Emerging Processes: 3D Printing

PRRE1003
Resources, Processes & Materials Engineering

LECTURE 12a

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Curtin University

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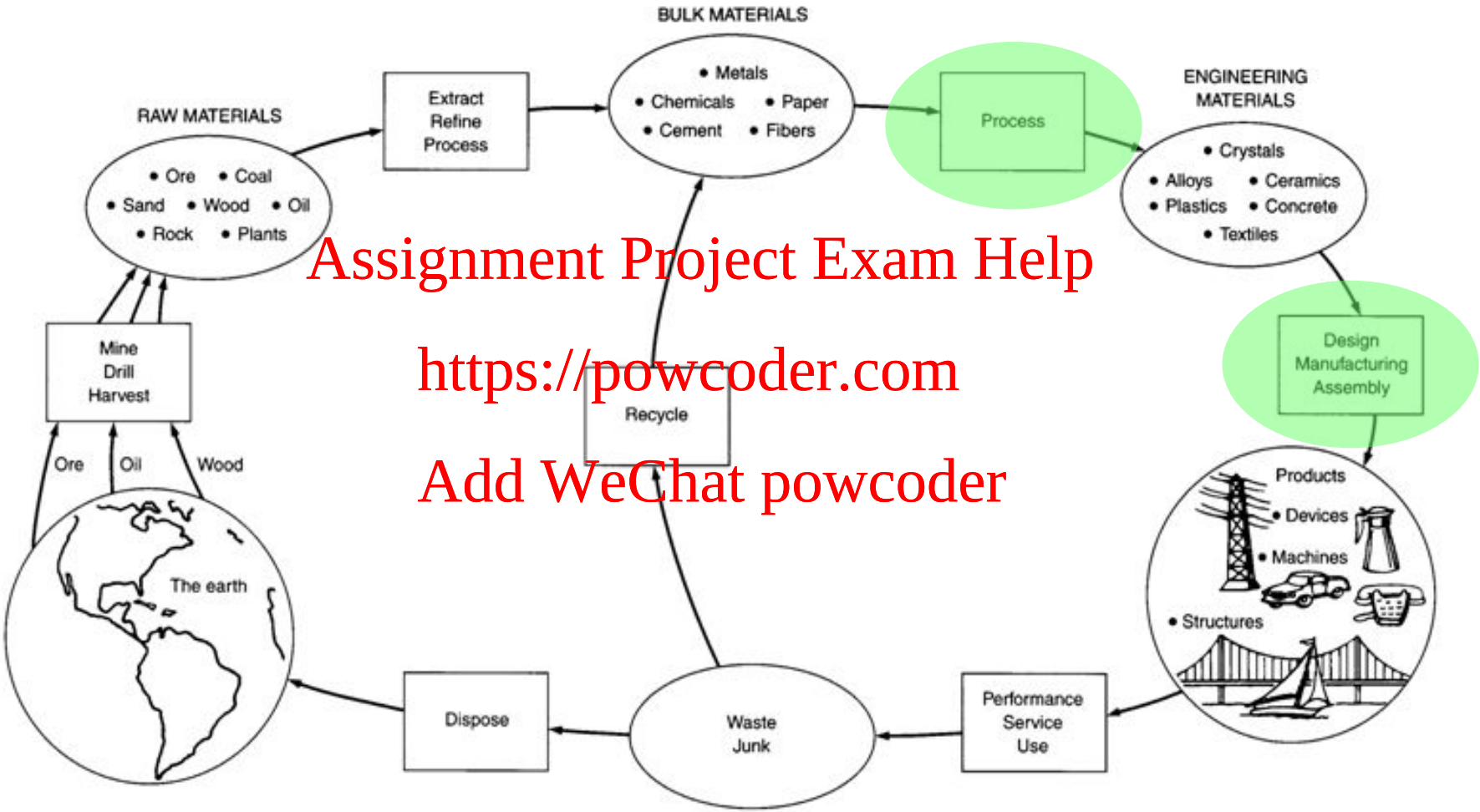
Lecture Outline

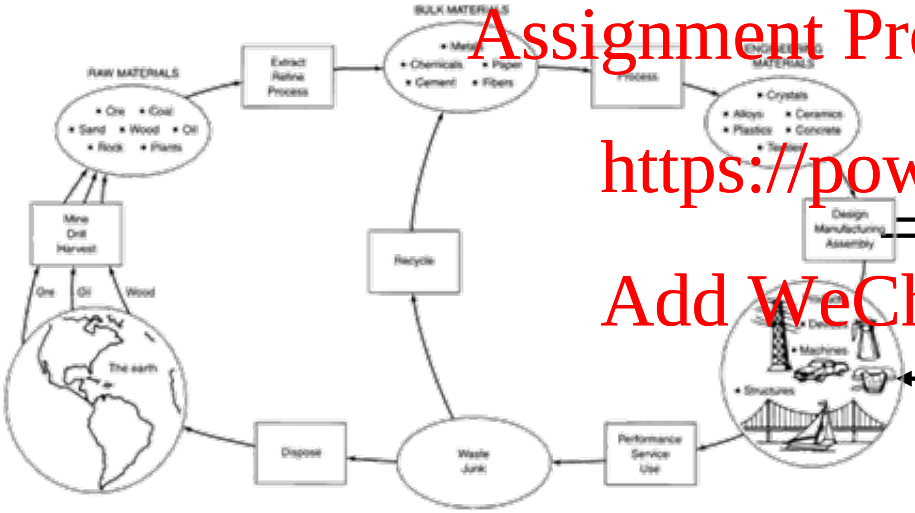
- Context
- Nature to engineering?
- 3D printing
  - Why?
  - What and
  - How?
- 3D printing and you as engineers
- Open discussion and questions

Lecture focus



Reproduced from "Materials and Man's Needs", National Academy of Sciences, Washington D.C., 1974.

Design manufacture assembly?



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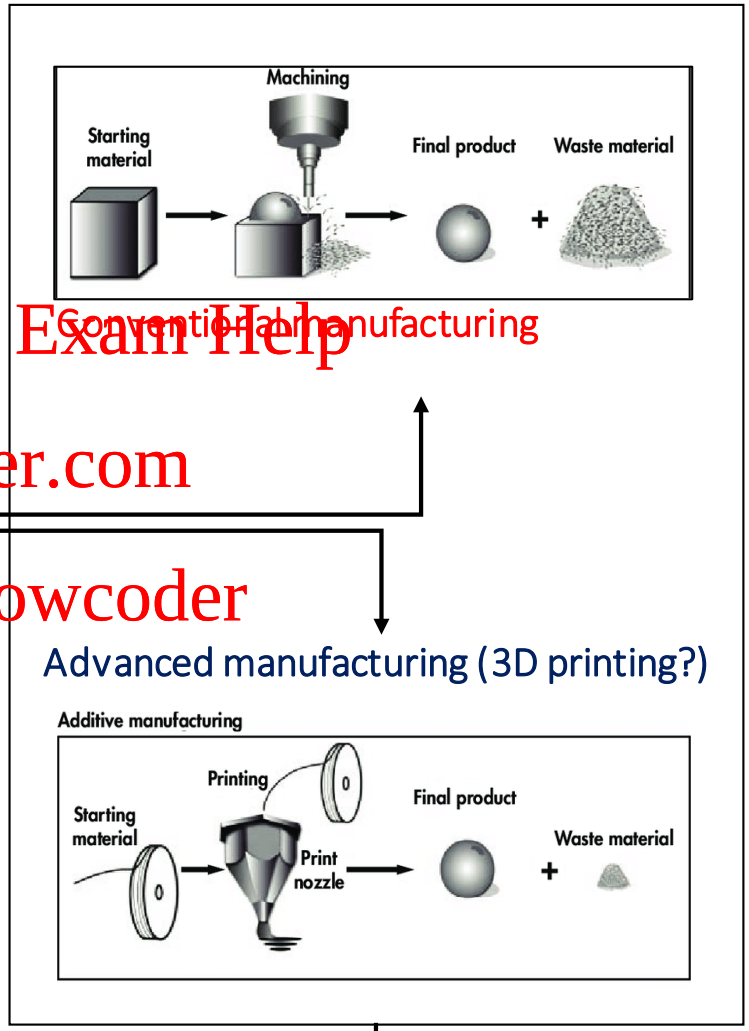
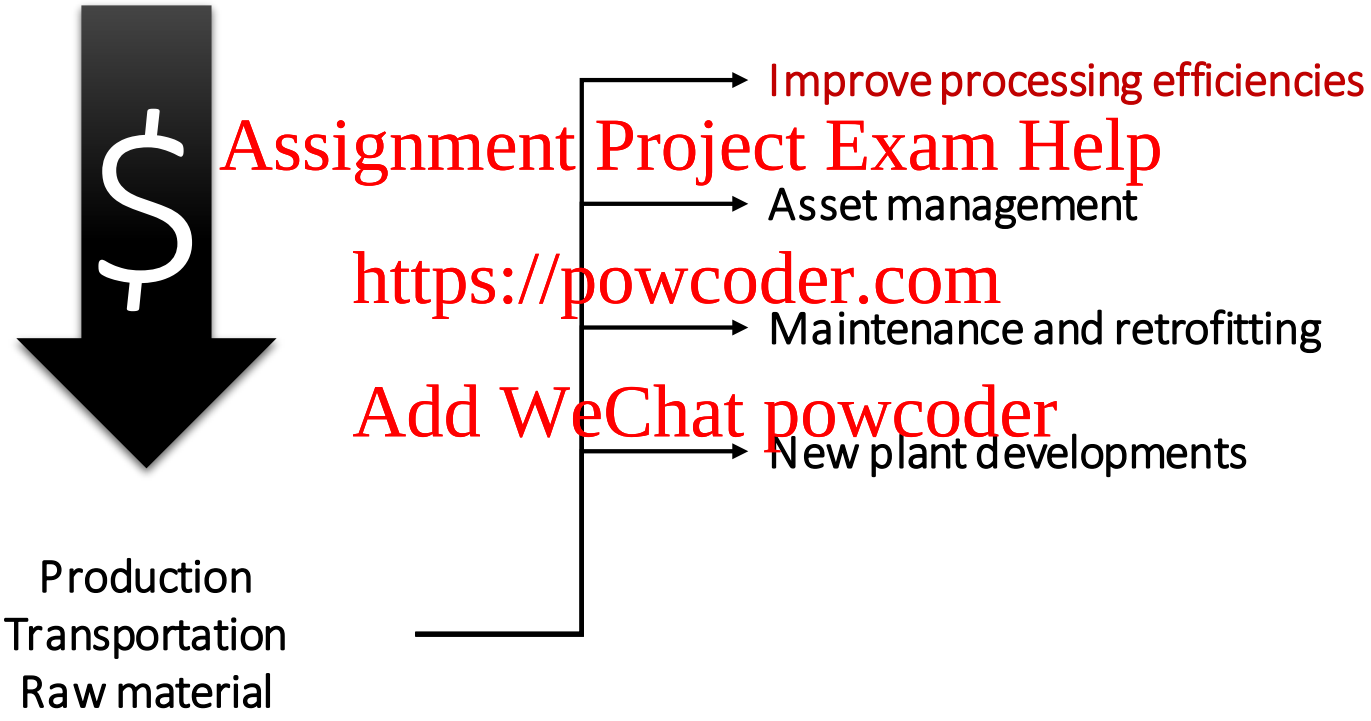
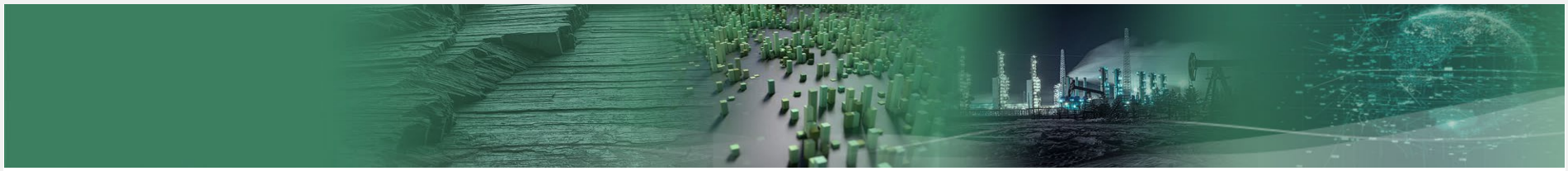


SOURCE: U.S. Government Accountability Office, 2015.

Why should we even consider Advanced manufacturing

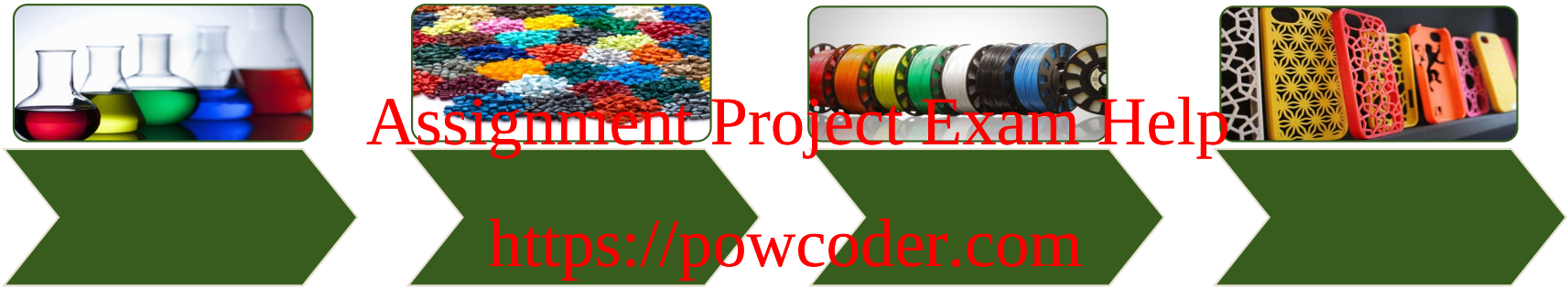




What does *improving efficiency* mean?

- It must increase at least an order of magnitude performance on one or more criteria
- It should reduce the operating cost
- It should reduce the environmental footprint
- It should reduce energy or material use
- It should increase ability to perform tasks that were unable to be done previously
- It should improve throughput
- Either of the above
- All in all it should make it better

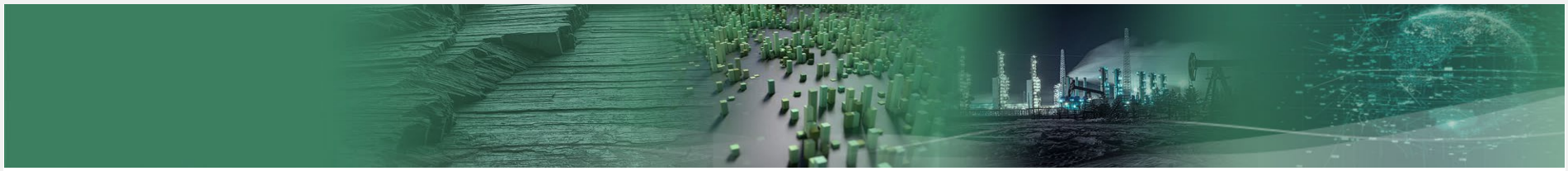
Lets look at 3D-printed mobile cover as an example.



Every step that we transfer the form of material we need to provide energy.

The key question we should be asking is, after going through these steps have we added any value/improved efficiency?

What do you think?



Role of Advanced manufacturing

Improve Processing efficiencies is very difficult, but not impossible

It must be evaluated against the cost of energy and material

How?

Define the problem

Ideation

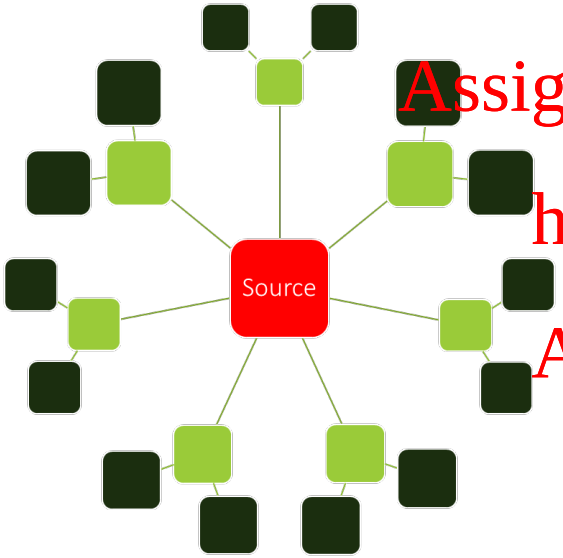
Calculation

Test

Repeat

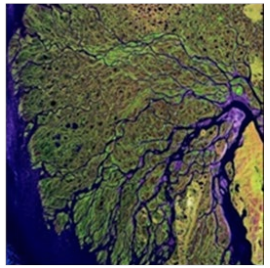
Optimise

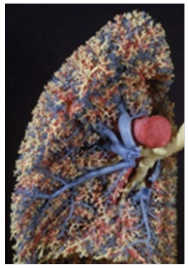
Simple fluid distributors



Principle of distribution is simple

Industrially distributors are designed based on ease of manufacturing

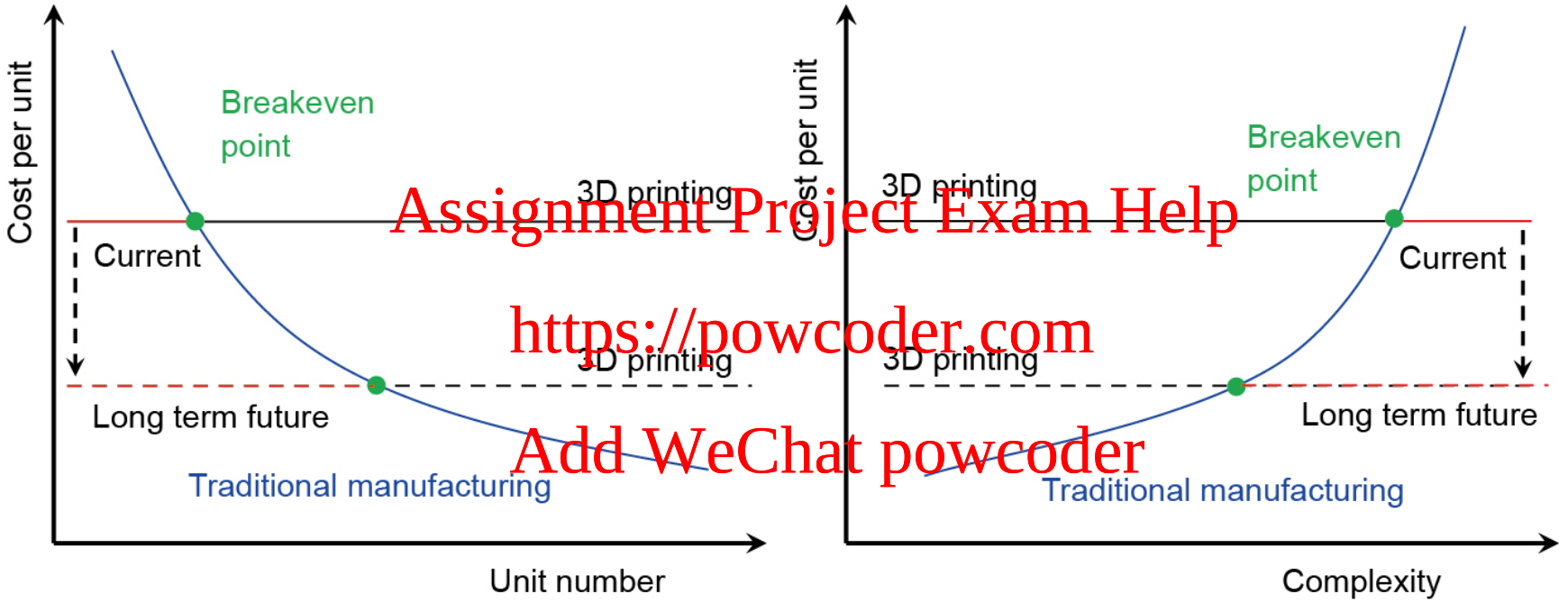




Ideal

Very difficult to manufacture

Is it always effective to use 3D printing?



Cost = energy = dollars

If it is simple and efficient, then leave it.

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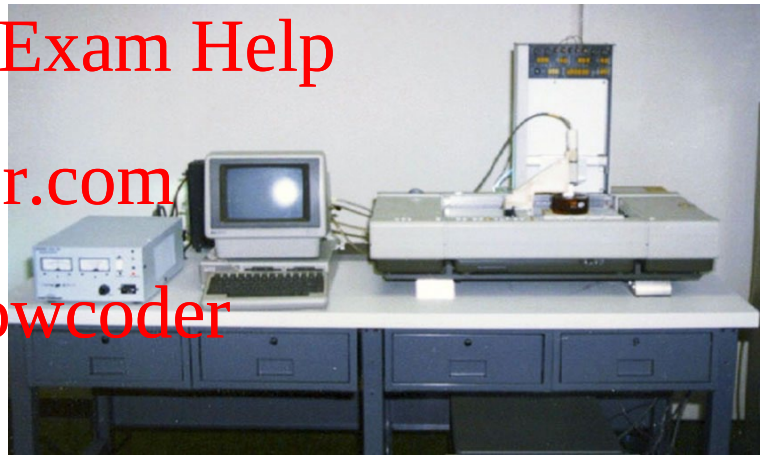
Learning Outcome Check

- Describe what *advanced manufacturing* is, with reference to the traditional processes that convert bulk materials into end products.
- List 5 criteria are used to decide between a traditional manufacturing process, and advanced manufacturing process, to make a product.

When was first 3D printing carried out?

Charles Hull



1980's

What is 3D printing?

Additive Manufacturing	Subtractive Manufacturing
Involves adding layers of material to create an object	Removes material from an object
Processes include 3D printing, direct digital manufacturing, rapid prototyping or additive and layered fabrication	The process is either by: manual removal, traditional machining or CNC machining
Uses computers and specialist 3D printing equipment to create products or prototypes	Uses computers and robotics to assist standard machining processes, e.g., turning, drilling or milling
The layering often leaves a slightly 'stepped' or rough surface which needs to be finished post-printing by sanding or blowing	A variety of surface finishes can be machined, including smooth, stepped, mottled, etc.
Intricate and hollow objects can easily be built up in layers	Milling undercuts and intricate shapes can be difficult
Best suited for smaller items or parts, especially in plastic	Best suited for manufacturing voluminous items and parts, especially in metal
Depending on the size of the object, 3D printing can be a slow process	Relatively fast process
Software is available to directly link the design to a 3D printer, so a machine operator isn't necessary	A CNC machinist is required to operate the mill or machine and oversee the production. However, new automated software means that programming machine-executable code is no longer needed
Overall, 3D printing is a fairly cheap process	Generally, more expensive than additive manufacturing

http://www.manufacturinglounge.com/additive-vs-subtractive-manufacturing-whats-the-difference/

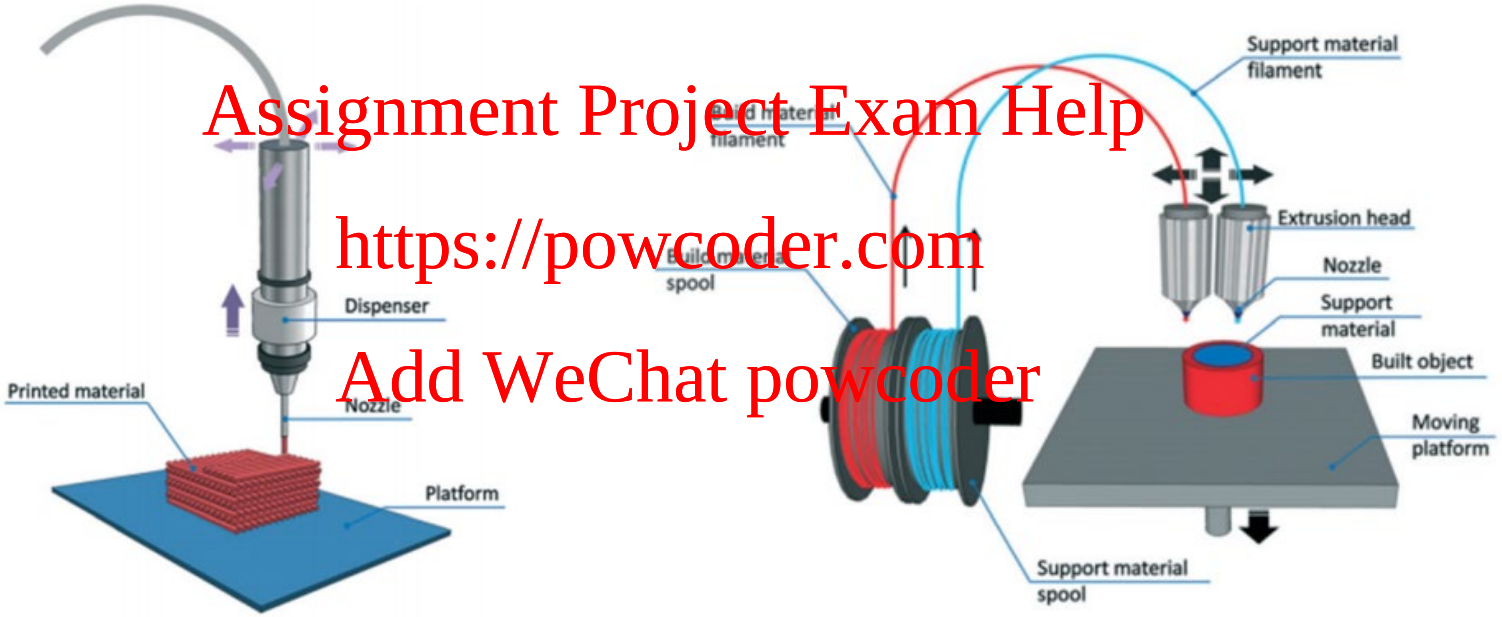
How does it all work?

https://commons.wikimedia.org/wiki/File:3d-printing-a-2014-horizonwatching-trend-summary-report-9-638.jpg

Is all 3D printing the same?

Process Category	Definition	Material Type	Search Hits (Google Scholar)	Related Technologies
Material extrusion	A process in which material is selectively dispensed through a nozzle or orifice	• Polymers • Sand	3,510	• Fused deposition modeling
Sheet lamination	A process in which sheets of material are bonded to form a part	• Polymers • Metals	1,920	• Laminated object manufacturing • Ultrasonic consolidation
Powder bed fusion	A process in which thermal energy selectively fuses regions of a powder bed	• Polymers • Metals • Ceramics, glass, and carbon	1,810	• Electron beam melting • Selective laser sintering • Selective heat sintering • Direct metal laser sintering
Material jetting	A process in which droplets of build material are selectively deposited	• Polymers • Metals • Wax and biomaterial	679	• Multi-jet modeling
Binder jetting	A process in which a liquid bonding agent is selectively deposited to join powder materials	• Polymers • Metals • Glass	602	• Powder bed and inkjet head • Plaster-based 3D printing
Directed energy deposition	A process in which focused thermal energy is used to fuse materials by melting as they are being deposited	• Powder • Metals	517	• Laser metal deposition
Vat photopolymerization	A process in which liquid photopolymer in a vat is selectively cured by light-activated polymerization	• Polymers • Ceramics and wax	205	• Stereolithography • Digital light processing

Fused deposition modelling



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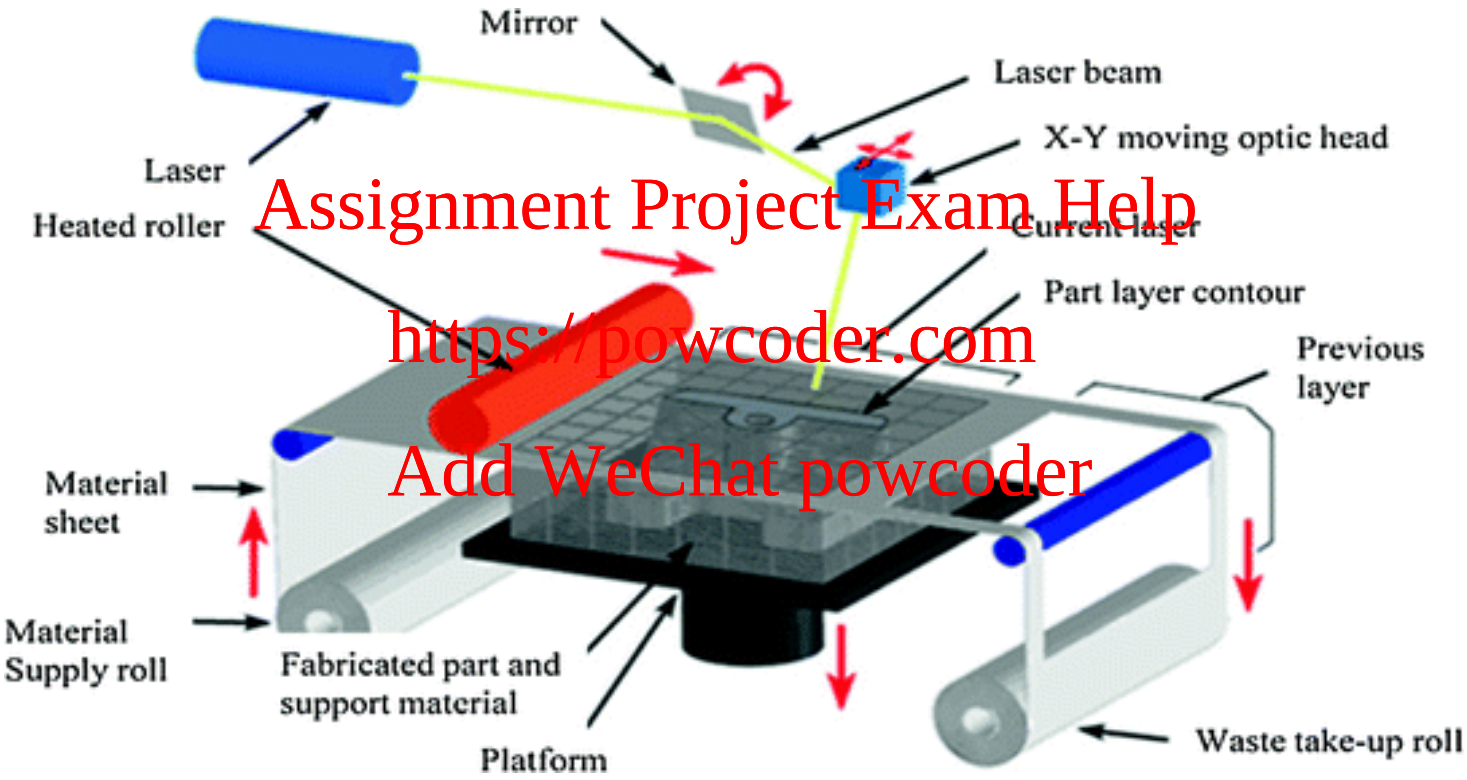
Laminated object manufacturing



https://link.springer.com/chapter/10.1007/978-81-322-2740-3_21

Powder bed fusion

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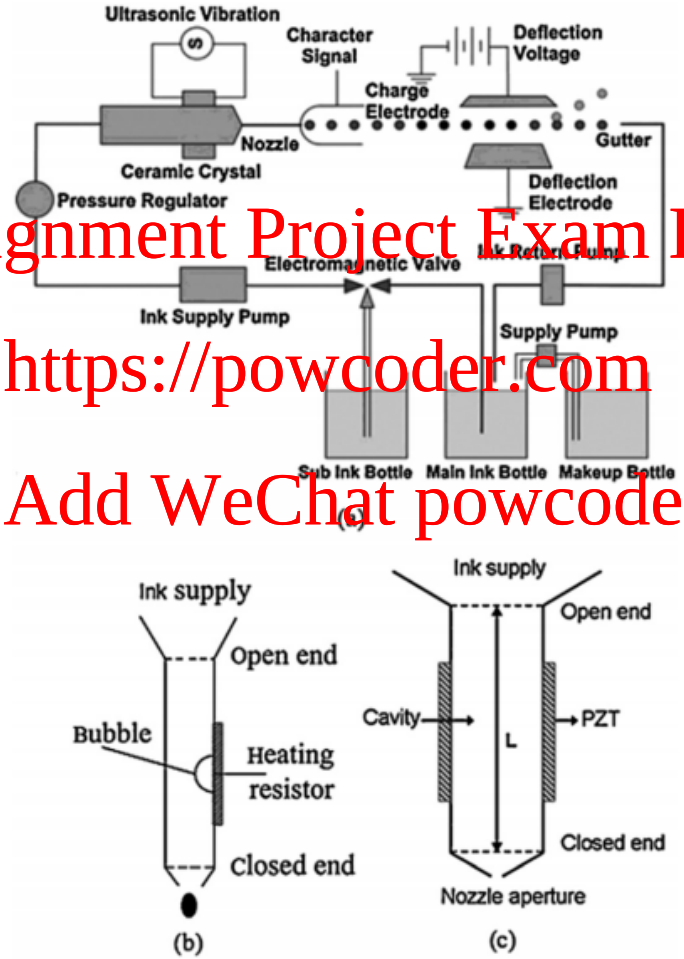
Binder Jet printing



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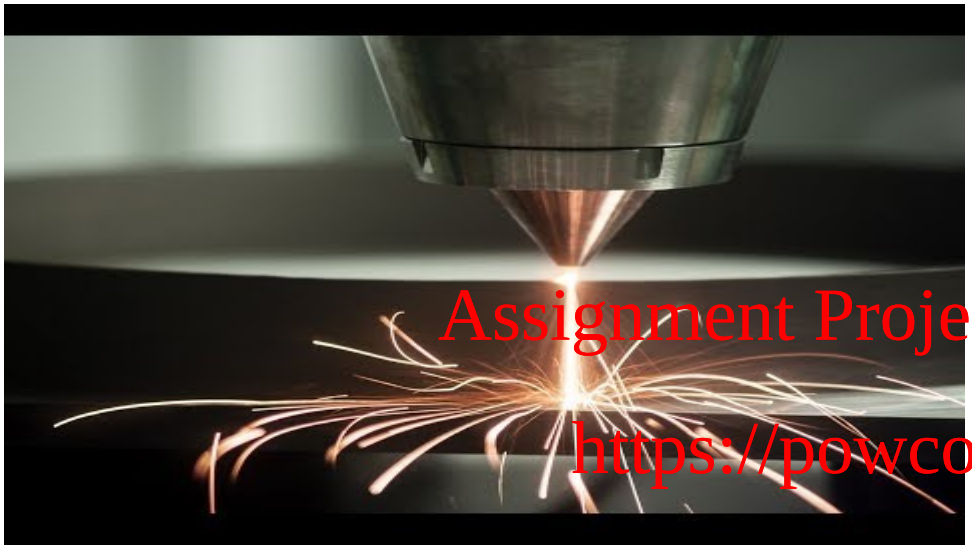
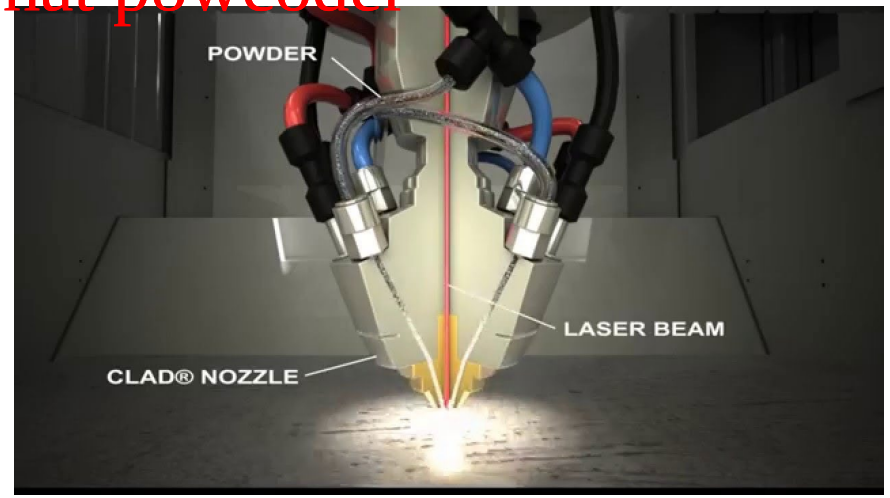
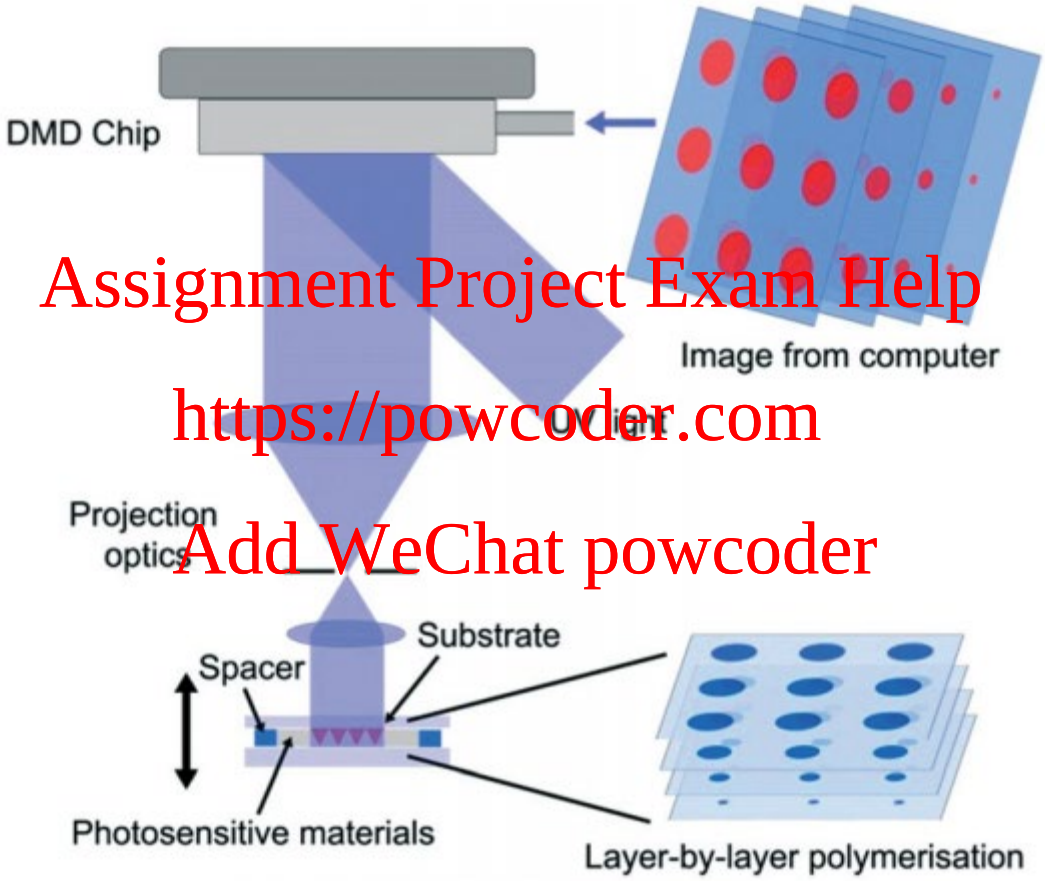
Directed Energy Deposition





Photopolymerization



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Is it always effective to use 3D printing?

Technology	Material	Energy	Processes
Conventional manufacturing	Cheap More wastage Recycling an option	Low	Advanced and proven Applications are wide
Plastic printing	Cheap Less wastage Non-recyclable	Low –medium	Fairly advanced Limited industrial application
Gen-1 metal printing	Very expensive Less wastage Non-recyclable to some extent	Very high	Proven process Application are limited but real
New metal printing	Cheap but hard to make at scale Less wastage Recyclable	Medium	New and limited

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Impact of 3D printing

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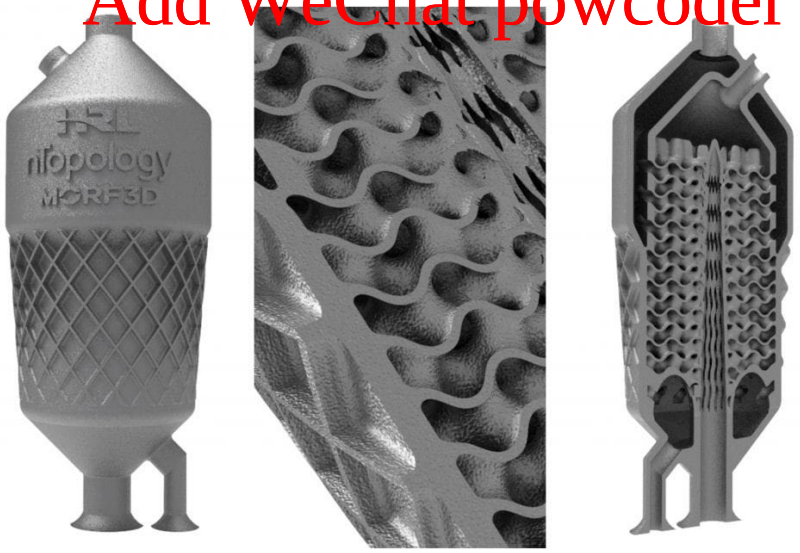
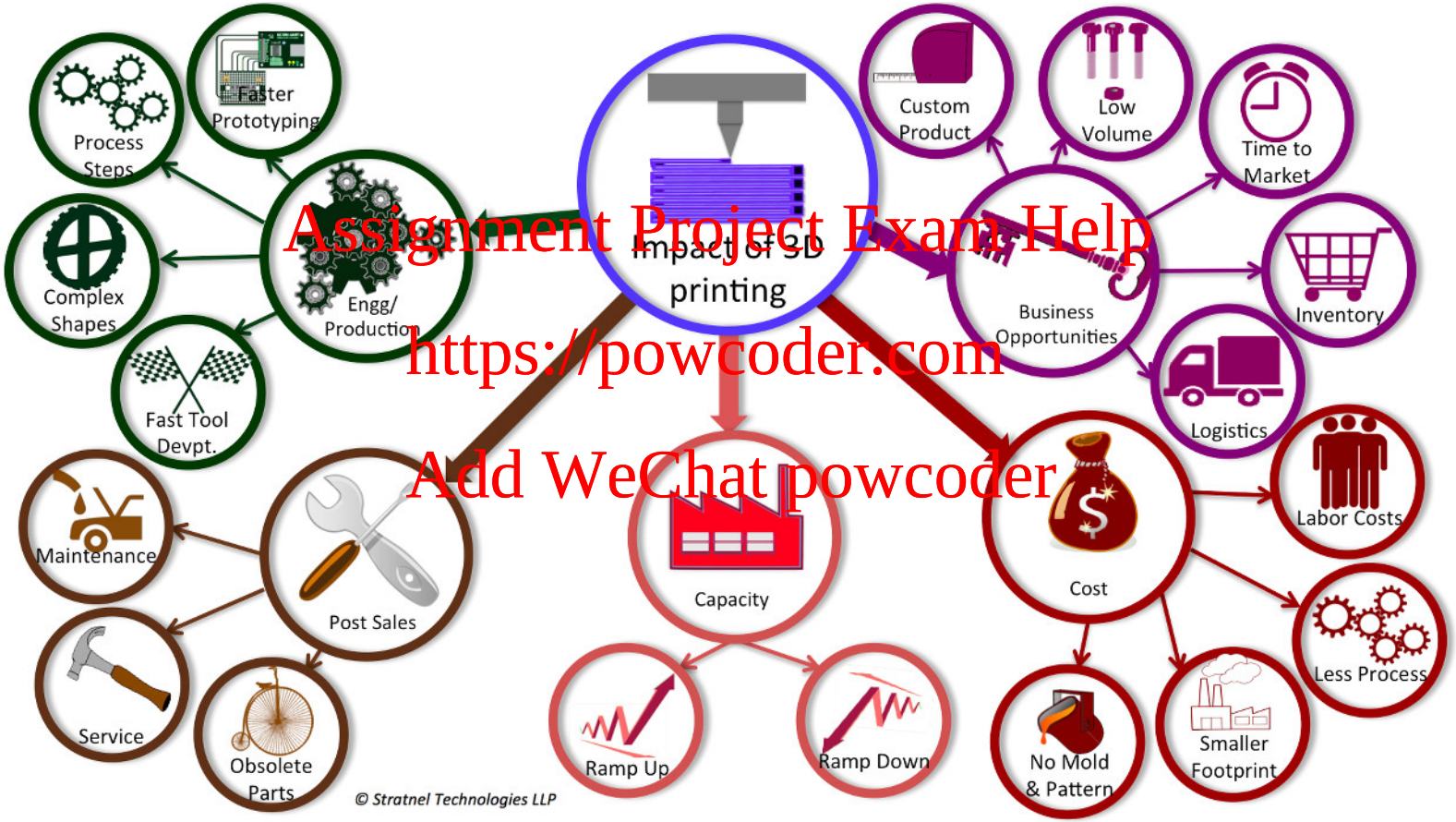


Impact of 3D printing and opportunities



Learning Outcome Check

- Briefly describe the terms *additive manufacturing* and *3D printing* in your own words.
- List 5 types of 3D printing, indicating whether they use metals/polymers/both.

Lecture Summary

- ✓3D printing will be/is already a manufacturing tool that opens the avenues for improving process efficiencies
- ✓It is costly but with time the costs are expected to come down
- ✓Wise use of 3D printing will:
  - ✓Reduce the material used in the processes
  - ✓Improve energy efficiencies
  - ✓Reduce capital and operating costs
  - ✓Open avenues to achieve what could not be achieved previously, such as synthesis of new materials or products
- ✓It has already shown huge impact in prosthetics but in future bio printing will improve the medical science
- ✓More work needs to be done in future in terms of improving printing speeds and reducing costs.