Extraterrestrial Metals Processing, Phase I Project

SBIR/STTR Programs | Space Technology Mission Directorate (STMD)

ABSTRACT

The Extraterrestrial Metals Processing (EMP) system produces ferrosilicon, silicon monoxide, a glassy mixed oxide slag, and smaller amounts of alkali earth compounds, phosphorus, sulfur, and halogens from Mars, Moon, and asteroid regolith by carbothermal reduction. These materials, in some cases after further processing with other in-situ resources, are used for production of high-purity iron and magnesium metals (for structural applications), high purity silicon (for photovoltaics and semiconductors), high purity silica (for clear glass), refractory ceramics (for insulation, thermal processing consumables, and construction materials), and fertilizer (from phosphorus recovered from carbothermal reduction exhaust gases). Carbothermal reduction also co-produces oxygen at yields on the order of 20 percent of regolith feed mass when integrating downstream processes to recover and recycle carbon. Many of the EMP products can be prepared in a fashion suitable for casting or additive manufacture methods and have broad application in support of advanced human space exploration. The EMP methods are based on minimal reliance on Earth-based consumables; nearly all of the gases and reagents required for processing can be manufactured from Mars in-situ resources or can be recovered and recycled for applications using Moon or asteroid resources.

ANTICIPATED BENEFITS

To NASA funded missions:

Potential NASA Commercial Applications: The primary application of EMP is for production of iron, silicon, and magnesium metals as well as refractory metal oxides and byproducts including phosphors and oxygen from Mars, Moon, or asteroid in-situ resources for manufacturing in support of advanced human space exploration. The EMP product suite includes many useful materials that will expand exploration and colonization capabilities while substantially reducing the costs

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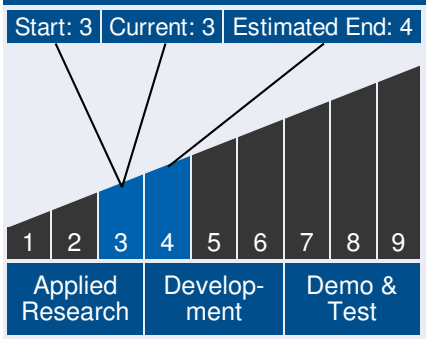
Technology Maturity



Management Team

Program Executives:

- Joseph Grant
- Laguduva Kubendran

Program Manager:

- Carlos Torrez

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and risks of bringing supplies from Earth. Many EMP product streams are suitable for use in advanced casting or additive manufacturing methods to allow for efficient use of resources.

To the commercial space industry:

Potential Non-NASA Commercial Applications: One potential terrestrial EMP application is the production of high-grade silicon metal or ferrosilicon. The hydrogen-enhanced carbon monoxide disproportionation method employed in the EMP system enables high rates of carbon deposition onto pure silica in the absence of a metal catalyst. Direct carbon deposition from CO generated during carbothermal reduction integrated with RWGS-electrolysis modules would reduce the purchase of carbon for the process while significantly reducing overall carbon emissions compared to current practice. In a closed-loop system including reverse water gas shift-electrolysis, silicon or ferrosilicon manufacturing could be accomplished with virtually no carbon emissions. The EMP techniques have additional potential for the processing of lower-grade ores and feed stocks including residues and wastes. As higher-grade ores on Earth are more-difficult to find and mine, feed costs for existing technologies rise. The EMP can help to reduce overall processing costs by enabling the use of non-conventional feed stocks.

Management Team *(cont.)*

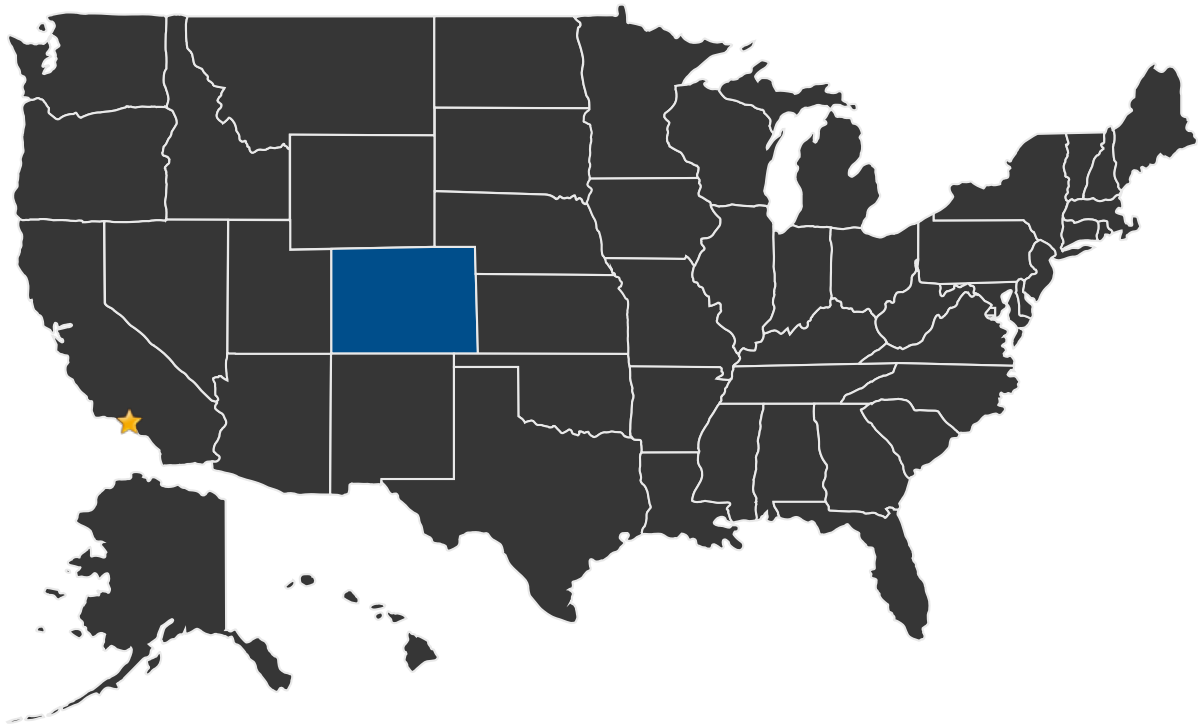
Principal Investigator:

- Mark Berggren

Technology Areas

Primary Technology Area:
Human Exploration Destination Systems (TA 7)
└ In-Situ Resource Utilization (TA 7.1)
  └ Manufacturing Products and Infrastructure Emplacement (TA 7.1.4)

U.S. WORK LOCATIONS AND KEY PARTNERS



U.S. States With Work

Lead Center:
Jet Propulsion Laboratory

Other Organizations Performing Work:

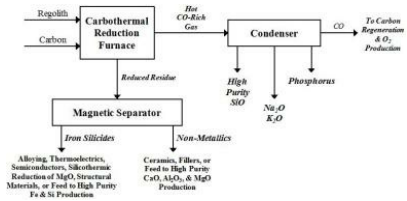
- Pioneer Astronautics (Lakewood, CO)

PROJECT LIBRARY

Presentations

- Briefing Chart
  - (http://techport.nasa.gov:80/file/23620)

IMAGE GALLERY



Extraterrestrial Metals Processing, Phase I

DETAILS FOR TECHNOLOGY 1

Technology Title

Extraterrestrial Metals Processing, Phase I

Potential Applications

The primary application of EMP is for production of iron, silicon, and magnesium metals as well as refractory metal oxides and byproducts including phosphors and oxygen from Mars, Moon, or asteroid in-situ resources for manufacturing in support of advanced human space exploration. The EMP product suite includes many useful materials that will expand exploration and colonization capabilities while substantially reducing the costs and risks of bringing supplies from Earth. Many EMP product streams are suitable for use in advanced casting or additive manufacturing methods to allow for efficient use of resources.