WHITEPAPER

VELO 3D

How Velo3D Metal AM is Fueling the **NewSpace Race**

Technological leaps in AM will provide the innovation in part design and supply chain flexibility to enable breakthroughs in the emerging entrepreneurial space sector

Velo3D.com

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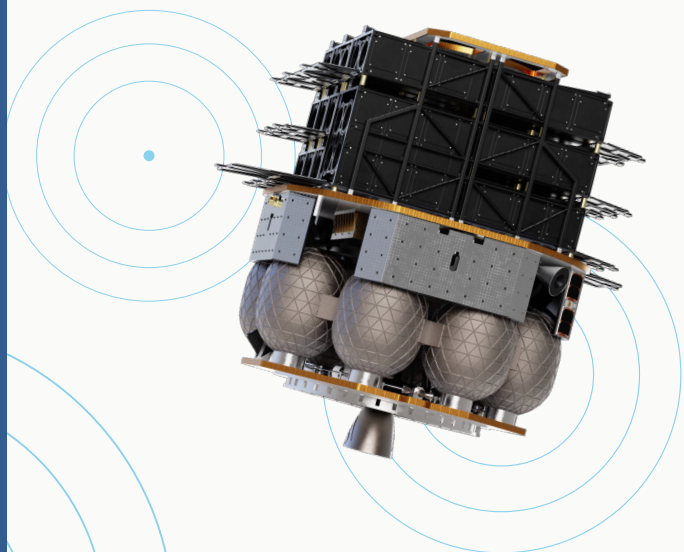
We're witnessing a boom in the space sector; so much so that it's even been given its own title: NewSpace. The modern space industry is a story of democratization, as countless technological advancements have become more accessible to startups and innovators. Today, we're seeing a revival of ambition to explore the moon, planets, stars, and our own planet, fueled by private investment and enterprise, modern software computing power, and highly advanced manufacturing platforms.

It's important to define terms, so when we talk about NewSpace we're referring to a small but growing cadre of companies that form a nascent industry building off the technological foundations of the original space industry. NewSpace covers a wide range of companies including operators, launch vehicles, satellites, software and ground technology, data analytics, and materials and components, all in service of different aspects of the space sector from colonization and tourism to communications and earth observation.

Many companies have been instrumental in enabling NewSpace. It took the confluence of countless innovations in everything from telecommunications to data analytics over decades to drive progress to this point.



Additionally, larger launch enterprises with the infrastructure and capacity for stage one launches are providing the transport payloads to get smaller technologies off the ground, ostensibly lowering the barrier to entry for innovators to bring their technology to orbit. And while those marquee launches garner the headlines, these NewSpace innovators are proving to be an economically fertile sector.

According to Tracxn, "NewSpace is one of the most active sectors for investors, with overall funding of USD 41.9B in 450+ companies. It is also interesting to note that more than half of the funding has been raised in the last 3 years (2019-2021)."[1] Morgan Stanley estimates that the broader space industry could be a trillion-dollar economy by 2040.[2]

[1] https://tracxn.com/d/emerging-startups/top-newspace-startups-2022

[2] https://www.morganstanley.com/ideas/investing-in-space

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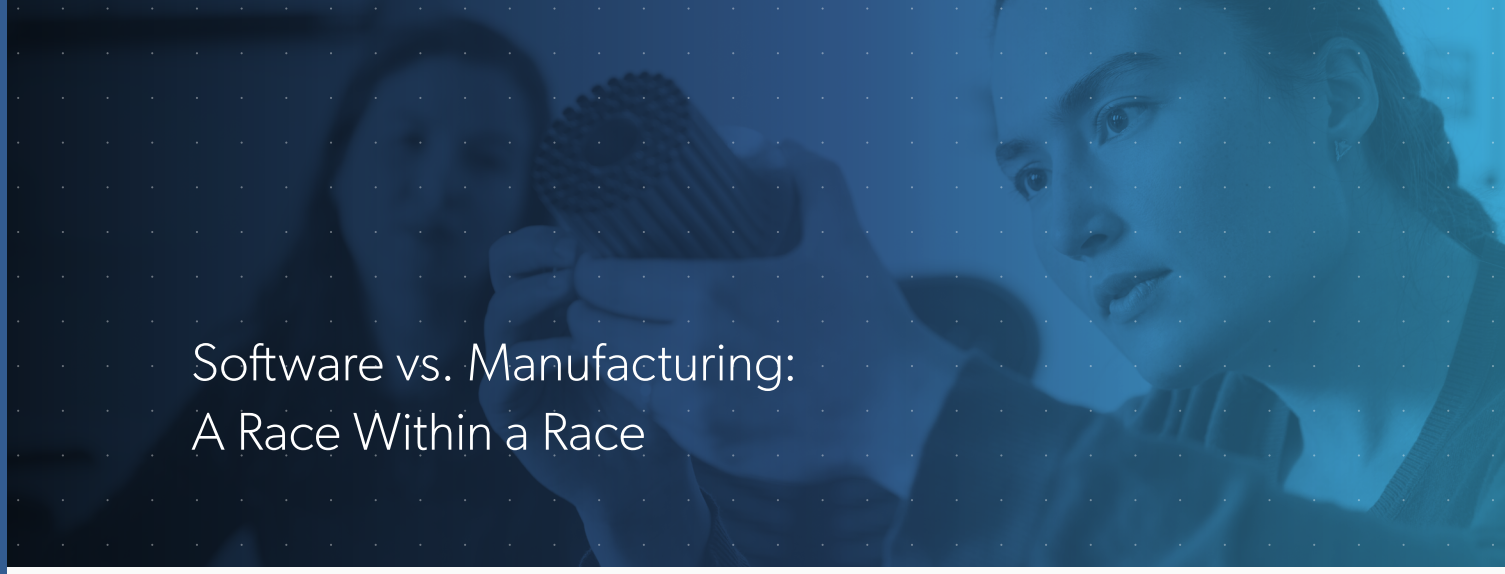
As these NewSpace companies move to bring their innovations to life, one of the key drivers of innovation into the future will be leveraging additive manufacturing (AM). With cutting-edge manufacturing techniques able to meet the complexity of design, increased performance through better materials and designs, and more agile supply chains with accelerated iterative ability and times to market, the challenges that faced the original space sector are being addressed to the benefit of emerging NewSpace companies.

As NewSpace takes its next leap forward, the use of AM will be even more critical to enable the innovations of the future. In this whitepaper, we'll explore some of the ways in which advanced metal AM—end-to-end metal 3D printing systems as exemplified by Velo3D—has evolved to enable innovation across the space sector, and how those manufacturing capabilities will help drive NewSpace as companies make the leap from dream to reality.

LAUNCHER ASTRA REACTION DYNAMICS HERMEUS



Software vs. Manufacturing: A Race Within a Race

There has always been a race within manufacturing. For years, with the new power of software-assisted design, the creators have had the edge as the theoretical limits of design struggled with the practicality of executing those designs.

CAD, simulation software, advanced modeling and more have worked to push the limits of imagination when it comes to potential part performance. And, for the longest time, established forms of manufacturing have been unable to meet those specifications. Or, if they were, the amount of time it would take from design to production would be years in the making and riddled with compromises in the process of design for manufacturability.

Rocket engine printed on Velo3D Sapphire 1MZ featuring a build configuration of 315mm Ø x 1000mm height with two 1kW lasers. **Left** – complete rocket engine, as-printed surface finish. **Right** – cut away, as-printed surface finish

GRCop-42 thrust chamber printed on Velo3D Sapphire 3D metal printer. GRCop-42 takes advantage of copper's thermal conductivity while increasing the strength, melting point, and corrosion resistance for liquid-oxygen-based thrusters.

Early iterations of additive manufacturing made some advancement possible, but there were limitations in materials in both quality and repeatability. And, in the design for additive manufacturing (DfAM) process, there would be another set of compromises to ensure a part could be suitable for printing. Today, the level of design freedom that's achievable through advanced metal AM systems enables innovation in the form of net-new parts, but it can also be used to improve and optimize existing systems for better performance. Let's examine some of these new capabilities in more detail.

Take the "quad" reaction control systems (RCS), for example. These systems, featured on each of NASA's Apollo Lunar and Service modules, supported six Moon landings during the original Apollo program. As NASA looks to the future, it sought to adapt and improve the design of their quad RCS to place unmanned Orion spacecraft into lunar orbit, with the eventual goal to achieve crewed landings on the Moon, which would then serve as a launching point for Mars exploration as part of their Artemis program.

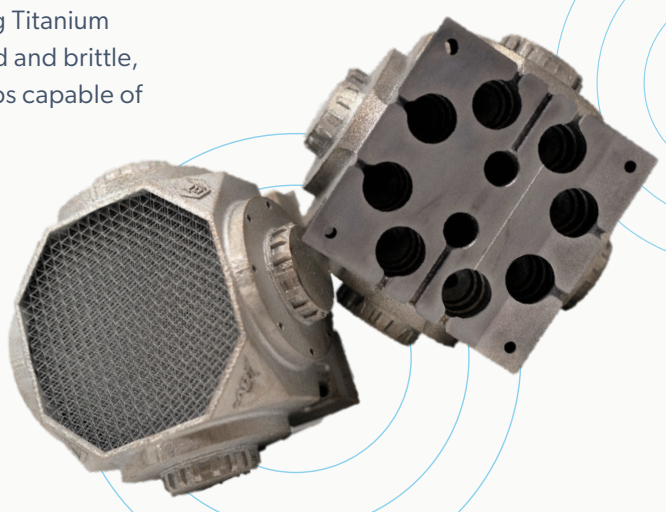
Aerojet Rocketdyne, working with advanced modeling company nTopology, were tasked to create lighter-weight, smaller RCS systems, and leveraged advanced metal additive manufacturing to execute on those designs. For traditional manufacturing such as casting, brazing, and welding, the required complexity of the internal channels were all but impossible to accomplish. Conventional metal AM systems also struggled with the part's delicate lattice features, used to increase stiffness.

By utilizing Velo3D's advanced metal AM system, Aerojet Rocketdyne was able to print the part with minimal supports, and without tilting the part relative to the build plate—a common technique used in traditional AM processes. This resulted in a print that accurately produced the fully optimized new design and eliminated significant amounts of post processing. In addition, Velo3D successfully printed the part using Titanium 6Al-4V, notorious for printing hard and brittle, with its advanced processing steps capable of minimizing thermal stresses.

"This resulted in a print that accurately produced the fully optimized new design and eliminated significant amounts of post processing."

The resulting RCS thruster is 1/5 the mass and 1/2 the size of the incumbent part while retaining all of the original functionality. The new part also boasted a cost 1/3 of the conventionally manufactured version. The end part contains far fewer components which makes it easier to assemble and is expected to have a lower risk of failure in operation.

Software innovation and modeling is only as good as a manufacturing system up to the task of executing on the designs. While Aerojet Rocketdyne is one of the oldest names in space, their successes in embracing new manufacturing technologies is an example of the innovation available to startups in NewSpace. Velo3D's Advanced metal AM system is delivering the part performance at the speed of innovation needed for NewSpace companies to move their businesses to the next level.



Top and bottom view of 3D printed RCS injector block.

The Sapphire Family of Printers

The Sapphire family of printers are state-of-the-art laser powder bed fusion metal AM printers capable of printing complex geometries including low angle prints down to zero degrees, high aspect ratio structures up to 6000:1, large inner diameters up to 100 mm, and parts previously thought impossible. The Sapphire XC 1MZ features the largest build volume of any leading metal LPBF supplier.

Sapphire

DIMENSIONS

315mm Ø x 400mm z

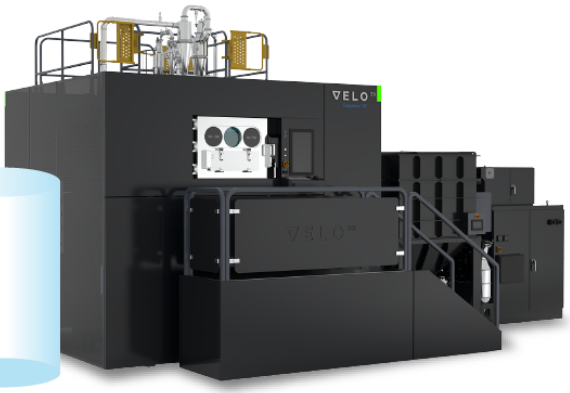
ORIGINAL SAPPHIRE

315mm Ø x 1000mm z

SAPPHIRE 1MZ

Sapphire XC

DIMENSIONS



600mm Ø x 550mm z

SAPPHIRE XC

600mm Ø x 1000mm z

SAPPHIRE XC 1MZ

The Manufacturing Agility to Move From Prototype to Production

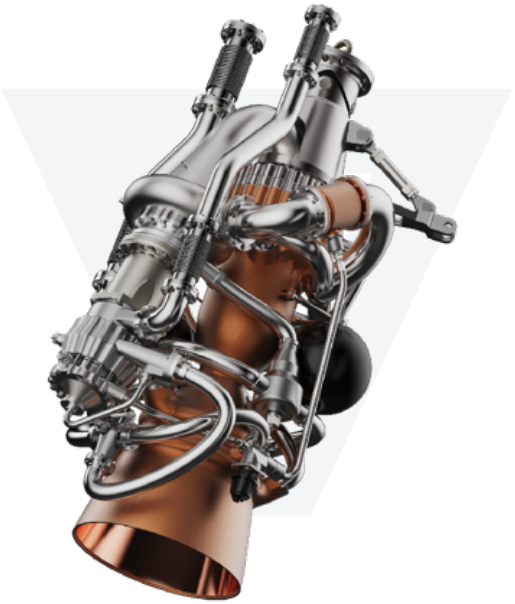
The advancement in AM technology is coming at the perfect time for emerging space companies that demand lower costs and faster results for their business models to remain viable. For example, rather than spending decades developing part design and system frameworks from the ground up, new entrants to the NewSpace sector can take existing part designs and IP, adapt them for modern purposes, and slash production times to manufactured parts through advanced metal AM.

Conventional Manufacturing	Velo3D's Additive Manufacturing
Slower iterations and ramp to part production	Faster testing cycles and time-to-market
Multiple pieces, joints, and connections	Print complex geometries as a single piece
Welding and brazing, challenging tolerance stacks	Reduced weight, higher performance, lower failure risk

The resulting landscape for NewSpace companies is wildly different than it would have been 30 years ago when it might take decades and billions of dollars to produce a functioning rocket engine. Innovators in the NewSpace industry can now create entire propulsion systems for a fraction of the cost, in a fraction of the time.

One of the major contributing factors to this agility is the growing global network of contract manufacturers capable of producing core parts through additive manufacturing. In the case of a metal 3D printing partner like Velo3D, the manufacturing partner works in close collaboration in the direct coordination of this extensive network, further taking the burden off of NewSpace startups.

Rather than needing to invest millions of dollars in in-house metal 3D printing systems and supporting resources for prototyping through production scale, a NewSpace startup can leverage CMs from around the world to get the parts they need, without major upfront investment in capital or R&D. These lower lead times create a significant technical velocity for startups in the NewSpace field and allows them to focus on their core strength, space, rather than having to worry about the manufacturing process.



Thrust: 22,000 lbf (sea level)

Propellant: LOX/RP-1

Performance: 365s Isp (2nd stage nozzle, vac)

LOX Cooled

Closed expander cycle with upgrade path to oxidizer-rich staged combustion

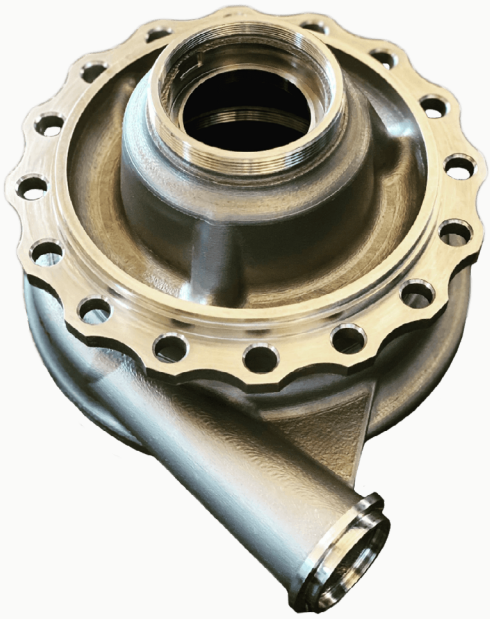
98% Combustion Efficiency (C*)

Copper Alloy

3D Printed

The Launcher Engine-2, a 3D Printed 22,000 lbf engine propelled by LOX/RP-1, is billed as the world's highest performing engine for small launchers.

A prime example of this success in velocity is Launcher. Building off existing Ukrainian rocket IP, Launcher set out to design the highest performance engine in the small satellite launcher class with the largest thrust, lowest propellant consumption, and lowest cost-per-pound of thrust. In other words, the most powerful, least expensive rocket in its class.



Metal volute printed on Velo3D Sapphire in Inconel 718. This part serves as an outlet for Launcher's liquid oxygen pump.

In order to reduce lead times for the turbopump and other critical components, Launcher opted to leverage advanced metal AM instead of conventional forms of manufacturing.

For their E-2 liquid rocket engine that will serve as a main propulsion component for their Light rocket, for example, Launcher needed a critical component: a highly precise and balanced turbopump impeller capable of spinning at the required 30,000 rpms, in cryogenic conditions, while transporting liquid oxygen. Leveraging advanced metal AM, a contract manufacturer produced the impeller without internal supports and without tilting the impeller. This ensured that the part printed axisymmetric without warp and enabled Launcher engineers to balance and spin test the part. After testing, the impeller met or exceeded all metrics of efficiency and durability.

> "Launcher is a study in how upstarts in the NewSpace sector could also accelerate their timelines using metal AM. In a highly competitive industry where time to market is essential to secure funding and outpace the competition, metal AM is a critical tool."

Launcher's original plan was to start in 2017 and reach revenue by 2027. Now with the flexibility provided by the Velo3D platform, they can take advantage of shifts in the marketplace to quickly reach revenue.

By prioritizing the Orbiter satellite system, Launcher can leverage SpaceX's rideshare program—which handles the first launch stage—and start serving customers in half the time. By partnering with Velo3D, Launcher was able to print core parts for the Orbiter satellite system, including propellant tanks, injector and nozzle assemblies, and more.

Launcher Orbiter propellant tank: Titanium pressure vessel printed in Ti-6Al4V shown as printed still attached to the build plate. Printed as a single piece, engineers can quickly have a fully functional assembly that is lighter, stronger, and reduces the risk for leaks.

They plan on a first launch with SpaceX in 2022 - half the original projected time - which will enable them to reach revenue much faster than if they had to also develop first-stage launch capacity.

This type of flexibility in a rapidly shifting market will be critical to any new entrants in the NewSpace race.

Where the NewSpace Sector is Headed

Leveraging stories of success from companies blazing the trail to space, the NewSpace entrants will have access to proven avenues of success. From established veterans like Aerojet Rocketdyne, to fast-moving innovators like Launcher, leaders in the space industry are making the way to space manufacturing clear; and that path is through advanced end-to-end additive manufacturing.

It's truly an exciting time to be in the NewSpace sector. With lower barriers to entry, large volumes of capital investment, and technological advancement in both software and manufacturing living up to the promise space exploration possesses, we're only beginning to scratch the surface of the industry's potential.

Metal additive manufacturing is the unheralded engine unlocking these ambitious goals by allowing innovations in design to be faithfully produced, in a fraction of the time. For the NewSpace sector to make the leap forward from a vision and a dream to a fully realized industry, they'll need the design freedom, manufacturing repeatability, and unprecedented agility of advanced metal AM.

Photo: Launcher/John Kraus

If you'd like to learn more about how your organization can transition critical parts to metal AM with the Velo3D end-to-end solution, get in touch with one of our experts today.

Without Compromise

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