two surfaces that will be connected by a volume.

**Note:** You can press the Command Key to select more than one ID in the graphics window.

4. Click **Preview**. The preview will show a blue line in the path that connects the two surfaces.
5. Click **Apply**.



Next

1. With the same settings on the command panel, click the **Operation - Decompose Geometry** button.
2. Select **Tool** from the drop-down menu.
3. Enter **3** in the **Volume ID(s)** field.

4. Enter **7** in the **Tool Volume ID** field. Volume **7** is the new body that was created in the last step.
5. Click **Preview**.
6. Click **Apply**.

Next

1. With the same settings on the Command panel, click the Operation - **Delete Geometry** button.
2. Enter **5 6 7** in the **Volume ID(s)** field.
3. Click **Apply**.

Next

1. With the same settings on the Command panel, click the **Operation - Delete Geometry** button, click the **Operation - Decompose Geometry** button.
2. Select **General Plane** from the drop-down menu.
3. With your cursor in the **Volume ID(s)** field. Click on **Volume 2** and **3** in the graphics window.
4. Select **YZ**
5. Click **Preview**.
6. Click **Apply**.

Next, you need to Imprint and Merge the volumes

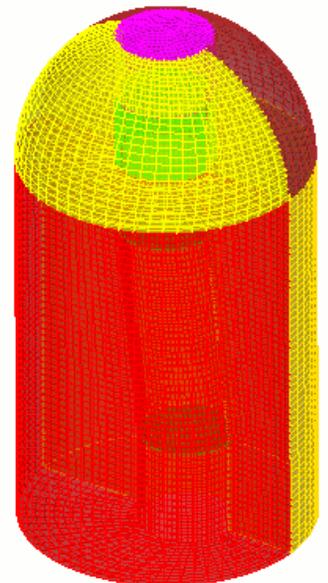
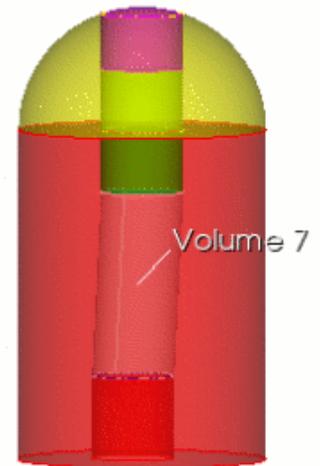
1. With the same setting on the Command Panel, click on the **Operation - Imprint and Merge** button.
2. Select **Imprint/ Merge** from the drop-down menu.
3. Enter **all** in the **Volume ID(s)** field.
4. Click **Apply**.

Finish by Meshing the Geometry

1. On the Command Panel, click on **Mesh** and then **Volume**.
2. Click on the **Intervals** action button.
3. Select **Approximate Size** from the drop-down menu.
4. Enter **all** in the **Select Volumes** field.
- 5.
6. Enter **0.15** in the **Approximate Size** field.
7. Click **Apply**.
8. Click **Mesh**.

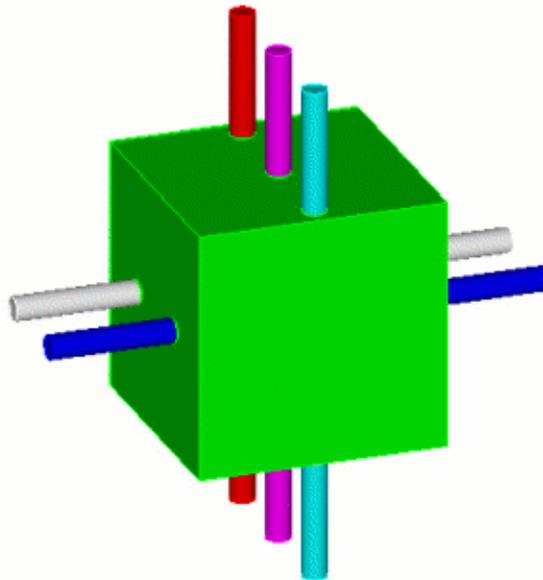
Final mesh

The final webcut model consists of a central shaft that can be swept top to bottom, and a surrounding casing that can be swept around. This is possible because the shared surface is a linking surface for both types of sweeps. The final mesh is created with a size of 0.15



## Example 5. Multiple sweep directions

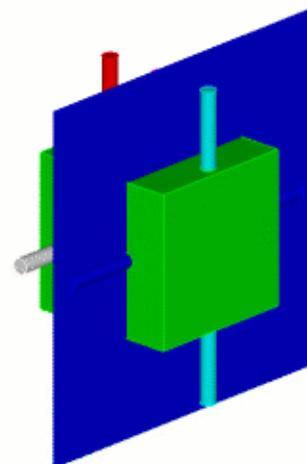
The next example gives another example of using different sweep directions on the same model. The following model shows a brick that is perforated by several cylindrical shafts. The shafts do not intersect each other.



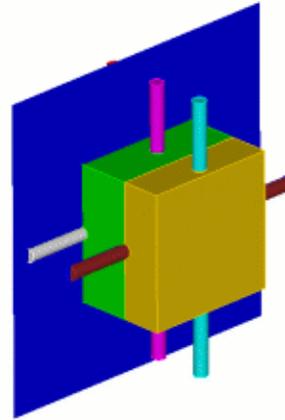
### Suggested webcuts

Begin by performing a series of Webcuts

1. On the Command Panel, click on the **Geometry** button and then **Operation - Decompose Geometry**.
2. Click on the **Entity - Volume** button.
3. Select **Coordinate Plane** from the drop-down menu.
4. Enter **all** in the **Volume ID(s)** field.
5. Click on **ZX**
6. Enter **20** in the **Offset Value** field.
7. Click **Preview**.
8. Click **Apply**.



1. With **Coordinate Plane** still selected from the drop-down menu enter **all** in the **Volume ID(s)** field.
2. Click on **ZX**
3. Enter **-20** in the **Offset Value** field.
4. Click **Preview**.
5. Click **Apply**.



Next, Imprint and Merge the Volumes

1. With the same settings on the Command Panel, click on the **Operation - Imprint and Merge** button.
2. Select **Imprint/ Merge** from the drop-down menu.
3. Enter **all** in the **Volume ID(s)** field.
4. Click **Apply**.

**Note:** All of the volumes in this model are now one-to-one sweepable. However, the source and target surfaces for the main block portions must be set explicitly

Next, set the Meshing Schemes to prepare the geometry to be meshed

1. On the Command Panel, click on **Mesh** and then **Volume**.
2. Click on the **Mesh** action button.
3. Select **Sweep** from the drop-down menu.
4. With your cursor in the **Select Entities to Mesh** field, click on **Volume 8** in the graphics window.
- 5.
6. Click on **Specify Source and Target**
7. With your cursor in the **Source Surface ID(s)** field, click on **Surface 94** in the graphics window.
8. With your cursor in the **Target Surface ID** field, click on **Surface 90** in the graphics window.
9. Click **Apply Scheme**.

Next

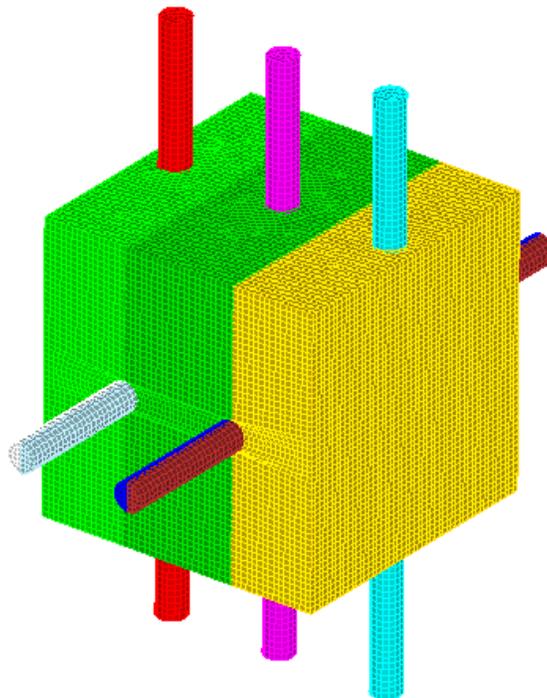
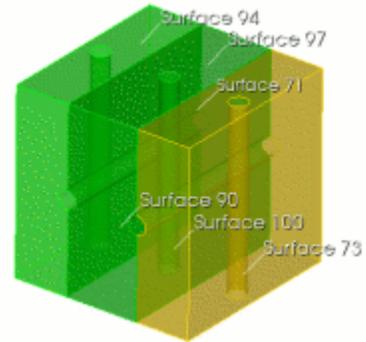
1. Enter **10** in the **Select Entities to Mesh** field.
- 2.
3. Click on **Specify Source and Target**.
4. With your cursor in the **Source Surface ID(s)** field, click on **Surface 71** in the graphics window.
5. With your cursor in the **Target Surface ID** field, select **Surface 73** in the graphics window.
6. Click **Apply Scheme**.

Next

1. Enter **12** in the **Select Entities to Mesh** field.
- 2.
3. Click on **Specify Source and Target**.
4. With your cursor in the **Source Surface ID(s)** field, click on **Surface 97** in the graphics window.
5. With your cursor in the **Target Surface ID** field, select **Surface 100** in the graphics window.
6. Click **Apply Scheme**.

Finish by Meshing the Geometry

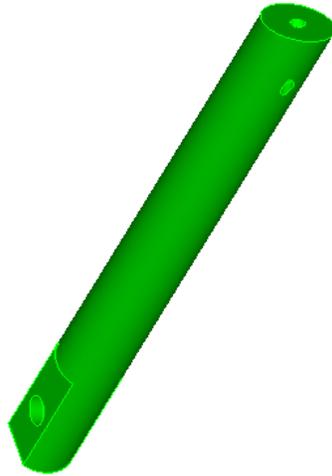
1. On the Command Panel, click on **Mesh** and then **Volume**.
2. Click on the **Intervals** action button.
3. Select **Approximate Size** from the drop-down menu.
4. Enter **all** in the **Select Volumes** field.
- 5.
6. Enter **2** in the **Approximate Size** field.
7. Click **Apply**.
8. Click **Mesh**.



## Advanced Decomposition Examples

### Example 6. Employing Symmetry

One technique for creating a symmetric mesh on a symmetric model is to mesh only half of the volume, then copy the mesh onto the other half. The following example employs this technique. This model at first appears quite simple, but it actually requires a good deal of webcutting to get a reasonable mesh that is not highly skewed.



#### Suggested webcuts

Begin by performing a series of Webcuts

1. On the Command Panel, click on the **Geometry** button and then **Operation - Decompose Geometry**.
2. Click on the **Entity - Volume** button.
3. Select **General Plane** from the drop-down menu.
4. With your cursor in the **Volume ID(s)** field, select the entity in the graphics window. **1** should appear.
5. Enter **YZ** in the **With Plane** field
- 6.
7. Click **Preview**.
8. Click **Apply**.

Next

1. With the same settings on the Command Panel, click on the **Operation - Delete Geometry** button.

