

CLASS ID: CP223099

Next level design workflows in Fusion 360: Mixing T-Splines, meshes, and Voronoi-based patterns for product design

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Learning Objectives

- Learn how to transform basic designs created in Fusion 360 into complex shapes that use generative design topologies such as Voronoi patterns.
- Discover options for importing and exporting different body types, including T-Splines, B-Reps, Meshes, Tri-faces, and Quad-faces.
- Learn how to use programs such as Fusion 360, Meshmixer, ReCap Pro, and Voronator to export, transform, and edit bodies.
- Explore how meshes can be imported back into Fusion 360 and be combined with T-Splines bodies.

Description

This class explores workflows for taking bodies modeled in Fusion 360 and converting them to complex topologies via Voronoi-based patterns. These types of patterns are organic and visually striking, resembling nature-based structures. This process is achieved by exporting bodies from Fusion into programs like Meshmixer, ReCap Pro and Voronator, where it's easy to apply different types of patterns. The resulting meshes can be brought back into Fusion and turn them back into T-Splines for further development. A key benefit of this workflow is that designs combine different types of geometries (i.e. solid faces with Voronoi-based patterns) in a single body. An example of this workflow can be found at: <https://gallery.autodesk.com/fusion360/projects/119363/stool-16>

Speaker bio

Alex Lobos is an industrial designer and educator, focusing in sustainable design, emotional attachment, user-centered design, and CAD applications. He is Graduate Director and Associate Professor of industrial design at Rochester Institute of Technology, New York. He is also an Expert Elite for Fusion 360 software, Autodesk University Featured Speaker, member of Autodesk University's Advisory Council, and a recipient of Fusion 360's Education Award. He has collaborated with Autodesk since 2011 on research projects and teaching methods for design, engineering, and sustainability.

Benefits of combining topologies

CAD (Computer-aided design) is a wide category of tools for creating three-dimensional bodies and assemblies with the use of computers. There are several types of CAD models, developed by different companies for various applications. Some of the most common types include “parametric,” which is based on boundary representations, and “NURBS,” which stands for non-uniform rational b-splines, and allows for direct modeling techniques.

Although applications vary by users and industries, parametric modeling is more common in mechanical/industrial applications, while NURBS is used for transportation and media & entertainment. Product and industrial design tend to sit in the middle of these two approaches, given that designers often combine the creativity of complex form generation with specific manufacturing and fabrication requirements.

It is important to understand how CAD model types work, including their benefits, limitations and differences. Just as important is the combination of different types into single, dynamic workflows. Each geometry type provides unique attributes that when combined, can provide designers and engineers with better results than if using a single type of model. For example, an important benefit of importing multiple files into a program, including meshes, is the ability of capturing physical objects with 3D scanning and bring them into CAD workspaces either as reference for modeling new bodies, or more recently, to be able to edit them as much as a body that was created in the computer. Combining different CAD types can be an effective way for achieving a wider type of workflows and geometries, rather than just being a list of geometry alternatives to choose from.

Along with understanding how CAD types work and how they can be combined, it is important to understand how they can be imported and exported between different programs. When Fusion 360 was released, for example, it was very hard to bring into the program file formats that were not native to it. Formats such as STL or OBJ could be imported into Fusion as static, “dumb” files, meaning that they could only be placed in the workspace but could not be edited beyond cutting them. Other programs such as Meshmixer, Mudbox and Recap Photo (previously ReMake and Memento) provide far better flexibility for editing and combining different file types. Recently, Fusion 360 has improved significantly its ability to import different file types as well as including ways for editing meshes within Fusion and combine them with native bodies. All these options provide more versatility for integrating multiple CAD data into single workflows that can be edited and shared without design intent.

Geometry types

Below is a brief list of different geometries that are common in CAD models, including their typical appearances in CAD workspaces (Figure 1). Most types will be able to define similar components of a body, such as faces, edges, vertices and control points. The difference in most cases is in how these components are created and how they are defined in space. Some cases such as B-Reps are able to fully define every component in a geometry, while other ones generate shapes that cannot be fully defined or edited. A better understanding of their qualities

and limitations is a key component for combining different types of geometries into single workflows.

B-Rep

B-Rep stands for Boundary representation typical of parametric models. It's a body comprised of multiple surfaces. As the surfaces touch each other, they define faces, edges, vertices, etc. B-rep's define geometries with great precision and surfaces are defined by equations. B-Rep's are completely editable.

T-Splines

It's a NURBS-based surface with control points that can start/finish at any point, without having to traverse the entire surface. T-Splines are completely editable. As opposed to B-Reps, T-Splines are not parametric because not all components in their topology can be fully defined with equations.

Mesh

It's a polyhedral 3D body tessellation comprised of vertices, edges and faces. Faces can be triangular or quadrilateral, which refers to the terms mesh-tri and mesh-quad. Meshes are as precise as B-reps as the geometry is defined by tessellations of faces instead of full equations. Meshes are not editable. They can be cut but their geometries cannot be changed.

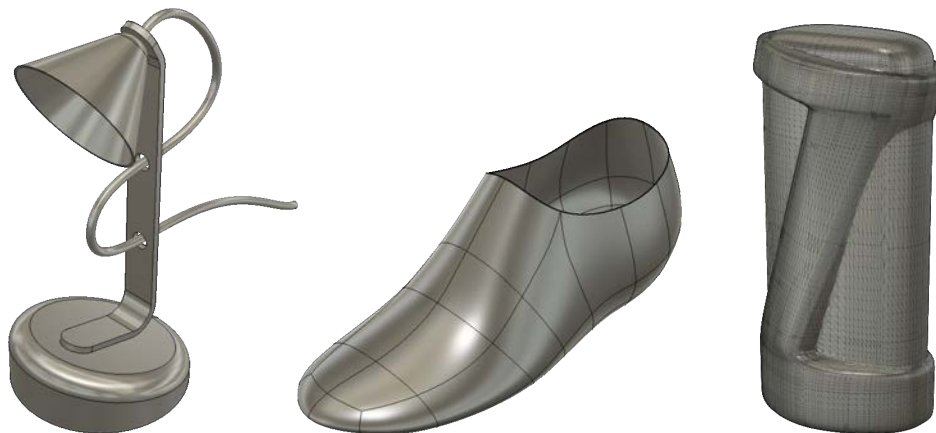


Figure 1: From left to right: B-Rep, T-Spline and STL bodies.

Interest in Generative topologies

The core benefit of generative design lies in automation and can be understood from two angles: processes and form generation. On one hand is the automation of repetitive processes, which is perhaps the most important benefit of generative design. Architecture, Engineering and Construction industry is an ideal scenario for applying automated processes where the planning construction of large buildings that require multiple systems working together. Automation is of great benefit in large scale projects such as buildings, bridges and urban infrastructure require repetitive implementation of similar components such as doors, windows, plumbing, electrical outlets, framing structures, lighting, etc.

Another benefit of generative design is the creation of forms that mimic nature. By using algorithms that generate forms out of follow basic, progressive rules it is possible to develop structures that are complex, intricate, and that have a naturally fluid and efficient. Designers look for ways of creating nature-inspired forms due to their unique appearance, intricate detail, and strong reaction from consumers.

Voronoi patterns

Voronoi patterns are subdivisions to a plane or surface that are all at the same distance from a specific point, named seed. Each resulting subdivision is called a Voronoi cell. They are found and applied in a wide variety of scenarios, and in the case of CAD, they are a fairly easy way of creating nature-inspired patterns that fit within a designated area. A reason why they have become popular for creation of designed structures is that they resemble biological structures (Figure 2). When used as tridimensional patterns, they tend to create structures that are stable and strong with minimal use of material, as opposed to structures that are solid or hollowed out with simple geometric sections.

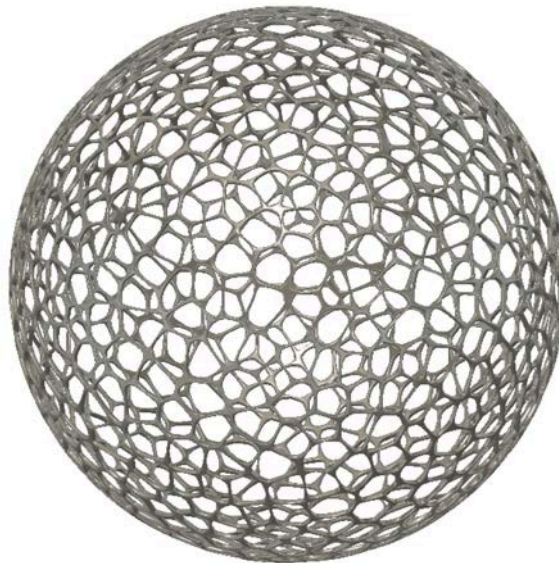


Figure 2: Sphere with three-dimensional Voronoi pattern

Design examples

There is a wide array of applications for this type of workflows. Below are two examples of geometries that were originally modeled in Fusion 360 and then converted into complex meshes with Voronoi-based patterns. Both the solid and Voronoi versions were re-meshed in other programs and brought back into Fusion 360. This workflow allows for taking advantage of complex geometry generation with the modeling flexibility of Fusion.

In both of these cases, the final design is envisioned to be fabricated with additive manufacturing, as complex meshes such as these are not suitable for traditional manufacturing process such as molding or carving.

Seating stool

The first example is a stool, which was originally designed as a solid, single piece (Figures 3 and 4). The body was then turned into a Voronoi-based body, and eventually brought back into Fusion (Figure 5). The top section remains solid and the bottom sections incorporate the Voronoi geometry. The result is a piece that is stronger and more visually engaging.

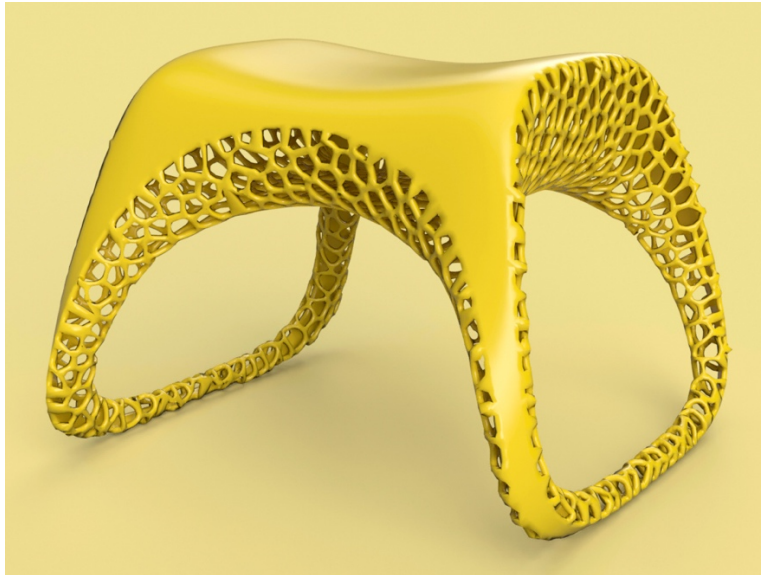


Figure 3: Stool modeled in Fusion 360.
Voronoi-pattern created in voronator.com

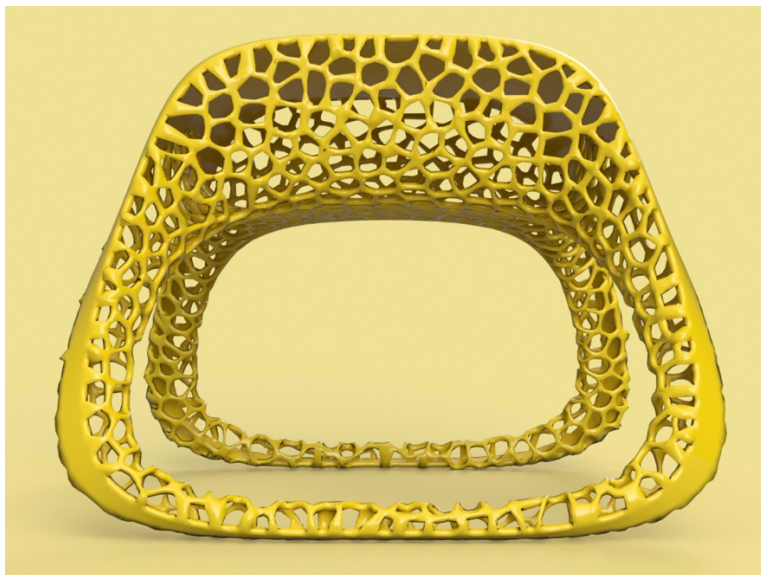


Figure 4: Stool modeled in Fusion 360.
Voronoi-pattern created in voronator.com

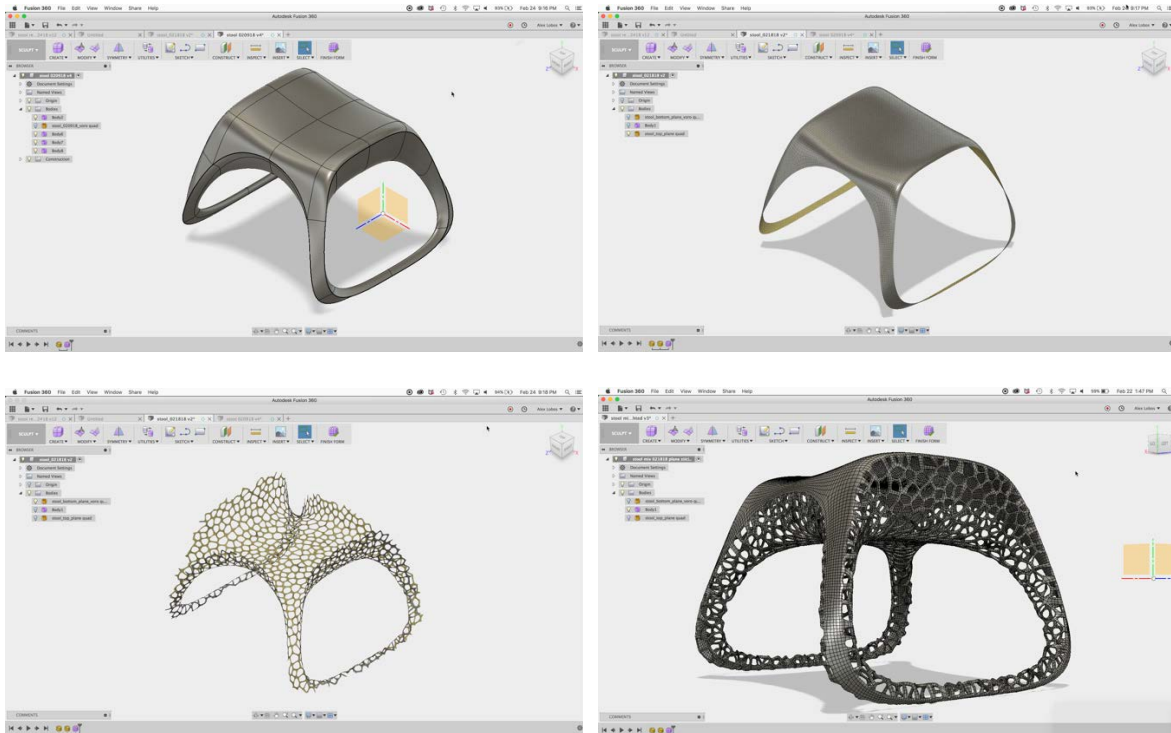


Figure 5: Screenshots of Fusion 360, showing how the geometry was developed separately and then connected.

Bass guitar

A second example is a bass guitar, which was also modeled as a solid piece. Voronoi patterns were applied to the main body and to the neck of the instrument (Figures 6 and 7). This creates a dramatic visual detail that also makes the bass guitar lighter. The body remains solid in the center, in order to fit electronic components and to maintain the acoustic qualities necessary for the instrument to produce a good sound.



Figure 6: Bass guitar modeled in Fusion 360.
Voronoi-pattern created in voronator.com

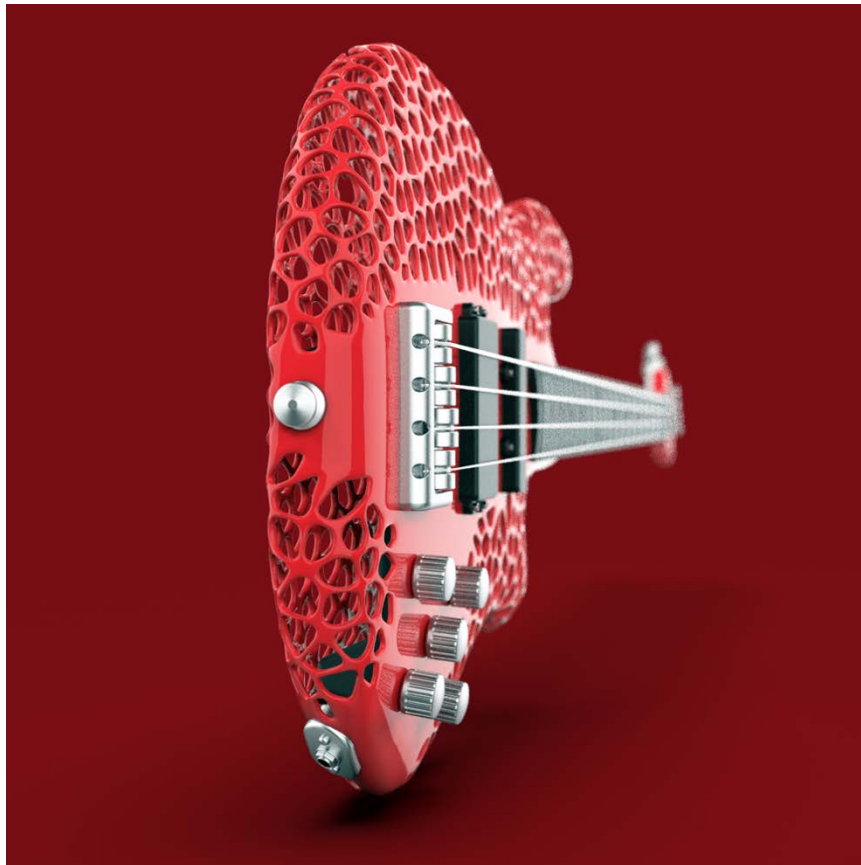


Figure 7: Bass guitar modeled in Fusion 360.
Voronoi-pattern created in voronator.com

Modeling workflows

Below are a series of workflows that illustrate common workflows for importing, exporting, editing and mixing different geometries. The tutorials cover several programs and applications, since it is hard to find a single one that can handle all of these different workflows. The tutorials illustrate the following common workflows:

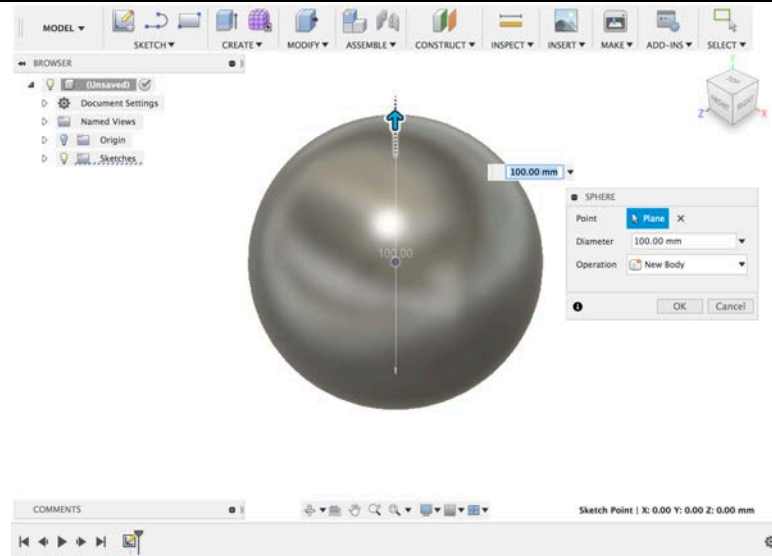
- 1- **Save body as STL.** This tutorial shows how a body in Fusion 360 is saved as STL, a fairly universal format for mesh geometries.
- 2- **Create patterns and geometries.** There are several ways of turning solid bodies into more complex ones. These tutorials show two examples: 2.a illustrates use of Voronoi patterns and 2.b illustrates variable meshes.
- 3- **Convert meshes from Tri to Quad.** In order to convert a mesh in Fusion 360 into a T-Spline body that can be edited, meshes need to have quad faces. This tutorial shows how to achieve this format (OBJ-quad) outside of Fusion 360.
- 4- **Meshes imported into Fusion in both Model (B-Rep) and Sculpt (T-Spline) environments.** B-Rep conversions work well when the mesh is used in more mechanical/parametric applications. T-Spline conversions work well when additional modeling/sculpting is needed.

- 5- **Mixing meshes and T-Splines.** This tutorial shows how to combine imported meshes that were converted to T-Splines, in applications similar to the bass guitar and stool that were illustrated above in this paper.

1- SAVE BODY AS STL (In Fusion 360)

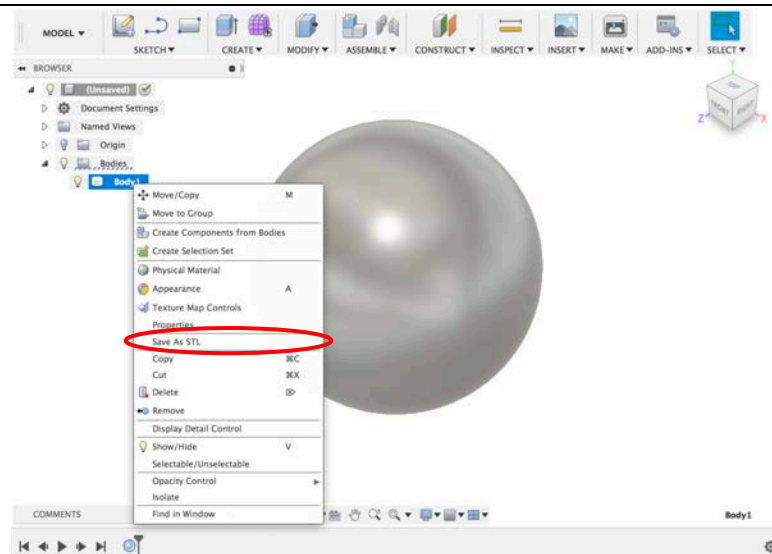
Go to Create > Sphere.
Pick any plane to create a sphere of 100mm diameter.

If modeling in “Sculpt” (T-Splines), make sure that you press “Finish Form” to bring it into “Model” (B-Rep) environment.



In the left panel, go to: Browser > Bodies and click the side arrow to expand the bodies in the model. Find the body corresponding to the sphere, “right-click” and select “Save as STL”

Adjust settings (default settings work well for most situations) and save STL file.



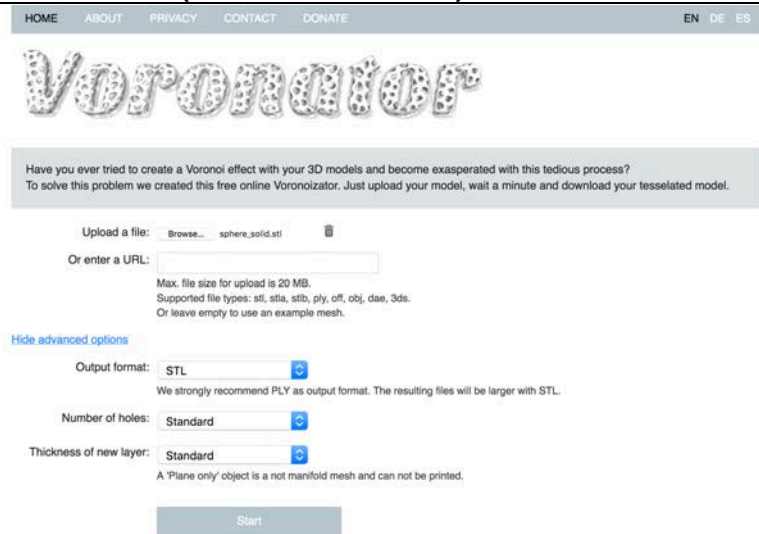
2.a - CREATE VORONOI-BASED BODY (In Voronator.com)

In a web browser, go to:
Voronator.com

In the website, upload the
STL file.

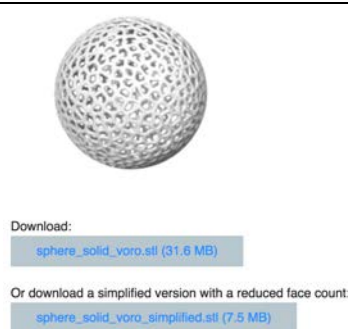
Click on “Show advanced
features”.

Select “Output Format” as
STL. Also select desired
“number of holes” and
“thickness of new layer”



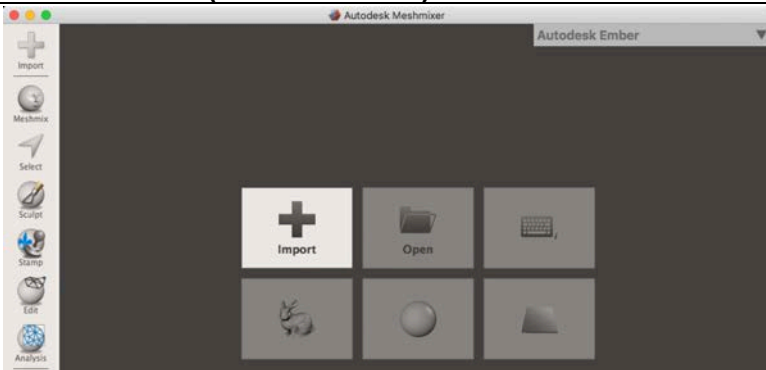
The screenshot shows the Voronator website interface. At the top, there is a navigation bar with links: HOME, ABOUT, PRIVACY, CONTACT, and DONATE. On the right, there are language options: EN, DE, ES. The main heading is "Voronator" in a stylized font. Below the heading, a text box explains the purpose: "Have you ever tried to create a Voronoi effect with your 3D models and become exasperated with this tedious process? To solve this problem we created this free online Voronoizator. Just upload your model, wait a minute and download your tessellated model." The interface includes an "Upload a file:" section with a "Browse..." button and a file name "sphere_solid.stl". There is also an "Or enter a URL:" input field. Below this, it states "Max. file size for upload is 20 MB." and "Supported file types: stl, stla, stlb, ply, off, obj, dae, 3ds. Or leave empty to use an example mesh." A link "Hide advanced options" is present. The "Output format:" is set to "STL", with a note: "We strongly recommend PLY as output format. The resulting files will be larger with STL." The "Number of holes:" is set to "Standard", and the "Thickness of new layer:" is set to "Standard". A warning message says: "A 'Plane only' object is a not manifold mesh and can not be printed." At the bottom, there is a "Start" button.

When the file is ready,
download it to your
computer.



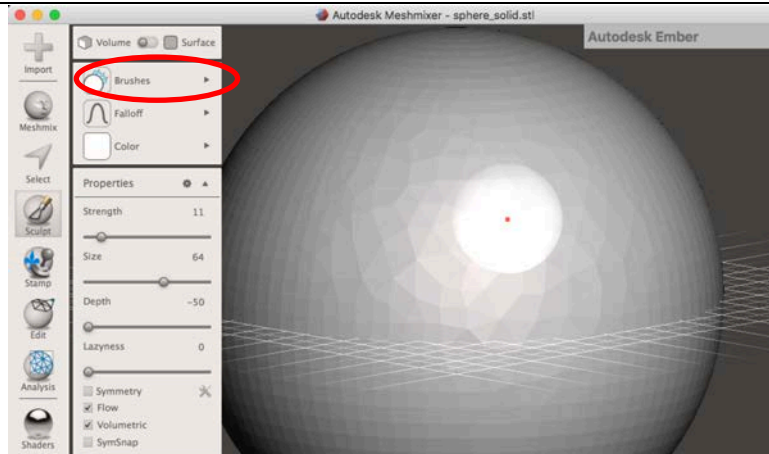
2.b - CREATE A VARIABLE-MESH BODY (In Meshmixer)

Import STL file



In order to randomize the density of the faces, go to: Left panel > Sculpt > Brushes > Reduce.

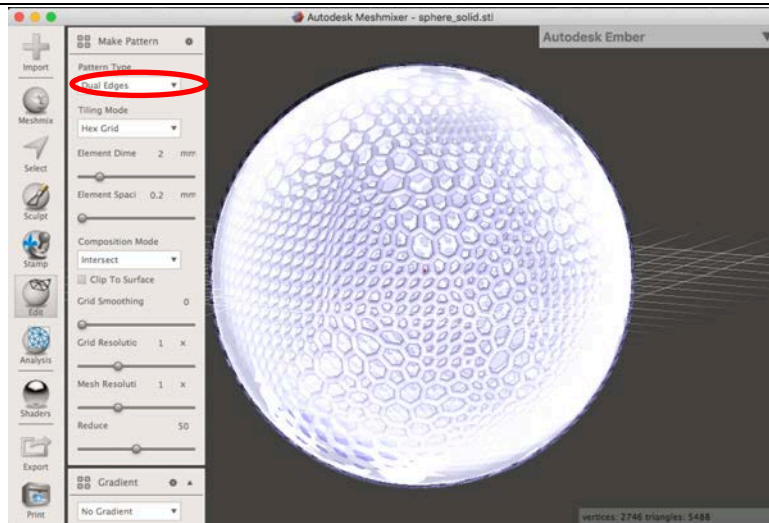
Click the sphere's faces to alter them.



In order to turn the body from solid to open mesh, go to: Left panel > Edit > Make Pattern

Change "Pattern Type" to Dual Edges and adjust settings as necessary.

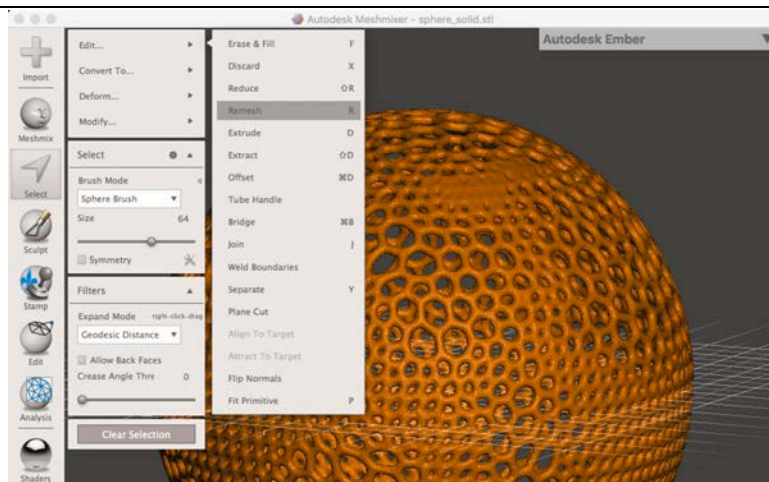
When done, click "Accept".



In left panel, go to: Analysis > Inspect to "Auto Repair" and select all faces (typing "Command+A" or with a selection window/lasso).

Go to Edit > Remesh to improve the quality of the face distribution.

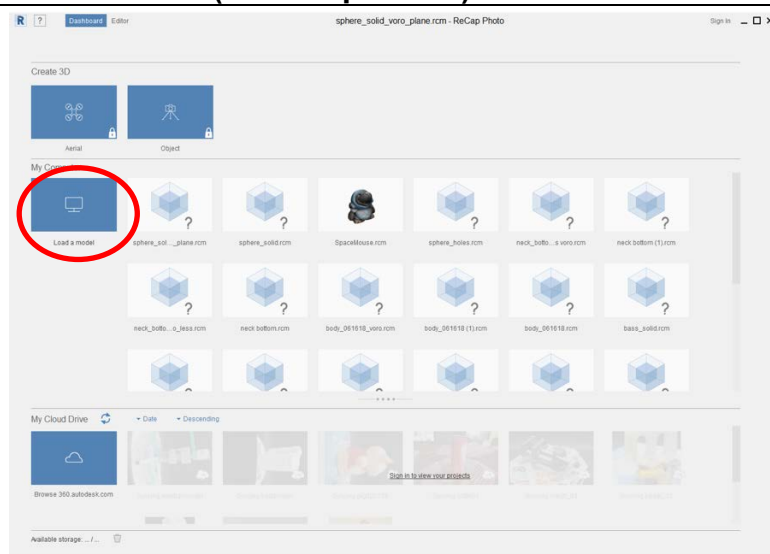
Go to Edit > Reduce to bring down the number of faces in the body.



Go to: File > Export and export file as STL.

3- CONVERT MESH FROM TRI TO QUAD (In ReCap Photo)

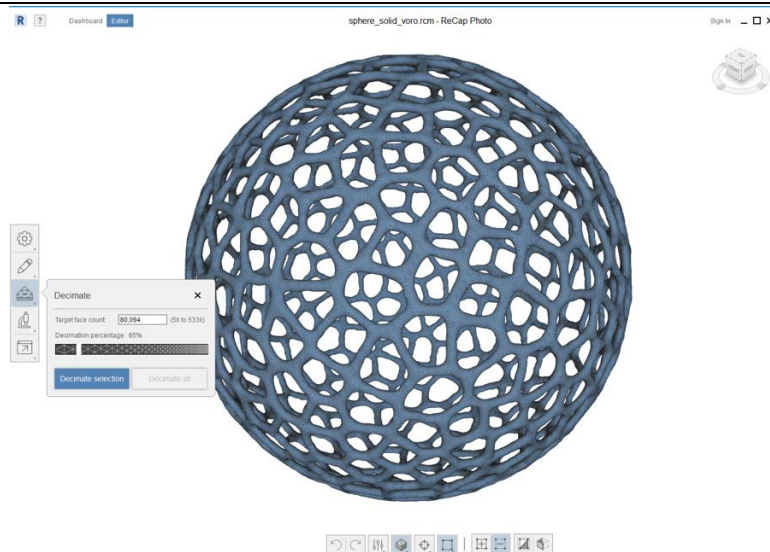
Open Recap Photo.
Select “Load a Model” and
choose the STL file
exported from Fusion.



Select the entire body.

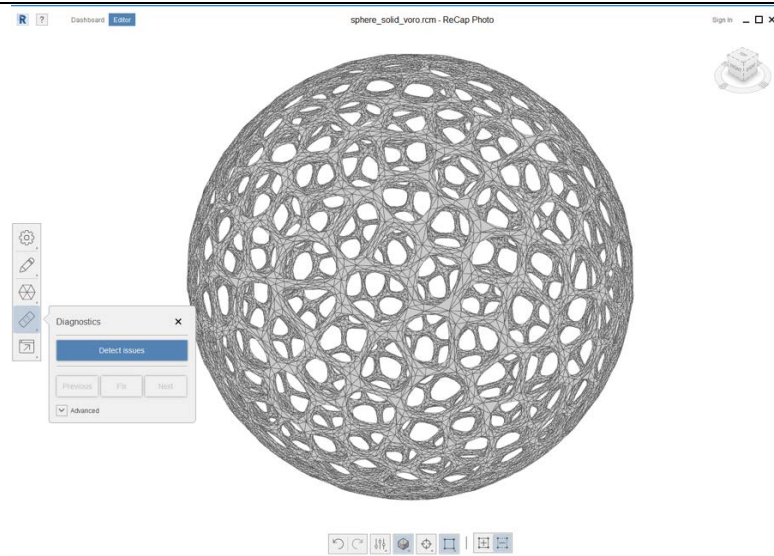
In the left panel, go to: Re-
Topologize > Decimate,
and reduce the number of
faces to under 100k.

Go to: Re-Topologize >
Retriangulate Selection, to
recreate the faces and
make them more even.



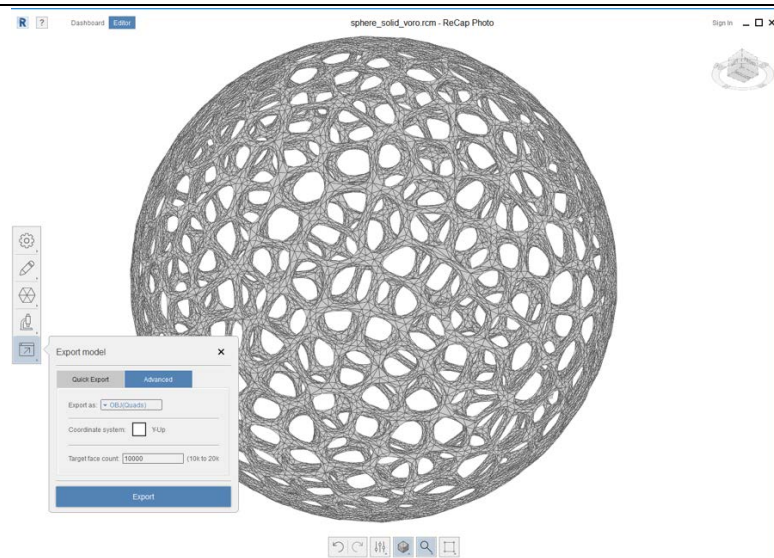
In the left panel, go to:
Analyze > Diagnostics.

Click on “Detect Issues”
and select to fix any issues
that Recap identifies. This
process might need to be
repeated several times
until no issues are
detected.



In the left panel, go to:
Export > Export model.

Export as “OBJ(Quads)”
This is the only format that
will allow to convert the
body to a T-Spline when
imported in Fusion 360.



4.a - CONVERT MESH (QUAD or TRI) TO B-REP

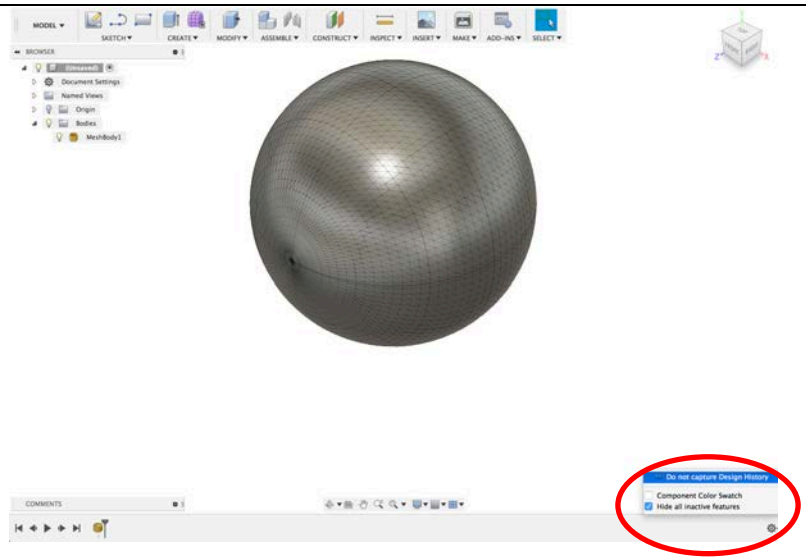
In Model environment, go to
the top panel and select:
Insert > Insert Mesh.

Select the STL file of the
solid sphere.



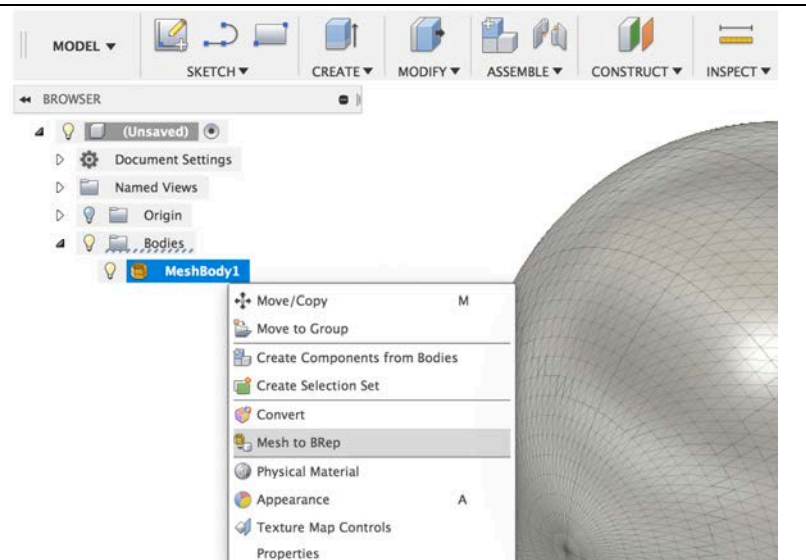
In the lower-right corner of the workspace, click on the “Options” icon (grey gear icon) and select “Do not capture Design History”

IMPORTANT: Mesh tools are available in Fusion **ONLY** when History is disabled.



In the left panel, expand “Bodies” and look for the sphere’s icon.

Right-click on the icon and select “Mesh to B-Rep”.

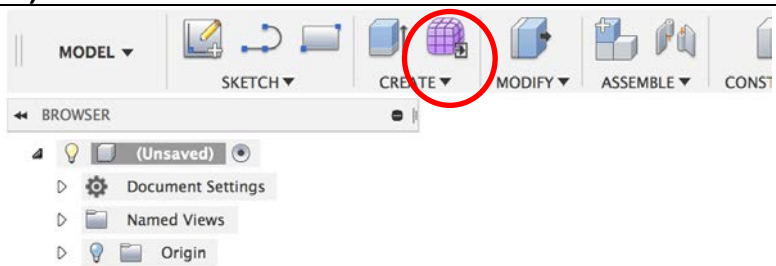


IMPORTANT NOTES:

- Fusion only converts meshes to B-Reps that have less than 10,000 faces.
- This limitation doesn’t apply to meshes converted to T-Spline in the Sculpt environment. However, bodies with large number of faces become unstable and affect Fusion 360’s performance.

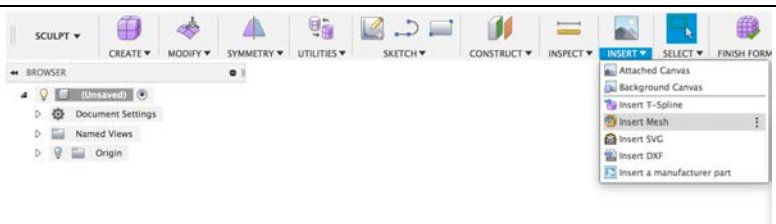
4.b - CONVERT MESH (QUAD) TO T-SPLINE

In the top panel, click on the purple box to enter “Sculpt” environment (T-Splines)

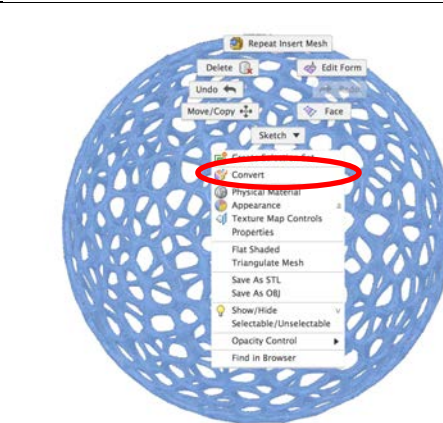


In the top panel, go to: Insert > Insert Mesh

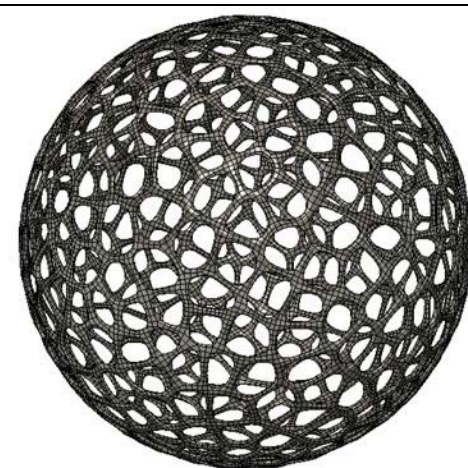
Select the OBJ-quad file that was created in Recap Photo.



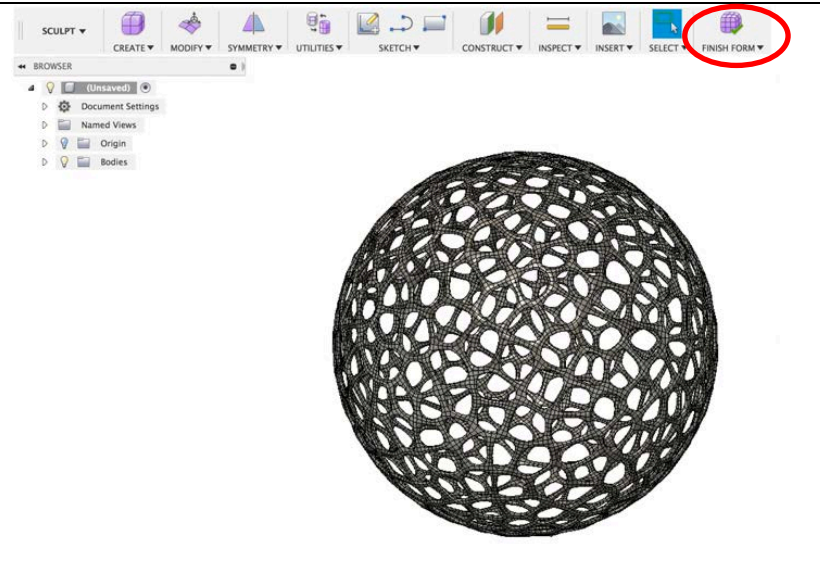
Right-click on the mesh body and select “Convert” to create a T-Spline version.



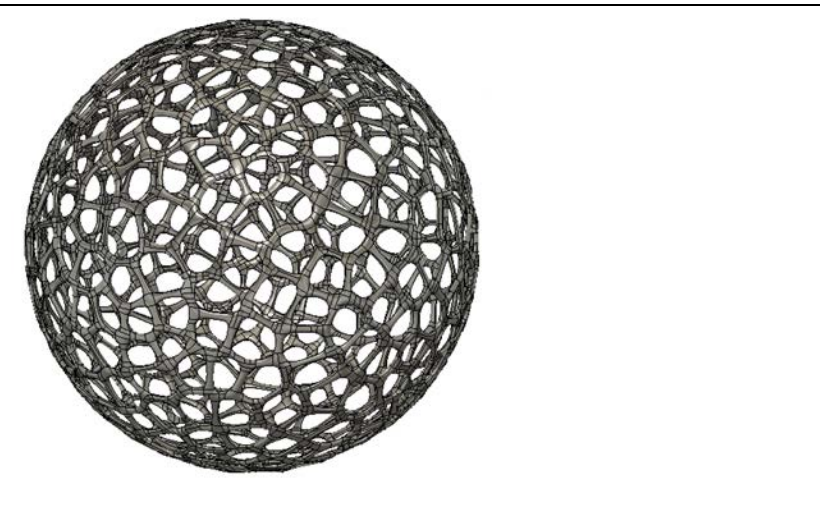
The body is now a T-Spline which can be further edited and/or combined with other T-Spline bodies.



In the top panel, click on “Finish Form” to convert the file from T-Spline to B-Rep and return back to Model environment.



The body is now a B-Rep body, which can be further edited and/or combined with other B-Rep bodies.



5 - CONVERT MESH (QUAD) AND MIX WITH T-SPLINE

Note: When combining bodies, it is important to have geometries as simple as possible. When using the method described here, it helps immensely to create versions of the body that are **just planes** and don't have thickness.

For the Voronoi version:

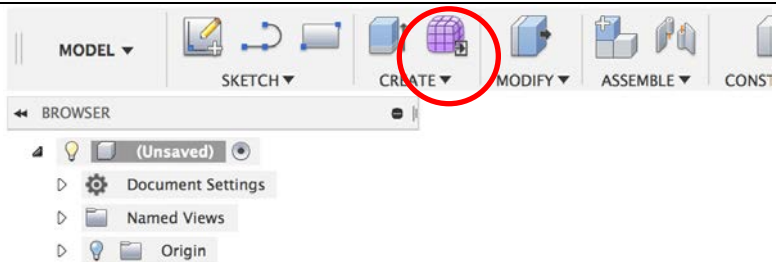
- Go to Voronator.com and create an STL with plane only (no thickness).
- Open the output STL in Recap Photo and go through similar steps as for the Voronoi version:
 - Reduce faces (aim for under **25,000 faces**).
 - Remesh the geometry.
 - Export as OBJ-quad (set target for about **5,000 faces**).

For the solid version:

- Use the solid STL created in Fusion 360.
- Open in Recap Photo and go through the similar steps as for the Voronoi version:
 - Reduce faces (aim for under **25,000 faces**).
 - Remesh the geometry.
- Export as OBJ-quad (set target for about **10,000 faces**).

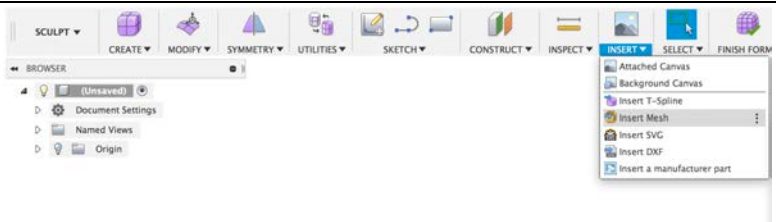
Once these two new OBJ files are ready, proceed with the steps below.

In the top panel, click on the purple box to enter “Sculpt” environment (T-Splines)

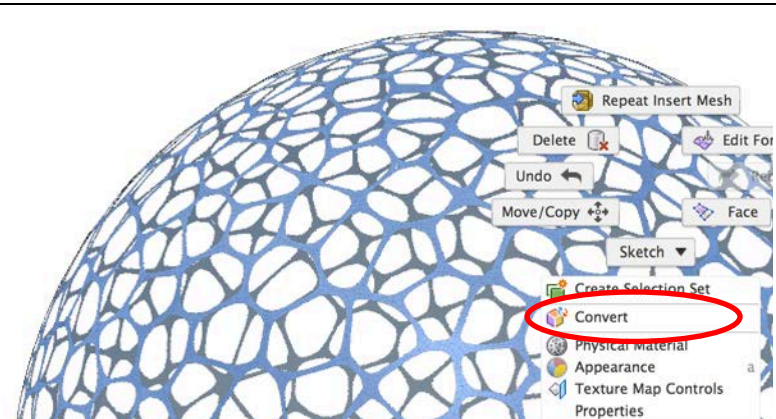


In the top panel, go to: Insert > Insert Mesh

Select the OBJ-quad file of the voronoi-based sphere with planes only (no thickness) that was created in Recap Photo.



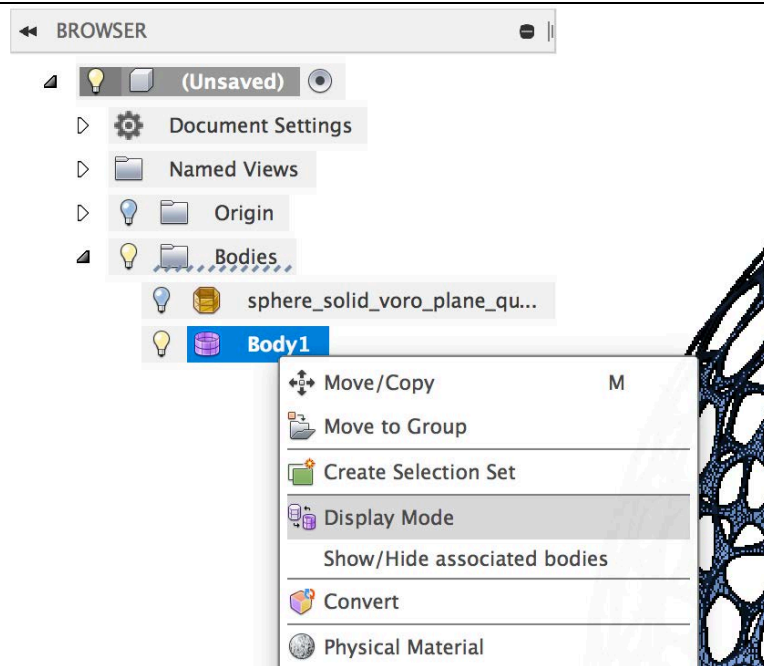
Right-click on the mesh body and select “Convert” to create a T-Spline version.



In the left panel, go to Bodies.

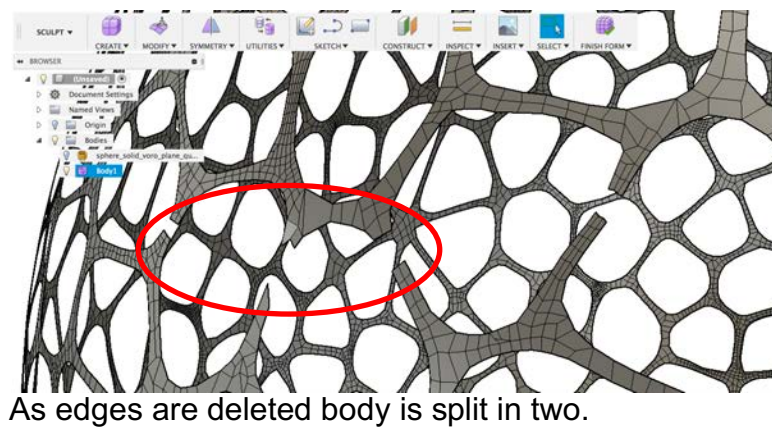
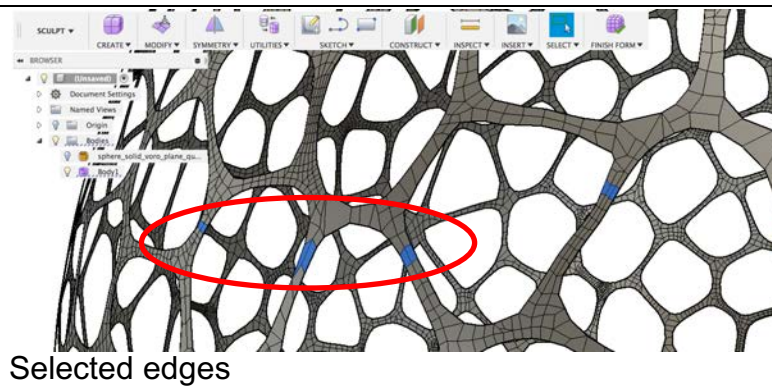
Right-click on the T-Spline body and change display mode to “box display”.

This will help to see the faces more clearly and to maintain the performance/speed of the computer.



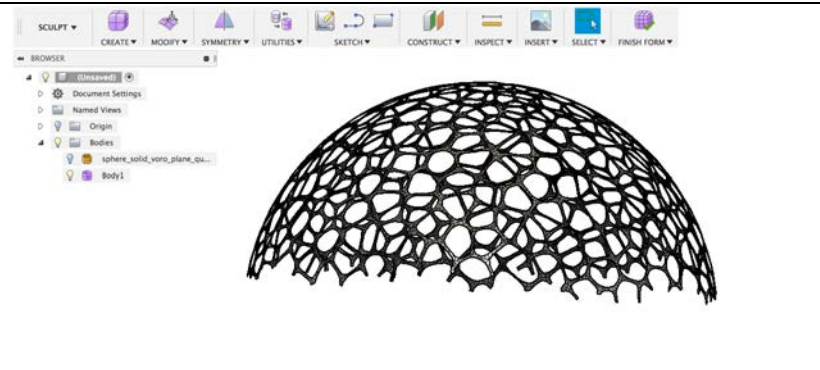
Select faces along the equator of the sphere (widest horizontal section) and delete them, in order to break the body into an “upper” and “lower” section.

Note: Make sure that you are looking at the model from the front/sides and not from an angle. Otherwise you won’t delete the faces at the right location



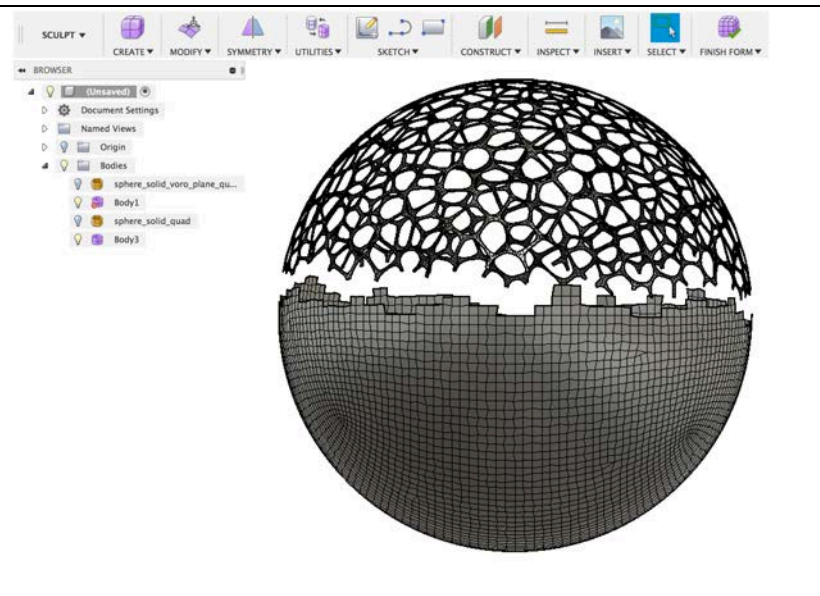
After going all around the sphere, delete the bottom portion.

In the right panel, go to the top portion body, right-click and make it “un-selectable”.



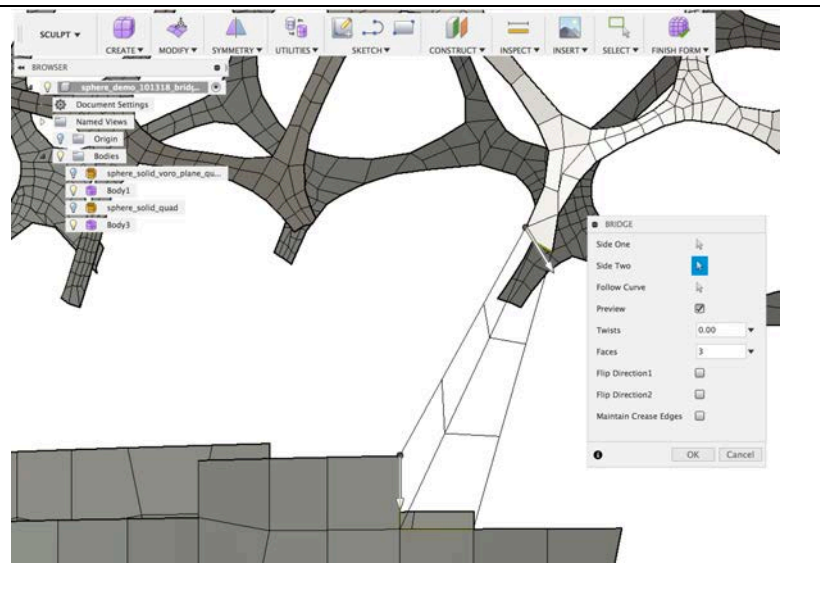
Repeat these steps for the solid version of the sphere, which will be used for the bottom part.

Make sure that there is a little bit of open space between the top (Voronoi) and bottom (solid) portions.

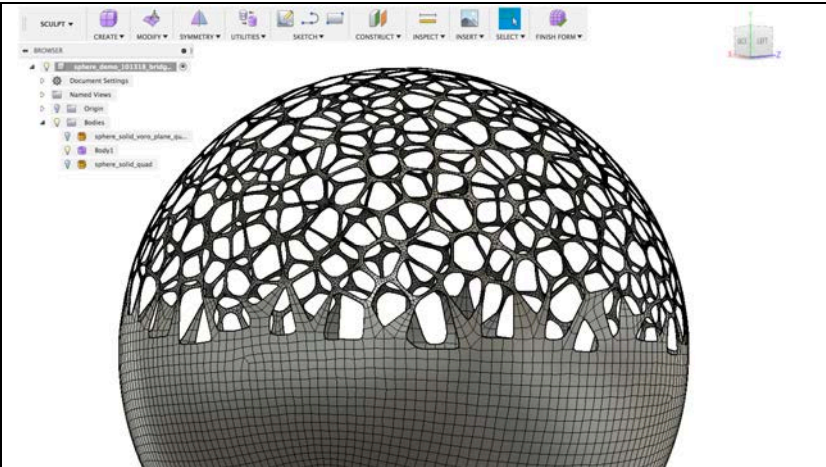


In order to connect the open edges of the top section with the bottom, go to: Modify > Bridge.

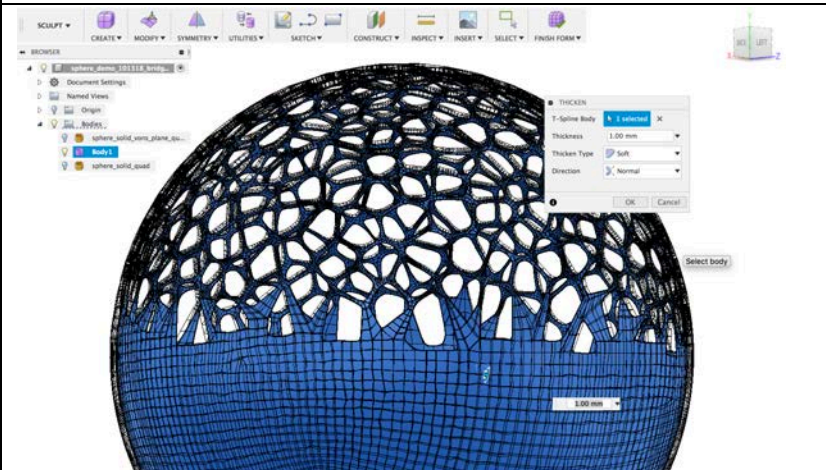
Continue doing this all around both bodies.



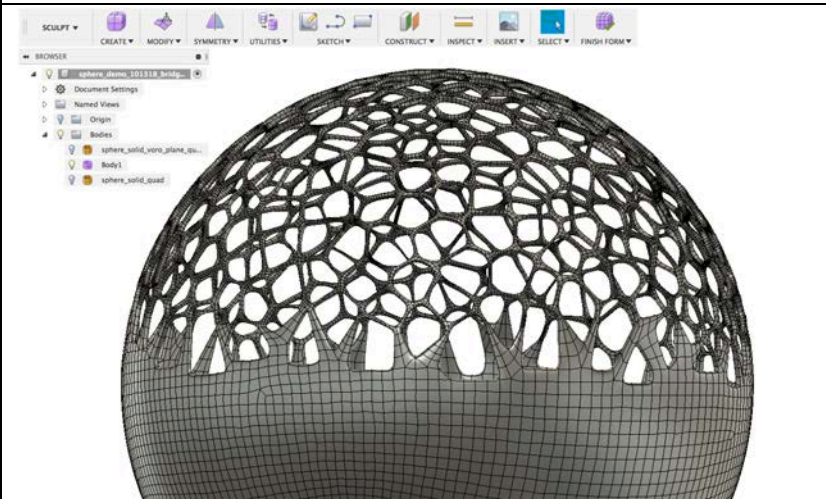
When finished connecting all edges with Bridge, the bodies should become a single unit again.



Go to: Modify > Thicken to add thickness to the body. Set thickness to 1mm, expanding outwards and thickness type to "Soft".



Body is finished. Press "finish form" to convert the file from T-Spline to B-Rep and return to Model environment.



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