History

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Concept of 3d printing: additive manufacturing

1981- Hideo Kodama (Japan) develops early rapid auto typing using photo polymer
1984- Charles Hull invents SLA, found 3d systems
1990s- FDM & SLS patented, used mainly for industrial prototyping
2000s- patent expiration lead to open source (RepRap) and affordable printers
2010s to present- growth in speed, materials, and industrial adoption.

Theory Behind

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1. Additive manufacturing: Objects built layer by layer from digital 3D models (CAD)
2. Process
- 3D model. In CAD or 3d scanning
- Slicing. Using slicing software
- Printing. Printer deposits layer by layer
- Post processing. Cleaning. Finishing

3. Advantage: Less waste than subtractive manufacturing

Subtractive manufacturing: make something by cutting material form bigger pieces.
Ex: craving wood, drilling, milling, grinding etc.

Additive manufacturing: building something by adding material layer by layer

Limitations

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- **Speed** — Large or detailed prints can take many hours.
- **Strength vs. traditional manufacturing** — Not always as strong as injection moulding unless using reinforced materials.
- **Surface finish** — Often requires post-processing to be smooth.
- **Material constraints** — Not all materials are printable on all machines.
- **Cost of materials** — Specialty filaments like carbon fiber nylon can be expensive

Types Present

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Technology	How It Works	Common Materials	Pros	Cons
FDM/FFF	Melts and extrudes filament layer-by-layer	PLA, ABS, PETG, Nylon, Carbon Fiber composites	Affordable, wide material range	Visible layer lines, slower for complex shapes
SLA	Uses UV light to cure liquid resin layer-by-layer	Photopolymer resin	Very high detail, smooth surface	Resin is messy, more expensive
SLS	Laser sinters powdered material	Nylon, TPU	Strong functional parts, no supports needed	Industrial, expensive
CFF (Continuous Fiber Fabrication)	Similar to FDM but lays continuous fiber strands	Carbon fiber, Kevlar, fiberglass	Very high strength	Higher cost, fewer models

1. FDM – Fused Deposition Modelling
- Melts and extrudes plastic filament through a nozzle, building objects layer-by-layer.
- Thermoplastics (PLA, ABS, PETG, TPU).
- Prototypes, hobby projects, educational models, low-cost manufacturing.
2. SLA – Stereolithography
- Uses a UV laser to cure liquid resin into solid layers
- Photopolymer resins
- Dental models, jewellery, detailed prototypes, art pieces.
3. SLS – Selective Laser Sintering
- Laser fuses powdered material to form solid layers
- Nylon, PA, composites
- Functional prototypes, low-volume production, industrial parts.
4. DMLS / SLM – Direct Metal Laser Sintering / Selective Laser Melting
- High-powered laser melts or sinters metal powder into solid parts
- Titanium, stainless steel, aluminum, cobalt-chrome
- Aerospace components, medical implants, high-strength tooling

- What it is
- Materials used
- Uses

.

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Process	Typical Materials	Strength	Hardness	Cost	Speed	Key Limitations
FFF / FDM	PLA, ABS, PETG, Nylon	Low–Moderate; anisotropic	60–120 MPa (tensile)	Low	Moderate	Layer adhesion weak along Z-axis; rough surfaces; limited feature detail; requires supports for overhangs
CFF (Continuous Fiber FDM)	Nylon + Carbon/Glass Fiber	High along fiber direction; directional	150–250 MPa (tensile)	Medium–High	Moderate	Strength directional; complex slicing; limited material combinations; expensive filaments
SLA / DLP	Photopolymer resins	Moderate–High	50–90 MPa (tensile), Shore D 80–95	Medium	Slow	Brittle; small build volumes; post-processing required; resin handling hazardous
SLS	Nylon, PA12, composites	Moderate; isotropic	50–75 MPa (tensile), Shore D 70–85	High	Moderate	Rough surfaces; expensive powder; part packing critical; limited to polymer powders
DMLS / SLM	Metals (steel, Ti, Al)	Very High; near or above forged	200–600 HB, HRC 30–55	Very High	Slow	Expensive machines & materials; residual stress; post-processing (supports, heat treatment) required; limited build size

Thermo-setting plastic

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Process	Thermoset Usable?	Notes
FFF / FDM	Rare / experimental	Needs post-cure; not standard
CFF	No	Only thermoplastic matrix works
SLA / DLP	Yes	Standard photopolymer resins are thermosetting
SLS	No	Requires meltable powder
DMLS / SLM	N/A	Metal-based

Capabilities

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- Rapid prototyping
- Creation of complex geometries
- Custom manufacturing
- Multimmaterial print
- On demand production
- Medical innovations prosthetics, implants, surgical models

1. **FFF/FDM:** Affordable, versatile, simple parts; good for prototyping.
2. **CFF:** Strength-focused polymer printing; best when mechanical performance matters.
3. **SLA/DLP:** Fine detail and smooth finish; small-to-medium precision parts.
4. **SLS:** Functional polymer parts with complex geometries; isotropic strength.
5. **DMLS/SLM:** High-performance metal parts; fully functional end-use components; supports complex designs unachievable with traditional machining.

Uses

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Industrial: Aerospace, automotive tooling, jigs, fixtures.
Healthcare: Prosthetics, dental crowns, surgical models, implants.
Architecture: Scale models, 3D-printed houses.
Consumer Goods: Custom accessories, jewelry, household tools.
Education: STEM learning, engineering projects.
Art & Fashion: Sculptures, wearable designs.

Software Used

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3D Printer Software & Linux Interface:

- 3D Modeling: Blender (design models)
- Slicing: Cura, PrusaSlicer (convert models to G-code)
- Printer Firmware: Marlin, Klipper (runs on printer hardware)
- Host Software: OctoPrint, Pronterface (control printer from Linux via USB/network)

Workflow:
Design (Blender) → Slice (Cura) → Send G-code (OctoPrint/Linux) → Printer firmware executes

Linux Interface:

- Communicates via USB serial or network
- OctoPrint is popular for Linux-based printer control

Step	Software example	Function
3d Modeling	Blender, Fusion 360	Creates 3D desing
Slicing	Cura, PrusaSlicer	Convert models to G-code
Host/Printer control	OctoPrint, Pronterface	Send commands, monitor prints
Firmware (Printer)	Marlin. Klipper	Controls printer hardware, runs G- code

Model Selection

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Printer	Price	Features	CF compatibility	Build volume
Creality K1C/K1 Max	65-85k	Core XY: 300`C hotend: Direct drive Enclosed chamber Auto-level AI camera High-speed printing	Supports PLA-CF PA-CF PET-CF	220 *220 *250mm
QIDI Tech Q1 pro	2.0-2.2L	Heated chamber(~30`C) 350`C hotend Auto-level Direct drive Fast speeds	Designed for Nylon-CF PET-CF etc	245 *245 *200mm
FlashForge creator 3	1.94L	Fully enclosed Dual extruder HEPA filtered Heated bed 120`C Ventilation fans	Nylon(PA) PLA ABS PC PETG Also supports CF composites	300 *250 *200mm
Fusion3	>2L	Industrial FFF Interchangeable heads High-temp (320`C) Large build volume	Certified for carbon fiber filaments	F306: 306 *306 *306mm F400: 355 *355 *315mm EDGE: 368 *368 *343mm
Bambu Lab X1 Carbon	1.45-2.37L	Lightweight Core XY with 7 µm lidar, hardened steel nozzle, 300 °C hotend,	PA PC CF	256 *256 *256mm
Raise3D E2CF	3.2-3.5L	Direct drive dual extruder Hardened steel nozzles and abrasion-resistant components Fully enclosed chamber Auto bed levelling + flexible build plate Independent dual extrusion (IDEX) — can print mirror mode or duplicate mode.	PA12 CF PA CF+ PETG CF PLA CF PC CF.	Single extruder: 330*240*240mm Dual extruder: 295*240*240mm

Slicing configuration

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Process	Common Slicers	Key Configurations	
FFF / FDM	Cura, PrusaSlicer, FlashPrint, Bambu Studio, IdeaMaker	Layer height (0.05–0.4 mm), Infill density/pattern (0–100%), Shell thickness (1–3 walls), Print speed (30–150 mm/s), Nozzle/Bed Temp, Supports	Smaller layer height → higher detail; higher infill & shell → stronger; supports for overhangs; speed vs quality trade-off
CFF (Continuous Fiber FDM)	Markforged Eiger, Bambu Studio (fiber module)	• Fiber orientation: Align fibers with stress for max strength • Layer height**:** 0.1–0.3 mm • Infill: Standard FFF infill; fiber added selectively • Matrix material settings**:** Temp, speed, flow for proper fiber bonding	Fiber orientation critical for strength; selective fiber placement maximizes stiffness; matrix extrusion similar to FFF
SLA / DLP	Chitubox, Bambu Studio, PreForm	Layer height (0.025–0.1 mm), Exposure time, Lift/retract speed, Support placement, Anti-aliasing / XY resolution	Exposure time affects hardness & cure depth; supports crucial for overhangs; fine layer height improves surface finish
SLS	Materialise Magics, 3D Sprint	Layer thickness (50–150 µm), Laser power & scan speed, Part orientation & nesting	Powder acts as support; scan parameters affect density & surface quality; packing impacts thermal consistency
DMLS / SLM	Materialise Magics, 3DXpert, Siemens NX	Layer thickness (20–60 µm), Laser power & scan speed, Hatch distance, Part orientation, Support structures	Settings critical for density, mechanical properties, and stress control; supports needed for overhangs & heat management

Hardness comparison

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Technology	Common Materials	Typical Hardness Range		Overall Strength
FFF / FDM	PLA, ABS, PETG, Nylon, CF-filled	60–120 MPa (Tensile), Rockwell R ~70–100	Thermoplastics; hardness is lower, reinforced filaments like CF or CFF increase stiffness Strength depends on layer adhesion; anisotropic (weaker along Z-axis)	Low - moderate
CFF (Continuous Fiber FDM)	Nylon + Carbon/Glass Fiber	150–250 MPa (Tensile), Rockwell R ~120–150	Fibers significantly improve hardness & stiffness Fibers greatly improve tensile and flexural strength; strength is directional along fiber	High (polymers)
SLA / DLP	Photopolymer resins	50–90 MPa (Tensile), Shore D 80–95	Rigid resins can reach higher hardness; brittle compared to FDM Can be brittle; good surface finish, but lower impact resistance	Moderate – high (rigid resins)
SLS	Nylon, PA12, composites	50–75 MPa (Tensile), Shore D 70–85	Sintered powders; decent hardness, isotropic after sintering Stronger than FDM due to isotropic sintering; still less than fiber-reinforced or metal prints	Moderate
DMLS / SLM	Stainless steel, Titanium, Aluminum	200–600 HB (Brinell), HRC 30–55	Metal prints; hardness can exceed cast/forged parts with heat treatment Comparable or superior to machined/forged metal; excellent tensile, compressive, and impact strength	Very high

- **FFF/FDM:** Focus on layer height, infill, and shell; simple but can be strengthened with fiber (CFF).
- **SLA/DLP:** Exposure & supports dominate; very high resolution possible.
- **SLS:** Laser parameters and part layout more important than supports.
- **DMLS/SLM:** Most complex; laser settings, orientation, and supports crucial for metal parts' strength and hardness.

Tool chain

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1. CAD / Design Tools

- **Purpose:** Create a 3D model of the part.
- **Common Tools:**
- **Fusion 360, SolidWorks, Tinkercad, Blender, Rhino**
- **Notes:**
- CAD model is the starting point for all additive processes.
- Must be **manifold ("watertight")** for successful printing.

2. Slicing Software

- **Purpose:** Converts CAD (STL/OBJ/3MF) into printer instructions (G-code for FFF/CFF, machine code for others).
- **Key Tasks:**
- Layering
- Infill patterns
- Supports & brims
- Temperature, speed, laser power (depending on process)
- **Examples:**
- **FFF/FDM:** Cura, PrusaSlicer, FlashPrint, Bambu Studio, IdeaMaker
- **CFF:** Markforged Eiger, Bambu Studio (fiber module)
- **SLA/DLP:** Chitubox, PreForm, Bambu Studio
- **SLS / DMLS / SLM:** Materialise Magics, 3DXpert, Siemens NX
- **Notes:** Proper slicing configuration is critical for strength, resolution, and surface quality.

3. Printer Firmware / Control

- **Purpose:** Interpret G-code / machine instructions and control motors, heaters, lasers, or curing systems.
- **Key Functions:**
- Motor control (X, Y, Z axes, extruder, recoater)
- Temperature / laser power regulation
- Monitoring sensors (bed leveling, filament detection)
- Safety interlocks
- **Examples:** Marlin (FFF), proprietary firmware for DMLS/SLM, Bambu Lab firmware for X1 Carbon

4. Post-Processing Tools

- **Purpose:** Improve mechanical properties, surface finish, or part accuracy.
- **Methods:**
- **FFF / CFF:** Sanding, annealing, acetone vapor smoothing (for ABS)
- **SLA/DLP:** UV curing, washing in isopropyl alcohol
- **SLS:** Powder removal, bead blasting, infiltration with resins
- **DMLS / SLM:** Heat treatment, support removal, machining, surface finishing

5. Monitoring & Cloud Tools

- **Purpose:** Track print progress, manage queues, and optimize workflow.
- **Examples:**
- **Bambu Handy / Bambu Cloud** (Bambu Lab)
- **RaiseCloud** (Raise3D)

- OctoPrint, AstroPrint (FFF/FDM)
- **Notes:** Allows remote control, analytics, and sometimes slicing integration.

1. **Design CAD Model →**
2. **Slice with appropriate slicer**
3. **Send instructions to printer (Firmware interprets G-code / machine code)**
   Print part
4. **Post-process for strength, surface, and functionality**
5. **Monitor and optimize workflow with cloud/software tools**

Features

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1. Core XY :

CoreXY is a design that lets a 3D printer’s head move fast and smooth by using two motors and special belts. It makes printing quicker, steadier, and more accurate

2. Hotend:

The part of a 3D printer that melts the filament so it can be squeezed out through the nozzle to make print.

3. Direct drive:

The filament feeder is placed right on top of the hotend, so it pushes the filament into the nozzle directly.
Better control of flexible or special filaments (like carbon fiber blends).
Faster retractions (pulling filament back to avoid stringing).

Downside: the print head is a bit heavier, so very high-speed printing can cause more vibration compared to other systems.

4. Enclosed chamber:

- Keeps heat in → important for materials like carbon fiber nylon that warp if they cool too fast.
- Protects the print from dust or wind.
- Quieter and sometimes safer, since hot parts are harder to touch by accident.

5. Auto-level:

the 3D printer checks and adjusts the print bed’s height automatically before printing.

It uses a small sensor or probe to measure the bed at different points and then adjusts the nozzle’s movement so the first layer sticks evenly.

6. AI camera:

An AI camera in a 3D printer is a built-in camera that uses software to watch your print and spot problems automatically.

It can:

- Detect failed prints or spaghetti-like messes.
- Pause the print or send you an alert.
- Let you monitor remotely from your phone or computer.

7. High-speed printing

- Stronger, lighter moving parts
- Stable designs (like CoreXY)
- Smart software that controls acceleration

8. Heated chamber

- Prevents warping and cracking in materials like carbon fiber nylon, ABS, or polycarbonate.
- Keeps the entire print at a steady temperature.

- Improves layer bonding, making parts stronger.

9. Dual extruder:

A dual extruder 3D printer has two nozzles (or two filament feeds) instead of one.

Print two different materials in one object (e.g., carbon fiber nylon + support material).

Print in two colors without swapping filament.
Use special dissolvable supports for complex shapes.

10. HEPA filtered

A HEPA filter in a 3D printer is a special air filter that traps tiny particles released while printing, especially with materials like carbon fiber, ABS, or nylon.

- Removes ultrafine particles that can be harmful if inhaled.
- Keeps the air cleaner in your workspace.
- Often paired with an activated carbon filter to also remove odors.

11. Industrial FFF

Industrial FFF (Fused Filament Fabrication) is basically the heavy-duty, big-league version of regular desktop 3D printing, built for factories, engineering labs, and high-volume production rather than hobbyists.

- FFF means printing objects by melting plastic filament and laying it down layer by layer.
- Industrial FFF is the same process, but with larger machines, higher precision, stronger materials, and full environmental control for consistent results.

12. Core XY with 7micrometer lidar
13. CoreXY already gives speed and positional precision.

LiDAR with 7 µm precision adds **micron-level quality control** — making it possible to print parts with much tighter tolerances and catch print failures early.

This combo is often seen in **high-end or industrial printers** where dimensional accuracy is critical.

- **LiDAR (Light Detection and Ranging):** Uses laser pulses to measure distances with extreme accuracy.
- **7 µm resolution:** This means the sensor can detect surface height changes as small as 0.007 mm — about 1/10th the thickness of a human hair.
- **In a 3D printer, LiDAR could be used for:**
- **Bed leveling** with ultra-high precision.
- **Live layer inspection** to detect defects or uneven extrusion.
- **Automatic model dimension verification** during printing.

13. Independent dual extrusion (IDEX)

Independent Dual Extrusion (IDEX) means the 3D printer has **two separate print heads (extruders)**, each mounted on its own carriage, that can move **independently** along the same axis.

- Printing a model with **different colors**.
- Combining **flexible and rigid materials** in one print.

- **No cross-contamination** between filaments (e.g., no PLA dripping into PETG print).
- **Two-material printing** (e.g., rigid material + dissolvable support).
- **Two-color printing** without purge towers (because one nozzle is idle and parked).
- **Duplication mode:** Both heads print the same part at the same time for double output.
- **Mirror mode:** They print mirrored versions simultaneously.

Mobile app of QIDI Tech Q1 pro

Key Features

- **Remote Monitoring**: View real-time print progress and camera feed.
- **Remote Control**: Start, pause, or stop prints remotely.
- **Preheating**: Prepare the printer for printing from a distance.
- **Time-Lapse Photography**: Capture time-lapse videos of your prints.
- **Print History**: Access records of past prints.
- **Firmware Updates**: Update printer firmware directly through the app

Component Selection

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