Desktop Metal

Live Sinter™

Sintering simulation and compensation software
for the successful production of powdered metal sintered parts

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Why Live Sinter?

Problem: Printed binder jet parts typically undergo significant shrinkage and distortion during the sintering process, rendering parts unusable and reducing yield. Traditional solutions such as “live” printed metal or fixed ceramic supports do not always prevent distortion and can significantly increase part costs.

Live Sinter was developed as a tool to reduce time-consuming process iteration cycles required to reliably achieve tight tolerances on binder jet parts and dramatically reduce or eliminate the cost of supports.

- Simulates part behavior during sintering cycles in a furnace using digital models (e.g. STEP, CAD, STL) and a high-speed GPU-based, multi-physics engine with embedded finite element modeling (FEM)
- Predicts sintering outcomes in minutes with high-accuracy to identify crack regions and geometry deformation based on user-inputted variables, including printing and sintering orientations
- Generates sinter-ready, printable “negative offset” models through automated distortion compensation that scales and counter warps parts to account for shrinkage, creep strain, and friction drag

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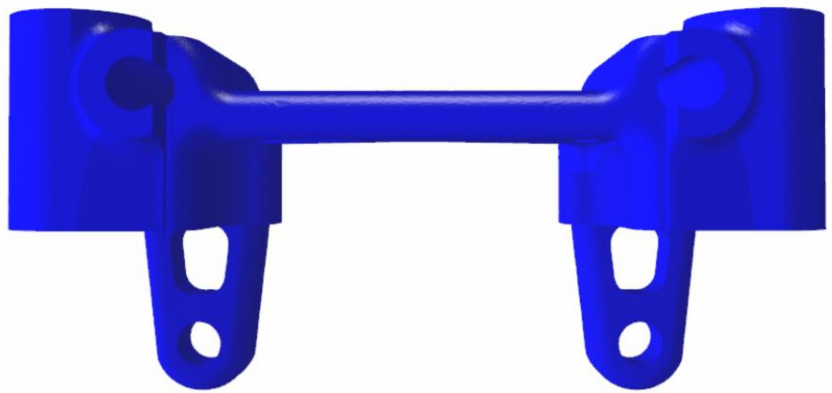
The sintering process causes shrinkage and distortion

Sintering challenges:

- Powder metal parts typically shrink 14–18%+ in each dimension as parts densify
- Distortion and potential cracking caused by several factors:
  - Friction
  - Gravity
  - Plastic creep strain
  - Printed density variations
- Sintering supports are a suboptimal solution



Printed as designed

Warped after sintering

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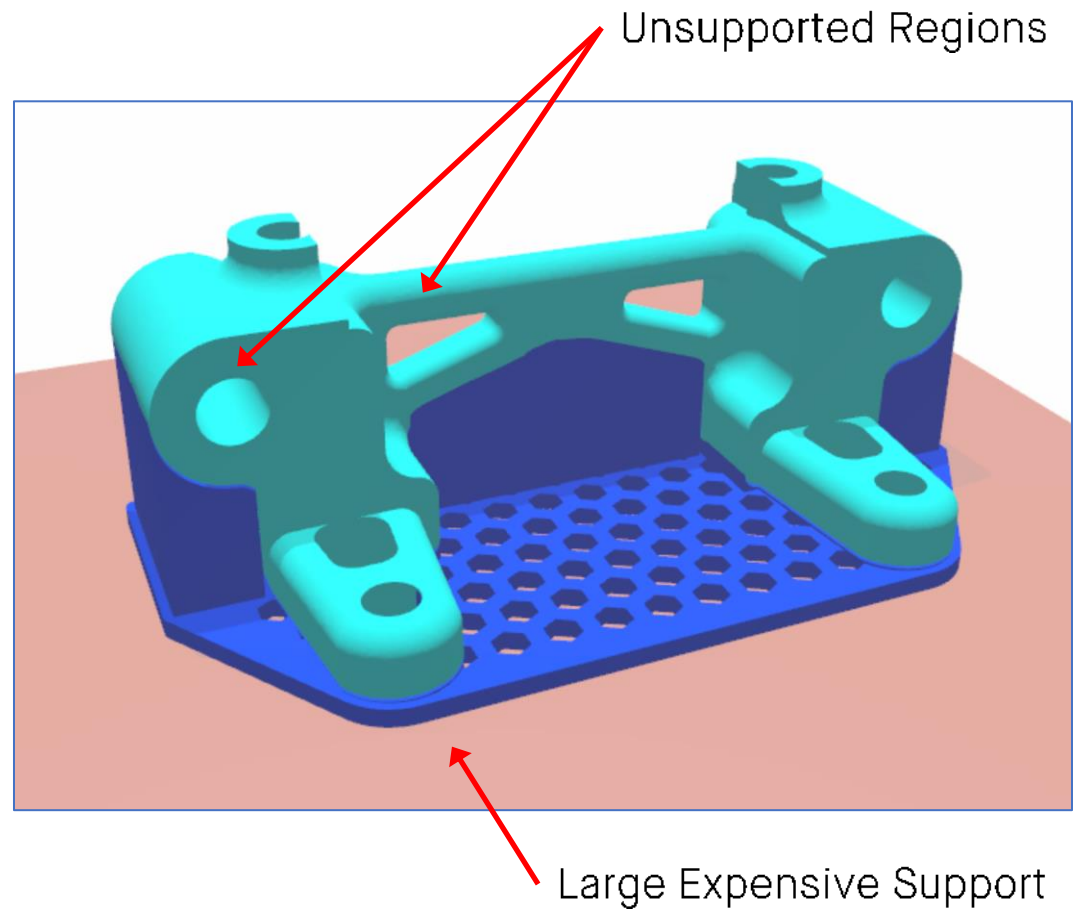
Traditional approaches to preventing distortion fall short

- Traditional sintering supports take 2 forms:
  - Large, expensive printed supports
  - Conventionally manufactured, re-usable ceramic supports
- These approaches still create challenges:
  - May jam, shrink unevenly, or cause cracking in final sintered parts
  - Unsupported regions (see right) may still experience distortion
  - Can meaningfully increase overall part cost (printed, metal supports)
  - Require design expertise and minimum volume thresholds (fixed ceramic supports)



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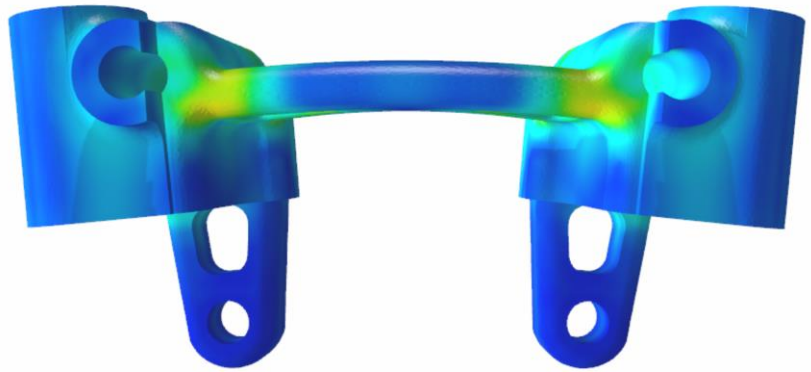
Simulation and distortion compensation produce tight tolerance parts

Live Sinter embraces the natural forces at work during sintering and provides advanced simulation to predict and correct errors when sintering binder jet printed parts

- Simulates part behavior, including shrinkage and distortion, during the sintering process
- Automatically generates “negative offset” geometry that can be printed and sintered, compensating for these effects
- Results in parts with tight tolerances, minimizing process iterations and reducing / eliminating the need for supports



“Negative offset” printed to compensate for shrinkage and distortion

Sintered to tight tolerance

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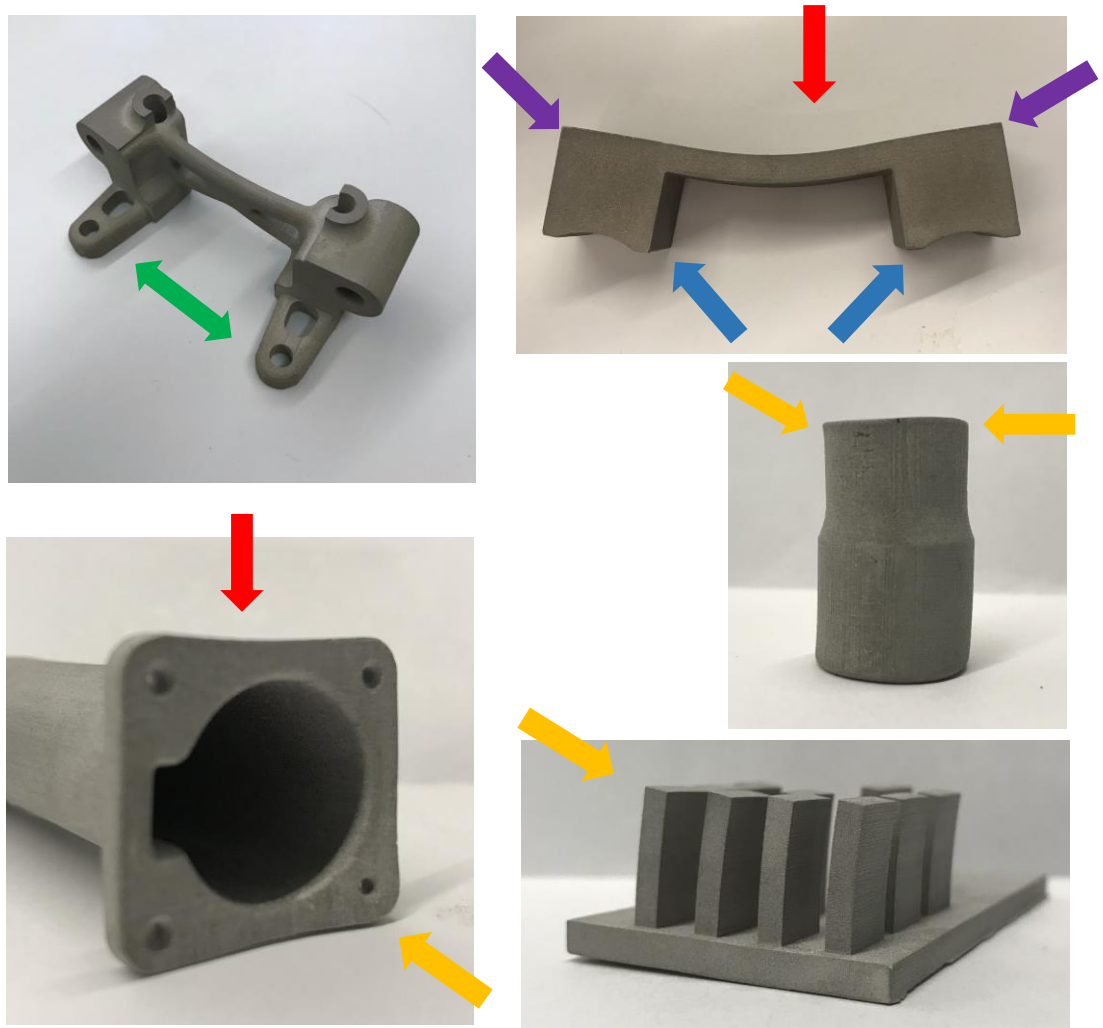
Live Sinter simulates the key contributors to sintering distortion

Multiple factors at work during sintering cycles:

- Gravity droop: elastic and plastic motion downwards
- Shrinkage pull: multi-directional contraction
- Friction: stationary regions against setters
- Centroid rotation: uneven weight distribution bending
- Density warp: varying shrinkage due to powder packing

Live Sinter simulates these factors **in minutes** with a high-speed GPU physics engine, tuned using machine learning



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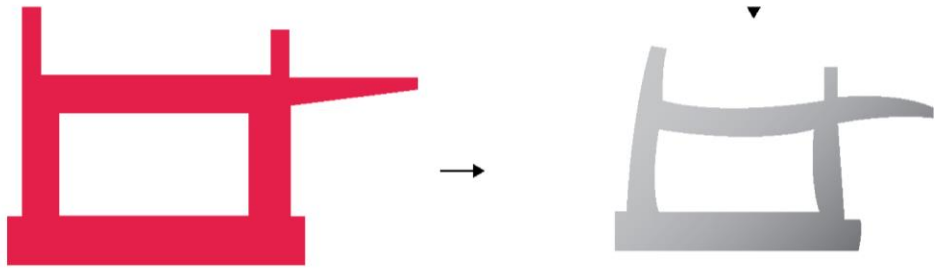
Results comparison – with and without Live Sinter

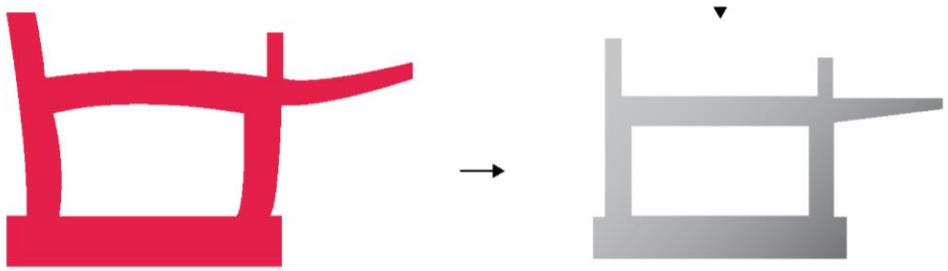
Without Live Sinter

Printed → *Sintered*



With Live Sinter

Printed → *Sintered*



Multi-Physics Sintering Simulation With Automated Compensation

Upload Part → Generate Support (Optional) → Run Simulation and Compensate → Send File(s) to 3D Printer → **QUICK RESULTS* +/- 1%**

Scan-Based Adjustment for Fine-Tuning

Scan Sintered Part → Compare to Desired CAD Model → Run Scan Adjustment → Send File(s) to 3D Printer → **QUICK RESULTS* as low as +/- 0.3%**

*Final results depend on geometry as well as material being sintered.

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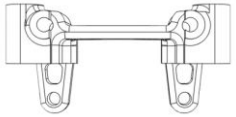
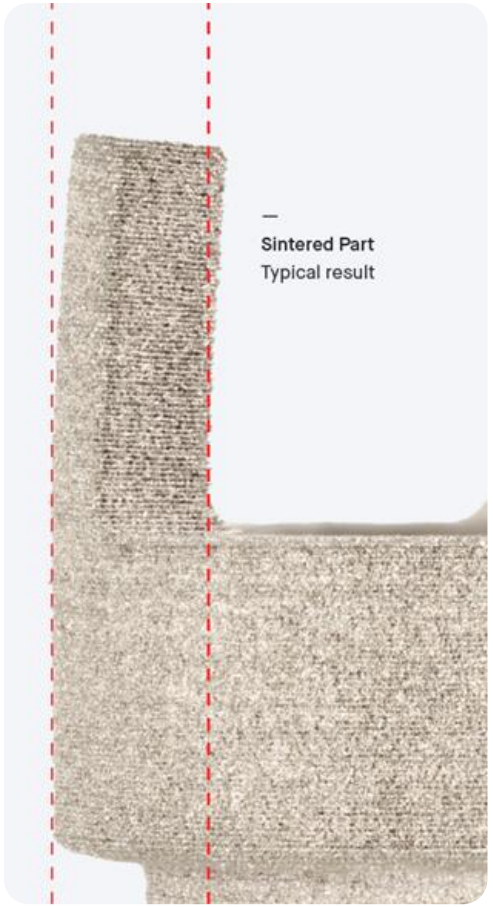
Examples of parts printed with and without Live Sinter

—
Sintered Part
Typical result

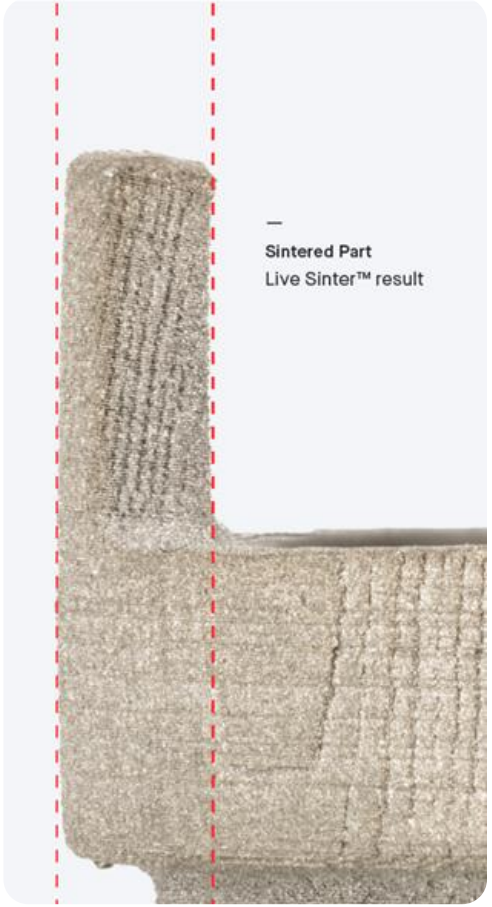
—
Sintered Part
Live Sinter™ result

Compensates for warping caused by uneven weight distribution and friction with supports



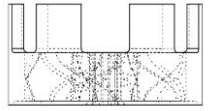


—
Sintered Part
Typical result



—
Sintered Part
Live Sinter™ result

Live Sinter compensates for warping caused by density variations in powder spreading



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Live Sinter is key to out-of-the-box metal binder jetting success

Live Sinter is trusted by users at more than a hundred DM binder jet 3D printer customers globally

"One of my biggest worries investing in this technology was the furnace and the frustration of failing that far into the process during sintering. Using Live Sinter, I'm blown away at our success with the sintering furnace. I don't have to use sintering supports anymore, so I don't have to charge for supports. I use Live Sinter for everything and it makes it more competitive."

Neil Glazebrook, Vice President of 3D Solutions, ABCorp

"We've found Live Sinter to be an extremely valuable tool for FreeFORM. The ability to print, scan, adjust, reprint, etcetera, has reduced our lead time by helping us yield product in spec faster than a traditional trial and error loop. The ability of the software to predictively deform products prior to first manufacturing or to take first-off parts and make adjustments have resulted in our customers getting to market faster with product so they can move on to their next development."

Chris Aiello, Co-Founder, FreeFORM Technologies

"We use [Live Sinter] all the time now, and it's a dramatic change. We simulate, print, scan and reprint and it comes out perfect."

Sean Harkins, President, AmPd Labs

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Live Sinter™ key to out-of-the-box binder jetting succes

ABCorp
Secure since 1795

CUSTOMER	ABCorp
LOCATION	Boston, MA
APPLICATION	Prosthetic weight
CHALLENGE	This weight is manufactured with precision to lock into the prosthetic socket. It is required to be a specific weight to accurately mimic the feel and function of a natural forearm while seamlessly integrating with the patient-specific socket

Solution

SYSTEM	Desktop Metal Shop System
MATERIAL	17-4PH
BENEFITS	• With traditional binder jetting production, the overhangs of the connectors would require support during sintering. Using Live Sinter to simulate the warpage and distortion during sintering ABCorp is able to 3D print a negative offset geometry that sinters straight • The ability to offer fast product development without tooling investments has expanded the business relationships of ABCorp

"One of my biggest worries investing in this technology was the furnace and the frustration of failing that far into the process during sintering. Using Live Sinter, I'm blown away at our success with the sintering furnace. I don't have to use sintering supports anymore, so I don't have to charge for supports. I use Live Sinter for everything and it makes it more competitive."

Neil Glazebrook, Vice President of 3D Solutions, ABCorp

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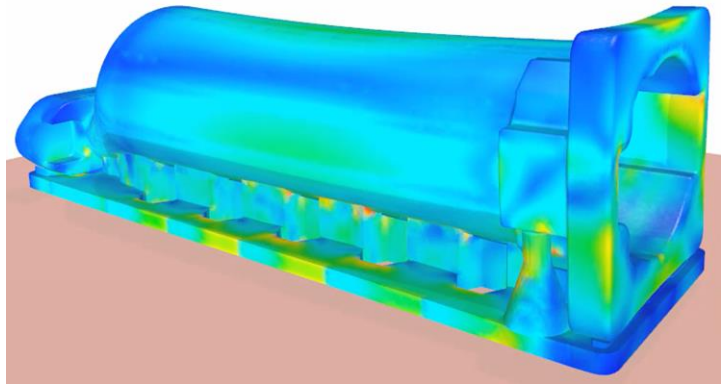
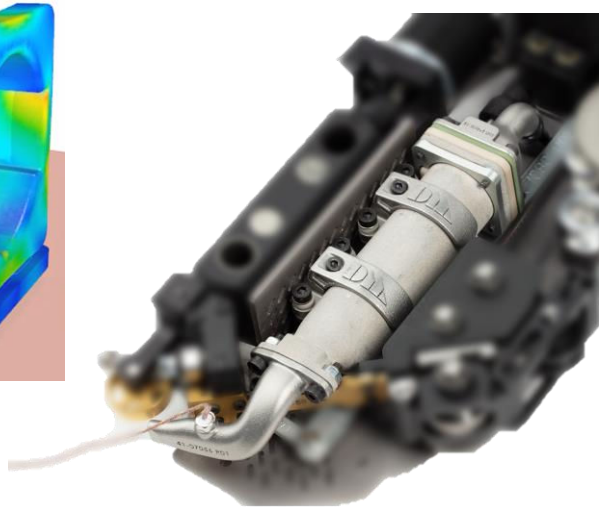
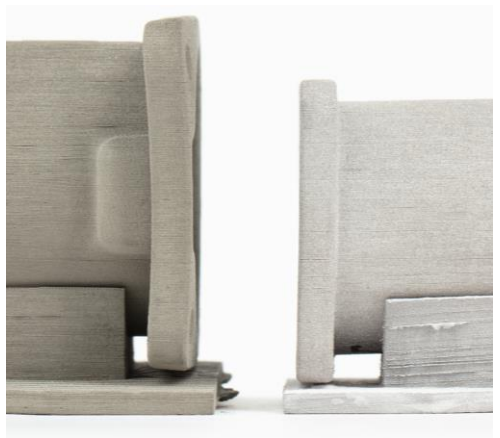
Application example: 17-4PH Stainless steel printer component

The heating chamber of this carbon fiber 3D printer required 17-4PH stainless steel construction

- Sintering resulted in either heavy deformation or live metal supports lodged inside the part
- Live Sinter created a sinter-ready, printable model that compensated for the distortion in roughly 15 minutes
  - Negative offset parts had counter-warped flanges and oblong oval shaped bodies
- Sintered parts achieved <1% deviation from nominal tolerances, eliminating the need for post-machining and reducing support material







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Live Sinter: How it Works

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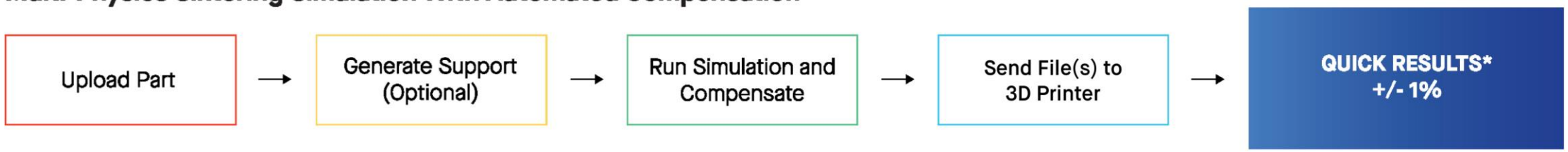
Live Sinter process overview

Set Up: Users customize sintering and printing orientations and other simulation parameters

Simulate & Compensate: Live Sinter runs a fully-automated iterative process of simulation and shrinkage / distortion compensation

Export: Live Sinter generates a high-fidelity "negative offset" model that is print- and sinter-ready

Multi-Physics Sintering Simulation With Automated Compensation



Scan-Based Adjustment for Fine-Tuning

*Final results depend on geometry as well as material being sintered.

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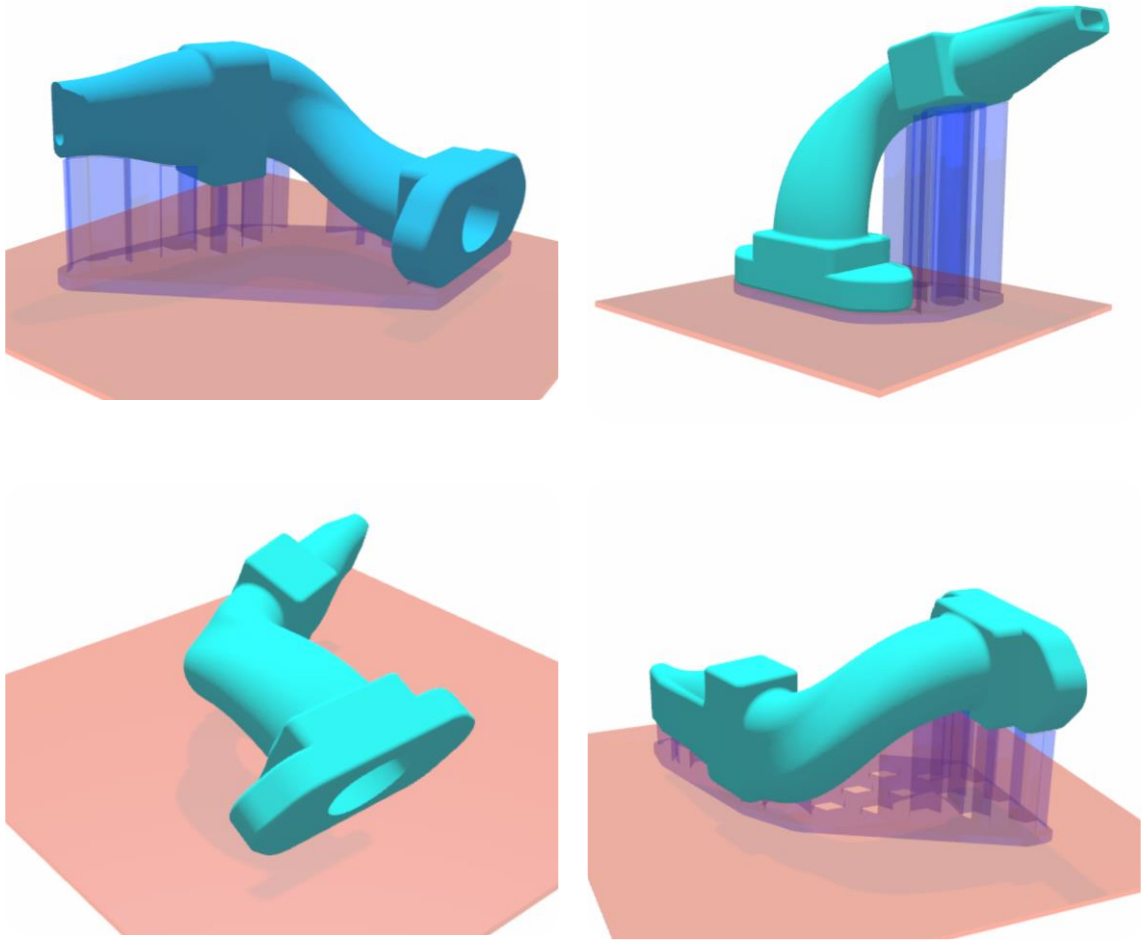
Step 1: Set up sintering

- Load part (STEP, STL, or CAD file formats) and optionally generate supports / load pre-made support geometry
  - Add optional radial or hex cuts to supports
  - Evaluate support volumes
  - Evaluate and adjust sintering orientations
- Optional: offset surfaces, add HIP simulation & compensation, or customize sintering process parameters



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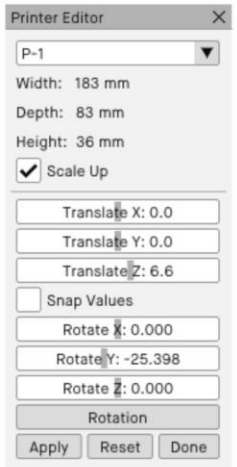
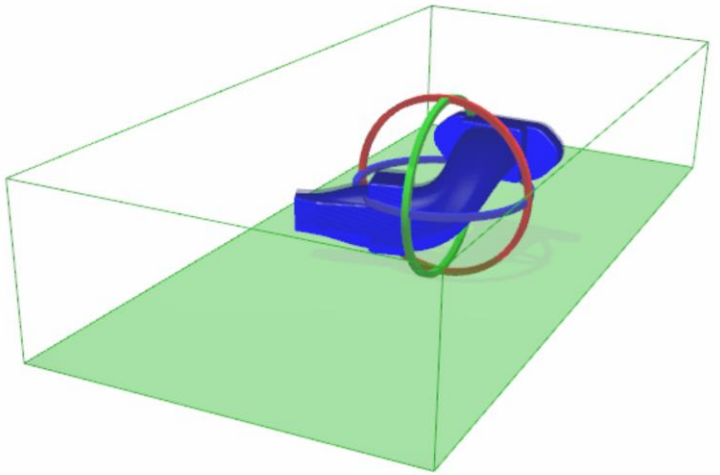
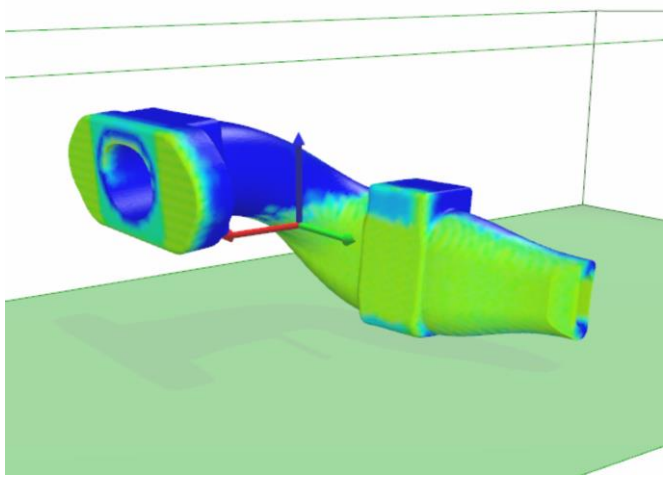
Step 2: Set up printing

- Optional: specify a print orientation to optimize print layer effects on part surfaces
  - For example: print key planar surface horizontal but sinter lying on setter
  - Orient parts to reduce printing / powder spreading density gradients
- Evaluate whether part + support fits in printer build box after scaling (and negative offset generation)







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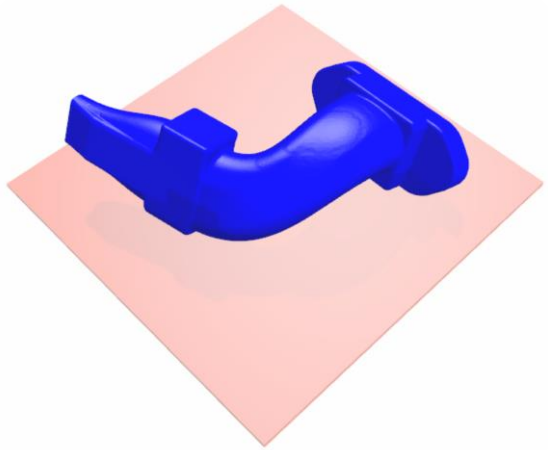
Step 3: Run sintering simulation

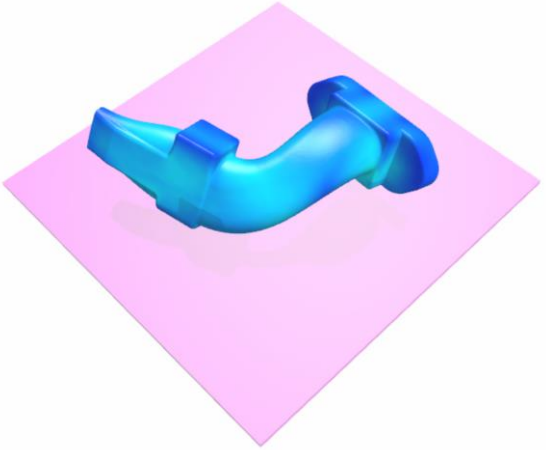
Live Sinter scales up the part + support and runs a sintering cycle simulation to predict the effects of:

- Gravity,
- Collisions,
- Friction drag,
- Elastic and plastic deformation,
- Shrinkage, and
- Powder spread density gradients

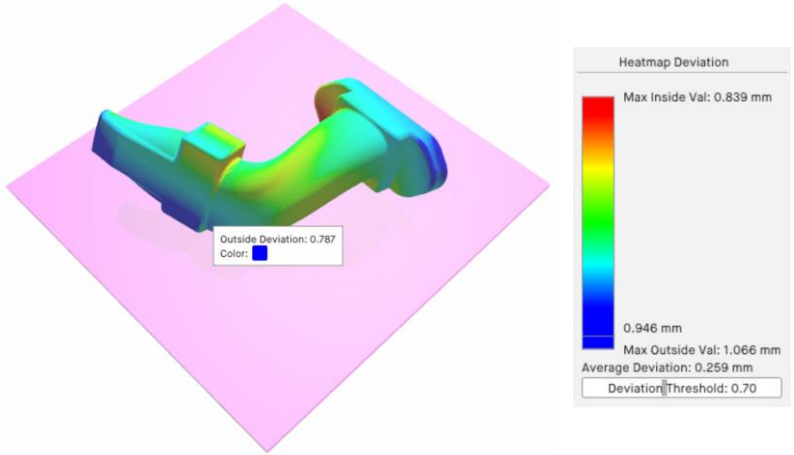
- When complete, the user can view deviations of Live Sinter's initial sintering simulation result to the original CAD model



Start of sintering simulation



Result of sintering simulation



Deviation analysis of Live Sinter's initial predicted deformation

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The technology behind Live Sinter's predictive sintering simulation

Live Sinter's simulation engine is a GPU-based, multi-physics environment capable of running full sintering cycle simulations in minutes. It models:

- Elastic and plastic deformable soft bodies as well as gravitational forces
- Periodic static stress and time-varying contacts through integrated meshless FEM
- Dynamic friction and collision interactions among sinter bodies (parts and supports) and rigid setters
- Minute-by-minute temperature and shrinkage
- Creep strain based on stress and temperature

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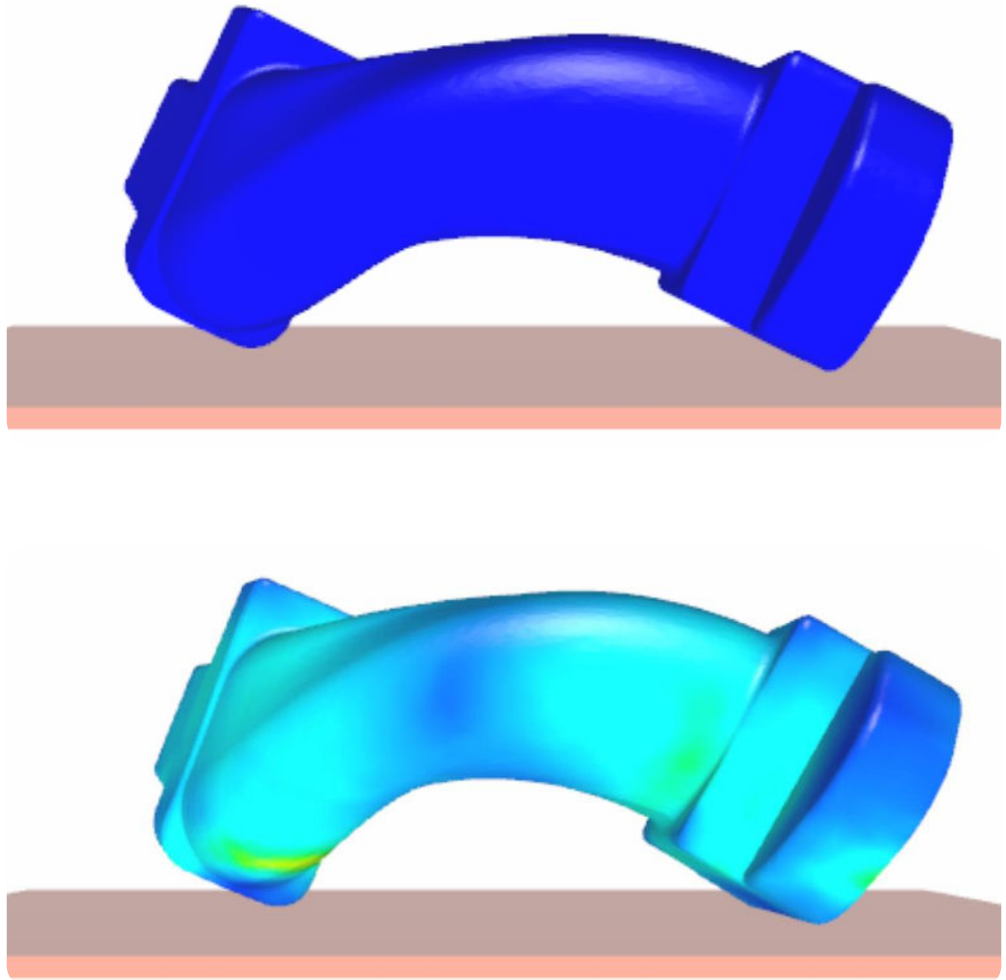
Step 4: Generate negative offset geometry

Live Sinter generates a negative offset model through a fully-automated iterative process

- Creates an initial negative offset model that compensates for the deviation
- Runs an additional sintering simulation and adjusts the negative offset model
- Repeats the prior step, comparing the simulation result after each loop to the original CAD design
- When the deviation converges below a minimum threshold the iteration loop stops and a final negative offset model is generated



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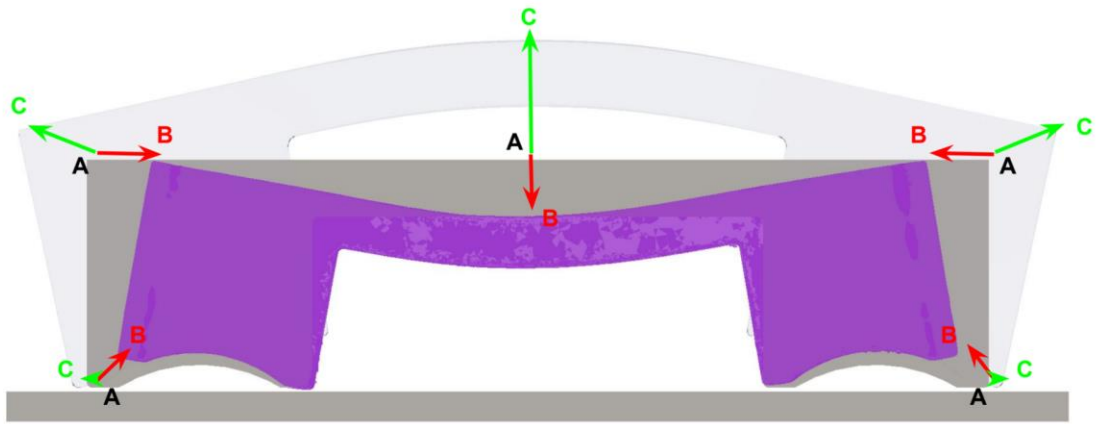
How Live Sinter generates negative offset geometries

Negative offset process

- The simulation of points A to B during sintering is used to generate a new negative offset model, which transforms points A to C
- This new negative offset model creates a new physics problem, so Live Sinter runs additional simulations
- This iterative process keeps tweaking the negative offset model upon the deviation of the final sintered shape from the original CAD geometry



Original CAD model (dark grey)
Predicted model after sintering simulation (purple)
Final, auto-generated negative offset model (light grey)

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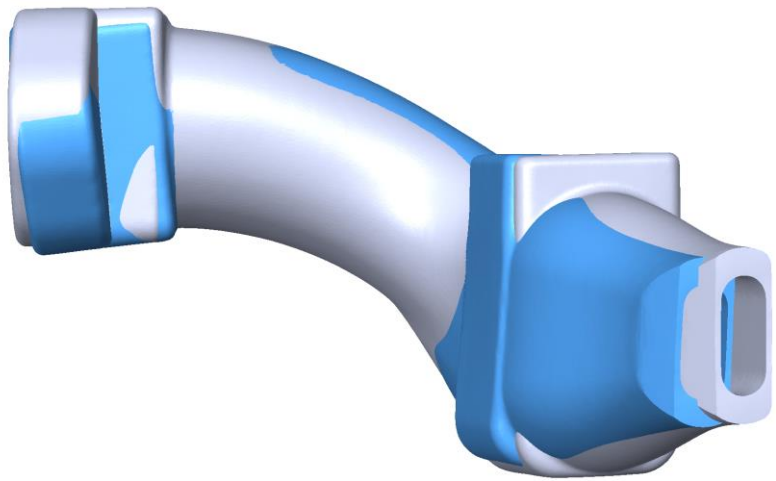
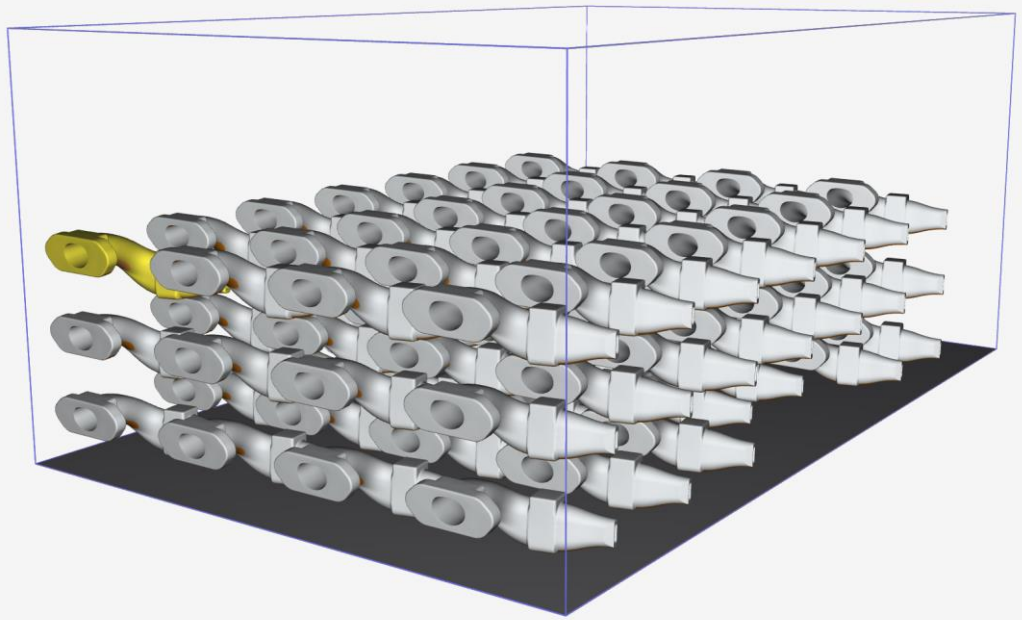
Step 5: Export high-fidelity sinter-ready, printable geometry

Live Sinter automatically generates a high-fidelity detailed model ready to print on a Desktop Metal binder jetting system



Final compensated geometry (blue) versus linear scale up (grey)



Live Sinter-generated models nested into printer build box

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Live Sinter: Key Features

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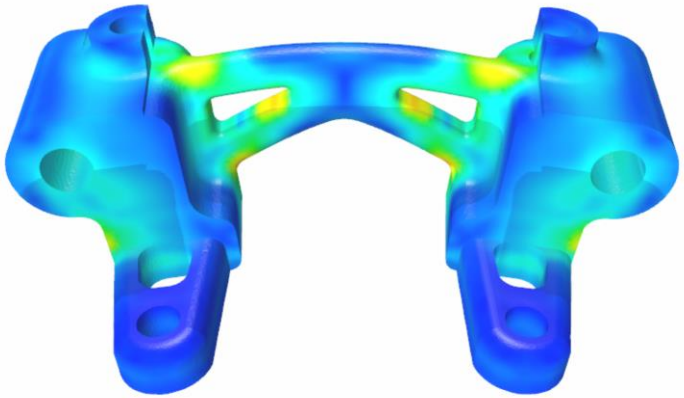
Live Sinter negative offset models preserves high feature detail

Negative offset models generated by Live Sinter preserve the original design's intricate features with high-fidelity

- Extremely small features are preserved from input STEP and STL files
  - For example: threads, small holes, patterns
- Enables fast solutions with high precision through the use of a GPU-based architecture

Preserved lettering detail

Preserved thread detail



Negative offset model cell representation during iterative simulation and compensation process

High-fidelity output model

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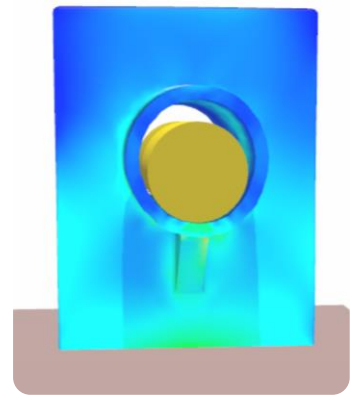
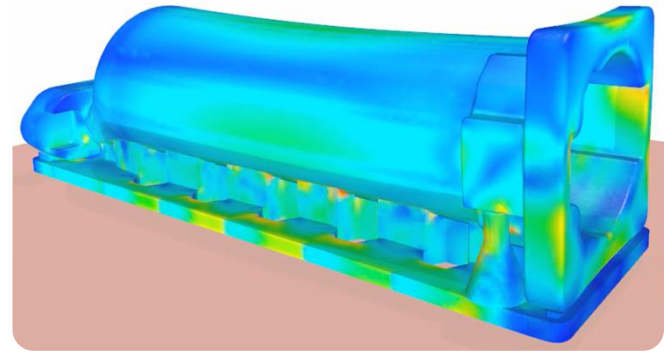
Compatibility with complex sintering environments

Live Sinter enables sintering simulation of parts interacting with multiple and/or complex metal printed supports and floating or fixed ceramic setters

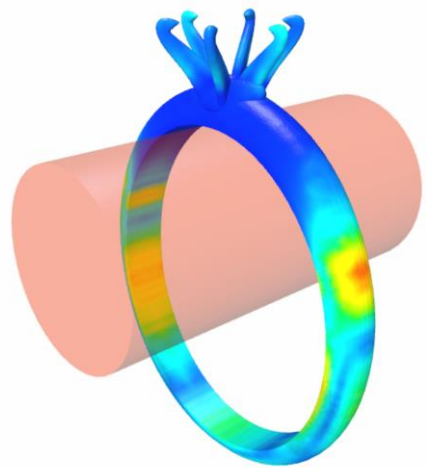
- “Live” metal printed supports are modeled using the same material as the parts
  - Shrink and distort along with parts
  - Negatively offset along with parts
- Floating and/or fixed ceramic setters are modeled as rigid bodies with complex, time-varying collisions



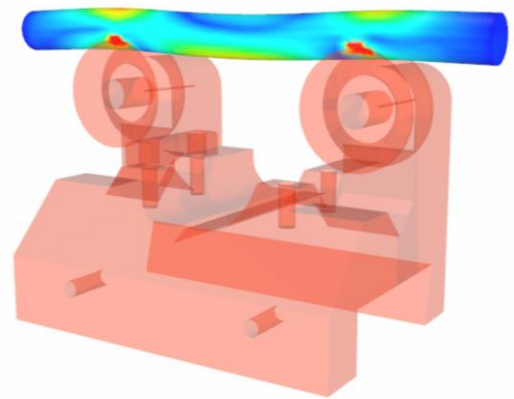
Floating setter insert



Ceramic setter with printed raft supporting the part



Part hanging from a fixed setter



Complex fixed and floating setters

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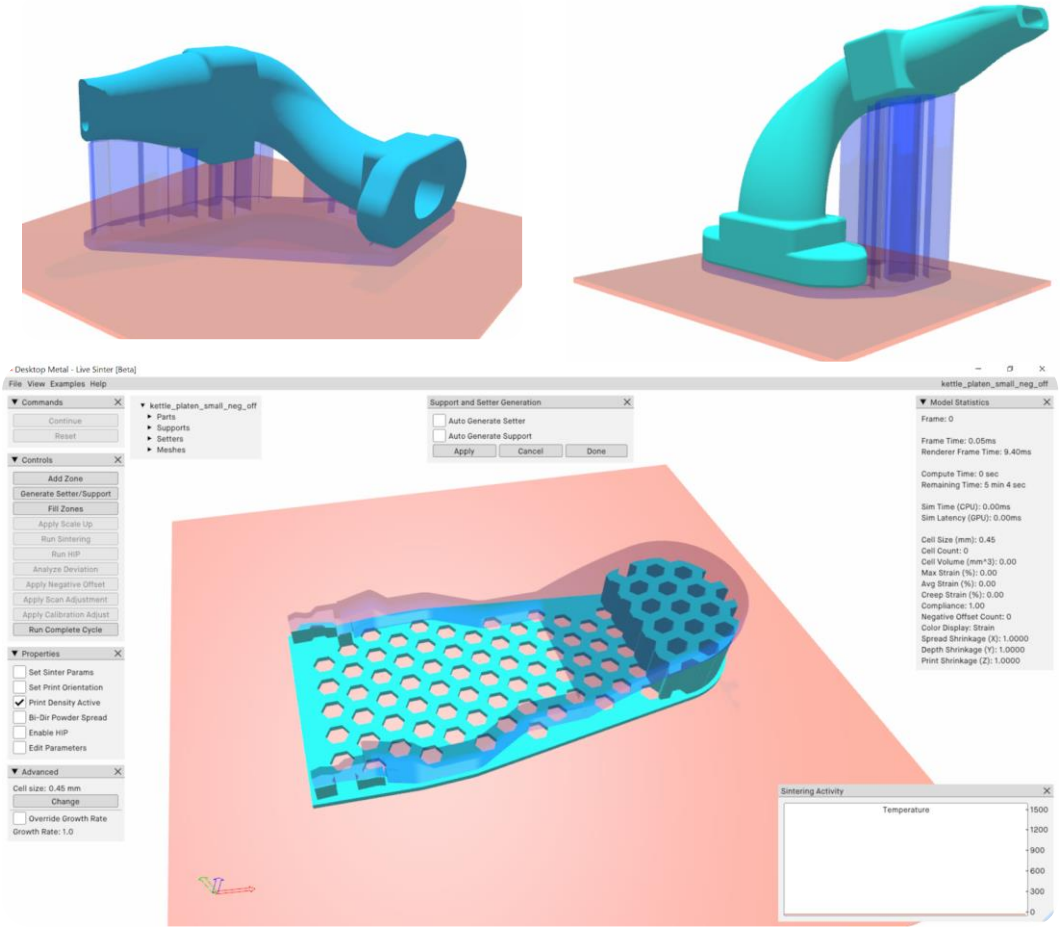
Comprehensive support generation

Live Sinter offers printed support generation optimized to reduce material usage while also automatically compensating for sintering shrinkage and distortion

- Interactively generate supports in a variety of sinter orientations while analyzing support volumes and stability characteristics as part of a trade-off analysis
- Minimize supports while stabilizing parts
- Reduces cost and enables easy depowdering and assembly for sintering
- Allows for distortion compensation to occur



Auto generated support with hex cuts

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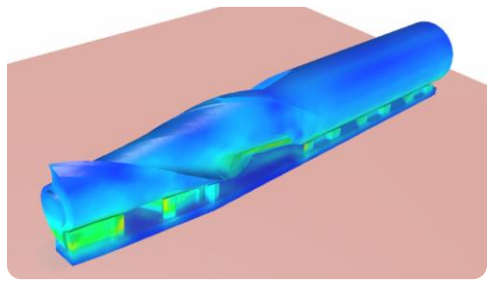
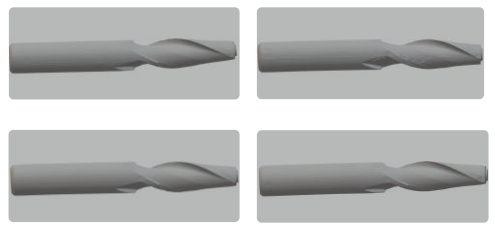
Scan-based adjustments

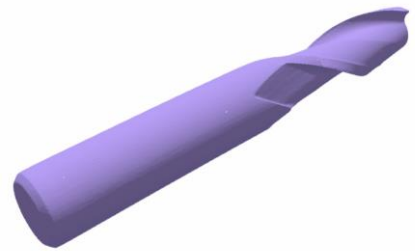
Live Sinter complements predictive sintering simulation with scan-based adjustments to fine tune negative offset models and correct for complex distortion effects – creating sinter-ready, printable geometries with even tighter shape and dimensional tolerance after sintering



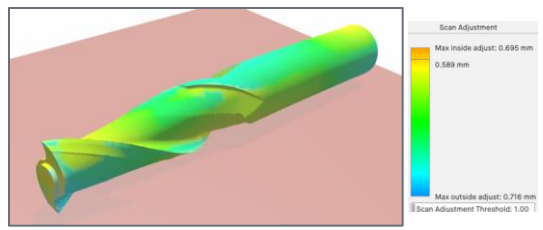
Original Live Sinter negative offset model (or simple scaled model)



Scans from multiple parts in a build



Auto-generated composite scan – created by Live Sinter



High-fidelity scan-adjusted model, ready for printing and sintering

- Reads and aligns multiple scans to generate a composite scan
- Supports missing scan data for complex geometries (e.g., small holes, internal passages)
- Performs volumetric deformation based on scans, ensuring thin walls and hidden internal features move in concert with exterior regions
- Prevents entry of scan noise into scan-adjusted model

Yields parts that consistently fall well within 1% of target dimensions with as low as ± 0.3% deviation

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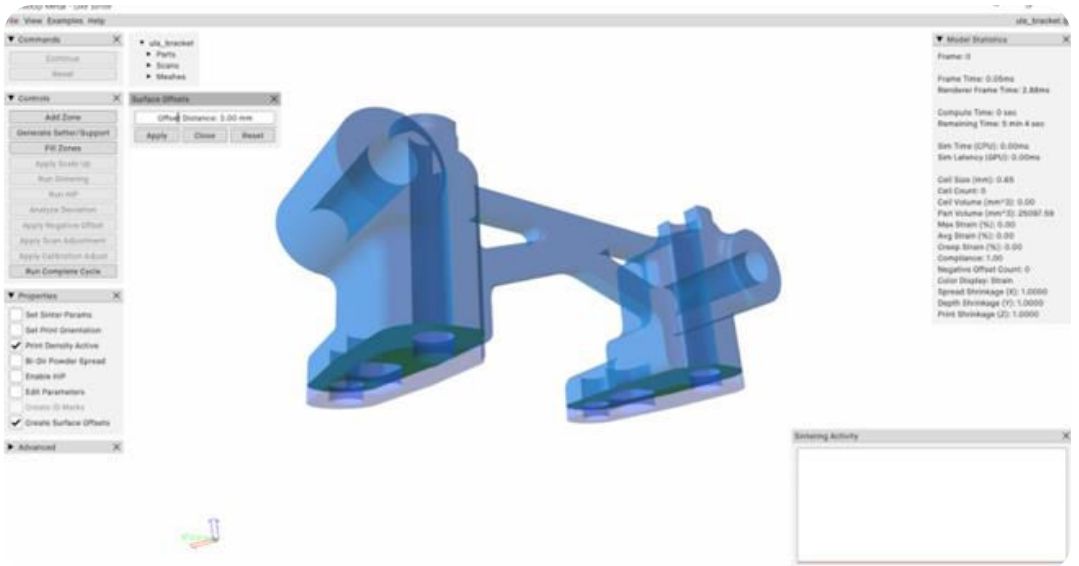
Post-processing surface offsets

Live Sinter allows users to select specific surfaces for material offsets to support downstream machining and post-processing operations

- Select multiple surfaces and apply offsets to each surface of similar or varying amounts
- Apply offsets to STL and STEP files natively in Live Sinter without previously doing so in during the design process in a CAD tool



Post-processing offsets applied to the bottom surface of the part (transparent blue)

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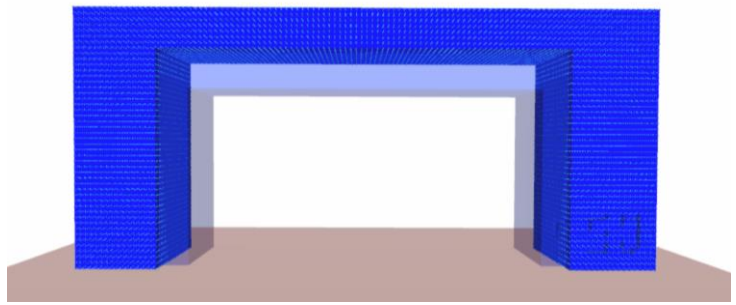
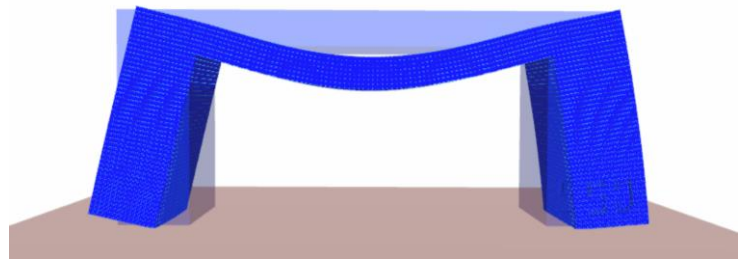
HIP simulation

Live Sinter offers optional Hot Isostatic Pressing (HIP) simulation following sintering simulation

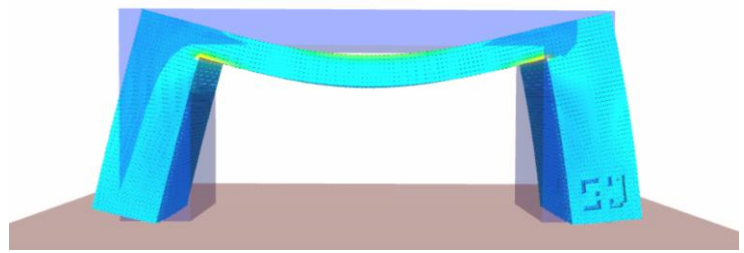
- Automated negative offset model generation compensates for both sintering and HIP
- Simplifies the workflow of scaling parts for shrinkage during both sintering and HIP processing
- Offers scan-based adjustments on post-HIP parts



Part scaling operation



Sintering simulation



HIP simulation

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