

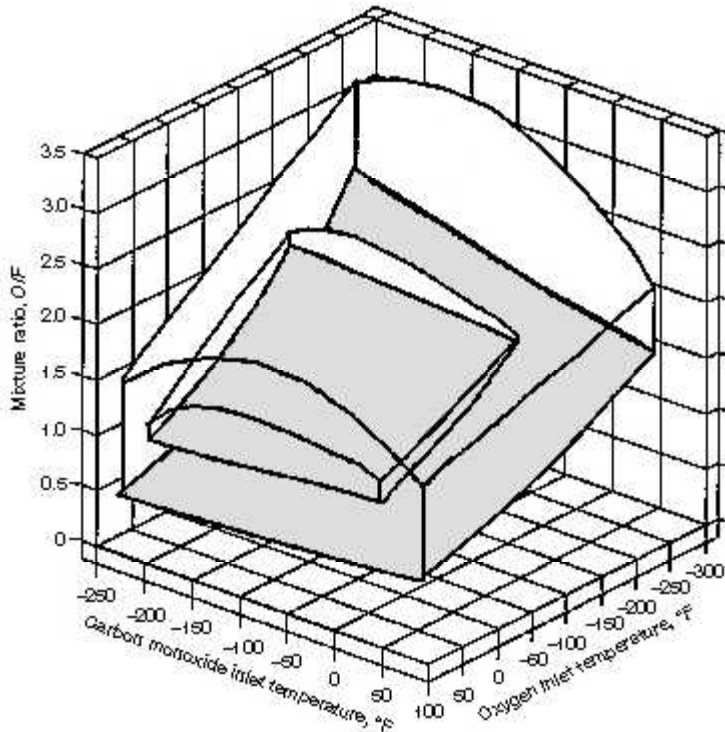
# Demonstration of Oxygen and Carbon Monoxide Propellants for Mars Missions

Currently, proposed planetary exploration missions must be small, with low costs and a short development time. Relatively high-risk technologies are being accepted for such missions if they meet these guidelines. For a Mars sample-return mission, one of the higher-risk technologies is the use of return propellants produced from indigenous materials such as the Martian atmosphere. This consists of 96 percent carbon dioxide, which can be processed into oxygen and carbon monoxide.

This year, the NASA Lewis Research Center completed the experimental evaluation and subscale technology development of an oxygen/carbon monoxide propellant combination. Previous research included ignition characterization, combustion performance, and heat transfer characterization with gaseous propellants at room temperature. In this year's tests, we studied the ignition characteristics and combustion of oxygen and carbon monoxide at near liquid temperatures.

The mixture ratio boundaries for oxygen and carbon monoxide were determined as a function of propellant temperature in a spark torch igniter. With both propellants at room temperature, the ignition range was between 0.50 and 1.44; and with both propellants chilled to near-liquid temperatures, it was between 2.4 and 3.1. Statistical analysis of the mean value of the ignition boundaries provided models that describe the combination of oxygen temperature, carbon monoxide temperature, and mixture ratio that resulted in ignition. This range is the larger boxed area shown in the figure. The smaller boxed area indicates the range at which there is a 90-percent confidence that ignition will occur. The relatively small range at only 90-percent confidence indicates that using the oxygen/carbon monoxide combination as its own ignition source may not be the best design for a remote engine operating on Mars.

Tests also were performed in a simulated small rocket engine that used oxygen/hydrogen combustion gases as the ignition source for oxygen/carbon monoxide. In these experiments, the oxygen/carbon monoxide was successfully ignited in eight of eight tests at a mixture ratio of 0.52. In addition, the oxygen/carbon monoxide maintained steady combustion after the oxygen/hydrogen ignition source was removed, verifying that the oxygen/carbon monoxide rocket engine should continue to be included in mission plans as return propulsion from Mars.



*Analytical model of the experimental ignition range of carbon monoxide/oxygen and a 90-percent confidence range.*

Using all of the previous experimental results, we designed a 500-lbf (Mars sea-level thrust) engine. This engine is the appropriate size for a Mars sample-return mission. Under a phase II Small Business Innovation Research (SBIR) contract with Ultramet, Inc., the engine is being fabricated from a unique combination of lightweight ceramics for structure and high-temperature refractory metals for combustion-side protection. It will eventually be tested with liquid oxygen and liquid carbon monoxide propellants at NASA Lewis.

## **Bibliography**

Linne, D.L., Experimental Evaluation of the Ignition Process of Carbon Monoxide and Oxygen in a Rocket Engine. AIAA 96-2943 (NASA TM-107267), 1996.

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