INTRODUCTION & DEFINING ADDITIVE MANUFACTURING & 3D PRINTING

Module 1

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MODULE 1: OVERVIEW OF ADDITIVE MANUFACTURING AND 3D PRINTING

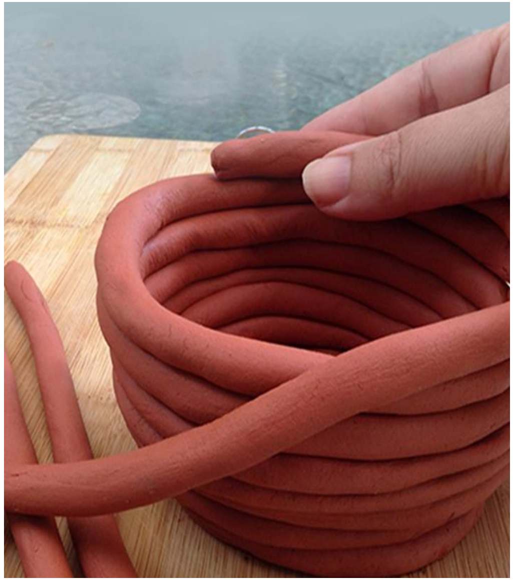
Learning Objectives

- Define AM (Additive Manufacturing) and 3D Printing
- Identify the advantages and pain-points of traditional manufacturing processes of cutting, subtractive, forming, and additive
- Differentiate advantages and constraints of 3D printing as compared to traditional manufacturing
- Recall how manufacturing has evolved (which came first)
- Cite the economic impact of 3D Printing

Additional Resources

- Embedded Videos

WHAT IS ADDITIVE MANUFACTURING?



A process of making a three-dimensional solid object by adding material

VS

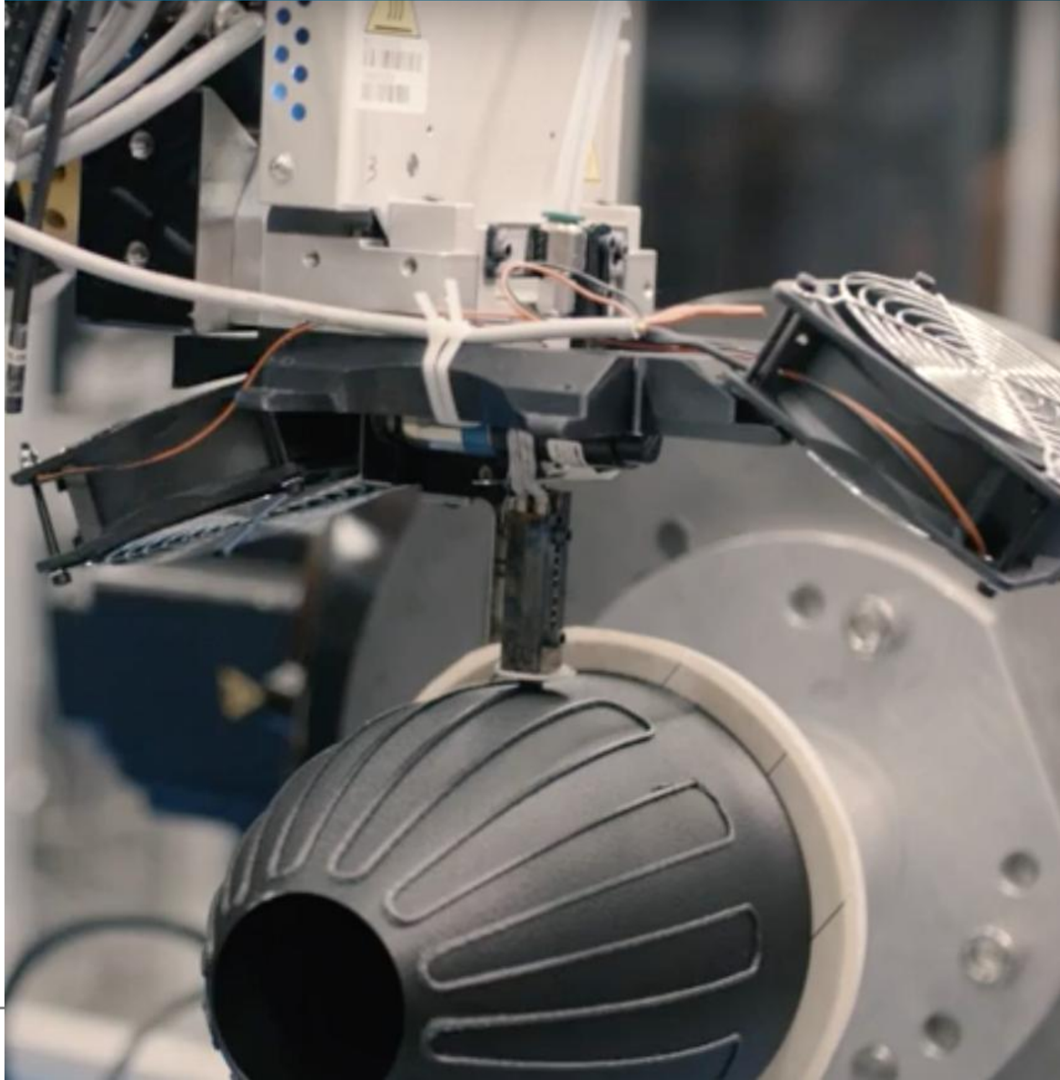
“A process of joining materials to make objects from 3D models data, usually layer upon layer”*

* The ASTM international committee F42, Wohler's Report 2014

AN ADDITIVE MANUFACTURING APPLICATION – 3D PRINTING

3D Printing

“Fabrication of objects through the deposition of a material using a print head, nozzle, or other printer technology. The term is often used synonymously with additive manufacturing”*



* The ASTM international committee F42, Wohler's Report 2014

WHAT IS 3D PRINTING?

https://www.youtube.com/watch?v=3rz97KBe4-k

TRADITIONAL MANUFACTURING PROCESSES

MOST COMMON MANUFACTURING PROCESSES

Cutting

Subtractive Manufacturing

Forming

Additive Manufacturing

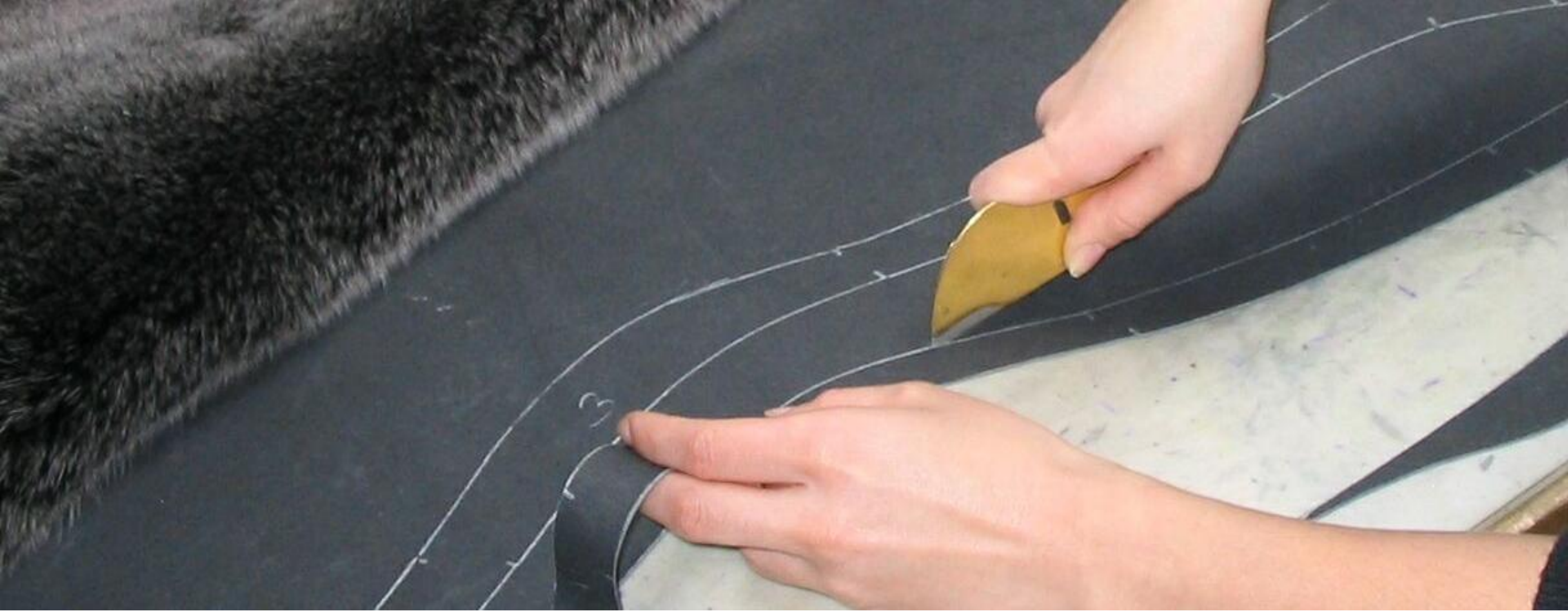
CUTTING

- What is it?
- What does it look like?
- What are its advantages?
- When would it be used?

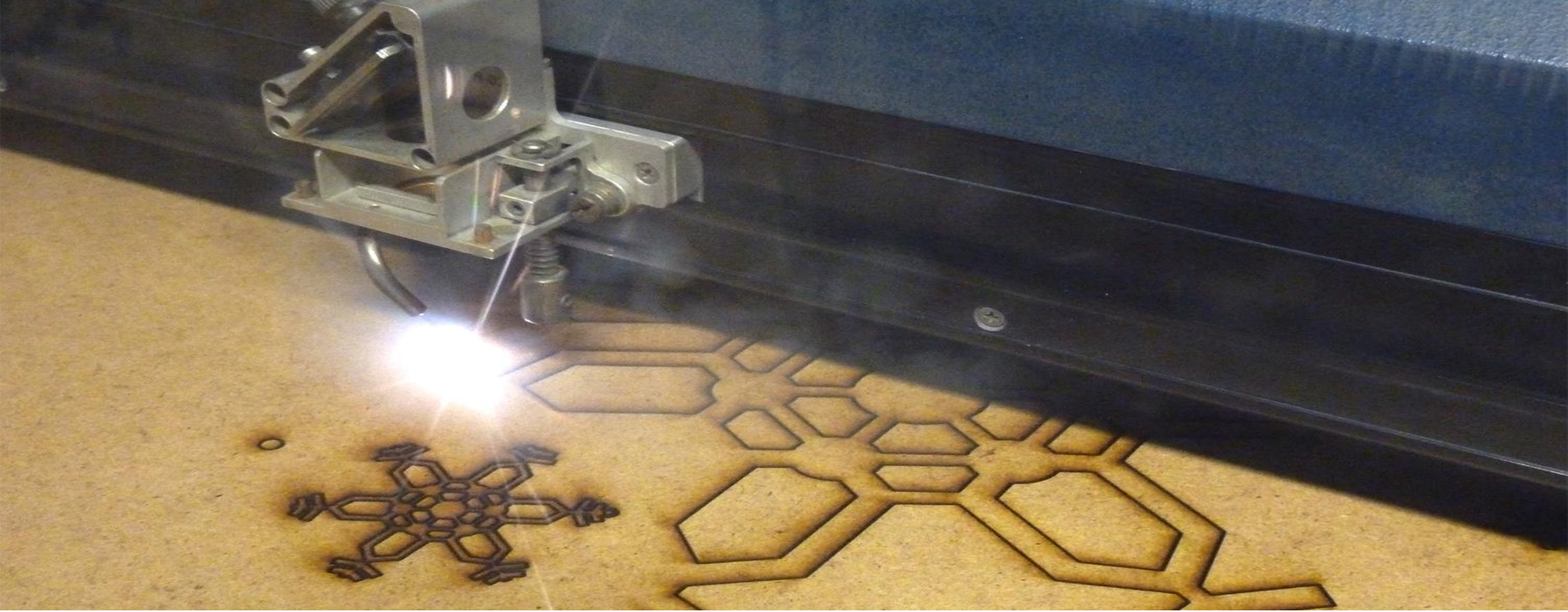
- Show an example of something manufactured by cutting

SUMMARY: CUTTING

Definition	A process of making products from varying materials using cutting tools such as laser cutters, vinyl cutters, razors and water jets
Uses	Modeling 2D products Modeling relatively simple products
Advantages	Relatively simple to manufacture and operate Simple 2D file input Quick fabrication Can be used with multiple materials Low material waste
Examples	



Fur and leather craft



Laser cutting

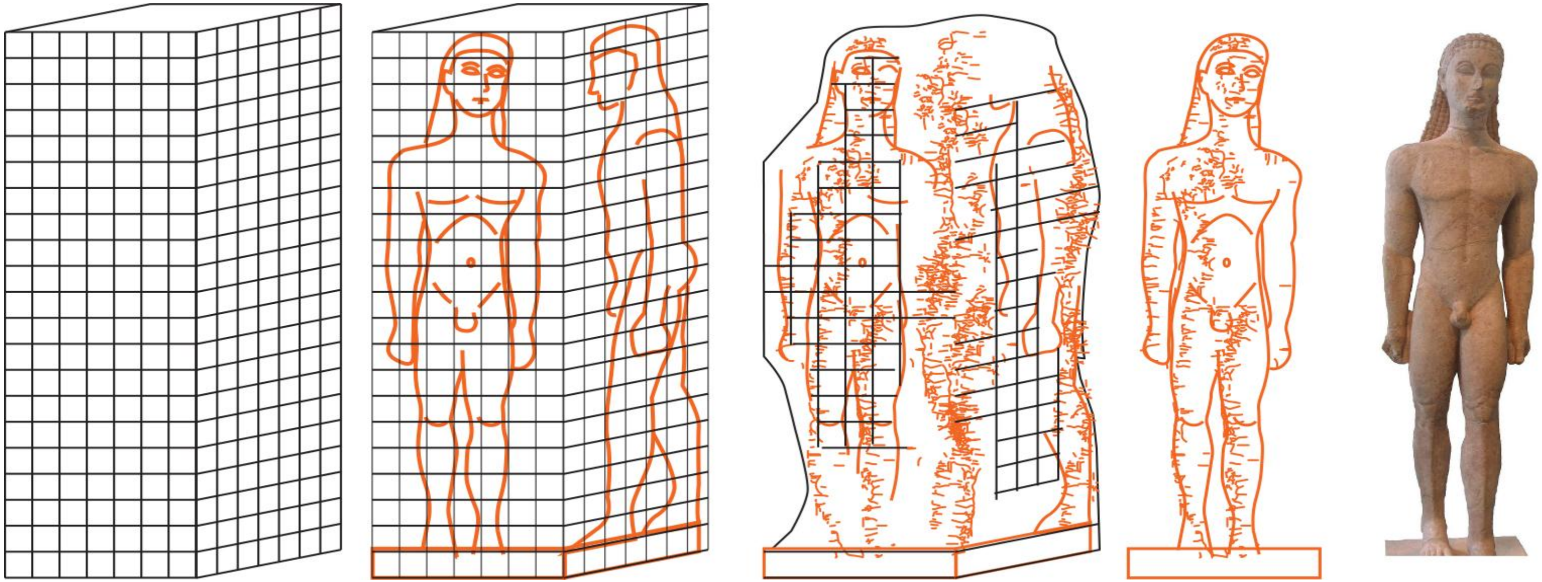
SUBTRACTIVE MANUFACTURING

- What is it?
- What does it look like?
- What are its advantages?
- When would it be used?

- Show an example of something manufactured by subtractive

SUMMARY: SUBTRACTIVE MANUFACTURING

Definition	A process of making products by removing material from a solid object
Uses	Creating 3D models and tooling Cutting “2D elements” in stronger or thicker materials which require a stronger machine
Advantages	Traditional, well-known method Long history of use Relatively simple to manufacture Milling bits are relatively low-cost Can be used to model strong/thick materials
Examples	



Carving

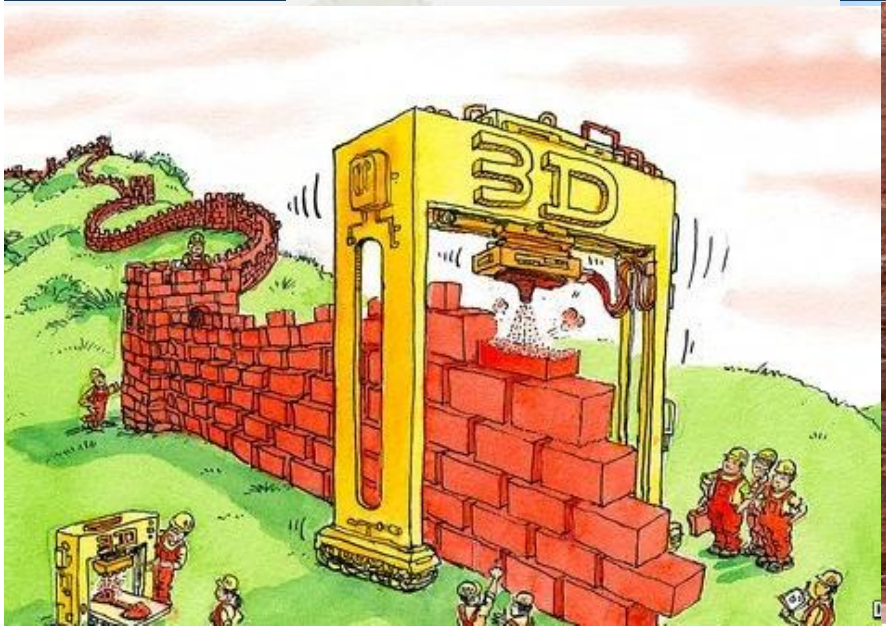
Drilling

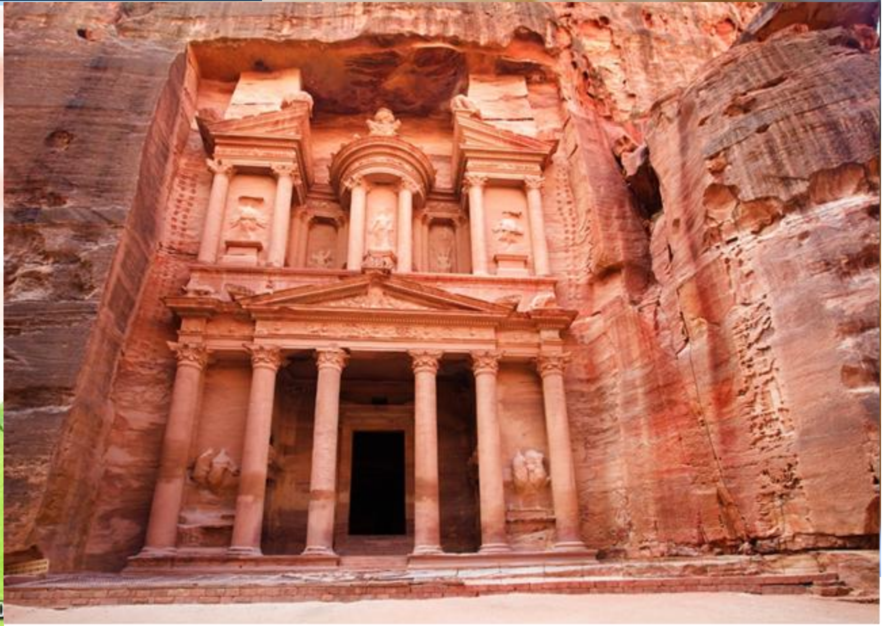
Milling

Chiseling

Additive

Subtractive





Additive manufacturing vs. subtractive manufacturing

FORMING

- What is it?
- What does it look like?
- What are its advantages?
- When would it be used?

- Show an example of something manufactured by forming

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SUMMARY: FORMING

Definition	A material deformation process that reshapes a work piece without reducing or adding material
Uses	Special materials
Advantages	Traditional, well-known method Long history of use Reducing storage space
Examples	

Glass Blowing

"Vacuum formed '42' moulds" by Dennis van Zuijlekom is licensed under CC BY-SA 2.0.

Vacuum Forming

Hydroforming

ADDITIVE MANUFACTURING

- What is it?
- What does it look like?
- What are its advantages?
- When would it be used?

- Show an example of something created by additive manufacturing

ADDITIVE MANUFACTURING – SUMMARY

Definition	A process for making 3D products by primarily adding material rather than removing it. It has become synonymous with 3D printing
Uses	Prototyping and tooling Complex designs Modeling that requires interlocking parts
Advantages	Design freedom Closed systems Quick production Less waste Low-cost manufacturing Multiple materials (PolyJet) Real thermoplastics (FDM)
Examples	

“Aven Orgnac Salle Sup” by Benh LIEU SONG licensed under CC BY-SA 3.0 via Wikimedia Commons

Stalagmites and Stalactites

Pottery

SUMMARY - MANUFACTURING PROCESSES

Cutting

Subtractive Manufacturing

Forming

Additive Manufacturing

ACTIVITY 1.1: Understanding the 4 Main Manufacturing Processes

Download the activity worksheet in the Resources section of module 1

Fill in the charts in the worksheet for each of the 4 manufacturing processes:

- Cutting
- Subtractive
- Forming
- Additive Manufacturing

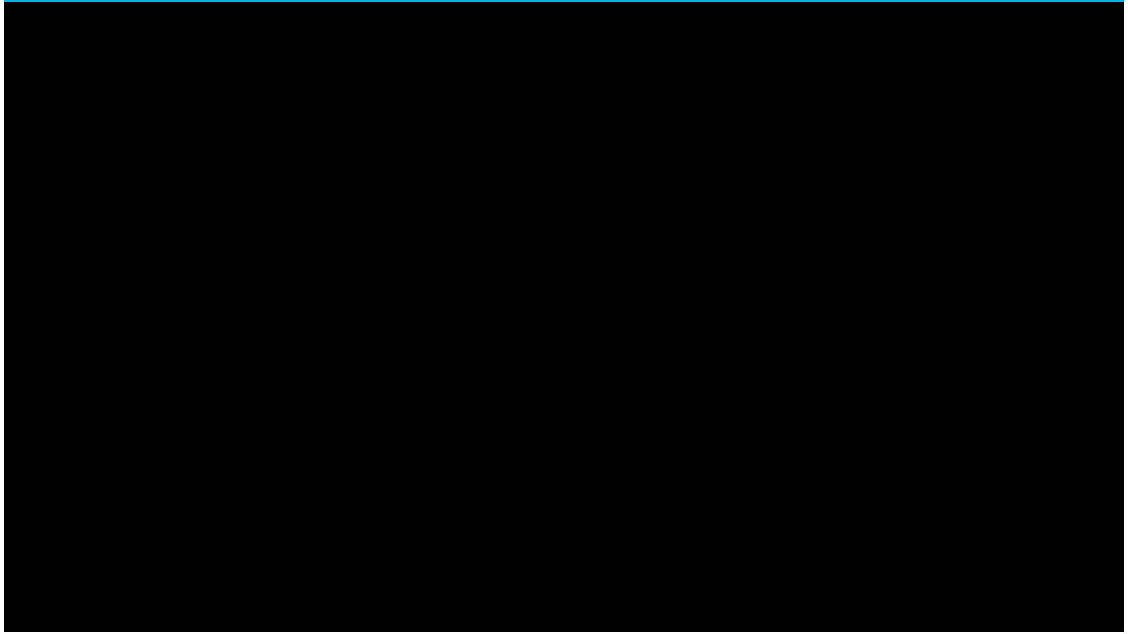
ADDITIVE ADVANTAGES

ADDITIVE MANUFACTURING – ADVANTAGES

Freedom

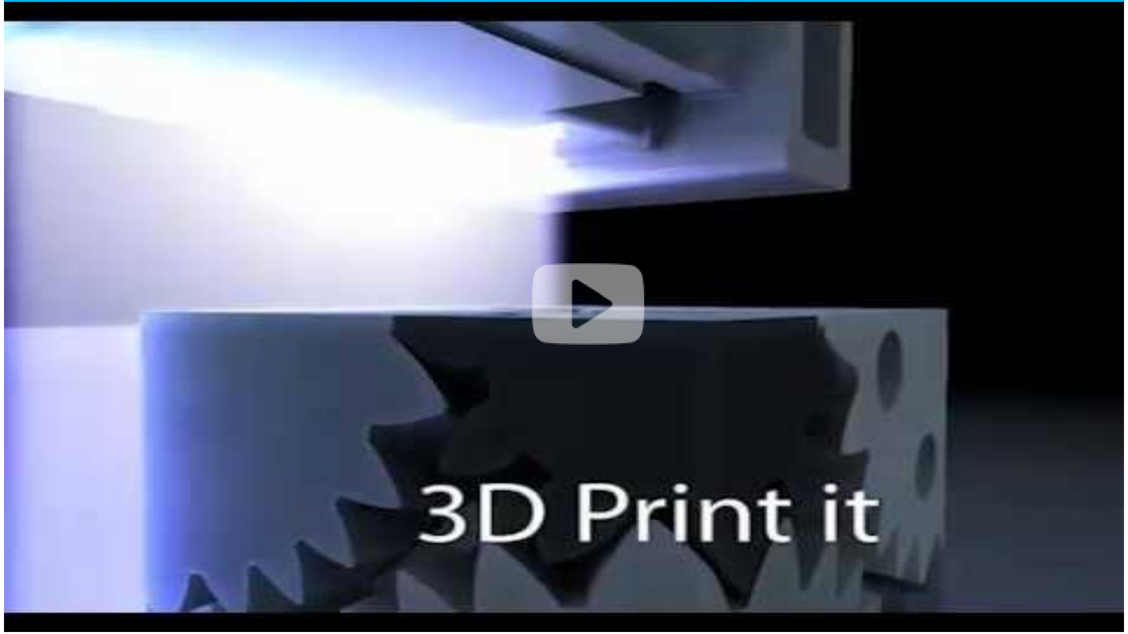
ADDITIVE MANUFACTURING – ADVANTAGES

Closed System



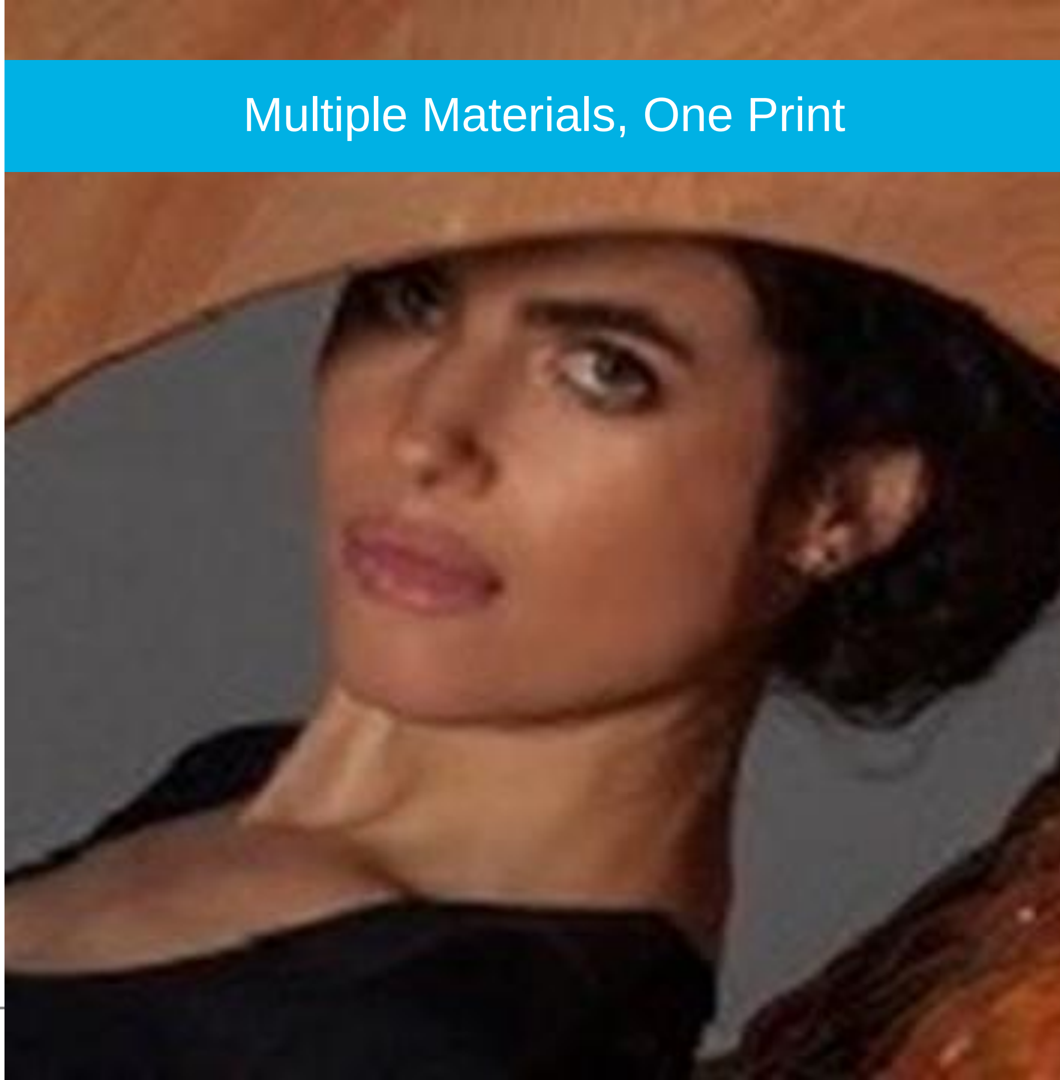
ADDITIVE MANUFACTURING – ADVANTAGES

Quick Production



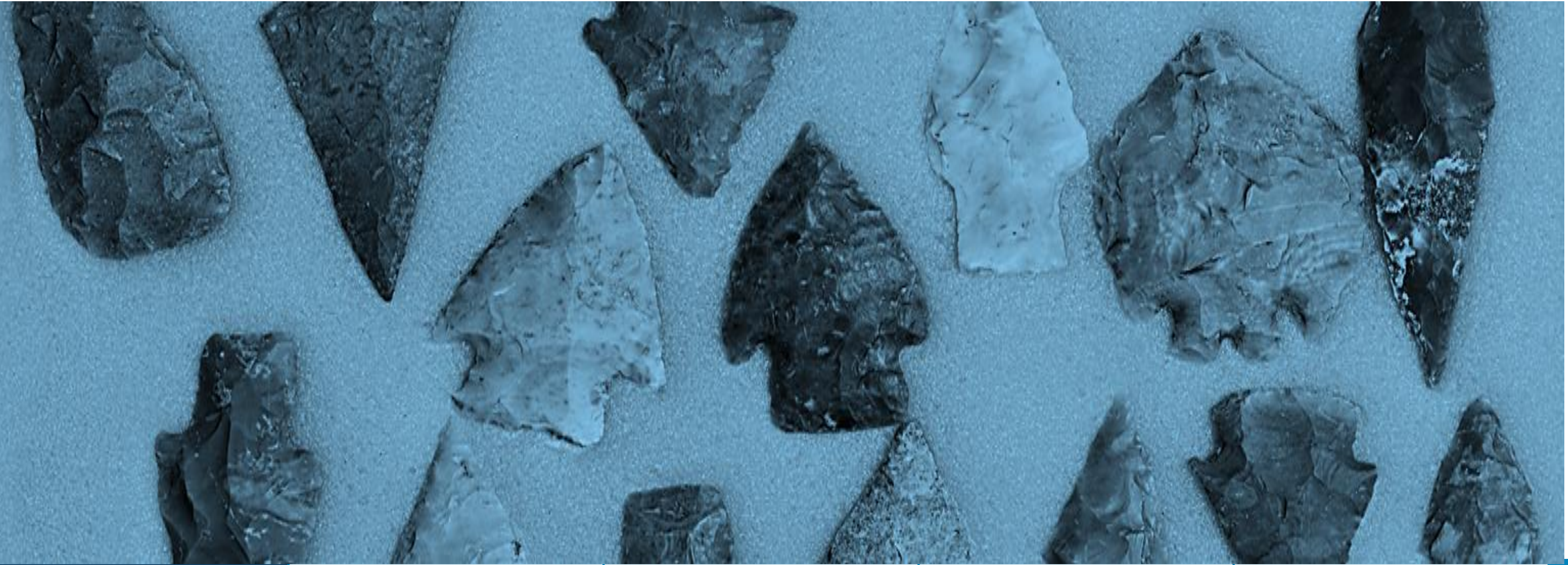
http://www.youtube.com/watch?v=mX6G-TluQHE

ADDITIVE MANUFACTURING – ADVANTAGES



http://www.youtube.com/watch?v=Uz7LpDR-Gew

MANUFACTURING EVOLUTION



Neolithic Revolution | 1st Industrial Revolution | 2nd Industrial Revolution | Digital Revolution | 3rd Industrial Revolution

Neolithic Revolution (8,000 B.C.E.)

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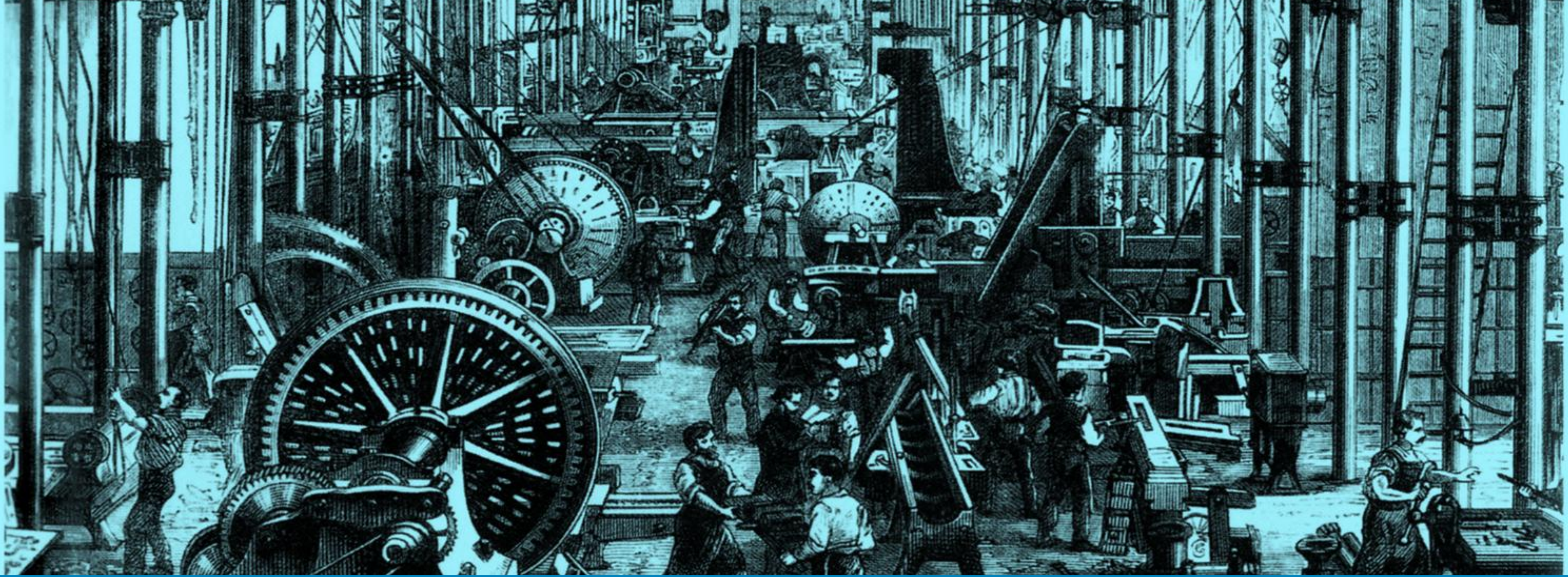
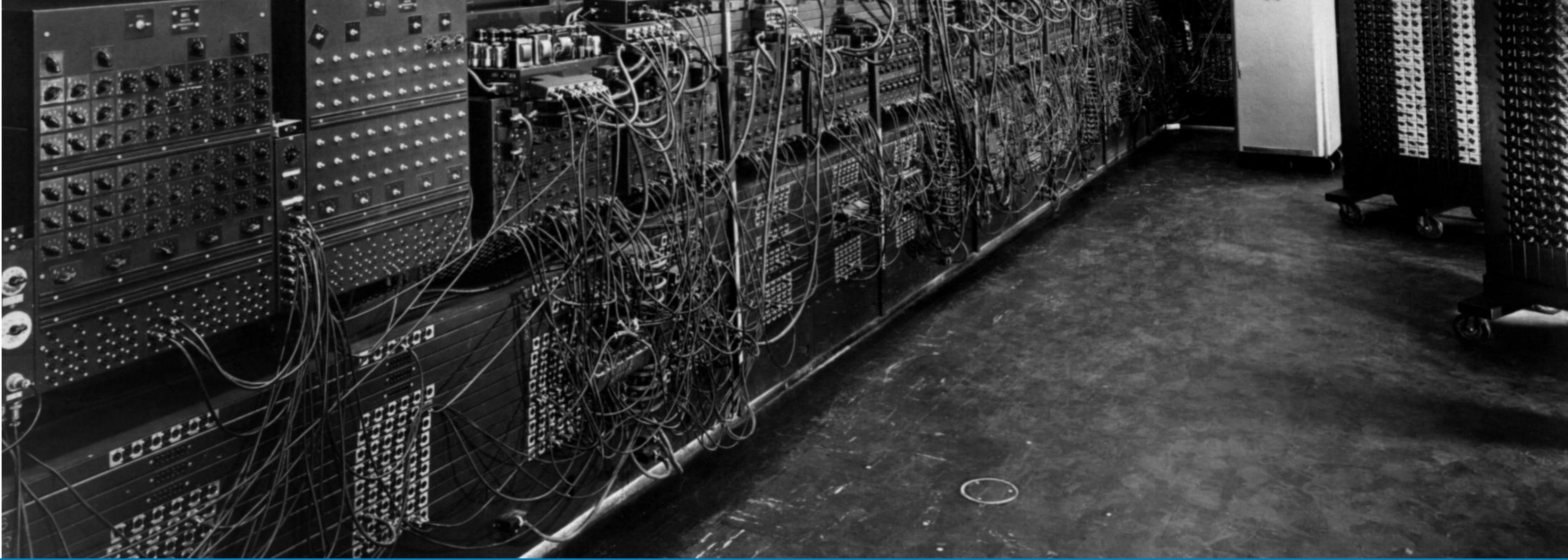


Neolithic Revolution | 1st Industrial Revolution | 2nd Industrial Revolution | Digital Revolution | 3rd Industrial Revolution

First Industrial Revolution (1760)

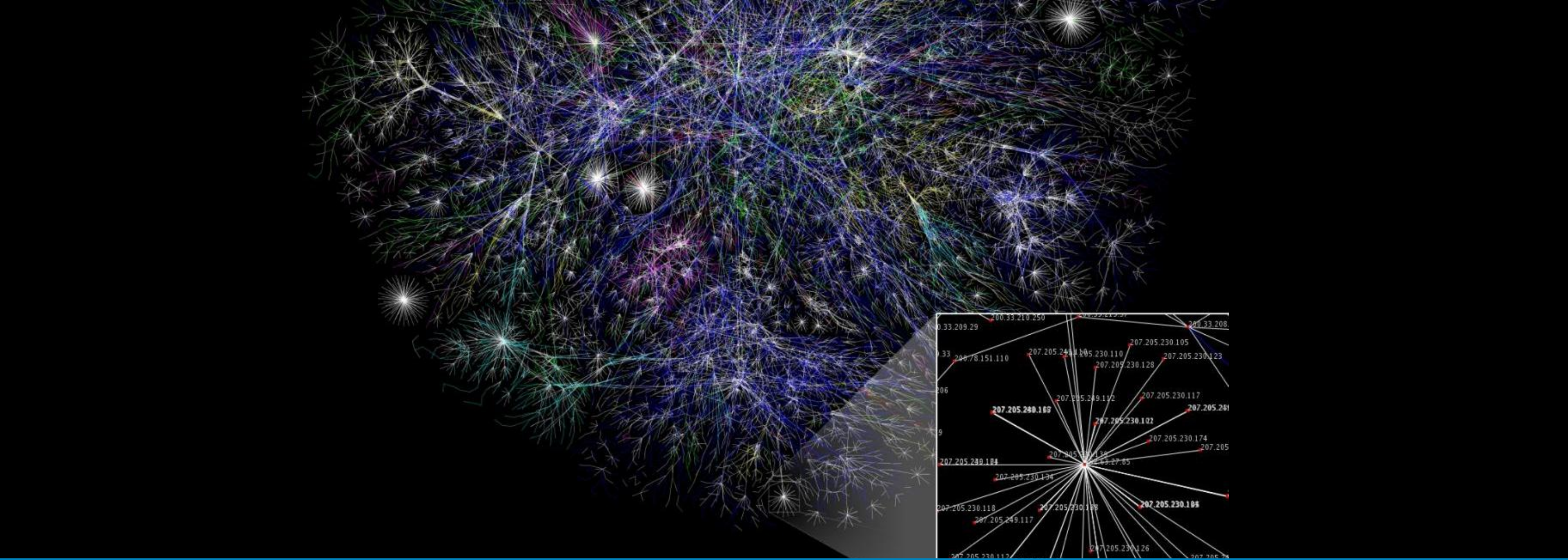
Neolithic Revolution | 1st Industrial Revolution | 2nd Industrial Revolution | Digital Revolution | 3rd Industrial Revolution

Second Industrial Revolution (1840)



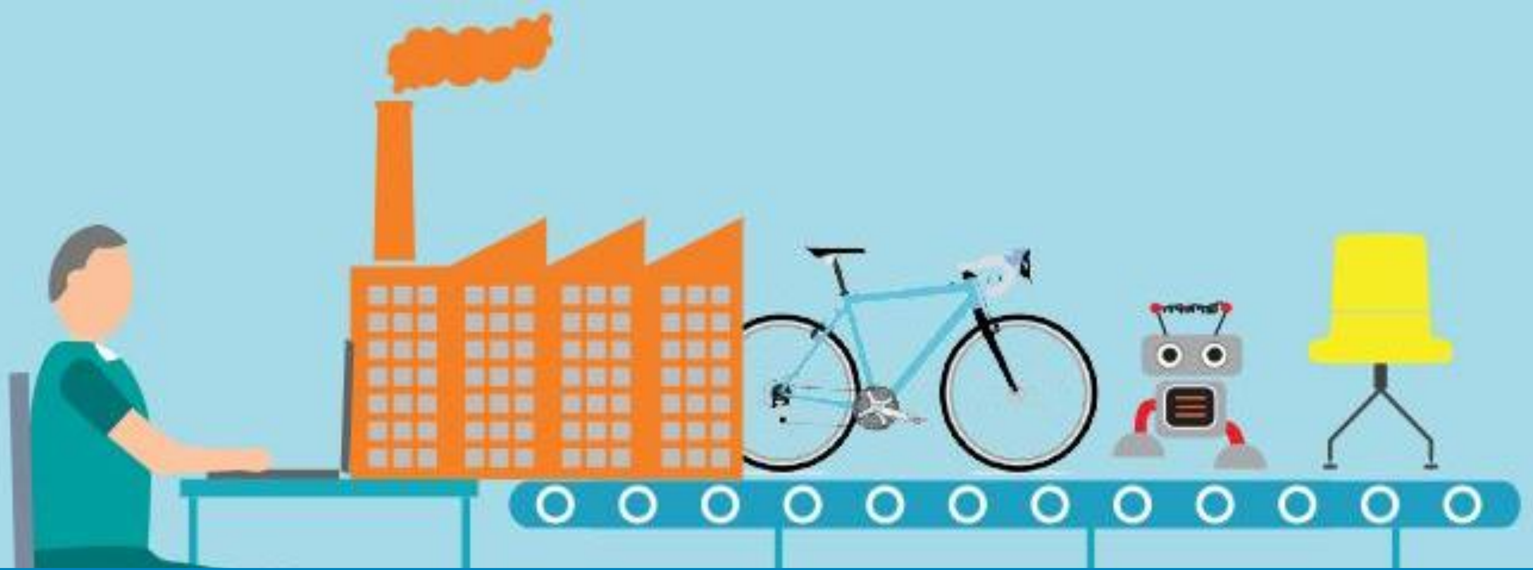
Neolithic Revolution | 1st Industrial Revolution | 2nd Industrial Revolution | Digital Revolution | 3rd Industrial Revolution

The first electronic computer (1939)



Neolithic Revolution | 1st Industrial Revolution | 2nd Industrial Revolution | **Digital Revolution** | 3rd Industrial Revolution

The digital revolution (1970)

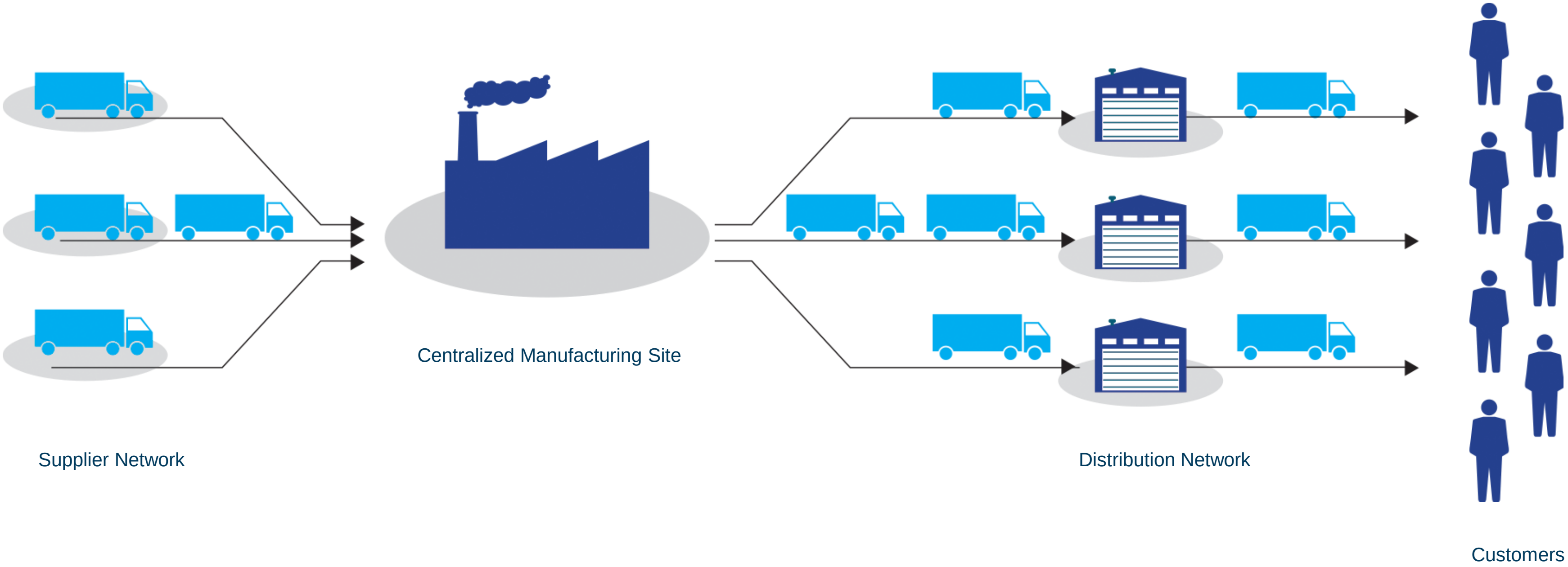


Neolithic Revolution | 1st Industrial Revolution | 2nd Industrial Revolution | Digital Revolution | **3rd Industrial Revolution**

The Third Industrial Revolution (2010)

ECONOMIC IMPACT

NEW BUSINESS MODELS AND SUPPLY CHAINS



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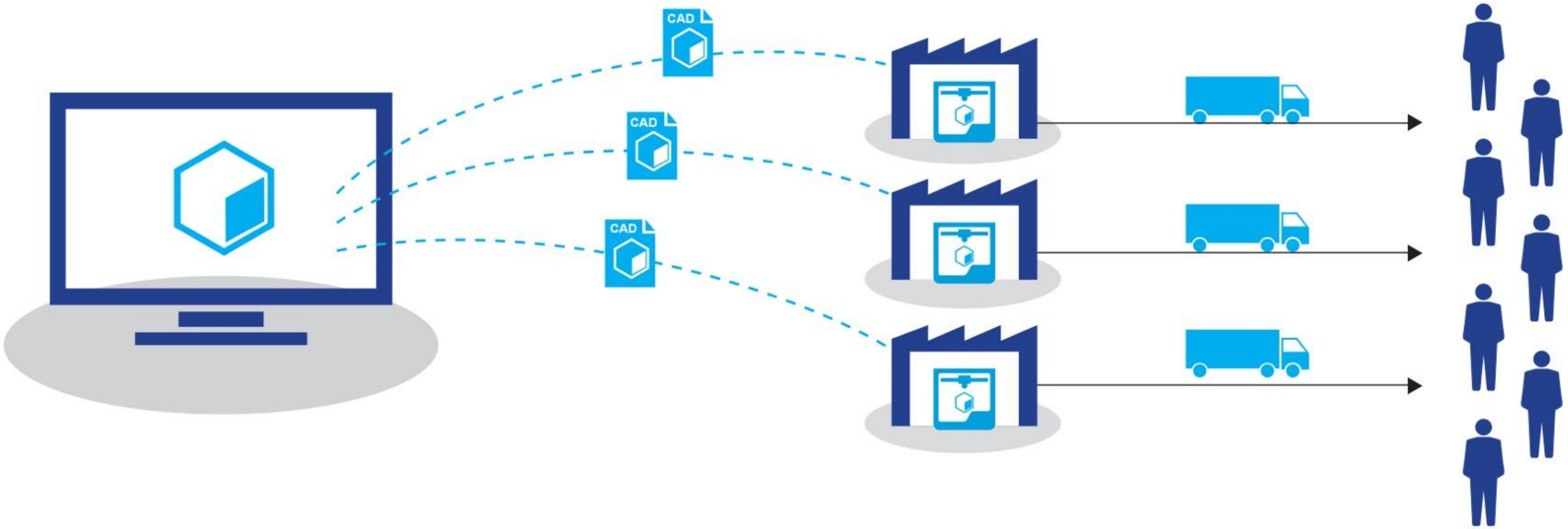
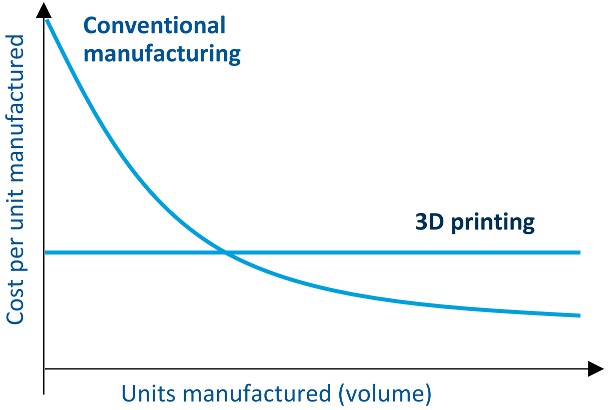
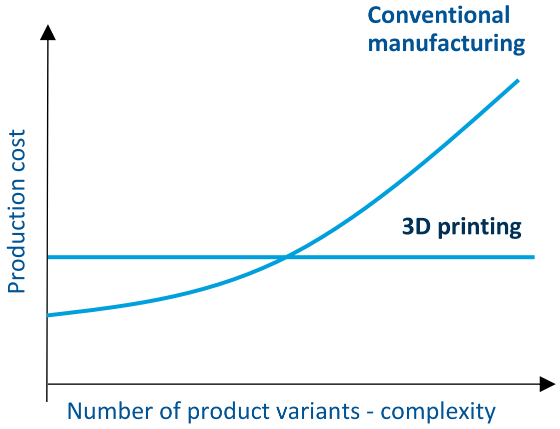
DECENTRALIZED MANUFACTURING



CHANGES IN THE ECONOMICS OF PRODUCTION



Economies of Scale



Economies of Scope

POTENTIAL FUTURE ECONOMIC IMPACT – BY 2025

5-10%

CONSUMER PRODUCTS

could be 3D printable*

30-50%

DIRECT PRODUCT MANUFACTURING

of relevant products are replaceable with 3D printing*

30-50%

TOOLS & MOLD MANUFACTURING

of injected molded Plastic produced with 3D printed molds*

*Source McKinsey & Company

POTENTIAL FUTURE ECONOMIC IMPACT – BY 2025

3D Printing could generate economic impact of

$230 - $550 billion

Per year across the applications
you see here by 2025*

*Source McKinsey & Company

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The Factory of Tomorrow is Here!

ADDITIVE MANUFACTURING (AM) TECHNOLOGIES FOR 3D PRINTING

Module 2

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MODULE 2: ADDITIVE MANUFACTURING TECHNOLOGIES

Learning Objectives:

- List the American Society for Testing Materials (ASTM) seven key Additive Manufacturing processes and associated technologies
- Define Material Extrusion technology FDM and how it works; list it’s advantages, disadvantages and key applications
- Define Vat Photopolymerization's core technologies: SL, SLA – Stereolithography and DLP – Digital Light Processing; list advantages, disadvantages and key applications
- Define Powder Bed Fusion's core technologies: SLS, DMLS,EBM; list advantages, disadvantages and key applications
- Define Binder Jetting's technology: ColorJet Printing; list advantages, disadvantages and key applications
- Define Material Jetting's core technologies: MJP & PolyJet; list advantages, disadvantages and key applications

AM LEADING TECHNOLOGIES

American Society for Testing Materials (ASTM) defines seven key processes under which Additive Manufacturing technologies exist:

Material Extrusion

FDM	Fused Deposition Modeling
FFF	Fused Filament Fabrication

Sheet Lamination

UC	Ultrasonic Consolidation
LOM	Laminated Object Manufacturing

Binder Jetting

CJP	ColorJet Printing
PP	Plaster-based 3D Printing

Vat Photopolymerization

SLA	Stereolithography
DLP	Digital Light Processing
3SP	Scan, Spin, & Selectively Photocure

Powder Bed Fusion

SLS	Selective Laser Sintering
DMLS	Direct Metal Laser Sintering
EBM	Electron Beam Melting
SHS	Selective Heat Sintering

Material Jetting

MJP	MultiJet Printing
PJ	PolyJet

Directed Energy Deposition

LMD	Laser Metal Deposition

AM LEADING TECHNOLOGIES

We will focus on the following technologies:

Material Extrusion	
FDM	Fused Deposition Modeling

Binder Jetting	
CJP	ColorJet Printing

Vat Photopolymerization	
SLA	Stereolithography
DLP	Digital Light Processing

Powder Bed Fusion	
SLS	Selective Laser Sintering
DMLS	Direct Metal Laser Sintering
EBM	Electron Beam Melting

Material Jetting	
MJP	MultiJet Printing
PJ	PolyJet

MATERIAL EXTURSION

FDM – FUSED DEPOSITION MODELING

FUSED-DEPOSITION-MODELING (FDM) - VIDEO

https://www.youtube.com/watch?v=a_kbMUzMKk0

FUSED-DEPOSITION-MODELING (FDM)

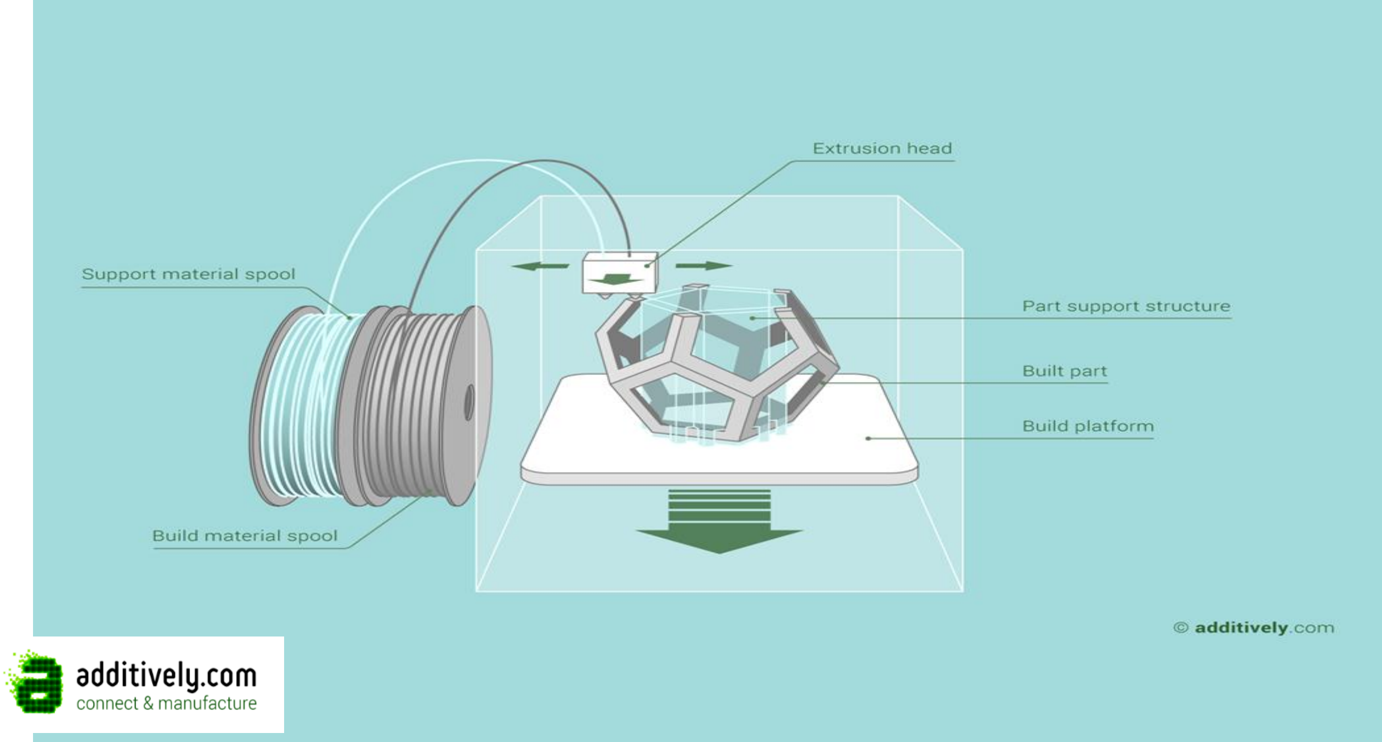


Illustration courtesy of Additively.com

FUSED-DEPOSITION-MODELING (FDM)

Advantages

- Parts have good mechanical properties and are durable over time
- Can build fully functional parts in standard plastics
- Parts can be post-processed

Courtesy of Additively LTD

FUSED-DEPOSITION-MODELING (FDM)

Disadvantages

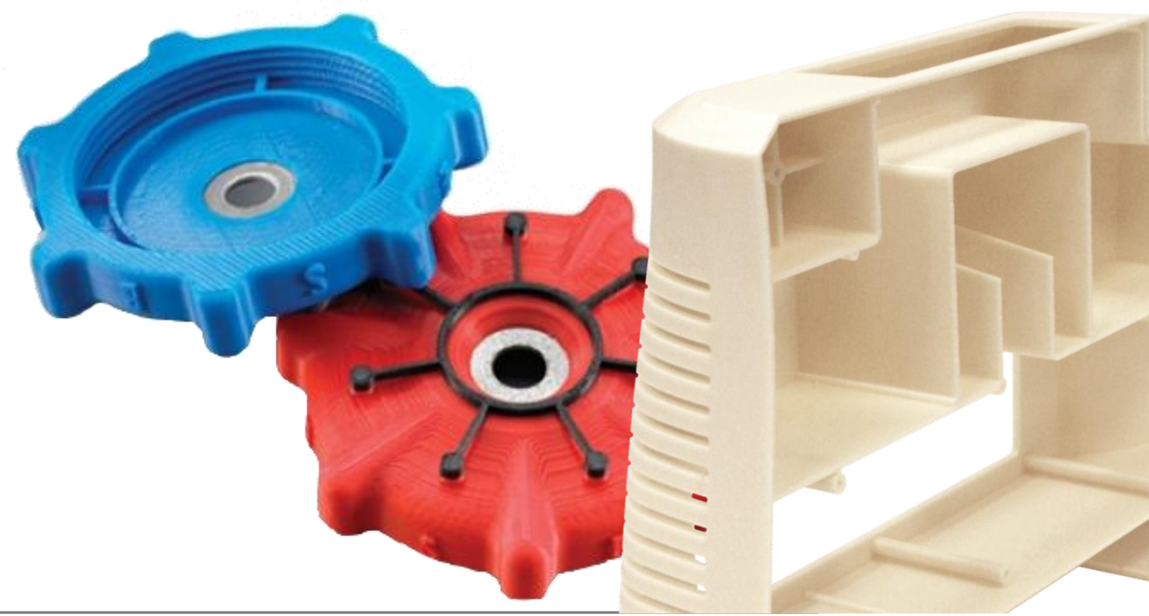
- Anisotropy* in the z-direction (vertical direction)
- Step structure on surfaces
- Fine details cannot be realized
- * Exception for Nylon

Courtesy of Additively LTD

FUSED-DEPOSITION-MODELING (FDM)

Applications

- Prototypes
- Manufacturing Aides
- Small series parts

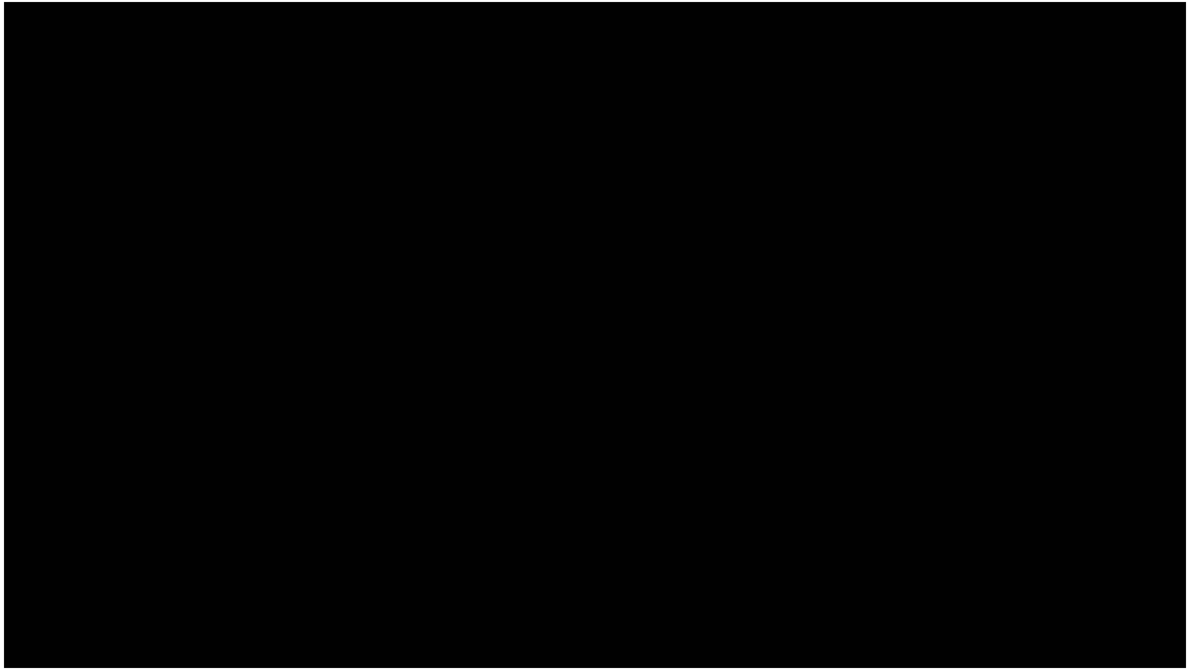


VAT PHOTOPOLYMERIZATION

SL, SLA – STEREOLITHOGRAPHY

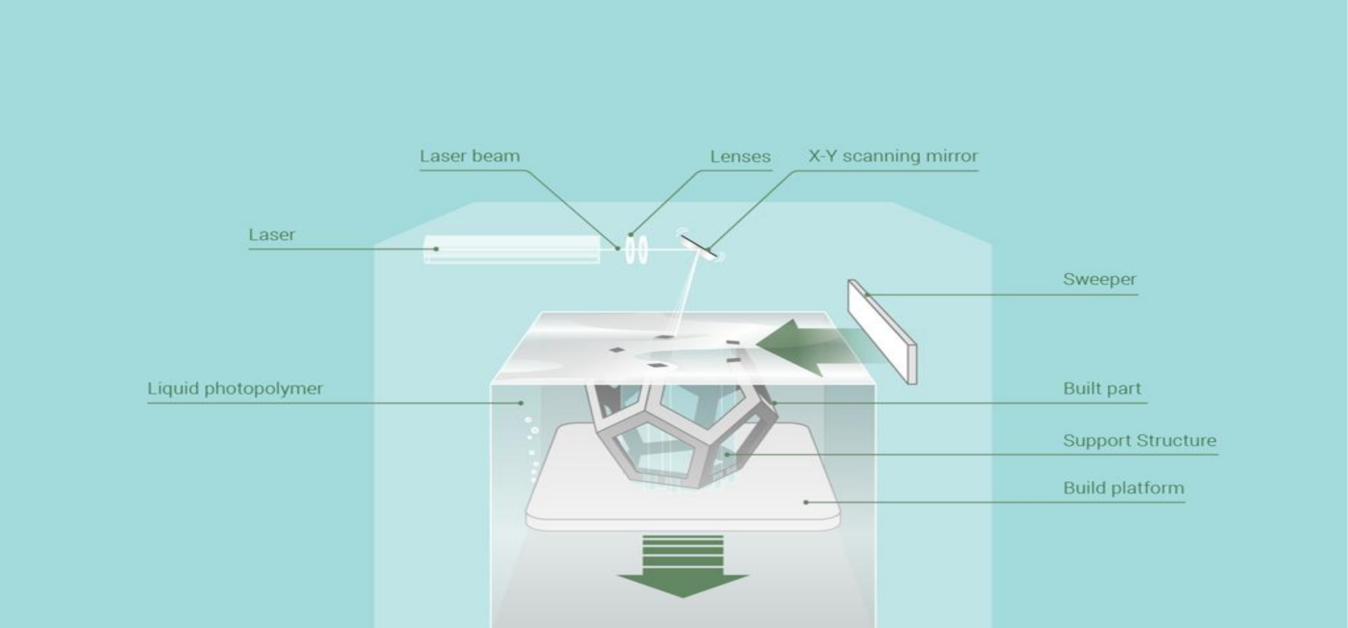
DLP – DIGITAL LIGHT PROCESSING

STEREOLITHOGRAPHY (SL, SLA) - VIDEO



https://www.solidconcepts.com/technologies/stereolithography-sla

STEREOLITHOGRAPHY (SL, SLA)



additively.com
connect & manufacture

Illustration courtesy of Additively.com

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STEREOLITHOGRAPHY

Advantages

- A wide range of material
- Very good accuracy, surface finishes and details
- Machines with large build volume enable large parts

Courtesy of Additively LTD

STEREOLITHOGRAPHY

Disadvantages

- Only works with photopolymers
- Mechanical properties of parts are therefore not stable over time
- Materials are expensive
- The build process can be slower

Courtesy of Additively LTD

STEREOLITHOGRAPHY

Applications

- Prototypes
- Casting patterns

Painted SLA Trade Show Figure

DLP TECHNOLOGY | INTRODUCTION

DLP TECHNOLOGY | SUPPORT STRUCTURES

DLP is a single-material,
vat-based technology:

- Support structures and model are built from the same material
- Support structures are removed manually in post-production
- Models are partially cured out of the printer, post-curing is essential

POWDER BED FUSION / LM – LASER MELTING

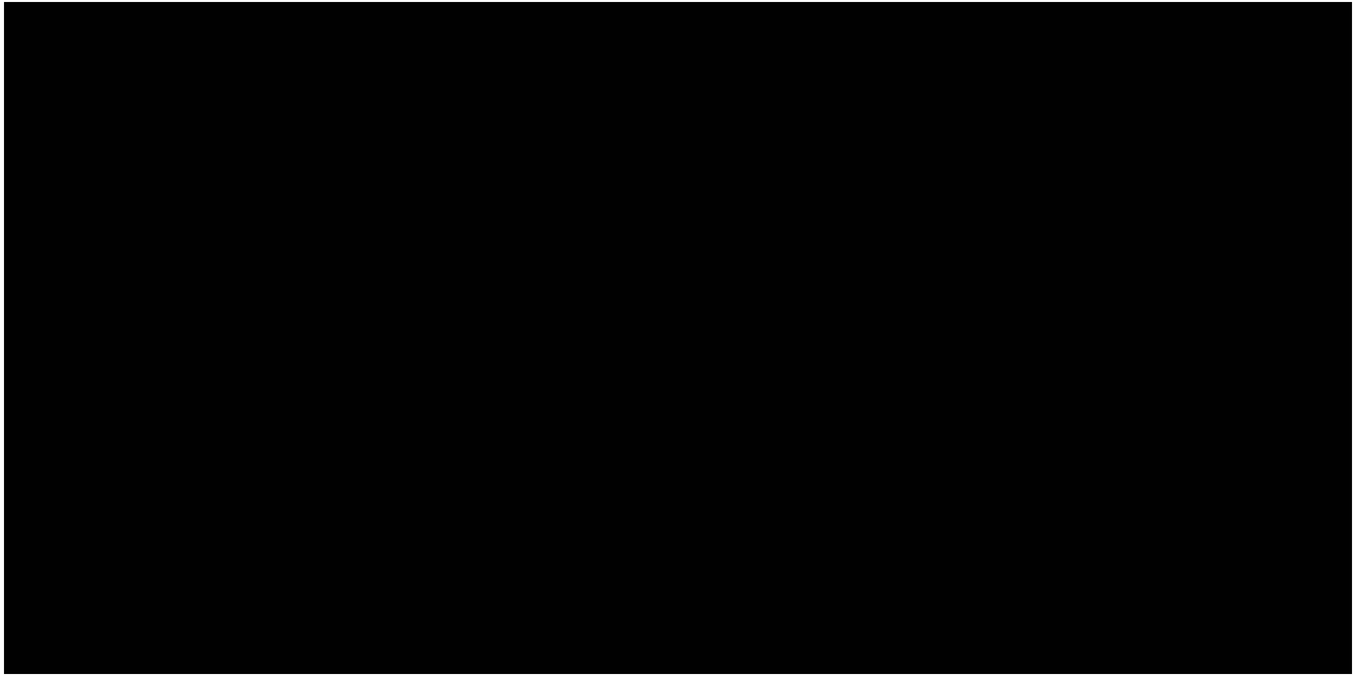
SLS – SELECTIVE LASER SINTERING

SMLS – DIRECT METAL LASER SINTERING

EBM – ELECTRON BEAM MELTING

POWDER BED FUSION/LASER MELTING (LM, SLM, SLS, DMLS)

https://www.solidconcepts.com/technologies/direct-metal-laser-sintering-dmls/



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POWDER BED FUSION/LASER MELTING (LM, SLM, SLS, DMLS)

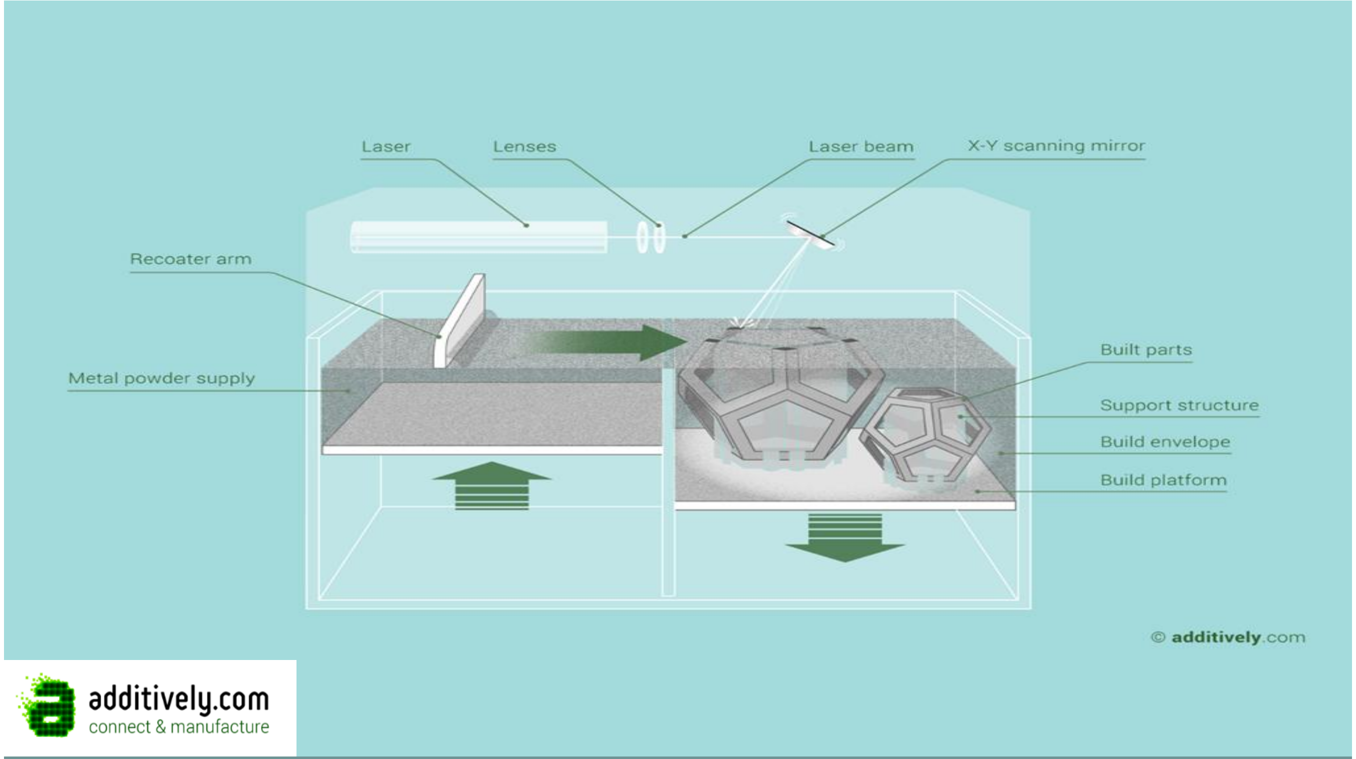


Illustration courtesy of Additively.com

POWDER BED FUSION/LASTER MELTING (LM, SLM, SLS, DMLS)

Advantages

- Can manufacture parts in standard metals with high density
- A constantly widening set of standard metals is available
- Parts can be further processed
- This process can also be used with thermoplastics as well as metals

Courtesy of Additively LTD

POWDER BED FUSION/LASTER MELTING (LM, SLM, SLS, DMLS)

Disadvantages

- The technology is rather slow and expensive
- Tolerances and surface finishes are limited

Courtesy of Additively LTD

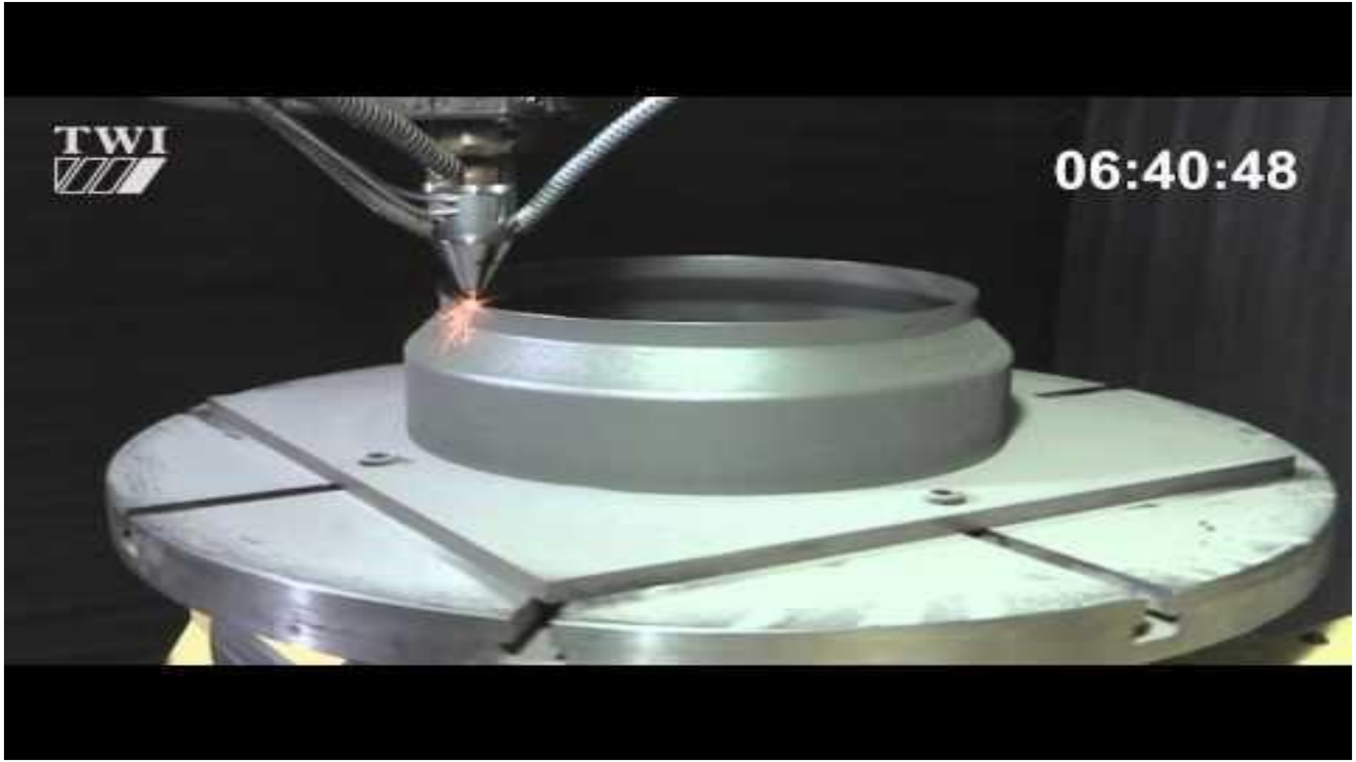
POWDER BED FUSION/ LASER MELTING (LM, SLM, SLS, DMLS)

Applications

- Prototypes
- Support parts
- Small-series parts
- Tools for injection molds

EBM VIDEO

https://www.youtube.com/watch?v=yKnlmfuMSgo



ELECTRON BEAM MELTING (EBM)

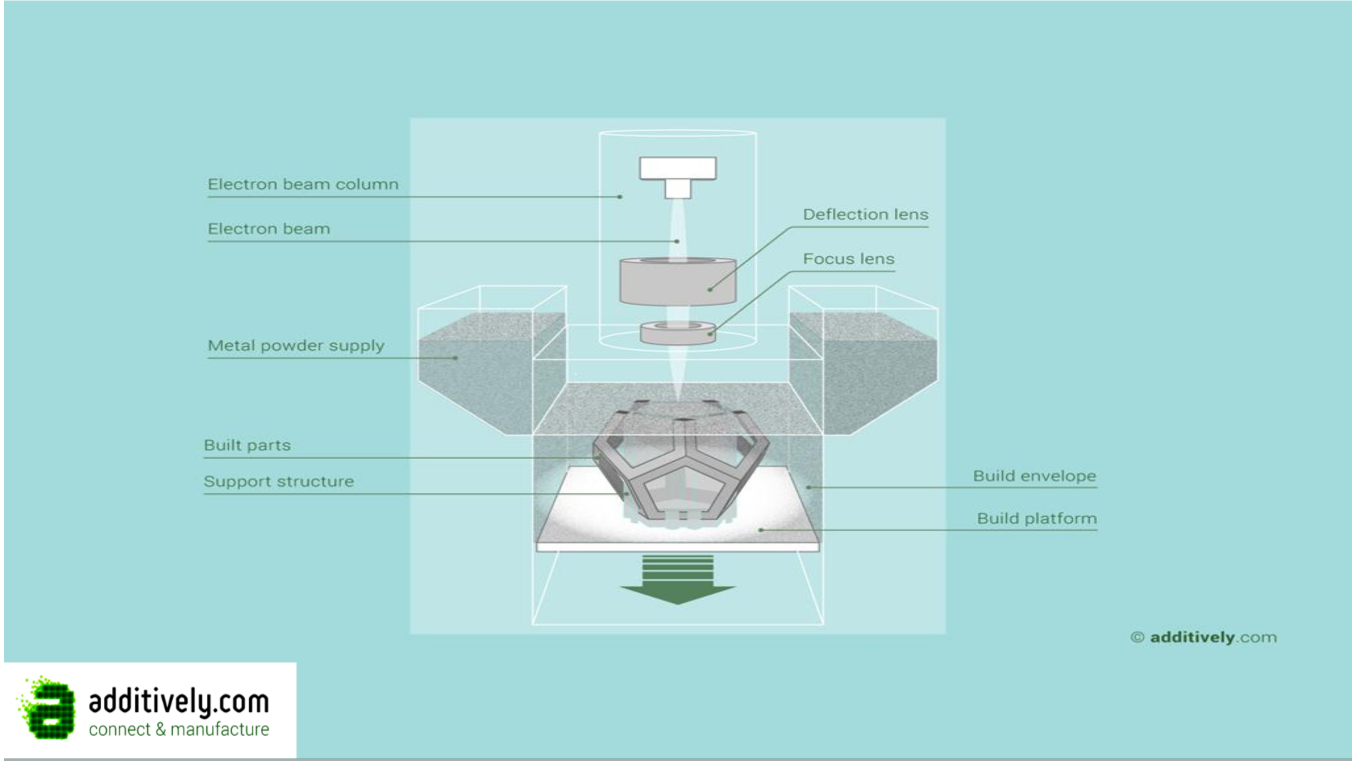


Illustration courtesy of Additively.com

ELECTRON BEAM MELTING (EBM)

Advantages

- Parts can be manufactured in some standard metals with high density by electron beam melting.
- Parts in standard metals with high density (above 99%) and good mechanical properties
- Requires less support structure (compared to LM)
- Builds parts faster (compared to LM)

Courtesy of Additively LTD

ELECTRON BEAM MELTING (EBM)

Disadvantages

- Electron beam is slow, expensive and works with limited set of metals
- Parts usually require quite a lot of post-processing
- Does not achieve equally good surface finishes to laser melting

Courtesy of Additively LTD

ELECTRON BEAM MELTING (EBM)

Applications

- Small-series parts
- Prototypes
- Support parts

BINDER JETTING

BJ – BINDER JETTING

CJP – COLORJET PRINTING

BINDER JETTING - VIDEO

https://youtu.be/RNNxEoXuvuw

BINDER JETTING (BJ)

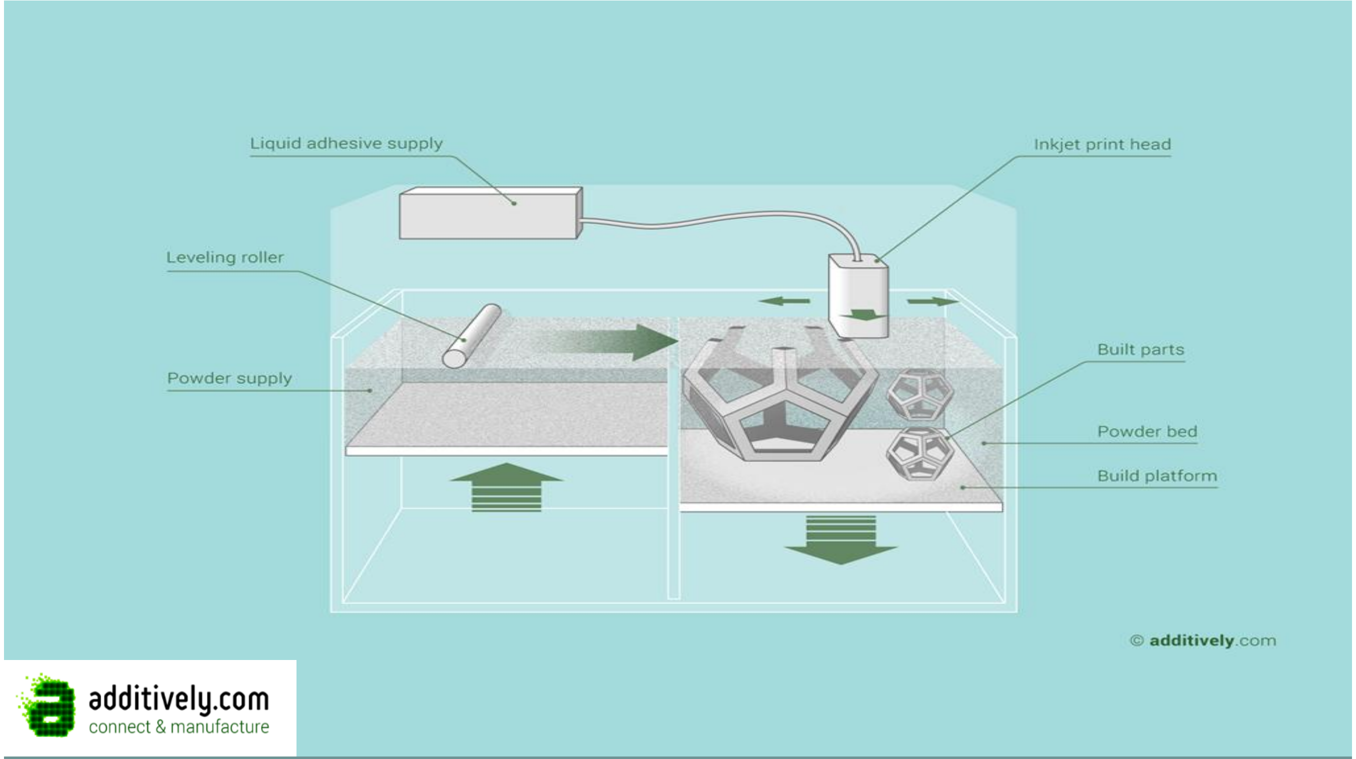


Illustration courtesy of Additively.com

COLORJET PRINTING (CJP) / BINDER JETTING (BJ)

Advantages

- Fast and cheap technology
- Wide arrange of material types
- Works with almost any material that is available in powder form
- Parts in full color are possible.

Courtesy of Additively LTD

COLORJET PRINTING (CJP) / BINDER JETTING (BJ)

Disadvantages

- Parts coming directly from the machine have limited mechanical characteristics.
- Parts are basically particles glued together resulting in fragile parts with limited mechanical properties (if not further processed).

Courtesy of Additively LTD

COLORJET PRINTING (CJP) / BINDER JETTING (BJ)

Applications

- Prototypes
- Green parts
- Casting patterns
- Molds and cores

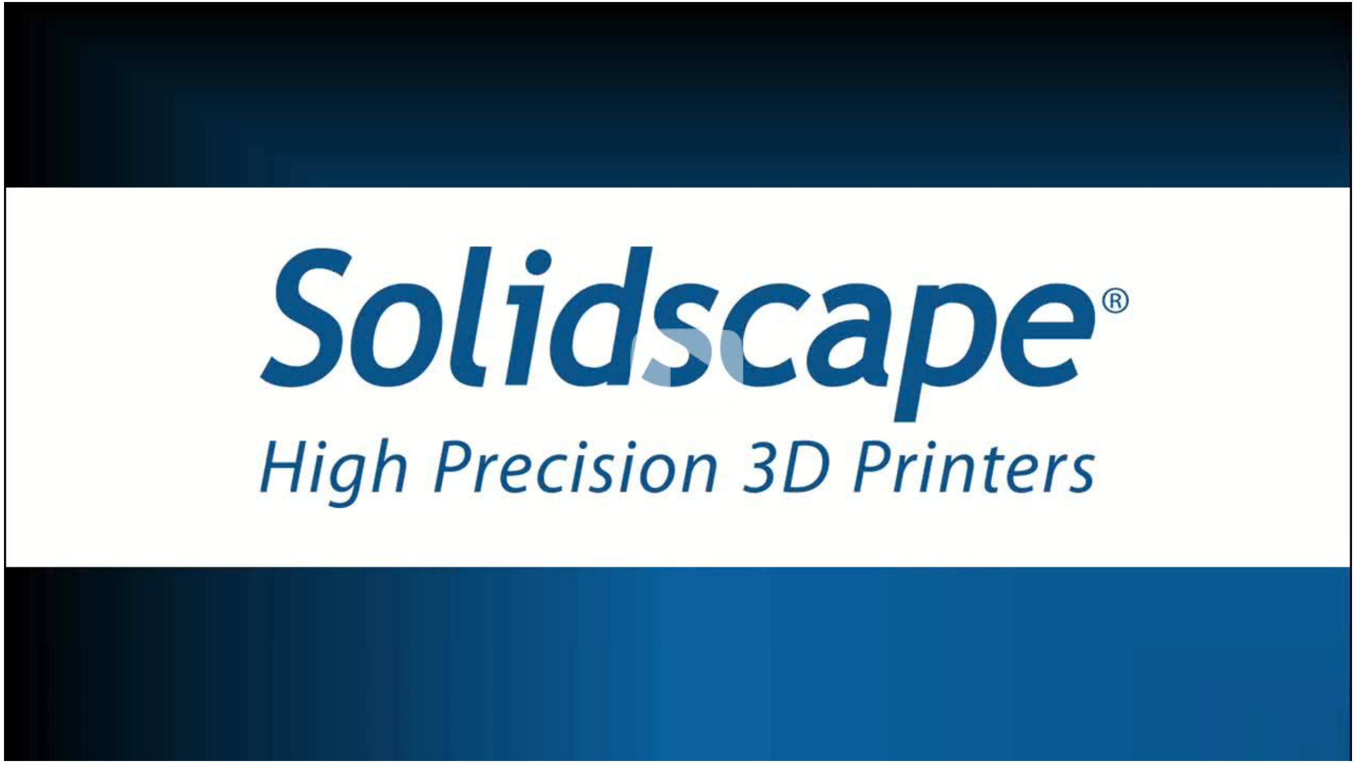
MATERIAL JETTING

MJ – MATERIAL JETTING

PJ – POLYJET – PHOTOPOLYMER JETTING

MATERIAL JETTING (MJ)

https://www.youtube.com/watch?v=gM86qxW7vP8



MATERIAL JETTING (MJ)

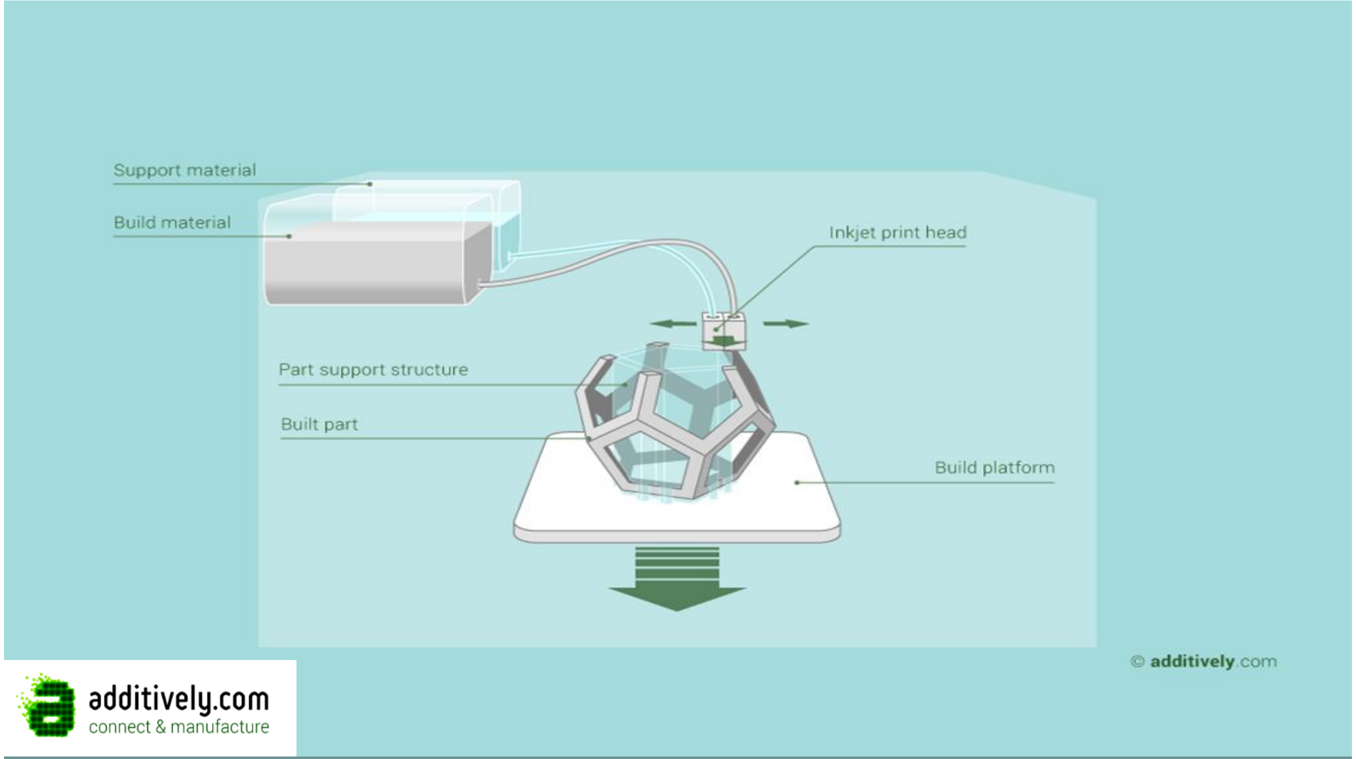


Illustration courtesy of Additively.com

MATERIAL JETTING (MJ)

Advantages

- Good accuracy
- Good surface finish

Courtesy of Additively LTD

MATERIAL JETTING (MJ)

Disadvantages

- Limited number of wax-like materials
- Fragile parts
- Slow build process

Courtesy of Additively LTD

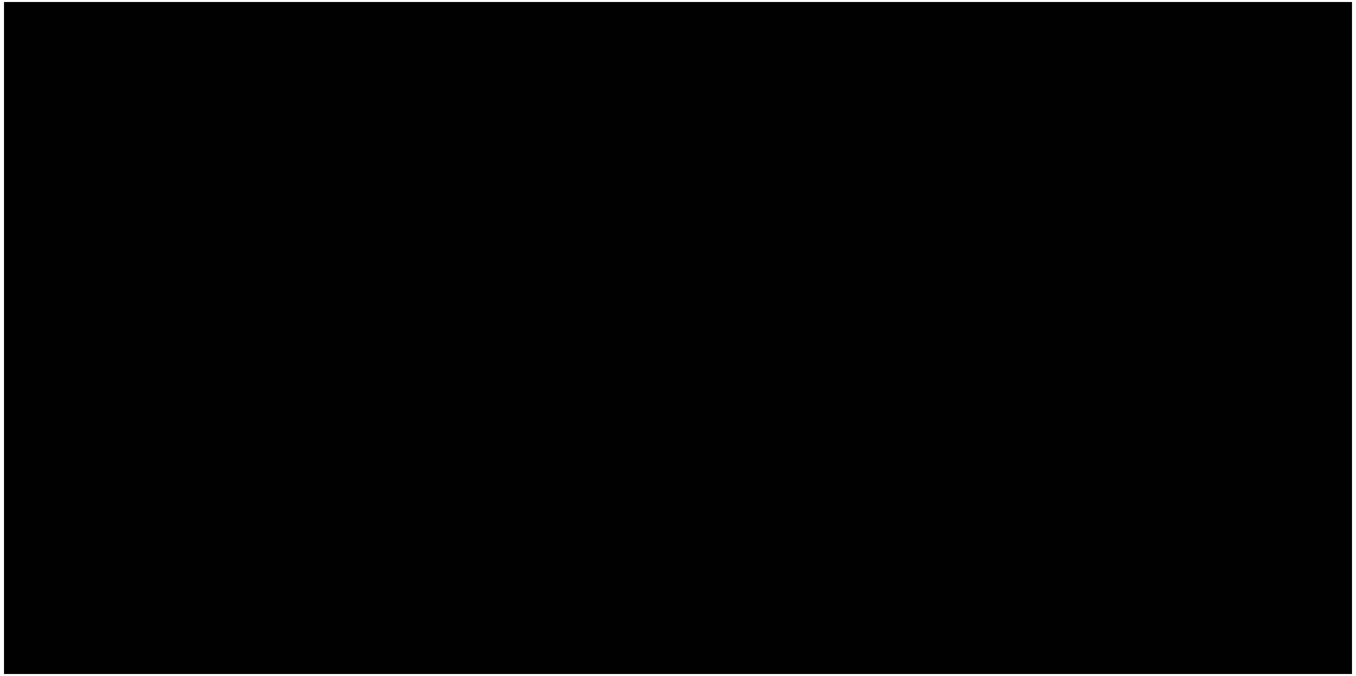
MATERIAL JETTING (MJ)

Applications

- Prototypes
- Casting patterns
- Lost wax casting (jewelry and dental)

PHOTOPOLYMER JETTING (POLYJET)

https://www.solidconcepts.com/technologies/polyjet/



PHOTOPOLYMER JETTING (POLYJET)

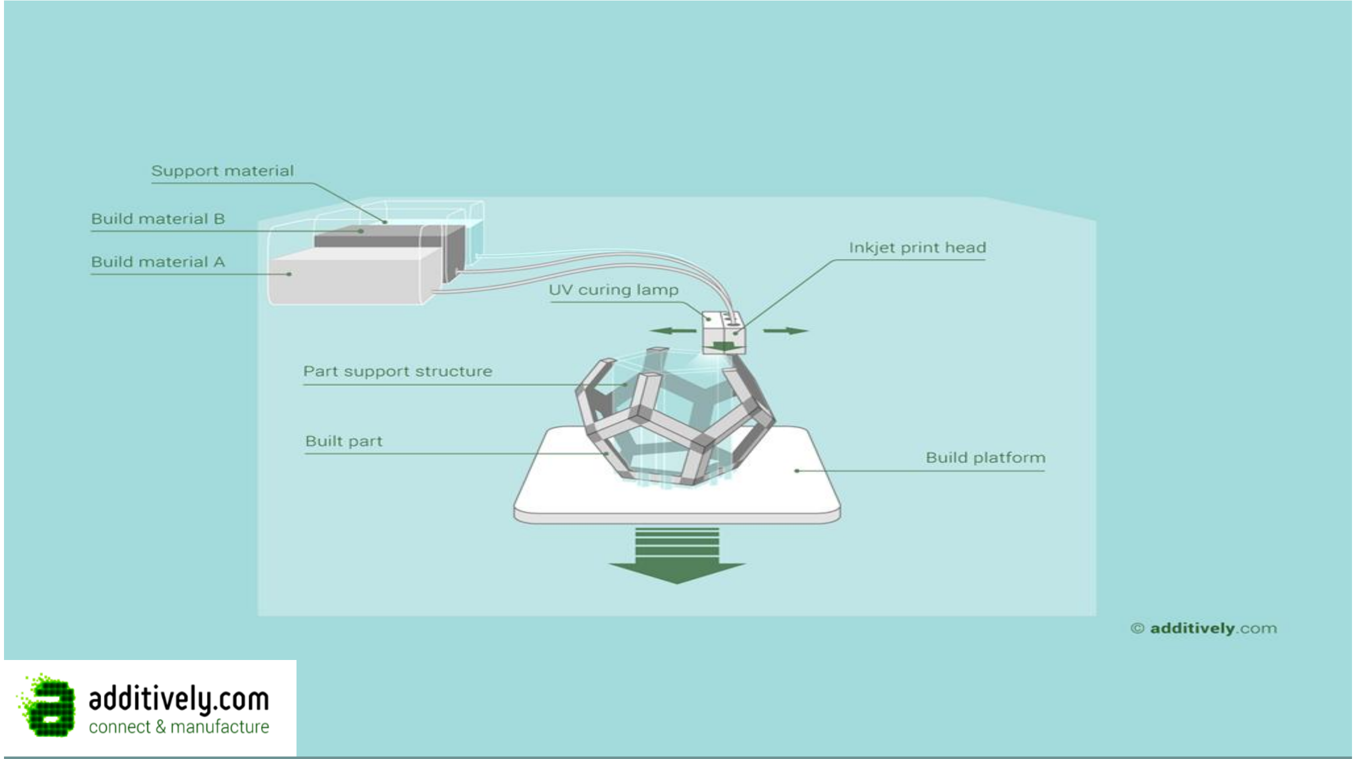


Illustration courtesy of Additively.com

PHOTOPOLYMER JETTING (POLYJET)

Advantages

- Multiple materials can be jetted together allowing multi-material and multi-color parts
- Functionally graded materials are possible.
- Multi-material and/or multi-color parts
- Can achieve good accuracy and surface finishes

Courtesy of Additively LTD

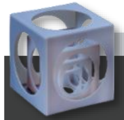
PHOTOPOLYMER JETTING (POLYJET)

Disadvantages

- Does not work with standard materials but with UV-active photopolymers which are not durable over time (thermoset)
- Works with UV-active photopolymers. Therefore, parts are not durable over time and have limited mechanical properties

Courtesy of Additively LTD

EVOLUTION OF STRATASYS POLYJET



2004. Eden
1 Material

Highly accurate, finely detailed models with ultra-thin walls

2007. Connex
2 Materials

The world's first multi-material 3D printer

2014. Connex 1/2/3
3 Materials

Stratasys introduces the first-ever color and multi-material 3D printer

2016. J750
6 Materials

The world's only full color, multi-material, high resolution 3D printer

PHOTOPOLYMER JETTING (POLYJET)

Applications

- Prototypes
- Casting patterns
- Tools for injection molding

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SUMMARY

ACTIVITY 2.1: The 7 Core Additive Manufacturing Technologies

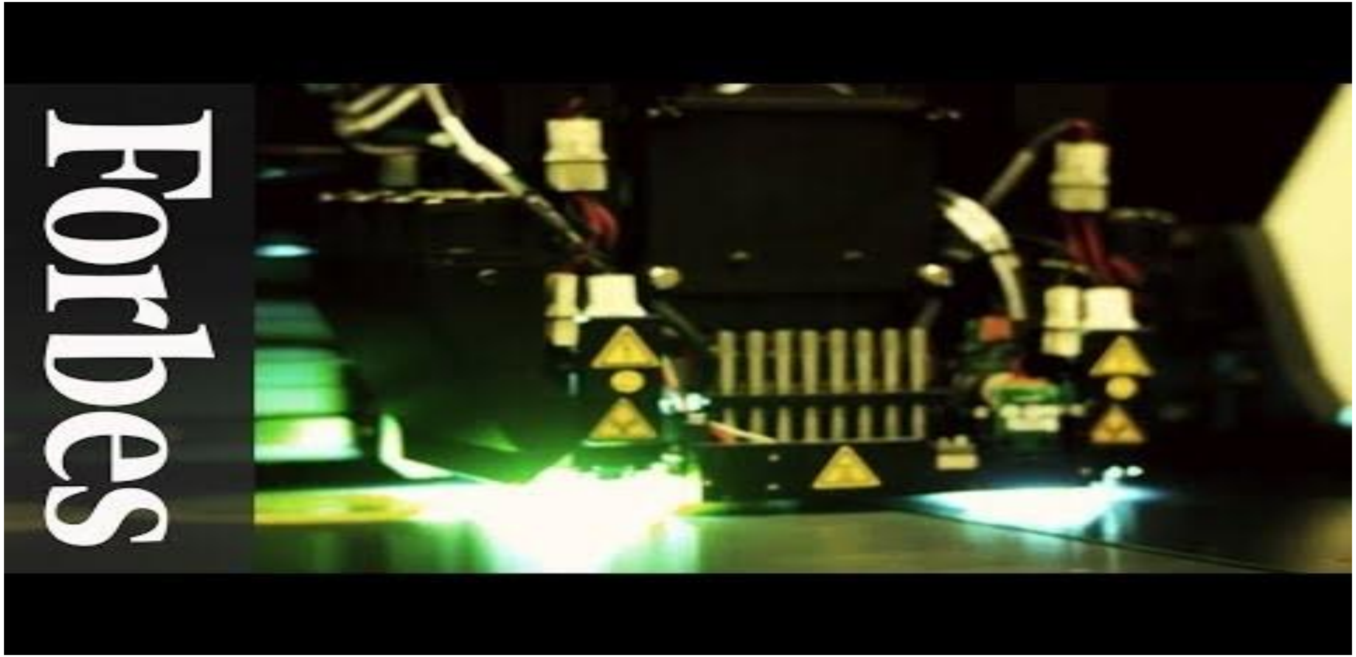
Download the activity worksheet in the Resources section of module 2.

Give an example of a design showing the best use of the following 7 technologies. Save these design choices for an activity in Module 4.

1. Vat Photopolymerization
2. Material Jetting
3. Material Extrusion
4. Powder Bed Fusion (Both Metals and Polymers)
5. Binder Jetting
6. Sheet Lamination
7. Directed Energy Deposition

CLOSING VIDEO

https://www.youtube.com/watch?v=o7eutklRhMU



NEXT STEPS

In Module 3 we will dive deeper into applications for FDM and PolyJet technologies.

Material Extrusion	
FDM	Fused Deposition Modeling

Material Jetting	
MJP	MultiJet Printing
PJ	PolyJet

INDUSTRIES & APPLICATIONS USING STRATASYS 3D PRINTING

Module 3

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MODULE 3: INDUSTRIES & APPLICATIONS USING STRATASYS

Learning Objectives:

- Define the benefits and use cases for rapid prototyping, tooling and production parts.
- Identify 6 key industries leading in additive manufacturing using Stratasys technology.
- Identify key 3D printing applications, their value and companies benefiting in the Aerospace Industry, Automotive Industry, Consumer Goods business, Healthcare: Medical and Dental
- Describe the types of tools, printing solution and needs that 3D printing aides and tools have to general manufacturing (fabrication and assembly, health and safety, quality control, workflow) across industries.
- Define Digital Manufacturing applications of Sandcasting, jigs and fixtures, EOAT, blow molding, End-use-parts, Silicone molding, Injection Molding and liquid silicone rubber parts.

INDUSTRIES & APPLICATIONS SHAPING OUR WORLD

https://www.youtube.com/watch?v=K11MWto9tKk

WHAT MATTERS MORE?

Clue

OR

3D PRINTING APPLICATIONS FOR MOST COMMON CUSTOMER APPLICATIONS

RAPID PROTOTYPING	
Improved time to market, lower cost of development cycles, greater design freedom, highest degree of realism and functionality	• Concept Modelling • Design verification • Functional prototype validation

TOOLING	
Increased productivity at the assembly line, lowest cost of ownership for tooling and faster time to market	• Manufacturing Aids • Composite & Sacrificial Tooling • Injection Molding

PRODUCTION PARTS	
Highest degree of customization, optimal supply chain efficiency, increased sustainability with less material waste /usage	• On demand Service • Production machinery & Expert Services • Robotics / Infinite build for large parts • Certification for specific materials

ACTIVITY 3.1: Tooling Mini Challenge

Download the activity worksheet in the Resources section of module

Read the scenario and answer these questions:

Question 1: Do the math… if 168 printing hours are available, what does the per-part printing time (in hours and minutes) have to be to complete the order assuming 80% machine utilization rate ("up-time") and that 10% of the printed fixtures will not pass quality standards?

Question 2: **Identify any TWO time-saving changes** that Team Member B made to Team Member A's design. The ready-to-print CMB files for both designs are provided to you in your USB.

Question 3: **Identify the TWO functionality improvements** that Team Member B added that assist the operator in placing brackets onto the fixtures.

Question 4: Remind the team: What did Team Member B specifically remind them of regarding the part's final use that makes Team Member C's concern irrelevant?

INDUSTRIES

Aerospace | Automotive | Consumer Products | Medical | Dental | Manufacturing

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AEROSPACE

SHAPING MANUFACTURING & SUPPLY CHAIN IN AEROSPACE

APPLICATION	THE VALUE	THE WHO	
• Wind tunnel testing • Carbon fiber layups • Surrogate parts • Tooling for composite aero-structures • Production parts including interior cabin parts	• Lighter weight parts • Advanced functionality • Improved fly-to-buy ratio • Increased supply chain efficiency with reduced inventory requirements • Reduced lead times and production costs • Part consolidation • Rapid, on-site production (assembly tools)	• Nasa • Airbus • Boeing • Aerialtronics • Evector	• ULA • Aurora Flight Sciences • Piper Aircraft • Swift Engineering

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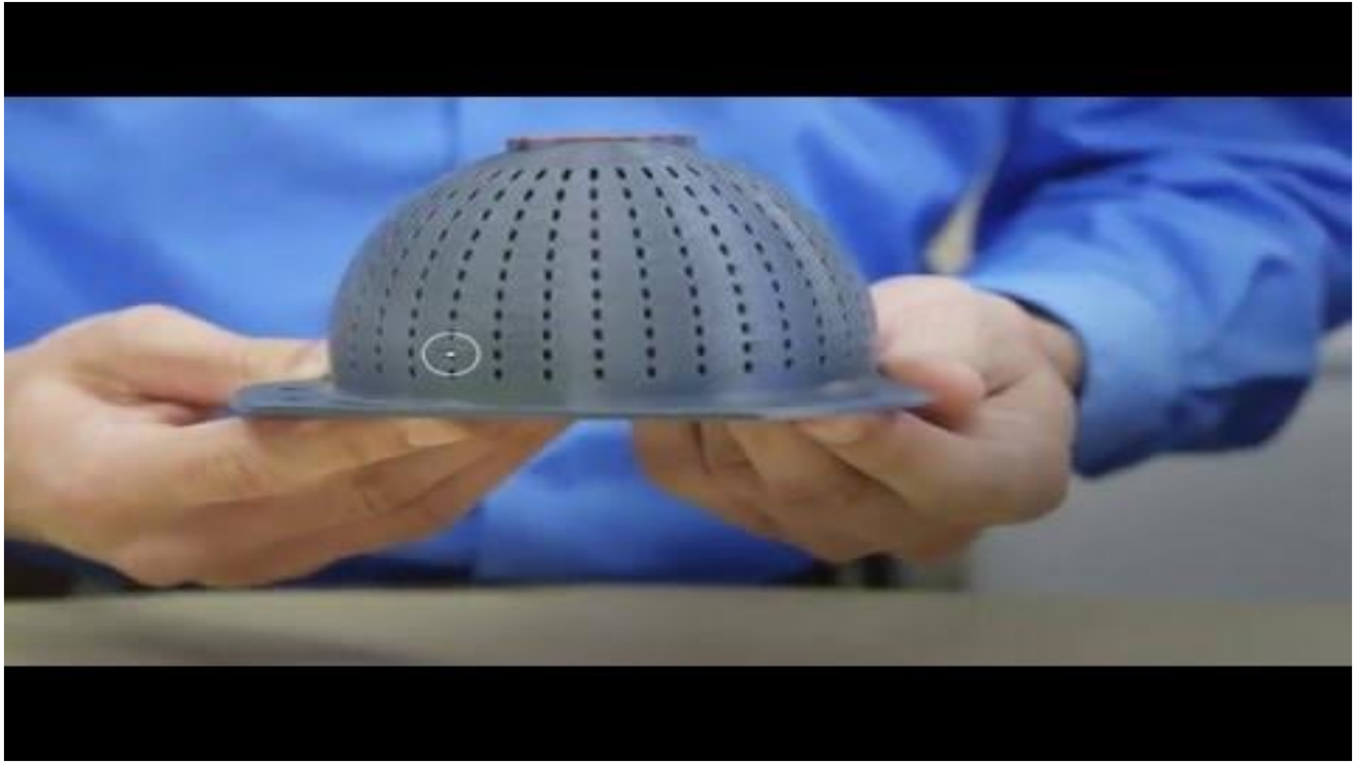
HOW ADDITIVE IS IMPACTING AN INDUSTRY - AEROSPACE



https://www.youtube.com/watch?v=-tRlxsTjsKA

AIRBUS CASE STUDY

Airbus Standardizes On Stratasys Additive Manufacturing Solutions

- Airbus implemented 1,000+ flight-approved FDM components to meet delivery of the A350 XWB program, now standardized for production. The impact of this was:

Increased supply chain flexibility

Provided valuable weight reduction compared to traditional components

Improves buy-to-fly ratio as significantly less material wasted than with conventional manufacturing methods

ULTEM™ 9085 thermoplastic material is FST compliant for aircraft interior applications (materials & certification)

Shaping the Art and Science of Travel

"This game-changing technology also decreases total energy used in production by up to 90 percent compared to traditional methods."

Peter Sander, Head of Emerging Technologies and Concepts at Airbus

DESIGN & GEOMETRIC FREEDOM VIDEO

AUTOMOTIVE

SHAPING INNOVATION IN AUTOMOTIVE

APPLICATION	VALUE	WHO
• Concept modeling, functional prototyping, design validation • Soluble core support for carbon fiber parts such as manifolds and turbo inlet pipes • Manufacturing aids • Production parts • Mass customization of design elements	• Speed, responsiveness & efficiency • Tooling – wide production spectrum • Print Engines – widest array • Electrical systems – complete part production • Ergonomic customized light weight production aids	• BMW • Volvo Trucks • McLaren Penske • Opel • Honda Access • Alseca • Daihatsu

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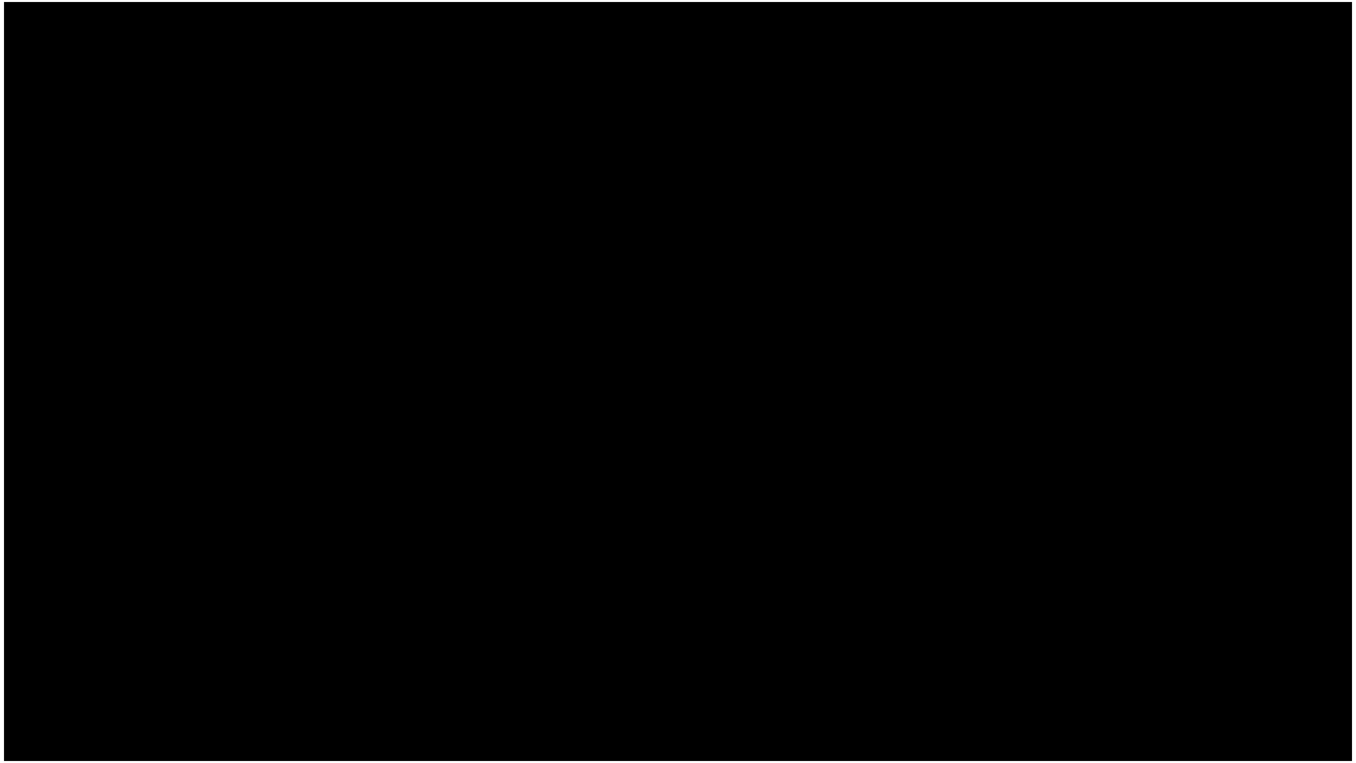
SHAPING INNOVATION IN AUTOMOTIVE



https://www.youtube.com/watch?v=1iS0j9le05M

VOLVO TRUCKS CASE STUDY

Increased plant production efficiency to ensure delivery times are met

Producing clamps, jigs and supports in just 2 days (compared to 36 days)

3D printed ABS tools costing as little as 1€/cm3, compared to up to 100€/cm3 if making the same item from metal

"The capability to produce a virtually unlimited range of functional tools in such a short timeframe is unprecedented, enables us to be more experimental and inventive to improve production workflow."

-- Pierre Jenny, Manufacturing Director at Volvo Trucks

CUSTOMIZATION IN AUTOMOTIVE

https://www.youtube.com/watch?v=-oFr1OYCl84

Shaping Machines that Move the Earth

“3D printing makes it possible to build mock-up engine components so the platform and manufacturing teams can provide feedback at a much earlier stage in the development process.”

Jeff Hartman, Product Designer,
Volvo Construction Equipment

CONSUMER GOODS

SHAPING INNOVATION IN HIGH TECH & CONSUMER GOODS

APPLICATION	VALUE	WHO	
• Concept modeling • Functional prototyping • Injection molding • Blow molding • EOA tooling • Jigs & fixtures • Production parts	• Reduced time-to-market • Cost efficiencies • Optimize design by removing manufacturing constraints	• SAP • Wincor Nixdorf • Xerox • adidas • Salomon • Black and Decker • Grohe • Nike	• Bianchi Bikes • Seuffer • Whales • Berker • OtterBox • Safilo

RAPID PROTOTYPING

https://www.youtube.com/watch?v=eZZZ3pmEYFU&t=44s

OTTERBOX CELL PHONE CASE:
DESIGN AND PRODUCT DEVELOPMENT

Otterbox's Design & Product Development Team benefits from:

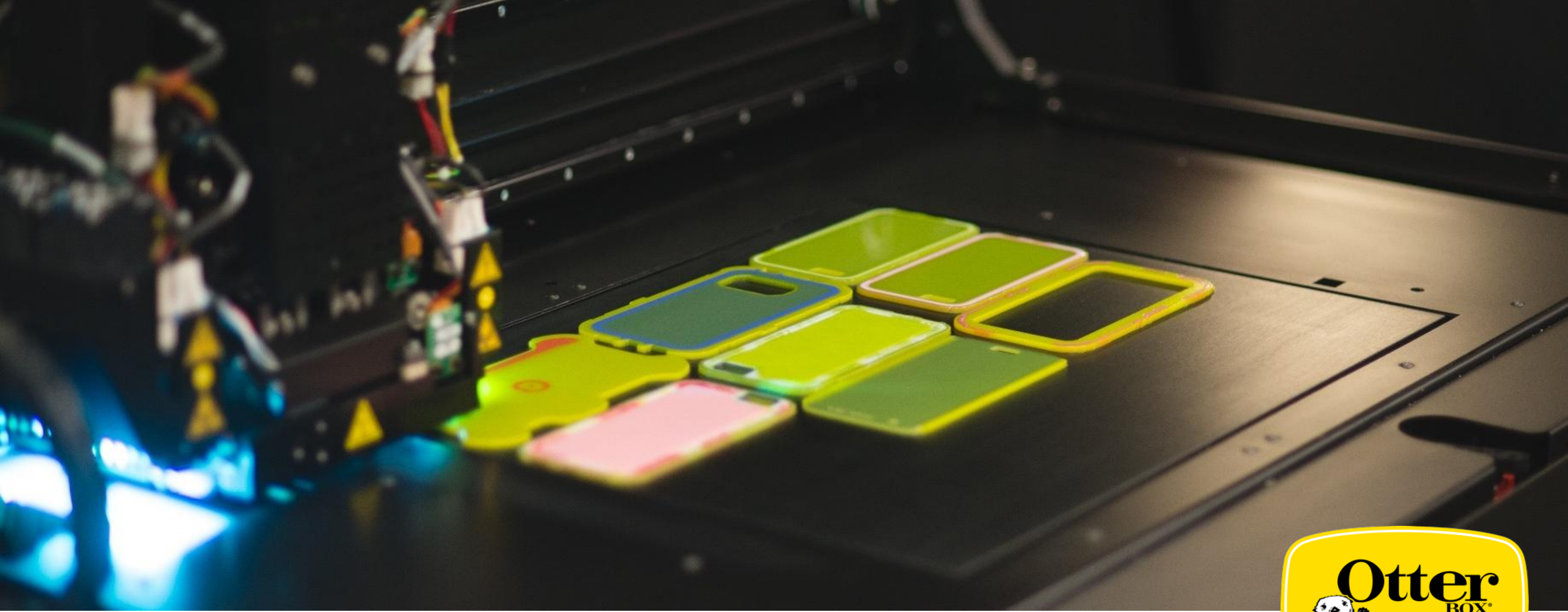
Concept Validation

- Allows the designer to order parts in various materials or design variations
- Technicians can prioritize and create exactly what the designers want

Design Verification - Verification prints to identify exact location of cameras, ports, sensors, buttons and other critical features

Performance Testing

- Fast print times allow for more prototype iterations and production runs right the first time (fewer changes while in production)
- Time to market has been reduced x 4
(from 26 weeks to 8 week)



https://www.youtube.com/watch?v=mifFnC3-zuI

Shape Customization

"Our goal at OtterBox is to get product on the peg the same day as the device launch, and the J750 helps us achieve that."

Brycen Smith, Engineering Technician Supervisor, OtterBox

MULTI-MATERIAL

Characteristics

- Palette-based
  - Light hues/dark hues
  - Monochrome (color+black+white)
  - Translucent color
  - Flexible color
- > 2 mm (0.8 in) thickness (for true colors)

Rigid and rubber like combination for living hinge and snap fit simulation

Rigid (orange) Digital Material with rubber-like overmolding

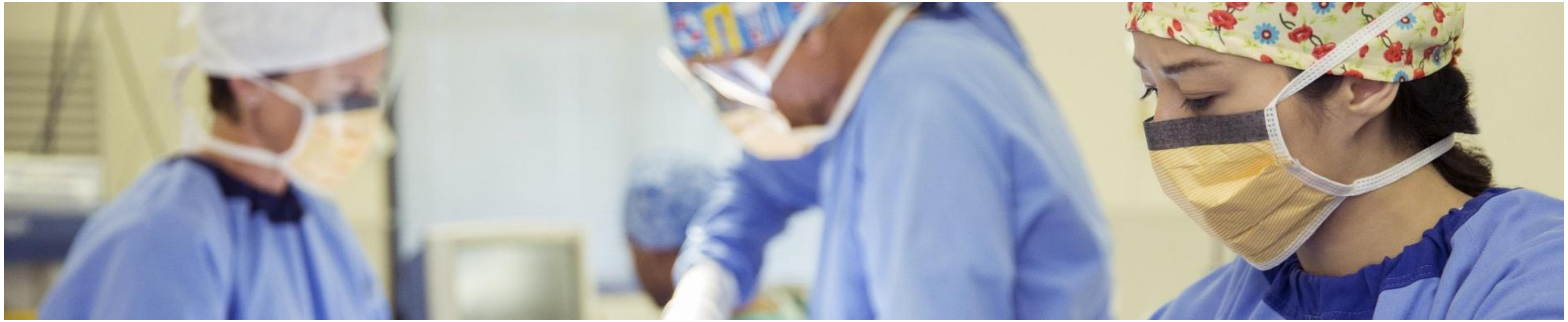
Eyewear printed with tinted lenses and multi-color frames

MULTI-MATERIAL CASE STUDY

https://www.youtube.com/watch?v=wcxMQ2qjF9M

MEDICAL

SHAPING PATIENT OUTCOMES IN HEALTHCARE



APPLICATION	VALUE	VALUE	WHO
• Pre-surgical models • Personalized prosthetics and orthotics • Prototyping for surgical instruments • Replace cadavers and animal in surgical training	Improve patient outcomes • Increased success/time savings in operating rooms • Improved individual procedure outcomes • Heightened practitioner clinical preparedness	Medical Device Innovation • Better preclinical device testing and evaluation • Cost-effective, rapid development and high performance • Shorter cycle times	• **Academic and Pediatric Hospitals**: Mayo Clinic, Cleveland Clinic, Boston Children's • **Medical OEMs**: Medtronic, Cardiovascular Systems Inc., Nidek, Syqe • **Research:** Jacobs Institute

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ECONOMICS AND OUTCOMES

3D printing can reduce costs, improve patient care or increase speed at every step in the medical device value chain.

- Improved profitability
- Increased technology adoption
- Agile market responsiveness





3D printing and additive manufacturing solutions enhance **economics** and **outcomes** of medical solutions

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ECONOMICS AND OUTCOMES

3D printing and additive manufacturing solutions enhance **economics** and **outcomes** of medical solutions

MEDICAL DEVICE VALUE CHAIN

RESEARCH & DEVELOPMENT	PRECLINICAL TESTING	MANUFACTURING	MARKETING & PHYSICIAN EDUCATION	CLINICAL	LIFECYCLE MANAGEMENT
RAPID PROTOTYPING	REALISTIC ANATOMICAL MODELS	PRODUCTION PARTS, JIGS AND FIXTURES	PHYSICIAN TRAINING AND SALES AIDS	PATIENT-SPECIFIC SOLUTIONS	FULL RANGE OF ADDIVITIVE MANUFACTURING USE CASES

SOLUTIONS





3D PRINTED MEDICAL MODELS

https://www.youtube.com/watch?v=n0t6pAYqMJE

SURGICAL TRAINING: MODELING HUMAN TISSUE

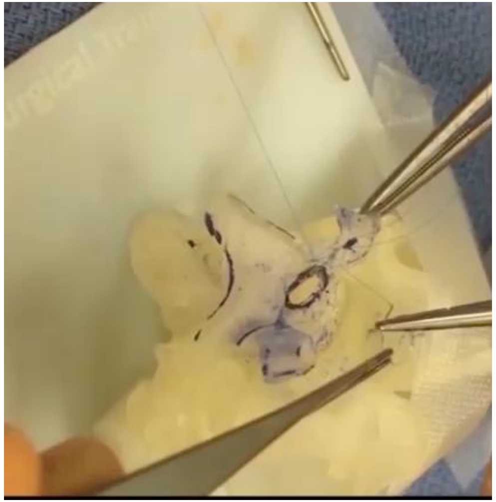
Physician Training & Education | Procedure Planning | Rapid Prototyping / Innovation

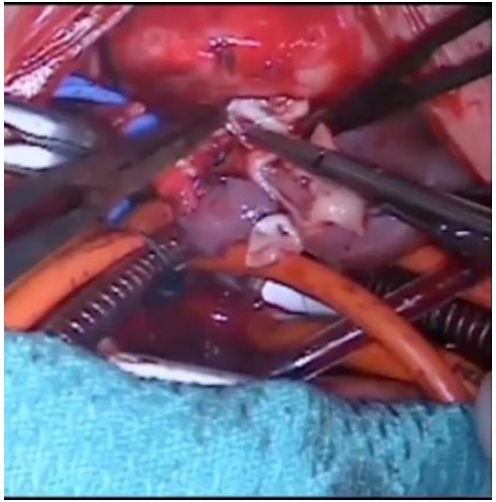
Users

- Academic Medical Centers & Children's Hospitals
  - Toronto Sick Kids Hospital
- Medical OEMs
  - J&J, Medtronic, St. Jude

The Use Case

- Segmented anatomical data from CT, MRI and/or ultrasound
- Solution from software to materials to systems
- Promise fulfilled via PolyJet multi-material, multi-color technology





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FIXING BROKEN HEARTS

https://youtu.be/lITGFz8G3L4

PRINTING IN HEALTHCARE TODAY & IN THE FUTURE

Physician Training & Education	**Procedure Planning**	Rapid Prototyping / Innovation

The Customer

- Today: Academic Medical Centers and Children's Hospitals
- Tomorrow: Medical OEMs to bundle solution with therapeutic products

The Use Case

- Rapid end-to-end acquisition of a patient's specific pathology to creation of 3DP data files
- Fulfilled in day/days to enable timely care
- Service for smaller hospitals, in-house solutions for larger hospitals

NEUROSURGERY AT GATES VASCULAR INSTITUTE

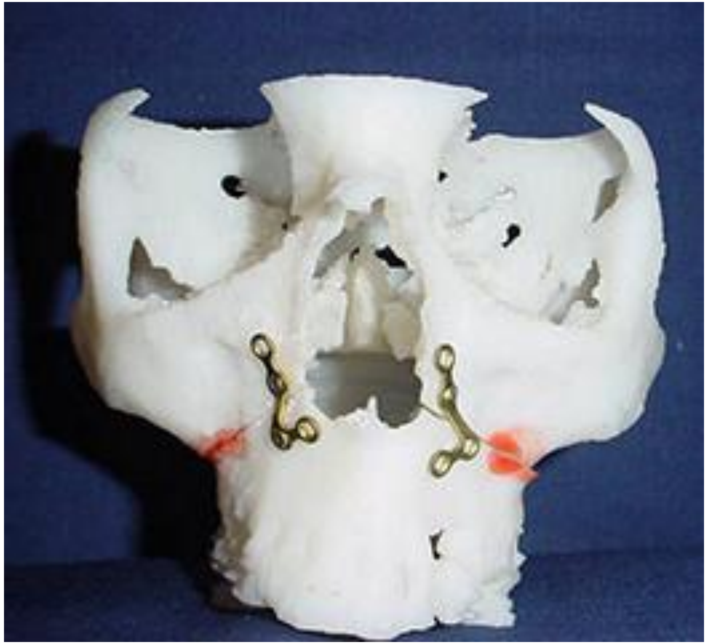
Gates Vascular Institute, Buffalo, NY

- Patient with cerebral aneurysm
- Dr. Adnan Siddiqui used a flexible, 3D printed model of the patient’s anatomy to perform dry-run procedure
- “Based on the Stratasys 3D model, we were able to pre-empt potential complications and devise a more optimal means of treating Teresa’s aneurysm.” — Dr. Adnan Siddiqui
- Read More: http://www.stratasys.com/resources/case-studies/medical/jacobs-institute

RECONSTRUCTIVE SURGERY AT CASA DI CURA VILLA SANT'APOLLONIA

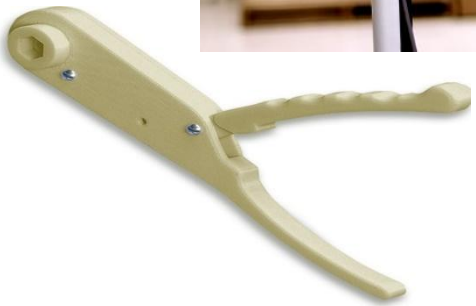
Casa di Cura Villa Sant'Apollonia, Bergamo, Italy

- Used in maxillofacial surgery, dentistry and aesthetic plastic surgery
- "We will literally simulate the entire surgery in advance…which means we are faster and that the risk of mistakes is greatly decreased." – Dr. Giorgio Tofanetti
- Procedures are 10-15% shorter
- Medical hardware can be produced, tested and sterilized in advance of the procedure
- Reduces time patients are under anesthesia
- Read More: http://www.stratasys.com/resources/case-studies/medical/casa-di-cura



PRINTING IN HEALTHCARE TODAY & IN THE FUTURE

Physician Training & Education	Procedure Planning	Rapid Prototyping / Innovation



The Customer

- Medical OEMs
- Hospitals and University

The Use Case

- RP and fast iterations
- Eliminate failures faster
- Functional parts for testing
- Short production run for clinical trials and early commercialization
- Testing devices on validated anatomical models

MEDICAL DEVICE: SYQE MEDICAL

Swift Relief

Creating an Advanced Drug Delivery System at Breathtaking Speed

https://www.youtube.com/watch?v=TE0_bsEPK-E

Shaping Young Hearts

"A 3D printed heart helped me take somebody from being inoperable to operable, and we've saved her life."

Redmond P. Burke, M.D. Nicklaus Children's Hospital

DENTAL

SHAPING NEXT GENERATION DENTISTRY

APPLICATION	VALUE	WHO
• Digital orthodontics • Partial frameworks, crowns and bridges • Digital Impressions • Soft Tissue, Surgical Guides	• Digitized workflows • Accuracy, Precision, Reliability • More efficient, cost-effective digital methods → productivity • Enhancing visualization, training and patient communication • Improved precision and aesthetics → Increased patient satisfaction	• ClearCorrect • NimroDENTAL • ProTec Laboratories • Leone S.p.A • ASO International

ORTHODONTICS

40% of Ortho Practices

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DIGITAL DENTAL

https://youtu.be/VDOMPgdDG2E

CROWN & BRIDGE LABORATORIES

20% of Dentists

Turnaround Time

Accuracy

Control Costs

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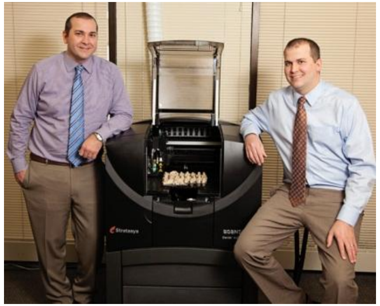
CROWN & BRIDGE LAB CASE STUDY

“We finally were able to increase our capacity with our existing workforce. We have faster turnaround times for our clients. And now with 3D printing, we have created new revenue streams.”

-Luke Caruso, President / Ottawa Dental Laboratory



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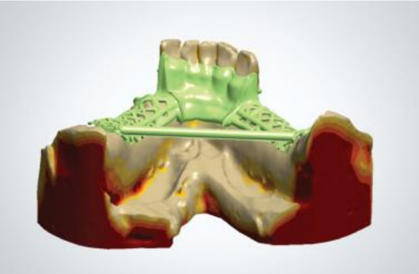
REMOVEABLE LAB CASE STUDY

“The Time required to print a typical removable partial denture frame is reduced by 80%, which Makes it possible to complete the partial denture framework in a day and a half.”

-Scott Udell, President / Udell Dental Laboratory

	MATERIAL COST PER MODEL	TIME TO PRODUCE FRAME
Traditional method	$6.18	2 days
Objet Eden260V	$2.84	1.5 days
Savings	$3.34 (vs. traditional) 54%	0.5 days (vs traditional process) 25%



ACTIVITY 3.2: Industry Vertical Additive Manufacturing Use Cases

Download the activity worksheet in the Resources section of module 3.

Search grabcad.com for 1 design file that is an appropriate, interesting use of additive manufacturing, and printable on the FDM or PolyJet equipment available in your classroom or lab for each of the following industries:

- Aerospace
- Automotive
- Consumer Goods
- Medical
- Dental
- Manufacturing Aides/Tooling

Fill in the chart on the worksheet to track your results and for easy reference later

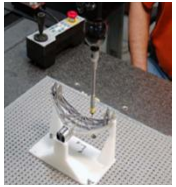
MANUFACTURING

3D PRINTED AIDES & TOOLS ACROSS INDUSTRIES

DIGITAL MANUFACTURING AIDES OVERVIEW

https://youtu.be/l7nodv7KzwM

WHERE ARE THEY USED?



Quality Control - Tooling to aid in the inspection and QC process, specialty holding devices or measurement aids.

Packaging & Logistics - Tooling designed to allow for movement of parts within a facility or during shipment.

Health & Safety - Specialty tooling designed to aid worker safety and address ergonomic issues in the production environment.

General Manufacturing Floor

Assembly - Tooling for the assembly process, aiding workers to align and hold parts during assembly.

Fabrication- Parts and tools associated with the equipment used in the fabrication process.

FABRICATION AND ASSEMBLY

MARKET SEGMENTS	Aerospace	Automotive	Consumer Products

TOOL TYPES

Alignment tools

Holding devices

Feeders

Hand tools

Check tools

Surrogate parts

End effectors

Work holding

Milling fixtures

Drill guides

SOLUTIONS

Technology:
PolyJet
FDM

Materials**:**
PJ Digital Materials
PJ High Temperature
All FDM

NEEDS

Design complexity integration

Customization for application

Lean manufacturing

On demand tooling

Low cost short run tooling

HEALTH AND SAFETY

MARKET SEGMENTS	Aerospace	Automotive	Consumer Products

TOOL TYPES	SOLUTIONS	NEEDS
Hand/wrist guards Holding devices Bumpers and guards Hand tools	Technology: PolyJet FDM Materials**:** PJ Digital Materials PJ Rubber Like PJ High Temperature All FDM	User customization Light weighting Ergonomics

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QUALITY CONTROL

MARKET SEGMENTS	Automotive	Consumer Products	Medical

TOOL TYPES

- Check gauges
- Work holding
- Test & inspection fixtures
- Go/no-go tools
- Surrogate parts

SOLUTIONS

Technology:
- PolyJet
- FDM

Materials**:**
- PJ Digital Materials
- PJ High Temperature
- All FDM

NEEDS

- Design Complexity integration
- Customization for application
- Easy integration
- Higher Accuracy

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PACKAGING & LOGISTICS

MARKET SEGMENTS	Automotive	Consumer Products	Medical

TOOL TYPES	SOLUTIONS	NEEDS
Surrogate parts Tool guards Dunnage trays Thermoforming Kit boxes	Technology: FDM Materials: Higher performance FDM Standard FDM materials	Design Complexity integration Customization for application On-demand tooling

STREAMLINE PRODUCTION FLOOR WORKFLOWS

A means to optimize manufacturing by:

- Reducing cost and cycle time
- Lower tooling burden rates
- Increasing product quality and repeatability

MANUFACTURING AIDS & TOOLING
MOST IMPORTANT CONSIDERATIONS

Accuracy

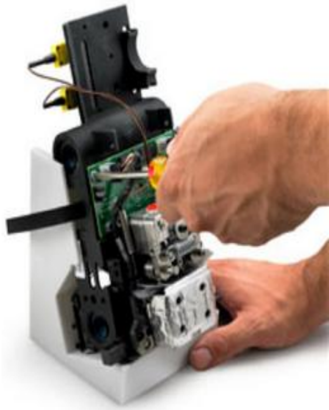
Economy in production

Durability

Tool life

Ease of use

Workforce safety



MANUFACTURING AIDS & TOOLS OBJECTIVE

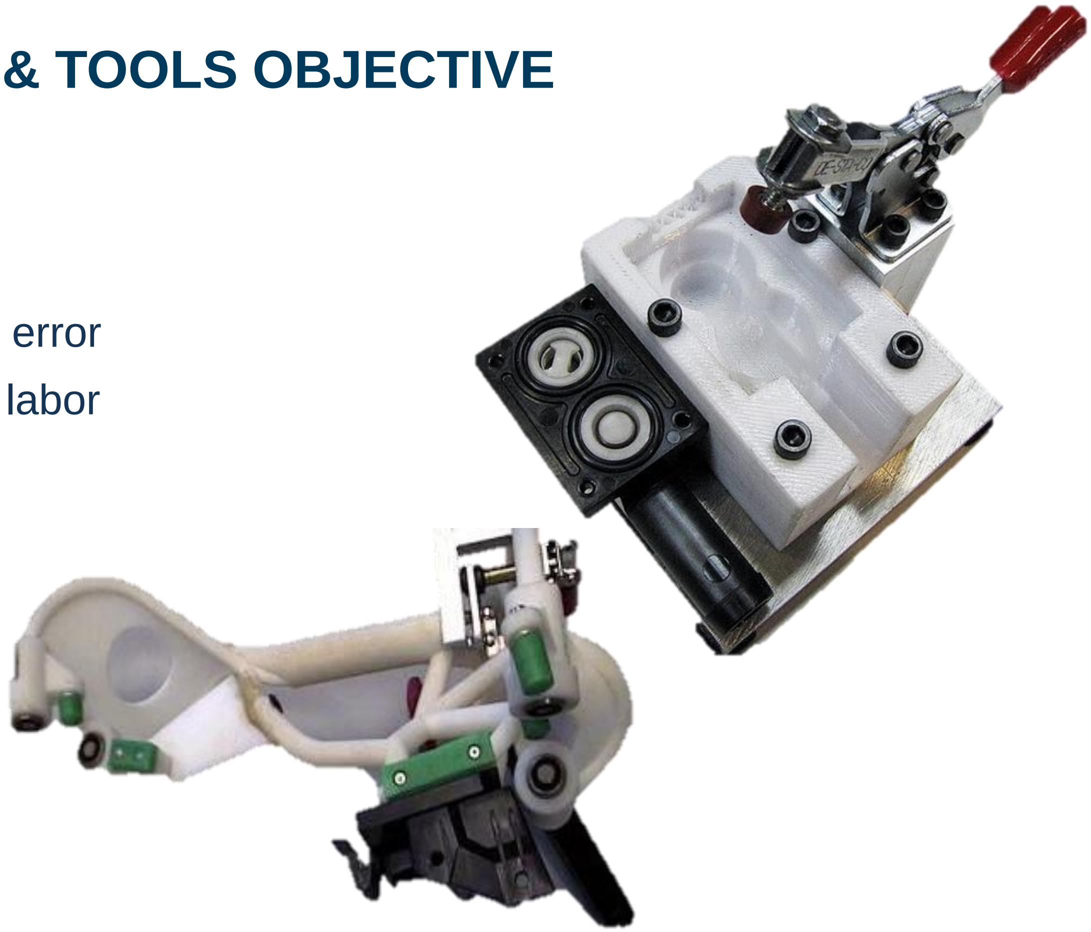
Ensure interchangeability and accuracy of parts manufactured

Minimize the possibility of human error

Permit the use of medium-skilled labor

Reduce the manufacturing time

Allow production of repeat orders without retooling



TODAY’S CHALLENGES

Long machine set-ups

Variation during assembly and fitting

Complicated part holding requirements

Quick packaging and trays for handling and transportation

Defects caught too far down production line

Ensuring employee safety and ergonomics

Time, storage, and cost prevent manufacturers from producing needed efficiency tools

ADDRESSING TODAY'S MANUFACTURING CHALLENGES

Shorten set-up times

Enabled manufacturing of complex geometries

Design flexibility

Part consolidation

Feature integration

Improved tooling ergonomics and light-weighting

Digital tooling inventory

BENEFITS OF ADDITIVE MANUFACTURING

Operational Efficiency

- Decrease burden rates
- Increased tool functionality
- Impacts multiple departments

Streamlined, efficient process

- Minimize PO & payment requirements
- Immediate response to needs from manufacturing floor

Digital inventory

- Reduction in storage space
- Quick replacement or revision
- Simple duplication

Identifying best fit – tools that:

Have increased complexity

Have several components that AM can consolidate

Can be improved for better ergonomics

Would benefit from weight reduction

Customization

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INCREASED PART FUNCTIONALITY VIDEO

https://www.youtube.com/watch?v=Xya49JHaIWI

QUICK TALK – DIGITAL MANUFACTURING APPLICATIONS

Step 1: Turn to your neighbor and talk about any of the digital manufacturing applications you might be familiar with and what industries might use these.

Step 2: Let's share our thinking…

Sand Casting

End-Use-Parts

Jigs and Fixtures

Silicone Molding

End Of Arm Tooling

Liquid Silicone Rubber

Blow Molding

Injection Molding

DIGITAL MANUFACTURING | BASIC AND ADVANCED

- Jigs and Fixtures | FDM
- Jigs and Fixtures | PJ
- End-Use-Parts

Basic Manufacturing

- Sand Casting
- End Of Arm Tooling
- Silicone Molding | PJ
- Silicone Molding | FDM
- Blow Molding
- Liquid Silicone Rubber
- Injection Molding

Advanced Manufacturing

BLOW MOLDING

Quantities

- 1 to 1,000
- Prototypes for evaluation
- Short-run production

Small to mid-sized parts

- 1 ml to 1 liter (0.03 to 35 oz.)

METHOD	TIME	COST
CNC machining	20 days	$2,500
PolyJet blow mold	2 hours	$280
Savings	18 days (90%)	$2,200 (89%)

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BLOW MOLDING | CASE STUDY

Plasel
PRECISION PLASTICS

LIQUID SILICONE RUBBER

Quantity
- 5 to 100 castings**

Size
- 6 mm (0.25 in) to 300 mm (12 in)*

Design
- Complex, intricate
- Revisions likely

METHOD	TIME	COST
CNC mold	14 days	$1,000
PolyJet mold	2 days	$400
Savings	12 days (86%)	$600 (60%)

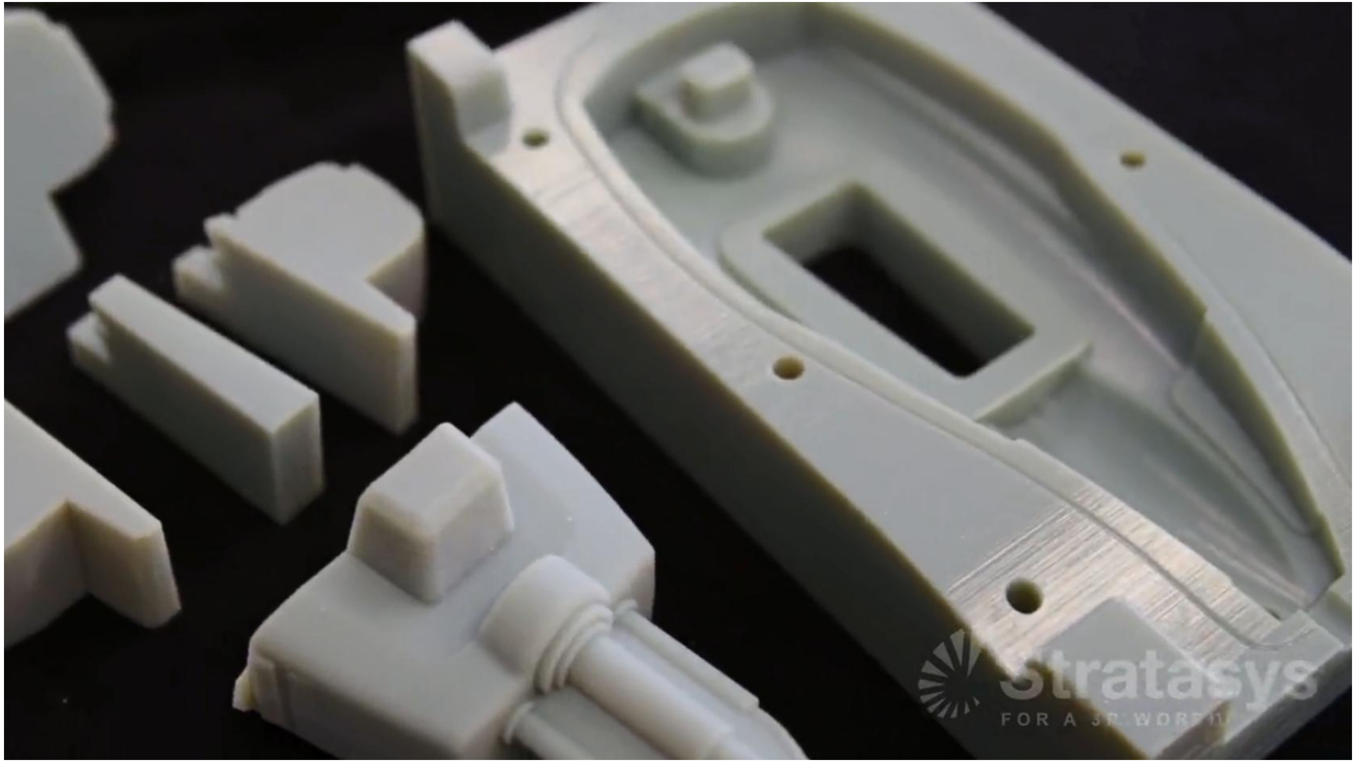
PolyJet mold made with Digital ABS.

Digital pressure gauge inside an LSR boot.

* Larger size feasible, may require mold production in multiple pieces
** Higher quantities possible, may require additional mold prints

LIQUID SILICONE RUBBER MOLDING WITH POLYJET

Design Reality
ideas at work

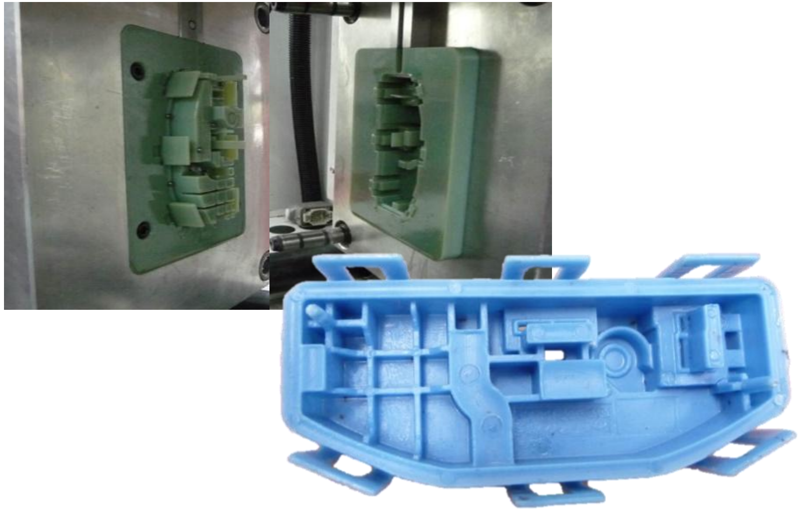


INJECTION MOLDING

Quantity: 5 to 100

- Size: < 165 cc (10 cu. in.)
  - 50 - 80 ton press
- Manufacturing requirements
  - Reasonable molding temperatures
    - < 300 °C (570 °F)
  - Candidates:
    - PE, PP, PS, ABS, TPE
    - PA, POM, PC-ABS
    - Including glass-filled resins

METHOD (IN-HOUSE)	TIME	COST
Machined Tool	56 Days	$52,725
PJ	2 Days	$1,318
Savings	54 Days (96%)	$51,000 (99%)



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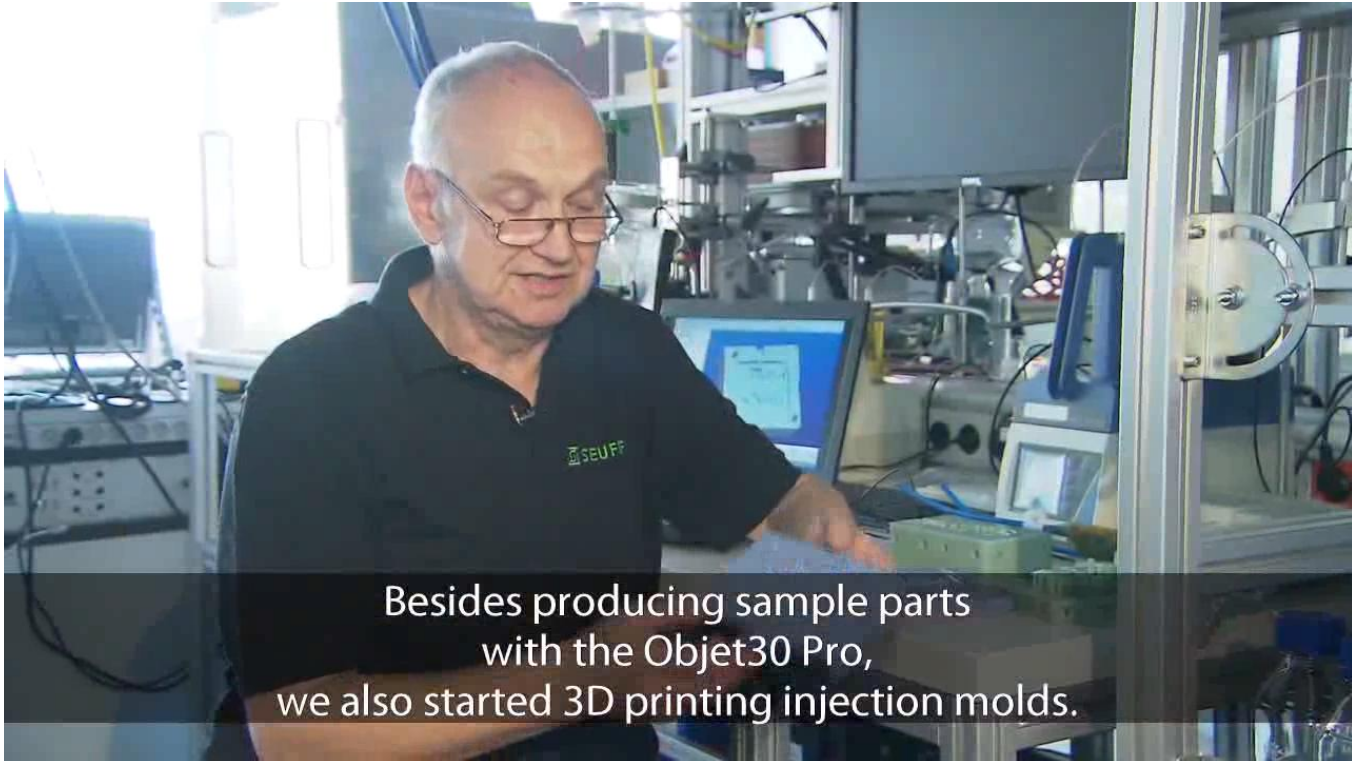
INJECTION MOLDING | CASE STUDY



JIGS AND FIXTURES | FDM

Quantity:

- 1-100+

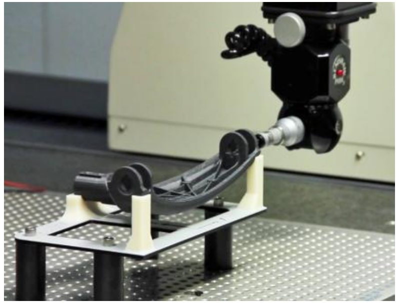
Size (XYZ):

- ≤ 300 mm (12 in.)

Manufacturing requirements:

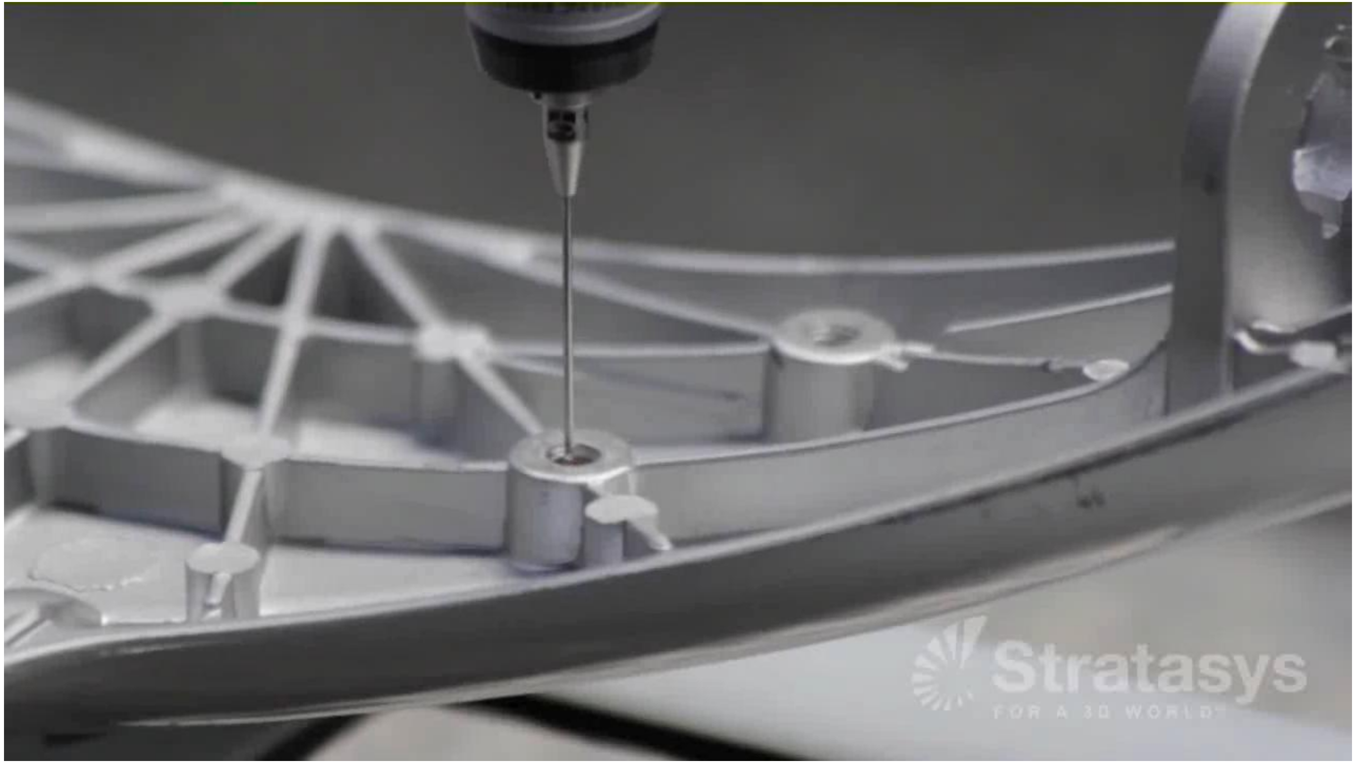
- Thermoplastic strength is acceptable
- Accuracy tolerance ≥ +/- 0.13mm (0.005 in.)
- Temperatures up to 200 °C (390 °F)

METHOD (IN-HOUSE)	TIME	COST	TOTAL INSPECTION TIME
CNC Aluminum	7 hours	$250	30 Days
FDM	3.5 hours	$55	1 Day
Savings	3.5 hours (50%)	$195 (78%)	29 Days (97%) (2900% Improvement)



JIGS AND FIXTURES | FDM CASE STUDY

ORECK
Clean Made Easy™



JIGS AND FIXTURES | PJ

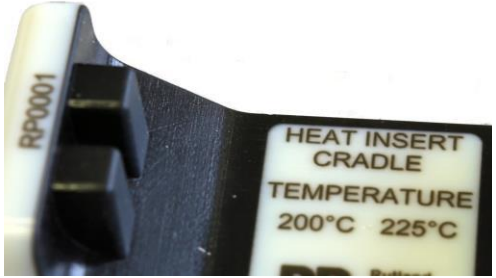
METHOD (IN-HOUSE)	TIME	COST
CNC	3 days	$1,500
PolyJet	1 day	$900
Savings	2 days (67%)	$600 (40%)

Direct production on PolyJet system

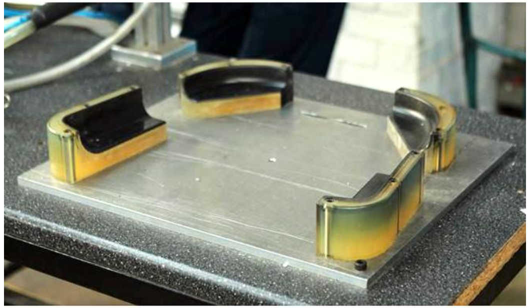
- Complex, organic shapes are feasible
- Integrate tool ID, part number, guides

Size & quantities required:

- 1 to 100s
- 1 to 30 cm (0.4 to 11 in)*
- Manufacturing requirements:
- Temperatures up to ~90 °C (194 °F)
- Moderate mechanical loads (70 MPa [10.1 ksi])
- No chemical exposure
- Design elements:
- Moderate to thick walls (5 – 13 mm [0.2 – 0.5 in])
- Frequent replacement or alteration
- Complex, intricate



Multi-material printing allows incorporation of text for fixture labeling.



FC720 fixture printed with TangoBlack™ interfaces.

JIGS AND FIXTURES | PJ CASE STUDY

END-USE PARTS | TRADITIONAL PROCESSES

Injection molding
- Machined tooling
- Plastic molding
- Low cycle time (seconds)

Machining (CNC / Manual)
- Fixture/set up
- Cut part
- High cycle times (hours)

RTV/RIM molding (silicone)
- Make pattern and/or mold
- Cast/inject urethane
- Moderate cycle times (minutes to hours)

For all
- Added features increase cost & time
- Requires skilled labor

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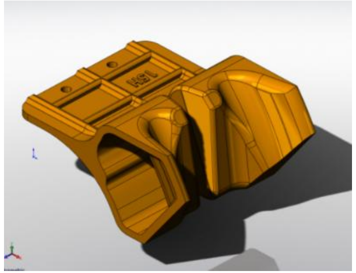
END-USE PARTS | DETAIL

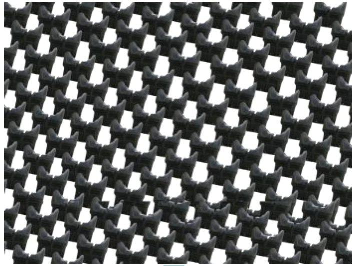
Quantities
- 1s to low 1,000s
- Linked to part size

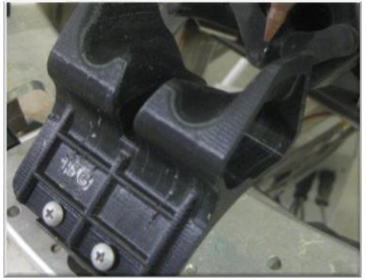
Size
- 300 mm (< 12 in.) per side

Manufacturing Requirements
- Thermoplastic properties
  - Mechanical, electrical, chemical
  - Thermal: < 200 °C (390 ° F)
- Tolerance
  - > +/-0.13 mm (0.005 in.)

METHOD	TIME	COST
Injection molding	4 weeks	$44,175
FDM	3 days	$1,490
Savings	25 days (89%)	$42,685 (97%)







NOVA-TECH ENGINEERING, INC

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END-USE PARTS | CASE STUDIES

SAND CASTING | DETAIL

METHOD	TIME	COST
CNC Matchplates	3 weeks	$5,000
FDM Matchplates	1.5 weeks	$2,000
Savings	1.5 weeks (50%)	$3,000 (60%)

Quantities

- Low to mid-volume (5,000+ castings)
- Prototype, pilot runs and production

Manufacturing Requirements

- Compaction pressure < 20.7 MPa
- (3,000 PSI) for ABS

Design

- Moderate to high design complexity

Size

- < Build envelope of FDM system

Finishing

- Features accessible for finishing

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SAND CASTING | CASE STUDY

END OF ARM TOOLING | DETAIL

Quantity

- 1 to 100 EOATs

Size

- 25 mm (1 in) to 400 mm (16 in)

Design

- Complex/organic shapes
- Lightweight end-effectors
- Changes or replacements possible

Tolerance

- ± 0.13 mm (0.005 in)

Materials

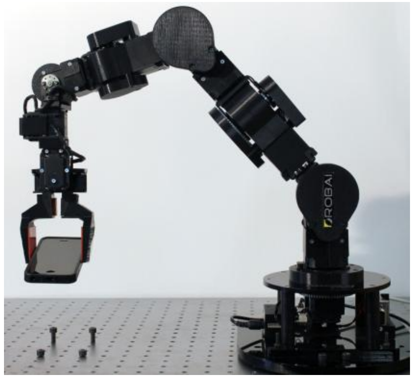
- Thermoplastics acceptable

Fabrication

- In-house needed

METHOD	TIME	WEIGHT
CNC Machining*	20 days	15.9 kg (35 lbs)
FDM **	3 days	1.4 kg (3 lbs)
Savings	17 days (85%)	14.5 kg (91%)

* CNC machining outsourced locally.
** FDM parts produced on in-house equipment.



END OF ARM TOOLING | CASE STUDY

SILICONE MOLDING | PJ

Quantity > 5 parts

- Prototyping (5 – 50 castings)
- Low-volume production (25+)

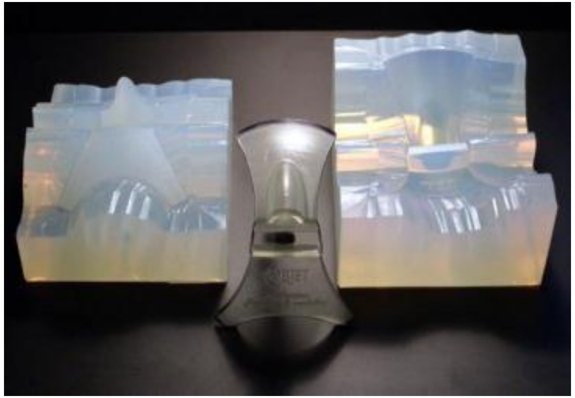
Small to mid-size patterns

- 0.25 in. (6 mm) to
- 12 in. (300 mm)

Complex/high detail

- Cost/time unaffected
- Minimal post-processing

METHOD	TIME	COST
Machined pattern	4 days	$275
PolyJet pattern	3 hours	$55
Savings	3.6 days (90%)	$220 (80%)



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SILICONE MOLDING | POLYJET CASE STUDY

The Adler Trio

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SILICONE MOLDING | FDM

Materials and quantity

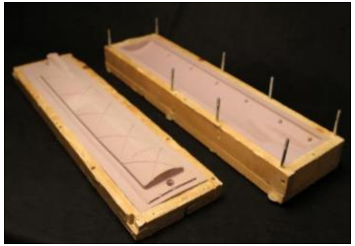
- Utilize high-cure-temp silicones
- 5 to 100+ castings

Pattern attributes

- Size: 25 mm (1 in) to 915 mm (36 in)
- Accuracy: ± 0.13 mm (0.005 in)

METHOD	TIME	COST
Machined pattern*	7 days	$1,000
FDM Pattern**	2 days	$400
Savings	5 days (71%)	$600 (60%)

* CNC machining outsourced locally.
** FDM parts produced on in-house equipment.



Silicone mold from FDM pattern

FDM pattern after finishing and painting

MRI coil with finished and painted urethane cover

SILICONE MOLDING | FDM CASE STUDY

ScanMed
The Image is Everything

https://www.youtube.com/watch?v=8cqgNazBEBg

MODULE SUMMARY

http://bcove.me/6crjllcp

STRATASYS MATERIALS & THEIR PROPERTIES

Module 4

MODULE 4: STRATASYS MATERIALS & THEIR PROPERTIES

Learning Objectives:

- Answer: Why do materials matter?
- List the advantages of PolyJet and FDM materials
- Define 8 main ASTM materials testing standards: thermal resistance, tensile (stretching), flexural (bending), IZOD impact, coefficient of thermal expansion, electrical properties, water absorption resistance, shore hardness
- Identify the purpose of a Stratasys data sheets: materials data sheets & safety data sheets (SDS), where to locate them and how to access and utilize the information
- Define thermoplastics and their qualities.
- Name and identify Stratasys FDM materials in 3 categories (Standard: PLA, ABS-PLUS, ABSM30, ABSI, ABS M30I,ABS-ESD7,ASA), Engineering: NYLON 12, NYLON 6, PC-ABS, PC-ISO & High Performance: ULTEM 9085, ULTEM1010 Thermoplastics) their benefits and applications.
- Differentiated between SR and BASS support structures and list the best practices for support removal.
- Name and identify Stratasys PolyJet families of materials: Rigid Opaque, Rigid Transparent: Veros, Simulated Polypropylene Family: Rigur & Durus, Flexible Rubber-like Family: Tango/Agilus, Digital Material: Digital ABS
- Identify when a material should be used and why

DISCUSSION - BOUNCING BALL

What things can effect the bounce of a ball?

MATERIALS MATTER – THE BAT & BALL

Material selection ensures the integrity of the design AND Structural integrity for the final part in it's end use

https://www.youtube.com/watch?v=KH3xjhmQ0dg

STRATASYS TECHNOLOGY & MATERIAL BENEFITS

PolyJet

FDM

POLYJET ADVANTAGES


Clear transparency


Multi-material realism

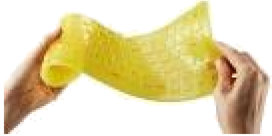

Smooth surface finish


Medical & dental


Molding & tooling


ABS functionality


Polypropylene-like


Choice of flexibility


Color range


Thin walls & cavities

FDM ADVANTAGES


Strong, durable ABS


Economic sparse fill


High performance end use parts

Tough, aesthetic colors


Versatile Nylon 12


ULTEM 1010 for medical and food contact

MATERIAL PROPERTIES

ASTM TESTING STANDARDS – A REVIEW

ASTM INTERNATIONAL

Thermal Resistance	Tensile (Stretching)	Flexural (Bending)	Izod Impact

Coefficient of Thermal Expansion	Electrical Properties	Water Absorption	Shore Hardness

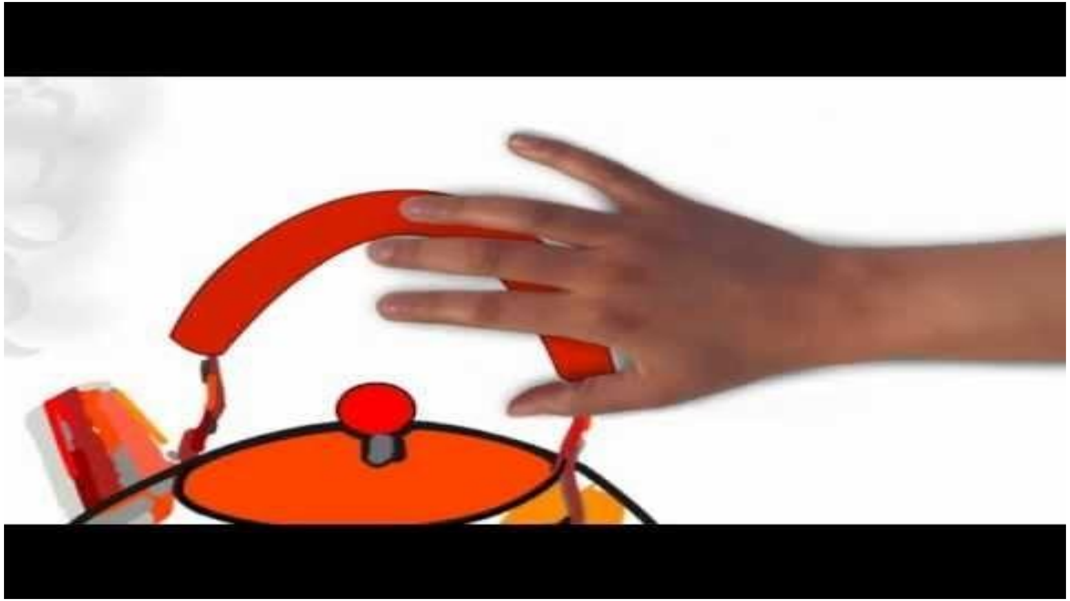
THERMAL RESISTANCE

Heat Deflection / Distortion Temp (HDT)

A measure of a material's resistance to distortion:

- Under a given load at elevated temperatures
    - Commonly 66 psi (0.46 MPa) or 264 psi (1.8 MPa)
- The temperature is increased at 2°C/min
- Until the specimen deflects 0.25 mm (0.010 in)
- Specimen dimension - 13mm x 128mm x 3mm

ABOUT THERMAL RESISTANCE



https://www.youtube.com/watch?v=fXjzqbRdR8g

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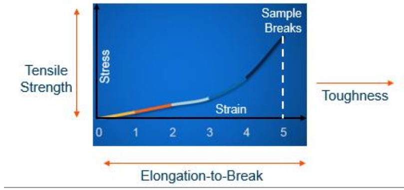
TENSILE (STRETCHING)



Tensile Strength

- The force needed to exert on the sample to break it
- Expressed in Pascal or psi (pounds per square inch)

Elongation to Break

- Refers to the change in length of a sample when it breaks
- Expressed as a ratio (%) between length at break to initial length

Toughness

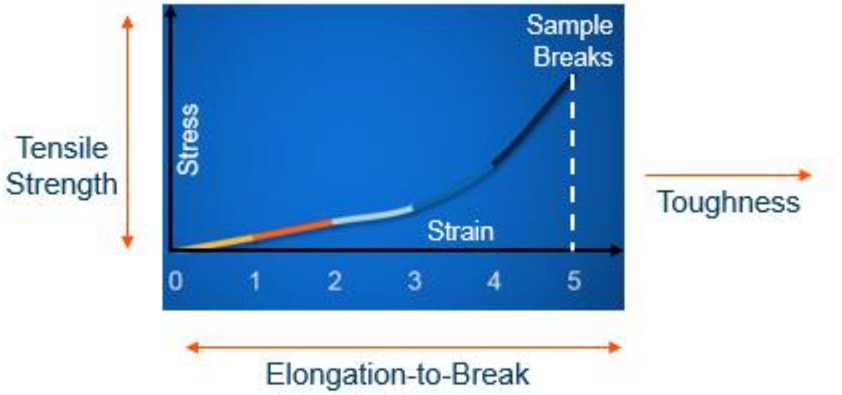
- The energy a sample can absorb before it breaks (area under curve)

https://www.astm.org/Standards/D638.htm

TENSILE (STRETCHING) CONT.

Stress-Strain Graph

- Stress: Force per unit area as the material is being stretched
- Strain: A measure of change in length of the sample



ALL ABOUT TENSILE

https://www.youtube.com/watch?v=BHZALtqAjeM

ACTIVITY 4.1: Tensile Strength Testing

Conduct a series of tests to determine the tensile strength, percent elogantion and tensile modulus of ____________ material. (Material assigned by your instructor based on machine availability).

Determine through your tests if build orientation make a difference in the tensile strength of a part?

Download the activity worksheet in the Resources section of Module 4.

FLEXURAL (BENDING)

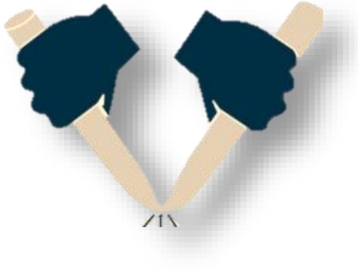
Flexural strength, determines the bending properties of a material

A test specimen is subjected to two-point bending

The specimen is deflected until it breaks

A stress - strain curve is plotted:

- Flexural Strength (MPa)
  - The maximum stress sustained by a specimen
- Flexural Modulus (MPa)
  - The ratio of stress to strain



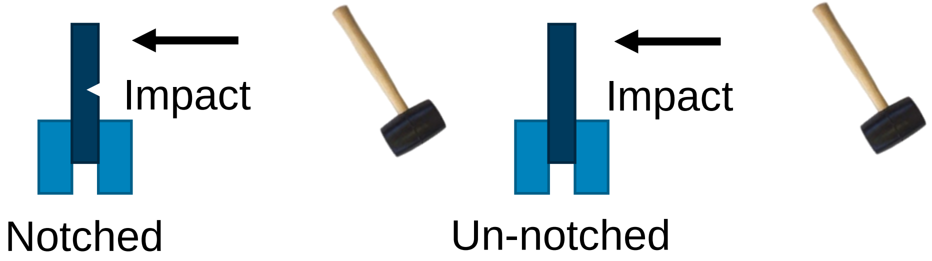
IZOD IMPACT

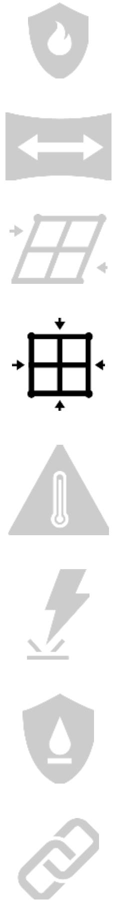
Measures material's resistance to impact

Specimen is hit with a swinging pendulum

The higher the fracture energy the more impact resistant the material

Expressed in *J/m* or *lb/inch*

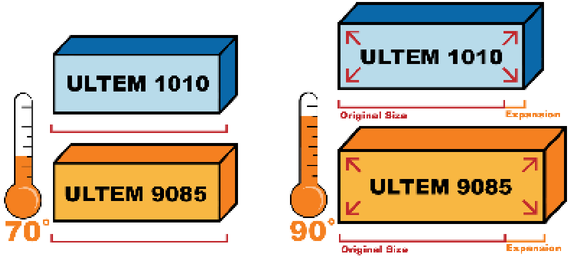




COEFFICIENT OF THERMAL EXPANSION

Lower CTEs lead to better dimensional stability over broad temperature ranges.

Lower coefficients of thermal expansion (CTE) are better for tooling applications.



MATERIAL	CTE 10^{-6} M/M C (10^{-6} IN/IN F)
Titanium	9 (5)
Aluminum	22 (12)
ULTEM 1010	47 (26)
ULTEM 9085	65 (37)
PPSF	70 (39)
PC	79 (45)
ABS-M30™	88 (50)

Find test reports here

ELECTRICAL PROPERTIES | 1

Static Dissipative

- **Definition**: Minimally conductive materials that slowly conduct static charges away
- These materials sit between a insulator and a conductor for electrical conductivity
- Static dissipative example:
  - Packing peanuts not sticking
- Static dissipative materials range
  - 10^4 to 10^{11} Ohms
- Unit of measure
  - Ohms (Ω)/m^2

Examples

- Insulator: ≥10^{12} Ohms
- Static dissipative: 10^4 - 10^{11} Ohms
- Conductor: ≤10^3 Ohms

ELECTRICAL PROPERTIES | 2

Static Resistance

- Electrical charge’s flow along surface
  - Measure of static dissipation
- Surface resistance example:
  - Wind tunnel – smoke over car
- Unit of measure
  - Ohms (Ω)/m2

Examples

- ABS: 3.5×10^{15} Ohms
- Aluminum: 2.6×10^{6} Ohms

ELECTRICAL PROPERTIES | 3

Volume Resistance

- Electrical charge's flow through part
- Volume resistance example:
  - X-ray of human body
- Unit of measure
  - Ohms/cm

Examples

• ABS:	~4.0 – 3.3 ohm-cm
• Aluminum:	~2.65 ohm-cm

WATER ABSORPTION

Determines the amount of water absorbed under specified conditions

Indicates material distortion in water or humid environments

Test Procedure

- Specimens are dried in an oven
- Upon cooling, the specimens are weighed
- The material is emerged in water - 23°C for 24hrs
- Specimens are removed, patted dry and weighed
- Water absorption is expressed in %, as increase in weight percent

SHORE HARDNESS | SCALE A, D

Measures the hardness of the materials

- Resistance of a material to indentation
- Values range from 0 (for full infiltration) to 100
- Shore A: Performed on flexible materials
- Shore D: Performed on rigid materials
- The higher the Shore level is, the harder the material.
- Material with a shore level of 27 is MORE flexible than a material with shore level of 61

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DATA SHEETS

MATERIALS DATA SHEETS & SAFETY DATA SHEETS (SDS)

ACCESSING & UNDERSTANDING MATERIALS DATA SHEETS

Materials Data Sheet Example – ABSplus

About:

ABSplus™ is a true production-grade thermoplastic that is durable enough to perform virtually the same as production parts. When combined with Design Series 3D Printers, ABSplus is ideal for building 3D models and prototypes in an office environment.

MECHANICAL PROPERTIES	TEST METHOD	ENGLISH XZ AXIS	METRIC XZ AXIS
Tensile Strength, Ultimate (Type 1, 0.125”, 0.2”/min)	ASTM D638	4,700 psi	33 MPa
Tensile Strength, Yield (Type 1, 0.125”, 0.2”/min)	ASTM D638	4,550 psi	31 MPa
Tensile Modulus (Type 1, 0.125”, 0.2”/min)	ASTM D638	320,000 psi	2,200 MPa
Tensile Elongation at Break (Type 1, 0.125”, 0.2”/min)	ASTM D638	6%	6%
Tensile Elongation at Yield (Type 1, 0.125”, 0.2”/min)	ASTM D638	2%	2%
IZOD Impact, notched (Method A, 23°C	ASTM D638	2.0 ft-lb/in	106 J/m

MECHANICAL PROPERTIES	TEST METHOD	ENGLISH XZ AXIS	ENGLISH ZX AXIS	METRIC XZ AXIS	METRIC ZX AXIS
Flexural Strength (Method 1, 0.05”/min	ASTM D790	8,450 psi	5,050 psi	58 MPa	35 MPa
Flexural Modulus (Method 1, 0.05”/min	ASTM D790	300,000 psi	240,000 psi	2,100 MPa	1,650 MPa
Flexural Strain at Break (Method 1, 0.05”/min	ASTM D790	4%	4%	2%	2%

THERMAL PROPERTIES[2]	TEST METHOD	ENGLISH	METRIC
Heat Deflection (HDT) @ 66 psi	ASTM D648	204°F	96°C
Heat Deflection (HDT) @ 264 psi	ASTM D648	180°F	82°C
Glass Transition Temperature (Tg)	DSC (SSYS)	226°F	108°C
Melting Point	- - - - - - - - -	Not Applicable[3]	Not Applicable[3]
Coefficient of Thermal Expansion	ASTM E831	4.90x10^{-05} in/in/°F	8.82x10^{-05} mm/mm/°C

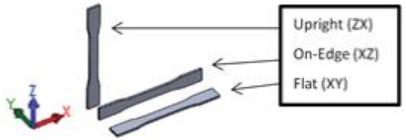
ACCESSING & UNDERSTANDING MATERIALS DATA SHEETS

Materials Data Sheet Example – ABSplus

XZ = X or "on edge"

XY = Y or "flat"

ZX = or "upright"



ELECTRICAL PROPERTIES[4]	TEST METHOD	VALUE RANGE
Volume Resistivity	ASTM D257	$2.6x10^{15}$-$5.0x10^{16}$ ohm-cm
Dielectric Constant	ASTM D150-98	2.3 – 2.85
Dissipation Factor	ASTM D150-98	0.0046 – 0.0053
Dielectric Strength	ASTM D149-09, Method A, XZ Orientation	130 V/mil
Dielectric Strength	ASTM D149-09, Method A, ZX Orientation	290 V/mil
OTHER[2]	**TEST METHOD**	**VALUE**
Specific Gravity	ASTM D792	1.04
Flame Classification	UL94	HB (0.09[2], 2.50mm)
UL File Number	- - - - - - - -	E345258
Rockwell Hardness	ASTM D785	109.5

SYSTEM AVAILABILITY	LAYER THICKNESS CAPABILITY	SUPPORT STRUCTURE	AVAILABLE COLORS
uPrint SE™	0.013 inch (0.330 mm)	Soluble Supports	Ivory, White
uPrint SE Plus™	0.010 inch (0.254 mm)	Breakaway Supports	Black, Dark Grey
Dimension Elite™	0.007 inch (0.178 mm)[5]	(BST 1200es only)	Red, Blue
Dimension SST 1200es™			Olive Green, Nectarine
Dimension BST 1200es™			Fluorescent Yellow
Fortus 250mc™			

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ACTIVITY 4.2: Choosing Materials for Industry Vertical Applications

Download the activity worksheet in the Resources section of module 4

Go to grabcad.com and log in. Access your “likes” from module 3 activity 2 and list the material you would use to print it and why.

SDS – THE SAFETY DATA SHEET

Stratasys provides customers with a Safety Data Sheet (SDS)

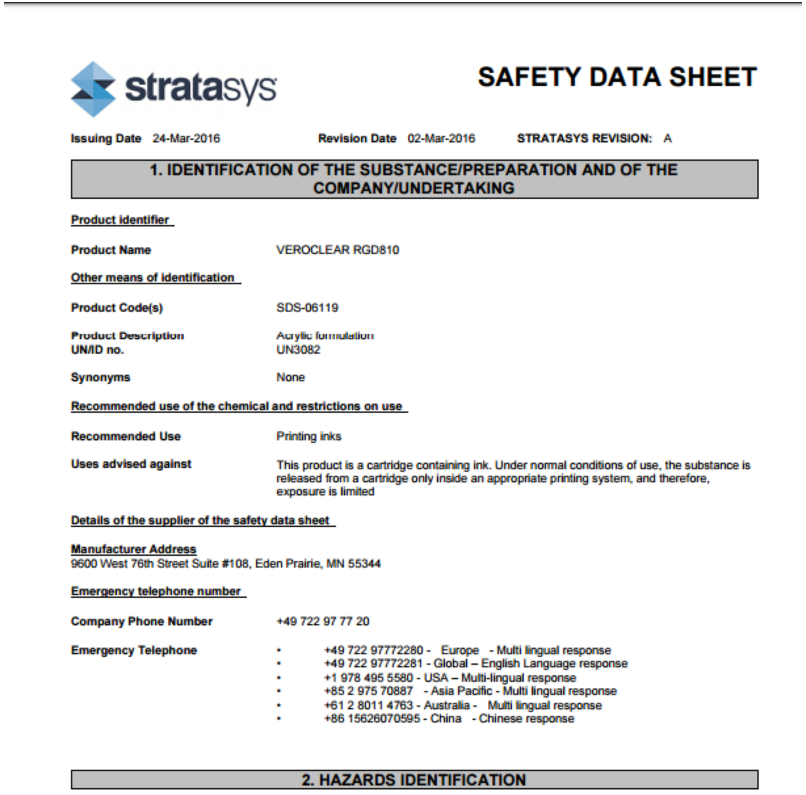
Safety Data Sheet are managed according to Regulation (EC) No. 1907/2006 (REACH)

SDSs must contain the following 16 headings according to Global Harmonized system (GHS)

1. Identification of the substance/preparation and of the company/undertaking;
2. Hazards identification;
3. Composition/information on ingredients;
4. First-aid measures;
5. Fire-fighting measures;
6. Accidental release measures;
7. Handling and storage;
8. Exposure controls/personal protection;
9. Physical and chemical properties;
10. Stability and reactivity;
11. Toxicological information;
12. Ecological information;
13. Disposal considerations;
14. Transport information;
15. Regulatory information;
16. Other information.

Access this at: http://www.stratasys.com/materials/material-safety-data-sheets

EXAMPLE: VEROCLEAR FULLCURE810 SDS



SAFETY DATA SHEET

Issuing Date 24-Mar-2016 **Revision Date** 02-Mar-2016 **STRATASYS REVISION:** A

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY/UNDERTAKING

Product identifier

Product Name	VEROCLEAR RGD810

Other means of identification

Product Code(s)	SDS-06119
Product Description	Acrylic formulation
UN/ID no.	UN3082
Synonyms	None

Recommended use of the chemical and restrictions on use

Recommended Use	Printing inks
Uses advised against	This product is a cartridge containing ink. Under normal conditions of use, the substance is released from a cartridge only inside an appropriate printing system, and therefore, exposure is limited

Details of the supplier of the safety data sheet

Manufacturer Address
9600 West 76th Street Suite #108, Eden Prairie, MN 55344

Emergency telephone number

Company Phone Number +49 722 97 77 20

Emergency Telephone

- +49 722 97772280 - Europe - Multi lingual response
- +49 722 97772281 - Global – English Language response
- +1 978 495 5580 - USA – Multi-lingual response
- +85 2 975 70887 - Asia Pacific - Multi lingual response
- +61 2 8011 4763 - Australia - Multi lingual response
- +86 15626070595 - China - Chinese response

2. HAZARDS IDENTIFICATION

STRATASYS FDM MATERIALS

FDM MATERIALS

FDM ADVANTAGES

Strong, durable ABS

Economic sparse fill

High performance end use parts

Tough, aesthetic colors

Versatile Nylon 12

ULTEM 1010 for medical and food contact

FDM MATERIALS INTRODUCTION

FDM Filament =

= Thermoplastic

Becomes pliable when heated above Glass Transition temperature

No chemical reaction or curing takes place during cooling

Thermoplastics are some of the most widely used materials in production today.

FDM MATERIAL SELECTION

Model Material:

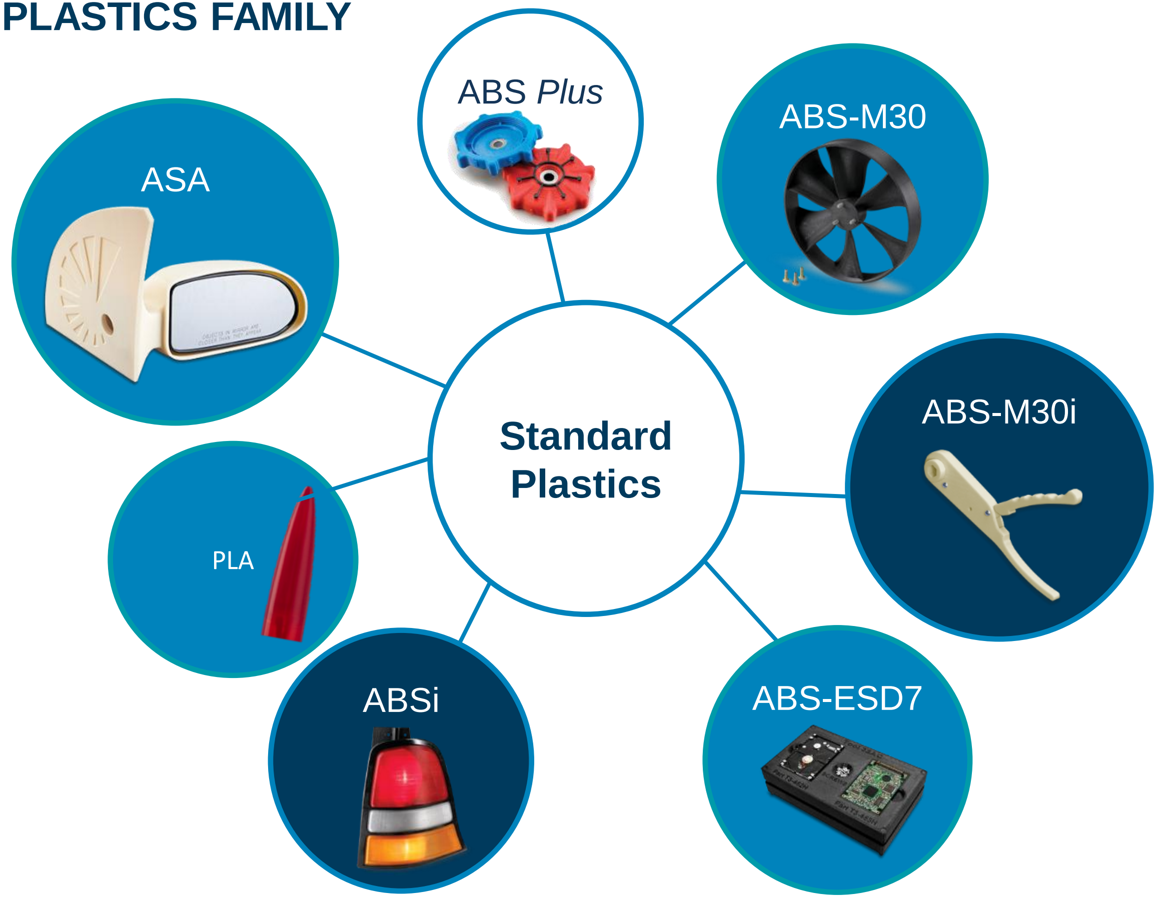
- **Standard**
  - PLA
  - ABSplus
  - ABSi
  - ABS-M30
  - ABS-M30i
  - ABS-ESD7
  - ASA
- **Engineering**
  - NYLON 6
  - NYLON12
  - PC-ABS
  - PC-ISO
  - PC
  - NYLON CF
- **High Performance**
  - ULTEM® 9085
  - ULTEM® 1010
  - ANTERO

Different platforms support different:

- Materials
- Colors
- Support

STANDARD FDM MATERIALS

STANDARD PLASTICS FAMILY



PLA - POLYLACTIC ACID

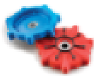
Benefits:

- PLA is a renewable plastic material offered as a low-cost material option for fast-draft part iterations
- It offers a higher stiffness than ABS and its low melting point and HDT mean less heat and power required to print parts
- It offers good tensile strength and is available in a wide range of colors
- PLA works well at high speeds, for quick concept verification and design development

Applications:

- The ideal applications for PLA include early concept modeling and fast prototyping
- More Resources: http://www.stratasys.com/PLA

ABS - ACRYLONITRILE-BUTADIENE-STYRENE



ABS*plus*
Opaque standard plastic in 9 colors

ABSi
Translucent standard plastic in 3 colors

ABS-M30
Opaque standard plastic in 6 colors

ABS-M30i
Biocompatible, sterilizable engineering plastic

ABS-ESD7
Static dissipative standard plastic

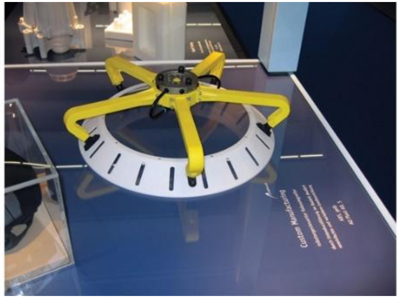
ABS PLUS

Benefits:

- Mechanically strong and stable over time (Durable)
- Available in 9 colors
- Lower Cost

Applications:

- Good general purpose prototyping material
- More Resources: http://www.stratasys.com/materials/fdm/absplus



ABS-M30

Benefits:

- Improved ABS Plus mechanical properties
- Higher tensile, impact, and flexural strength
- Available in 6 standard colors
- More Resources: http://www.stratasys.com/materials/fdm/absi

Applications:

ABSi

Benefits:

- Properties of traditional ABS (ABS-M30) but in a translucent material
- Parts can be smoothed on finishing stations
- Colored & metal finishes easily applied
- Durable & accepts threading well
- Available in 3 colors amber, natural, and red
- More Resources: http://www.stratasys.com/materials/fdm/abs-m30

Applications:

Aftermarket Lighting

ABS-M30i

Benefits & Applications:

- Biocompatible
  - ABS-M30 properties + ISO10993
  - ABS-M30i is a biocompatible 3D printing material that lets medical, pharmaceutical and food-packaging engineers and designers produce surgical planning models, tools and fixtures in-house
- Heat deflection (near 100C)
- Paired with soluble support material

More Resources:

http://www.stratasys.com/materials/fdm/abs-m30i

Applications:

ABS-ESD7

Benefits:

- Electrostatic Dissipative

Applications:

- Lets electronics manufacturers expand the use of 3D printing onto the assembly line
- For applications where a static charge could damage components, impair performance, or cause an explosion

More Resources:
http://www.stratasys.com/materials/fdm/abs-esd7

ABS PLUS & ABS-M30 / M30i

MATERIAL	MECHANICAL PROPERTIES	COLORS	SYSTEM AVAILABILITY	SUPPORT	LAYER RESOLUTION
ABS Plus	Good general purpose prototyping material Mechanically strong and stable over time		Mojo uPrint Dimension Fortus250mc F123	Breakaway Soluble	0.007” - 0.013” (0.178 - 0.330mm)
ABS-M30	Improved ABS Plus mechanical properties High tensile, impact, and flexural strength		Fortus 900 Fortus 380/450	Soluble	0.005” - 0.013” (0.127 - 0.330mm)
ABS-M30i	Biocompatible Identical Properties to ABS-M30		Fortus: 400mc/450mc 900mc	Soluble	0.005” - 0.013” (0.127 - 0.330mm)

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ASA - ACRYLIC-STYRENE-ACRYLONITRILE

An “improved ABS” material

Easy processing – no special steps

UV Stability

Excellent Part Aesthetics

Enhanced Mechanical Properties

- ASA’s enhanced mechanical properties allow for longer bridging when using sparse mode
- Less material is required to make sparse mode parts
- Lighter weight parts with shorter build times as well

9 Colors

ASA

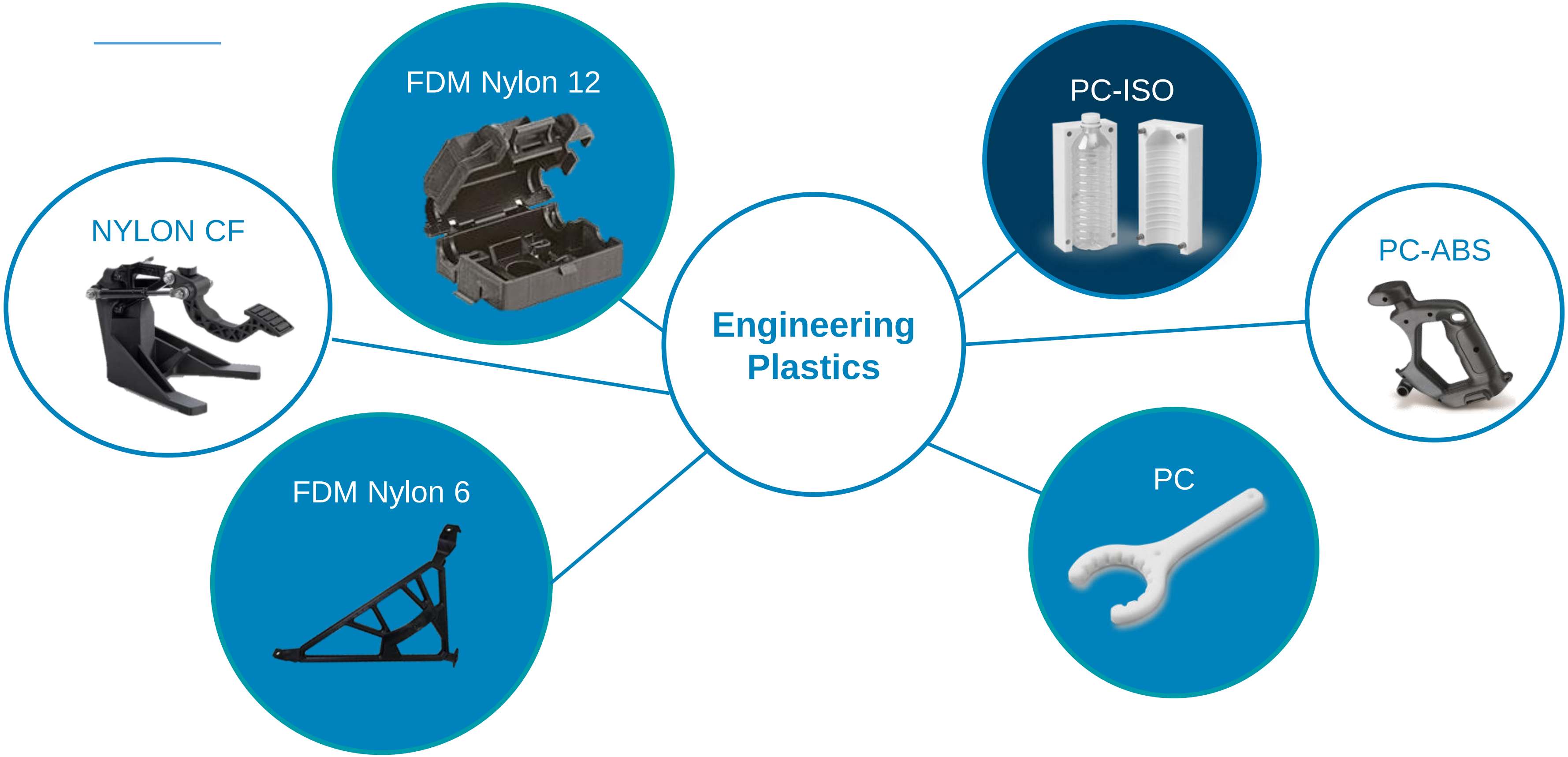
MATERIAL	MECHANICAL PROPERTIES	COLORS	SYSTEM AVAILABILITY	SUPPORT	LAYER RESOLUTION
ASA	UV stability Strength, toughness and flexibility Excellent aesthetics		Fortus Line F123	Soluble	0.005” - 0.013” (0.127 - 0.330mm)

ABS-M30 vs. ASA

MATERIAL	ELONGATION @ BREAK	TENSILE STRENGTH	IZOD IMPACT (UNNOTCHED)	HDT @264 PSI (HEAT DEF. TEMP)
ABS-M30	7%	4680 psi (32 MPa)	5.6 ft-lb/in (300 J/m)	82°C
ASA	9%	4720 psi (33 MPa)	6 ft-lbs/in (320 J/m)	88°C

ENGINEERING GRADE FDM MATERIALS

ENGINEERING PLASTICS FAMILY



NYLONS & POLYCARBONATES

FDM NYLON 12

Benefits:

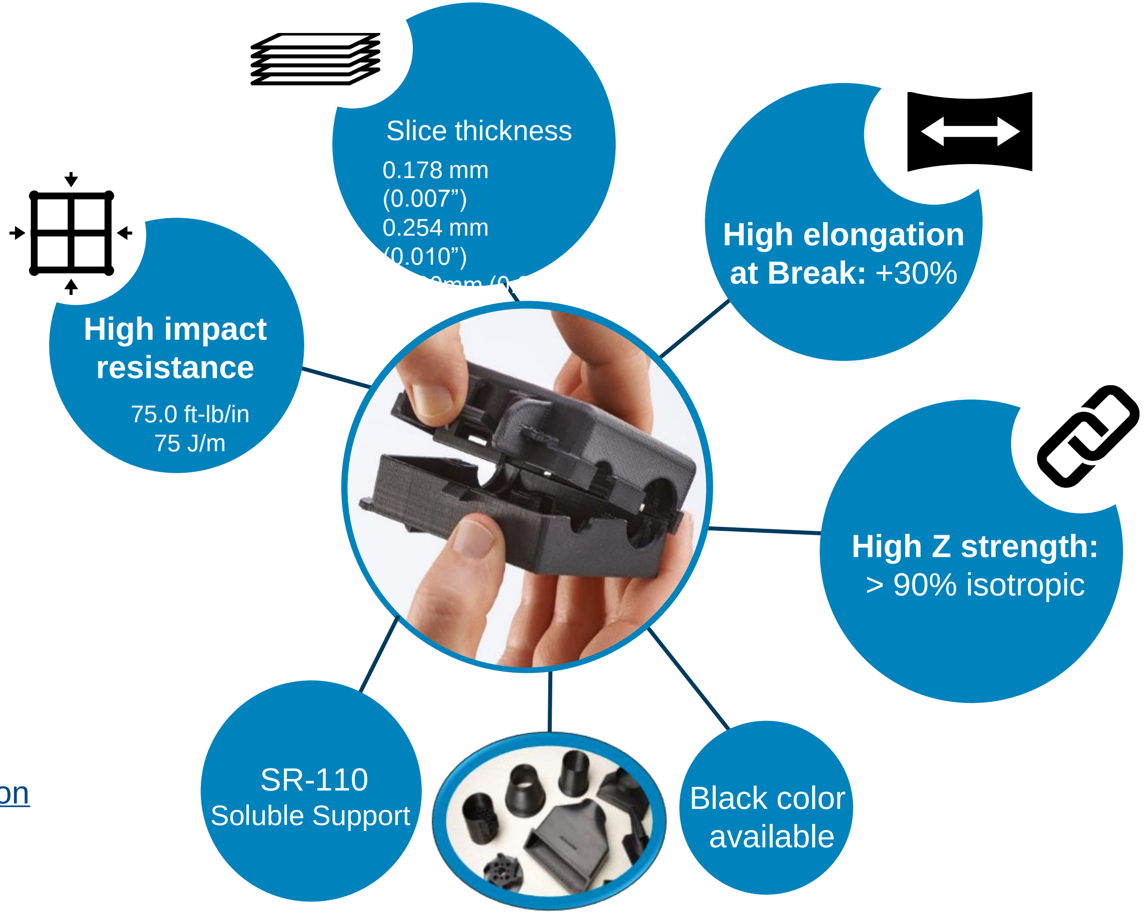
- Known for: Toughness, Strength, and Flexibility
- Toughest Nylon 12 in Additive Manufacturing

Applications:

- Used for:
  - Pressed metal inserts
  - Snap fits
  - Living hinges
  - Fatigue resistant parts

More Resources:

http://www.stratasys.com/materials/fdm/nylon



FDM NYLON12

MATERIAL	MECHANICAL PROPERTIES	COLORS	SYSTEM AVAILABILITY	SUPPORT	LAYER RESOLUTION
FDM Nylon12	High Elongation at Break: +30% Highest FDM Z Strength: >90% isotropic	●	Fortus Line	Soluble	0.007” - 0.013” (0.178 - 0.330mm)

FDM NYLON 12 CF

http://www.stratasys.com/materials/search/fdm-nylon-12cf

MATERIAL	MECHANICAL PROPERTIES	COLORS	SYSTEM AVAILABILITY	SUPPORT	LAYER THICKNESS CAPABILITY
FDM Nylon12 CF	Tensile Elongation at Break (Type 1, 0.125”, 0.2”/min) % **XZ Axis 1.9%**	●	Fortus 450mc Stratasys F900	Soluble	0.010”

ADDITIONAL MECHANICAL PROPERTIES:

Tensile Strength 63.4 MPa (XZ Axis) 28.9 MPa (ZX Axis)
Tensile Modulus 7515 MPa (XZ Axis) 2300 MPa (ZX Axis)
HDT @ 264 psi 143 °C
izod impact, notched 85 J/m (XZ Axis) 21.4 J/m (ZX Axis)

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NYLON 6

Benefits:

- Combines
  - **Strength of ULTEM™ 9085 resin**
    - >9k psi
  - **Toughness of Nylon**
    - >30% elongation at break
    - >15 ft-lb/in impact strength
- Overall, **higher strength/stiffness** and **better appearance** compared to Nylon 12
- **Specially formulated for FDM printing,** delivering the right balance of Nylon 6 properties and ability to successfully print FDM parts

Limitations:

- Compared to pure Nylon 6 in traditional manufacturing, FDM Nylon 6 has slightly lower heat resistance and elongation. It is considered a Nylon 6,10 blend.

More Information: http://www.stratasys.com/materials/fdm/nylon-6

FDM NYLON 6

MATERIAL	MECHANICAL PROPERTIES	COLORS	SYSTEM AVAILABILITY	SUPPORT	LAYER RESOLUTION
FDM Nylon 6	Nylon – Toughnes Ultem - Strength	●	Fortus 900MC	Soluble	0.010” - 0.013” (0.254 - 0.330mm)

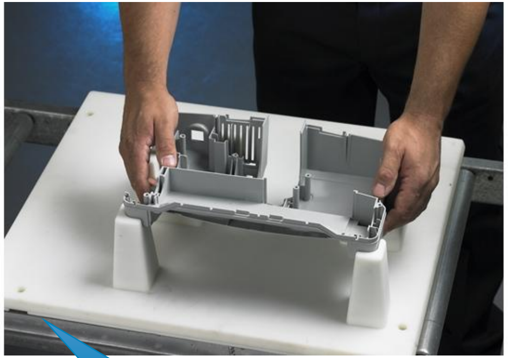
PC - POLYCARBONATE

Benefits:

- A widely used industrial thermoplastic
- High tensile & flexural strength
- Moderate heat resistance
- Dual support system technology
    - breakaway or soluble

Applications:

- High requirement prototypes
- Manufacturing tools, fixtures, and carriers
- Tools & patterns for composites, metal bending, etc.



Fixture

stratasys

PC-ABS

MATERIAL	MECHANICAL PROPERTIES	COLORS	SYSTEM AVAILABILITY	SUPPORT	LAYER RESOLUTION
PC Polycarbonate	High tensile & flexural strength Moderate heat & chemical resistance	◯	Fortus	Breakaway Soluble	0.005” - 0.013” (0.127 - 0.330mm)

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PC-ABS

Benefits:

- An “improved ABS” material
- High impact strength
    - 2nd only to nylon among FDM materials
- Excellent feature definition & surface finish
    - 0.005” (0.127mm) layers

More Information:

http://www.stratasys.com/materials/fdm/pc-abs

Applications:

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PC-ABS

MATERIAL	MECHANICAL PROPERTIES	COLORS	SYSTEM AVAILABILITY	SUPPORT	LAYER RESOLUTION
PC- ABS	High impact strength Excellent feature definition & surface finish	●	Fortus Classic Fortus Plus	Soluble	0.005” - 0.013” (0.127 - 0.330mm)

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PC-ISO

Benefits:

- Biocompatible
  - ISO 10993 & USP Class VI
- Sterilizable
- Superior part properties vs. ABS-M30i

Applications:

PC-ISO

MATERIAL	MECHANICAL PROPERTIES	COLORS	SYSTEM AVAILABILITY	SUPPORT	LAYER RESOLUTION
PC- ISO	Biocompatible Sterilizable Superior part properties*		Fortus: 400mc/450mc 900mc	Breakaway	0.007” - 0.013” (0.178 - 0.330mm)

HIGH-PERFORMANCE FDM MATERIALS

HIGH PERFORMANCE PLASTICS FAMILY

ANTERO™ 800NA

ULTEM® 1010

ULTEM® 9085

High Performance Plastics

ULTEM® 9085

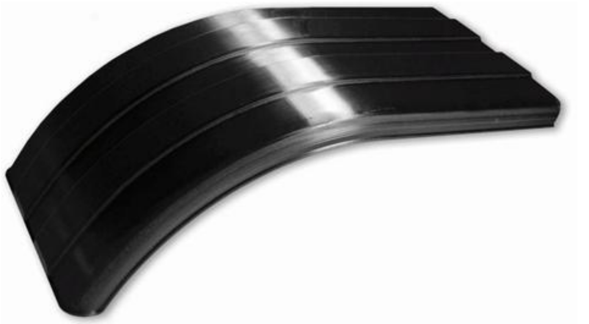
Benefits:

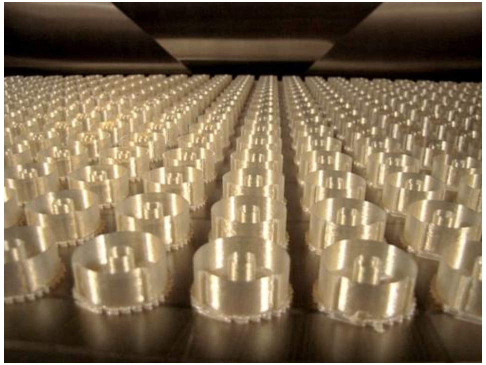
- High heat & chemical resistance
- Mechanically superior in nearly all categories
- Excellent strength to weight ratio

More Information:

http://www.stratasys.com/materials/fdm/ultem-9085

Applications:





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ULTEM® 9085

MATERIAL	MECHANICAL PROPERTIES	COLORS	SYSTEM AVAILABILITY	SUPPORT	LAYER RESOLUTION
ULTEM® 9085	FST Tested High heat & chemical resistance Mechanically superior in nearly all categories		Fortus: 400mc/450mc 900mc	Breakaway	0.010” - 0.013” (0.254 - 0.330mm)

ULTEM® 1010

Benefits:

- Highest heat resistance among all FDM materials
- Stronger with greater temperature resistance than ULTEM 9085
- FST Certified - Flame, Smoke and Toxicity
- NSF 51 & 10993 Biocompatibility (Can be sterilized)

More Information:

http://www.stratasys.com/materials/fdm/ultem-1010

Applications:

ULTEM® 1010

MATERIAL	MECHANICAL PROPERTIES	COLORS	SYSTEM AVAILABILITY	SUPPORT	LAYER RESOLUTION
ULTEM® 1010	Highest FDM Tensile Strength Temperature resistance ↑ chemical resistance FST Tested Certified Biocompatibility Food production ↑ support removal*		Fortus: 900mc	Breakaway	0.010” (0.254mm)

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ULTEM® 9085 VS ULTEM® 1010

Which types of applications ULTEM 1010 best for?

ULTEM 1010 is better for:

- High temperature resistance and strength applications
- Medical and food applications
- Tooling applications

Which types of applications is ULTEM 9085 best for?

ULTEM 9085 is better for:

- Higher toughness (notched Izod impact)
- Flexibility

ANTERO™ 800NA

Antero™ 800NA is a PEKK-based FDM® thermoplastic. It combines FDM's design freedom and ease of use with the excellent strength, toughness and wear-resistant properties of PEKK material. Antero 800NA exhibits high heat resistance, chemical resistance, low outgassing and dimensional stability, particularly in large parts.

Appropriate applications include aircraft components exposed to jet fuel, oil and hydraulic fluid, spacecraft parts that demand low outgassing and chemical-resistant industrial parts. Using Antero 800NA with FDM technology avoids the waste and design limitations associated with subtractive manufacturing of high-cost bulk PEKK

MATERIAL	MECHANICAL PROPERTIES	COLORS	SYSTEM AVAILABILITY	SUPPORT	LAYER THICKNESS CAPABILITY
ANTERO 800NA	Chemical Compatibility (MIL-STD-810G) No visible damage Heat Deflection (HDT) @ 264 psi 147 °C (296.6 °F)		Fortus 450mc	SUP8000B Breakaway	0.010 inch (0.254 mm)

FDM SUPPORT MATERIALS

SOLUBLE VS. BREAKAWAY SUPPORT

Soluble Release Support (SR) material can be washed away in a solution of heated-water and a cleaning agent

Breakaway Support Structures (BASS) are manually removed.

Notable differences between soluble support and BASS materials are as follows:

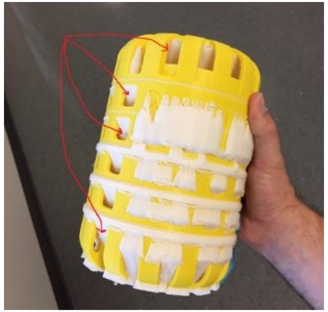
SUPPORT MATERIALS COMPARISON	
SOLUBLE SUPPORT	BREAKAWAY SUPPORT STRUCTURES (BASS)
SR-20, SR-30, SR-100, and SR-110	PC_S, PPSF_S, ULT_S, and ULTEM 1010 Support Supports removed manually Do not require the use of a tank Faster for simple support structures, which may require the use of hand tools to reach and remove all support material and may be time consuming
Supports wash away in a detergent bath	
Build internal cavities/channels	
Hands-free support removal	

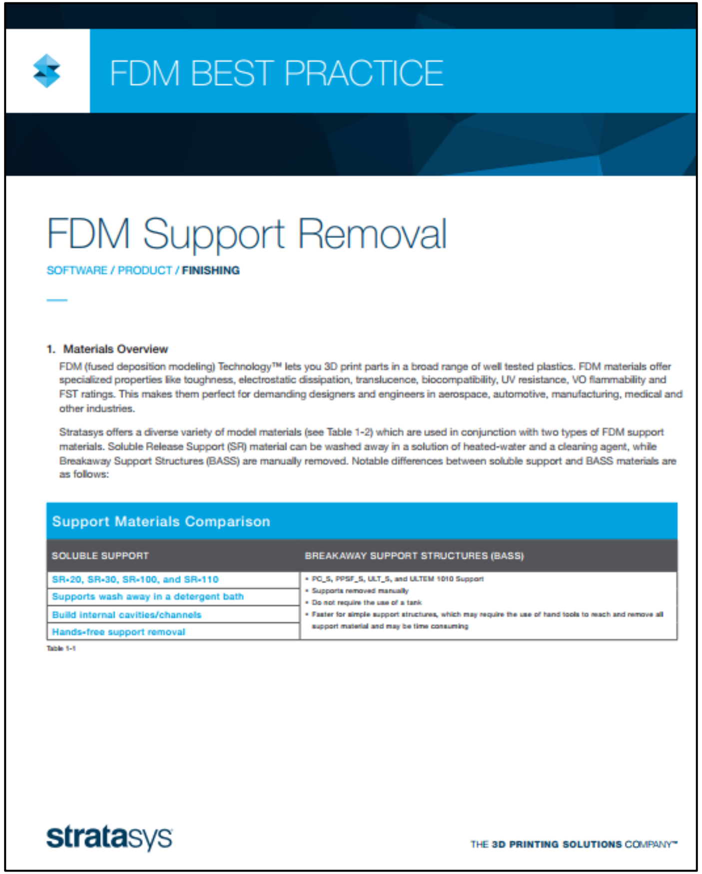
MODEL AND SUPPORT

MATERIALS HIGHLIGHTS	
MODEL MATERIAL	SUPPORT MATERIAL
ABSi	Used with SR-20 support material
ABS_ESD7	Used with SR-30 support material
ABS-M30	Used with SR-20 or SR-30 support material
ABS-M30i	Used with SR-20 or SR-30 support material
ASA	Used with SR-30 support material
Nylon 12	Used with SR-110 support material
PC-ABS	Used with SR-20 support material
PC	Used with SR-100 or PC_S support material
PC-ISO	Used with PC_S support material
PPSF	Used with PPSF_S support material
ULTEM 9085 resin	Used with ULT_S support material
ULTEM 1010	Used with U1010S1 support material

SUPPORT MATERIAL

Download & review the FDM Support removal best practice document.





FDM BEST PRACTICE

FDM Support Removal

SOFTWARE / PRODUCT / **FINISHING**

1. Materials Overview

FDM (fused deposition modeling) Technology™ lets you 3D print parts in a broad range of well tested plastics. FDM materials offer specialized properties like toughness, electrostatic dissipation, translucence, biocompatibility, UV resistance, VO flammability and FST ratings. This makes them perfect for demanding designers and engineers in aerospace, automotive, manufacturing, medical and other industries.

Stratasys offers a diverse variety of model materials (see Table 1-2) which are used in conjunction with two types of FDM support materials. Soluble Release Support (SR) material can be washed away in a solution of heated-water and a cleaning agent, while Breakaway Support Structures (BASS) are manually removed. Notable differences between soluble support and BASS materials are as follows:

Support Materials Comparison

SOLUBLE SUPPORT	BREAKAWAY SUPPORT STRUCTURES (BASS)
SR-20, SR-30, SR-100, and SR-110	• PC_S, PPSF_S, ULT_S, and ULTEM 1010 Support • Supports removed manually • Do not require the use of a tank • Faster for simple support structures, which may require the use of hand tools to reach and remove all support material and may be time consuming
Supports wash away in a detergent bath	
Build internal cavities/channels	
Hands-free support removal	

Table 1-1

stratasys THE 3D PRINTING SOLUTIONS COMPANY™

POLYJET MATERIALS

POLYJET MATERIALS

Clear transparency

Multi-material realism

Smooth surface finish

Molding & tooling

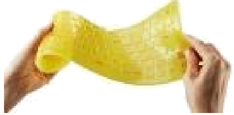
ABS functionality

Medical & dental

Polypropylene-like

Thin walls & cavities

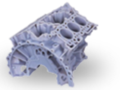
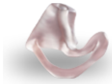
Color range



Choice of flexibility

POLYJET ADVANTAGES

POLYJET MATERIALS | STANDARD PLASTICS SIMULATION

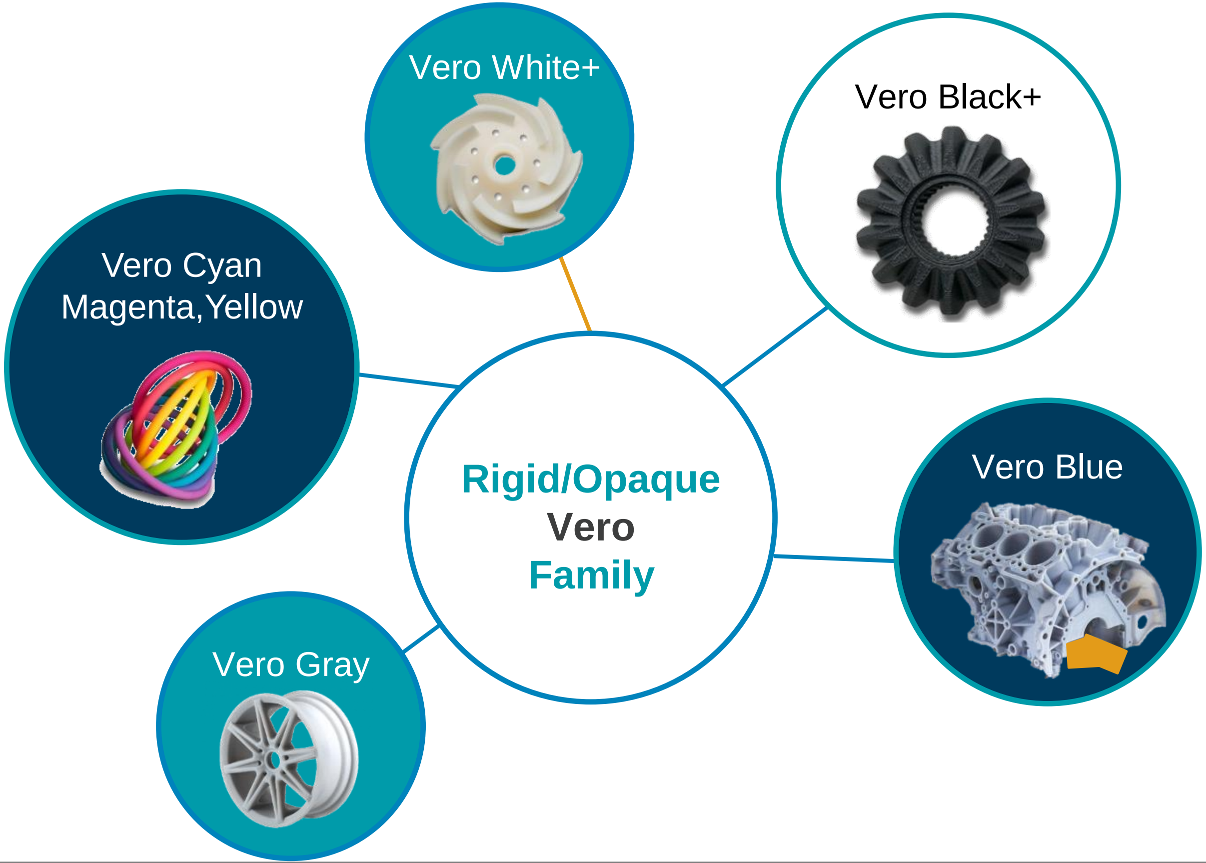
Rigid				Flexible	Medical
					
Transparent Rigid	Simulated Polypropylene	Vero (Opaque) Rigid	Vero (Opaque) Rigid - Colors	Tango Rubber-like	Medical
RGD720	DurusWhite	VeroWhitePlus	VeroYellow	TangoPlus	Biocompatible Clear
VeroClear	Rigur	VeroBlue	VeroCyan	TangoGray	Hearing Aid Family
		VeroGray	VeroMagenta	TangoBlack	VeroGlaze
		VeroBlackPlus		TangoBlackPlus	VeroDent
				Agilus30	VeroDentPlus

Engineering

…RGD525
and more than 1000 Digital Materials

Compare PolyJet Materials At: http://www.stratasys.com/materials/polyjet/compare-polyjet-materials

RIGID OPAQUE FAMILY



VERO FAMILY | RIGID OPAQUE

Applications:

Benefits:

- Accurate, attractive prototypes that test fit, form and function.
- Smooth, accurate jigs, fixtures and manufacturing tooling.
- Connex & J750 systems create thousands of digital colors.

More Resources:

- http://www.stratasys.com/materials/polyjet/rigid-opaque

VERO FAMILY | RIGID OPAQUE

For multi-material systems, the Vero family includes:

- VeroGray (RGD850)
- VeroBlue (RGD840
- VeroBlackPlus (RGD875)
- VeroCyan
- VeroMagenta
- VeroYellow
- VeroBlack
- VeroWhitePlus
- Vero PureWhite, a brilliant white 20 percent brighter than VeroWhitePlus with twice the opacity

More Resources:

http://www.stratasys.com/materials/polyjet/rigid-opaque

Applications:

VEROCLEAR AND RGD720

RIGID TRANSPARENT FAMILY

VeroClear

Transparent (Rigid) Family

RGD720

TRANSPARENT FAMILY | RIGID

Benefits:

- True transparency
- Great dimensional stability
- Excellent Surface finish
- Great fine details appearance
- **More Resources:** http://www.stratasys.com/materials/polyjet/transparent

Applications:

SIMULATED POLYPROPYLENE FAMILY: RIGID

Durus

Simulated Polypropylene Family

Rigur

SIMULATED POLYPROPYLENE FAMILY | DURUS

Benefits:

- High Toughness
- High Flexibility Rigid material
- Applications:
  - Simulation of Polypropylene
  - Snap fit assemblies
  - Packaging applications
  - Form/fit/function testing

More Resources:
http://www.stratasys.com/materials/polyjet/simulated-polypropylene

Applications:

SIMULATED POLYPROPYLENE FAMILY | RIGUR

Rigur is an advanced Simulated Polypropylene material that offers durability and a beautiful surface finish.

Great-performing prototypes with impressive dimensional stability

Applications:

Snap fit

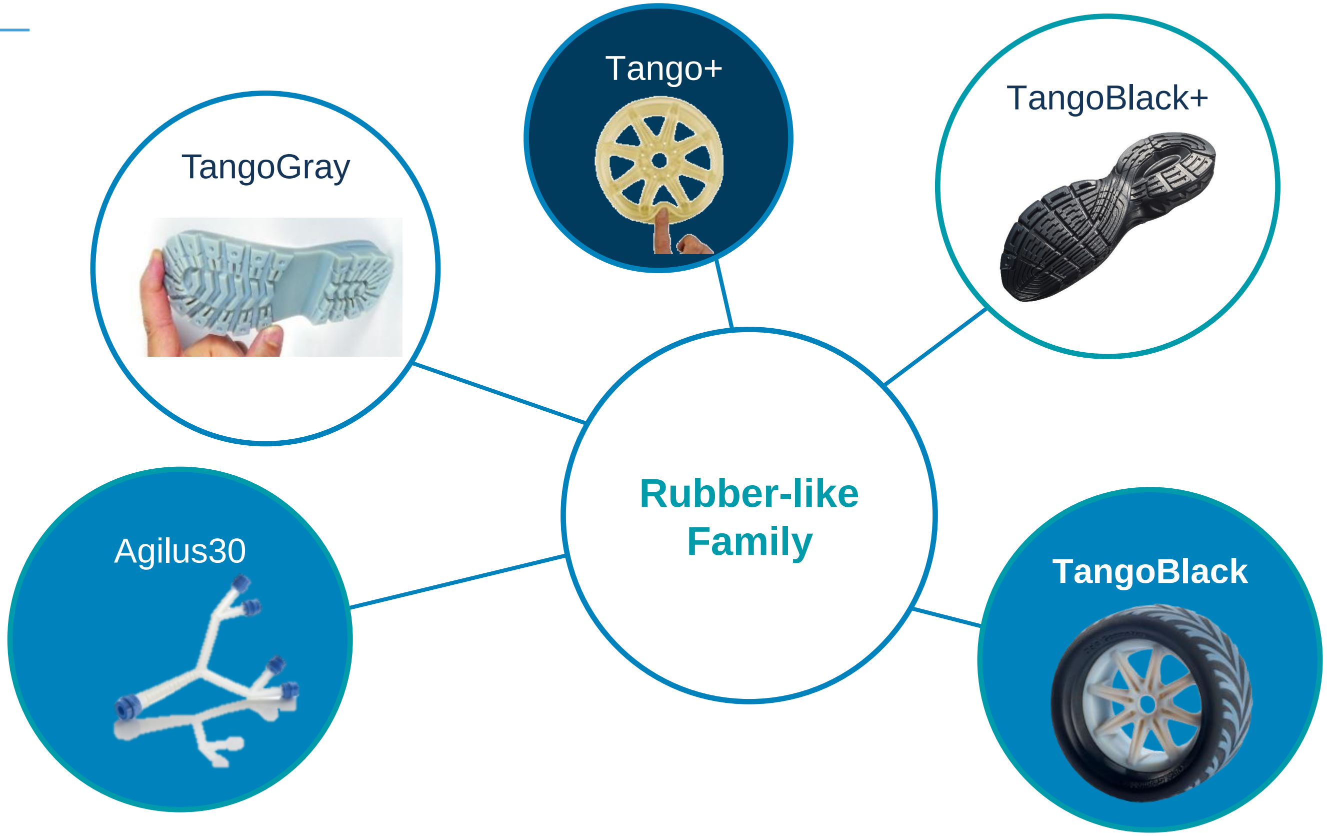
Fit & Assembly

Flexibility

More resources: http://www.stratasys.com/materials/polyjet/simulated-polypropylene

TANGO

FLEXIBLE RUBBER-LIKE FAMILY



TANGO / AGILUS FAMILY | RUBBER-LIKE

Benefits:

- Different Levels of Hardness, Elongation and tear resistance

Applications:

- Exhibition and communication models
- Rubber surrounds and over-molding
- Soft-touch coatings and nonslip surfaces for tooling or prototypes
- Knobs, grips, pulls, handles, gaskets, seals, hoses, footwear

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FLEXIBLE RUBBER LIKE MATERIALS

Soft & Flexible:

- TangoPlus FLX 930 (Shore 27A)
- TangoBlackPlus FLX 980 (Shore 27A)
- Agilus30 FLX935 (Shore 30A)
- Agilus30 Black FLX985 (Shore 30A)

Semi-Flexible:

- TangoGray FLX950 (Shore 70A)
- TangoBlack FLX973 (Shore 70A)

More Resources:

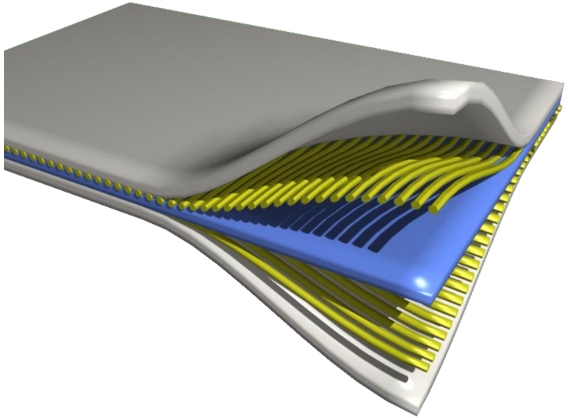
http://www.stratasys.com/materials/polyjet/rubber-like

Applications:

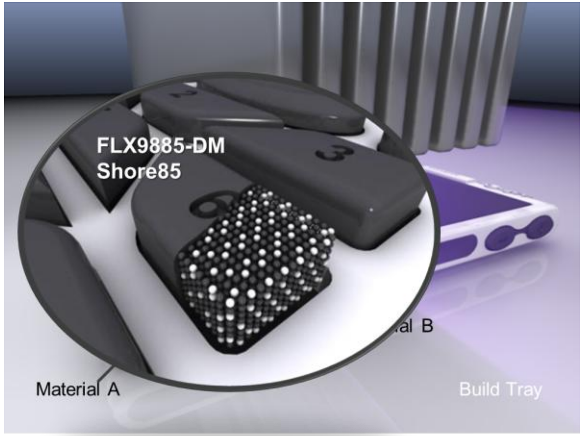
DIGITAL MATERIALS

DIGITAL MATERIALS

Digital Materials are Composite Materials



Possible due to Simultaneous Material Jetting



Composites are formed by combining materials together to form an overall structure that is better than the sum of the individual components

GENERATING DIGITAL MATERIALS

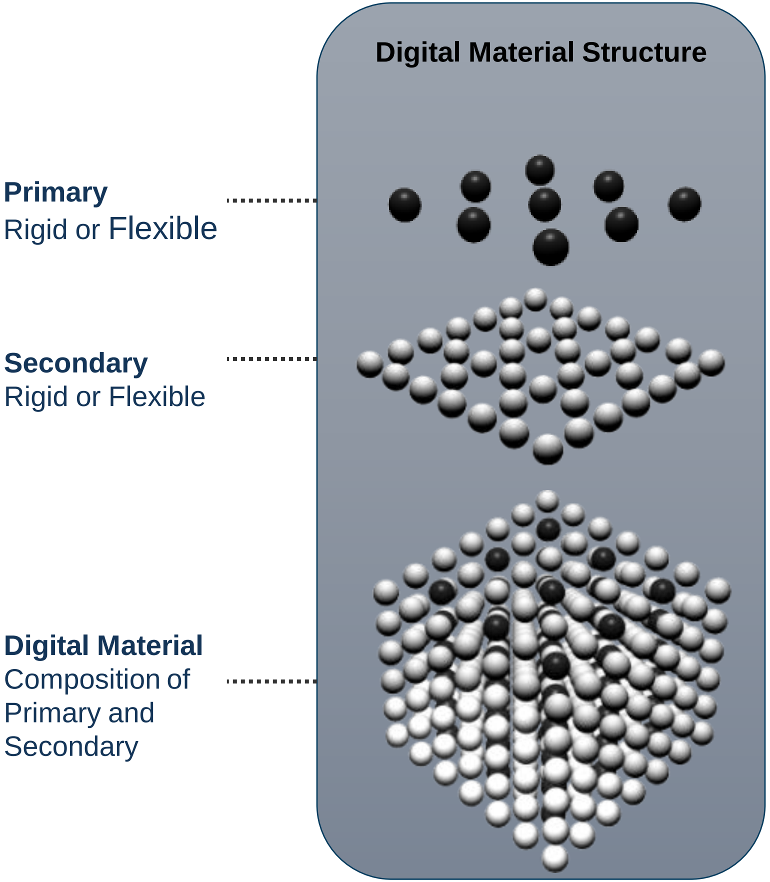
Unique to

- Connex2 (2 jets),
- Connex 3 (3 jets)
- J750 (7 jets)

1000+ Digital Materials available

Digital ABS material

Multiple materials on the same tray



PRINTING POSSIBILITIES

Mixed Tray

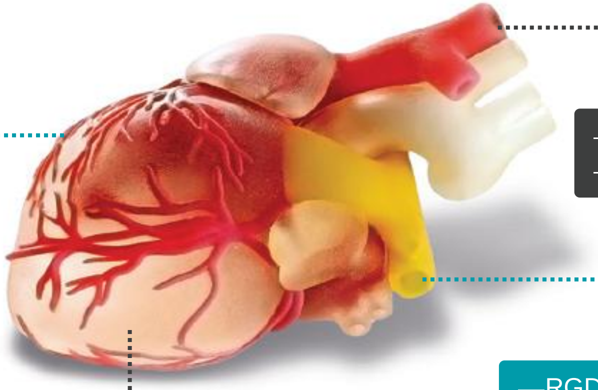
Mixed Colors

Digital Materials

Mixed Part

Digital ABS

WHAT DO DIGITAL MATERIALS LOOK LIKE?



- —Vero Magenta
- —**Rigid**

- —RGD-MY002-DM
- —**Rigid**

- —RGD-MY006-DM
- —**Rigid**

- —Tango+
- —Elong. at break 170-220%
- —Shore A 27

J750 SIMULATES VIRTUALLY ANYTHING

Engineering-grade plastic (Digital ABS) to general-use plastics

Single-material parts to over-molded parts

Single color to full color

Flexible to rigid

Matte to glossy

Fine to large features

Hard to soft

Smooth to rough

Opaque to transparent to clear-tinted

Shell or texture VRML

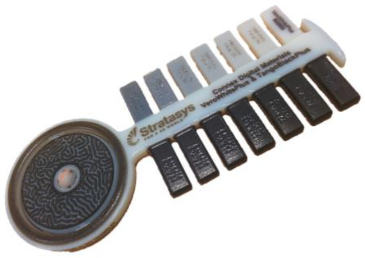
DIGITAL ABS: THE ALL-ROUND GENERAL PURPOSE MATERIAL

Applications:

Benefits:

- Simulate snap-fit parts & contact surfaces
- Simulate living hinges
- Endure high stress falls and blows or high pressure
- Withstand outdoor environments
- Suitable for drilling, assembly, gluing & painting

EXAMPLE | RIGID WHITE + FLEXIBLE BLACK



VeroWhitePlus — Primary Rigid

TangoBlackPlus — Secondary Flexible

New mechanical properties

New gray shades

Uniform Rigidity at Different Gray Shades

Simulated PP DM

VeroWhite+	Digital Material RGD8505-DM	Digital Material RGD8510-DM	Digital Material RGD8515-DM	Digital Material RGD8520-DM	Digital Material RGD8525-DM	Digital Material RGD8530-DM	TangoBlack+ Shore27

EXAMPLE | FLEXIBLE BLACK + RIGID WHITE

Primary Flexible — **TangoBlackPlus**

Secondary Rigid — **VeroWhitePlus**

New mechanical properties
Shore A range

Hardness Range:
From Shore Scale A 27 - 95

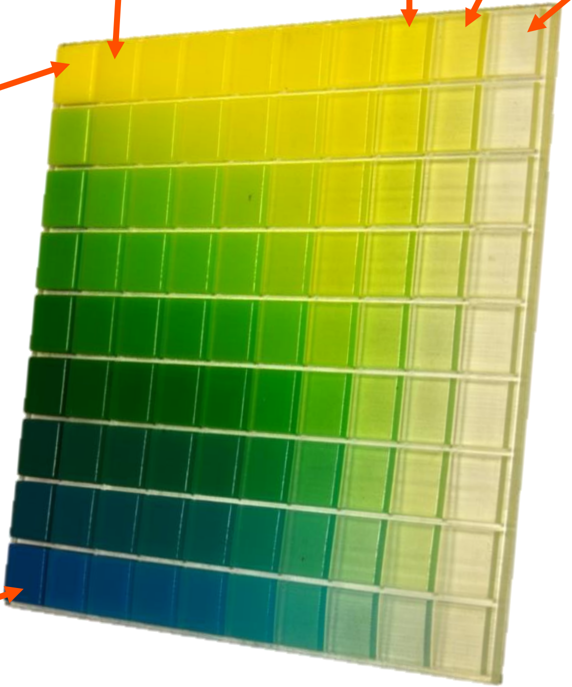
OTHER POSSIBILITIES: GRADIENTS COLORS & RIGID/FLEXIBLE

Combinations of

- Black, White, Cyan, Magenta, Yellow, Clear

Applications

- Final Product Part Realism
- Focus Groups
- Communication Tools
- …and many more!



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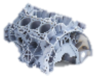
REVIEW VIDEO

https://www.youtube.com/watch?v=5bxLmmM3ftg

POLYJET MATERIALS SUMMARY

	MATERIAL	KEY CHARACTERISTICS	APPLICATIONS
	Vero Family	Durable and Rigid in a variety of opaque colors	Standards plastic simulation for wide range of form and fit applications
	Tango/Agilus Family	Various levels of elastomer characteristics in different colors	Rubber Surrounds, over molding, soft tough, appearance models
	Vero Clear	Rigid clear Material with great transparent visualization	Form and fit testing of clear or see-through parts, Glass, eye-wear, lighting covers and light-cases
	RGD720	Multi Purpose transparent Material	Standard plastic simulation, see through applications
	Rigur/ DurusWhite	Polypropylene simulated properties in opaque color	Snap fit assemblies , Packaging applications Form/fit/function testing
	Digital ABS	ABS simulated properties, exceptional dimensional stability	Functional prototypes, molds, snap fit applications.
	Vero Rigid Colors	1000+ color choices with up to 75 color options per build	Production part like prototypes
	Flexible Colors	Color options with over-molding like capabilities, flexible colors	Simulated production parts with rubber like features and colors

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SUMMARY

MATERIALS DISCUSSION

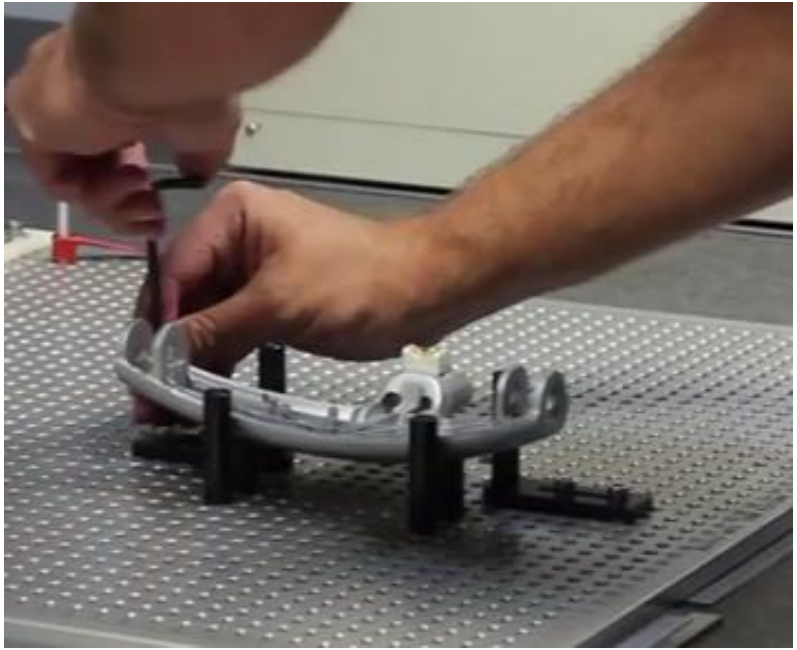
WHAT WOULD YOU RECOMMEND?

This manufacturer of consumer goods uses over 50 assembly and inspection fixtures on each of the device they create.

They have several work holders, drill guides, and CMM inspection tools that optimizes their factory floor efficiency.

Today they produce each with an outside vendor each by molding and casting. They need to do things quicker.

These need to be strong and hold their shape over time. The geometries are complex. Some may be exposed to water and heat.



WHAT WOULD YOU RECOMMEND?

This design firm is creating the newest prototype in the Rubbermaid Flex & Seal Line they need to:

- Need to simulate rubber.
- Need superior tear resistance.
- Elongation at break at 230%
- Part need to be flexed and strained, over and over.

WHAT WOULD YOU RECOMMEND?

This manufacturer is attempting to re-create a robotic gripper used on their shop floor

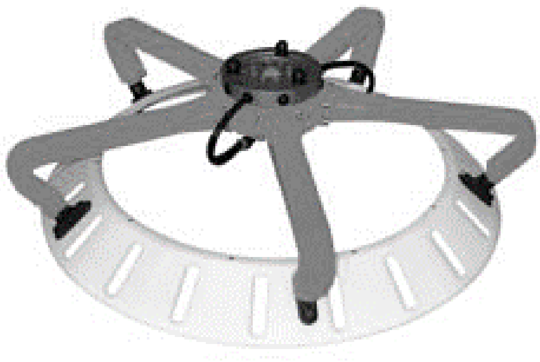
Design features internal vacuum channels and it is very expensive.

The used to machine this same gripper out of aluminum but are looking for a better way.

They own a Fortus.

They need the part in less than a week.

They will need to do functional testing.

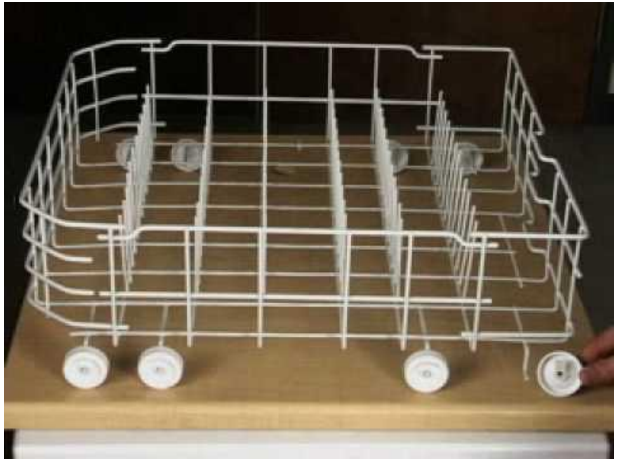


WHAT WOULD YOU RECOMMEND?

This design firm is working on designing new rollers for inside of a dishwasher as the ones on their old model is wearing out quickly and causing customer complaints.

They have identified that the material they previously used did not stand up to heat and moisture within dishwasher, and the rollers and water drive began to degrade about 18 months after purchase.

They want to be able to design and test many new rollers with their 3D printer.



WHAT WOULD YOU RECOMMEND?

Joe Gibbs Racing (JGR), a premier NASCAR race team, regularly tests 40-percent scale models in a full–span, rolling-floor wind tunnel. Test results help improve performance characteristics, such as down force, side force and drag. In the tunnel, JGR simulates the aerodynamic loads on its race cars at conditions equivalent to 200 mph.

They need to create and test a fuel nozzle on three different cars, in 2 days.

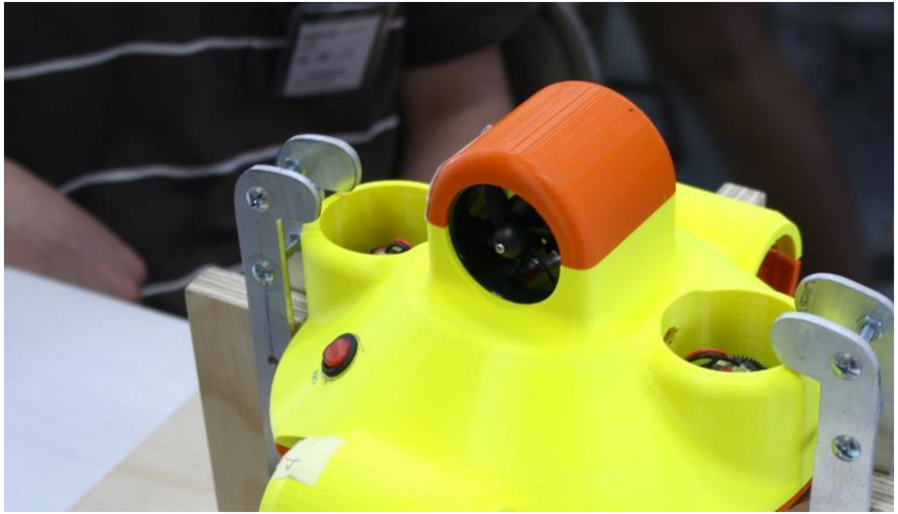
WHAT WOULD YOU RECOMMEND?

Janice has a lot of ideas for her next big invention.

She is looking for a way to do cheap and fast conceptual models from her CAD design.

She has 6 possible designs to print and test.

She wants 3 to be translucent, and 3 opaque and all to be rigid.

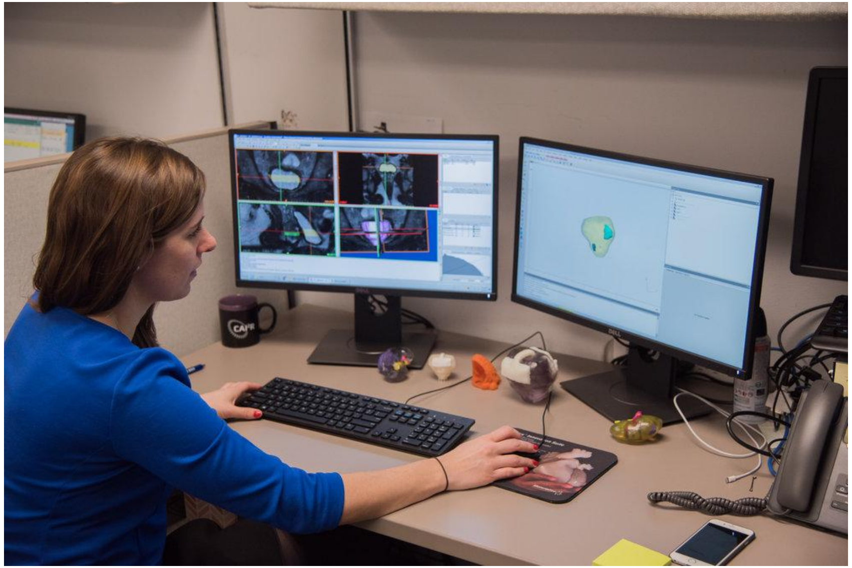


WHAT WOULD YOU RECOMMEND?

Nicole is a PhD Student working with a Urologist to study tumors in the prostate.

She is testing the results of surgical planning using a 3D model vs 2D imaging.

Differentiating anatomy and disease in color is important. Being able to see through the prostate is critical. However, the full model is flexible.



STRATASYS TECHNOLOGY & KEY SPECIFICATIONS

Module 5

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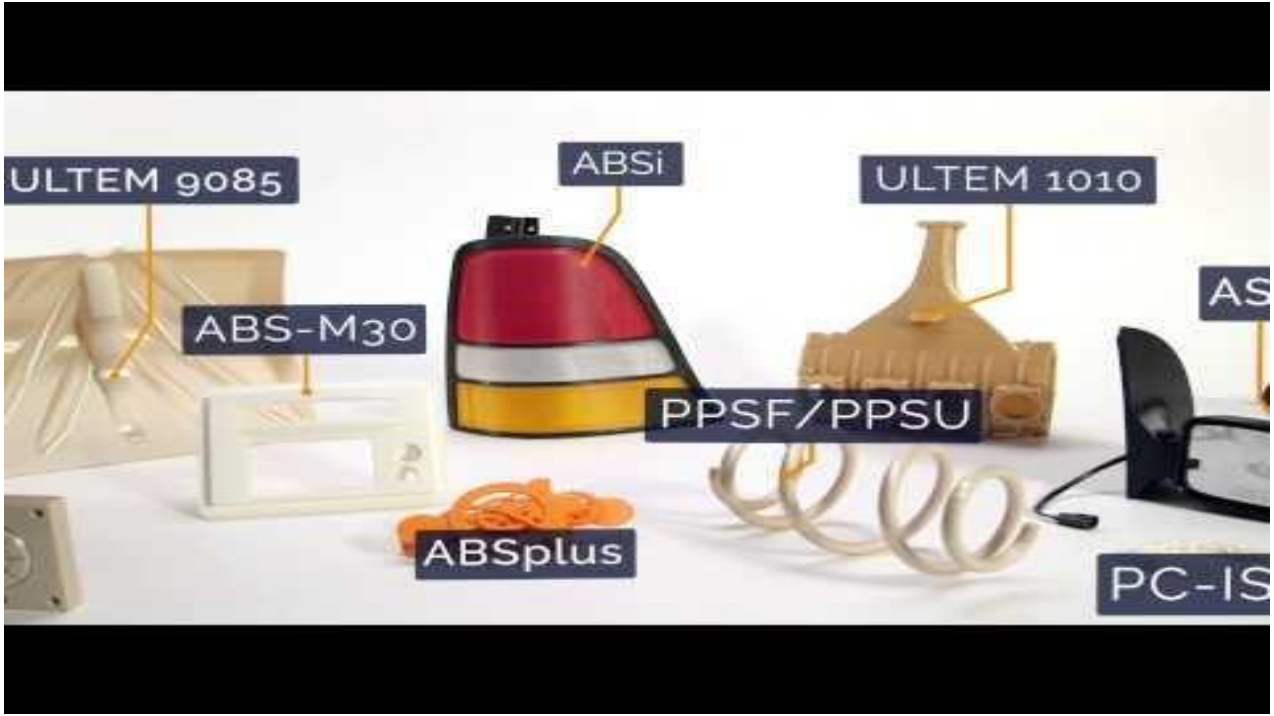
MODULE 5: STRATASYS TECHNOLOGY & KEY SPECIFICATIONS

Learning Objectives:

- Recall how FDM got it's start and the core benefits of the technology
- Recall the evolution of PolyJet from 1 material to 6
- Identify the F123 series, Fortus 450MC and J750's printer's specifications such as build size, materials, slice heights, size/weight, software, cleaning stations…
- Label the parts of the F123 series, Fortus 450MC and J750 printers
- Explain how and why to calibrate the F123 series, Fortus 450MC and J750
- Identify key applications/use cases for the F123 series, Fortus 450MC and J750

STRATASYS TECHNOLOGY & KEY SPECIFICATIONS

INTRODUCTION TO FDM



https://www.youtube.com/watch?v=jk7cWLjaJAg

INTRODUCTION TO POLYJET

https://www.youtube.com/watch?v=ZjXh1RJfA34

Business must embrace technological advances to improve productivity, compete against rivals, and maintain an edge with customers

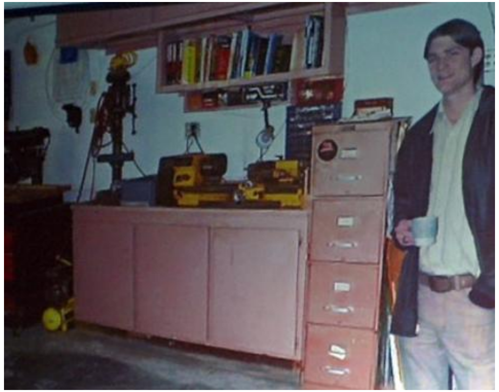
~ 2016 Industrial Manufacturing Trends & Strategy

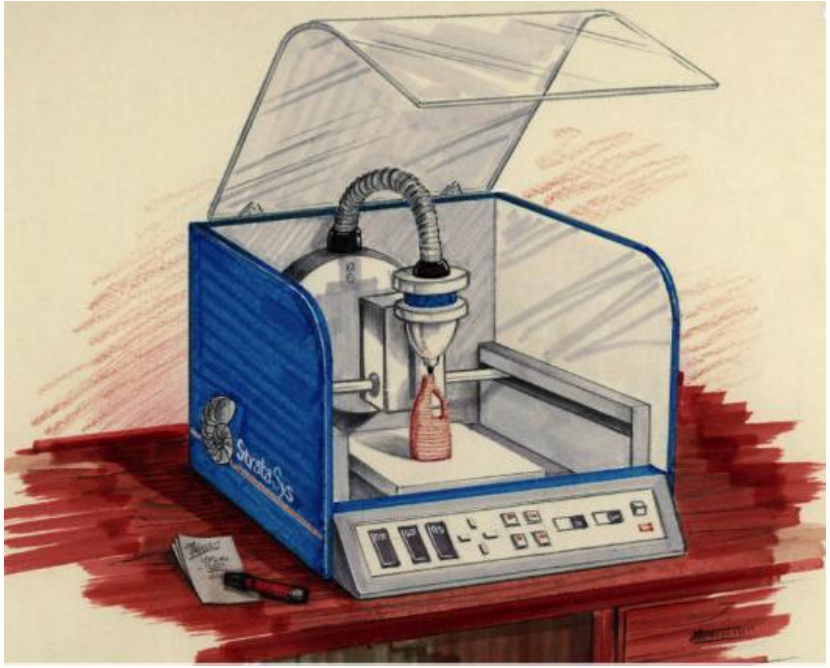
INTRODUCTION TO FDM

STRATASYS FDM SOLUTIONS

STRATASYS FDM 3D PRINTING 1988

STRATASYS®
3D Printers and
Production Systems





Stratasys is still, changing the game

BREAKTHROUGHS CONTINUE THROUGH TODAY…

https://www.youtube.com/watch?v=u_pSEhF3q3Q

BREAKTHROUGHS CONTINUE THROUGH TODAY…

INFINITE BUILD

https://www.youtube.com/watch?v=uIy6rgwulT0

BREAKTHROUGHS CONTINUE THROUGH TODAY…

CONTINOUS BUILD

https://www.youtube.com/watch?v=uIy6rgwuIT0

REVIEW - FDM TECHNOLOGY - ADVANTAGES

Production Grade Thermoplastics	Prototype in real production materials Durable materials with excellent mechanical and thermal properties Capable of end-use part production
High Accuracy	Stable material properties lead to accurate parts Accuracy up to +/- .089 mm or +/- .0015 mm per mm (+/- .0035 inch or +/- .0015 inch per inch) Whichever is greater
Stable Materials	Accurate assessment of design, regardless of environment Accurate functional testing over time
Repeatability	Stable and predictable materials allow for repeatable results Enables DDM (Direct Digital Manufacturing) applications

REVIEW - FDM TECHNOLOGY - ADVANTAGES

Production Grade Thermoplastics	Increased accessibility, expanded prototyping opportunity Simplified cost justification
High Accuracy	Unattended, “lights out” printing Simple printing process - increased user accessibility Convenient “hands free” supports simply wash away
Stable Materials	Quiet and fits in any office environment No facility modifications required

KEY STRATASYS FDM PRINTERS

uPrint SE Plus

F370

Fortus 380mc™

Fortus 380CF™

Fortus 450mc™

Fortus 900mc™

ASSIGNMENT – READ & REVIEW

located in the Resources section of this module

F123 SERIES - FDM

PRINTER SPECIFICATIONS

STRATASYS F123 SERIES – STRATASYS F170 / F270 / F370

For the most effective prototyping for all levels of users to get high-quality parts printed right the first time

- Easy to use, GrabCAD Print, office friendly
- Accuracy, detail and repeatability of complex geometries
- Fast-draft mode, big build envelope,
  2X the throughput
- Engineering-grade materials and new, cost-effective PLA option, soluble support

Advanced print capabilities yet simple for all user levels

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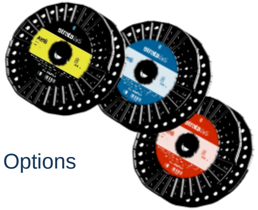
STRATASYS F123 SERIES SOLUTION

Mobile Monitoring

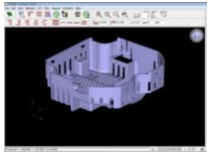
Intuitive Interface

Reliable Hardware



Material Options

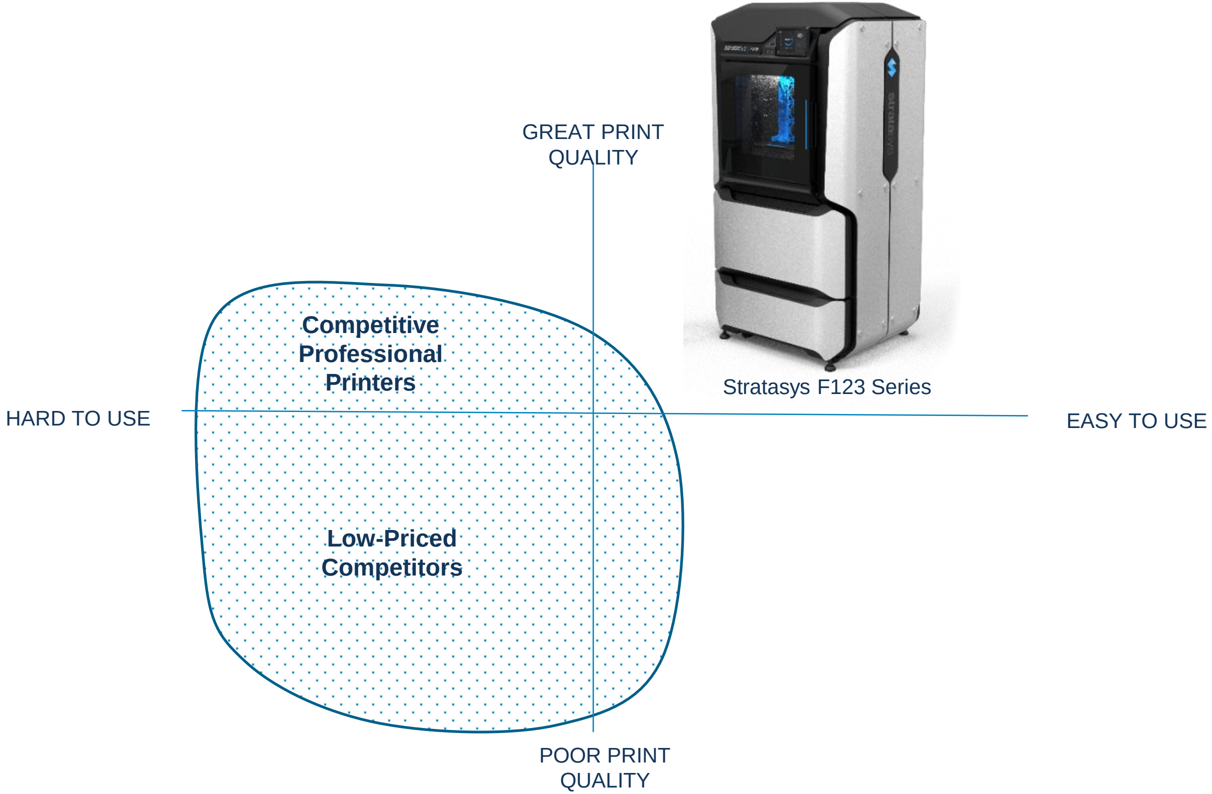
GrabCAD Print



Insight™ (F370 only)

Soluble Support

STRATASYS F123 3D PRINTER SERIES



STRATASYS F123 SERIES – STRATASYS F170 / F270 / F370

Stratasys F170

Affordable and reliable
3D printing

Schools and professionals seeking to generate low-cost concept models and parts

10"x10"x10"

- 254 x 254 x 254 mm

ABS, PLA, ASA

GrabCAD Print

4 slice heights

2 material bays

Stratasys F270

2x material capacity, larger tray

For design and engineering firms with multiple users who need the flexibility to create high volumes of concept, functional and presentation prototypes.

12"x10"x12" (**44% bigger than F170**)
305 x 254 x 305 mm

ABS, PLA, ASA

GrabCAD Print

4 slice heights

4 material bays

Auto material change-over

Stratasys F370

Highest capability and
largest build size

Create complex, durable parts for prototyping applications as well as manufacturing jigs, fixtures and tools.

14"x10"x14" (**36% bigger than F270**)

- 356 x 254 x 356 mm

ABS, PLA, ASA, **PC-ABS**

GrabCAD Print

4 slice heights

4 material bays

Auto material change-over

Insight

STRATASYS F123 MATERIAL COLORS

Stratasys F170 & F270 Materials

Stratasys F370 Materials

QSR Support	PLA	ABS	ASA	PC-ABS
Soluble Support	Black* White* Light Gray* Medium Gray Red Blue Natural Trans Red Trans Blue Trans	White* Black* Dark Gray* Red Blue Green Orange Yellow Ivory*	White* Black* Light Gray* Dark Gray Red Blue Green Orange Yellow Ivory*	White Black*

* Indicates materials available in both 60 and 90 ci

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PRINTER SPECIFICATIONS

PRODUCT SPECIFICATIONS	
System Size and Weight	64” W x 34” H x 28” D; 500 lbs. (227 kg) with consumables
Network Connectivity	Wired: TCP/IP protocols at 100Mbps minimum 100 base T, Ethernet protocol, RJ45 connector Wireless: IEEE 802.11n, g, or b; Authentication: WPA2-PSK, 802.1x EAP; Encryption: CCMP, TKIP
Software	GrabCAD Print is included for F170, F270, F370; Insight license included for F370
System Requirements	Windows 7, 8, 8.1, and 10 (64bit only) with a minimum of 4GB RAM (8GB or more recommended)
Environment	Operating: 59-86 ºF (15-30ºC), Storage: 32-95 ºF (0-35ºC) Humidity: Operating 30-70% RH, Humidity: Storage 20-90% RH
Noise	46dB maximum during build, 35 dB when idle.
Power Requirements	100-132V /15A or 200-240V, 7A. 50/60 Hz
Regulatory Compliance	Low Voltage Directive, CE, TUV, FCC, RC, RCM, EAC, RoHs, WEEE, Reach.

CLEANING STATION OPTIONS

SCA-3600 Cleaning Station

SCA 1200 Cleaning Station

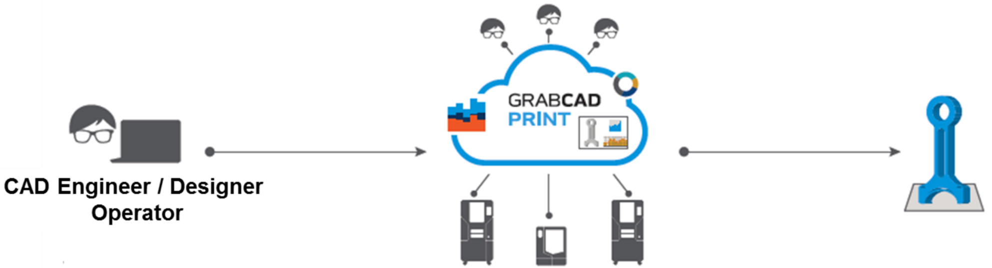
PARAMETER	SCA 1200	SCA 3600
Tank capacity	12.2 Gallons / 46.3 Liters	27 Gallons / 102 Liters
Physical Dimensions	26L x 17.5W x 20.5H inches / 66 x 44.5 x 52 cm	36.5L x 22.8W x 42.8H inches / 93 x 58 x 109 cm
Large Parts Basket Capacity	10 x 10 x 12 inches / 25 x 25 x 30 cm	16 x 16 x 14 inches / 40.6 x 40.6 x 35.6 cm
Small Parts Basket Capacity	4 x 4 x 4 inches / 10 x 10 x 10 cm	4 x 4 x 4 inches / 10 x 10 x 10 cm
Power Requirements	100-120V~ 50/60 Hz 12A 220-240V~ 50/60 Hz 9A	208-240VAC, 20A, 50/60Hz, single phase, grounded
Allowable Liquid Solution Temperature	10ºC - 85ºC (50ºF – 185ºF)	5ºC - 40ºC (41ºF – 104ºF)

INTRODUCTION: GRABCAD PRINT

GRABCAD PRINT

STREAMLINED DESIGN-TO-3D PRINT

- Read native CAD files
- Connect to Stratasys FDM printers, plus the Stratasys J750
- Increase productivity with print management & remote print monitoring



Note: GRABCAD PRINT will be covered in detail in the Fabrication Section.

To Do: Please take time to visit www.grabcad.com/print and download your copy to familiarize yourself.

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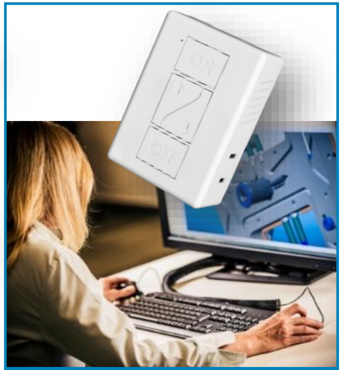
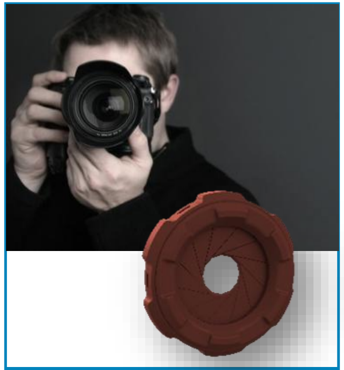
F123 SERIES - FDM

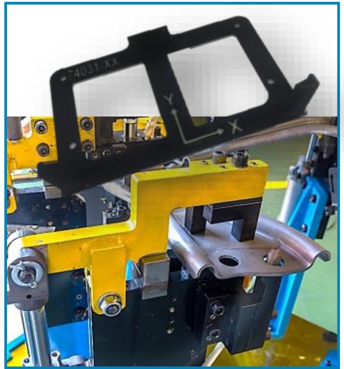
APPLICATIONS / USE CASES

EXAMPLES: F123 SERIES - USE CASES


CONCEPT VERIFICATION


DESIGN VALIDATION


FUNCTIONAL PERFORMANCE


JIGS & FIXTURES

RAPID PROTOTPYING

PROTOTYPING STAGE: CONCEPT VERIFICATION

Market Segment: Product Design Firm

Use case:
Design of a Motocross helmet air vent component

Greater ability to "fail fast"

- With PLA, print twice as many concepts in the same amount of time.
- With PLA, print three times as many concepts at the same cost as one.
- Eliminates the need for outsourcing to prototyping shops and gives engineers and designers more control and confidence in their projects

Complex designs early in development

- Complex surfaces on this air vent part present a challenge for traditional prototyping methods
- Complex geometry doesn't require special processing or training.

The F123 Series excels at making 3D printing complex, curved geometries such as this motocross helmet air vent.

PROTOTYPING STAGE: DESIGN VERIFICATION

Design Adjustments → Management Reviews → Form & Fit Testing

Market Segment: Consumer Electronics

Use case:
Design of a smart home switch housing

Fast and effective

- Ability to make critical design decisions more quickly and effectively
- Enabling more design optimization with accurate prototypes overnight
- Hands free support removal makes it simple and easy to get a finished part with complex features and functions

Evaluate designs with greater complexity

- Ability to print complex geometries & assemblies with fine feature details that traditional prototyping can't duplicate
- PC-ABS has higher strength than ABS and can be used to create unique features like living hinges in this example
- Ability to print solid, durable parts that can be handled repeatedly during validation

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PROTOTYPING STAGE: FUNCTIONAL PROTOTYPING

Field Testing → Functional Testing → Final Validation

Market Segment: Consumer Products

Use case:
Design of a mechanical iris to fit a commercial standard camera lens

Greater accuracy

- Part accuracy that enables printing of fine details and complex assemblies
- Insight software allows optimizing features for functional performance requirements

Greater confidence in your designs

- Collect actual field test feedback before investing in production tools to validate and potentially enhance market value
- Traditional prototyping methods would be cost and/or time prohibitive, increasing the potential to find significant issues only after injection molded tools are created

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QSR SOLUBLE SUPPORT (Quick Support Release)

Create complex parts with internal voids and cavities that are not possible without soluble support

Print full assemblies in a single print

Hands-free post-processing with soluble support

QSR Soluble Support brings new design freedom and capability to produce complex, high-quality 3D printed parts

F123 SERIES - FDM

PRINTER COMPONENTS & DEMO

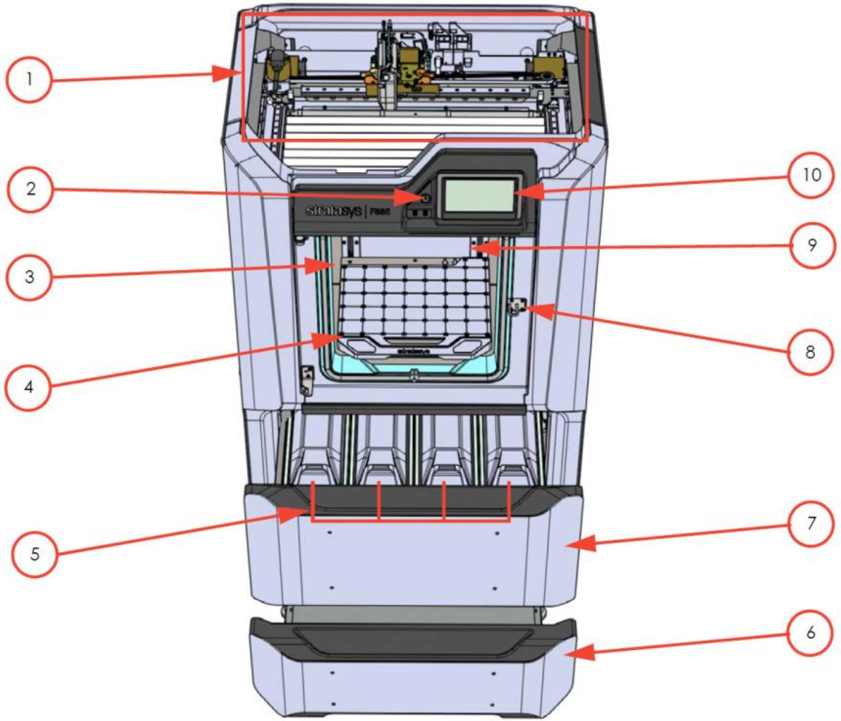
HANDS-ON OR VIRTUAL DEMO SESSION – VIRTUAL PRINTER DEMO

https://www.youtube.com/watch?v=imkIaWZCltk

ACTIVITY 5.1: MACHINE OVERVIEW F SERIES

Technology Specifications: Label parts of the F123

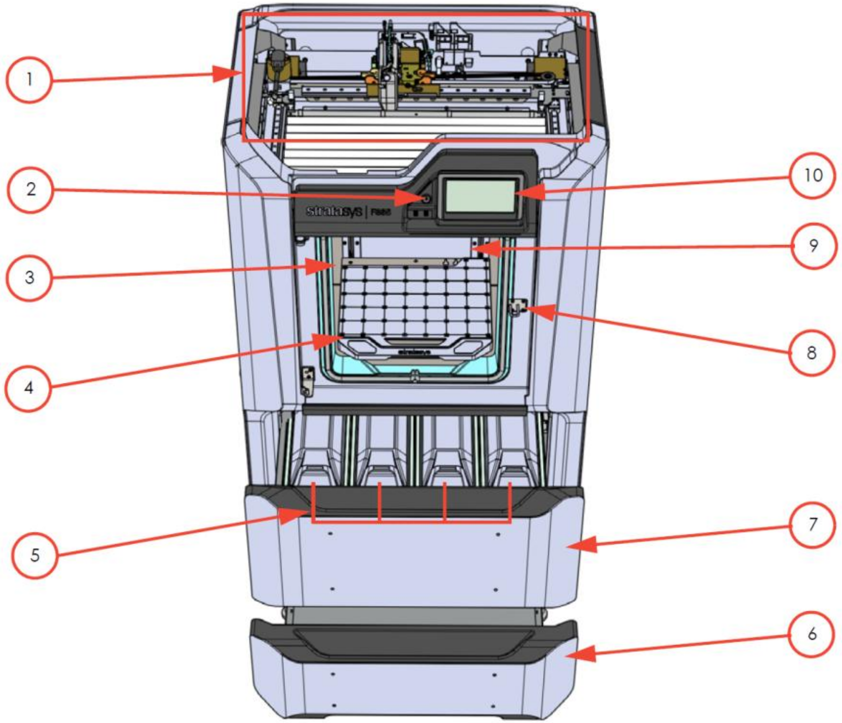
ID	DESCRIPTION	ID	DESCRIPTION
1		6	
2		7	
3		8	
4		9	
5		10	



Download the activity worksheet in the Resources section of module 5

MACHINE OVERVIEW F123: FRONT VIEW DETAILS

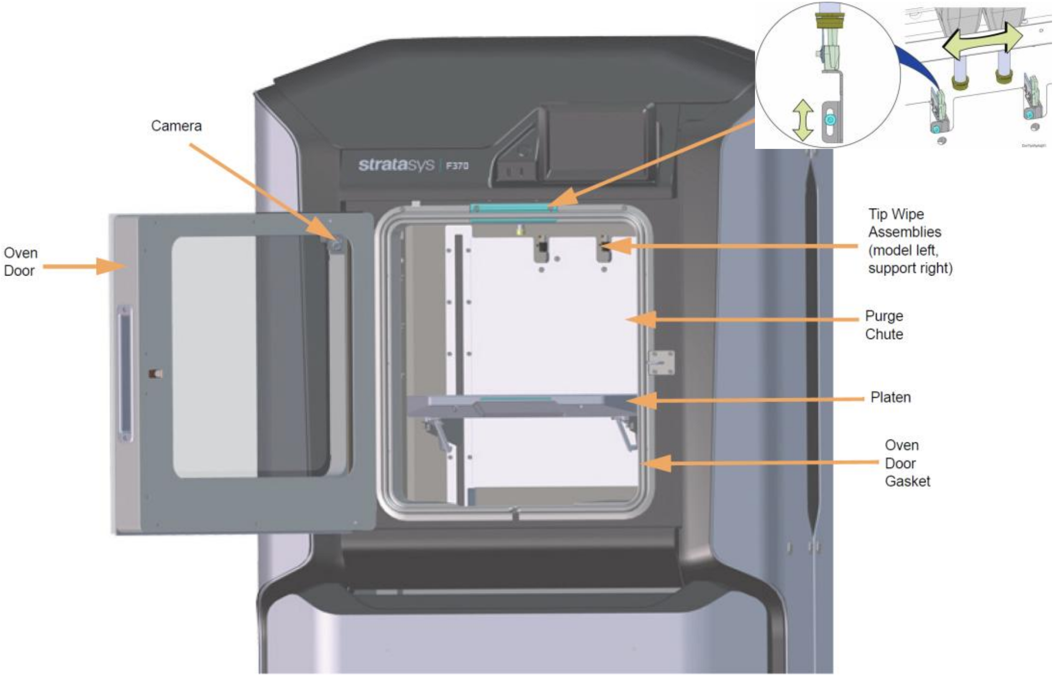
ID	DESCRIPTION	ID	DESCRIPTION
1	Gantry	6	Storage Drawer
2	On/Off Power Button	7	Material Bay Drawer
3	Oven	8	Oven Door Latch
4	Platen	9	Purge Chute
5	Material Bays	10	Touchscreen Display



OVEN

The oven door utilizes an electromagnetic lock along with optical sensors.

The top cover will automatically unlock in conjunction with the oven door, allowing you to manually open the top cover. (The oven door must be open prior to opening the top cover.)



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OVEN

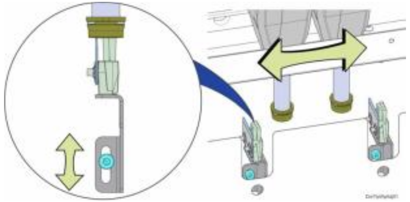
Horizontal plane air circulation

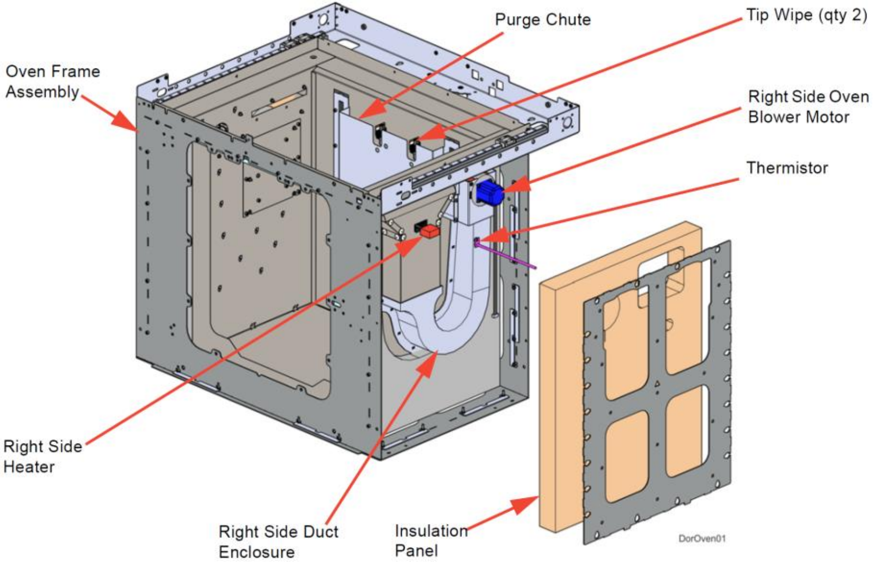
User replaceable brush/wipe

Purge part (no buckets)

Left / right AC powered heaters

The oven has two heaters with dedicated thermocouples to control temperature. A heater temperature reading over 230C will cause the oven to shut off.





BUILT-IN CAMERA

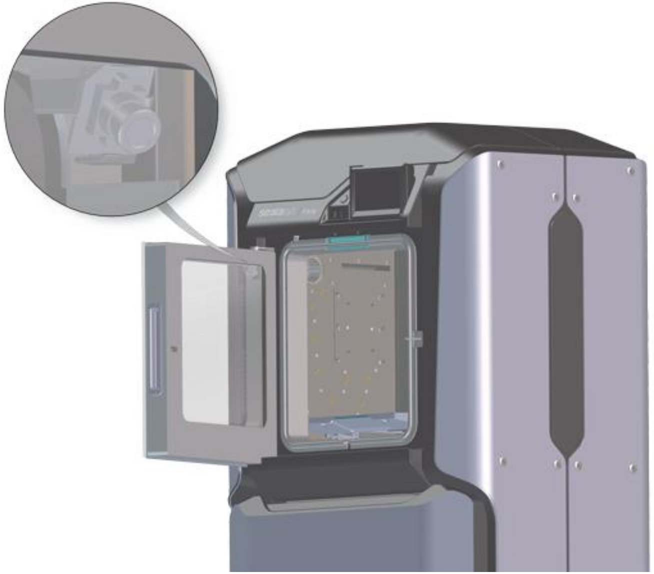
Camera built into the oven door.

User can access images remotely, from Control Center, GrabCAD Print software, or its mobile application

Camera image resolution:

- Resolution of 1024x768 pixels, 256 colors, 32 bit color.

Note: Camera provides still images (not video)



BUILD SUBSTRATES (TRAYS)

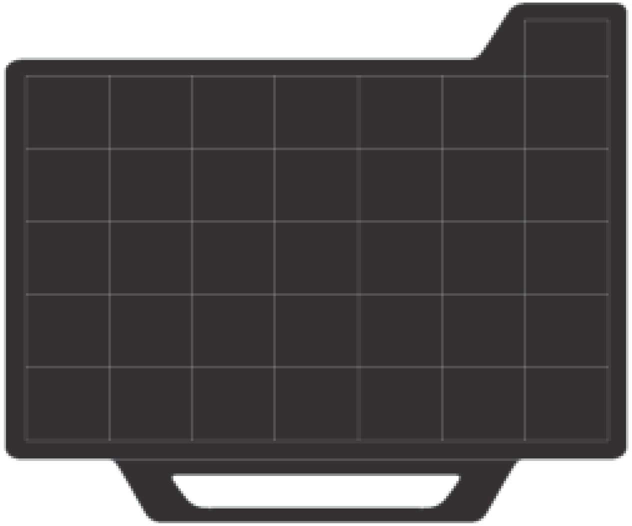
Substrates for the F1/2/3 Series are made of ABS

A black substrate used with all model materials

Substrates are sized by system

Recommended to populate trays from front to back

Be sure to remove all materials when reusing trays



HOOD PRESENTATION WORKFLOW

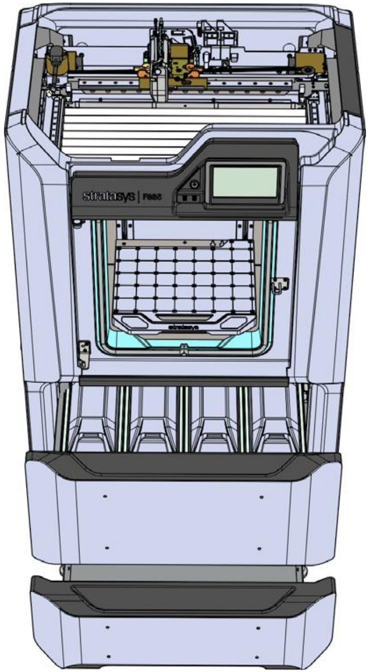
Lock/Unlock with the door – must open oven door before popping the hood

Two types of heads, standard for most materials (black) and PLA (gray)

- No distinction between standard heads until they are loaded – then they can only be used for model (any model material) or support
- PLA heads is only for PLA, sidekick blower for fine detailed PLA parts
- Lifetime of 1500 hrs. – warning at 1350

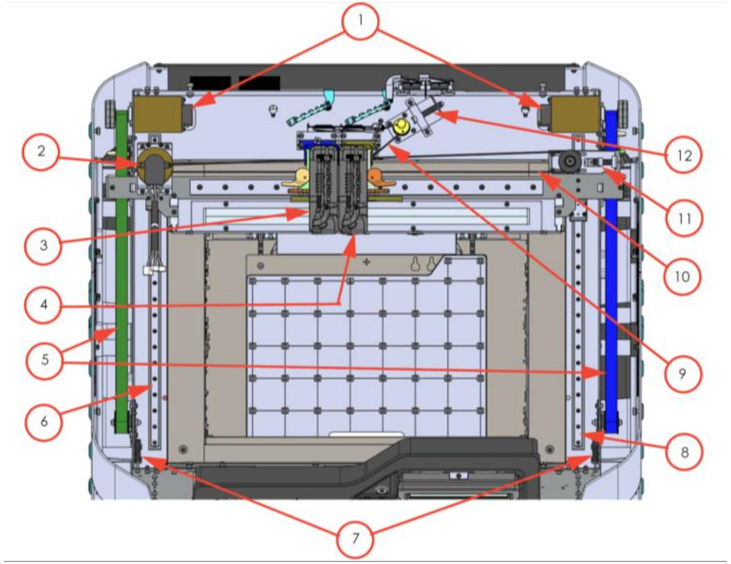
Heads are removed by unplugging power and material and unlocking cams

Note: Heads must be tightened down to prevent vertical wall issues

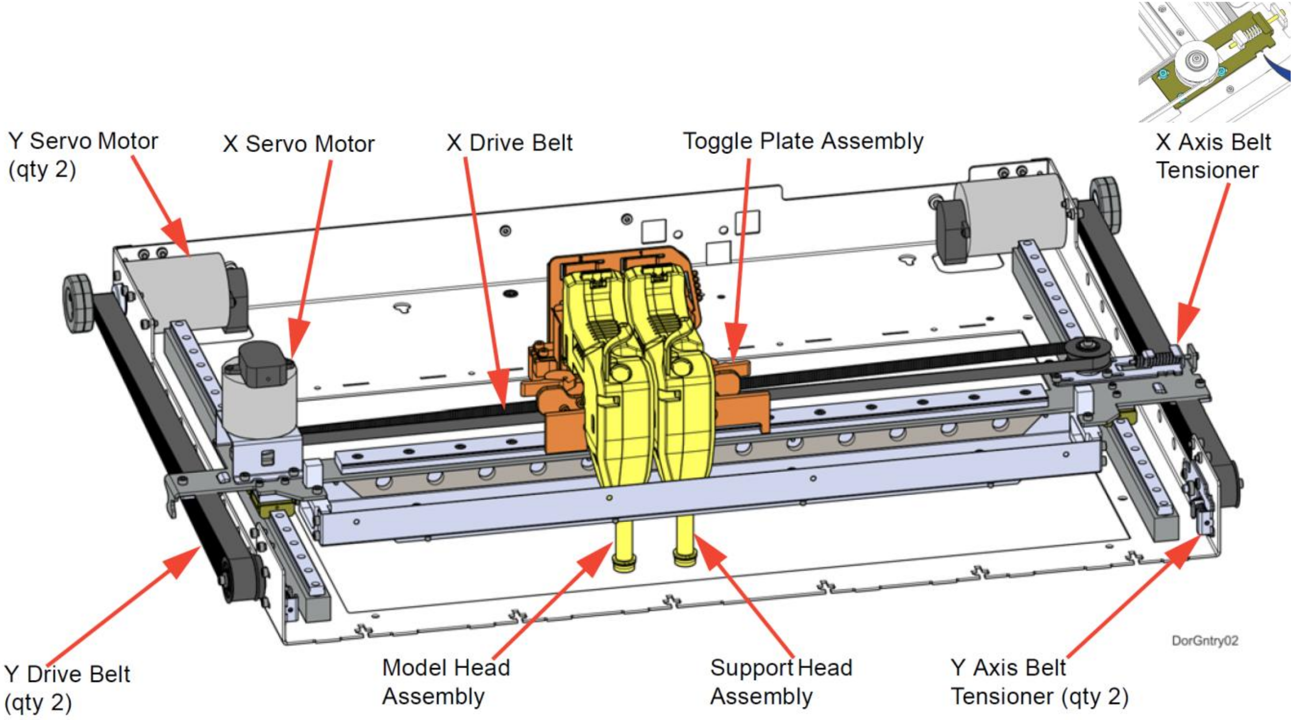


GANTRY VIEW DETAILS

ID	DESCRIPTION	ID	DESCRIPTION
1	Y Motors	7	Y Belt Tension Adjust
2	X Motor	8	Slave Y Rail
3	Model Head Assembly	9	Z Belt
4	Support Head Assembly	10	X Belt
5	Y Belt	11	X Belt Tension Adjust
6	Master Y Rail	12	Z belt Tension Adjust



GANTRY



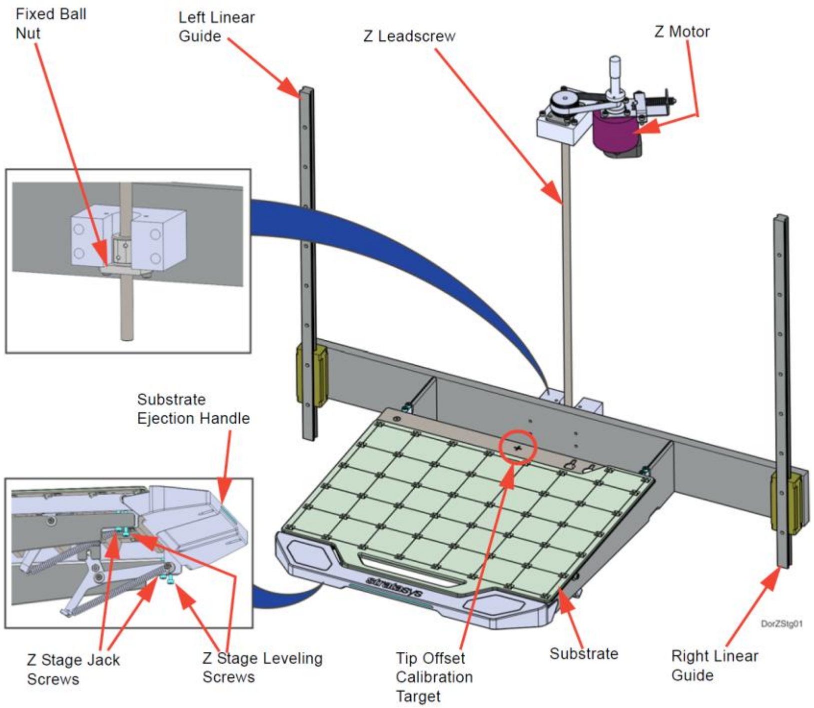
Y Servo Motor
(qty 2)
X Servo Motor
X Drive Belt
Toggle Plate Assembly
X Axis Belt
Tensioner
Y Drive Belt
(qty 2)
Model Head
Assembly
Support Head
Assembly
Y Axis Belt
Tensioner (qty 2)
DorGntry02

ALL NEW Z STAGE

Ball screw (as opposed to a lead screw) driven by a servo with encoder, connected via timing belt.

Profiled linear rails

Belts kept tensioned by springs



HEAD DESIGN

Consumable low mass head design optimized for multiple materials, layer heights, and easy replacement

- The same head can be used for all 4 layer resolutions (.005/.007/.010/.013), excluding PLA

Average head life ~ 1 year

Manual cable connection to head with locking mechanism

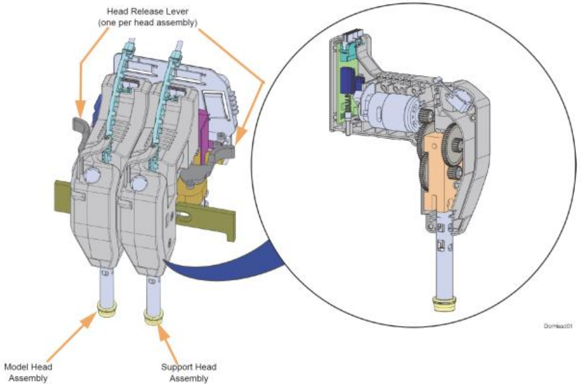
Motor performance and life monitoring

Dual zone heating to achieve throughput close to Fortus 400mc

Customized heating parameters based on tool path behaviors

The same head can be used for most model materials and support

- Once used as Model, can only be used as Model until EOL
- Once used as Support, can only be used as Support until EOL



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SEPARATE HEADS FOR PLA ONLY

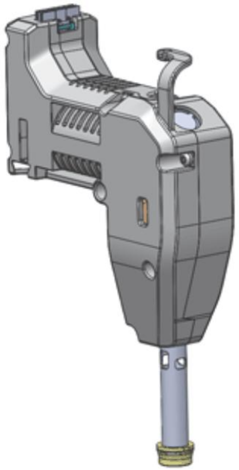
On the Left: PLA Model Head Print head for use with PLA model material only

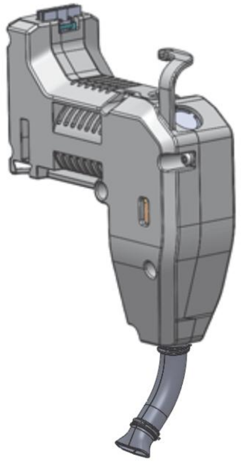
On the right: PLA Cooling Module Cooling module to be used in conjunction with the PLA model head

Unlike the standard head, which has T14 tip. The PLA head has a T16 tip

PLA is only available at a resolution of .010”

PLA Material requires a separate cooling head along with an additional head used only for cooling the support at point of contact





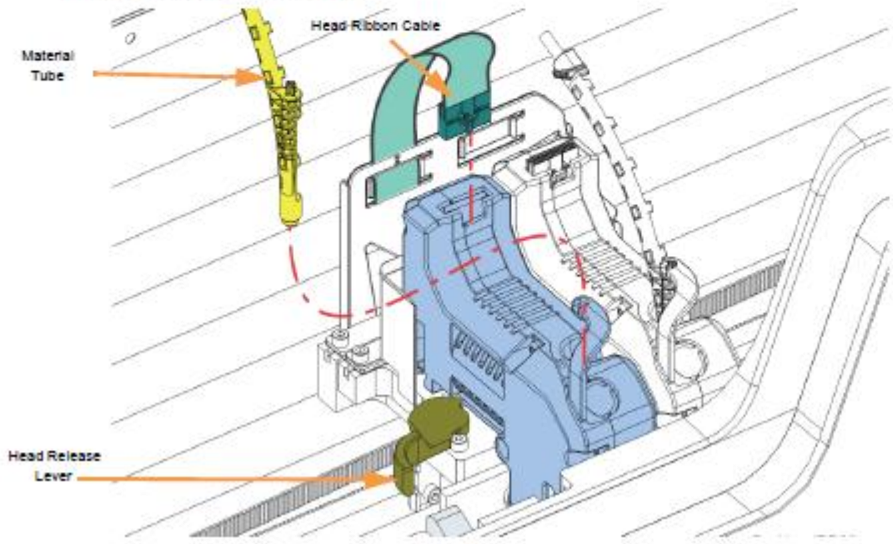
HANDS-ON ACTIVITY 5.2: HOW TO CHANGE PRINT HEADS

Download the Activity Worksheet from the Module 5 Resources section. Note: Activities: 5.2, 5.3, 5.4, 5.5, 5.7, 5.8 are on one worksheet.

Reference F123 Series User Guide in RESOURCES section.

Follow the directions to remove the ABS and Support Heads and replace with PLA heads.

Figure 5-11: Head Connections



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MATERIAL DRIVE SYSTEM

User feeds tail into bay drive block for automatic load to head

Fixed center D-drive grabs filament for 270°rotation, releases for 90°

After load, D oriented to disengage from filament

Material drive controller board:

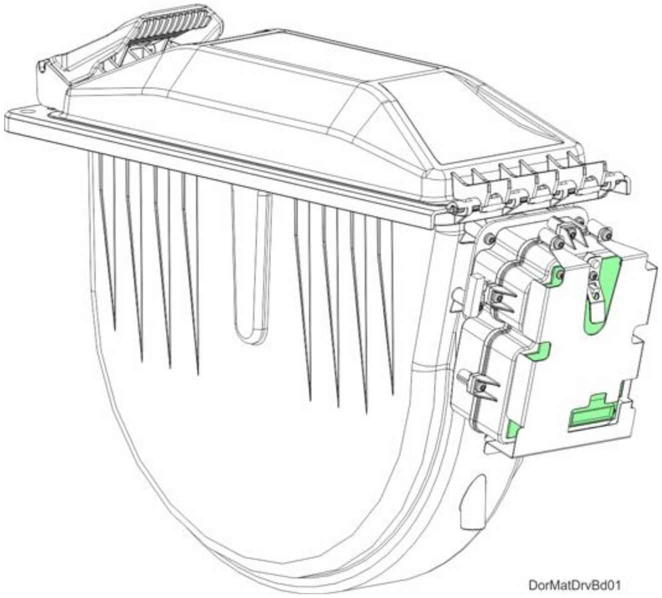
Auto-load and auto changeover of filament

Sense filament presence

Sense spool presence

Sense D-wheel position for material loading/unloading

Interface with spool interface



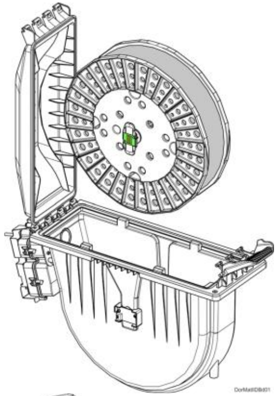
MATERIAL HANDLING

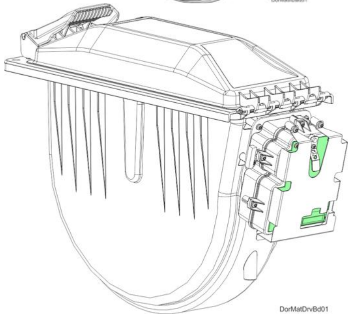
Each material bay is a low permeability drybox.

- This means that there is no active drying system

Proper storage of materials is critical.

- When removing spools from the system, put them into the Mylar bag immediately.
- For extended non-use periods greater than 72 hours, unload the material from the head and wind back onto the spool. Store in the material bay.
- Environments with high humidity should unload the material after 36 hours
- For extended non-use periods greater than 2 weeks, unload the material, store the material, vertically, in an air tight bag and power off the system.



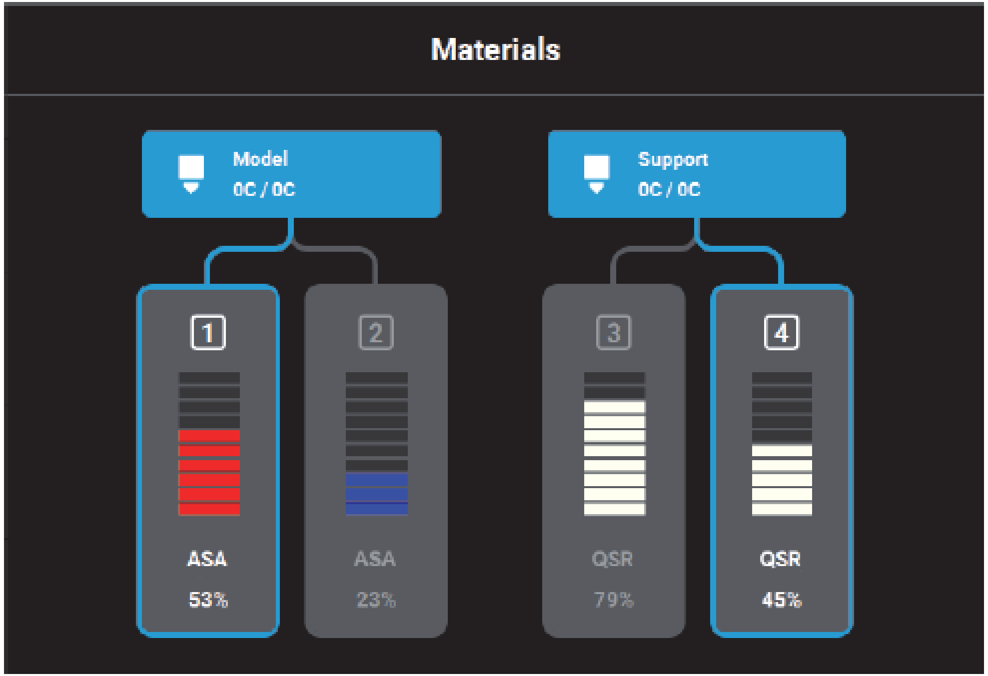


HANDS-ON ACTIVITY 5.3: HOW TO CHANGE F123 MATERIAL

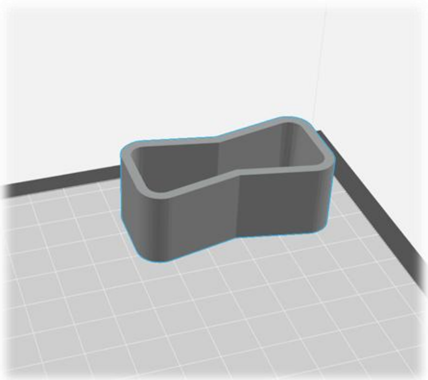
Download the Activity Worksheet from the Module 5 Resources section. Note: Activities: 5.2, 5.3, 5.4, 5.5, 5.7, 5.8 are on one worksheet.

Reference F123 Series User Guide in RESOURCES section.

Follow the directions to remove the ABS material spool and replace with PLA.



PURGE PART

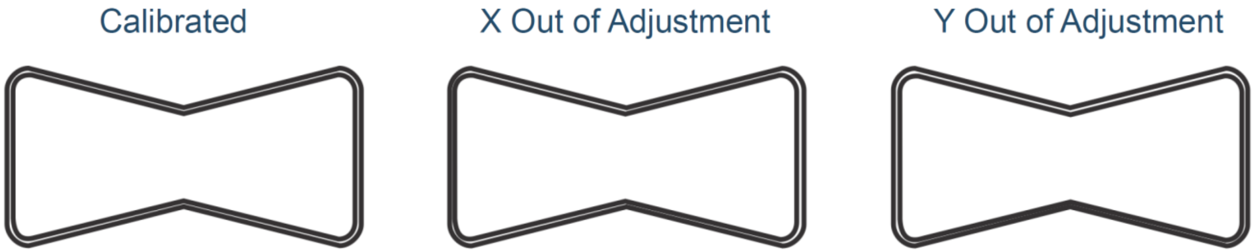


Every print requires a purge part.

- The use of a purge part enables:
  - Faster head swaps
  - Better control of purge material (conditions the liquefier) which ensures part quality.

Best Practice: Place the purge part close to the first part in the pack or next to the tallest part.

- The purge part can be used to verify tip offset calibration and can therefore be used to eliminate that variable when troubleshooting. (Examples included below)



USER INTERFACE

Touch screen interface

F123 SERIES - FDM

CALIBRATION

CALIBRATION - WHEN TO CALIBRATE

After material and tip replacement (required by software)

Before a long build, an important build or time critical builds

If part quality changes

- Monitor your parts
  - If you see part quality change/deteriorate
  - If you have a build failure

Also recommended:

- Power Failure or Reboot
- After machine has been off for a period of time
- Monthly at a minimum

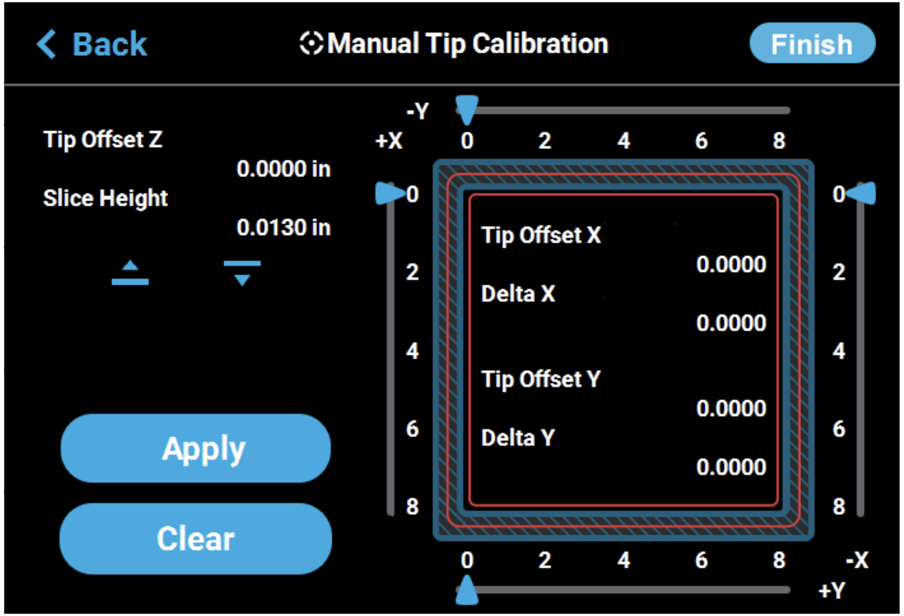
HOW TO CALIBRATE - MANUAL TIP CALIBRATION

This calibration requires you to analyze a calibration part once it's built, and manually supply the printer with correction values, as needed, in order to calibrate the printer.

The location of the calibration part is fixed.

When should you manually calibrate:

- After replacing the head.
- If you are seeing issues after using the automatic calibration.

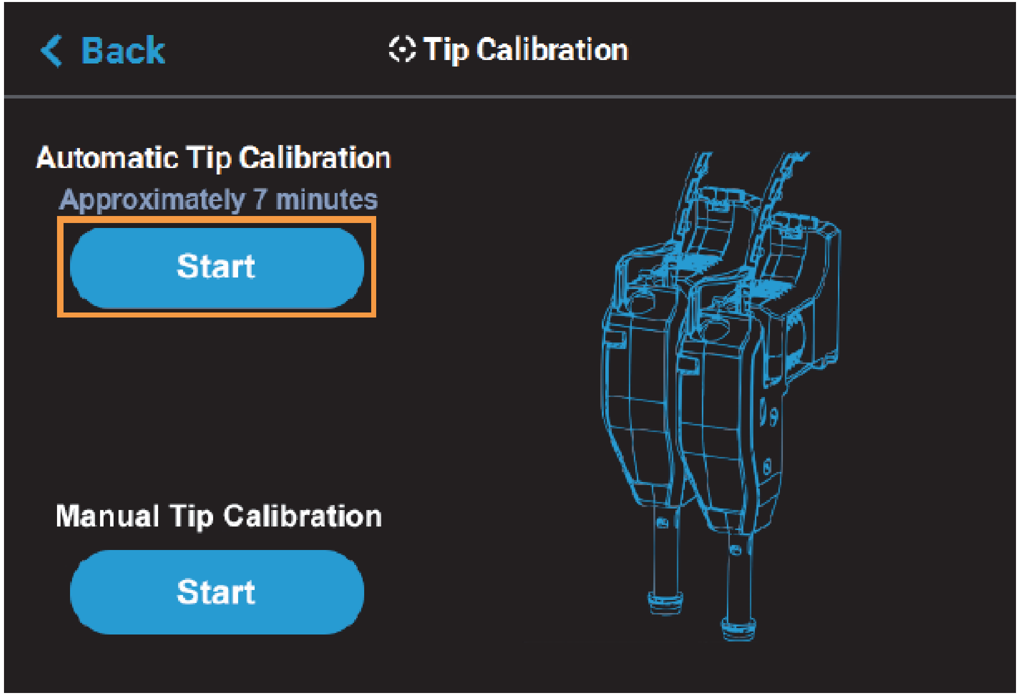


HANDS ON ACTIVITY 5.4: RUN CALIBRATION F123 Series

Download the Activity Worksheet from the Module 5 Resources section. Note: Activities: 5.2, 5.3, 5.4, 5.5, 5.7, 5.8 are on one worksheet.

Reference F123 Series User Guide in RESOURCES section.

Follow the directions to run a calibration.



F123 SERIES - FDM

REVIEW

REVIEW – F123

https://www.youtube.com/watch?v=gwmbP0Lqkog&t=3s

INTRODUCTION TO FORTUS FDM PRINTERS

FORTUS® PRINTERS

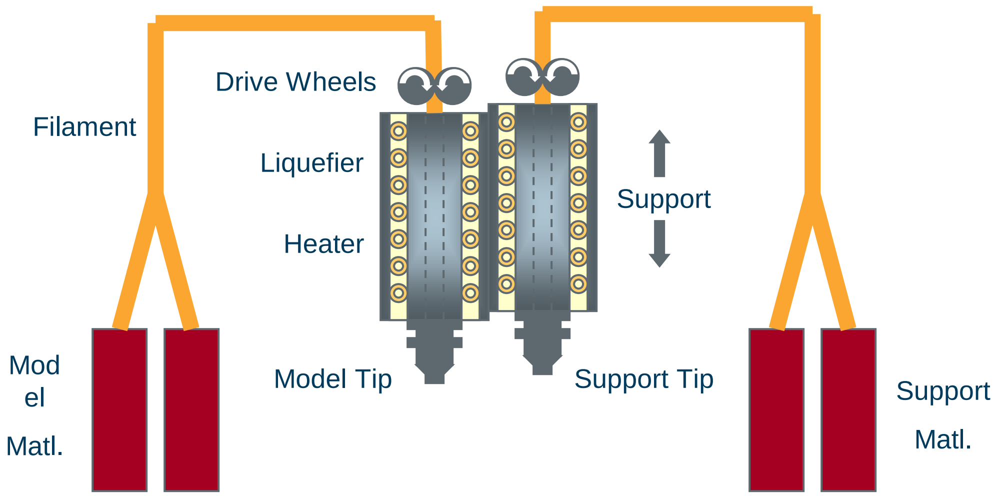
Fortus 380mc™

Fortus 380CF™

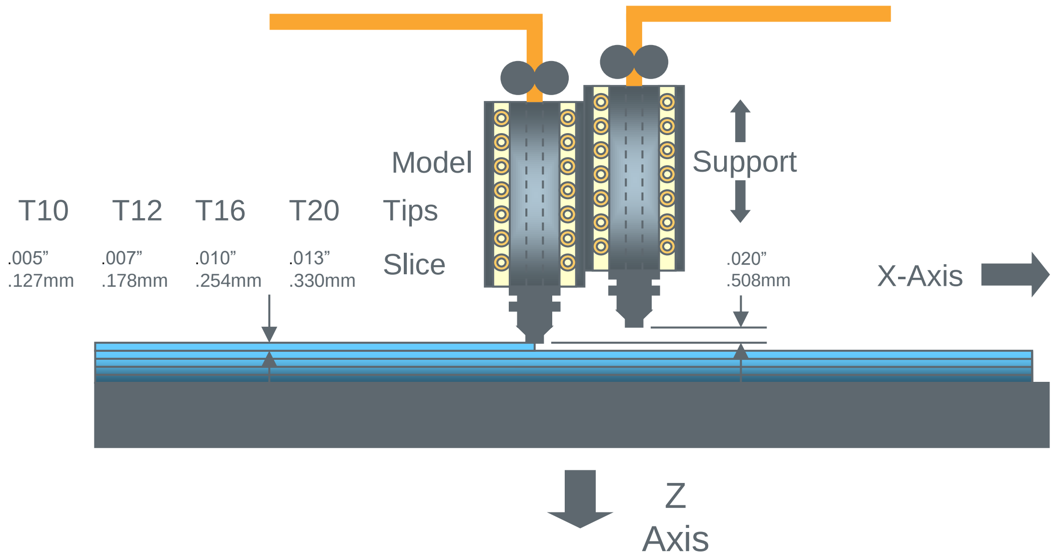
Fortus 450mc™

Fortus 900mc™

FORTUS SYSTEM MATERIAL DRIVE



FORTUS SYSTEM Z-SLICE



FORUTS 450MC - FDM

PRINTER SPECIFICATIONS

FORTUS VIDEO

https://www.youtube.com/watch?v=YsRBwIM95xI

ABOUT THE FORTUS 450 MC

Envelope size/Build Volume:

16 x 14 x 16 inch
(406.40 x 355.60 x 406.40mm)

Material canister bays: 2 model, 2 support

Touchscreen graphical user interface

SYSTEM SPECFICATIONS

OTHER SPECIFICATIONS	
Systems Size and Weight	129.5 cm x 90.2 cm x 198.4 cm (51 x 35.5 x 78.1 in.) 601 kg (1325lbs.)
Achievable Accuracy	Parts are produced within an accuracy of ± .127 mm (± .005 in.) or ± .0015 mm/mm (± .0015 in/in), whichever is greater). Z part accuracy includes an additional tolerance of -0.000/+slice height. Note: accuracy is geometry dependent. Achievable accuracy specification derived from statistical data at 95% dimensional yield.
Network Communications	10/100 base T connection. Ethernet protocol.
Operator Attendance	Limited attendance for job start and stop required.
Power Requirements	208VAC 3 phase, 50/60 Hz, consumes 18 Amps
Regulatory Compliance	CE
Software	All Fortus systems include insight™ and Control Center™ job processing and management software.
Operating System	Microsoft Windows 8.1 and Windows 8 (Pro, Enterprise), Microsoft Windows 7 (Pro, Enterprise, Ultimate), Microsoft Windows Vista (Business, Enterprise, Ultimate), Microsoft Windows Server 2008, Microsoft Windows Server 2003

MATERIAL OPTIONS

Standard

- ABS-M30 (all colors), ABS-M30i, ABS-ESD7, and ASA (all colors) model material with SR-30 support material

Engineering

- PC, PC-ISO, and Nylon12 model material with associated PC_S, SR-100 and SR-110 support materials

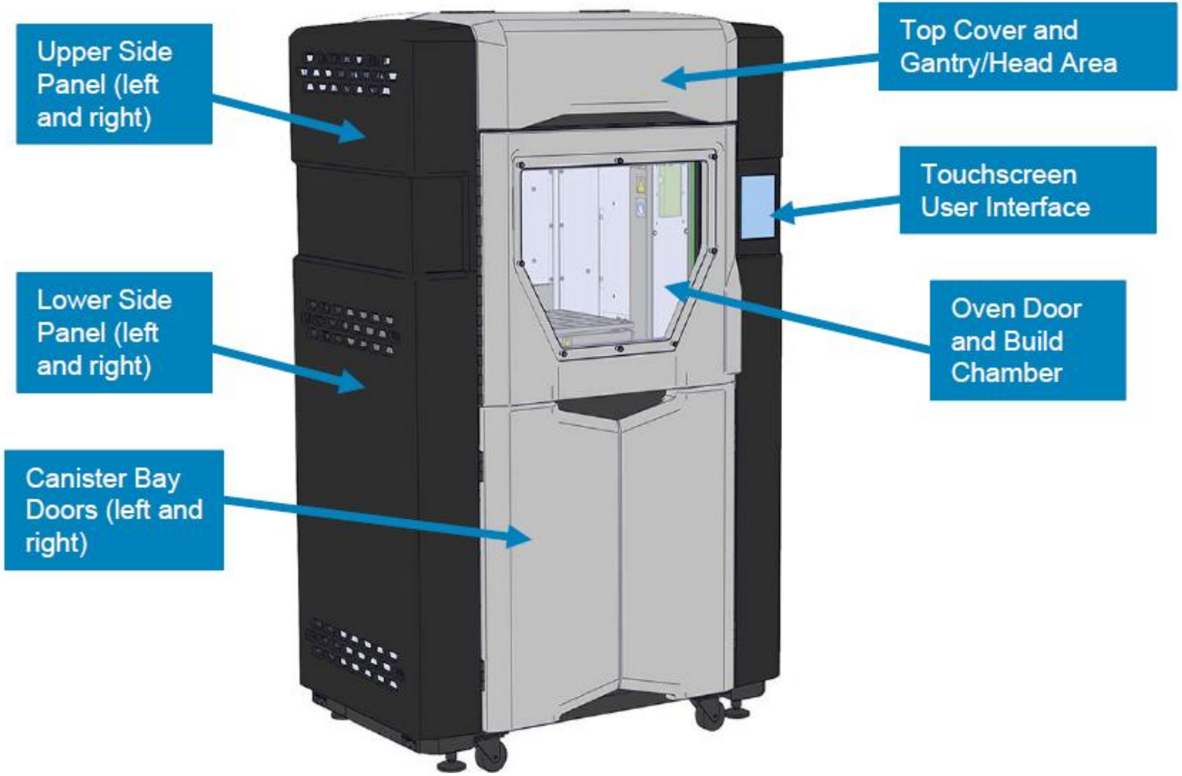
High Performance

- ULTEM 9085 and ULTEM 1010 model material with associated Ultem support material (ULT_S)

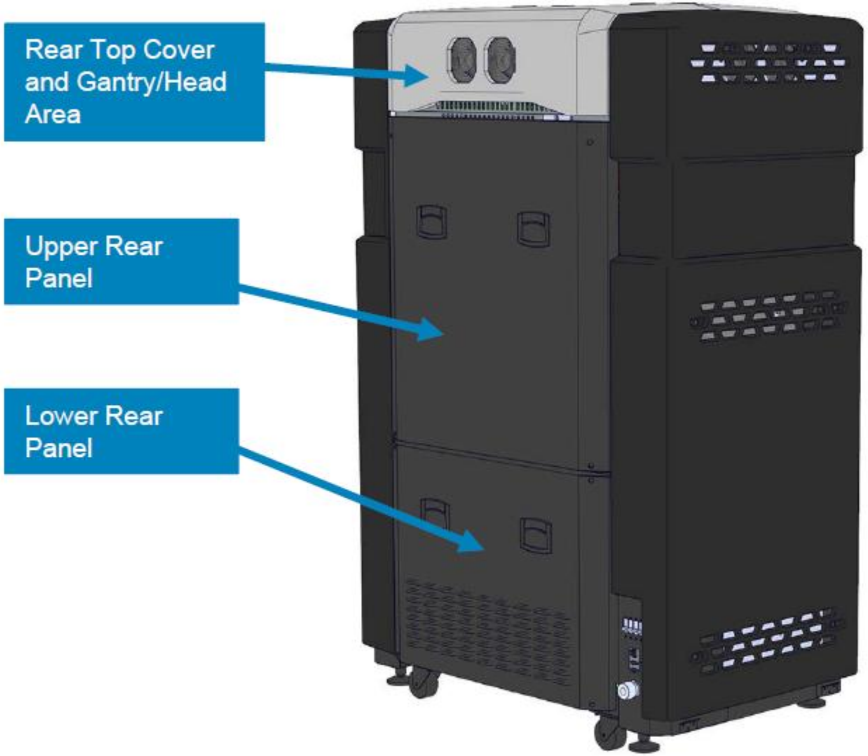
FORUTS 450MC - FDM

PRINTER COMPONENTS & DEMO

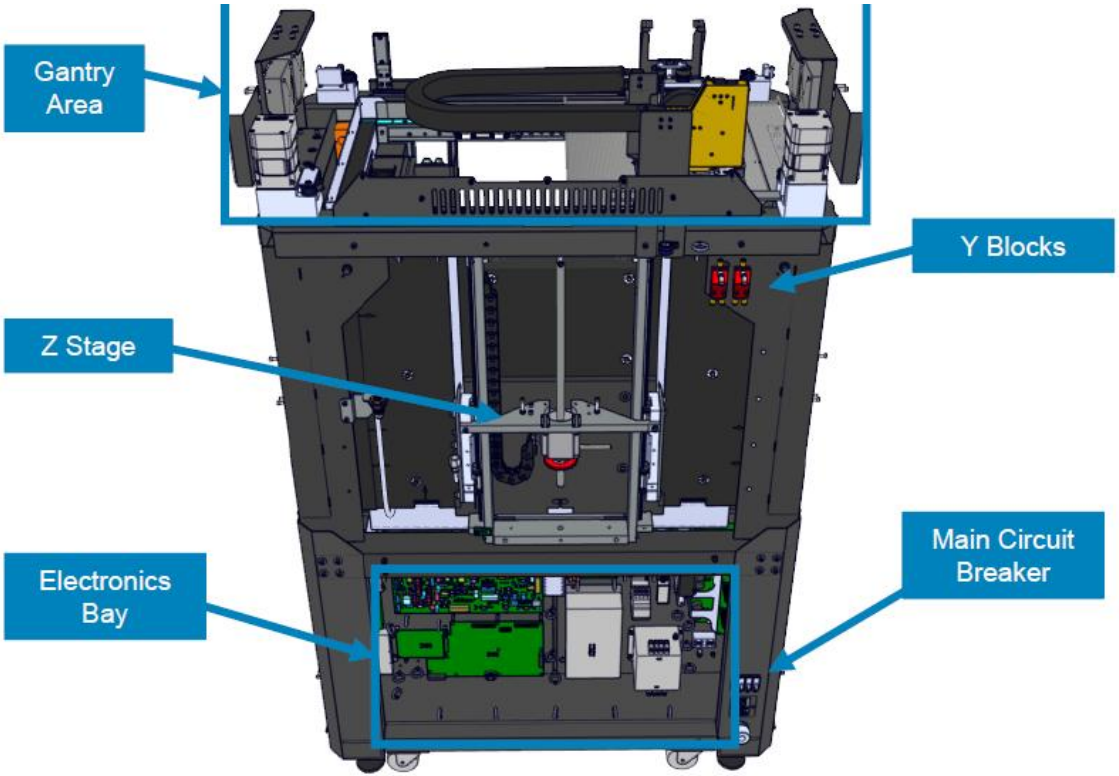
FORTUS 450 – FRONT VIEW



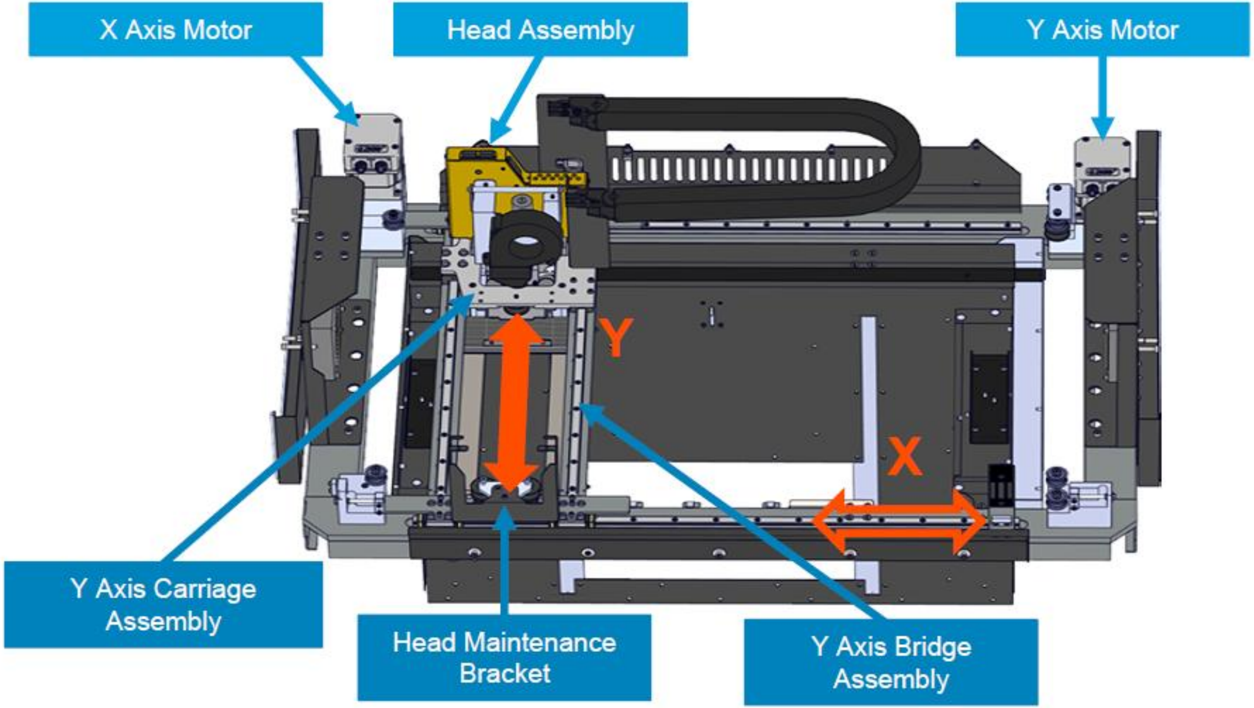
FORTUS 450 – REAR VIEW



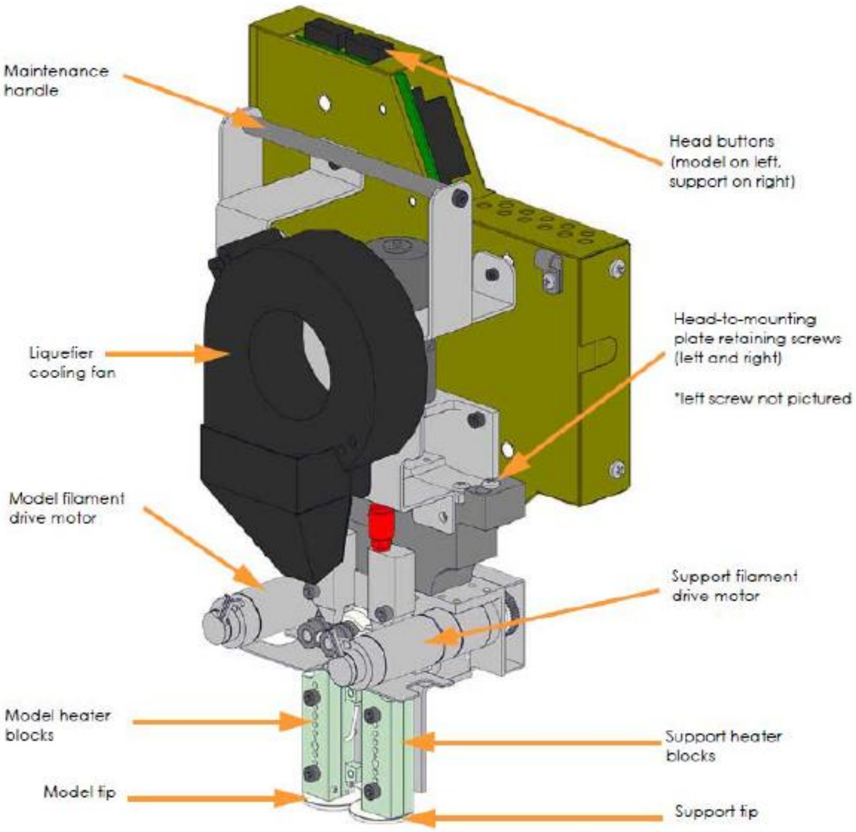
REAR VIEW INSIDE



FORTUS 450 GANTRY



HEAD ASSEMBLY



TIPS

10, T12, T14, T16, T20

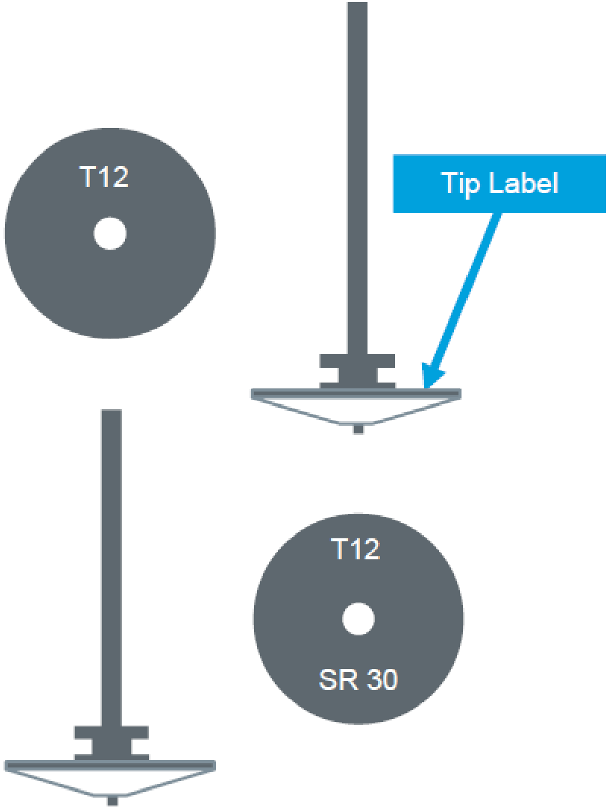
All model materials

Breakaway support materials

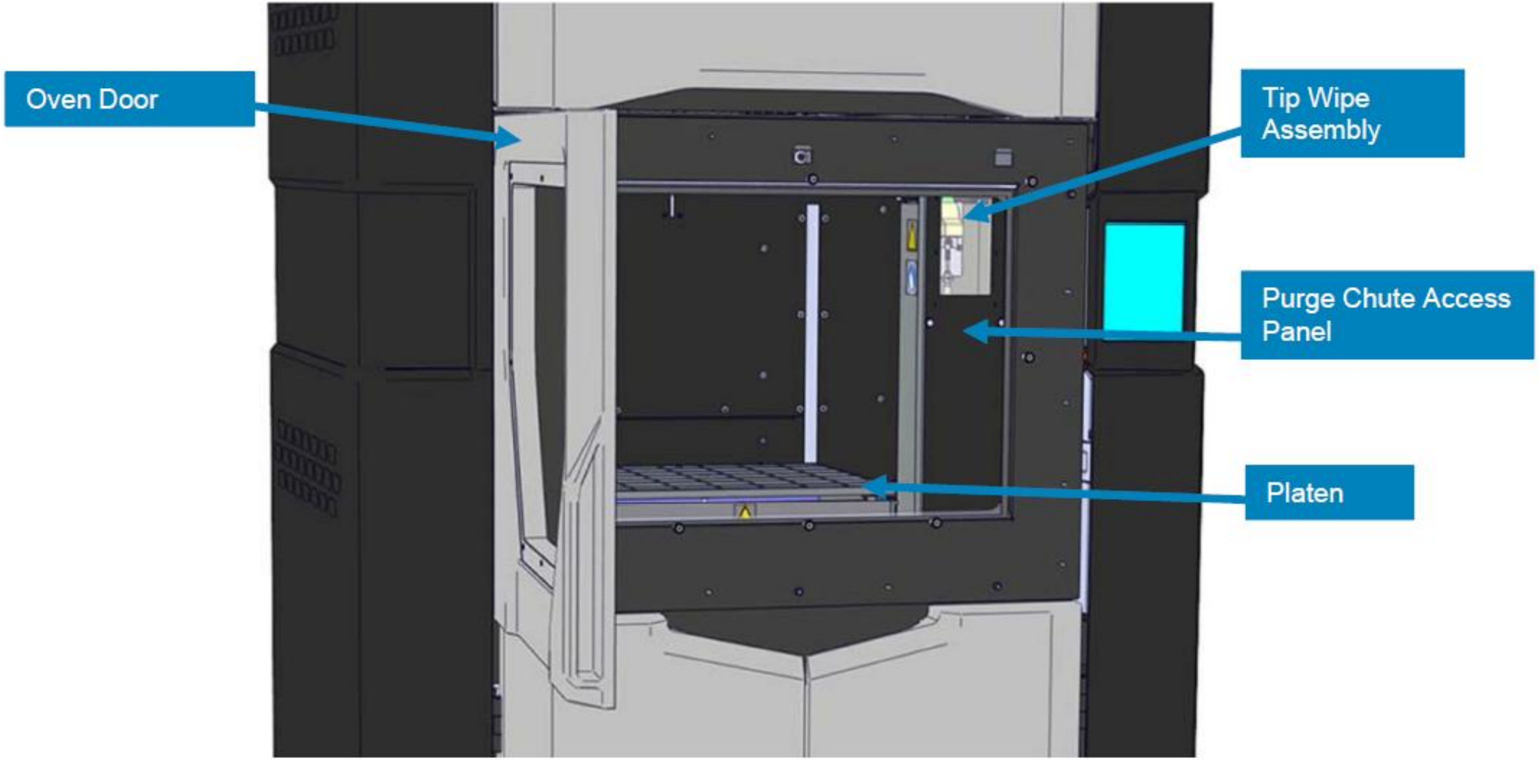
T12 (SR 20, SR 30, SR 100, SR 110)

All soluble support material

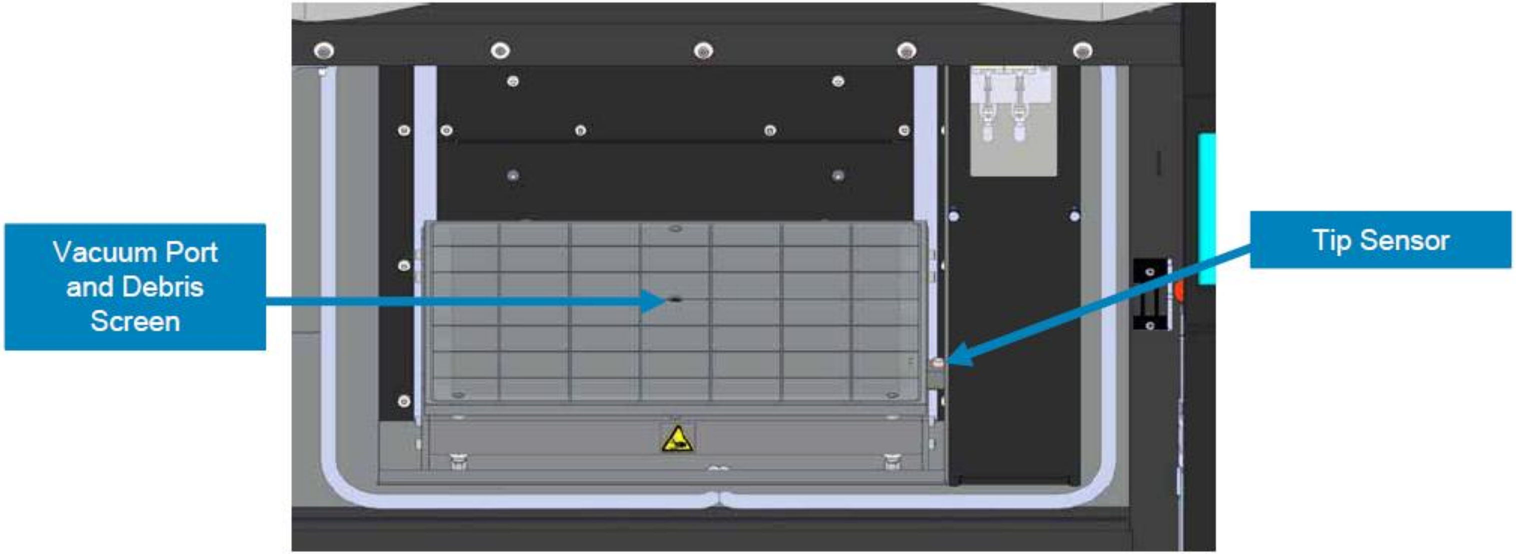
Slightly shorter liquefier



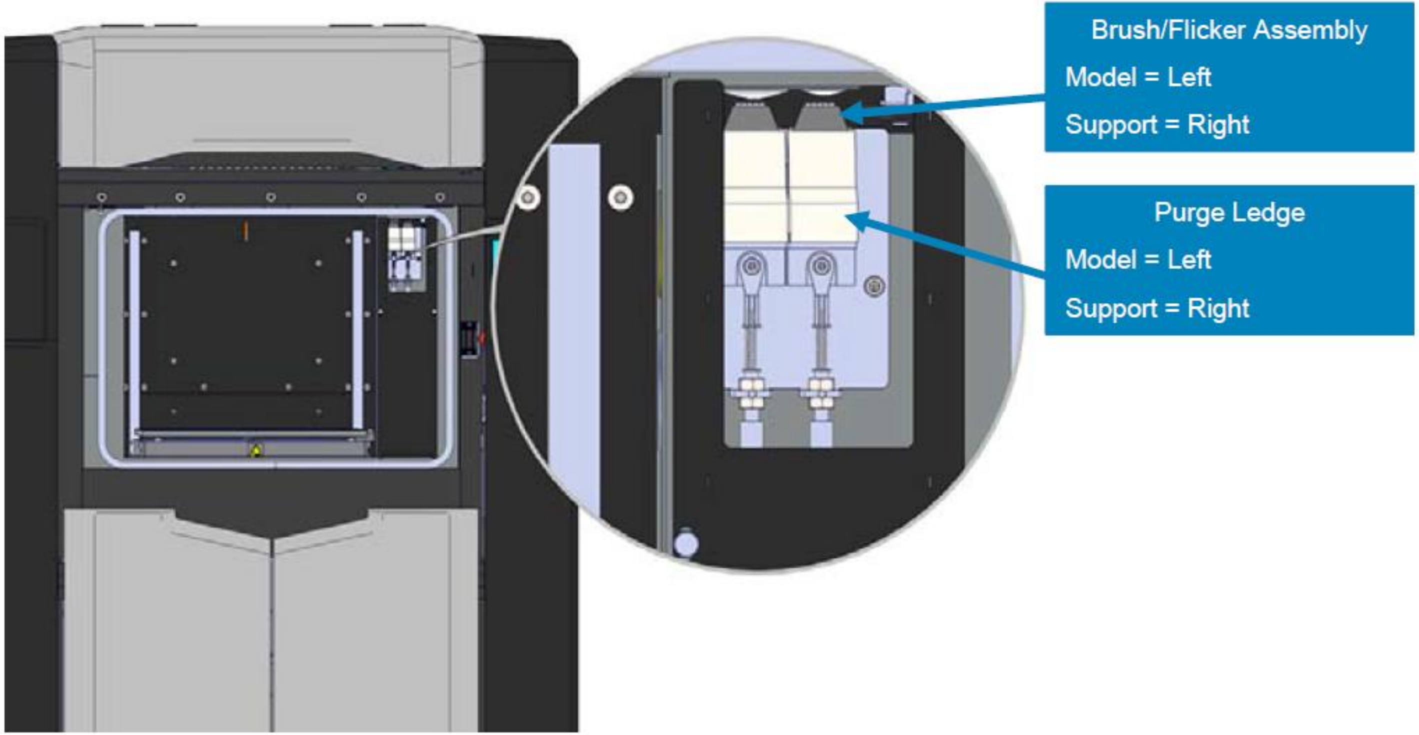
OVEN


Oven Door
Tip Wipe Assembly
Purge Chute Access Panel
Platen

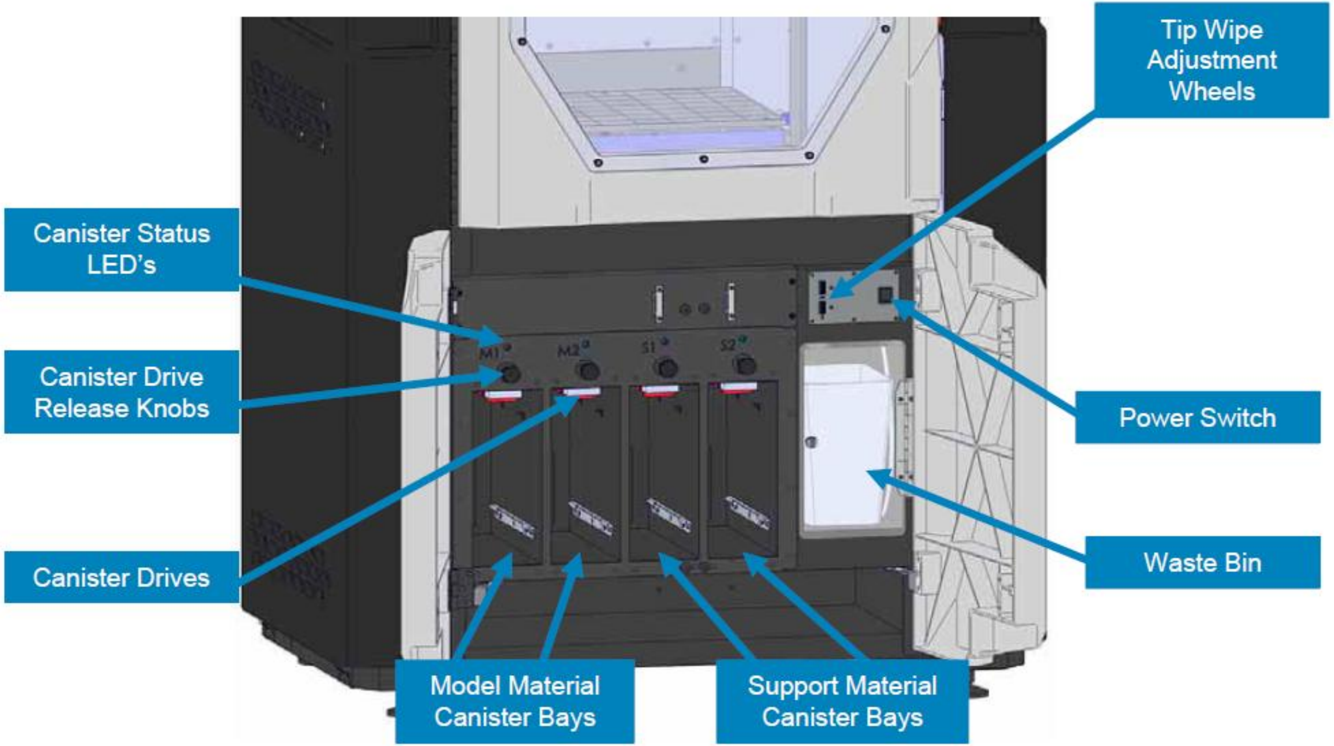
PLATEN



BRUSH FLICKER ASSEMBLY



CANISTER BAY AREA



MATERIAL CANISTERS

Can be removed and reinstalled

EPROM chip contains

- Type of material
- Amount of material

Extra material for 10 load/unload cycles

VIRTUAL TOUR: FORTUS IN ACTION

https://www.youtube.com/watch?v=n32DQJYqjLg

FORUTS 450MC - FDM

CALIBRATION

CALIBRATION - WHEN & WHY TO CALIBRATE

WHEN?

After material and tip replacement (required by software)

Before a long build, an important build or time critical builds

Monitor your parts

- If you see part quality change/deteriorate
- If you have a build failure

Also recommended:

- Power Failure or Reboot
- After machine has been off for a period of time
- Monthly at a minimum

WHY?

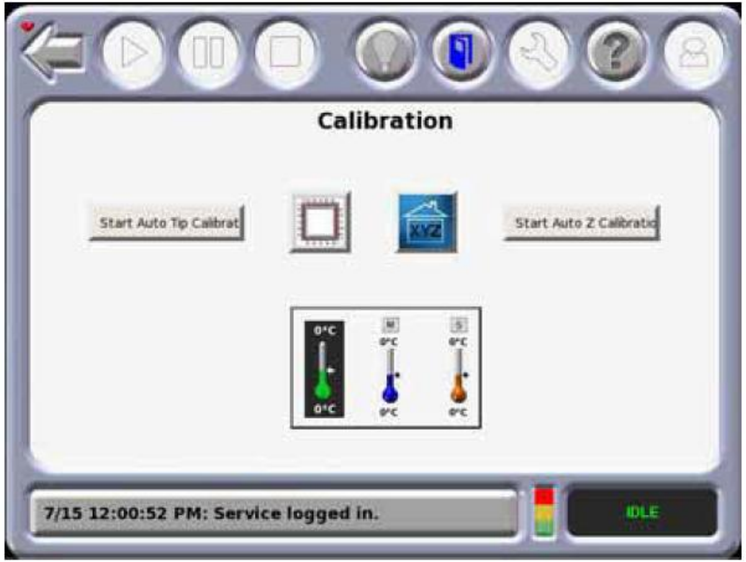
It only takes a few minutes of time to:

- Protect part quality
- Avoid build problems
- Increase efficiency

SYSTEM CALIBRATIONS

4 Types of Calibrations:

- Auto Home XYZ
- Auto Z Calibration
- Auto Tip Calibration
- XYZ Tip Offsets Calibration



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AUTO HOME XYZ

Automatic Procedure to set home position for axes

Perform after:

- Reboot or power up
- Error or pause due to limited movement in gantry or
- Z-stage
- Overfill or part curl condition
- Parts tipped over
- Does not require build sheet and vacuum to be present

AFTER TIP CHANGE

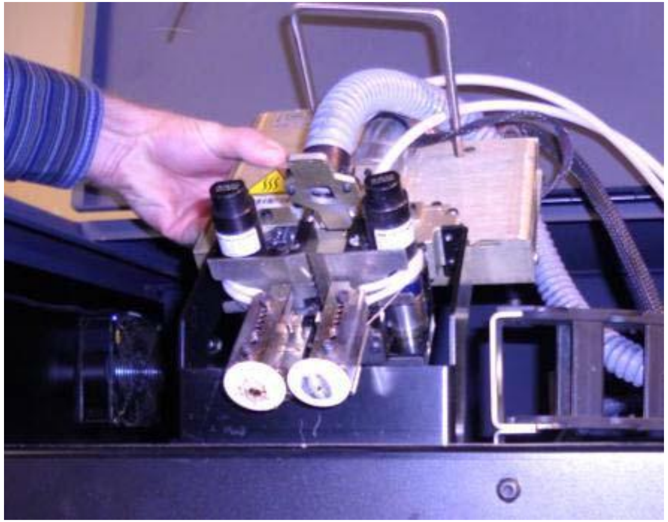
2 options while changing tips

Tip Change Wizard – Recommended

- Runs through all necessary calibrations
- Only requires user input at very end

Manual calibration

- Requires user input after each step
- 3 main steps are:
- Auto Z Zero Calibration
- Auto Tip Calibration
- XYZ Offsets or Calibration Job



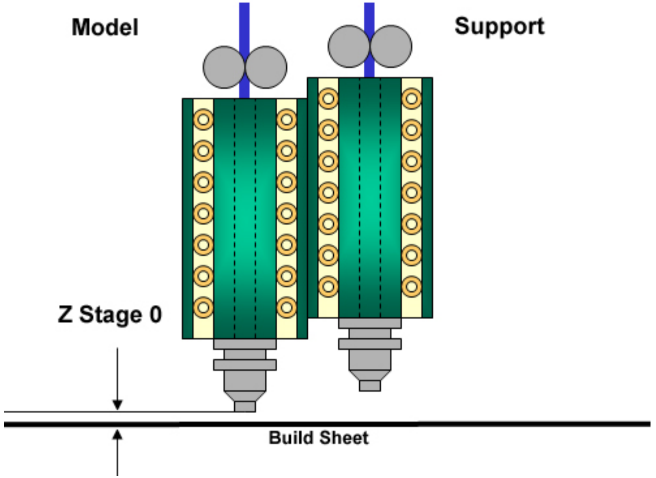
Z ZERO CALIBRATION

Sets Model Tip to the top of the Build Sheet

- Too high – parts can shift or tip over
- Too low – overfill, tip plugging, and/or loss of vacuum

Auto Z Zero Calibration

- Must be run after tip change
- Only calibration that runs prior to EVERY build (unless User Placement set to off)
- Build sheet not required to be present



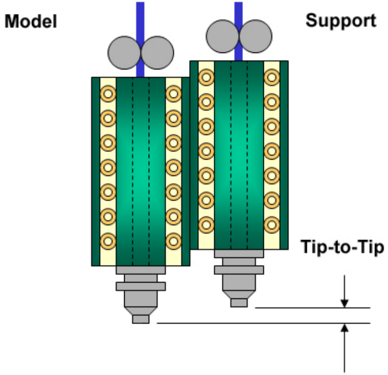
AUTO TIP CALIBRATION AND XYZ TIP OFFSET CALIBRATION

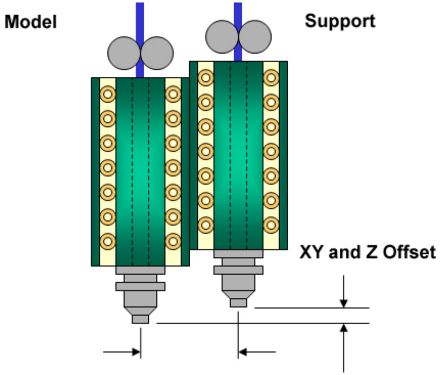
Auto Tip Calibration

- Performs as part of tip change wizard
- Coarsely sets tip-to-tip offset in Z direction
- Registers support tip relative to model tip

XYZ Tip Offsets Calibration (Calibration Job)

- Run after Auto Tip Calibration
- Verifying and fine-tuning of offsets
- Manual procedure requiring operator interaction after job completes

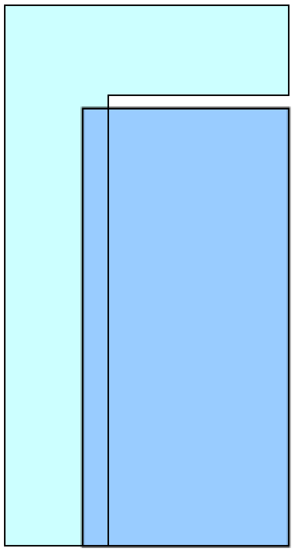




XYZ OFFSET

If poorly calibrated:

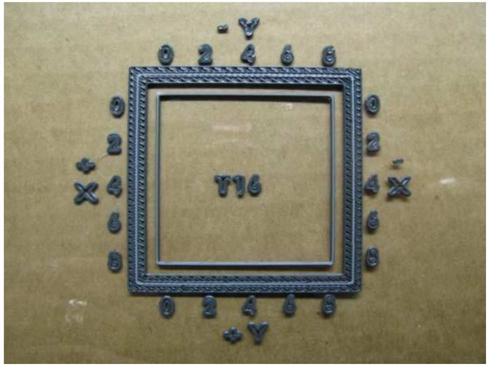
- Improper gap between part and supports
- Embedded or features not properly supported
- Part quality issues and/or failures
- Can be run anytime to begin diagnosing issues

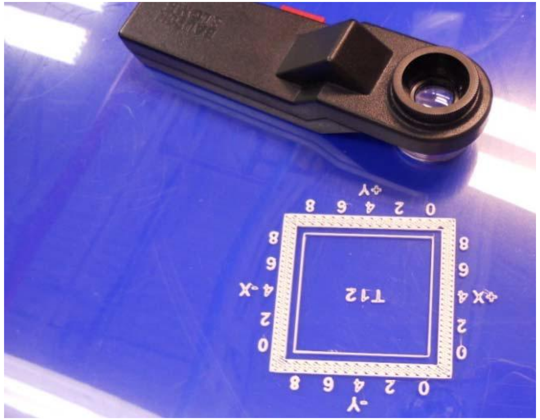


XYZ OFFSET CALIBRATION

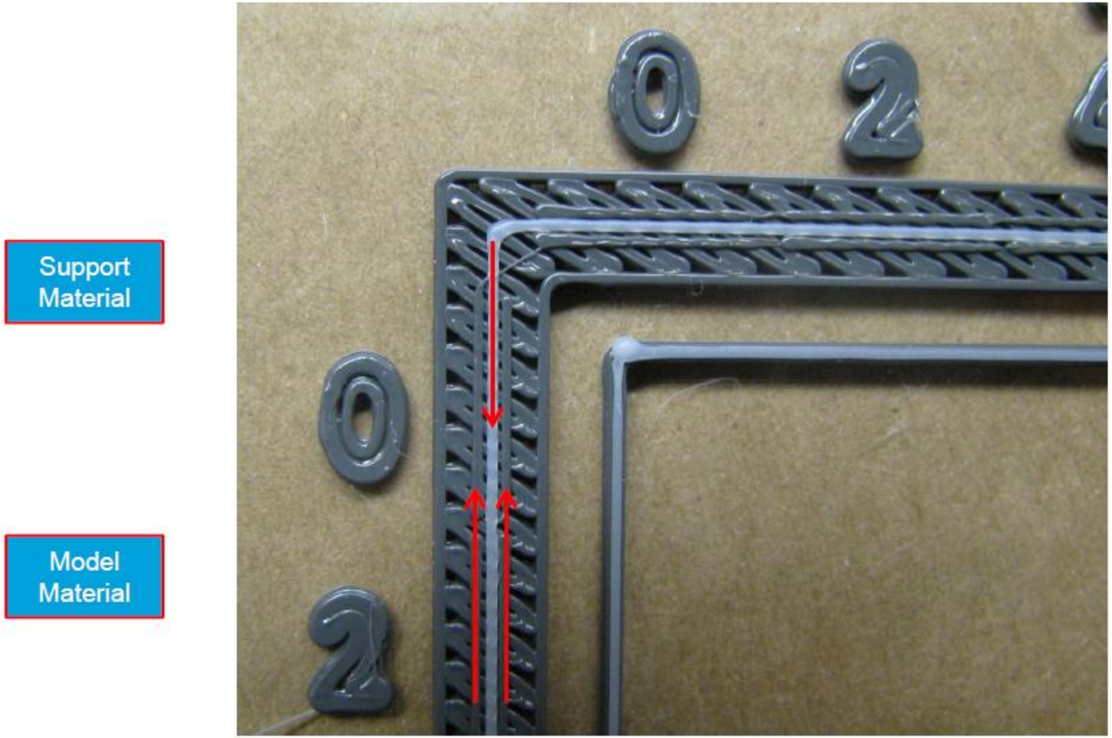
Procedure Overview

- Build calibration job
- Review part under magnification
- Input XY offsets
- Repeat as necessary
- Only after XY offsets are acceptable
- Measure for Z offset
- Input Z offset
- Repeat as necessary





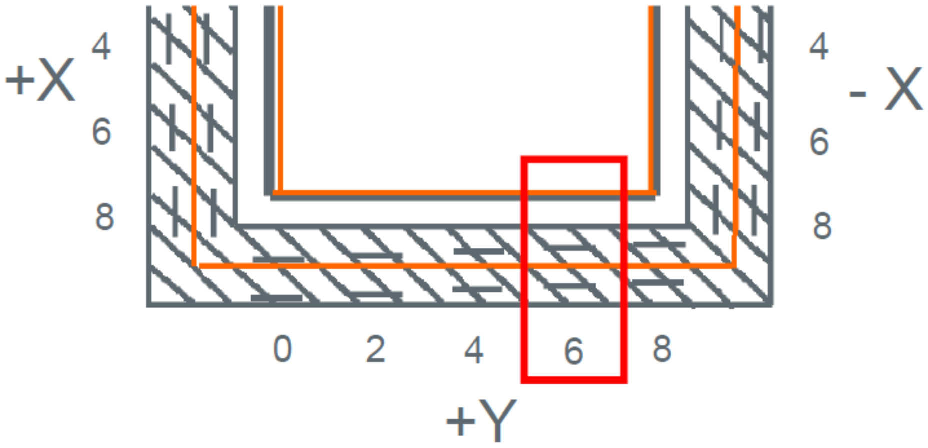
CALIBRATION MAGNIFIED VIEW



CALIBRATION JOB – X AND Y OFFSETS

Locate point where support toolpath is best centered between two model toolpaths and note nearest X and Y values

- Only 1 value for X and 1 value for Y (positive or negative)



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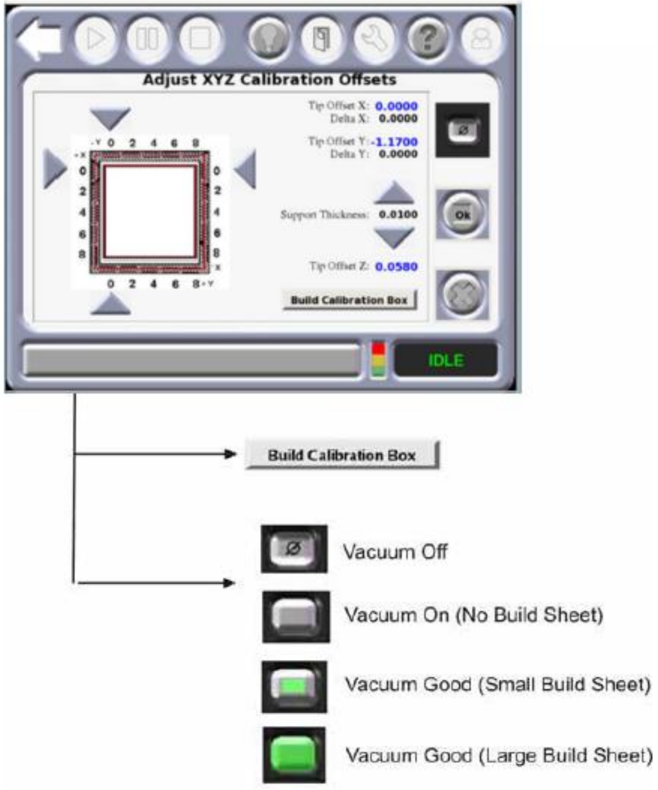
PRINT A CALIBRATION BOX

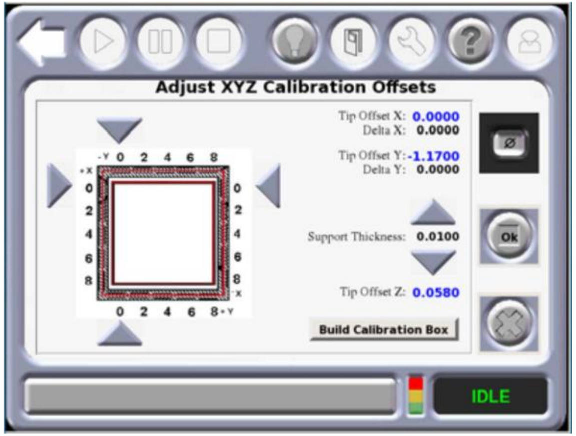
Adjust XYZ Calibration registers the support tip relative to the model tip. The system automatically builds the calibration model when the Build Calibration Box button is pressed.



CALIBRATION JOB – X AND Y TIP OFFSETS

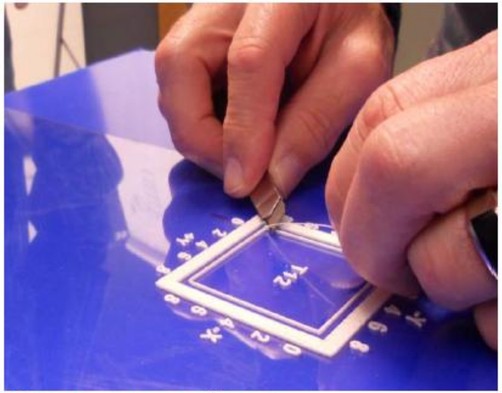
Slide the arrow on the screen to match where the support is most centered.

Only move arrows on two of the four sides of the calibration part.



If either value exceeds ±0.002 in. (±0.05 mm), repeat calibration job
If both values are less than ±0.002 in. (±0.05 mm), proceed to Z offset

ADJUST XYZ CALIBRATION – Z OFFSET



Remove support layer

ADJUST XYZ CALIBRATION – Z OFFSET

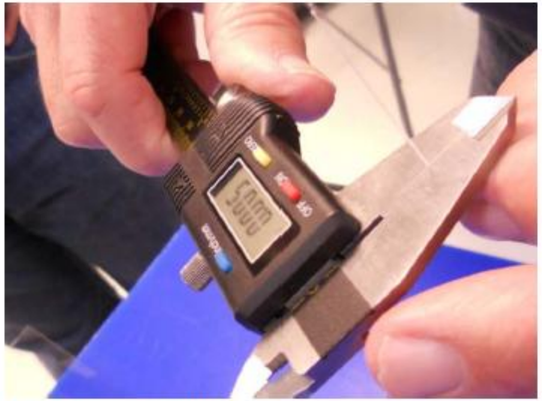
Measure thickness at the center point of each side

- ≤ ±0.0005 in (±0.01 mm) of tip slice height, no adjustment needed
- Enter the value that is read from the caliper for Z in Support Thickness Field

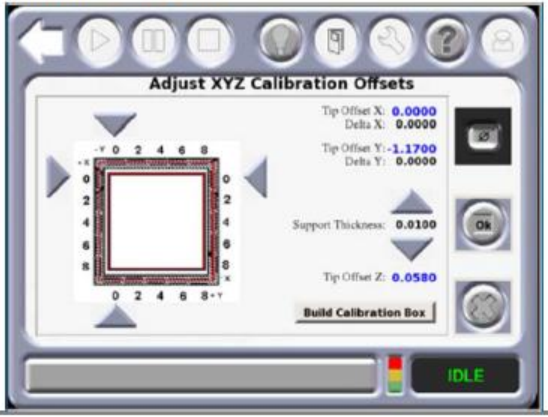
Helpful hint

Indication that Z offset might be too small when:

- Difficult to peel layer
- Layer breaks easily
- Varying measurement



Measure at center



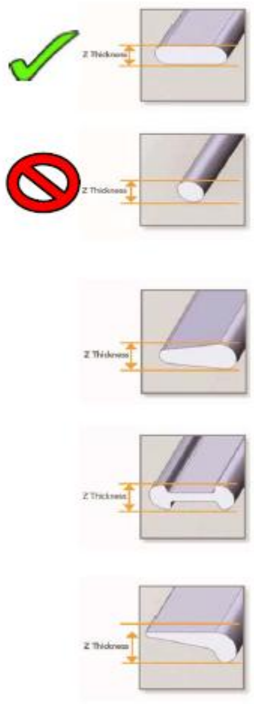
ADJUST XYZ CALIBRATION – Z OFFSET

Confirming accurate Z measurement

- Cut inner box support layer with sharp blade at center of one or more sides

Under magnification, examine profile

- Rectangular or oval – acceptable
- Circular – unacceptable (too big)
- Wedge, dog bone, or rain drop –unacceptable (too small)



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HANDS ON ACTIVITY 5.5: RUN CALIBRATION - FORTUS

Download the Activity Worksheet from the Module 5 Resources section. Note: Activities: 5.2, 5.3, 5.4, 5.5, 5.7, 5.8 are on one worksheet.

Reference Fortus User Guide in RESOURCES section.

Follow the directions to run a calibration.

FORUTS 450MC - FDM

APPLICATION / USE CASES

FORTUS USE CASE

https://www.youtube.com/watch?v=yfe_FkUu_jU

INTRODUCTION TO POLYJET

POLYJET

BENEFITS OF POLYJET

Realistic Finish

Create complex shapes, astonishingly fine details, and smooth surfaces with speed and precision to match the look and feel of your end product. PolyJet is best suited for small parts when accuracy, detail, and surface finish are essential.

Multiple Materials and Colors

PolyJet jets multiple materials and full CMYK colors into a single print allowing for a quick production of realistic parts and design iterations early in the product development process

Greater Choices

With over 100 material combinations to choose from, you can incorporate diverse material properties and aesthetics – including color, flexibility, opacity – directly into your component.

POLYJET TECHNOLOGY BENEFITS

Superior Print Quality

- Ultra-fine 16-micron layers
- High accuracy - 0.1mm
- Thin walls - down to 0.6mm
- Smooth surfaces

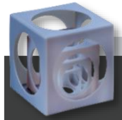
Exceptional Material Versatility

- Over 100 material combinations
- Flexible to Rigid
- Transparent to Opaque
- Standard to Engineering Plastics

STRATASYS POLYJET PORTFOLIO

https://youtu.be/vsYy8z_rOTg

STRATASYS POLYJET MULTI-MATERIAL TECHNOLOGY



2004. Eden

1 Material

Highly accurate, finely detailed models with ultra-thin walls.

2007. Connex

2 Materials

The world's first multi-material 3D printer.

2014. Connex 1/2/3

3 Materials

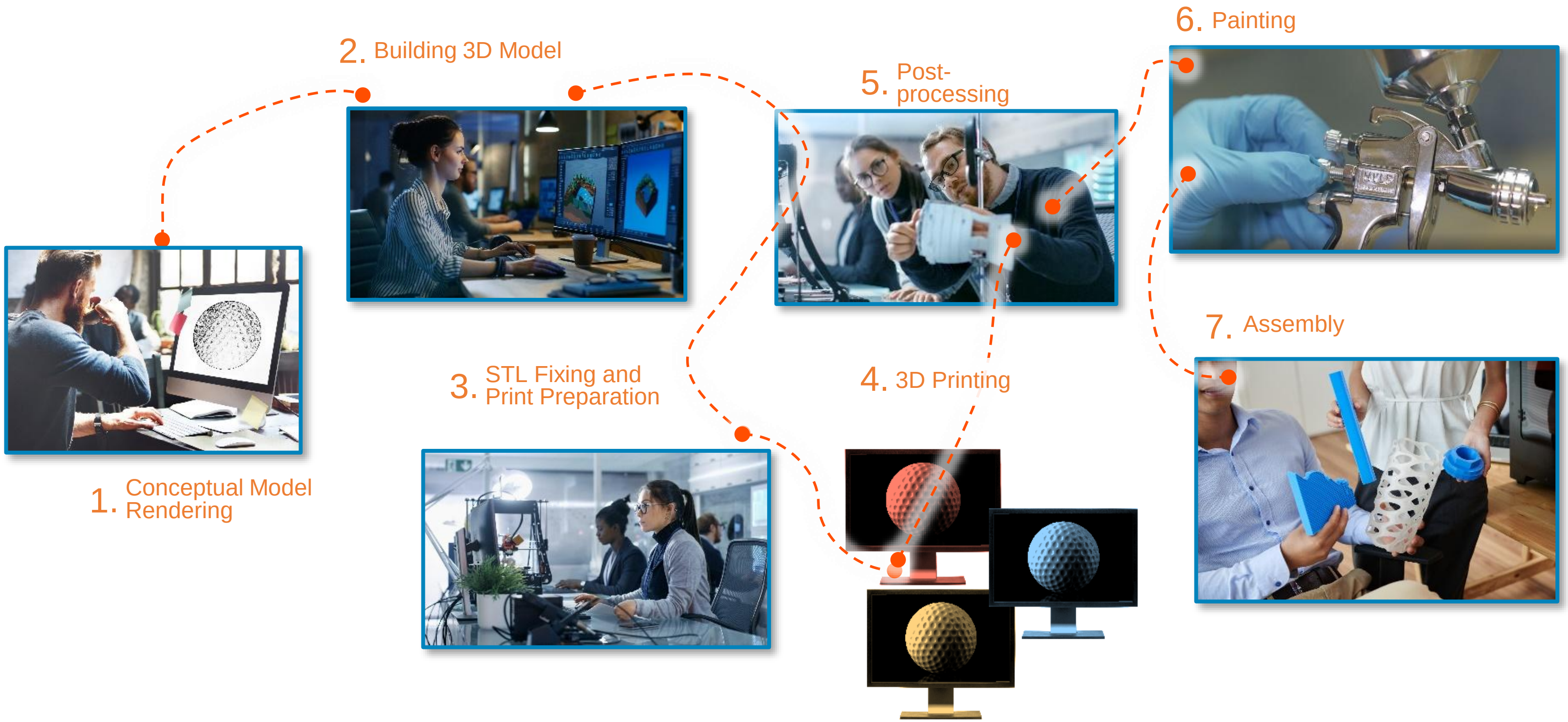
Stratasys introduces the first-ever color and multi-material 3D printer.

2016. J750

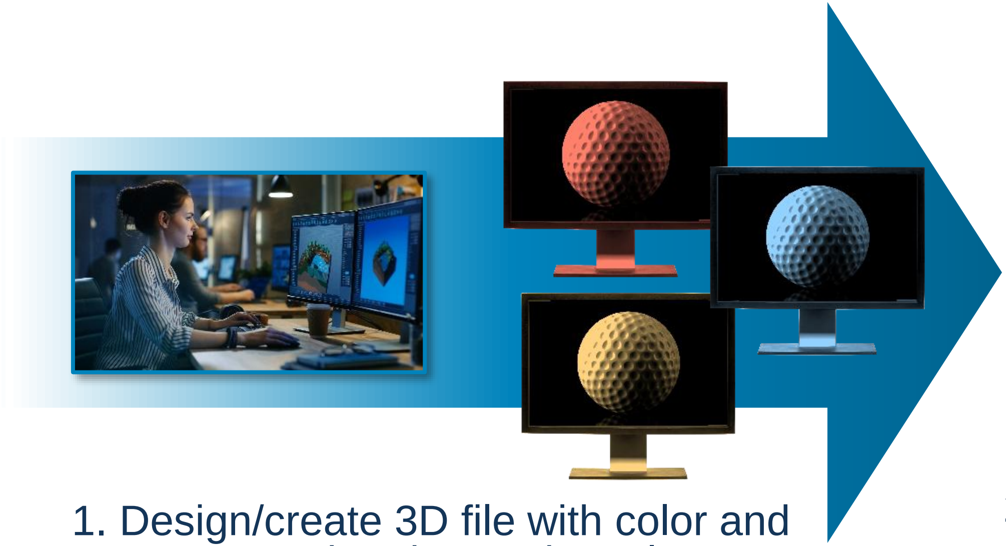
6 Materials

The world’s only full color, multi-material, high resolution 3D printer.

CHALLENGES TO MULTI-MATERIAL: COMPLEX WORKFLOW



STREAMLINED DESIGN-TO-3D PRINT WORKFLOW



1. Design/create 3D file with color and texture in print-ready tools

2. Print-ready files result in finished-part quality, straight off the printer

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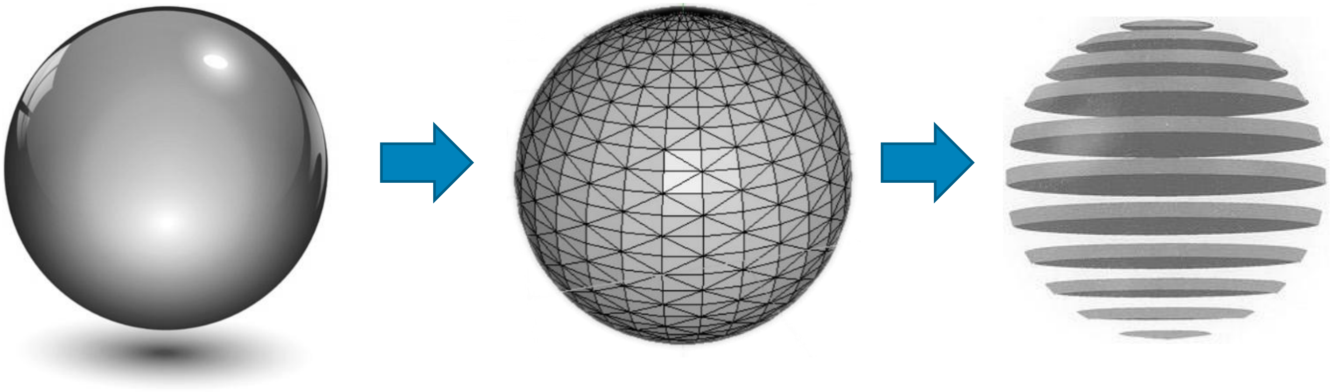
POLYJET TECHNOLOGY

Slicing	PolyJet	Layering (Recoating)	UV Curing



POLYJET TECHNOLOGY

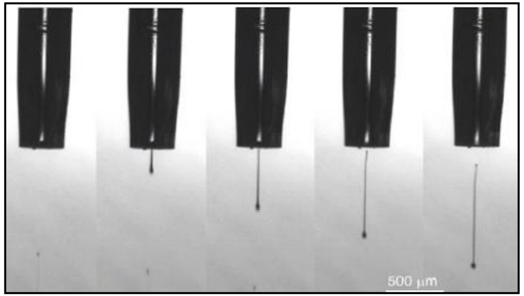
Slicing | **PolyJet** | Layering (Recoating) | UV Curing

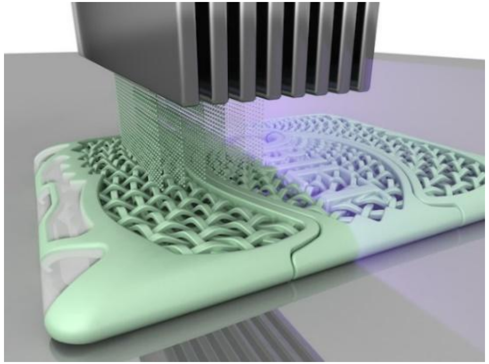
Selective jetting of liquid material (photopolymer) in scanning direction (X /Y axis)

Photopolymer is a polymer that cures, or becomes solid, when exposed to light (in our case: UV or ultraviolet light)

Small drops of ~90NanoGr AND ~10m/sec drop velocity (~36 Km/Hr)

Nozzles diameter: 40 microns





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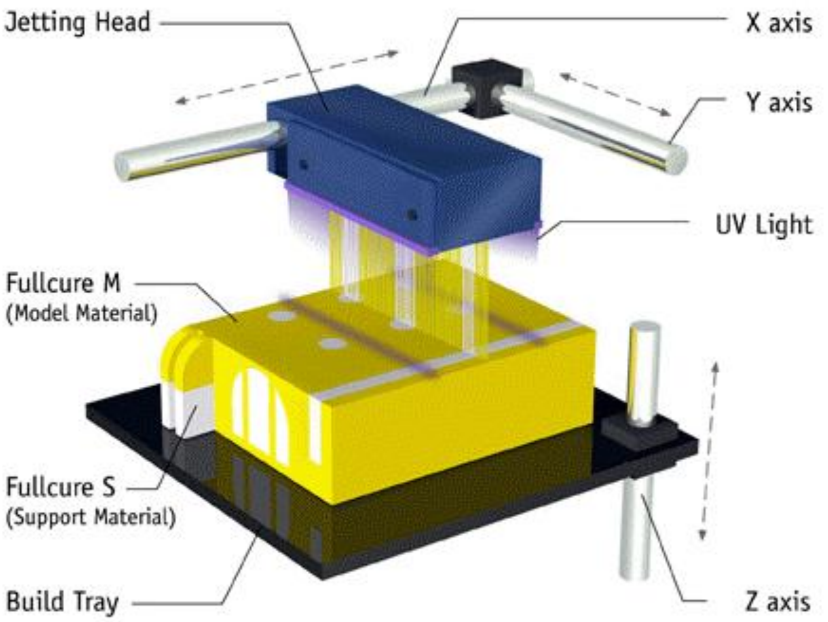
POLYJET TECHNOLOGY

Slicing

PolyJet

Layering (Recoating)

UV Curing



POLYJET TECHNOLOGY

Slicing	PolyJet	Layering (Recoating)	**UV Curing**

Solidifying the liquid (polymer material) by UV

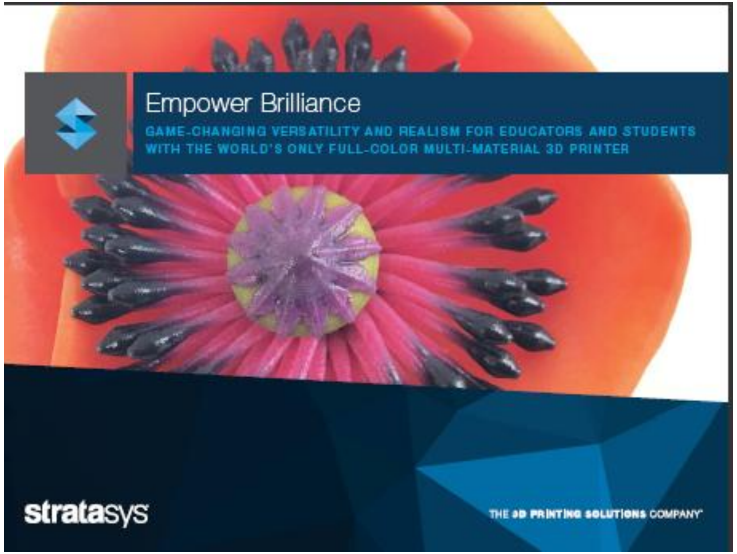
J750 - POLYJET

PRINTER SPECIFICATIONS

ASSIGNMENT

Read the e-book Empower Brilliance–Centered around J750 PolyJet Technology…

(download from the resources section of this module)



STRATASYS J750

https://www.youtube.com/watch?v=HMMJnn_gHWw

STRATASYS J735 and J750 SPECS

SPECIFICATIONS	
MACHINE SIZE (Height, Width, Depth)	Machine: W:140cm (55.1in), H:126cm (49.6in), D:110cm (43.3in) Material Cabinet: W: 67cm (26.4in), H:117cm (46.1in), D:64cm (25.2in)
Machine Weight	Machine: 430 Kg (948lb); Material cabinet: 152 Kg (335lb)
Maximum Build Size (Xyz)	Stratasys J735: 350 x 350 x 200 mm (13.8 x 13.8 x 7.9 in.) Stratasys J750: 490 x 390 x 200 mm (19.3 x 15.35 x 7.9 in.)
Build Resolution	X-axis: 600 dpi; Y-axis: 600 dpi; Z-axis: 1800 dpi
Software	PolyJet Studio: Next generation 3D printing software with new look and feel, full color including gradient and texture mapping through VRML support, and new color selection capabilities. Supported input formats: STL, VRML
Material Delivery Options	Six types of model materials and one type of support material loaded simultaneously. Material cabinet has hot-swap capability for all materials. All materials are available in 3.6 Kg cartridges. Select materials available also in 1.44 Kg cartridges
Workstation Compatibility	Windows 7 and Windows 8.1 64 bit
Power Requirements	- 100–120 VAC, 50–60 Hz, 13.5 A , 1 phase - 220–240 VAC, 50–60 Hz, 7 A , 1 phase
Regulatory Compliance	CE, FCC, EAC

Resolution: 1800dpi

PolyJet Studio: Innovative Software

6 Material Channels

Hot-Swap Materials

STRATASYS J750 MATERIALS

SPECIFICATIONS	
Base Resins	**Vero** family of opaque materials, including various neutral shades and vibrant colors **Tango™** family, rubber-like flexible materials **Digital ABS** and **Digital ABS2™** in ivory and green Transparent: **VeroClear™** and **RGD720**
Digital Materials	Immense number of composite materials can be manufactured: **Digital ABS** **Rubber-like materials** in a variety of Shore A values **Translucent color tints**

Great material versatility

Immense number of composite materials

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J750 loaded with:

- VeroCyan
- VeroMagenta
- VeroYellow
- Vero PureWhite
- VeroBlack

Connex3 loaded with:

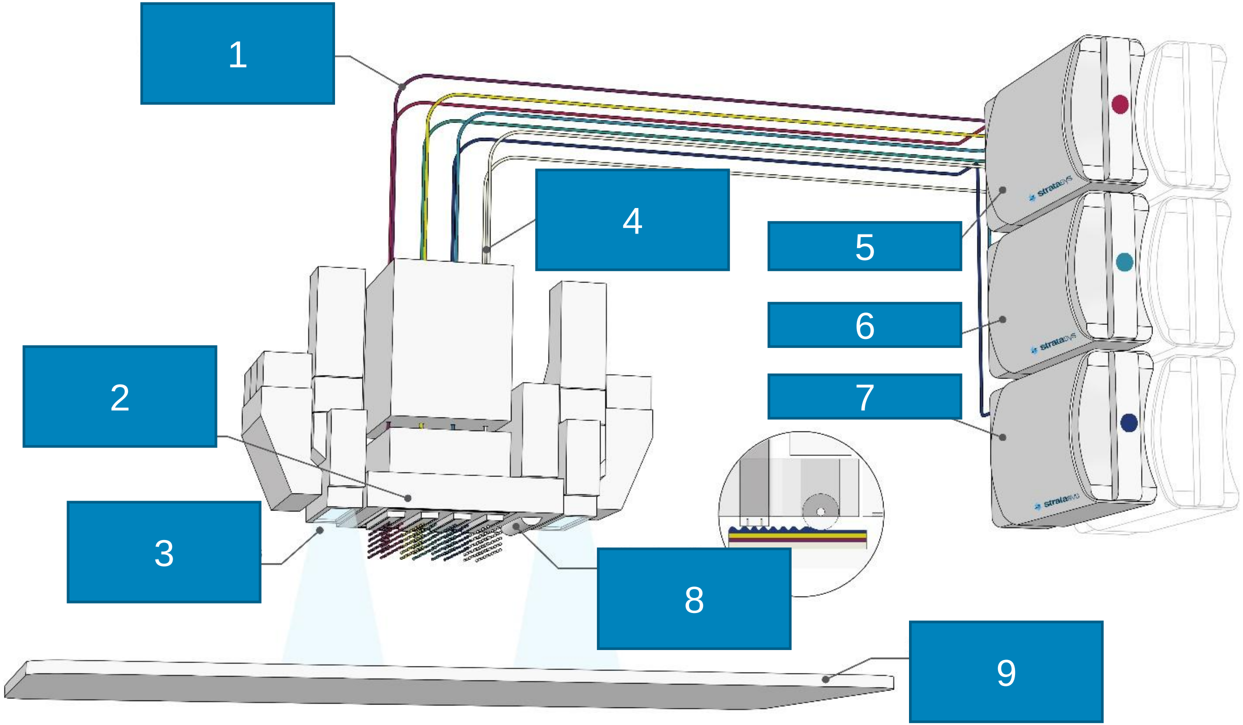
- VeroCyan
- VeroMagenta
- VeroYellow

Why color matters?

J750 PRINTER

ACTIVITY 5.6: LABEL PARTS ON THE J750

Download the activity worksheet in the Resources section of module 5.



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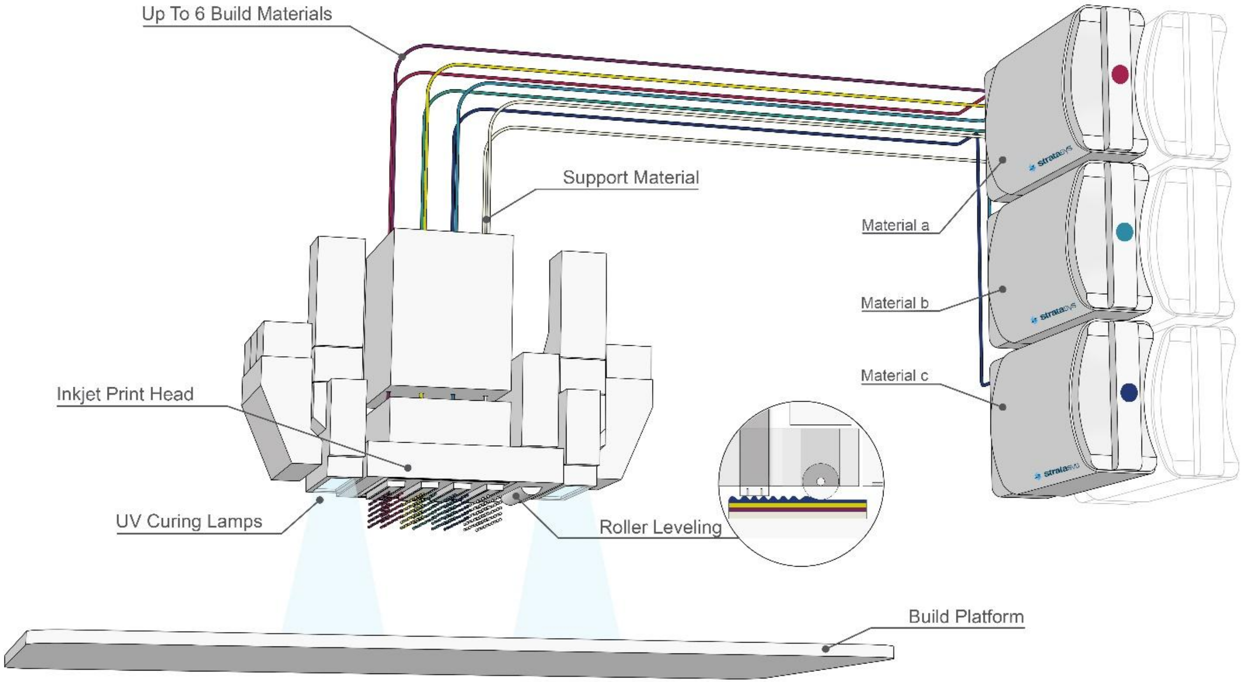
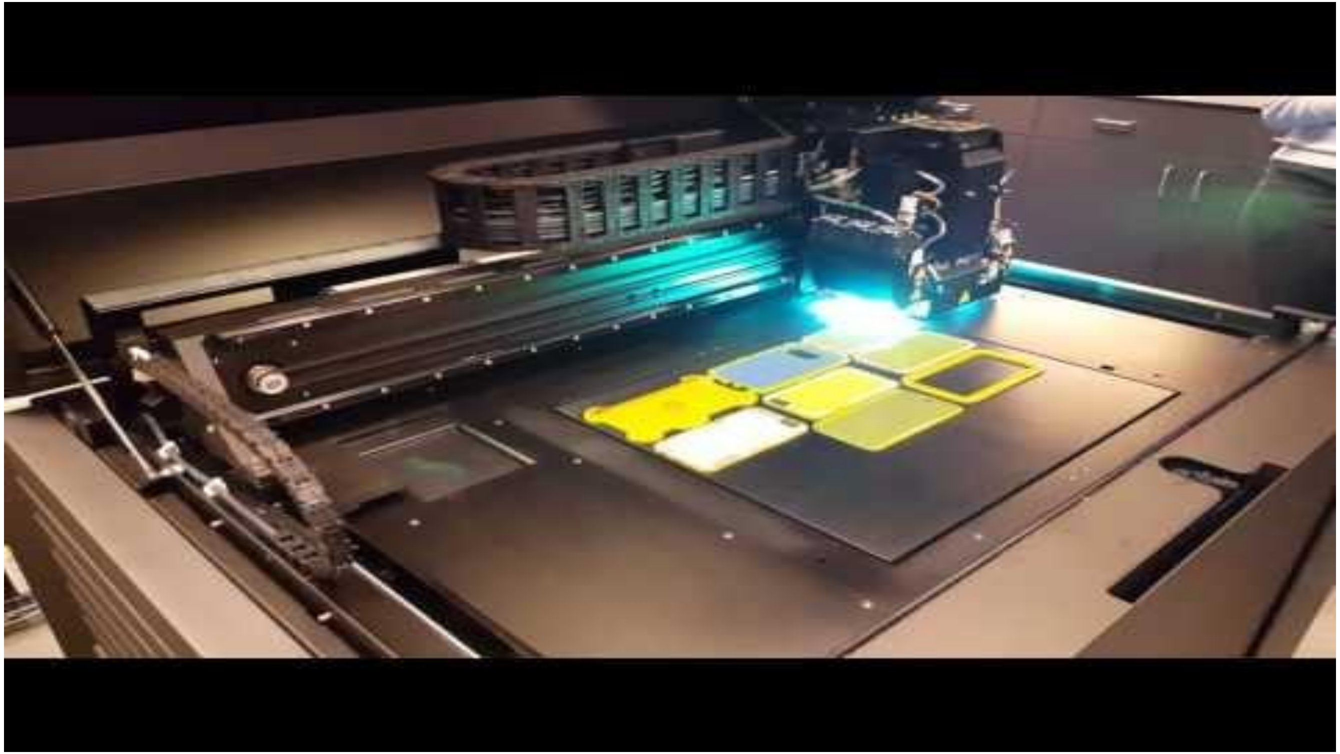
J750 PRINTER



J750 IN ACTION



https://youtu.be/mifFnC3-zuI

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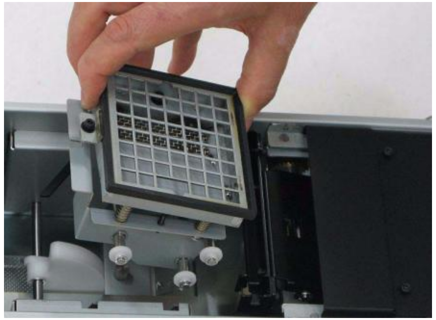
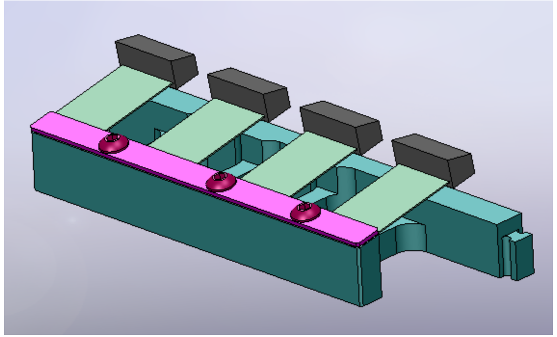
NET & Purge Unit

The wiper removes excess material from the print heads and keeps them clean. The wiper cleaning includes the cleaning of the waste trap, the Purge Unit.

Purge Unit

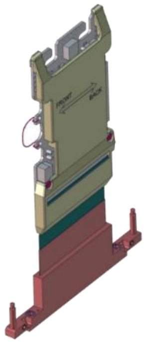


Wiper

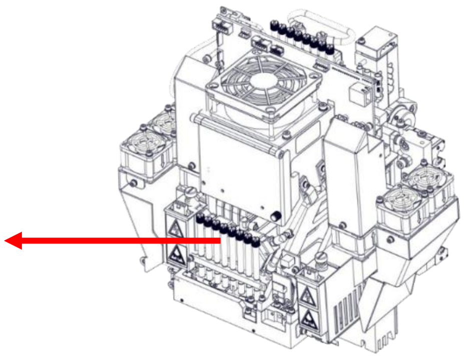


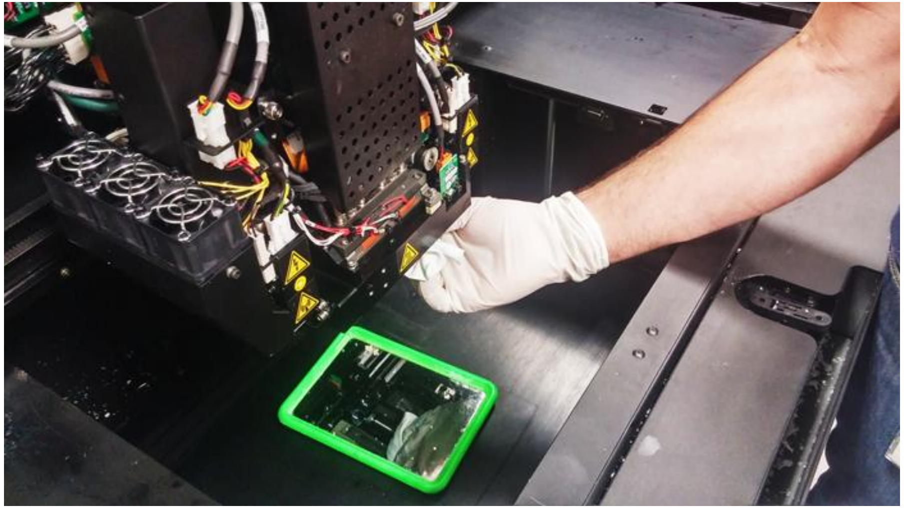
PRINT HEAD

What: The print heads jet model and support material on the tray.



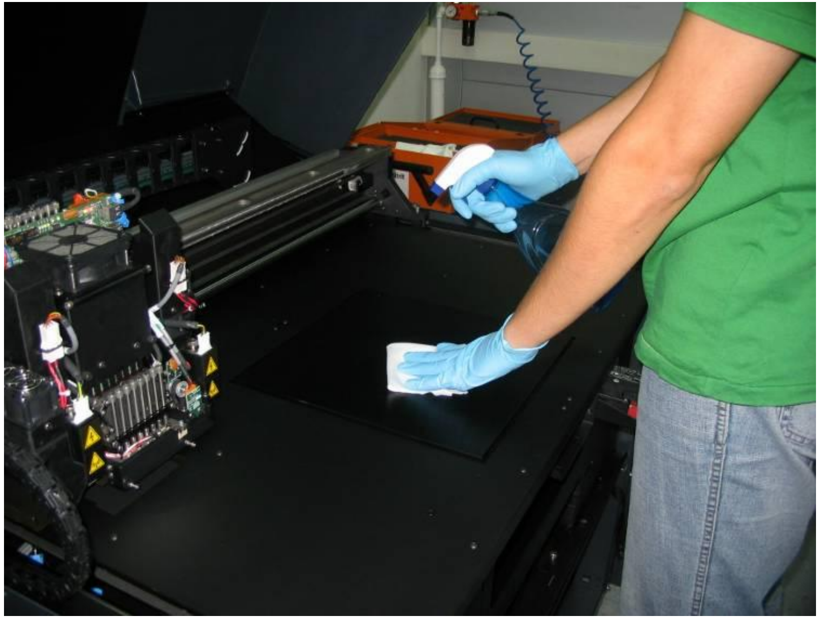
Single Print Head





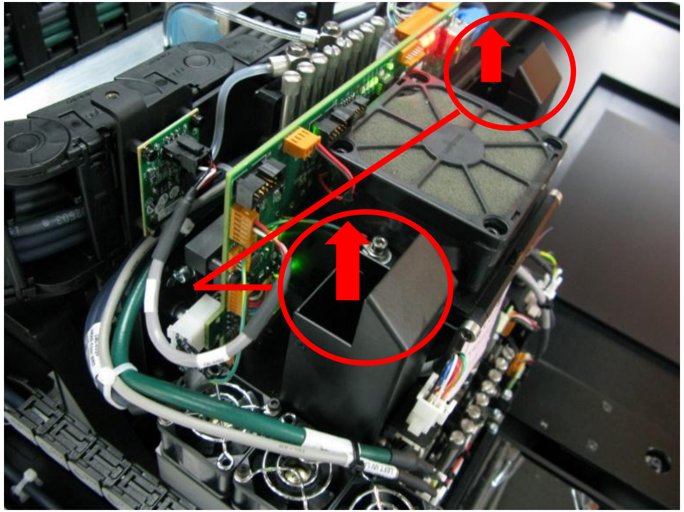
BUILD TRAY

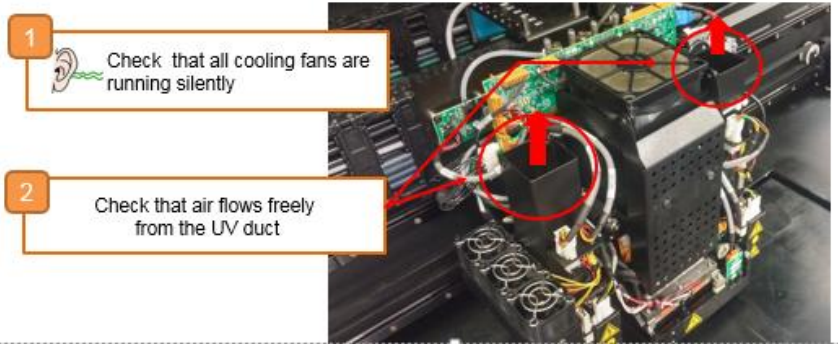
The build tray is where the printer builds the model.



UV TEMPERATURE INDICATOR & UV FANS

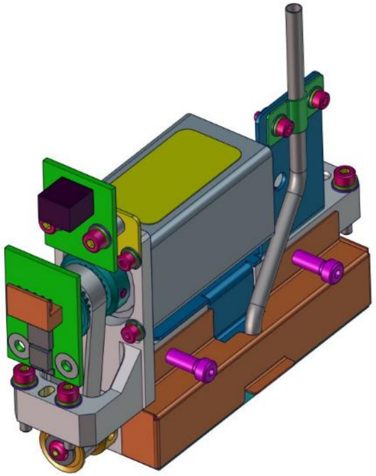
The cooling fans responsible for removing heat from the UV lamps

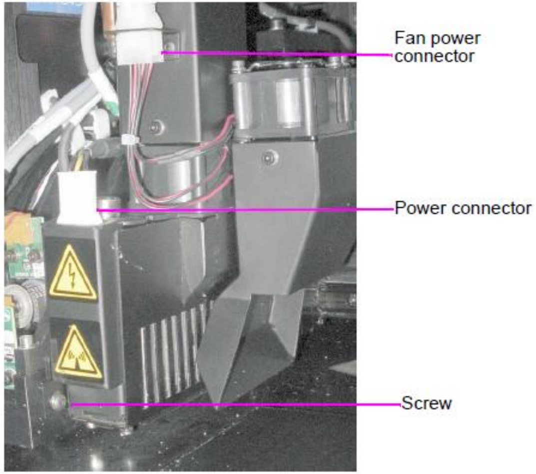




ROLLER WASTE COLLECTOR

The roller waste collector collects residue of uncured and excessive resin; these residues are transferred to the waste container through tubes and a pump.





WASTE CONTAINER

The waste container contains partially cured polymeric material produced during the printer operation. This material is kept in a special, leak-proof, disposable container.

HANDS-ON ACTIVITY 5.7: HOW TO CHANGE POLYJET MATERIAL

Download the Activity Worksheet from the Module 5 Resources section. Note: Activities: 5.2, 5.3, 5.4, 5.5, 5.7, 5.8 are on one worksheet.

Reference your PolyJet Series User Guide in RESOURCES section, or download from http://www.stratasys.com/3d-printers

Follow the directions to remove the material spool and replace.

J750 - POLYJET

MAINTENANCE & CALIBRATION

THE BENEFITS OF ROUTINE MAINTENANCE

Prevent malfunctions that might occur.

Ensure high printing quality.

Increase printer reliability.

Improve printer productivity.

Daily

Weekly

Monthly

PREVENTIVE MAINTENANCE PROCEDURES

Preventive Maintenance Procedures – ongoing, prevent malfunctions

Daily	Weekly	Monthly
Wiper Assembly Cleaning	Pattern Test	Head Alignment
Print Heads Cleaning	Roller Waste Collector Cleaning	Cleaning Z-axis Shaft
Build tray & cover glass cleaning	Restart Printer & Host Computer	Load Cells calibration
Check UV Temp' and UV fans	UV Lamps cleaning	Exhaust System inspection

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REACTIVE MAINTENANCE PROCEDURES

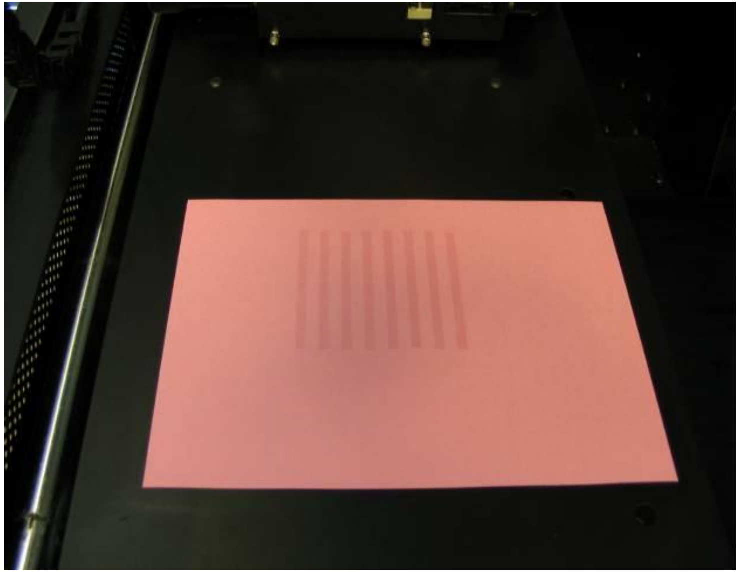
When needed	Stratasys J750
Material Replacement	Head Optimization
Head Replacement	
HCU- Head Calibration Utility	
Roller Blade Replacement	
UV Calibration	
UV Lamp Replacement	
Built-In Test (BIT)	
System Shutdown	

CALIBRATION

Part quality and calibration
go hand and hand

CALIBRATION: PATTERN TEST

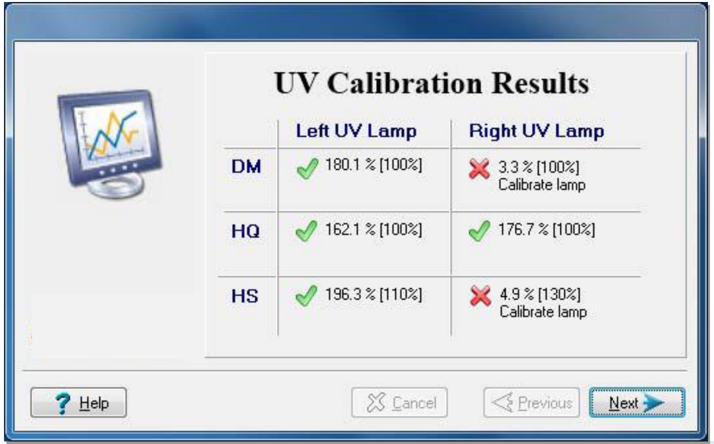
The pattern test is the basic verification of the printer's ability to produce quality models.

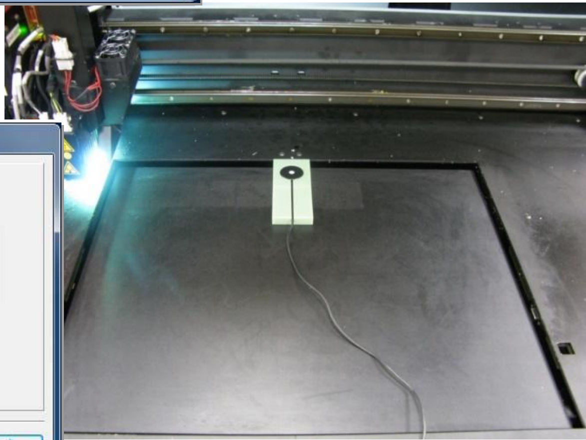


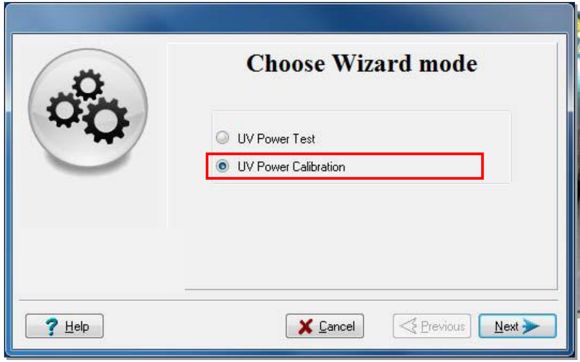
UV CALIBRATION

What: calibrate and test the UV radiation from the lamps.

Why: the effectiveness of the UV radiation can change over time. to ensure optimum curing of models during printing, a pop-up message reminds you to test and calibrate the UV lamps will appear after every 300 hours of printing.







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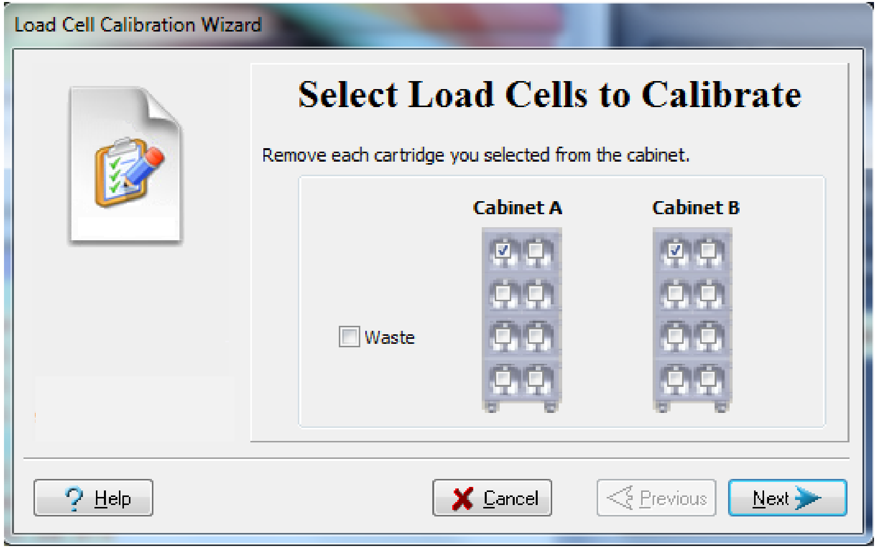
STRATASYS J750 | LOAD CELL CALIBRATION

2 material cabinets.

Option to calibrate 1 to 16 load cells

The Wizard screen cartridge location is the same as in the material cabinet

An additional cartridge location map label is attached to the inside of the material cabinet door



BUILT-IN TEST (BIT)

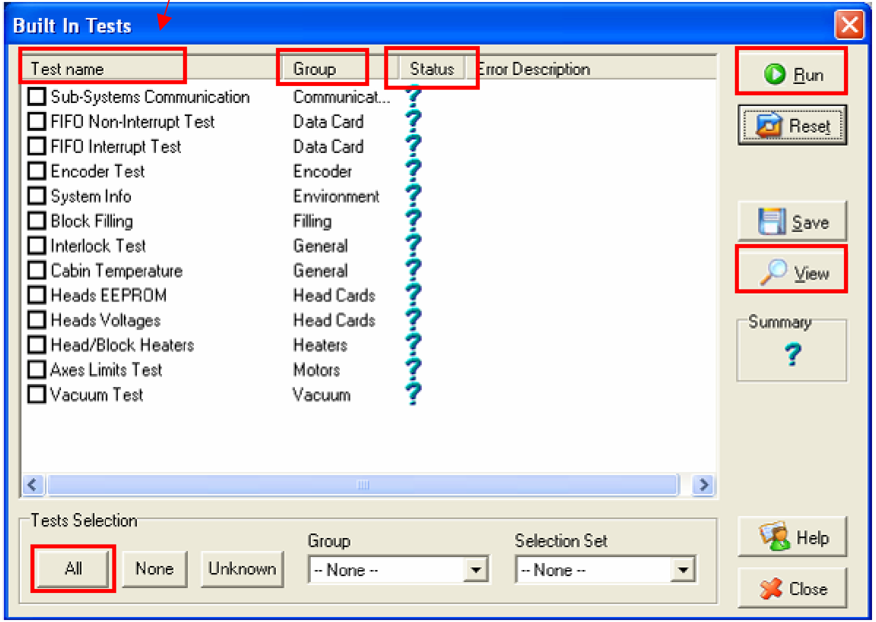
What:
A suite of tests for regularly checking the hardware & software ensuring optimum printing results, and for troubleshooting.

Why:
Running these tests can help identify problems in the printer hardware and software.

When:

- As a routine test, once every two weeks
- As a system check, before major (long) jobs
- As needed, for troubleshooting

List of pre-configured tests, grouped by component categories.



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HOW TO REDUCE DOWNTIME

Maintenance

Daily \ Weekly \ Monthly \ Yearly

Pro – Active Maintenance

Calibrations, Components inspection & cleaning, printer checklist

Before Big Trays

Printer overall checklist and calibrations especially before sending big trays for printing (like preparing big aircraft for long flight)

Tray Plan Optimization + STL's Verifications

Try to plan the tray for the best model orientation

ACTIVITY 5.8: RUN A CALIBRATION ON YOUR POLYJET SYSTEM

Download the Activity Worksheet from the Module 5 Resources section. Note: Activities: 5.2, 5.3, 5.4, 5.5, 5.7, 5.8 are on one worksheet.

Reference the User Guide for your PolyJet system.

Follow the directions to run a calibration.

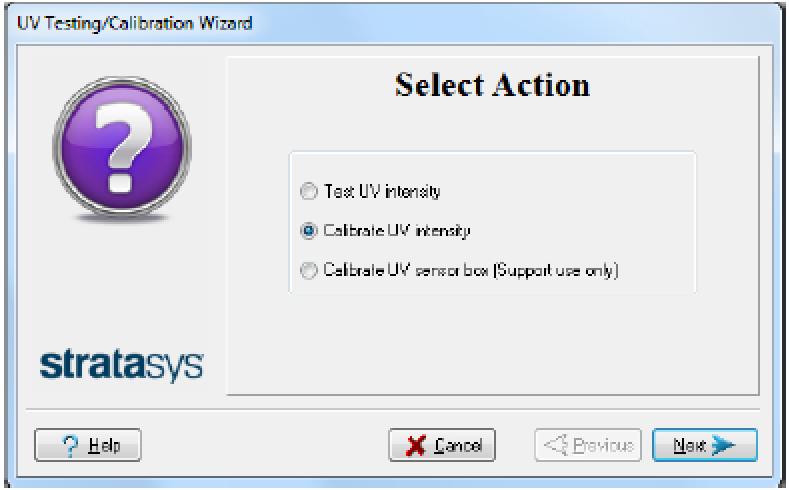


Figure 4-96 UV Test/Calibration selection

J750 - POLYJET

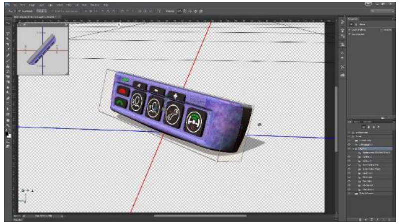
APPLICATIONS / USE CASES

REINVENTING INVENTION

Synergy

A single print eliminates the need to outsource:

- CNC machining
- Water printing
- Casting
- Sanding
- Silicone engraving
- Pad printing



Development time reduced from two weeks to a few hours

Cost of prototype was cut by over 70%

“Now our customers can make instant decisions about the ergonomics of a product – about the touch and feel – as well as test how it fits into its environment.”
- Tamar Fleisher, Art Director

J750 USE CASE: SYNERGY

https://www.youtube.com/watch?v=qLV0hvA9Yhg&t=9s

DESIGN CONSIDERATIONS FOR 3D PRINTING: FROM CAD TO CAM

Module 6

MODULE 6: DESIGN CONSIDERATIONS: FROM CAD to CAM

Define slicing, support and part density and how they impact 3D printed model

Define wall thickness, tolerance, support, support removal, infill, and mesh

Identify the components of a mesh and list the requirements for a smooth and detailed 3D structure

Define STL and detail how to export and STL

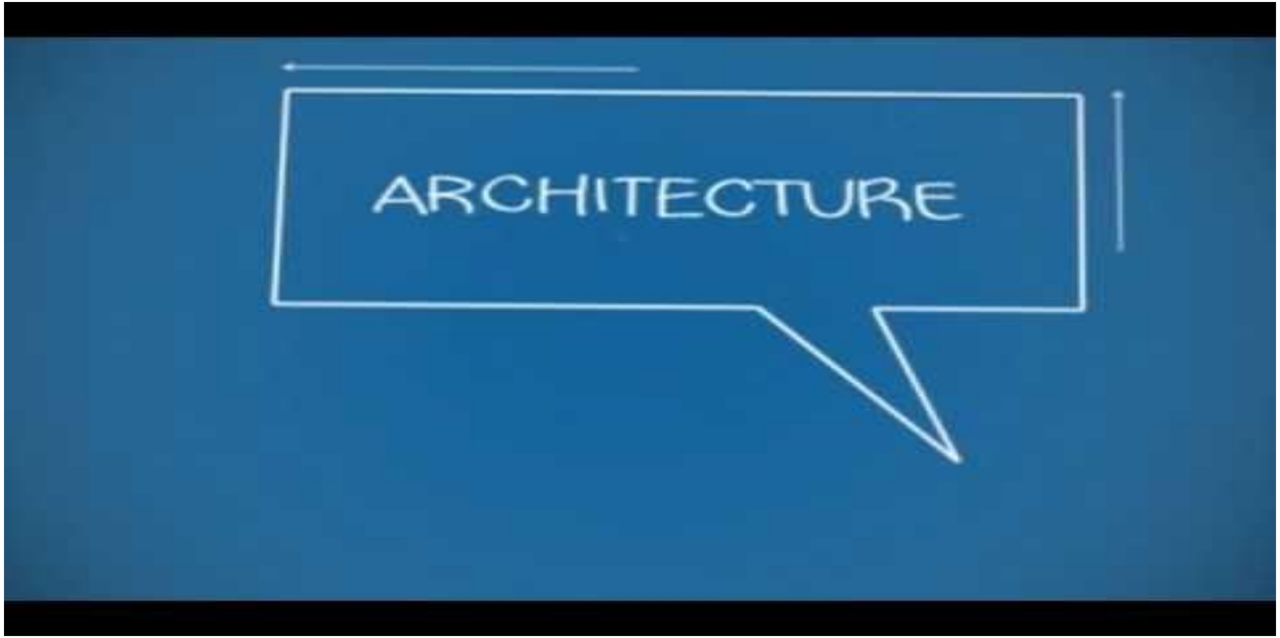
Differentiate between ASCII and Binary files

List the design considerations for FDM & PolyJet

Identify methods of texture mapping design for printing on the J750

ARCHITECTURE & DESIGN CONSIDERATIONS

Cup Video & Discussion



https://www.youtube.com/watch?v=E55OcGB0L8o

3D PRINTING OPENING CONVENTIONAL CONSTRAINTS ON DESIGN

IT IS ALL POSSIBLE BUT, FIRST CONSIDER…

End Use

What do I want this part to do?

What are the post processing is needed?

Optimal Materials

What qualities should this part have?

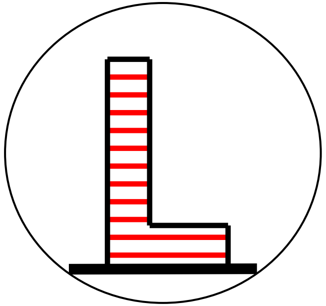
What materials should I use to create this part?

Tools or Technology

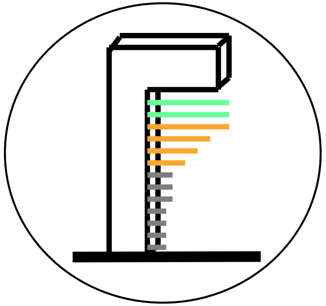
What technology (printer) will give me the desired results?

What CAD/Design software is needed?

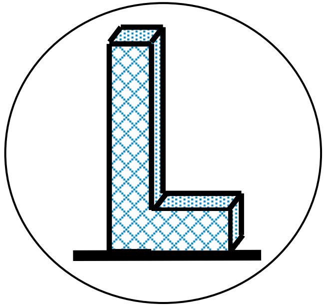
AND UNDERSTAND THE PROCESSES



Model is sliced into horizontal layers so toolpaths can be generated.



Support material is added to support overhangs and other structures.



Density of the material fill influences the model's weight and strength.

All three appear with nuance in all 3D printing technologies and impact design.

DESIGNING FOR ADDITIVE

https://www.youtube.com/watch?v=Vrbu4LUxAtY

GENERAL DESIGN DECISIONS

MINIMUM FEATURE SIZE

- The minimum **printable** feature size is dictated by the nozzle diameter (FDM) or the droplet size (PolyJet) in conjunction with the material rheology (flow).
- The minimum **usable** feature size is dictated by the level of detail that is required or the strength necessary for the feature to endure. These considerations lead to other general recommendations presented later.

Material flowing from an FDM nozzle

Material flowing from a PolyJet nozzle

CLEARANCE

- Clearance is particularly important for printing closed systems.
- The clearance between parts is chosen to prevent parts that are supposed to move relative to one another from fusing together.
- In FDM, the XY clearance needs to be sufficient for the width of a bead of support material to separate the parts. The Z clearance needs to be at least equal to the layer thickness of the support material used to print the part.
- In the case of FDM and PolyJet, the clearance must also allow for the removal of the support material from between the moving parts.

TOLERANCE

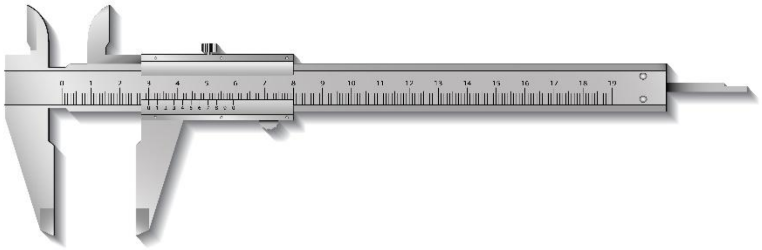
- Tolerance represents the deviation from a theoretically perfect size.
- Several things contribute to deviations in 3D Printing: accuracy and resolution of the mesh file; machine accuracy, resolution and repeatability; the capabilities of the control system; material rheology.
- Each one of the above factors contribute subtle deviations from perfection. Sometimes the deviations cancel one another out and sometimes they are cumulative.
- Keep in mind that there are typically 3 axes of motion that are used in most 3D printer technologies and each axis has its own set of ‘tolerance’ circumstances in addition to the material rheology issues.

OTHER CONTRIBUTORS TO TOLERANCE

- Although it is easy to think of **tolerance** in terms of mechanical capability and fluid properties, there are other factors that contribute to 'deviations from perfection'.
- **Temperature gradients** – mechanical components grow/shrink with change in temperature. So do the materials being used for the print.
- **Vibrations** – everything in the universe is a spring. Springs vibrate when excited. Force, motion, impacts, acceleration/deceleration are all sources of excitation.
- **Deflections** – everything in the universe is a spring. No spring is infinitely stiff and therefore all springs change shape when excited.

ACCURACY AND PRECISION

- The **accuracy** of a part is a function of resolution and precision.
- The more accurate the part is, the smaller the deviation (tolerance) from perfection.
- **Precision** quantifies **accuracy**. Is the part accurate to 1mm, 0.1mm, 0.01mm or 0.001mm (micron)? Smaller measurement increments used to represent accuracy represent higher resolution.



RESOLUTION

- **Resolution** and **Precision** are related. The more precisely the part is printed and measured, the higher the resolution of both the printing process and the measuring process.

- For instance, if Printer ‘A’ can locate its nozzle using 5 micron (0.0002”) increments of motion then it has a higher **resolution** than Printer ‘B’ that uses increments of motion of 50 microns (0.002”). Thus, Printer ‘A’ has a higher potential of printing more accurate parts than Printer ‘B’ because its increased resolution allows higher precision.

REPEATABILITY

- **Repeatability** is the ability of the 3D Printer to be able to replicate its actions of motion and/or material flow over and over and over and produce the same identical results.
- In fact, the **tolerance** of the 3D Printer is a reflection of how **repeatable** it is.
- **Repeatability** is the degree to which the system is non-random.
- **Tolerance** represents the zone in which non-repeatable events at certain levels of precision are random and, therefore, cannot be controlled to any higher level of precision.

RHEOLOGY

- **Rheology** is the study of how materials flow. The materials of interest are primarily liquids (photopolymers used in PolyJet) or soft solids (melted thermoplastic used in FDM).
- Controlling the placement of a droplet of photopolymer is up to the machine. How that droplet changes its shape prior to polymerization (solidification) with the UV light is a function of rheology.
- Similar issues exist with FDM. The machine is responsible for dispensing softened plastic at specific locations but how that plastic changes shape as it exits the nozzle prior to solidification (cooling) is a function of rheology.

WHAT DOES IT ALL MEAN?

- Machine specifications typically tell you what the resolution of the machine is: how fine the increments of motion are, what diameter the nozzle is, how small the droplets are.
- Some specifications will indicate the typical tolerances that you can expect for the XY plane and for the Z height between layers.
- One major difference in part quality between ‘commercial’ 3D Printers and hobbyist 3D Printers is that the properties of the printing materials used in ‘commercial’ printers is more tightly controlled than the materials used in hobby type printers. This is so that material rheology can be made more repeatable.

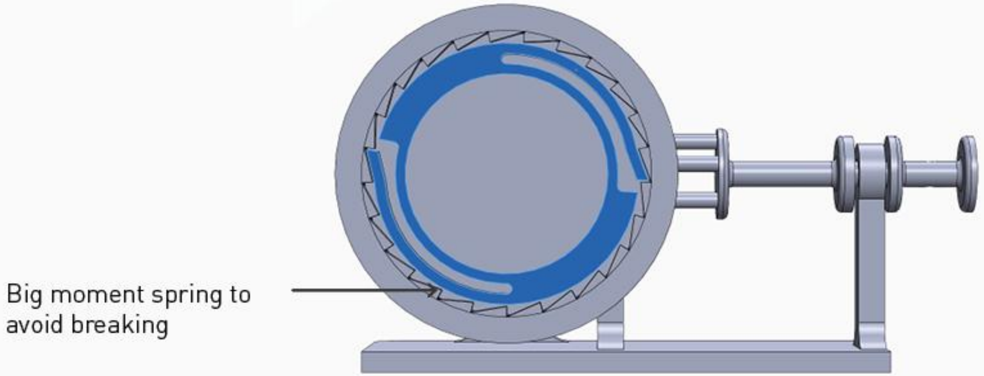
MACHINE SPECIFICATIONS

- **Fortus 450 MC** – Build resolutions include .005’’, .007’’, .010’’, and .013’’ in the Z-direction. Typical achievable tolerance +/- .005”, or +/- .0015 inches per inch.
- **F123** – Build resolutions of .013“, .010”, .007”, and .005“ in the Z-direction (dependent on material). Dimensional accuracy will vary based upon part size, geometry, and orientation. These systems are designed to produce 3D concept models within an accuracy of +/- .008”, or +/- .002 inches per inch.
- **Stratasys PolyJet (J750)** – Build resolution at 600dpi in X by 300dpi in Y, on high quality mode is 14µm (micron) or (0.014mm or 0.00055”) in Z direction; High Mix mode 27µm (micron) or (0.027mm or 0.001”) Up to 200µm (microns) or (0.2mm or 0.0078”) in the Z direction for full model size (for rigid materials only, depending on geometry, build parameters and model orientation.)

EACH TECHOLOGY HAS ITS PARAMETERS

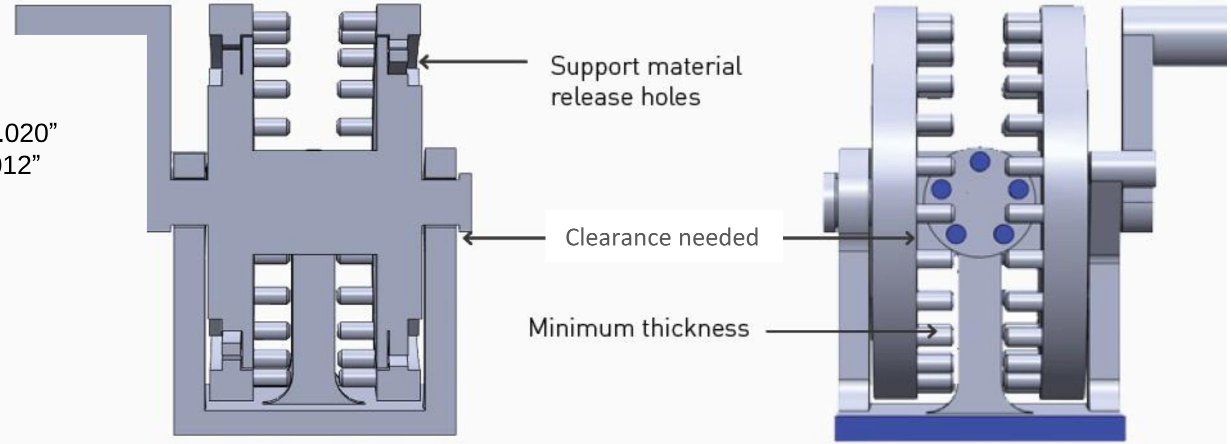
FDM

- 0.010” Layer Thickness
- Clearance in Z axis 0.020”
- Clearance in XY axis 0.012”
- Minimum wall thickness 0.020”
- Consider support removal



Polyjet

- 30 micron layer thickness
- Minimum wall thickness 0.020”
- Clearance in XYZ axis 0.012”
- Consider support removal



MAKE DESIGN DECISIONS

Wall Thickness
Wall thickness is the distance between surfaces of a solid part

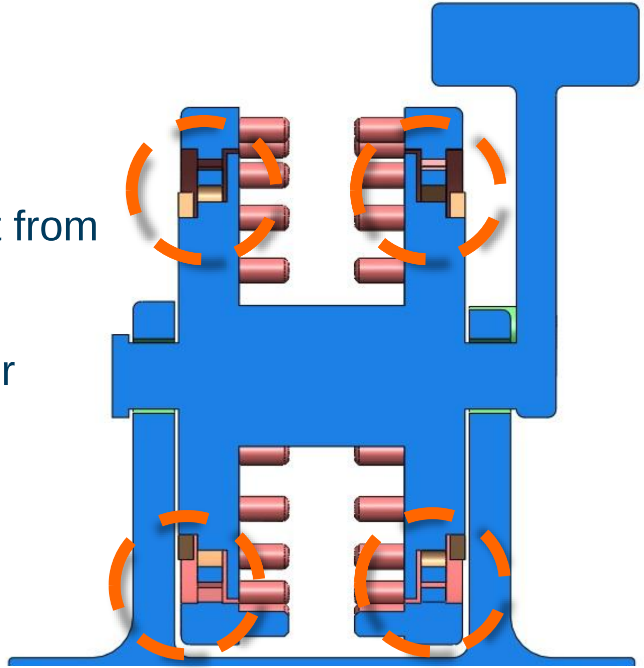
Clearance
The gaps between parts

Supports & Support Removal
Design for less and understand how to remove support from hard-to-reach places

Infill
The density of the solid. Material population within inner space of the solid model

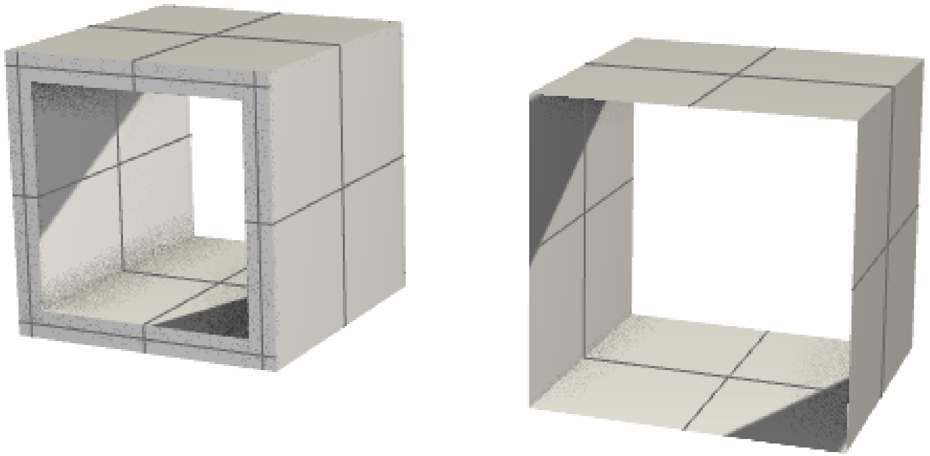
File conversion
Converting a file format to adapt with CAM software

Post Processing
Finishing, sealing, sanding, cleaning



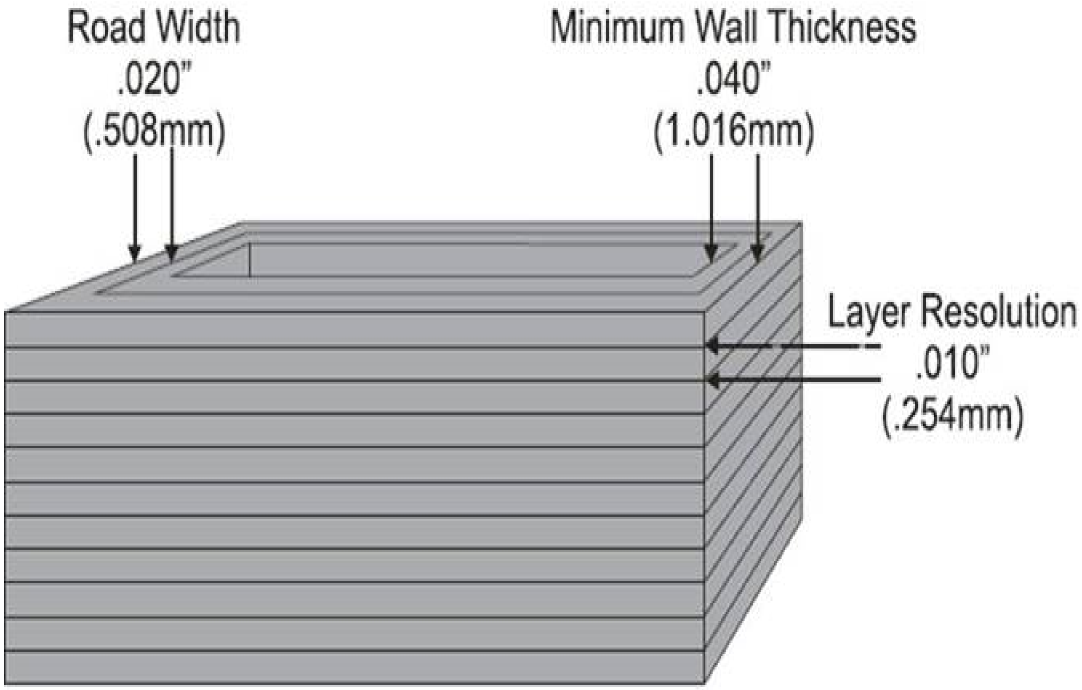
WALL THICKNESS

- A surface does not have 3 dimensions (cannot be held).
- To be able to print, each surface should be assigned to a volume – wall thickness.
- Wall thickness is the distance between surfaces of a solid part.



MINIMUM WALL THICKNESS

- Minimum wall thickness is the minimum distance between two faces of a model at any giving point.
- Minimum wall thickness is determined by your printer droplet size (extruder/nozzle diameter) Remember this when designing your models.
- For best part production remember to consider the material behavior of YOUR printer.



SUPPORT

Why is 45 degrees important when designing?

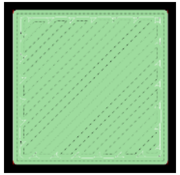
What happens with and without support?

Breakaway Support

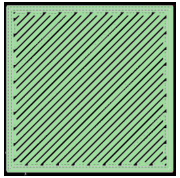
Soluble Support

INFILL

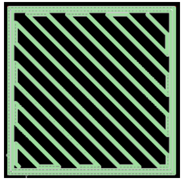
- While designing, remember that the inner space of the solid model large will be filled with an infill structure. Think of it as internal support.
- Unlike milling and cutting with homogeneous materials, when 3D printing you can control the infill, and therefore the weight, strength and product behavior.



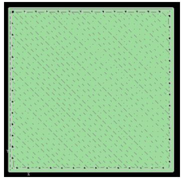
Solid Fill



High Density Sparse



Low Dense Sparse

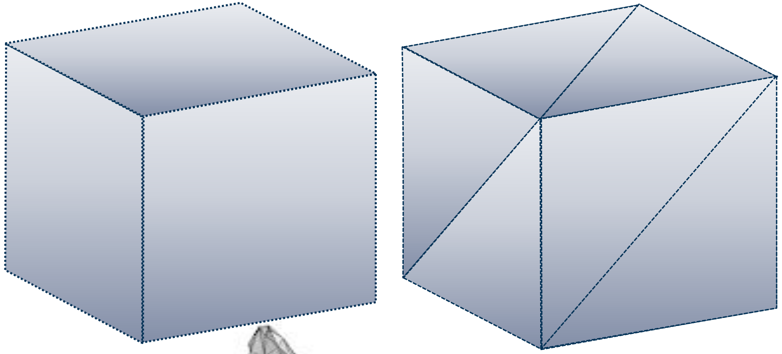


Support Face

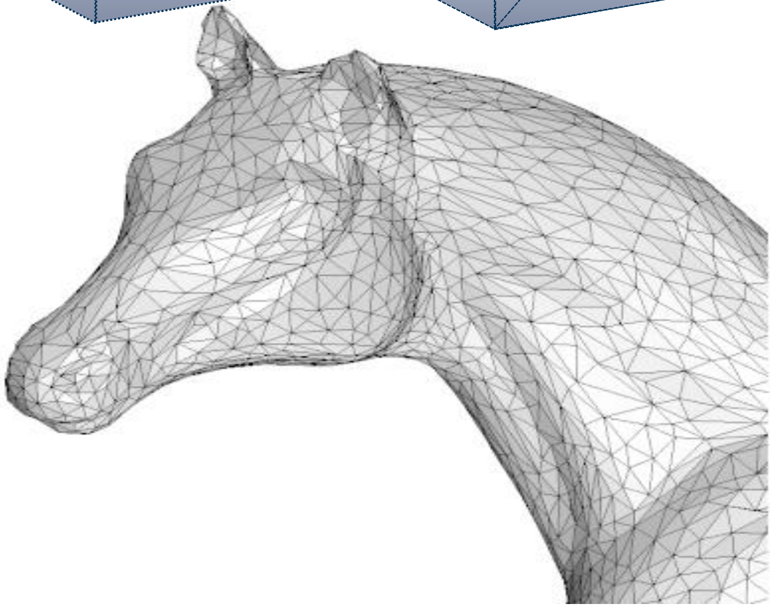
Double Dense
Basic Pattern

Regular Dense
Breakaway Pattern

CAD to CAM (WHAT IS A MESH?)



- After designing a model in a CAD (computer aided design) program, the model needs to be sent to a CAM (computer aided manufacturing) software.
- The most familiar file format for fabrication is called an STL file.
- STL is a MESH standard file type used by most or all rapid prototyping systems.
- MESH files approximate the surfaces of a solid model with triangles.
- The number and size of the triangles determine how accurately curved surfaces are printed.
    - The more complex the surface, the more triangles produced.



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SUGGESTED READING

3D HUBS

How to design parts for FDM 3D Printing:

This is a good overview of the limitations and constraints of FDM. While the author describes concepts in some differing terms you should be able to connect to what was just introduced.

https://www.3dhubs.com/knowledge-base/how-design-parts-fdm-3d-printing?action#overhangs

Table of contents

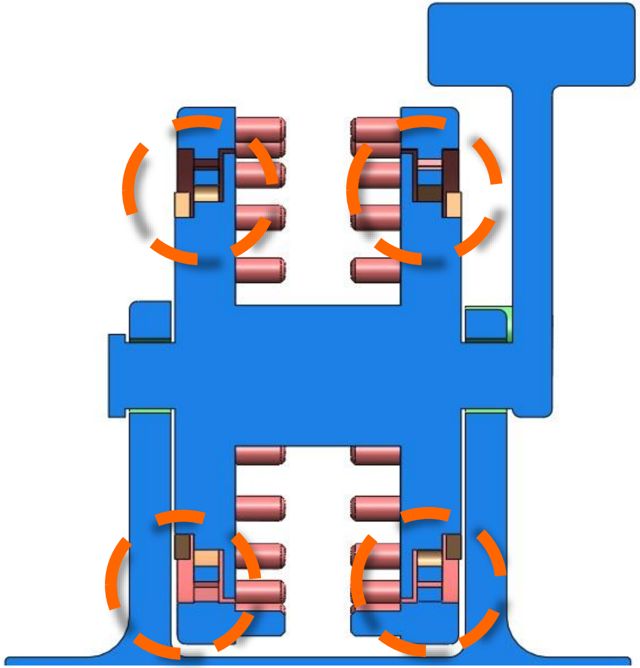
ACTIVITY 6.1 and 6.2: HOW WOULD YOU DESIGN IT DIFFERENTLY?

Download the Activity Worksheet from the Module 6 Resources section. Note: Activities: 6.1 and 6.2 are on one worksheet.

Select one of the GrabCAD designs you found during the applications section activity.

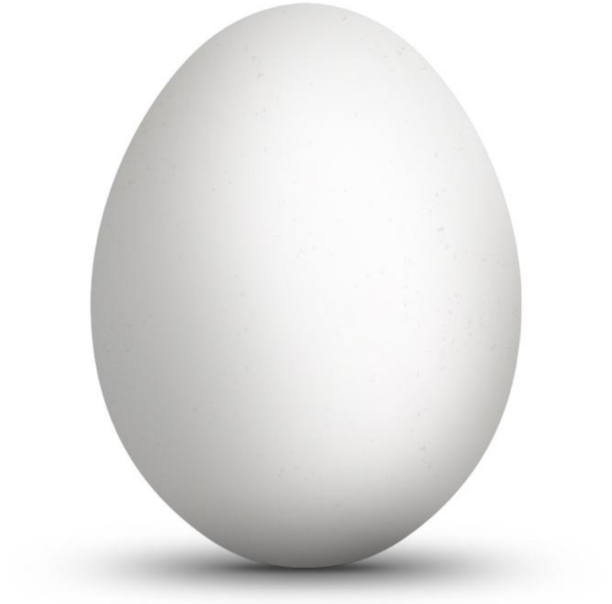
Consider how you could design this part differently, or enhance its design, by understanding: minimum feature size, clearance, tolerance, accuracy and precision of print technology, resolution, repeatability, rheology, and machine specifications.

Bring the file into your CAD program and make the appropriate design changes to impact: wall thickness, clearance, support removal, infill and post-processing.



UNDERSTANDING MESH

IN-CLASS ACTIVITY: CREATE AN EGG



GEOMETRY IS CRITICAL

Understand how to create a smooth and watertight mesh

GEOMETRY REVIEW: WHAT AM I?

?

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GEOMETRY TERMS

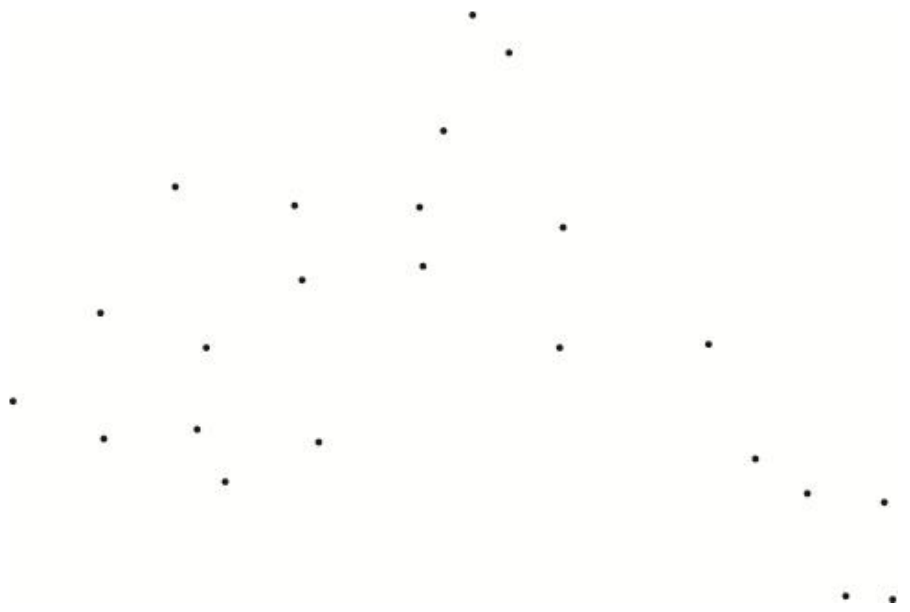
What am I?

I am a unique location in Euclidean space.

I do not have any length, area, volume, or any other dimensional attribute.

GEOMETRY TERMS

Point



GEOMETRY TERMS

What am I?

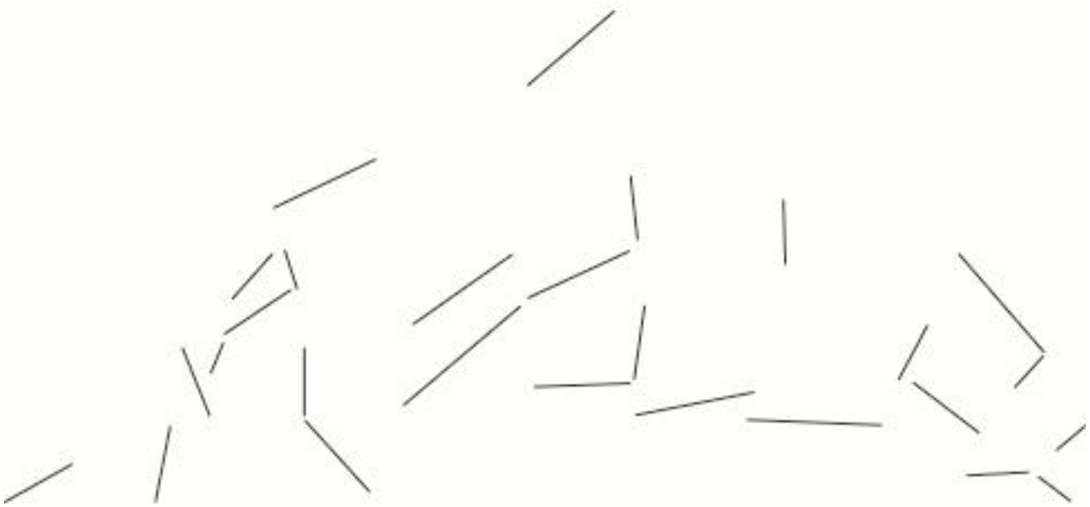
I include (but am not limited to) an infinitely extended, one-dimensional figure with no curvature.

I am equally extended between two points.

I do not have any area, volume or width.

GEOMETRY TERMS

Line



GEOMETRY TERMS

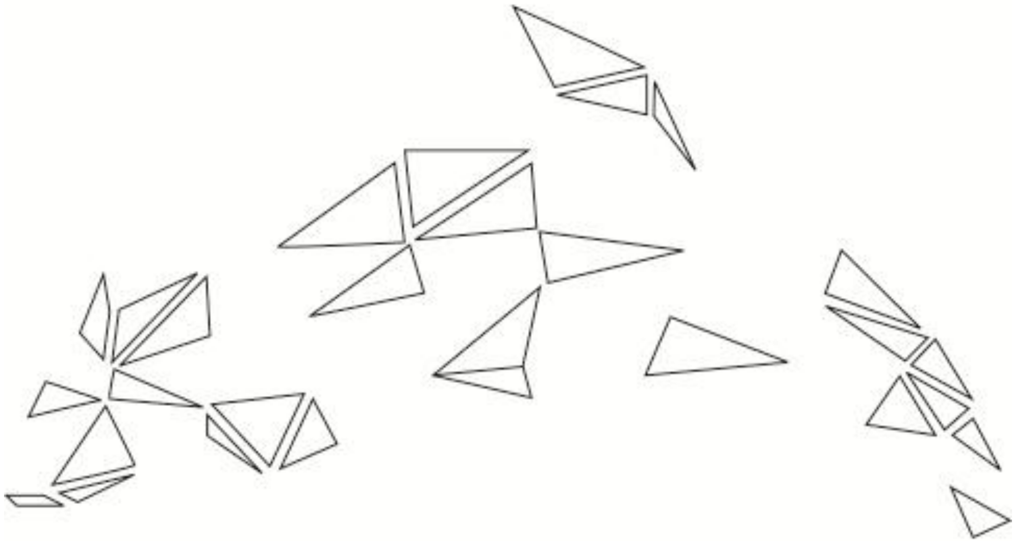
What am I?

I am a two-dimensional, topological manifold.

I am at least three lines defined by at least three points.

GEOMETRY TERMS

Surface



GEOMETRY TERMS

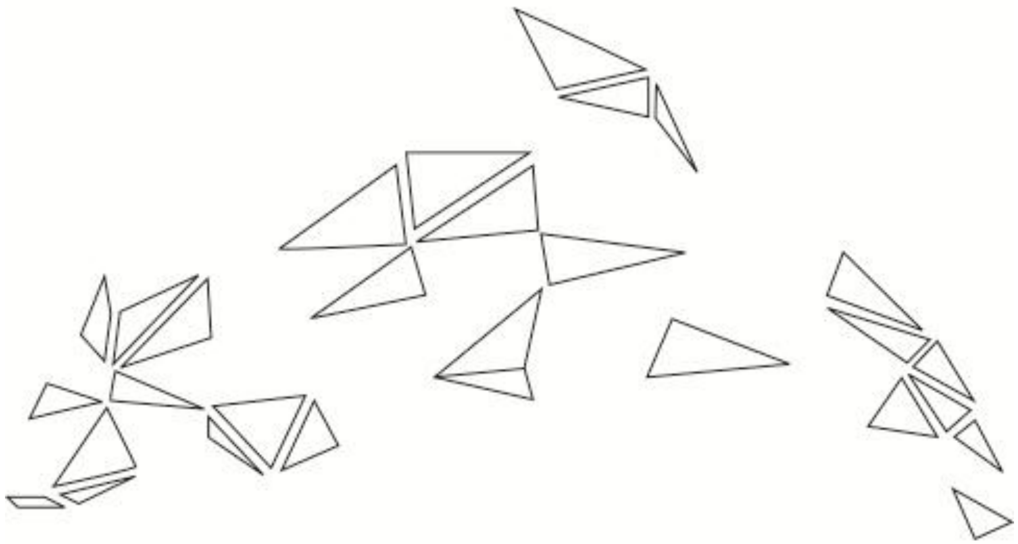
What am I?

I am a two-dimensional surface on one plane.

I am created by a chain of at least three straight lines on the same plane.

GEOMETRY TERMS

Polygon



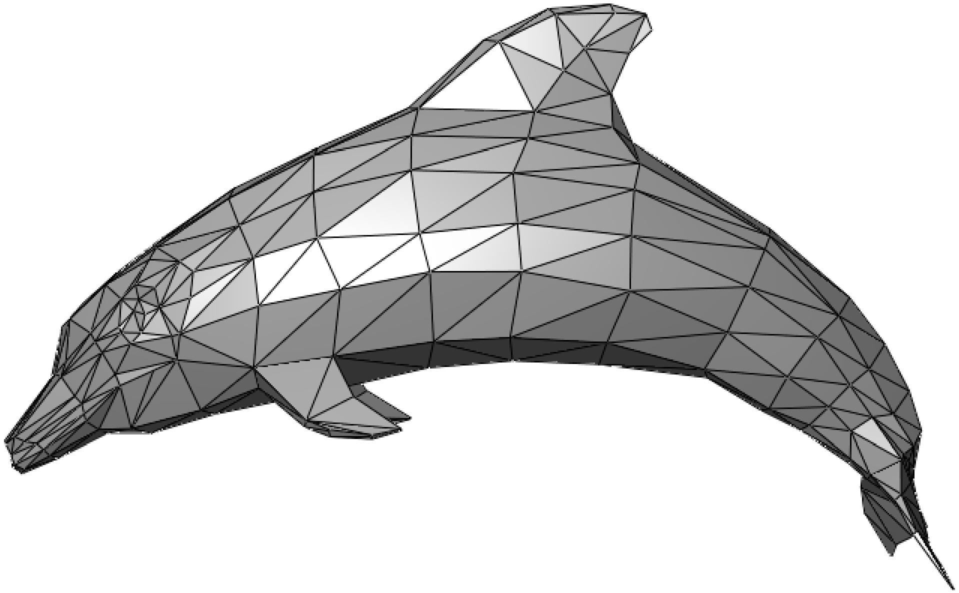
GEOMETRY TERMS

What am I?

I am a three-dimensional, watertight closed model.

GEOMETRY TERMS

Solid



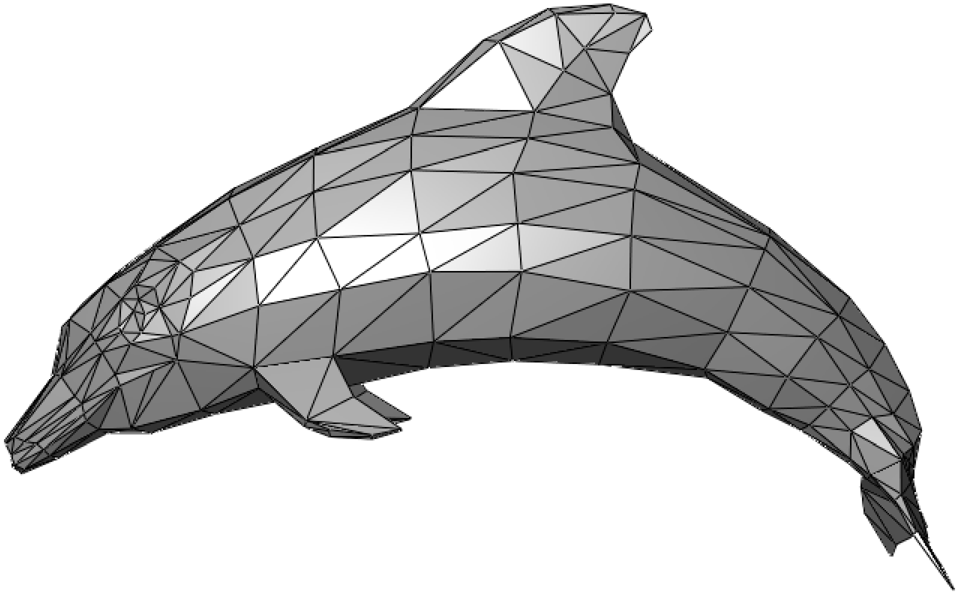
GEOMETRY TERMS

What am I?

I am a way to represent solid objects through polygon division.

GEOMETRY TERMS

Mesh or Polysurface



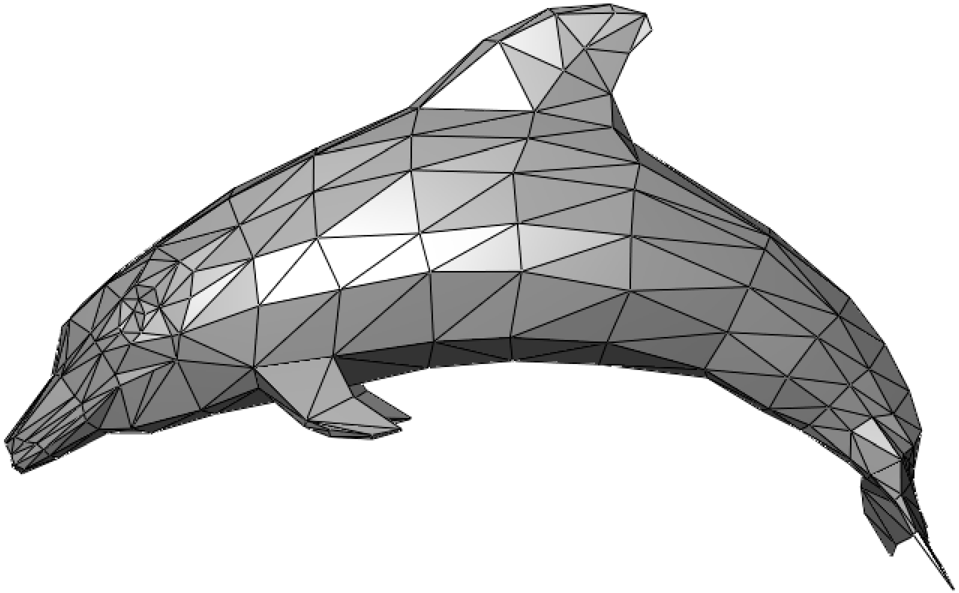
GEOMETRY TERMS

What am I?

I am a mesh but I am not closed and watertight

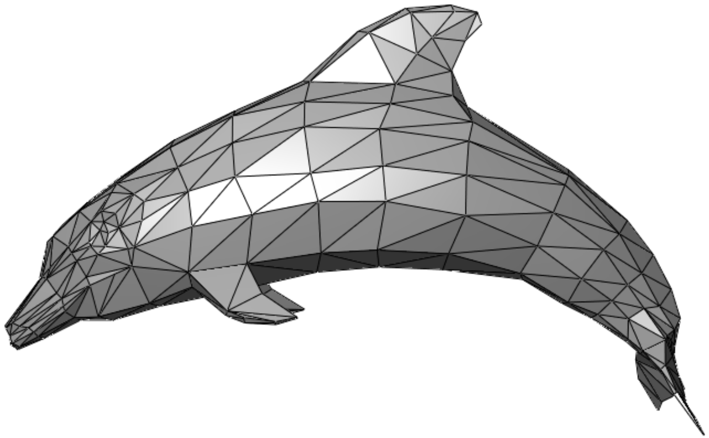
GEOMETRY TERMS

Open Mesh



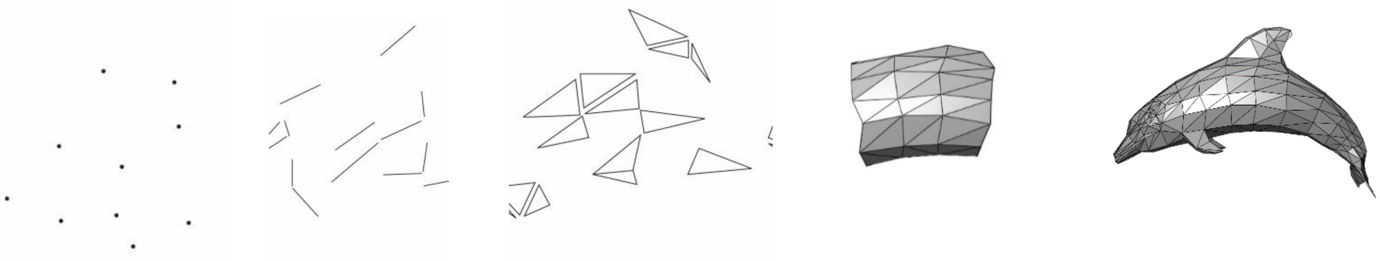
GEOMETRY TERMS

POINTS LINES SURFACES POLYGONS MESH



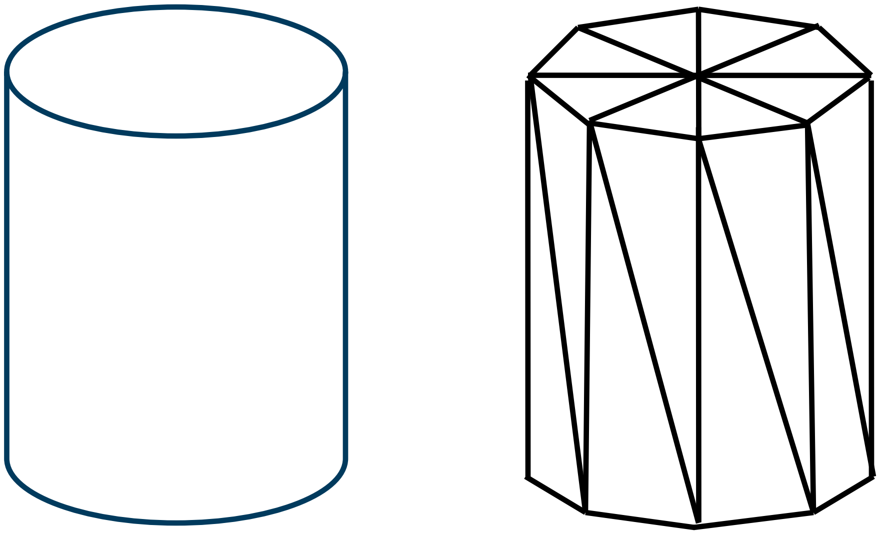
GEOMETRY TERMS

POINTS LINES SURFACES POLYGONS MESH



GEOMETRY TERMS

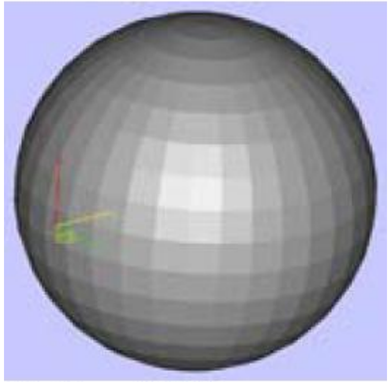
What is this?



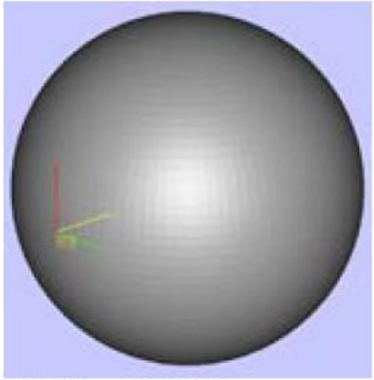
GEOMETRY TERMS

What is this?

Solid Mesh



File Size: 705KB



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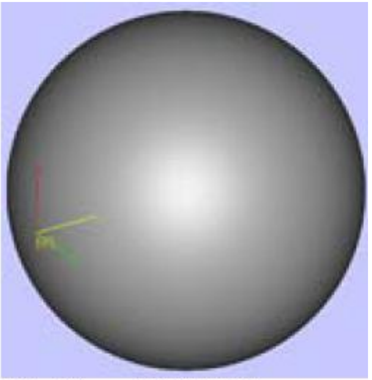
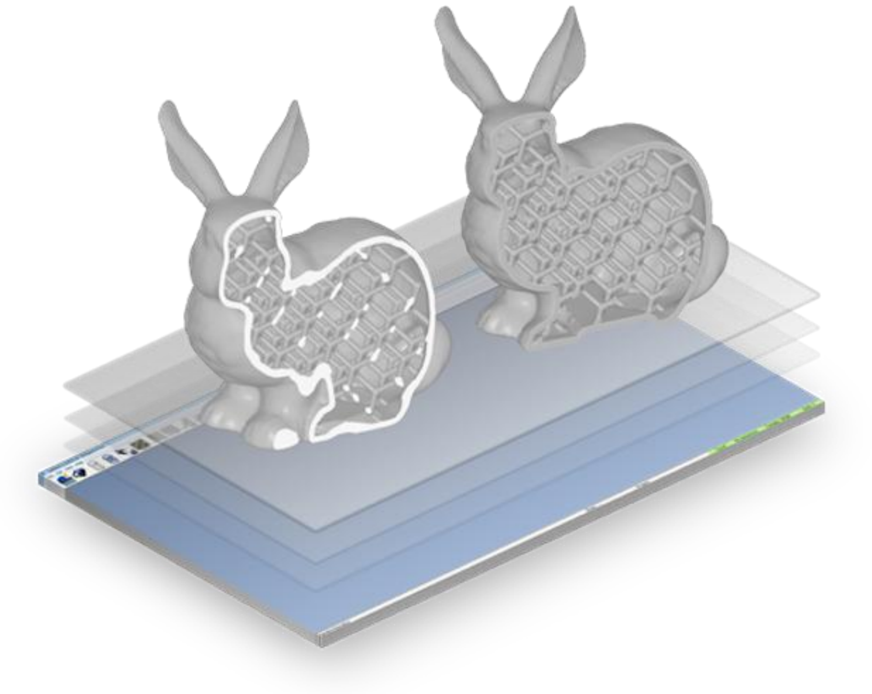


File Size: 17,350KB

HOW TO CREATE A SMOOTH AND WATERTIGHT MESH

Things to consider:

- Surface resolution
- Mesh holes
- File format



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1. SMOOTH SURFACE

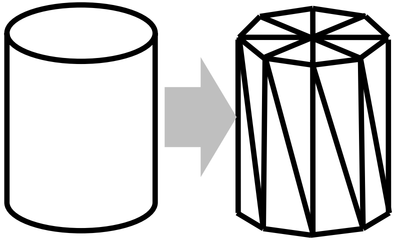
High resolution meshes contain a higher density of smaller polygons for a smoother end product

The higher the mesh resolution, the longer it will take to process a file

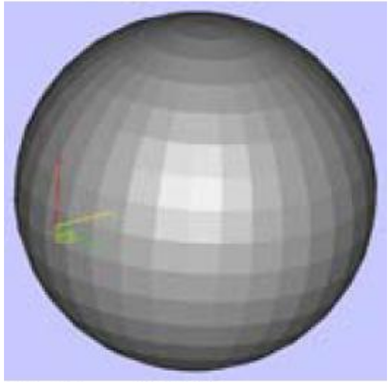
Resolution must be aligned with your 3D printer’s capabilities

SINCE A MESH IS AN ARRAY OF POLYGONS, IT WILL NEVER BE SMOOTH

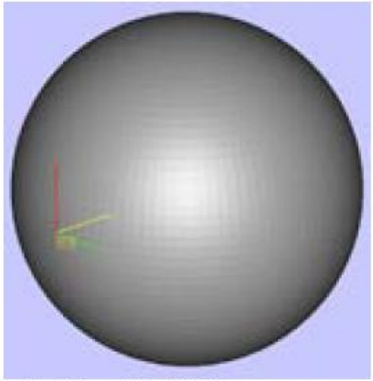
1. SMOOTH SURFACE



SINCE A MESH IS AN ARRAY OF POLYGONS, IT WILL NEVER BE SMOOTH



File Size: 705KB



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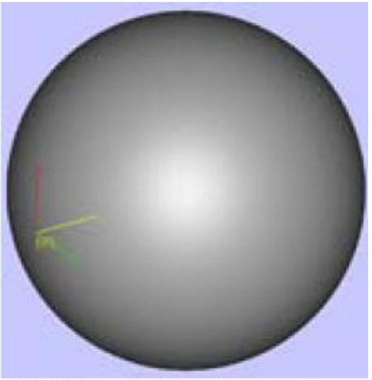
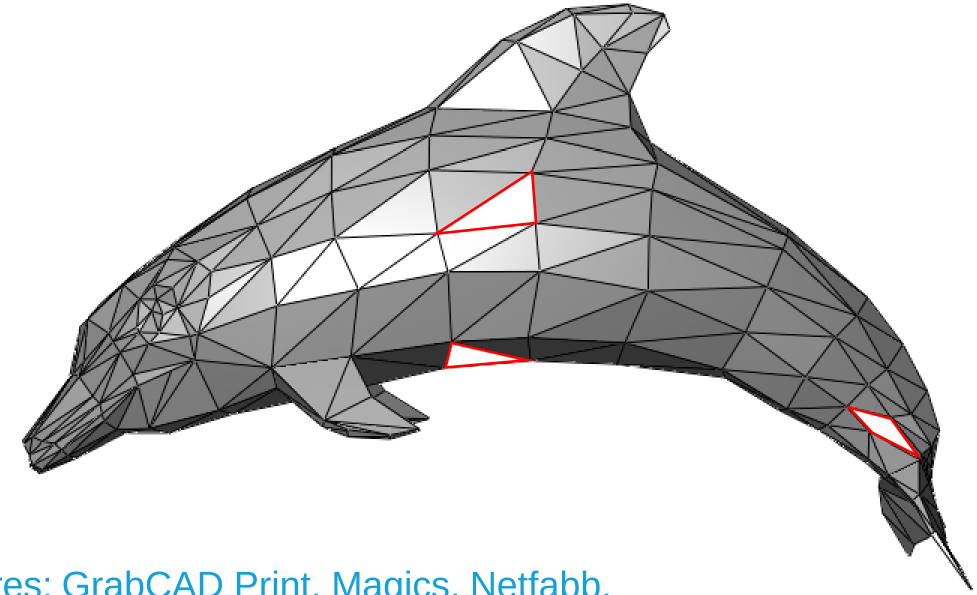


File Size: 17,350KB

2. MESH HOLES

Mesh must be watertight for 3D printing



Mesh repair softwares: GrabCAD Print, Magics, Netfabb, Autodesk print utility

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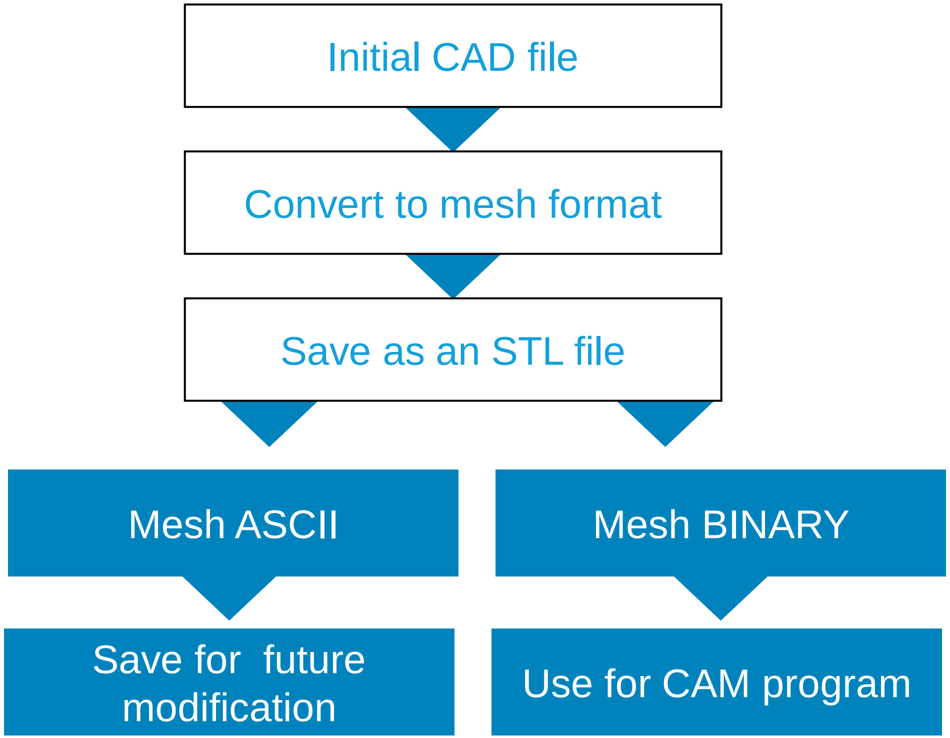
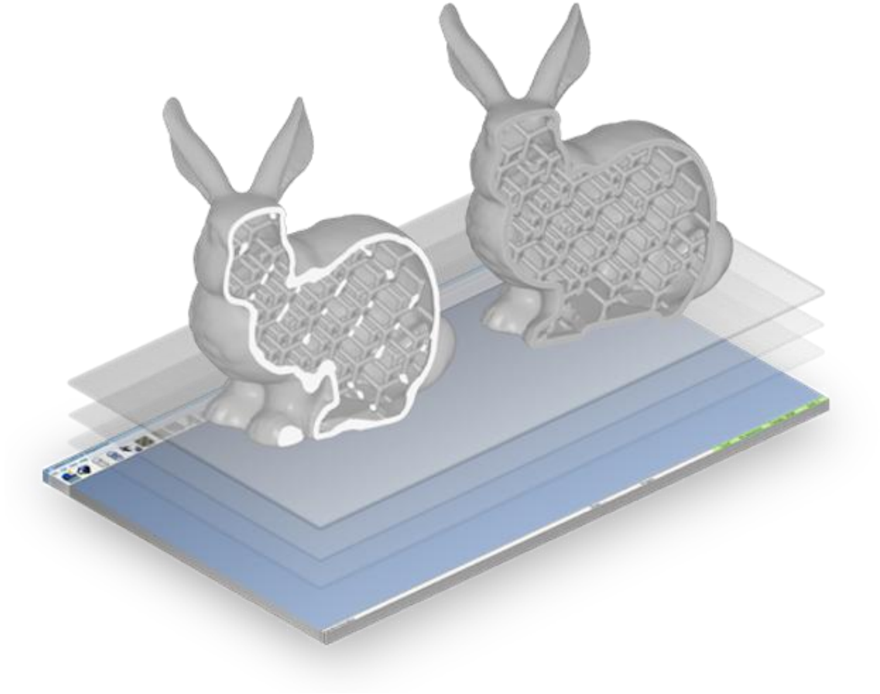
3. FILE FORMAT



TO REVIEW

Things to consider

- Surface resolution
- Mesh holes
- File format

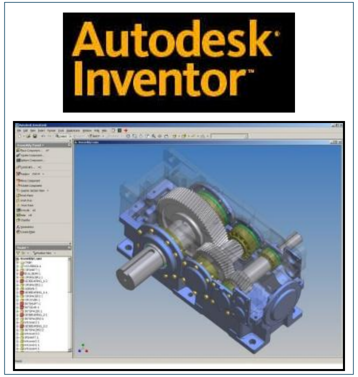


CAD TO STL

CAD – COMPUTER AIDED DESIGN

A CAD system is a combination of hardware and software that enables engineers and architects to design everything from furniture to airplanes

Below are just a few:



ABOUT THE STL?

An STL is a format used by digital manufacturing software to generate information needed to produce 3D models.

The STL format approximates the surfaces of a solid, surface or scanned model with triangles.

Creating an STL

- Several key settings need to be adjusted in creating the STL in order to make sure you get the part you want. The angle, deviation and chord height control determines the roughness and smoothness of the part.
- When the part is too coarse you can see spots on curved surfaces. On the other hand, excessively faceting can cause delays in processing and uploading because of the large size. Faceting should be just detailed enough so that features build to the dimension but, not excessive
- STL should be free of missing surfaces, surfaces that overlap, inversed normal or bad edges.

CAD to STL

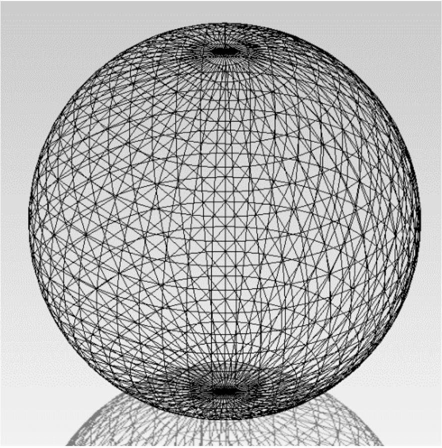
When creating a STL file, the goal is to achieve a balance between file size and a fully-defined model with smooth curved geometries.

File size

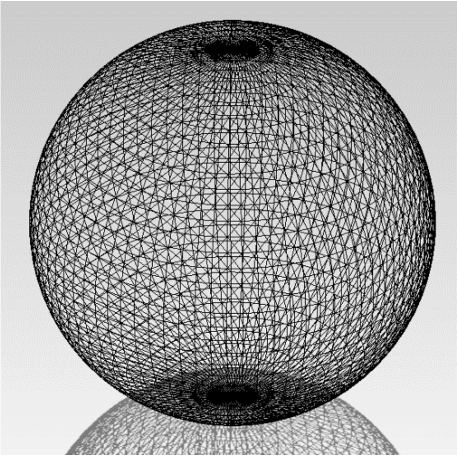
Smooth curved geometries

CAD TO STL

When creating a STL file, the goal is to achieve a balance between file size and a fully-defined model with smooth curved geometries.



Faceted STL - file translated with **coarse tolerance** (2352 Triangles | 117684 Bytes)



File translated with **fine tolerance** (6162 Triangles | 308184 Bytes)

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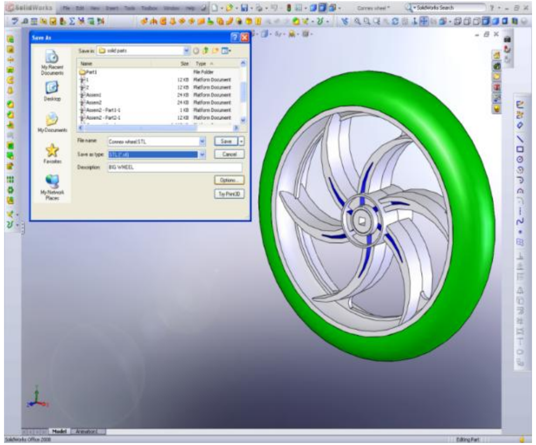
HOW TO SAVE AN STL FILE

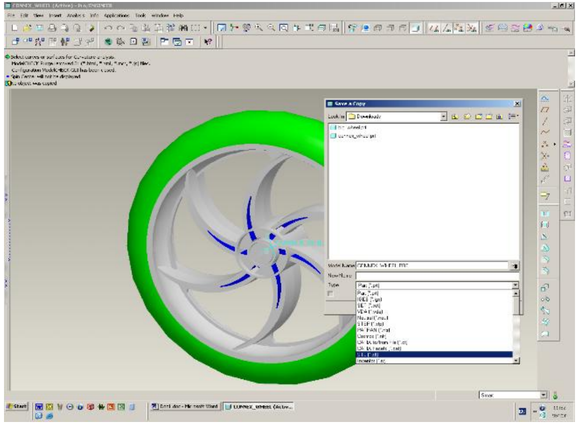
All CAD systems supports the saving of model designs in STL format

The process is often as simple as: File → Save As →*.STL

Save As dialog box in SolidWorks



Save As dialog box in PRO / E



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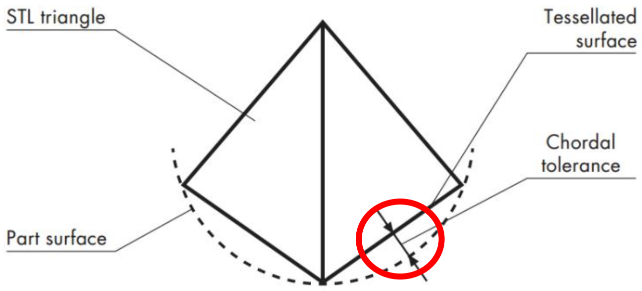
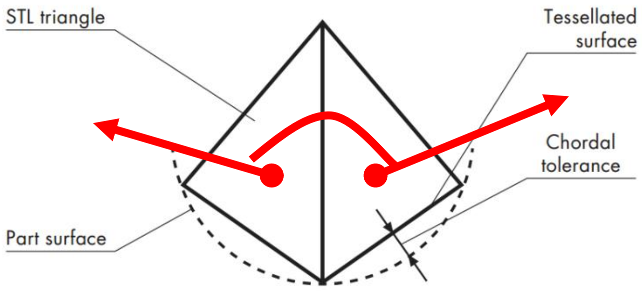
EXPORT OPTIONS

You control the number and size of the triangles by setting the following parameters when you create the STL file from the CAD design:

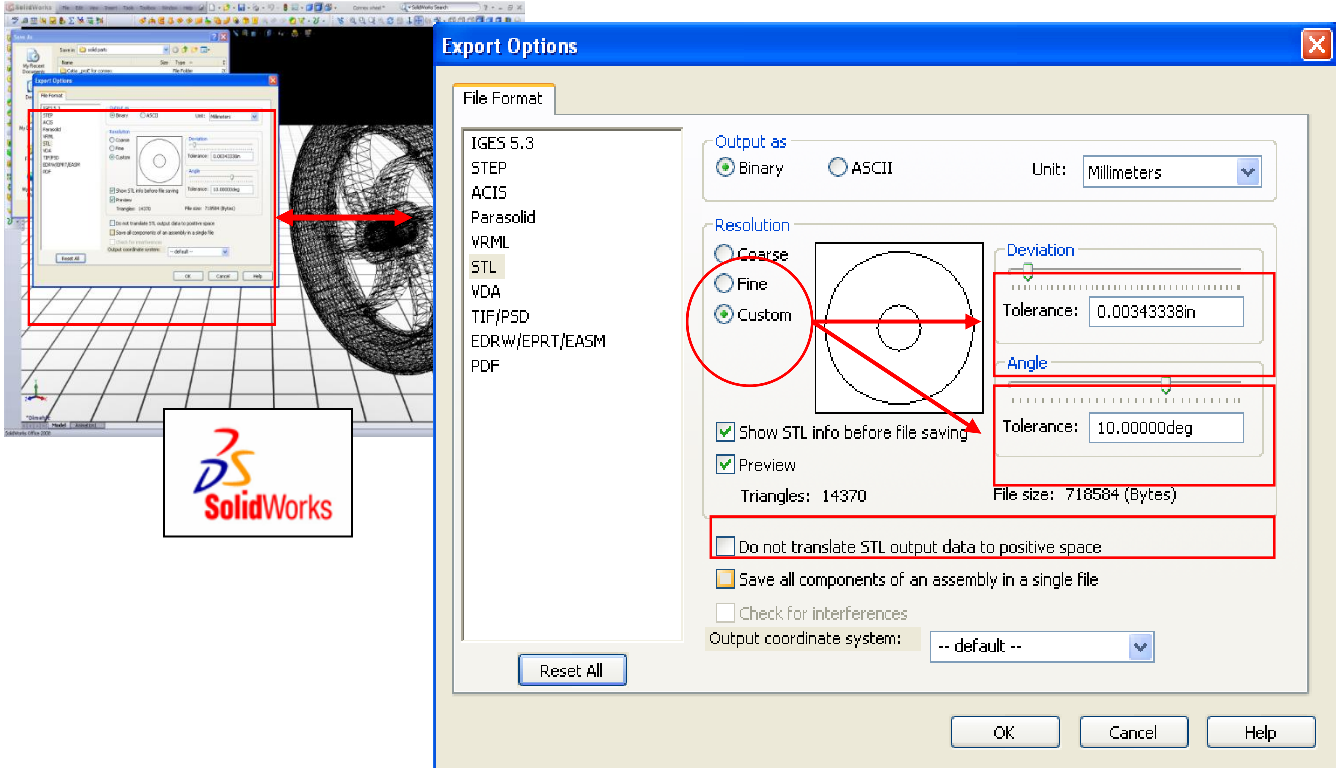
Deviation / Chordal Tolerance



Angle Control



EXPORT OPTIONS



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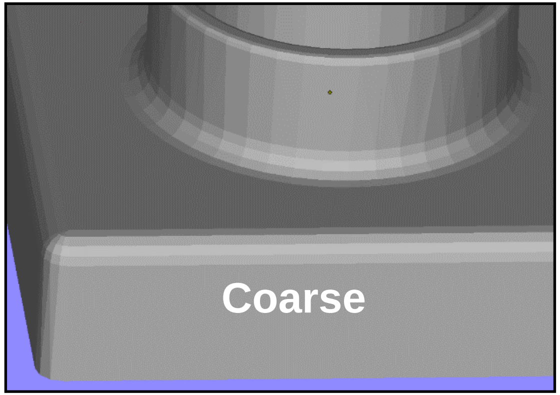
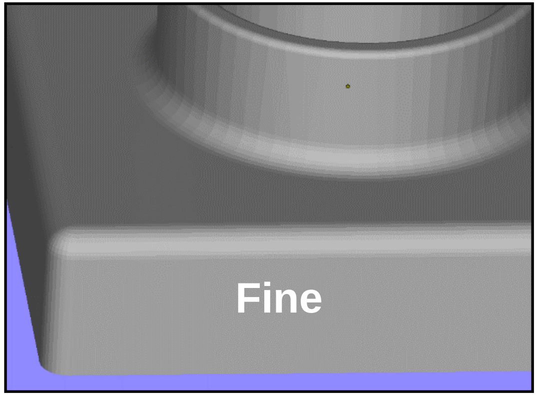
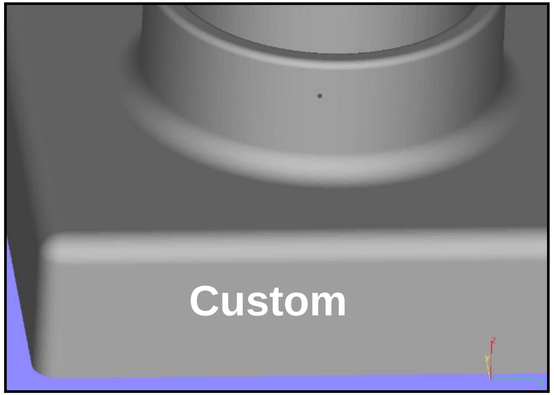
FILE RESOLUTION - SLICE HEIGHT







THE STL FILE – STORAGE FORMAT

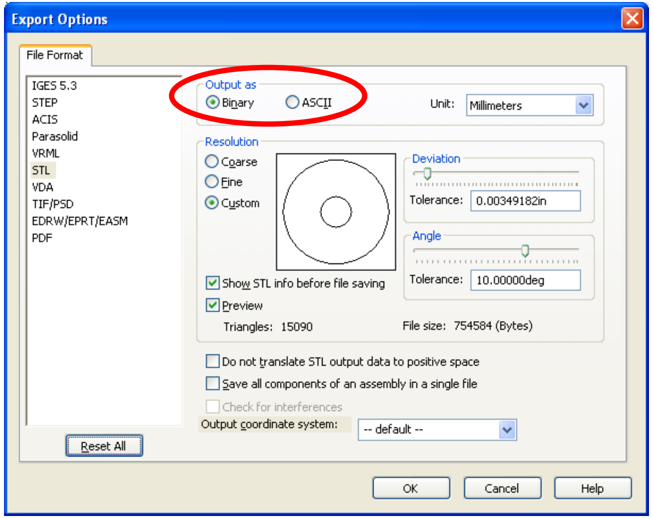
There are two storage formats available for STL files, which are ASCII and BINARY

- **ASCII file** is human-readable and can be modified by a text editor if required. However, The large size of its files makes it impractical for general use.
- **Binary file** is a computer -readable file in which each character position can hold any one of 256 different binary codes.

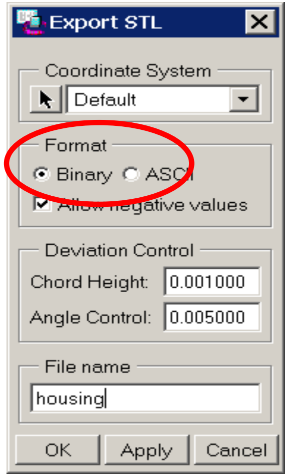
IN ORDER TO SAVE TIME AND FILE SIZE ALWAYS EXPORT YOUR STL FILE AS A BINARY FILE (6 TO 1 RATIO)

THE STL FILE – STORAGE FORMAT

There are two storage formats available for STL files, which are ASCII and BINARY.



Export Options dialog box - SolidWorks

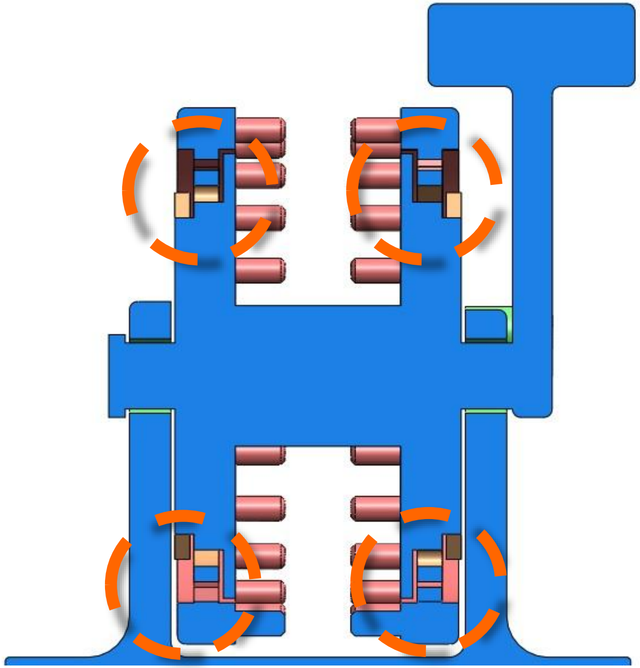


Export Options dialog box - Pro / E

ACTIVITY 6.2: HOW WOULD YOU DESIGN IT DIFFERENTLY?

Download the Activity Worksheet from the Module 6 Resources section. Note: Activities: 6.1 and 6.2 are on one worksheet.

Now that you know have an understanding of mesh and understand the process of going from CAD to STL, review your part, make necessary changes, and bring it into GrabCAD to prepare it to print.



DESIGN CONSIDERATIONS FOR POLYJET MULTI-MATERIALS

CAD FOR MULTI-MATERIAL PRINTING

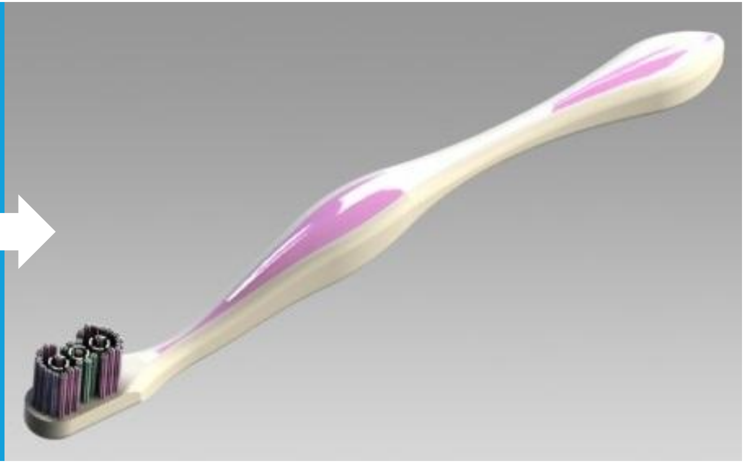
Connex/J750 technology enables printing with more than just one material

To utilize this capability, part design in the CAD environment should be created using multiple bodies

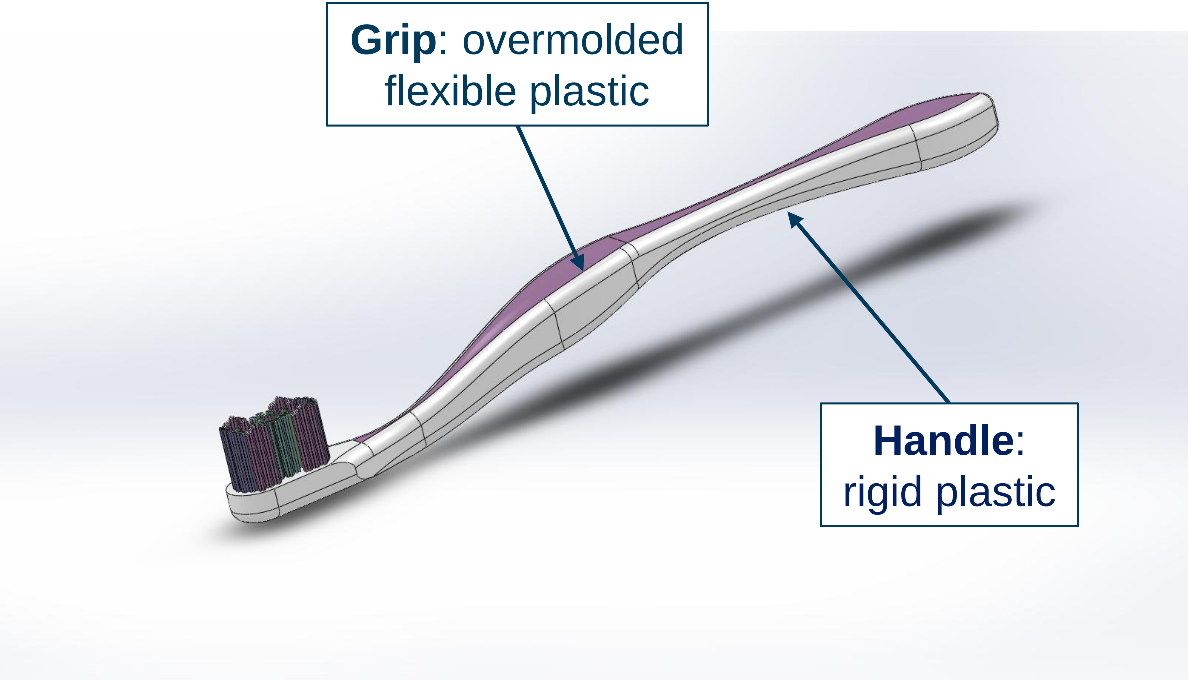
The prototype toothbrush is modeled in the CAD as a single body

The real product will be composed from two materials:

- **Rigid** plastic for the handle
- **Flexible** plastic for the grip



CAD FOR MULTI-MATERIAL PRINTING



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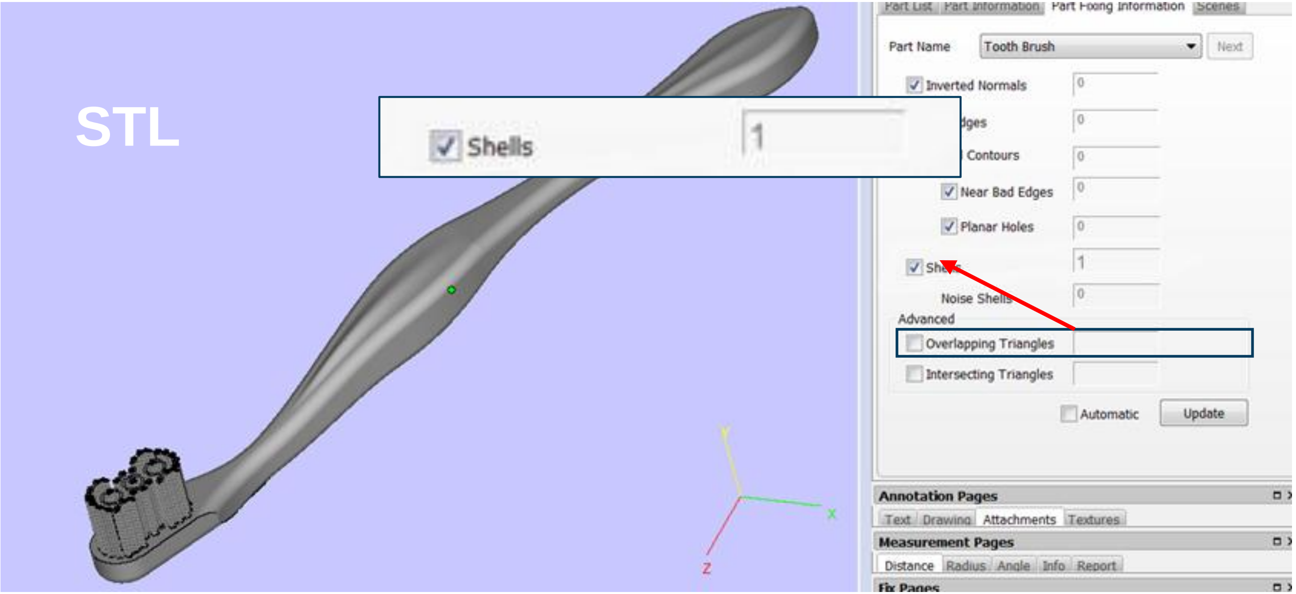
CAD FOR MULTI-MATERIAL PRINTING

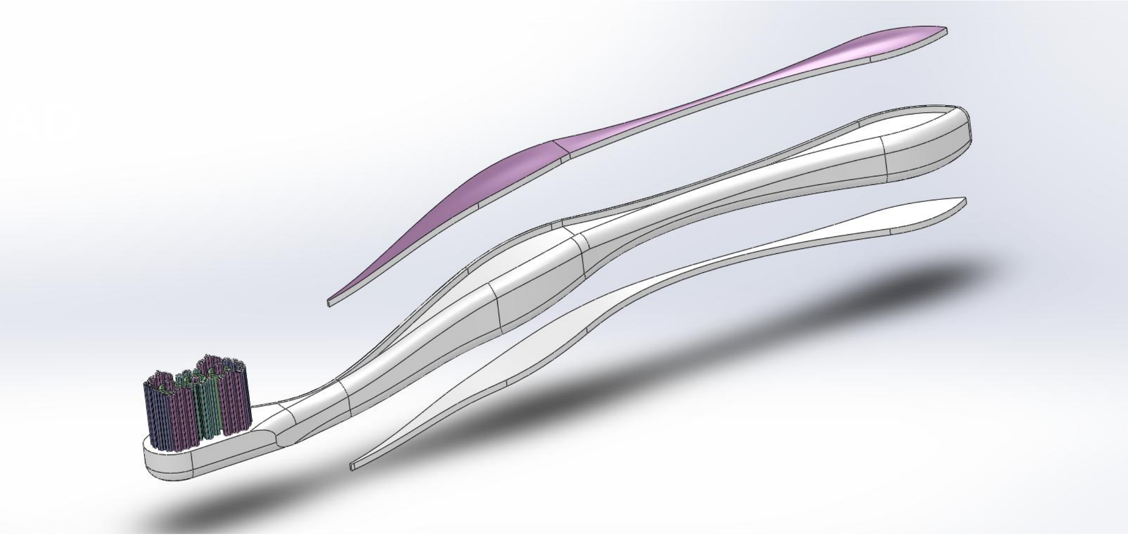
When converted to stl, only one shell exists, therefore cannot be printed in multi-material, unless STL manipulation software is at hand



CAD FOR MULTI-MATERIAL PRINTING

Using multibody CAD, each solid body in the part will later be converted to a different STL file

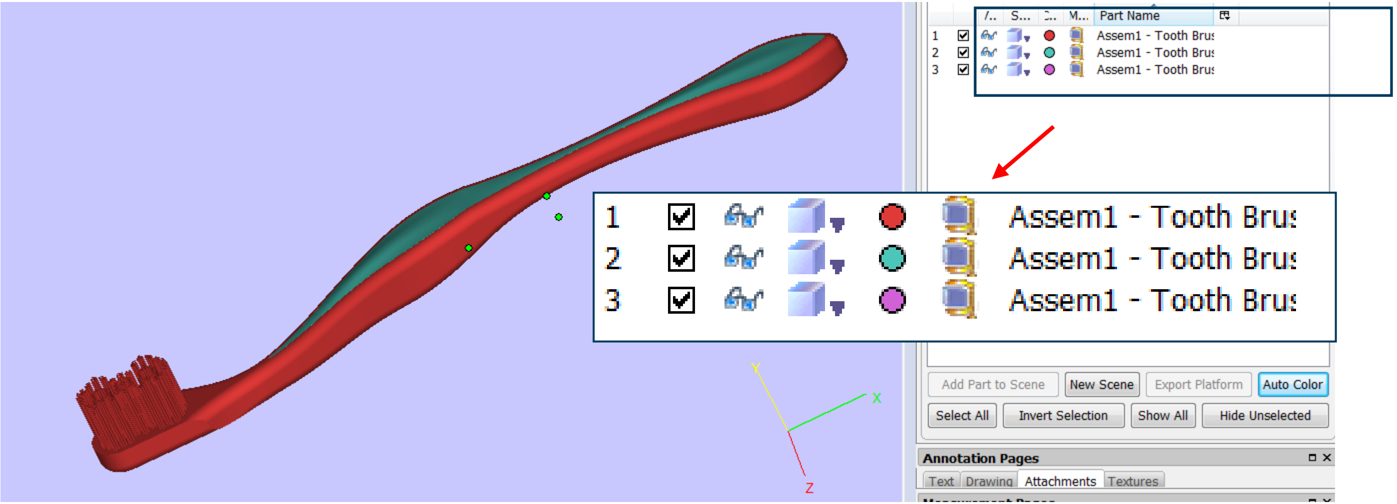
Material assignment will be performed per STL file



CAD FOR MULTI-MATERIAL PRINTING

When converted to STL, 3 shells or 3 STLs exists.

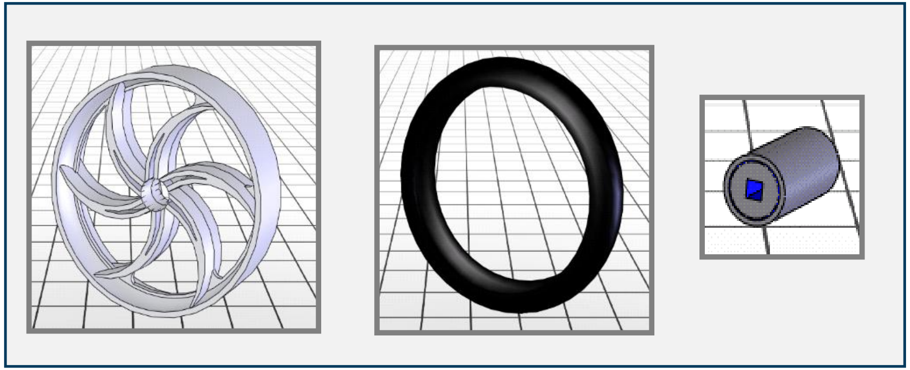
Different materials can be assigned in the GrabCAD Print



CAD to STL | CONNEX/J750 ASSEMBLIES

When using STL manipulation software for example Magics, the part can be saved as a multiple STL files or as a single stl file and than be separated into shells with objet studio.

Three Parts → One assembly



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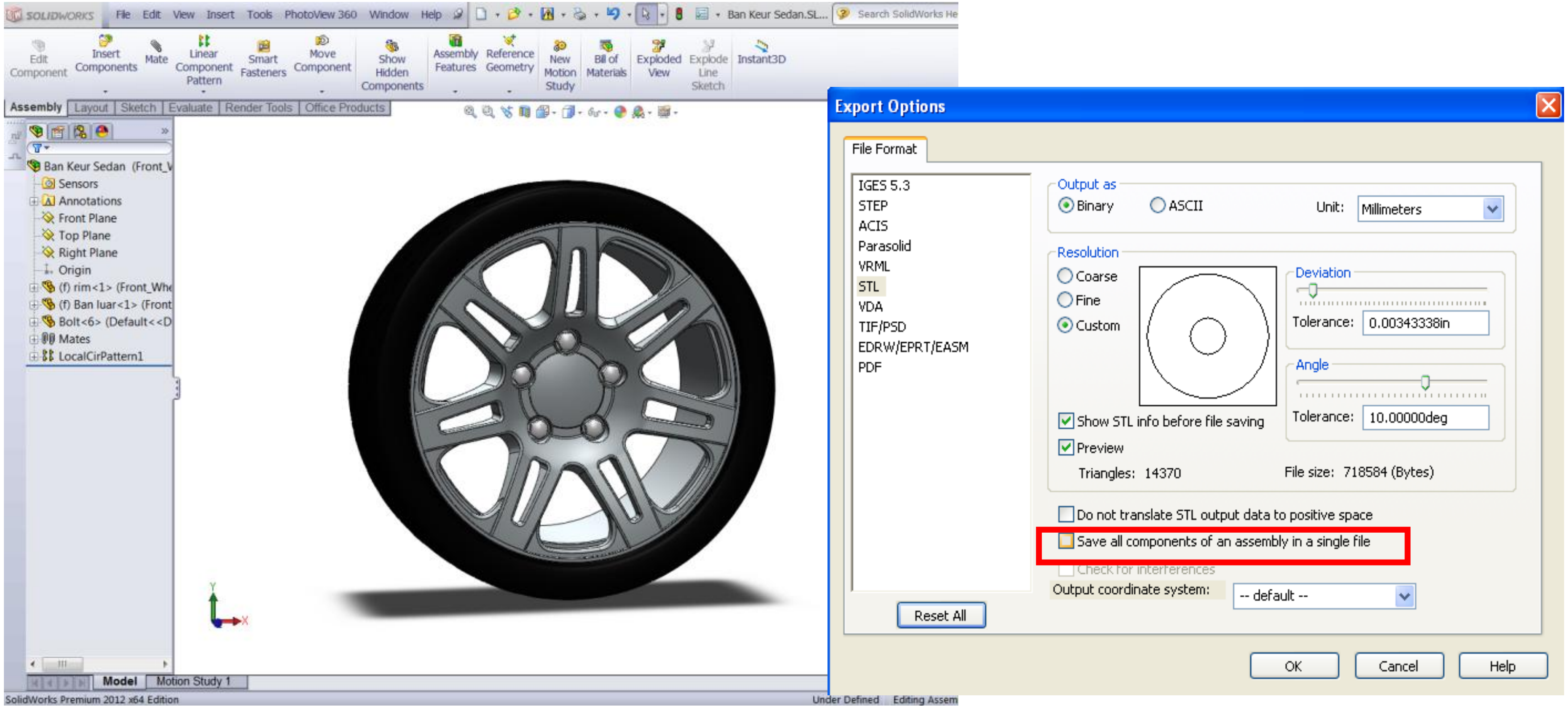
CAD TO STL | CONNEX/J750 ASSEMBLIES



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SUMMARY

Quality of the STL directly affects the quality of the printed model!

When exporting CAD to STL the main parameters to keep are:

- File type → Binary
- Resolution → Custom
  - Deviation: 0.3-0.03 (depending on model complexity)
  - Angle: 5-10 (depending on model complexity)

WHAT IS POSSIBLE

POLYJET PRE-PROCESSING: TEXTURE MAPPING

COLOR/TEXTURE MAPPING – BASIC TERMINOLOGY

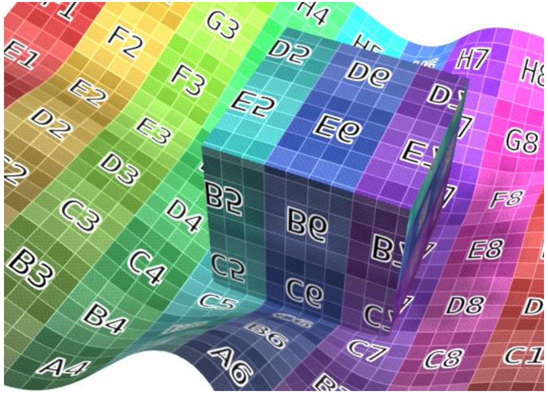
Popular in computer graphics, games & 3D animation

No actual 3D texture created

For 3D printing we only need Color/Diffuse maps

Textures can be any digital image:

- Photos
- Digitally painted
- Scanned
- Etc.

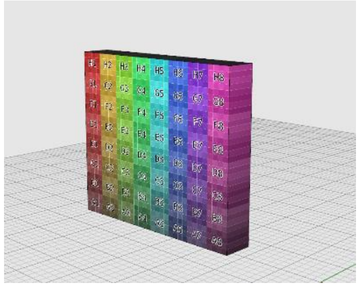


The process of adding a **2D** image or graphics to the surface of a 3d model in order to achieve a more realistic and detailed appearance.

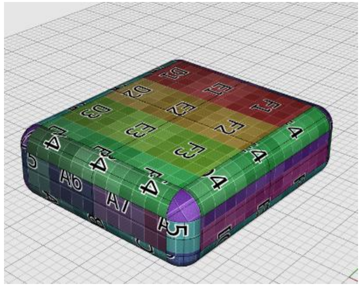
COLOR/TEXTURE MAPPING

The 2D representation of the 3D mesh – texture coordinates

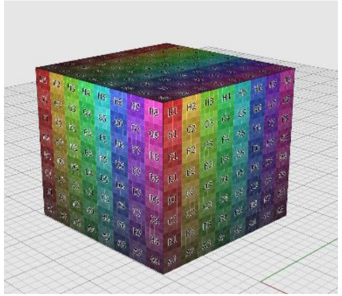
Planar / Projection



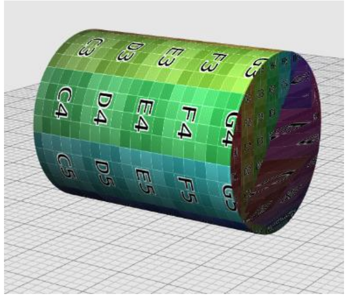
Surface / Face



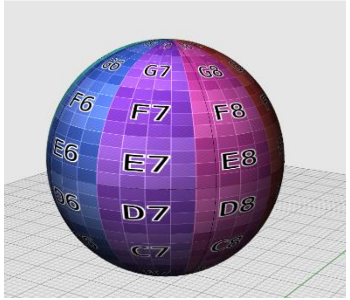
Cubic / Box



Cylindrical



Sphere



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CUSTOM COLOR/TEXTURE UNWRAPPING

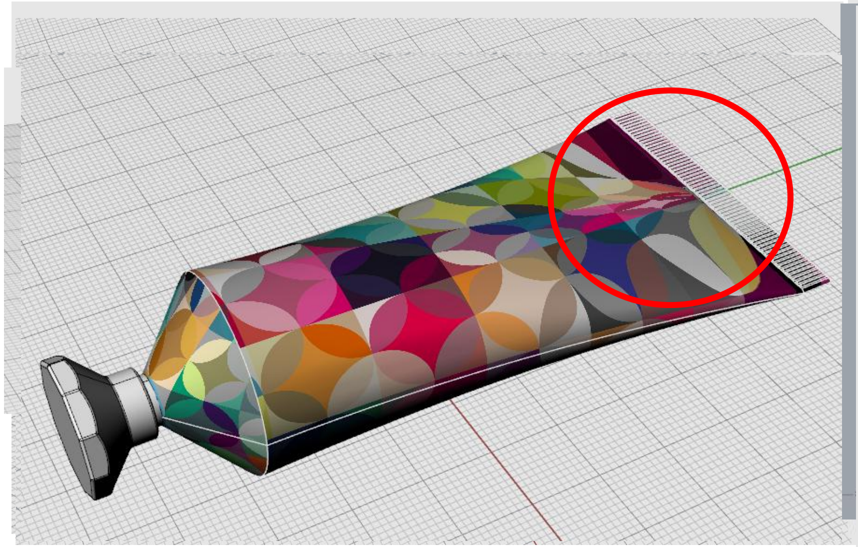
CUSTOM COLOR/TEXTURE UNWRAPPING

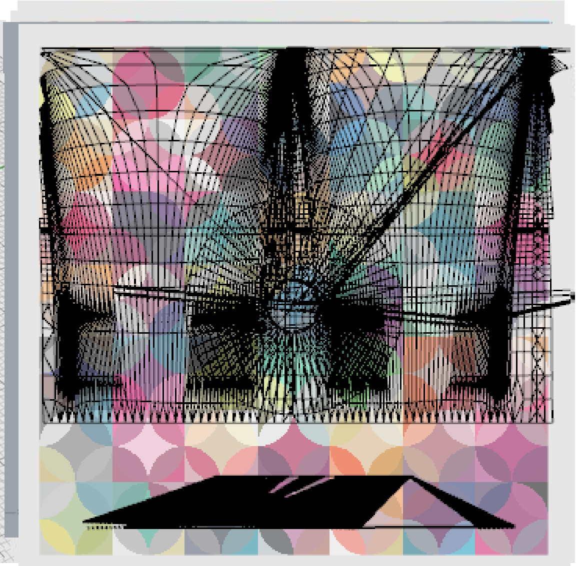
Let’s demonstrate some custom Mapping Methods

Planar mapping

Cubic mapping

Cylindrical mapping





EXAMPLE: PRINT COLORED MODEL WITH J750

Color per Object / Mesh

Color per Vertex

Color per Face

Texture Map

All of the Above

SUMMARY CHALLENGE

A DESIGN FOR YOUR PRINTER

ACTIVITY 6.3: DESIGN AND PRINT A 3D CALIBRATION RULER

Download the Activity Worksheet from the Module 6 Resources section.

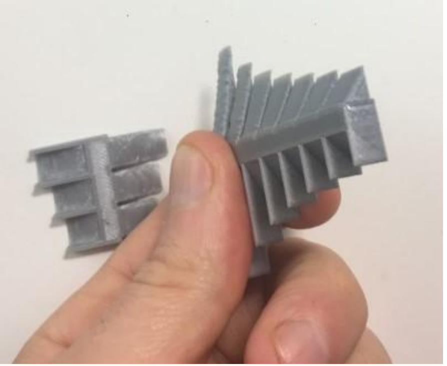
ACTIVITY 6.3 – BONUS PROJECT: SOLUBLE SUPPORT CHALLENGE

SHARE YOUR CALIBRATION RESULTS WITH STRATASYS

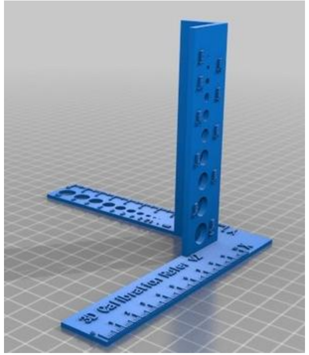
Create a GrabCAD.com account if you don't already have it

Upload your STLs or CAD Files, descriptions and photos of your calibration tool; remember to note what printer it was designed for

Email us the link at: edu.curriculum@stratasys.com

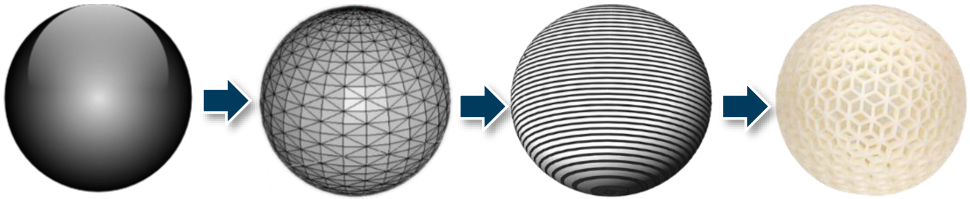


Jakob Nilsson - Design and photo credit



Thingiverse - thing:25763

SUMMARY & HOMEWORK ASSIGNMENT



3D CAD file
Design a CAD model

STL file
CAD software saves the model as an STL file

STL Slicing
Print preparation software slides the STL file

Printing
Model Printed layer by layer

HOMEWORK ASSIGNMENT
Ask students to design a part that will use maximum print time for a specific reason and explain why. Students should download GrabCAD Print, and use the settings to view different parameters.

FABRICATION CONSIDERATIONS FOR FDM AND POLYJET TECHNOLOGY

Module 7

stratasys

MODULE 7: FABRICATION CONSIDERATIONS

Learning Objectives:

- Explain the basic 3D printing workflow (01)
- Describe the fabrication considerations for PolyJet and how to insure model quality, minimize print time, achieve desired surface finish, print fine details, fit surfaces, and conserve model material (02)
- Describe how nesting and orientation (spacing, stacking, part heights and overlap impact time, strength and material usage) affects mechanical design properties of a printed part (03)
- Describe how support material affects mechanical design properties (03)
- Demonstrate successful ability to prepare a part to print within GrabCAD print (04)
- Show proficiency in using Insight in - Green flag mode (5-step setup), Automatic processing mode and Manual Mode with an understanding of the steps pre-processing to orientation, how to slice, fix & view, how support impact part and tips/toolpaths (05)

FABRICATION CONSIDERATIONS – VIDEO

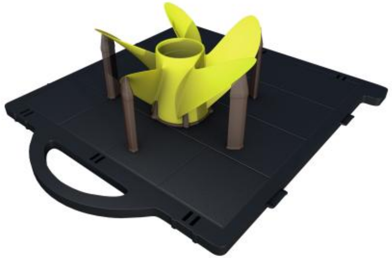
https://www.youtube.com/watch?v=RciYGdQViSk

https://youtu.be/RciYGdQViSk

STRATASYS 3D PRINTING WORKFLOW

1- Pre-Processing

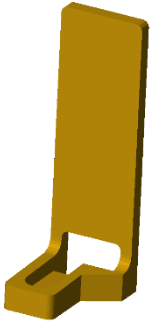
2- Production



3- Support Removal

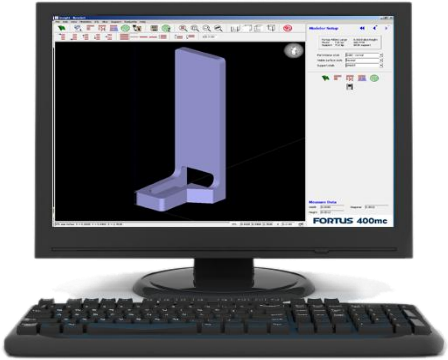
FDM PRE-PROCESSING

CAD Model



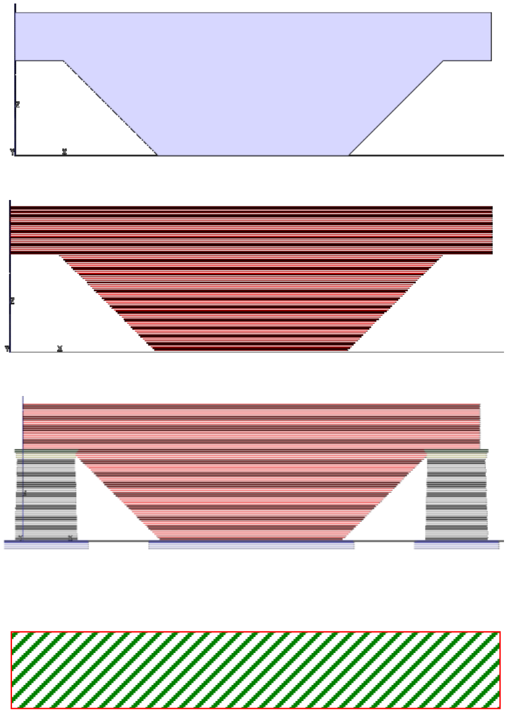
STL File

Software:
GrabCAD Print or Insight

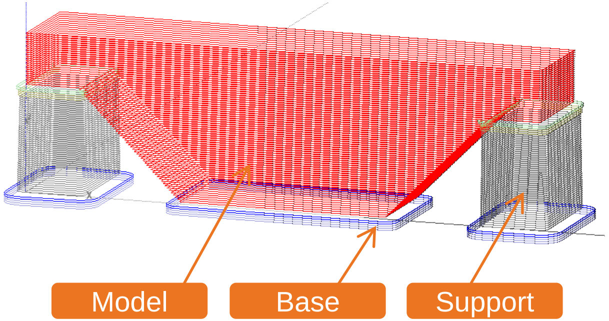


CMB File

FDM PRE-PROCESSING SOFTWARE



1. Import STL
2. Slice STL
3. Add Supports



- Note: FDM has a self-supporting build angle to 45º

4. Generate Toolpaths

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LAYER THICKNESS

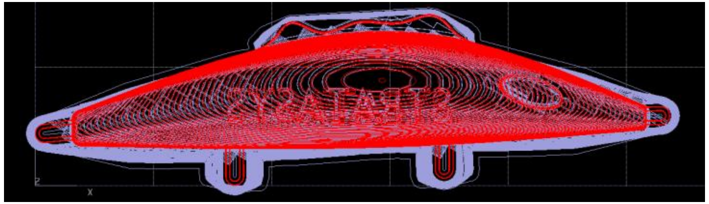
Layer Resolution Options:
(varies by machine)

- .007” (.18mm)
- .010” (.25mm)
- .013” (.33mm)

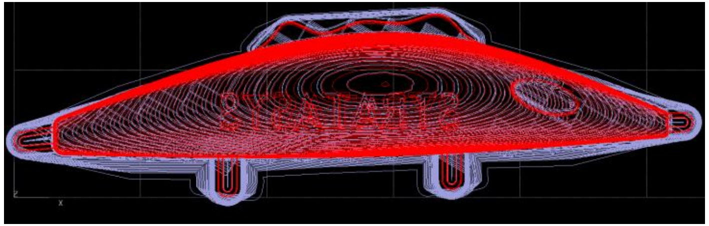
Layer Resolution Affects:

- Surface Finish
- Build Time
- Part Strength
- Feature Detail

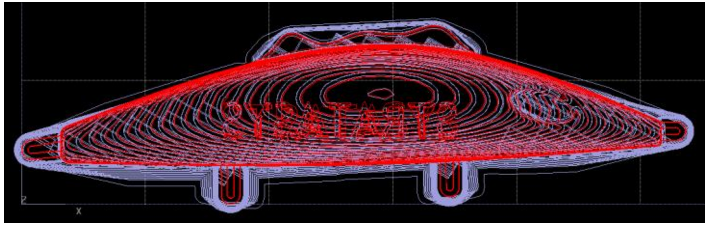
.007” Layers, Build Time: 4h09m



.010” Layers, Build Time: 1h48m

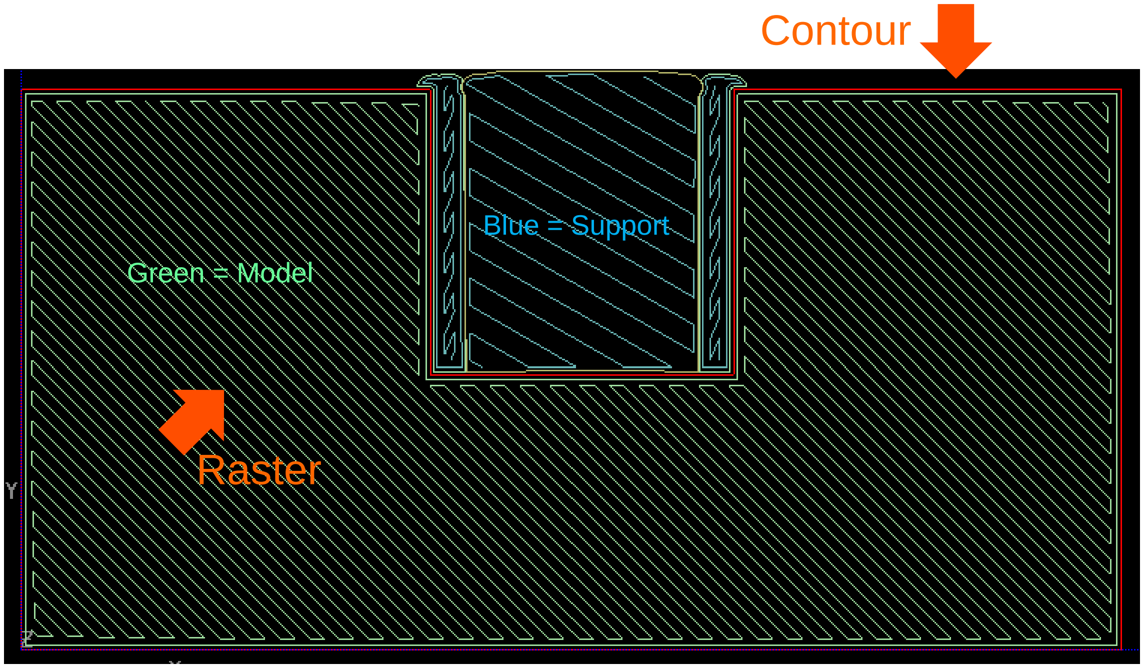


.013” Layers, Build Time: 1h27m

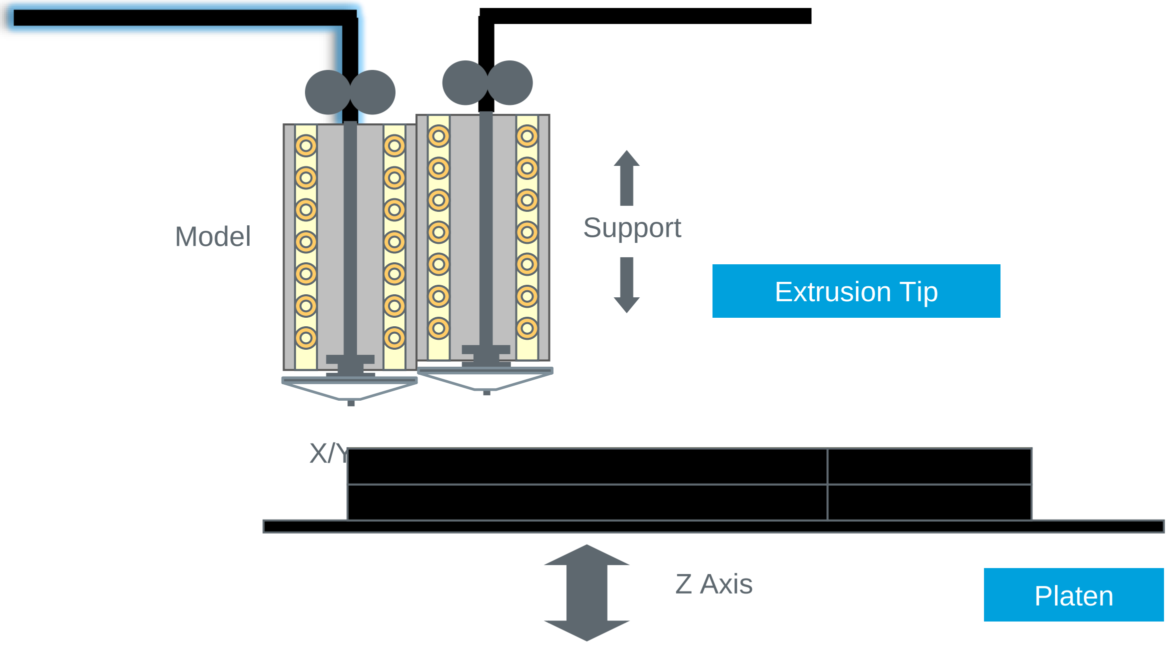


FDM EXTRUSION TOOLPATHS

Toolpath (extrusion path, road, raster, contour or path)

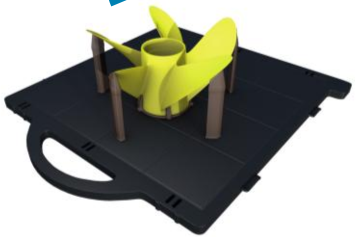


PART PRODUCTION - FDM EXTRUSION



FDM SUPPORT REMOVAL

Remove the Tray /
Build Sheet



Remove the Part(s)

Place Part(s) in Tank

Finished Part(s)
Ready to go!

FABRICATION CONSIDERATIONS FOR: POLYJET

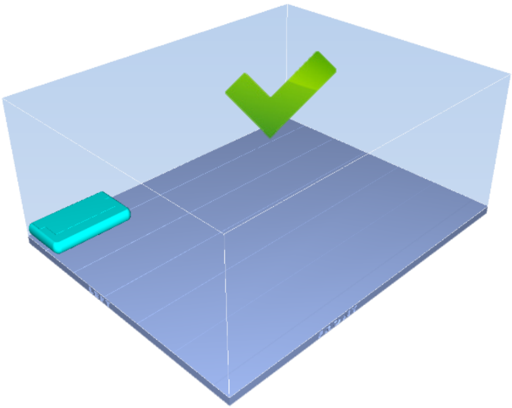
PRE-PRINTING CONSIDERATIONS

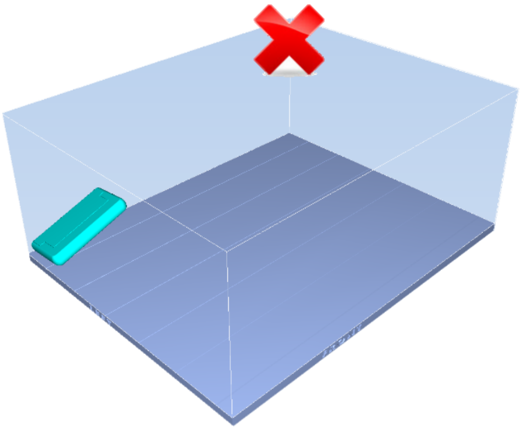
The orientation and placement of the model on the build tray affects:

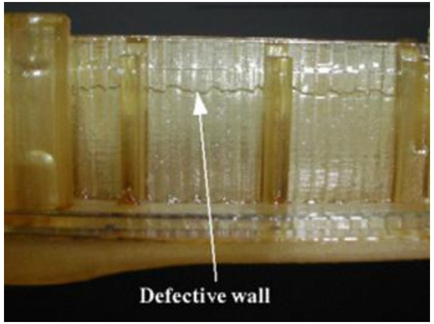
- Model quality
- How quickly and efficiently the models will be printed
- Where and how much support material is used
- Whether or not model parts will have matte/glossy finish

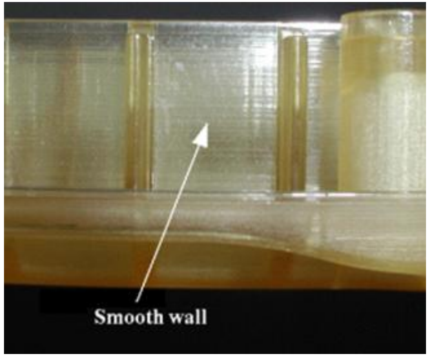
INSURE MODEL QUALITY

Align the model to the X,Y or Z axis of the tray especially if the model has straight line walls to assure smooth walls





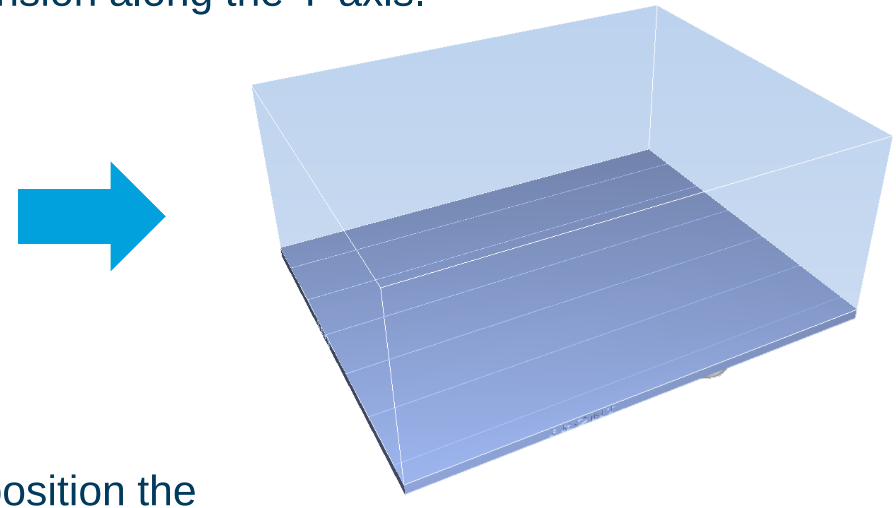




MINIMIZING PRINTING TIME

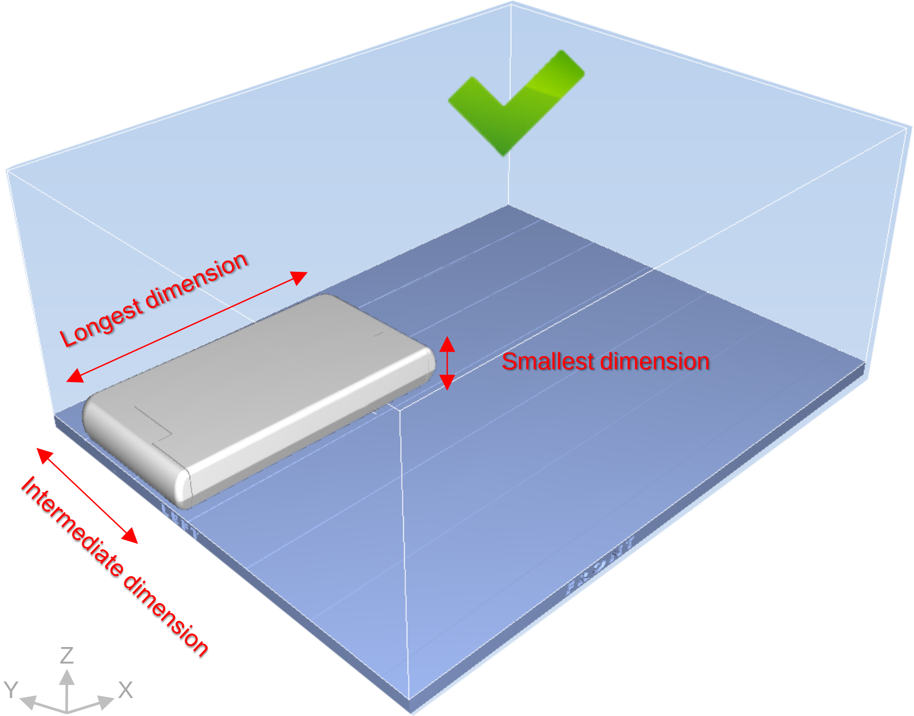
Place the model **largest** dimension along the X-axis.
Place the model **smallest** dimension along the Z-axis.
Place the model **intermediate** dimension along the Y-axis.

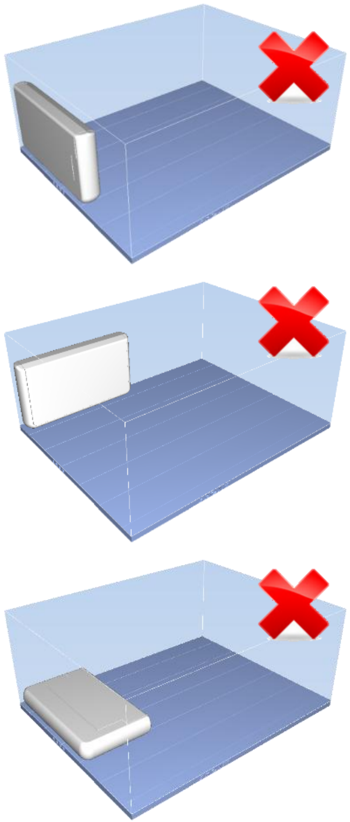
Card Holder



What will be best way to position the card holder model on the build tray?

MINIMIZING PRINTING TIME

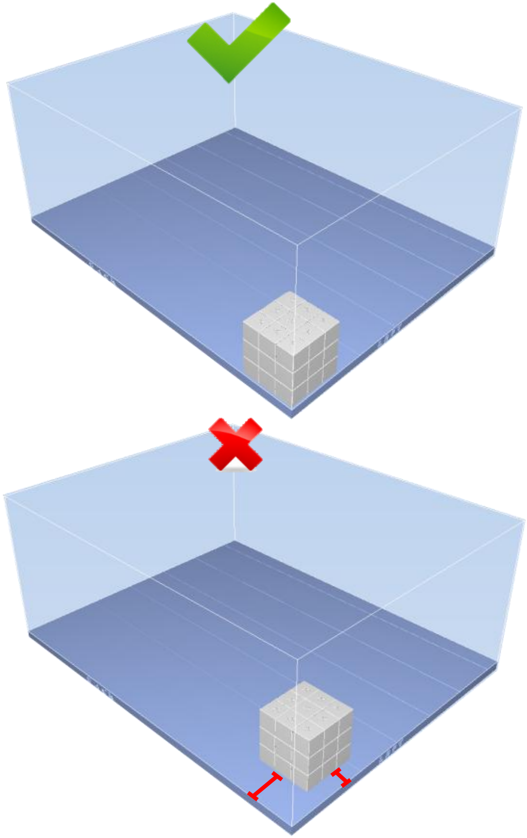




MINIMIZING PRINTING TIME

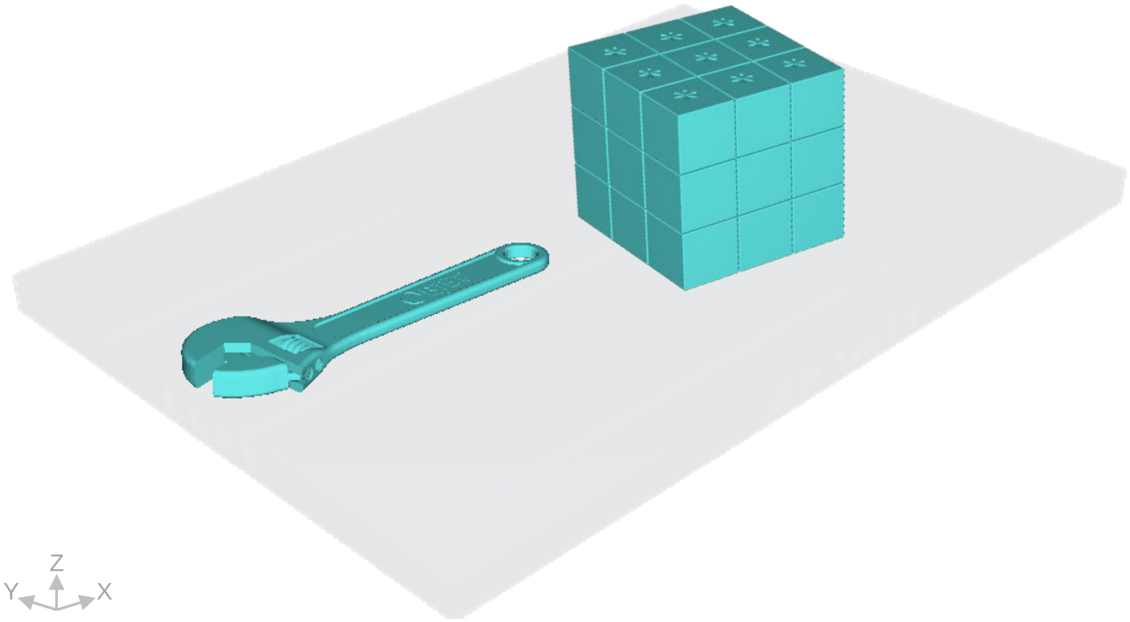
Align the model to fit minimum passes of the printing head

Keep in mind that the print heads measure about 2 inches (5 centimeters) on the Y-axis



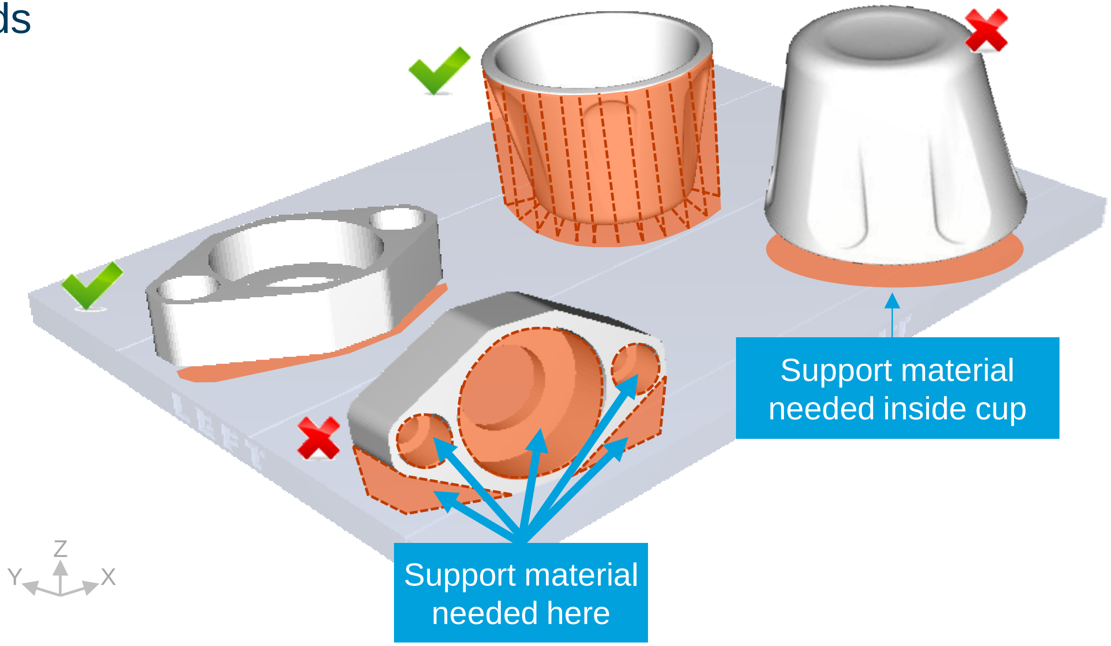
MINIMIZING PRINTING TIME

Place tallest parts on the top left of the tray.



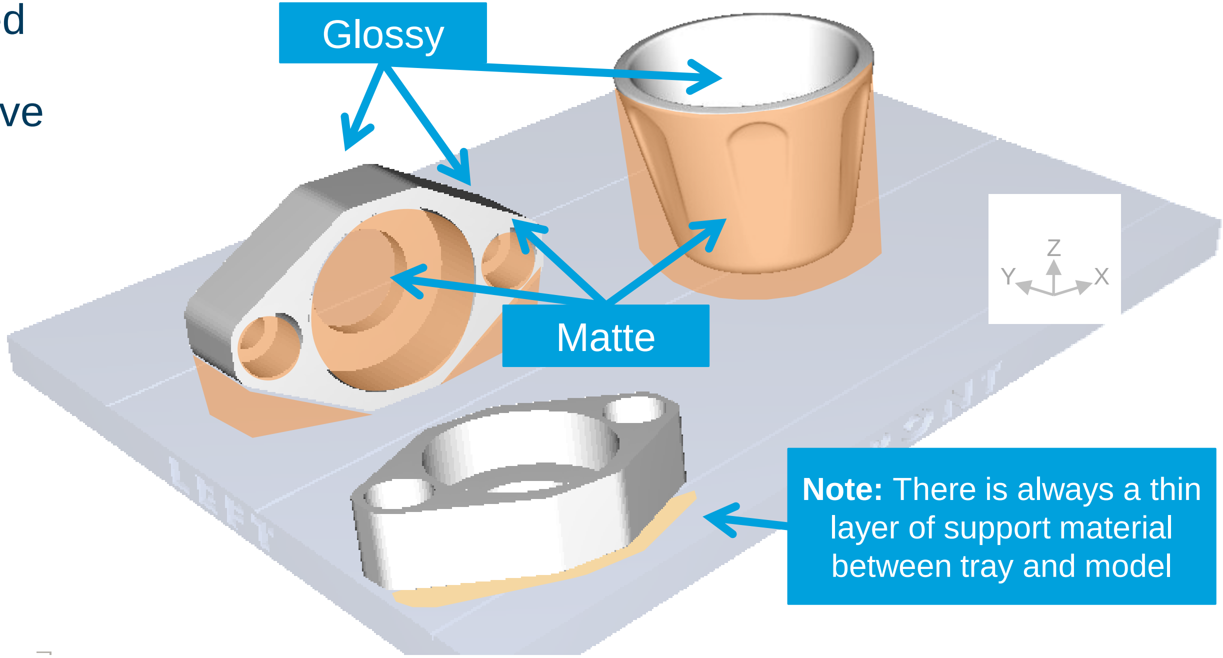
MINIMIZING SUPPORT MATERIAL USED

When model material needs to be printed on top of empty space, as in holes, hollows, and negative angles, support material is used as a temporary placeholder, which is removed after printing.



SURFACE FINISH | MATTE OR GLOSSY

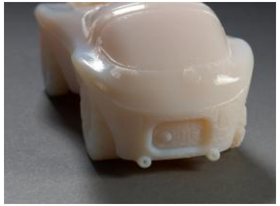
Surfaces coated with support material will have a matte finish



Note: There is always a thin layer of support material between tray and model

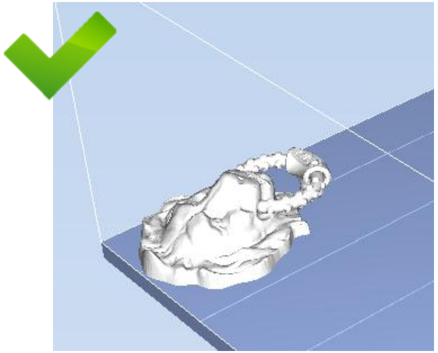
SURFACE FINISH | MATTE OR GLOSSY

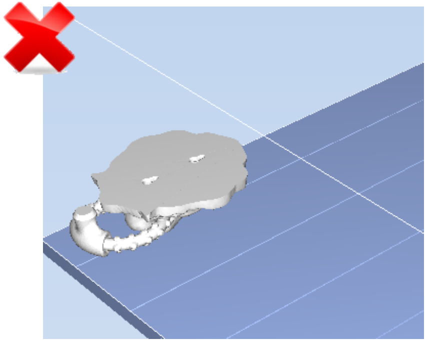
Some geometries **do not allow** for full glossy printing



PRINTING MODELS WITH FINE DETAILS

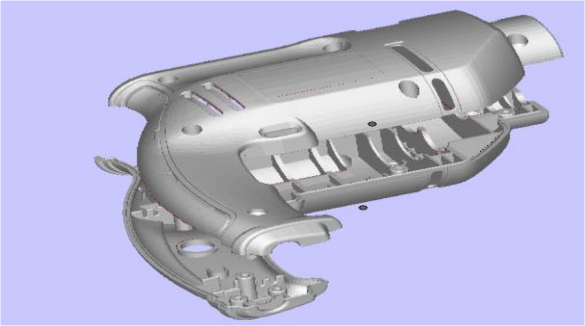
The side with fine details should be positioned face-up and printed with a glossy finish.

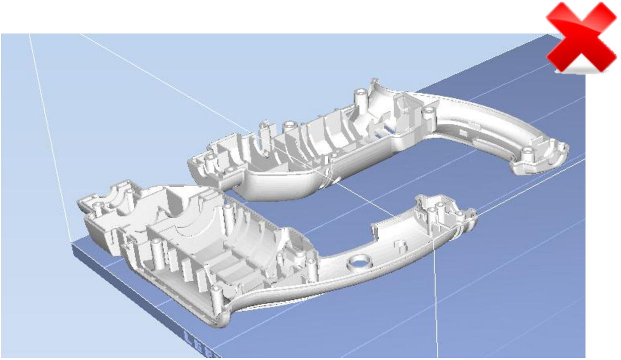


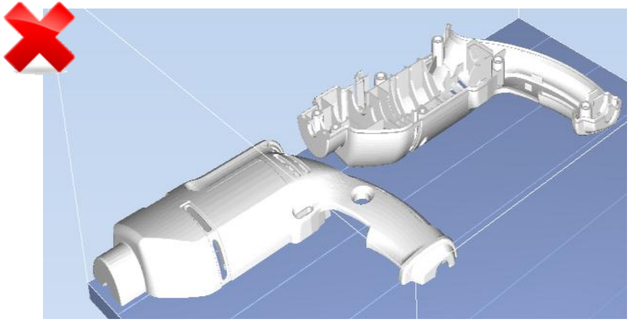


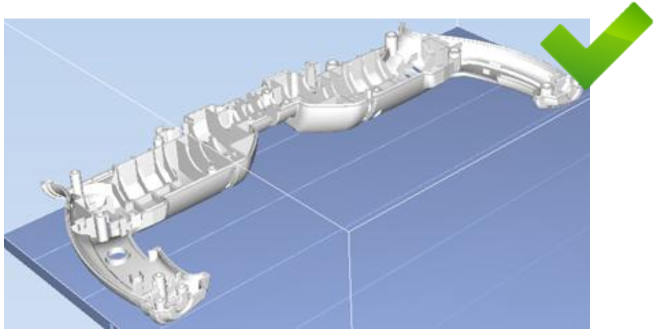
FITTING SURFACES

Fitting surfaces should be positioned **facing up** in the same orientation





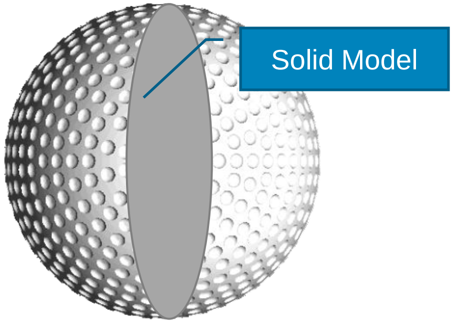


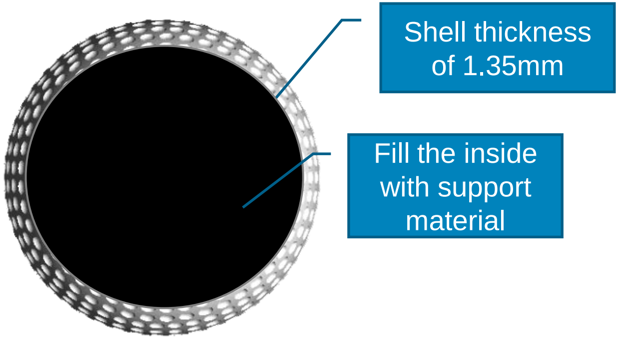


SAVING MODEL MATERIAL

Hollow- filling models with Support Material

- This feature is most affective on models that are large in volume and solid all the way through
- The model can be printed hollow with a selected shell thickness for the outer shell and support material instead of model material to fill the inside of the model
- The printed model properties and quality will not be affected
- The shell thickness can be adjusted





NESTING & PART ORIENTATION

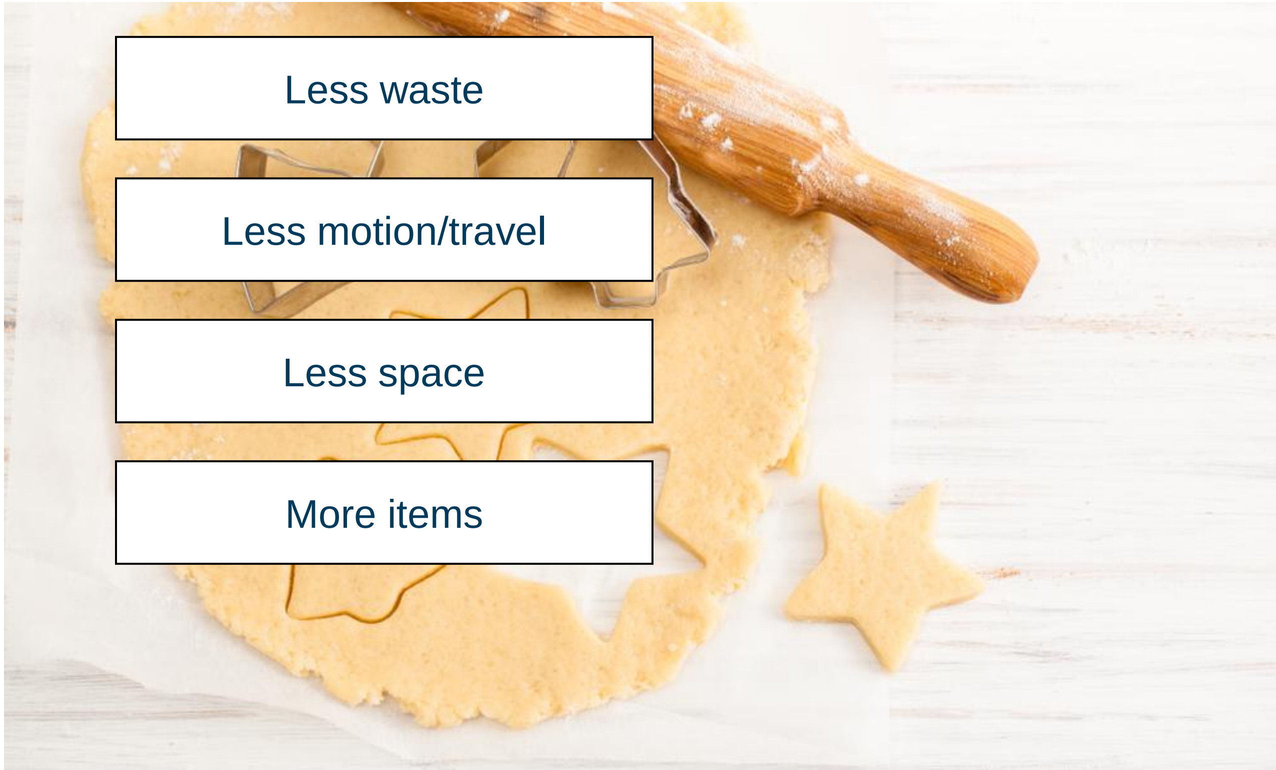
NESTING

REVIEW

- Nesting concepts: 2D
- Nesting concepts: 3D
- Nesting for 3D printing

NESTING – 2D CONCEPTS

NESTING - ADVANTAGES



Less waste

Less motion/travel

Less space

More items

NESTING - ADVANTAGES

Less waste

Less motion/travel

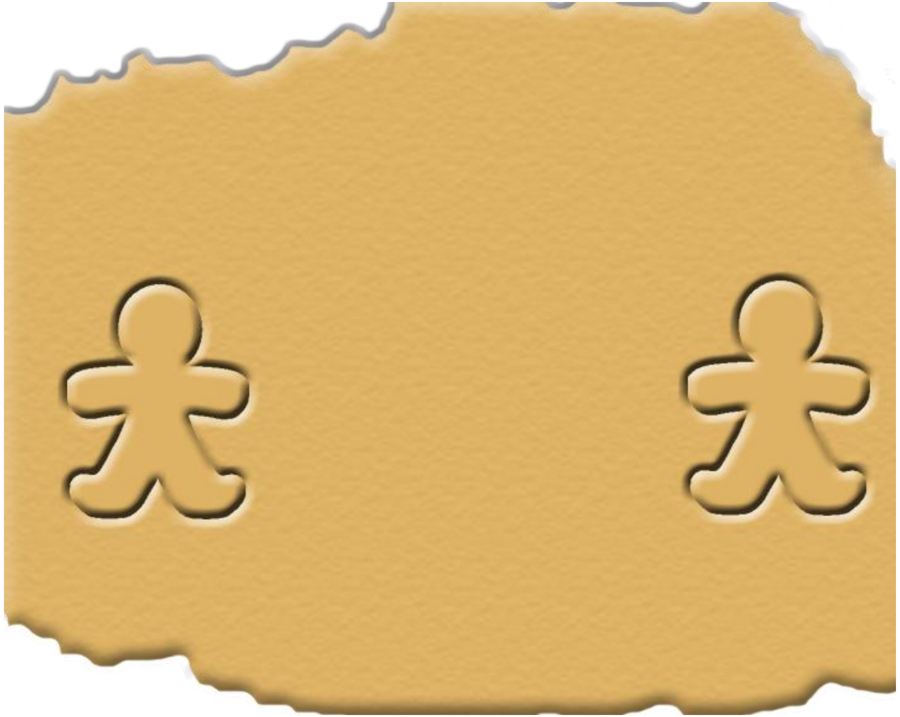
Lower cost

Less space

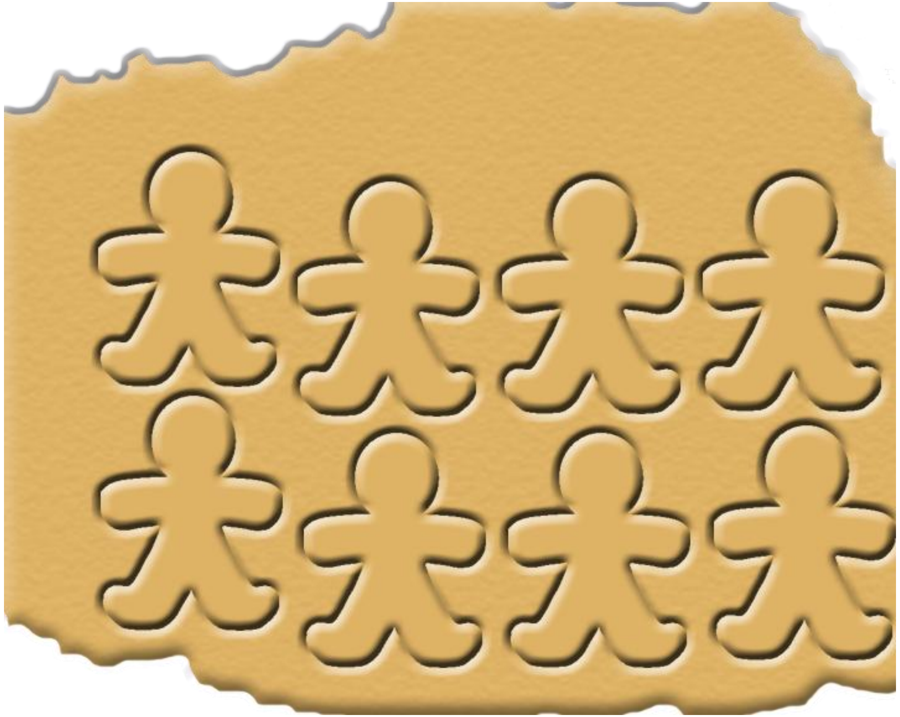
More items

stratasys

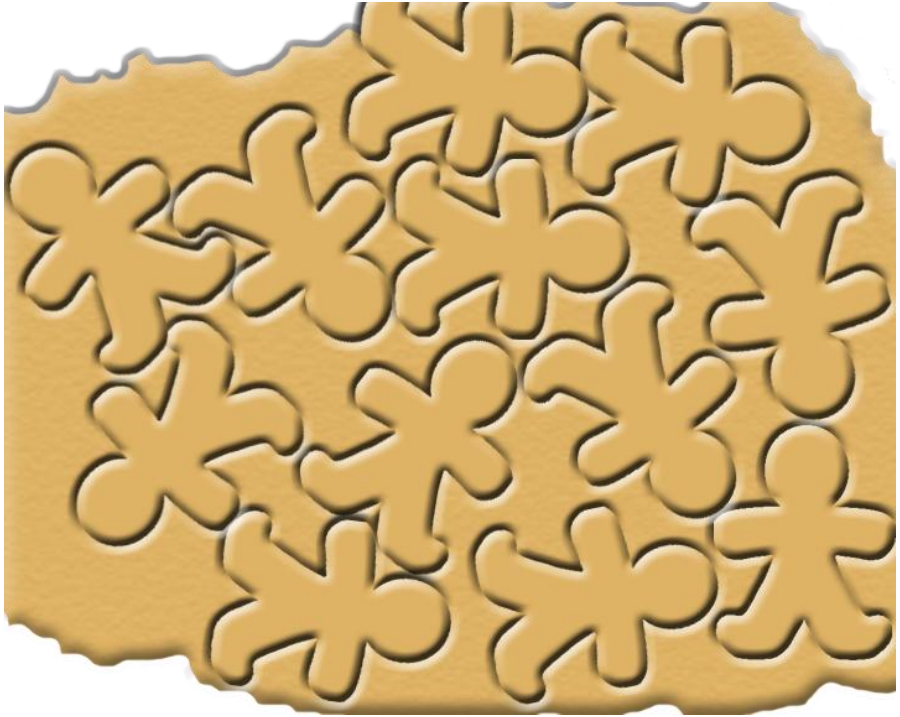
NESTING - 2D



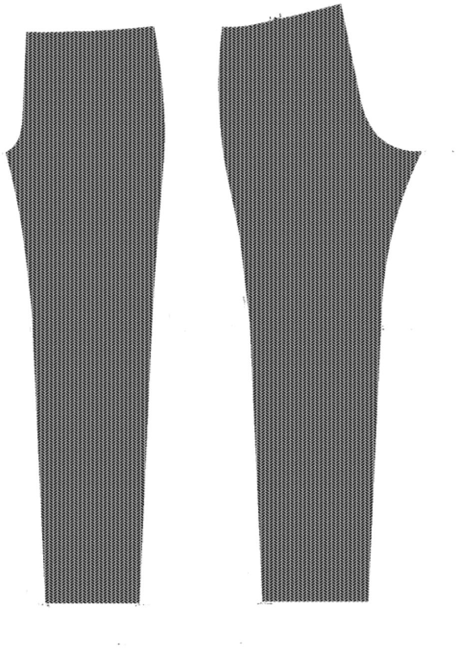
NESTING - 2D

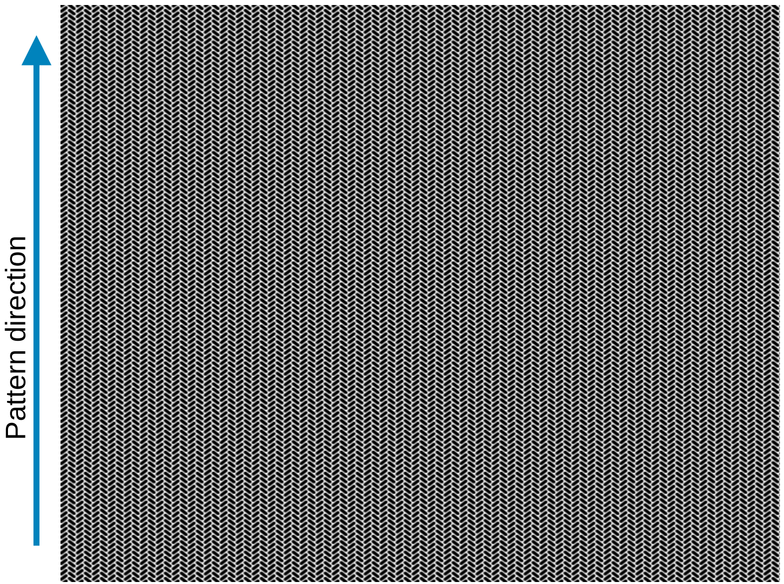


NESTING - 2D

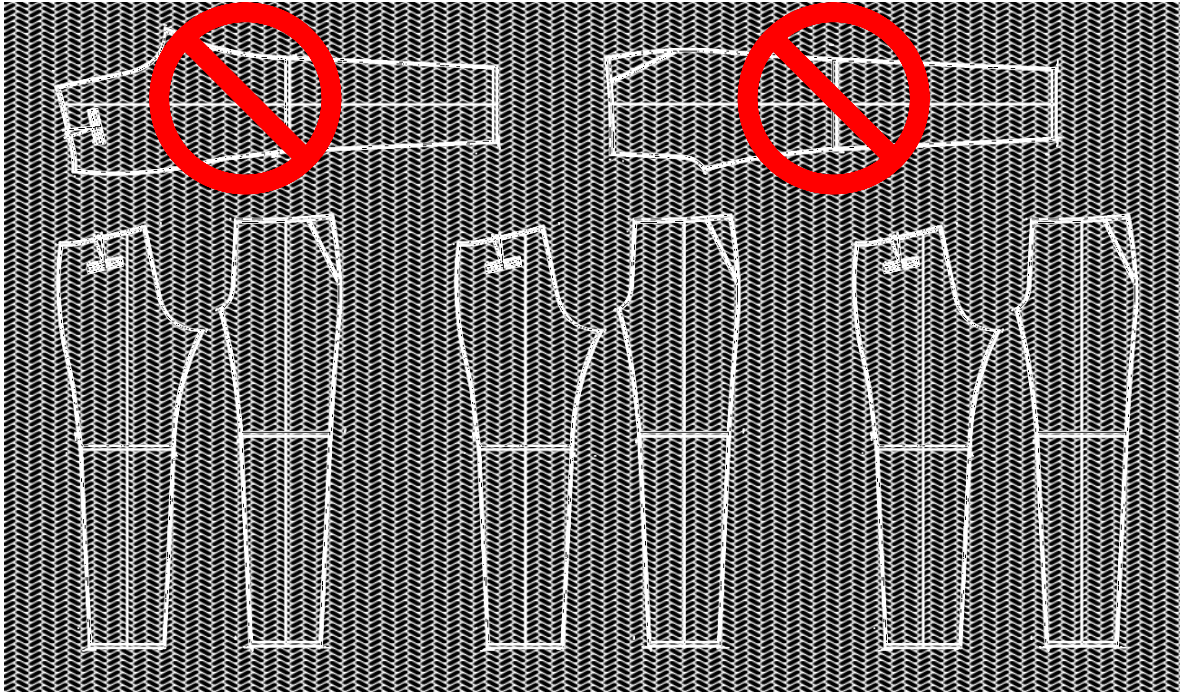


2D NESTING - ORIENTATION

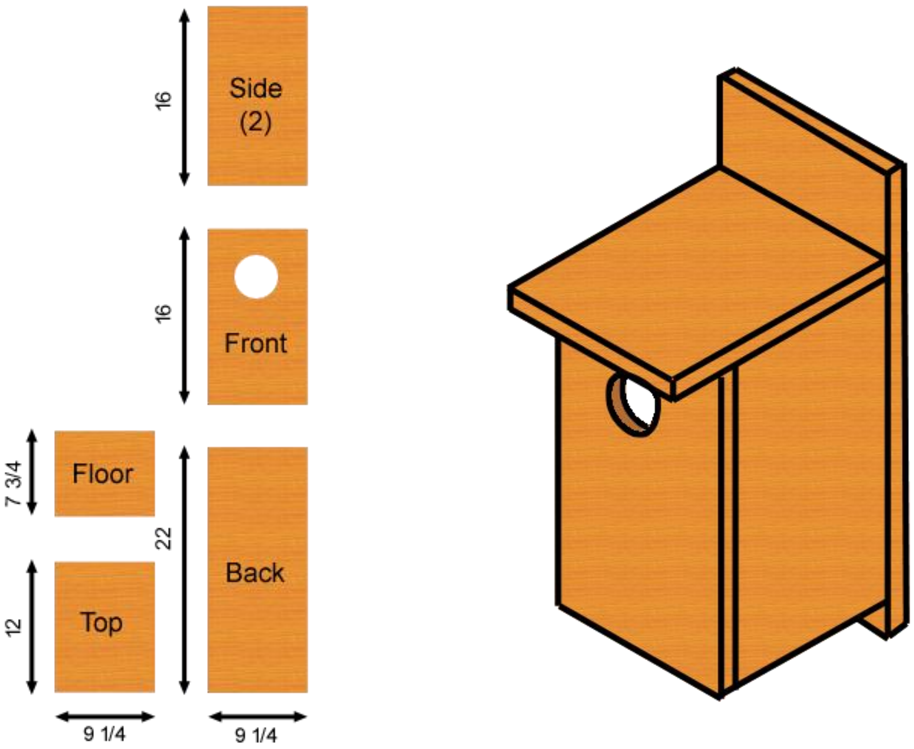




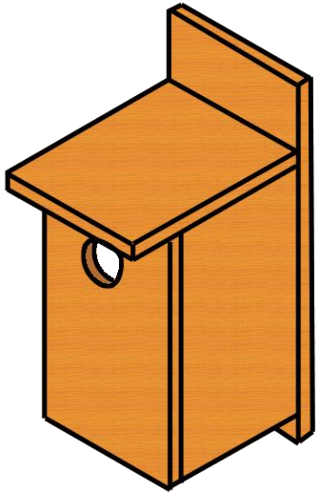
2D NESTING - ORIENTATION

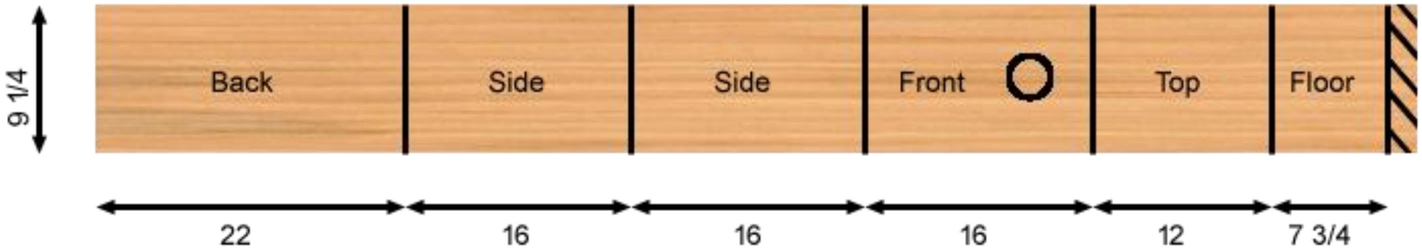


2D NESTING - ORIENTATION



2D NESTING – ORIENTATION & SPACING





2D NESTING - MANUFACTURING

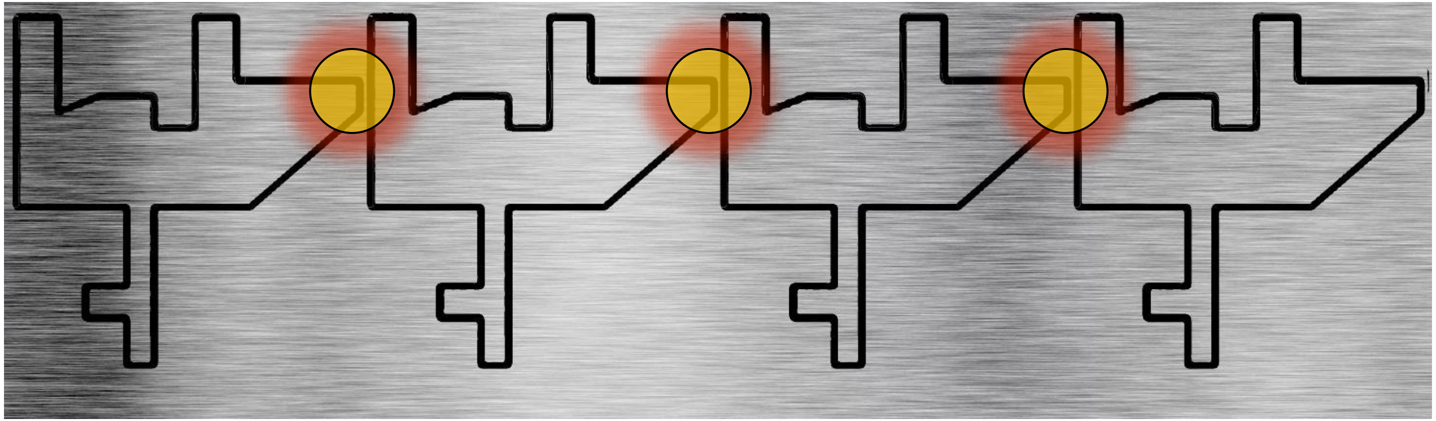
SHEET METAL

CUTTING

WATERJET CUTTING

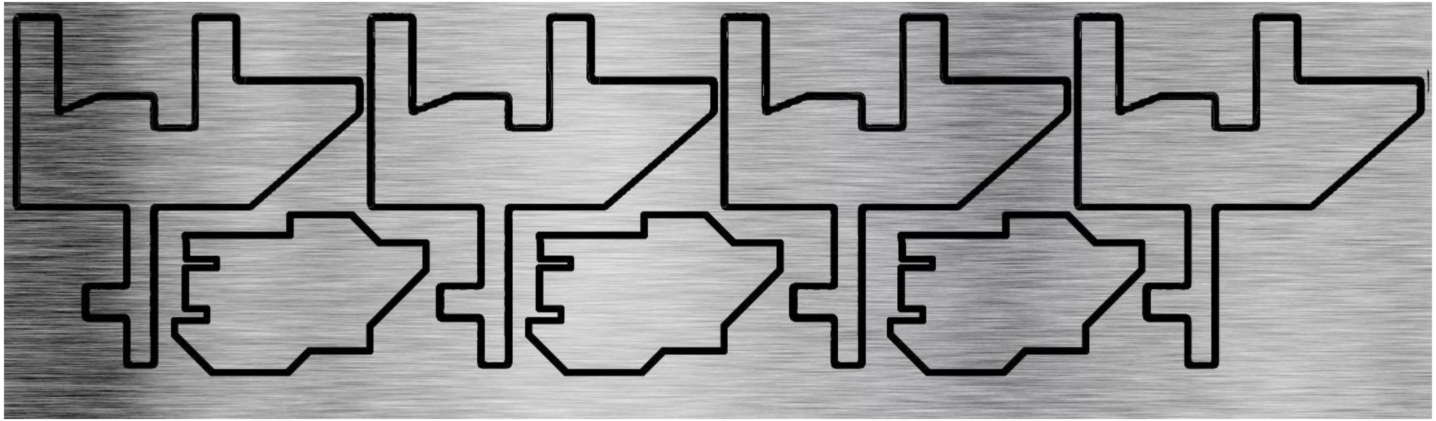
2D NESTING - MANUFACTURING

Orientation

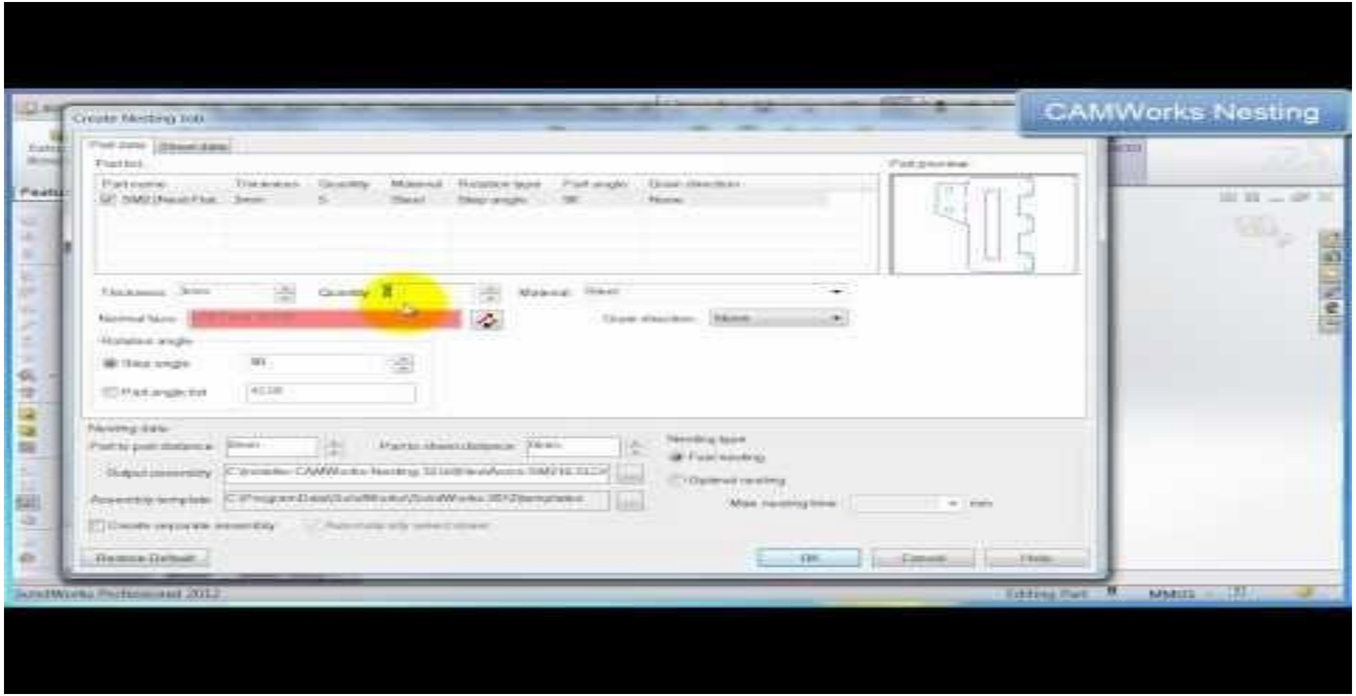


2D NESTING - MANUFACTURING

Part Combinations



NESTING – AUTOMATIC LAYOUT



https://youtu.be/7V5YBrRMhhM

3D NESTING – COOKIE DOUGH OR COOKIE SHEET?

NESTING – 3D CONCEPTS

Image credit : Dreamstime 27600482

NESTING - STACKING

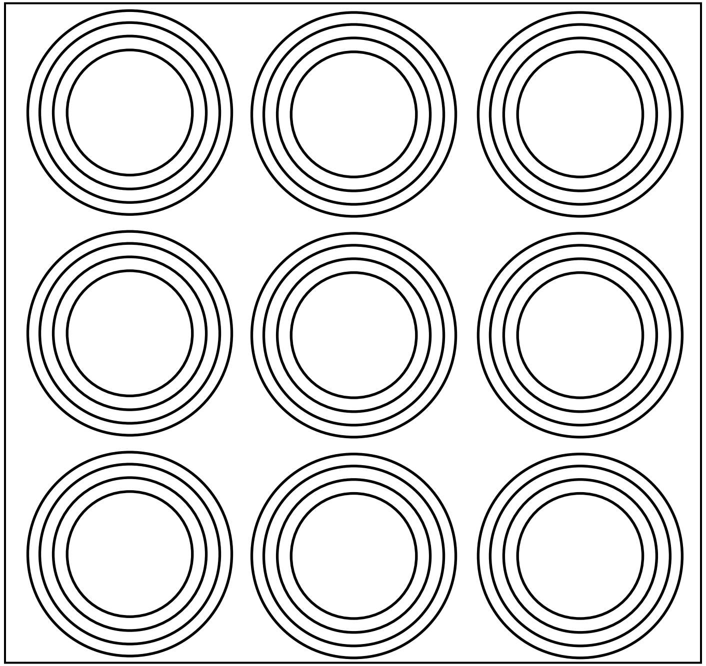
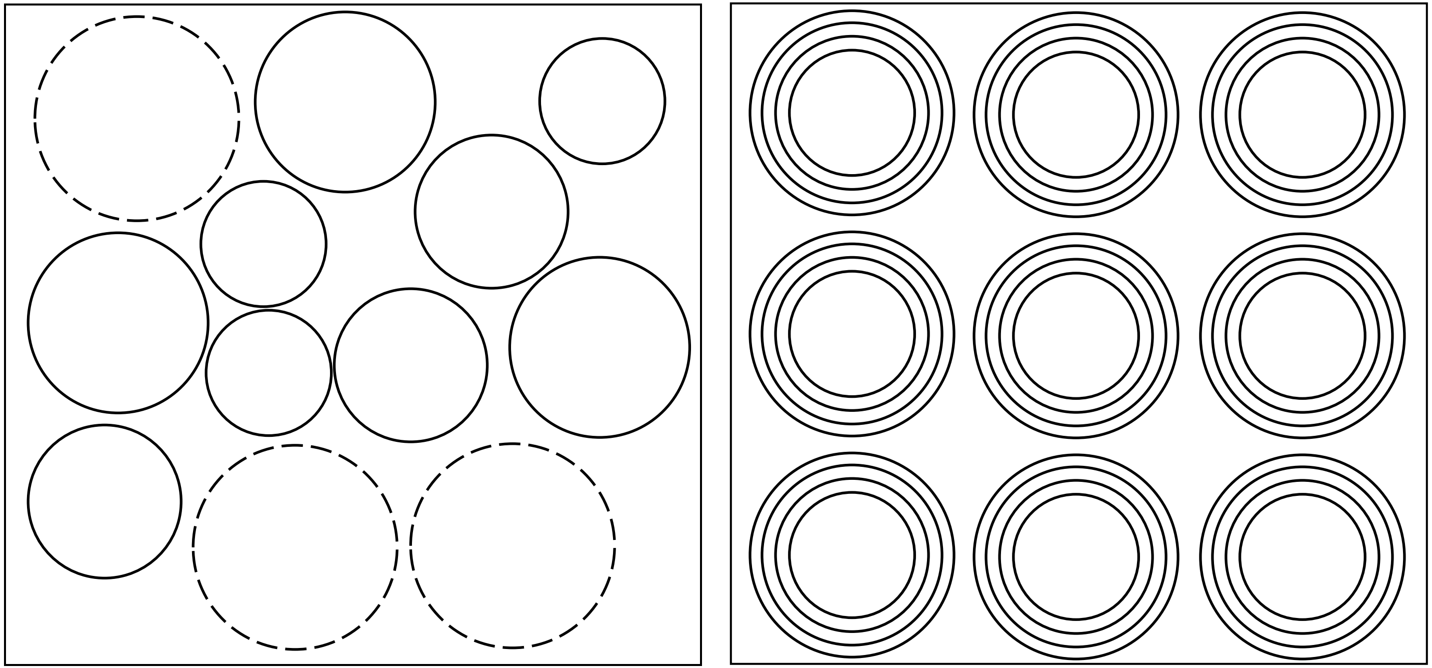


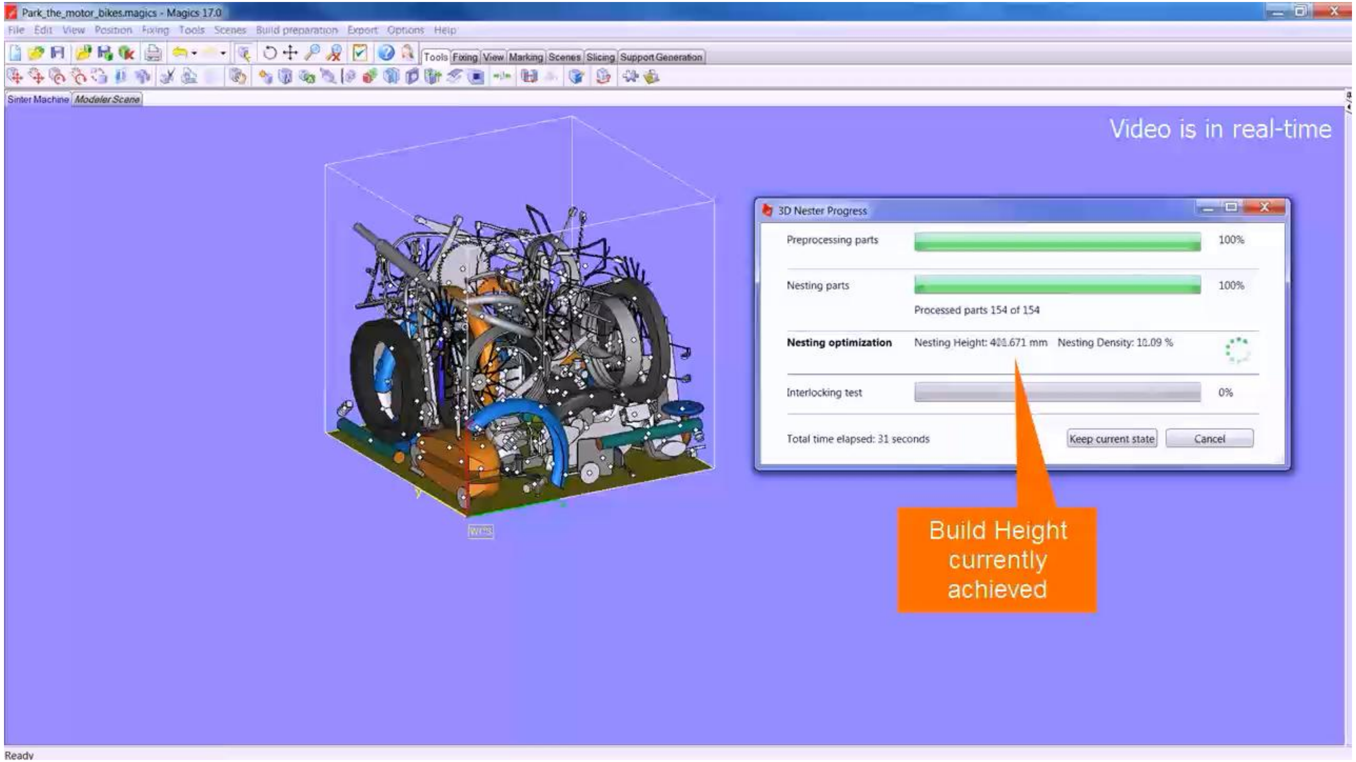
Image credit : Dreamstime 21820578

NESTING - STACKING

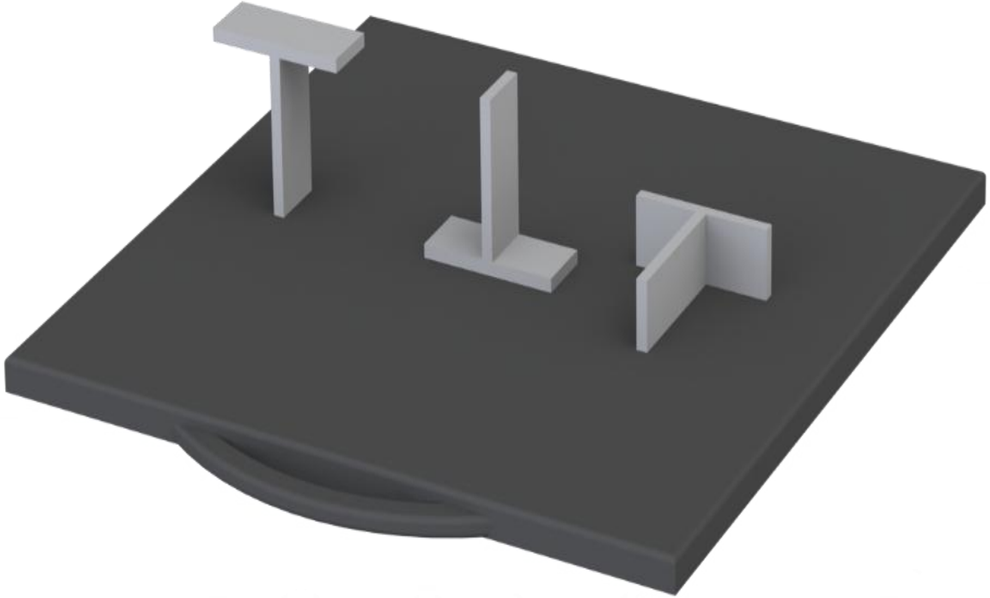


NESTING – AUTOMATIC LAYOUT

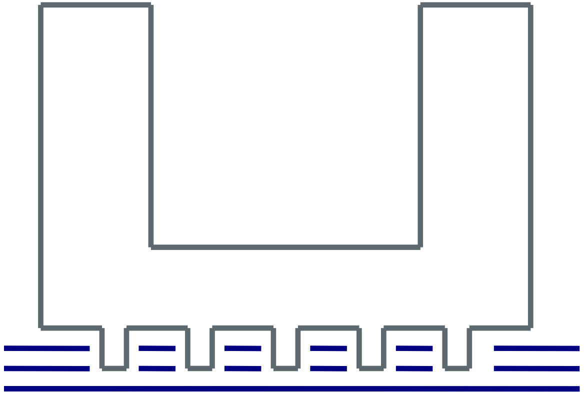
https://www.youtube.com/watch?v=wDj8h5wKsek



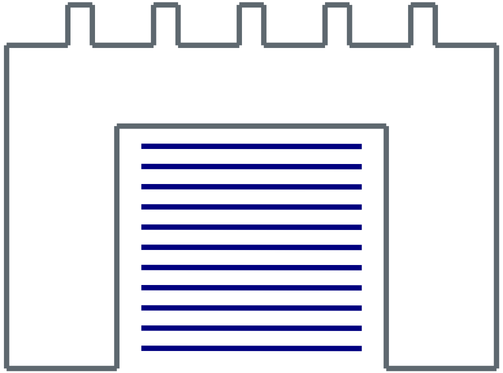
NESTING CONSIDERATIONS - ORIENTATION



NESTING CONSIDERATIONS – ORIENTATION – SUPPORT REMOVAL

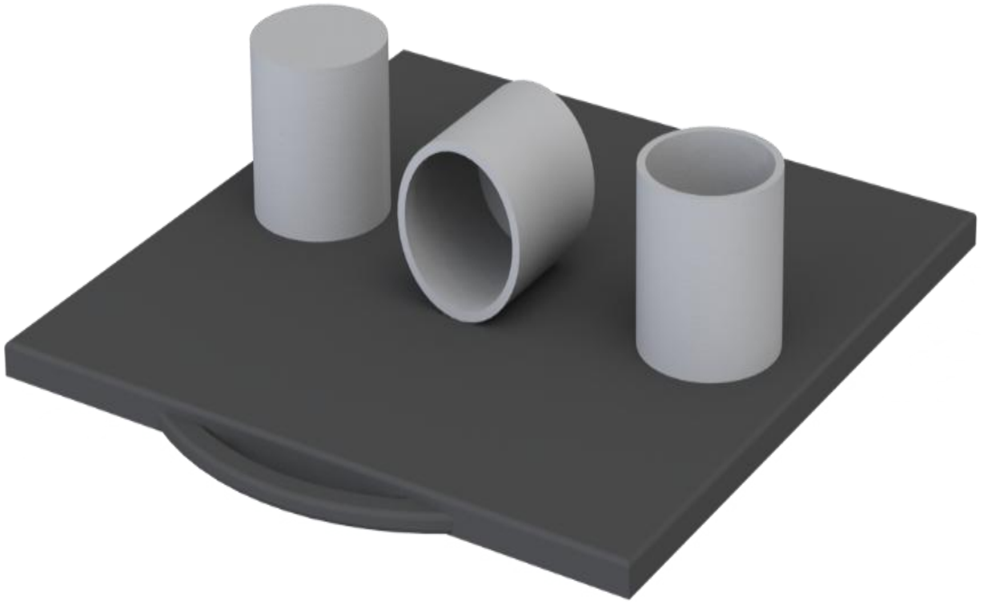


Orientation 1
would use less support material



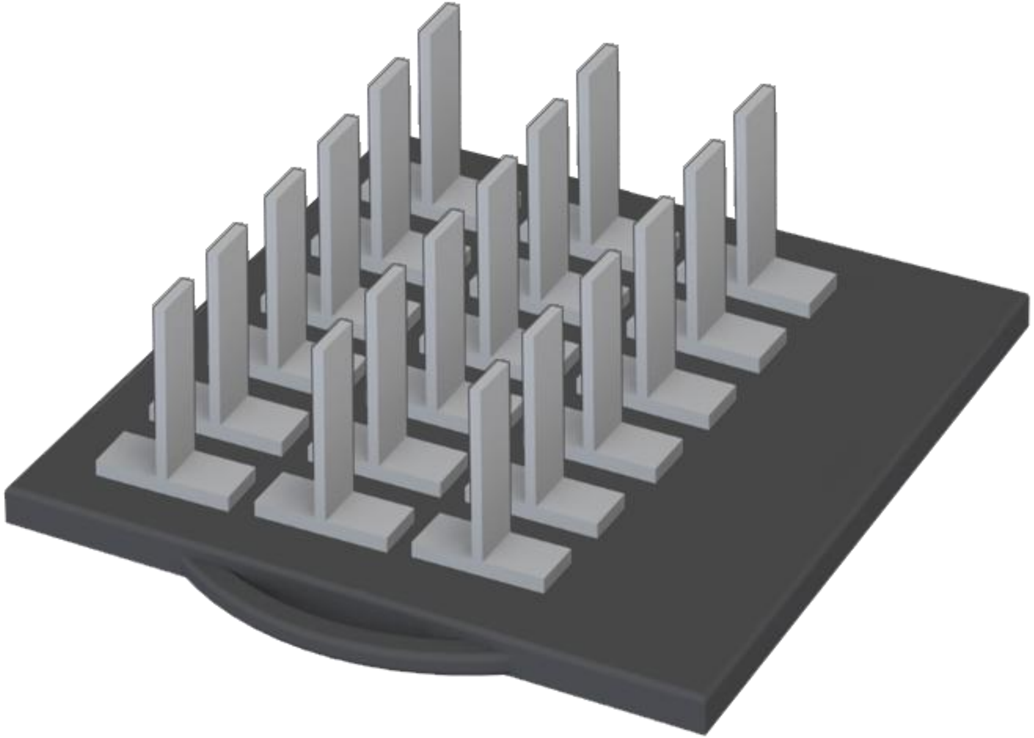
Orientation 2
better for breakaway supports

NESTING CONSIDERATIONS - ORIENTATION

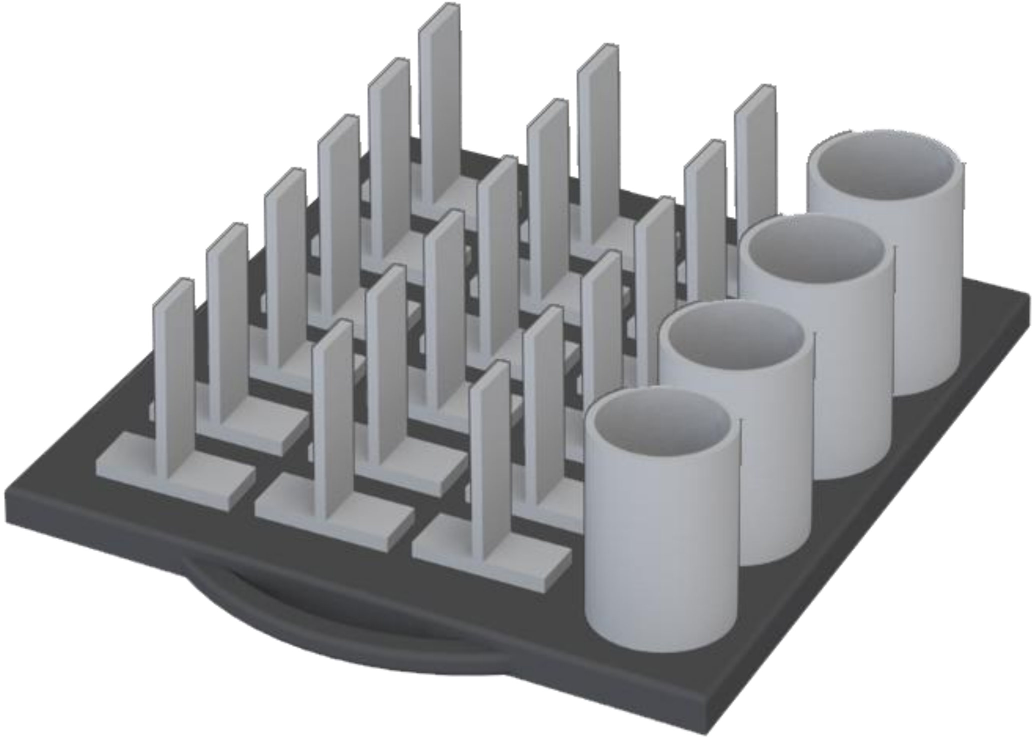


NESTING CONSIDERATIONS - ORIENTATION

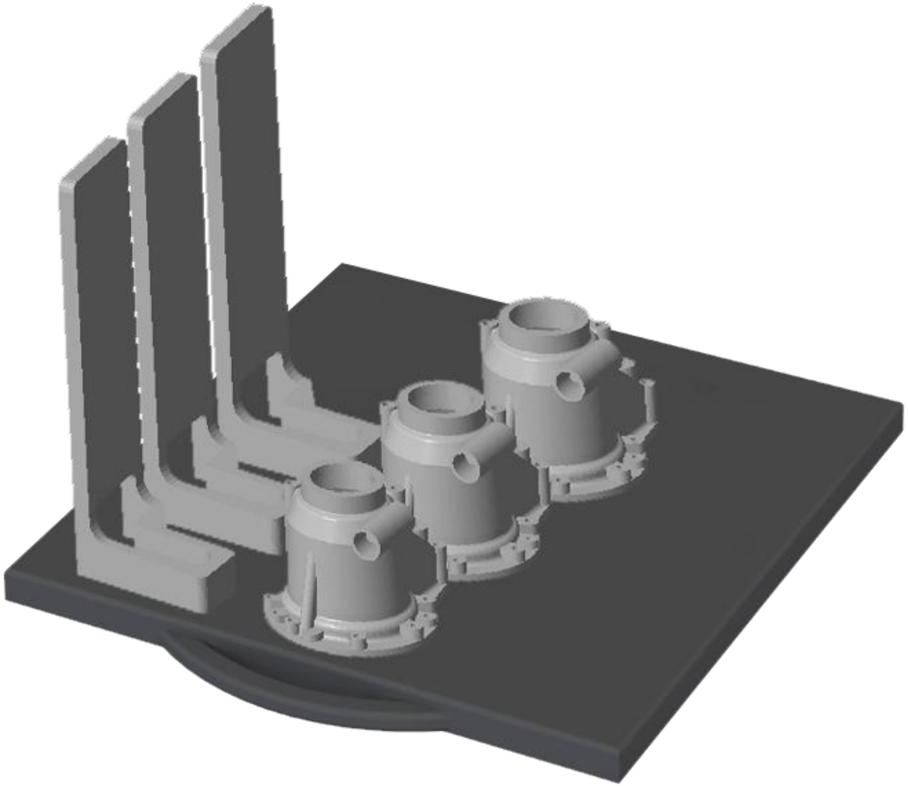
NESTING CONSIDERATIONS - SPACING



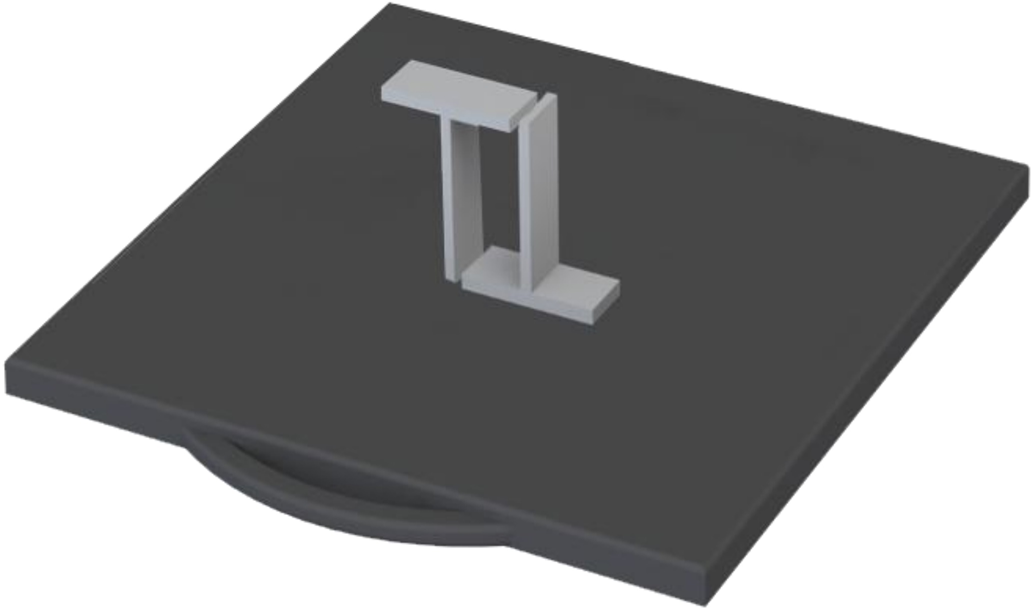
NESTING CONSIDERATIONS – VARIED PARTS



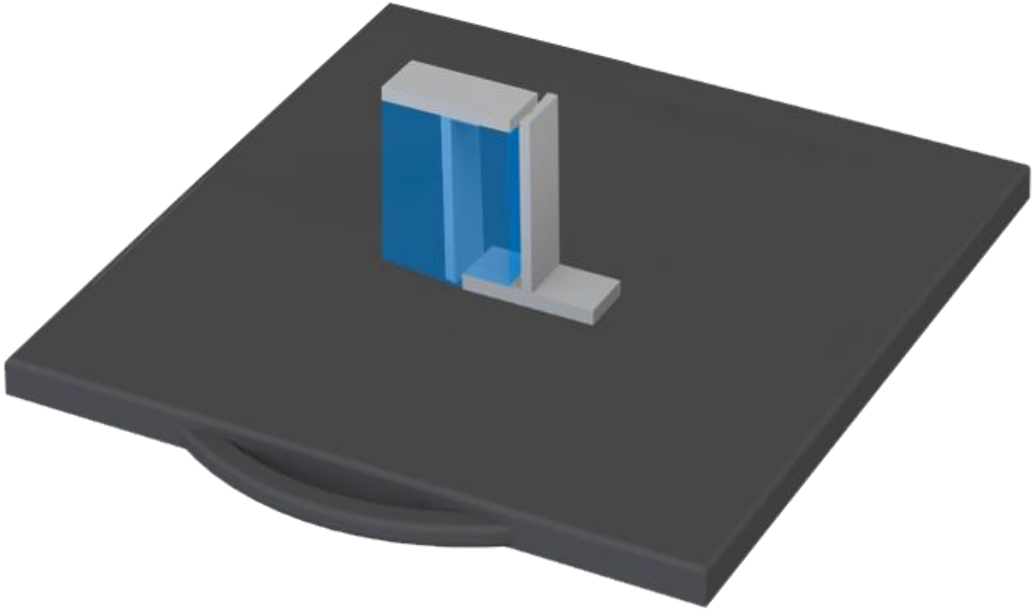
NESTING CONSIDERATIONS – PART HEIGHTS



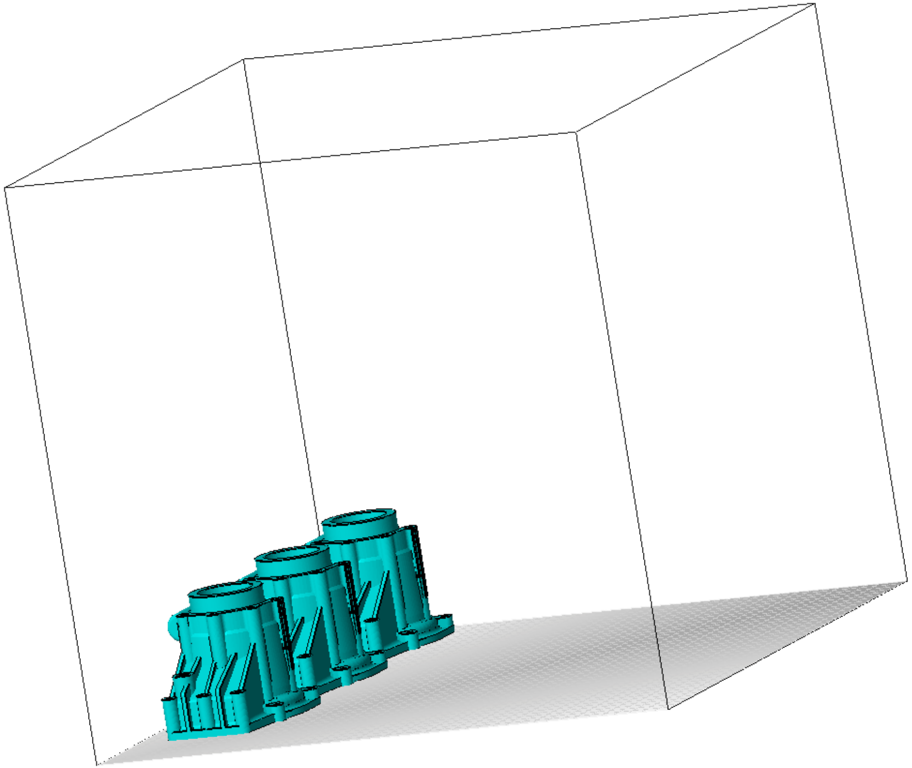
NESTING CONSIDERATIONS – OVERLAP



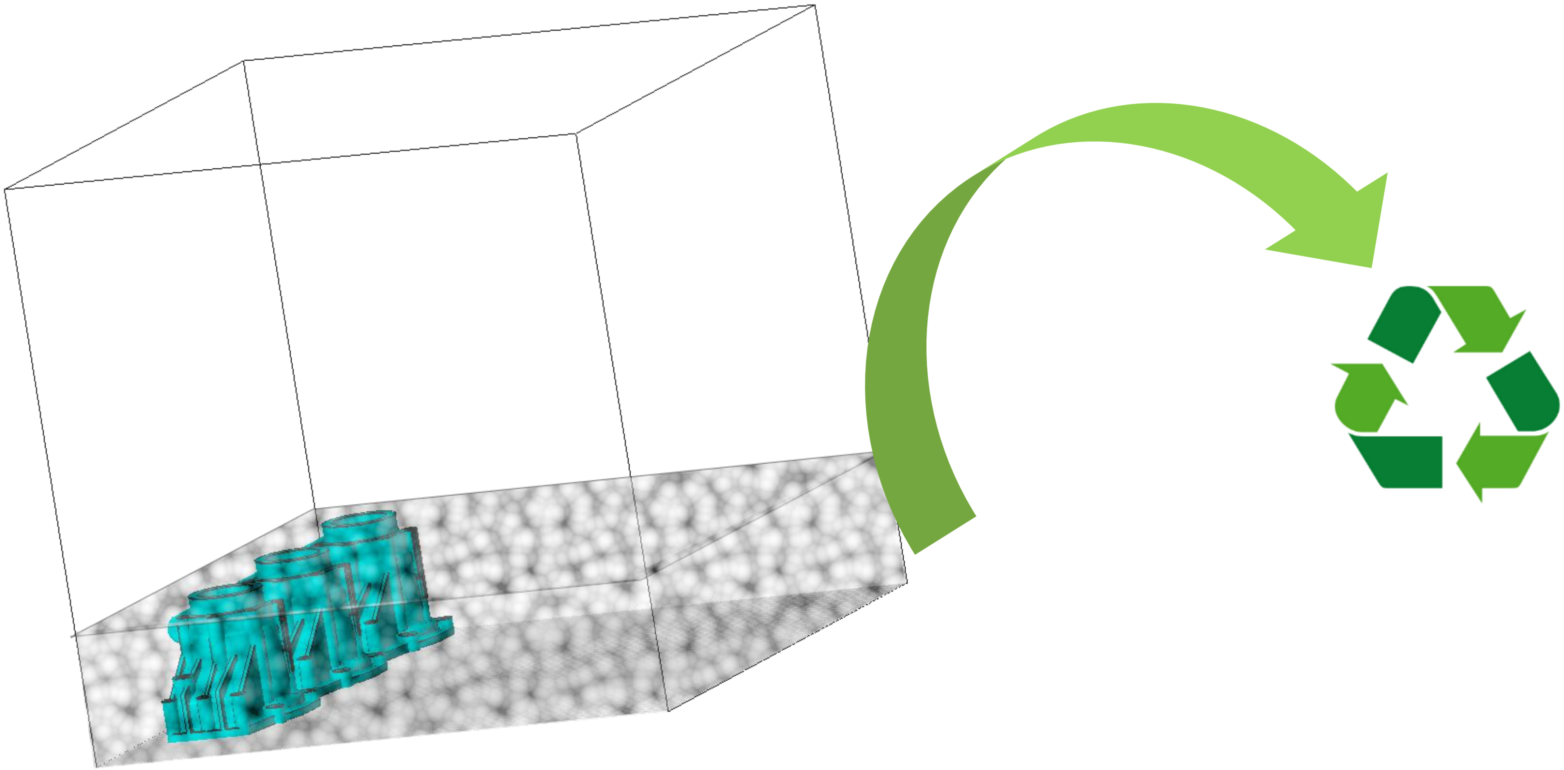
NESTING CONSIDERATIONS – OVERLAP



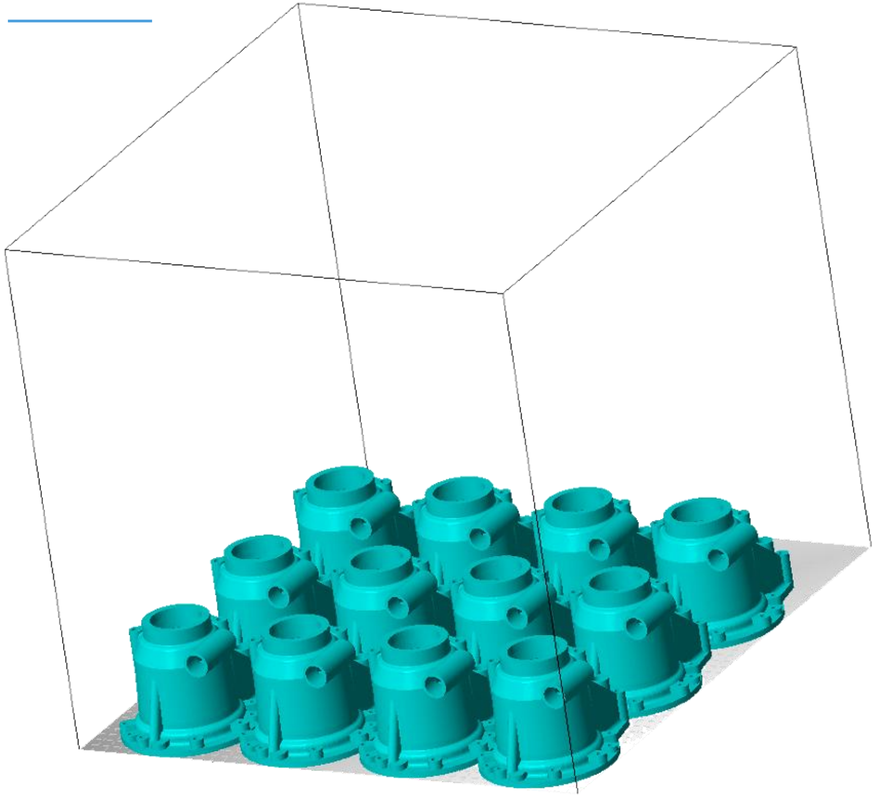
NESTING ADVANTAGES: DECREASING WASTE



NESTING ADVANTAGES: DECREASING WASTE



NESTING ADVANTAGES: INCREASING YIELD



NESTING ADVANTAGES: DECREASING TIME

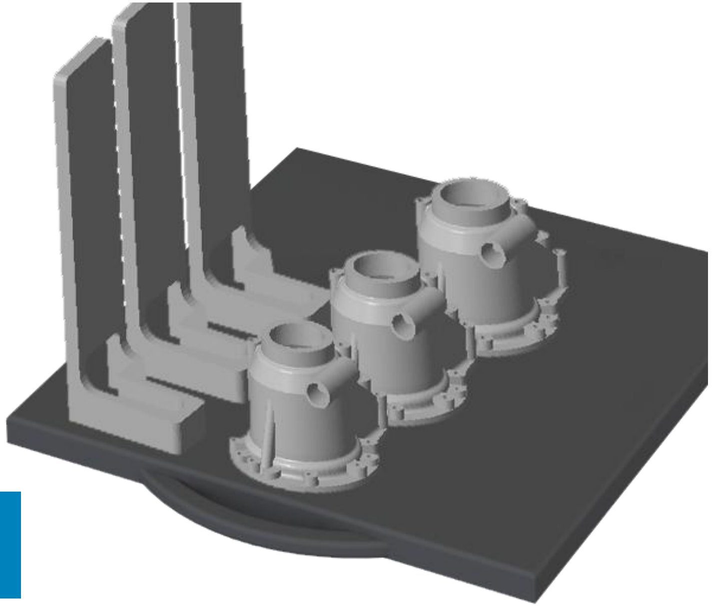
Overhead per layer

Print time per part

Total time

Combined: 15 hrs

Separate: 45 hrs



NESTING ADVANTAGES: DECREASING TIME

Overhead per layer

Print time per part

Total time

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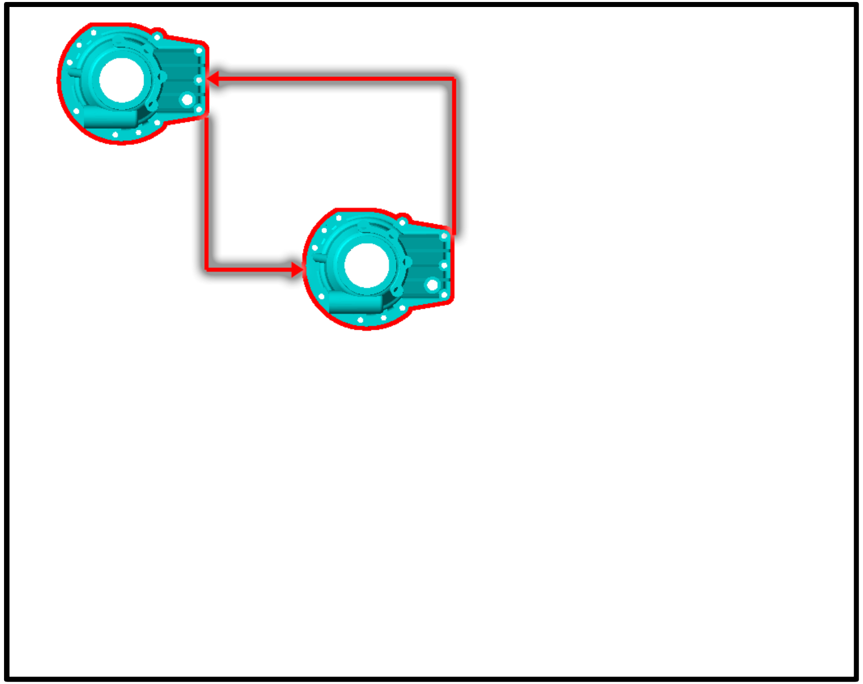
NESTING ADVANTAGES: DECREASING TIME

Overhead per layer

Print time per part

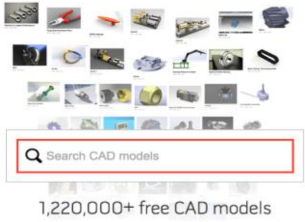
Total time



GRABCAD PRINT: CAM SOFTWARE FOR FDM AND POLYJET

stratasys → GRABCAD

GRABCAD community



World's largest free CAD model database

4 million+ members

Free

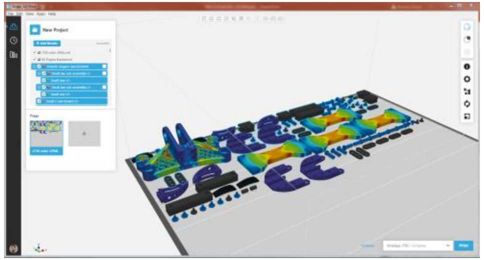
GRABCAD workbench

Online version control, CAD storage, design collaboration

170,000+ users

Free

GRABCAD print



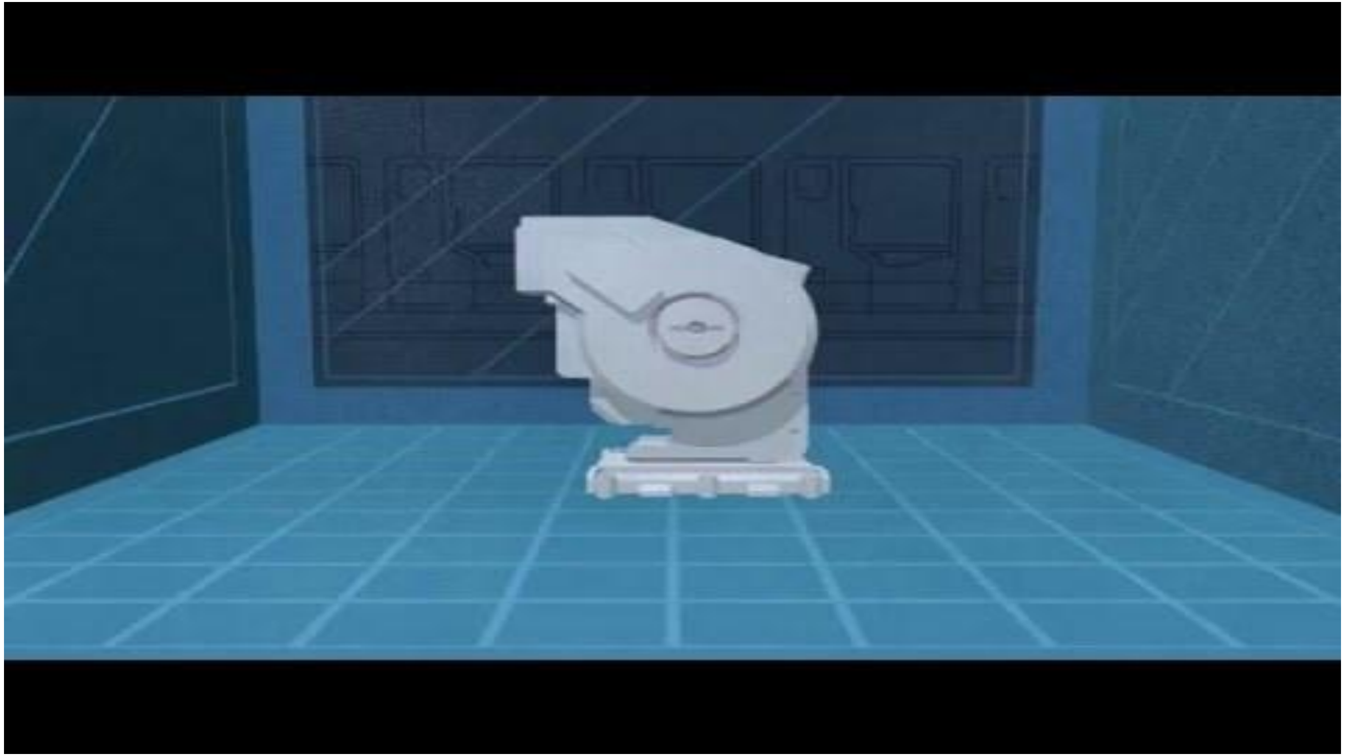
CAD to print

Shared scheduling/ remote monitoring

Reporting of materials, jobs

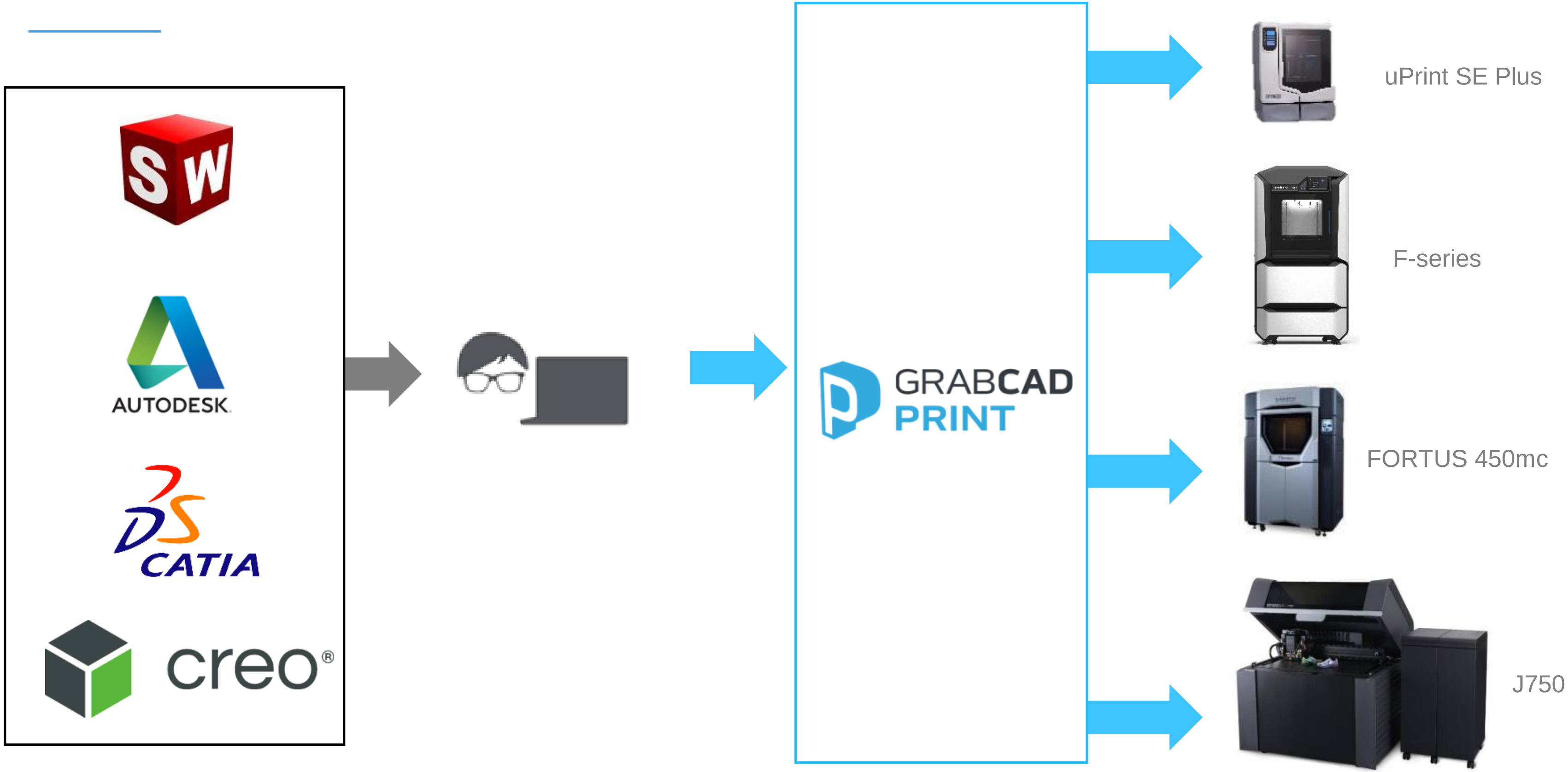
Free

GRABCAD OVERVIEW



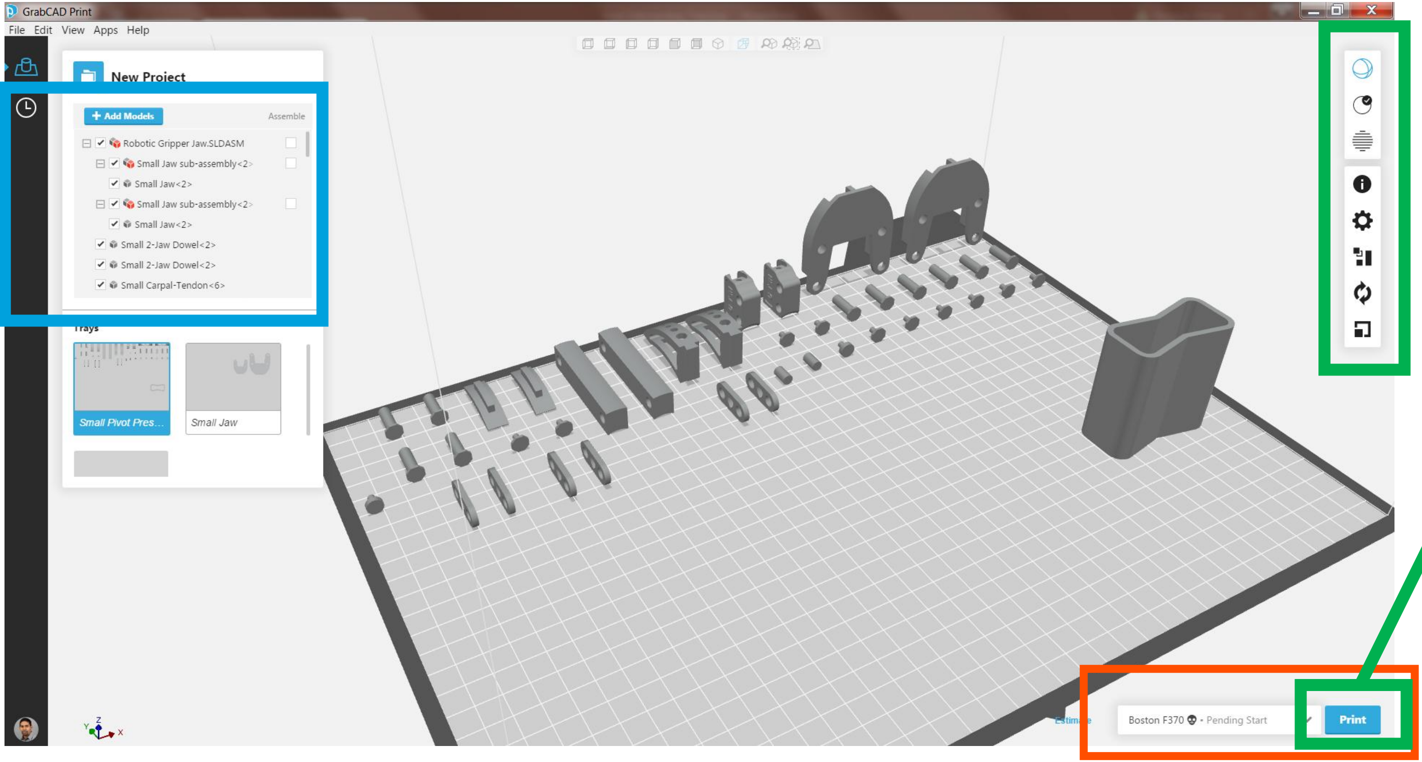
https://www.youtube.com/watch?v=Pa0d5LAT2ak&t=35s

WHAT IS GRABCAD PRINT?



GRABCAD PRINT INTERFACE

2. Insert your CAD files

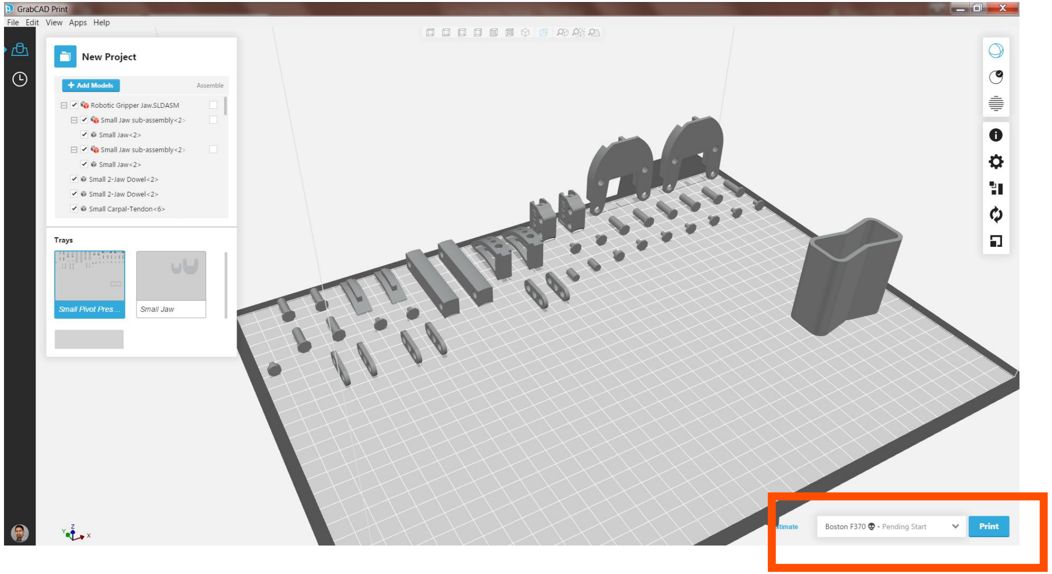


3. Slice, arrange and..

...PRINT!

1. Choose a printer

1. CHOOSING YOUR PRINTER

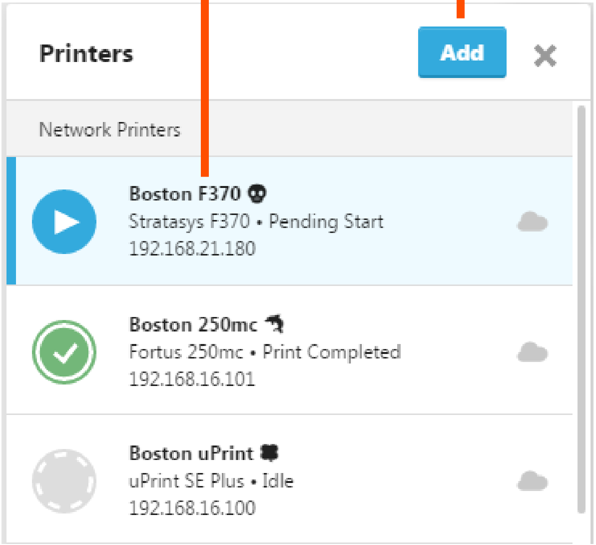


1. Choose your printer

GrabCAD automatically finds any supported printer on your Local Area Network (LAN)

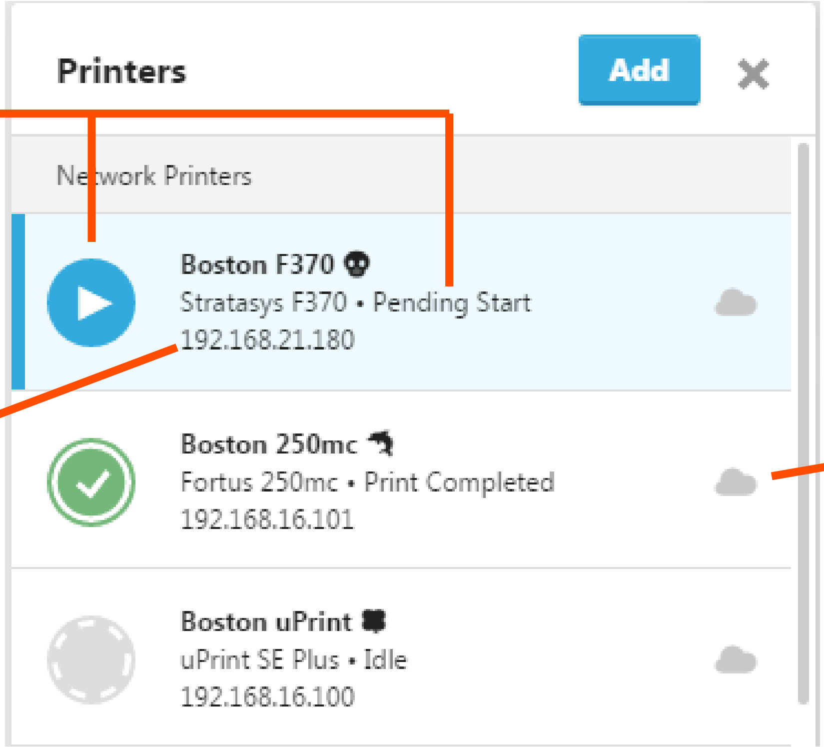
You can also “Add” desired printers

You can give your printers names to tell them apart



1. CHOOSING YOUR PRINTER

Printer Status

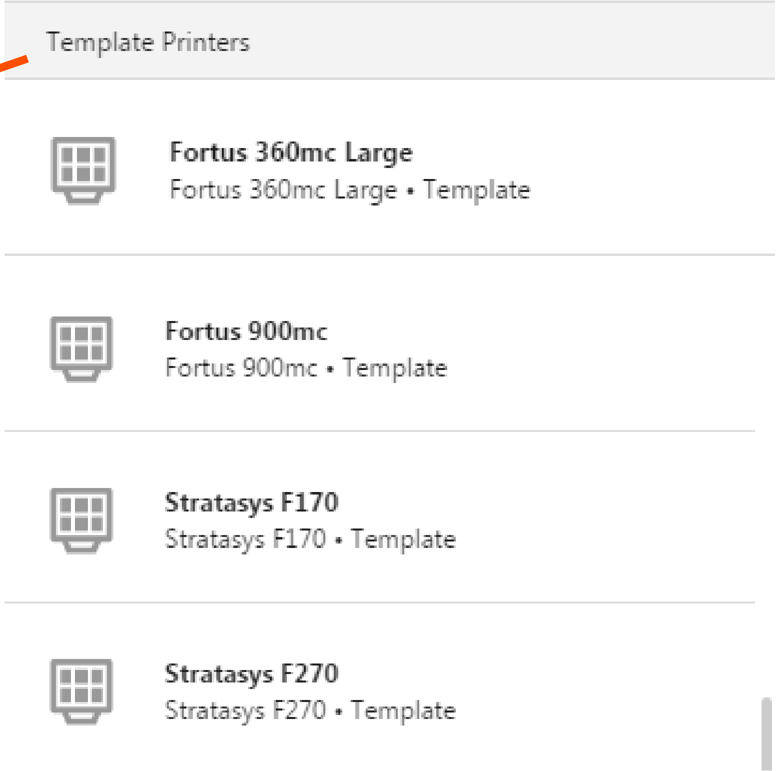


Printer IP address

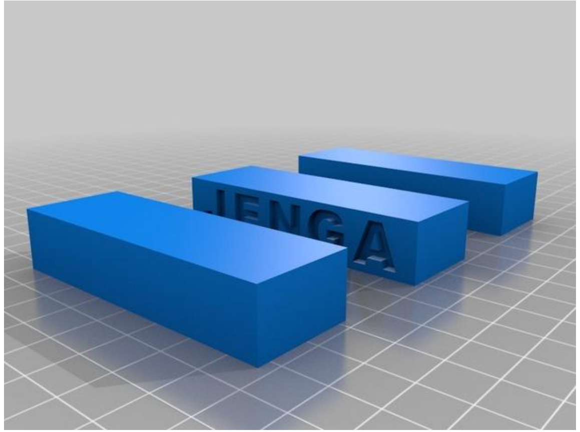
Cloud symbol means you are remote from the printer (not on same LAN)

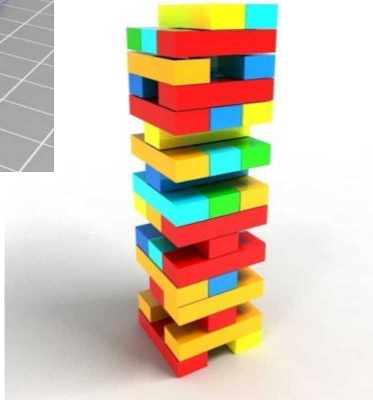
1. CHOOSING YOUR PRINTER

Template Printers allow you to choose printers you don’t currently have.



ACTIVITY 7.1: BUILDING BLOCKS OF DESIGN - GRABCAD





Work through the steps in GrabCAD with the Jenga block file

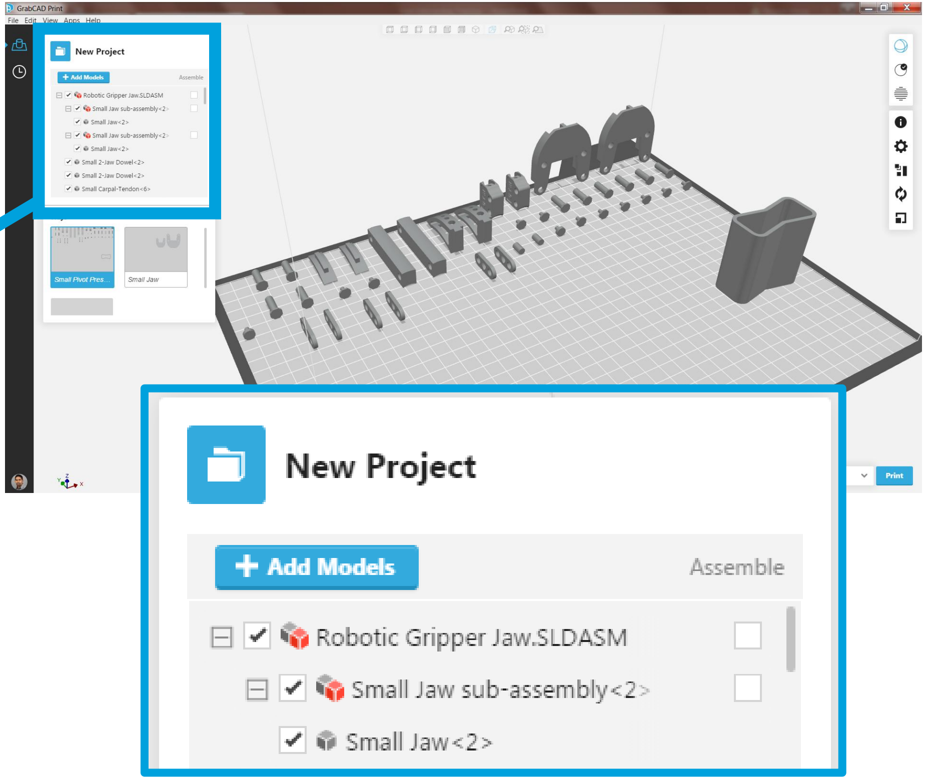
Source file:
https://www.thingiverse.com/thing:630852/#files

OR use our exposed infill bricks downloadable at –
https://stratasys.box.com/s/41ami9viipdt15u6dw379s1ia8ljlr20

Download the Activity Worksheet from the Module 7 Resources section. Note: Activities: 7.1, 7.2, 7.5 are on one worksheet.

Source: https://www.thingiverse.com/thing:630852/#files

2. INSERTING YOUR CAD FILES

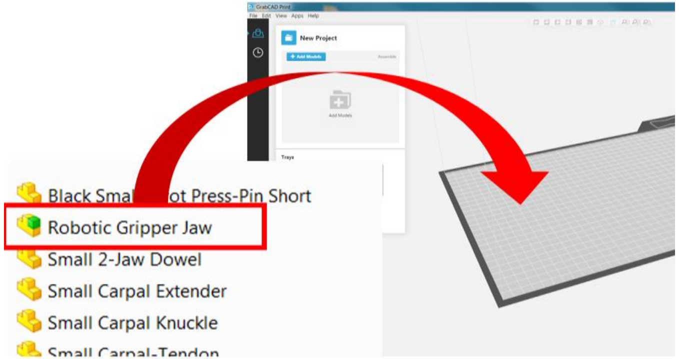


2. Insert your CAD files

It's better to insert your CAD files (SOLIDWORKS, Pro/E, Inventor, CATIA, etc.) directly.

STL, VRML, STEP and IGES files can also be used.

If all part files are in the same folder, just drag the assembly file in:



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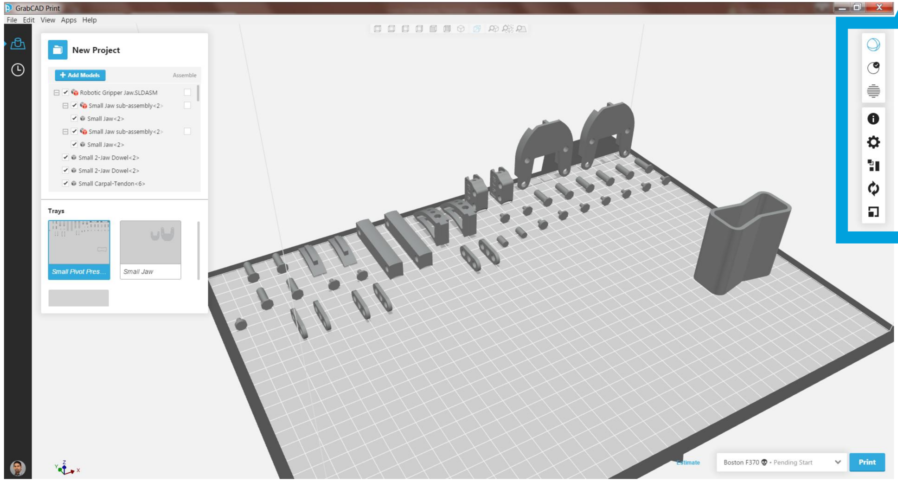
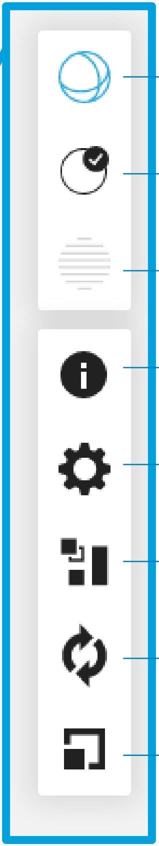
3. SLICING AND ARRANGING THE TRAY





Model View (You will spend most of your time here)

Repair View (For faulty STLs)

Slicing View (Hit to slice current tray)

Selected Model Info (Set scale of imported STLs)

Tray Settings (Set slice height, materials, support type)

Arrange Tray (Automatic packing)

Rotate Model (You'll use this button a lot.)

Scale Model (Scale CAD and STLs up or down.)

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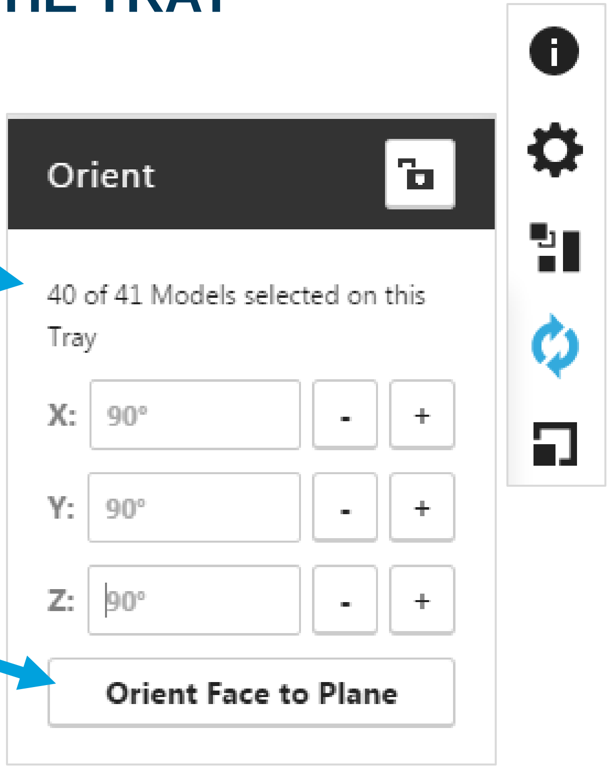
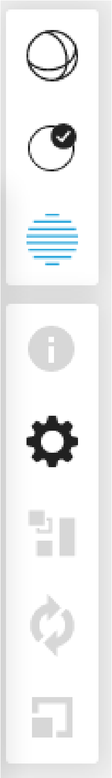
3. SLICING AND ARRANGING THE TRAY

Only rotates selected models (can multiple select)

Most of the time, using this button with flat surfaces is the fastest way

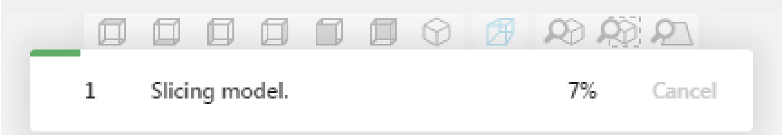


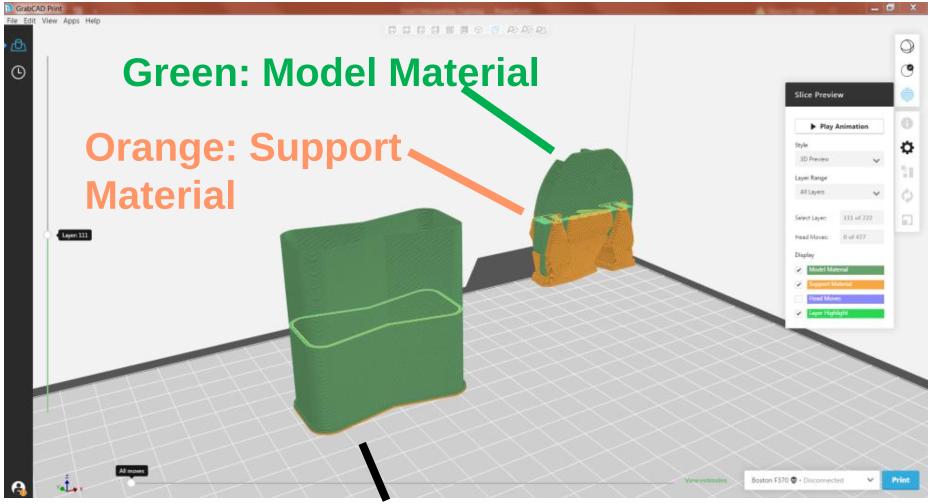
3. SLICING AND ARRANGING THE TRAY



Slice button slices all models on current tray all at once

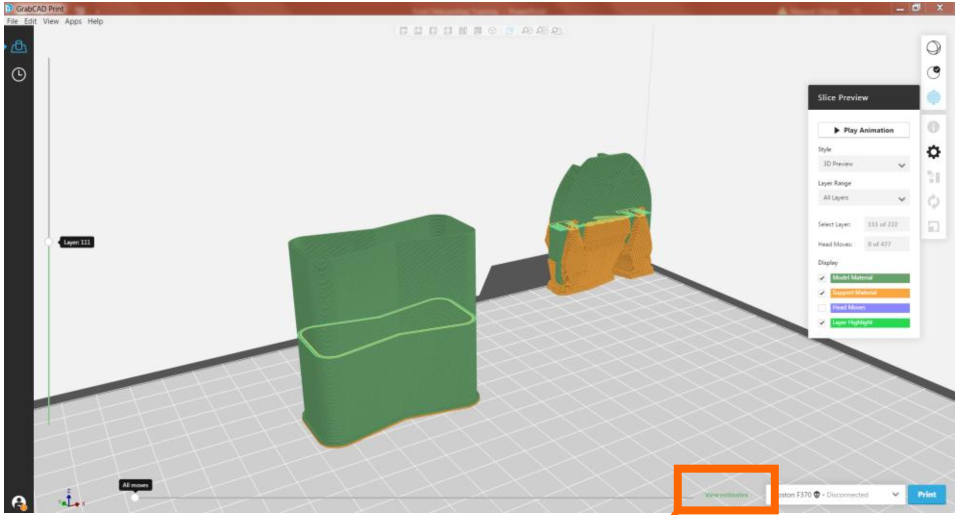
The more models on the tray, the longer it will take to slice:

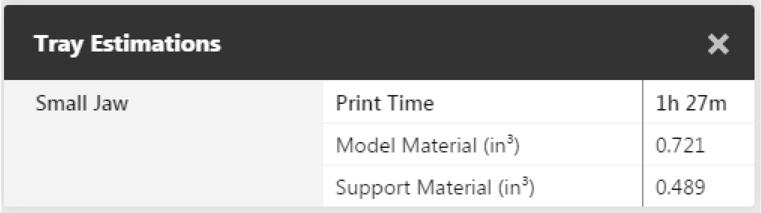




Mandatory purge tower on F123 series (makes prints faster & more accurate)

3. SLICING AND ARRANGING THE TRAY





Tray Estimations		
Small Jaw	Print Time	1h 27m
	Model Material (in^3)	0.721
	Support Material (in^3)	0.489

After slicing, this button allows viewing estimate of tray printing time

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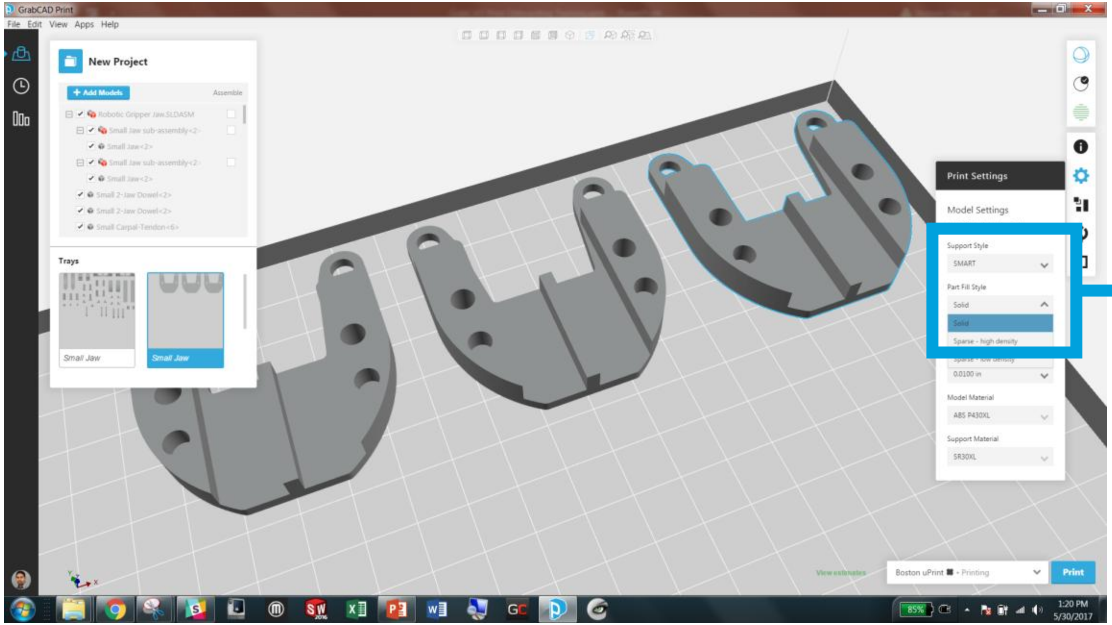
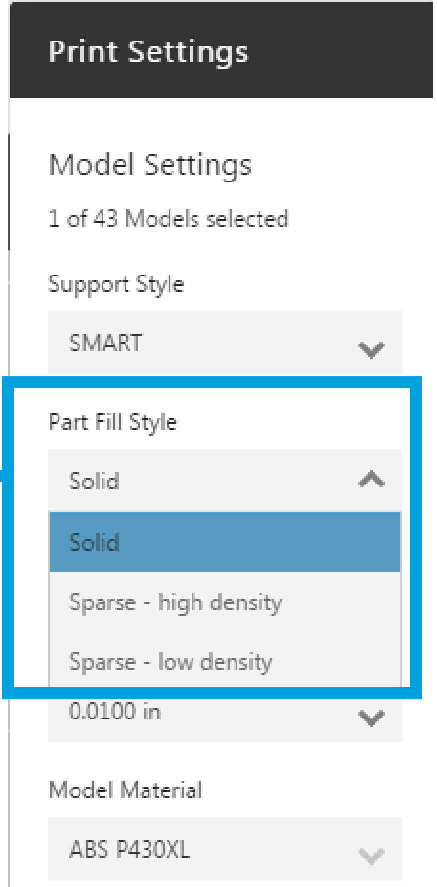
FDM INFILL STYLE

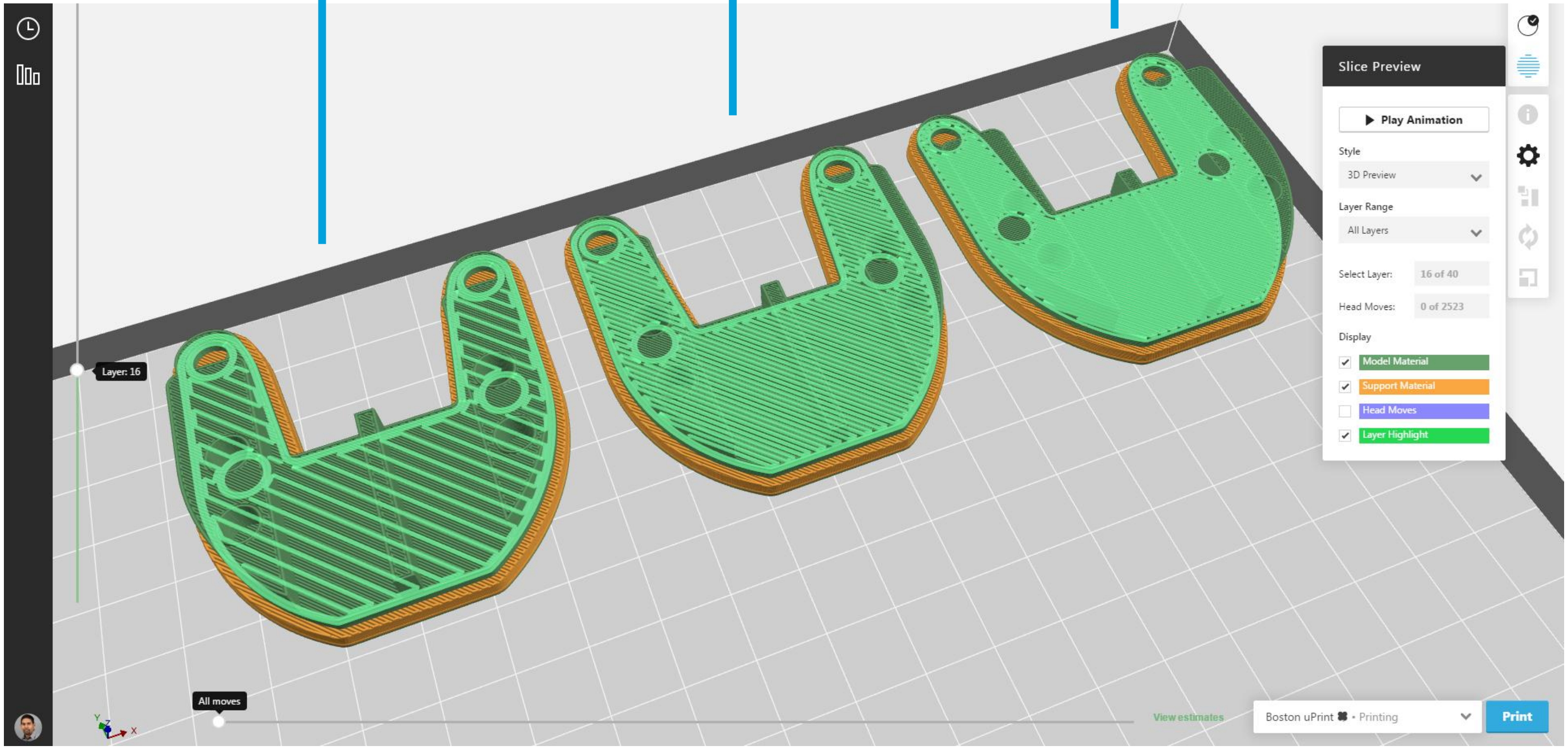




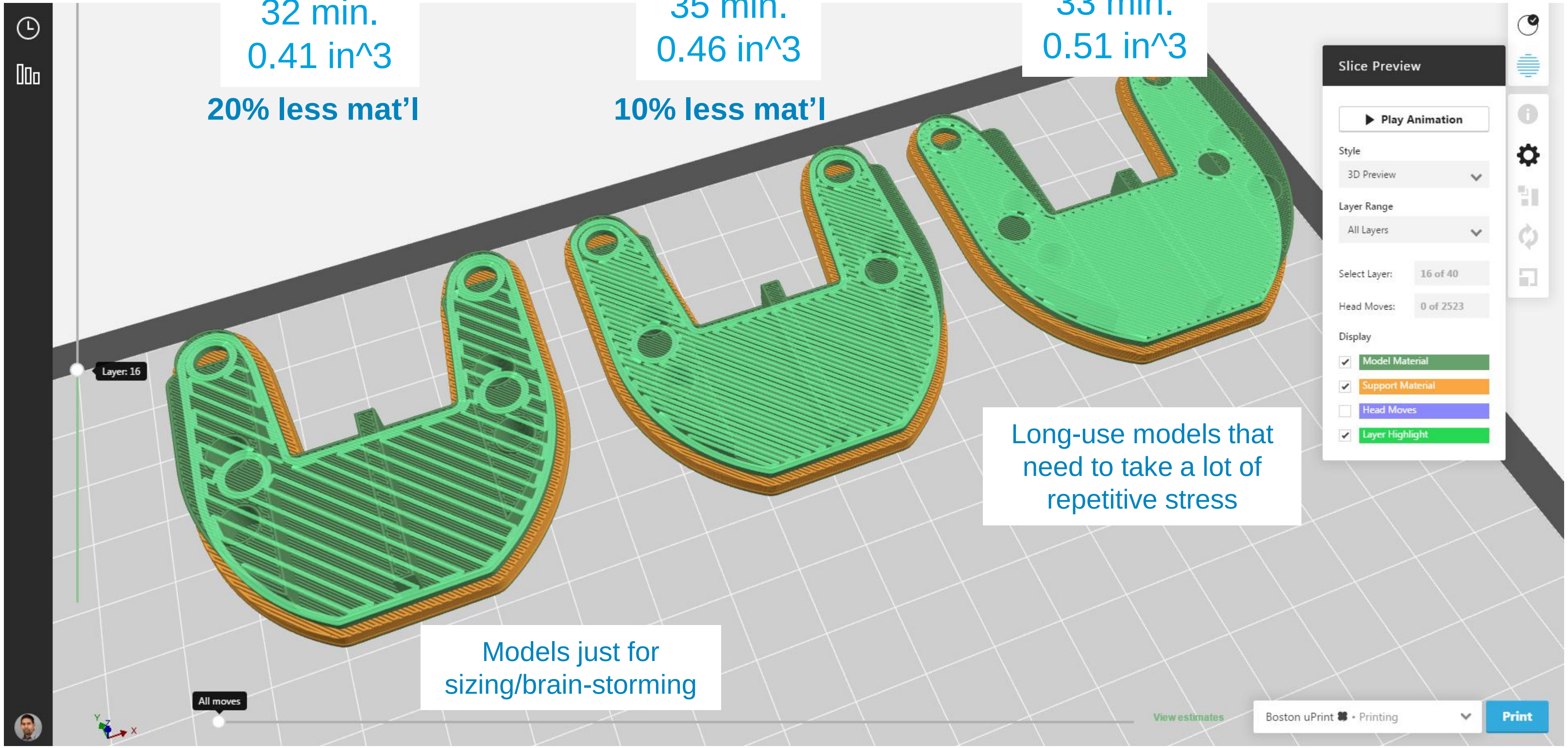
Sparse
Low-Density

Sparse
High-Density

Solid



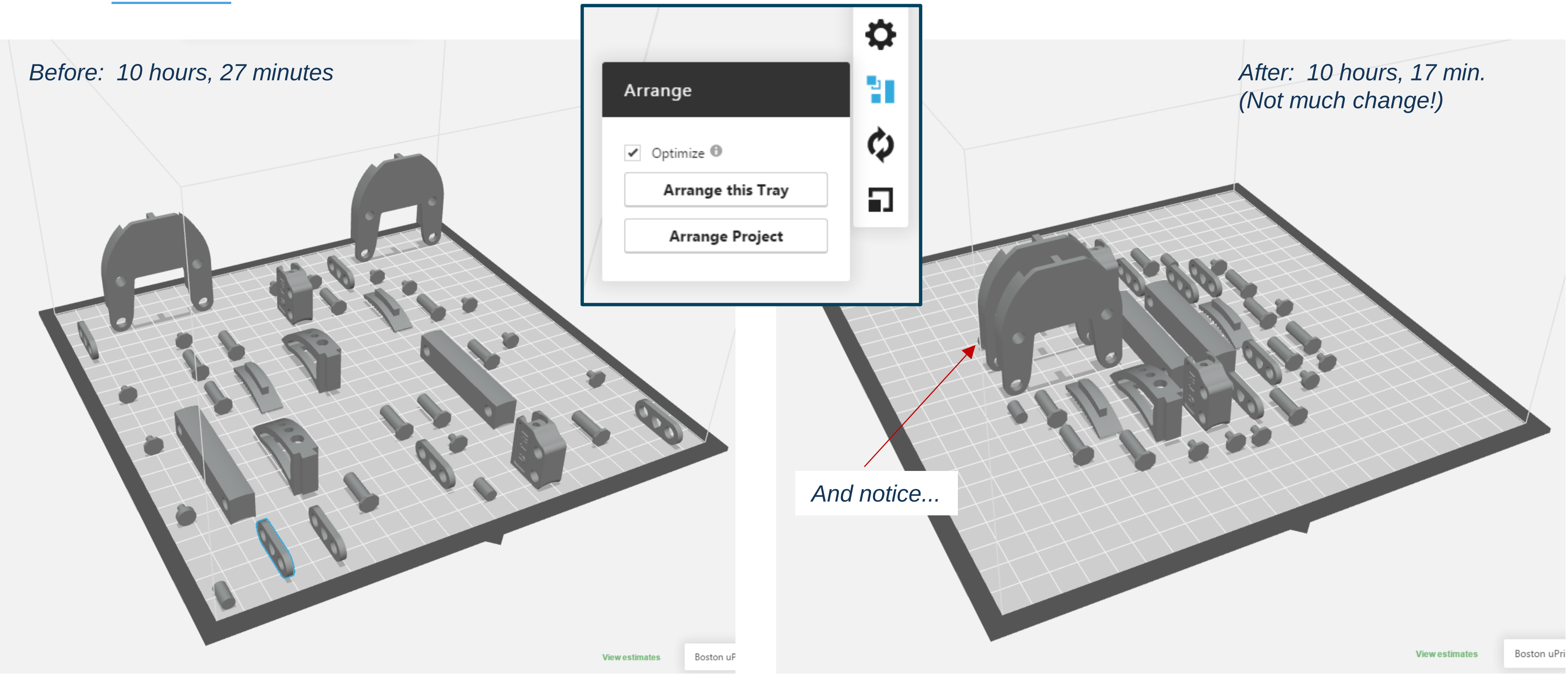
Sparse Low-Density	Sparse High-Density	Solid
32 min. 0.41 in^3	35 min. 0.46 in^3	33 min. 0.51 in^3
20% less mat'l	**10% less mat'l**	



Models just for sizing/brain-storming

Long-use models that need to take a lot of repetitive stress

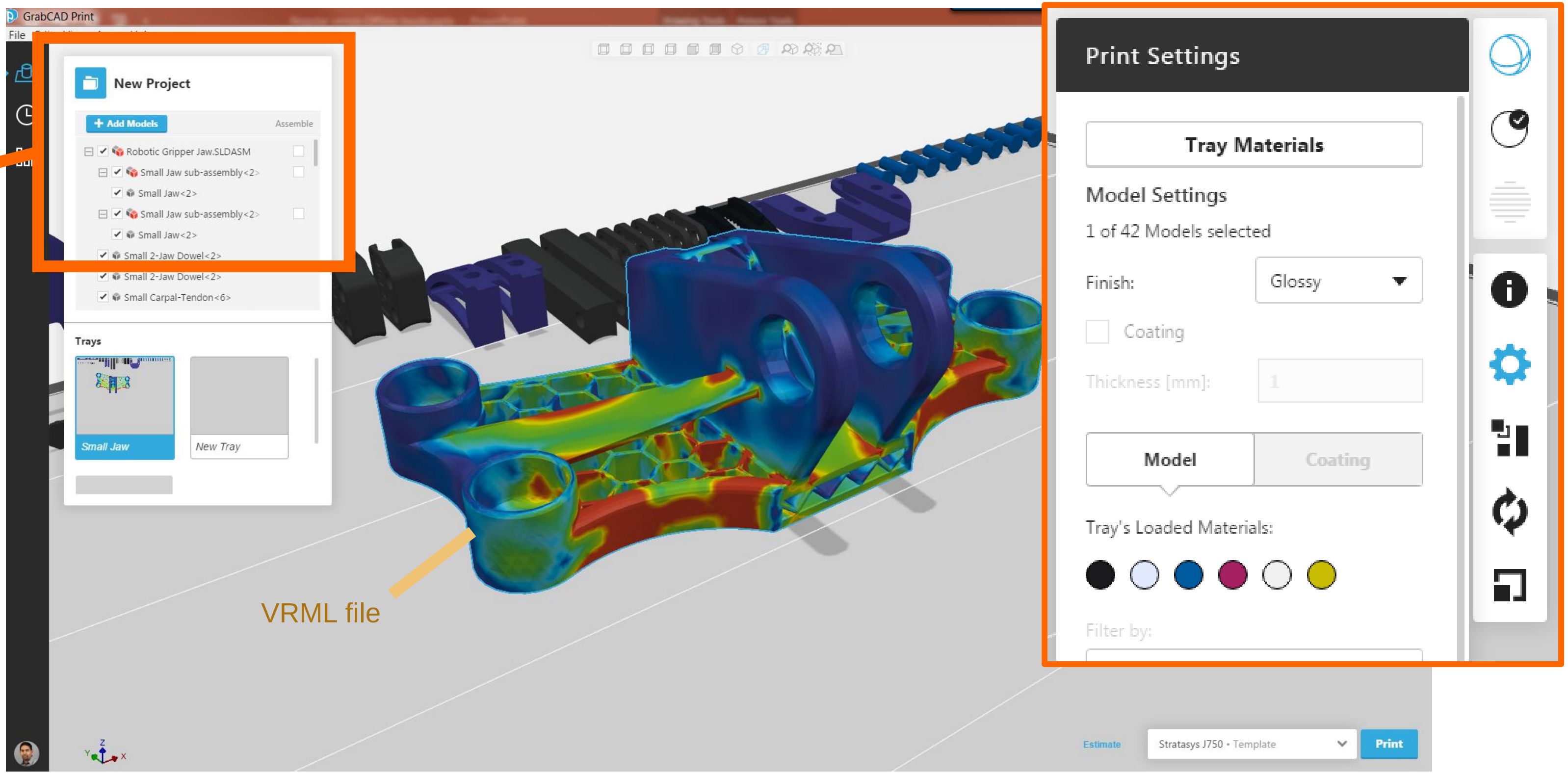
OPTIMIZATION HELPS PACK TRAYS TIGHTER



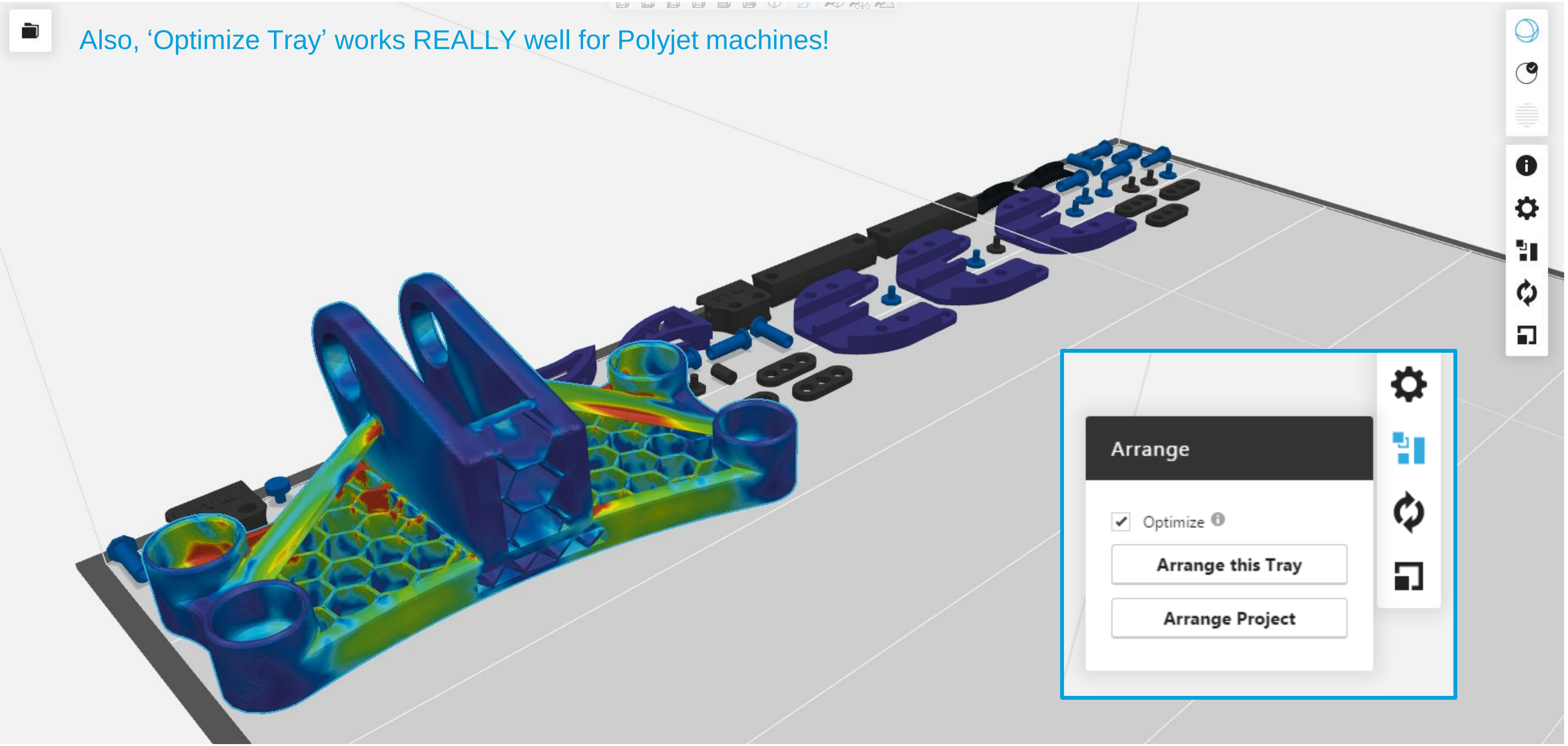
POLYJET

Can print in multiple materials at ONCE:

Open VRML files for color textures



POLYJET



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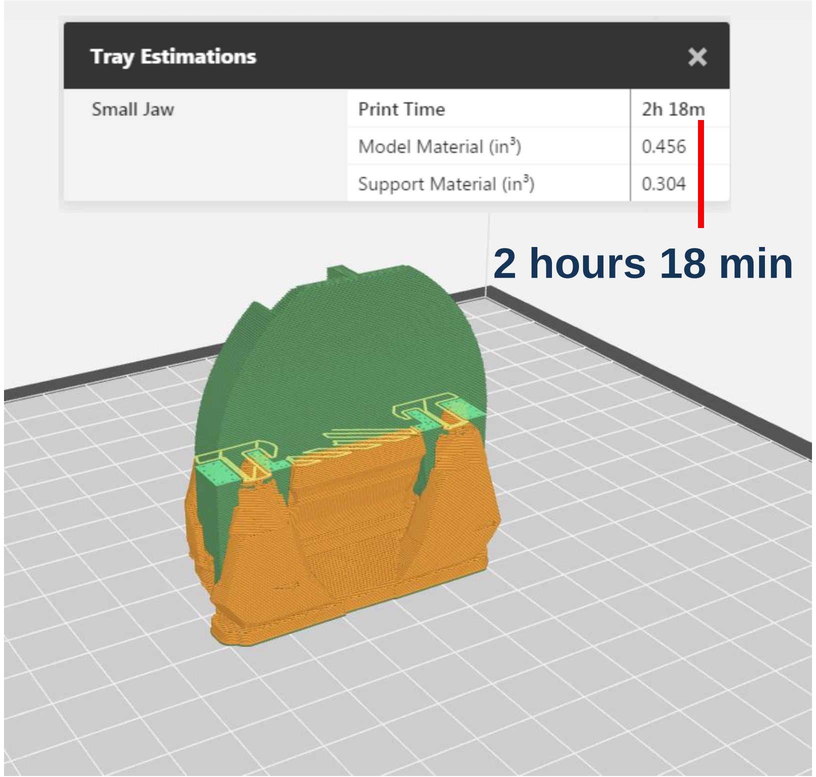
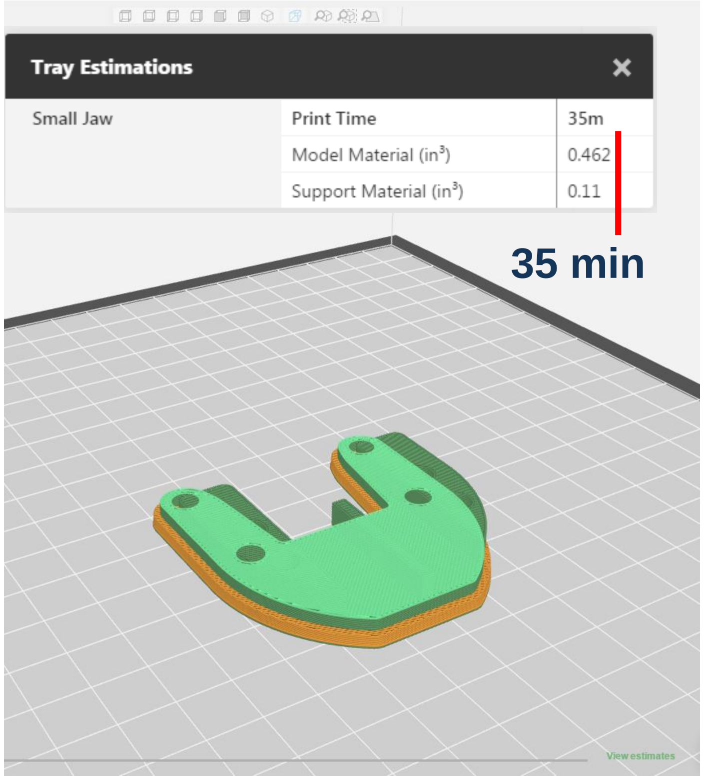
TIME ESTIMATES





WHY?

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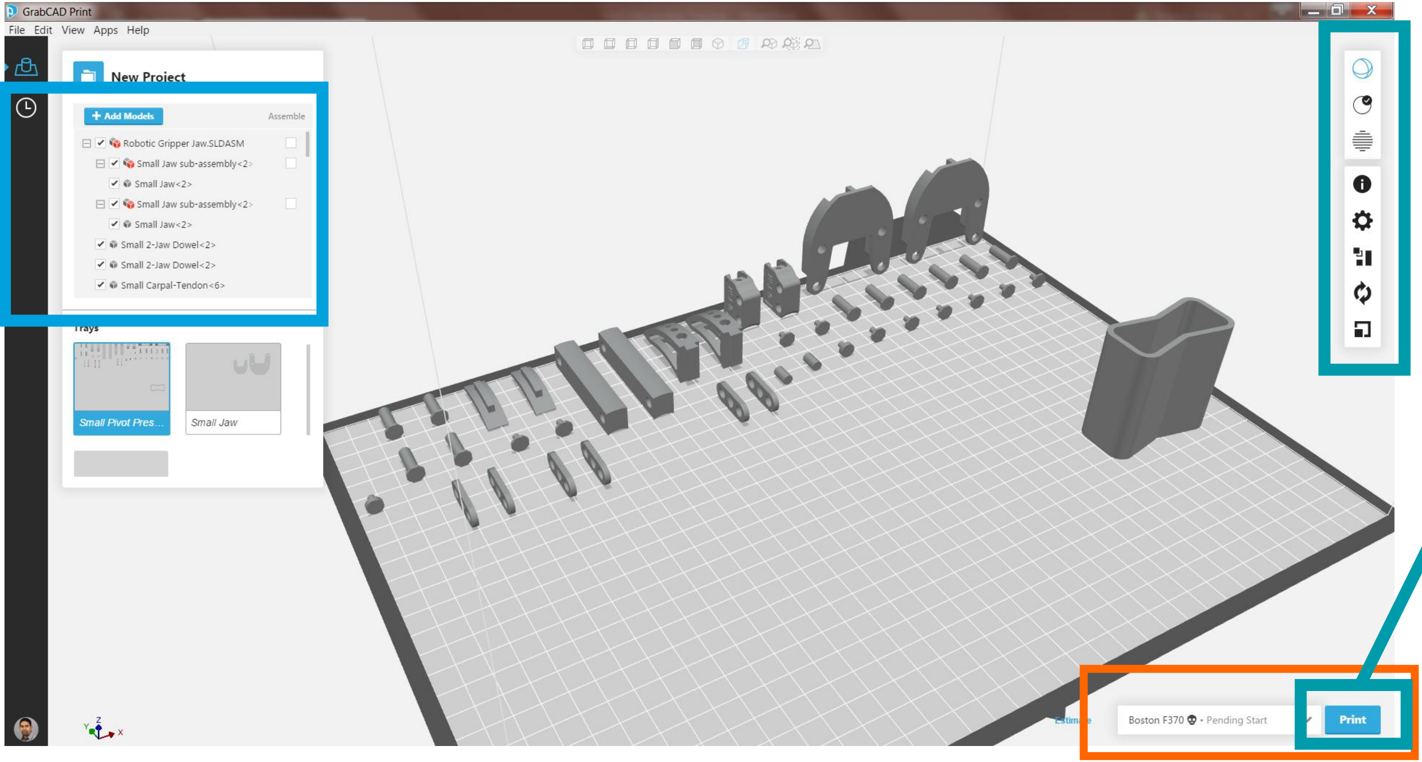
RECAP

2. Insert your CAD files

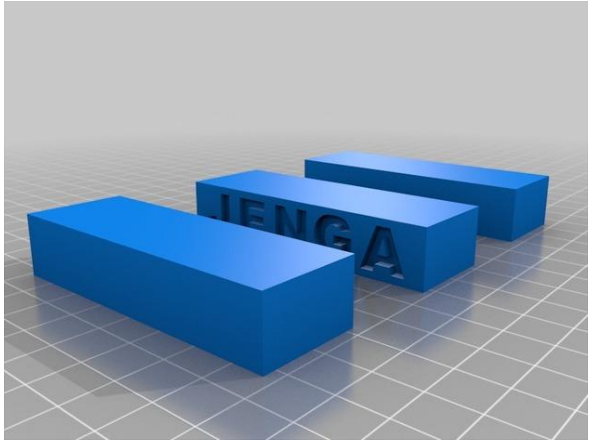


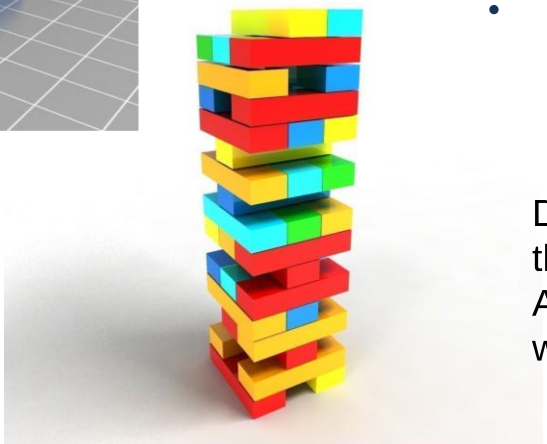
3. Slice, arrange and..

...PRINT!

1. Choose a printer

ACTIVITY 7.2: NESTING BUILDING BLOCKS - GRABCAD





How many blocks can you nest on your printer's build tray?

- Download file from Thingiverse
- Upload file to GrabCAD Print
- Layout the design on your printer's build tray in GrabCAD Print
- Print out a screen shot of your build tray and submit to your instructor

Download the Activity Worksheet from the Module 7 Resources section. Note: Activities: 7.1, 7.2, 7.5 are on one worksheet.

Source: https://www.thingiverse.com/thing:630852/#files

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ACTIVITY 7.3: FDM PART FABRICATION IN GRABCAD PRINT

Go back to your FDM selection of GrabCAD designs. Go through the process to bring this design into GrabCAD Print and make the necessary decisions to prepare file to print on your FDM printer. Check your work with your instructor and follow his/her instructions on how to queue your part to print.

* Instructors, you may want to pair students and ask them to nest their parts on one build tray.

Download the Activity Worksheet from the Module 7 Resources section. Note: Activities: 7.3 and 7.4 are on one worksheet.

ACTIVITY 7.4: POLYJET PART FABRICATION IN GRABCAD PRINT

Go back to your PolyJet selection of GrabCAD designs. Go through the process to bring this design into GrabCAD Print and make the necessary decisions to prepare file to print on your PolyJet printer. Check your work with your instructor and follow his/her instructions on how to queue your part to print.

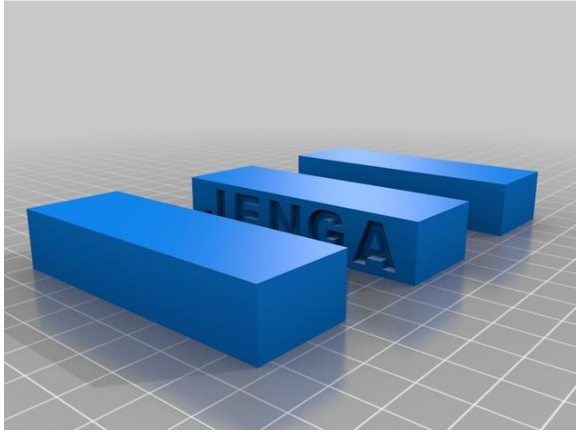
* Instructors, you may want to pair students and ask them to nest their parts on one build tray.

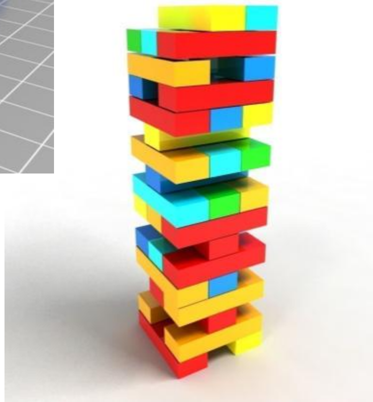
Download the Activity Worksheet from the Module 7 Resources section. Note: Activities: 7.3 and 7.4 are on one worksheet.

ADVANCED CAM SOFTWARE FOR STRATASYS FDM

INSIGHT SOFTWARE

ACTIVITY 7.5: BUILDING BLOCKS OF DESIGN - INSIGHT





Work through the steps in Insight with the Jenga block file

Source file: https://www.thingiverse.com/thing:630852/#files

OR use our exposed infill bricks downloadable at – https://stratasys.box.com/s/41ami9viipdt15u6dw379s1ia8ljlr20

Download the Activity Worksheet from the Module 7 Resources section. Note: Activities: 7.1, 7.2, 7.5 are on one worksheet.

Source: https://www.thingiverse.com/thing:630852/#files

INSIGHT

Green flag mode

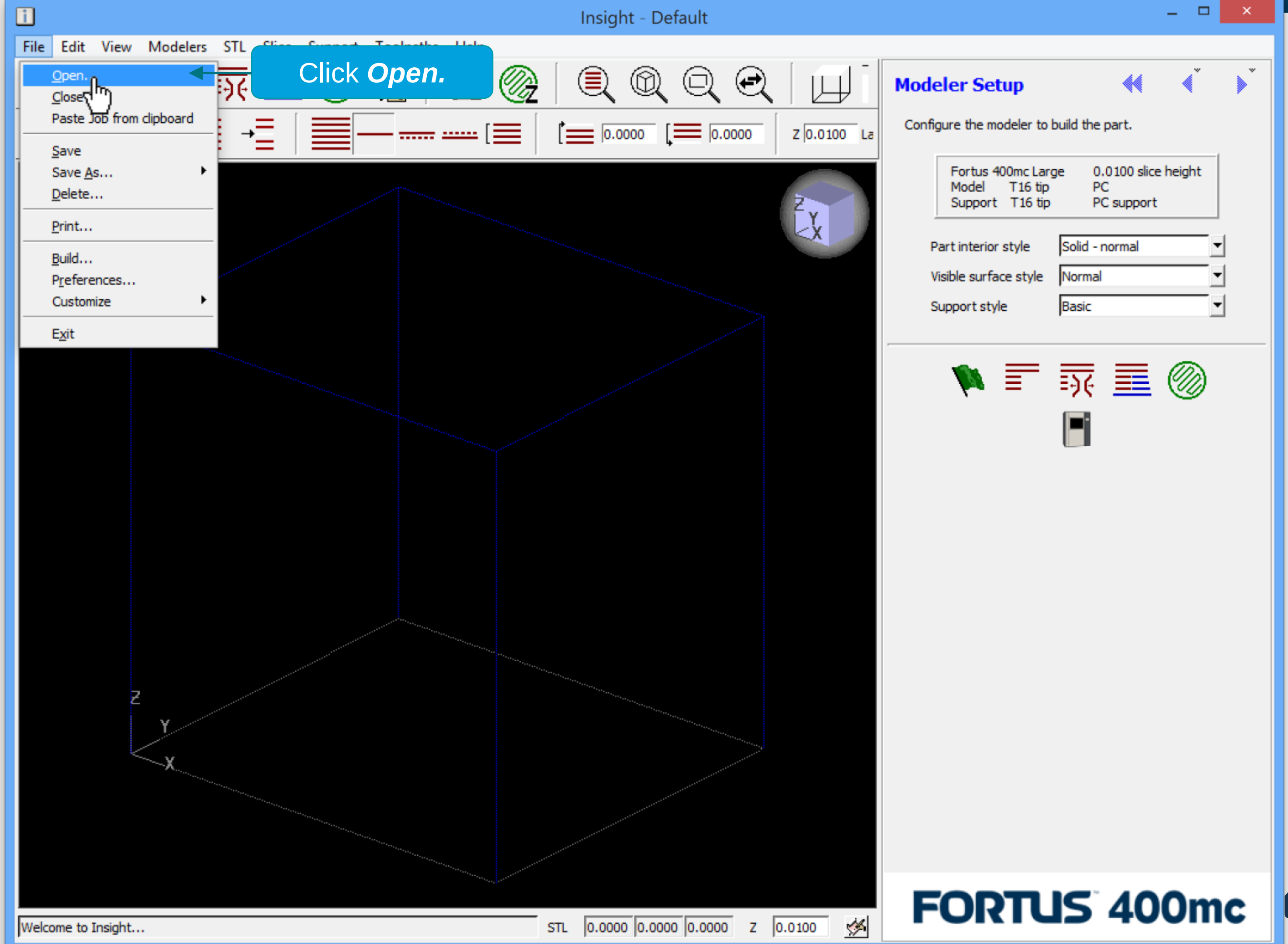
- 5-step setup
- Automatic processing using defaults

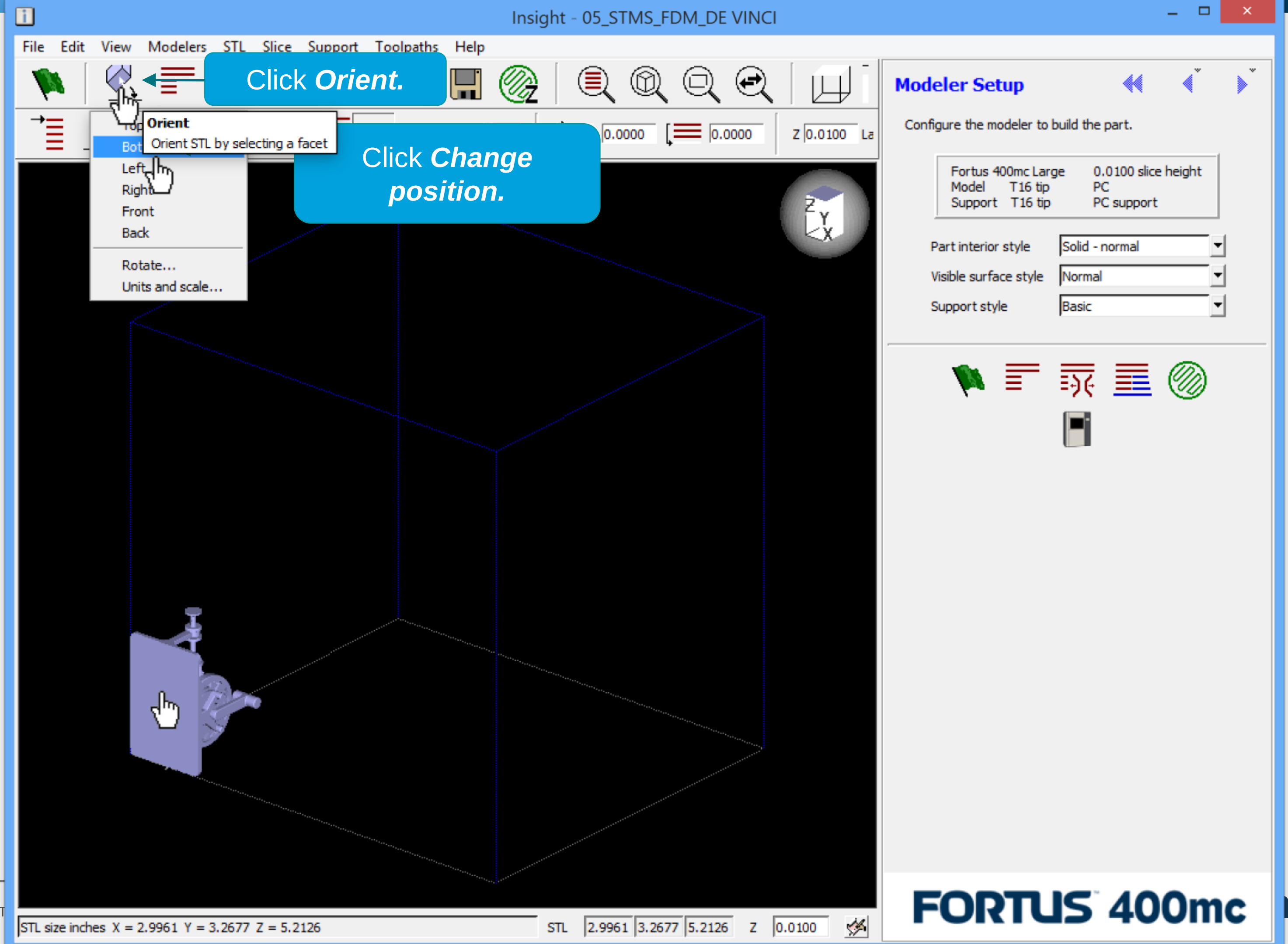
Manual mode (recommended)

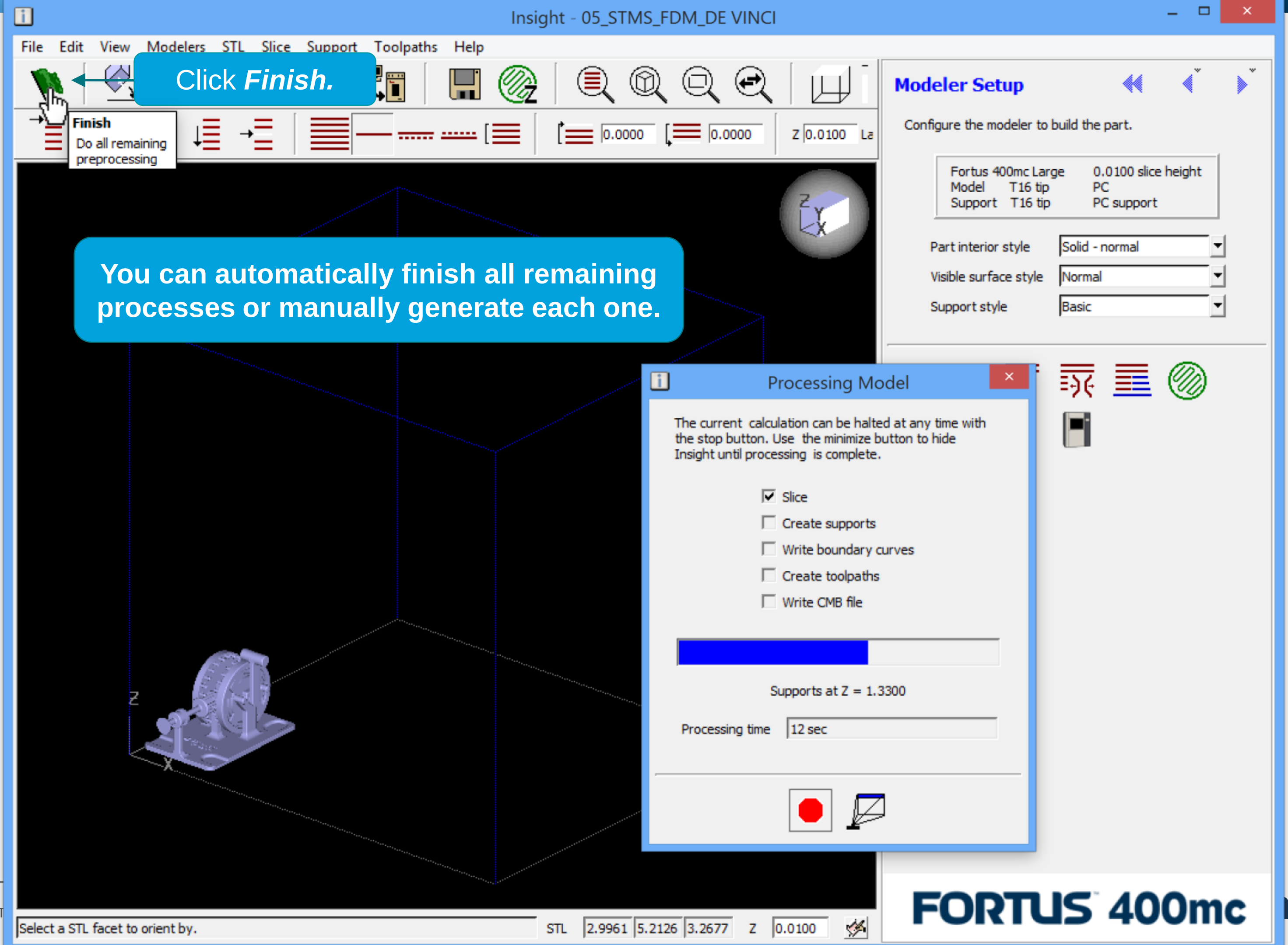
- User defines all settings

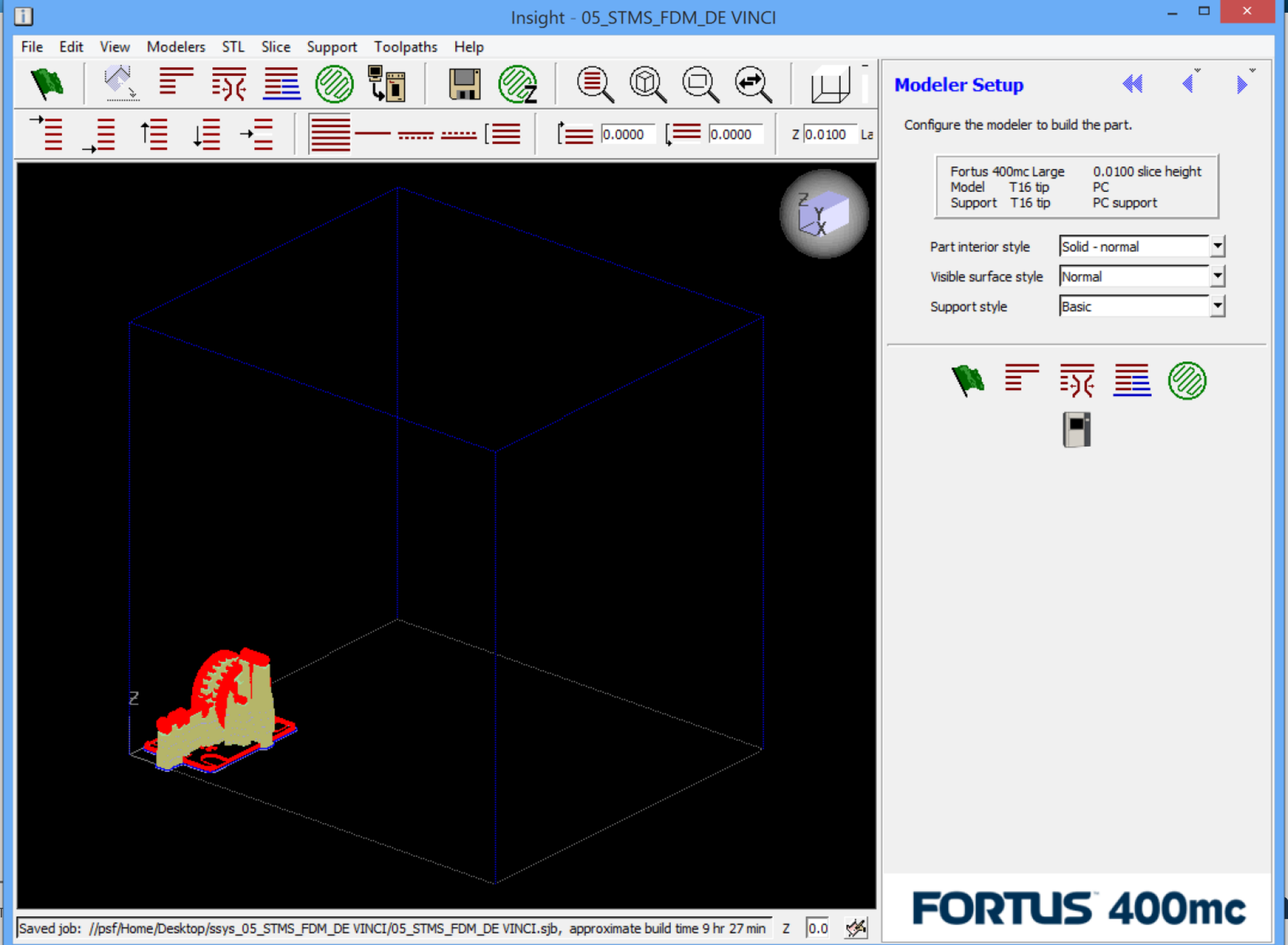
Insight – Deep dive

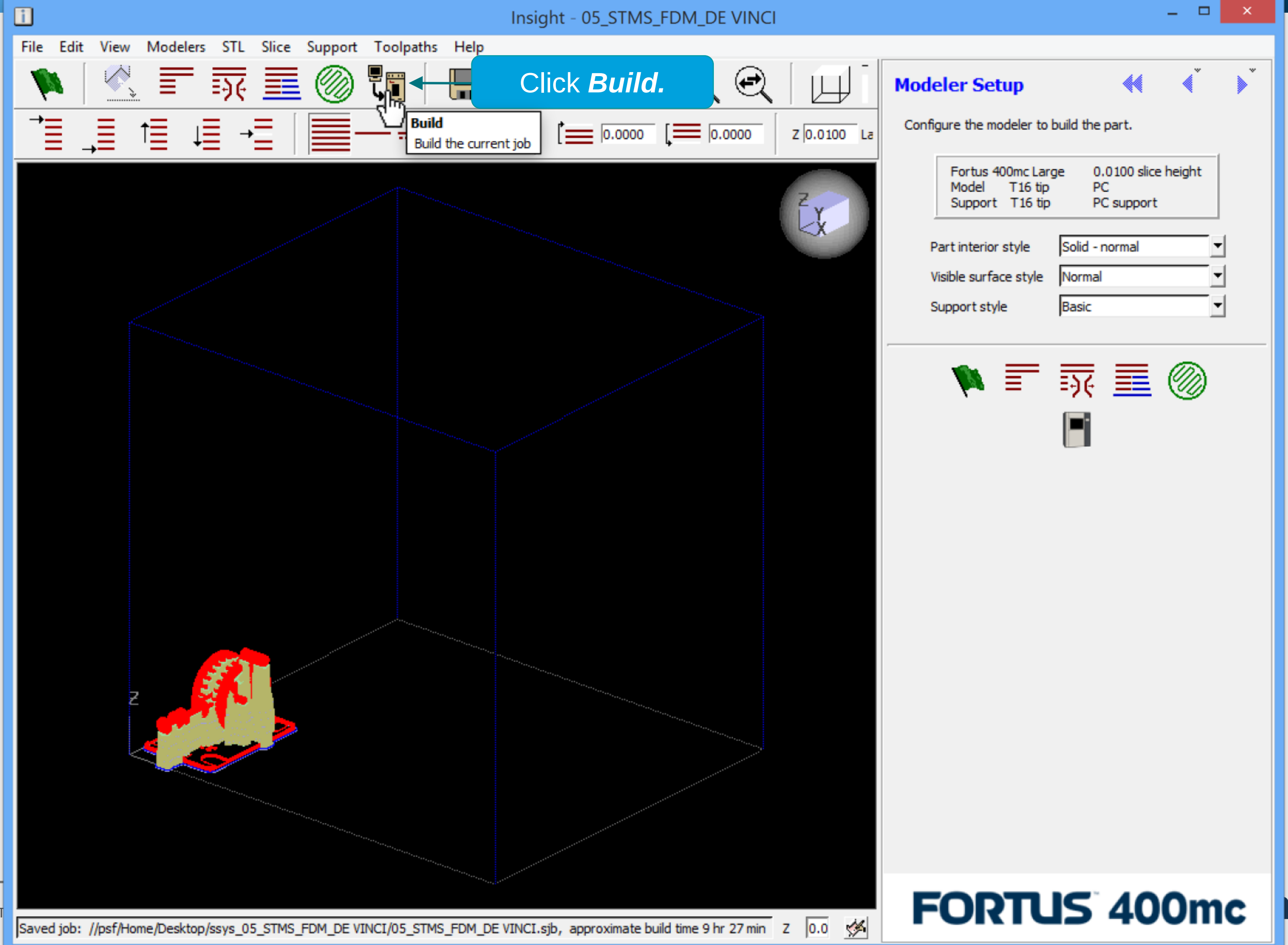
- Understanding options and alternatives


Insight - Default
File
Edit
View
Modelers
STL
Open...
Close
Paste Job from clipboard
Save
Save As...
Delete...
Print...
Build...
Preferences...
Customize
Exit
Click Open.
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large
0.0100 slice height
Model T16 tip
PC
Support T16 tip
PC support
Part interior style
Solid - normal
Visible surface style
Normal
Support style
Basic
Welcome to Insight...
STL
Z
FORTUS 400mc


Insight - 05_STMS_FDM_DE VINCI
File Edit View Modelers STL Slice Support Toolpaths Help
Click Orient.
Orient
Orient STL by selecting a facet
Click Change position.
Left
Right
Front
Back
Rotate...
Units and scale...
0.0000
0.0000
Z 0.0100
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large 0.0100 slice height
Model T16 tip PC
Support T16 tip PC support
Part interior style Solid - normal
Visible surface style Normal
Support style Basic
FORTUS 400mc
STL size inches X = 2.9961 Y = 3.2677 Z = 5.2126
STL 2.9961 3.2677 5.2126 Z 0.0100


Insight - 05_STMS_FDM_DE VINCI
File Edit View Modelers STL Slice Support Toolpaths Help
Click *Finish.*
Finish
Do all remaining preprocessing
0.0000
0.0000
Z 0.0100
You can automatically finish all remaining processes or manually generate each one.
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large
Model T16 tip
Support T16 tip
0.0100 slice height
PC
PC support
Part interior style
Solid - normal
Visible surface style
Normal
Support style
Basic
Processing Model
The current calculation can be halted at any time with the stop button. Use the minimize button to hide Insight until processing is complete.
Slice
Create supports
Write boundary curves
Create toolpaths
Write CMB file
Supports at Z = 1.3300
Processing time
12 sec
Select a STL facet to orient by.
STL
2.9961
5.2126
3.2677
Z
0.0100
FORTUS 400mc


Insight - 05_STMS_FDM_DE VINCI
File Edit View Modelers STL Slice Support Toolpaths Help
0.0000
0.0000
Z 0.0100
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large 0.0100 slice height
Model T16 tip PC
Support T16 tip PC support
Part interior style Solid - normal
Visible surface style Normal
Support style Basic
Saved job: //psf/Home/Desktop/ssys_05_STMS_FDM_DE VINCI/05_STMS_FDM_DE VINCI.sjb, approximate build time 9 hr 27 min
FORTUS 400mc


Insight - 05_STMS_FDM_DE VINCI
File Edit View Modelers STL Slice Support Toolpaths Help
Click Build.
Build
Build the current job
0.0000
0.0000
Z 0.0100
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large
Model T16 tip
Support T16 tip
0.0100 slice height
PC
PC support
Part interior style
Solid - normal
Visible surface style
Normal
Support style
Basic
FORTUS 400mc
Saved job: //psf/Home/Desktop/ssys_05_STMS_FDM_DE VINCI/05_STMS_FDM_DE VINCI.sjb, approximate build time 9 hr 27 min
Z 0.0

INSIGHT

Green flag mode

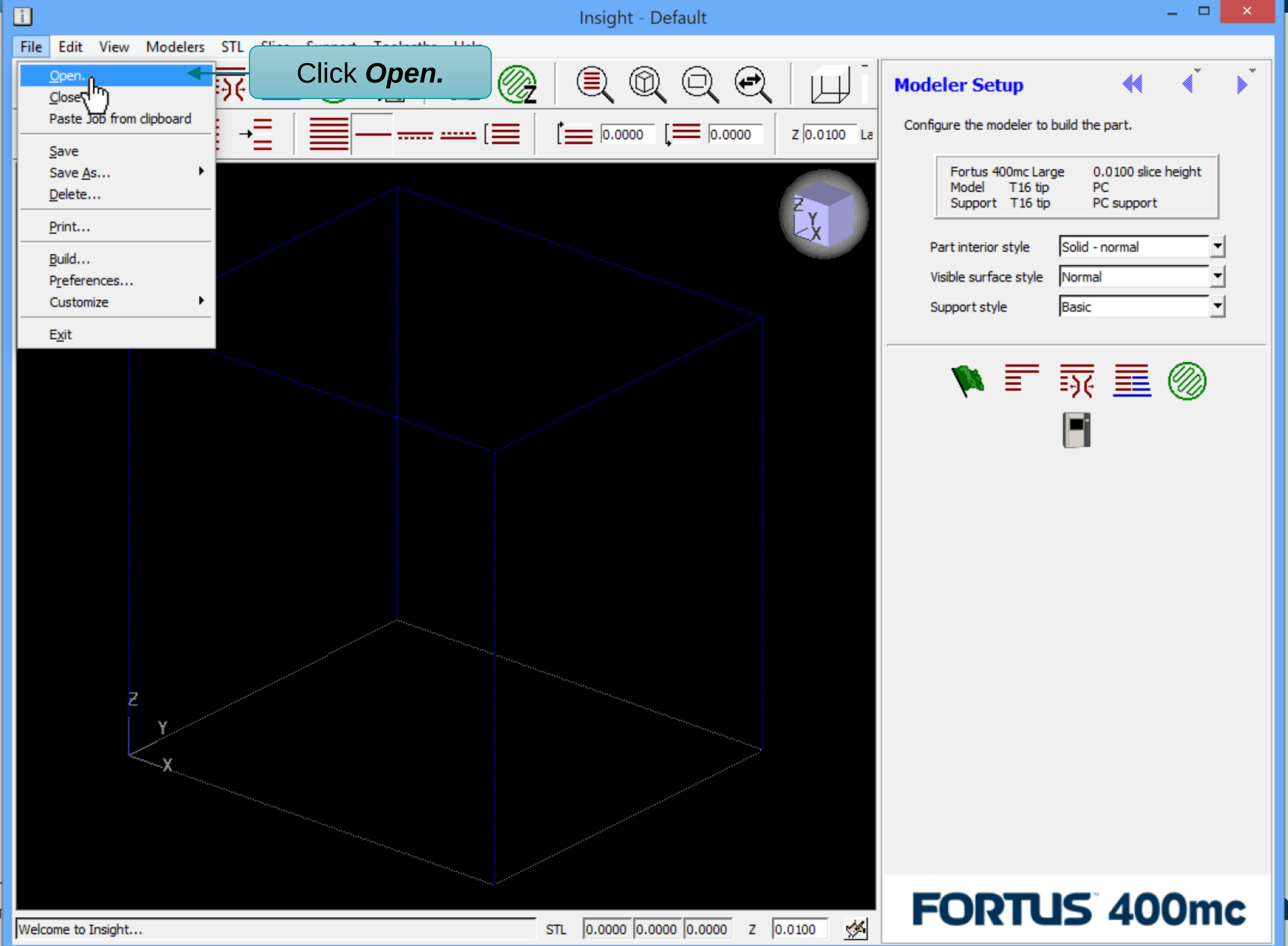
- 5-step setup
- Automatic processing using defaults

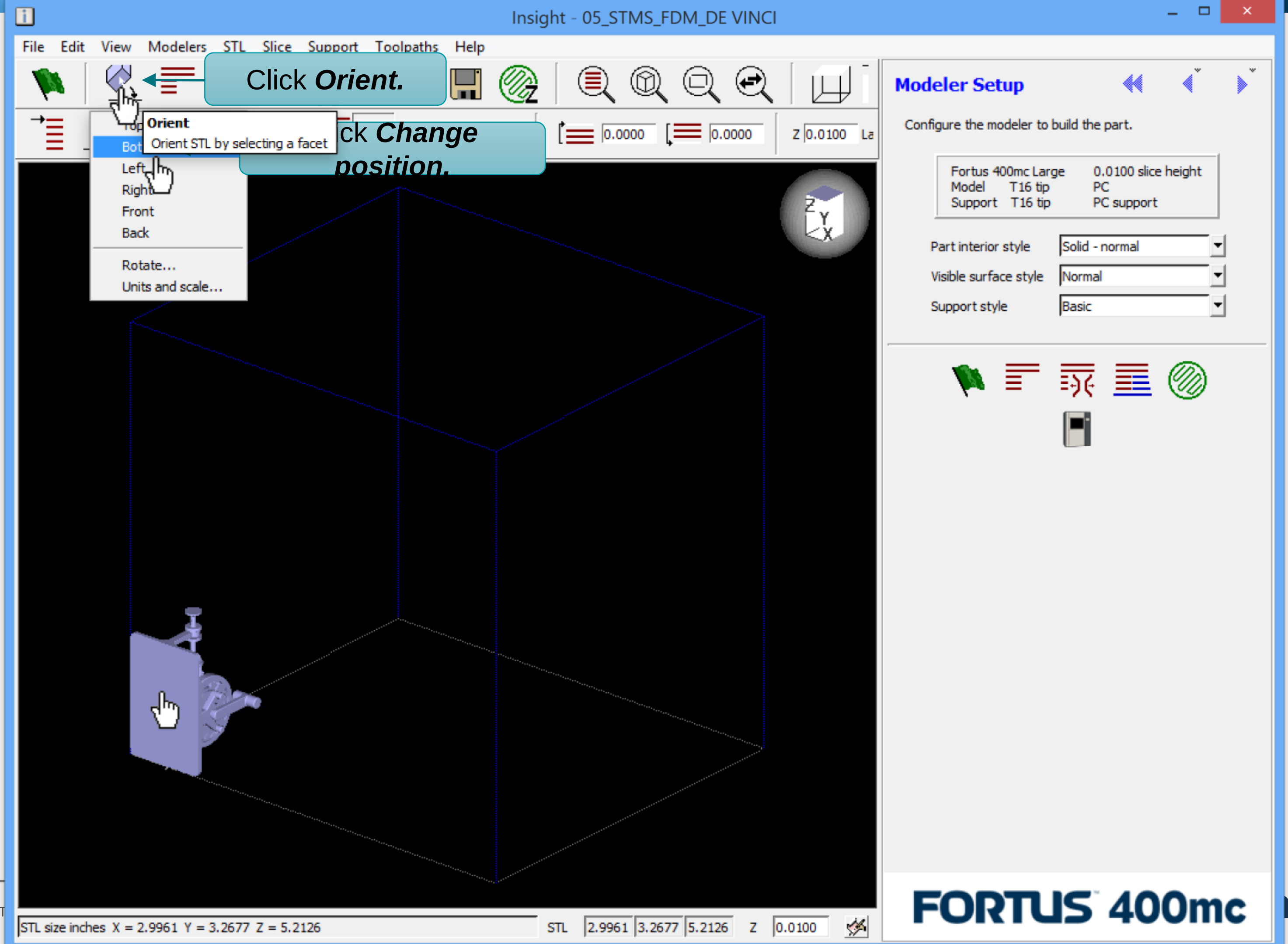
Manual mode (recommended)

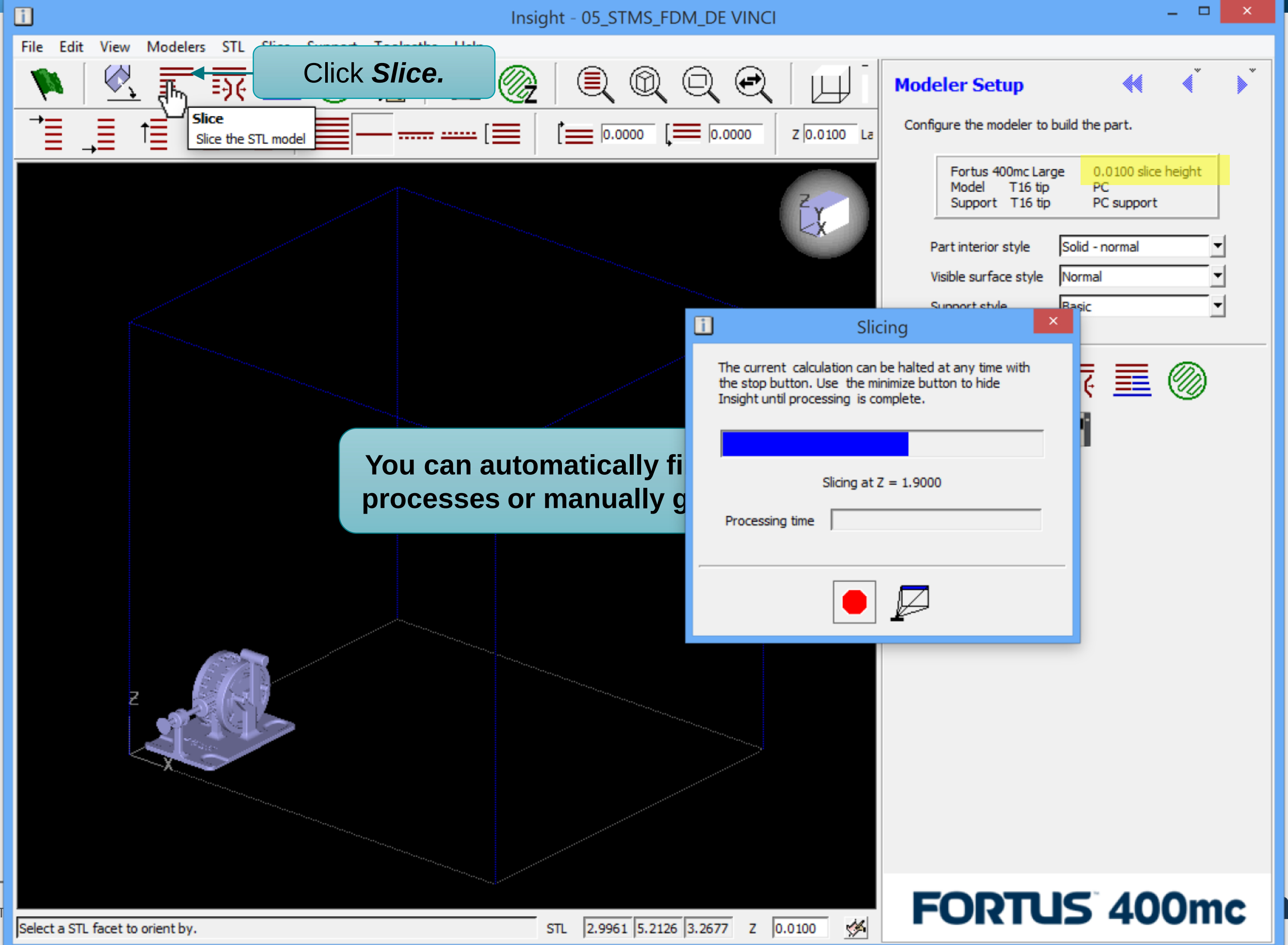
- User defines all settings

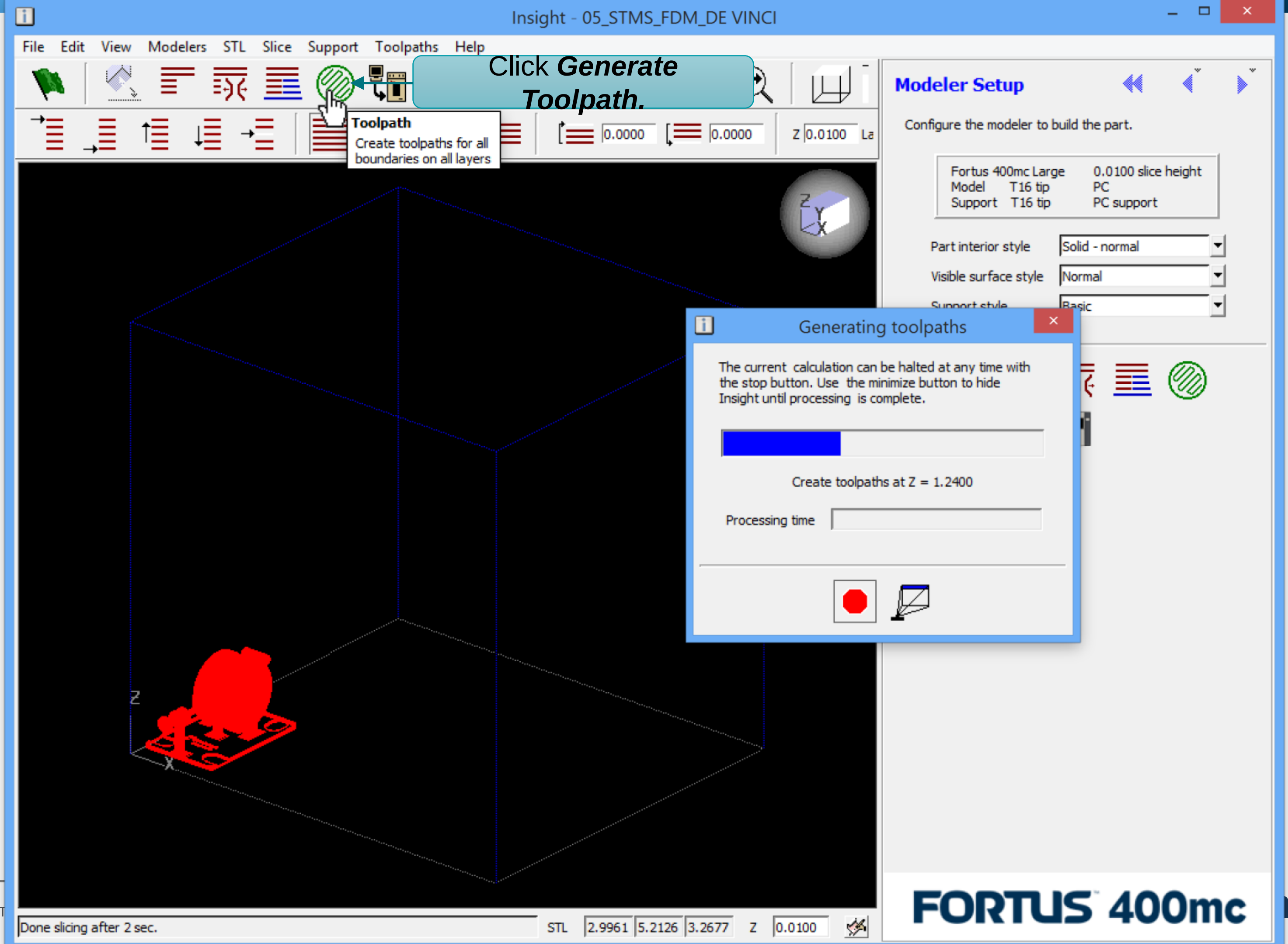
Insight – Deep dive

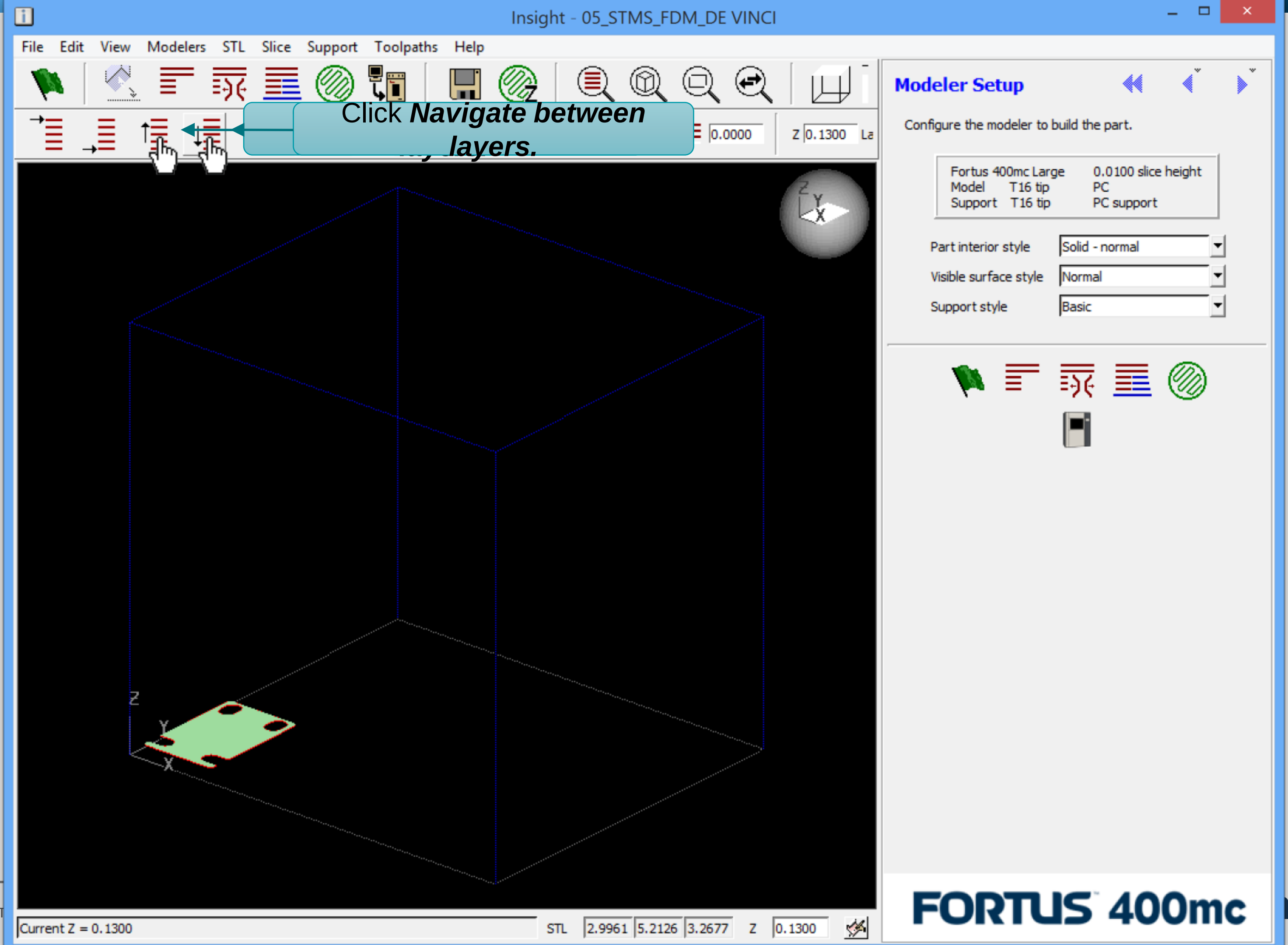
- Understanding options and alternatives

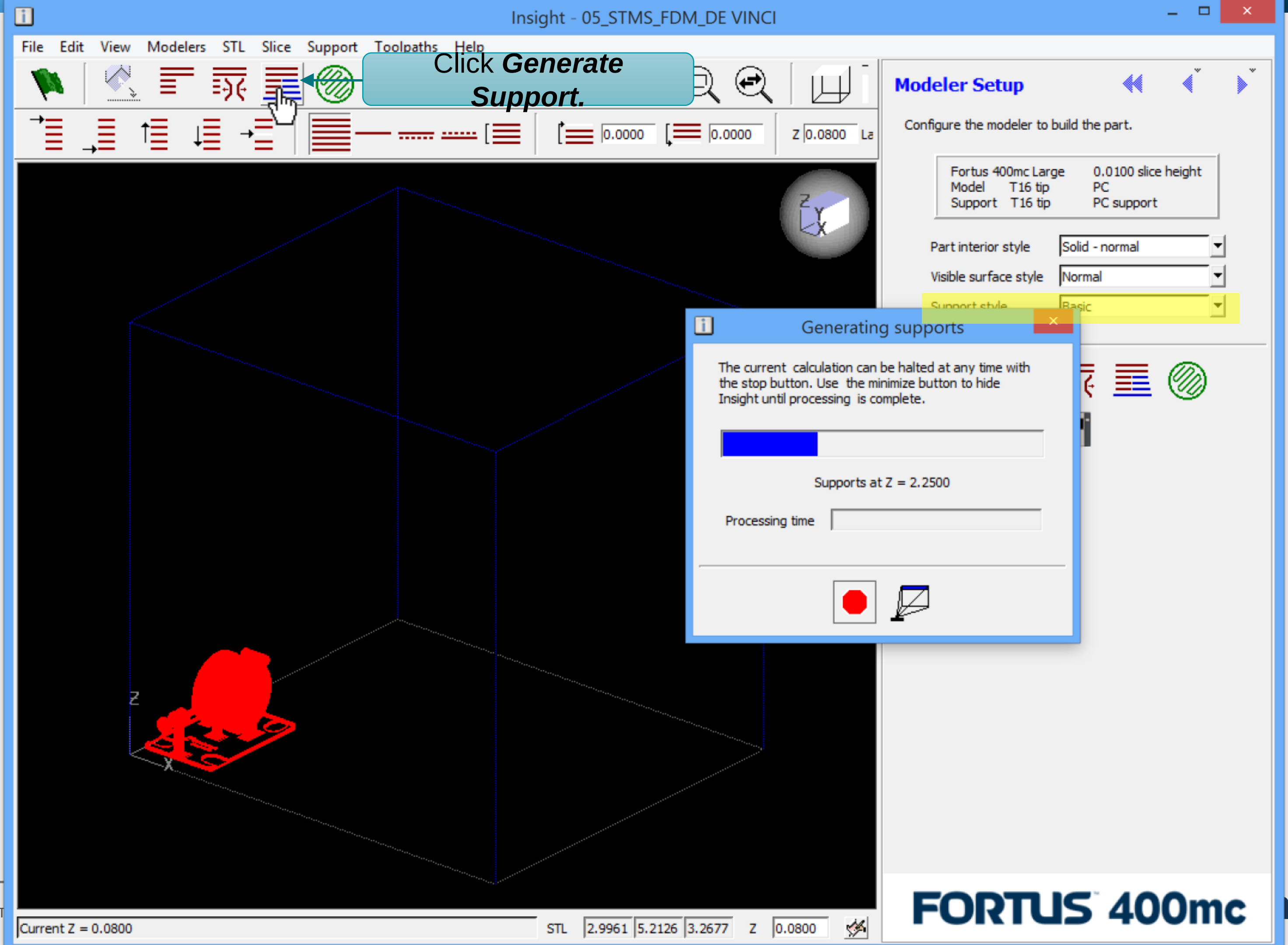

Insight - Default
File
Edit
View
Modelers
STL
Open...
Close
Paste Job from clipboard
Save
Save As...
Delete...
Print...
Build...
Preferences...
Customize
Exit
Click **Open.**
0.0000
0.0000
Z 0.0100
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large
0.0100 slice height
Model T16 tip
PC
Support T16 tip
PC support
Part interior style
Solid - normal
Visible surface style
Normal
Support style
Basic
Z
Y
X
Welcome to Insight...
STL
0.0000
0.0000
0.0000
Z
0.0100
FORTUS 400mc

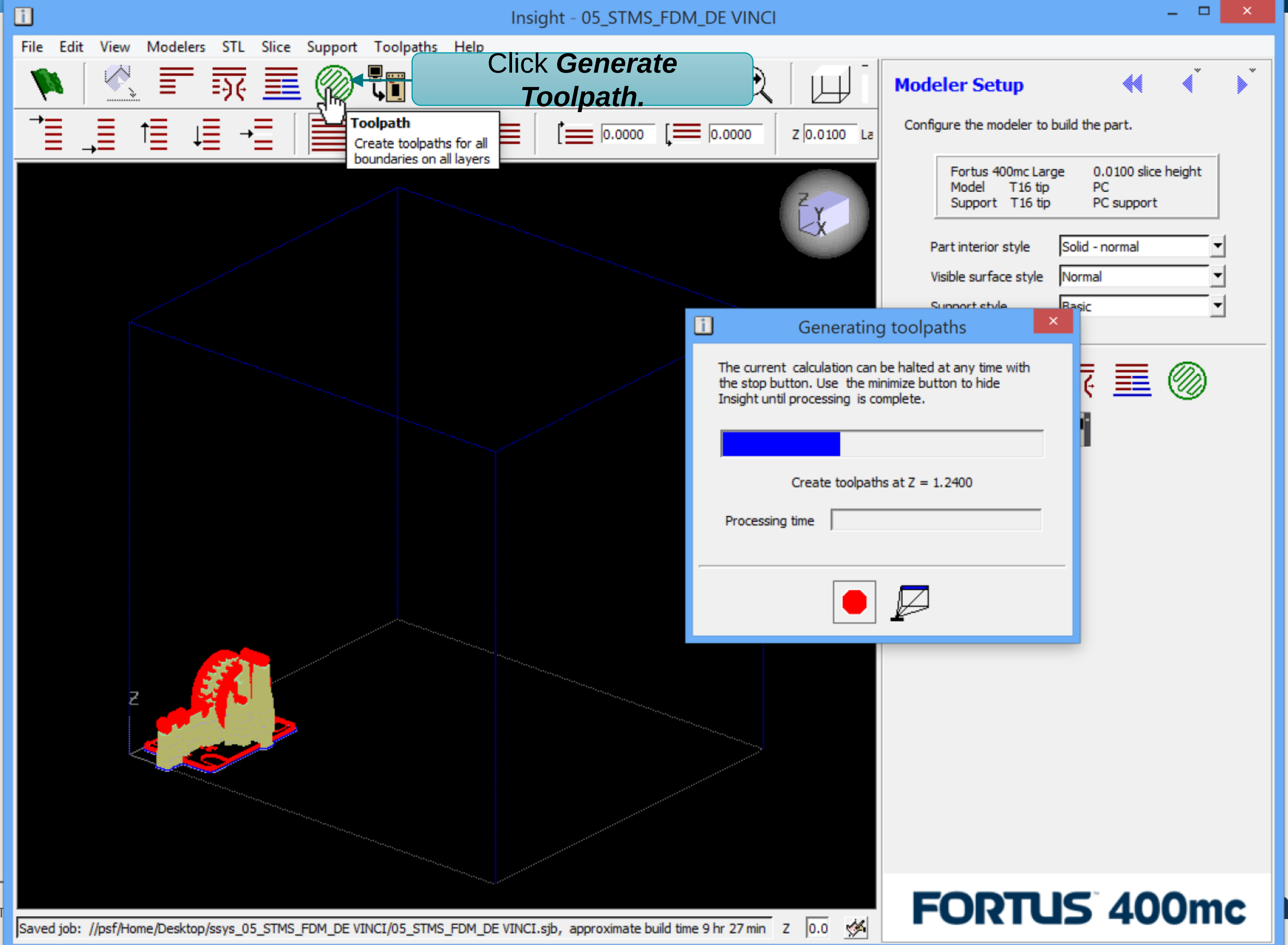

Insight - 05_STMS_FDM_DE VINCI
File Edit View Modelers STL Slice Support Toolpaths Help
Click Orient.
Orient
Orient STL by selecting a facet
ck Change position.
Left
Right
Front
Back
Rotate...
Units and scale...
0.0000
0.0000
Z 0.0100
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large 0.0100 slice height
Model T16 tip PC
Support T16 tip PC support
Part interior style Solid - normal
Visible surface style Normal
Support style Basic
STL size inches X = 2.9961 Y = 3.2677 Z = 5.2126
STL 2.9961 3.2677 5.2126 Z 0.0100
FORTUS 400mc

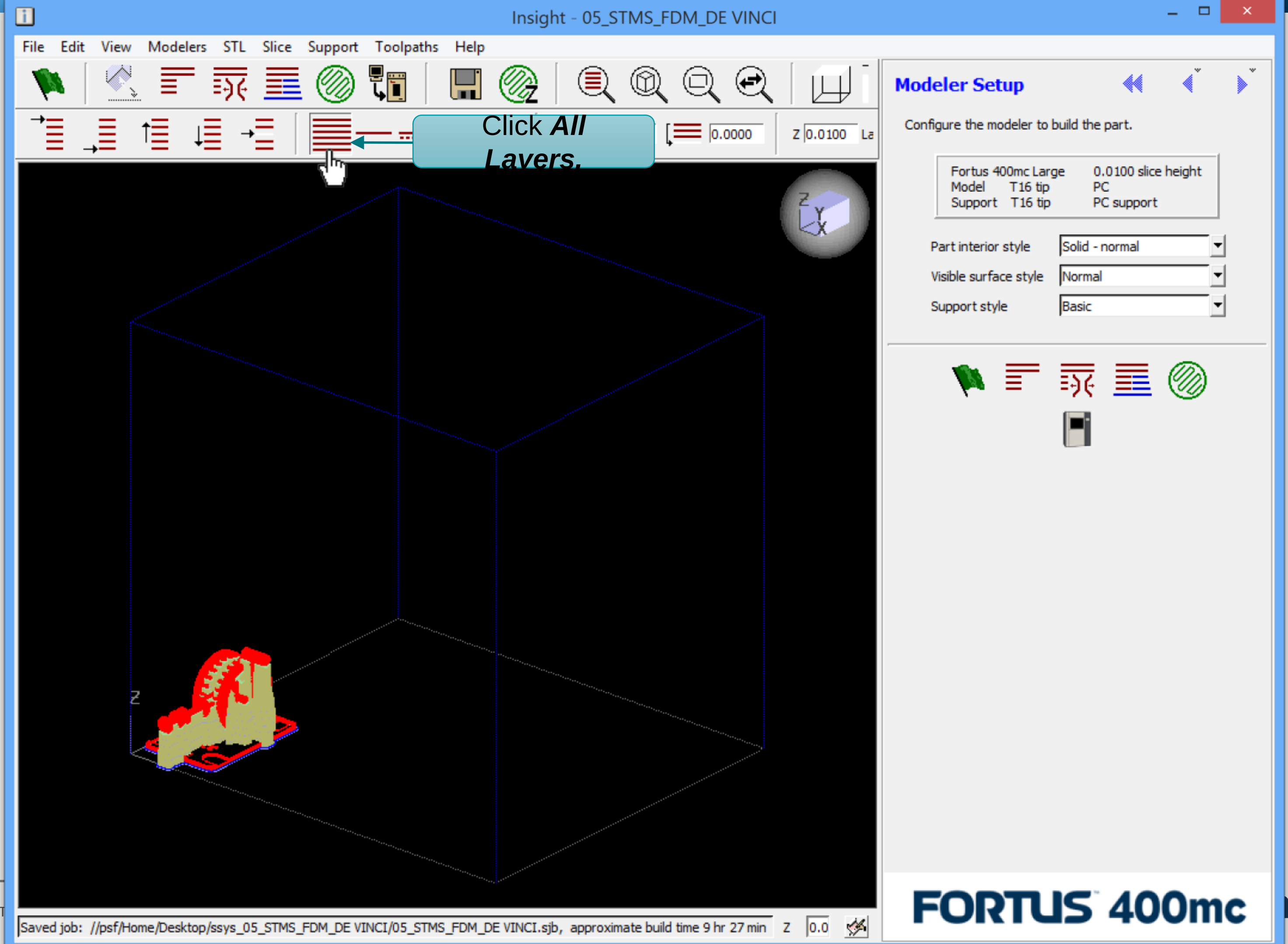

Insight - 05_STMS_FDM_DE VINCI
File Edit View Modelers STL
Click Slice.
Slice
Slice the STL model
0.0000
0.0000
Z 0.0100
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large
Model T16 tip
Support T16 tip
0.0100 slice height
PC
PC support
Part interior style
Solid - normal
Visible surface style
Normal
Basic
You can automatically fi
processes or manually g
Slicing
The current calculation can be halted at any time with the stop button. Use the minimize button to hide Insight until processing is complete.
Slicing at Z = 1.9000
Processing time
Select a STL facet to orient by.
STL
2.9961
5.2126
3.2677
Z
0.0100
FORTUS 400mc

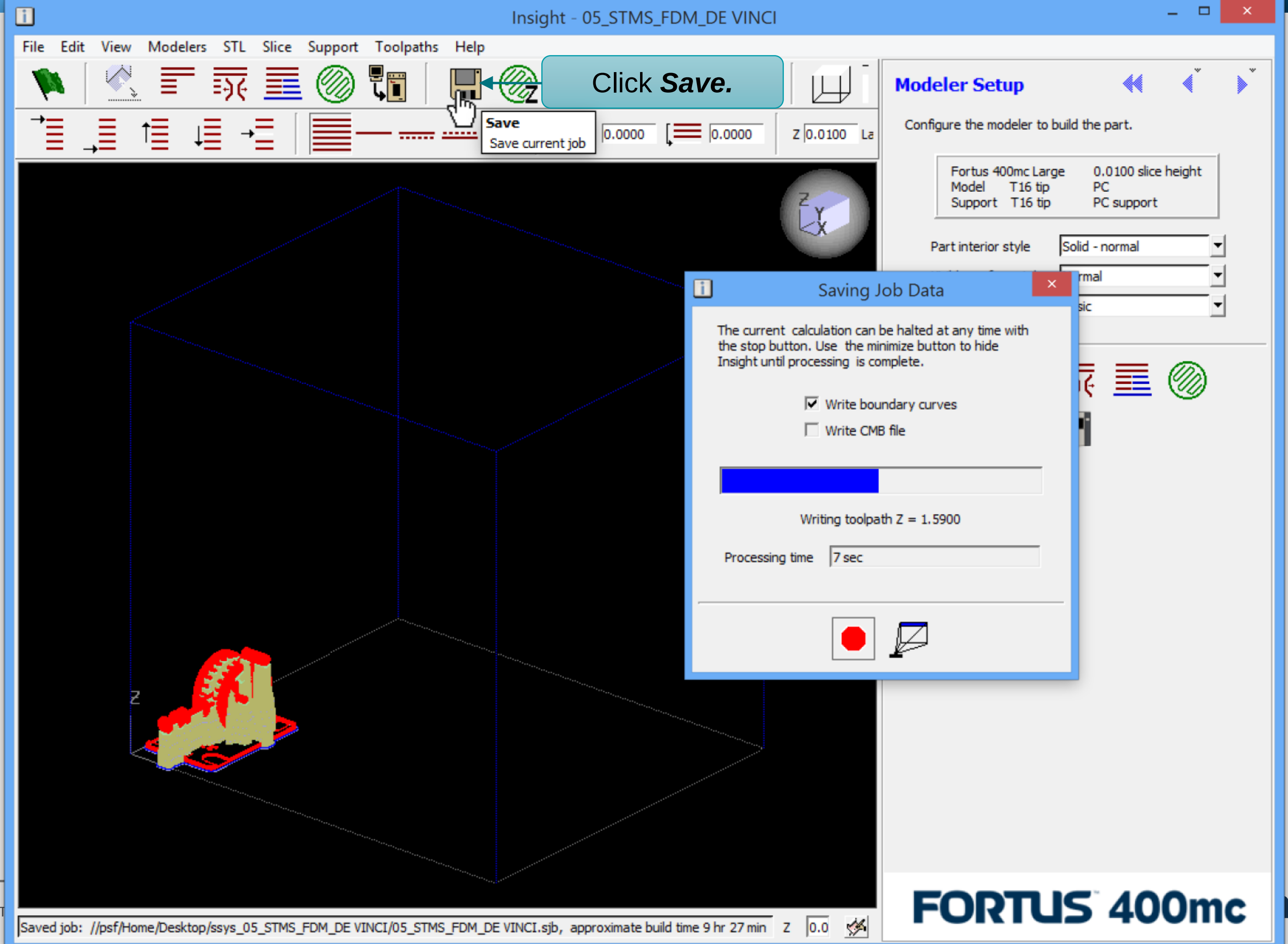

Insight - 05_STMS_FDM_DE VINCI
File Edit View Modelers STL Slice Support Toolpaths Help
Click **Generate Toolpath.**
Toolpath
Create toolpaths for all boundaries on all layers
0.0000
0.0000
Z 0.0100
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large 0.0100 slice height
Model T16 tip PC
Support T16 tip PC support
Part interior style Solid - normal
Visible surface style Normal
Support style Basic
Generating toolpaths
The current calculation can be halted at any time with the stop button. Use the minimize button to hide Insight until processing is complete.
Create toolpaths at Z = 1.2400
Processing time
Done slicing after 2 sec.
STL 2.9961 5.2126 3.2677 Z 0.0100
FORTUS 400mc

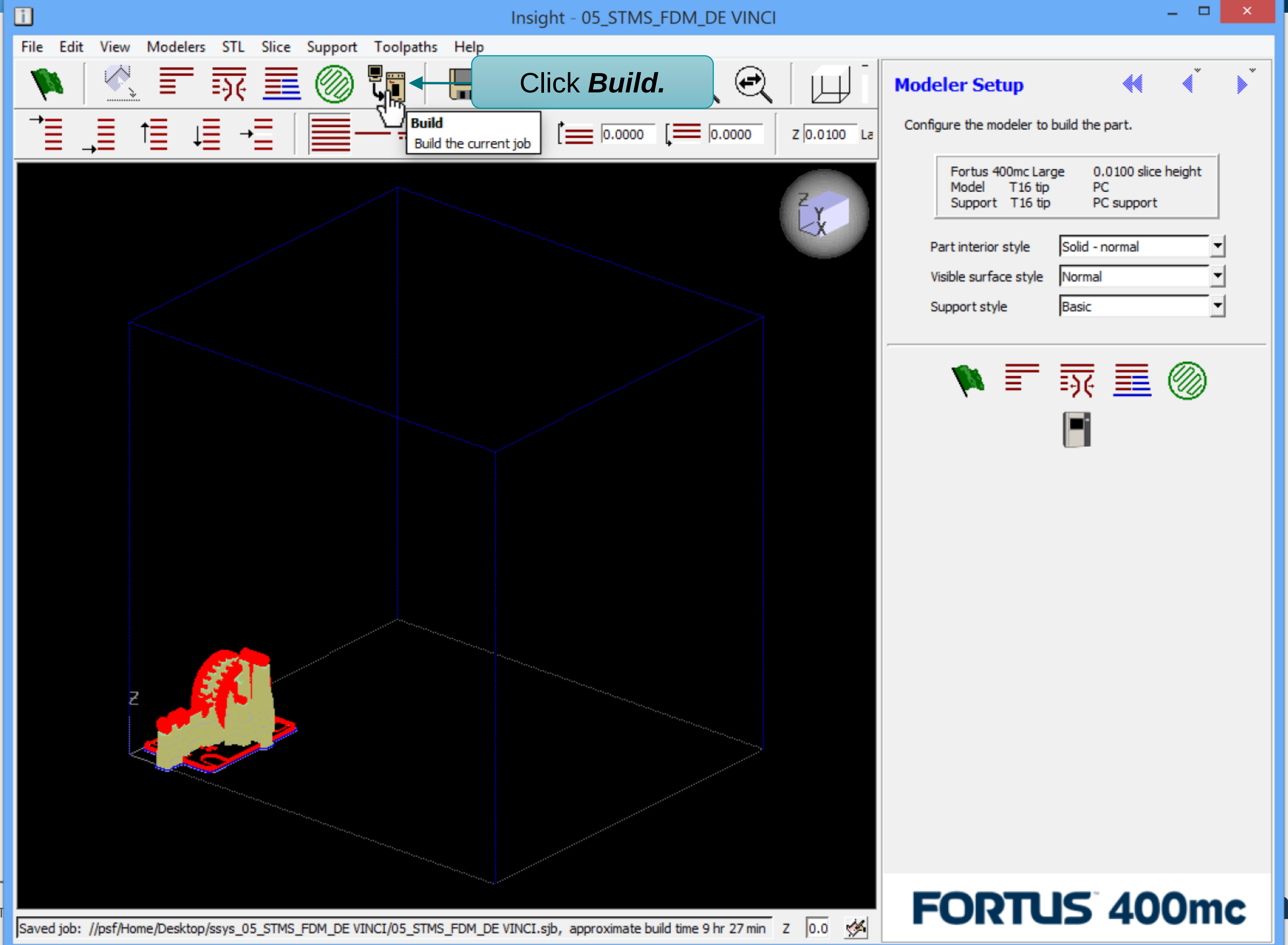

Insight - 05_STMS_FDM_DE VINCI
File Edit View Modelers STL Slice Support Toolpaths Help
Click Navigate between layers.
0.0000
Z 0.1300
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large 0.0100 slice height
Model T16 tip PC
Support T16 tip PC support
Part interior style Solid - normal
Visible surface style Normal
Support style Basic
Current Z = 0.1300
STL 2.9961 5.2126 3.2677
Z 0.1300
FORTUS 400mc


Insight - 05_STMS_FDM_DE VINCI
File Edit View Modelers STL Slice Support Toolpaths Help
Click Generate Support.
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large 0.0100 slice height
Model T16 tip PC
Support T16 tip PC support
Part interior style Solid - normal
Visible surface style Normal
Support style Basic
Generating supports
The current calculation can be halted at any time with the stop button. Use the minimize button to hide Insight until processing is complete.
Supports at Z = 2.2500
Processing time
Current Z = 0.0800
STL 2.9961 5.2126 3.2677
Z 0.0800
FORTUS 400mc

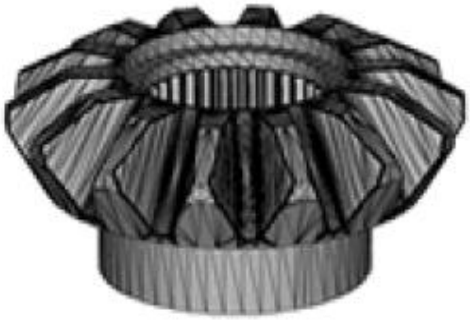

Insight - 05_STMS_FDM_DE VINCI
File Edit View Modelers STL Slice Support Toolpaths Help
Click Generate Toolpath.
Toolpath
Create toolpaths for all boundaries on all layers
0.0000
0.0000
Z 0.0100
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large 0.0100 slice height
Model T16 tip PC
Support T16 tip PC support
Part interior style Solid - normal
Visible surface style Normal
Support style Basic
Generating toolpaths
The current calculation can be halted at any time with the stop button. Use the minimize button to hide Insight until processing is complete.
Create toolpaths at Z = 1.2400
Processing time
Saved job: //psf/Home/Desktop/ssys_05_STMS_FDM_DE VINCI/05_STMS_FDM_DE VINCI.sjb, approximate build time 9 hr 27 min
FORTUS 400mc


Insight - 05_STMS_FDM_DE VINCI
File Edit View Modelers STL Slice Support Toolpaths Help
Click *All Layers.*
0.0000
Z 0.0100
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large 0.0100 slice height
Model T16 tip PC
Support T16 tip PC support
Part interior style Solid - normal
Visible surface style Normal
Support style Basic
FORTUS 400mc
Saved job: //psf/Home/Desktop/ssys_05_STMS_FDM_DE VINCI/05_STMS_FDM_DE VINCI.sjb, approximate build time 9 hr 27 min


Insight - 05_STMS_FDM_DE VINCI
File Edit View Modelers STL Slice Support Toolpaths Help
Click Save.
Save
Save current job
0.0000
0.0000
Z 0.0100
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large 0.0100 slice height
Model T16 tip PC
Support T16 tip PC support
Part interior style Solid - normal
Saving Job Data
The current calculation can be halted at any time with the stop button. Use the minimize button to hide Insight until processing is complete.
Write boundary curves
Write CMB file
Writing toolpath Z = 1.5900
Processing time 7 sec
Saved job: //psf/Home/Desktop/ssys_05_STMS_FDM_DE VINCI/05_STMS_FDM_DE VINCI.sjb, approximate build time 9 hr 27 min
FORTUS 400mc


Insight - 05_STMS_FDM_DE VINCI
File
Edit
View
Modelers
STL
Slice
Support
Toolpaths
Help
Click Build.
Build
Build the current job
0.0000
0.0000
Z 0.0100
Modeler Setup
Configure the modeler to build the part.
Fortus 400mc Large
0.0100 slice height
Model T16 tip
PC
Support T16 tip
PC support
Part interior style
Solid - normal
Visible surface style
Normal
Support style
Basic
FORTUS 400mc
Saved job: //psf/Home/Desktop/ssys_05_STMS_FDM_DE VINCI/05_STMS_FDM_DE VINCI.sjb, approximate build time 9 hr 27 min

STL INTO CMB



```
CMB version = 8.9
Summary information:
  Software build version = 8.2 (4314)
  Machine type           = vt21
  Estimated build time   = 242 seconds
  Number of layers       = 40
  Slice height           = 0.010000
  Part material/tip      = ULT9085/T16
  Support material/tip   = ULT_S/T16
  System mode            = none
  Part volume            = 0.013768
  Support volume         = 0.000000
  Bounding box: min      = (7.810255, 6.847403, 0.014136)
                max      = (8.439749, 7.409952, 0.457919)
  Part bead min/max area              = (0.000202, 0.000283)
  Support bead min/max area           = (100000.000000, -100000.000000)
  Part bead min/max width             = (0.020194, 0.028272)
  Support bead min/max width          = (100000.000000, -100000.000000)
  Part bead min/max aspect ratio      = (2.019400, 2.827160)
  Support bead min/max aspect ratio = (100000.000000, -100000.000000)
Comment: Written by Insight!!!!!Model color: tan.
Packing list: test
Footprint list: 1
Contour points: 12
Contour pt: (0.146875, 0.557719)
Contour pt: (0.000000, 0.273762)
Contour pt: (0.000000, 0.252151)
Contour pt: (0.145472, 0.000000)
Contour pt: (0.490534, 0.000000)
Contour pt: (0.629494, 0.243180)
Contour pt: (0.629494, 0.320897)
Contour pt: (0.489005, 0.557974)
Contour pt: (0.487160, 0.559787)
Contour pt: (0.484660, 0.560449)
Contour pt: (0.151360, 0.560449)
Contour pt: (0.148735, 0.559713)
Type descriptors:
  Type: 17      Size: 4
  Type: 18      Size: 8
  Type: 19      Size: 16
  Type: 20      Size: 4
New layer: 7.810255, 6.847403, 0.014136
           8.439749, 7.409952, 0.074233
Layer Est model: paths 1 length 1.870
 support: paths 0 length 0.000

Mode = 102, Part Surface
Moveto: 8.282387, 7.392599, 0.014136    0.000000
Moveto: 7.967594, 7.392560, 0.014136    0.000283
Moveto: 7.810255, 7.119962, 0.014136    0.000283
Moveto: 7.967662, 6.847403, 0.014136    0.000283
Moveto: 8.282409, 6.847442, 0.014136    0.000283
Moveto: 8.439749, 7.120040, 0.014136    0.000283
Moveto: 8.282387, 7.392599, 0.014136    0.000283
Moveto: 8.183904, 7.409952, 0.014136    0.000000
```

INSIGHT

Green flag mode

- 5-step setup
- Automatic processing using defaults

Manual mode (recommended)

- User defines all settings

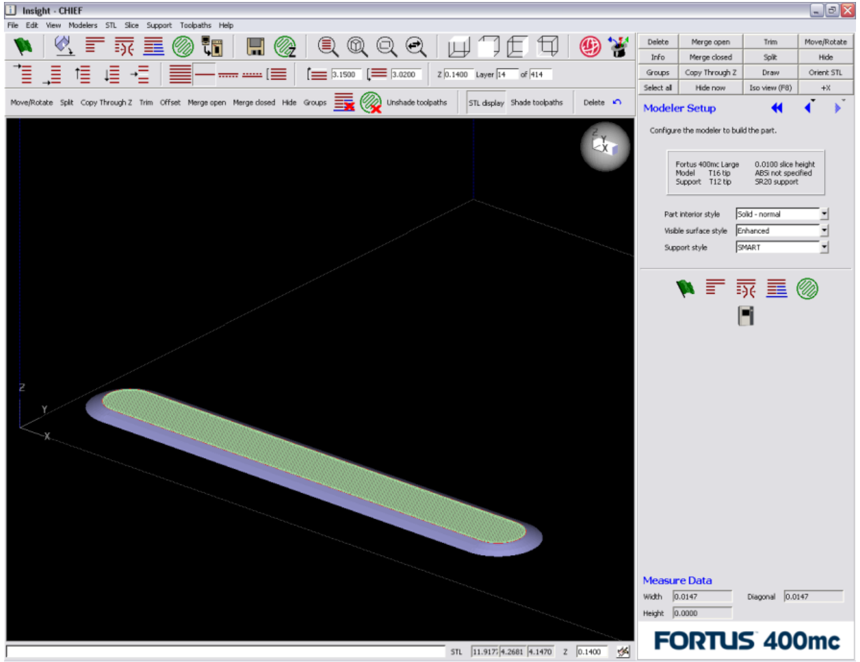
Insight – Deep dive

- Understanding options and alternatives
- Pre-processing to Orientation
- Slice, fix & view
- Support
- Tips & toolpaths

STL INTO CMB WORKFLOW

- OPEN .STL IN INSIGHT
- MODELER SETUP
- ORIENT PART
- SLICE
- GENERATE TOOLPATHS
- FIX PROBLEMS
- CREATE SUPPORTS
- CREATE TOOLPATHS
- SEND TO CONTROL CENTER
- SEND TO MODELER

INSIGHT INTERFACE



- OPEN .STL IN INSIGHT
- MODELER SETUP
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- SLICE
- GENERATE TOOLPATHS
- FIX PROBLEMS
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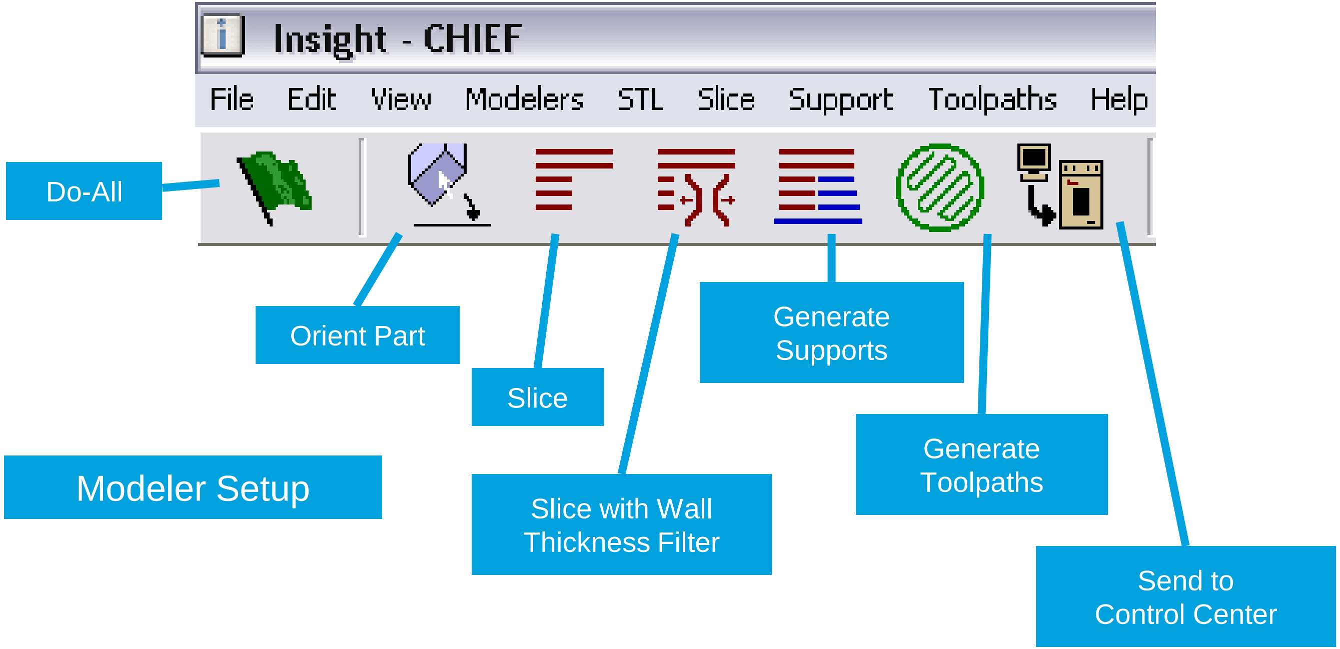
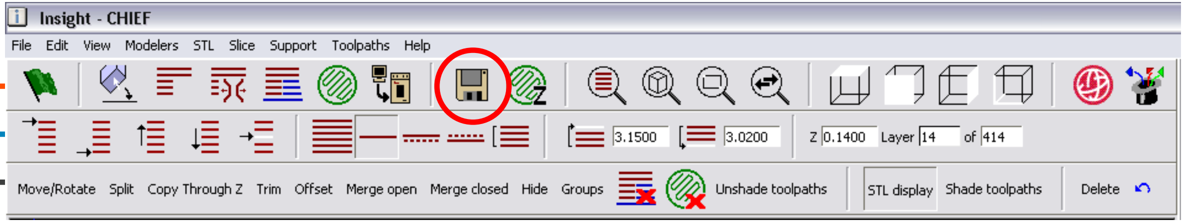
- CREATE TOOLPATHS
- SEND TO CONTROL CENTER
- SEND TO MODELER

INSIGHT INTERFACE



INSIGHT INTERFACE



Main Toolbar

Z Toolbar

Custom Toolbar

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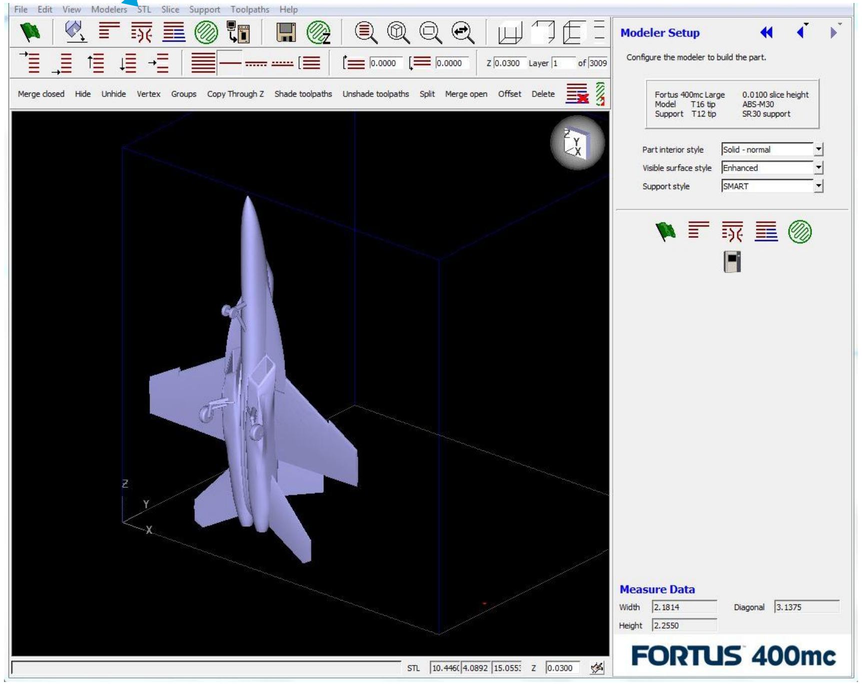
MODELER SETUP

Click ***Modelers.***



- OPEN .STL IN INSIGHT
- MODELER SETUP
- ORIENT PART
- SLICE
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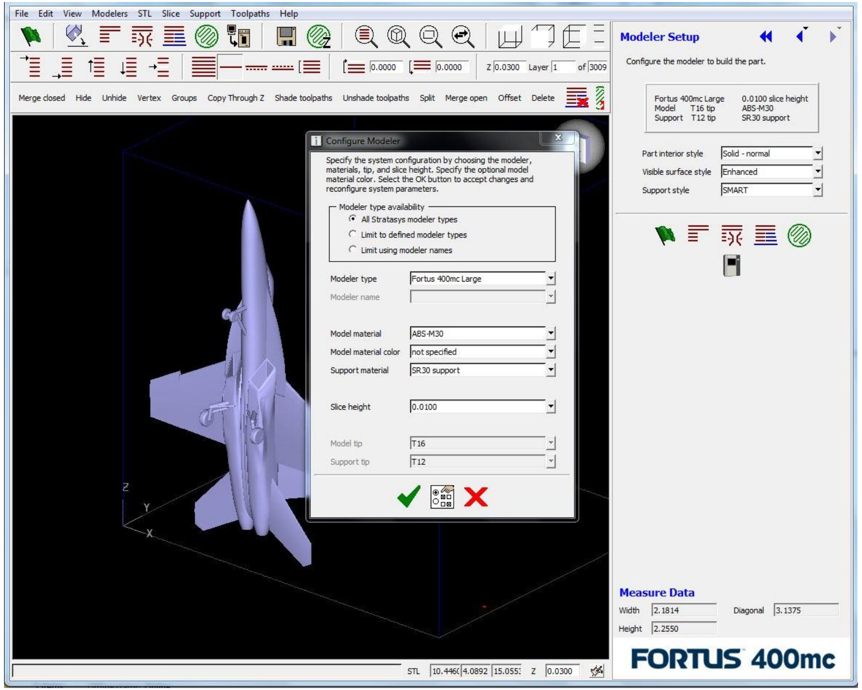
- FIX PROBLEMS
- CREATE SUPPORTS
- CREATE TOOLPATHS
- SEND TO CONTROL CENTER
- SEND TO MODELER

MODELER SETUP CONFIGURATION



INSIGHT

Green flag mode

- 5-step setup
- Automatic processing using defaults

Manual mode (recommended)

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Insight – Deep dive

- Understanding options and alternatives
- Pre-processing to Orientation
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ORIENTATION

- OPEN .STL IN INSIGHT
- MODELER SETUP
- **ORIENT PART**
- SLICE
- GENERATE TOOLPATHS
- FIX PROBLEMS
- CREATE SUPPORTS
- CREATE TOOLPATHS
- SEND TO CONTROL CENTER
- SEND TO MODELER

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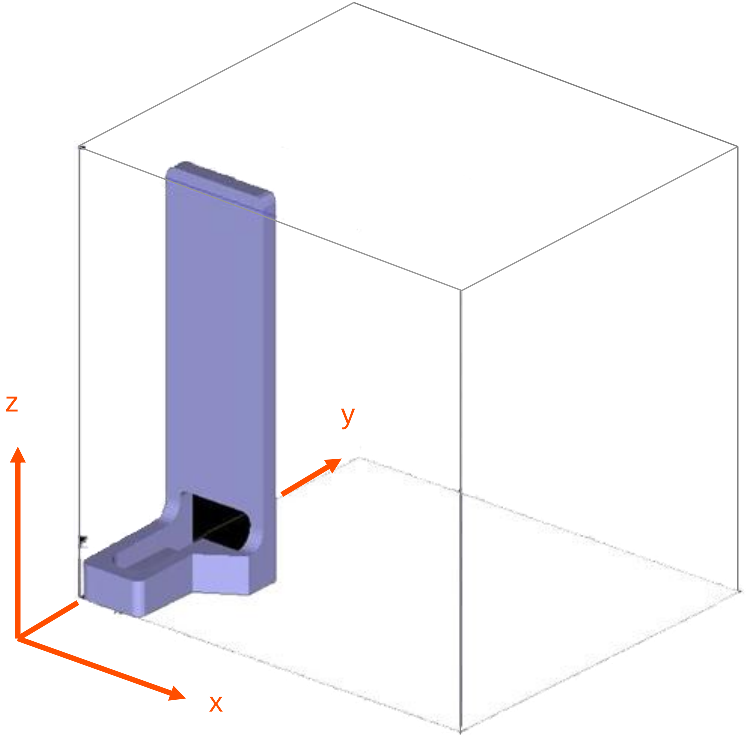
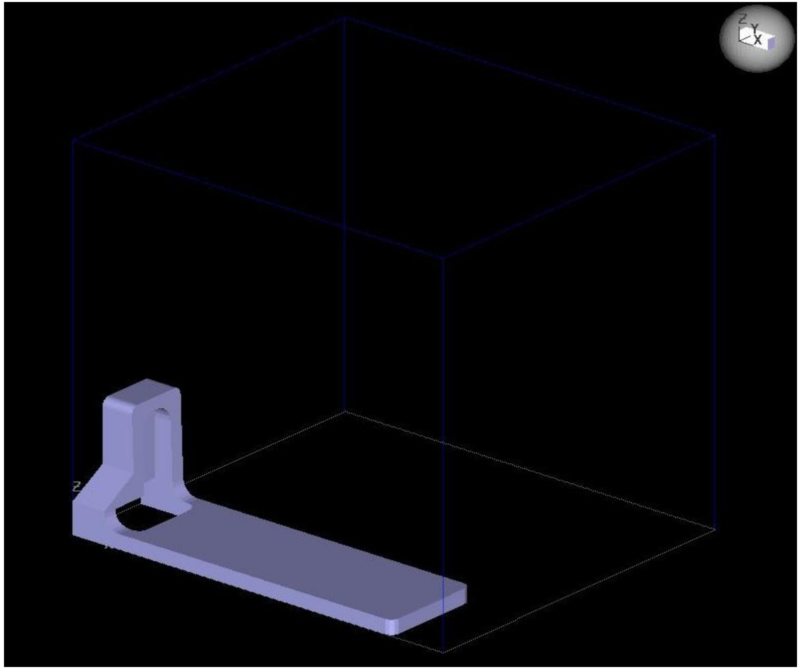
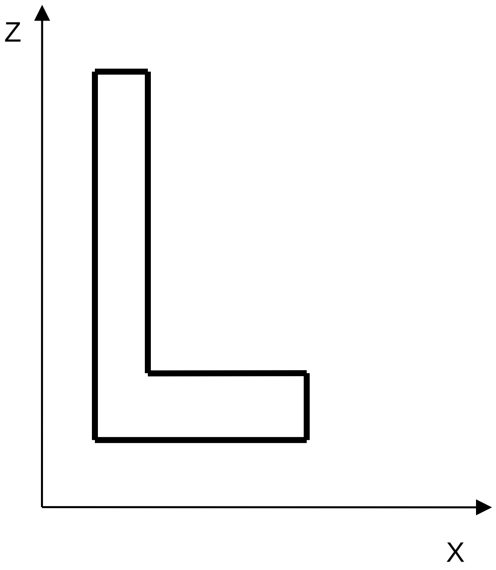
XYZ AXIS



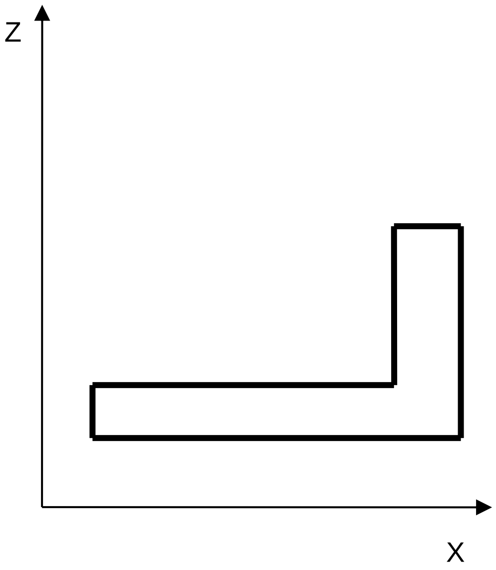
ORIENTATION: SPEED



CHALK TALK 1

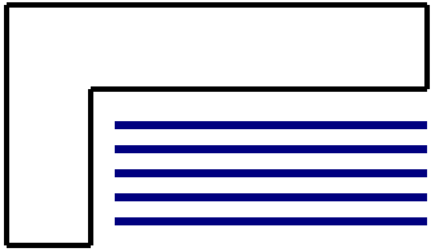


As Imported



Oriented for Speed

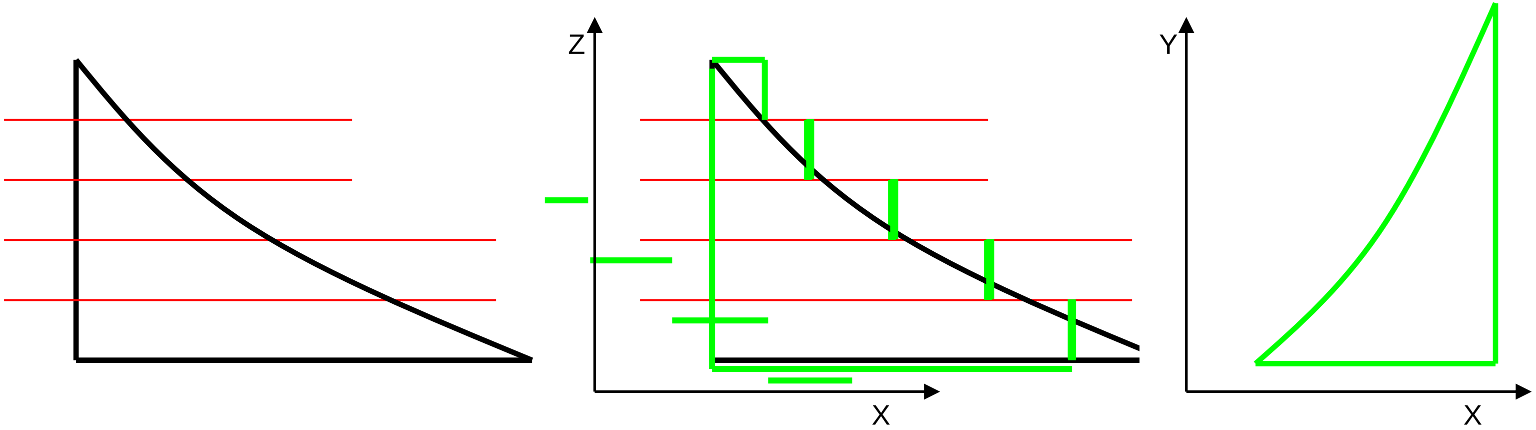
ORIENTATION: SUPPORT STRUCTURES



Orientation 1

Orientation 2

ORIENTATION: SURFACE QUALITY



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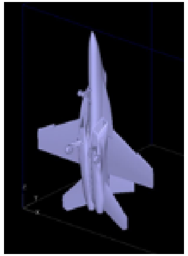
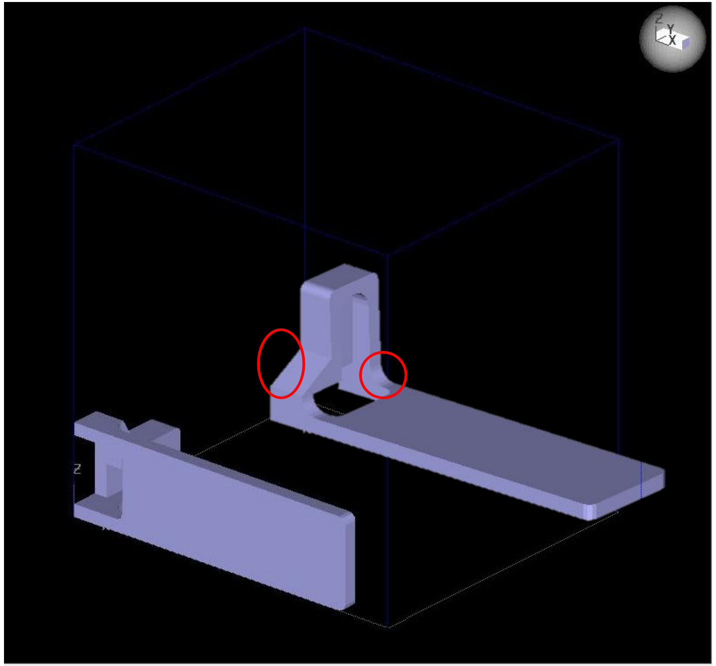
ORIENTATION: SURFACE QUALITY

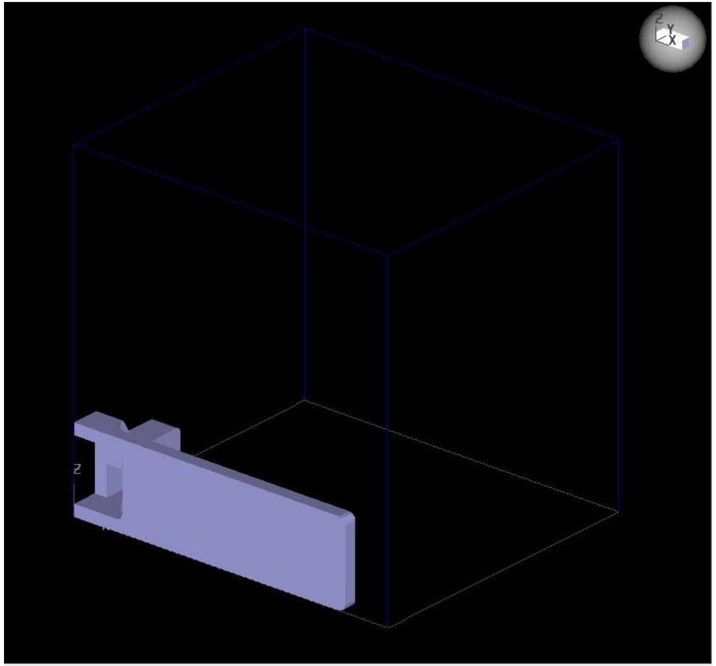




ORIENTATION: SURFACE QUALITY

Layering process means strength differences in X,Y,&Z planes (non-isotropic)

Consider where forces will be applied to final part



CHALK TALK 2

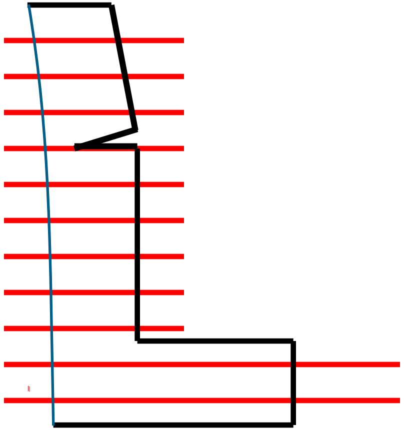


Figure1

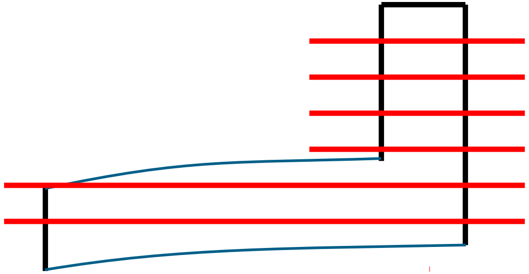


Figure 2

CHALK TALK 2

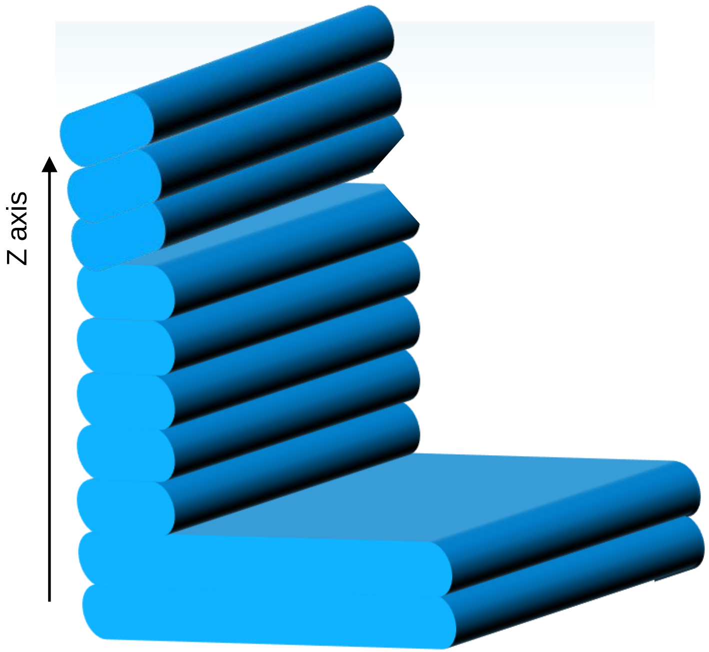


Figure1

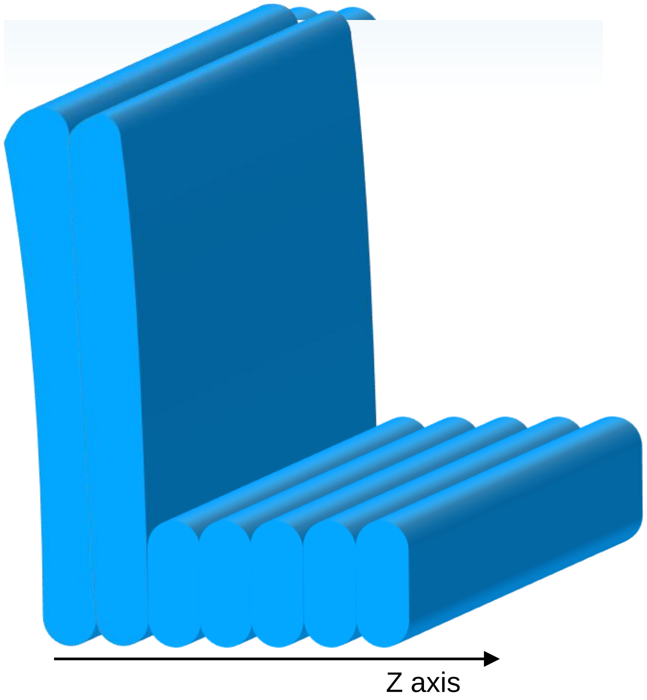
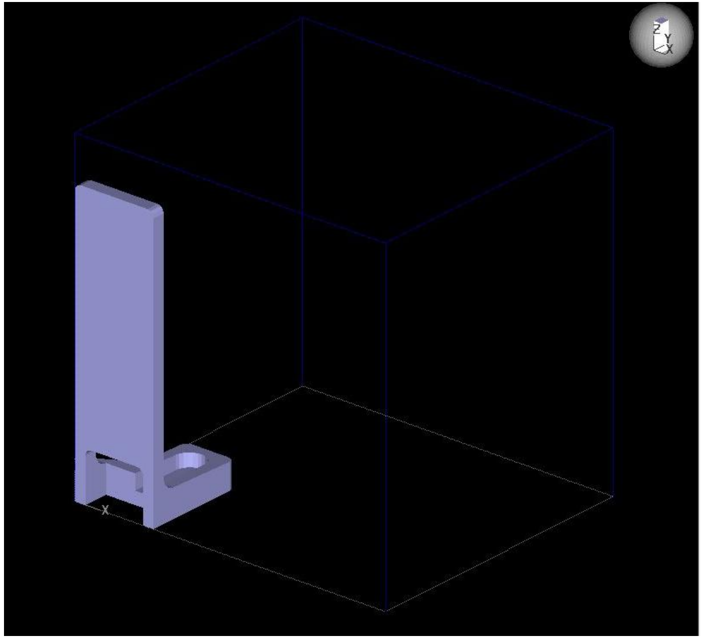
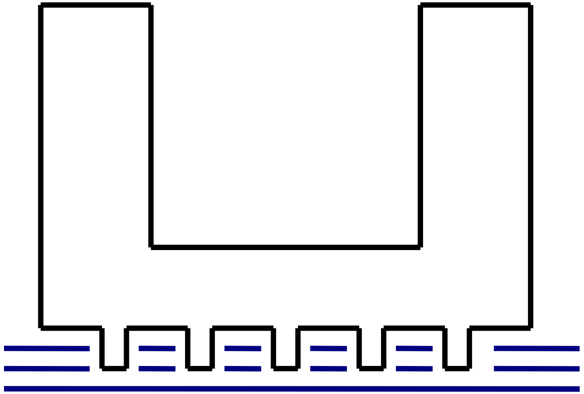


Figure 2

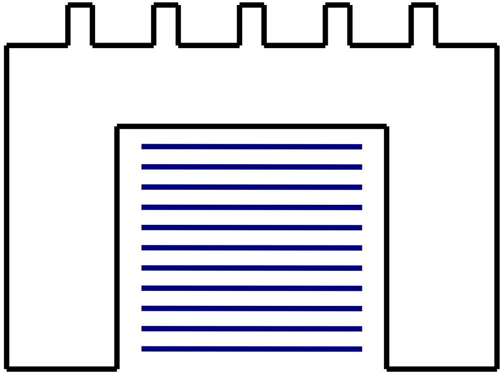
ORIENTATION: SUPPORT REMOVAL



CHALK TALK 3



Orientation 1



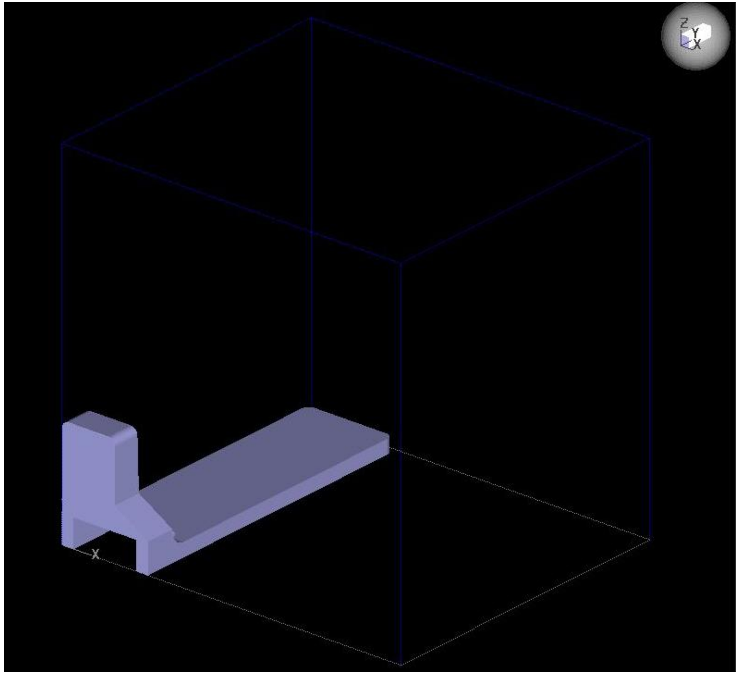
Orientation 2

ORIENTATION: AIRFLOW

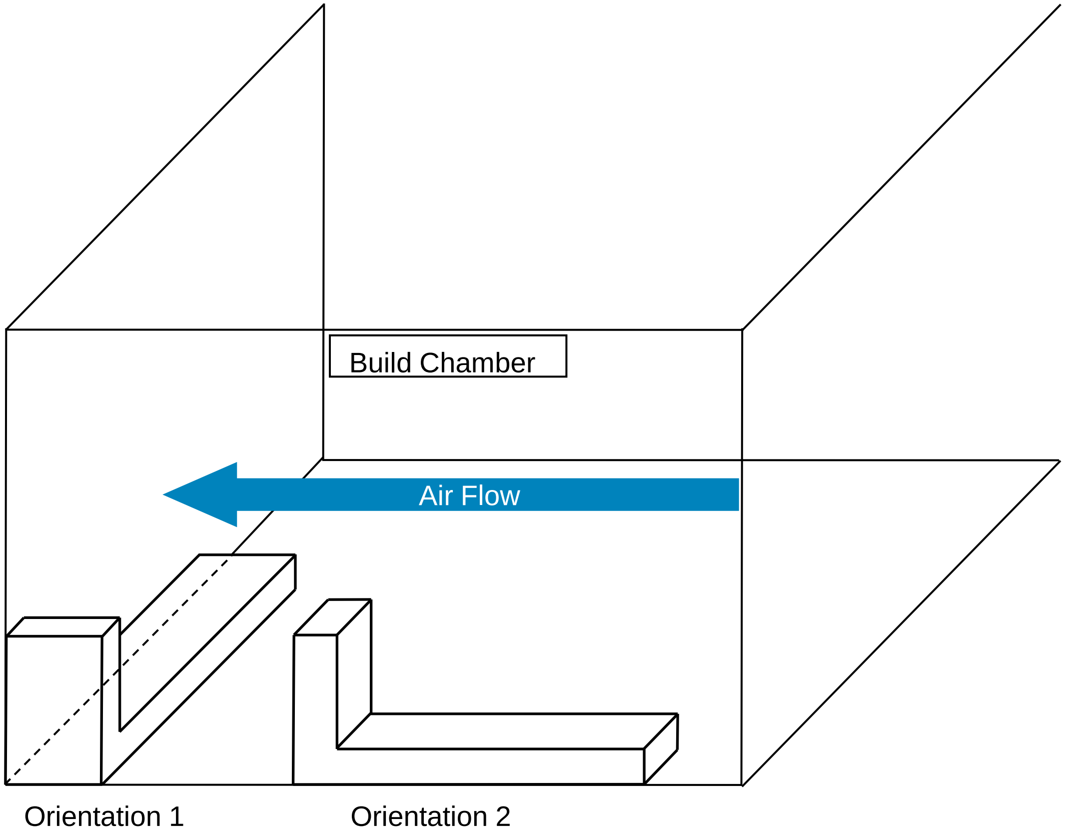
Uniform Airflow affects

- Temperature across part
- Layer-to-layer bonding

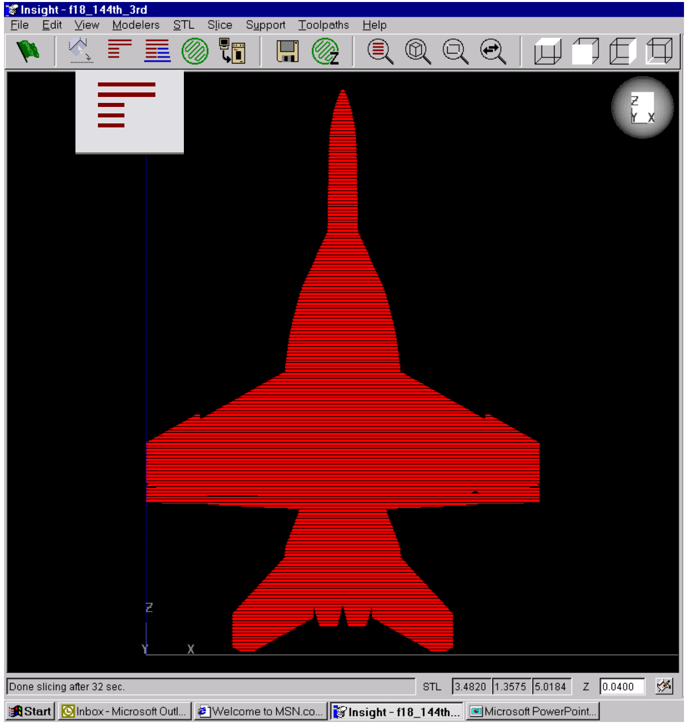
Orient parts to allow maximum airflow across most of the part(s).



CHALK TALK 4



SLICE FILE



- OPEN .STL IN INSIGHT
- MODELER SETUP
- ORIENT PART
- **SLICE**
- GENERATE TOOLPATHS
- FIX PROBLEMS
- CREATE SUPPORTS
- CREATE TOOLPATHS
- SEND TO CONTROL CENTER
- SEND TO MODELER

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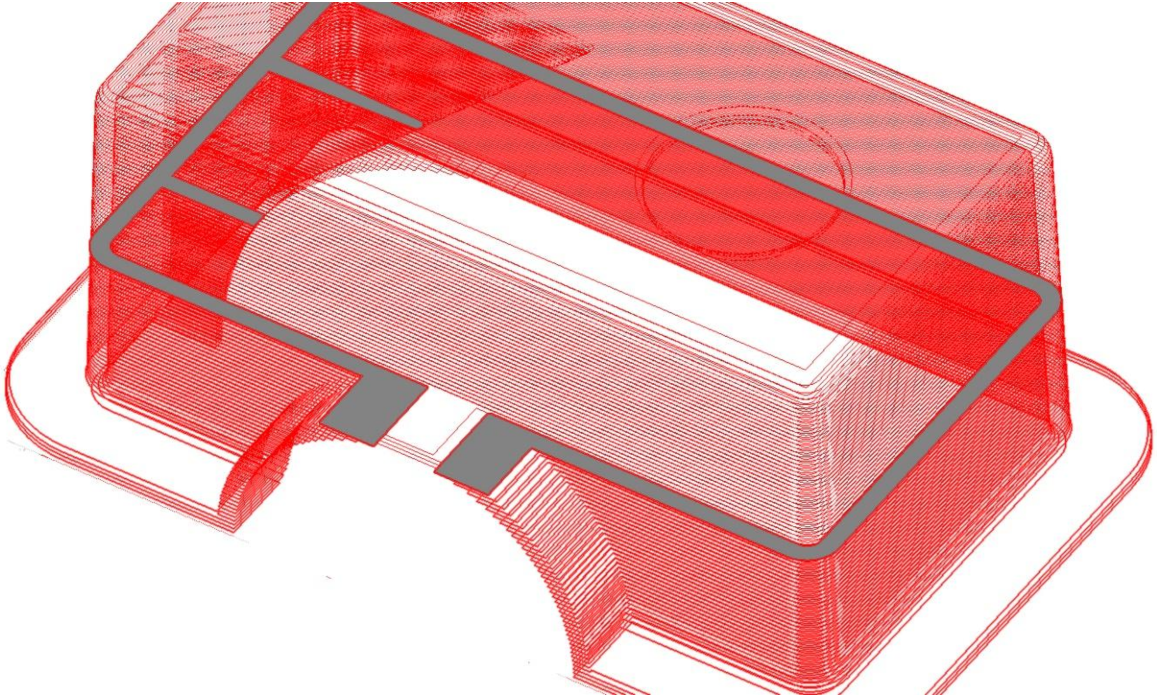
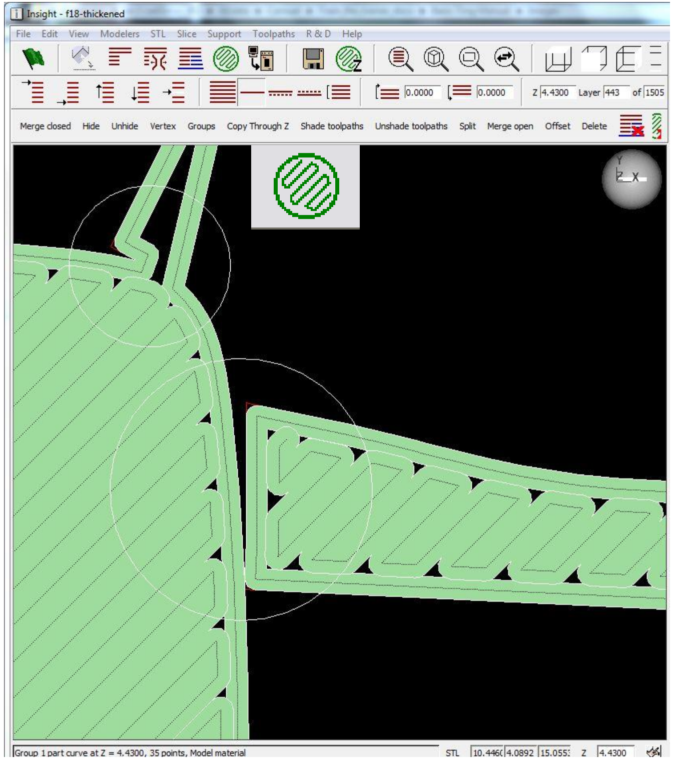
SLICE FILE



GENERATE TOOLPATHS



OPEN .STL IN INSIGHT

MODELER SETUP

ORIENT PART

SLICE

GENERATE TOOLPATHS

FIX PROBLEMS

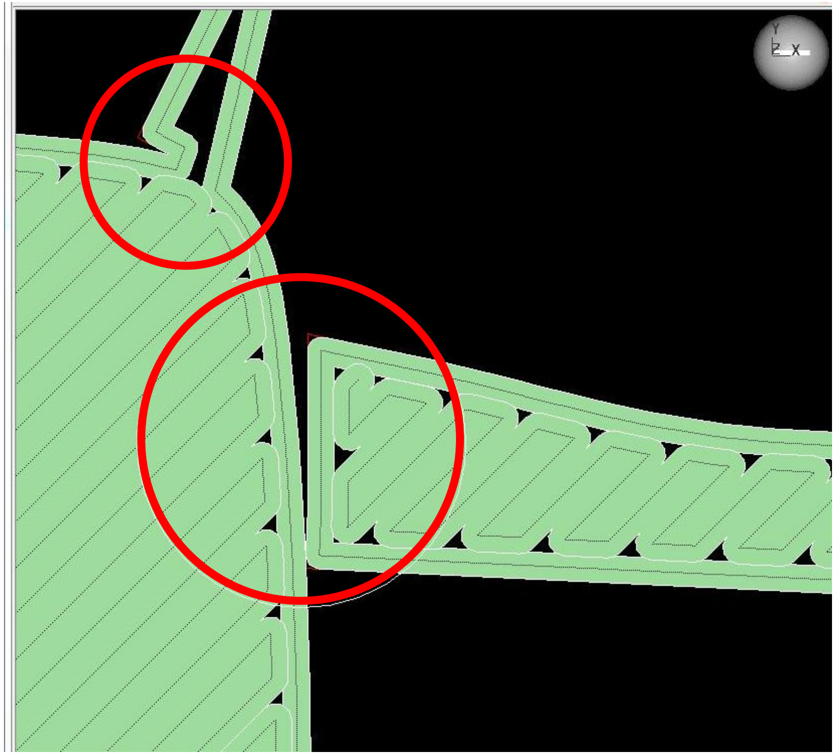
CREATE SUPPORTS

CREATE TOOLPATHS

SEND TO CONTROL CENTER

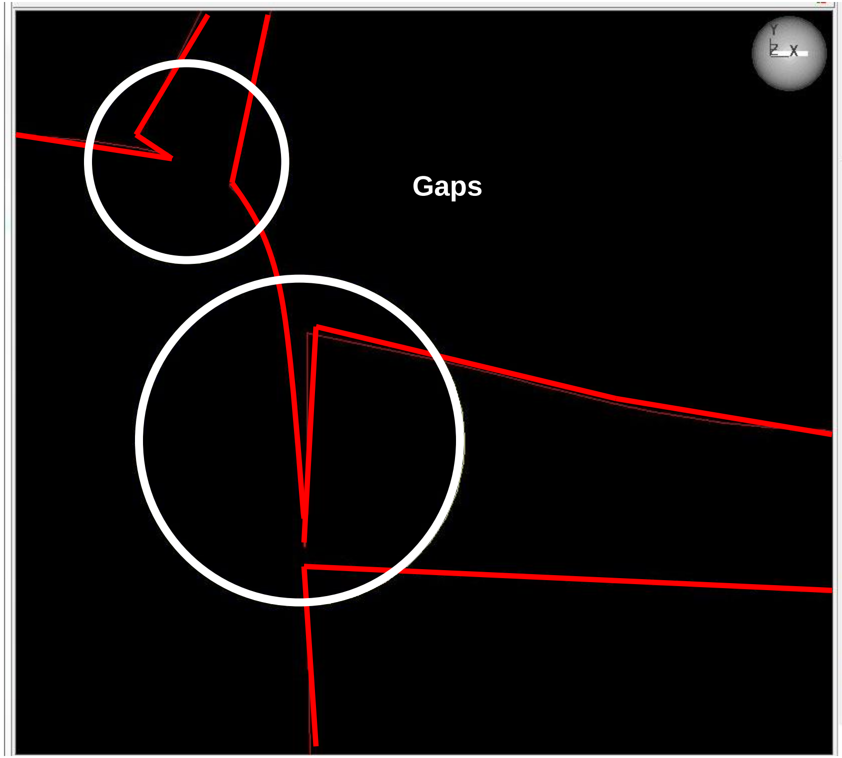
SEND TO MODELER

IDENTIFY AND FIX PROBLEMS

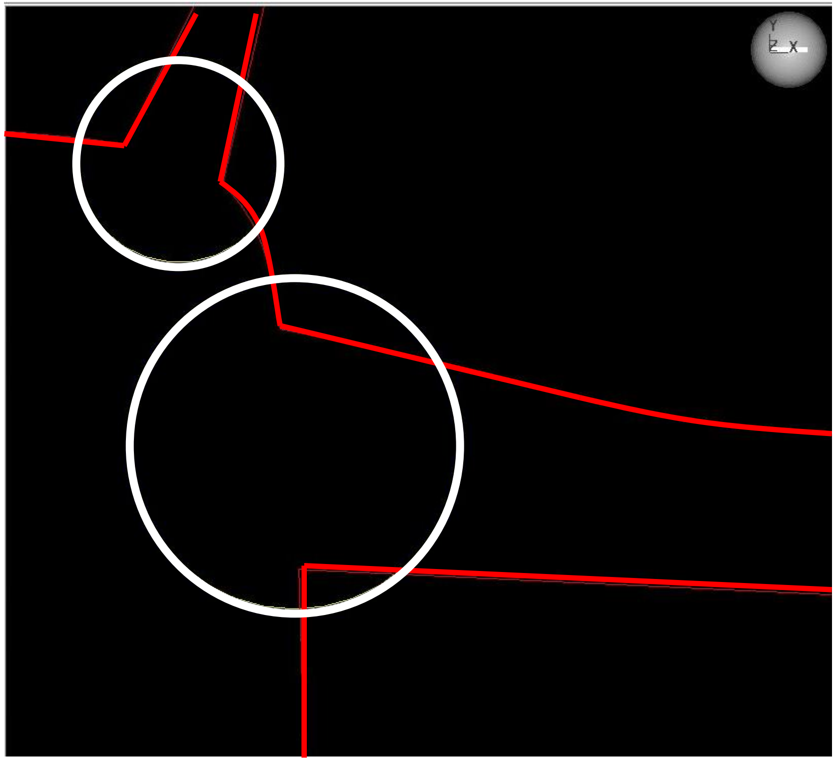


- OPEN .STL IN INSIGHT
- MODELER SETUP
- ORIENT PART
- SLICE
- GENERATE TOOLPATHS
- **FIX PROBLEMS**
- CREATE SUPPORTS
- CREATE TOOLPATHS
- SEND TO CONTROL CENTER
- SEND TO MODELER

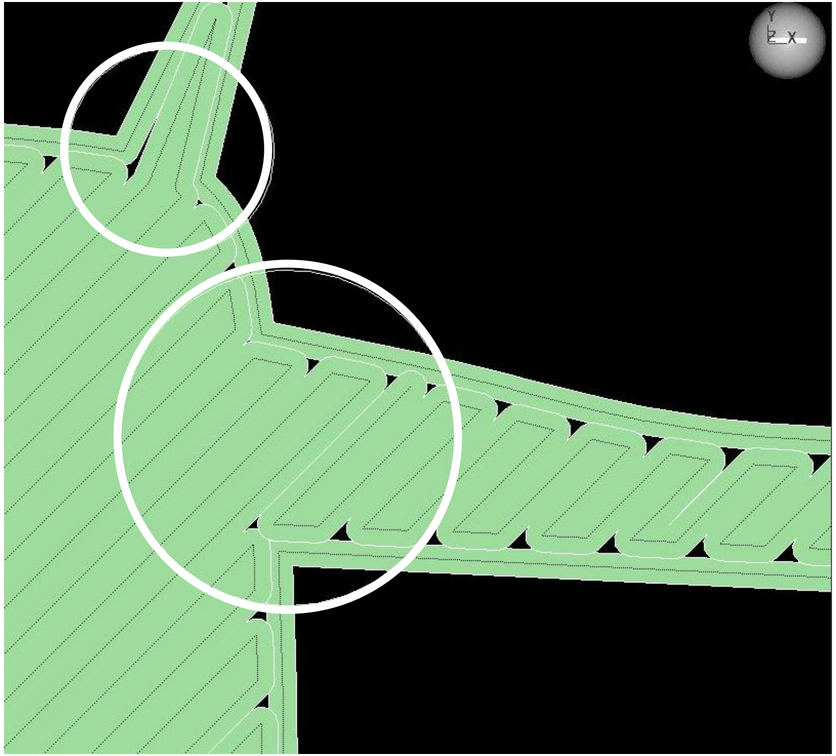
IDENTIFY PROBLEMS



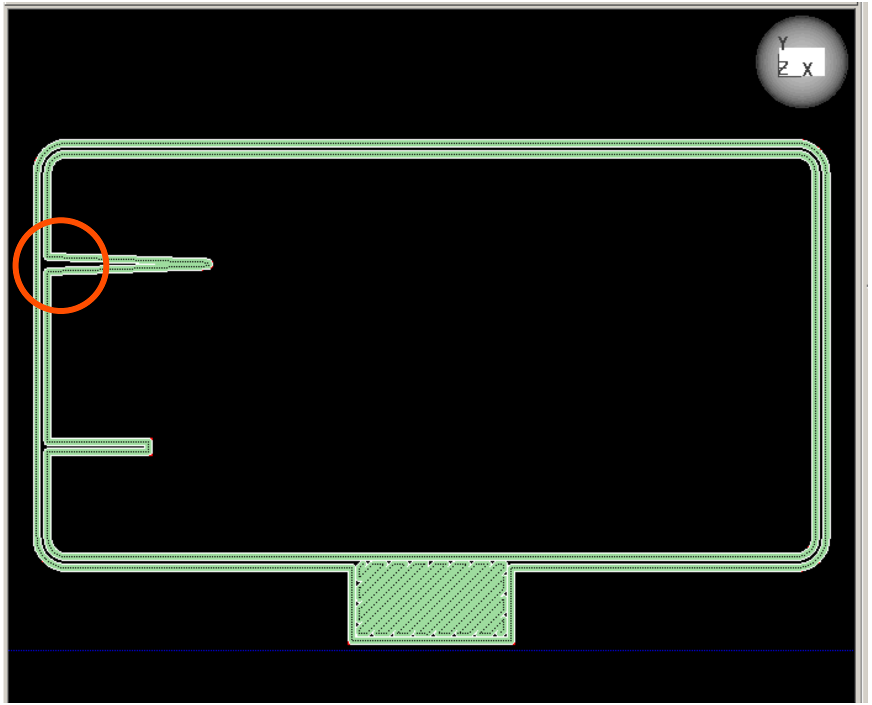
FIX PROBLEMS



FIX PROBLEMS



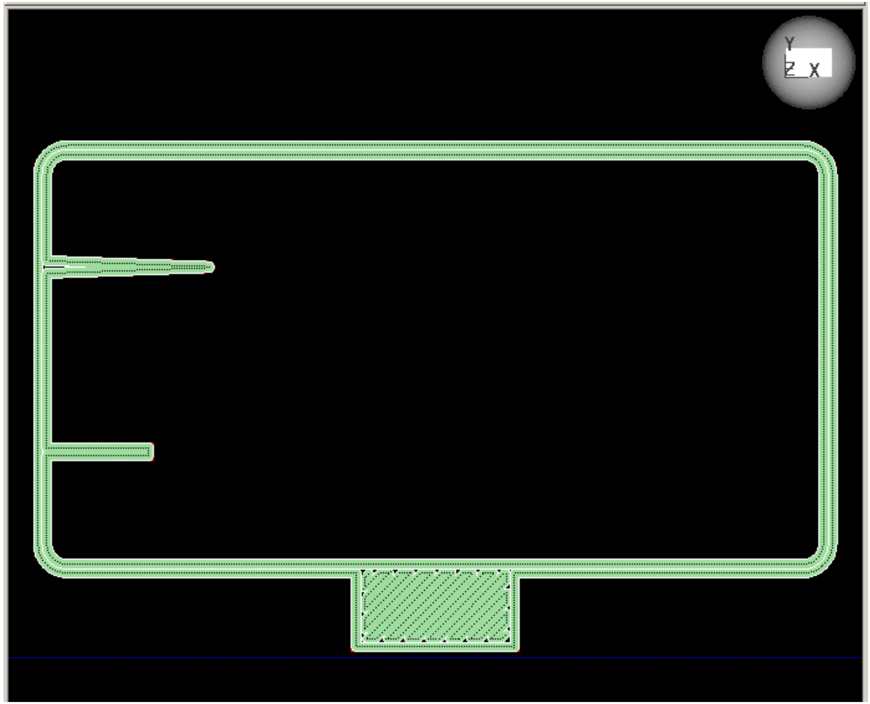
IDENTIFY PROBLEMS



FIX PROBLEMS

Insight has the ability to adjust the width of the extrusion based on the a measurement of the wall thickness.

Result is a stronger structure.



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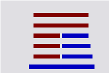
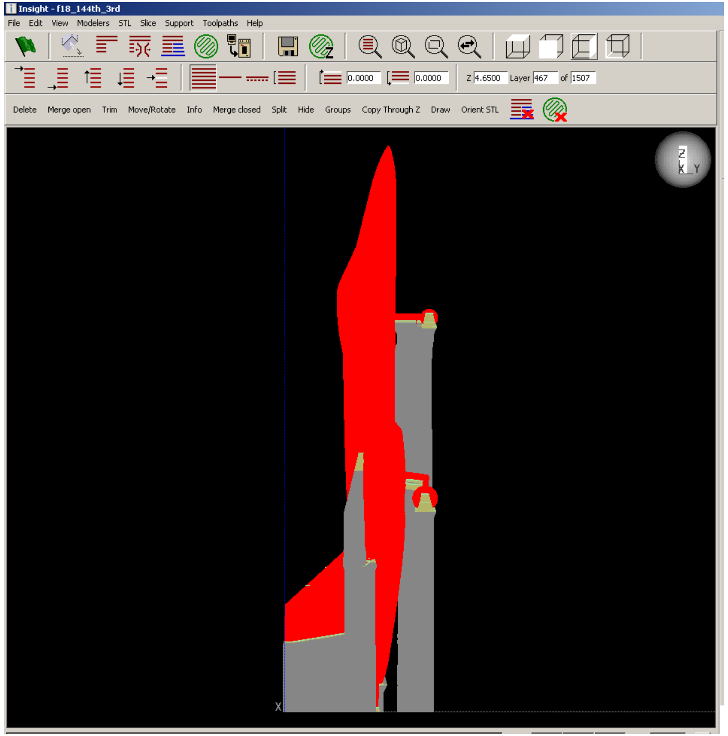
Create Supports





- OPEN .STL IN INSIGHT
- MODELER SETUP
- ORIENT PART
- SLICE
- GENERATE TOOLPATHS
- FIX PROBLEMS
- **CREATE SUPPORTS**
- CREATE TOOLPATHS
- SEND TO CONTROL CENTER
- SEND TO MODELER

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SUPPORT STYLES

- Smart
- Sparse
- Basic
- Breakaway
- Stabilize wall

SURROUND STYLE

Smart

Sparse

Basic

Breakaway

Newer Machines

Older Machines

Soluble Model Material

Newer Machines

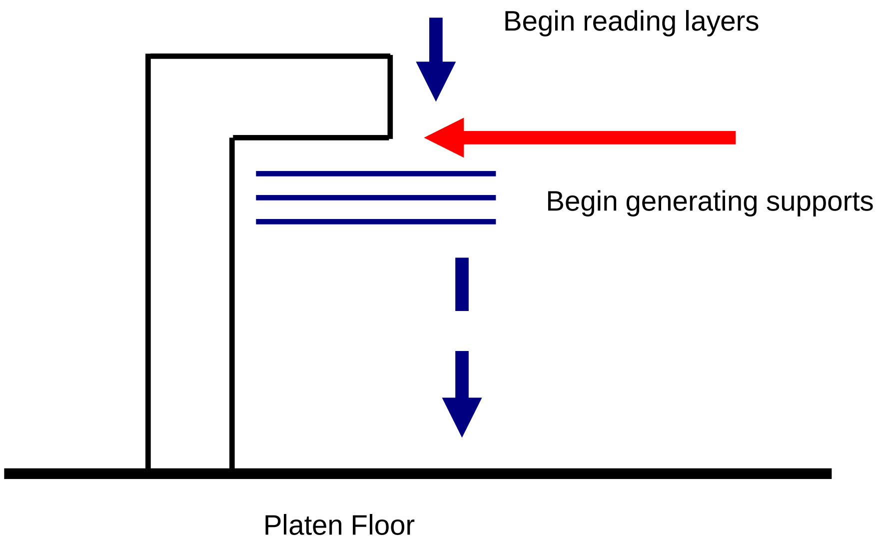
Older Machines

Breakaway Model Material

Stabilize Wall

Add as needed

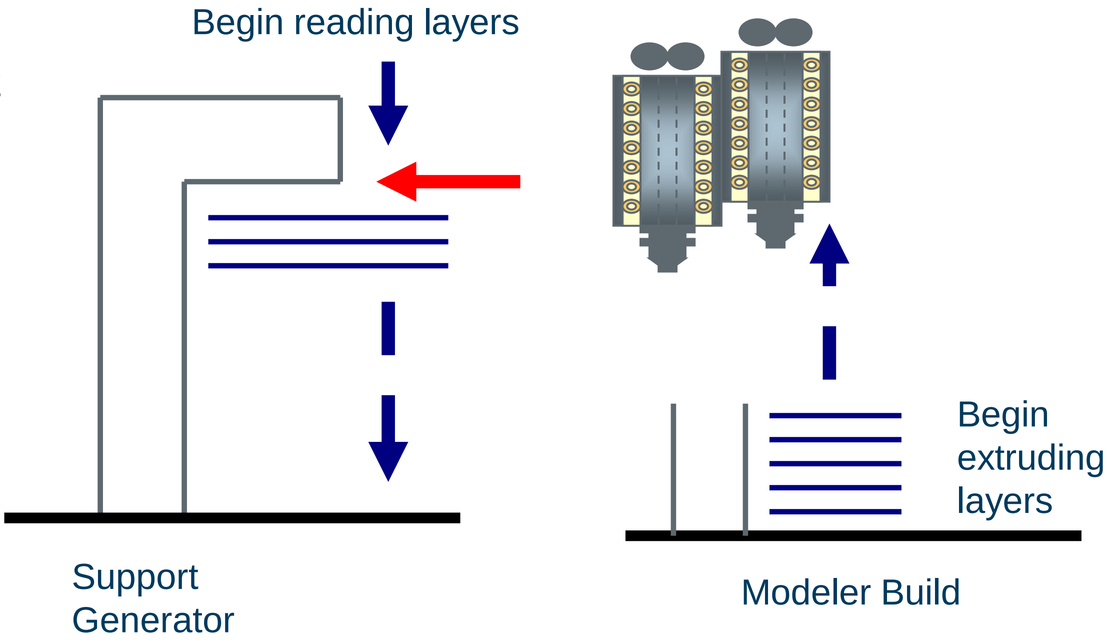
SUPPORT GENERATORS



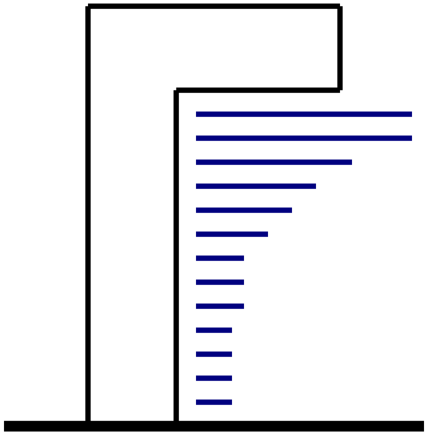
SUPPORT GENERATION

Model is built from the bottom up, support generation begins at the top and works downward.

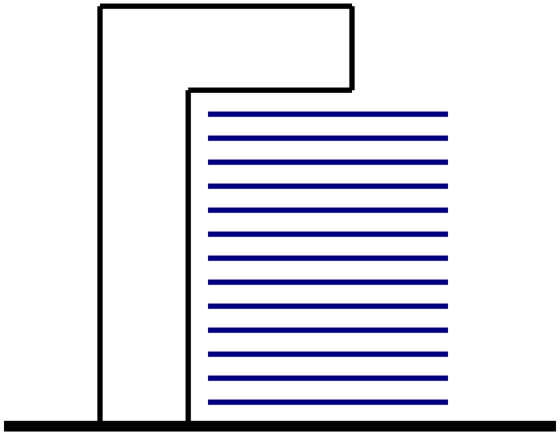
Supports are created for overhangs, holes, and other changes in the structure.



SMART VS. SPARSE SUPPORTS

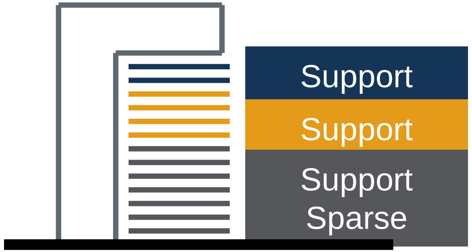


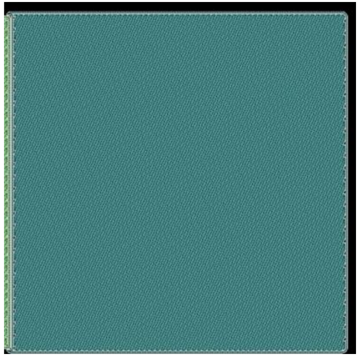
SMART SUPPORTS

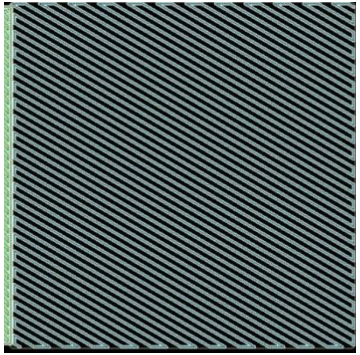


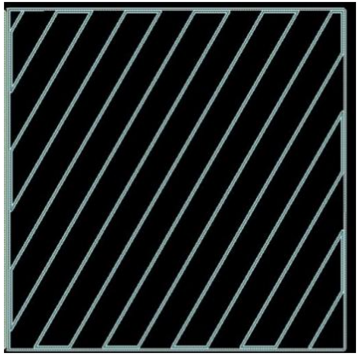
SPARSE SUPPORTS

SUPPORT EXTRUSION GROUPS

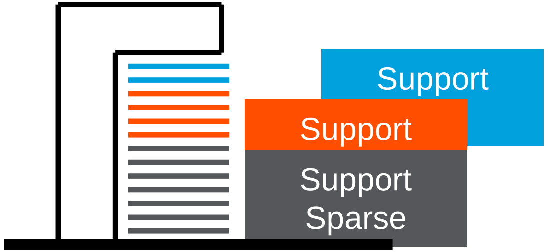



Support Face

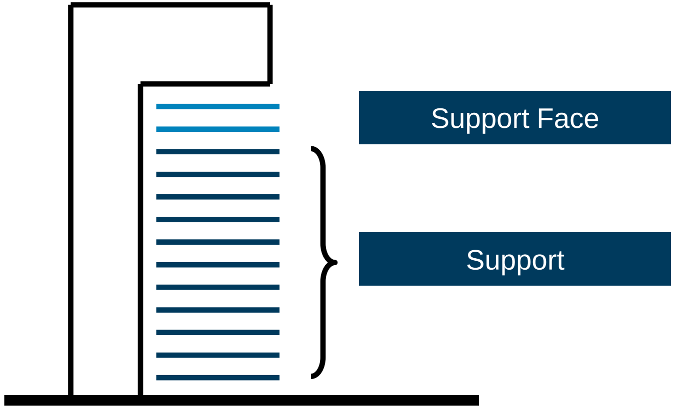

Support


Support Sparse

BASIC & BREAKAWAY SUPPORTS

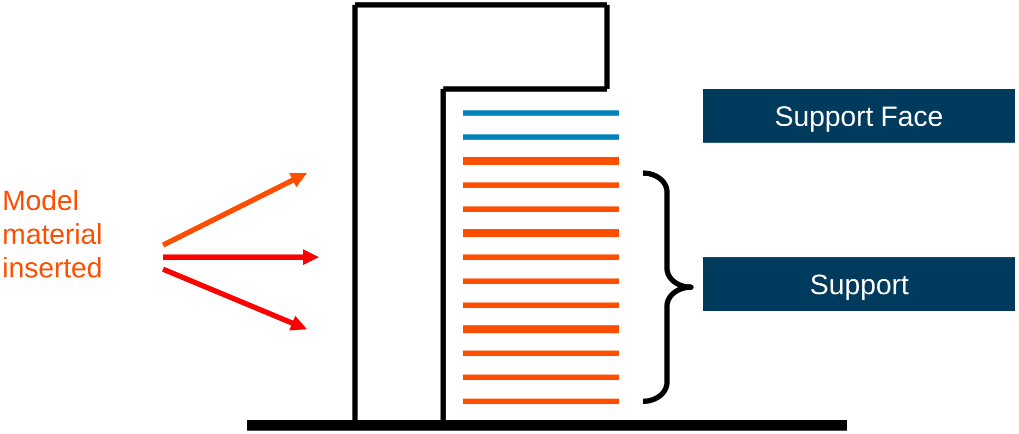


Sparse Supports

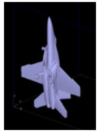


Basic & Breakaway Supports

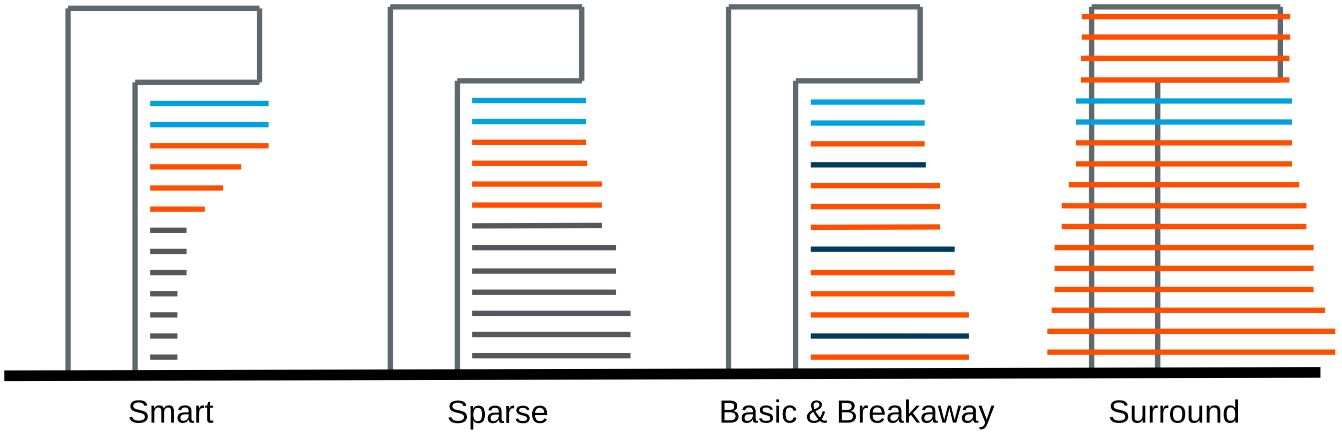
BASIC & BREAKAWAY SUPPORTS



Basic & Breakaway Supports



SUPPORT EXTRUSION GROUPS



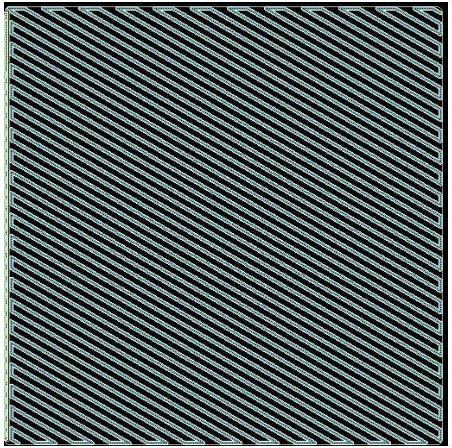
Support Face

Support

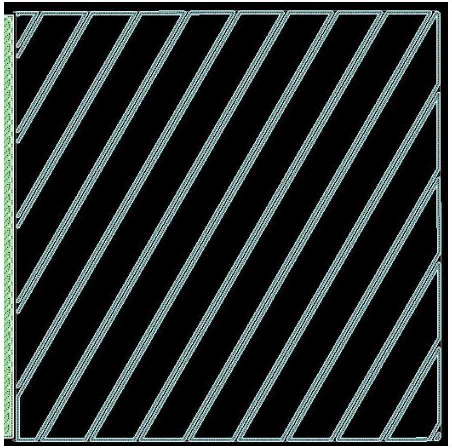
Support Sparse

Support Perf (Model)

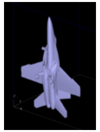
BASIC VERSUS BREAKAWAY



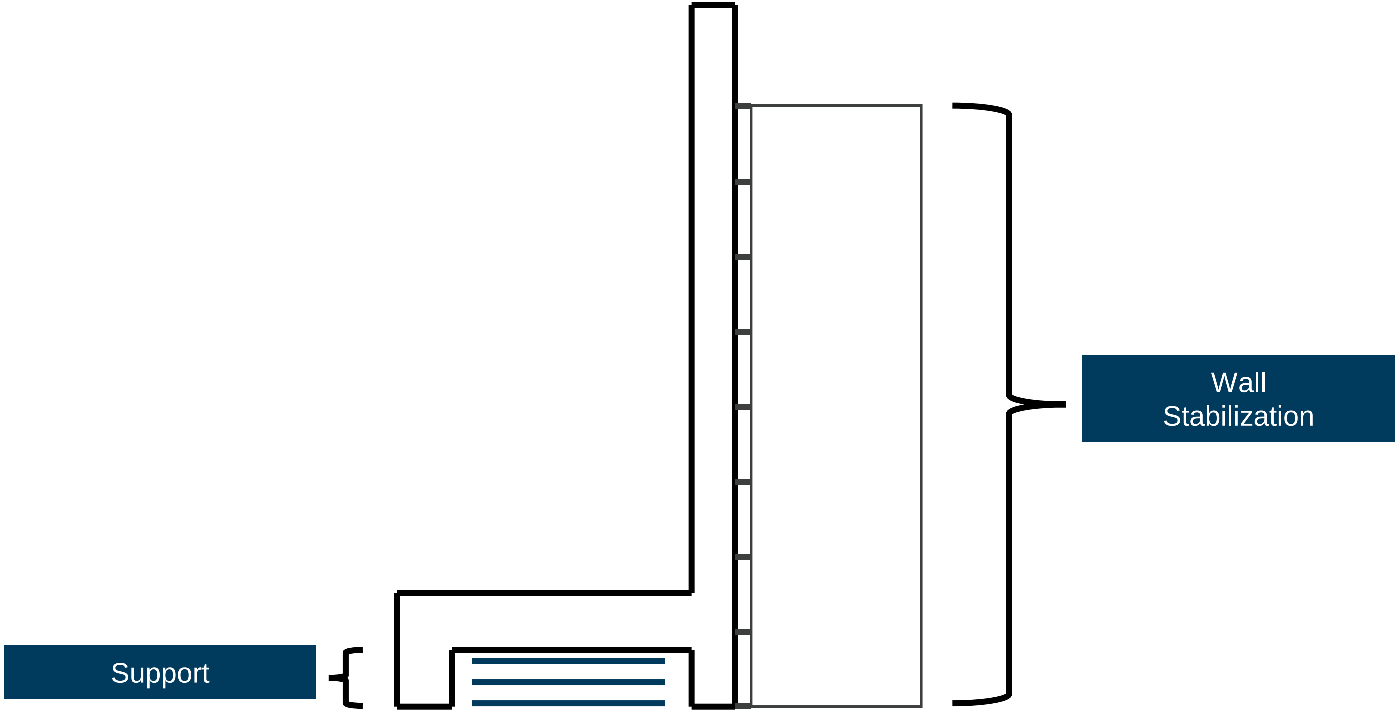
Basic Pattern



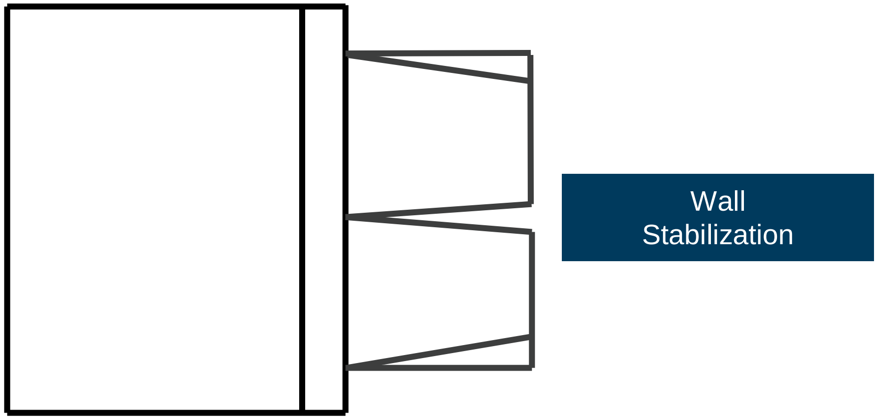
Breakaway Pattern



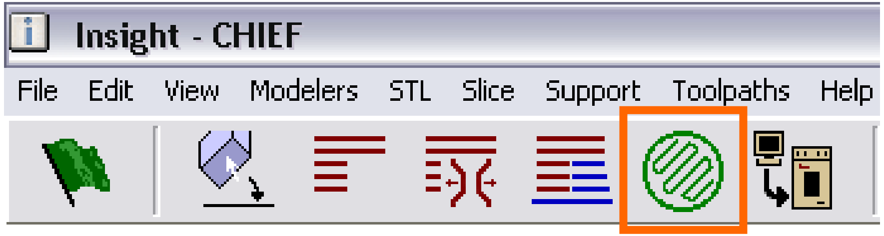
STABILIZE WALL



STABILIZE WALL



CREATING TOOLPATHS



- OPEN .STL IN INSIGHT
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- **CREATE TOOLPATHS**
- SEND TO CONTROL CENTER
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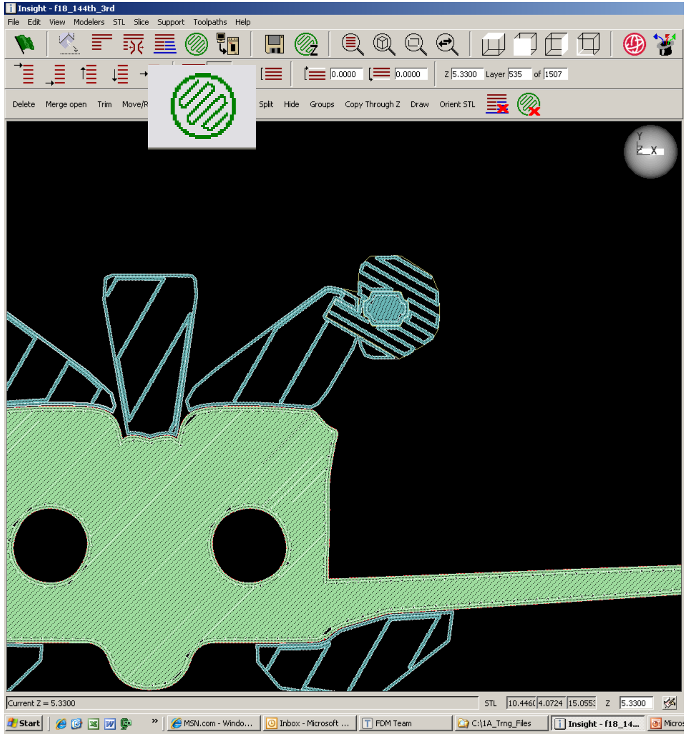
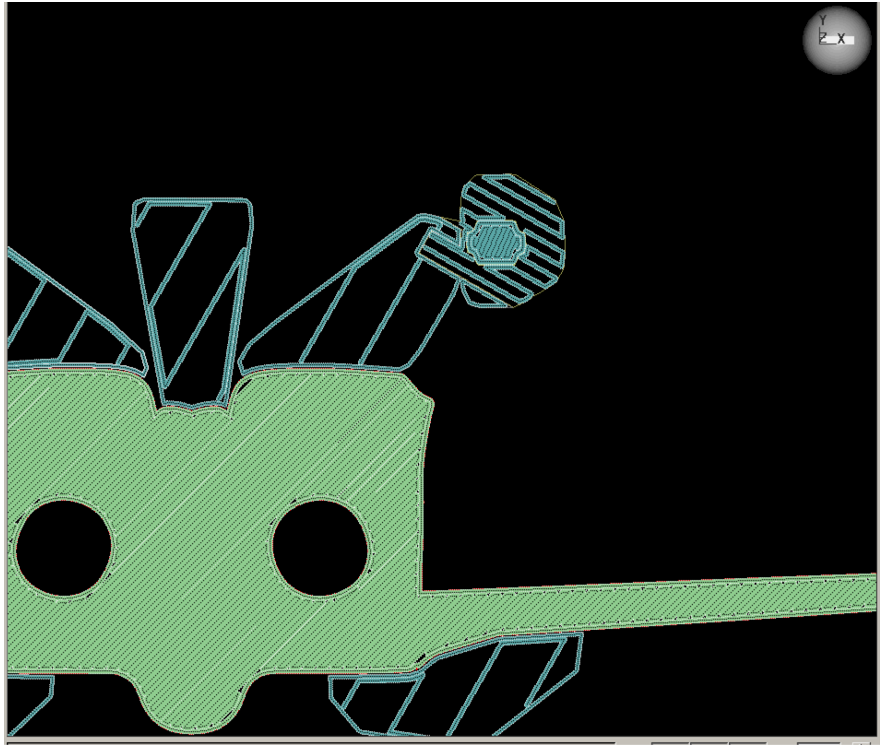
CREATING TOOLPATHS



SUPPORT TOOLPATHS



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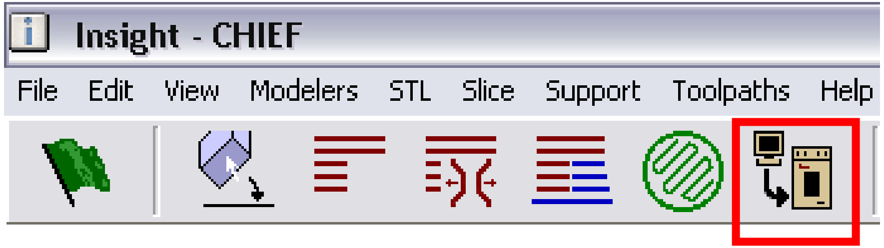
CONTROL CENTER



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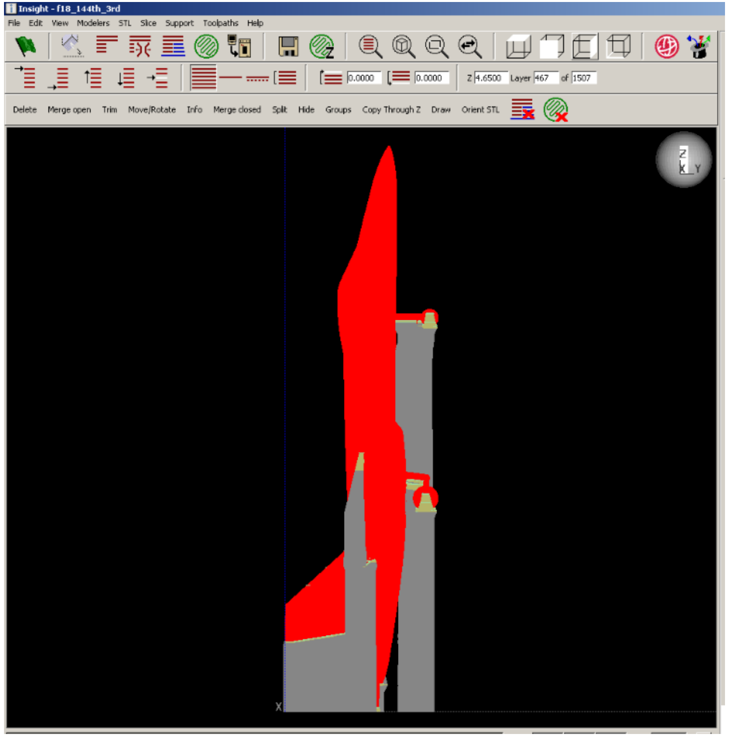
FDM – INSIGHT CONTROL CENTER



INSIGHT – MODEL SETUP

OPEN IN CONTROL CENTER

PLACE MODEL

COPY/ADD MODELS

FINALIZE JOB

SEND TO MODELER

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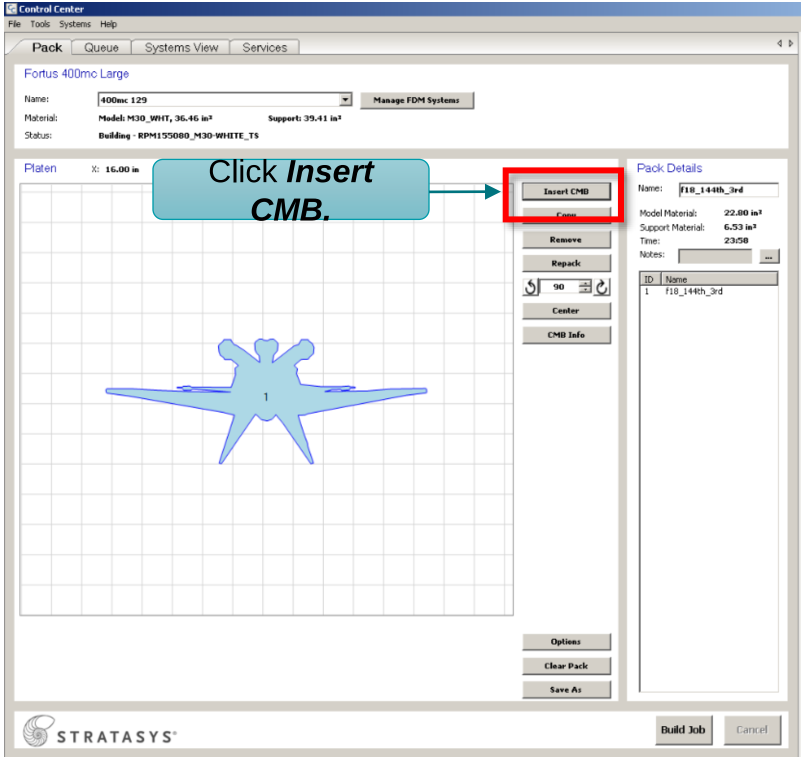
FDM – INSIGHT CONTROL CENTER



INSIGHT – MODEL SETUP

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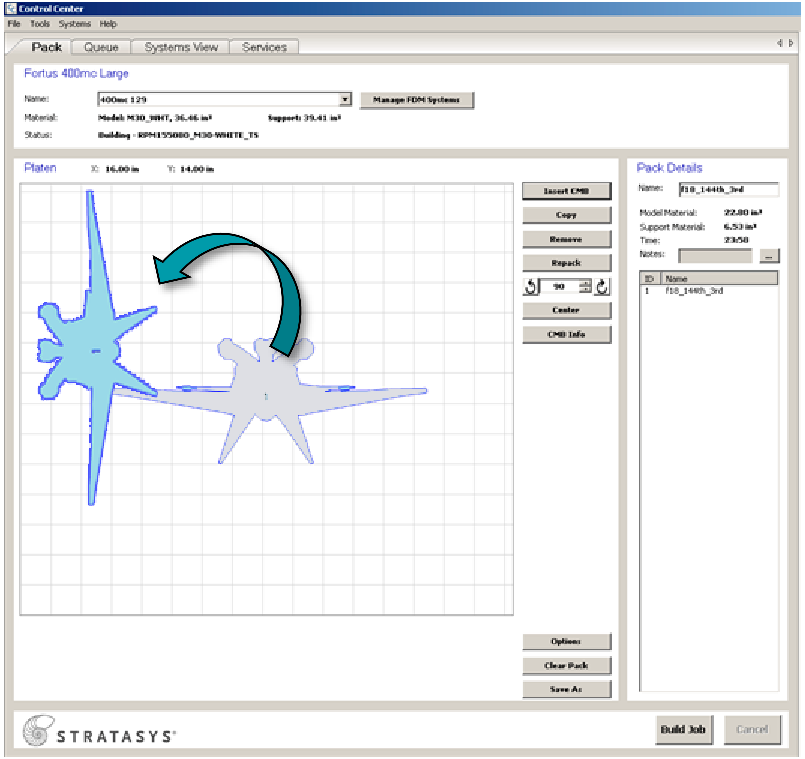
PLACE MODEL

COPY/ADD MODELS

FINALIZE JOB

SEND TO MODELER

FDM – INSIGHT CONTROL CENTER



INSIGHT – MODEL SETUP

OPEN IN CONTROL CENTER

PLACE MODEL

COPY/ADD MODELS

FINALIZE JOB

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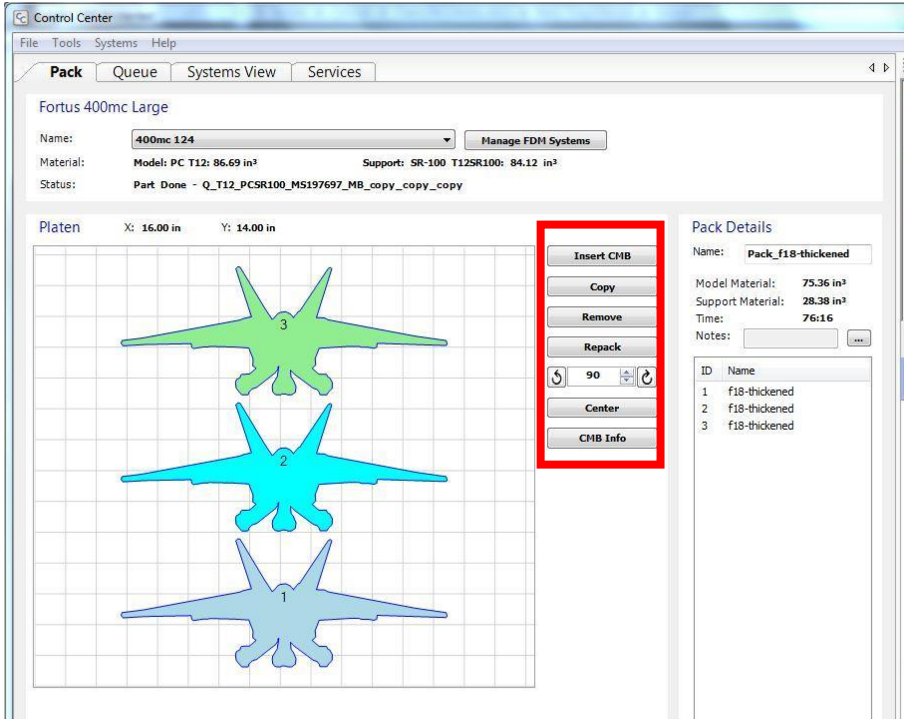
FDM – INSIGHT CONTROL CENTER

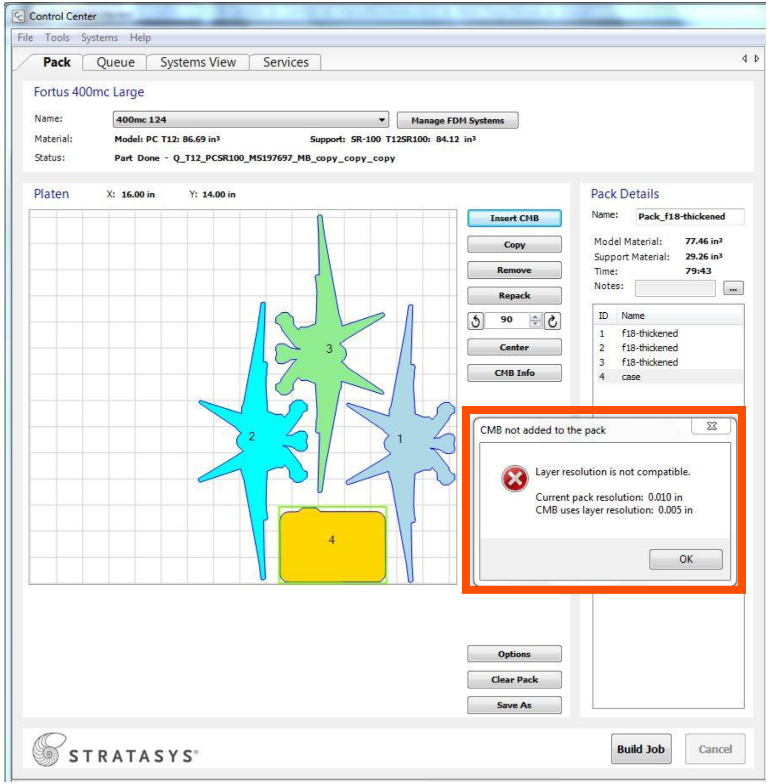


- INSIGHT – MODEL SETUP
- OPEN IN CONTROL CENTER
- PLACE MODEL
- **COPY/ADD MODELS**
- FINALIZE JOB
- SEND TO MODELER

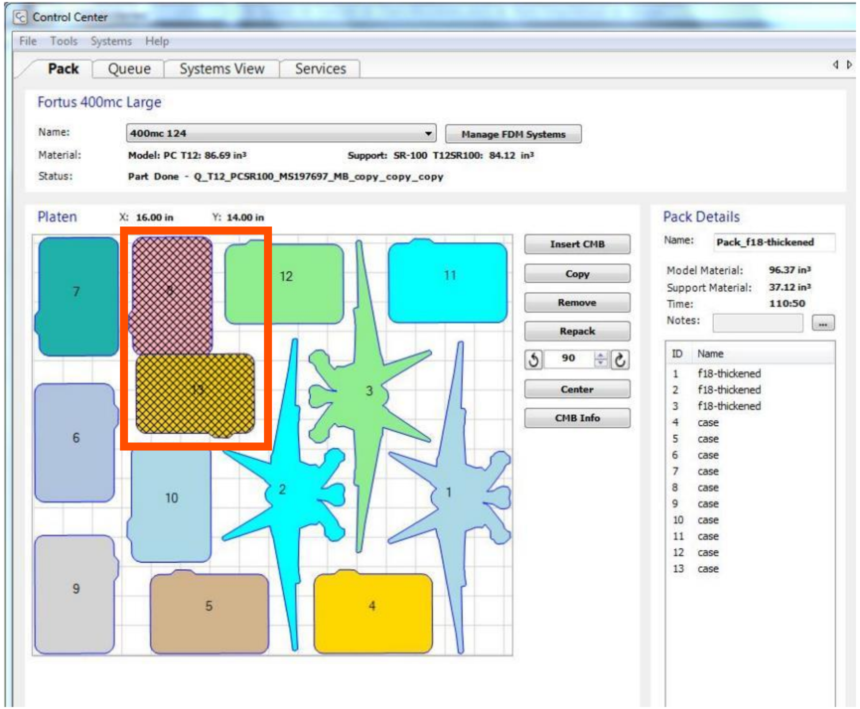
CONTROL CENTER: PACK

All parts share

- Machine
- Material
- Slice Thickness



FDM – INSIGHT CONTROL CENTER



- INSIGHT – MODEL SETUP
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- PLACE MODEL
- COPY/ADD MODELS
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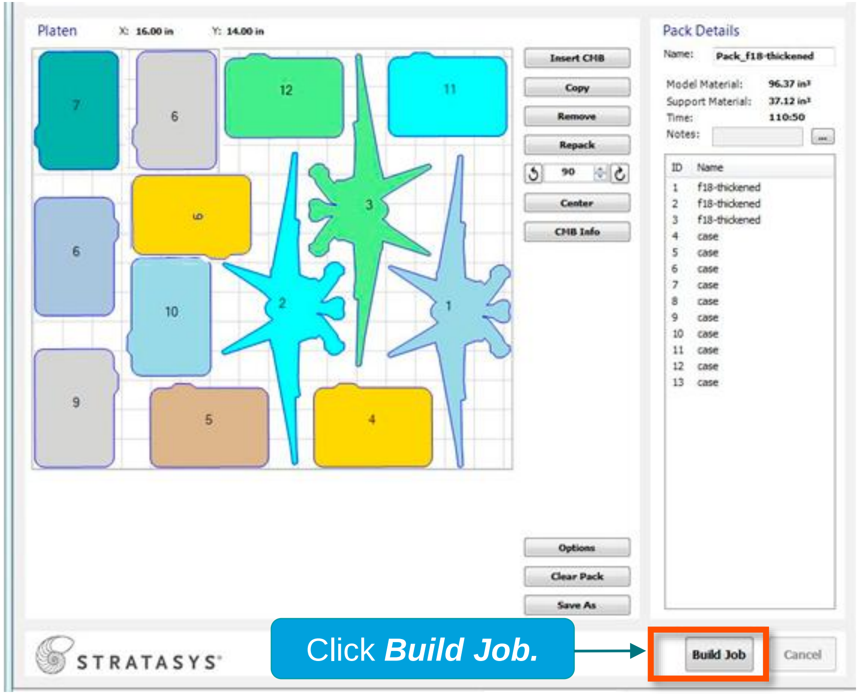
FDM – INSIGHT CONTROL CENTER

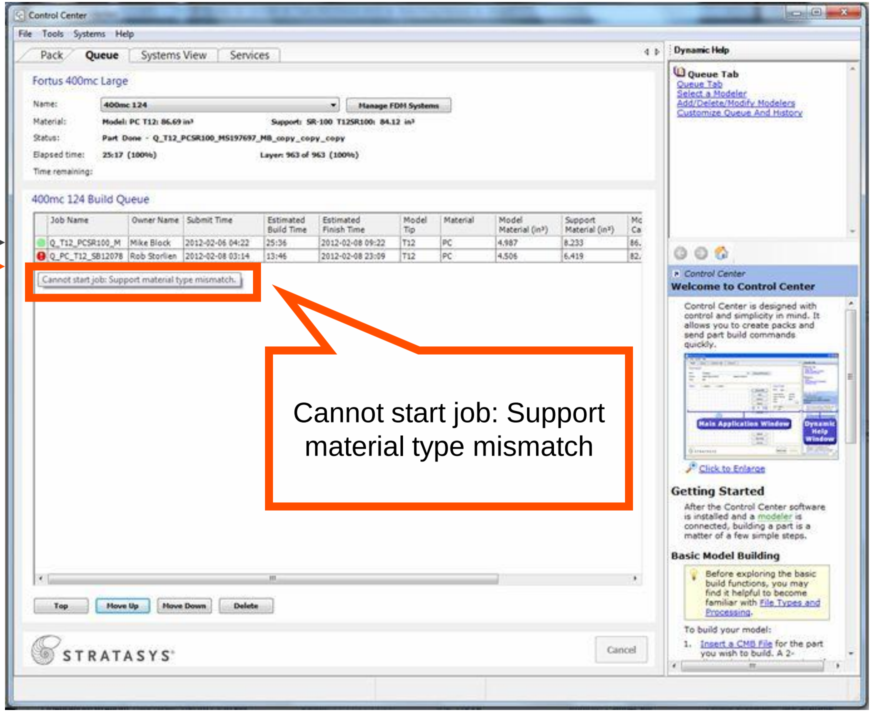


- INSIGHT – MODEL SETUP
- OPEN IN CONTROL CENTER
- PLACE MODEL
- COPY/ADD MODELS
- FINALIZE JOB
- **SEND TO MODELER**

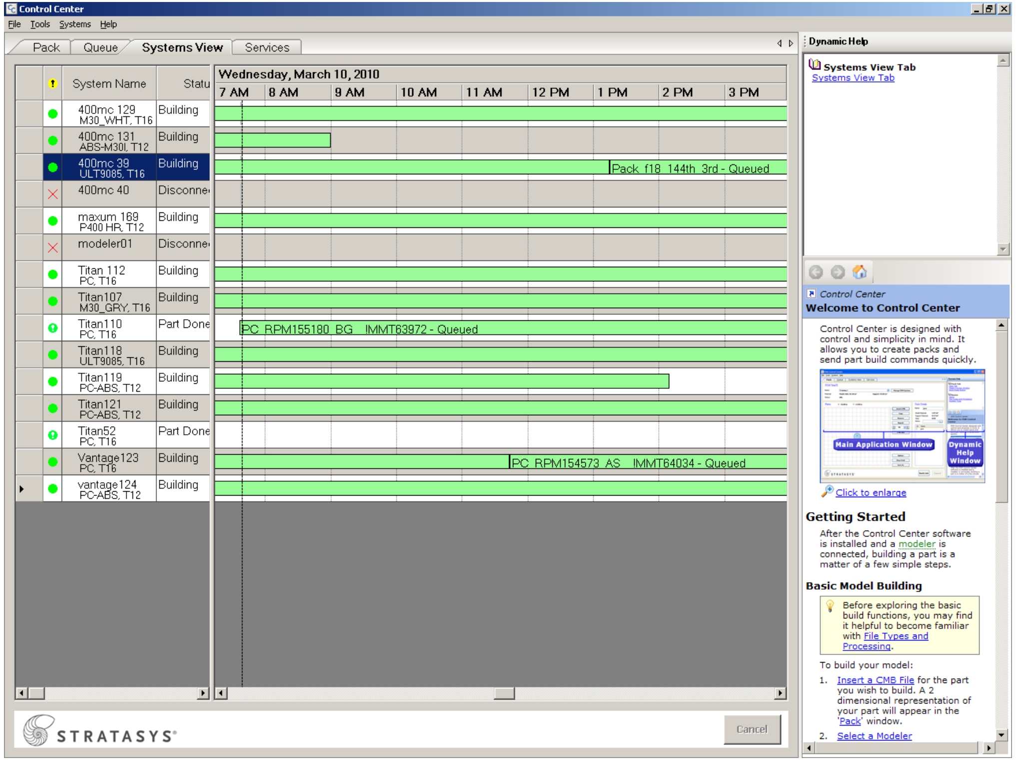
CONTROL CENTER: QUEUE

Queue information

- Job name
- Job owner
- Start date
- Estimated build time



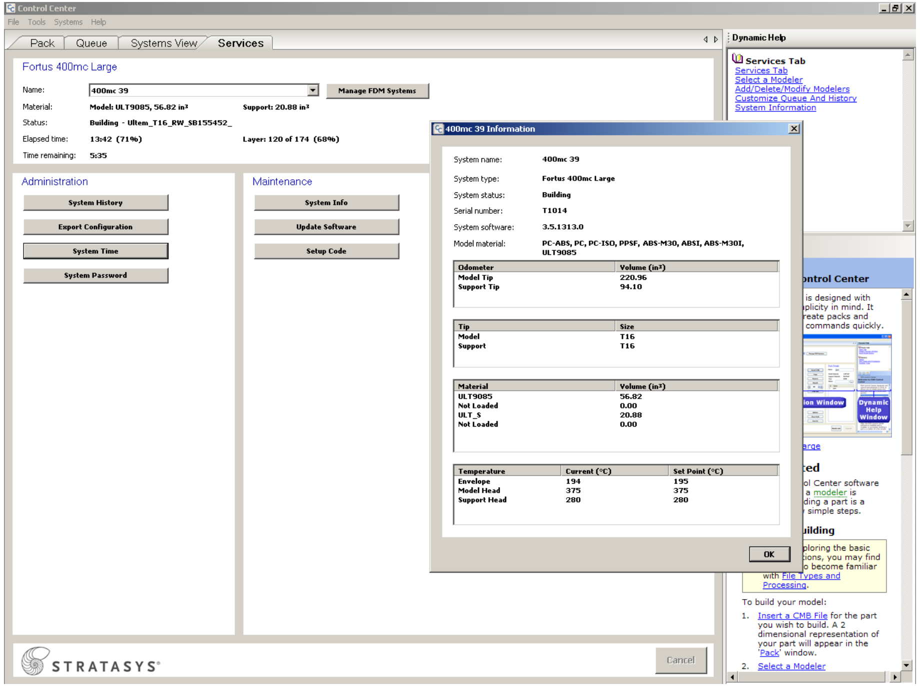
CONTROL CENTER: SYSTEMS VIEW



CONTROL CENTER: SERVICES

Machine Information

- Current state
- Tip size
- Amount of material extruded
- Amount of material remaining
- Tips to replace
- Temperature



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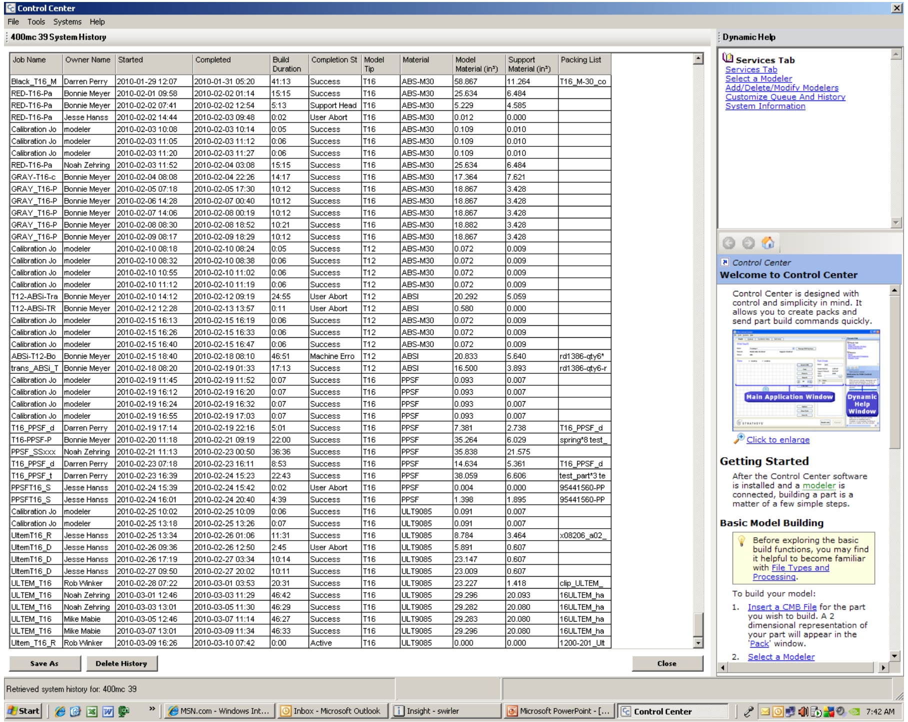
CONTROL CENTER: SYSTEM HISTORY

System History

- Job name
- Job owner
- Start time
- Completion time
- Material used



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SYSTEM TYPES

- OPEN .STL IN INSIGHT
- MODELER SETUP
- ORIENT PART
- SLICE
- GENERATE TOOLPATHS
- FIX PROBLEMS
- CREATE SUPPORTS
- CREATE TOOLPATHS
- SEND TO CONTROL CENTER
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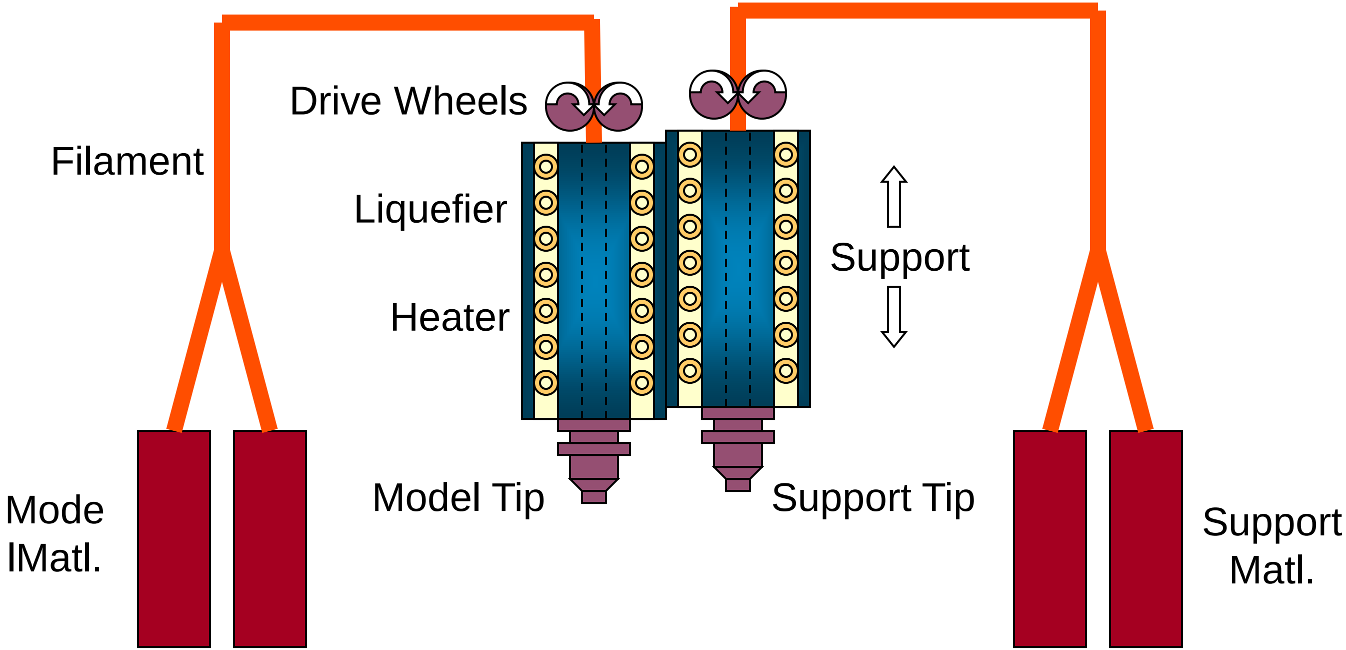
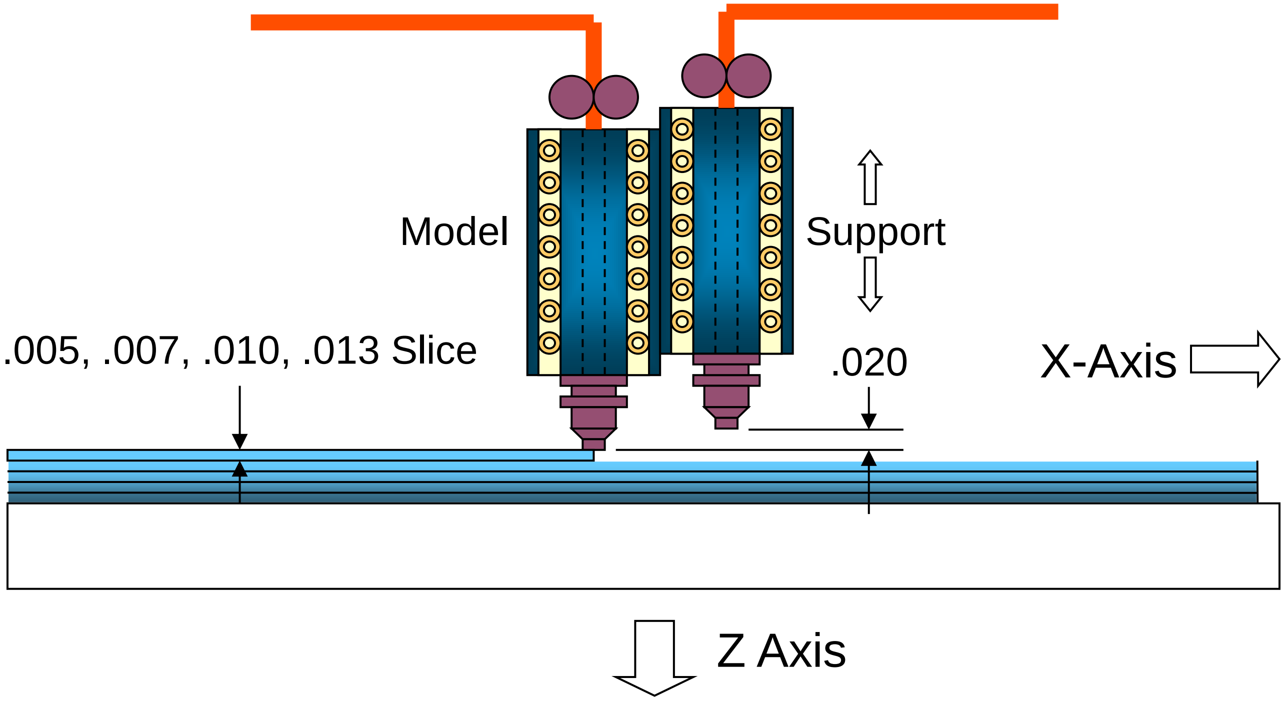
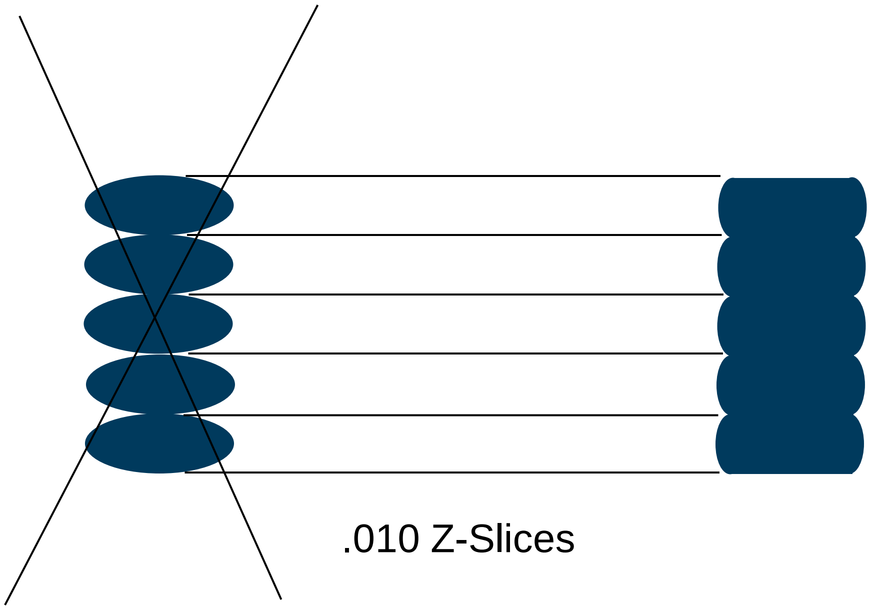
SYSTEM


Drive Wheels
Filament
Liquefier
Heater
Support
Model Tip
Support Tip
Mode
lMatl.
Support
Matl.

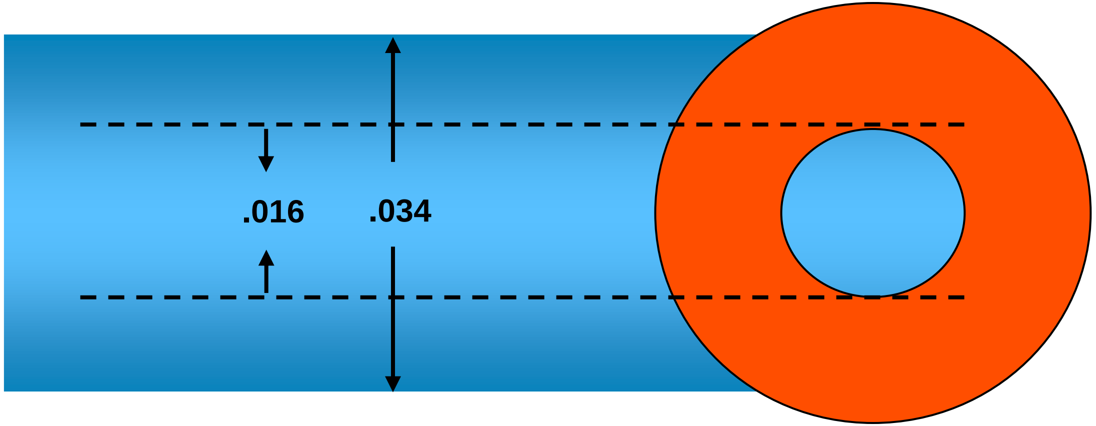
FORTUS Z - SLICE



ROAD END VIEW



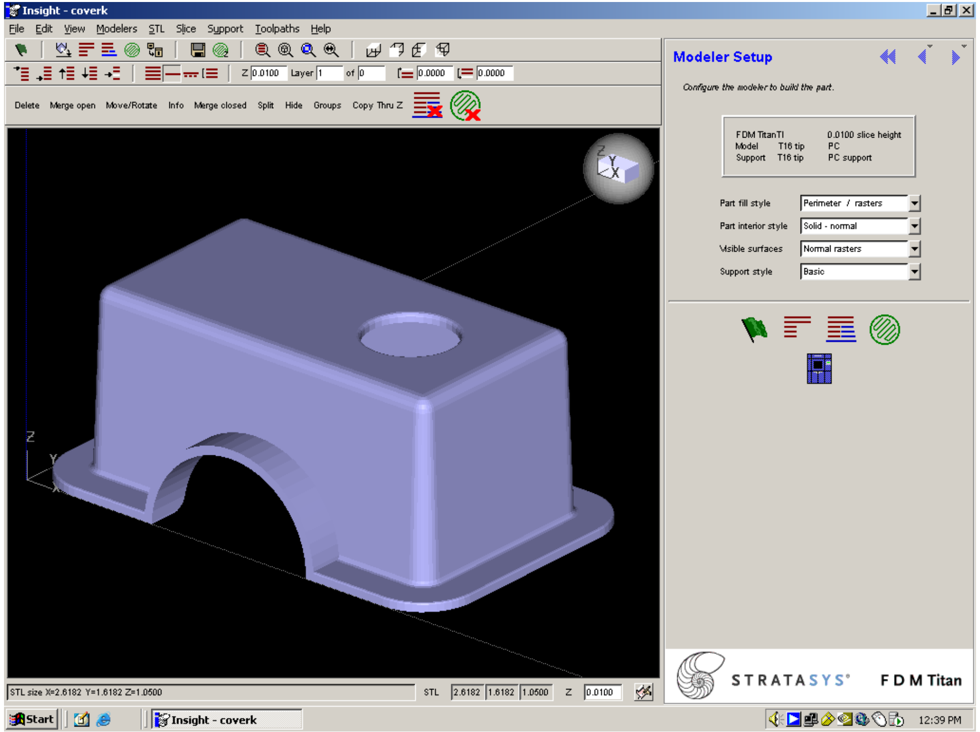
ROAD END VIEW



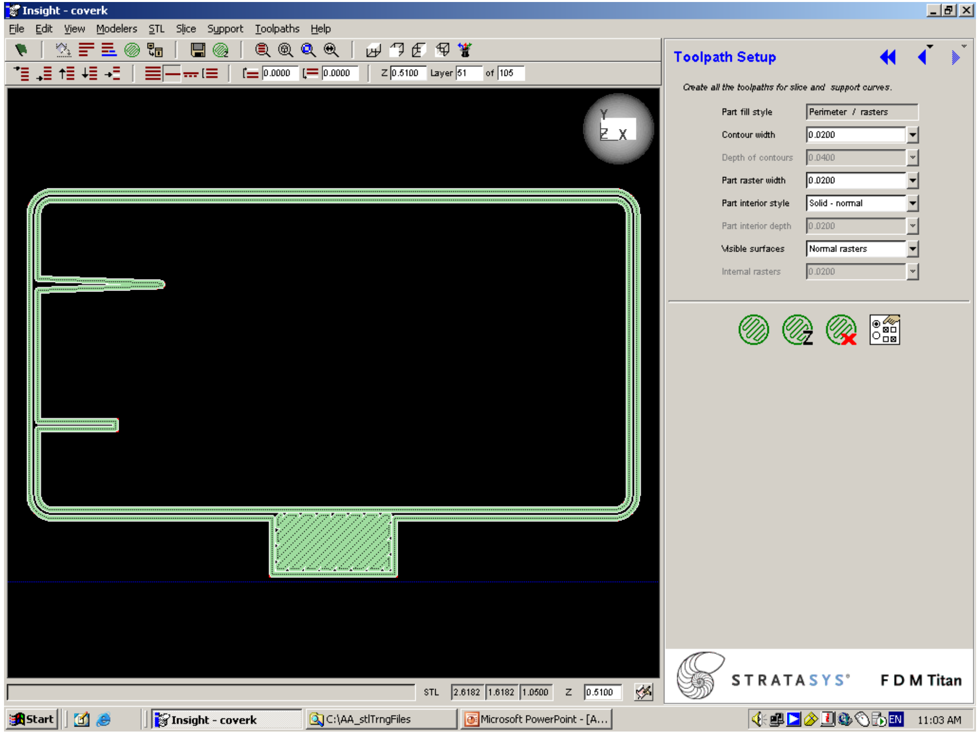
MATL.	TIP	SLICE	DEFAULT	MIN ROAD	MAX ROAD
ABS	T10	0.005	0.010	0.008	0.022
PC	T12	0.007	0.014	0.010	0.026
ABS	T16	0.010	0.020	0.016	0.034
PC	T16	0.010	0.020	$\boxed{0.016}$	0.034
PPSF	T16	0.01	0.010	0.016	0.030

0.016 – 0.034

WALL THICKNESS



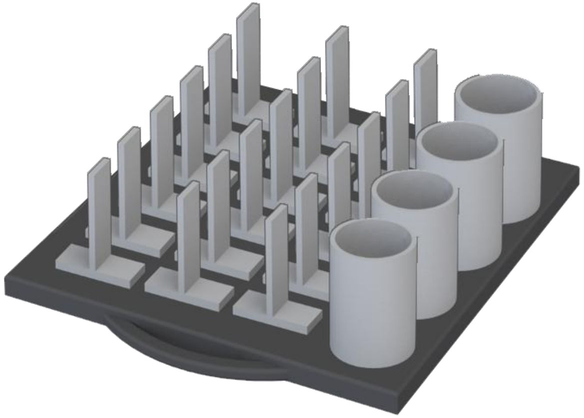
WALL THICKNESS



SUMMARY DISCUSSION

DISCUSSION: ORIENTATION

Make recommendations on how to orient a variety of specific parts



- OPEN .STL IN INSIGHT
- MODELER SETUP
- **ORIENT PART**
- SLICE
- GENERATE TOOLPATHS
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BASIC POST PROCESSING: FINISHING FOR FDM AND POLYJET

Module 8

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MODULE 8: POST PROCESSING

Learning Objectives:

- Define post-processing and finishing
- Identify the basic tools needed for post-processing.
- Describe the purpose for and the steps in the following primary FDM post-processing processes: BASS removal, Soluble Support removal, general fixing: (voids, brown marks, sanding), bonding, gluing, painting, sealing, plating, smoothing and mass finishing.
- Describe the purpose for and the steps in the following secondary FDM post-processing processes: painting, sealing, plating, smoothing and mass finishing.
- Describe the purpose for and the steps in the following PolyJet post-processing processes: support removal, transparency, dying, painting ,metal coating and thermal treatment.

How is this picture related?

WHAT IS POST PROCESSING?

The term “Post Processing” refers to a range of processes that can be applied to a 3D printed parts after print to provide:

Look and Feel / Finishing	Mechanical Properties	Seal Adaptation
Mass Finishing	Composite method	Coating
Painting	Thermal treatment	Bio Computability
Transparency	Gluing	
Material mimic		
Smoothing		
Support removal		

This is NOT a “must do” step in the 3D printing process

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WHAT IS FINISHING?

The term “finishing” is refers to a subset of post-processes that can be applied to your 3D printed parts to achieve specific properties related to:

- Appearance
- Surface friction
- Permeability
- Adhesion

This is NOT a “must do” step in the 3D printing process

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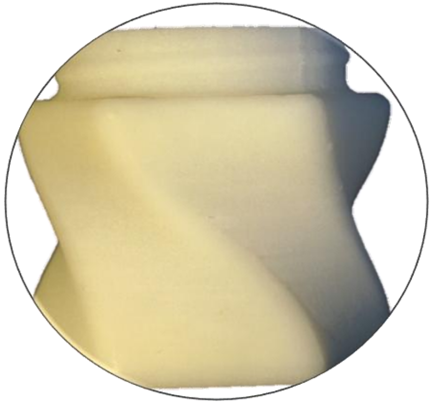
WHAT CAN WE ACHIEVE?

Smooth surfaces

Techniques: hand sanding, vapor smoothing or mass finishing

BEFORE



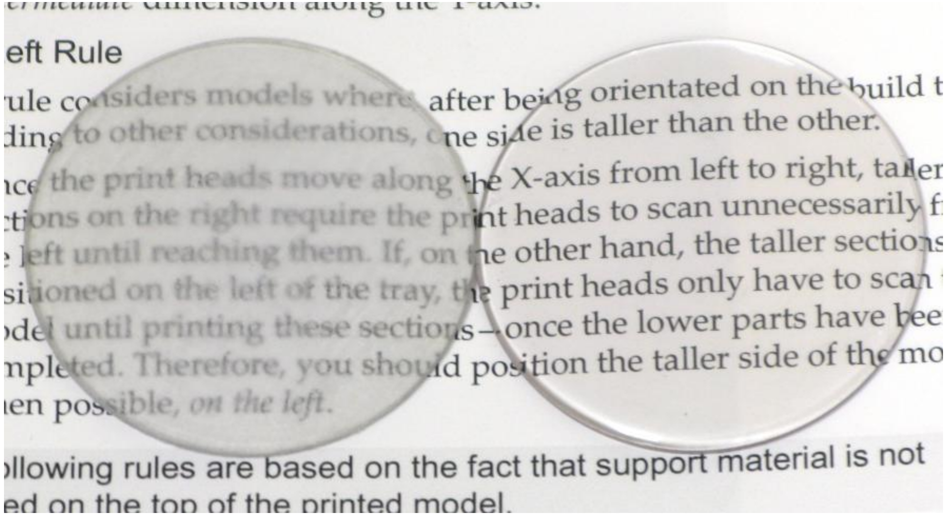
AFTER

WHAT CAN WE ACHIEVE?

Transparency

Techniques: polishing and lacquering

BEFORE **AFTER**



WHAT CAN WE ACHIEVE?

Artistic effects

Technique: Painting

BEFORE

AFTER

WHAT CAN WE ACHIEVE?

Metallic look

Techniques: electroplating, coating

BEFORE

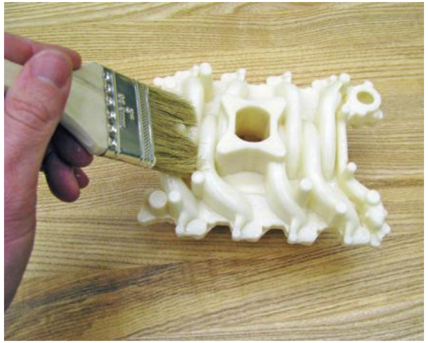
AFTER

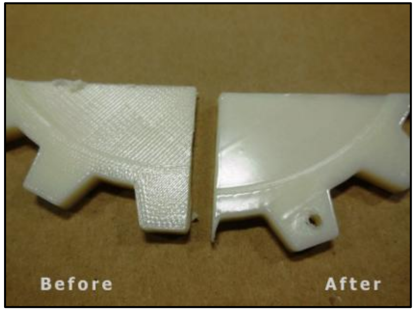
WHAT CAN WE ACHIEVE?

SEALING - The term “sealing” is refers to a range of post-processes that can be applied to your 3D printed by using another material to seal the model as coating.

Since sealing is covering the model it can effect the model thickness and surface friction.

We recommend to think of sealing while designing the model to make sure the sealing will cover all model surface and can reach all small details.





Are you ready?

TOOLS FOR POST-PROCESSING

TOOLS FOR POST-PROCESSING

3D Printed Model → Additional Machines → Hand Tools → Additional Materials

3D Printed Model

- While designing remember to think of the finishing process – it will effect the detail level of the printed model.
- At the CAM step consider your post process outcome.

Additional Machines

- Water Jet.
- Sand blaster.
- Bead blaster.
- Plastic polish.
- Painting rack with compressor / paint brush, Paint booth.
- Oven.
- Illumination chamber.
- Compressor tank.
- Smoothing station

Hand Tools

- Traditional wood, metal, surgery tools.
- Filling Voids
- Open Seams
- Around holes
- Brown Marks
- Burnt material
- Embedded support
- Light sanding
- Edges, Corners, Seams
- Sand paper
- Wisps of Material
- Hot Air

Additional Materials

- Glues.
- Coating materials.
- Spray.
- Solvent.
- Dying.

SAFETY FIRST

- This list covers main process only
- These stages may not be necessary in some cases

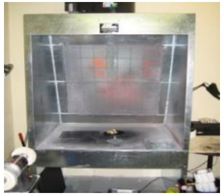
TOOLS FOR POST-PROCESSING

Additional Machines

Water Jet

Compressor tank

Bead blaster



Sand blaster

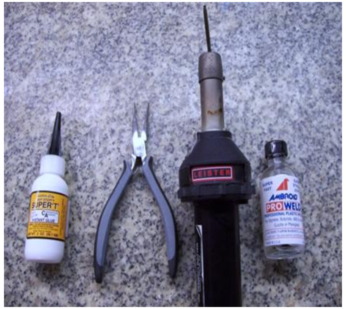
Illumination chamber.

Smoothing station

Paint brush

TOOLS FOR POST-PROCESSING

Hand Tools



TOOLS FOR POST-PROCESSING

Additional Materials

NEXT UP: FDM AND POLYJET POST-PROCESSING METHODS

FDM

Polyjet

PRIMARY FDM POST-PROCESSING METHODS

FDM POST-PROCESSING METHODS

Basic Processes

Support Removal

Fixing, sanding, bonding, gluing

Secondary Processes

Painting

Sealing

Plating

Mass finishing

Smoothing

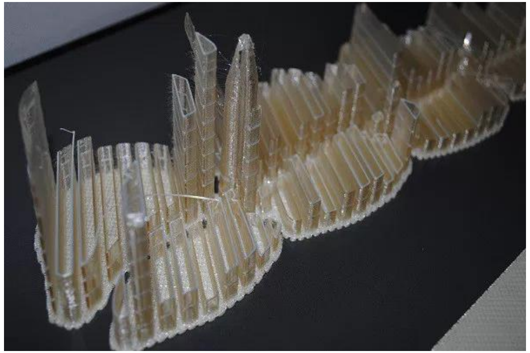
Keep the safety regulations in mind for every tool and material you use

SUPPORT REMOVAL BASS

Break Away Support (BASS)

- Break away supports manually
- No need for a tank
- Faster for simple support structures
- May not be able to reach all supports
- Hand Tools required
- Can be time consuming

PLA BASS
(MODEL USED AS SUPPORT)



ULTEM BASS

ASA BASS

SUPPORT REMOVAL BASS

Suggested tools shown

May need to fabricate custom tools

ULTEM and PPSF easier to remove if heated

- ULTEM up to 160ºC, PPSF up to 180ºC
- More heating-cooling cycles = support more difficult to remove

Take care to not scratch or gouge part with tools

Fragile parts - take your time

Note: Safety googles should be worn!

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SUPPORT REMOVAL - BASS

Note: Safety googles should be worn!

https://youtu.be/E-VltiOAKbc

SUPPORT REMOVAL

Soluble Support

- Wash away in detergent bath
- Build internal cavities/channels
- Hands-free support removal
- Soluble core applications
- Retain feature detail without breaking

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SUPPORT REMOVAL / SOLUBLE

Tank Agitation may be circulation or ultrasonic

Temperature Range

- 70oC for SR-20 and SR-30
- 80-85oC for SR100 or 70oC longer dissolve time

Remove some support by hand to save tank time and water life span

Keep parts submerged

Enclosures for fragile parts

Sparse parts

- Parts will absorb water - add hole(s) for drainage
- Parts will float - anchor to basket or tank

GENERAL FIXING

Filling Voids
- Open Seams
- Around holes

Brown Marks
- Burnt material deposited in part by tip
- Embedded support

Light sanding or touch up
- Edges, Corners, Seams
- Use Sandpaper or File

Wisps of Material
- Hair-like appearance

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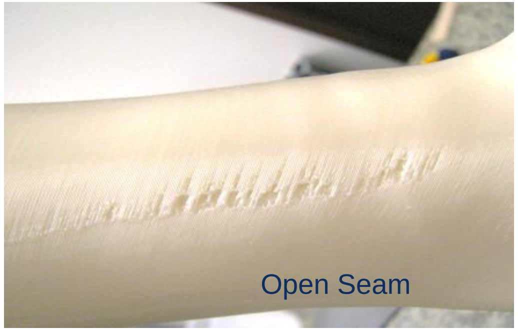
FIXING / VOIDS

Repairing Open Seams

- Fill void with super glue
- Blot with paper towel
- Sprinkle baking soda over super glue
- Repeat until void is filled and sand smooth

Alternate method

- Melt material into void and sand smooth
- Make paste with solvent and material



Open Seam

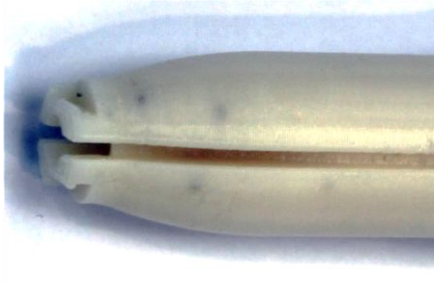
FIXING / VOIDS AND BROWN MARKS

Repairing Brown Marks

- Dig mark out of part
- Fill void with super glue
- Blot with paper towel
- Sprinkle baking soda over super glue
- Repeat until void is filled and sand smooth

Alternate method

- Fill with material by melting it into void (hot air welder)
- Make paste with solvent and material



Embedded/burned material

FIXING / LIGHT SANDING

Seams

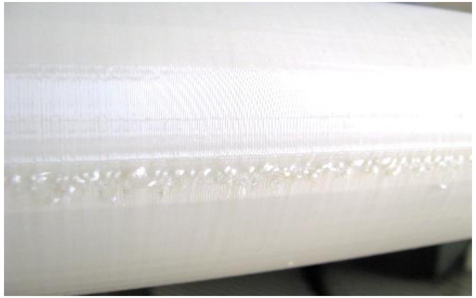
- Lightly sand or file to level the seam
- File tends to work best

Keep edges and corners clean

- Touch up as needed with sand paper or file
- File tends to work best

Wisps or “hairs”

- Melt with heat gun or hot air welder
- Lightly sand to remove if needed

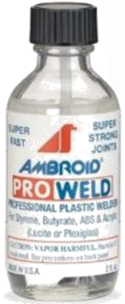


BONDING METHODS

Solvent
- Joint is stronger than the part itself
- Simple process
- Clamp to hold in place until solvent cures

Hot Air Welding
- Very strong joint
- More difficult technique - needs practice!
- Usually no need for clamps and cure time

Epoxy
- Not as strong as other methods
- Generally easy but can get messy
- May need to clamp to hold for curing



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BONDING / SOLVENTS

Align joint and clamp if needed

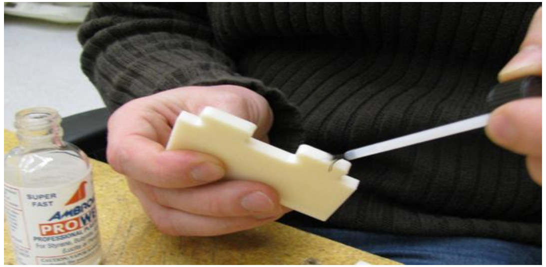
- Make sure everything lines up
- Clamp or spot tack part with super glue

Apply solvent to joint

- Using a brush or whatever you desire
- Make sure joint is not over saturated
- Securely clamp to avoid shifts
- Allow to cure 8-12 hours

Finish joint

- Hand or power sand
- Fill any remaining low spots using fixing methods
- Allow to cure again and sand smooth



BONDING / EPOXY

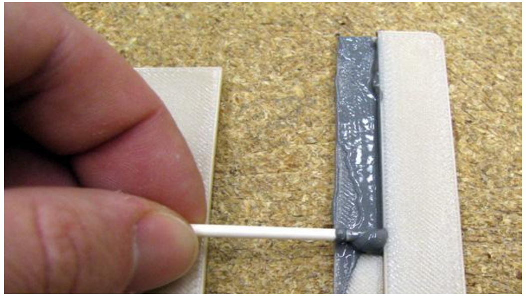
Match epoxy mechanical properties with material used

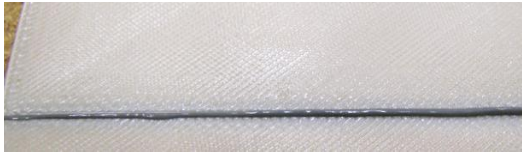
Consider cure time and working time

Most epoxies will cure faster if heat is applied

Process

- Mix well the two components - part A and part B
- Apply with putty knife or similar tool
- Clamp pieces together to hold in place
- Wipe off excess epoxy with rag or paper towel
- Allow to cure - heat may speed up curing process
- Finish as desired



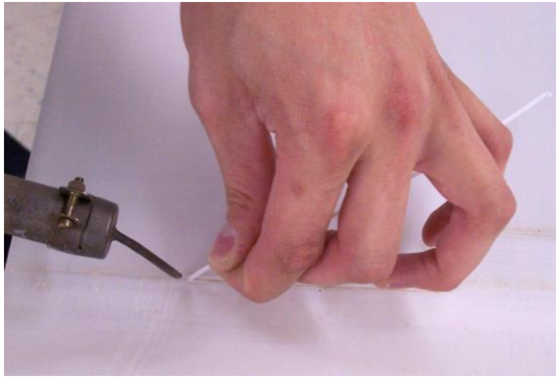


BONDING / HOT AIR WELDING

Align joint and tack weld the entire part to avoid clamping

Weld joint

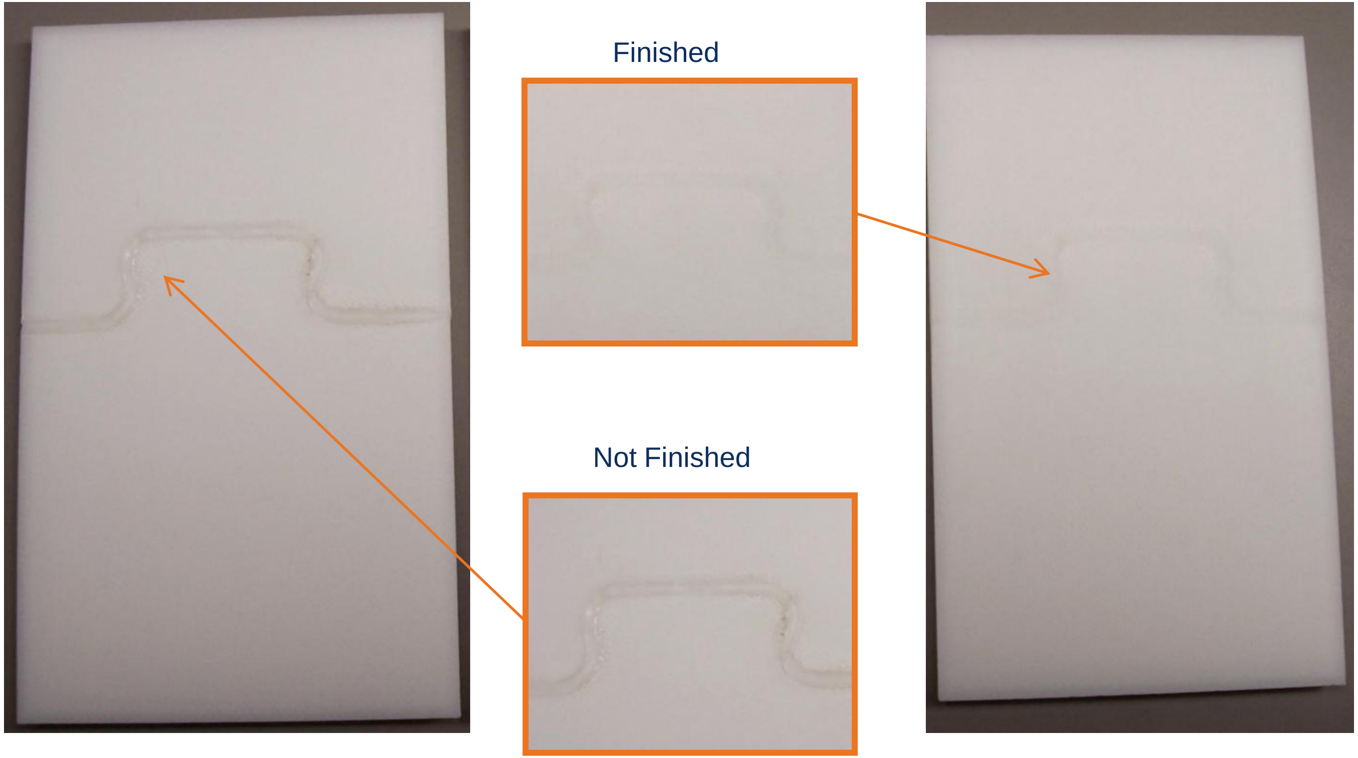
- Use desired filament as welding rod
- Set the welder to the desired settings
- Heat joint and filament and push along joint
- Keep moving to avoid burning material
- May need to make multiple passes to fill gap



Finish joint

- Sand smooth by hand or power sander
- Fill any low spots with material and sand smooth

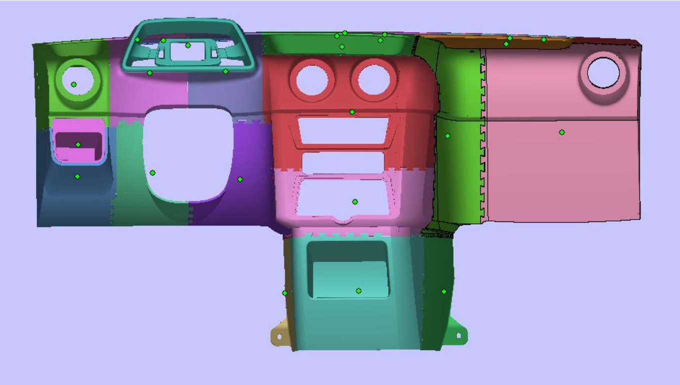
BONDING / HOT AIR WELDING



GLUING

Used when larger than tray size model is required

Or when it is more practical to print individual parts and than glue together



GLUING

Preparing the CAD files

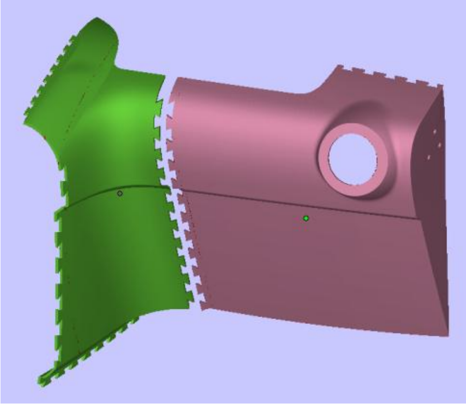
Separate the model at an easy to glue location

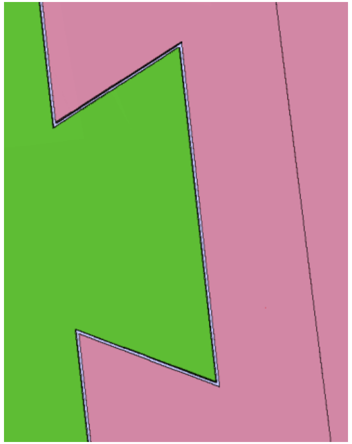
- Either in the CAD or STL manipulation SW

Add clearance between parts to account for space taken by the glue

- Typically 0.1mm

Create matching surfaces in the joint to maximize surface area for the glue





GLUING

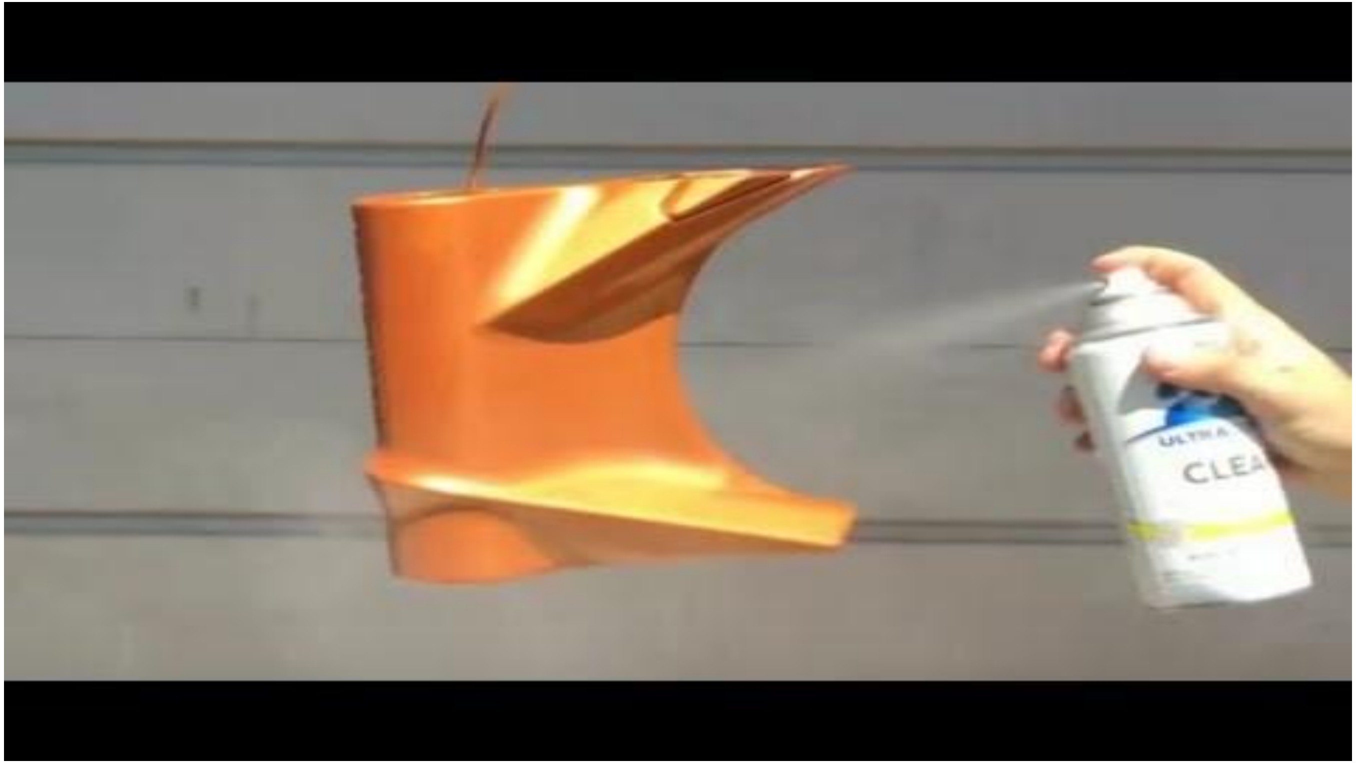
Required Tools and Materials

- Protective gloves
- Protective goggles
- Sodium hydroxide solution
- Glue for rigid parts, such as:
  - Super-glue (ciano acrylate)
  - Alteco-ACE-D and an activator spray
  - LOCTITE 401 (medium viscosity)
  - 2K Epoxy based long setting adhesive (for big parts)
  - Kleiberit 851.0

Glue for flexible parts, such as:

- Sico Met 8300 and Accelerator Spray (for elastomers)
- Permabond Black Magic 737 (for flexible parts)

SUMMARY

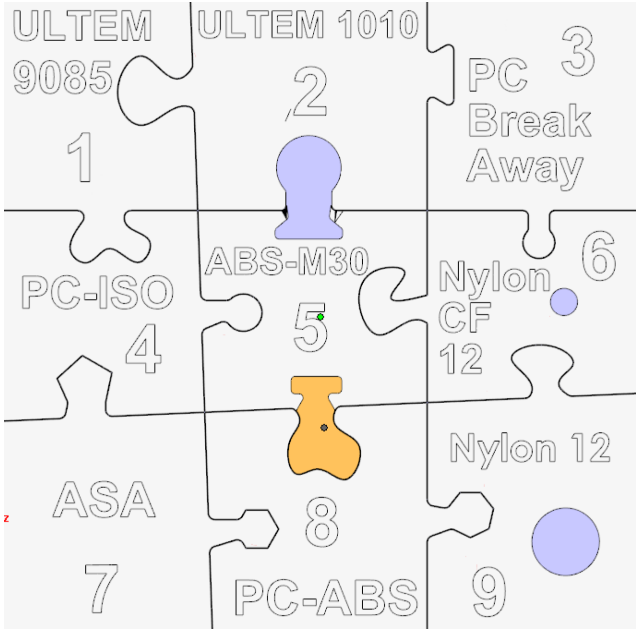


https://www.youtube.com/watch?v=jGKCUrDlybA

INSTRUCTOR-LED ACTIVITY: POST-PROCESSING PUZZLE PIECES

Parts for:

- Mass Finishing
- Support Removal –
  - Soluble & Breakaway
- Sanding
- Bonding
- Drill and Tapping Holes
- Inserts – Press Fit (Nylon 12)



MASS FINISHING: HANDS-ON DEMO

System Type: Almco V2051 tub

Media Type: Ceramic - star shape

System Setting: 1700 RPMs

Run Time: approx. 1.5 hours

MASS FINISHING

https://www.youtube.com/watch?v=qZryU-Wr6zY

FINISHING TOUCH™ SMOOTHING STATION

1. Part placed in the cooling chamber
2. Part transferred from cooling chamber to smoothing chamber for 10-30 seconds
3. Part then hung to cure 15-20 minutes
4. Lightly sand one side and repeat steps 2 and 3

FINISHING TOUCH™ SMOOTHING STATION

BREAKAWAY SUPPORT REMOVAL

1. Place ULTEM/PC parts in the oven
   - Heat up to 180oC
2. Wear heat resistant gloves and safety glasses
3. Use pliers and picks to remove supports

SOLUBLE SUPPORT REMOVAL

1. Parts have been submerged overnight
2. Note temperature for SR100 = 80-85oC
3. PC parts should soak for less than 24 hours
4. Rinse parts in clean water

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SANDING

1. Inspect surfaces to find areas of overfilled seams.
2. Lightly sand or file to level the seam
3. Note: File tends to work best

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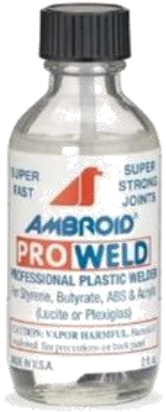
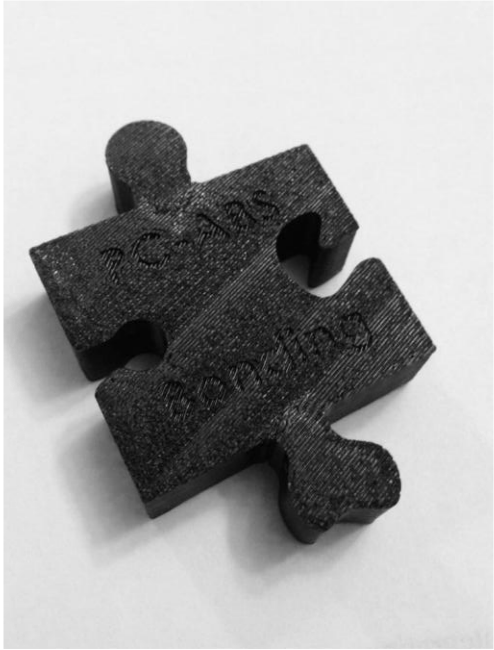
BONDING

1. Align joints
2. Use a brush to apply solvent to joint
3. Make sure joint is not over saturated
4. Allow to cure per manufacturers recommendations





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DRILL AND TAP

1. Use #7 drill bit to ream the hole
2. Tap the hole with ¼-20 threads

Note: Multiple Contours around hole provides more material (meat) for the threads to hold.

INSERTS – PRESS FIT (NYLON 12)

1. Align insert
2. Using the Arbour Press, Press Insert into part.

SECONDARY FDM POST-PROCESSING METHODS

FDM POST-PROCESSING METHODS

Basic Processes

Support Removal

Fixing, sanding, bonding, gluing

Additional Processes

Antimicrobial Coating

Secondary Processes

Painting

Sealing

Plating

Mass finishing

Smoothing

Keep the safety regulations in mind for every tool and material you use

PAINTING

When to paint:
- Display models
- Low volume production
- Custom products
- Pilot projects
- End use parts

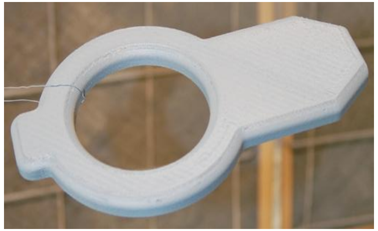
Considerations
- Materials – ABS-M30 is easiest to finish
- Slice height - Finer slice height = less finishing
- Orientation - minimize stepping on curved slightly surfaces

PAINTING PROCESS

Surface Preparation → Sanding and Filling → Painting and Finishing

Surface cleaning → Sanding and filling → Painting →

Applying Primer → Blemishes* → Applying clear finish



PAINTING - REQUIRED TOOLS AND MATERIALS

Required Tools and Materials

- Primer (spray can or paint sprayer)
- Paint (spray can or paint sprayer)
- Sandpaper (220 and 400-grit wet/dry)
- Body-filler (optional)
- Sodium hydroxide solution
- Tack cloth
- Nitrile gloves
- Spray mask

ADVANCED FDM TIPS: PAINTING

https://www.youtube.com/watch?v=cS8cybl5_Qc

SEALING

Functional testing applications

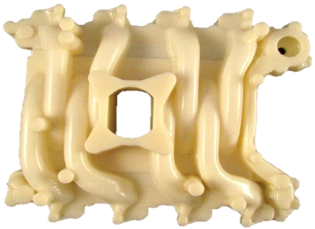
Low volume production 1-500 pcs.

Performance characteristics meet specs

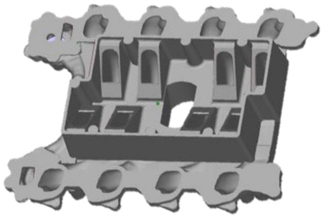
- Sealing pressure
- Chemical, thermal resistance

Epoxy coating process

- Two part epoxy
- Brushed on part in small sections
- No investment in equipment
- Coating will remain airtight up to 65 psi (448 kpa)



FDM Manifold for Functional Testing



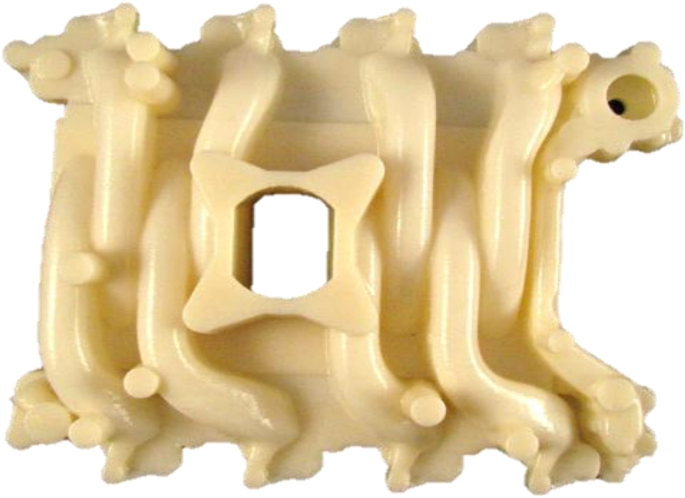
CAD model showing internal features

Production Manifold

SEALING

Epoxy infiltration

- Two part epoxy
- Penetrates the surface of porous/semi porous parts
- Parts immersed in resin and vacuum chamber to draw
- Oven needed to pre-heat and cure the epoxy
- Remain air and water tight up to 65 psi (448 kpa)



FDM Manifold for Functional Testing

PLATING

Increased mechanical properties

Flight ready aerospace parts

EMI shielding

End use parts / aesthetics

Consult with vendor on process specifics, estimate coating thickness, temperature exposed and other variables. Choose the right FORTUS material and adjust part according to vendor specifications

PLATING PROCESS

Before building part - adjust CAD file to compensate for thickness of plating

Sand Surfaces to remove layer lines and stepped surfaces

- Coarse sanding 120-220 grit

Seal Surfaces

- Option 1 Finishing Station
- Option 2 Solvent Dipping
- Option 3 Epoxy coating

Allow part to cure - if using Solvents allow minimum of 18 hours

Re-sand Surfaces

- Sand any remaining layer lines or stepped surfaces
- Wet Sand with 500-1200 grit
- Repeat until free of defects

MASS FINISHING

Hands-free surface smoothing and polishing

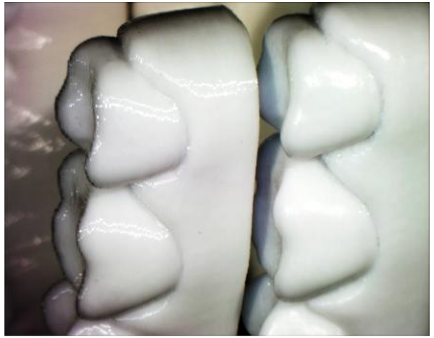
Centrifugal barrel or vibratory tub

Typically used for higher volumes (> 25 pieces)

Benefits

- Minimal labor
- Consistent quality
- No harsh chemicals or solvents
- Compatible with all Stratasys materials & platforms

ULTEM 9085: cut (top) & polished



Dental models: raw (left) & polished

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MASS FINISHING

ULTEM 9085 duct: polished (left) & cut

MASS FINISHING

Dental models: raw (left) & polished

MASS FINISHING / CENTRIFUGAL BARREL

Smooth fragile parts without damage

Versus vibratory tubs

- Shorter processing time
- Less facility space needed
- Less media
- Quieter
- Parts less than 5 x 5 x 5 in. (127 x 127 x 127 mm)

Select machine with variable drive speeds

Need access to water supply and drain

Turret

Loading media in barrel

Barrel holds part and media

MASS FINISHING / VIBRATORY

Fragile parts may be damaged due to weight of surrounding media

Versus centrifugal barrel

- Smoothing within bores
- Larger capacity
- Bowls (smaller parts, less aggressive) or tubs (large parts, more aggressive)
- Longer processing times
- Very loud

Select machine with variable drive speeds

Need water supply line and drain

Most machines need 3-phase power

Loading media

Parts and media in tub

MASS FINISHING / MEDIA TYPES

Ceramic: Most aggressive
- Cutting or polishing
- Best suited for PC, PPSF, & ULTEM

Plastic: Less aggressive
- Lighter, more media per pound
- Best for ABS materials, but suitable for all

Synthetic: Less aggressive
- Cleaner finishes (low residue)
- Longer life (more wear resistant vs. plastic)

Corncob: Least aggressive
- Polishing and gentle cutting
- Best suited for ABS materials


Ceramic angle-cut cylinders


Plastic cones


Corncob

MASS FINISHING / MEDIA SHAPES

Hard-edged with flat surfaces

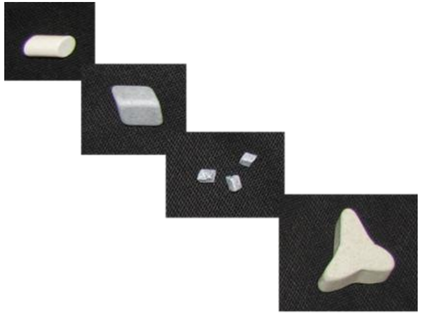
- Greater cutting action
- More likely to nick or gouge
- Examples: Pyramids, triangles, tri-stars and blocks

Soft-edged with round surfaces

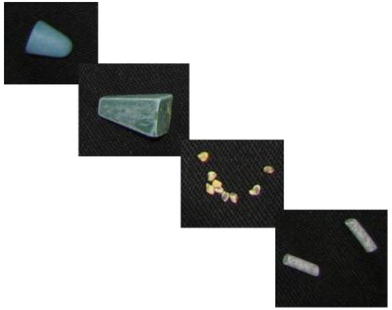
- Less cutting action
- Better smoothing of holes, bores, etc.
- Less likely to lodge in features
- Examples: Cones, cylinders and ellipses

Use a size smaller than smallest negative feature

- Can combine different shapes and sizes



Varied shapes and sizes



MASS FINISHING FILE PREPARATION

CAD model

- Thin, tall features (aspect ratio > 4:1)
  - Modify or eliminate if damage is likely

Narrow channels, holes and slots

- Media may not enter or may lodge
- Enlarge if possible

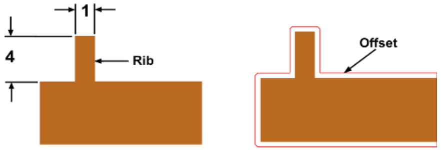
Compensate for material removal

- Typically 0.0015 – 0.0030 in. (0.04 – 0.08 mm) per surface
- Offset surfaces when precision is needed

Generate STL

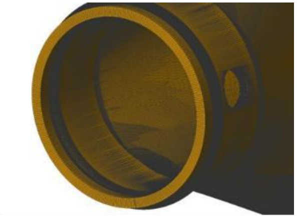
- Fine mesh (small facets) - less finishing time required

STL file for duct



Aspect ratio

Surface offset (red line)



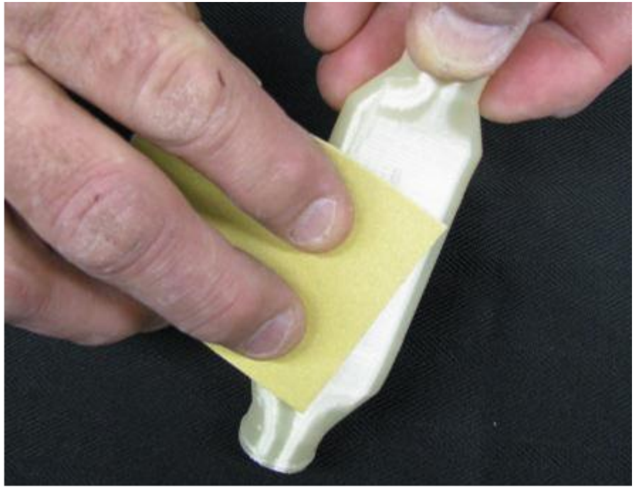
Generate fine mesh for STL

MASS FINISHING / PART PREPARATION

Remove supports

Pre-sanding (optional)

- Mass-finishing removes equal amount from all surfaces
- High spots will remain
- Coarse sanding - 120 to 220 grit
- Focus on seams and layer lines
- Avoid gouging



Optional pre-sanding

MASS FINISHING

https://www.youtube.com/watch?v=qZryU-Wr6zY

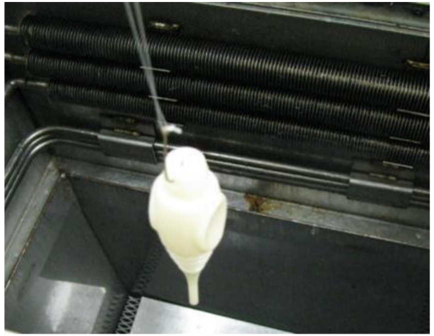
FINISHING TOUCH™ SMOOTHING STATION

Smoothing Chamber

- 13 x 16 x 20 inches (330 x 406 x 508 mm)

How it works

- Two chambers: one for cooling and curing, the other for smoothing
- Smoothing agent is heated to a vapor
- Vapor confined to the machine by cooling coils



Part suspended in vapor smoothing chamber

Sand pattern to smooth finish

FINISHING TOUCH™ SMOOTHING STATION

Process

- Part placed in the cooling chamber
- Part transferred from cooling chamber to smoothing chamber for 10-30 seconds
- Part then hung to cure 15-20 minutes
- Lightly sand (optional) and repeat as necessary
- To achieve matte finish use sand blasting cabinet
  - Minimum working area of 40 x 22 x 20 inches (1016 x 509 x 508 mm)
  - POLYHARD type III bead media 20/30 bead screen size .841-.595 mm (.0331-.0234 inches)

FINISHING TOUCH™ SMOOTHING STATION

Low volume (typically less than 100 pieces)

Smooth surface is required

Show quality models

Paint ready parts

Electroplating

RTV molding (master patterns)

Investment/sand casting (master patterns)

Sealing surfaces at ambient pressures

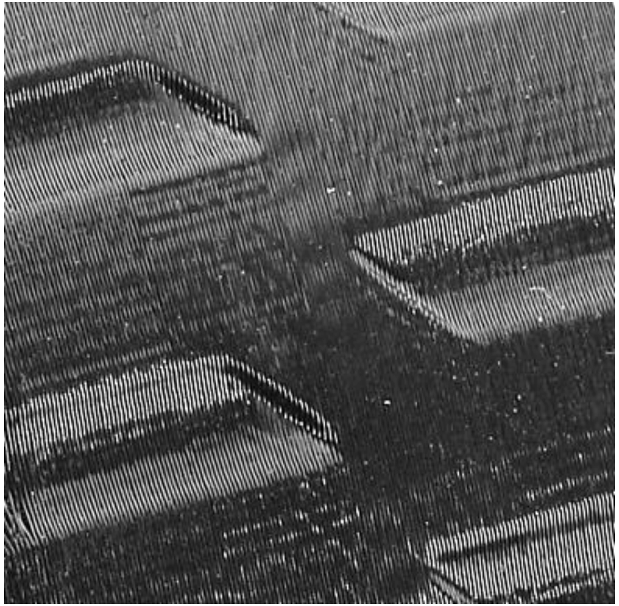
Retains part accuracy

Minimize direct labor

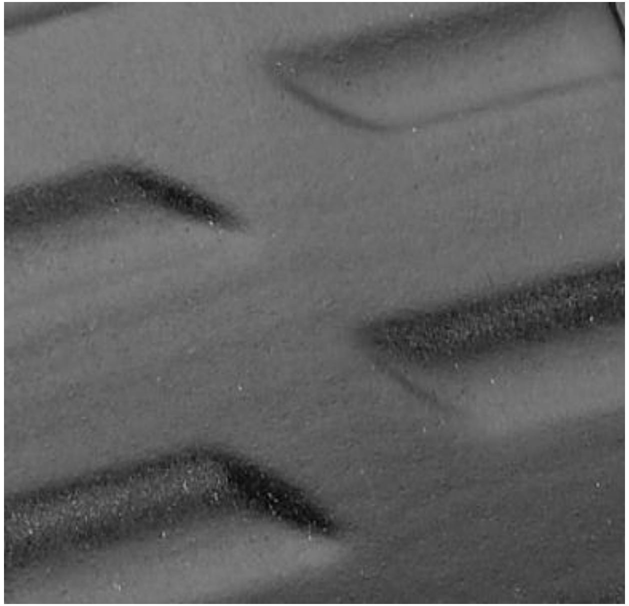
Fast, simple process

FINISHING TOUCH™ SMOOTHING STATION

Before Smoothing



After Smoothing



FINISHING TOUCH™ SMOOTHING STATION

Paint ready parts
- Allow 12-18 hours fully cure before priming and painting

Master pattern prep
- Investment casting
- Sand casting
- RTV/silicone molding

Sealing
- Seal and smooth all surfaces exposed to vapor

Electroplating
- Smooth and seals the parts




FINISHING TOUCH™ SMOOTHING STATION

- Retains part accuracy +/- .0009in (.023mm) with no sanding up to three exposures
- Protects small features
- Minimizes labor
- Reduces lead time for smoothing FDM parts
- Seals FDM parts at ambient pressures and liquid applications
- Limited to ABS materials (ABS, ABSi, ABS plus, ABS M-30, and ABS M-30i)
- Parts may blister at temperatures at or above 176 ºF (80 ºC)

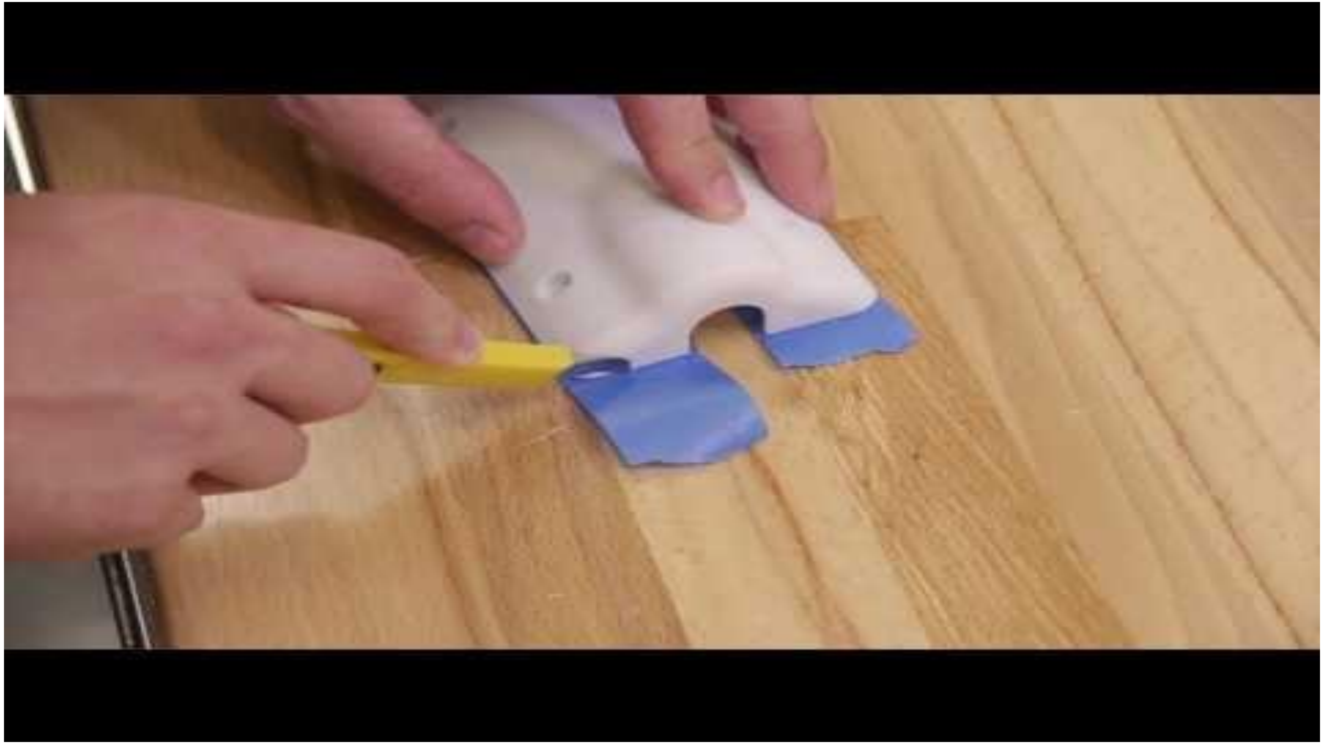
VAPOR SMOOTHING FDM PARTS

https://www.youtube.com/watch?v=ozUbeCThsg0

SMOOTHING STEP-BY-STEP TUTORIAL – GRABCAD

Visit -- https://grabcad.com/tutorials/how-to-give-your-3d-printed-fdm-part-the-smoothness-of-injection-molding

ADVANCED FDM TIPS: MEDIA BLASTING



https://www.youtube.com/watch?v=-XhbTUublao

MEDIA BLASTING STEP-BY-STEP TUTORIAL – GRABCAD

Visit: https://grabcad.com/tutorials/how-to-media-blast-fdm-parts--1

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INSTRUCTOR-LED ACTIVITY: SECONDARY POST-PROCESSING METHOD

Choose a Secondary post-processing method and apply the technique to one of your puzzle pieces, the GrabCAD model you have been using, or your Extreme Redesign part.

Secondary Post-Processing Methods

- Painting
- Sealing
- Plating
- Mass finishing
- Smoothing

POLYJET POST-PROCESSING METHODS

POLYJET POST-PROCESSING METHODS

Support Removal

Transparent Parts: Processing Vero Clear

Dying Translucent Parts

Painting & Clear Coat

Thermal treatment

Keep the safety regulations in mind for every tool and material you use

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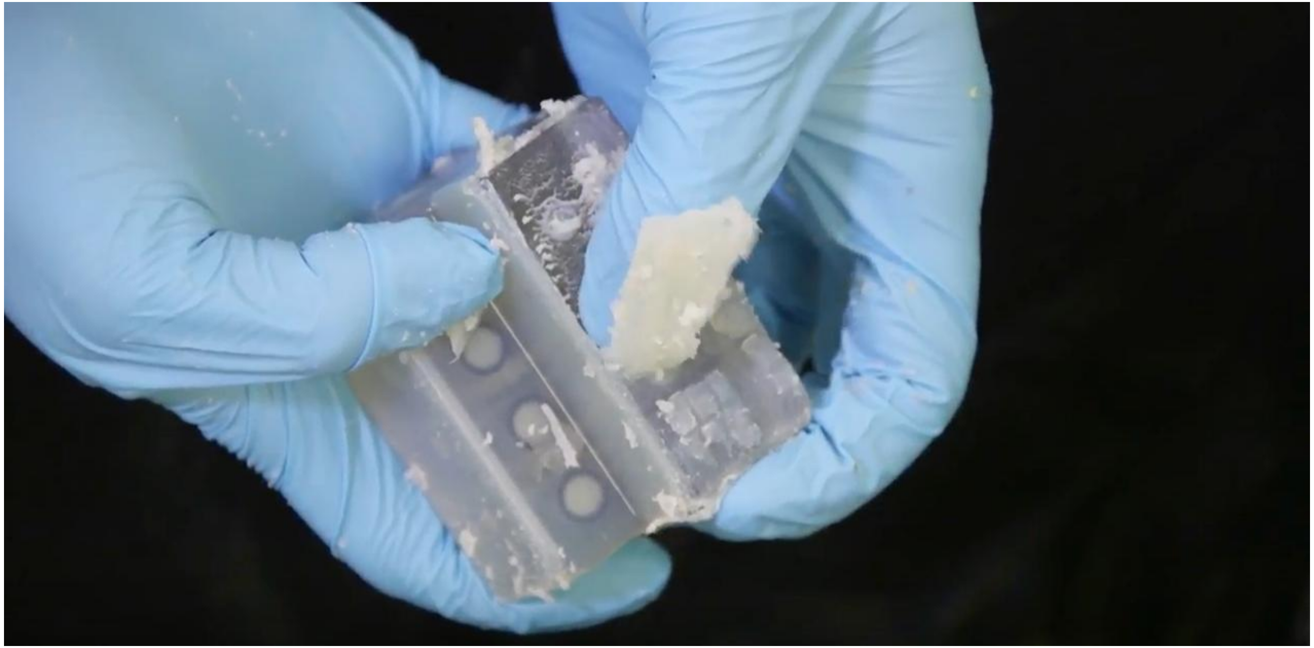
ADVANCED POLYJET TIPS: SUP706 SOLUBLE SUPPORT REMOVAL

https://www.youtube.com/watch?v=Y-uA95rt7R0

SOLUABLE SUPPORT REMOVAL STEP-BY-STEP TUTORIAL – GRABCAD



Visit: https://grabcad.com/tutorials/how-to-remove-sup706-soluble-support-removal

TRANSPARENT MODELS POLYJET

Appearance of VeroClear models ranges between transparent and translucent

Level of transparency of VeroClear models is affected by:

Printing:

- Machine cleanness
- Model orientation and tray configuration

Post processing:

- Sanding
- Photobleaching

TRANSPARENT MODELS/ PRINTING POLYJET

Traces of previous materials in the printer affect the clarity of VeroClear parts

Before printing with VeroClear:

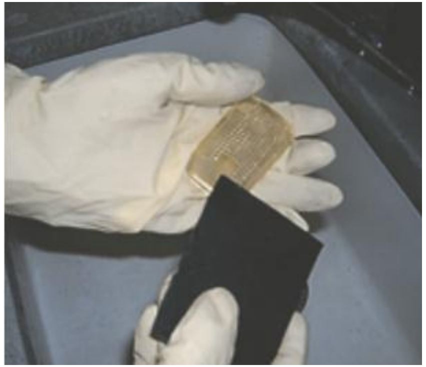
- Replace one or both of the currently installed cartridges with VeroClear
- Run the Material Replacement Wizard and select the flushing option appropriate for your printer

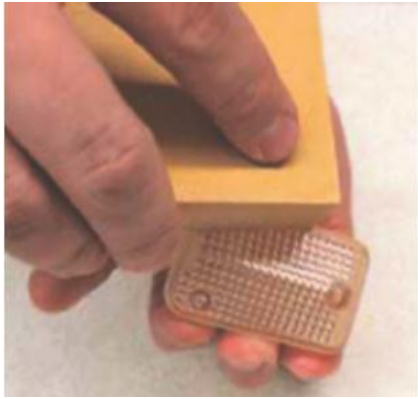
Clean the print heads, wiper, and roller waste collector thoroughly.

TRANSPARENT MODELS/ POST PROCESSING POLYJET

Sanding

- Sanding enhances clarity of the model by smoothing of the surface and removal of imperfections.
- Several sanding stages may be performed to achieve optimum results:
  - **Dry sanding**: Sand dry surfaces with 200-grit sandpaper. To improve the clarity even further, sand it again with 320-grit sandpaper.
  - **Wet Sanding**: Use if dry sanding leaves scratches on the model. Use 400, 600, and 1000 grit wet sand paper
  - **Micromesh sanding**: use 1500 and up grit sandpaper for exceptional finish





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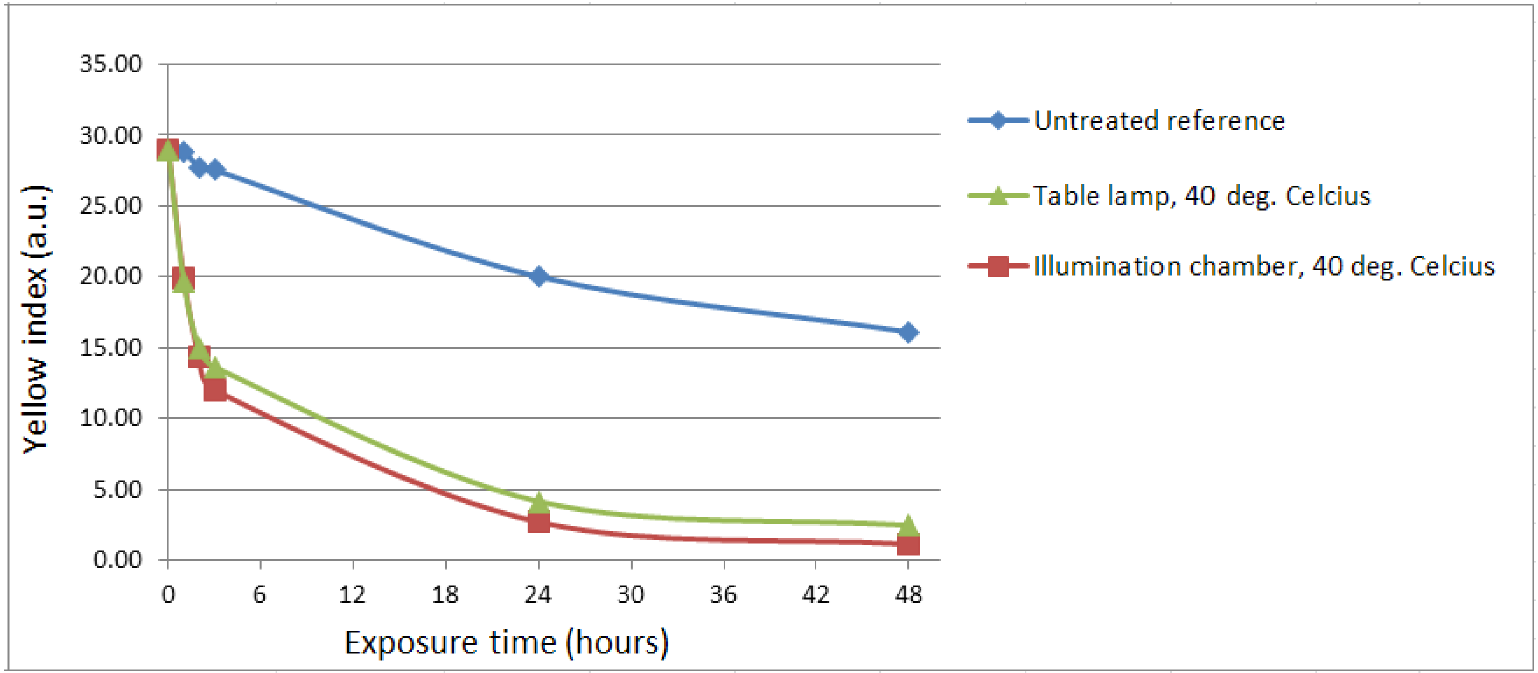
TRANSPARENT MODELS/ POST PROCESSING POLYJET

Polishing and Buffing

- Apply a polishing compound, such as 3M Plastic Polish, to a buffing wheel or a polishing tool.
- Work the polishing compound onto all surfaces of the model then buff off the compound with a soft cloth or clean buffing pad.
- Finally, spray a thin layer of lacquer to enhance clarity

TRANSPARENT MODELS/ POST PROCESSING POLYJET

Photobleaching (exposure to UV light)



TRANSPARENT MODELS/ POST PROCESSING POLYJET

Photobleaching (exposure to UV light)

- Stratasys VeroClear parts have a slight yellow tint when removed from the printer.
- This yellow tint fades naturally over time
- This process can be accelerated by using a suitable photobleaching treatment
- Photobleaching can reduce the yellow tint by 70% in only six hours, and by over 90% in 24 hours
- Final clarity depends on the model geometry

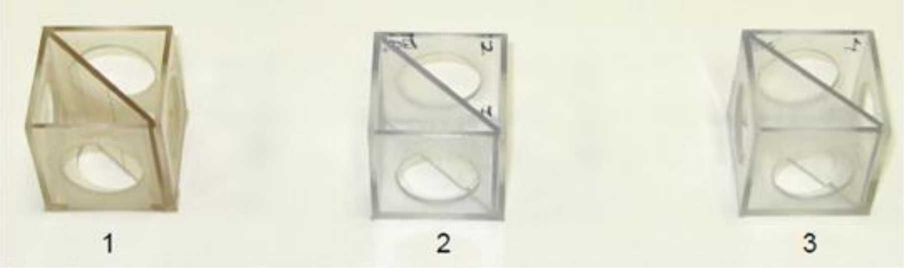


Figure 3: Sample model before treatment (1); after photobleaching in chamber (2); and after photobleaching with table lamps (3)

TRANSPARENT MODELS / POST PROCESSING POLYJET

Photobleaching (exposure to UV light)

- Methods:

ILLUMINATION CHAMBER	TABLE LAMP
Enables controlling temperature and light intensity.	Results vary due to lack of precise control over temperature and light intensity.
Assures predictable results.	Self-assembled from readily available parts.
Costs approximately US$1,300.	Low cost solution

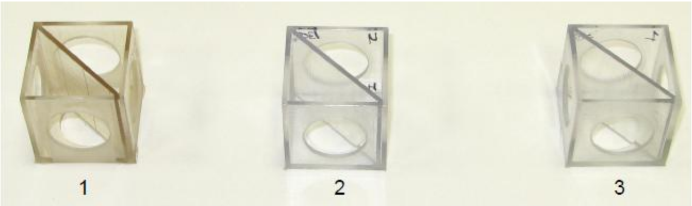


Figure 3: Sample model before treatment (1); after photobleaching in chamber (2); and after photobleaching with table lamps (3)

TRANSPARENT MODELS/ POST PROCESSING POLYJET

Photobleaching in an Illumination Chamber:

- Use a 150 liter illumination chamber.
- Make sure that the fluorescent lamps are 45 W, 6500K.
- Arrange the printed models inside the illumination chamber with enough distance between them to allow light to reach all sides of the model.
- After photobleaching the model for six hours, inspect them. If necessary, continue for up to 18 hours more.

CAUTION: With both methods, ensure that the model temperature is 40 °C (104 °F). Higher temperatures may cause model distortion; lower temperatures may not produce satisfactory results

TRANSPARENT MODELS/ POST PROCESSING POLYJET

Photo bleaching using Table lamp

- Cover the inside of a container with aluminum foil.
- Arrange the models inside the container with enough distance between them to allow light to reach all sides of the model.
- Position the lamps approximately 10 cm above the models and turn them on. Use at least two 45 W, 6500K table lamps
- After photo bleaching the model for six hours, inspect them. If necessary, continue for up to 18 hours more.

CAUTION: With both methods, ensure that the model temperature is 40 °C (104 °F). Higher temperatures may cause model distortion; lower temperatures may not produce satisfactory results

ADVANCED POLYJET TIPS: BETTER TRANSPARENT PARTS

https://www.youtube.com/watch?v=pz777LIxMMc

BETTER TRANSPARENT PARTS STEP-BY-STEP TUTORIAL – GRABCAD

https://grabcad.com/tutorials/how-to-get-better-3d-printed-transparent-parts

DYING TRANSLUCENT MODELS

Dyes add color to clear models while retaining their translucency

Faster and easier than painting

Use off the shelf powdered dye

Dyed models retain their original dimensions

PAINTING POLYJET: SURFACE PREPARATION

Cleaning the model
Careful removal of support promotes paint adherence

Applying primer
Promotes bonding of the paint to the model

TIP:
Before sanding, apply a red or white primer as the first coat and then apply a grey primer. When sanding, the color difference indicates when you are getting close to the model’s surface

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PAINTING POLYJET: SANDING AND FILLING

Dry sanding
Use 400 grit sandpaper to sand until primer coat begins to show

Filling
Fill blemishes with auto-body potty if necessary (Freeman TUF-Carv or premixed glazing putty, such as 3MTM Acryl-Blue)

Wet sanding
Use 220 and 400 grit wet sandpaper to finish off after putty has dried

PAINTING POLYJET: PAINTING AND FINISHING

Painting the model

After surface is dry, use a tack cloth to remove dust and apply several thin layers of paint, allowing layers to dry between each one

Applying clear finish

Apply additional layer of lacquer to enhance protection of the paint

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ADDITIONAL PROCESSES/ METAL COATING POLYJET

- The method of applying a metallic outer layer to another material
- Increasing sturdiness and provide a hard shell
- Giving off an attractive finish
- Performed by specialists rather than in house
- Common metals applied: Nickel, Copper and Chrome

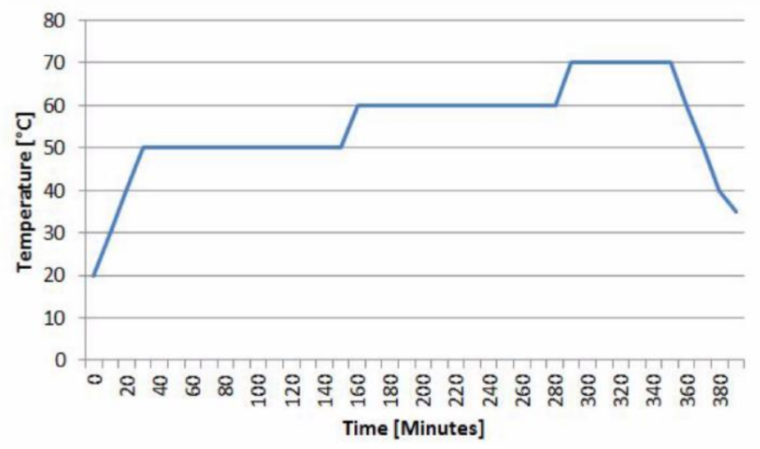
Chrome plated printed model of a car’s head light

Copper and Nickel coated faucet models

THERMAL TREATMENTS POLYJET

Why post cure?

- Though models are fully cured out of printer, additional exposure to heat cycles increases their temperature resistance
- For ABS it increases in HDT from 65 to 90°C
- For HT (high temperature materials) it increases in HDT from 65 to 80°C



Example for heat treatment cycle for HT