INTELLIGENCE BRIEF

Refractory High-Entropy Alloys for Extreme Applications

AI-synthesized material intelligence for hypersonic, turbine, fusion, and space hardware programs.

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Platform Grok-3 + RAG · 143 sources · 2,195 indexed chunks

Studio Argead Venture · Vancouver, BC

Classification CONFIDENTIAL — Authorized Recipients Only

01 EXECUTIVE SUMMARY

Key Findings

Argead Venture's AI research platform synthesized 143 peer-reviewed sources — spanning arXiv preprints, NASA technical reports, and Semantic Scholar publications — to identify the highest-performance refractory high-entropy alloys (RHEAs) for temperatures exceeding 1,200°C. The analysis reveals a clear hierarchy of Mo-containing BCC systems that outperform conventional Ni-superalloys by 2–4× at extreme temperatures.

Mo-containing BCC RHEAs are the strongest candidates for hypersonic, turbine, and space hardware.

· HfNbMoTaTiZr retains 556 MPa yield strength at 1,200°C — and 814 MPa at 1,000°C.

· MoNbTaTiW and MoNbTaTiVW achieve 620–753 MPa yield at 1,000°C with a characteristic plateau to 1,400K.

· ZrHfNbTaW via high-pressure torsion yields single-phase nanograined BCC at 860 Hv hardness.

· VEC < 4.4 drives intrinsic ductility; group-IV additions (Hf, Zr, Ti) enhance W/Mo-base systems.

· Amorphous WTaCrVHf coatings (magnetron-sputtered) show thermal stability for fusion/radiation environments.

SOURCES

⍰ Developing a single-phase and nanograined refractory HEA · arXiv:2412.19006 · 2024

⍰ Microstructure and elevated-temperature mechanical properties · arXiv:1801.00263 · 2017

⍰ Mechanisms of high temperature strength of refractory HEAs · arXiv:2510.04589 · 2025

⍰ High-Performance Materials For Extreme Temperature Applications · Semantic Scholar · 2024

02 CANDIDATE ALLOYS

Ranked Refractory HEA Compositions

#	Composition	Max Temp	Yield Strength	Primary Application	Priority
1	HfNbMoTaTiZr	1,200°C	556 MPa	Hypersonic leading edges	HIGH
2	MoNbTaTiVW	1,100°C	753 MPa	Turbine blades, jet engines	HIGH
3	MoNbTaTiW	1,100°C	620 MPa	Gas turbine components	HIGH
4	ZrHfNbTaW	1,400°C+	860 Hv	Space hardware, nuclear	HIGH
5	HfMoTaTiZr	1,200°C	404 MPa	Re-entry thermal protection	MED
6	HfNbTaTiZr	1,200°C	92 MPa	Structural (ductile)	MED
7	WTaCrVHf	1,300°C+	N/A	Fusion reactor walls	MED
8	TaNbHfZrTi	1,000°C+	~400 MPa	Space structural	LOW

All yield strength values sourced from peer-reviewed experimental data. Processing routes: powder metallurgy (PM), high-pressure torsion (HPT), arc melting + suction casting, and additive manufacturing (AM).

03 MISSION 02 — ORBITAL

Autonomous Orbital Debris Removal

With over 27,000 tracked objects and millions of untracked fragments, orbital debris represents an escalating national security and commercial infrastructure risk. NASA analyses require 5+ large-object removals per year for 200-year LEO stability. Argead's autonomous AI coordinates satellite swarms using reinforcement learning on real-time astrodynamics data.

Method	Approach	Autonomy	TRL
Ion Beam Shepherd	Collimated ion beam — no docking required	HIGH	5
RL Multi-Target	Masked PPO agent, dynamic TSP/MDP	HIGH	4
Net/Harpoon Capture	RemoveDebris / ELSA-d demonstrated	MED	6
Laser Ablation	Best for fragments < 20cm	MED	4

SOURCES

- Engineering Challenges for Active Debris Removal · NASA NTRS:20110005437
- Optimizing Mission Planning for Multi-Debris Rendezvous Using RL · arXiv:2602.05075 · 2026
- Ion Beam Shepherd for Contactless Space Debris Removal · arXiv:1102.1289 · 2011
- Dynamics of Space Debris Removal: A Review · arXiv:2304.05709 · 2023

04 COMPETITIVE POSITION

Why Argead Venture

No existing company has combined generative AI for refractory HEA discovery with autonomous orbital debris removal under a single deep-tech studio. The dual-mission thesis is not a coincidence — the customers who need survivable materials in space are the same customers who need clean orbits to operate in.

Company	HEA AI	Orbital AI	Dual Mission	Space-Grade
Argead Venture	⍰	⍰	⍰	⍰
Citrine Informatics	⍰	—	—	—
Astroscale	—	⍰	—	⍰
ClearSpace (ESA)	—	⍰	—	⍰
Kebotix	⍰	—	—	—

TARGET CUSTOMERS

NASA · Pentagon / DARPA / AFRL / ONR · SpaceX · Blue Origin · Amazon Project Kuiper · Rolls-Royce · GE Aviation · Commonwealth Fusion Systems · Northrop Grumman

"Quietly forging the empire."

One alloy. One orbit. At a time.

ARGEAD VENTURES