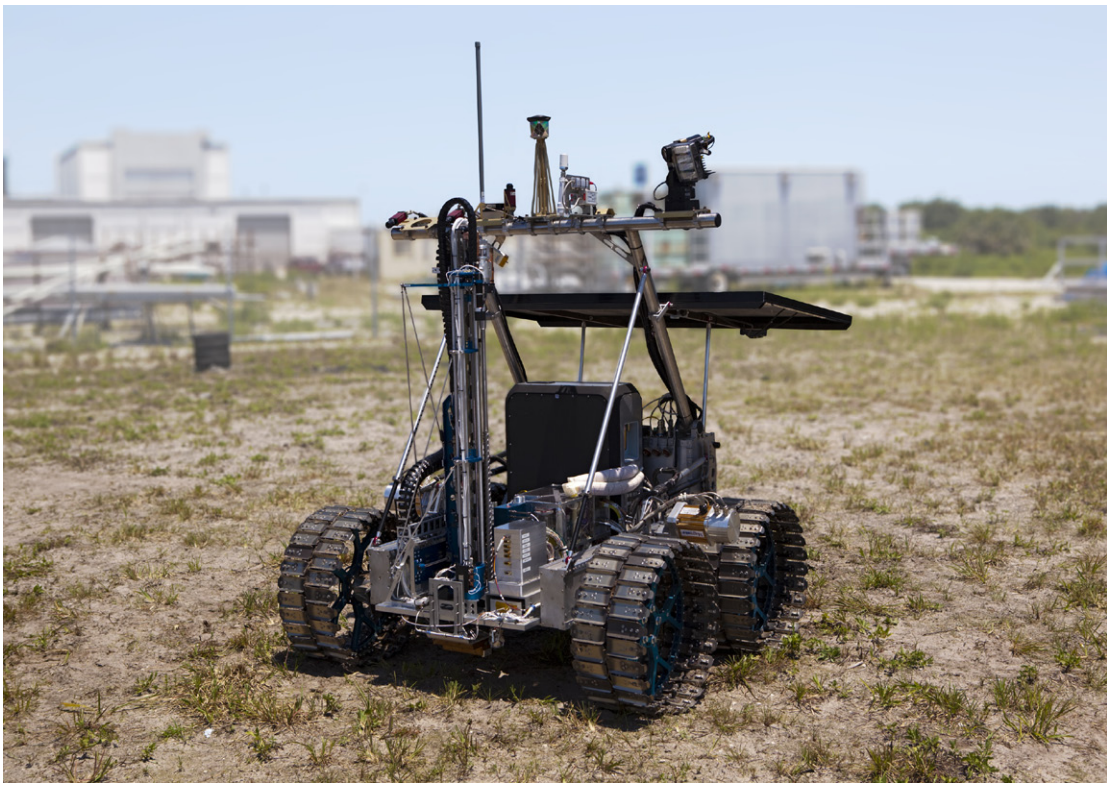
In-Situ Resource Utilization Mission

NASA**facts**



The RESOLVE experiment package includes multiple science instruments and is pictured here sitting atop the Artemis Jr. Rover.
Photo credit: NASA/Dmitri Gerondidakis.

Background

NASA is actively planning to expand the horizons of human space exploration, and with the Space Launch System and the Orion Multi-Purpose Crew Vehicle, humans will soon have the ability travel beyond low Earth orbit. This will open up a solar system of possibilities and will allow NASA to send humans to explore near-Earth asteroids, the moon, and Mars and its moons. But, to reach these deep-space destinations, the work must start now.

NASA is developing the technologies and systems to transport explorers to multiple destinations, each with the potential to provide resources such as oxygen, fuel, water and building materials that are necessary for sustained human space exploration. The practice of harnessing local resources is called in-situ-resource utilization (ISRU), and it becomes increasingly important with long-duration missions because cargo resupply efforts are expensive and exclusively relying on them may put crews at risk.

NASA conducts mission simulations, known as analog missions, at extreme and often remote locations on Earth to prepare for robotic and human missions to extraterrestrial destinations. Analogs allow NASA astronauts, engineers and scientists to work with representatives from other government agencies, academia and industry to gather requirements, test operational concepts and develop the technologies necessary to ensure an efficient, effective and sustainable future for human space exploration.

ISRU Analog Missions

The In-Situ Resource Utilization (ISRU) analog mission is a collaboration of NASA partners, primarily the Canadian Space Agency (CSA) with help from the Pacific International Space Center for Exploration Systems (PISCES). Together, they perform demonstrations of ISRU technologies. This year, the analog mission is focusing on prospecting for lunar ice. In the future, water and oxygen extracted from lunar soil could be used for life support, and methane produced from the

Martian atmosphere could be used to refuel spacecraft for the trip back to Earth.

ISRU is a necessary element in NASA's plans for exploration and will eventually help explorers to live on extraterrestrial surfaces. Each pound of propellant, air, food, water and shelter that is launched into space requires a significant amount of fuel and thrust, limiting the potential duration and scope of a mission. Learning to extract resources from space destinations will reduce the cost of future missions and expand their potential.

2012 ISRU Demonstrations

Demonstrations will be conducted on the Big Island of Hawaii. The terrain and soil at these sites are similar to that of the moon, and the volcanic ash deposits, called tephra, have a mineral composition and range of particle sizes similar to that of lunar regolith. Regolith is a layer of loose material made up of dust, soil and broken rocks that cover areas of solid rock. It is present on Earth, the moon, some asteroids and other terrestrial planets and moons. The Big Island also provides diverse terrain and rock distribution within just a few miles, creating the same sort of mobility challenges that rovers on the moon would face. NASA has conducted ISRU demonstrations in this area before – in 2008 and 2010, and in geology training for astronauts during the Apollo Program.

The two main tests for the 2012 ISRU mission will be the Regolith and Environment Science and Oxygen and Lunar Volatile Extraction (RESOLVE) and the Moon Mars Analog Mission Activities (MMAMA). Scientists and researchers from NASA's Johnson Space Center in Houston; Kennedy Space Center in Florida; Ames Research Center at Moffett Field, Calif.; Goddard Space Flight Center in Greenbelt, Md.; the CSA; the Smithsonian Institute; and University of Mainz in Germany will conduct the tests over 10 days. Mission control centers will be located at Johnson, Kennedy, and CSA headquarters in Montreal, Canada. A science team at Ames Research Center will provide backup support to the scientists in Hawaii through its remote science backroom.

RESOLVE

RESOLVE is an experiment package designed to find, characterize and map the presence of ice and other volatiles in almost permanently shadowed areas at the lunar poles. Volatiles are a group of chemical elements and compounds with low boiling points that are associated with a planet's or moon's crust or atmosphere. In their solid state, they often make up large proportions of the crusts of moons and dwarf planets, and it is believed that the volatiles are contained in the regolith on the moon, some asteroids and other planets and moons. Regolith and volatiles could contain resources necessary for space exploration, and being able to obtain them at the destination would save valuable cargo room for explorers.

To demonstrate this concept, RESOLVE will perform small-scale oxygen extraction from a layer of regolith found on the volcanic deposits of Hawaii's Big Island, just as it could with regolith found on the moon.

RESOLVE includes multiple science instruments:

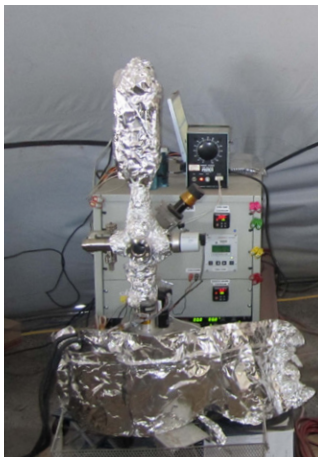
- A neutron spectrometer and near-infrared spectrometer (NIR) to help locate volatiles and identify the minerals in the regolith, such as hydrogen and water vapor.
- A one-meter drill system to enable it to take samples from below the lunar surface for evaluation. These samples will be divided into smaller pieces for multiple tests.
- An oven used to bake the samples, separating the elements of interest from the soil itself.
- A volatile characterization mass spectrometer/gas chromatograph to identify the type and amount of volatiles present.

The RESOLVE experiment will sit atop the Artemis Jr. rover provided by the CSA. This will give RESOLVE the mobility needed to map a large region where there is potential for volatiles.

MMAMA

MMAMA is a group of small projects and tests that will help NASA understand how to perform new exploration techniques on the surface of the moon or Mars. These projects define the requirements for navigation, mobility, communications, sample processing and curating and other critical mission elements that could be used in future exploration missions. The MMAMA suite of tests includes:

- **VAPoR**: The Volatile Analysis by Pryolysis of Regolith (VAPoR) test will analyze samples with a mass spectrometer to help understand mineral and chemical composition. Samples are prepared before analysis using the Mechanized Sample Processing and Handling System **(MeSH)** instrument.
- **Robotic Resource Mapping**: To demonstrate methods of mapping resources found on and below the surface of the terrain, CSA's prototype exploration rover, Juno, will be outfitted with ground-penetrating radar and a magnetometer. These tools will compare the mapping capabilities of robotic systems like those on Juno to human surveying.
- **MIMOS II/IIA**: A Miniaturized Mossbauer Spectrometer (MIMOS II) and a combined Miniaturized Mossbauer and X-Ray Fluorescence Spectrometer (MIMOS IIA) will be used with the Juno rover to find resources that could be present in the regolith or below the surface. These sensor systems will be able to identify the makeup of rock and debris samples to determine if certain resources are present.
- **Testing Operations:** A team of engineers and researchers will monitor all of these tests with the goal of developing testing scenarios to assess the capabilities of each piece of equipment. A miniature mission control will be set up in Hawaii to support the MMAMA test operations.



VAPoR is a miniature version of a sample analysis instrument flying on the Mars Science Laboratory. Photo credit: NASA/Danny Glavin.

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