

3D Printing of Supply Sensitive Parts

Presented by M. Skowronska

August, 2024

BT & SDMT Joint Panel Meeting

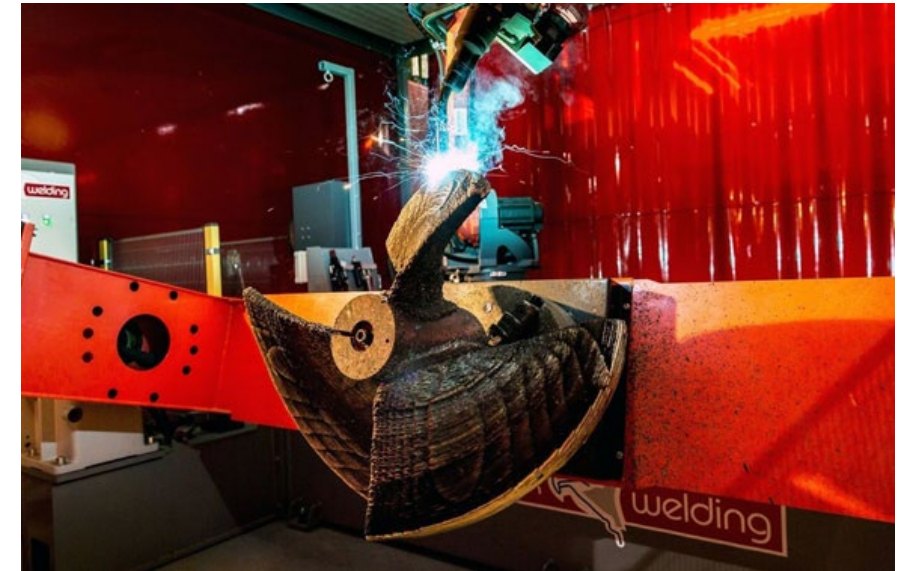


GENERAL DYNAMICS
NASSCO

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Agenda

- Background
- Castor Software Introduction & Example
 - Collaboration with NSRP Shore-Based Additive Manufacturing in Support of Military Sealift Command (2022-329-001)
- Analyzing Parts
 - Meta Data, 2-D Drawings, & 3D Cad
- Summary



RAMLAB full scale prototype ship propeller in production

Project History and Objective

- Project idea developed in response to NSRP + NAVSEA Gap Item #24
 - Development of a SY AM strategy to align with DoD AM strategy



Potential Use Cases

- Determine printer for printing spare parts on Submarine or Surface ship
 - Find printers for underway vessels that would maximize capability
- Reduce lead time on parts at shore based facility
 - Help fill necessary parts for vessels under construction
 - Reduce lead time on obsolete parts

Project endorsed by the following:

- Support and oversight from NAVSEA including:
 - Justin Rettaliata, the Additive Manufacturing (AM) Technical Warrant Holder
 - James S. Pluta, Additive Manufacturing (AM) Program Manager
 - Ryan Hayleck, Technical Director, NAVSEA 05T- Technology Office
- Support and oversight from PEO SSBN:
 - Whitney Joes, Director, Submarine Industrial Base, PEO SSBN
- Participation as on observer from General Dynamics- Electric Boat:
 - Adam Spreccace, Engineering Supervisor, Composites Engineering
 - Timothy Goddard, Composites Engineering Specialist
- PTR
 - Victoria Dlugokecki
- ATI Support
 - Nick Laney, ATI

AM Software Market Research Summary

Rank	Company	Notes
1	3YOURMIND	Worked with Navy, software not off the shelf, 3YOURMIND needs a year to work with us to develop a need based software, 150k for service- too expensive for Panel Project. NAVWAR in San Diego should have one license of the software
2	CASTOR	Everything we are looking for, off the shelf, able to input 3D parts, FEA capability, 40k. Working on 2D import capability. Partnering with Materialise.
3	Senvol	ONR and DoD Work; Not exactly what we are looking for (could use more features) Optimizes AM Process Parameters, Predicts material properties, monitors data to support quality assurance, minimize data generation costs. Predicts fatigue life, machine learning, asks for data collection.
4	Dinsmore	More of an AM printing company than a design optimization company
5	Materialise	Belgium Company; Not exactly what we're looking for (more production support than design optimization).
6	SelectAM	Not a recognizable/searchable company

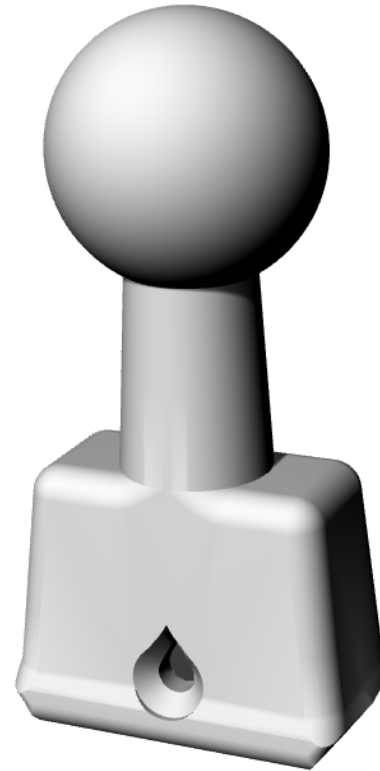
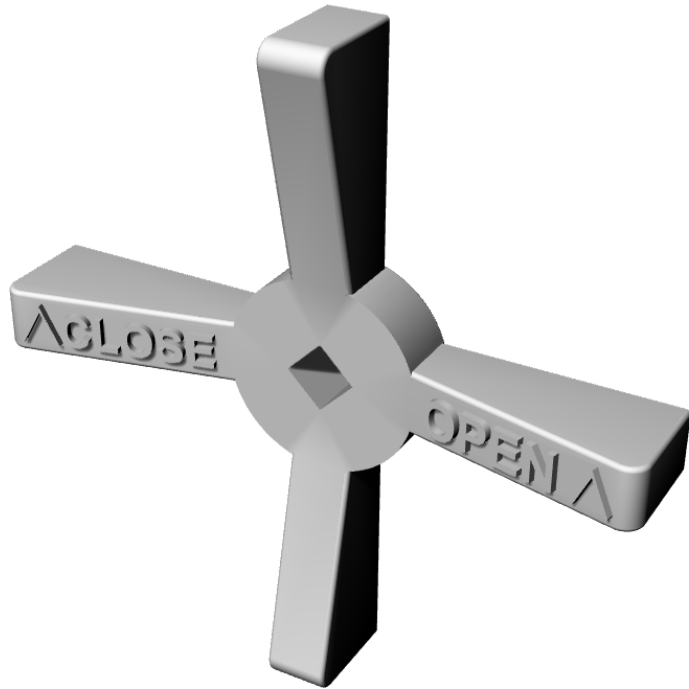


Program Details

- Benefits
 - Filters for best potential AM candidates
 - Identify parts suitable for AM (geometry)
 - Cost estimation of AM vs Traditional Means
 - Suggests printing configuration of material with printer
 - Identifies potential weight reductions or consolidation
 - Program run via cloud or internal server
 - Continued support for questions
- Potential for customization
 - Set In-house Printers
 - Customization of settings is extensive
 - Additional printers or materials can be added

Collaboration with ABS NSRP RA

- 2022-329-001 NSRP Shore-Based Additive Manufacturing
 - Hand wheel and Breaker



CASTOR- Input

1. Details

Project name

i This project life cycle is planned for


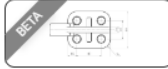

Estimated yearly production quantity

What is your current estimated standard cost? *i*

Use CASTOR's Traditional Manufacturing cost estimation

2. Type

Files Type:

 3D CAD  2D Drawing  Meta Data

Please set the materials for the uploaded parts/assembly

Upload a BOM from your CAD software with a specified material for each part. [LEARN HOW](#)

Use a single material for all parts

Original Material Type	Original Material Category	Original Material
<input type="button" value="Metal"/> <input checked="" type="button" value="Plastic"/>	<input type="button" value="Plastics"/>	<input type="button" value="ABS PC"/>


Use material from drawing files only


[ADVANCED SETTINGS](#)

This project's tolerance according to DIN ISO 2768 standard is *i*

CASTOR

3. Files



 **Drop your files or click here to upload**

Native 3D CAD file formats are supported (Creo, SOLIDWORKS, NX, CATIA, Inventor, Solid Edge), files and STL files

Project Unit Type

Your files will not be shared with any 3rd party


CASTOR- Summary

CASTOR

Results
 An overview of the project results

✓

Printability Analysis
 Out of a project of 2 parts **2 are printable.**




100.0%

Index

- Printable
- Unprintable
- Printable with changes
- Not cost effective





↗

Benefit Analysis
 Out of a project of 2 printable parts found **3 different benefits.**



Index

- Cost saving
- High Buy to Fly
- Weight reduction opportunity
- Time saving
- Complex part geometry
- Part consolidation opportunity

	Name	Status	Benefits	AM Technology	Original Material	AM Material
	Breaker	✓ Printable	💰	FDM (Plastics)	ABS PC	PLA 
	Handwheel	✓ Printable with changes	🏠	DMLS	AISI Type 316L stainles...	Stainless Steel 316L 

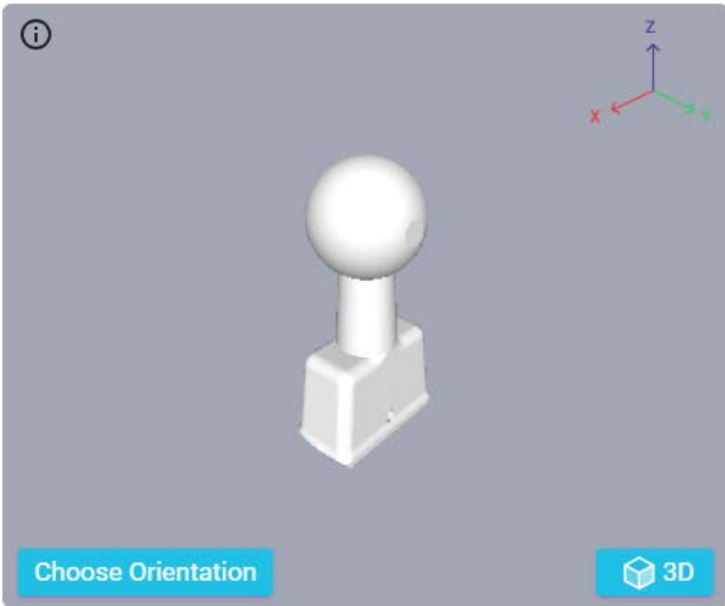
CASTOR- Part Result



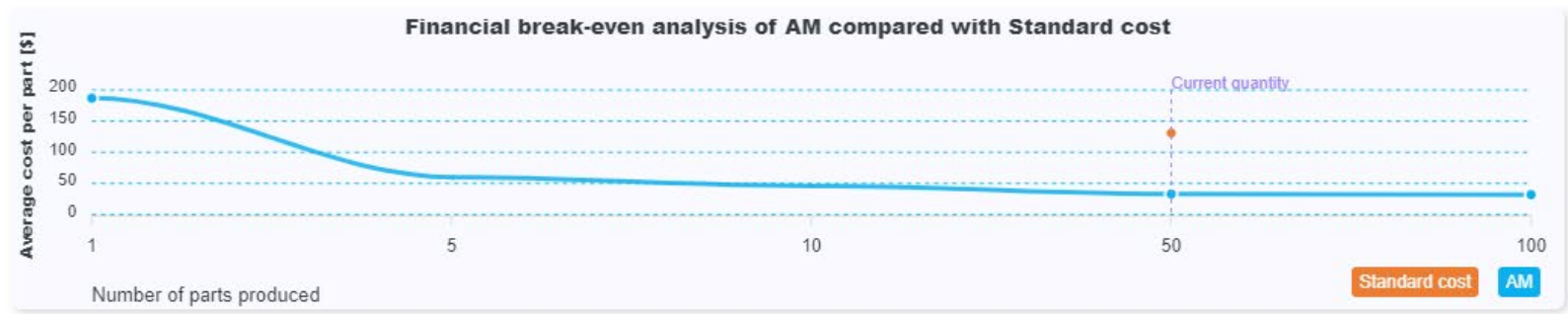
Best Match In-House Printer Cheapest

COST SAVING CONFIGURE GENERATE REPORT LEADING

Result Printable	Cost estimation Production cost: \$25 - 33 Total cost of ownership: \$29 - 37 Product life cycle: Low volume production (Qty: 50)	Lead time 5 days for first shipment	Recommended printer Jet Fusion 4200	Recommended material HP 3D HR PA 12
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Material Analysis Geometry Analysis **Cost Analysis** Lead time Analysis Stress Analysis



The part is cost effective
This is assuming a production run of 50 parts Change quantity
Compare with another manufacturing method: Standard cost

Cost analysis table view

CASTOR- Part Result



Best Match **In-House Printer** Cheapest +

COST SAVING TIME SAVING

CONFIGURE GENERATE REPORT LEADING

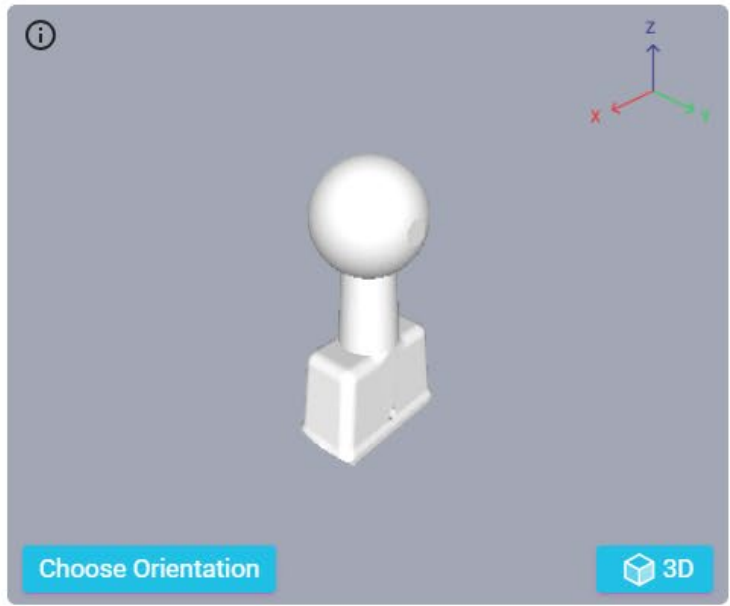
Result
Printable

Cost estimation
Production cost: \$52 - 68
Total cost of ownership: \$55 - 71
Product life cycle: Low volume production (Qty: 50)

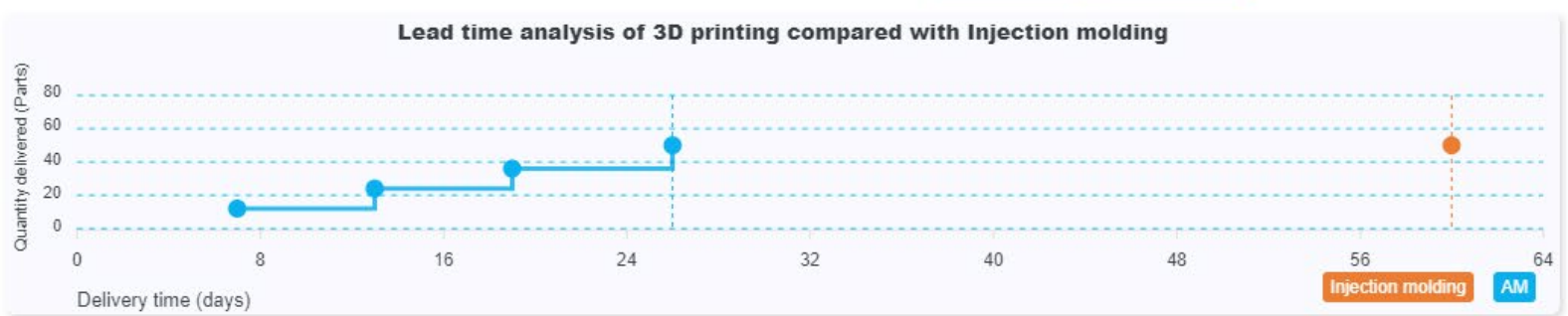
Lead time
9 days
for first shipment

Recommended printer
Replicator+

Recommended material
PLA



Material Analysis Geometry Analysis Cost Analysis **Lead time Analysis** Stress Analysis



12 out of 50 parts will be delivered in 9 days when using AM
50 out of 50 parts will be delivered in 60 days when using Injection molding

This is assuming a production run of 50 parts [Change quantity](#)

Lead time parameters [Edit](#)

Compare with another manufacturing method: Injection molding

CASTOR- Reports

Additive Manufacturing Analysis Report

Part name: Breaker

April 23, 2024 7:27 AM

CASTOR

Part Information

Project name: ABS Test Part: Breaker

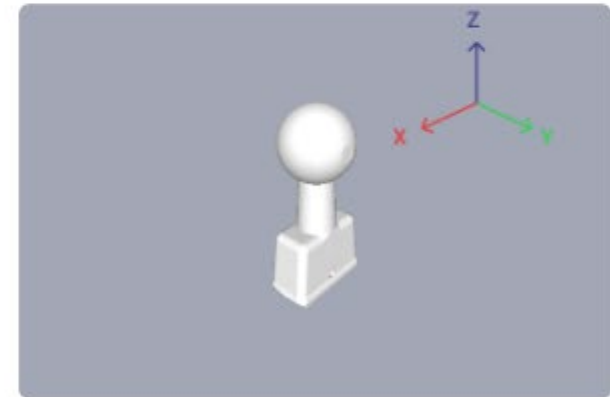
Part name: Breaker

Original material: ABS PC

Dimensions [mm]: 61.6 x 43.75 x 121.03

Volume [mm3]: 109725

Tray Orientation



CASTOR- Reports

Additive manufacturing solution

In-House Printer \$

Result	Cost estimation	Lead time	Recommended printer	Recommended material
✓ Printable	Production cost: \$52 - 68 Total cost of ownership: \$55 - 71 Product life cycle: Low volume production (Qt...	9 days for first shipment	Replicator+	PLA

3D Printing vs. Standard cost

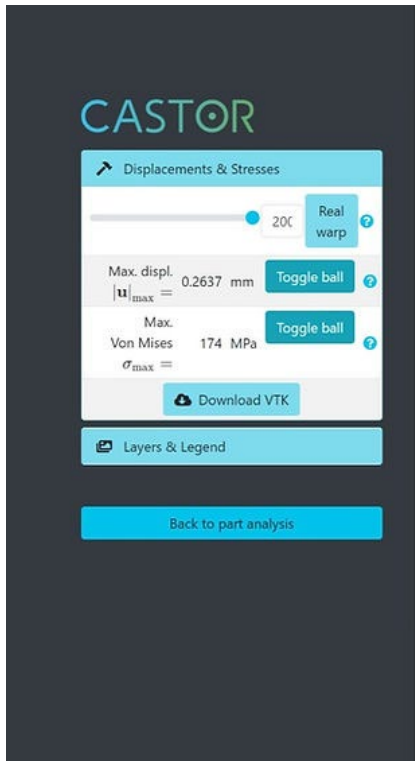
Manufacturing method	3D printing ✓ Printable	Standard cost
Total part cost [\$]	\$ 55 - 71	114.00
Lead time (days)	28	N/A
Material	PLA	ABS PC

Cost Parameter

Product life cycle	Low volume production
Surface area machining added	-
Initial technology setup costs	✓
Complex part	-
Estimated yearly production quantity	50 parts

CASTOR- FEA

Material Characteristics

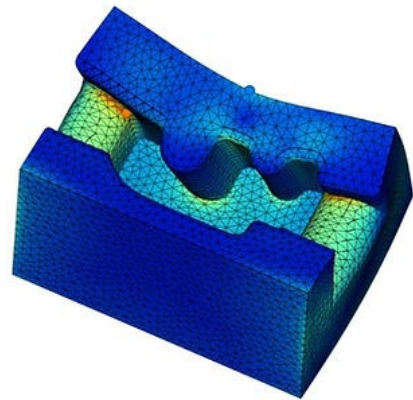


Bulk (1)

1. Problem

2. Mesh

3. Results



Comparison	Printed Material	Original Material	% Deviation
Material	AlSi10Mg	6061 Alloy	—
Ultimate Tensile Strength [MPa]	XY: 427 ± 15 Z: 424 ± 15	310 ± 24	136%
Elongation At Break [%]	4 ± 2	12 ± 2.2	33%
Stiffness (Youngs Modulus) [GPa]	XY: 80 ± 13 Z: 74 ± 5	68.3 ± 1.7	108%
Yield Strength [MPa]	XY: 258 ± 5 Z: 248 ± 5	260 ± 20	95%
Density [g/cm ³]	2.67	2.7	98%
Thermal Conductivity [W/(m•°K)]	140 ± 10	160 ± 8.5	87%
Surface Finish (Ra) [μm]	13 ± 2	—	—
Accuracy [μm]	60 ± 30	—	—

Criteria

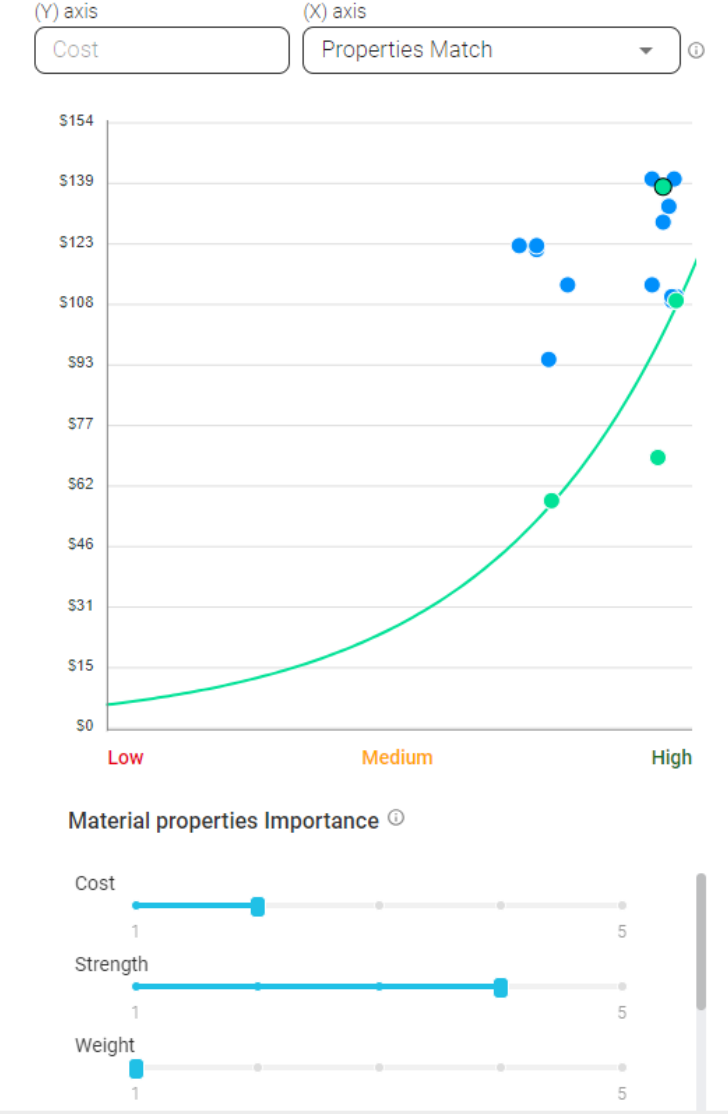
Selection Criteria

- 1. Material
- 2. Size
- 3. Configuration

Acceptance Criteria

- 1. Cost reduction 
- 2. Lead time reduction 

Select	Type	Description	Actions
<input checked="" type="checkbox"/>	Part size	Dimensions are 61.60 x 43.75 x 121.03 mm, in this configuration the part fits 12 times on a tray.	
<input type="checkbox"/>	Thickness	The part passed 0.8 mm minimal thickness test.	<button>Customize</button>
<input checked="" type="checkbox"/>	Tolerance	No tolerance requirement set in CAD file or by user.	<button>Update tolerance</button>
<input type="checkbox"/>	Holes	The part passed the minimal holes diameter size test.	
<input type="checkbox"/>	Threads	No threads found in the part.	

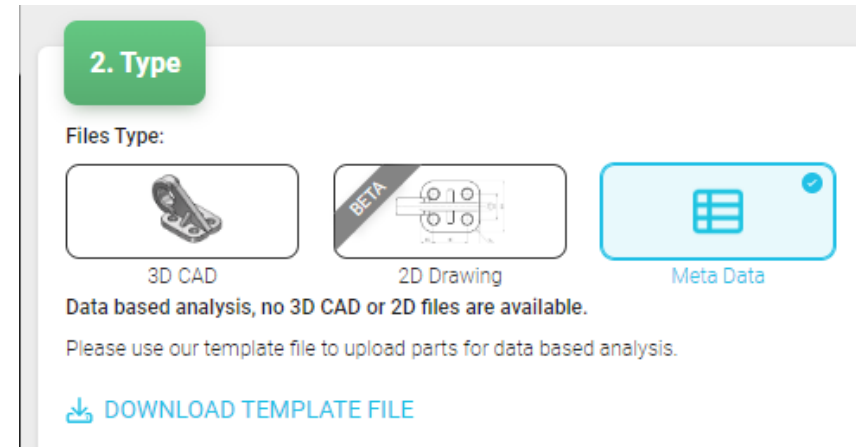


Database of Submarine Parts

- PEO Subs provided an excel database of submarine AM part candidates designated by NIIN number and part name
- Database includes:
 - Ohio Class (SSBN 738)
 - LA Class (SSN 751 & 764)
 - Virginia Class (SSN 778)

Meta Data- Consolidated Submarine Parts

- Sorted PEO Submarine Parts that had x,y,z dimension and material listed (128 parts met this selection)
- Sorted Parts into Castor Meta Data format



A	B	C	D	E	F	G	H
<i>Item No. (Optional)</i>	<i>Part Name (Required)</i>	<i>Description (Optional)</i>	<i>Original Material (Required)</i>	<i>QTY. (Optional)</i>	<i>Bounding Box - X [mm] (Required)</i>	<i>Bounding Box - Y [mm] (Required)</i>	<i>Bounding Box - Z [mm] (Required)</i>
I	J	K	L	M	N	O	
<i>Mass [Kg] (interchangeable with volume)</i>	<i>Volume [mm³] (interchangeable with mass)</i>	<i>Standard cost [\$] (Optional)</i>	<i>Manufacturing Method (Optional)</i>	<i>Product life cycle (Optional)</i>	<i>Tolerance class (Optional)</i>	<i>Is this part "Off the shelf"? (optional)</i>	

Meta Data Results

- Summary Sheets of Parts

	Totals
# of parts	128
# of printable parts	0
# of parts printable with changes	103
# of unprintable parts	12
# of not cost effective parts	13

- Reasons for parts not to be printed
 - Printable with Changes
 - Not a 3D Model (128)
 - Unprintable Results
 - Exceeds Tray Printers Volume Limit (9)
 - Too big to fit in tray (3)
 - Not Cost Effective
 - Too small (13)

Meta Data Results- Breakdown

1. SLM-280 2.0	
#	AM Material
24	Stainless Steels 316L
11	CuNi2SiCr
1	IN625
2	Invar 36
38	Total Parts



3. X160Pro	
#	AM Material
6	Inconel 718
5	Stainless Steel 316L
4	Stainless Steel 304L
12	Total Parts



Size (LxWxH): 2.6 x 1.2 x 2.7 m
 Power Requirements: 400 Volt, 63 A,
 50/60 Hz Usage: 3.3-5.5kW

2. Jet Fusion 4200	
#	AM Material
20	HP 3D HR PA 12
4	HP 3D HR PA 11
1	Nylon 12
25	Total Parts

Size: 2.2 x 1.2 x 1.4 m
 Power Requirements: 380-415 V, 30 A max,
 50/60 Hz, 3 phase Usage: 9-11kW




Size: 3.6 x 2.4 x 2.6 m
 Power Requirements: 400 V, 50/60
 Hz, 3-phase

2-D Drawing


- Pulls information from PDF
- Material can be set for all parts or read from input files
- Views represented used to create "3D" representations

2. Type


Files Type:



3D CAD



2D Drawing




Meta Data

Please set the materials for the uploaded parts

Use material from drawing files only

Use a single material for all parts

3. Files

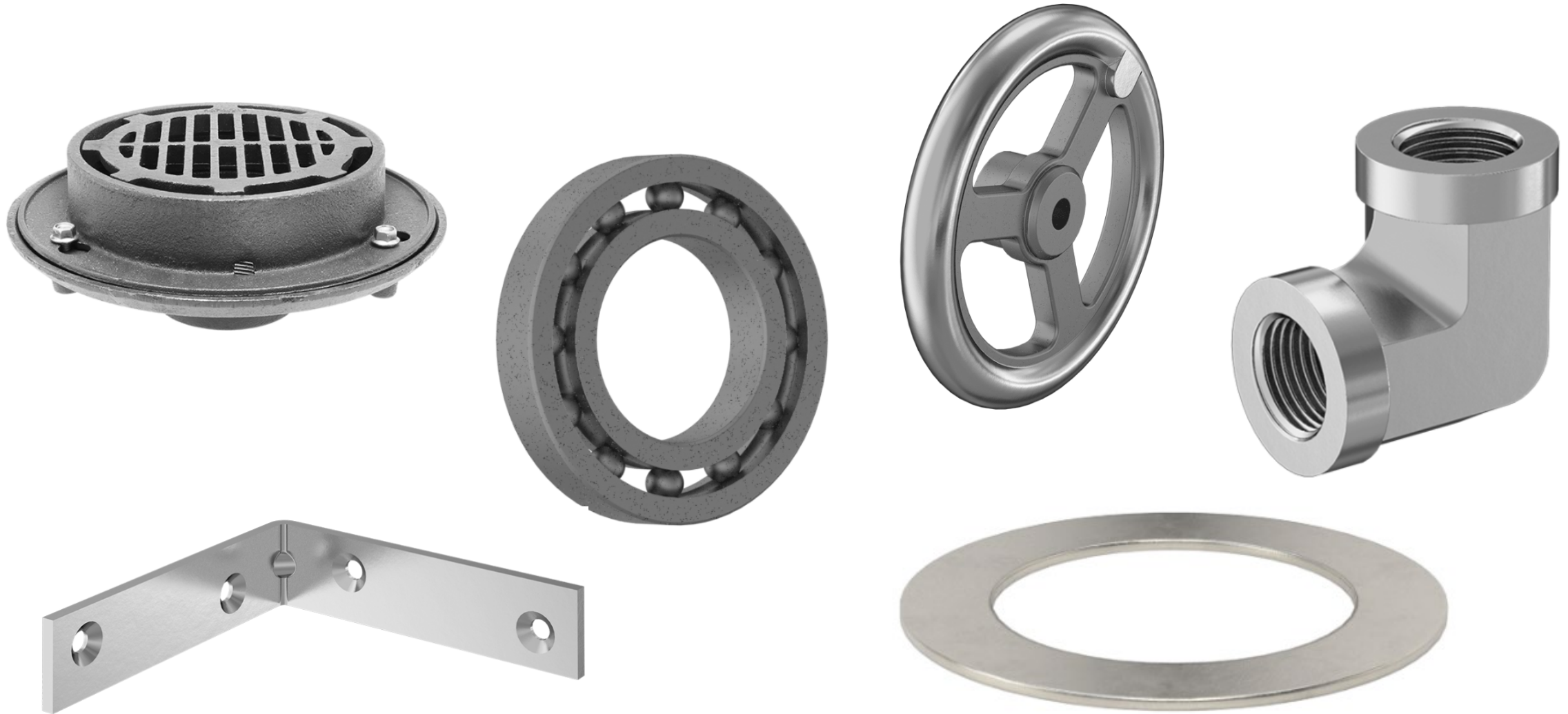


Drop your files or click here to upload

Drawings in PDF format are supported

⚠ Please choose a material before you drop your files

3D Equivalent Part Model Acquisition



3D Equivalent Parts Results

- Summary parts analyzed

Project Name	Number of parts	Number printable with some changes	Number of unprintable parts
Bearings	30	22	8
Check Valve	9	2	7
Coiled Spring Pins	6	3	3
Cotter Pin	5	4	1
Deck Drain	4	1	3
Globe Valve	8	2	6
Hand Crank	9	9	0
Hand Wheel	10	10	0
Mounting Bracket	12	12	0
Quick Release Pin	5	5	0
V Belt	2	2	0
Valve Seat	4	4	0
Adapters	9	5	4
Spacer	5	3	2
Totals	118	84	34

- Reasons for parts not to be printed

- Unprintable Results

- Thickness (7)
 - Holes (1)
 - Threads (19)
 - Heat Deformation (8)
 - Milling Metal Support (12)

3D Equivalent Results- Breakdown

1. SLM-280 2.0	
#	AM Material
27	Stainless Steels 316L
6	Stainless Steel 17-4PH
1	AlSi10Mg
34	Total Parts



3. M2 cusing Multilaser	
#	AM Material
6	AlSi10Mg
5	17-4 PH Stainless Steel
12	Total Parts



Size (LxWxH): 2.6 x 1.2 x 2.76 m
 Power Requirements: 400 Volt, 63 A,
 50/60 Hz Usage: 3.3-5.5kW

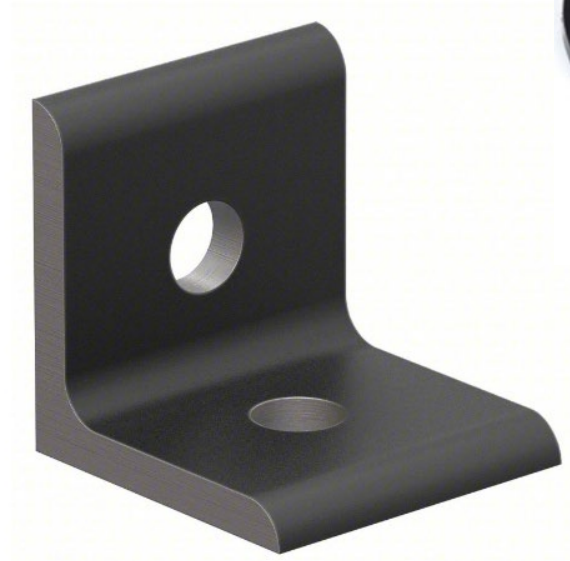
2. EOS M400-4	
#	AM Material
16	Stainless Steel 316L
2	AlSi10Mg
18	Total Parts

Size: 4.181 x 1.613 x 2.355 m
 Power Requirements: 3 x 50A
 Power Usage: 22-45kW



Size: 2.695 x 1.818 x 2.185 m
 Power Requirements: 3P/N/PE AC 400V,
 50/60Hz

3D Equivalent Parts - Polymer Refinement

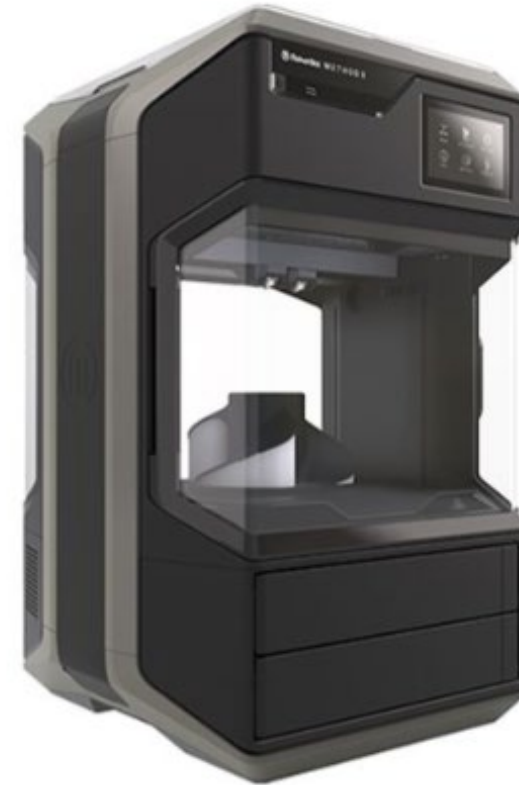


3D Equivalent Parts – Polymer Results

- All 18 parts were printable
- Method X Printer printed most parts

Project Name	Number of parts
Mounting Brackets	3
Valve Seat	4
Corner Bracket	1
Sleeve Bearing	5
V-Belt	2
Thrust Bearing Washer	3
Totals	18

Printer Name	Number of printable parts
P 800	5
Method X	6
H350	1
P 770	2
Raise 3D Pro2 Plus	3
Jet Fusion 4200	1
Total	18



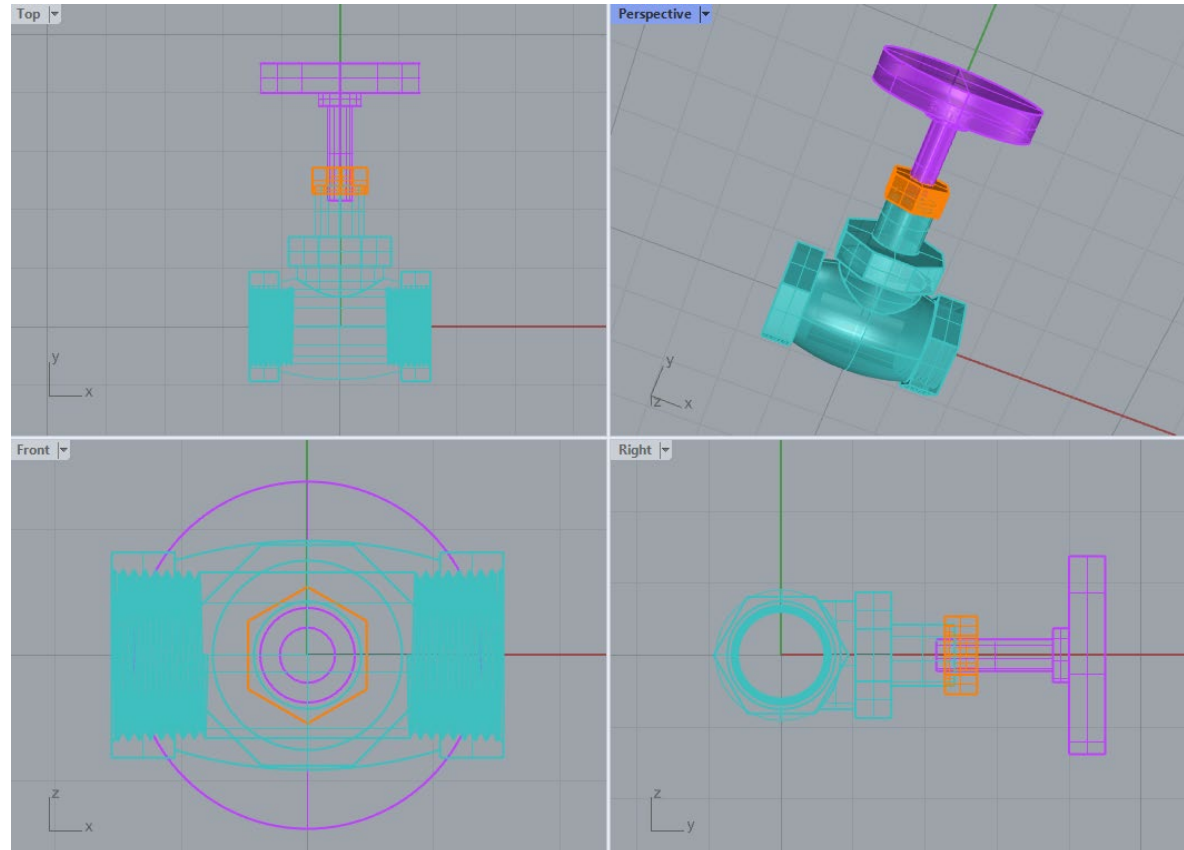
Printer name: Method X
Size (LxWxH): 41.3 L x 43.7 w x 64.9 H cm
Power Usage: 800 W

3D Equivalent Parts- Assemblies Run



3D Equivalent Parts- Assemblies Run

- Capability to run assemblies with multiple material types
- Individual components need to be blocked
- BOM for each component with material type




3D Equivalent Parts- Assemblies Run

- All components passed with changes
- Polymer component offers cost savings

Results
 An overview of the project results

✓ **Printability Analysis**
 Out of a project of 3 parts **3 are printable.**




100.0%

Index

- Printable
- Unprintable
- Printable with changes
- Not cost effective

↗ **Benefit Analysis**
 Out of a project of 3 printable parts found **3 different benefits.**

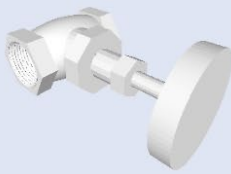


1
2

Index

- Cost saving
- High Buy to Fly
- Weight reduction opportunity
- Time saving
- Complex part geometry
- Part consolidation opportunity

Assembly/Valve (4695K59)



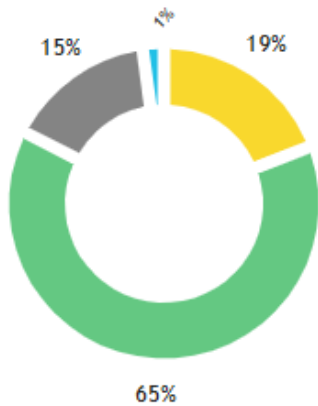
Component Name	Best Match Printer	AM Lead Time (days)	Cost Savings?
Wheel	Raise 3D Pro2 Plus	10	Yes
Middle	SLM-280 2.0	5	No
Body	SLM-280 2.0	14	No

Return on Investment





127 
Parts save money

219 
Parts save time

My Projects



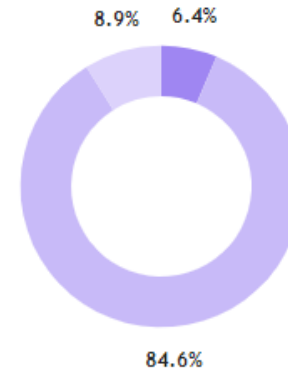
527 Uploaded Parts

-  344 Printable
-  99 Not printable
-  78 Not cost effective
-  6 Not suitable for 3D printing




3D Printing Savings

Calculate benefits according to

All Printable And Cost-Effective Parts ▾



Total savings: \$1,241,148

-  \$79,658 - Upfront costs savings
-  \$1,050,523 - Manufacturing costs savings
-  \$110,967 - Inventory costs savings

ROI Time needed to return the 3D printer investment


Calculate your ROI according to

All Parts Include "Standard Cost" ▾

Enter the relevant printer details

SLM Solutions ▾

SLM-280 2.0 ▾

 Machine purchase cost \$ 490,000

2.1 Years
Compared to traditional manufacturing methods

Summary

- Conclusions

- Castor provides simple framework for reviewing parts suitability for AM
- Based on parts analyzed, most suitable printers:
 - Metal parts: SLM-280 2.0
 - Polymer parts: Method X
- AM is a suitable option for submarine parts to speed up production quantity and yield
- Recommending as a tool for onboard printer selection for repair workshops



SLM-280 2.0

34/118 Parts (28%)



Method X

6/18 Parts (33%)

Questions?