


ASTR 4800 - Space Science: Practice & Policy

Today: Guest lecture by Elliot Carol, CEO of start-up company *Lunar Resources*.

- **Next Class:** Guest lecture by AJ Germer, start-up Colorado company *Lunar Outpost*.
- Reading: *Lunar Outpost* website linked to class webpage for Nov. 11.
- Exam 2 Nov. 16.



Astronomy 4800 - Space Science: Practice & Policy

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LUNAR

RESOURCES

LEADING AMERICAN SPACE INDUSTRIALIZATION

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WHAT WE DO

Lunar Resources is a **SPACE INDUSTRIAL COMPANY** funded by the **US GOVERNMENT** and partnered with **LEADING SPACE COMMERCIAL COMPANIES** to develop **SCALABLE TECHNOLOGIES** to **INDUSTRIALIZE SPACE**.

CURRENT GOVERNMENT PARTNERS INCLUDE:

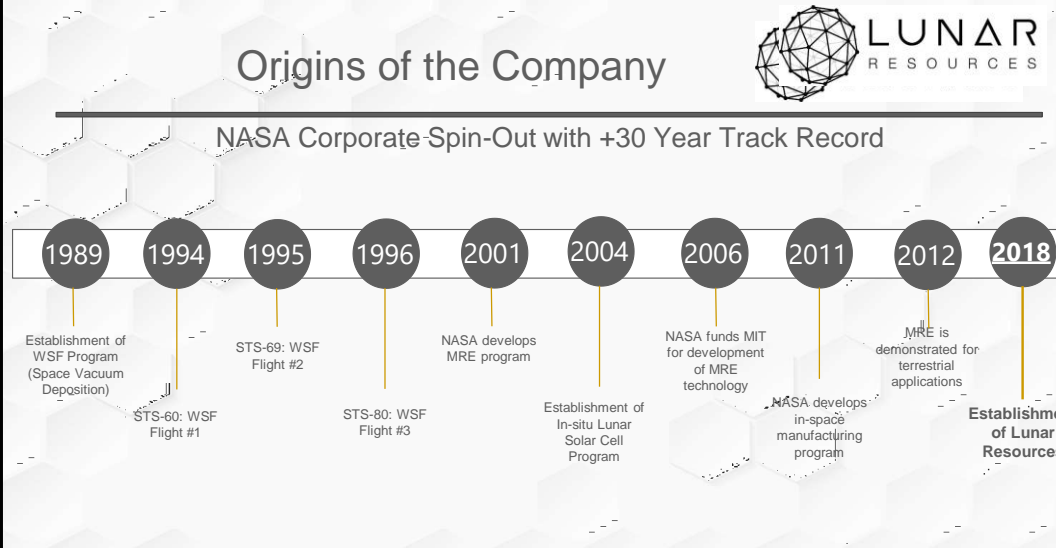


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Origins of the Company

NASA Corporate Spin-Out with +30 Year Track Record



1989: Establishment of WSF Program (Space Vacuum Deposition)

1994: STS-60: WSF Flight #1

1995: STS-69: WSF Flight #2

1996: STS-80: WSF Flight #3

2001: NASA develops MRE program

2004: Establishment of In-situ Lunar Solar Cell Program

2006: NASA funds MIT for development of MRE technology

2011: NASA develops in-space manufacturing program

2012: MRE is demonstrated for terrestrial applications

2018: Establishment of Lunar Resources

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Corporate Leadership




- Elliot Carol, CEO
- Dr. Alex Ignatiev, CTO, Principal Technologist
- Dr. Peter Curreri, CSO, Principal Scientist
- Dr. Donald Sadoway, Director of Resource Extraction and Metallurgy
- Ben Tobor, General Counsel

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THE SOLUTION

LUNAR RESOURCES GOAL:

CONVERT LUNAR SOIL INTO FINISHED PRODUCTS



1. Refine lunar soil with **Molten Regolith Electrolysis**. Convert lunar soil to refined, purified raw commodities for in-situ manufacturing.
2. Build structures with **Additive Manufacturing**. Convert raw commodities to structures with precision micro-gravity additive manufacturing.
3. Fabricate finished products with **Thin-Film Space Deposition**. Manufacturing with atomic-layer precision to create advanced thin film materials and functional products.

THESE MATERIALS CAN BE SOLD SEPARATELY OR COMBINED TO CREATE HIGH-TECH PRODUCTS

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LUNAR RESOURCES CAPABILITIES

Supplier of raw, basic and finished materials in the space environment.

- 1 RAW MATERIALS** – O, Fe, Si, Al, Mg, metal oxide slag.
- 2 BASIC MATERIALS** – Functional coatings, additive manufacturing feedstock, deposition feedstock, glass, structural elements, casted metallic products, other functional materials.
- 3 FINISHED MATERIALS** – Solar cells, electrical transmission wires, antennas, other functional structures, other thin film materials

DEFINITION OF SPACE INDUSTRIALIZATION

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LUNAR RESOURCES PROGRAMS

Technology R&D Programs

- 1 Molten Regolith Electrolysis** – Extraction, refinement and purification of oxygen and metals from lunar soil.
- 2 PE3D** – Additive manufacturing of high temperature metals and metal oxides in the 1G, low-gravity, and microgravity environments.
- 3 Space Deposition** – Vacuum deposition of functional coatings and thin film materials in the vacuum of space (and Moon).

Mission Programs

- 1 Satellite Servicing** – On-orbit repair of satellites external coatings and thin film materials on -orbit
- 2 On-Orbit Joining and Manufacturing** – In-space manufacturing and joining of metal structures
- 3 MW Program** – Lunar in-situ fabrication of MW scale photovoltaic power grids on the Moon.
- 4 FarView** – Lunar far side low frequency RF observatory built in-situ from lunar materials.

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LUNAR RESOURCES RAW MATERIALS OFFERING

EXTRACTED FROM LUNAR RESOURCES MOLTEN REGOLITH ELECTROLYSIS TECHNOLOGIES

1 OXYGEN: 99.5% PURITY	6 FERROSILICON
2 IRON: 99% PURITY	7 CERAMIC METALLIC OXIDE
3 SILICON: 99.99% PURITY	8 METALLIC OXIDE SLAG
4 ALUMINUM: 99% PURITY	9 METAL ALLOYS
5 MAGNESIUM: 99% PURITY	

FINAL FORM FACTORS
(dependent on materials)

COMPRESSED GAS (OXYGEN)

↓

INGOTS

↓

WIRE

↓

POWDER

↓

CASTED STRUCTURAL ELEMENTS

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LUNAR RESOURCES MOLTEN REGOLITH ELECTROLYSIS IMPLEMENTATION AND COMMERCIALIZATION TIMELINE

MISSION	YEAR	REGOLITH EXTRACTION
DEMO	2024	1MT
PILOT PLANT	2026 – 2027	50MT
COMMERCIAL MINING OPERATIONS	2028+	>1000MT

LUNAR RESOURCES IS FUNDED BY US GOVERNMENT FOR DEVELOPMENT OF ITS FLIGHT QUALIFIED DEMO REACTOR

TECH // MOLTEN REGOLITH ELECTROLYSIS

LARGE SCALE EXTRACTION OF METALS FROM LUNAR REGOLITH

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Lunar Resources MRE Program.

Lunar Resources MRE-01x large-scale reactor to be tested in Summer, 2022.

TECH // MOLTEN REGOLITH ELECTROLYSIS

MRE Program Timeline:

MRE Extractor System Development	Status
MRE Extractor Cell Testing	Completed
MRE-01x Extractor Reactor Fabrication	Completed
MRE-01x Extractor Reactor Ambient Air Test	Completed
MRE-02x Extractor Reactor Fabrication	August, 2022 – December 2022
MRE-02x Extractor Reactor Vacuum Testing (JSC)	February, 2023
MRE-03x (KSC) Extractor Reactor Fabrication	December, 2022 – April, 2023
MRE-03x (KSC) Extractor Reactor Testing (KSC)	May, 2023
MRE-04x Extractor Reactor Fabrication and Testing (Lunar Surface Flight Hardware)	April, 2023 – October, 2023
MRE-04x Lunar Surface Demonstration Mission	2024

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TURNING IN-SITU RESOURCES INTO PRODUCTS

- 1 Space Deposition System** – Thin film materials
- 2 PE3D** – Additively manufactured products
- 3 Casting** – Casted feedstock and structural elements

TECH


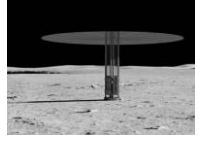
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SPACE INDUSTRY COMPARISON

BENEFITS:

1. People
2. Meaningful Work
3. Huge Growth Opportunities

Drawbacks:

1. Small Commercial Market
2. Lower Compensation
3. Government Reliance

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STARTUP/SME VS. LARGE PRIMESNASA

1. Make immediate impact on mission and tech dev.
2. Gain experience faster ... but not necessarily better
3. Tend to deal with real tech dev vs. mission assembly and operations
3. Culture

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Starting a Space Company



1. **Huge opportunities for tech dev**
 - Primes and USG are reliant on startups to develop the technology
2. **Government funding available to bootstrap company**
3. **Some VC/PE company to grow company**
4. **Space hardware is a long-term game.**

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THANK YOU

INQUIRIES

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