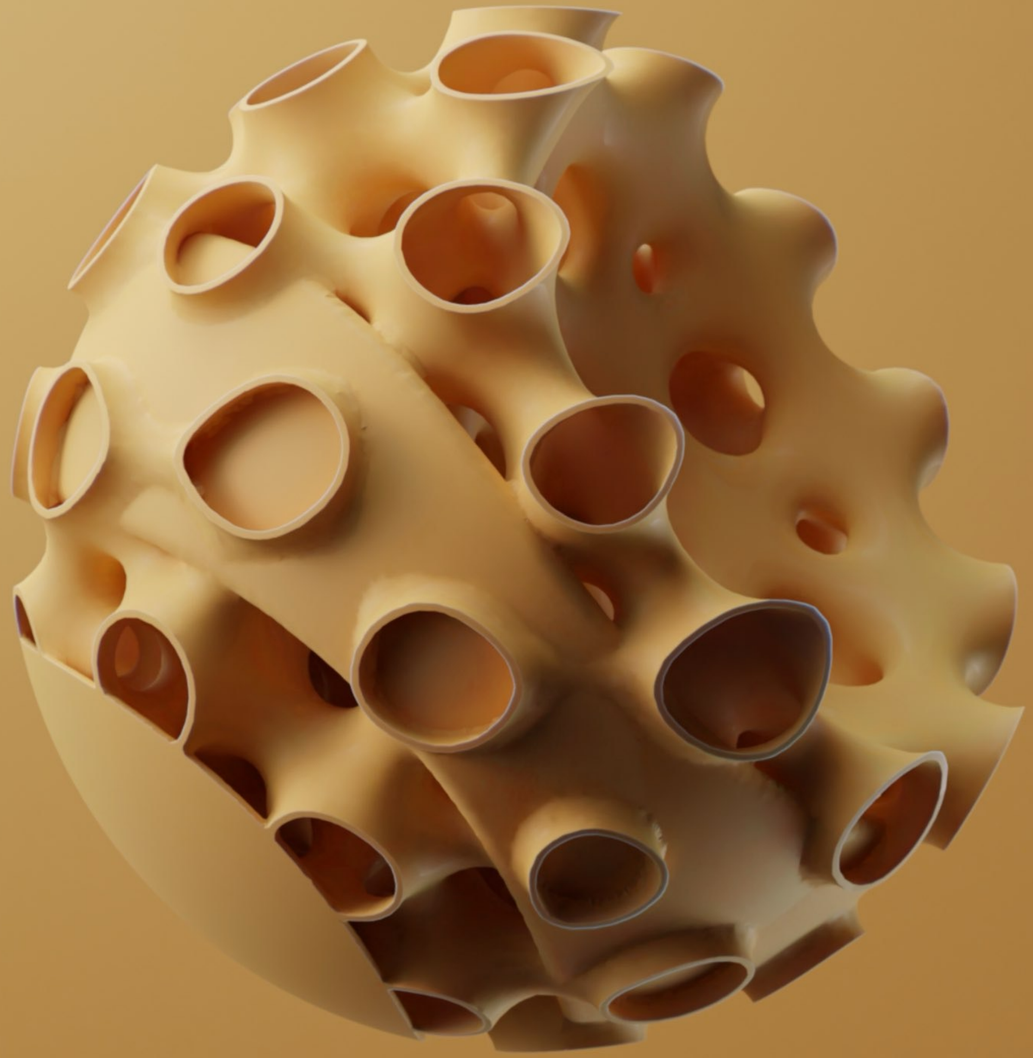


AM Experten-Talk bei Ecoparts 12.09.2024

spherene™

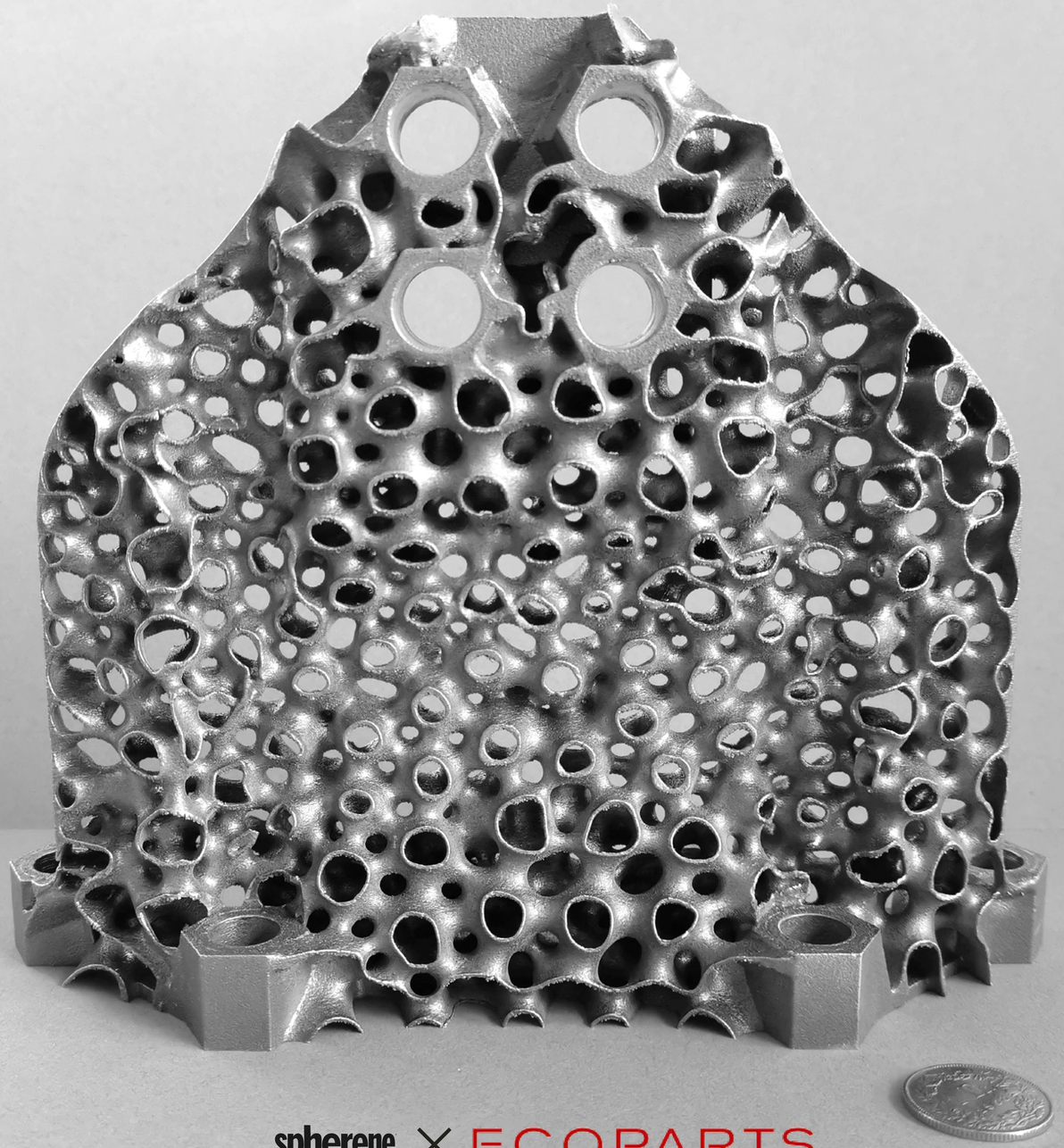
2018

spherene × ECOPARTS

2022

spherene × ECOPARTS

2022



spherene × ECOPARTS

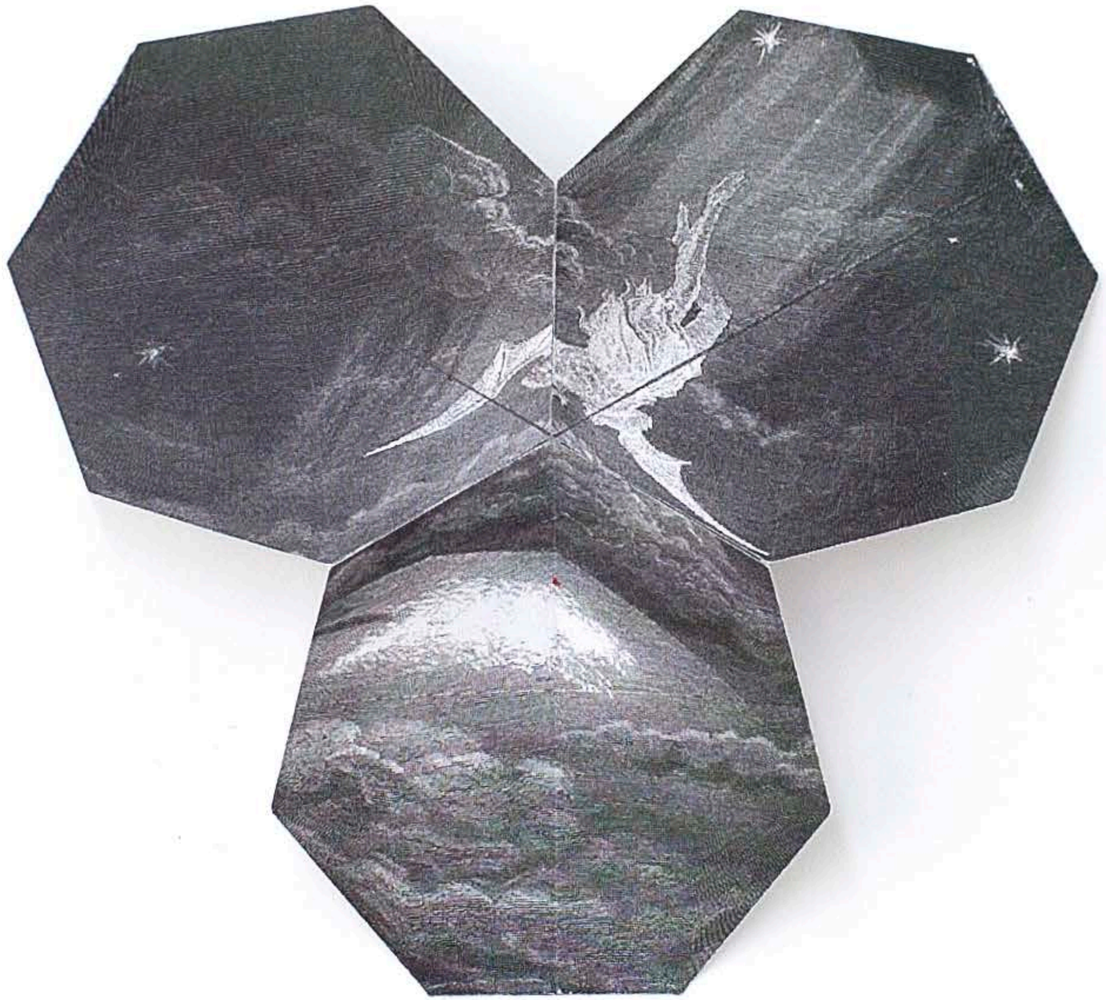
Three of my art projects that precluded the discovery of spherene:

Archangel Gabriel expelled from Heaven, because his heptagons couldn't tile the infinite plane.

Inkjet on paper, pencil, tape

82×74mm, Ed. 5, 2012

Private Collection



Steady drip of wax into random motion creates sphere.

Aluminum, carbon, ball bearings, motors, random generator, microcontroller, software, cotton, copper, heating elements, high temperature insulation, paraffin, fire.

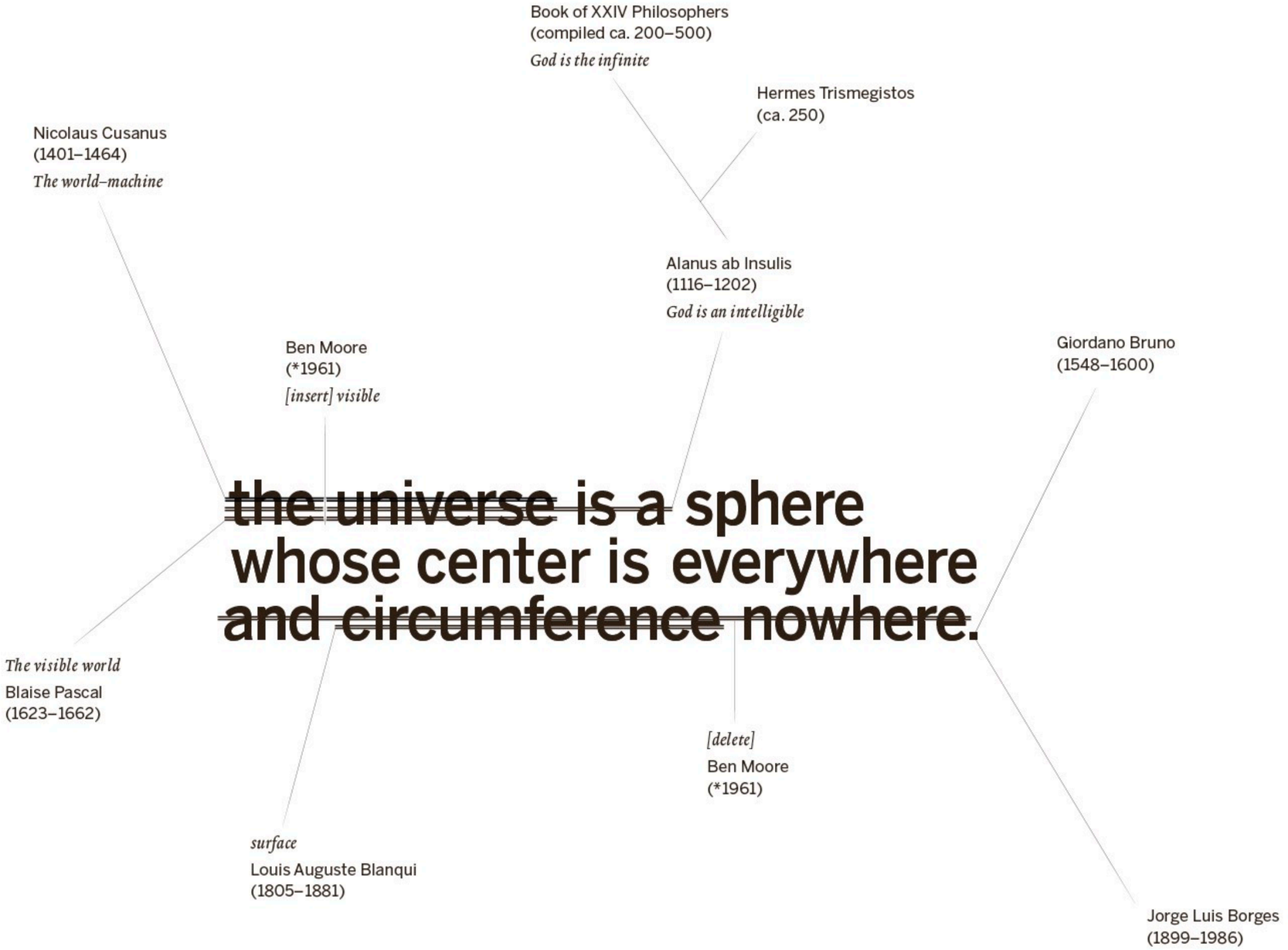
835 × 835 × 2230 mm, Ed. 3, 2013

Collection Morra Greco, Napoli

spherene

Ancient Universe model which is still true today.

Contribution to Frieze d/e No. 22, 2015

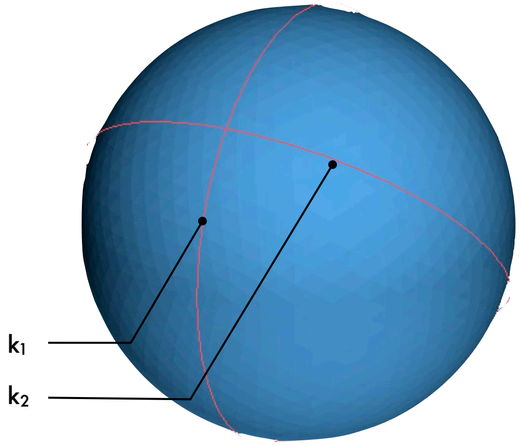


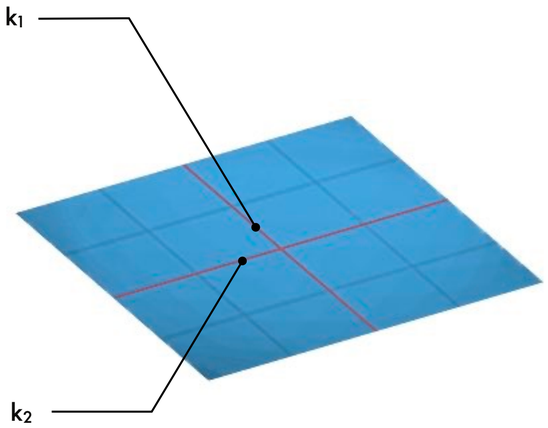
spherene

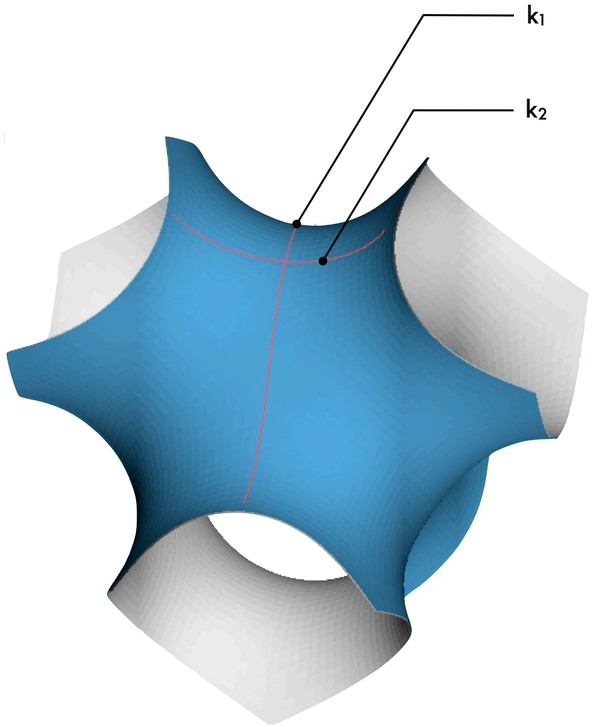

Countless paper models later, spherene Ltd. was founded in 2018, with headquarters in Zürich.
spherene

Minimal Surface:

Zero mean curvature at every point







SPHERE

Constant Positive Curvature
$k_1 = k_2 > 0$

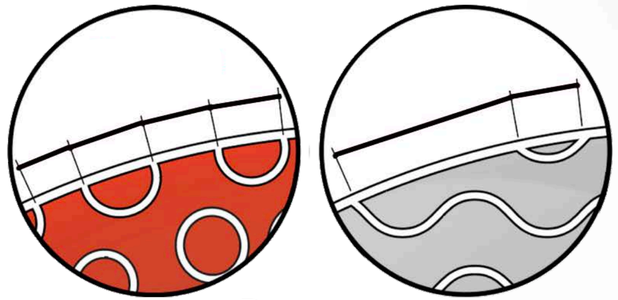
PLANE

Zero Curvature
$k_1 = k_2 = 0$

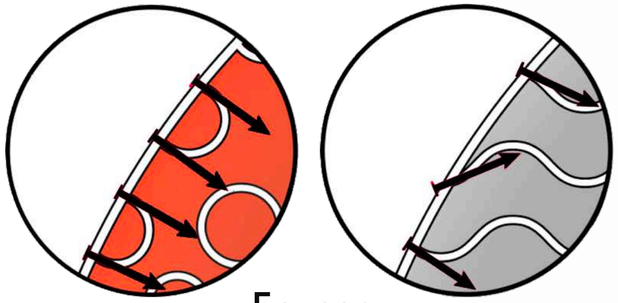
MINIMAL SURFACE

Zero Mean Curvature
$k_1 = -k_2 = 0$

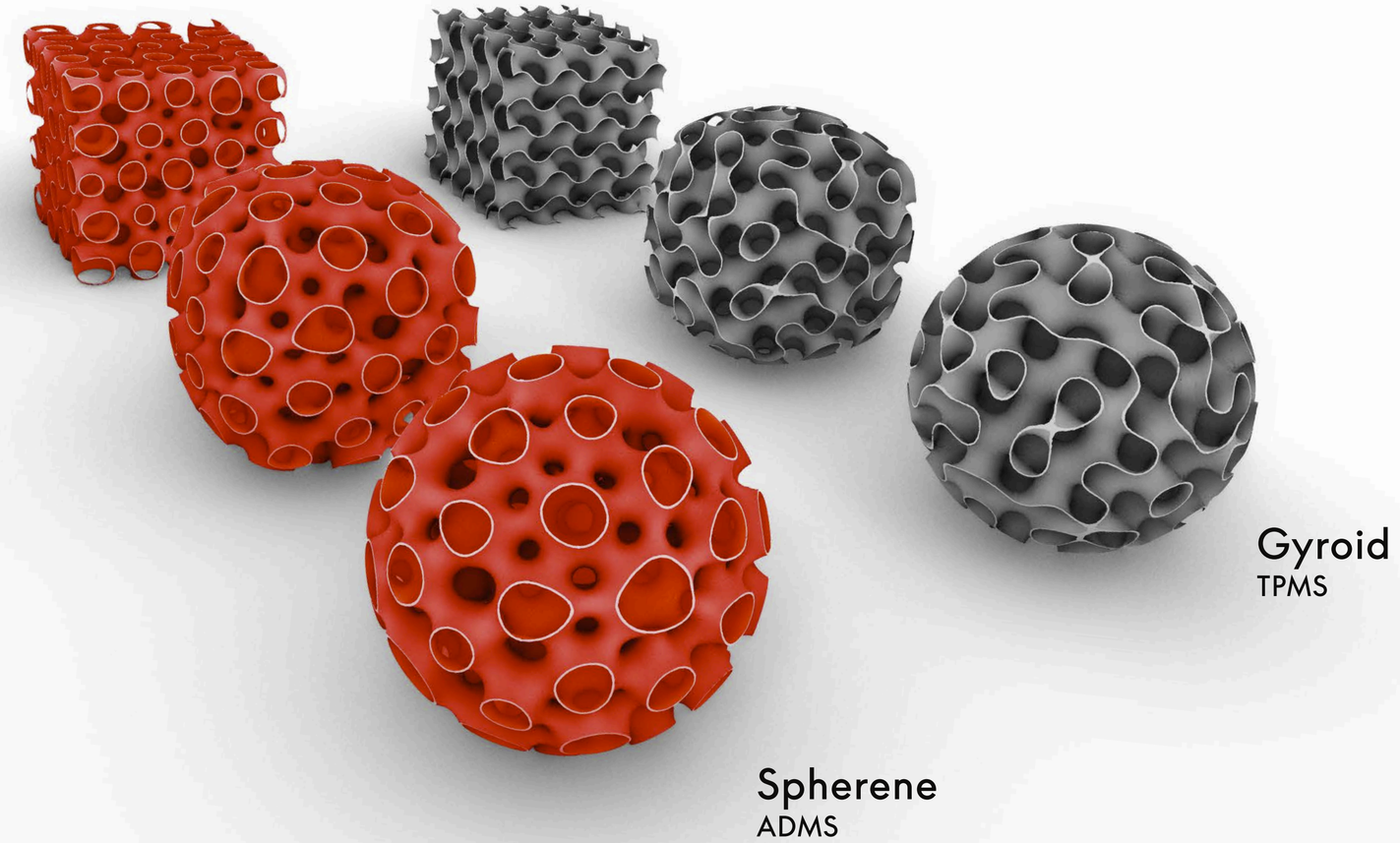
Spherenes:
Minimal Surfaces (ADMS)
True Isotropic
Surface Conformal



Distance



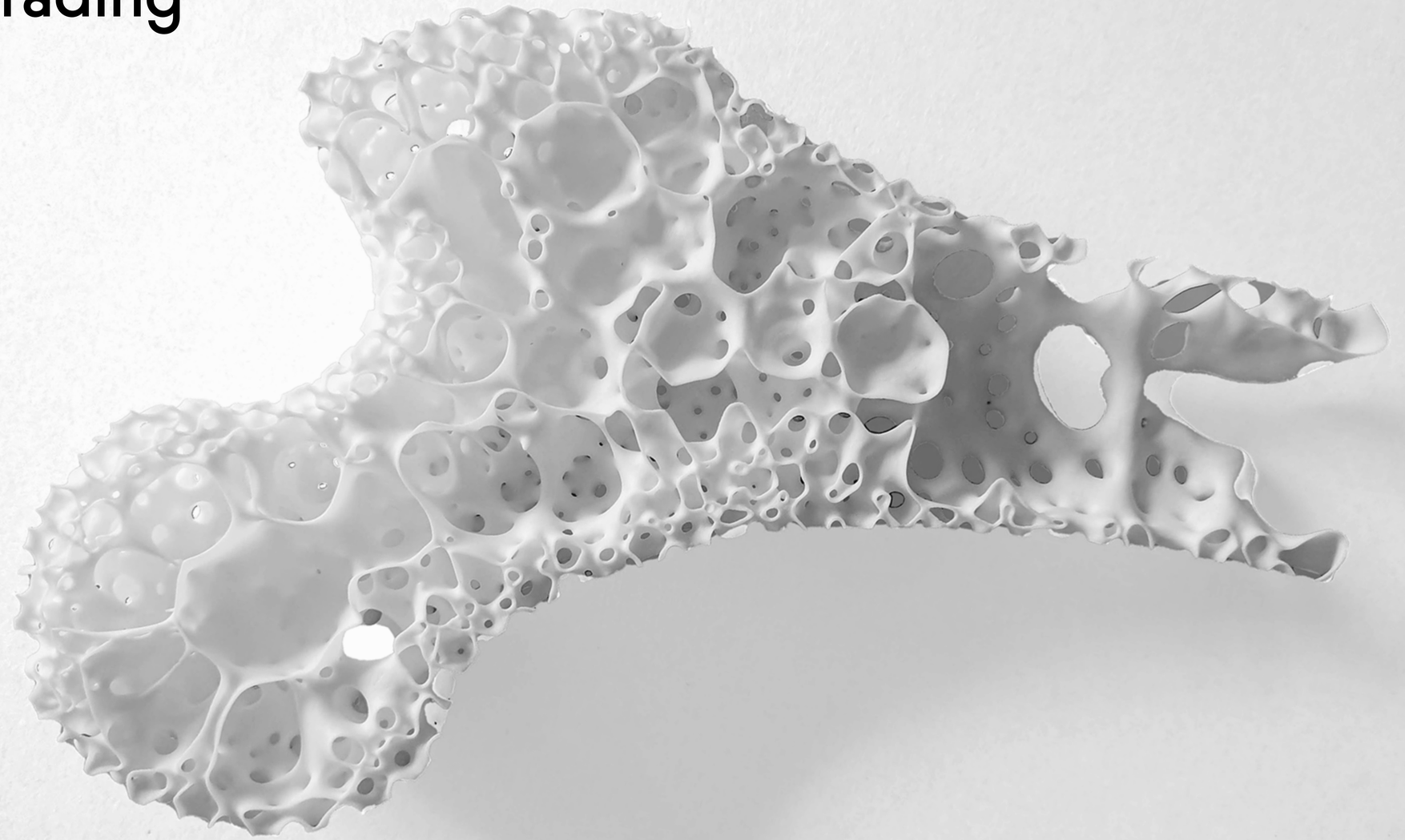
Forces



Gyroid
TPMS

Spherene
ADMS

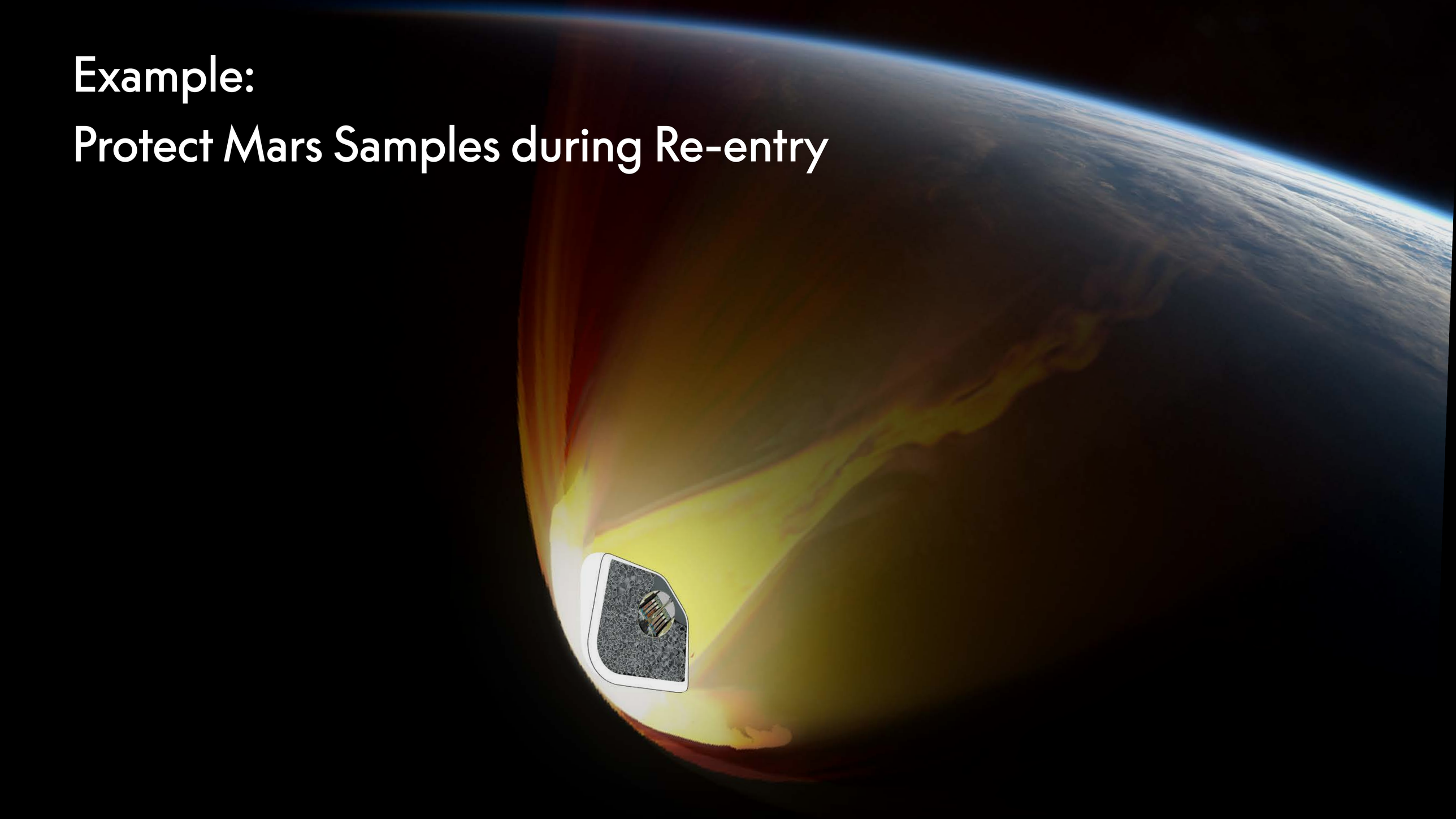
Example:
Organic Grading



Example:

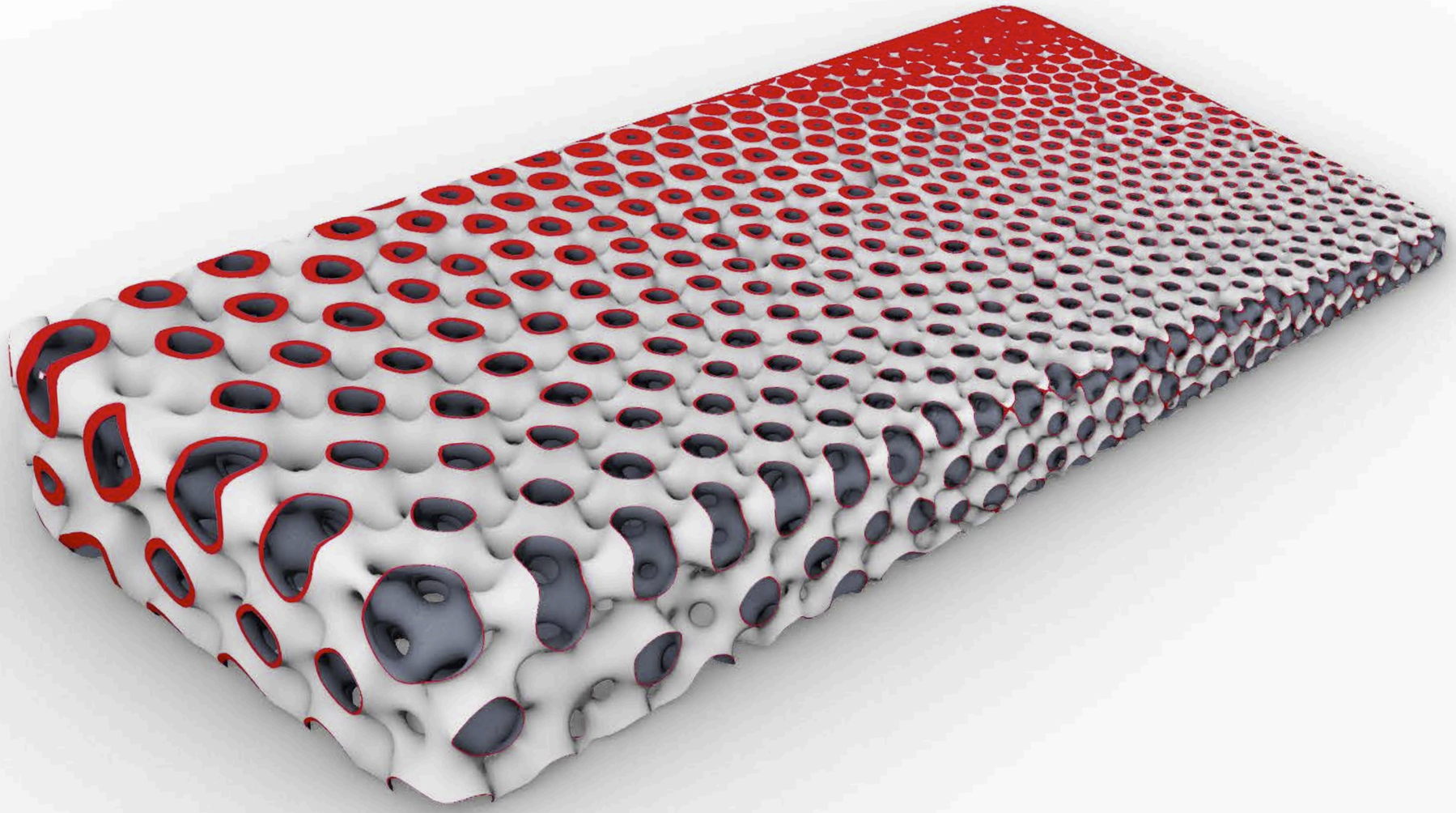
Emulate Aluminium Mass in a Steel Print.

Example:
Protect Mars Samples during Re-entry

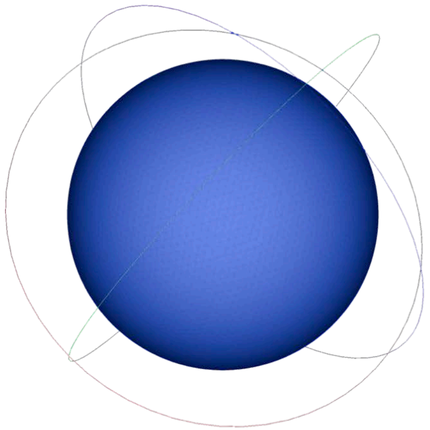


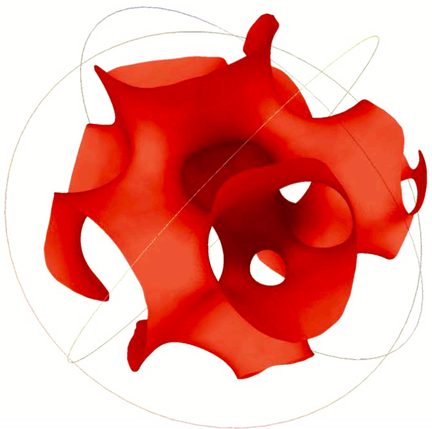
Spherenes are:

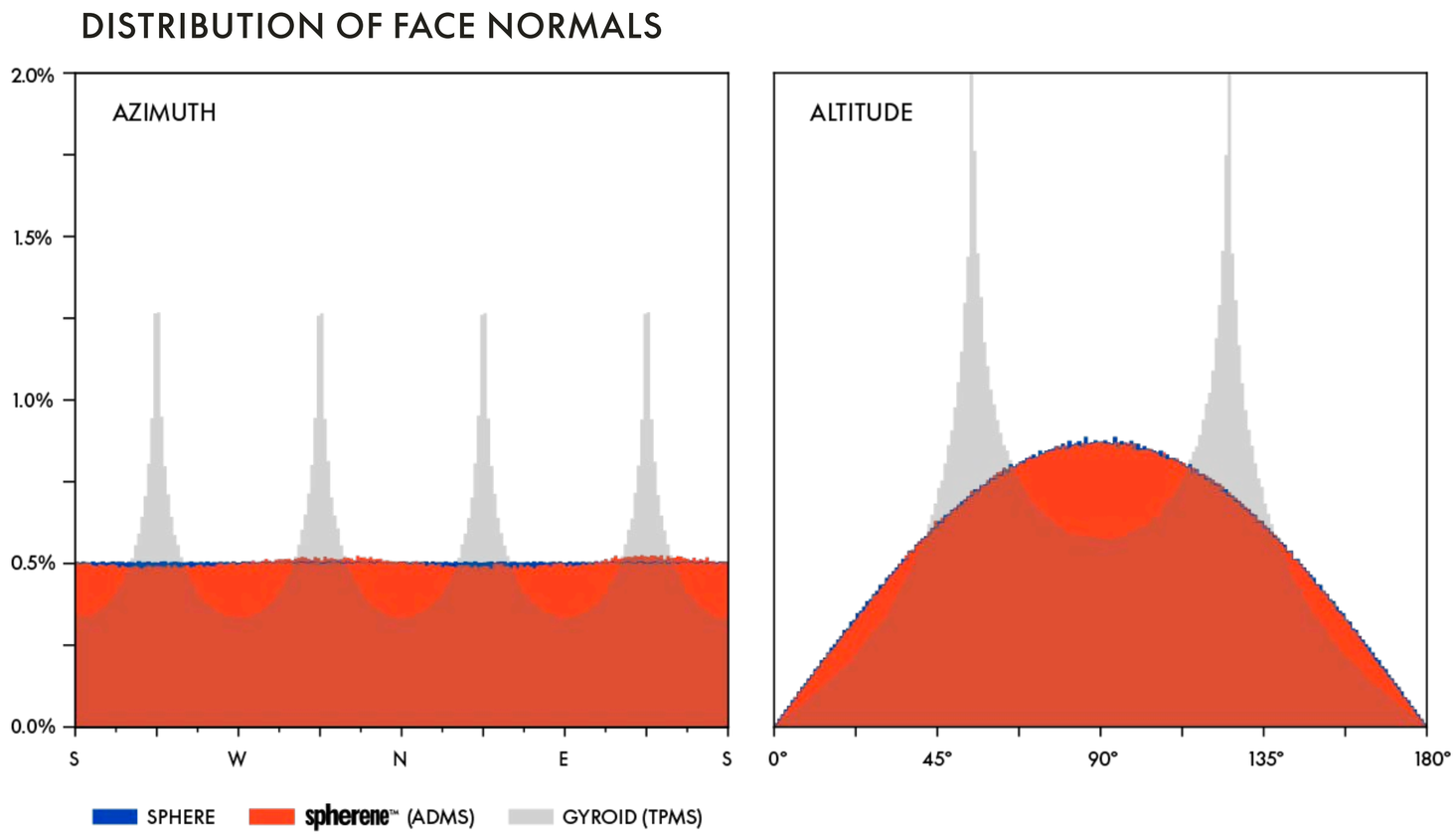
Controlled.



Inverted spheres, isotropic.







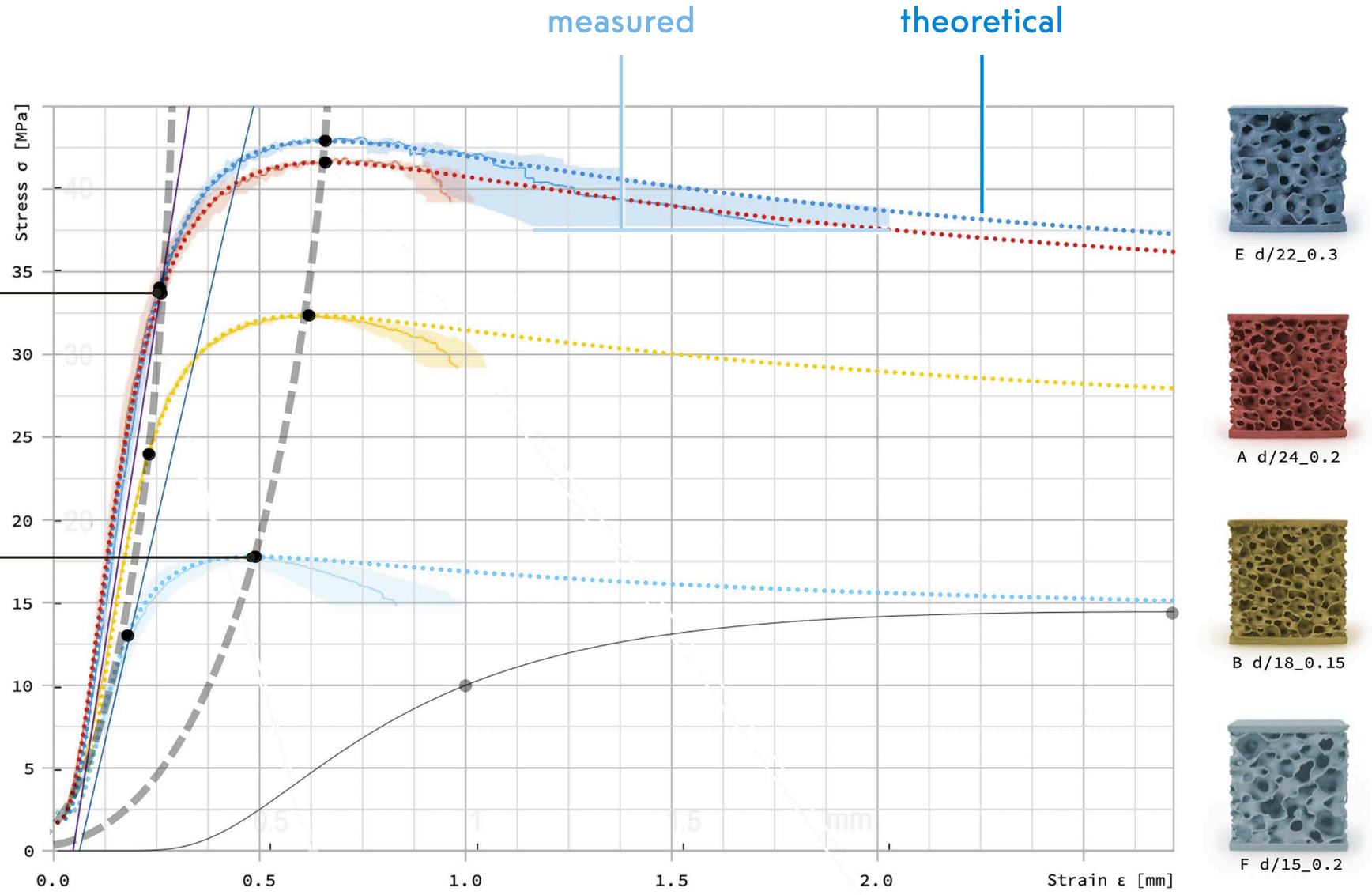
Predictable.

yield at x = 1.00 equiv.

break at x = 2.7182 equiv.

$$\text{stress} = \sqrt[\text{strain}]{\text{strain}}$$

(parametrisation tbd.)



E d/22_0.3

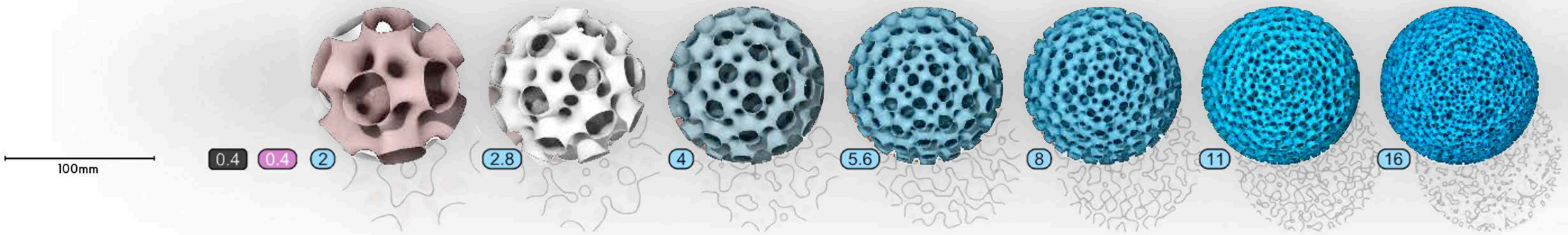
A d/24_0.2

B d/18_0.15

F d/15_0.2

spherene

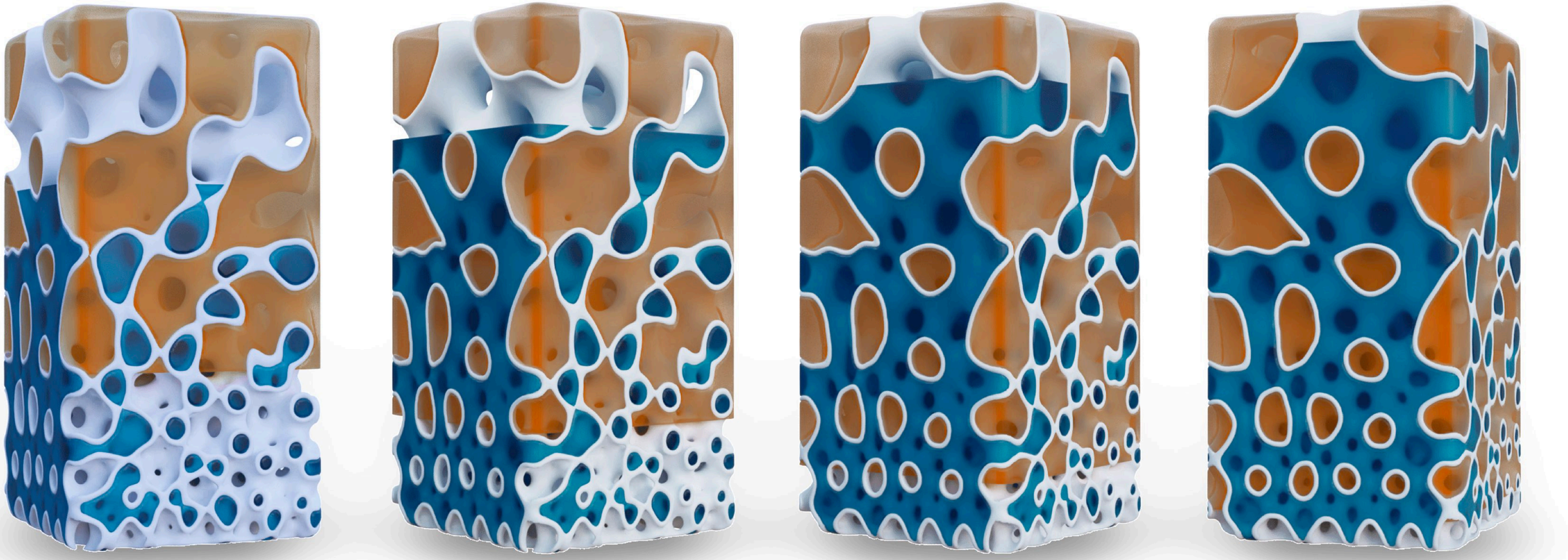
Stochastic, yet regular.



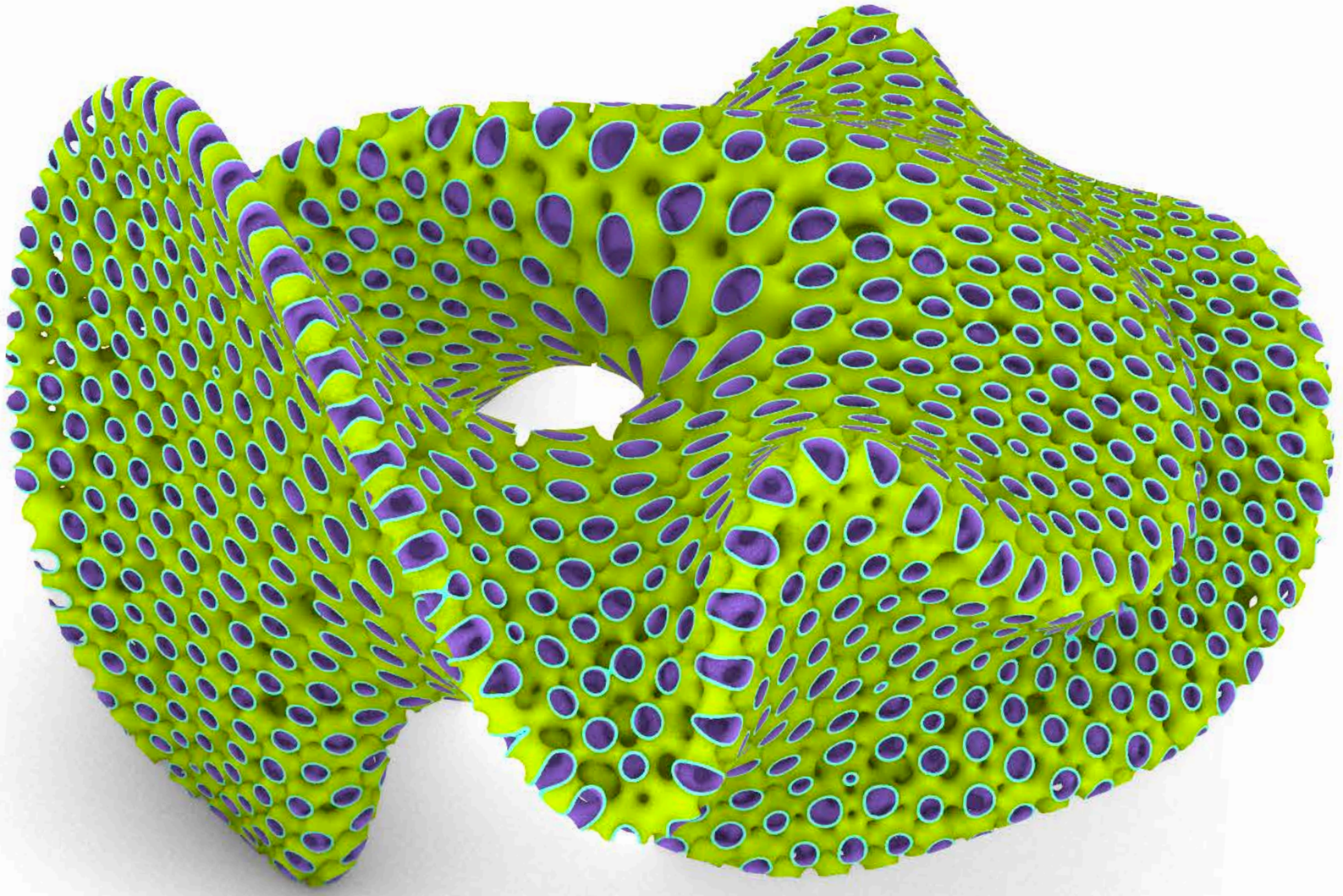
d-stop	*d/2*	*d/2.8*	*d/4*	*d/5.6*	*d/8*	*d/11*	*d/16*
Volume percentage	2.0%	2.8%	4.0%	5.6%	8.0%	11.0%	16.0%
Pore size estimate	46mm	21mm	14mm	10mm	7mm	5mm	3mm
Outer hole diameter	100mm	43mm	27mm	18mm	12mm	9mm	6mm
Genus	3	24	83	265	835	2271	6860
Triangle count	100k	200k	400k	600k	800k	1000k	4000k
Average edge length	2.0mm	2.0mm	2.0mm	1.5mm	1.1mm	0.8mm	0.5mm

Dual Domain.

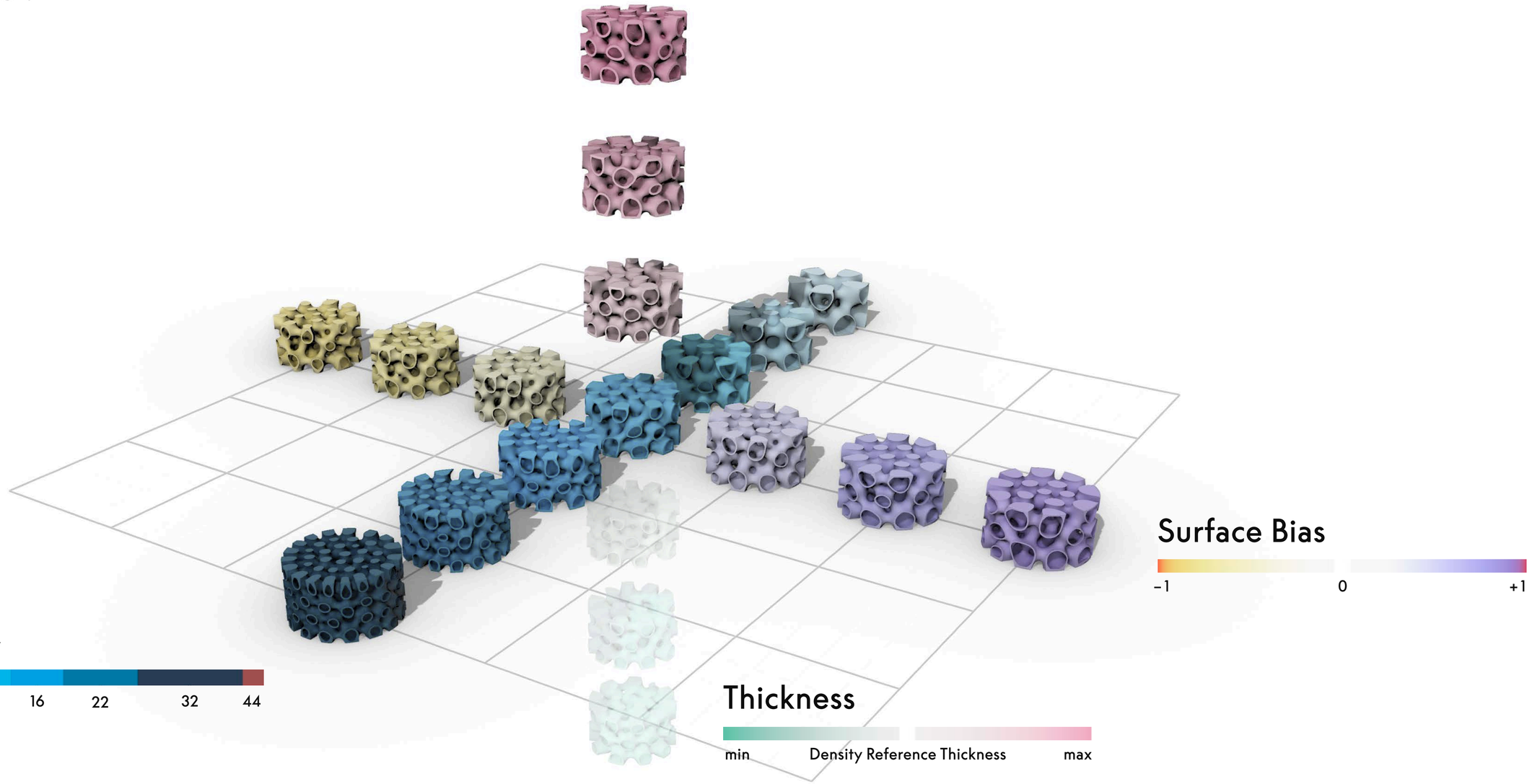
(two labyrinths)



Surface Conformal.



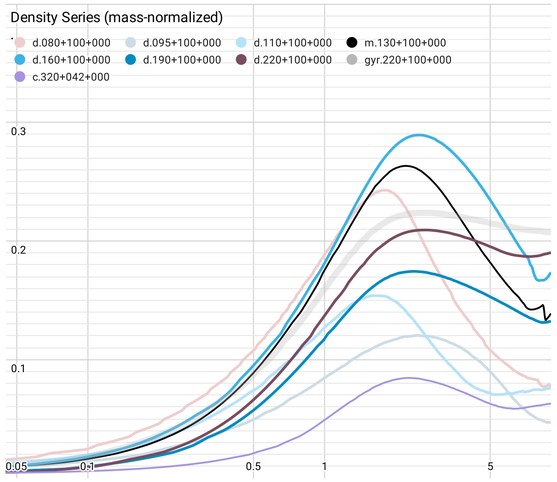
Intuitive.


Density
2 4 8 11 16 22 32 44
Thickness
min
Density Reference Thickness
max
Surface Bias
−1
0
+1

(Stress & Strain Curves)

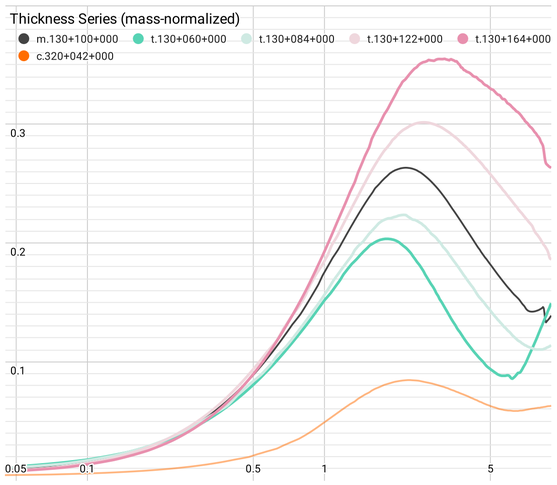
Density

2 4 8 11 16 22 32 44



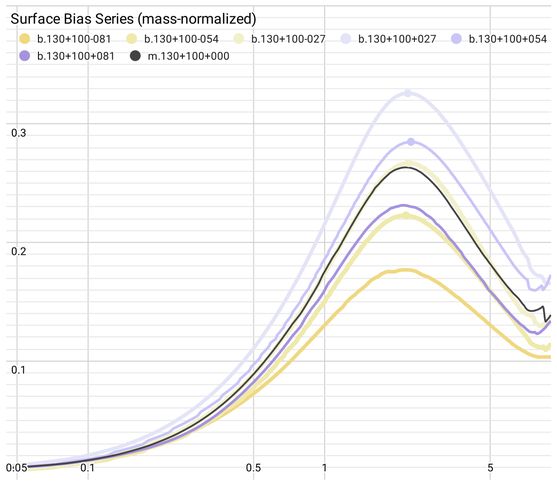
Thickness

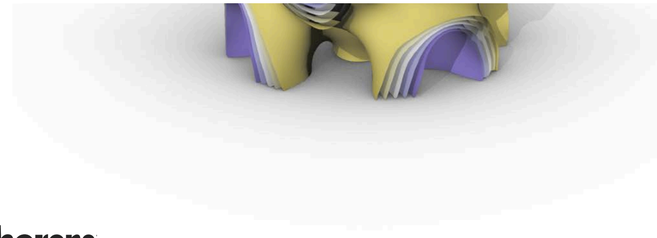
min Density Ref. Thickness max



Surface Bias

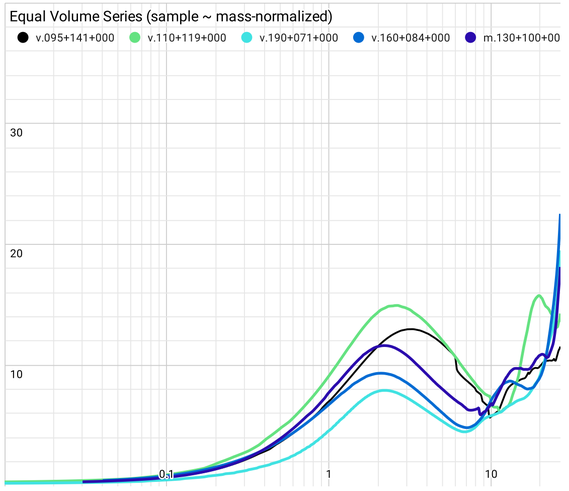
−1 0 +1

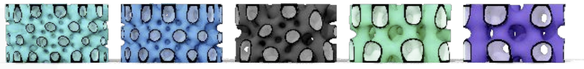




Equal Volume

d/9.5, 11, 13, 16, 19
TH 1.41, 1.19, 1.00, 0.84, 0.71
SB 0





spherene

Implementation:

Accessed via API.

CAD Clients:

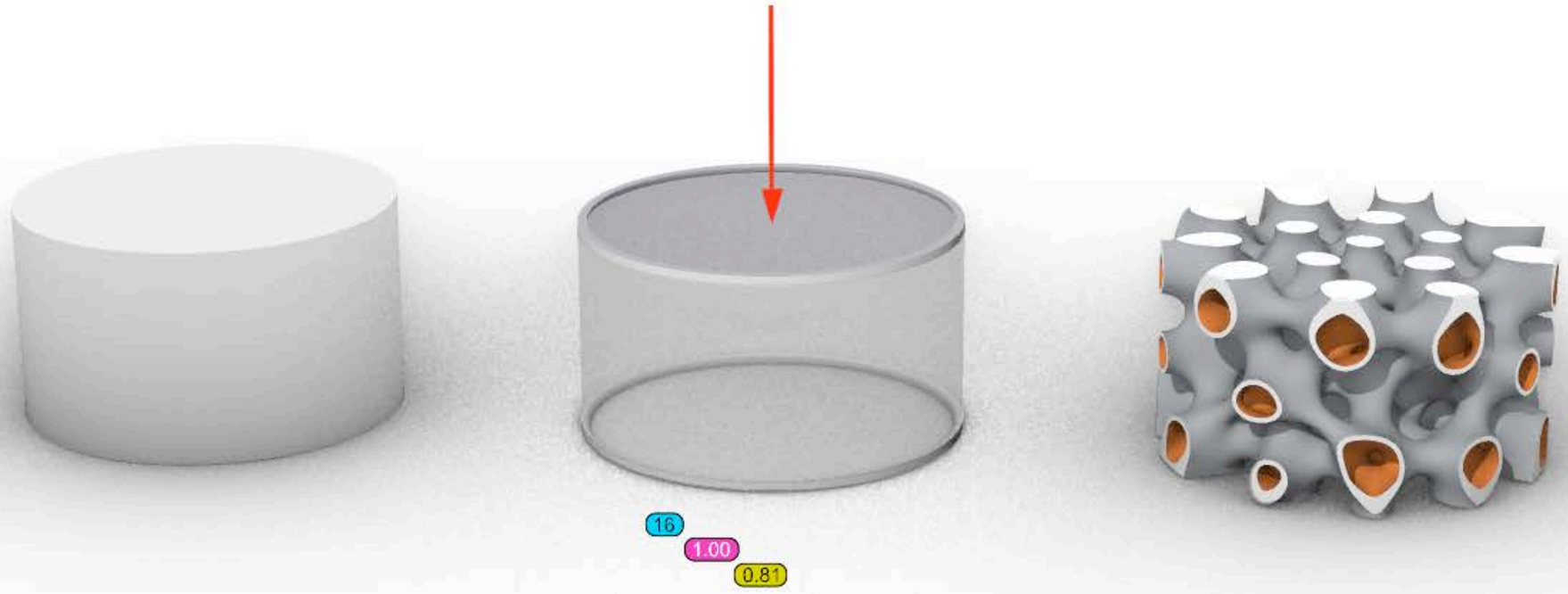
— Rhinoceros3D

— Grasshopper (Pre-Release)

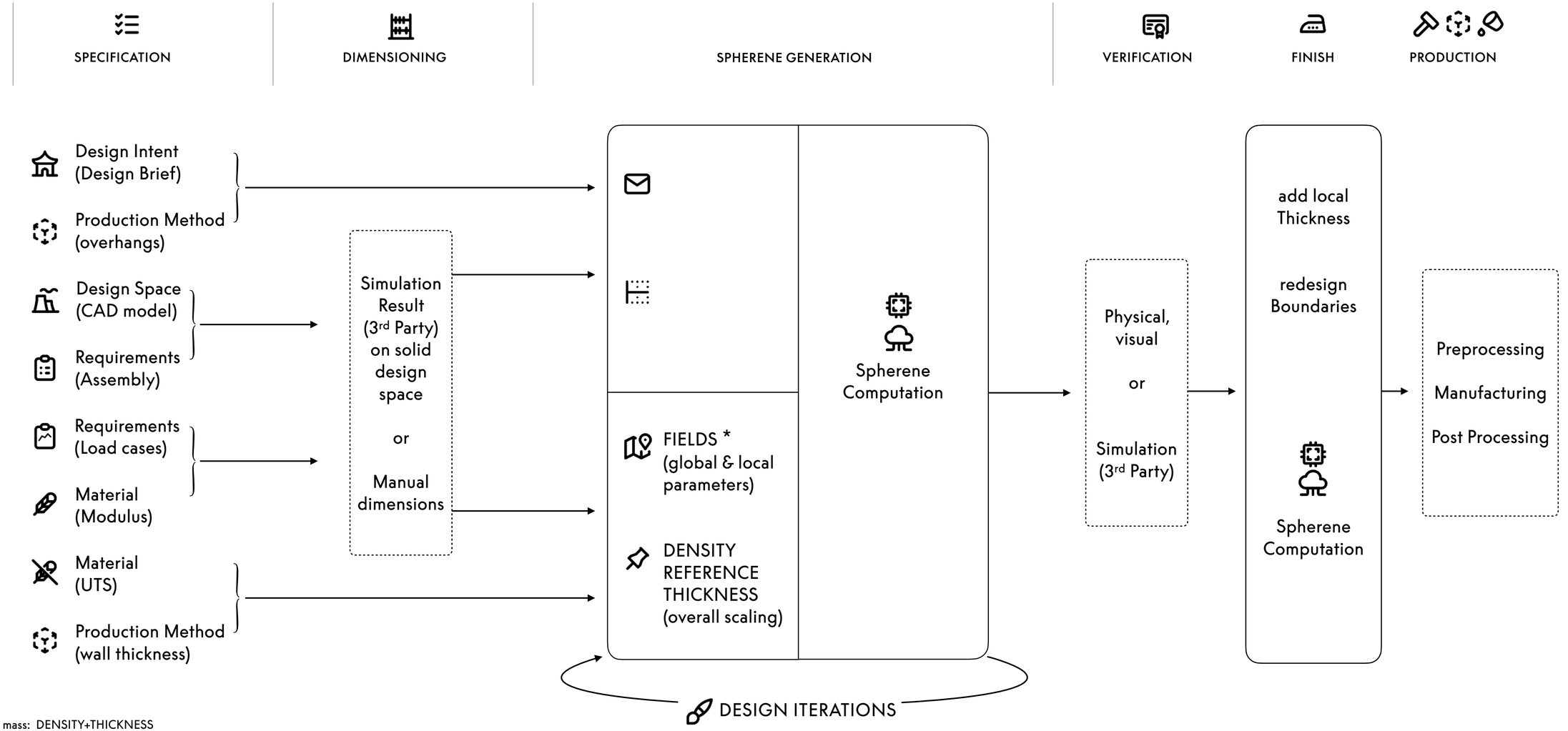
And more to come.

Simple workflow.

Load Envelope → Set Requirements → Compute Metamaterial



Embedded in yours.

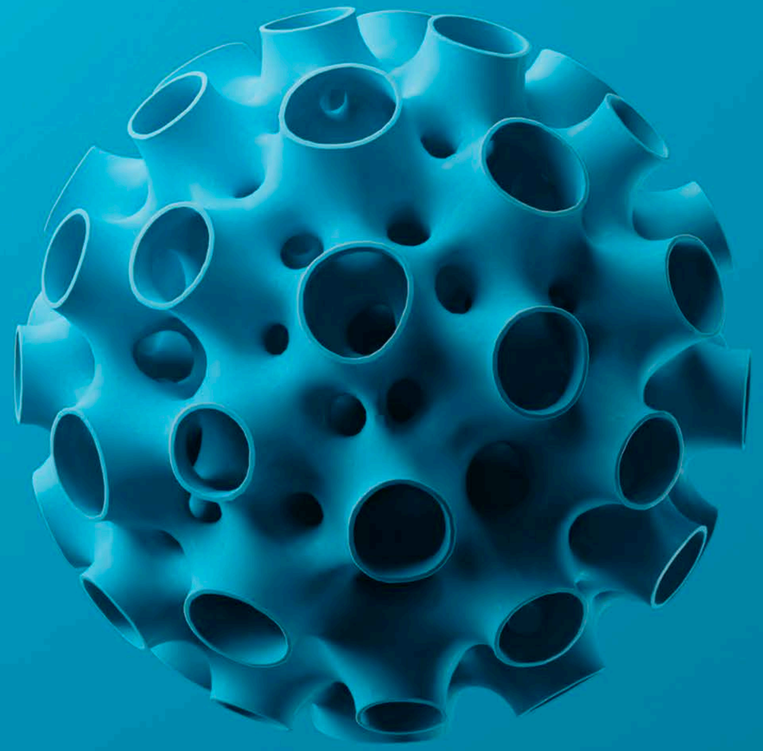


* control strength, stiffness, mass: DENSITY+THICKNESS
center of mass, local lightweighting: DENSITY, CAVITY
eradicate stress concentrations: THICKNESS
increase elasticity: SURFACE BIAS

spherene

spherene Metamaterial:

Provides locally adjustable density, yet retains characteristics of bulk material. And it's isotropic. And surface conformal, too.



spherene Metamaterial:

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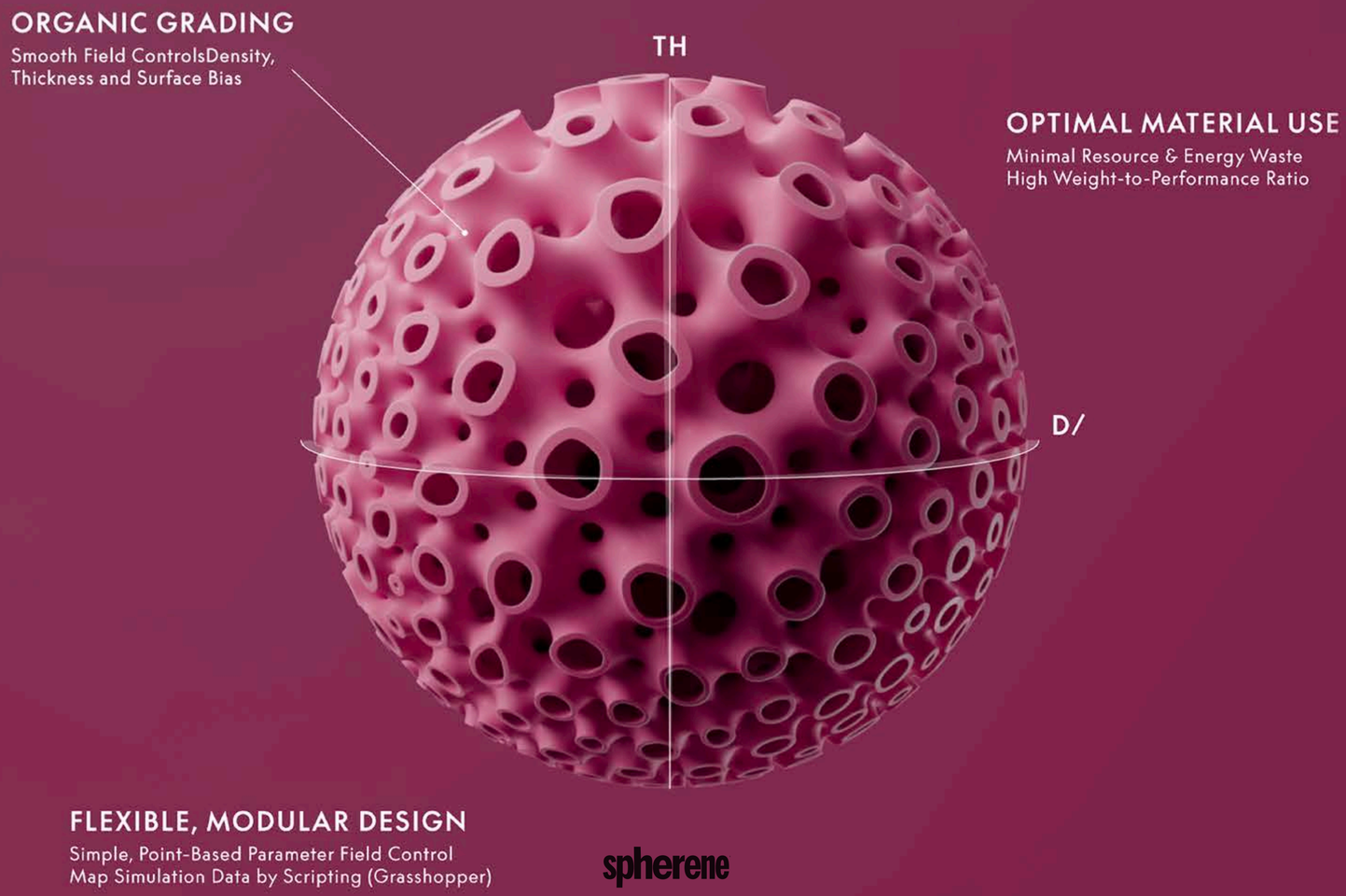


spherene Metamaterial:

Provides locally adjustable density, yet retains characteristics of bulk material. And it's isotropic. And surface conformal, too.

CAVITY
Repel Surface Geometry
Maintain Support-Free Printability

BOUNDARY
Control Shape Closure
Integrate Assembly

DESIGN INTENT FIRST
Best-in-Class Workflow
API access via Rhino3D Client
Metamaterial Forms Autonomously

spherene

next up: live software demo


hh:mm:ss
Begin Live Software Demo: spherene v0.9.6 (RC1) running in Rhino 8 for macos.

spherene

00:00:00 Design space, loads, interfaces

CDFAM_2024_demo.3dm — Edited

Viewport
Title Perspective
Width 2928
Height 2140
Projection Perspective
Display mode Rendered
Locked

Camera
Lens Length (mm) 46.0
Rotation 0.0
X Location 274.441
Y Location -529.713
Z Location 114.778
Distance to Target 547.369
Location Place...

Target
X Target 0.398
Y Target -77.214
Z Target -25.784
Location Place...

Wallpaper
Filename (none)
Show
Gray

0 objects selected
Reset Apply

Size:
X: 0.000 Uniform
Y: 0.000 Increment:
Z: 0.000 0.5

Scale:
X: 1 Uniform
Y: 1 Increment:
Z: 1 0.0333

Position:

I/O
HELP

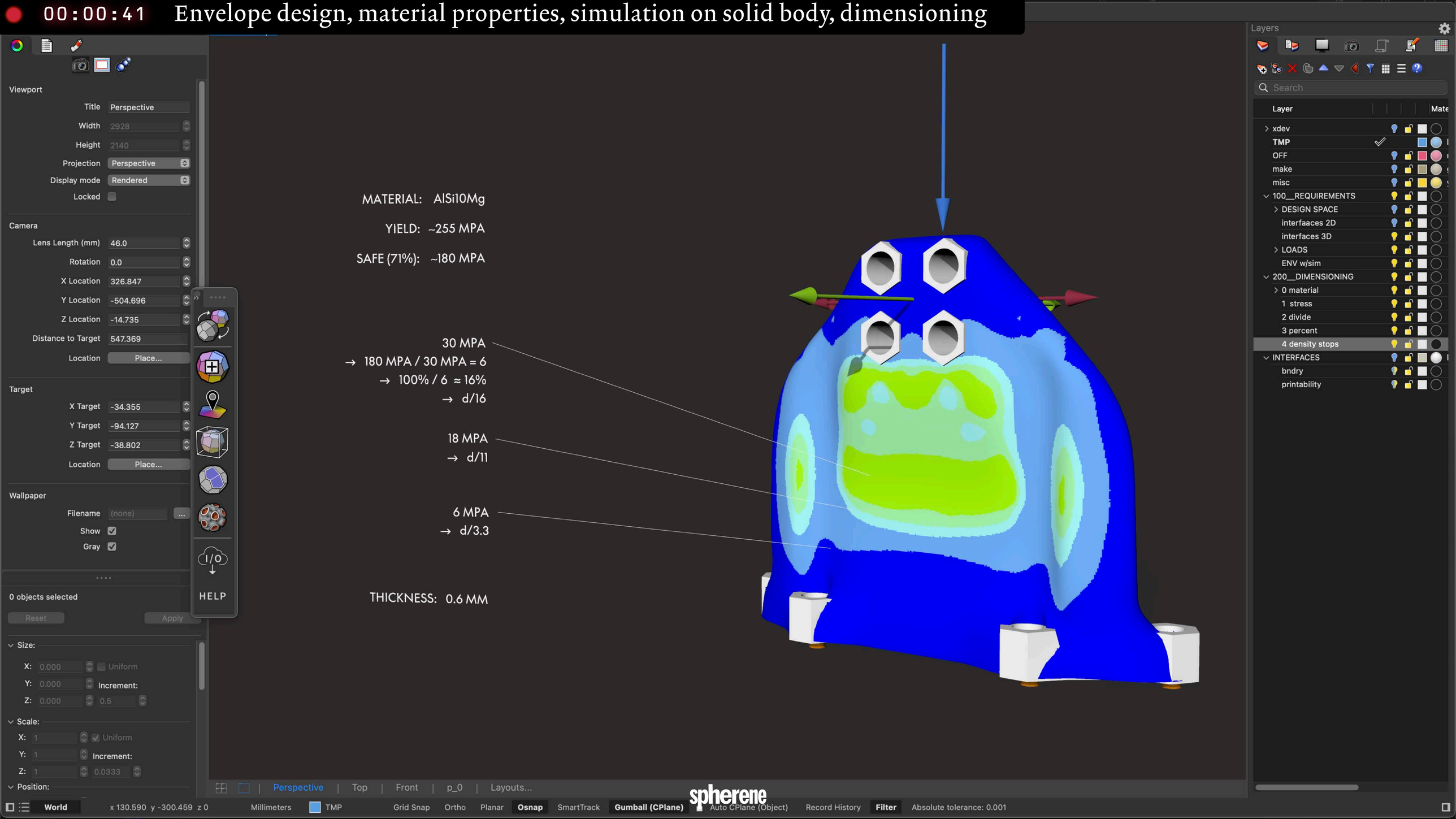
Layers
Search
Layer Mate
xdev
TMP
OFF
make
misc
100__REQUIREMENTS
DESIGN SPACE
interfaaces 2D
interfaces 3D
LOADS
ENV w/sim
200__DIMENSIONING
0 material
1 stress
2 divide
3 percent
4 density stops
INTERFACES
bndry
printability

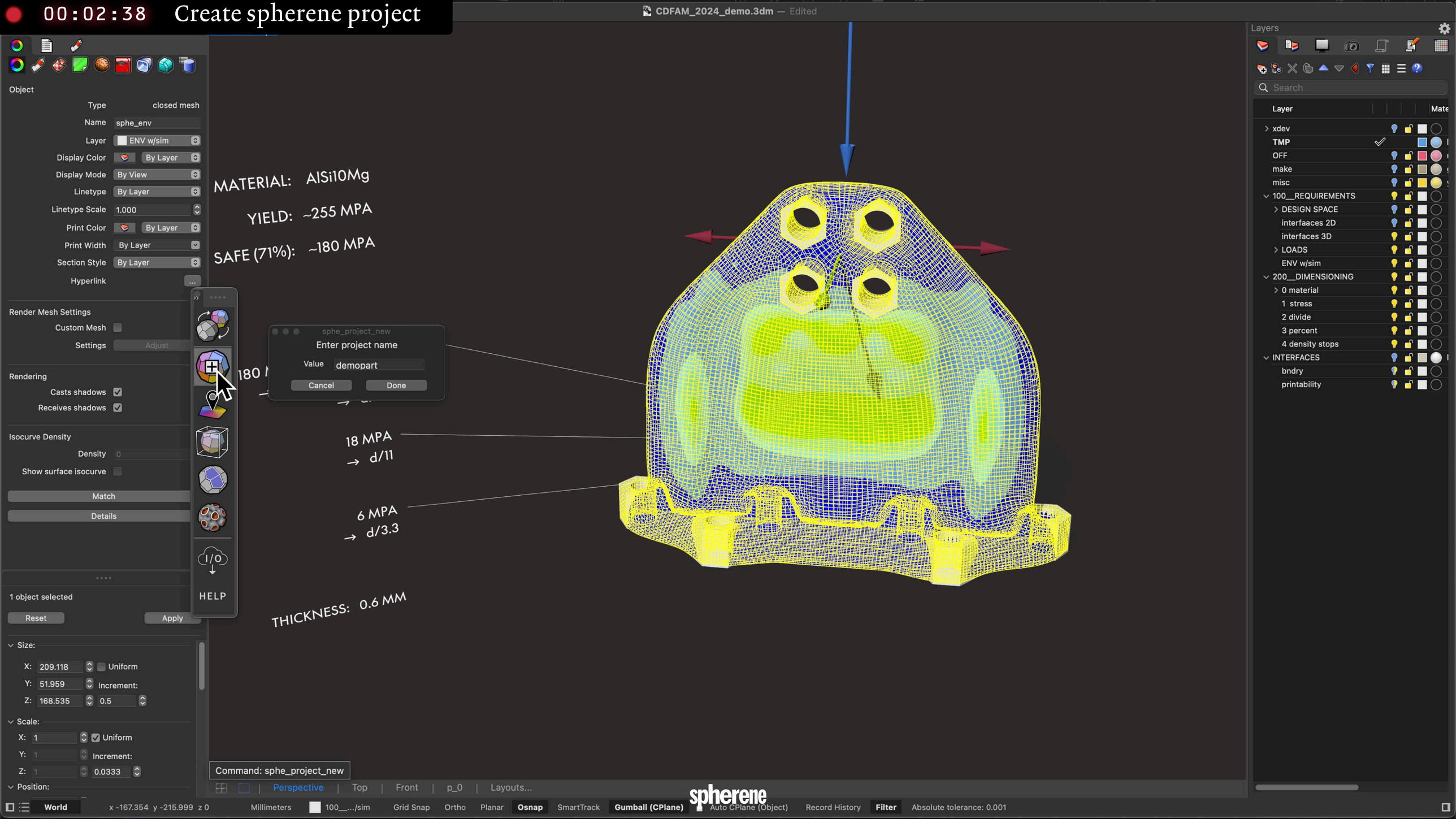
Perspective | Top | Front | p_0 | Layouts...

spherene

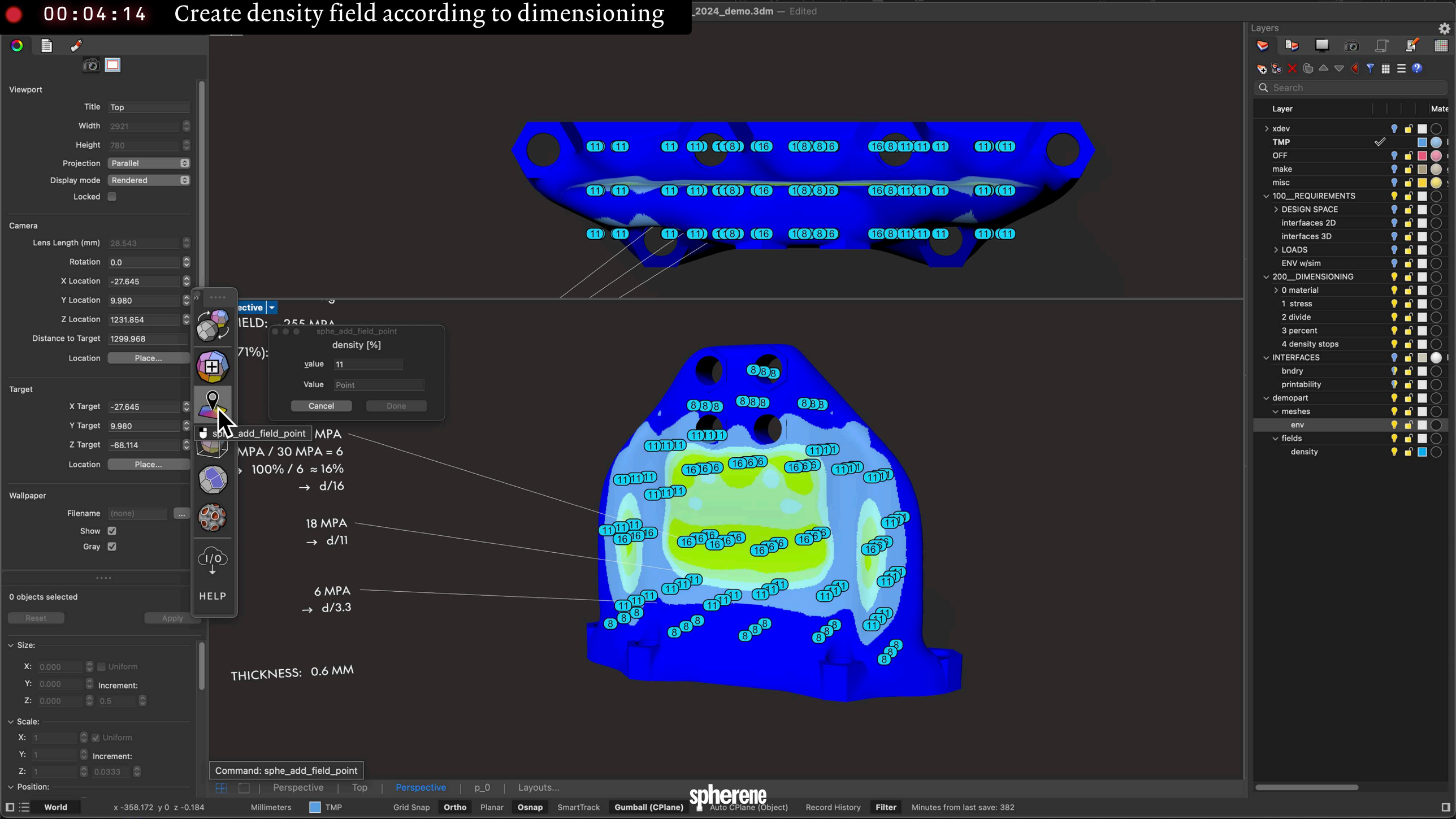
World x 180.622 y -280.564 z 0 Millimeters TMP Grid Snap Ortho Planar Osnap SmartTrack Gumball (CPlane) Auto CPlane (Object) Record History Filter Minutes from last save: 357

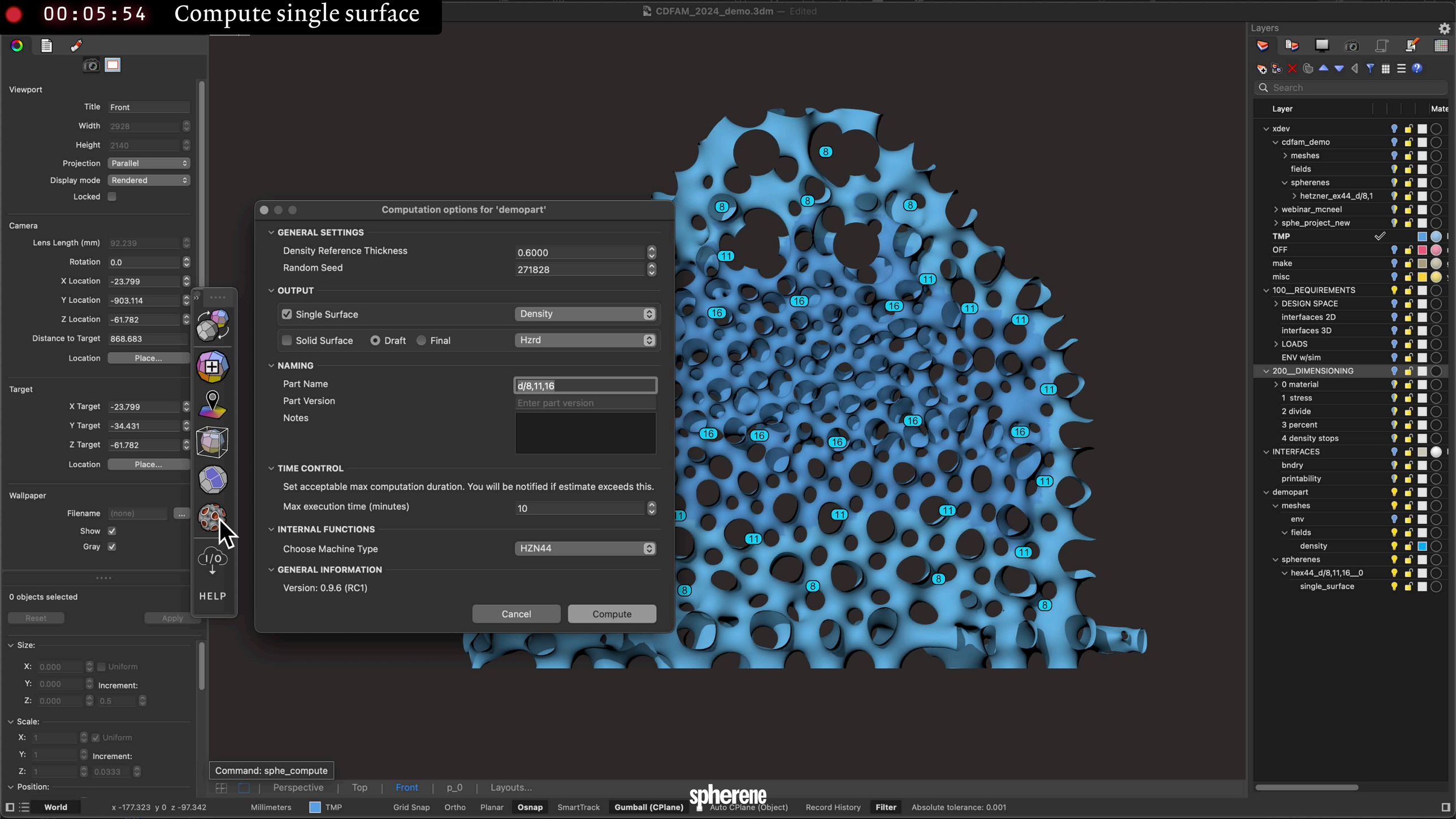
00:00:41 Envelope design, material properties, simulation on solid body, dimensioning

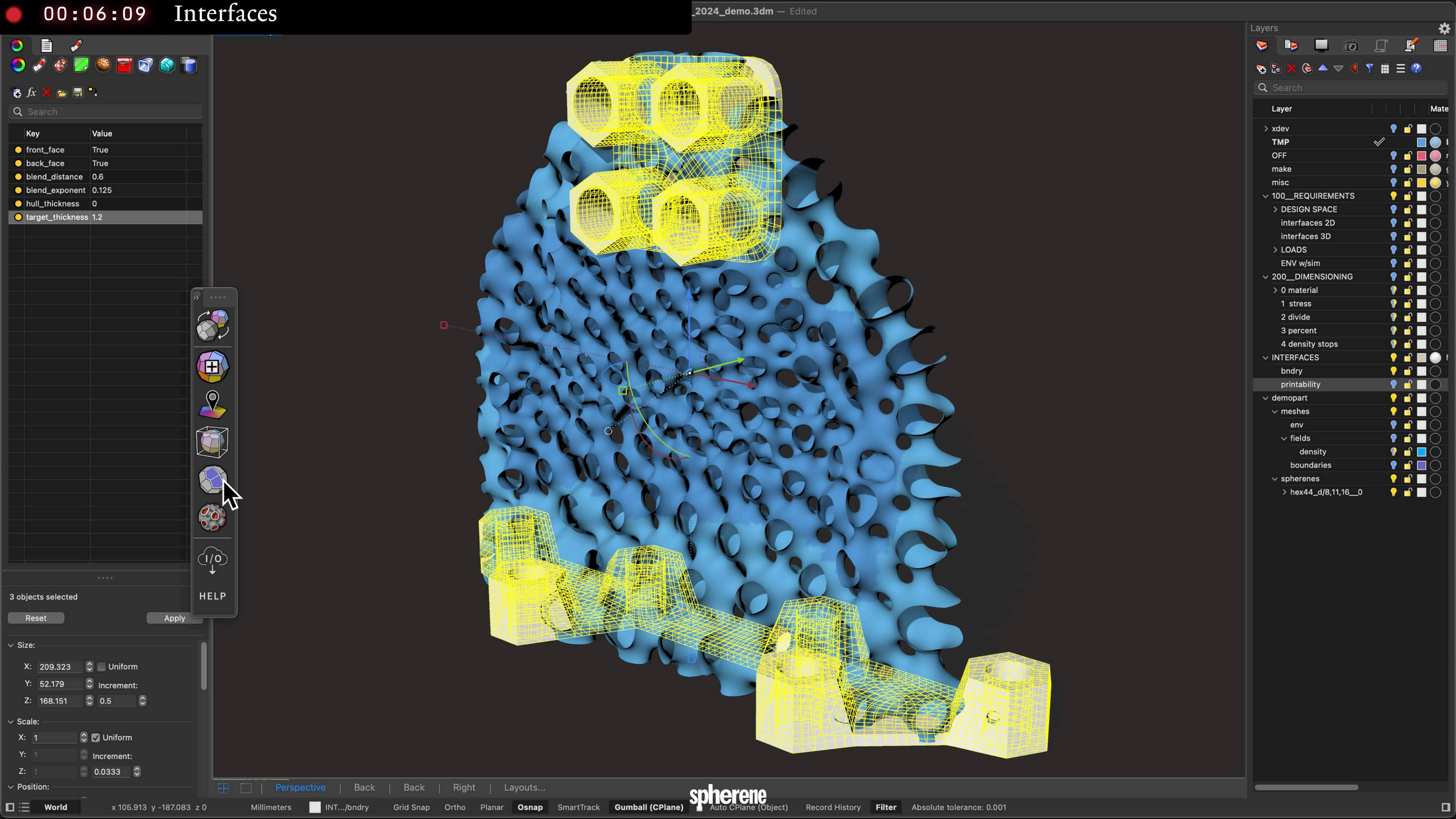



00:02:38
Create spherene project
CDFAM_2024_demo.3dm — Edited
Object
Type closed mesh
Name sphe_env
Layer ENV w/sim
Display Color By Layer
Display Mode By View
Linetype By Layer
Linetype Scale 1.000
Print Color By Layer
Print Width By Layer
Section Style By Layer
Hyperlink
Render Mesh Settings
Custom Mesh
Settings Adjust
Rendering
Casts shadows
Receives shadows
Isocurve Density
Density
Show surface isocurve
Match
Details
1 object selected
Reset
Apply
Size:
X: 209.118 Uniform
Y: 51.959 Increment:
Z: 168.535 0.5
Scale:
X: 1 Uniform
Y: 1 Increment:
Z: 1 0.0333
Position:
MATERIAL: AlSi10Mg
YIELD: ~255 MPA
SAFE (71%): ~180 MPA
sphe_project_new
Enter project name
Value demopart
Cancel Done
18 MPA
→ d/11
6 MPA
→ d/3.3
THICKNESS: 0.6 MM
I/O
HELP
Layers
Search
Layer
xdev
TMP
OFF
make
misc
100__REQUIREMENTS
DESIGN SPACE
interfaaces 2D
interfaces 3D
LOADS
ENV w/sim
200__DIMENSIONING
0 material
1 stress
2 divide
3 percent
4 density stops
INTERFACES
bndry
printability
Command: sphe_project_new
Perspective Top Front p_0 Layouts...
spherene
World x -167.354 y -215.999 z 0 Millimeters 100_.../sim Grid Snap Ortho Planar Osnap SmartTrack Gumball (CPlane) Auto CPlane (Object) Record History Filter Absolute tolerance: 0.001

00:04:14 Create density field according to dimensioning



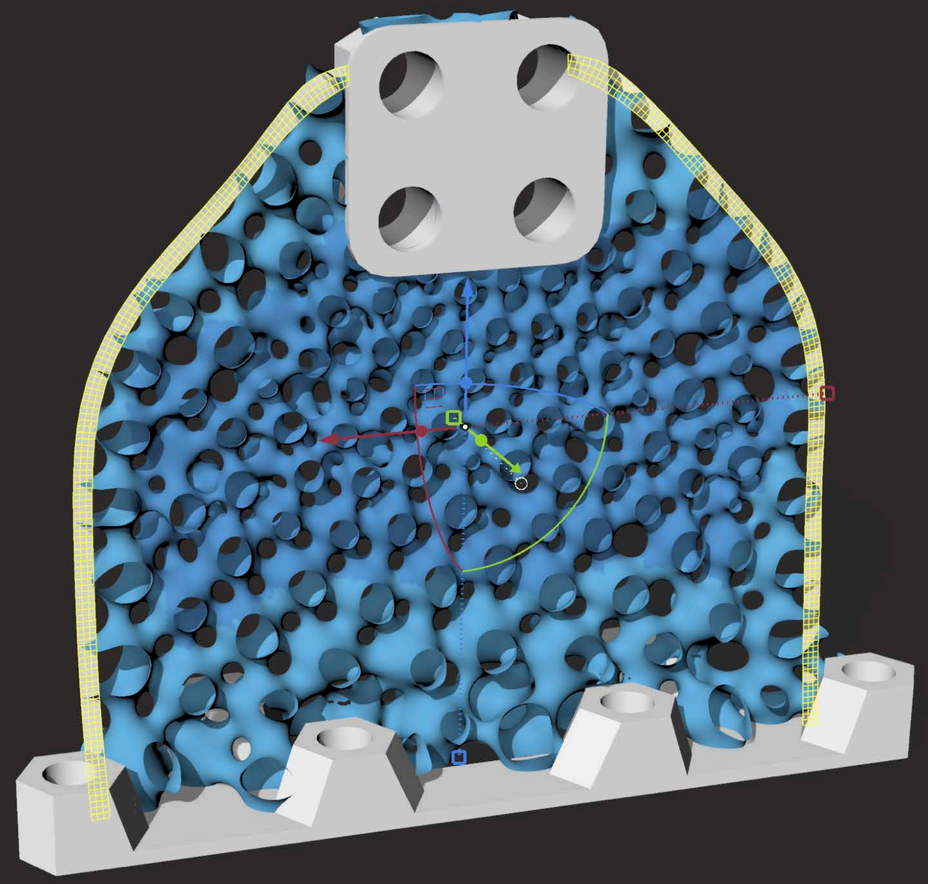

00:05:54
Compute single surface
CDFAM_2024_demo.3dm — Edited
Viewport
Title Front
Width 2928
Height 2140
Projection Parallel
Display mode Rendered
Locked
Camera
Lens Length (mm) 92.239
Rotation 0.0
X Location -23.799
Y Location -903.114
Z Location -61.782
Distance to Target 868.683
Location Place...
Target
X Target -23.799
Y Target -34.431
Z Target -61.782
Location Place...
Wallpaper
Filename (none)
Show
Gray
0 objects selected
Reset
Apply
Size:
X: 0.000 Uniform
Y: 0.000 Increment:
Z: 0.000 0.5
Scale:
X: 1 Uniform
Y: 1 Increment:
Z: 1 0.0333
Position:
Computation options for 'demopart'
GENERAL SETTINGS
Density Reference Thickness 0.6000
Random Seed 271828
OUTPUT
Single Surface Density
Solid Surface Draft Final Hzrd
NAMING
Part Name d/8,11,16
Part Version Enter part version
Notes
TIME CONTROL
Set acceptable max computation duration. You will be notified if estimate exceeds this.
Max execution time (minutes) 10
INTERNAL FUNCTIONS
Choose Machine Type HZN44
GENERAL INFORMATION
Version: 0.9.6 (RC1)
Cancel
Compute
I/O
HELP
Layers
Search
Layer
xdev
cdfam_demo
meshes
fields
spherenes
hetzner_ex44_d/8,1
webinar_mcneel
sphe_project_new
TMP
OFF
make
misc
100__REQUIREMENTS
DESIGN SPACE
interfaaces 2D
interfaces 3D
LOADS
ENV w/sim
200__DIMENSIONING
0 material
1 stress
2 divide
3 percent
4 density stops
INTERFACES
bndry
printability
demopart
meshes
env
fields
density
spherenes
hex44_d/8,11,16__0
single_surface
Command: sphe_compute
Perspective Top Front p_0 Layouts...
spherene
World x -177.323 y 0 z -97.342 Millimeters TMP Grid Snap Ortho Planar Osnap SmartTrack Gumball (CPlane) Auto CPlane (Object) Record History Filter Absolute tolerance: 0.001


_2024_demo.3dm — Edited
Search
Key
Value
front_face
True
back_face
True
blend_distance
0.6
blend_exponent
0.125
hull_thickness
0
target_thickness
1.2
HELP
3 objects selected
Reset
Apply
Size:
X: 209.323
Uniform
Y: 52.179
Increment:
Z: 168.151
0.5
Scale:
X: 1
Uniform
Y: 1
Increment:
Z: 1
0.0333
Position:
Layers
Search
Layer
Mate
xdev
TMP
OFF
make
misc
100__REQUIREMENTS
DESIGN SPACE
interfaaces 2D
interfaces 3D
LOADS
ENV w/sim
200__DIMENSIONING
0 material
1 stress
2 divide
3 percent
4 density stops
INTERFACES
bndry
printability
demopart
meshes
env
fields
density
boundaries
spherenes
hex44_d/8,11,16__0
Perspective
Back
Back
Right
Layouts...
spherene
World
x 105.913 y -187.083 z 0
Millimeters
INT.../bndry
Grid Snap
Ortho
Planar
Osnap
SmartTrack
Gumball (CPlane)
Auto CPlane (Object)
Record History
Filter
Absolute tolerance: 0.001

CDFAM_2024_demo.3dm — Edited

Search

Key	Value
front_face	True
back_face	True
target_thickness	1.2
hull_thickness	0.9
blend_distance	0.6
blend_exponent	0.125



HELP

2 objects selected

Reset Apply

Size:

X: 174.964 Uniform

Y: 14.687 Increment:

Z: 157.317 0.5

Scale:

X: 1 Uniform

Y: 1 Increment:

Z: 1 0.0333

Position:

Layers

Search

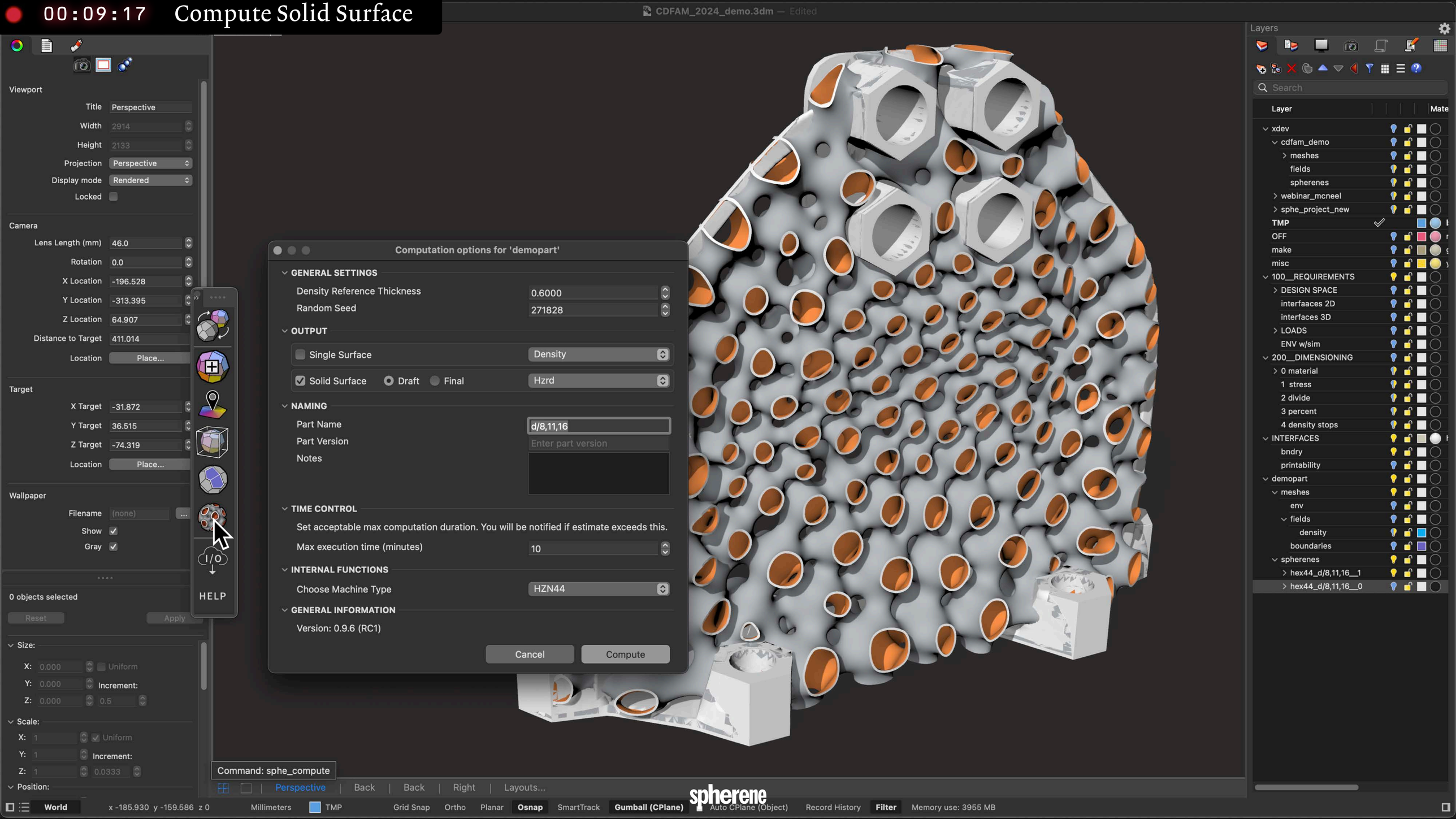
Layer Mate

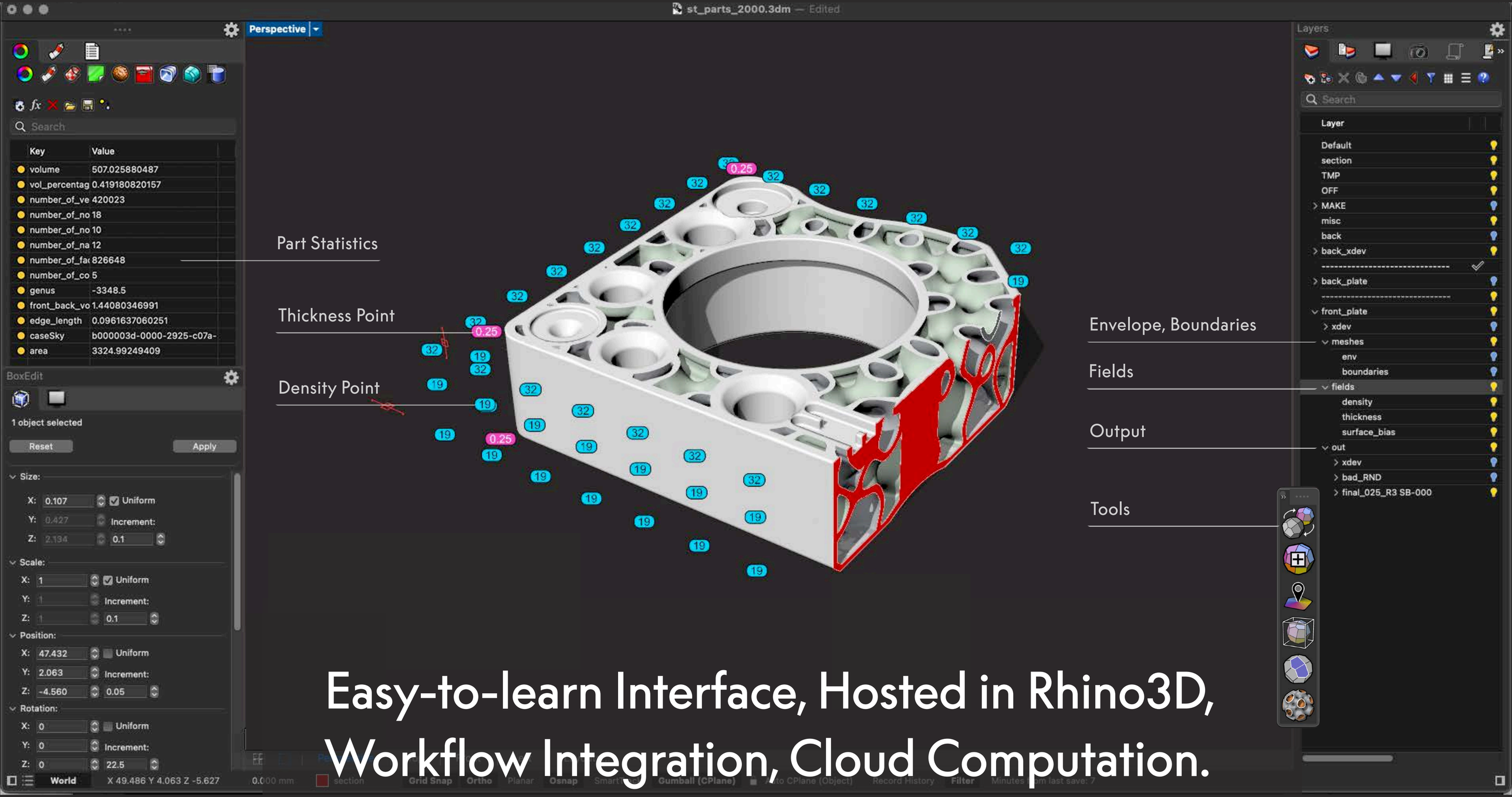
- xdev
- TMP
- OFF
- make
- misc
- 100__REQUIREMENTS
  - DESIGN SPACE
  - interfaaces 2D
  - interfaces 3D
  - LOADS
  - ENV w/sim
- 200__DIMENSIONING
  - 0 material
  - 1 stress
  - 2 divide
  - 3 percent
  - 4 density stops
- INTERFACES
  - bndry
  - printability
- demopart
  - meshes
    - env
    - fields
      - density
    - boundaries
  - spherenes
    - hex44_d/8,11,16__0

Perspective | Back | Back | Right | Layouts...

spherene

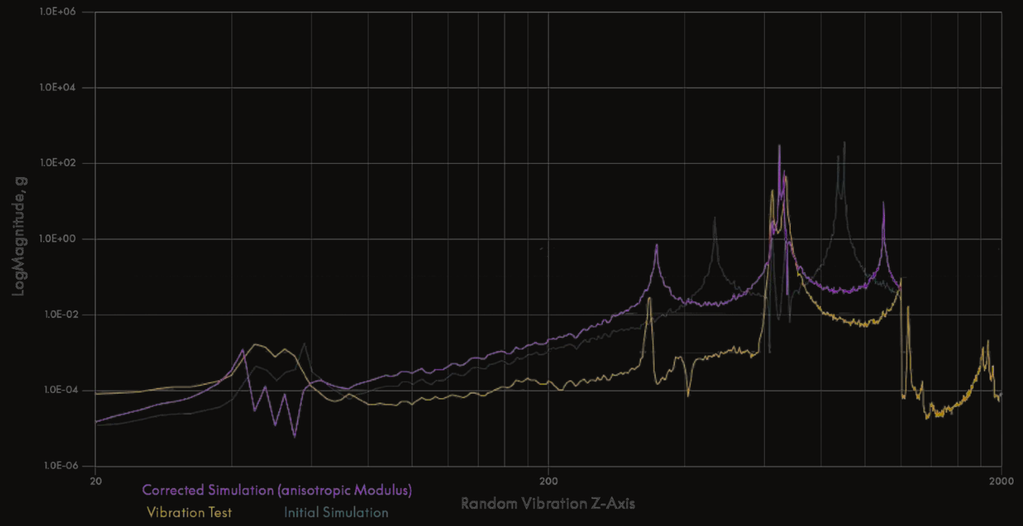
World x 203.350 y 228.660 z 0 Millimeters .../printab... Grid Snap Ortho Planar Osnap SmartTrack Gumball (CPlane) Auto CPlane (Object) Record History Filter Minutes from last save: 417


00:09:17
Compute Solid Surface
CDFAM_2024_demo.3dm — Edited
Viewport
Title Perspective
Width 2914
Height 2133
Projection Perspective
Display mode Rendered
Locked
Camera
Lens Length (mm) 46.0
Rotation 0.0
X Location -196.528
Y Location -313.395
Z Location 64.907
Distance to Target 411.014
Location Place...
Target
X Target -31.872
Y Target 36.515
Z Target -74.319
Location Place...
Wallpaper
Filename (none)
Show
Gray
0 objects selected
Reset
Apply
Size:
Scale:
Position:
I/O
HELP
Computation options for 'demopart'
GENERAL SETTINGS
Density Reference Thickness 0.6000
Random Seed 271828
OUTPUT
Single Surface Density
Solid Surface Draft Final Hzrd
NAMING
Part Name d/8,11,16
Part Version Enter part version
Notes
TIME CONTROL
Set acceptable max computation duration. You will be notified if estimate exceeds this.
Max execution time (minutes) 10
INTERNAL FUNCTIONS
Choose Machine Type HZN44
GENERAL INFORMATION
Version: 0.9.6 (RC1)
Cancel
Compute
Layers
Search
Layer
xdev
cdfam_demo
meshes
fields
spherenes
webinar_mcneel
sphe_project_new
TMP
OFF
make
misc
100__REQUIREMENTS
DESIGN SPACE
interfaaces 2D
interfaces 3D
LOADS
ENV w/sim
200__DIMENSIONING
0 material
1 stress
2 divide
3 percent
4 density stops
INTERFACES
bndry
printability
demopart
meshes
env
fields
density
boundaries
spherenes
hex44_d/8,11,16__1
hex44_d/8,11,16__0
Command: sphe_compute
Perspective Back Back Right Layouts...
spherene
World x -185.930 y -159.586 z 0 Millimeters TMP Grid Snap Ortho Planar Osnap SmartTrack Gumball (CPlane) Auto CPlane (Object) Record History Filter Memory use: 3955 MB

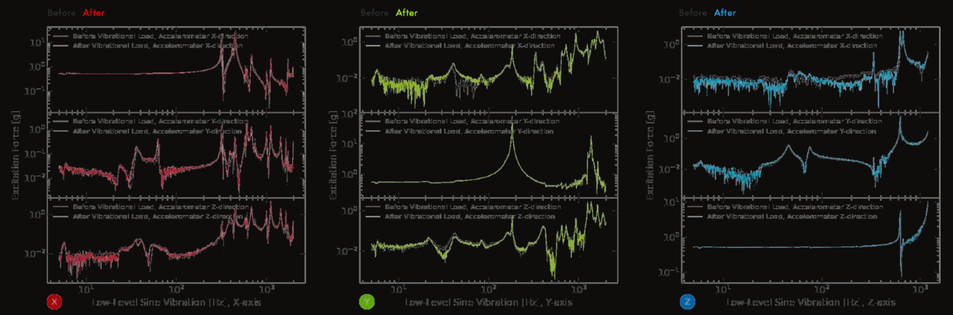

st_parts_2000.3dm — Edited
Perspective
Search
Key
Value
volume
507.025880487
vol_percentag
0.419180820157
number_of_ve
420023
number_of_no
18
number_of_no
10
number_of_na
12
number_of_fa
826648
number_of_co
5
genus
-3348.5
front_back_vo
1.44080346991
edge_length
0.0961637060251
caseSky
b000003d-0000-2925-c07a-
area
3324.99249409
Part Statistics
Thickness Point
Density Point
BoxEdit
1 object selected
Reset
Apply
Size:
Scale:
Position:
Rotation:
Uniform
Increment:
World
Layers
Search
Layer
Default
section
TMP
OFF
MAKE
misc
back
back_xdev
back_plate
front_plate
xdev
meshes
env
boundaries
fields
density
thickness
surface_bias
out
xdev
bad_RND
final_025_R3 SB-000
Envelope, Boundaries
Fields
Output
Tools
Easy-to-learn Interface, Hosted in Rhino3D,
Workflow Integration, Cloud Computation.
spherene


[satellite bracket being vigorously shaked]
spherene

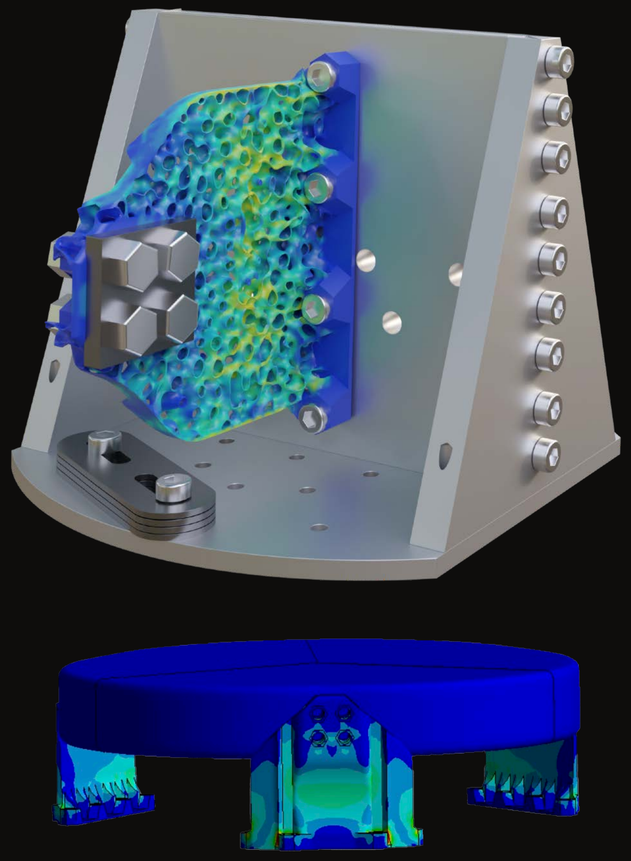
Satellite Bracket
ESA OSIP Early Technology Development Study.



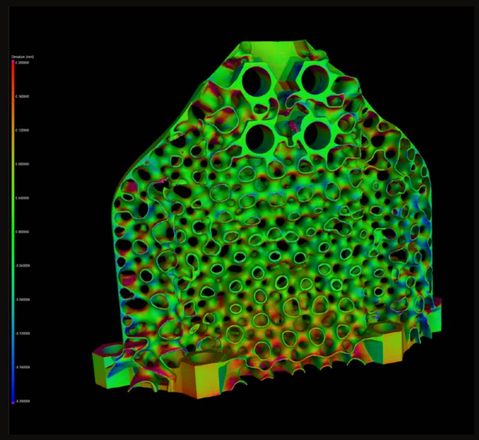
Frequency Response (IPPE test / ANSYS 2022R1)



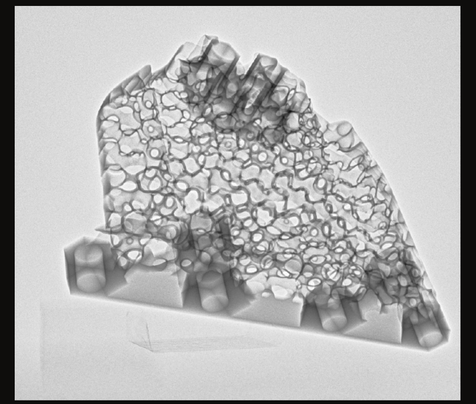
Random oscillation, before/after (x, y, z)



Simulations (ANSYS 2022R1)



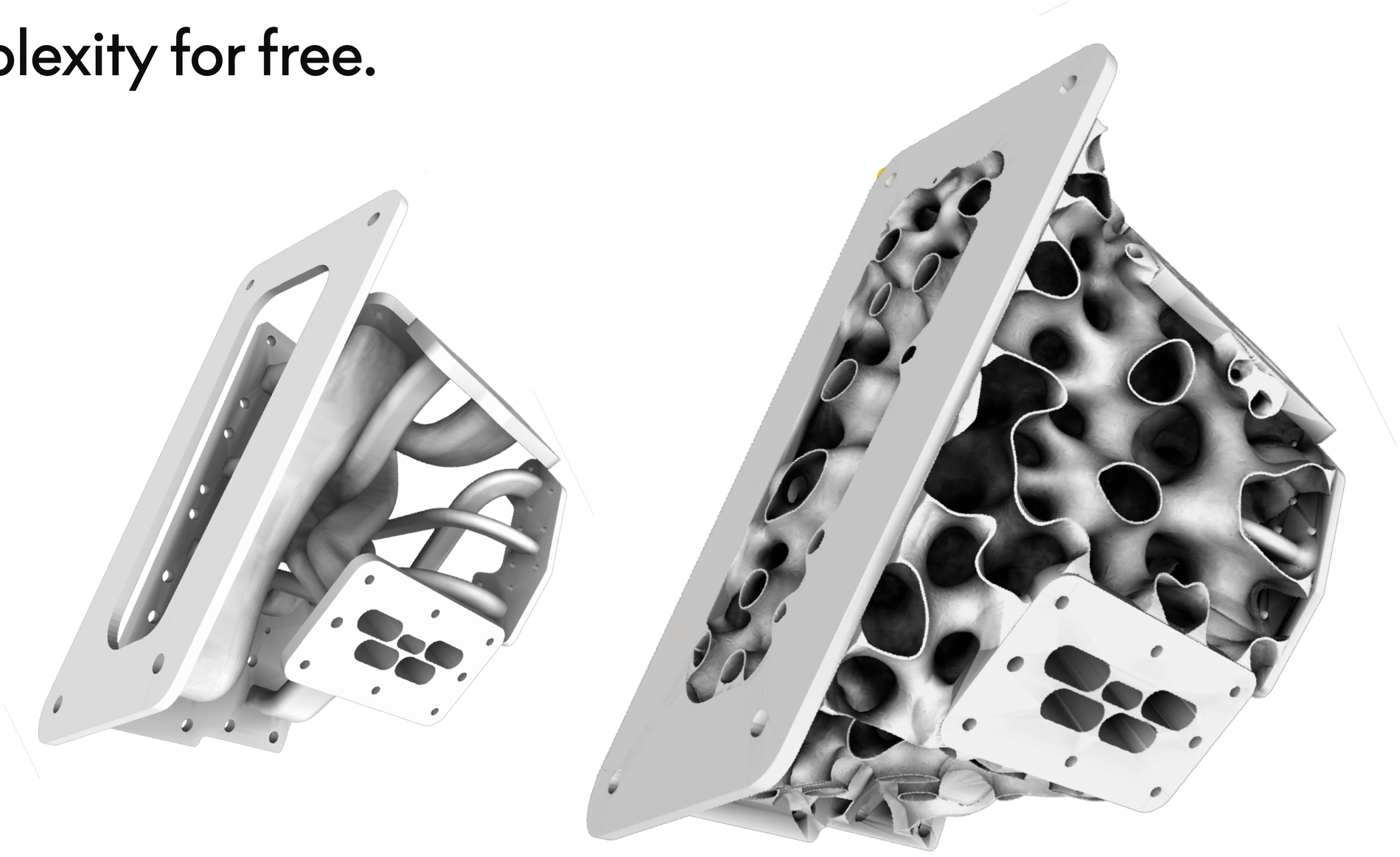
Nominal vs actual (x-ray)



Radiography (post test)

spherene

Complexity for free.
Fast.



Customise.
Autonomously.

spherene

And shoot for the Moon!