HOW SAND 3D PRINTING IS REVIVING FOUNDRIES

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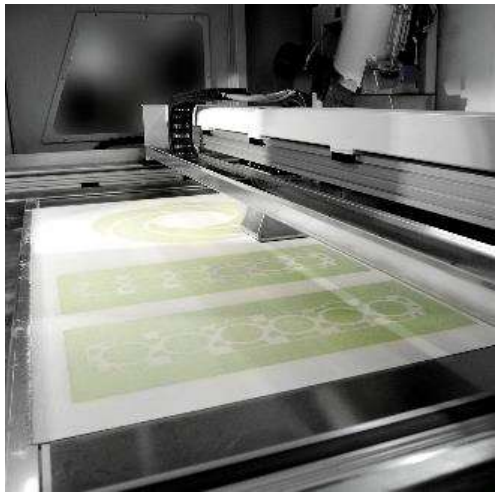
Desktop Metal

About ExOne

Part of the Desktop Metal family since 2021, ExOne is the pioneer in sand binder jet 3D printing. Since 1995, we've delivered powerful 3D printers that help foundries survive and thrive with more efficient and innovative production technology.



Established in the Industry | 20 Years of Sand 3D Printing

200+ ExOne printers installed in foundries around the world. Learn more at exone.com/sandsuccess

Humtown

- Third-generation family-owned business transformed its outlook with the largest fleet of sand 3D printers in the U.S.

Hoosier Pattern

- First pattern shop in North America to own and operate a sand 3D printer in-house offers customers fast turnaround times

Kimura Foundry America

- Prototype foundry places sand binder jetting at the core of its business to deliver top-quality rapid prototypes

Xylem

- OEM simplifies production with 3D printed cores that improve quality while decreasing production costs

Eisengiesserei Mezger

- Iron foundry expands services with sand 3D printing and semi-automated desanding to grow with less labor

Sand 3D Printing | Transformational Benefits

Faster delivery times, done-in-one pours, and new design freedoms

OEMs and foundries optimize business with binder jetting to deliver castings with complex designs and fast turnarounds, while saving money on patterns, molds, and labor.

SPEED

Reduce delivery times

- Regardless of complexity, deliver molds and cores within hours or days, not the weeks and months needed for traditionally manufactured patterns

SAVINGS

Eliminate patterns, molds, and labor

- Eliminate the added time, labor, and expense of mold creation, extraction, repair, and assembly and deliver complex cores at a lower total cost than core shooters

NO PATTERN STORAGE

Replace physical inventory with digital storage

- Print direct from CAD files without the need to store patterns or molds for core shooters while removing the risk of lost patterns or repair for degraded molds

RAPID DESIGN CHANGES

Improve designs without a cost penalty

- Save time and money while reducing waste and optimizing designs by iterating instantly without scrapping existing or creating new patterns and molds for core shooters

EXCEPTIONAL DESIGN FREEDOM

Optimize final parts and mold package design

- Complex and organic geometries for both final parts and rigging and riser design deliver higher-quality castings and enable low-pressure pouring at no extra cost

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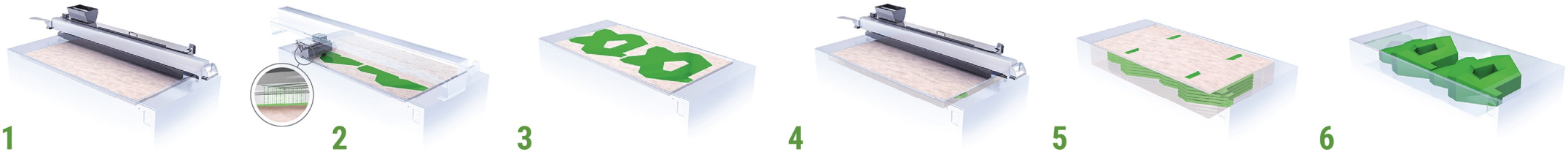
Binder Jetting | Process Overview

Liquid binder applied to powder to form parts and tooling

Digital File Prep → Machine & Material Prep → 3D Printing



1. Powder is deposited.
2. Inkjet applies binder.
3. Each layer is printed fast.
4. Powder is recoated.
5. The process repeats.
6. 3D printing is complete.

Next steps depend on material and application →

- NEW — Sand molds & cores → Depowder → Cure optional
- Sand tooling → Depowder → Coat or infiltrate
- Desktop Metal — Metal & ceramics → Cure → Depowder → Debind & sinter

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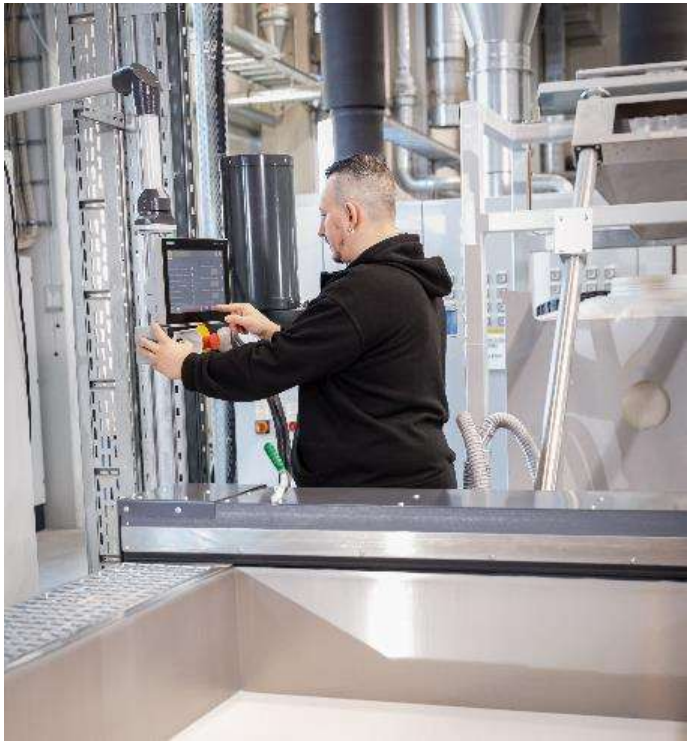
THE ECONOMICS OF SAND 3D PRINTING

True Cost of Traditional Foundry Technology

Beyond cost per cubic inch

Factors to consider when evaluating 3D printing and other processes affected where cost savings may occur:

- Traditional tooling (lead time & iterations)
- Consumables (resin, media, activator, cleaner)
- Assembly labor
- Downstream operations (machining, grinding, balancing, etc.)
- Erosion of traditional tooling
- Rework (welding, grinding, etc.)
- Quality check & scrap



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When is Sand 3D Printing a Fit?

From rapid prototyping to production volume castings without conventional tooling

Sand 3D printing is another tool in the foundry toolbox. Taking advantage of digital manufacturing makes sense for:

- Quick-turn, tooling-less castings
- Low volume / small batch production
- Fast design iterations
- Complex assembled cores
- Organic geometries not possible with traditional methods

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Mold Production

Design freedom to create complex mold rigging

Watch the complete video
bit.ly/3DMoldVideo

When time is of the essence, complete mold packages can be 3D printed without traditional tooling.

Done-in-one pours are also enabled with the design freedoms that provide the ability to throttle the velocity of the pour and achieve the optimal feeding distance to reduce casting defects.

- Eliminate the need for drafts
- New design options for rigging, risers, gates
  - Optimized cross sections for runners and gating
  - Hyperbolic and conical helix sprues
  - Spherical risers to guide flow of liquid metal

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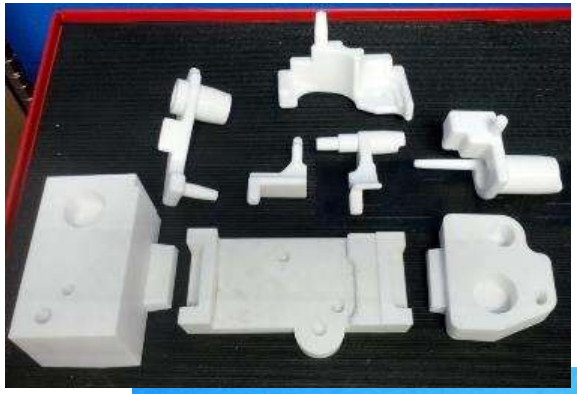
Core Production

Complex designs that lead to core consolidation

When expensive tooling is required, 3D printing is advantageous for low quantity production.

For highly complex parts, sand 3D printing may be cost effective, even if tooling exists or for high quantity production, especially in situations where core assembly can be reduced.

- Eliminate the need for assembly labor and increase productivity
- Removal of stacking tolerances
- Increased accuracy and decreased scrap rates from core shift



Traditional 8 core assembly reduced to one 3D printed core at Humtown

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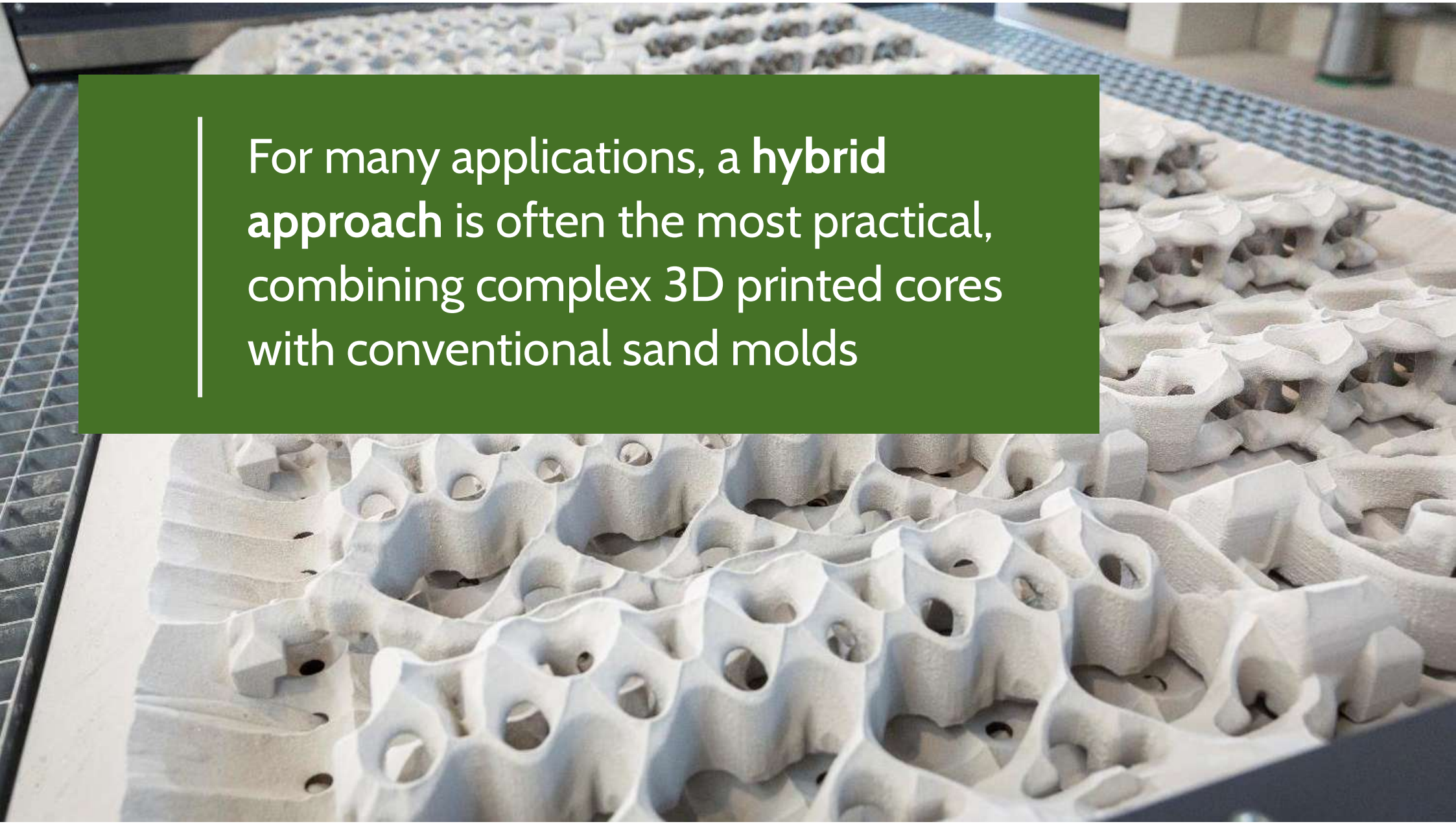


For many applications, a **hybrid approach** is often the most practical, combining complex 3D printed cores with conventional sand molds

Beyond 3D Printing | OneCast Sandcasting Solutions

Full 360° support from combined binder jet and metalcasting experts

VIRTUAL CASTING WITH SOLIDIFICATION MODELING

- Simulate solidification to determine hot spots
- Calculate rigging system components to optimize pour velocity and perform fluid flow and solidification modeling
- Iterate designs quickly without trial castings

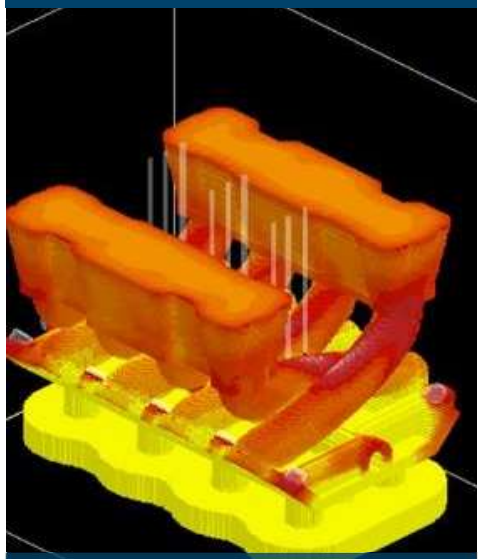
DESIGN AND ENGINEERING

- Complex mold and core package design
- Optimize rigging and riser designs and enhance castings with elements such as hyperbolic sprues and bottom gates

SUPPORTING OEMs, FOUNDRIES, PATTERN SHOPS, & DESIGNERS

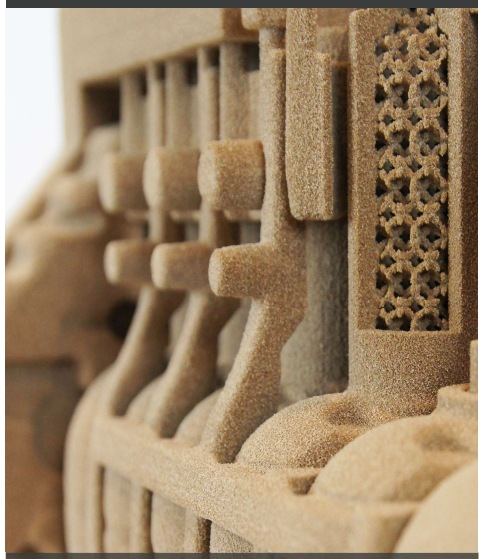
- Sand 3D printing and foundry sourcing
- Full inspection services
- On-site pour supervision
- Training for digital mold package design

VIRTUAL CASTING MODELING



Liquid phase analysis of a virtual casting model to optimize rigging design

OPTIMIZE FROM CAD TO CAST



New possibilities for complex geometries and done in-one-pour, high-quality castings

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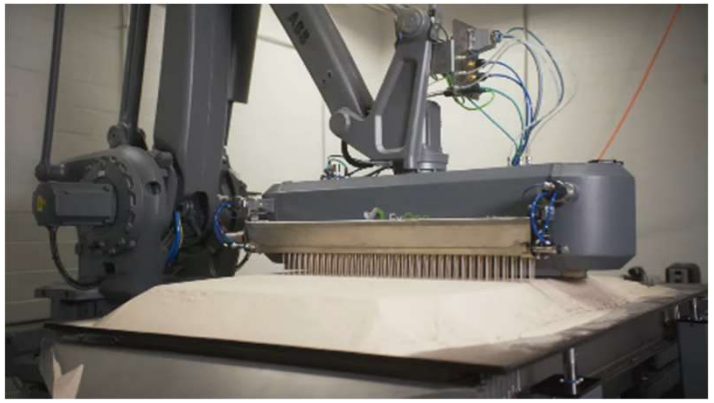
Efficient Operation

Do more, even without hard-to-find labor

- Digital manufacturing enables foundries to operate more efficiently, despite labor shortages
  - Print complete job boxes in 12 hours
  - Lights-out core and mold production
  - Consolidated cores eliminate assembly labor

> *We're able to do more with the people that we have*
>
> Jeff Burek, Vice President
> D.W. Clark



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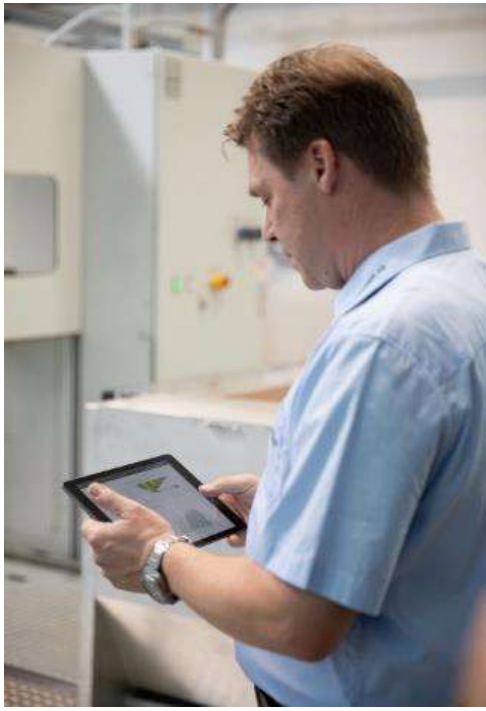
Labor Attraction

Engaging a new generation of workers familiar with the digital age

- The next generation of foundry talent is attracted to modern manufacturing that enables working smarter, not harder
  - Design optimization
  - Digital manufacturing
  - Lights-out production
  - Automation and robotics
  - Digital monitoring for real-time insights



SAND 3D PRINTING SOLUTIONS

Sand 3D Printing | Scalable Foundry Solutions

Binder jetting for sand molds, cores and new tooling options

S-Max® Flex

User-friendly and affordable robotic sand 3D printer. Features an industrial robot with an end effector using advanced Single-Pass Jetting. Launched in 2022.

MAIN SPECIFICATIONS
Job box (L x W x H): 1,900 × 1,000 × 1,000 mm
Build volume: 1,900 l (67 ft³)
Build rate**: up to 115 l/h
Layer height***: 0.28 – 0.5 mm
Loss on ignition (LOI)****: 1.1 %

S-Print®

A fast, flexible, reliable and compact sand 3D printing machine. Delivering highly accurate complex parts from digital data since 2005.

MAIN SPECIFICATIONS
Job box (L x W x H): 800 × 500 × 400 mm
Build volume: 160 l (5.6 ft³)
Build rate**: up to 40 l/h
Layer height***: 0.2 – 0.5 mm
Loss on ignition (LOI)****: 1.0 – 2.1 %

S-Max®

A large and robust sand 3D printer known for reliable performance. Double job box option. Printing cold-hardening binders since 2010.

MAIN SPECIFICATIONS
Job box (L x W x H): 1,800 × 1,000 × 700 mm
Build volume: 1,260 l (44 ft³)
Build rate**: up to 125 l/h
Layer height***: 0.2 – 0.5 mm
Loss on ignition (LOI)****: 1.0 – 2.1 %

S-Max® Pro

Our fastest and smartest large sand 3D printer. All-new automated printhead and recoater. Innovative production features. Introduced in 2019.

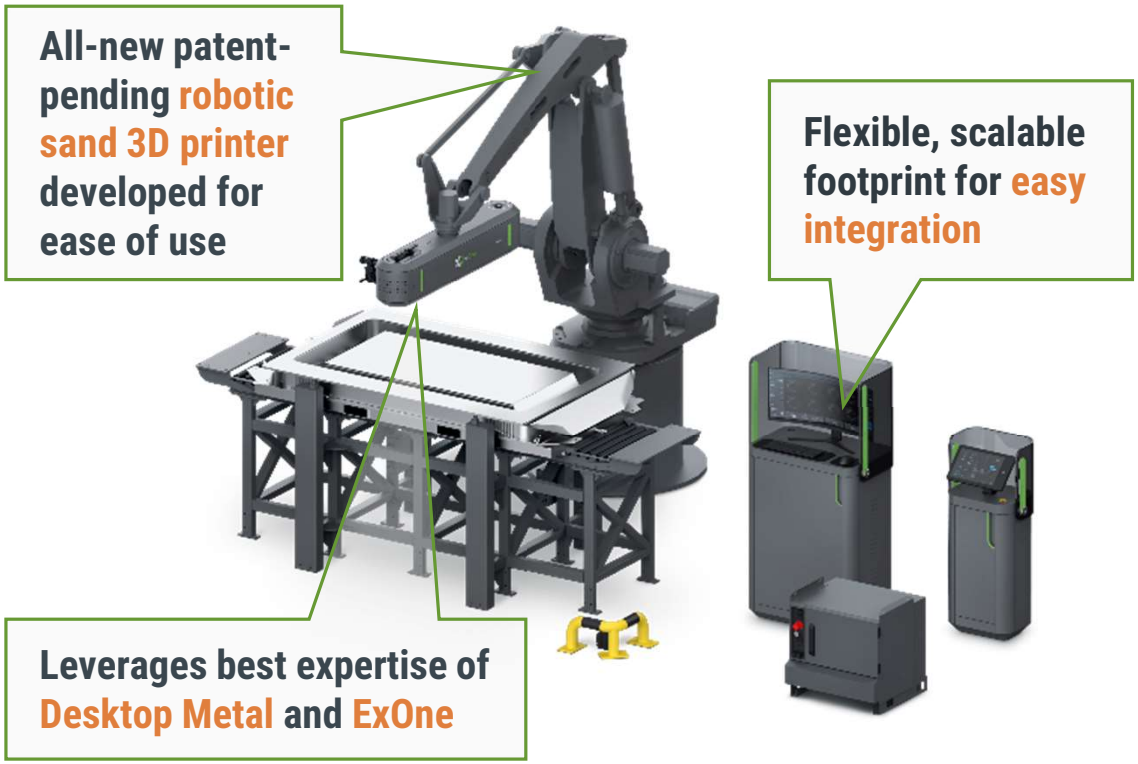
MAIN SPECIFICATIONS
Job box (L x W x H): 1,800 × 1,000 × 700* mm
Build volume: 1,260 l (44 ft³)
Build rate**: up to 145 l/h
Layer height***: 0.2 – 0.5 mm
Loss on ignition (LOI)****: 1.0 – 2.1 %

** Available 400 mm option box-in-box system. ** Depending on layer height. *** Depending on material. **** Depending on part size and geometry (0.1% of part size)*

ExOne | S-Max® Flex

The most affordable sand 3D printer ever offered by ExOne for a fast payback

- Industrial robot arm with innovative printhead end effector binder jets into telescoping job box
- Patent-pending Single Pass Jetting for fast print speeds
- Easy-mount printhead design ensures accuracy and maximizes uptime
- Enhanced robot calibration process provides 100-micron accuracy in XYZ space
- Turnkey system is customizable to different space configurations and safety requirements



TECHNICAL SPECIFICATIONS

Job box: (L x W x H)	1,900 x 1,000 x 1,000 mm (74.8 x 39.3 x 39.3 in)	**External dimensions: (L x W x H)**	8,5 x 4,9 x 4,9 m (28 x 16 x 16 ft)
Build volume:	1,900 l (67 ft³)	**System weight:**	5,900 kg (13,000 lbs)
Build rate*:	up to 115 l/h	**Binder system:**	Furan
Layer height:**	0.28 to 0.5 mm (280 to 500 µm)	**Electrical requirements:**	480V, 3 phase, 15 amps
Dimensional accuracy*:**	+/- 0.5 mm (500 µm)	**Exhaust air:**	26 m³/h

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** Depending on layer height ** Depending on part size and geometry*
**** Depending on part size and geometry (0.1% of part size)*

3D printing system

A Industrial robot
B Single Pass Jetting printhead
C Telescoping build box
D Build station
E Cleaning station
F Fluids cabinet
G Robot controller
H Printer operator station
I Bulk sand conditioning hopper
J Depowdering station
K Depowdering bins
L Ancillary operation station
M Safety curtain

Turnkey Configuration with Flexible Footprint and Safety Solution

S-Max® Flex | All-New Printhead Design

Easy operation and maintenance with fast print speeds

- Single-Pass Jetting (SPJ) strategy with three actions each directional pass for fast throughput:
  - Drop – sand drops from the depositor trough
  - Spread – sand is spread flat across the build table
  - Print – binder is jetted onto the sand surface
- Titanium spreader bar ensure repeatable dimensional accuracy across a range of operating conditions
- Easy-install printhead mount design eliminates timely calibration and alignment for greater uptime and accuracy

Complete job box printed in 12 hours

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S-Max® Flex | Automated Telescoping Job Box & Desanding

Unique design works similar to a collapsing drink cup

- Print builds layer-by-layer as sides automatically lift with the job
  - Contains powder to prevent spills and protect integrity of the build
- Finished job box slides to the desanding station
  - Release gate opens for bulk depowdering as the job box collapses around the build
  - Unbound powder falls into containment system and is available for reuse
  - 3D printing can resume in parallel in a separate job box

Telescoping Job Box

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S-Max® Flex | 3D Printing Foundry Sand

Seamless integration into existing foundry operations

- Dry-mixture of sand plus dry activator
  - Source your own silica sand
- Room temperature cure
- No post processing required
- Unbound sand is recyclable back into future builds to keep part costs down
- 3-6 month shelf life of pre-mixed sand

Partner with ExOne for your mixing S.O.P.

ExOne

Binder Jetting | Exceeding Customer Expectations

Accessible 3D printing enables precision core delivery for components with complex interior geometries

INDUSTRY Energy
APPLICATION Vapor recovery fuel nozzle
LOCATION Alpha Foundry Wright City, MO
CHALLENGE Intricate component required six individual cores to be assembled with high labor and hard tooling costs

SOLUTION
3D PRINTERS ExOne S-Max® Flex
MATERIAL Printed silica sand with furan binder for aluminum casting
BENEFITS 3D printing opens new design possibilities and Alpha Foundry is able to produce intricate, complex cores in one piece. The complex nozzle includes fuel delivery and vapor recovery passages within the part. Segments weave in and out of each other and connection points are small cross sections, but no assembly is required.

Alpha foundry produces over 60 cores with each S-Max Flex build cycle, running 2-3 jobs per day on a continuous basis

"The system comes in at a price point that is achievable for a business of our size and allows us to get into industry technology that makes us more competitive. I don't know how else you would produce this part other than a 3D printed sand core"

Ryan Barron, President, Alpha Foundry Co.

ExOne

X1 Tooling Portfolio

Rapid tooling printed in sand for the production of metal, plastic, and composite parts

X1 SandCast

Sand 3D printing quickly and accurately produces complex molds and cores for metalcasting. ExOne premium machine tools deliver organic geometries and consolidated assemblies that improve the quality of cast products.

X1 ThermoForm

On-demand tooling for thermoforming, vacuum forming, or other compression applications delivers tools more durable than other low-cost options that can withstand production without delamination or failure.

X1 Layup

Whether low-cost prototyping or production tools, 3D printed sand molds deliver complex geometries durable enough to withstand the temperatures and pressures of autoclave with a CTE comparable to aluminum and fast turnaround times.

X1 Washout

Eliminate the expense, lead time, and manufacturing challenges of composite part production with trapped geometries. Sacrificial sand cores for hollow objects wash away with tap water after layup and autoclaving.

TeamDM | We Turn Powder into Parts

Binder jetting a wide range of powder materials

POWDER MATERIALS WE PROCESS

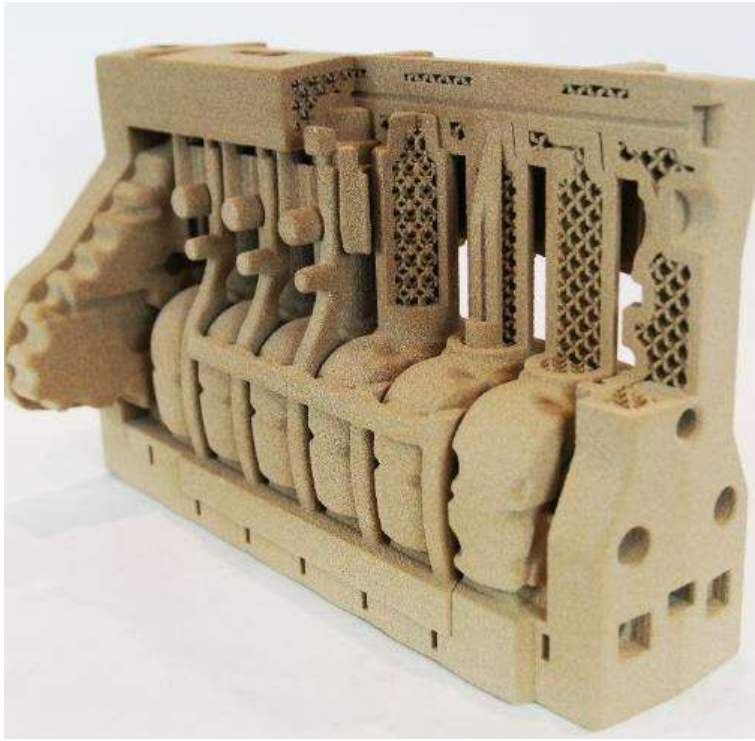
SAND	METAL	CERAMICS	COMPOSITES
Industrial Sands for metal casting	Ultra-fine metal MIM powders	Wide variety of ceramic powders	Industrial-grade composites
EX: Silica sand, ceramic sands, and more ...	EX: 316L, 304L, 17-4PH, and more ...	EX: Silicon carbide and more ...	EX: Tungsten Carbide Cobalt and more ...

ExOne™

Print, Pour, Produce | Questions?

"Every part is always right. Quality remains high across the entire production run, including years down the road when you have to make the part again and just start with the digital file."

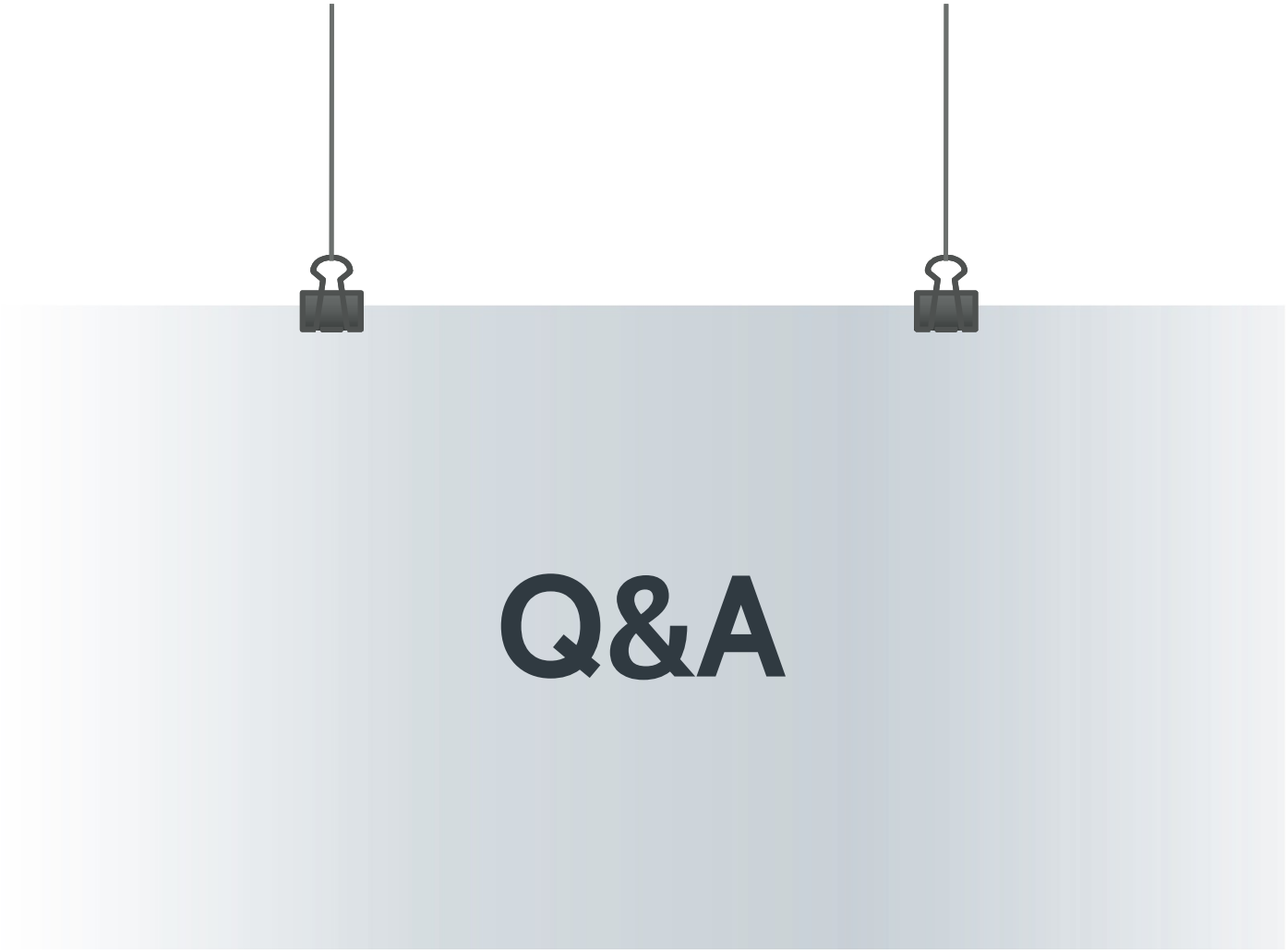
"500% revenue increase in the five years after investing in ExOne sand binder jetting."



"We not only eliminated steps of assembly that allow us to avoid core shift or variation in the parting line... the freedom of design allows us to respond to our customers quicker."

"We're able to do more with the people that we have."

"The post-processing of the cast part requires much less time and effort because the printed core does not have any drafts."


Q&A