

Additive Manufacturing/3D Printing in Shipping Industry Opportunities and Challenges

Dr Jilin Ye

Jilin.Ye@Solent.ac.uk

Main Contents

- **Introduction to AM**
 - **Principles of AM technologies**
 - **State-of-the-art AM technologies**
 - **Applications of AM technologies**
- **AM in shipping industry**
 - **Issues in shipping industry**
 - **AM opportunities in shipping**
 - **AM challenges in shipping**

AM Terminologies

- **3D Printing (3DP)**
- **Rapid Prototyping (RP)**
- **Rapid Manufacturing (RM)**
- **Direct Manufacturing (DM)**
- **Additive Fabrication (AF)**
- **Layered-Based Manufacturing (LBM)**
- **Freeform Fabrication (FFF)**
- **e-Manufacturing**
- **...**

What is AM?

Definition (ASTM International)

Process of joining materials to make objects from 3D model data, usually layer upon layer, as opposite to subtractive manufacturing methodologies

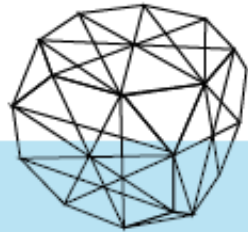


AM Basis: 5-Step Process



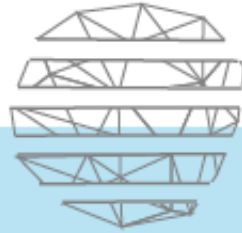
1

CAD-based
3D model



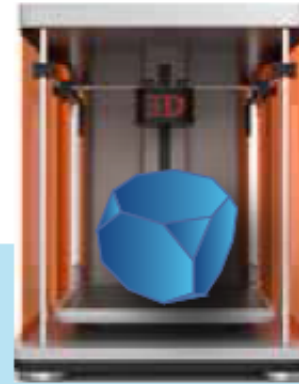
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.STL file



3

Sliced layers



4

AM system



5

End-part
finishing

AM Processes (by Material Types)

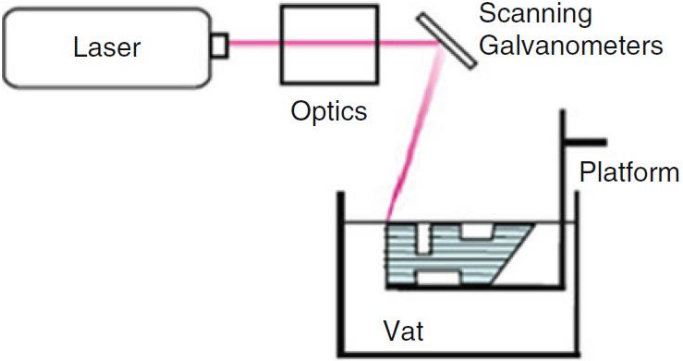
- **Liquid material-based:** Stereolithography and mask projection stereolithography
- **Powder material-based:** Selective laser sintering and three-dimensional printing
- **Molten material-based:** Fused deposition modelling and droplet deposition printing
- **Solid material-based:** Laminated object manufacturing

AM Processes (by ASTM F42)

Total 7 AM process types defined by ASTM F42

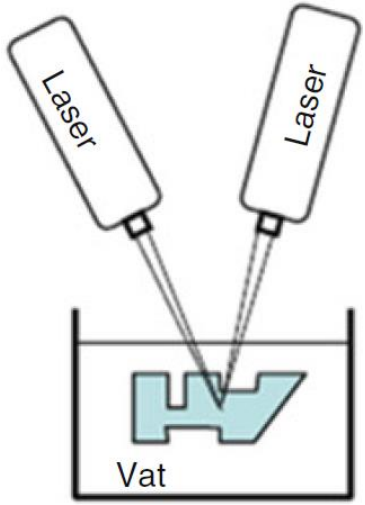
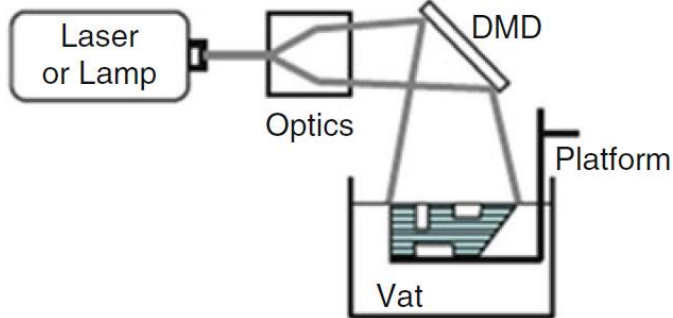
Process Type	Technique Definition	Example Technology	Material
Vat Photopolymerisation	Liquid photopolymer in a vat is selectively cured by light-activated polymerisation.	Stereo lithography (SLA), digital light processing (DLP)	Polymers and ceramics
Material Jetting	Droplets of build material are selectively deposited.	3D inkjet printing	Polymers and composites
Binder Jetting	Liquid bonding agent is selectively deposited to join powder materials.	3D inkjet printing	Metals, polymers, and ceramics
Material Extrusion	Material is selectively dispensed through a nozzle or orifice.	Fused deposition modelling (FDM)	Polymers
Powder Bed Fusion	Thermal energy selectively fuses regions of a powder bed.	Selective laser sintering (SLS), Selective laser melting (SLM), electron beam melting (EBM)	Metal, polymer, composites and ceramics
Sheet Lamination	A process in which sheets of material are bonded to form an object.	Ultrasonic Consolidation (UC)	Hybrids, metals and ceramics
Directed Energy Deposition	A process that focused thermal energy and fuses materials by melting as the material is being deposited.	Laser metal deposition (LMD)	Metals and hybrid metals

Liquid Material-based Processes



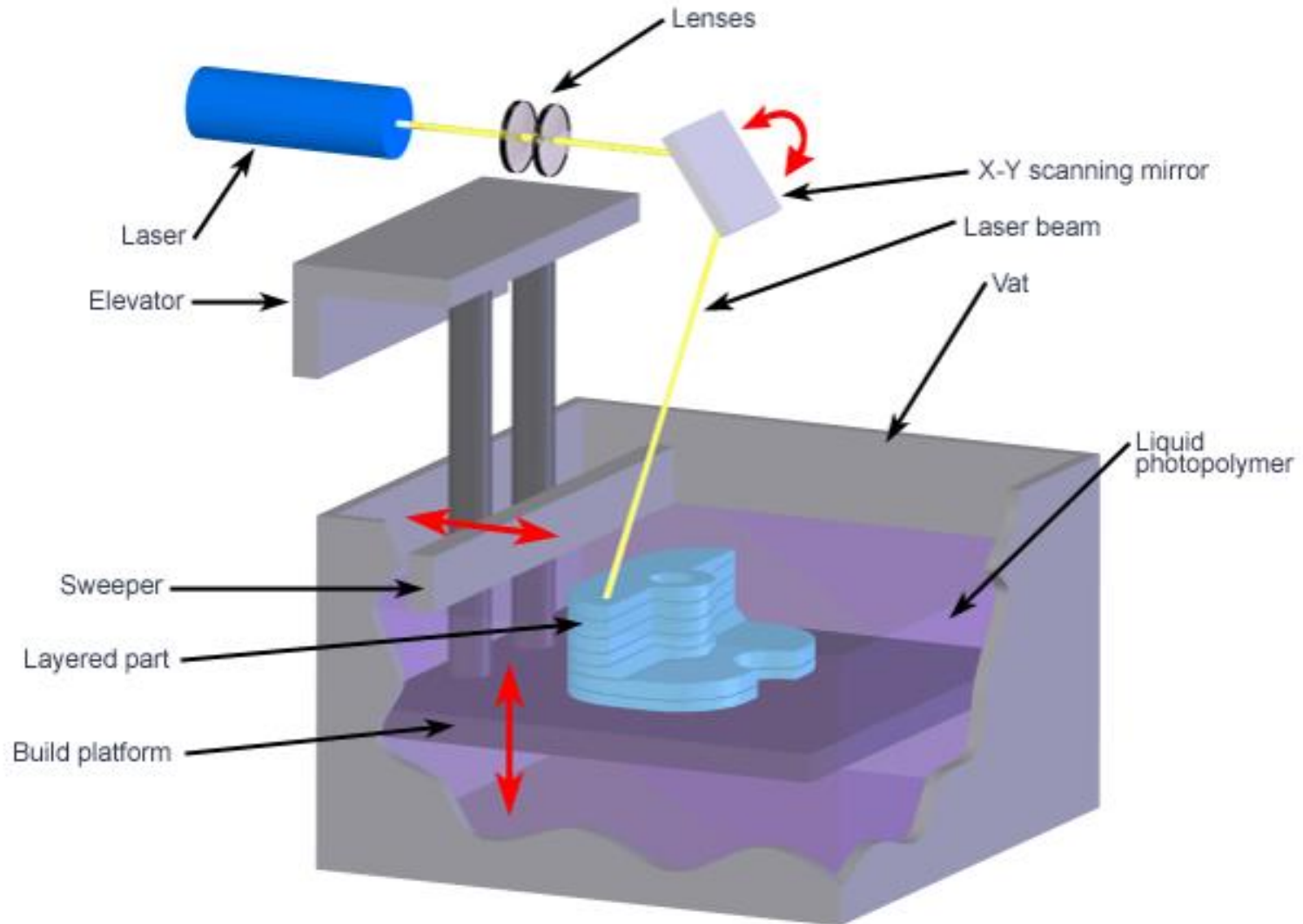
- **Vector scan stereolithography (SL)**

- **Mask projection approach**



- **Two-photon approach**

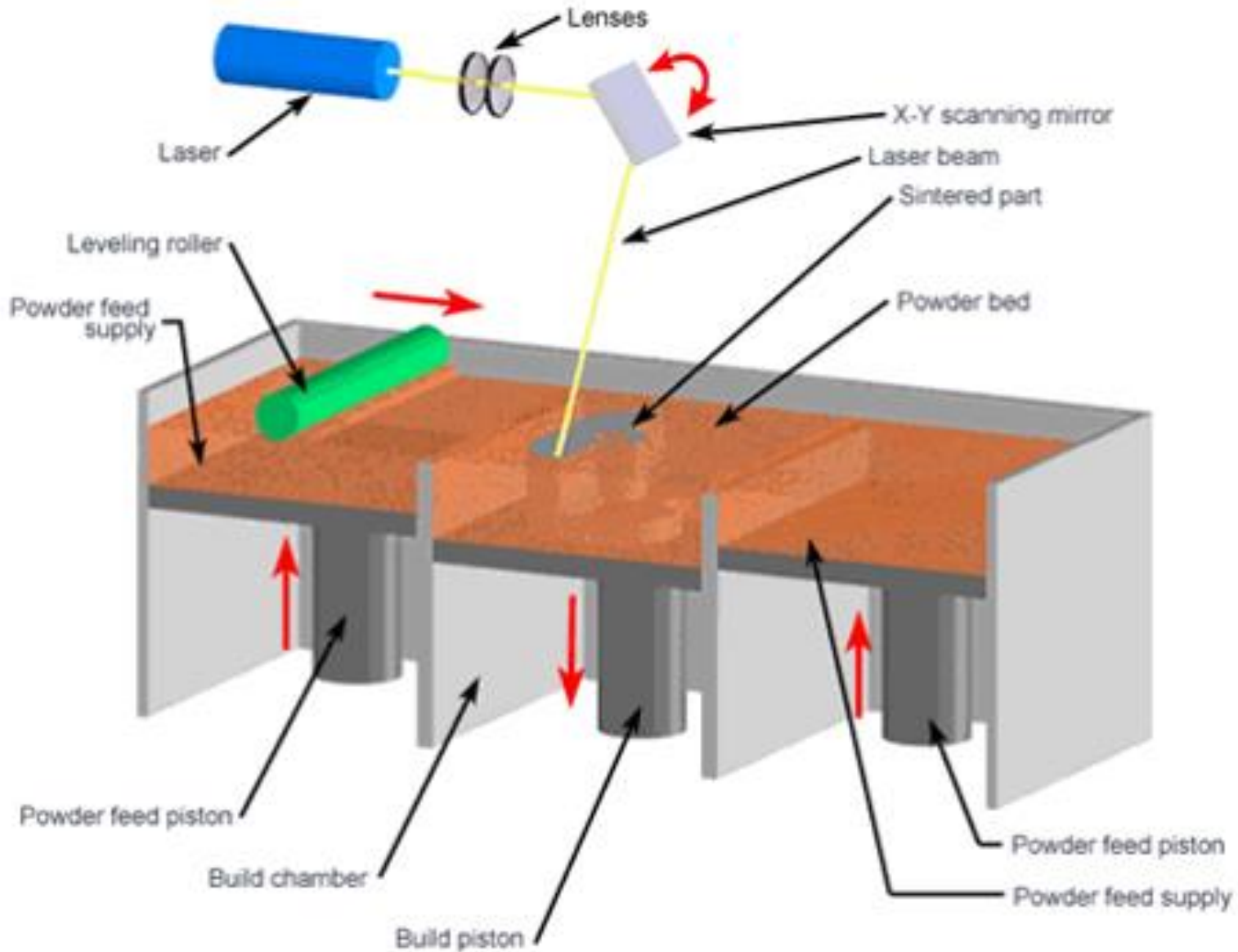
StereoLithography Apparatus (SLA)



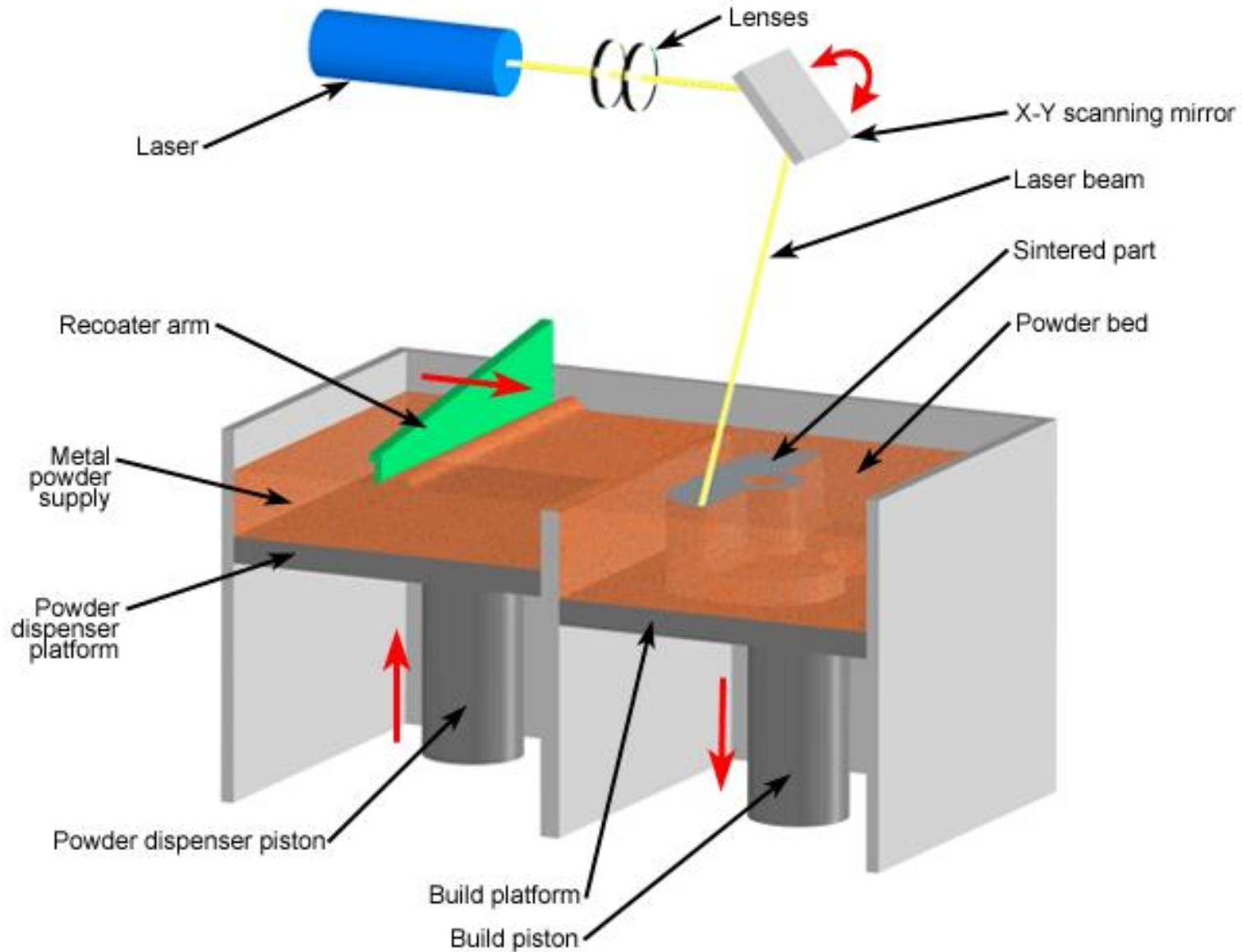
Powder Material-based Processes

- **Selective Laser Sintering (SLS)**
- **Selective Laser Melting (SLM)**
- **Direct Metal Laser Sintering (DMLS)**
- **Electron Beam Melting (EBM)**
- **Binder Jetting Process**

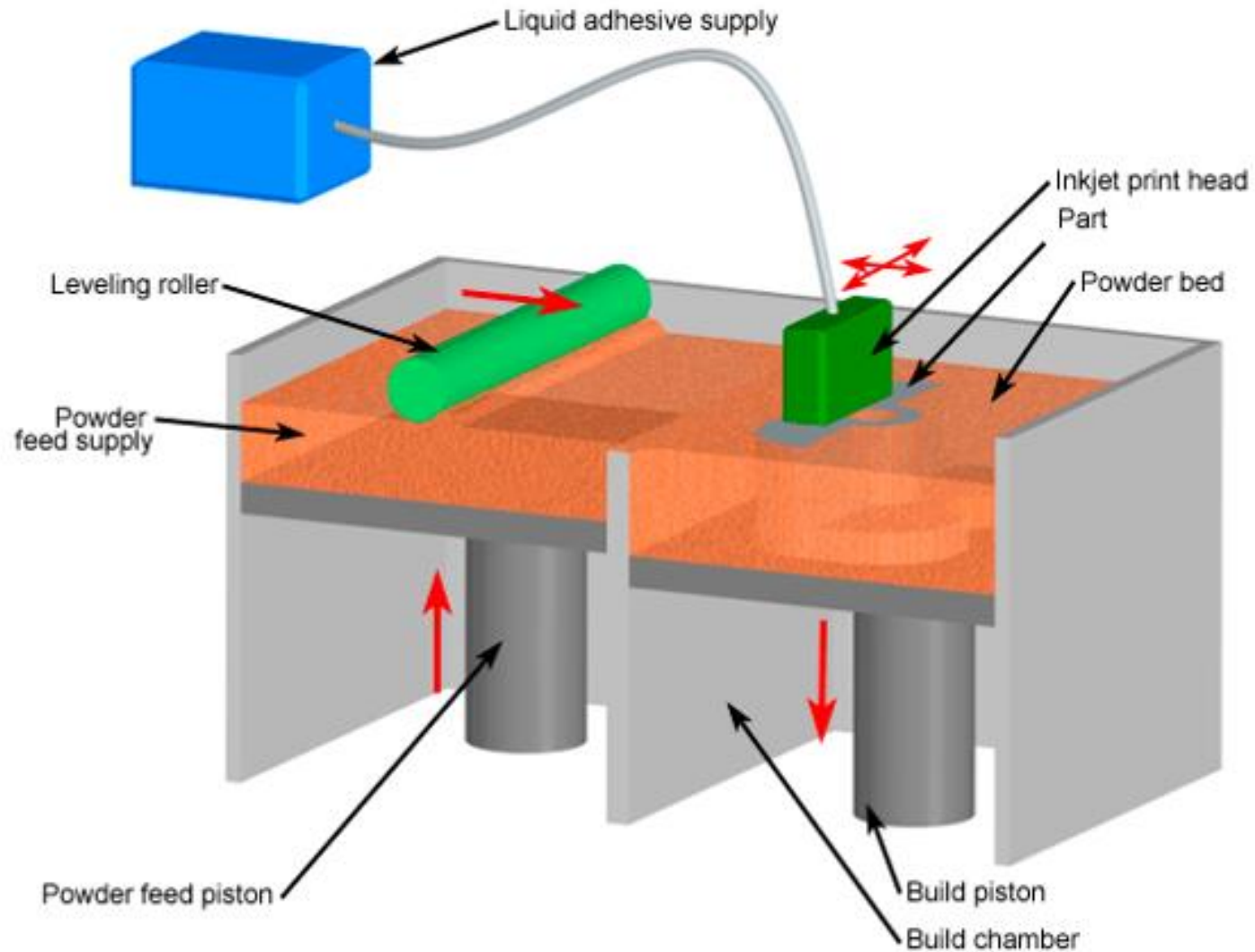
Selective Laser Sintering (SLS)



Direct Metal Laser Sintering (DMLS)

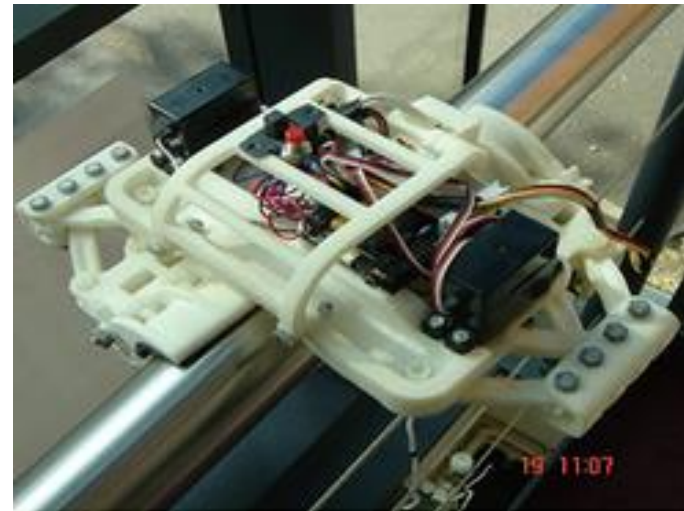


Binder Jetting Process

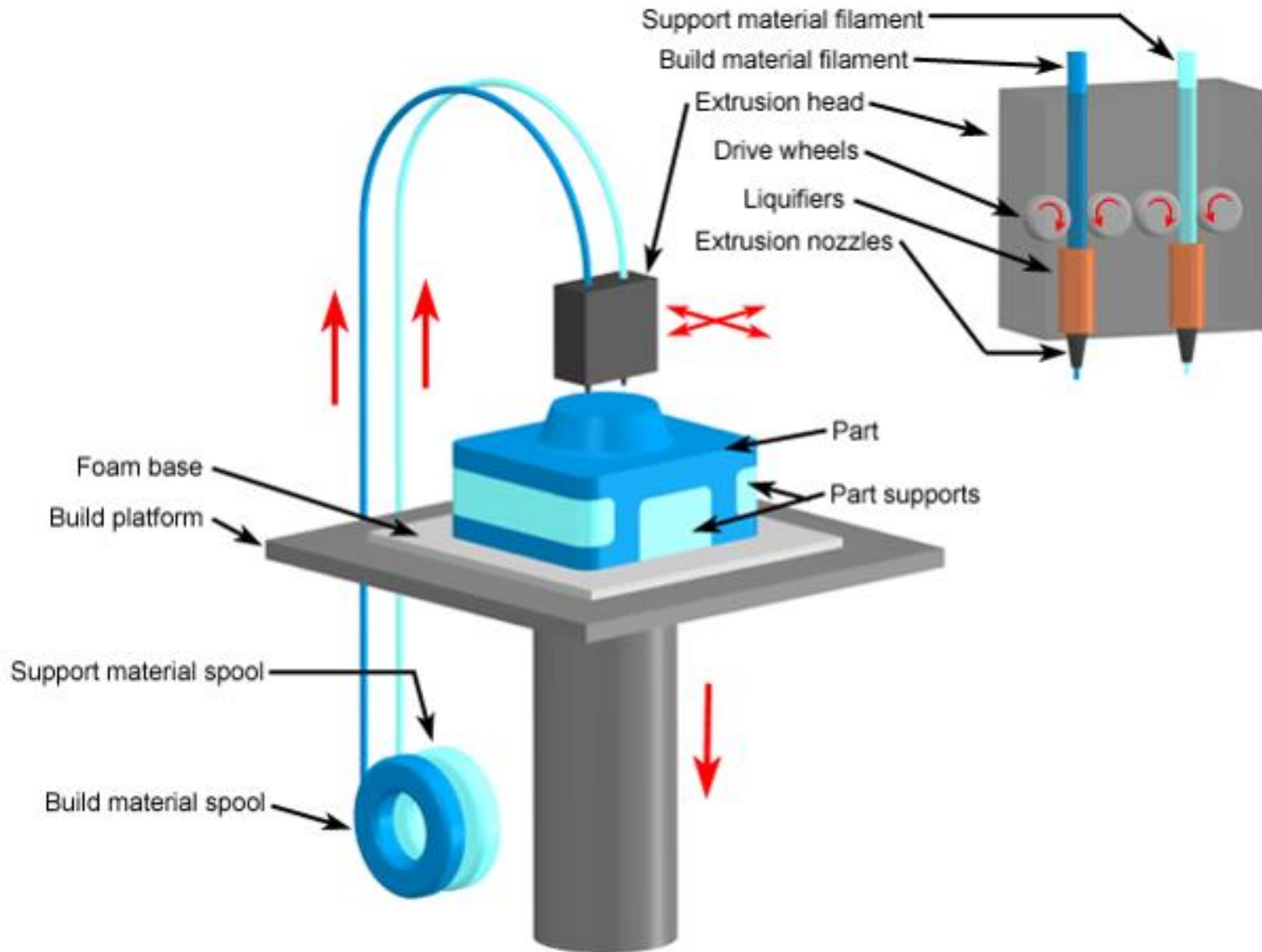


Molten Material-based Processes

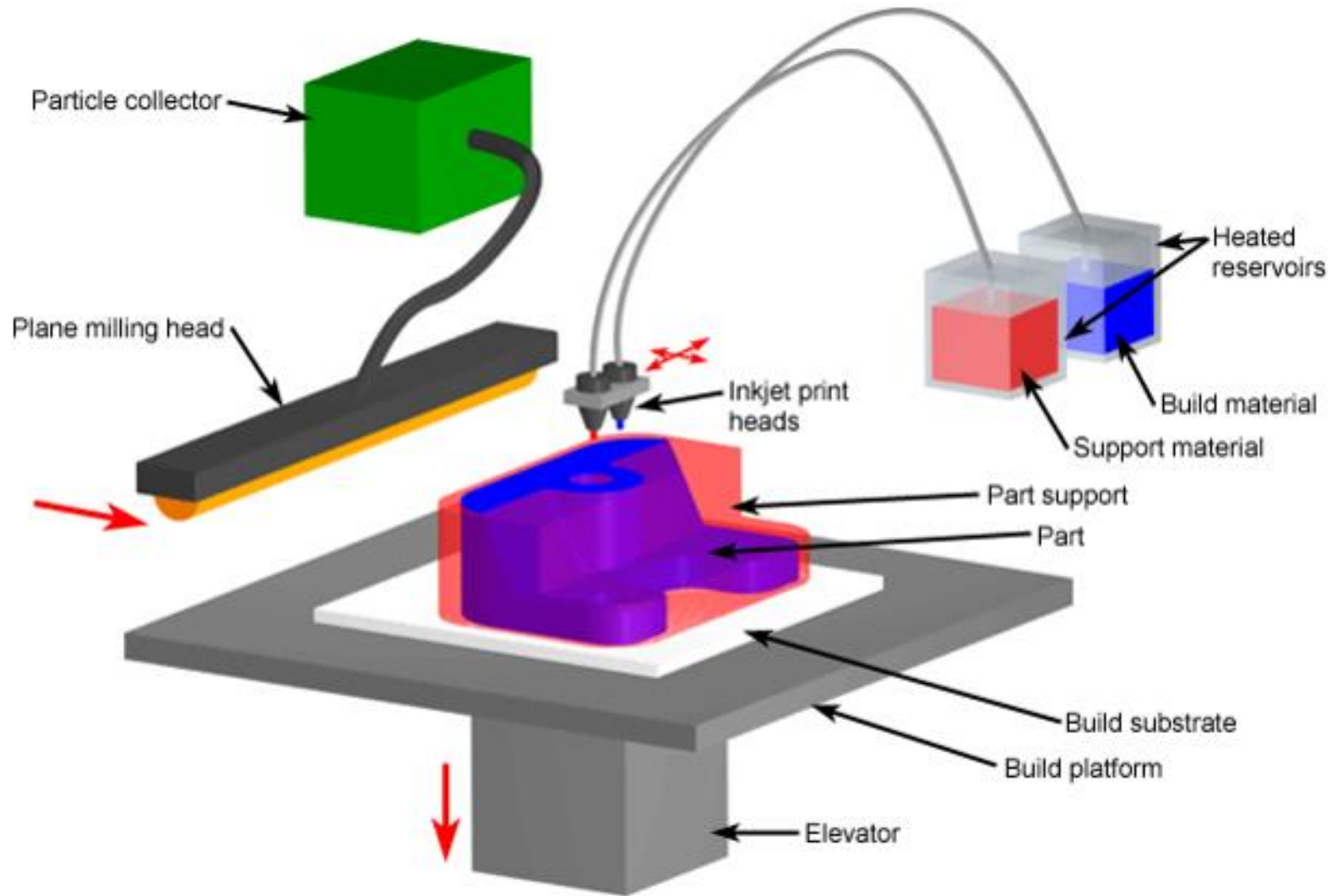
- Fused Deposition Modelling (FDM)
- Material Jetting Processes



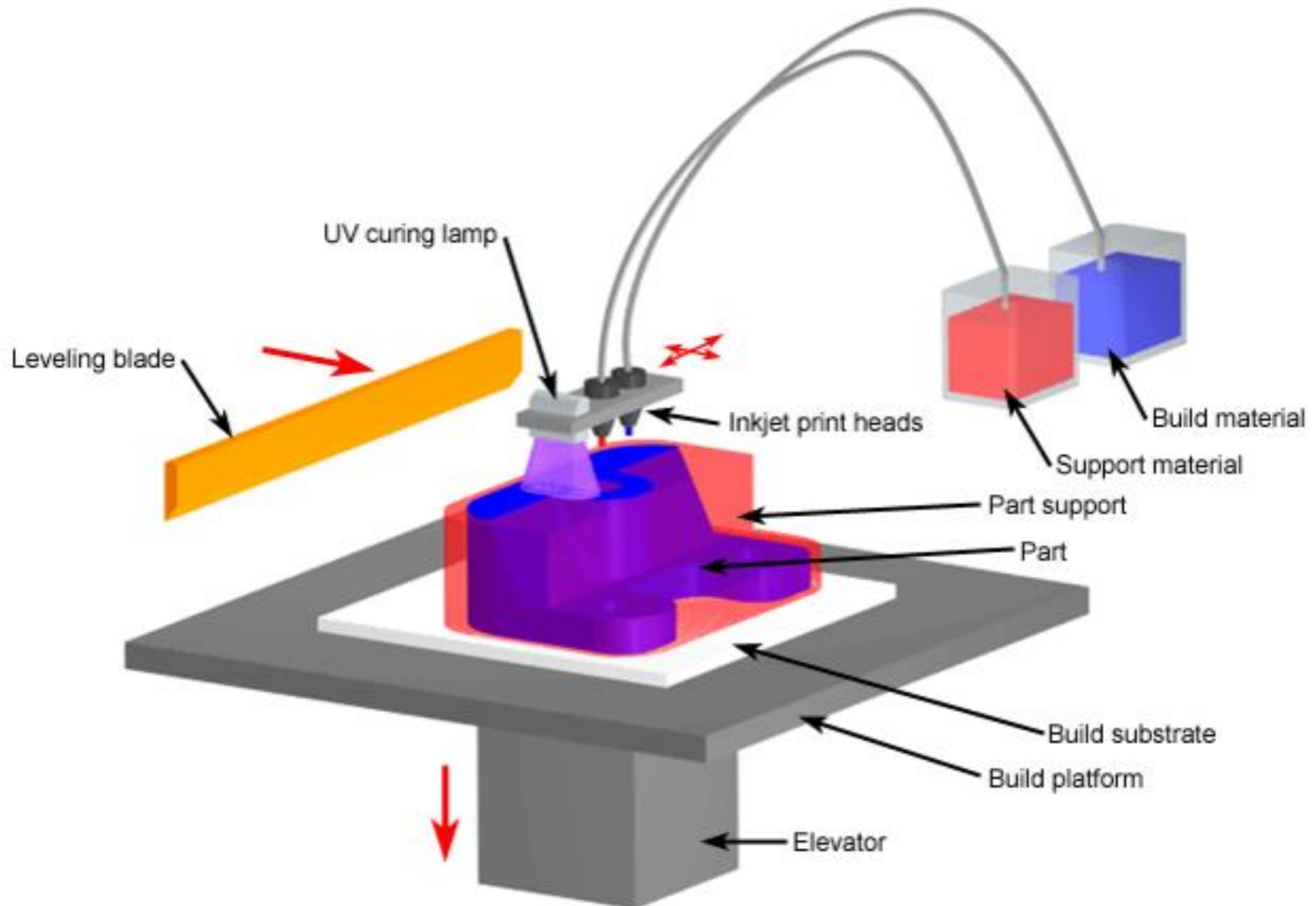
Fused Deposition Modelling (FDM)



Material Jetting Processes (I)

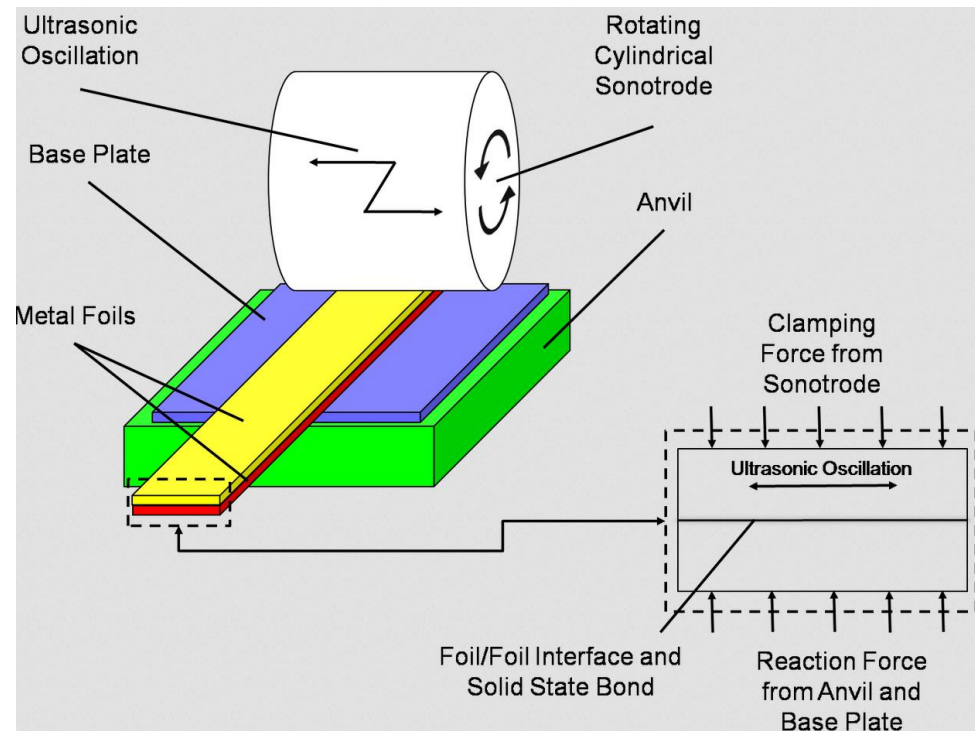


Material Jetting Processes (II)

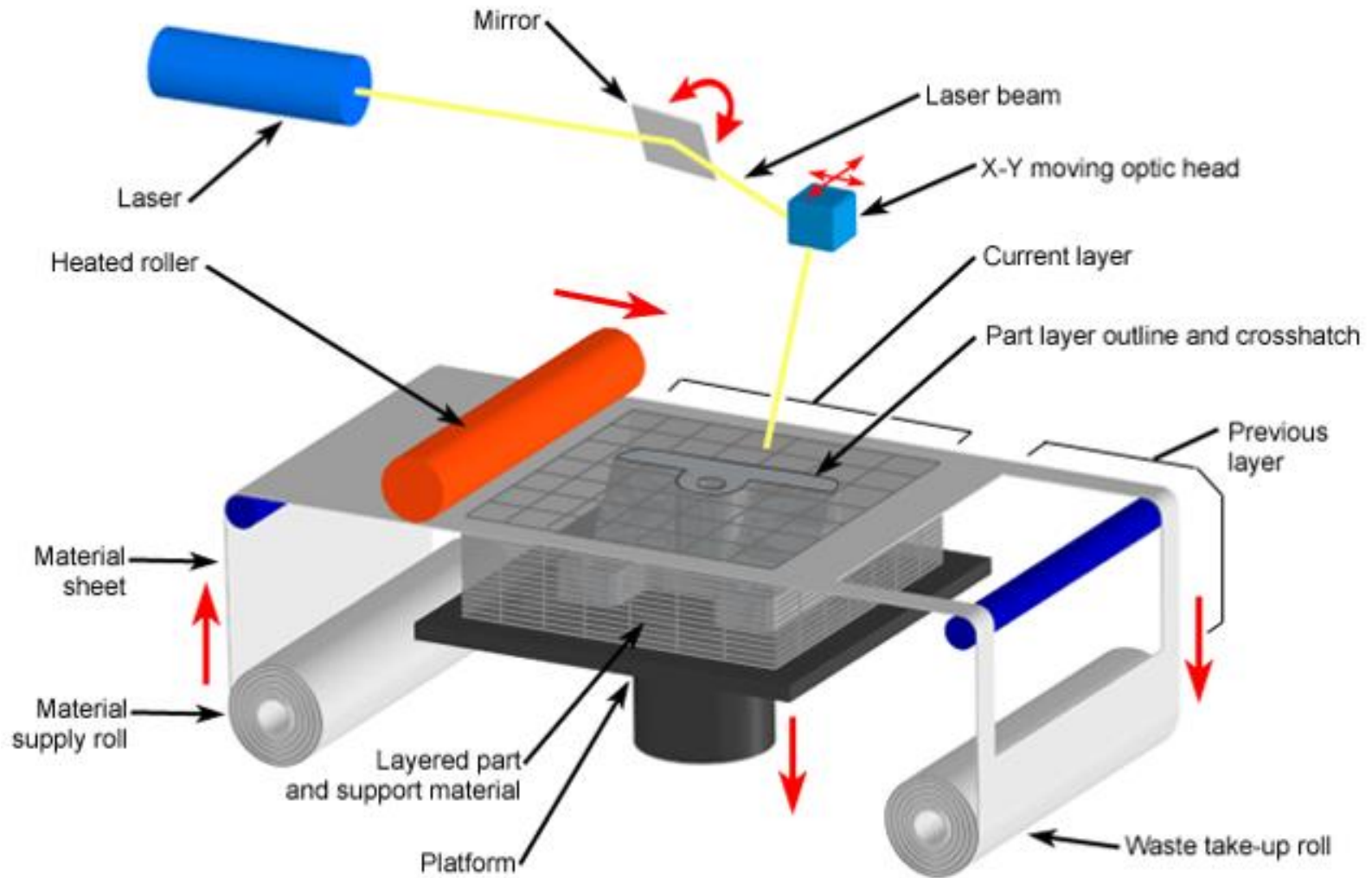


Solid Material-based Processes

- Laminated object manufacturing (LOM)
- Ultrasonic consolidation (UC)



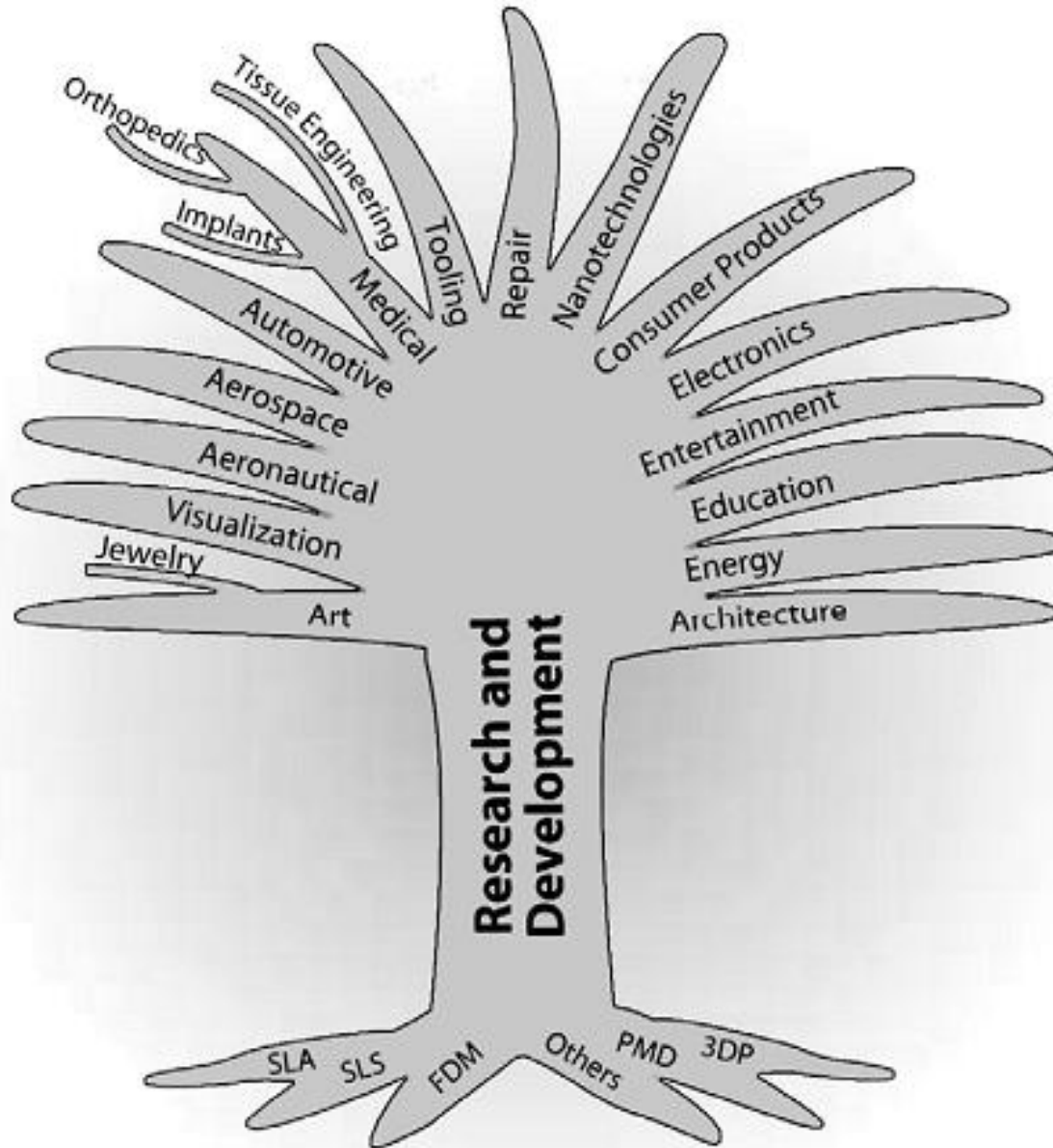
Laminated Object Modelling (LOM)



AM/3DP Key Benefits

- **Lower costs**
- **Better design**
- **Customisation**
- **Sustainability**
- **New business models**

AM/3DP Application Tree



AM Applications in Automobiles

CURRENT

Fluid handling

Applications: Pumps, valves
AM technology: Selective laser melting, electron beam melting
Materials: Aluminum alloys

Manufacturing process

Applications: Prototyping, customized tooling, investment casting
AM technology: Fused deposition modeling, inkjet, selective laser sintering, selective laser melting
Materials: Polymers, wax, hot work steels

Exhaust/emissions

Applications: Cooling vents
AM technology: Selective laser melting
Materials: Aluminum alloys

Exterior/exterior trim

Applications: Bumpers, wind breakers
AM technology: Selective laser sintering
Materials: Polymers

Powertrain, drivetrain

Applications: Engine components
AM technology: Selective laser melting, electron beam melting
Materials: Aluminum, titanium alloys

Frame, body, doors

Applications: Body panels
AM technology: Selective laser melting
Materials: Aluminum alloys

OEM components

Applications: Body-in-white
AM technology: Selective laser melting, electron beam melting
Materials: Aluminum, steel alloys

FUTURE

Interior & seating

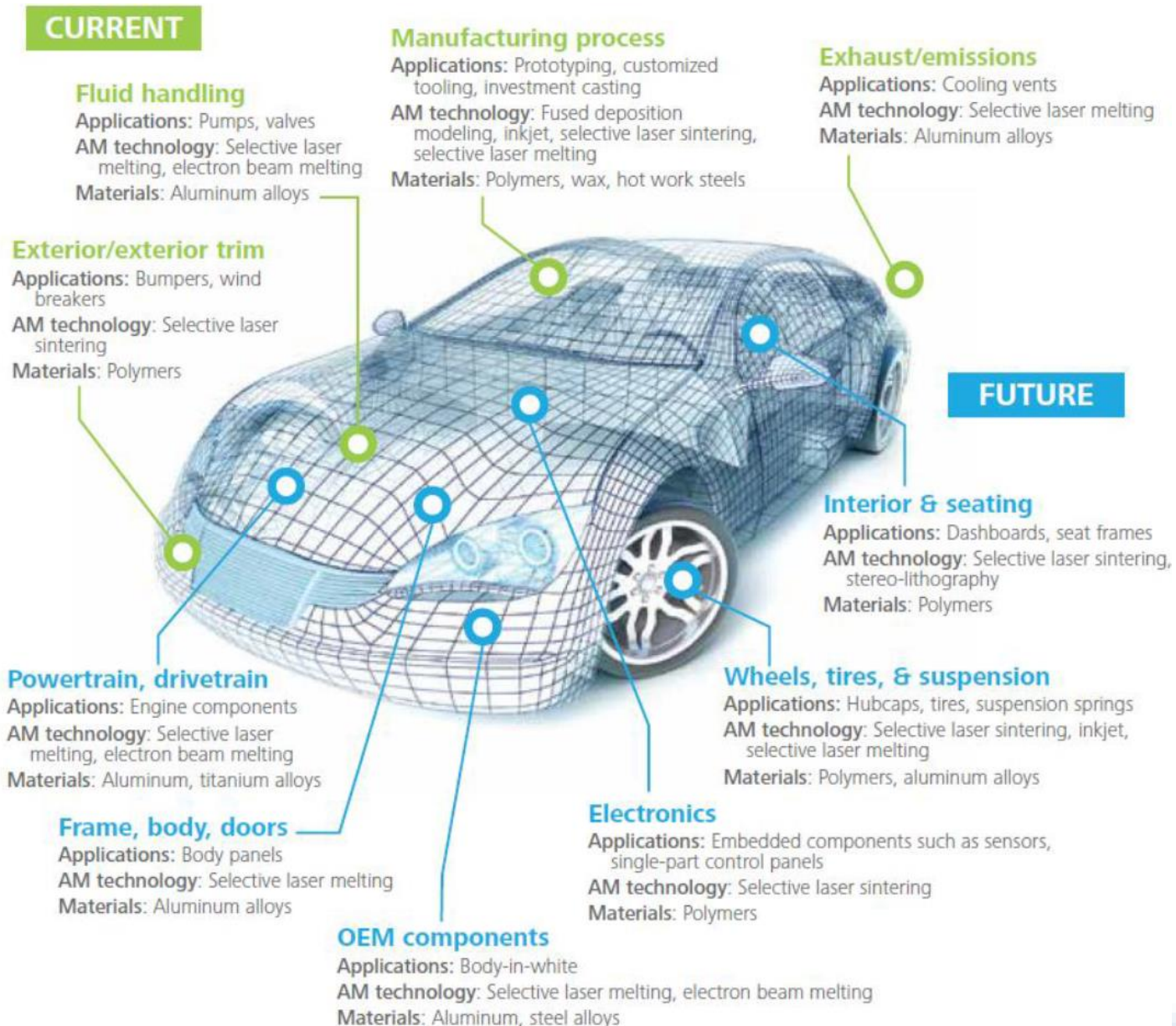
Applications: Dashboards, seat frames
AM technology: Selective laser sintering, stereo-lithography
Materials: Polymers

Wheels, tires, & suspension

Applications: Hubcaps, tires, suspension springs
AM technology: Selective laser sintering, inkjet, selective laser melting
Materials: Polymers, aluminum alloys

Electronics

Applications: Embedded components such as sensors, single-part control panels
AM technology: Selective laser sintering
Materials: Polymers

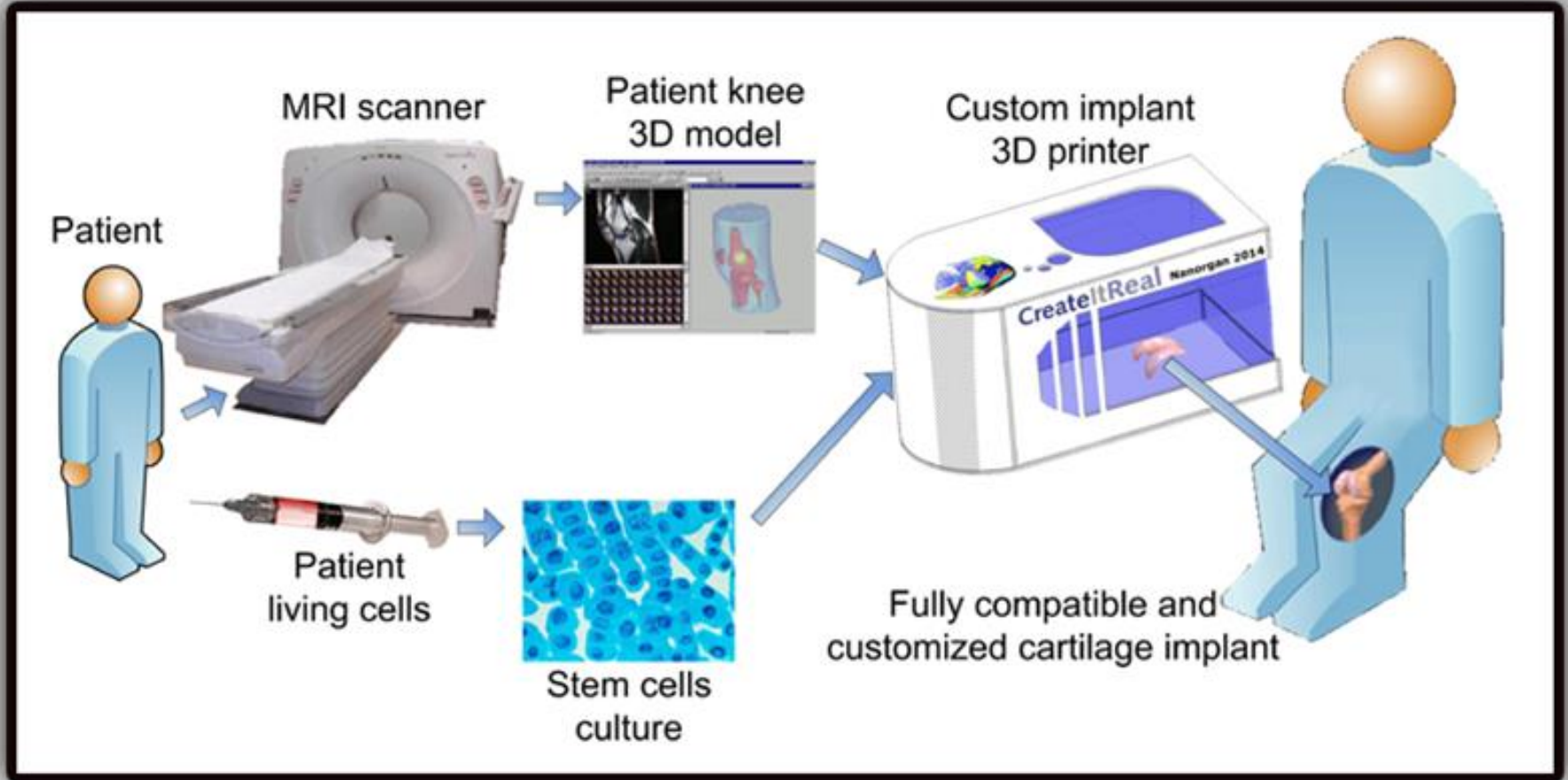


AM in Prosthetic Applications

Creating customised parts: Scan-Design-Print



AM Bio-Manufacturing Applications



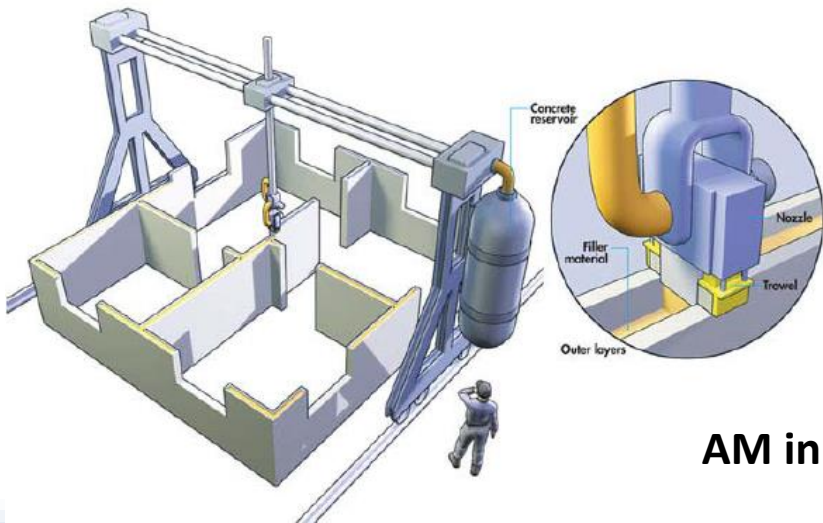
AM in Space/Sahara Desert/Building



Conducting AM zero gravity tests in space



Solar-powered AM creating crude glass out of sand in the Sahara desert



AM in Construction



AM Opportunities in Shipping Industry

Issues:

What would happen when a part on a ship/vessel breaks down?

Solution:

- **The ideal scenario is that you order a spare part from the manufacturer's website, download a digital file, then press a button on an AM/3DP machine and it prints out**
- **After a couple of hours, the part is ready for you to replace the damaged one**

AM Opportunities in Shipping Industry



Spare Parts
Accurate and fast spare parts manufacturing.



AM Opportunities in Shipping Industry

Issue:

What would happen when you need ONE real-detailed ship/equipment model (size scaled) for demonstration?

Solution:

Transfer the ship/equipment model data file to AM/3DP machines to print out



Ship / Equipment Model

Your masterpiece should be as real as it can be.

AM Opportunities in Shipping Industry

Issue:

What would happen when you need ONE prototype for a trial to see whether any design errors exist?

Solution:

Send the digital designed data file to an AM/3DP machine to print out



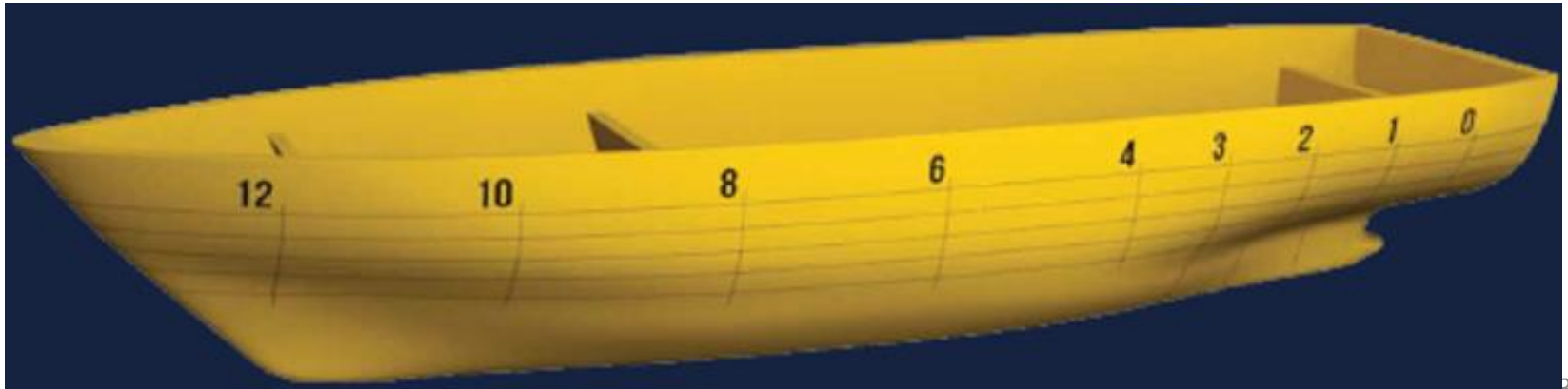
AM Opportunities in Shipping Industry

Issue:

What would happen when you need ONE functional model for performance testing?

Solution:

Using AM/3DP machines to make the functional models for performance testing



AM challenges in Shipping Industry

- **Materials and size restrictions**
- **Finish and tolerances**
- **Standardisation, qualification, certification and validation**
- **Intellectual property (IP) issues**
- **Education and training**

Summary

AM/3DP when used appropriately:

- Reducing time from design to product
(Faster)
- Reducing product development costs
(Cheaper)
- Making the best customised parts
(Better)
- Revolutionising the spare part supply chain
(Faster, Cheaper and Better)

Questions?

