HEAT TREATING FOR SPACE AND 3D PRINTED PARTS

aalberts surface technologies

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EXECUTIVE SUMMARY

The Space Race 2.0 is well underway as private sector companies compete for opportunity in this next frontier. Advancements in tech and materials have the potential to take humankind further than ever before.

But in this race, it's not just a matter of who can find the greatest innovative solutions, but also make them ready for repeatable, scalable production.

In this guide, we'll cover how the latest advancements in additive manufacturing are shaping the future of space, and how heat treating is bringing these innovations to fruition.

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3D PRINTING FOR SPACE

254 miles from Earth's surface

Even with commercial space travel on the horizon, this industry still faces serious challenges when it comes to sustaining human life off-planet. One of the biggest is manufacturing.

The ISS currently depends on cargo resupply missions to deliver spare parts that aren't stored on the station. Orbiting 254 miles from Earth's surface, astronauts can go three months between shipments. That's a long time to wait for a part that's needed now. On Mars, those lead times become impossibly long.

This is one of the core challenges keeping us tied to single-planet life. OEMs are solving it with additive manufacturing.

BENEFITS OF 3D PRINTING

3D printing offers more than portability. It's changing what's possible in part design and production for space.

Traditional subtractive machining starts with a block of material and removes what isn't needed. Additive manufacturing builds layer by layer, which means engineers can produce complex internal geometries like cooling channels and lattice structures.

AM also enables part consolidation. What once required multiple welded or brazed components can now be printed as a single unit. Fewer joints mean fewer failure points.

Then there's weight. Every gram carries a launch cost. Through topology optimization, AM allows engineers to use material only where it's structurally needed. The result is parts that are lighter without sacrificing performance. of standards for proprietary material and 3D printing applications. The R&D process for discovering these standards can be lengthy and expensive.

As a thermal processing partner, we're joining OEMs in the drive to bring AM into mainstream manufacturing with new industry standards and production-ready solutions that help achieve ROI.

3D PRINTING LIMITATIONS

The printing process inherently creates challenges that have to be addressed before parts can meet the demands of space.

- Porosity. In processes like laser powder bed fusion, printing leaves small internal voids throughout the part. These voids compromise mechanical strength and fatigue resistance. They also reduce performance at extreme temperatures. Conventional heat treatment doesn't fully address them. Without a targeted solution, porous parts won't hold up in space.

- Residual stress. The rapid heating and cooling cycles during printing create internal stress throughout the material. Left unaddressed, that stress leads to distortion and cracking, particularly in the complex geometries.

- Lack of standards. For many proprietary alloys and AM applications, established industry specs simply don't exist yet. The R&D process for qualifying new materials and printing methods is time-consuming and expensive. Moving efficiently from test cycles to production-ready parts requires a partner who knows how to navigate it.

This is where thermal processing becomes critical. Processes like hot isostatic pressing (HIP) and vacuum heat treating directly address these limitations. They eliminate porosity and relieve residual stress, producing parts with the mechanical properties space demands.

hot isostatic pressing

Hot isostatic pressing (HIP) combines high temperature and pressure to improve a part's mechanical properties and performance at extreme temperatures. The sealed HIP vessel provides uniform pressure to bring parts to 100% theoretical density with minimal distortion. The high level of control and uniformity has made HIP the gold standard for AM parts for space.

3D printed materials tend to have porous microstructures that can compromise part performance. HIP is the only process that's able to eliminate these pores without compromising the complex geometries and near-net dimensions that are achieved in the printing process.

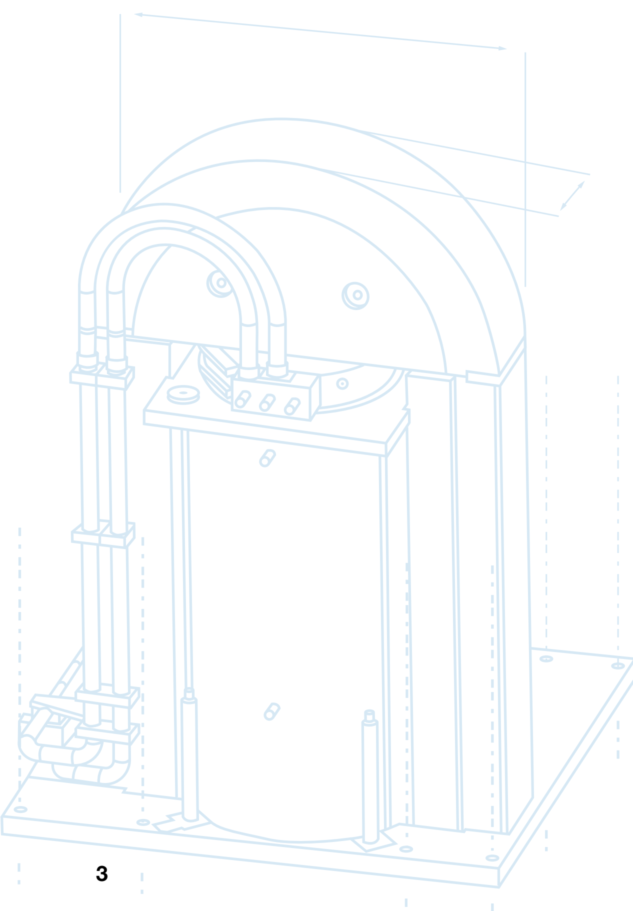
Benefits of HIP for space parts:

- Greater resistance to impact, wear, and abrasion
- Improved performance at extreme temperatures
- Better fatigue resistance
- Improved ductility

We've found that aerospace HIP recipes for traditionally casted parts are a great starting point for many novel space applications that don't yet have industry spec and standards. Starting with existing recipes opens the opportunity to do initial coach cycles with other parts, which can reduce the upfront cost of R&D before going to unique cycles for optimization.

For this process, our Quintus QIH-122 HIP is specially modified with additional thermocouples to track every variable of HIP. Robust cycle data reports provide an efficient path forward in the iterative R&D process and toward production-ready development.

Some commercial heat treaters don't have the level of data or dynamic cycle offerings like this and will only run HIP coach cycles with set parameters. Without custom cycles, it's impossible to push the boundaries of what's possible.



Your R&D Fueled by Data and Automation

The technology and techniques used in heat treating today have become just as innovative as the materials and parts being created for space applications. Suppliers that drive innovation and push boundaries within their own specialty are better equipped to support your own research and development efforts.

At AST-Paulo, we're setting a new standard with automated process controls, advanced data collection, and batch tracking that allows us to deliver a new level of efficiency and precision to heat treating—and help OEMs like you sharpen your edge in the race to space.

AST-Paulo...

Proprietary software that tracks every step to ensure your parts are delivered on spec and on time.

AST-Paulo Universal Batch System automatically adjusts temperature and atmospheric conditions according to your part's recipe.

HIP vessels have been modified to have 9 thermocouples, allowing for more control and data collection.

We offer offers both coach and custom HIP cycles.

VS

Other Heat Treaters...

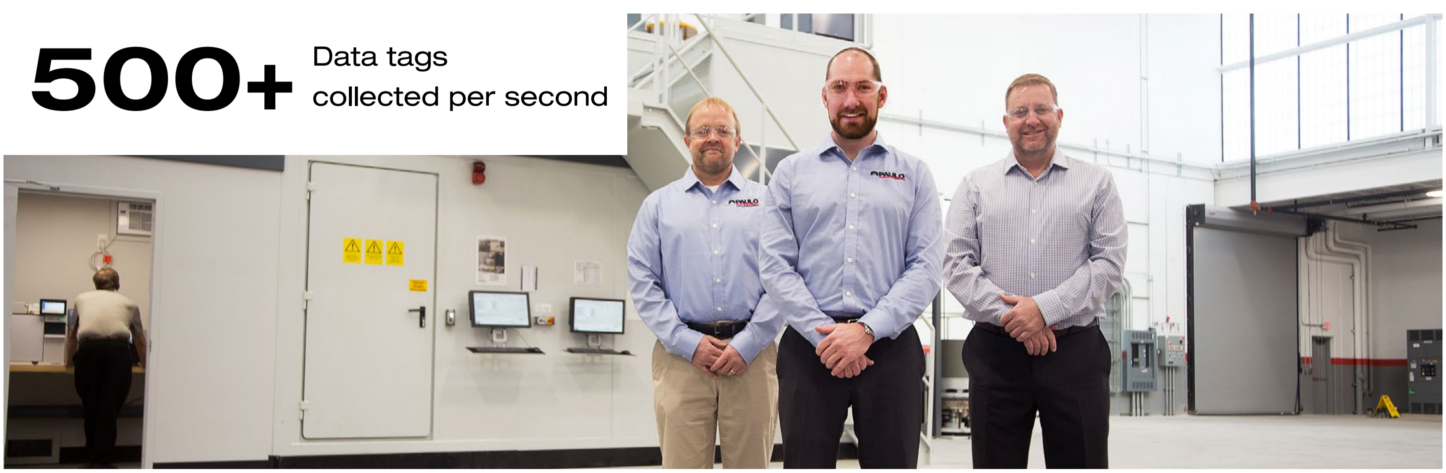
Less sophisticated part tracking used by some competitors can lead to unplanned delays.

Manual controls traditionally used by other heat treaters leave room for human error and out-of-spec conditions.

Out-of-box HIP vessels have only 6 thermocouples, which means less data and more unknowns when it comes to part specs.

Most heat treaters offer only coach cycles for HIP.

500+ Data tags collected per second



SPACE PARTS WE HEAT TREAT

Vacuum, Solution & Age, Anneal, Stress Relieve

Vacuum treatments are used to help combat the internal stress from 3D printing, HIP, and previous thermal processing. The controlled environment uses a combination of gas and temperature to heat and cool parts at a specified rate to reduce their likelihood of cracking in service.

Solution and age using an argon gas quenchant is an especially common process for treating space parts. Since homogeneity of the part is vital for strength, we use computer-controlled vacuums that ensure uniformity. Our proactive PCIS software tracks every part and every cycle variable, adjusting as needed to make sure every part is brought up to spec the first time.

High-Pressure Heat Treatment (HPHT)

High pressure heat treating combines HIP and solution treating into a single step. This eliminates an entire thermal cycle, which can help prevent further stress and sometimes results in superior material properties. Combining these processes also improves turnaround time and significantly reduces a part's time in the supply chain.

Vacuum Brazing

In traditional machining, vacuum brazing is used for part joining to create intricate part geometries. However, additive manufacturing can achieve geometric complexity without the need to join several components together. This ability to print a near-net shape has eliminated much of the need for vacuum brazing for space.

However, there are some traditionally machined parts that do require brazing for space applications including cooling jackets and cooling plates.

SPACE PARTS REQUIRING THERMAL PROCESSING

The future of space travel requires parts that can not only perform under high levels of mechanical pressure and extreme temperatures, but are durable enough for long-range and repeat missions. Heat treatment is a critical step in preparing rocket engine components, among others, for commission.

Since the inception of NASA's Space Shuttle Program, Paulo has treated countless integral components for launch and propulsion, along with many parts currently in orbit on the International Space Station. And today we process many parts for private-sector innovators who are developing equipment for repeated use and advanced application.

Space parts that are most commonly heat treated include:

- Volutes
- Turbine manifolds
- Bearing houses
- Fuel inlets
- Housings, support housings
- Bearing supports
- Turbo components

COMMON MATERIALS USED IN SPACE PARTS

In this still-nascent industry, new materials and applications are being explored every day as companies look for an advantage in the race to space. Proprietary alloy blends bring unique properties and promising potential in the push for stronger, faster, longer-lasting parts. But with unique properties comes the need for unique heat treating processes.

Partnering with the right commercial heat treater is essential for efficiently finding a production-ready process and bringing these great innovations to life.

High-performance superalloys commonly used for space include:

- Inconel 718, 625
- Aluminum (Al F357)
- Titanium (Ti-6Al-4V)
- Hastelloy C22

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