Design for FFF 3D Printing

Matthew Griffin
Director of Community Development, Ultimaker
m.griffin@Ultimaker.com
On Talking Additive, we sit down with business innovators and allies to discuss the benefits of adopting additive manufacturing.

What benefits can companies expect from 3D printing, and what will be possible in the future? The show is hosted by Matt Griffin and brought to you by Ultimaker.
Most common forms

1) Extrusion-based
2) Vat photo polymerization
3) Powder bed fusion
4) Direct energy deposition
5) Binder jetting
6) Material Jetting
7) Sheet lamination
Most Common Technology Today

Extrusion-based

FFF (FDM)
Approach

**Ultimaker**

3D printing workflow

1. **Choose CAD program**
2. **3D modeling**
3. **Material selection (open filament system)**
4. **Intent for 3D printing**
5. **Open in Ultimaker Cura (manually or via plugin)**
6. **Prepare model for 3D printing**
7. **Set printing parameters** (recommended or custom settings)
8. **Send file to 3D printer** (Cura Connect or USB)
9. **Set printer configuration settings** (if needed)
10. **3D print**
11. **Remove from 3D printer**
12. **Post-processing**
13. **Print ready**
14. **Use your part**
15. **Optimize**
16. **Set product requirements**
17. **Based on requirements**

Ultimaker
# Design Rules for 3D Printing

<table>
<thead>
<tr>
<th>Supported Walls</th>
<th>Unsupported Walls</th>
<th>Support &amp; Overhangs</th>
<th>Embossed &amp; Engraved Details</th>
<th>Horizontal Bridges</th>
<th>Holes</th>
<th>Connecting / Moving Parts</th>
<th>Escape Holes</th>
<th>Minimum Features</th>
<th>Pin Diameter</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls that are connected to the rest of the print on at least two sides.</td>
<td>Un-supported walls are connected to the rest of the print on less than two sides.</td>
<td>The minimum angle of a wall can be printed without requiring support.</td>
<td>Features on the model that are raised or recessed below the model surface.</td>
<td>The span of technology can print without the need for support.</td>
<td>The recommended clearance between two moving or connecting parts.</td>
<td>The minimum diameter of escape holes to allow for the removal of build material.</td>
<td>The recommended minimum size of a feature to ensure it will not fall to print.</td>
<td>The minimum diameter of a pin can be printed at.</td>
<td>The expected tolerance (± dimensional accuracy) of a specific technology.</td>
<td></td>
</tr>
<tr>
<td>Fused Deposition Modeling</td>
<td>0.8 mm</td>
<td>0.8 mm</td>
<td>45°</td>
<td>0.6 mm wide &amp; 2 mm high</td>
<td>10 mm</td>
<td>Ø2 mm</td>
<td>0.5 mm</td>
<td>2 mm</td>
<td>3 mm</td>
<td>±0.5% (lower limit ±0.5 mm)</td>
</tr>
<tr>
<td>Stereolithography</td>
<td>0.5 mm</td>
<td>1 mm</td>
<td>support always required</td>
<td>0.4 mm wide &amp; high</td>
<td>1 mm wide &amp; high</td>
<td>Ø0.5 mm</td>
<td>0.5 mm</td>
<td>4 mm</td>
<td>0.2 mm</td>
<td>0.5 mm</td>
</tr>
<tr>
<td>Selective Laser Sintering</td>
<td>0.7 mm</td>
<td>1 mm</td>
<td>support always required</td>
<td>1 mm wide &amp; high</td>
<td>1 mm wide &amp; high</td>
<td>Ø1.5 mm</td>
<td>0.3 mm for moving parts &amp; 0.1 mm for connections</td>
<td>5 mm</td>
<td>0.8 mm</td>
<td>0.8 mm</td>
</tr>
<tr>
<td>Material Jetting</td>
<td>1 mm</td>
<td>1 mm</td>
<td>support always required</td>
<td>0.5 mm wide &amp; high</td>
<td>0.5 mm wide &amp; high</td>
<td>Ø0.5 mm</td>
<td>0.2 mm</td>
<td>0.5 mm</td>
<td>0.5 mm</td>
<td>±0.1 mm</td>
</tr>
<tr>
<td>Binder Jetting</td>
<td>2 mm</td>
<td>3 mm</td>
<td>support always required</td>
<td>0.5 mm wide &amp; high</td>
<td>0.5 mm wide &amp; high</td>
<td>Ø1.5 mm</td>
<td>5 mm</td>
<td>2 mm</td>
<td>2 mm</td>
<td>±0.2 mm for metal &amp; ±0.3 mm for sand</td>
</tr>
<tr>
<td>Direct Metal Laser Sintering</td>
<td>0.4 mm</td>
<td>0.5 mm</td>
<td>support always required</td>
<td>0.1 mm wide &amp; high</td>
<td>2 mm</td>
<td>Ø1.5 mm</td>
<td>5 mm</td>
<td>0.6 mm</td>
<td>1 mm</td>
<td>±0.1 mm</td>
</tr>
</tbody>
</table>
Product requirements

Aesthetics
- Is it a visual product?
- What surfaces will be visible?

7h 27min
0.4 Nozzle
0.1 Layer height

3h 47min
0.4 Nozzle
0.2 Layer height

1h 46min
0.8 Nozzle
0.3 Layer height
Product requirements

- Why important?
  - Product design process
  - Efficiency – Less iterations
  - Material choice
  - Get the product you have in mind
- What questions to ask yourself?
Product requirements

Strength, hardness & wear

- Is there a load on the product?
- Where is the load applied on your product?
- When in use, will the part wear?
Current research into Cura settings priorities for certain applications
Product requirements

Also think of...

- Accuracy
- Operating environment
- Ergonomics
- Post processing
- Assembly
- Etc...
Design of the part

1. Nozzle diameter
2. Bottom layer
3. Support material
4. Small details
5. Tolerances
6. Fast printing
7. Modularity
Select nozzle diameter

- Smaller diameter for high detail printing
- Smaller diameter for sharper corners
- Minimum wall thickness should be the same or bigger than the diameter of your nozzle
- Fast print -> Design for the right nozzle

0.25 nozzle high precision

0.4 nozzle normal print

0.8 nozzle quick print
Bottom layer

Bottom layer surface
The bigger the more surface for adhesion

Try to avoid fillets onto the build plate
Chamfers are more recommended

Try to avoid sharp edges
To avoid warping
Guidelines for Design Features

Combining chamfers and fillets for FFF

Support material

< 45°  Support material not needed

> 45°  Support material advised
Support material

- Try to avoid bridging
  - If needed, the shorter the better
  - Use support material if bridge is too big
- Add chamfer if possible
Guidelines for Design Features

Ribs and Gussets for additional strength

Highest load = 12.36 MPa

Highest load = 7.67 Mpa
Decrease of 38%

Increase load distribution in all directions

Guidelines for Design Features

Add ribs and gussets for increased stiffness and strength

Small details

- Use a smaller nozzle diameter
- Give the print more time to cool
  - Add prime tower
  - Print multiple parts at once
  - Minimum layer time
  - Lift head
Tolerances

• Shrinkage of material filament

How to optimise?
• Perform printing tests before printing the whole model (dimensions)
Fast printing

Play with nozzle diameter
Use a lower infill percentage
Set a bigger layer height in Cura

• Also, think of: Thickness of bottom and top layers
• Check calculated print time in Ultimaker Cura
Modularity

• Print faster with the use of multiple printers
• Bigger models possible than the build volume of the printer
• Easy to replace a part (think of wear for example)
• Combination of different materials
• Iteration on one part at a time
Thank you for your time
3D Printing Materials Overview

Matthew Griffin
Director of Community Development, Ultimaker
m.griffin@Ultimaker.com
The S5 Pro Bundle
Build materials

- **PLA**
  - Biggest variety of colors
  - Good tensile strength
- **ABS**
  - High durability
  - High toughness
- **Nylon**
  - Wear/corrosion resistant
  - High impact strength
- **TPU 95A**
  - High flexibility
  - High impact strength
- **CPE**
  - Chemical resistance
  - High toughness
- **CPE+**
  - Heat resistance up to 100°C
  - Increased impact strength
- **PC**
  - High hardness (shore D)
  - Heat resistance up to 110°C
- **PP**
  - Chemical resistance
  - Fatigue resistance

*Ultimeaker*
Support materials

PVA
- Water soluble
- Easy to print complex geometries

Breakaway
- Design freedom with more materials
- Time and cost-effective
## Materials Properties Reference Overview

<table>
<thead>
<tr>
<th></th>
<th>Printability</th>
<th>Stiffness</th>
<th>Strength</th>
<th>Ductility</th>
<th>Toughness</th>
<th>Hardness</th>
<th>Temperature resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Printing difficulty</td>
<td>Flexural modulus</td>
<td>Tensile modulus</td>
<td>Flexural strength</td>
<td>Tensile stress at yield</td>
<td>Tensile stress at break</td>
</tr>
<tr>
<td>PLA</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Tough PLA</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>ABS</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>Nylon</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>CPE</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>CPE+</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>TPU S5A</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>PC Transparent</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>PC Black/White</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>PP</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
</tr>
<tr>
<td>PVA</td>
<td>●</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Brasscaway</td>
<td>●</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
## Material combinations & adhesion

<table>
<thead>
<tr>
<th></th>
<th>PLA</th>
<th>ABS</th>
<th>Nylon</th>
<th>CPE</th>
<th>CPE+</th>
<th>PC</th>
<th>TPU 95A</th>
<th>PP</th>
<th>PVA</th>
<th>Breakaway</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLA</td>
<td>✓</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>◯</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>ABS</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>◯</td>
<td></td>
<td>◯</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Nylon</td>
<td></td>
<td></td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>◯</td>
<td></td>
<td>✗</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>CPE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>◯</td>
<td></td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPE+</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>◯</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>◯</td>
<td></td>
<td></td>
<td></td>
<td>◯</td>
</tr>
<tr>
<td>TPU 95A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>◯</td>
<td></td>
<td>◯</td>
</tr>
<tr>
<td>PP</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>PVA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✗</td>
</tr>
<tr>
<td>Breakaway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- ✓ Officially supported
- ◯ Experimental
- ✗ Not supported
Ultimaker Partners with Global Material Companies

- DSM
- BASF
- Henkel
- SOLVAY
- MITSUBISHI CHEMICAL
- DUPONT
- Owens Corning
- Clariant
- Kuraray
Material Partners

Start partnering with material companies to lower barrier for introducing relevant new materials.

Chemical Companies use print profile assistant to make tuned 3rd party profile based on baseline.

Ultimaker provides Baseline profiles

UM Print Profile Assistant

UM Cura Marketplace
Material Alliance Portfolio

**COMMERCIAL HIGH PERFORMANCE THERMOPLASTICS**

- PC
- PC/ABS
- PI
- PEI
- PES
- PSU
- PPS
- PPA
- PEK
- PI
- PEEK

**COMMODITY THERMOPLASTICS**

- PC/ABS
- ASA
- SAN
- PS
- PVC
- PLA
- PVA
- PE

**AMORPHOUS SEMI CRYSTALLINES**

- Co-polyester (incl. PETG)
- HT Co-polyester
- Co-polyester (incl. PETG)
- Co-polyester (incl. PETG)
- Co-polyester (incl. PETG)
- Co-polyester (incl. PETG)
- Co-polyester (incl. PETG)

**ENGINEERING THERMOPLASTICS**

- PC
- HT Co-polyester
- Co-polyester (incl. PETG)
- Co-polyester (incl. PETG)
- Co-polyester (incl. PETG)
- Co-polyester (incl. PETG)
- Co-polyester (incl. PETG)

**IN DEVELOPMENT**

- PA (6/66, 6 & 12)
- ELasticomers TPU/TPC/TPE (85A-100A)
- PA (6/66, 6 & 12)
- PA (6/66, 6 & 12)
- PA (6/66, 6 & 12)
- PA (6/66, 6 & 12)
- PA (6/66, 6 & 12)

**IN DEVELOPMENT**

- PA (6/66, 6 & 12)
- ELasticomers TPU/TPC/TPE (85A-100A)
- PA (6/66, 6 & 12)
- PA (6/66, 6 & 12)
- PA (6/66, 6 & 12)
- PA (6/66, 6 & 12)
- PA (6/66, 6 & 12)

**IN DEVELOPMENT**

- PA (6/66, 6 & 12)
- ELasticomers TPU/TPC/TPE (85A-100A)
- PA (6/66, 6 & 12)
- PA (6/66, 6 & 12)
- PA (6/66, 6 & 12)
- PA (6/66, 6 & 12)
- PA (6/66, 6 & 12)
The answer for any requirement exists

To narrow down the material possibilities

- Temperature resistant
- Impact resistant
- High stiffness
- Chemical resistant
- Biocompatibility
- Flame Retardant
- Flexibility
- ESD
- Optical Clarity
- Wear resistant
- Aesthetic / Visual
- Food Contact
- Recycled
- Post processable
- Support
### Key considerations

To narrow down the material possibilities

<table>
<thead>
<tr>
<th>ESD Safe materials:</th>
<th>(High) Temperature resistant materials</th>
<th>Food Contact Approved materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>3DXSTAT ESD PETG</td>
<td>Arkema FluorX PVDF (150 °C)</td>
<td>3R3DTM ABS ELIX FC</td>
</tr>
<tr>
<td>Clariant PC ESD</td>
<td>BASF PAHT CF15 (150-180 °C)</td>
<td>Copper3D PLActive</td>
</tr>
<tr>
<td>Clariant PC+ABS ESD</td>
<td>BASF PP-GF30</td>
<td>Facilan HT</td>
</tr>
<tr>
<td>Clariant PET-G ESD</td>
<td>DSM Arnitel HT TPC 61D (175-190 °C)</td>
<td>Igus IglidurI150</td>
</tr>
<tr>
<td>Jabil PET-G ESD</td>
<td>DSM Novamid CF10 (150-180 °C)</td>
<td></td>
</tr>
<tr>
<td>Jabil TPU ESD</td>
<td>DSM Novamid 1070 (150 °C)</td>
<td></td>
</tr>
<tr>
<td>Kimya ABS ESD</td>
<td>DuPont Zytel CF20 (150 °C)</td>
<td></td>
</tr>
<tr>
<td>Lhvoss Luvocom PAHT CF ESD</td>
<td>Lhvoss PaHT CF (150-180 °C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Luvocom 3F PaHT (120-160 °C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Luvocom 3F PET CF (125 °C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Matterhackers NylonG (up to 160 °C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polymaker CoPA (180 °C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Polymaker Pa6-CF (180 °C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ProtoPasta HTPLA (155 °C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ensinger PA 6 GF30 black (150 °C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solef® PVDF AM filament (130 °C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lubrizol ESTANE® F94A-055 (130 °C)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lubrizol ESTANE® 3D TPU F70D-065</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lubrizol ESTATE® 3D TPU F70D-065</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flexible materials:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Arkema/3DXFlex TPE 92-95A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BASF Ultrafuse TPU 80A LF</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BASF Ultrafuse TPU 85A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clariant TPU 85A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clariant TPU 95A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DSM Arnitel HT TPC 61D</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DuPont Hytrel TPE 60D</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DSM Arnitel TPC 34D</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Huntsman IROPRINT F 80213 Neutral TPU85A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ultimaker TPU 95A</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lubrizol ESTANE® 3D TPU F70D-065</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lubrizol ESTATE® 3D TPU F94A-055</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lubrizol ESTATE® 3D TPU F98A-030</td>
<td></td>
</tr>
</tbody>
</table>

### Flame Retardant materials:

- BASF Inno FR
- Clariant PA6/66 FR
- Clariant PA6/66-GF20 FR (certified)
- DSM Novamid AM 1030 FR (UL certified)
- Solef® PVDF AM filament

### High Impact resistant materials

- 3R3DTM ABS ELIX HI
- All regular PP materials
- BASF TPU 85A
- Clariant PLA-HI-GF10
- Matterhackers NylonG
- Matterhackers NylonX
- Ultimaker TPU 95A
- Lubrizol ESTANE® 3D TPU F70D-065

### (High) Temperature resistant materials

- Arkema FluorX PVDF (150 °C)
- BASF PAHT CF15 (150-180 °C)
- BASF PP-GF30 (150 °C)
- DSM Arnitel CF10 (150-180 °C)
- DSM Novamid CF10 (150 °C)
- DSM Novamid 1070 (150 °C)
- DuPont Zytel CF20 (150 °C)
- DuPont Zytel GF30 (150 °C)
- Lhvoss PaHT CF (150-180 °C)
- Luvocom 3F PaHT (120-160 °C)
- Luvocom 3F PET CF (125 °C)
- Matterhackers NylonG (up to 160 °C)
- Polymaker CoPA (180 °C)
- Polymaker Pa6-CF (180 °C)
- ProtoPasta HTPLA (155 °C)
- Ensinger PA 6 GF30 black (150 °C)
- Solef® PVDF AM filament (130 °C)
- Lubrizol ESTANE® F94A-055 (130 °C)

### Biocompatible materials

- 3R3DTM ABS ELIX FC
- Arkema FluorX PVDF
- Copper3D PLActive
- DSM Arnitel TPC 34D
- FibreTuff Medical grade filament
- Huntsman IROPRINT F 80213 TPU85A
- Nile Polymers Fluorinar-C PVDF

### Food Contact Approved materials

- 3R3DTM ABS ELIX FC
- Copper3D PLActive
- Facilan HT
- Igus IglidurI150
### Key considerations

**To narrow down the material possibilities**

<table>
<thead>
<tr>
<th>Chemical resistant materials</th>
<th>High Stiffness materials</th>
<th>UV resistant materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arkema FluorX PVDF</td>
<td>3D Universe Nylon CF</td>
<td>3DXTech 3DXMAX ASA</td>
</tr>
<tr>
<td>BASF PAHT CF15</td>
<td>3DXTech CarbonX CF-Nylon Gen 3</td>
<td>Arkema FluorX PVDF</td>
</tr>
<tr>
<td>BASF PPGF 30</td>
<td>BASF PAHT CF15</td>
<td>BASF PPGF 30</td>
</tr>
<tr>
<td>BASF Ultrafuse TPU 85A</td>
<td>BASF PET CF15</td>
<td>DSM ArnitelID2045</td>
</tr>
<tr>
<td>Clariant PET-G</td>
<td>BASF PPGF 30</td>
<td>Filamentive ASA</td>
</tr>
<tr>
<td>Clariant PP</td>
<td>Clariant PA6/66-GF20 FR</td>
<td>Formfutura ApolloX ASA</td>
</tr>
<tr>
<td>DSM Arnitel TPC 34D</td>
<td>Clariant PC+ABS GF15</td>
<td>Lehvoss Luvocom 3F PET CF15</td>
</tr>
<tr>
<td>DuPont Zytel CF20</td>
<td>Colorfabb XT-CF20</td>
<td>Lubrizol ESTANE® 3D TPU F70D-065</td>
</tr>
<tr>
<td>DuPont Zytel GF30</td>
<td>DuPont Zytel CF20</td>
<td>Mitsubishi Chemical 3Diakon PMMA</td>
</tr>
<tr>
<td>Nile Polymers Fluorinar-C PVDF</td>
<td>DuPont Zytel GF30</td>
<td>Lehvoss Luvocom 3F PET CF15</td>
</tr>
<tr>
<td>Jabil PET-G</td>
<td>Ensinger TECAMID PA 6 GF30</td>
<td>Lubrizol ESTANE® 3D TPU F70D-065</td>
</tr>
<tr>
<td>Owens Corning XSTRAND GF30-PP</td>
<td>eSUN ePA-CF</td>
<td>Mitsubishi Chemical 3Diakon PMMA</td>
</tr>
<tr>
<td>Push Plastic PC-PBT</td>
<td>Jabil PETG ESD</td>
<td>Lehvoss Luvocom 3F PAHT CF15</td>
</tr>
<tr>
<td>Solef® PVDF AM filament</td>
<td>Lehvoss Luvocom 3F PAHT CF15</td>
<td>Lehvoss Luvocom 3F PET CF15</td>
</tr>
<tr>
<td>Ultimaker PP</td>
<td>Lehvoss Luvocom 3F PET CF15</td>
<td>Matterhackers NylonG</td>
</tr>
<tr>
<td>Ultimaker CPE</td>
<td>Matterhackers NylonX</td>
<td>Matterhackers NylonX</td>
</tr>
<tr>
<td>Ultimaker CPE+</td>
<td>Owens Corning XSTRAND GF30-PP</td>
<td>Owens Corning XSTRAND GF30-PP</td>
</tr>
<tr>
<td>Ultimaker TPU 95A</td>
<td>Owens Corning XSTRAND GF30-PA6</td>
<td>Owens Corning XSTRAND GF30-PA6</td>
</tr>
<tr>
<td></td>
<td>Polymaker Polymide PA6-CF</td>
<td>Polymaker Polymide PA6-CF</td>
</tr>
<tr>
<td></td>
<td>Push PlasticPC-PBT</td>
<td>Push PlasticPC-PBT</td>
</tr>
<tr>
<td></td>
<td>Vartega VartegaFil ABS CF5-10% recycled</td>
<td>Vartega VartegaFil ABS CF5-10% recycled</td>
</tr>
</tbody>
</table>
Key considerations

To narrow down the material possibilities

**Wear Resistant materials**
- Arkema FluorX PVDF
- BASF Ultrafuse TPU 85A
- Fluorinar-C PVDF
- igus Iglidur I150
- igus Iglidur I180
- Nile Polymers Fluorinar-C PVDF
- Owens Corning XSTRAND GF30-PA6
- Polymaker CoPA
- Solef® PVDF AM filament

**Aesthetic / Visual materials**
- 3D4Makers Facilan C8
- ColorFabb Color on Demand
- Colorfabb Woodfill
- FibreTuff Bone-like filament
- Formfutura Galaxy PLA
- Formfutura Stonefil
- Proto-Pasta Brass / Bronze / Copper Composite HTPLA
- Proto-Pasta Magnetic Iron PLA
- Proto-Pasta Stainless Steel PLA
- Proto-Pasta Translucent / Sparkly HTPLA
- The Virtual Foundry Copper Filament

**Optical Clarity materials (transparency)**
- eSUN PETG
- Clariant PET
- Mitsubishi Chemical 3Diakon PMMA
- Mitsubishi Chemical DURABIO
- Taulmann TGLASE
- Ultimaker CPE / CPE+
- Lubrizol ESTANE® 3D TPU F70D-065
- Lubrizol ESTANE® 3D TPU F98A-030

**Post Processable materials**
- BASF Ultrafuse 316L
- FibreTuff Bone-like filament
- Polymaker Polycast
- Polymaker Polysmooth
- The Virtual Foundry Copper Filament

**Support materials**
- Infinite solutions Aquasys 120
- Matterhackers Ionic
- Ultimaker PVA
AquaSys™ is a water-soluble 3D printing support resin for high-temperature build material that significantly reduces the cost and time of downstream processing for high-temperature printing materials like (PEAK, PEI, PEKK, PPSU) was awarded the 2018 Best Development in 3D printing” at the annual IDTechEx Awards.
Thank you for your time