Desktop Metal

CASE STUDY

Unlocking the Space Economy with 3D Printing

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Canopy Aerospace uses the flexibility of binder jetting to secure and transform critical supply chains

Customer
Canopy Aerospace

Location
Littleton, Colorado

Industry
Aerospace and defense, automotive, semiconductor manufacturing

Application
Thermal protection systems

Machine
Desktop Metal InventX™

Website
www.canopyaerospace.com

Commercializing heat protection technologies

Traditional supply chains are rigid and include long-established production methods that require hard-tooling investments, knowledge of niche manufacturing processes, and increasingly hard-to-find manual labor. According to the National Association of Manufacturers 2024 fourth quarter outlook survey, and majority of U.S. manufacturers still consider filling open positions – and keeping them filled – a primary business challenge[1].

In the ceramic materials industry, lead times for U.S. domestically sourced components range between 16 and 30 weeks, with most low-volume orders not even being quoted[2]. In this environment, applications that require extreme thermal management solutions are directly limited in performance due to a lack of an innovative ceramics supply chain.

Canopy Aerospace was founded in 2021 to solve these supply chain issues that are causing bottlenecks in the commercial space economy. High-temperature materials used in extreme environments such as space launch and re-entry were critically constrained; historically, companies vertically integrated manufacturing processes for government contract performance while others could only access small manufacturing capabilities within NASA. Canopy's founders recognized that new business models such as asteroid mining, lunar resource harvesting, or microgravity drug manufacturing could not be realized without a reliable and cost-effective manufacturing base to supply key components for these new space industries.

So the company set out to commercialize the heat protection technologies developed under the Space Shuttle Program and still used today to protect the Orion spacecraft as it returns to Earth.

Among its primary missions, the National Aeronautics and Space Administration (NASA) fosters technology transfer to reinforce U.S. commercial access to space activities. By supporting entrepreneurs and sharing inventions developed within the agency that are prime for commercialization, NASA aims to spur exploration and support the space marketplace.

In the company's early days, Canopy signed a Space Act Agreement with NASA Ames to formally transition the process know-how of low-density, reusable thermal protection system (TPS) technology. The team also secured funding to invent a 3D-printable, higher-performing material to unlock true scale in the supply chain.

"As our founding team initially looked to address the supply chain problem, they realized it could not be solved with simple 1:1 transfer of know-how," said Will Dickson, Chief Commercial Officer at Canopy Aerospace. "It required investment in new materials development built on top of an elastic, advanced manufacturing infrastructure. This formed the basis for Canopy's approach to product development and innovation. We are at a unique inflection point in NASA's history as the organization transitions away from its traditional space technology leadership role into more of a collaborative role as a facilitator, and Canopy is positioned to capitalize on this and support this mission in a big way."

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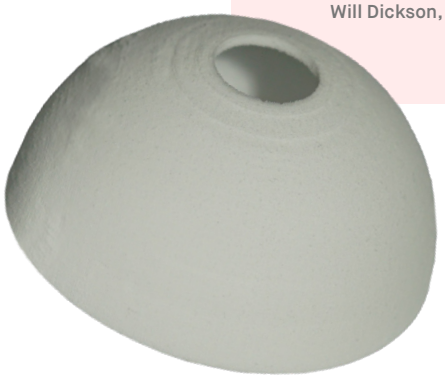
Will Dickson, Chief Commercial Officer, Canopy Aerospace



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This fully fired Canopy proprietary reusable thermal protection system (TPS) formulation in a representative shape 3D printed with binder jetting on the InventX.

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Canopy's manufacturing innovation facility in Littleton, Colorado where the company develops a range of mission-tested thermal protection systems and next-gen ceramic components.

Today, the company operates an 18,000ft^2 (1,672 m^2) manufacturing and innovation facility outside of Denver, Colorado, developing a range of mission-tested thermal protection systems and next-gen ceramic components for a variety of use cases across different industries. Its Reusable Heatshields through Additive Manufacturing (RHAM) platform serves as the basis for the company's broad portfolio of new materials and manufacturing innovations for commercial customers, NASA, the U.S. Air Force, and the U.S. Missile Defense Agency.

Optimizing supply chain risks to expand the aerospace ecosystem

Space travel is quickly transitioning from a remote ambition to a burgeoning industry. In the decade between 2013 and 2024, licensed commercial space launches increased from just 8 to 157 [3]. With this increased space travel comes an increased need for high-performance components, including the heat shields to protect a payload returning from space.

Traditionally, these tiles are made by casting a slurry of silica, alumina fiber, and borosilicate glass before drying and sintering the large billet to fuse the fibers. The preform is then machined down to its final form before being hand-coated in exotic materials that increase toughness and emissivity. This traditional workflow faces scalability issues, with high scrap rates and a reliance on skilled operators that require high training investments. So the Canopy team began brainstorming ways to improve the process.

The company explored new options to drive productivity and enable rapid responses. From software tools and robotics to additive manufacturing, Canopy invested in solutions to make it a next-generation service provider. "You can't just be a supplier that makes stuff that requires one-off tooling. We need processes that are really elastic, malleable, and flexible," Dickson emphasized. "Our nation's demand signals for these materials are urgent but very choppy, and the commercial markets ebb and flow based on technology

accessibility and customer demand. We have to think radically differently about how we build our business."

In 2023, Canopy installed an InnoventX to investigate binder jetting for the production of low-density ceramic material. Additively manufacturing forms layer-by-layer by binding powder together, the team can significantly reduce processing time and waste generation compared to the casting workflow.

Producing near-net shapes with binder jetting, Canopy is optimizing the buy-to-fly ratio by eliminating over half of the material waste from traditional production. "We normally have to make large cakes and then machine those down," Dickson stated. "With binder jet prints, we're just doing a light finish touch, so it's around 50% material savings," he continued. "It's the perfect opportunity for additive because the process eliminates a lot of the waste and is fundamentally scalable. Binder jetting, among other near-net shape 3D forming technologies being brought to market for ceramic materials, allows you to build a business and scale something that previously was just not scalable."

Using the binder jet process significantly improves Canopy's production workflow, enabling a reduction in equipment footprint as well as simpler and more repeatable raw material prep.

> "With technologies like binder jetting, we can 3D print parts for space exploration one day and then use the same investment in equipment and personnel to manufacture automotive power electronics components, satellite heat exchangers, in-space propulsion components, and radomes the next. We could respond to a surge in demand very quickly."
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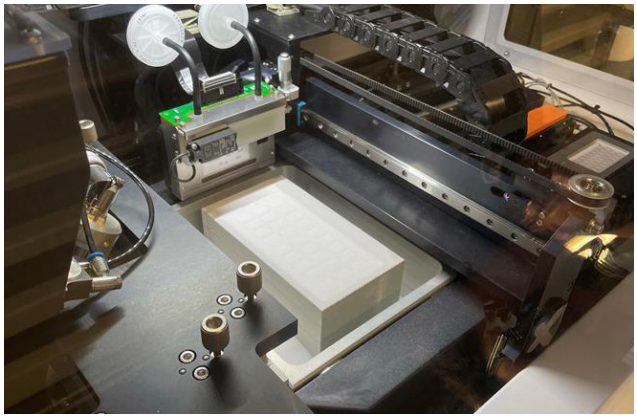
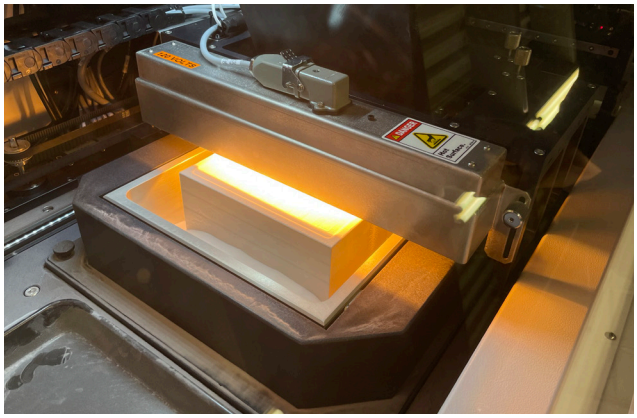
> **Will Dickson, Chief Commercial Officer, Canopy Aerospace**





As an automated process, binder jetting also allows Canopy to address another threat to the supply chain – the skilled labor gap. “There are only three undergraduate ceramics-focused engineering programs in the United States,” Dickson noted. “So, there‘s a huge workforce shortage of folks who are experts in that field.” By leveraging additive manufacturing technology, Canopy can train machine technicians on the InnoventX without needing material experts to execute the traditional production methods manually.

The goal for its customers is for the 3D printed tiles to fit and perform the same as the traditional tiles but to be produced at a fraction of the cost. The Canopy team is also working on further innovations in system-level designs, such as embedding wireless sensors directly into the TPS. As Canopy continues to optimize its binder jetting process, it is discovering ways to deliver order-of-magnitude efficiency improvements that will help further unlock the space economy.

Reaping the rewards of flexible production to bring down costs

Elasticity is a core element of Canopy’s business model. Dickson explained how digital technologies like additive manufacturing that don‘t require hard tooling enable the company to offer flexible production solutions to the supply chain. “With technologies like binder jetting, we can 3D print parts for space exploration one day and then use the same investment in equipment and personnel to manufacture automotive power electronics components, satellite heat exchangers, in-space propulsion components, and radomes the next. We could respond to a surge in demand very quickly.”

Elasticity is also essential for the equipment the company invests in, and the flexibility of binder jetting enables the Canopy team to innovate and optimize.

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Top left, the InnoventX binder jetting system in operation printing the Canopy reusable TPS ceramic material. Thin layers of powder are spread before a binder is deposited and dried, similar to jetting ink on sheets of paper. After printing, green-state parts are removed from the powder bed and loaded into a high-temperature furnace for sintering, bottom left.

"We want to use quasi-off-the-shelf equipment and build proprietary material systems," Dickson said.

The open architecture of the InnoventX allows the Canopy team to step away from industry norms and customize builds suited to the high-performance needs of various industries.

"Canopy Co-Founder and CTO Dr. John Howard had the insight to take advantage of what is perceived as one of binder jet's primary technical gaps, which is forming fully dense components," Dickson explained. "When we look at extreme thermal management applications, engineering the density is a strong differentiator. As an example, we are now exploring how to binder jet print silicon carbide to enable transpiration cooling for space re-entry systems."

Successful thermal protection systems depend on two things – light weight and the ability to withstand the high temperatures of re-entry. Traditionally, cast billets comprise over 90% air, optimizing insulation capabilities by combining the sizeable void volume with the large surface area.

Refined to provide customizable development with scalability in mind, the InnoventX can print a range of powders, including metal, ceramics, and proprietary material sets like Canopy's innovation. Piezoelectric printheads provide the flexibility to process a variety of binders targeting tailored performance – such as low-density strength – to meet the needs of a range of manufacturing challenges.

"We love the fact that binder jetting as a technology is leveraged in large form factor applications; it's scalable, and we're able to leverage our proprietary materials on the InnoventX while also doing tons of optimizations to modify the processing parameters for our low-density targets – nozzle physics and droplet dispersion is the engineering equation we're working on now," Dickson said.

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Canopy testing thermal insulation and ablation properties of a proprietary ablative TPS material that was 3D printed on the InnoventX using binder jet technology.

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Sample of Canopy's proprietary reusable TPS formulation coated with silicide coatings to increase toughness and emissivity for spaceflight applications.

As the team finalizes material sets, they will further exploit the design freedom of additive manufacturing to experiment with all types of innovative shapes. Eliminating the hard tooling of traditional methods allows Canopy to not only easily switch between or co-manufacture designs but also build once-geometrically-impossible or economically impractical parts.

NASA's Orion spacecraft features 1,300 thermal protection system tiles[4]. While some standardization of tile size has allowed for minor manufacturing efficiency gains, loading a 5-axis mill with precise dimensions to cut blank tiles to their shapes, sometimes with special cutouts for instruments, remains time consuming and generates a lot of material waste.

Binder jetting not only creates near-net shapes that don't require bulk material removal, but building designs layer-by-layer enables unique shapes that can enhance performance. Designers can utilize simple options such as cutouts that enable more efficient packaging, or they can implement much more complex features such as trifurcated channels. None of these options require any hard tooling.

Improving performance enables more value to be extracted, Dickson said. "In most high-density power applications, performance is improved when you can operate at higher temperatures. This means we can miniaturize components; we can just be a lot more efficient and offer that value proposition to our customers." These production advantages benefit not only space shuttle tiles but stand to bring innovation to a range of industries.

"Advanced technologies like binder jetting enable that scalable business model," Dickson explained. "Buying an entire set of tools for each customer is not scalable. In space alone, we expect that every vehicle designer is going to have their own set of custom shapes that they've already done aerodynamic testing on and feel very strongly about. So, we're preparing production around flexibility – preparing for not a lot of systematic uniformity but being able to efficiently manufacture different shapes on demand to create a sustained supply base that helps bring down costs."

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Fully fired Canopy proprietary reusable TPS formulation in representative shapes, showcasing overhang angles that are achievable with binder jet 3D printing.

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> **Will Dickson, Chief Commercial Officer, Canopy Aerospace**

Supporting growth through flexibility

For Canopy Aerospace, additive manufacturing technology together with its proprietary material sets provides the economies of scale to further unlock a space economy that has doubled in size over the past decade[5]. Commercial satellite manufacturing and launch revenues have doubled in the last two years and Canopy plans to provide the raw materials and components to grow in parallel with those companies reaching for the stars – in a future where daily launches and reentries could be the norm.

Governments are also increasing military space budgets as they recognize the importance of space to national security. Canopy was recently awarded a contract from the U.S. Air Force to accelerate the commercialization of next-generation thermal protection systems technologies for hypersonic and re-entry systems. Hypersonic assets, capable of reaching speeds greater than Mach 5, operate in some of the most extreme environments known to science. The supply base for these types of materials dwindled after NASA’s sunsetting of the Space Shuttle program, so the Canopy team is eager to step in and innovate to help grow this sector as well.

Dickson also noted new applications that have come to the company because of its binder jetting capabilities, including interest in 3D printing heat shields and insular pipe components for small electronics or insulator blocks that are radio frequency (RF) transparent.

Throughout the discussion, Dickson kept returning to one word – elasticity. “3D printing has great part-to-part benefits we can exploit, such as geometric flexibility or tunable material systems, but what’s key to our mission set is really the elasticity as defined as the ability to scale very quickly in response to demand,” he emphasized. “We care deeply about supporting critical missions across a variety of industries in a big and impactful way and feel this approach positions us best to do so.”

From on-demand, tooling-free production to material revolutions and performance-enhancing designs, binder jetting enables innovative and flexible solutions that help Canopy Aerospace fortify supply chains while unlocking new economic possibilities.

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[1] https://nam.org/2024-fourth-quarter-manufacturers-outlook-survey
[2] Internal Canopy Aerospace research 2023-2024
[3] https://www.faa.gov/data_research/commercial_space_data
[4] https://www.nasa.gov/reference/orion-components
[5] https://www.spacefoundation.org/2024/07/18/the-space-report-2024-q2

About Canopy Aerospace

Canopy is a materials engineering company revolutionizing high-temperature ceramics for space, defense, and power systems. Its mission is to push the boundaries of materials science to enable breakthroughs in the world's most critical industries.

Canopy's Approach: Canopy develops proprietary technologies with government, commercial, and academia to power the next generation of engineered hardware systems. Its factory is purpose-built for advanced ceramic materials engineering around additive manufacturing and robotic automation to design and produce superior, high-performance products. By leveraging the data it gathers, Canopy builds the foundation for future breakthroughs in AI/ML-driven solutions that will continuously enhance performance and adaptability of technical ceramics. This forward-looking approach allows the Canopy team to tackle the toughest thermal management challenges and deliver faster, smarter, and more effective solutions where they're needed most.

About Desktop Metal Inc.

Desktop Metal (NYSE:DM) is driving Additive Manufacturing 2.0, a new era of on-demand, digital mass production of industrial, medical, and consumer products. Our innovative 3D printers, materials, and software deliver the speed, cost, and part quality required for this transformation. We're the original inventors and world leaders of the 3D printing methods we believe will empower this shift, binder jetting and digital light processing. Today, our systems print metal, polymer, sand and other ceramics, as well as foam and recycled wood. Manufacturers use our technology worldwide to save time and money, reduce waste, increase flexibility, and produce designs that solve the world's toughest problems and enable once-impossible innovations. Learn more about Desktop Metal and our #TeamDM brands at www.desktopmetal.com