CUSTOMER SUCCESS STORY

Quadrus Rocket Engines Get Propulsion from 6K Additive Powders

Rocket Propulsion Systems Development at Quadrus

Quadrus is an aerospace contract manufacturer that specializes in the design and development of rocket propulsion technology. As director of advanced manufacturing, Joseph Sims has spent the past thirty years as a propulsion technologist and leads development projects for Quadrus. Sims' previous professional experiences with NASA and Lockheed Martin provide him with the unique knowledge and experience to create solutions for defense, government, and other aerospace clients and collaborators. He received his Ph.D. in Aerospace Engineering from the University of Alabama in Huntsville and is a very proud Alabama Crimson Tide football fan.

In 2014, Joe convinced his management at Quadrus to invest in laser powder bed fusion (LPBF) metal additive manufacturing technology, installing his first-ever Concept Laser machine. LPBF enables Quadrus to design next-generation propulsion systems for missiles, projectiles, CubeSats, and small-launch vehicles. Manufacturing these systems requires highly specialized refractory metals that are capable of withstanding extreme temperatures and can operate in harsh environments. Refractory metal powders such as tungsten, rhenium, and niobium are rare to find in additive manufacturing and difficult to process. This requires a reliable supply chain of suppliers that can produce the breadth of refractories at production scale – which has led to the partnership with 6K Additive.

Additive Manufacturing & Metal Powder Spheroidization

LPBF is capable of producing highly complex designs that would otherwise be impossible with conventional methods. One of the most common metal 3D printing technologies, LPBF uses high-

CHALLENGE:
Quadrus requires high-quality refractory metal powder at scale to additively design and manufacture rocket propulsion systems.

SOLUTION:
6K's UniMelt microwave-based plasma system produces perfectly spherical powder with no defects or satellite particles.

RESULTS:
Quadrus is able to confidently produce advanced rocket propulsion systems using 6K Additive refractory metals for LPBF and is enabled to take on new government and commercial projects.

> **"Tungsten rhenium is one of the primary reasons we're here in additive manufacturing, we can develop new combustion products that are optimized with internal channels and features, allowing for maximum flow and performance. These applications and geometries are not possible without the high-quality, spheroidized powder supplied by 6K Additive.**

powered lasers to selectively melt metal powder. The parts are built layer-by-layer (additively) until the part is complete. Whereas subtractive technologies remove material from a block of metal, LPBF only sinters the necessary powder where it is needed, this allows users to build products with internal features such as cooling channels. The design benefits and the compatibility with varying metal powders makes LPBF an ideal technology for flow device development and rocket propulsion engineering.

The Quadrus mission is to optimize the design and development of thruster devices for better performance. Some rocket combustion chambers will approach 3000°C so they are forced to work with exotic metals, such as tungsten rhenium. In order for these materials to be compatible with the 3D printer, they must be refined to a spheroidized metal powder with no imperfections. However, tungsten rhenium has one of the highest melting points of metallic metal and is highly resistant to thermal shock, making it very difficult to machine and process. Powder produced from conventional methods were unsatisfactory and according to Sims, "there's no room for error, and it all starts with the powder."

The Quadrus team identified problems with satellite particles from the powder produced from atomization powder manufacturing processes and began their search for a new solution. This path led to 6K's UniMelt® microwave plasma system.

REFERENCE CHART

Metal	Melting Point
Titanium	1670°C
Stainless Steel	1900°C
Niobium	2600°C
Carbon Matrix Composites	3000°C
Rhenium	3100°C
Tungsten	3300°C

Superior Refractory Metal Powders from 6K Additive

6K's microwave-based plasma system produces advanced materials used in additive manufacturing, battery material production, and other industrial markets. The UniMelt technology precisely refines metal powders while controlling the chemistry and porosity of the final product. The microwave-engineered plasma provides a thermal production zone of extreme uniformity, guaranteeing every particle sees the same thermal kinetics and process history, resulting in perfect, spheroidized metal powder. *6K Additive is one of the only companies* capable of producing high-quality tungsten rhenium for additive manufacturing and this is why Quadrus selected them as a partner.

Non-eroding throat insert for a solid rocket motor nozzle. Printed by Quadrus using 6K Additive tungsten rhenium powder

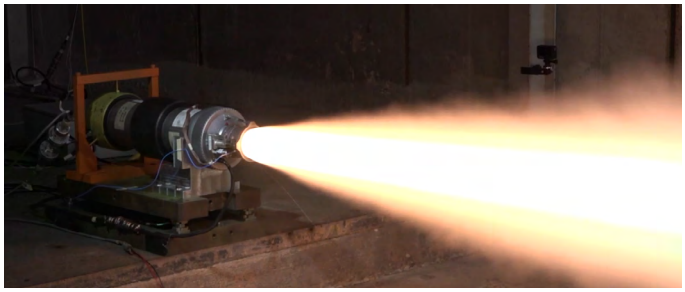
"Tungsten rhenium is one the primary reasons we're here in additive manufacturing," said Sims, who further explains the combined benefits of additive design and advanced metals for rocket propulsion systems. "Using 3DP technology, we can develop new combustion products that are optimized with internal channels and features, allowing for maximum flow and performance. These applications and geometries are not possible without the high-quality, spheroidized powder supplied by 6K Additive." Furthermore, Sims suggests that conventional materials, such as Carbon Matrix Composites (CMC) have long lead times (14-15 months), whereas Sims states "we can make the same part in a month... at a fraction of the cost."

As Quadrus sets out on its mission to be the nation's leader in producing metal AM parts using refractory metals, they understand how valuable it is to partner with a reliable company that shares the same vision of engineering excellence and material superiority.

> **Today, a lot of our work is government funded but we anticipate more commercial projects and expect our production rates to expand with 6K Additive in the future.**

Mission Success Requires a Reliable Ecosystem of Partnerships

"On average, we process approximately 75-100 pounds of refractory metals annually with 6K Additive," said Sims. "Today, a lot of our work is government funded but we anticipate more commercial projects and expect our production rates to expand with 6K Additive in the future." NASA and the FAA have already begun separate paths to qualify additive manufacturing for critical flight applications. Companies that specialize in this sort of development, like Quadrus, are relied on to drive testing, standardization, and influence new processes.



Actuated hot fire test of the tungsten rhenium 3D printed throat insert.

The Future of Rocket Propulsion

The conventional battlefield is expanding beyond our atmosphere. Nanosatellites are no longer science-fiction projects. The future of rocket propulsion will lead to the exploration of the unimaginable. Brilliant minds like Joe Sims, reliable contract manufacturers like Quadrus and innovative partners like 6K Additive are collaborating to maximize these opportunities. Technology was once considered a barrier, but we are beginning to see a transformation take place. Per Sims' estimate, we are less than three years away from AM production parts in critical applications for aerospace systems. If testing and qualification can become normalized for additive manufacturing, then the sky is no longer the limit. Roll Tide.

If you are interested in 6K Additive powders or want to learn more about the powder buy-back program, visit 6KAdditive.com.

RESULTS

	Conventional	Additive Manufacturing	Benefit
Material	Carbon Matrix Composites (CMC)	Tungsten Rhenium Powder	Optimized Design + Capabilities
Melting Point	3000°C	3300°C	Higher Melt Performance
Lead Time	14-15 Months	30 Days	92% Faster