Additive Manufacturing Laboratory

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Goal

- Additive Manufacturing introduction and multi-user Lab presentation

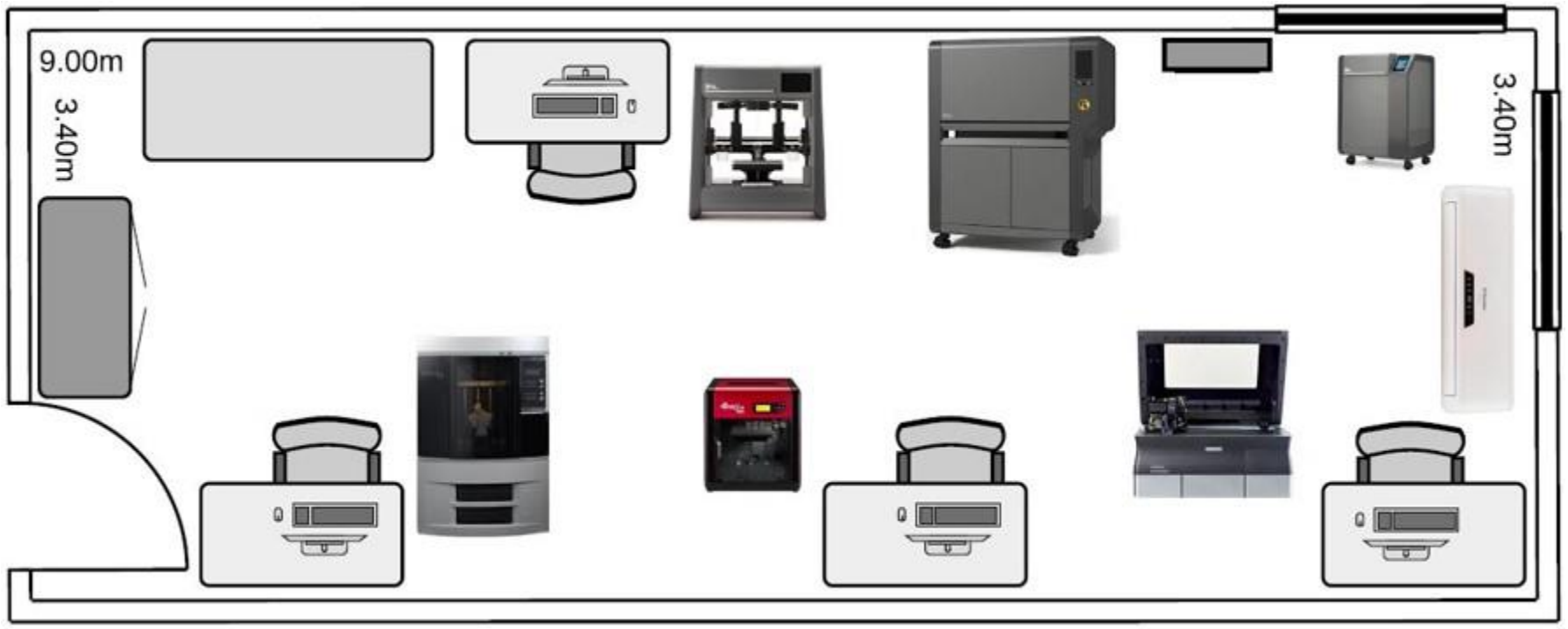
AM Lab Facility

- Equipment – AM Lab

Model Machine	Dimension Elite	Objet30 PRO	UPBOX	DM Studio
				
Print Technology	FDM - Fused Deposition Material	Polyjet	FDM - Fused Deposition Material	BMD – Bound Metal Deposition
Build volumeX Y Z (mm)	300 x 300 x 300	300 x 200 x 150	255 x 205 x 205	300 x 200 x 200
Build rate (cm^3/h)	5	5	3	16
Nozzle diameter (µm)	250	600 dpi	750	400
Layer thickness (µm)	250	36	750	50
Power consumption (W)	1500	760	220	980
Power supply	110 V / 15 A	110 V / 7 A	110 V / 10 A	120 V / 20 A
Machine Dimensions L x H x W (mm)	914 x 686 x 1040	830 x 600 x 600	493 x 493 x 517	830 x 950 x 530
Weight(kg)	136	106	20	97
Material state	Fillament	UV Photosensitive resin	Fillament	Solid bound metal rod
Materials	ABS PLA	Rigid Opaque Rigid transparent	ABS PLA	17-4 PH 316 L Titanium Ti-6Al-4V Steel 4140 Tool Steel H13
Post processing	Yes	Yes	Yes	No

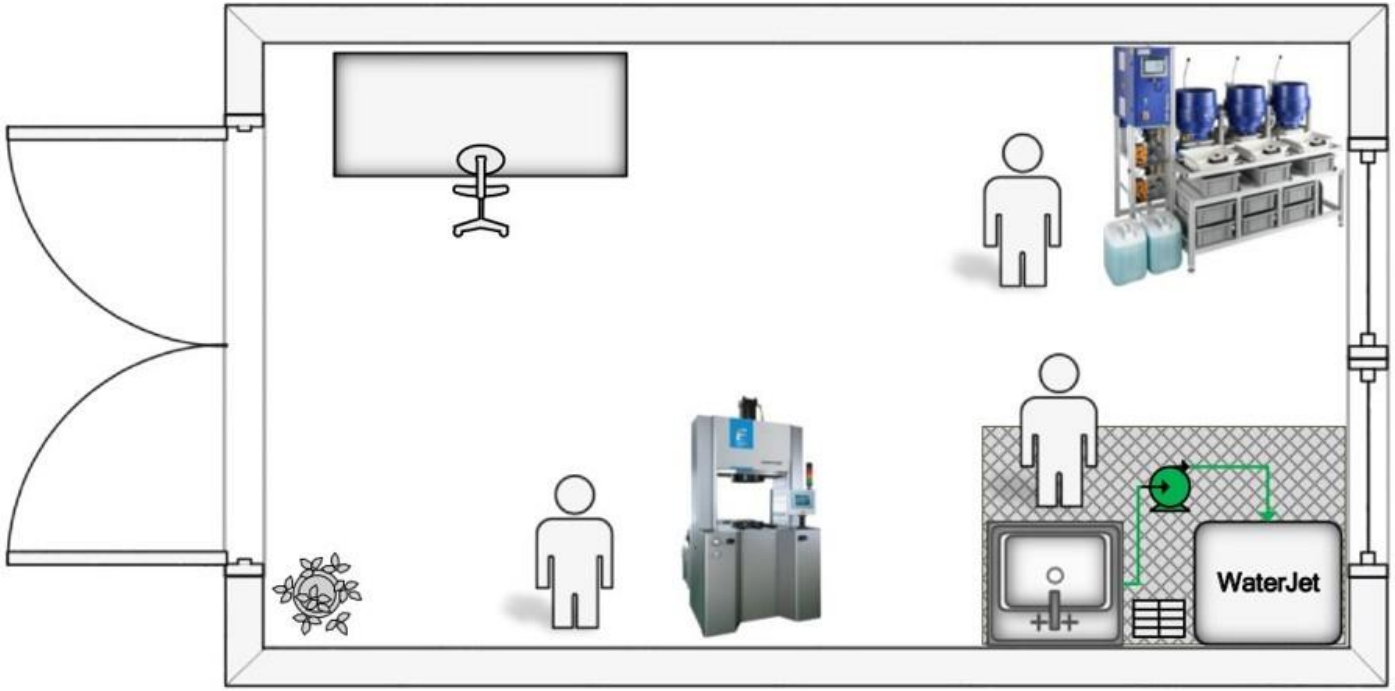
AM Lab Facility

- Layout – AM Lab



AM Lab Facility

- Finishing Lab – in Quote



AM Lab Facility

- RCGI management
- Academic customer → consumables cost
- External customer → market cost

Additive Manufacturing

- Additive manufacturing (AM) is defined by the ASTM as:

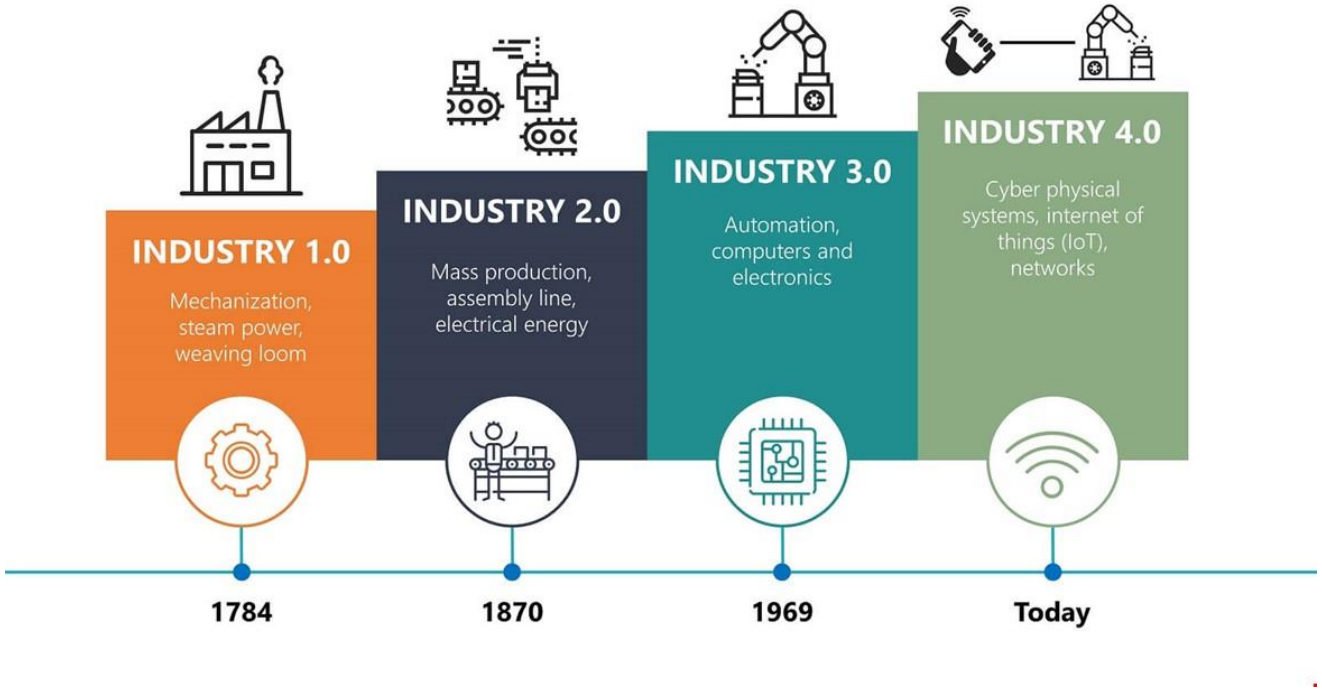
"A process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies".

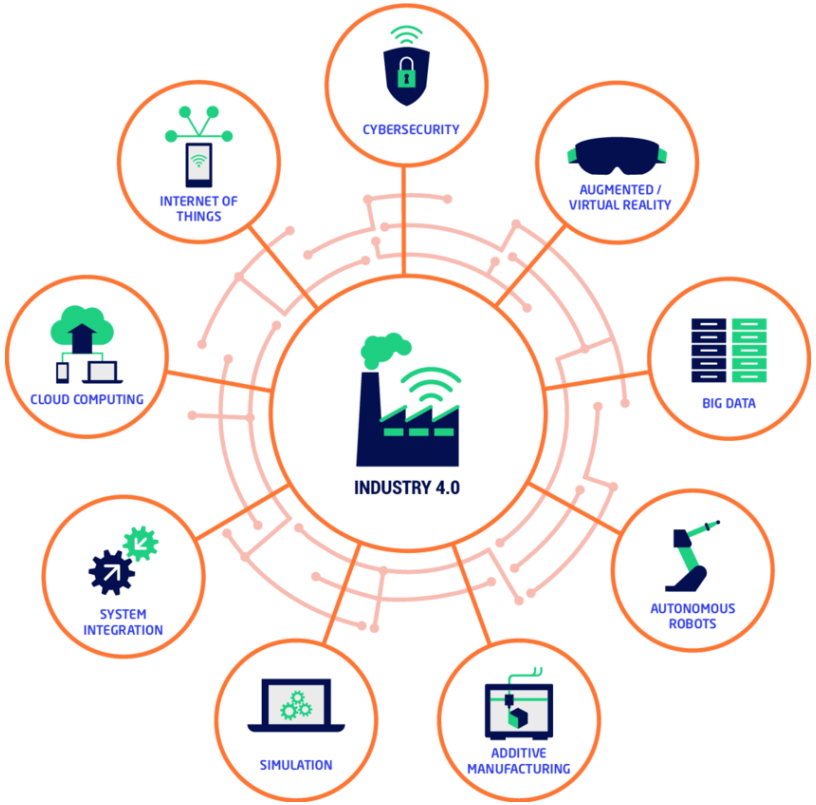
- These new techniques, while still evolving, are projected to exert a profound impact on manufacturing. They can give industry new design flexibility, reduce lifecycle energy use, and shorten time to market.

Source: 3D Printing and Additive Manufacturing State of the Industry: Annual Worldwide Progress Report." Wohlers Associates, 2014

Additive Manufacturing

- Additive Manufacturing – Industry 4.0





Additive Manufacturing

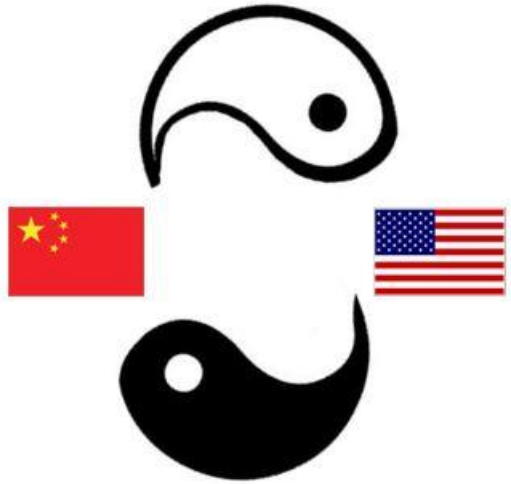
- Supply Chain Shift – Direct to Part

From

To

Additive Manufacturing

- Supply Chain



Source: Chinese Production, The Economist Jun, 2017

Additive Manufacturing

Additive Manufacturing

Ford **slashes** prototyping time

At Ford, a traditional part prototype takes 8 to 16 weeks and can cost over US$100,000. With 3D printing, Ford can produce, assemble, and prep it for testing **in less than a week for just a few thousand dollars**.

Source: "Harold Sears, additive manufacturing technical expert, Ford Motor Co."

Airbus radically **reduces** material waste

With traditional manufacturing techniques, Airbus needs 300 tons of material to build 32 tons of parts. 3D printing requires just **30 tons of metal powder**.

Source: "Peter Sander, vice president, emerging technology and concepts, Airbus"

GE consolidates parts while making them **stronger**

GE Aviation has created a fuel nozzle that **consolidates 20 parts into 1**, while making the assembly five times more durable.

Source: "Tom Sinnett, applications manager, Additive Development Center, GE Aviation"

Additive Manufacturing

Micro-scale features

- Direct ceramic deposition
- Direct written sensors

Ceramics printing

Direct write

U/S probes

CBM Sensors

- Ultrasound probes
- Integrated circuitry
- Direct-written CBM sensors

15 µm

Macro-scale features

- DMLM & Electron beam
- Commercial polymer AM

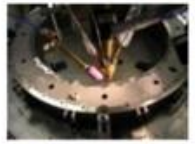
Functional metal, ceramics & polymer parts
Commercial polymer & metal machines

- Turbomachinery applications
- Test hardware
- Limited production since 2014

200 µm

Large-scale features

- Spray technologies
- Laser & EB cladding
- Sand casting mold and core



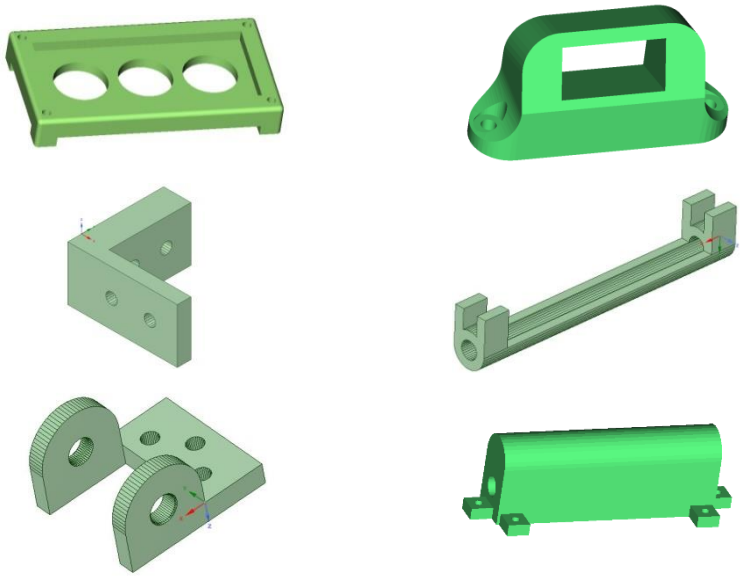
Large low volume functional metal parts
Custom built machines
Foundry of the future enabler

- Repair & feature addition; reduced buy-to-fly
- LRIP casting; NPI acceleration
- In use

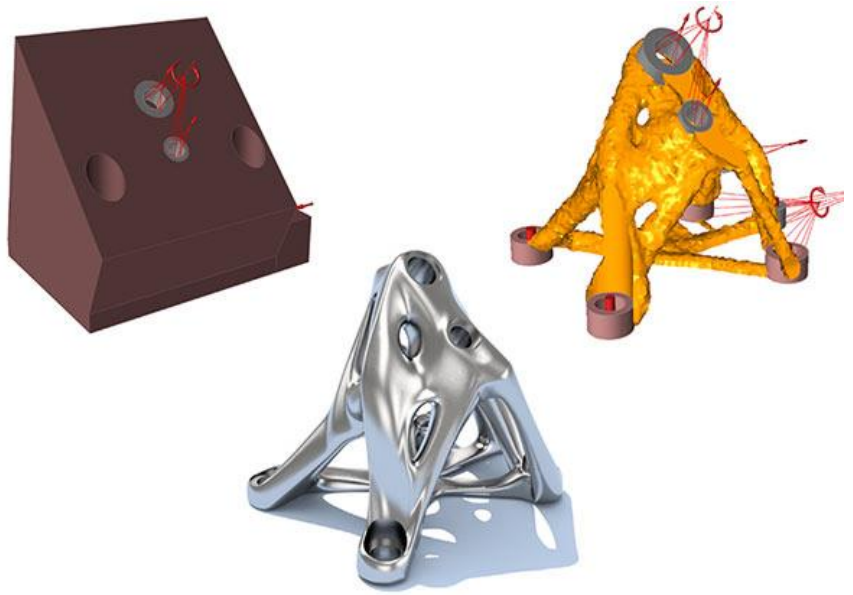
500 µm

Design for Additive Manufacturing – DfMA

Design Thinking
Manufacturing & Conventional Applications



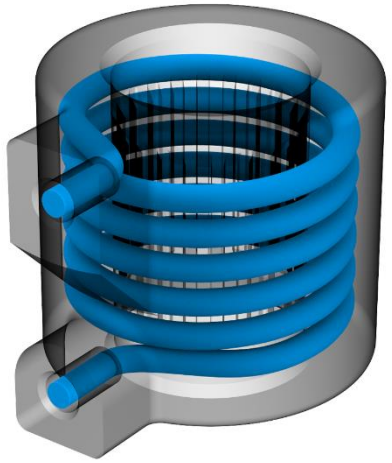
Design Thinking
Manufacturing & Innovative Applications



Design for Additive Manufacturing – DfMA

- Innovative Designs

Swirler for gas turbine provided by EOS.

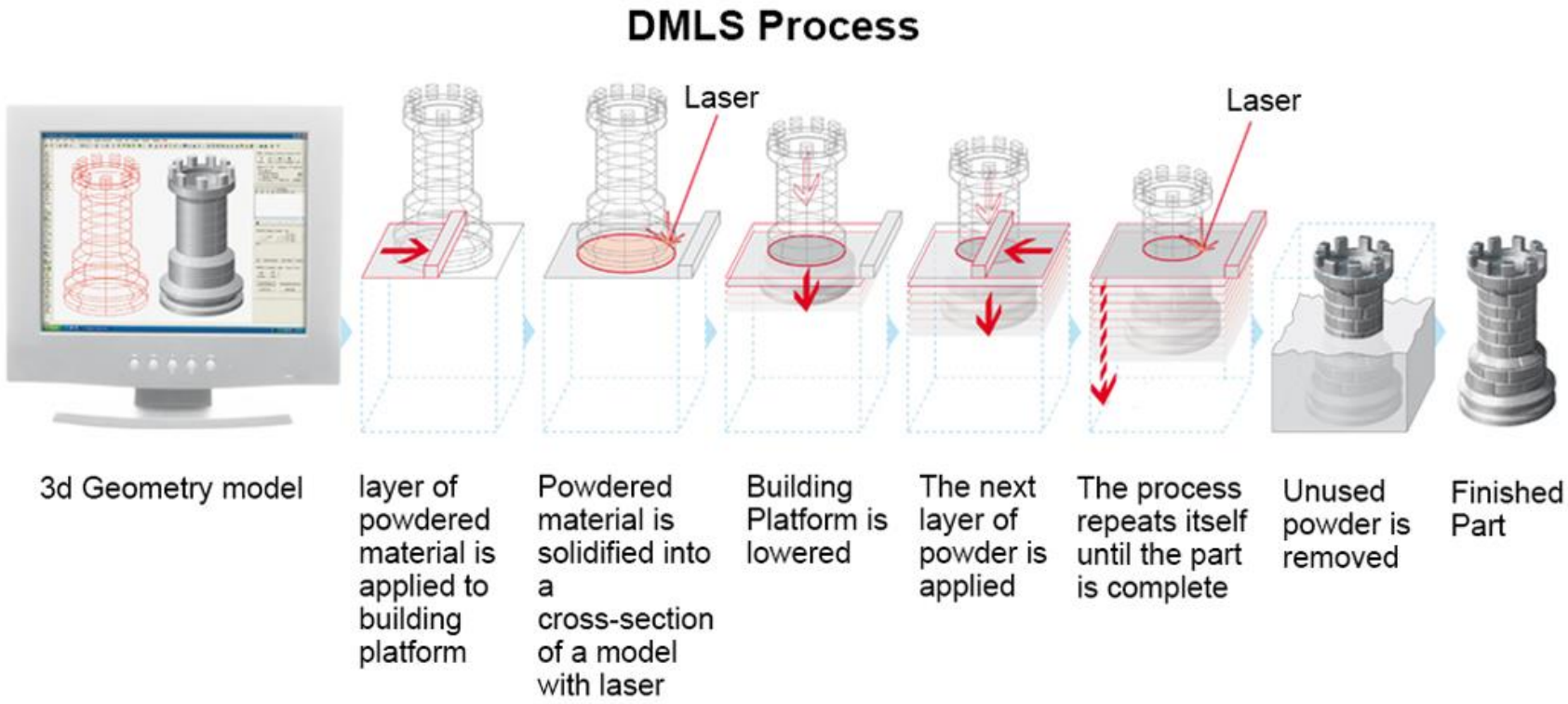


Tooling - conformal cooling channels by DM.

Metal AM – Technologies

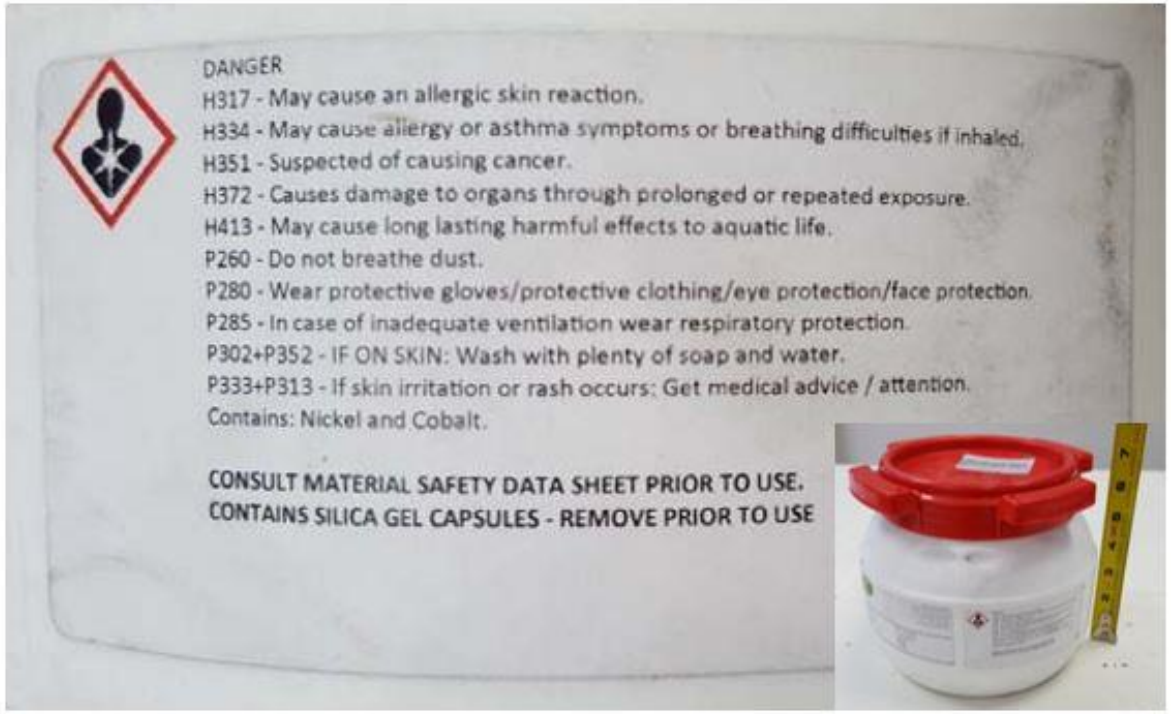
			Metal	Heat Source	Speed	Precision	Size	Comments
Powder Bed	DMLM Direct Metal Laser Melting		Powder Bed	Laser				LEAP Fuel Nozzle
	EBM Electron Beam Melting		Powder Bed	Electron Beam				Alternate Process for Castings
Deposition	LPF Laser Powder Forming		Powder Deposition	Laser				Large Prototypes
	EBFF Electron Beam Free Form		Wire	Electron Beam				Large Prototypes
	Hot Wire		Wire	TIG/ Laser				Large Prototypes
Consolidation	MIM Metal Injection Molding		Binder Injection	Consolidation				Small Part, High Volume
	Binder Jet		Binder Jet	Consolidation				
					H	M	L	

Metal AM – DMLM

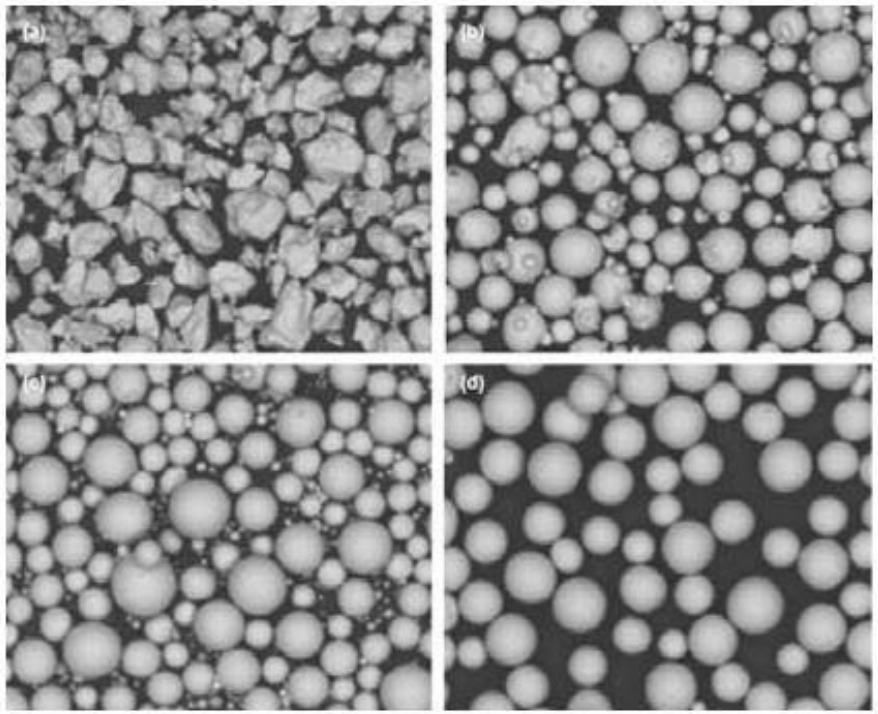


Source: GE Additive , www.ge.com/additive

Metal AM – DMLM Safety



Hazard material information



Diameter can vary 1 - 500 µm

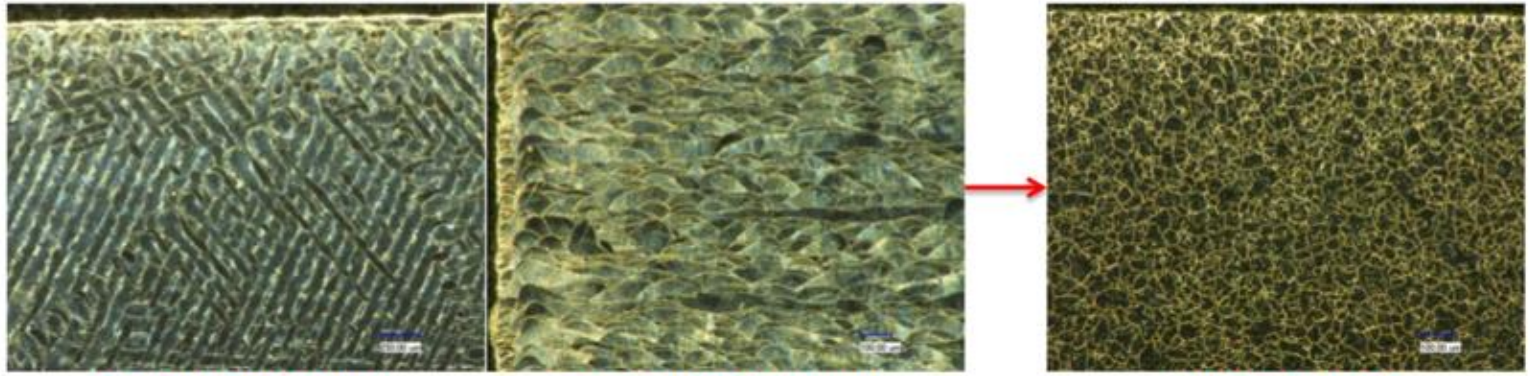
Metal AM – DMLM Safety

Metal AM – DMLM Post Process

Stress Relief – Required to eliminate residual thermal stresses left during build process

Hot Isostatic Press – High temperature, high pressure thermal cycle to eliminate sub-surface porosity

Solution – Completes conversion of material to near wrought, isotropic structure



As-built (Top View) As-built (Side View) Heat Treated

Metal AM – DMLM Post Process

Metal AM – No Laser-Based

STUDIO SYSTEM

OFFICE-FRIENDLY, AFFORDABLE METAL 3D PRINTING.
DESIGNED FOR ENGINEERS.

PRODUCTION SYSTEM

100X FASTER. QUALITY & COST-PER-PART NEEDED TO SCALE.
DESIGNED FOR THROUGHPUT.

Metal AM – SPJ

Metal AM – SPJ

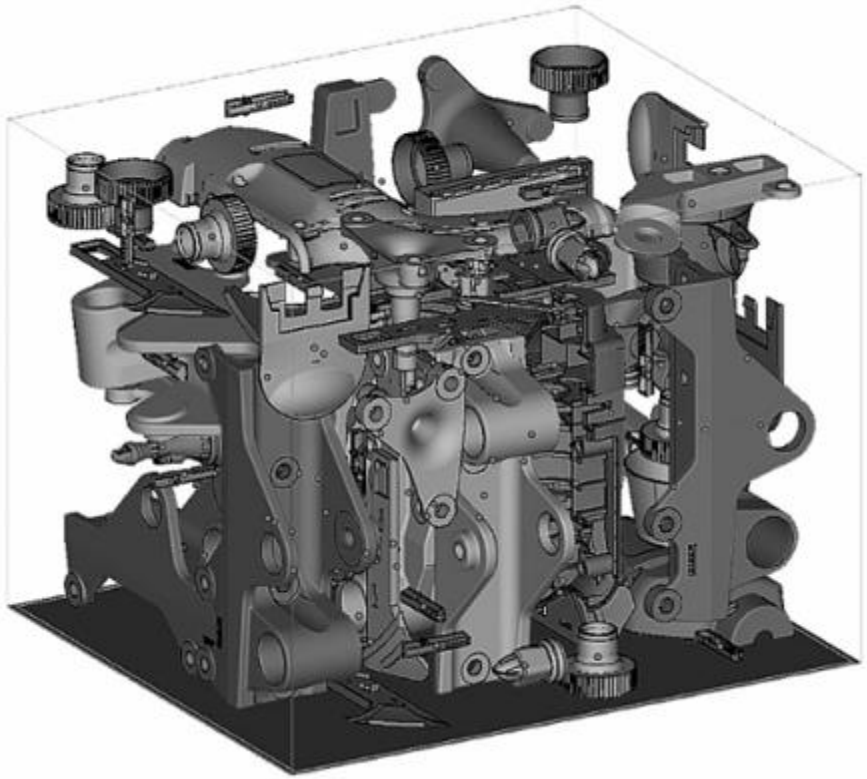
- Single Pass Jetting – SPJ

20X CHEAPER

LOW-COST MIM POWDER, HIGH THROUGHPUT, AND SIMPLE POST-PROCESSING DELIVER PER-PART COSTS THAT ARE COMPETITIVE WITH TRADITIONAL MANUFACTURING PROCESSES – AND UP TO 20X LOWER THAN TODAY'S METAL 3D PRINTING SYSTEMS.

HIGH DENSITY NESTING

NO BUILD PLATES – HIGHER YIELD & PRODUCTIVITY

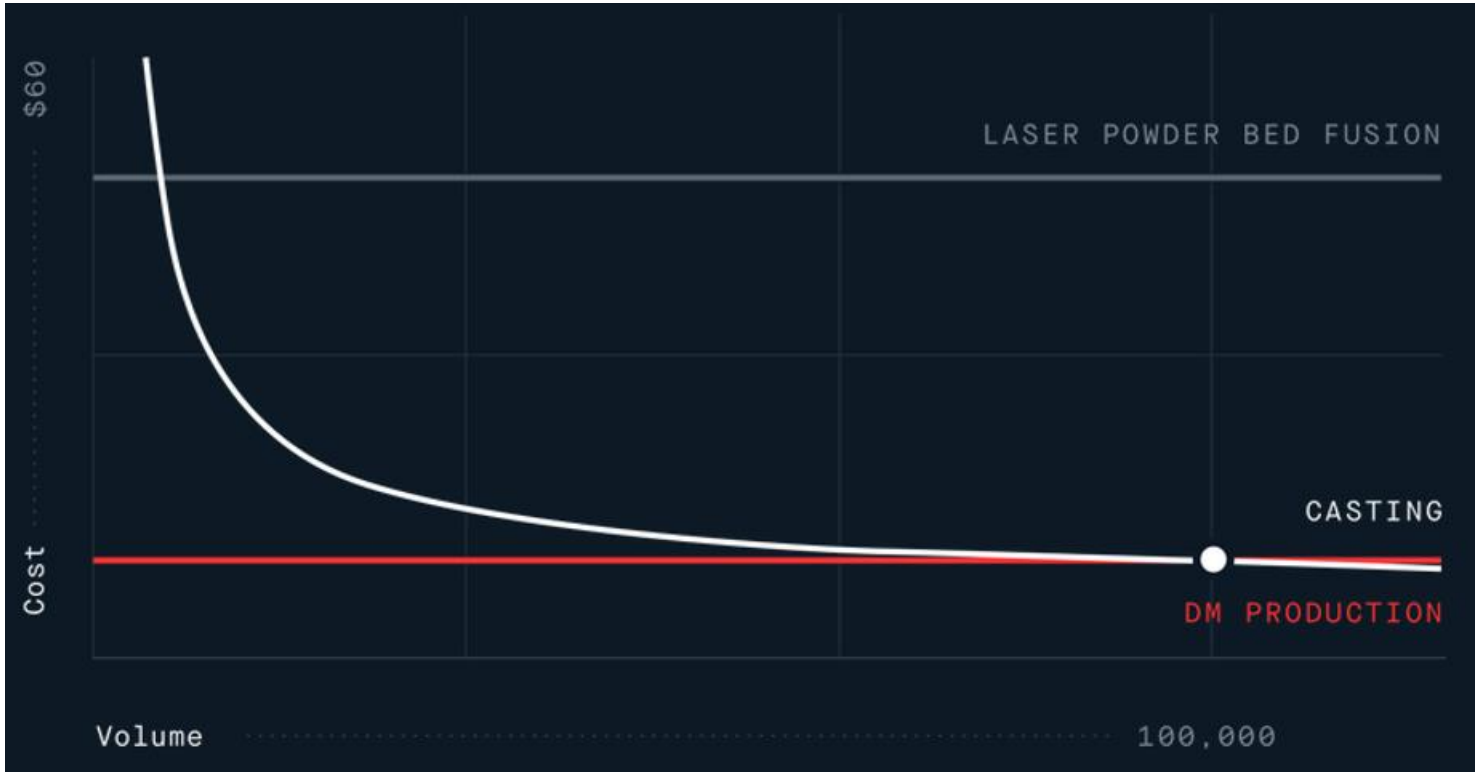


Metal AM – SPJ

- Single Pass Jetting – SPJ

Metal AM – SPJ

BMW water pump impeller
Total cost-per-part vs production volume



Metal AM – BMD

- Bound Metal Deposition – BMD

SAFE

NO HAZARDOUS POWDERS
NO EXTERNAL VENTILATION
NO STRESS RELIEF
NO 3RD PARTY EQUIPMENT
NO WELDED SUPPORTS

NO RESPIRATORS
NO 480V 3-PHASE POWER
NO DANGEROUS LASERS
NO DEDICATED OPERATORS
NO SPECIAL FACILITIES

Metal AM – BMD

- Bound Metal Deposition – BMD

Up to 80% cheaper

BASF We create chemistry

SANDVIK

CARPENTER

ATW

Veloxint

Metal AM – BMD


Ready
JOBS IN QUEUE 2
Estimated completion time
--
Current Layer
--/--
Material Supply
STATUS
Good
MATERIAL NEEDED TO COMPLETE JOB
Metal --
Interface --
Parts
Tracking ID --
Fabrication instruction --
Owner --
XBV XBV XBV XBV XBV XBV
Start
Printer
DM-1234
LOCATION
Lab
316L Stainless
Metal 000 g
Interface 000 g

Metal AM – Materials

316L
STAINLESS STEEL

- HIGH TOUGHNESS
- EXCELLENT CORROSION RESISTANCE
- SUITABLE APPLICATIONS:
  - FOOD PROCESSING
  - PHARMACEUTICAL MANUFACTURING
  - SALT WATER & MARINE ENVIRONMENTS

Metal AM – Materials

17-4 PH
STAINLESS STEEL

- HIGH STRENGTH
- PRECIPITATION HARDENING
- CORROSION RESISTANT
- SUITABLE APPLICATIONS:
  - AEROSPACE/PETROLEUM/CHEMICAL/FOOD PROCESSING INDUSTRIES
  - JIGS/FIXTURES/BRACKETS
  - PRODUCTION PARTS SUCH AS GEARS, VALVES, & PUMP SHAFTS

Metal AM – Materials

4140

LOW ALLOY STEEL

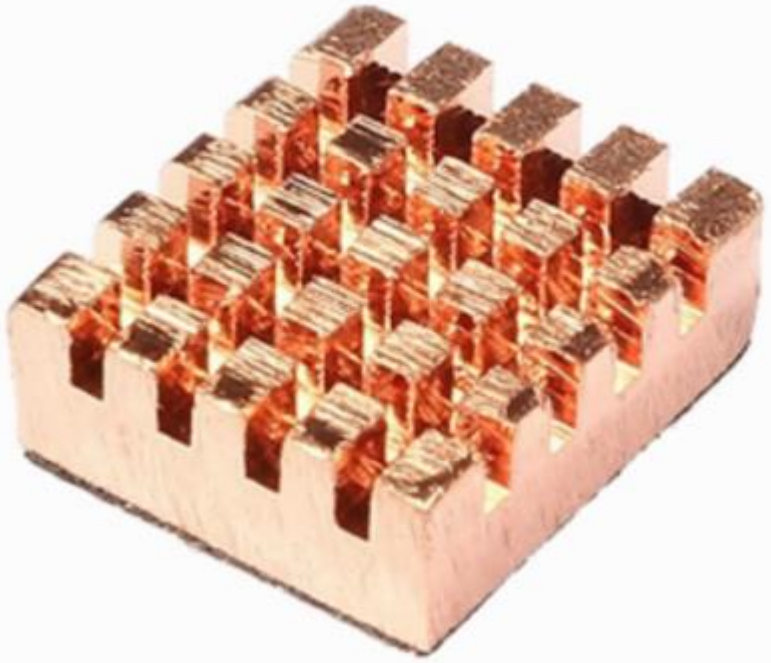
- ALSO KNOWN AS CHROMOLY
- SUPERIOR HARDNESS & STRENGTH
- GOOD STRENGTH-TO-WEIGHT RATIO
- SUITABLE APPLICATIONS:
  - AEROSPACE & AUTOMOTIVE INDUSTRIES
  - JIGS & FIXTURES, MOLD BASES, FORMING DIES
  - REPLACEMENT PARTS FOR INDUSTRIAL MACHINERY

Metal AM – Materials

C11000

COPPER

- ALSO KNOWN AS ALLOY 110 – COMMON COPPER
- EXCELLENT THERMAL & ELECTRICAL CONDUCTIVITY
- BROAD RANGE OF TEMPERS
- SUITABLE APPLICATIONS:
  - CONSUMER ELECTRONICS
  - ELECTRICAL GOODS SUCH AS BUSES
  - MOTORS & HEAT SINKS



Metal AM – Materials

INCONEL 625

SUPER ALLOY

- NICKEL-BASED SUPER ALLOY
- EXCELLENT STRENGTH & PERFORMANCE AT ELEVATED TEMPERATURES
- REMARKABLE CORROSION & OXIDATION RESISTANCE
- SUITABLE APPLICATIONS:
  - AEROSPACE, NUCLEAR, MARINE, & CHEMICAL PROCESSING
  - HIGH PRESSURE EQUIPMENT SUCH AS PUMPS & VALVES
  - AIRCRAFT DUCTING & JET ENGINE EXHAUST SYSTEMS

Metal AM – Materials

KOVAR F-15

LOW EXPANSION ALLOY

- CONTROLLED EXPANSION ALLOY CONTAINING NICKEL, COBALT, & IRON
- CTE MATCHED TO BOROSILICATE GLASS (PYREX)
- TEMPERATURE RANGE FROM ABSOLUTE ZERO TO EXTREMELY HIGH HEAT
- SUITABLE APPLICATIONS:
  - AEROSPACE AND ELECTRONICS INDUSTRIES
  - ELECTRONIC FIBER OPTIC & MICROWAVE PACKAGES
  - MICRO-ELECTRONIC MECHANICAL SYSTEMS
  - SUPERCONDUCTING SYSTEMS

Metal AM – Materials

H13

TOOL STEEL

- STANDARDIZED FOR HOT WORKING APPLICATIONS
- CR-MO-V CONTENT PROVIDES PROTECTION AGAINST THERMAL SHOCK AND FATIGUE CRACKING
- GREAT STRENGTH & HEAT RESISTANCE
- HIGH HARDNESS, ABRASION RESISTANCE, AND WEAR CHARACTERISTICS
- VERY MACHINABLE
- SUITABLE APPLICATIONS:
  - SHEAR KNIVES AND OTHER CUTTING INSTRUMENTS
  - VARIOUS MOLD & DIE APPLICATIONS

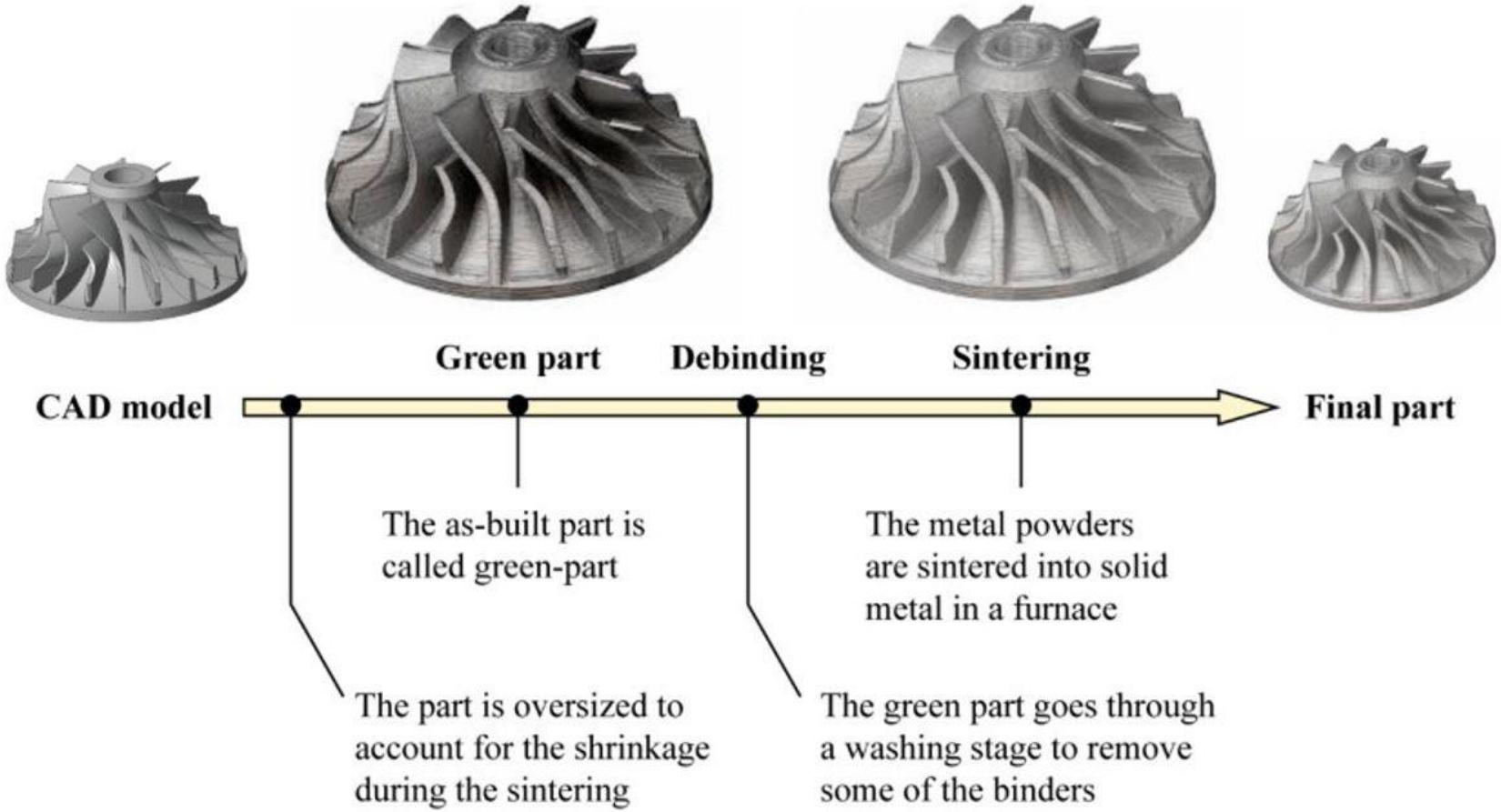
Metal AM – Sintering

FURNACE

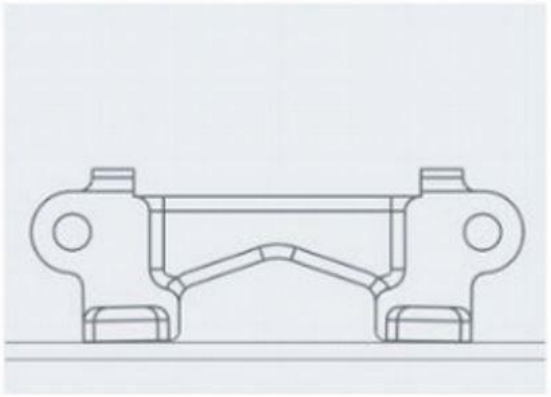
MICROWAVE-ASSISTED

- FIRST OFFICE-FRIENDLY SINTERING FURNACE
- FITS THROUGH THE DOOR – NO VENTING OR SPECIAL FACILITY REQUIREMENTS
- NO RESIDUAL STRESSES LIKE THOSE INTRODUCED IN LASER-BASED SYSTEMS
- DELIVERS EXCELLENT METALLURGICAL PROPERTIES WITH VACUUM AND PARTIAL GAS PRESSURE
- EXPERT METALLURGY BUILT-IN: FULLY AUTOMATED SINTERING PROFILES

Metal AM – Sintering



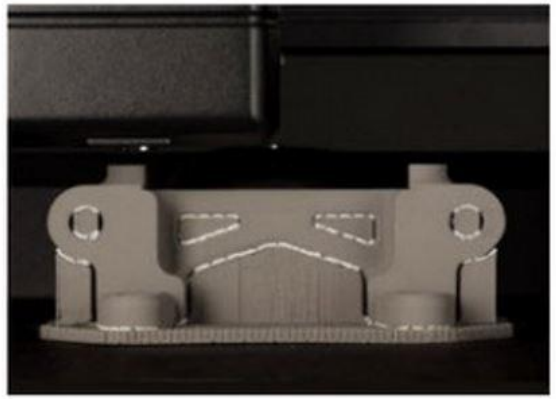
Metal AM – Sintering



1 PREP

Digital model

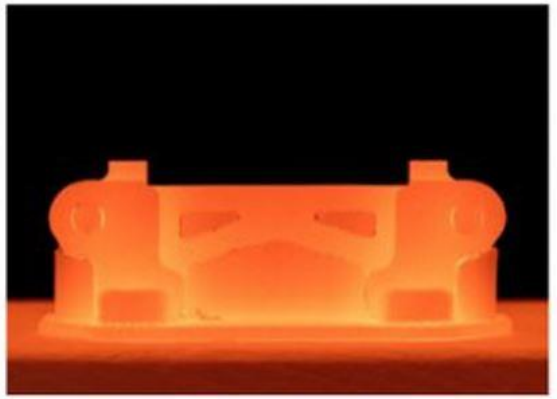
The software accepts a variety of formats–not just STL. Web-based, it runs on a remote or local server so that it is possible to manage jobs from any device securely.



2 PRINT

Green Part

Similar to FDM, the Studio printer shapes a "green" part layer-by-layer by heating and extruding specially formulated bound metal rods. The green part can be easily sanded by hand.



3 DEBIND AND SINTER

Sintered Part

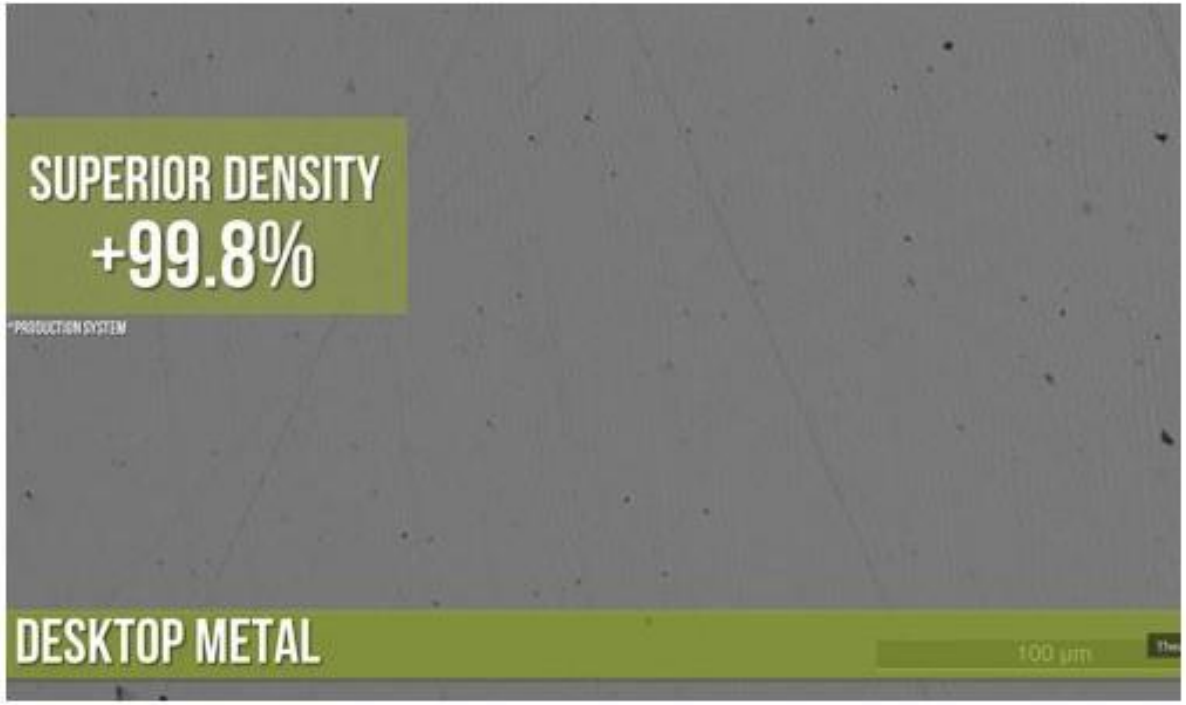
A portion of the plastic binder is first removed. The furnace then heats the part to temperatures near melting, causing the metal powder to densify to 96-99.8%.

4 POST PROCESS

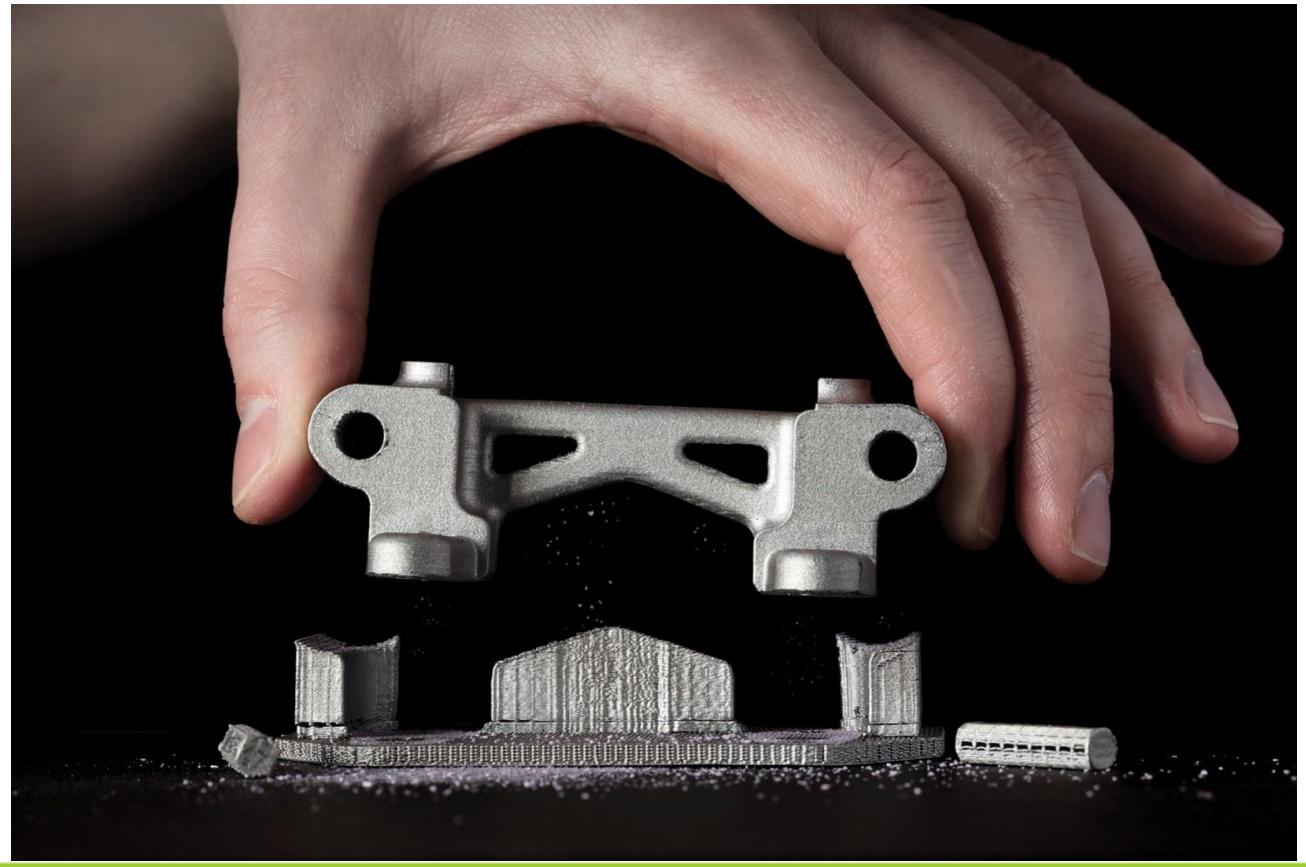
Finished Part

Apply optional finishing methods such as machining or bead blasting for critical tolerances and finishes. Supports are removed by hand.

Metal AM – Sintering



Metal AM – Post Process



Metal AM – Post Process

BEFORE

AFTER

BEFORE

AFTER

Research Centre for
Greenhouse Gas Innovation

THANK YOU!

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