

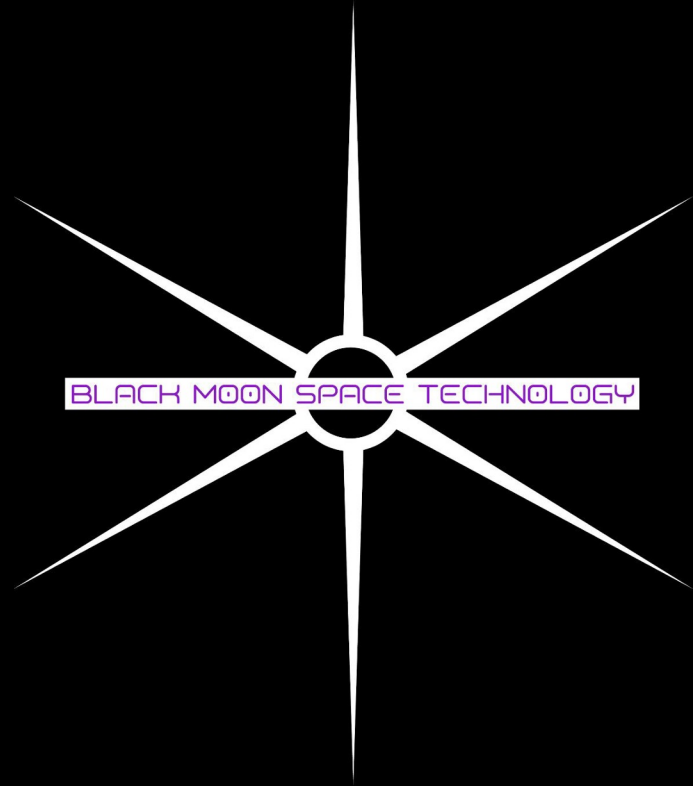
# Welding In Space

Black Moon Space Technology

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Welder Fabricator CEO



# History of Welding in Space

- 1969 - Soviet Soyuz 6 Mission By George Shonin and Valeri Kubasov using the Vulkan Tool.
- 1st to experience how dangerous space repairs can be.
- 3 processes: Electron Beam Welding, Low-pressure compressed arc welding, & Arc welding with consumable electrode.
- During the test, they almost burned through the hull.
- The weld quality of titanium, aluminum alloys, and stainless steel were comparable to that found on earth.



<https://awo.aws.org/2015/07/welding-in-space/>

# Current welding in Space

- Made In Space is developing a laser welding system.
- Busek is developing a semi-autonomous teleoperated welding robot for joining of external (or internal metallic uninhabited volume at zero pressure) surfaces in space.
- Black Moon Space Tech is developing 2 welding in space techniques.
- Different welding processes have different applications and the more options we have the better.



# Advanced Technologies

- Welding related industries construct power plants, factories, bridges, vehicles, and pipelines. Everything from computers to coffee pots are welded or manufactured with welded machinery.
- Innovations in welding have repeatedly facilitated the development & efficient production of innumerable parts & products.
- Advanced in welding itself have transformative effects on industry, and this will reflect in space.

<https://awo.aws.org/2016/06/welding-the-driving-force-of-our-economy>

Art by Jia Sing

<https://www.artstation.com/artwork/14Ww88>



# Welding and ISRU

- Additive manufacturing, Co-bot
- One of BMST's goals is to obtain metal powder extracted from the regolith and work with the material to see what it does naturally as a baseline to work with, and then refine the process and create alloys. From here we can establish standards and procedures to the best of our ability on the ground while working to account for challenges that will be faced in space.
- Welding requirements may or may not be different on the Lunar Surface but there is no true way to test on earth and we will not know until we are there.
- Repairing and building ISRU equipment
- Autonomous Rover Welder and welding robots



# Important things to know about metal in space

- Some alloys are challenging to produce on Earth. A class of alloys, known as Superalloys or high-performance alloys, contain heat and wear-resistant metals like tungsten, niobium, and molybdenum. These elements, also called refractory metals, are often employed in high-heat, high-stress environments, such as gas engine turbine blades, nuclear power reactors, and rocket engines. But the very properties that make these materials attractive (their heat- and wear-resistance) also prevent them from being machined or processed easily on Earth due to their high melting points.
- Microgravity enables different methodologies for processing and melting the desired amount of alloy material and allows for better control of microstructure uniformity throughout the alloy. For example, alloy creation can be conducted without a container in microgravity. “Containerless” processing allows researchers to examine the unique properties of refractory metals not easily studied on Earth, and presents a significant opportunity for manufacturing novel, high performance Superalloys.

# Highlights, Challenges, & Technology Development Areas

- Dust Mitigation
- Power
- Vacuum and Microgravity have unique benefits and disadvantages
- Space Qualified Welding PPE
- Electronics and equipment that is space qualified
- Communication with welding robots
- Automated and manual welding
- Heat transfer/unknown welding environments
- Welding has already shown a surprising amount of success in space
- Lunar welding will be different than LEO welding

# Key takeaways

- The advancement of welding technology is essential to a successful space mission of any kind.
- Everything from launching rockets to building structures, manufacturing, ISRU, recycling, equipment repair and maintenance, and more will directly or indirectly rely on welding somehow.
- Processing metal will be different in space and we won't know until we try.

Soyuz 6



Georgy Shonin and Valeri Kubasov on 1969 commemorative stamp of Soviet Union

[https://en.m.wikipedia.org/wiki/Soyuz\\_6](https://en.m.wikipedia.org/wiki/Soyuz_6)



[www.spacefacts.de/mission/english/soyuz-6.htm](http://www.spacefacts.de/mission/english/soyuz-6.htm)