3D Printing of Supply Sensitive Parts

Presented by M. Green

May 1st, 2024

BT & SDMT Joint Panel Meeting

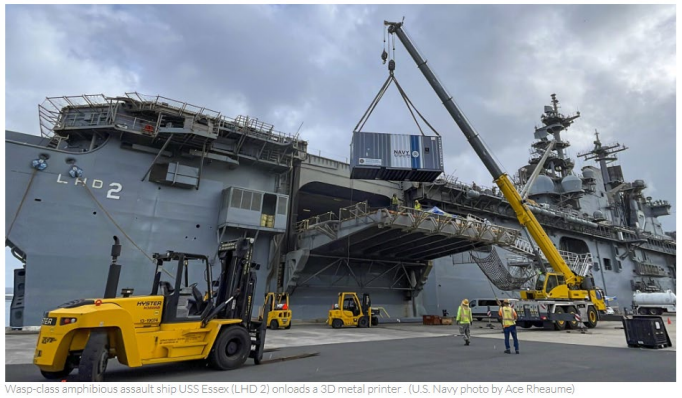
Additive Manufacturing (AM) in Shipbuilding

Motivations to pursue AM:

- Eliminate long lead time parts
- Reduce unit cost for unique parts
- Expanded material and geometry capabilities
- Fleet readiness with capability for at sea repair

Challenges to incorporate AM:

- Significant CAPEX cost associated with incorporating AM into production
- Certification process for shipboard parts is not clearly defined



Wasp-class amphibious assault ship USS Essex (LHD 2) onloads a 3D metal printer. (U.S. Navy photo by Ace Rheaume)

US Navy Tests New 3D Parts Printer

GCaptain
Total Views: 0
July 11, 2022

Project History

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

Project Objectives

2 Problems to Address

1. Navy is concerned with supply chain for the Submarine parts and wants to explore other manufacturing processes like AM to speed up production quantity and yield
2. Many companies across the industry are struggling to make a business case for investing in AM

3 Key Objectives

1. Identify a commercially off the shelf software that can be used to rapidly identify if a part of assembly is suitable for production via AM
2. Identify a standard metric by which parts can be categorized for being suitable to be produced with AM
3. Via various analyses, recommend a concise list AM technologies worth pursuing that is most suited for printing parts that meet the needs of submarines and other navy vessels*

*Dependent on inventory of parts collected and recognized technologies available in the software. Parts not analyzed, and technologies not represented are recognized, should not be dismissed.

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 Sprecace, Engineering Supervisor, Composites Engineering
  - Timothy Goddard, Composites Engineering Specialist

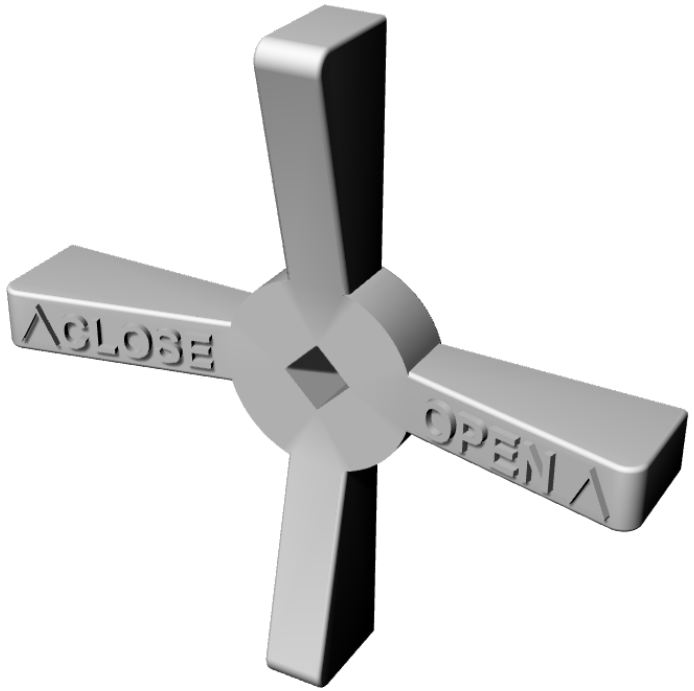
Program Details

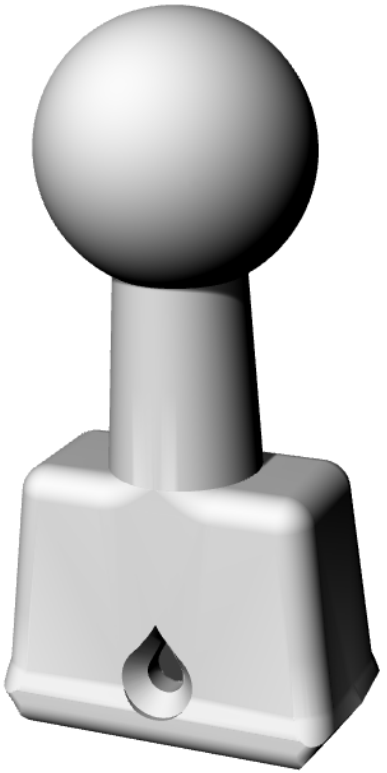
- Benefits
  - Filters for best potential AM candidates
  - Identify parts suitable for AM (geometry)
  - Cost estimation of AM vs Traditional Means
  - Suggests printing configuration of material with printer
  - Identifies potential weight reductions or consolidation
  - Program run via cloud or internal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

CASTOR

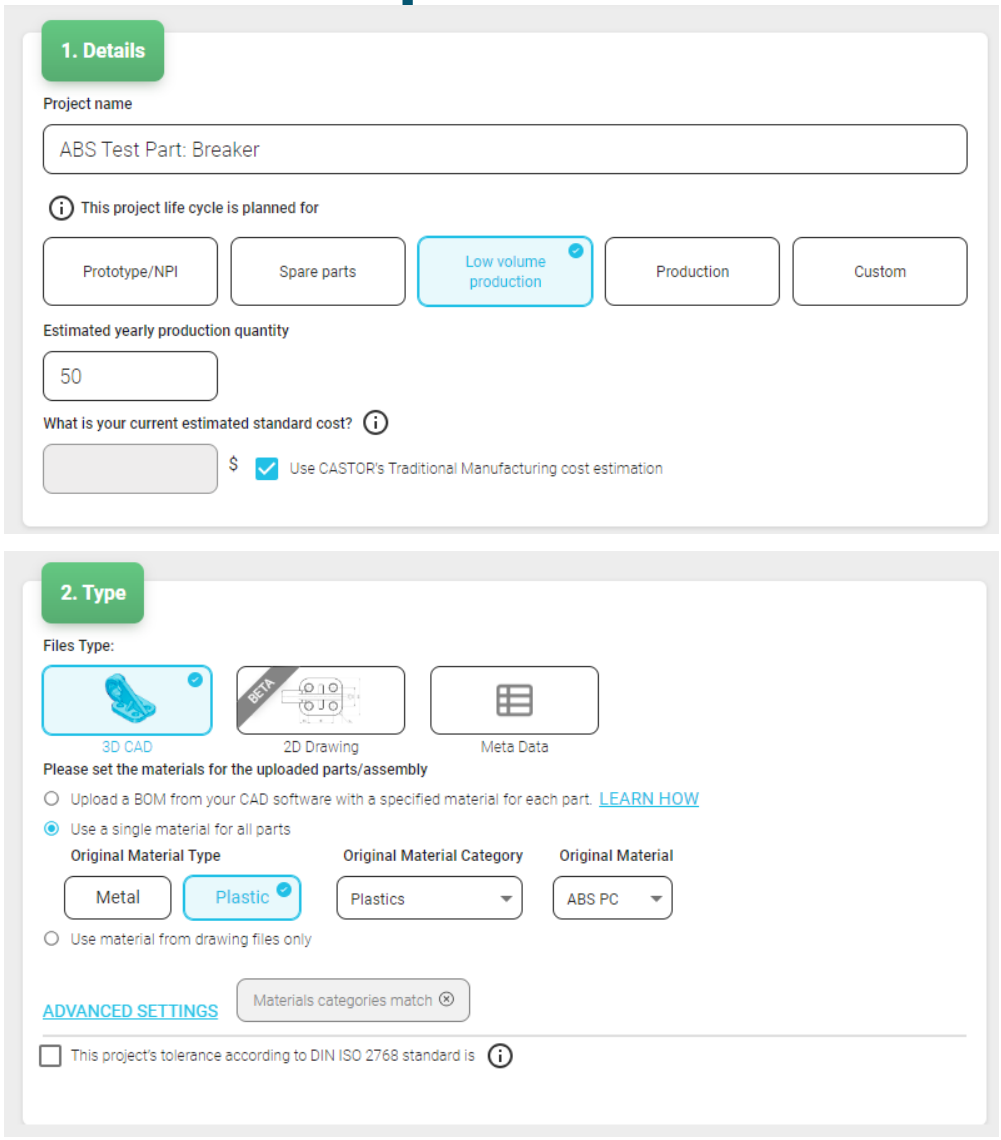
Collaboration with ABS NSRP RA

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

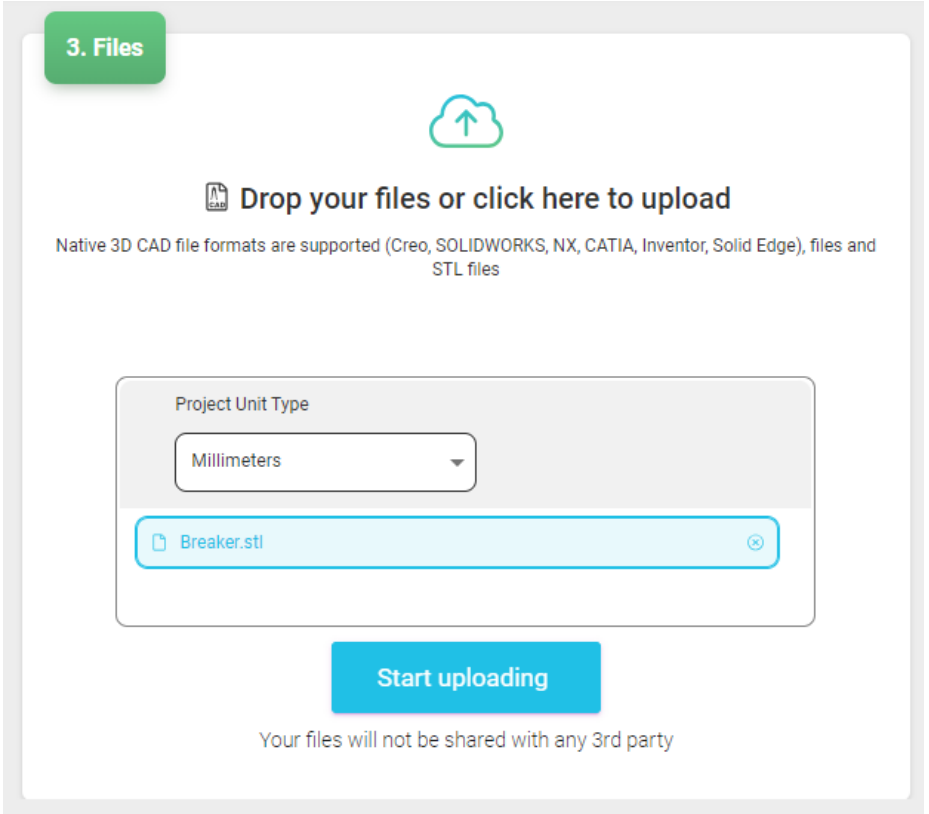




CASTOR- Input



CASTOR



CASTOR- Summary

CASTOR

Results
An overview of the project results

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

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

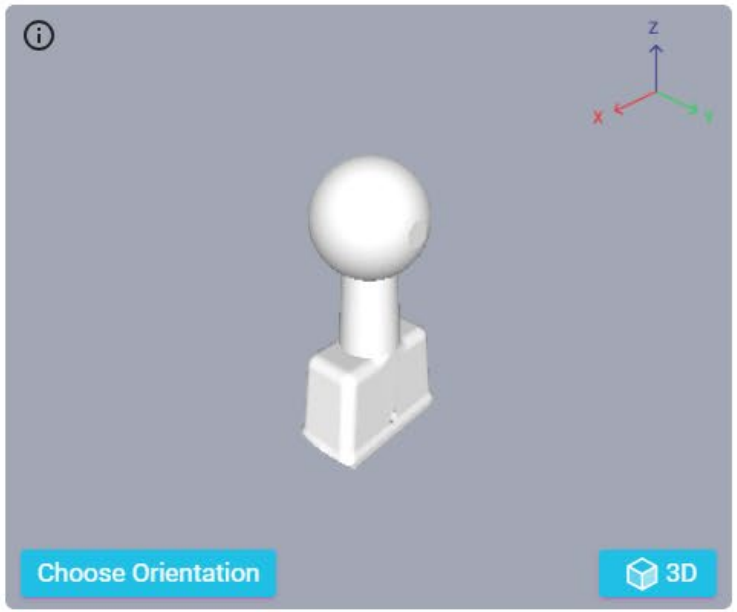
CASTOR

Best Match | In-House Printer | Cheapest

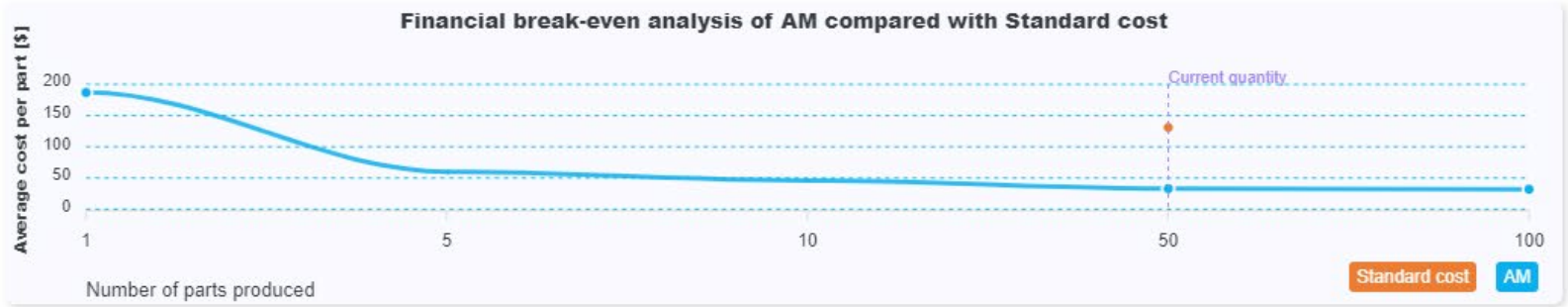
$ COST SAVING

CONFIGURE | GENERATE REPORT | LEADING

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



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

CASTOR

Best Match | In-House Printer | Cheapest

$ COST SAVING | TIME SAVING

CONFIGURE | GENERATE REPORT | LEADING

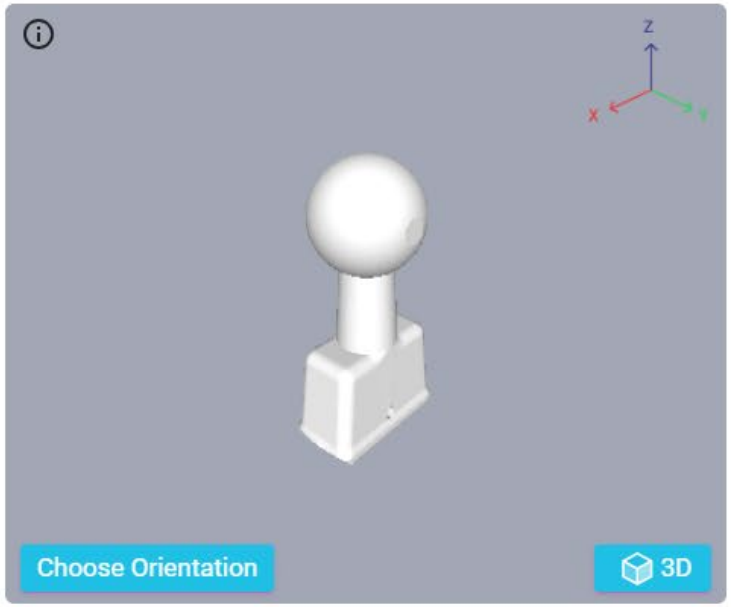
Result
Printable

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

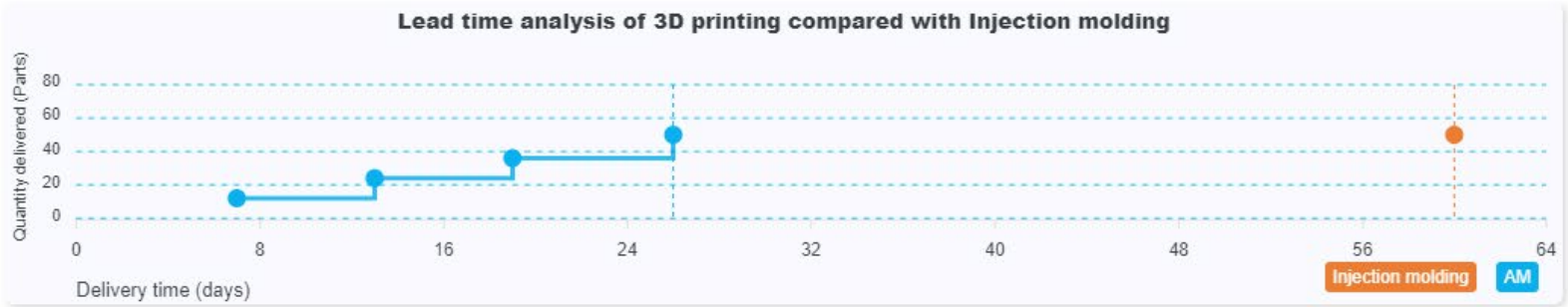
Lead time
9 days
for first shipment

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

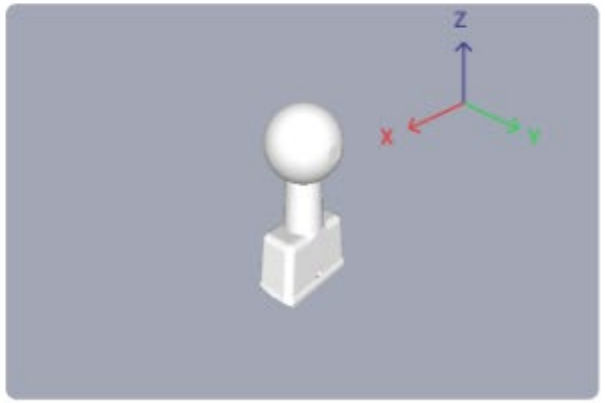
Part name: Breaker

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

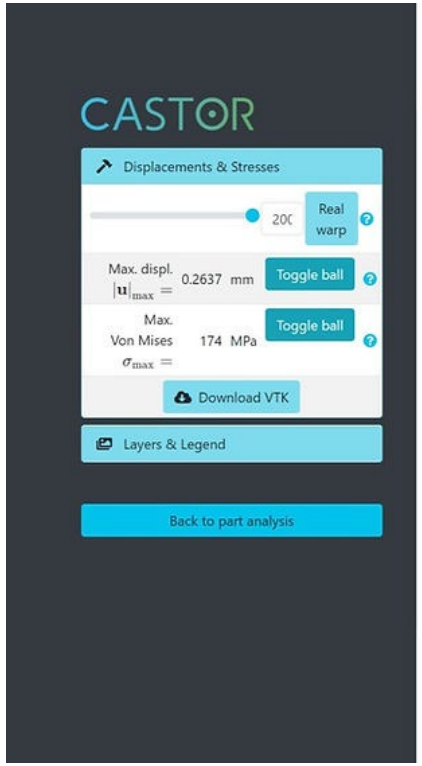
Manufacturing method	3D printing Printable	Standard cost
Total part cost [$]	$ 55 - 71	114.00
Lead time (days)	28	N/A
Material	PLA	ABS PC

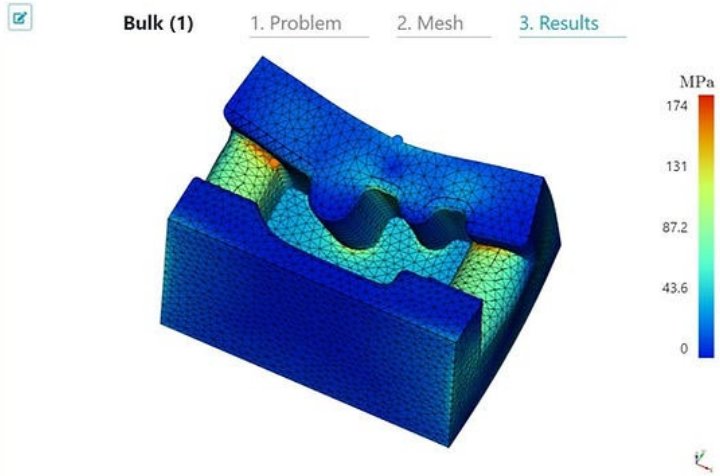
Cost Parameter

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



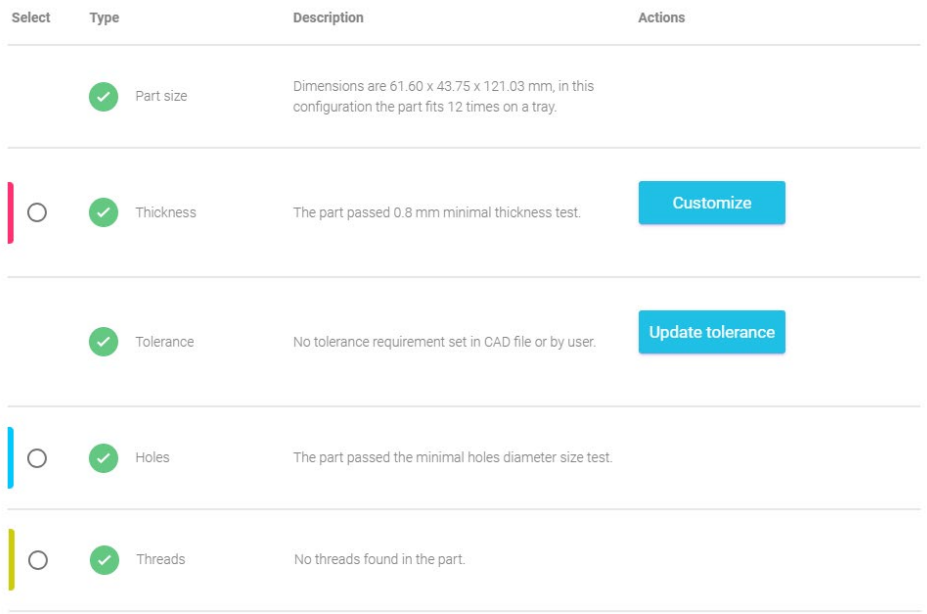


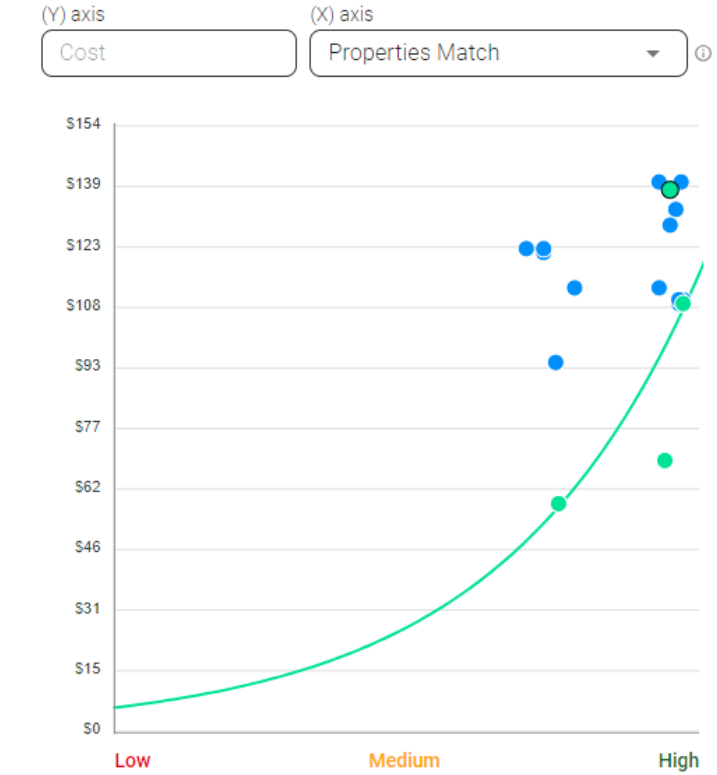
Comparison	Printed Material	Original Material	% Deviation
Material	AlSi10Mg	6061 Alloy	—
Ultimate Tensile Strength [MPa]	XY: 427 ± 15 Z: 424 ± 15	310 ± 24	136%
Elongation At Break [%]	4 ± 2	12 ± 2.2	33%
Stiffness (Youngs Modulus) [GPa]	XY: 80 ± 13 Z: 74 ± 5	68.3 ± 1.7	108%
Yield Strength [MPa]	XY: 258 ± 5 Z: 248 ± 5	260 ± 20	95%
Density [g/cm³]	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

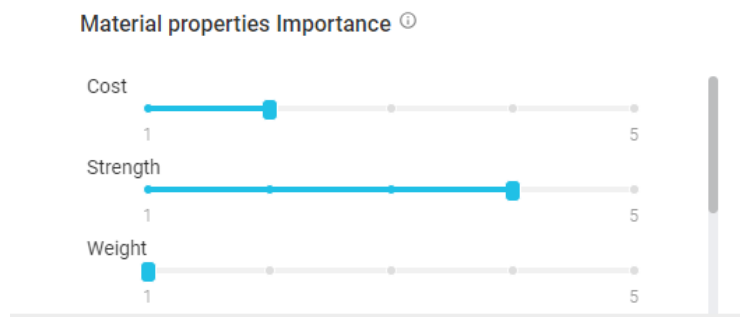
1. Material
2. Size
3. Configuration





Acceptance Criteria

1. Cost reduction
2. Lead time reduction

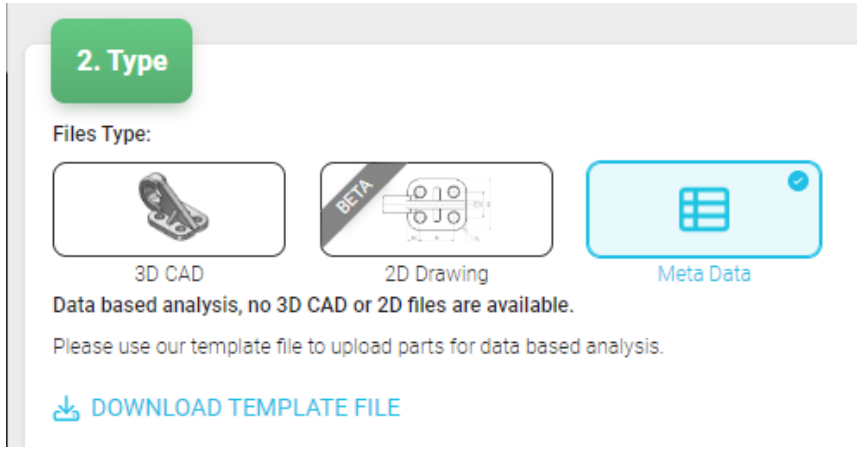


Database of Submarine Parts

- 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
Item No. (Optional)	***Part Name (Required)***	*Description (Optional)*	***Original Material (Required)***	*QTY. (Optional)*	***Bounding Box - X [mm] (Required)***	***Bounding Box - Y [mm] (Required)***	***Bounding Box - Z [mm] (Required)***

I	J	K	L	M	N	O
Mass [Kg] (interchangable with volume)	***Volume [mm^3] (interchangable with mass)***	*Standard cost [$] (Optional)*	*Manufacturing Method (Optional)*	*Product life cycle (Optional)*	*Tolerance class (Optional)*	*Is this part "Off the shelf"? (optional)*

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
  - 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

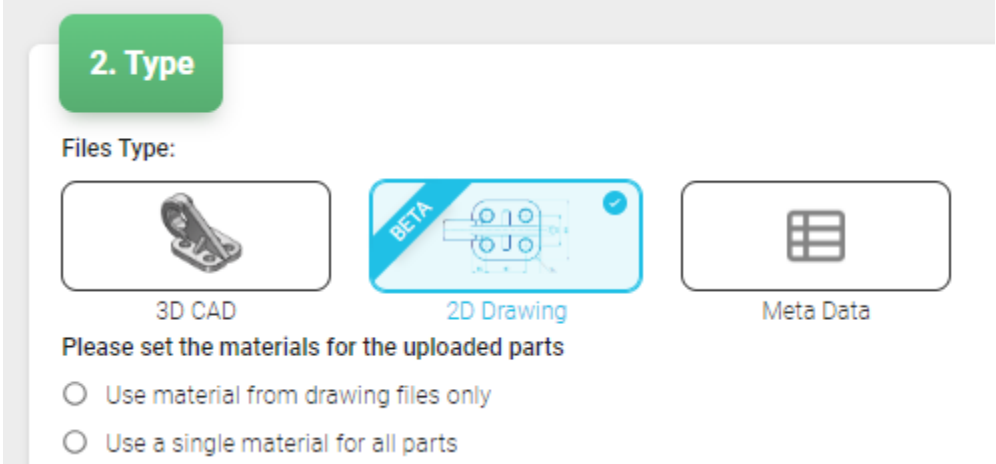
1. SLM-280 2.0	
#	AM Material
24	Stainless Steels 316L
11	CuNi2SiCr
1	IN625
2	Invar 36
38	Total Parts

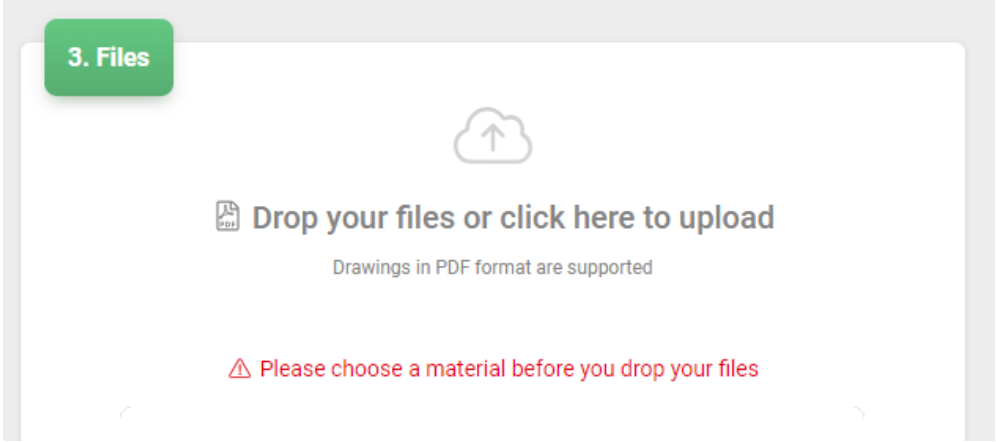
3. X160Pro	
#	AM Material
6	Inconel 718
5	Stainless Steel 316L
4	Stainless Steel 304L
12	Total Parts

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

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





3D Model Acquisition

- Finding commercially available parts
  - Example: Threaded Check Valve

Results- MetaData vs 3D Cad

Meta Data											
Part name	Solution Name	Printability check	Original material Name	Printer	AM material	AM cost estimation [$]	TM cost estimation [$]	AM lead time estimation [days]	AM cost saving	AM time saving	Complex geometry
High Flow Check Valve	Cheapest	Printable with changes	Copper	Jet Fusion 4200	HP 3D HR PA 12	262.38	1128.25	19	Yes	No	No
High Flow Check Valve	Best Match	Printable with changes	Copper	SLM-280 2.0	CuNi2SiCr	8356.65	1139.68	78	No	No	No
High Flow Check Valve	Weight reduction	Printable with changes	Copper	SLM-280 2.0	CuNi2SiCr	8356.65	1139.68	78	No	No	No

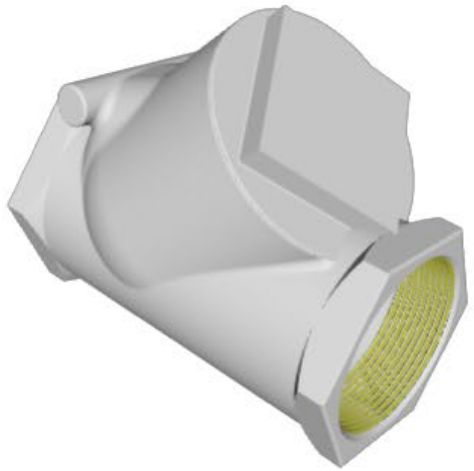
3D Cad											
Part name	Solution Name	Printability check	Original material Name	Printer	AM material	AM cost estimation [$]	TM cost estimation [$]	AM lead time estimation [days]	AM cost saving	AM time saving	Complex geometry
High Flow Check Valve	Cheapest	Printable	Copper	Jet Fusion 4200	HP 3D HR PA 12	368.98	868.17	23	Yes	Yes	No
High Flow Check Valve	Best Match	Printable with changes	Copper	SLM-280 2.0	CuNi2SiCr	8105.72	895.42	63	No	No	No
High Flow Check Valve	Weight reduction	Printable with changes	Copper	SLM-280 2.0	CuNi2SiCr	3989.52	868.17	53	No	Yes	No

Potential Errors

Review, fix & customize printability issues

Part Display

Display all issues on model



Select	Type	Description	Actions
○	Threads	One or more threads were detected. To ensure threads accuracy, post processing may be required.	Undo accept risk
	Heat deformation	Part have bulky areas, heat related deformation may occur during printing.	Accept risk

Show All Results

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
Check Valve	9	2	7
Spacer	5	3	2
Totals	127	86	41

- Reasons for parts not to be printed
  - Unprintable Results
    - Thickness (9)
    - Holes (1)
    - Threads (26)
    - Heat Deformation (10)
    - Milling Metal Support (16)

3-D 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

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

Summary

- Conclusions
  - Castor provides simple framework for reviewing parts suitability for AM
  - Based on parts analyzed, the SLM-280 2.0 was suitable for the most parts
- Nest Steps
  - Based on most suitable printer, how many of the test parts could be printed
  - Use Castor to test assemblies

Questions?

NSRP
NATIONAL SHIPBUILDING RESEARCH PROGRAM™
Taking Shipbuilding and Repair to the Next Level