for flight testing, perhaps on NASA's SOFIA platform.

This work was done by Benjamin D. Buckner and Vladimir Markov of MetroLaser, Inc. and James C. Earthman of the University of California for Dryden Flight Research Center.

Title to this invention, covered by U.S. Patent No. 7,221,445, has been waived under the provisions of the National Aeronautics and Space Act {42 U.S.C. 2457 (f)}. Inquiries concerning licenses for its commercial development should be addressed to MetroLaser Inc. 8 Chrysler, Irvine CA 92618 Refer to DRC-007-065, volume and number of this NASA Tech Briefs *issue, and the page number. Refer to DRC-007-065.*

Fuel-Cell Power Source Based on Onboard Rocket Propellants

This high-energy density power source is an alternative to radioisotopes or primary batteries.

NASA's Jet Propulsion Laboratory, Pasadena, California

The use of onboard rocket propellants (dense liquids at room temperature) in place of conventional cryogenic fuel-cell reactants (hydrogen and oxygen) eliminates the mass penalties associated with cryocooling and boil-off. The high energy content and density of the rocket propellants will also require no additional chemical processing.

For a 30-day mission on the Moon that requires a continuous 100 watts of power, the reactant mass and volume would be reduced by 15 and 50 percent, respectively, even without accounting for boil-off losses. The savings increase further with increasing transit times. A high-temperature, solid oxide, electrolyte-based fuel-cell configuration, that can rapidly combine rocket propellants — both monopropellant system with hydrazine and bi-propellant systems such as monomethyl hydrazine/ unsymmetrical dimethyl hydrazine (MMH/UDMH) and nitrogen tetroxide (NTO) to produce electrical energy — overcomes the severe drawbacks of earlier attempts in 1963–1967 of using fuel reforming and aqueous media. The electrical energy available from such a fuel cell operating at 60-percent efficiency is estimated to be 1,500 Wh/kg of reactants. The proposed use of zirconia-based oxide electrolyte at 800–1,000 °C will permit continuous operation, very high power densities, and substantially increased efficiency of conversion over any of the earlier attempts. The solid oxide fuel cell is also tolerant to a wide range of environmental temperatures. Such a system is built for easy refueling for exploration missions and for the ability to turn on after several years of transit. Specific examples of future missions are *in-situ* landers on Europa and Titan that will face extreme radiation and temperature environments, flyby missions to Saturn, and landed missions on the Moon with 14 day/night cycles.

This work was done by Gani Ganapathi and Sri Narayan of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-44977

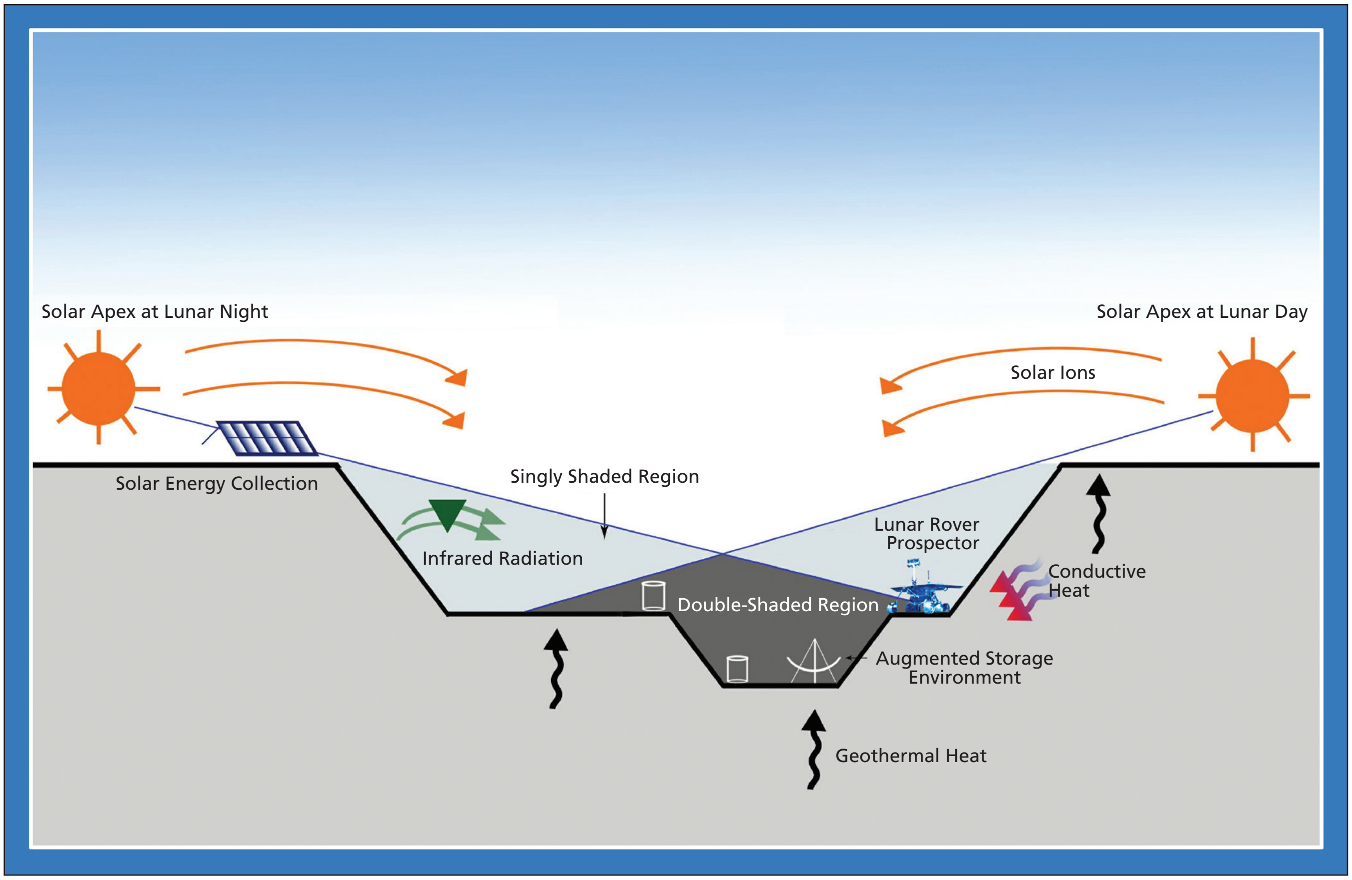
Polar Lunar Regions: Exploiting Natural and Augmented Thermal Environments

High vacuum cryogenic environments can be augmented with lightweight thermal shielding.

Stennis Space Center, Mississippi

In the polar regions of the Moon, some areas within craters are permanently shadowed from solar illumination and can drop to temperatures of 100 K or lower. These sites may serve as cold traps, capturing ice and other volatile compounds, possibly for eons. Interestingly, ice stored in these locations could potentially alter how lunar exploration is conducted. Within craters inside craters (double-shaded craters) that are shaded from thermal re-radiation and from solar illuminated regions, even colder regions should exist and, in many cases, temperatures in these regions never exceed 50 K. Working in these harsh environments with existing conventional systems, exploration or mining activities could be quite daunting and challenging. However, if the unique characteristics of these environments were exploited, the power, weight, and total mass that is required to be carried from the Earth to the Moon for lunar exploration and research would be substantially reduced.

In theory, by minimizing the heat transfer between an object and the lunar surface, temperatures near absolute zero can be produced. In a single or double-shaded crater, if the object was isolated from the variety of thermal sources and was allowed to radiatively cool to space, the achievable temperature would be limited by the 3 K cosmic background and the anomalous solar wind that can strike the object being cooled. Our analysis shows that under many circumstances, with some simple thermal radiation shielding, it is possible to establish environments with temperatures of several degrees Kelvin. Electrostatic or other approaches for shielding from the solar wind and other high energy particles would enable the object to come into close thermal equilibrium with thermal cosmic background radiation. To minimize the heat transfer (conduction and radiation) between the ground and an object on the Moon (where the gravity is relatively small), a simple method to isolate even a relatively large object would be to use a low thermal insulating suspension structure that would hold both the thermal shield and the object above the thermal shield. The figure depicts a lunar polar region revealing a permanently shaded crater and a double-shaded crater. Within the double-shaded crater, a suspended thermal shield reflecting 50 K gray body radiation back towards the lunar



A **Single- and a Double-Shaded Crater** are shown on the lunar surface. Inside a double-shaded region within a single shaded crater, a thermal radiation shield reduces the heat transfer from the surface.

surface, is shown. Extremely low heat conduction between the object and the lunar surface could also be produced by using superconducting magnetic levitation, such as the Meissner Effect, to support the thermal shield and object. The thermal radiation shield should be shaped so that it blocks the lunar surface thermal radiation from all directions.

Advanced thermal management architecture based upon the augmentation of thermal conditions in these craters would be able to support a wide variety of cryogenically based applications. Lunar exploration and habitation capabilities would significantly benefit if permanently shaded craters, augmented with thermal shielding, were used to permit the operation of near-absolute-zero instruments, including an array of cryogenically based propulsion, energy, communication, sensing, and computing devices. For example, many gases used for life support or propulsion systems could be stored as solids, eliminating or minimizing the need for storage vessels. Storage of cryogens and other volatiles in solid form could substantially reduce the mass that would have to be launched from the Earth to the Moon. Additionally, the ability to condense gases could serve as a means to purify air for breathing and other purposes.

Other uses for ultra-low temperature lunar craters (enhanced with artificial thermal radiation shielding) include the storage of biological samples, energy storage, advanced sensors, and even high-energy lasers for power transmission purposes. Since superconductors can theoretically store currents for billions of years, superconducting toroids serving as Superconducting Magnetic Energy Storage Systems could limitlessly store electrical energy from solar panels or other sources. Superconducting magnets could support a variety of applications, such as superconducting flywheel energy storage, drills, rail guns, and motors for vehicles. When cooled, semiconductor lasers can approach 100 percent wall-plug efficiency and could be used for transmitting power from one location to another. This technology could be used to beam power or information to land rovers and other mobile exploratory vehicles. Superconducting computers operating near terahertz clock speeds could potentially enable the development of consolidated, compact, high-end lunar-based computing devices.

Finally, these thermally cooled environments could also support the use of advanced magnetometers and infrared detector sensors. Additional augmentation to thermal environments with a hybrid passive and active cooling system could facilitate the operation of these sensors and other devices at temperatures as low as a fraction of a degree Kelvin, thereby enabling, for example, superfluid helium frictionless bearing devices for advanced gyroscopes. These colder temperatures could be used for many other technologies, like Transition Edge Sensors, that are used for radiation and infrared detection. In summary, permanently shaded polar craters in either their natural or augmented state could potentially reduce the required burden of carrying massive life-support components, mining tools, and research instrumentation from the Earth to the Moon.

This work was done by David Brannon of Stennis Space Center and Robert E. Ryan, Lauren W. Underwood, and Kristen Russell of Science Systems and Applications, Inc.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Intellectual Property Manager at Stennis Space Center (228) 688-1929. Refer to SSC-00259-1.