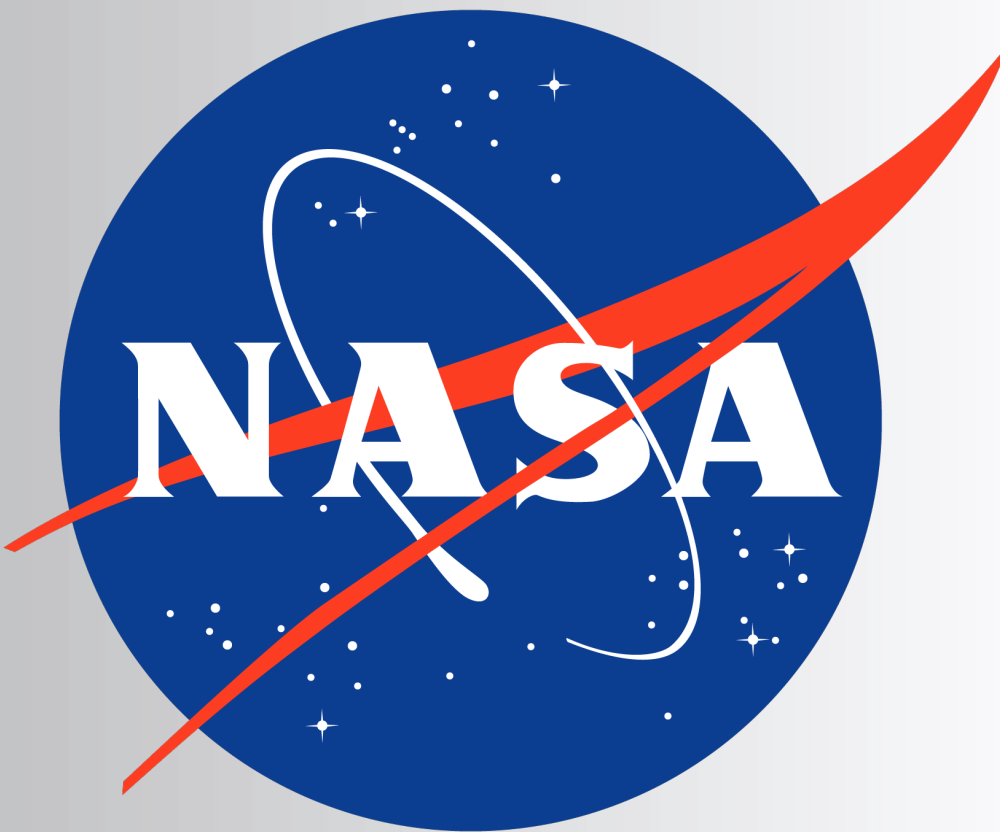


Enabling Small-Batch Custom Alloy Feedstock Development for Additive Manufacturing

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Alloy Development Laboratory Capabilities

EM31 alloy development efforts and capabilities investment is focused on upgrading laboratory spaces to get unique equipment that can be used to discover and study process-structure-property relationships in the next generation of materials for aerospace applications made by both traditional and additive manufacturing processes. Current and future capabilities are highlighted below.

Alloy Development Laboratory (4602/1126)

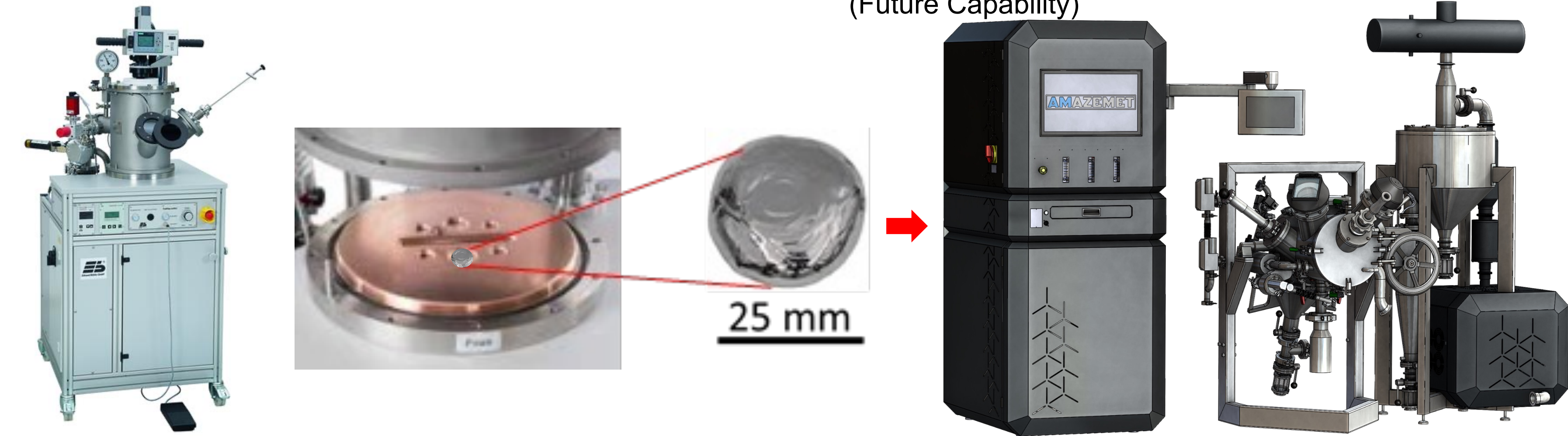
- High temperature vacuum heat treating up to 2100 - 2200 °C
- High temperature heat treating up to 1700 °C using air or inert atmospheres and large samples/components
- Heat treating up to 1100 °C of small samples and can be vacuum encapsulated on quartz ampoules .
- Alloy Synthesis using Arc-Melter (Any Metal)

AM and Powder Processing Laboratory (4602/1183)

- EOS M100 L-PBF AM Machine
- Tek-15 Plasma Spheroidizer
- Resodyn Acoustic Mixer (for coating powders)
- Planetary Ball Mil

Powder Feedstock Development Laboratory (4602/1154)

- Small-batch custom alloy powder feedstock development (Future Capability)

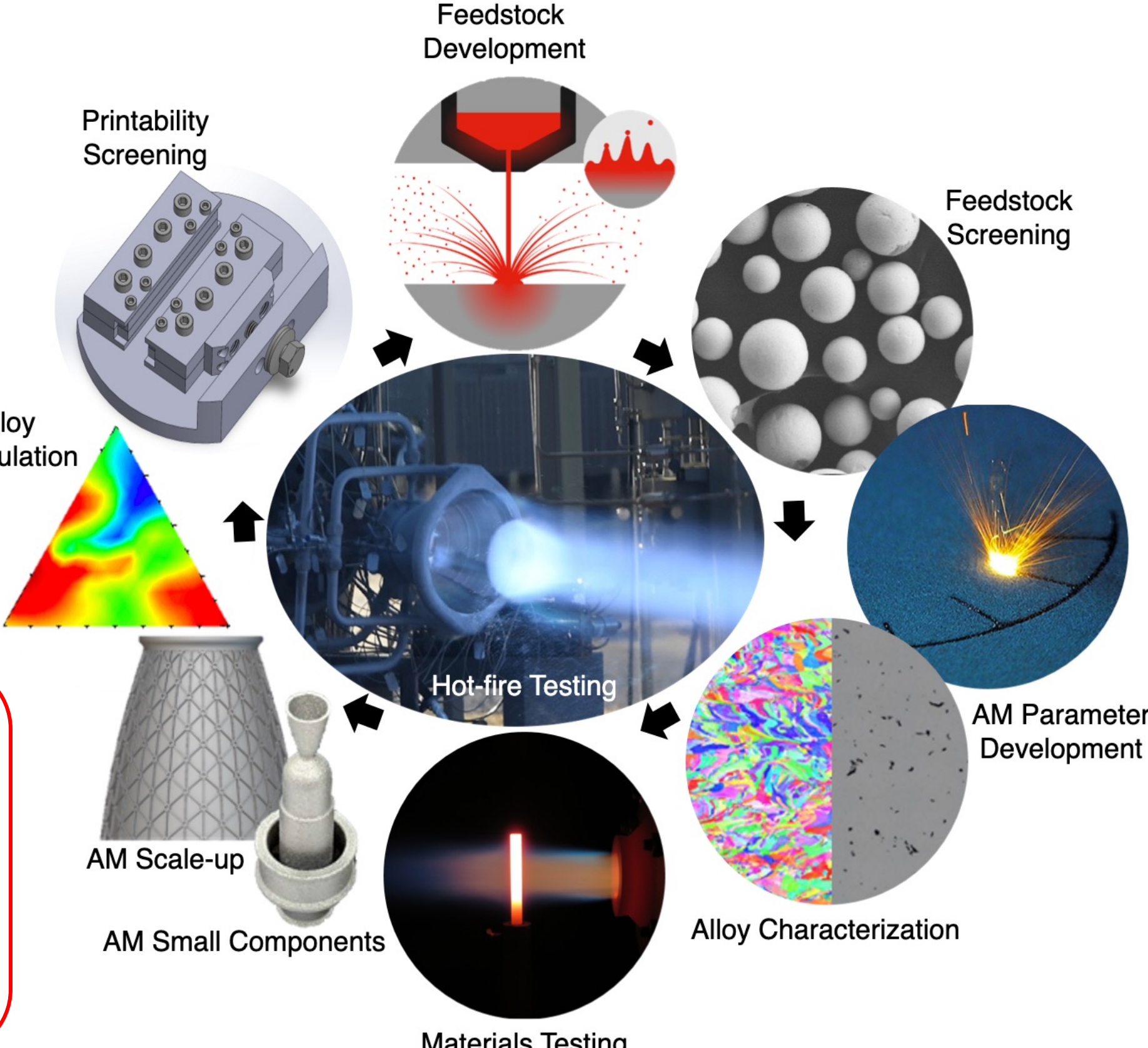
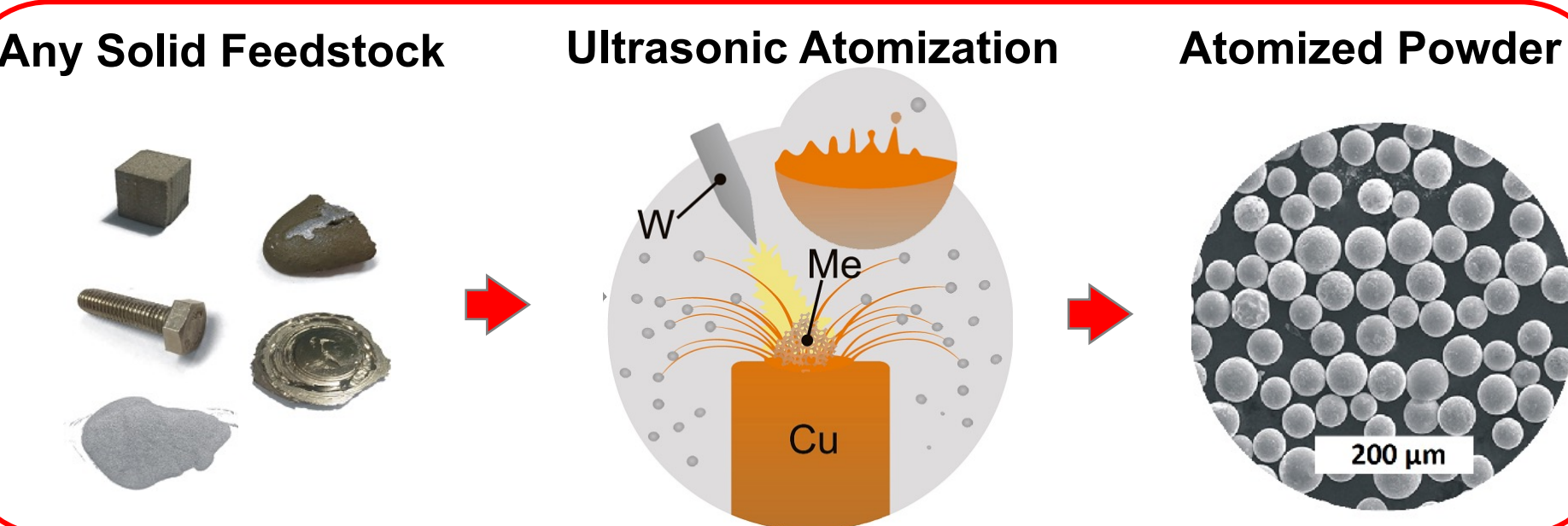


Feedstock Development for Additive Manufacturing

- Problem:**
- Propulsion, hypersonic, and space nuclear power (SNP) applications require high strength/high temperature components produced by AM but rely on expensive, supply-chain limited, non-AM optimized metals that lead to high buy-to-fly ratios.
 - Custom alloy development for AM is extremely expensive given the high-cost associated with feedstock development.

- Objective:**
- To develop cost-effective comprehensive process to enable application driven high-throughput AM-optimized feedstock development using small powder batch processing (< 3 Kg) for feasibility studies that lead to powder batch scale-up.

- State of the Art**
- Non-existent AM materials development process due to high limiting cost.
 - Current component design for AM limited to performance of legacy alloys
 - Typical development cost of adapting legacy alloys to AM: \$5-10M/5yr, while custom alloy development for AM >\$15M/5yr
 - Limited refractory alloy powder alloys not develop for AM with limited supply chain.
 - Example use-Case: AM C103 at TRL 5, C103 feedstock cost approx. \$1.7k/Kg. C103 has a melting point of 2,350 °C and it is highly printable (99.9% dense).



Refractory Alloys Additive Manufacturing Build Optimization

Traditional refractory manufacture is difficult and expensive:

- Bar, plate, tube, sheet stocks and sizes limited (constrains design).
- Powder feedstock are angular and not usually alloyed.
- High feedstock cost.
- Relatively difficult to form/machine (fracture prone).
- Heat treatment requires specialized facilities (O, C, N sensitive).

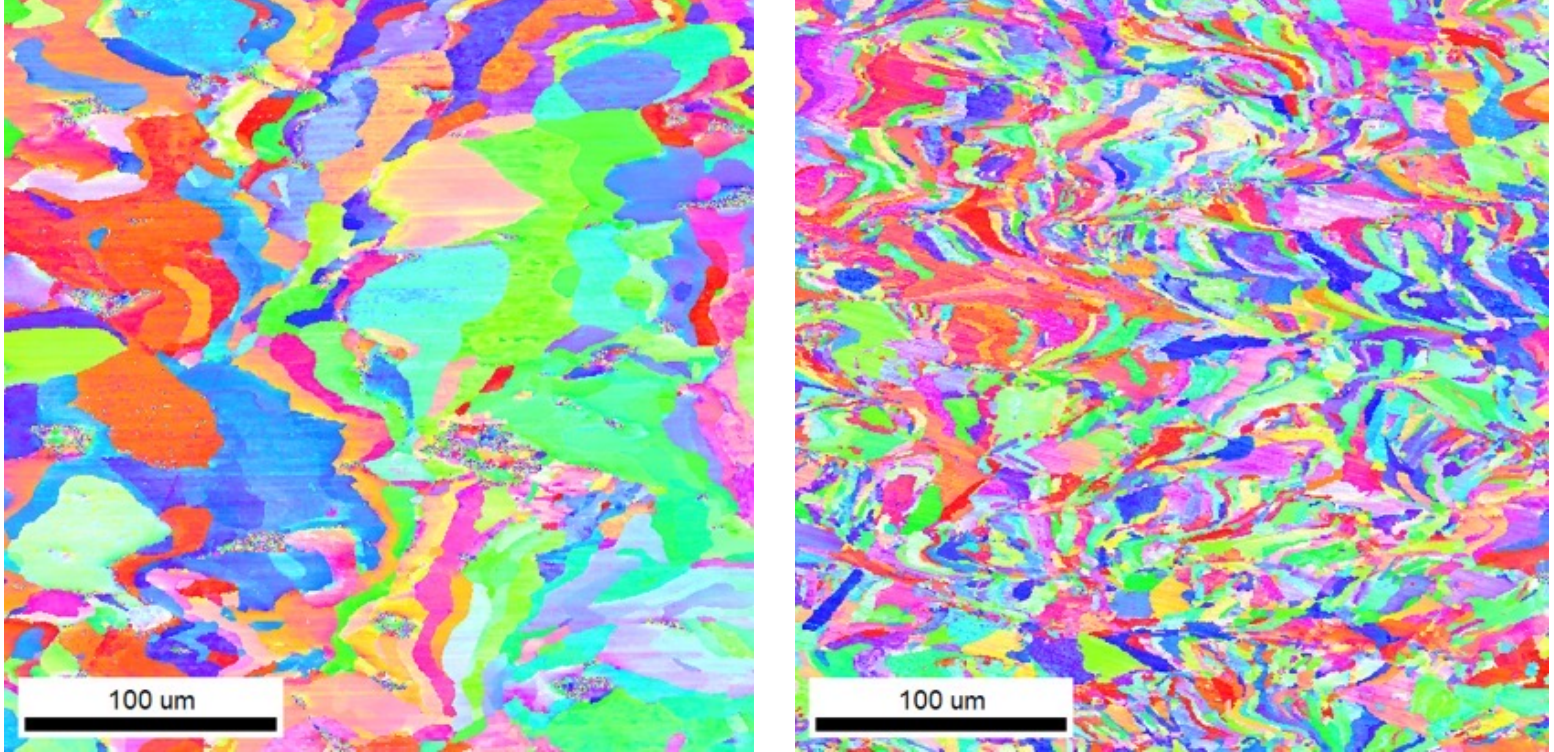
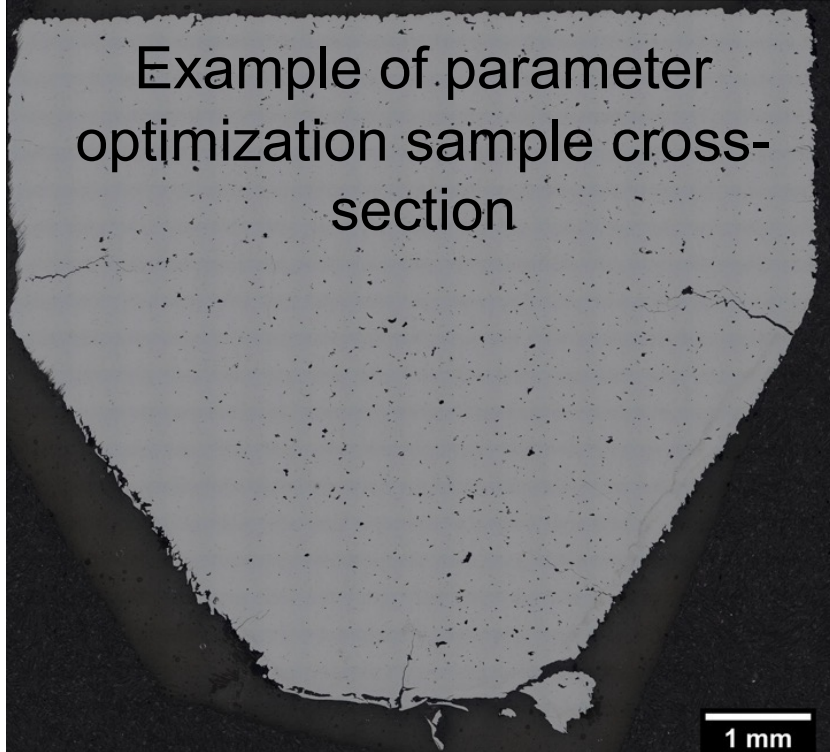
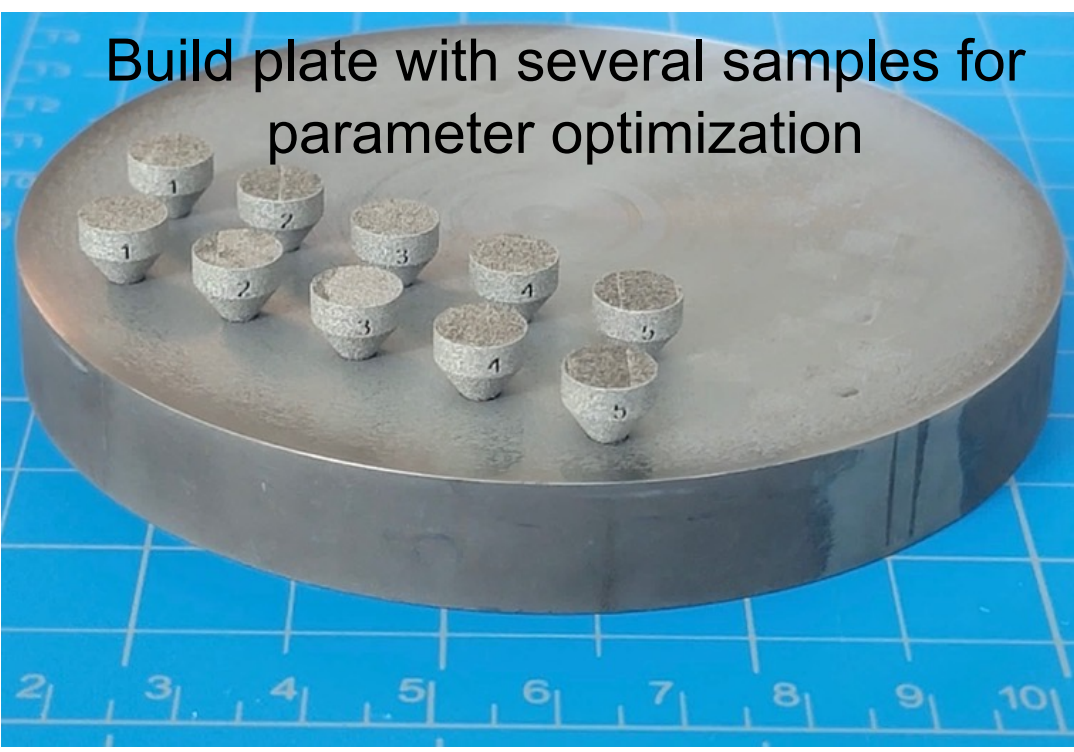
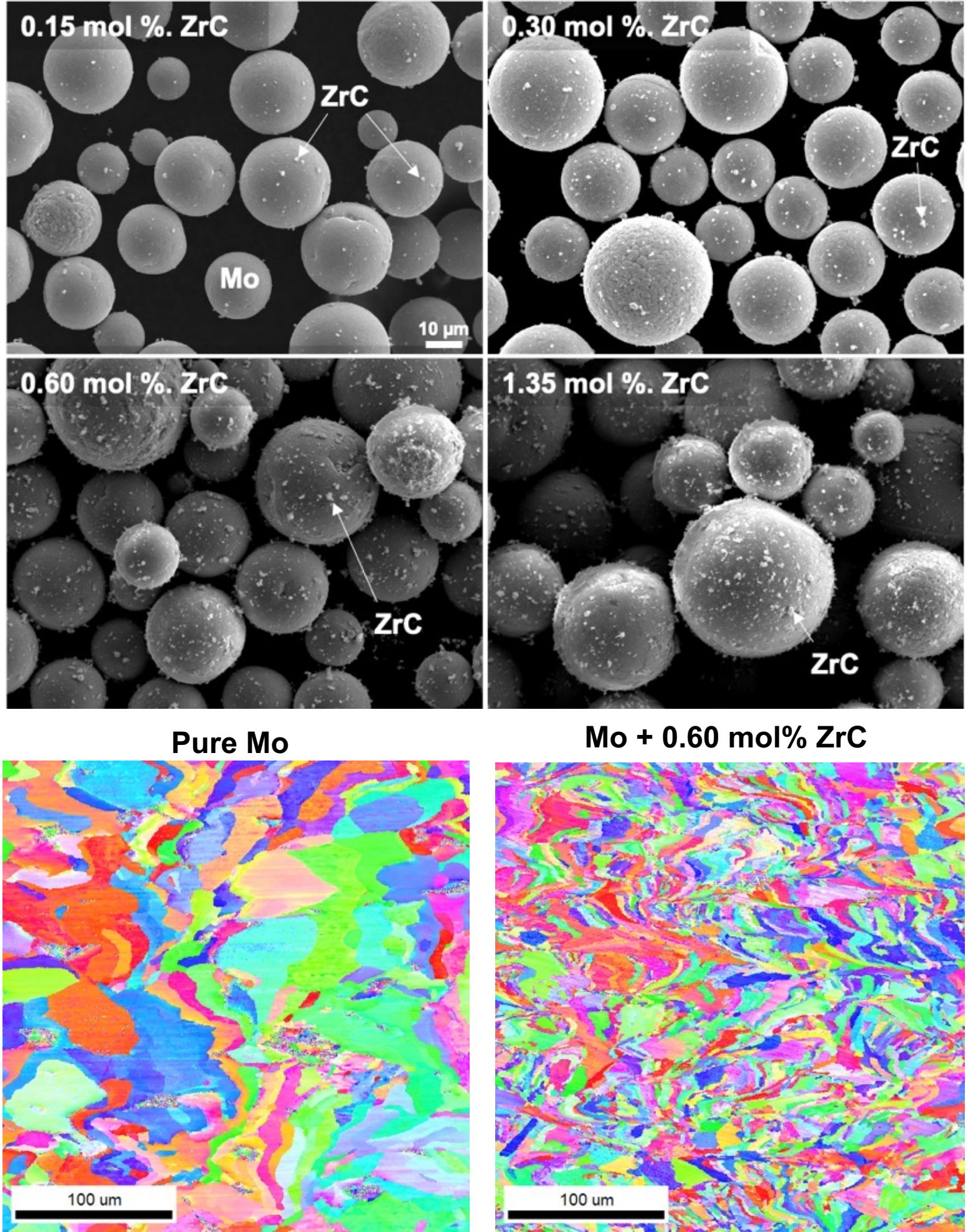
Alloys designed for traditional manufacture:

- Powder metallurgy (CIP, HIP, others), Forging, Wire and/or plunge EDM.
- W (\$100/kg) or Mo (\$80/kg) alloyed with 25-47.5 wt% Re (\$2.8k/kg) to improve ductility.

Feedstock vendors limited:

- Angular/unalloyed powder does not meet AM specs.
- Gas atomization methods limited by high T_m .

Current efforts focused on feedstock dispersion enhancements to improve refractory metal printing using Laser-Powder Bed Fusion.



Laser Additive Technique Tailored for Iridium Catalyst Engineering

Problem:

- Traditional manufacturing of green propulsion catalyst is time-consuming, and expensive.
- Current, ceramic/carbon-based Ir coated catalyst exhibit anisotropic properties leading to low performance and inferior mechanical properties with limited reproducibility.

Objective:

- Advance Platinum Group Metal (PGM)-based AM TRL by developing processes to create PGM AM optimized isotropic catalyst for integration in refractory AM green propulsion chambers to test under prototypic environments.

State of the Art:

- Carbon/ceramic Ir/PGM coated foams serve as catalyst but exhibit anisotropic properties, are expensive and have long lead time with only a few vendors. No capabilities to produce AM optimized catalyst made from an Ir-based metal are currently available for use.

Preliminary results

