University of the Aegean
Department of Shipping,
Trade and Transport

Digital Ship
CONFERENCE & EXHIBITION
Athens, 1 & 2 November 2017

Digital maritime Spare Parts: 3D printing shortens the supply chain

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Athens, 1 & 2 November 2017

Presentation Structure

THE AVAILABLE TECHNOLOGY
Definition - Processes-Materials

THE GROWTH OF THE ADDITIVE MANUFACTURING INDUSTRY

Lessons learned from the introduction of additive manufacturing in other industries

CHARACTERISTICS OF THE MARITIME SECTOR
Additive manufacturing in/and the shipping industry

The spare parts supply chain in the shipping industry

Discussion - Conclusion

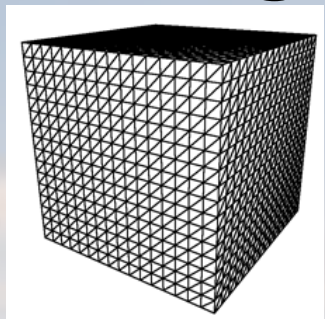
Subtractive –Additive Manufacturing

http://www.techshop.ws

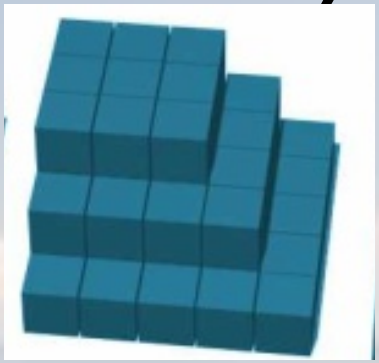
http://www.dmgmori.com/webspecial/journal_2014_1/us-EN/lasertec-65.htm

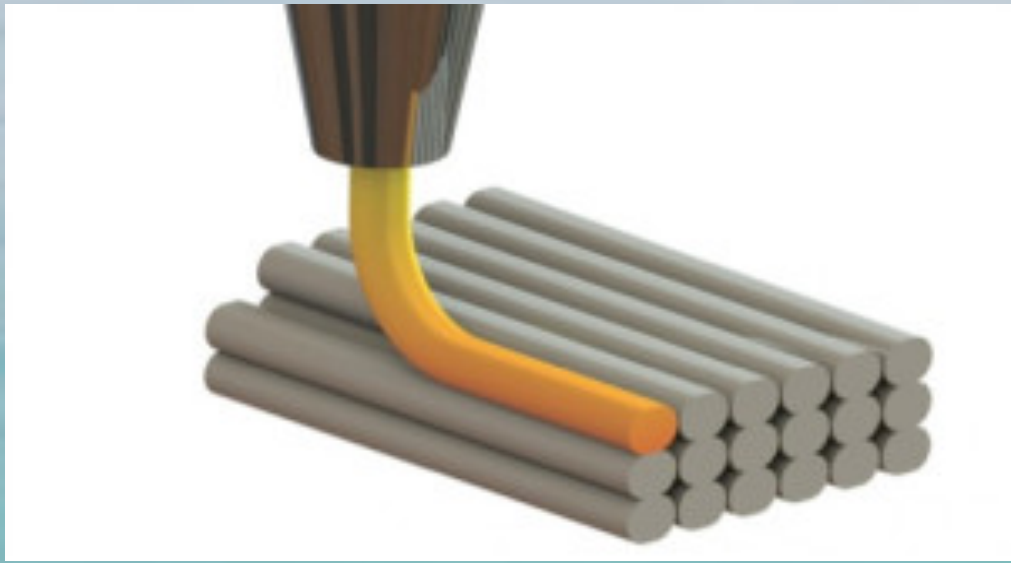
Additive manufacturing *(ASTM F2792)*

is the process of **joining materials to make objects from 3D model data,** usually **layer upon layer,** as opposed to subtractive manufacturing methodologies.

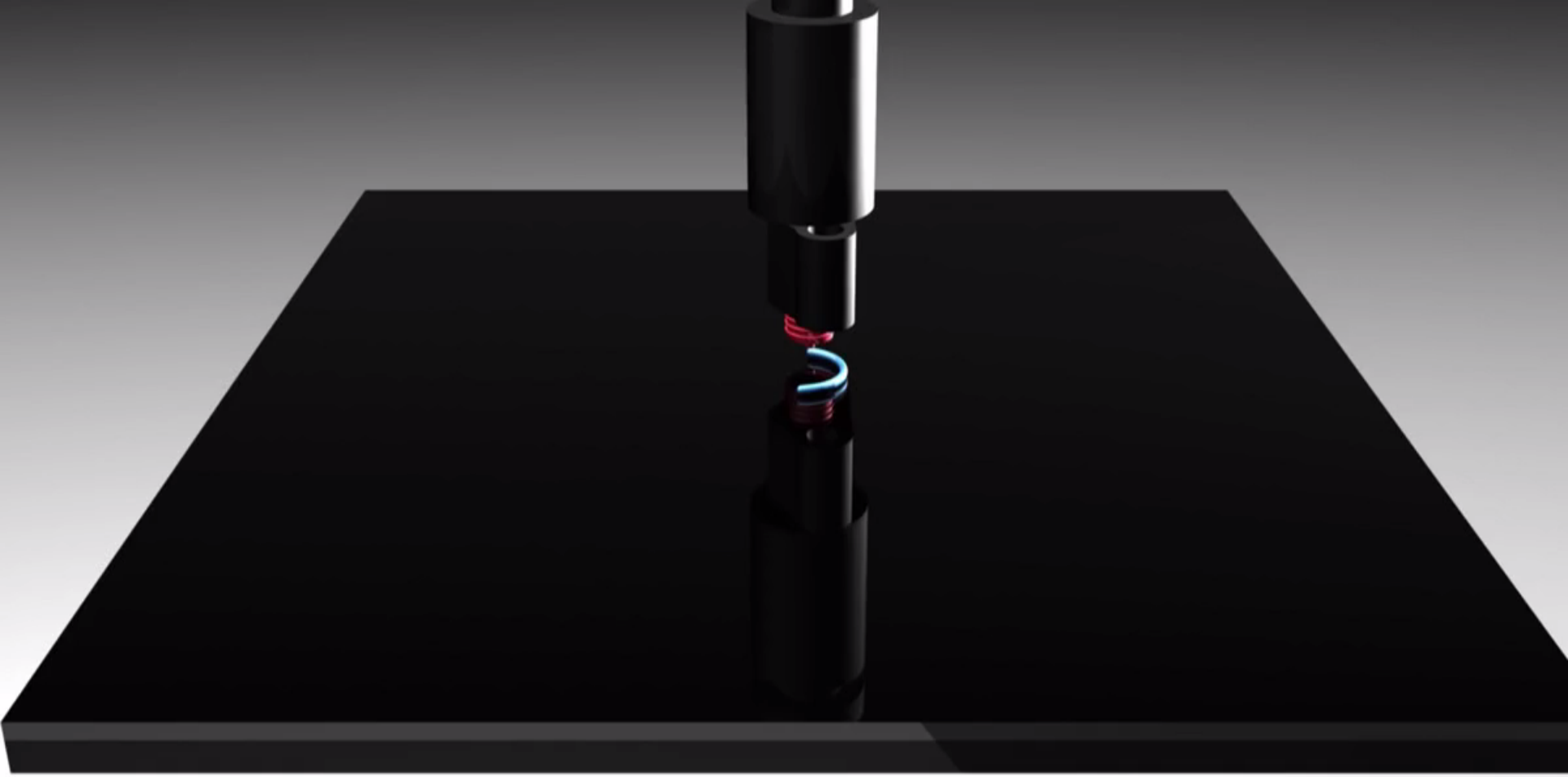


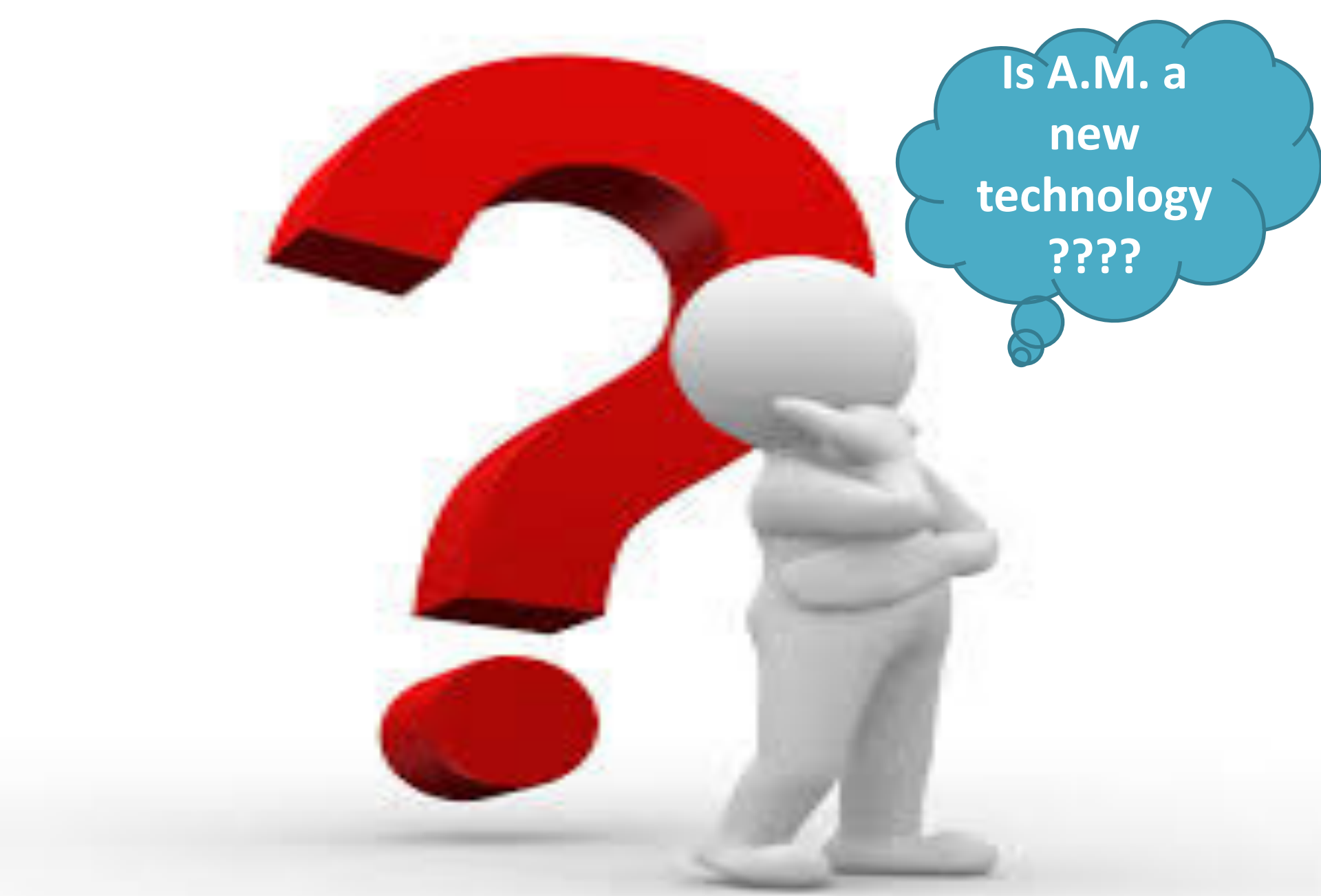
Triangular mesh





http://www.brdisolutions.com/about-3-d-printing-aka-additive-manufacturing




Is A.M. a new technology ????

It is not too new!

Charles Hull

Stereolithography

1983

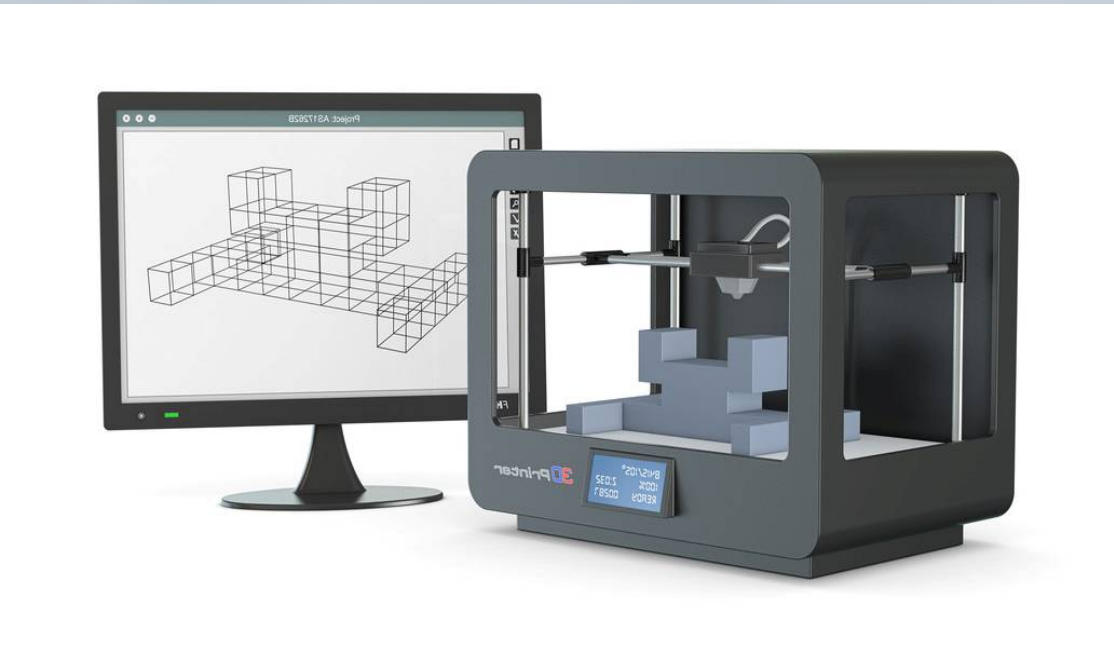
Hideo Kodama

Rapid prototyping

1980

From the digital design to manufacture

Digital design → **Physical object**



https://www.3dsupplyguys.com

From the digital design to manufacture

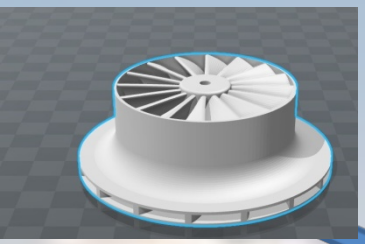
Digital design

Physical object

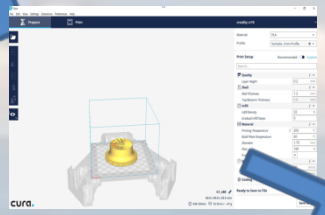
http://marketsreports.blogspot.gr/2014/03/additive-manufacturing-medical-devices.html

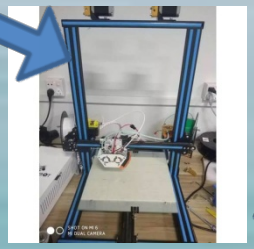
Exploring the Potential of 3D Printing of the Spare Parts Supply Chain by Evanthia Kostidi

From the digital design to manufacture



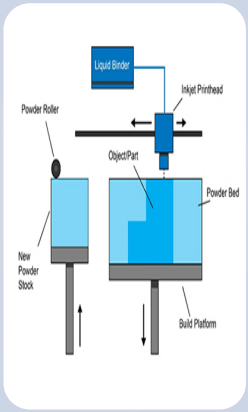
CAD to STL

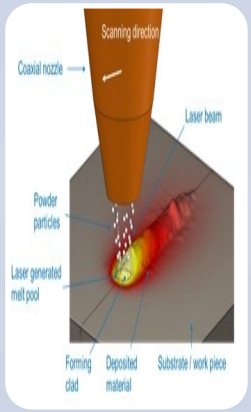


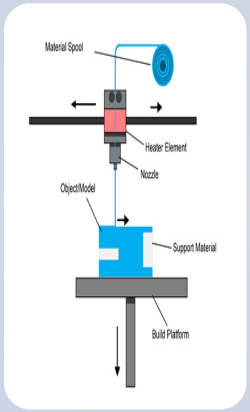


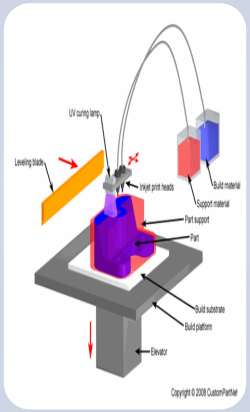
Physical object

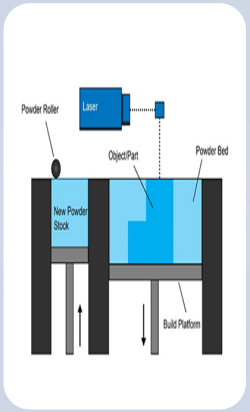
ASTM (2013) groups them in seven types

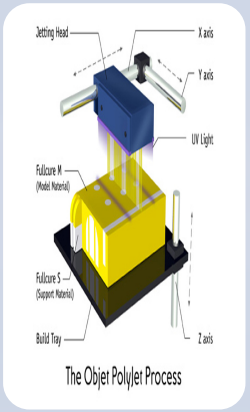












1) Binder jetting (3D printing)

–a liquid bonding agent is deposited

to join powdered materials together.

2) Direct energy deposition (direct manufacturing)

–thermal energy fuses or melts materials together as they are added

3) Material extrusion (fused deposition modeling) –allows for depositing material via a nozzle

4) Material jetting

-droplets of material are deposited

5) Powder bed fusion (laser sintering)

–thermal energy fuses or melts material from a powder bed.

6) Sheet welding - sheets of materials are Bonded together

7) Photo-polymerization (digital light processing) -liquid photopolymer in vat is cured by light.

ASTM (2013) groups them in seven types

In some processes the material is

-squirted,

-squeezed or

-sprayed

and in others

-fused,

-bind or

-glued.

The power source is

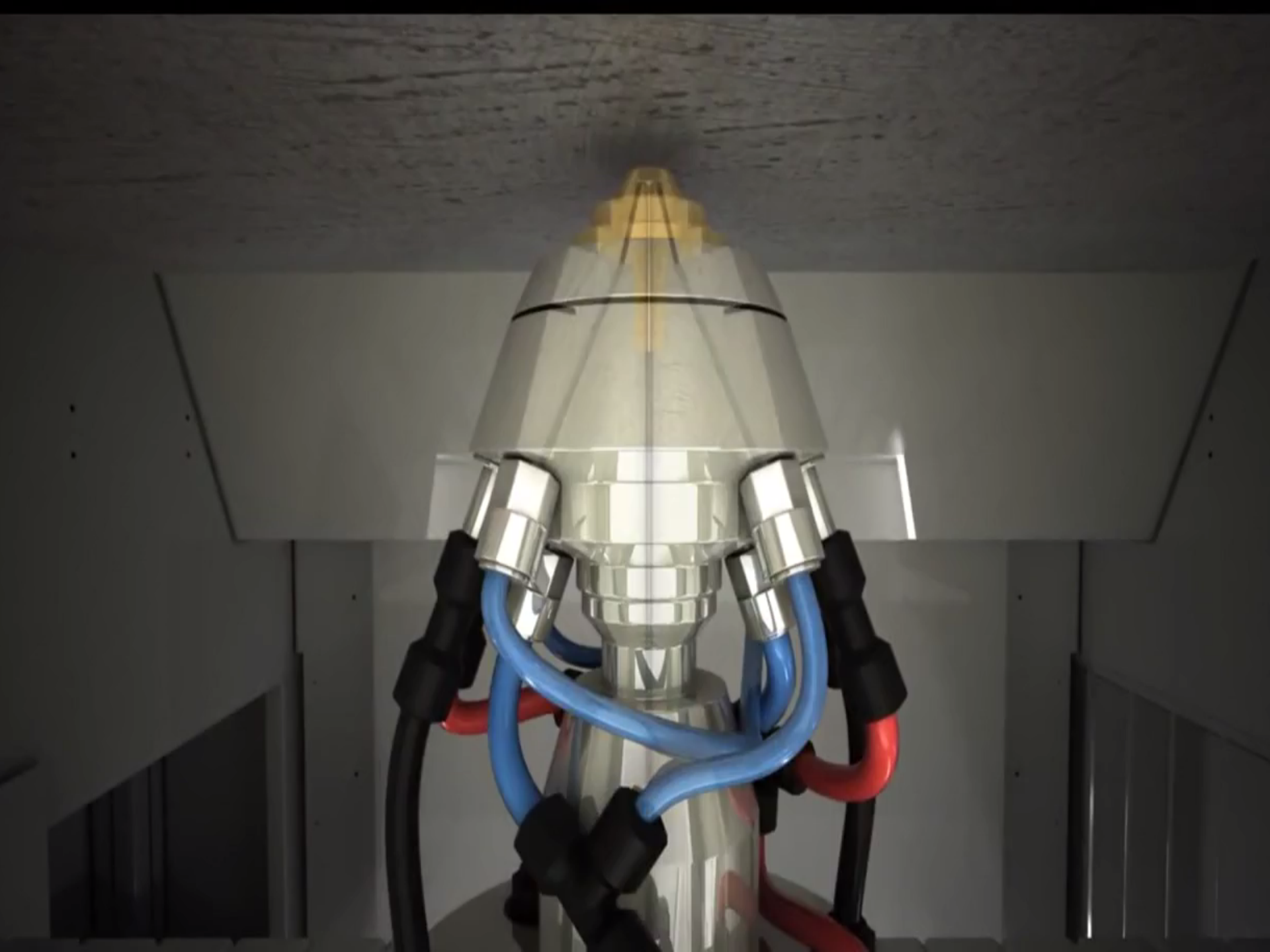
-thermal,

-high-powered laser beam,

-electron beam,

-ultraviolet laser,

-or photo curing.



Raw Materials for the process

ABS plus(Acrylonitrile butadiene styrene),pla,petg

metals

Pilot Project 3D printing of Marine spares

ceramics

biological materials

polymers

Ceramic filters

Photo: Shah TEAM 3dprint.com/29454/3d-printed-fuel-cells/

… Alloys

the most common metallic materials are:

steels (tool steel and stainless),

pure titanium and titanium alloys,

aluminum casting alloys,

nickel-based super alloys,

cobalt-chromium alloys,

gold, and

silver

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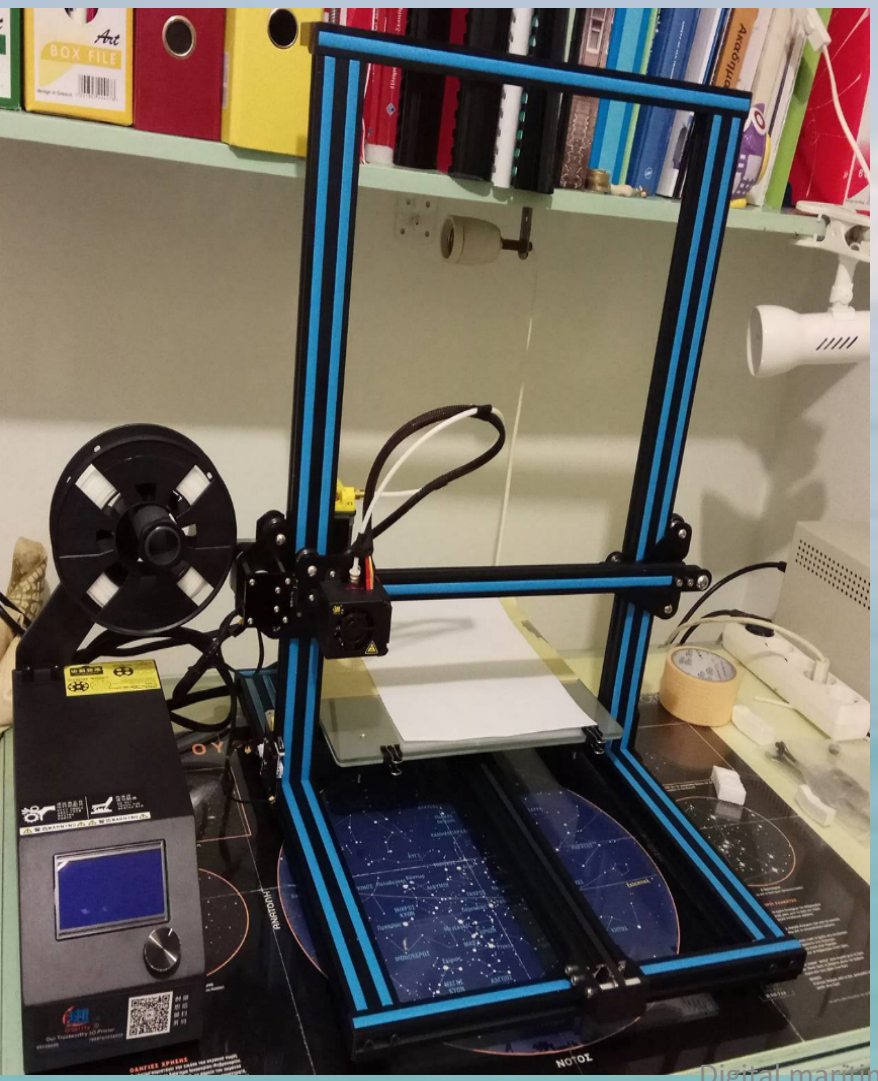
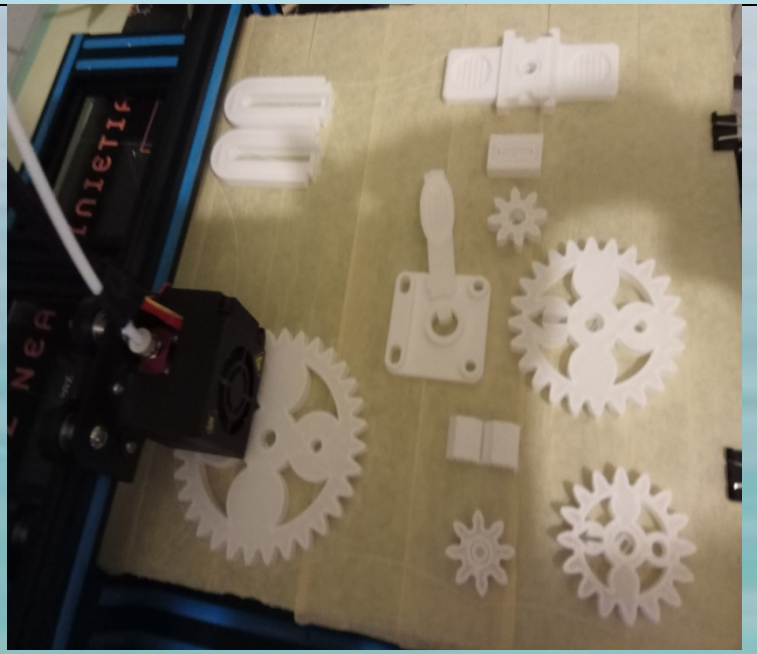
http://www.phenix-systems.com/en/materials

Capabilities



E.Kostidi personal 3d printer

It is an integrated production machine



Evanthia Kostidi 3d printing

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Capabilities

Freedom of complexity

http://www.engadget.com/2014/04/02/japan-3d-printer-alliance/

Capabilities

Offers flexibility

One machine many products

Evanthia Kostidi 3d printing

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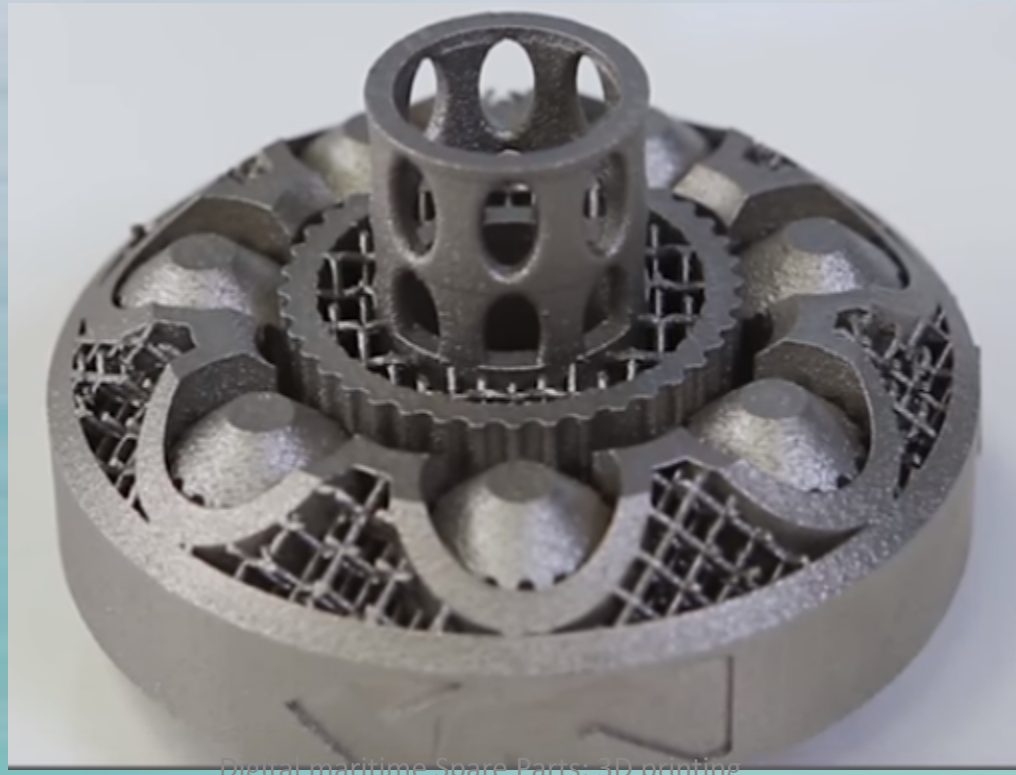
http://www.mtialbany.com/turbo-collector-project-stainless-steel-3d-printing/

Capabilities

Elimination of assembly



Evanthia Kostidi 3d printing

http://sintermedia.gkn.com

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Market size

3D Printing Industry

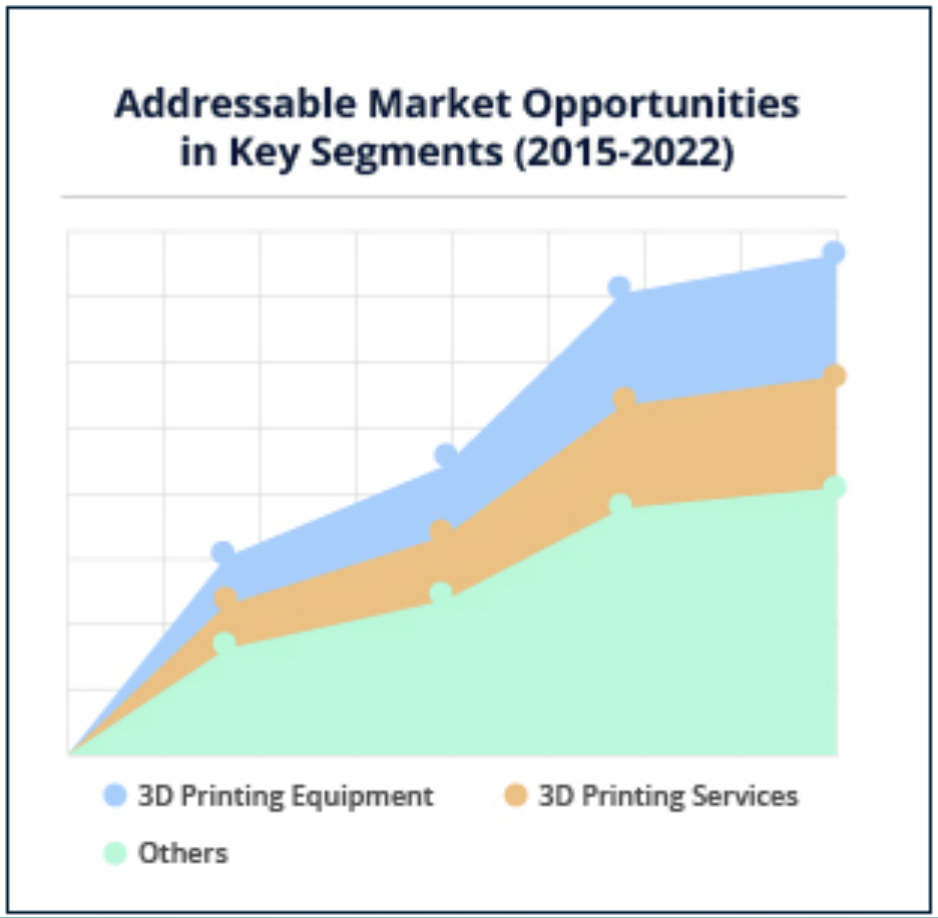
Surpassed $5.1 Billion

Digital maritime Spare Parts: 3D printing shortens the supply chain by Evanthia

(Wohlers Report 2016)

www.forbes.com/.../wohlers-report-2016-3d-printer-**industry**-surpassed-5-1-billion/

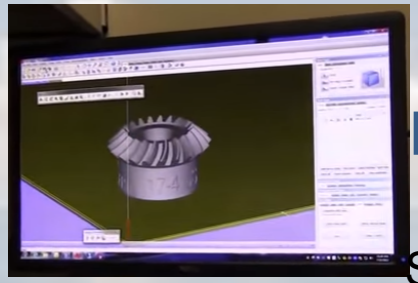
The global market for 3D Printing is projected to reach US$16.8 billion by 2022 (Published April 2017)



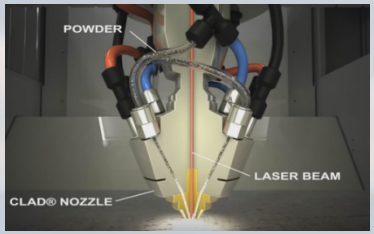
http://www.strategyr.com/Marketresearch/3D_Printing_Market_Trends.asp

Impact

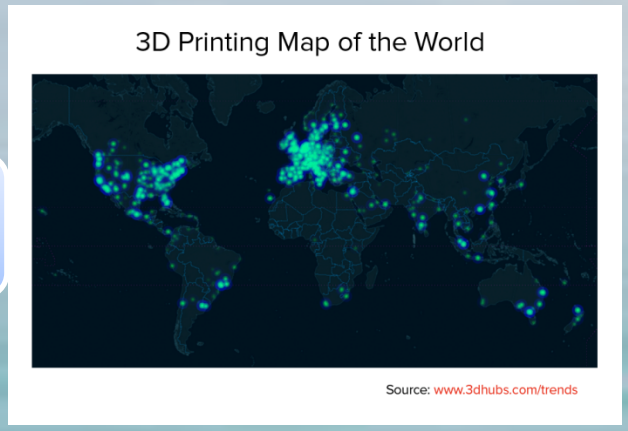
Market structure



Sale before production



Decentralized production



Impact on transportation

Environmental impact

Industries with similar characteristics (moving assets) to maritime industry

- Automotive (truck manufacturer)
- Aircraft industry
- Aerospace industry
- Defence

Lessons learned from the introduction of additive manufacturing in other industries(2)

Additive manufacturing is a promising technology

The inventory costs for low turnover spare parts
can be lowered and at the same time increase in customer service.

AM could be beneficial for low demand, single-item situations,
if it is difficult to make it otherwise.

Lessons learned from the introduction of additive manufacturing in other industries(3)

The centralized production of spare parts is most likely to succeed.

The total inventory of spare part can be significantly reduced using additive manufacturing.

The most important goal is to secure the supply of spare parts, followed by respectively improving service and reducing costs.

CHARACTERISTICS OF THE MARITIME SECTOR

Maritime assets are capital intensive and downtime has financial consequences.

Operate away from the base in remote areas and are in constant movement.

Maintenance networks involve many actors

The IMO and classification societies impose rules.

Spare parts supply may involve emergency transport.

Assets can be classified as long-lived.

The apparatus is in an environment that is highly corrosive, with vibrations & shocks.

Additive manufacturing in/and the shipping industry
Port of Rotterdam

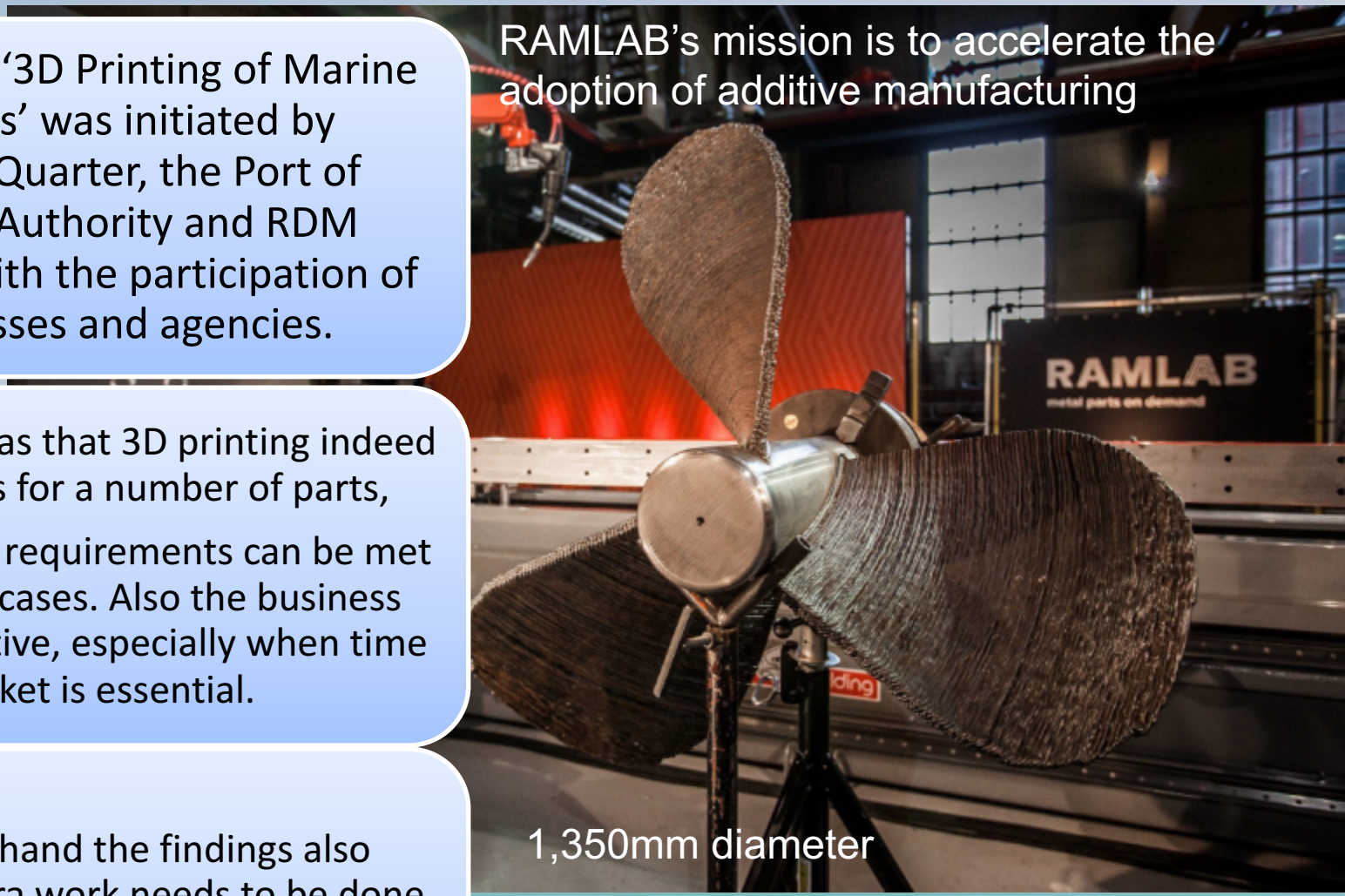
A pilot project '3D Printing of Marine Spare Parts' was initiated by Innovation Quarter, the Port of Rotterdam Authority and RDM Makerspace with the participation of 28 businesses and agencies.

The conclusion was that 3D printing indeed holds promises for a number of parts,

and that product requirements can be met in a number of cases. Also the business case can be positive, especially when time to market is essential.

On the other hand the findings also indicate that extra work needs to be done

to get regulations adjusted to be able to qualify 3D printed parts.



https://3dprint.com/172387/ramlab-autodesk-propeller/

(Zanardini, Bacchetti, Zanoni, & Ashourpour, 2016).

tens the supply chain by Evanthia Kostidi

Additive manufacturing in/and the shipping industry

MAN Diesel & Turbo

MAN Diesel & Turbo claims that they are the first manufacturer in the world to use complex 3D-printed metallic components not only for test runs but also for serial production.

From the 3D printer to patent pending: Guide vane segment for a MAN Diesel & Turbo gas turbine

"MAN Center for Additive Manufacturing," will to extend to further components and products, for example compressor impellers or fuel nozzles for engines.

Additive manufacturing in/and the shipping industry(2)

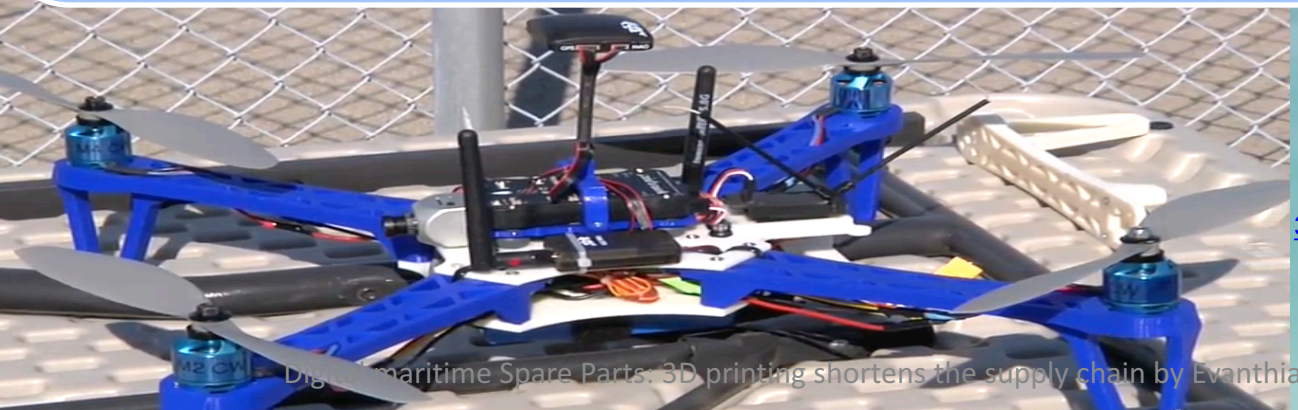
US Navy

US Navy has already tested the technology for maintenance activities.

The reason why AM technologies are under evaluation is

the possibility to reduce the time to supply spare parts and components to remote zone,

eliminating unnecessary actors and lead time.



3dprint.com

(Scheck et al., 2016)

Green Ship of the Future (2016)(4)

20+ industry partners have explored the opportunity space of the technology and derived opportunities for the maritime industry.

They end up with the need to explore how shipping and the maritime industry can be on the forefront of development and be part of the disruption.

greenship.org

Additive manufacturing in/and the shipping industry(3)

developed the following: a theoretical supply chain model with a deeper elaboration of the different roles of spare parts .

Additive manufacturing in/and the shipping industry(5)

http://www.3ders.org

Hyundai Heavy hopes to print multiple ship components by 3D printers, in order to save time and money in the process of production and promote the industry

Additive manufacturing in/and the shipping industry(6)

http://www.3ders.org/articles/20170206-siemens

Siemens is using EOS metal printers to print gas turbine components

Impact of 3d printing on supply chain(1)

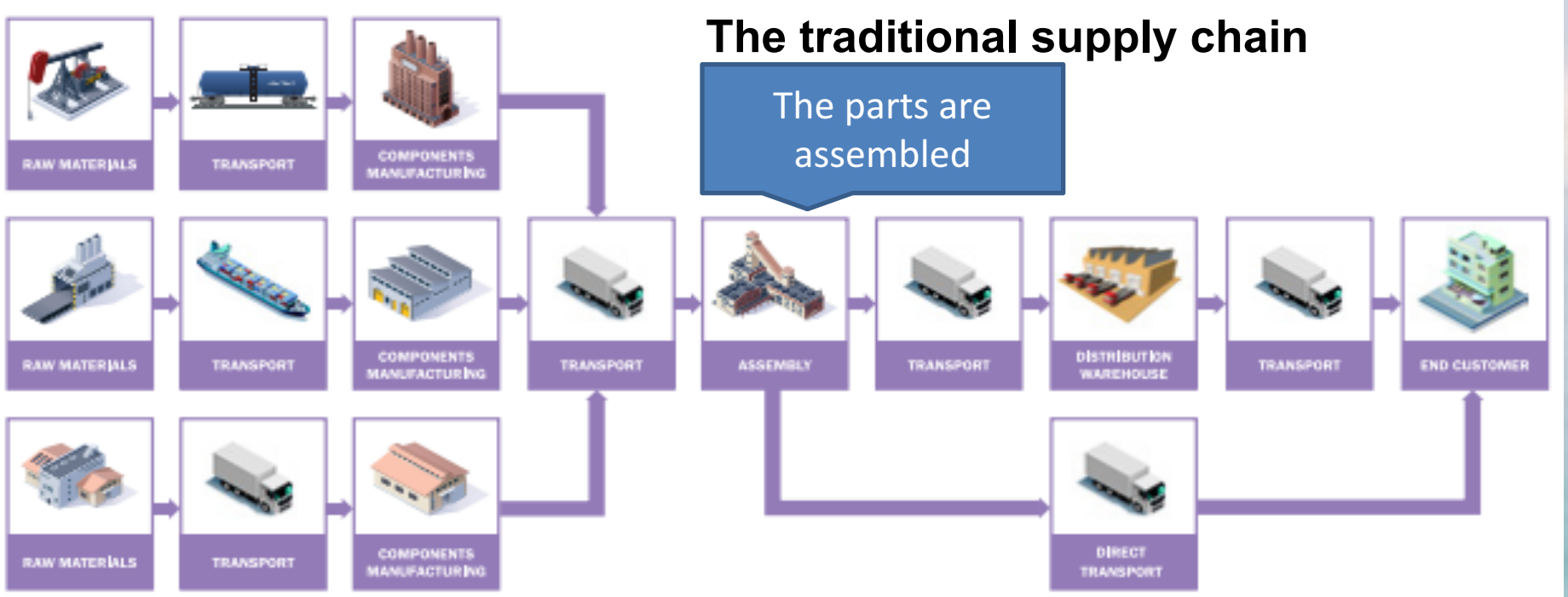


Figure 8: Simplified traditional supply chain network structure

(Janssen et al. 2014)

Impact of 3d printing on supply chain(2)

With 3d printing

No assembly

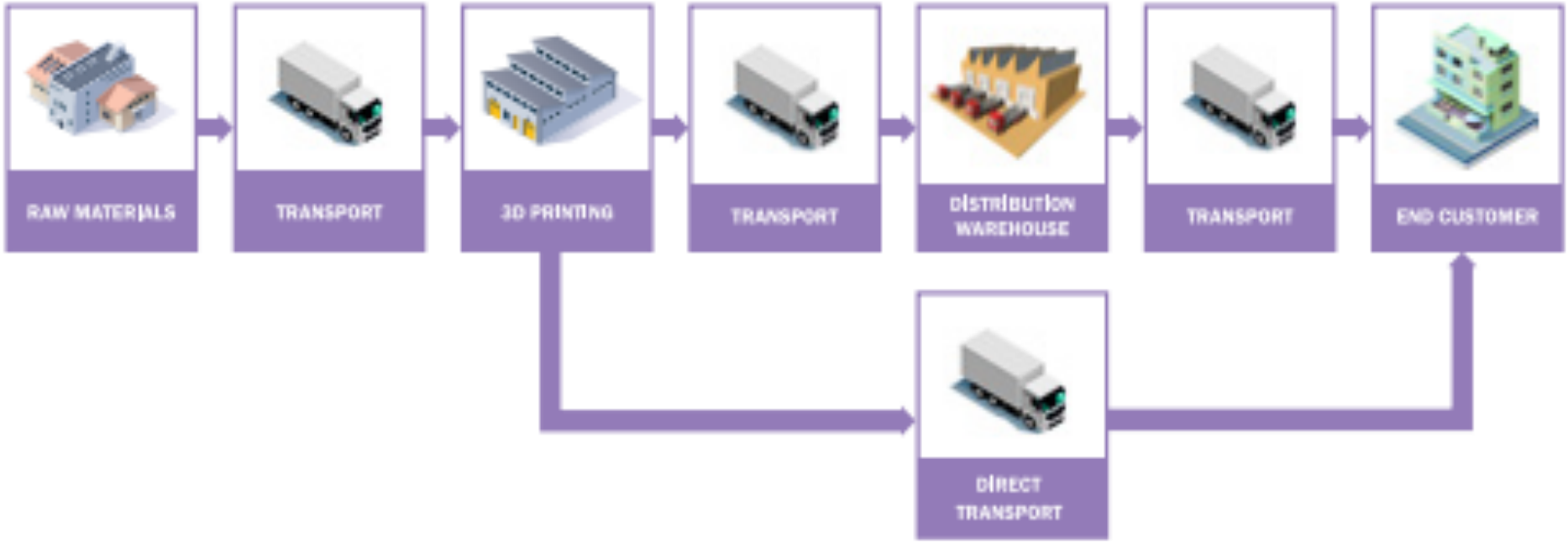


Figure 9: Supply chain network structure with 3-D printing competence

(Janssen et al. 2014)

The spare parts supply chain in the shipping industry

Ship (Position A)

Ship (Position B)

Technical Dep.

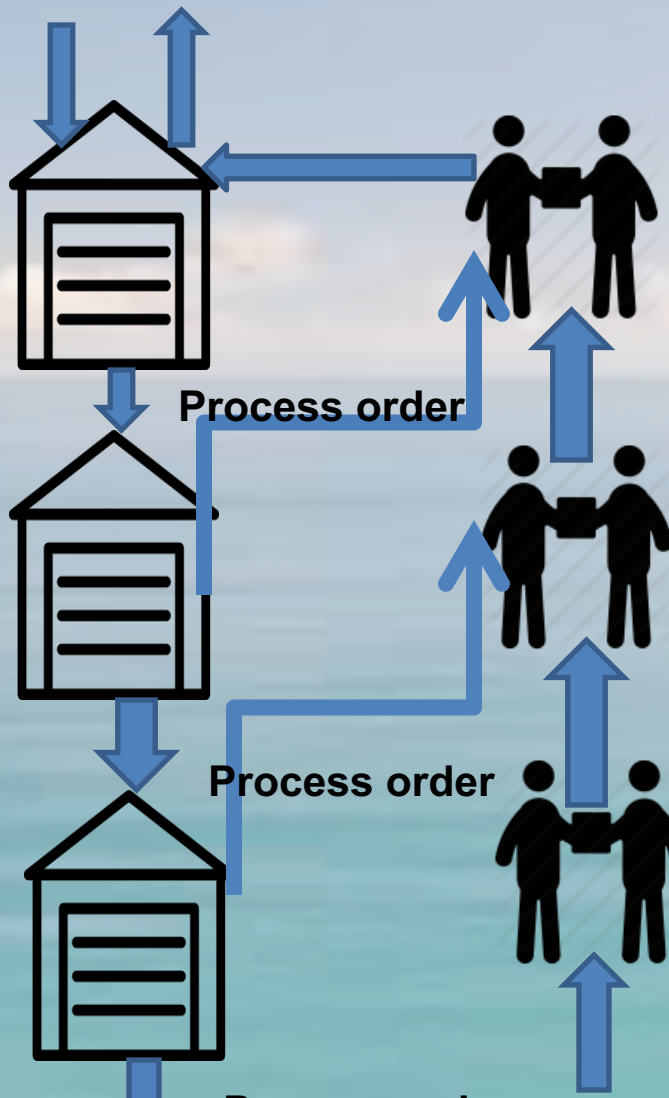
Land office

Procurement Dep.

Supplier

(E. Kostidi)

Local, Regional or Central Inventory



(E. Kostidi)

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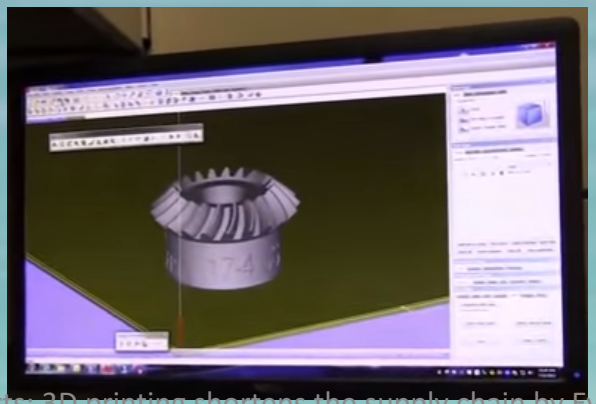
Spare parts manufacturing

Instead of inventory

+



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ww.windindustrial.com/3d-metal-powder.html

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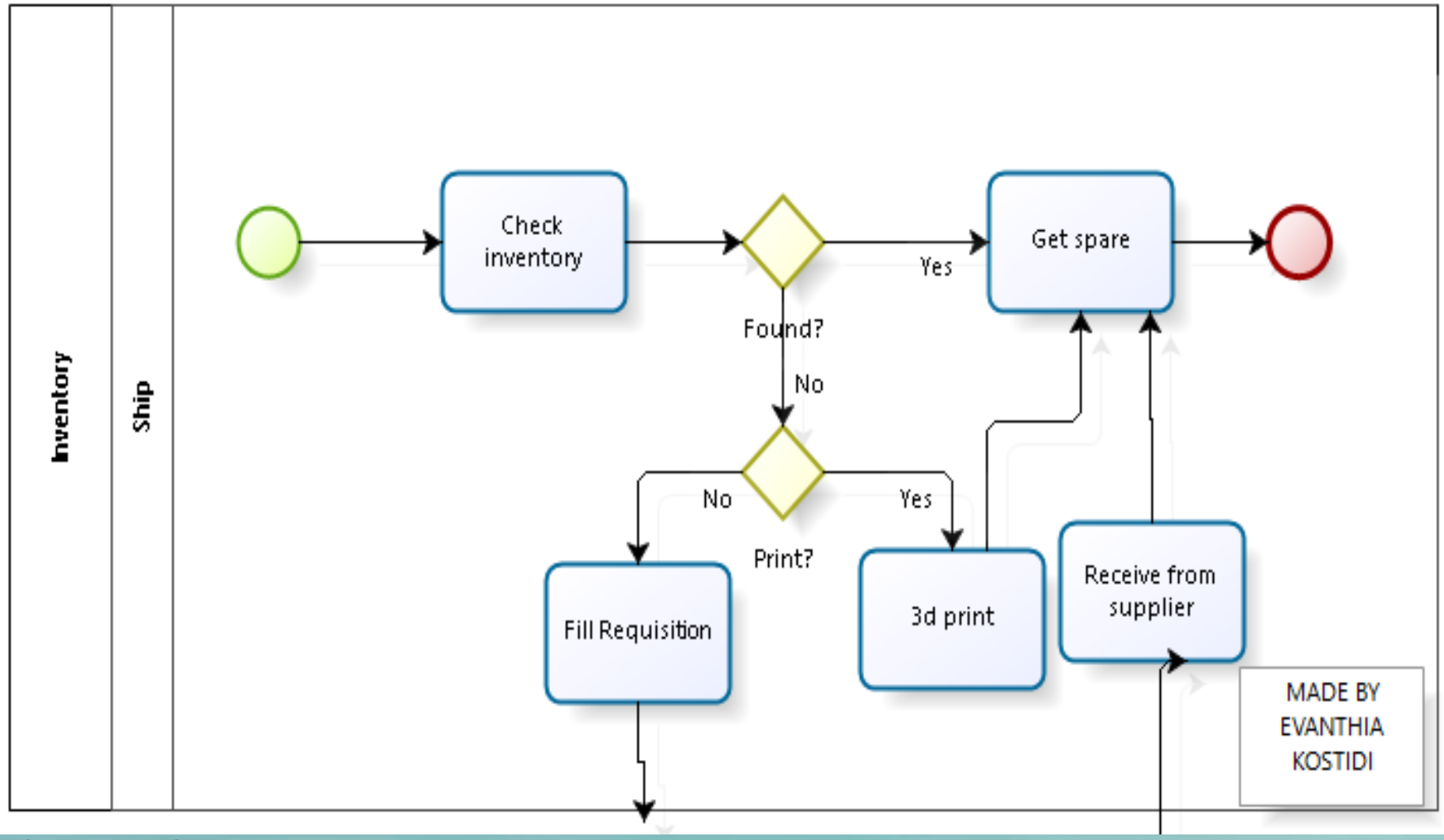
https://www.youtube.com/watch?v=rEfdO4p4SFc

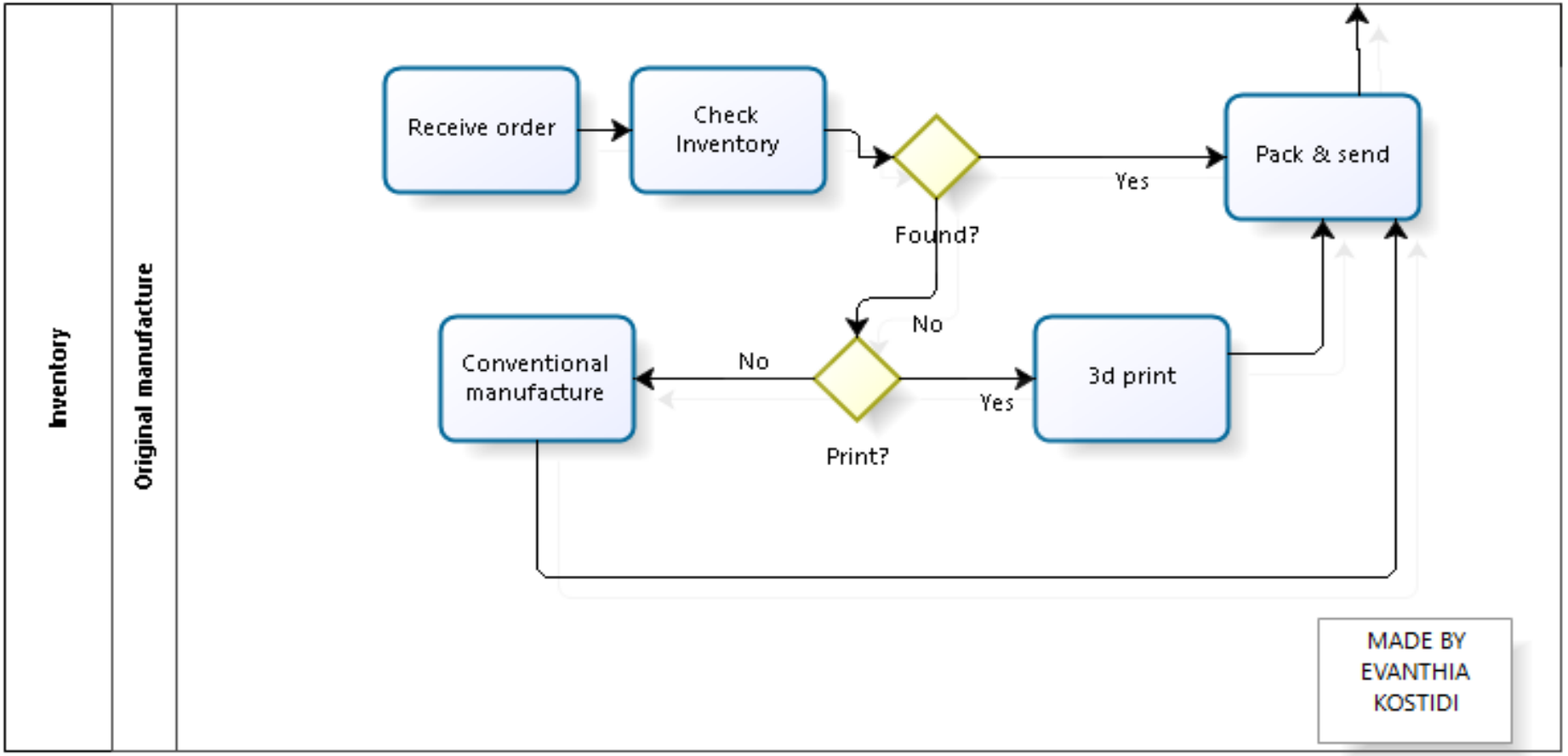
(3D PRINTING) An alternative new technology future scenario



(E. Kostidi)

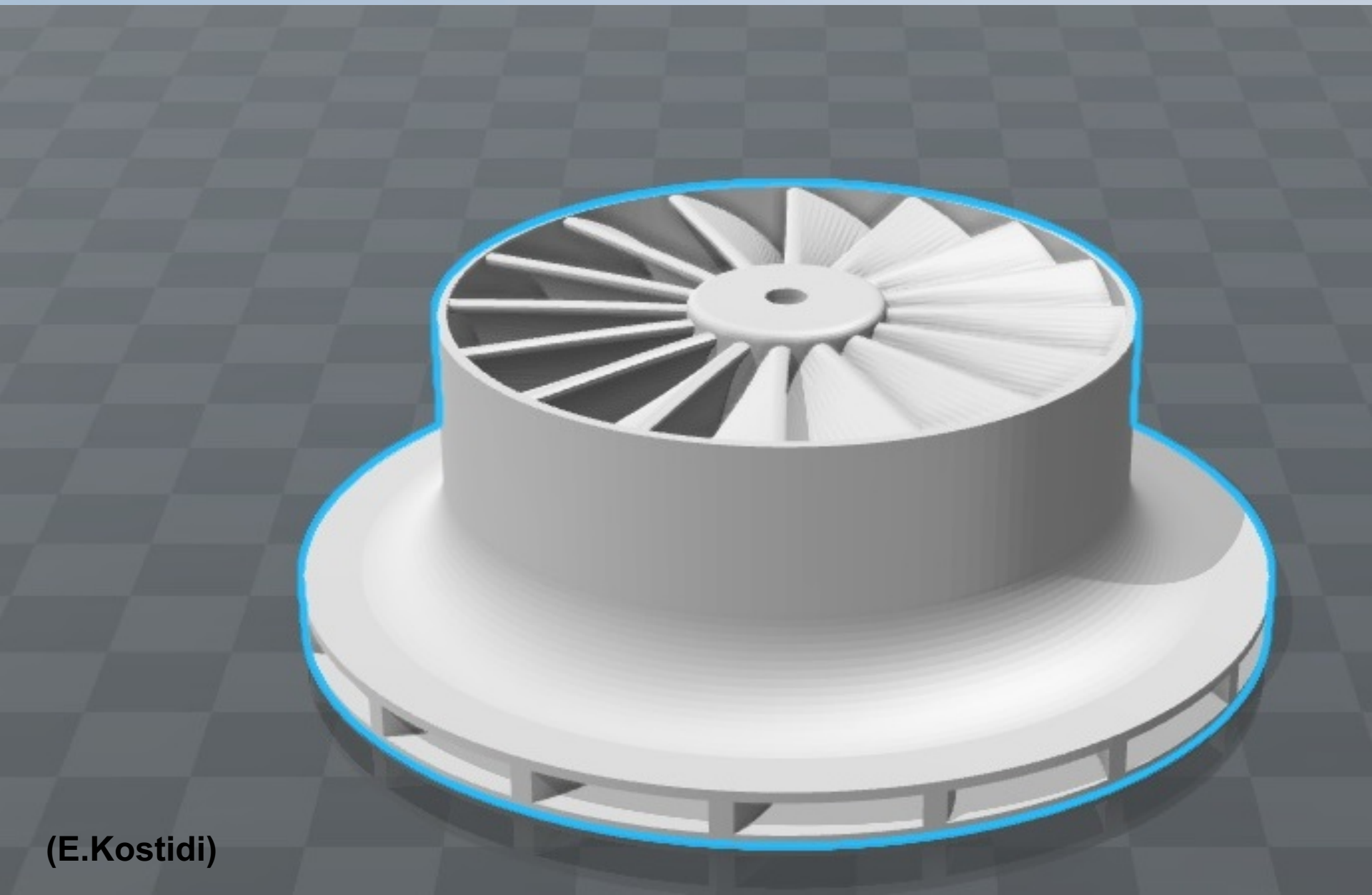
To Be scenario at the manufacturer

Conventional Or 3d printing



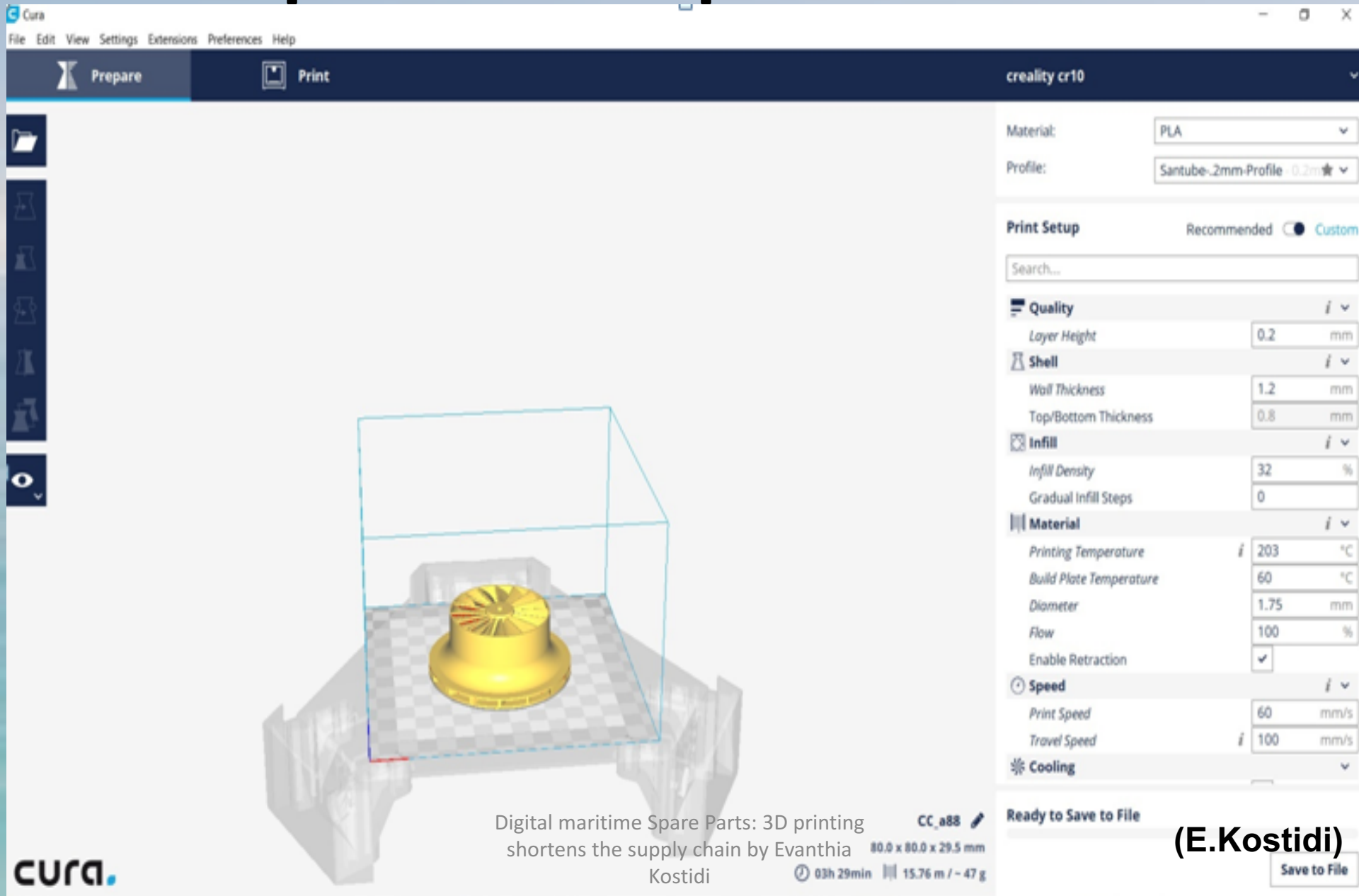
Case study

Impeller 3d file



(E.Kostidi)

Impeller to 3d printable file



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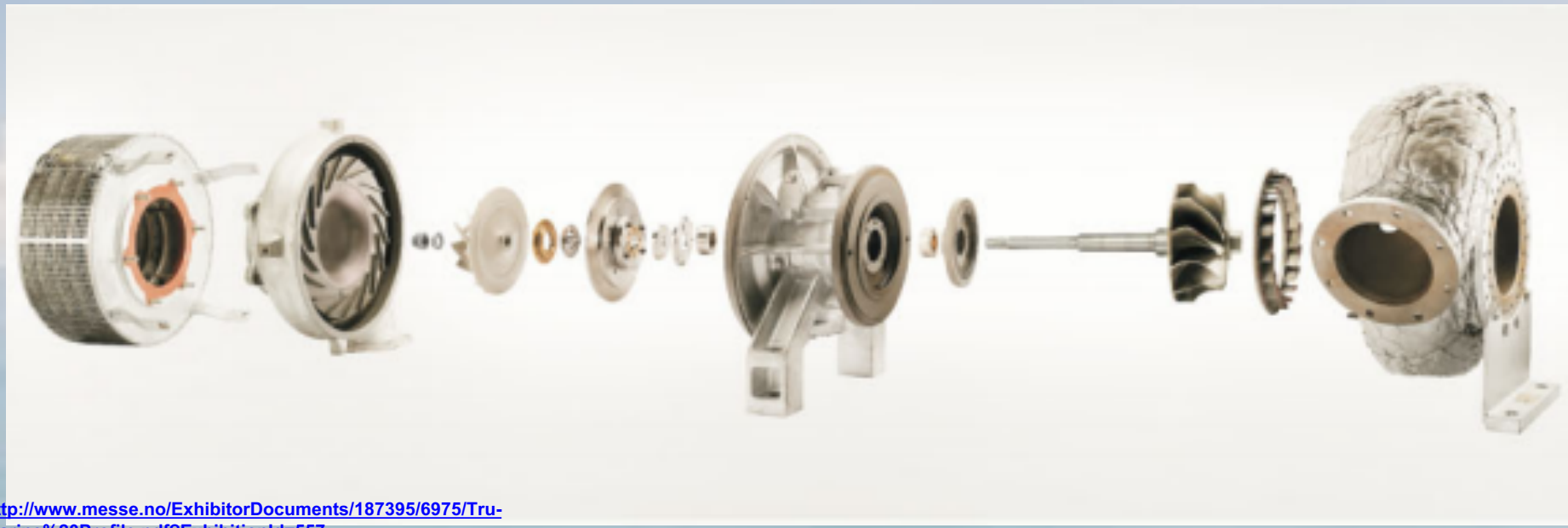
(E.Kostidi)

Impeller final item

(E.Kostidi)

Commercial case



http://www.messe.no/ExhibitorDocuments/187395/6975/Tru-Marine%20Profile.pdf?ExhibitionId=557

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Damaged and refurnished part (Tru-Marine)

Discussion

Most of the people we talked (semi structured interview) had an idea of what 3D printing is

(we did not ask about AM).

Almost all had a positive attitude for the new technology

and the rest were sceptical, but not negative.

Their main concern was if the spare part made by the AM

is comparable with the part made by the traditional method.

Another concern was the cost of the AM machine, and

the cost to build the part.

Overcoming skepticism

Overcoming skepticism

Is a spare part made by the AM

comparable with the part made by the traditional method?

Standards for the materials

	Material	DIN
Aluminium Alloys	AlSi10Mg	3.2381
	AlSi7Mg	3.2371
	AlSi12	3.3581
Cobalt Based Alloys	ASTM F75	2.4723
	CoCrWC	
Tool Steels	AISI 420	1.2083
	Marage 300	1.2709
	H13	1.2344
	AISI D2	1.2379
	AISI A2	1.2363
	AISI S7	1.2357
Nickel Based Alloys	Inconel 718	2.4668
	Inconel 625	2.4856
	Inconel 713	2.4670
	Inconel 738	
	Hastelloy X	2.4665
Stainless Steels	SS 304	1.4301
	SS 316 L	1.4404
	SS 410	1.4006
	SS 440	1.4110
	15-5 PH	1.4540
	17-4 PH	1.4542
Titanium Alloys	Titanium Grade 2	3.7035
	Ti6Al4V	3.7165
	Ti6Al4V ELI	3.7165 ELI
	TiAl6Nb7	
Precious Metal Alloys	Jewellery Gold	18 Carat
	Silver	930 Sterling
Copper Alloys	CC 480 K	2.1050

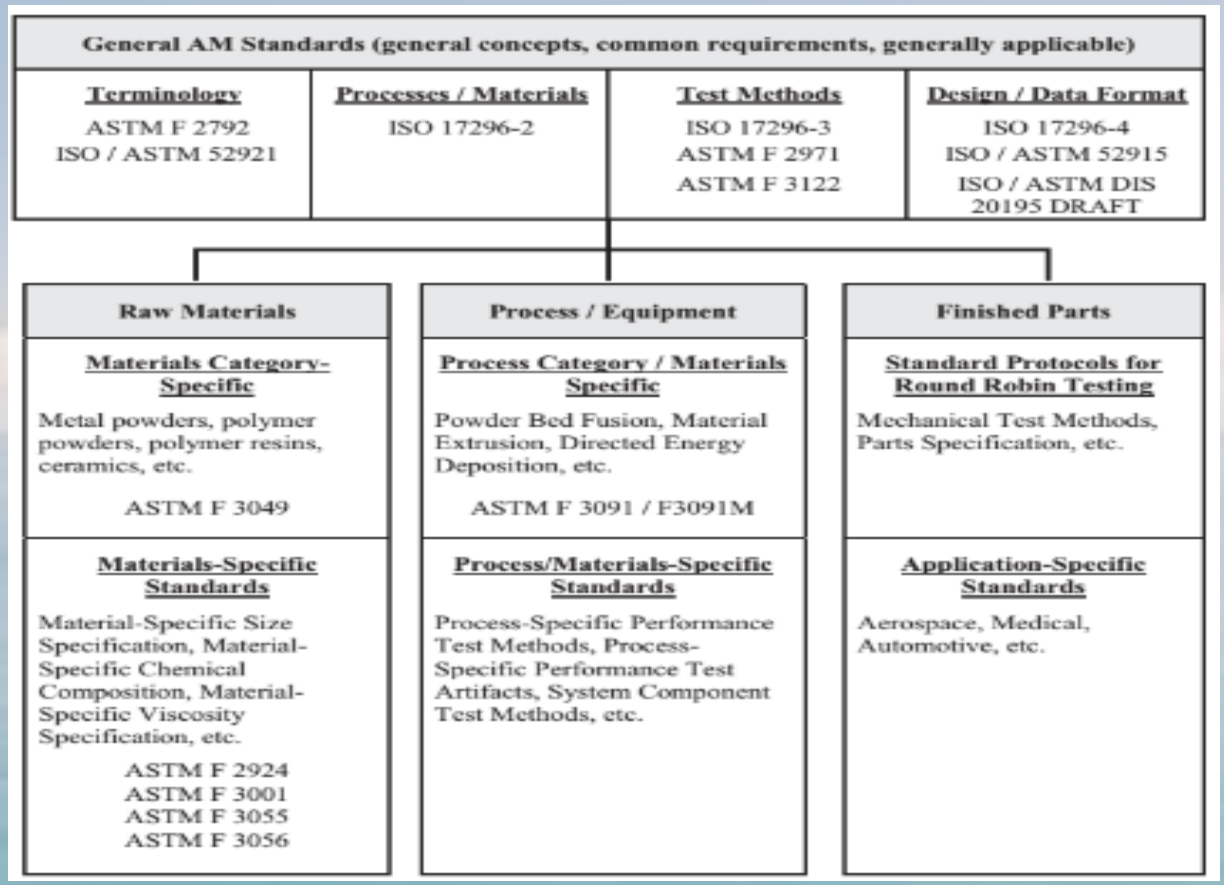
ASTM and ISO Standards

ISO/TC 261 and ASTM F42 joint plan

for AM Standards work in the direction

to assure that there will be methods

to test processes and parts.



ASTM και ISO prototypes of A.M. (Thompson et al., 2016).

ASTM INTERNATIONAL
Standards Worldwide

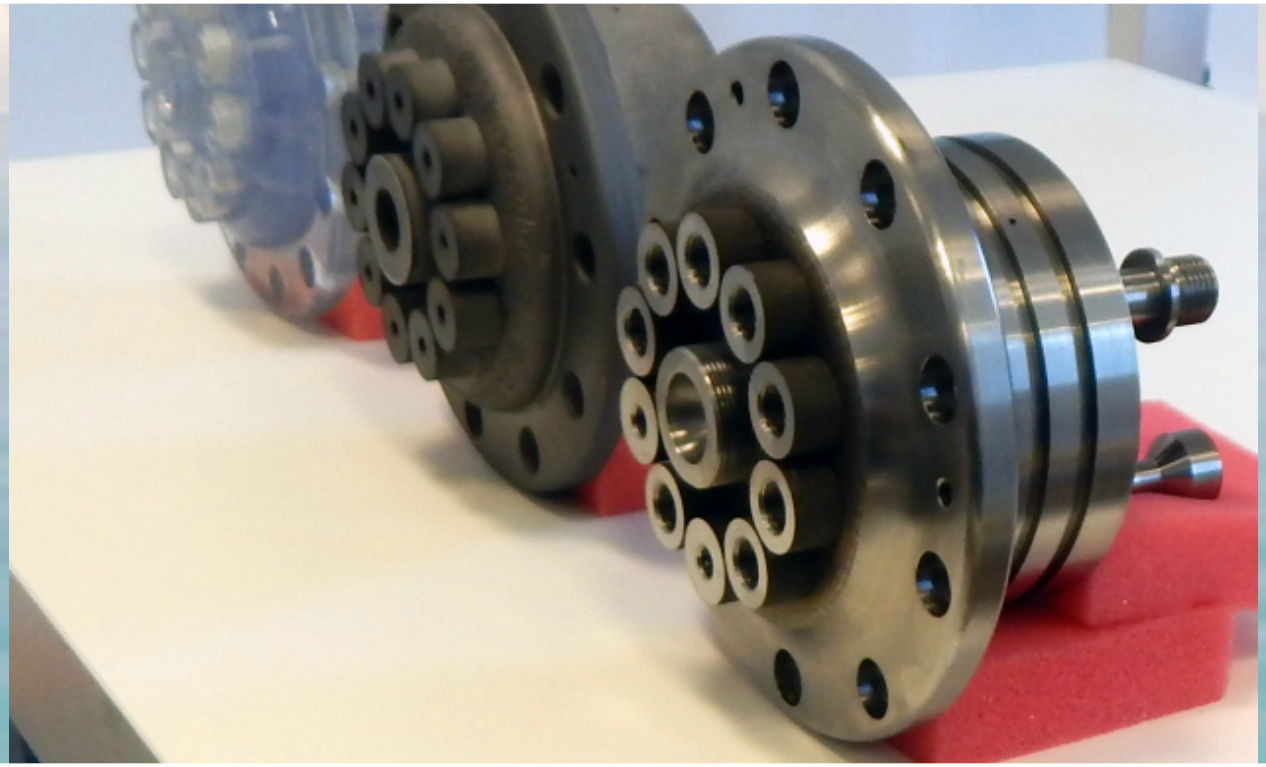
ISO International Organization for Standardization

Lloyd's Register Energy

Lloyd's Register Energy

Part certified

Lloyd's Register (LR) announces the first certification of a part produced through additive manufacturing (AM) for the oil and gas industry (5 September 2017)



From left to right, Safer Plug's gateway manifold is show in three states of manufacture: Transparent stereolithographic prototype, additively manufactured in titanium but not machined, and the final, machined titanium part.

Overcoming skepticism

The cost of the AM machine, and the cost to build the part.

as the market advances, patents expire, and demand grows,

the machine cost as well as the production cost will fall.

Further Research

Which of the processes best suits the installation on board a ship?

How will the intellectual rights be protected?

How the required files will be distributed?

Where in the supply chain is optimum to have the AM of the parts?

How will the personnel be trained in the new technology, taking into consideration that

the salesman at the supplier will be made manufacturer?

Summing up

The shipping industry can learn from other industries that already adapted AM in one way or the other, but further study that will take into consideration the special characteristics is needed.

Thank you