gravity fields, at low partial pressure of oxygen, and makes use of *in situ* regolith for system insulation.

The innovation extracts oxygen from lunar regolith using a method similar to vacuum pyrolysis, but with hydrogen cover gas added stoichiometrically to react with the oxygen as it is produced by radiatively heating regolith to 2,500 K. The hydrogen flows over and through the heating element (HE), protecting it from released oxygen. The H_2–O_2 heat of reaction is regeneratively recovered to assist the heating process. Lunar regolith is loaded into a large-diameter, low-height "pancake" reactor powered by photovoltaic cells. The reactor lid contains a 2,500 K HE that radiates downward onto the regolith to heat it and extract oxygen, and is shielded above by a multi-layer tungsten radiation shield. Hydrogen cover gas percolates through the perforated tungsten shielding and HE, preventing oxidation of the shielding and HE, and reacting with the oxygen to form water vapor. The water vapor is filtered through solid regolith to remove unwanted extraction byproducts, and then condensed to a liquid state and stored at 300 to 325 K. Conversion to usable oxygen is achieved by pumping liquid water into a high-pressure electrolyzer, storing the gaseous oxygen at high pressure for use, and diverting the hydrogen back to the reactor or to storage.

The results from this design effort show that this oxygen-generating concept can be developed in an efficient system with low specific mass. Advantages include use of regolith as an oxygen source, filter, and thermal insulator. The system can be tested in Earth gravity and can be expected to operate similarly in lunar gravity. The system is scalable, either by increasing the power level and output of a standard module, or by employing multiple modules.

This work was done by Rodney Burton and Darren King of CU Aerospace LLC for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32933-1.

Uplift of Ionospheric Oxygen Ions During Extreme Magnetic Storms

NASA's Jet Propulsion Laboratory, Pasadena, California

Research reported earlier in literature was conducted relating to estimation of the ionospheric electrical field, which may have occurred during the September 1859 Carrington geomagnetic storm event, with regard to modern-day consequences.

In this research, the NRL SAMI2 ionospheric code has been modified and applied the estimated electric field to the dayside ionosphere. The modeling was done at 15-minute time increments to track the general ionospheric changes. Although it has been known that magnetospheric electric fields get down into the ionosphere, it has been only in the last ten years that scientists have discovered that intense magnetic storm electric fields do also. On the dayside, these dawn-to-dusk directed electric fields lift the plasma (electrons and ions) up to higher altitudes and latitudes. As plasma is removed from lower altitudes, solar UV creates new plasma, so the total plasma in the ionosphere is increased several-fold. Thus, this complex process creates super-dense plasmas at high altitudes (from 700 to 1,000 km and higher).

This work was done by Bruce T. Tsurutani, Anthony J. Mannucci, and Olga P. Verkhoglyadova of Caltech; Joseph Huba of Naval Research Laboratory; and Gurbax S. Lakhina of the Indian Institute of Geomagnetism for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-48762

Miniaturized, High-Speed, Modulated X-Ray Source

An extremely robust photon-driven electron source is used that can tolerate weeks or more of exposure to air.

Goddard Space Flight Center, Greenbelt, Maryland

A low-cost, miniature x-ray source has been developed that can be modulated in intensity from completely off to full intensity on nanosecond timescales. This modulated x-ray source (MXS) has no filaments and is extremely rugged. The energy level of the MXS is adjustable from 0 to more than 100 keV. It can be used as the core of many new devices, providing the first practical, arbitrarily time-variable source of x-rays. The high-speed switching capability and miniature size make possible many new technologies including x-ray-based communication, compact time-resolved x-ray diffraction, novel x-ray fluorescence instruments, and low- and precise-dose medical x-rays.

To make x-rays, the usual method is to accelerate electrons into a target material held at a high potential. When the electrons stop in the target, x-rays are produced with a spectrum that is a function of the target material and the energy to which the electrons are accelerated. Most commonly, the electrons come from a hot filament. In the MXS, the electrons start off as optically driven photoelectrons. The modulation of the x-rays is then tied to the modulation of the light that drives the photoelectron source. Much of the recent development has consisted of creating a photoelectrically-driven electron source that is robust, low in cost, and offers high intensity.

For robustness, metal photocathodes were adopted, including aluminum and magnesium. Ultraviolet light from 255- to 350-nm LEDs (light emitting diodes) stimulated the photoemissions from these photocathodes with an efficiency that is maximized at the low-wavelength end (255 nm) to a value of roughly 10^{-4}. The MXS units now have much higher brightness, are much smaller, and are made using a number of commercially available components, making them extremely inexpensive.

In the latest MXS design, UV efficiency is addressed by using a high-gain electron multiplier. The photocathode is vapor-deposited onto the input cone of a Burle Magnum™ multiplier. This system yields an extremely robust photon-driven electron source that can tolerate long — weeks or more — exposure to air with negligible degradation. The package is also small. When combined with the electron target, necessary vacuum fittings, and supporting components (but not including LED electronics or high-voltage sources), the entire modulated x-ray source weighs as little as 158 grams.

This work was done by Keith Gendreau, Zaven Arzoumanian, Steve Kenyon, and Nick Spartana of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16287-1

Hollow-Fiber Spacesuit Water Membrane Evaporator

Commercial applications include personal coolers for infantry, humidifiers for pilots, and personal coolers for hazmat suits.

Lyndon B. Johnson Space Center, Houston, Texas

The hollow-fiber spacesuit water membrane evaporator (HoFi SWME) is being developed to perform the thermal control function for advanced spacesuits and spacecraft to take advantage of recent advances in micropore membrane technology in providing a robust, heat-rejection device that is less sensitive to contamination than is the sublimator. After recent contamination tests, a commercial-off-the-shelf (COTS) microporous hollow-fiber membrane was selected for prototype development as the most suitable candidate among commercial hollow-fiber evaporator alternatives. An innovative design that grouped the fiber layers into stacks, which were separated by small spaces and packaged into a cylindrical shape, was developed into a full-scale prototype for the spacesuit application.

Vacuum chamber testing has been performed to characterize heat rejection as a function of inlet water temperature and water vapor backpressure, and to show contamination resistance to the constituents expected to be found in potable water produced by the wastewater reclamation distillation processes. Other tests showed tolerance to freezing and suitability to reject heat in a Mars pressure environment. In summary, HoFi SWME is a lightweight, compact evaporator for heat rejection in the spacesuit that is robust, contamination-insensitive, freeze-tolerant, and able to reject the required heat of spacewalks in microgravity, lunar, and Martian environments.

The HoFi is packaged to reject 810 W of heat through 800 hours of use in a vacuum environment, and 370 W in a Mars environment. The device also eliminates free gas and dissolved gas from the coolant loop.

This work was done by Grant Bue and Luis Trevino of Johnson Space Center; Gus Tsioulos of Wyle; Keith Mitchell of Jacobs Technology, Inc.; and Joseph Settles of Barrios. Further information is contained in a TSP (see page 1). MSC-24849-1

High-Power Single-Mode 2.65-μm InGaAsSb/AlInGaAsSb Diode Lasers

This innovation is useful for targeted gas detection instruments in environmental monitoring, safety, quality control, and fundamental science applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

Central to the advancement of both satellite and in-situ science are improvements in continuous-wave and pulsed infrared laser systems coupled with integrated miniaturized optics and electronics, allowing for the use of powerful, single-mode light sources aboard both satellite and unmanned aerial vehicle platforms.

There is a technological gap in supplying adequate laser sources to address the mid-infrared spectral window for spectroscopic characterization of important atmospheric gases. For high-power applications between 2 to 3 μm, commercial laser technologies are unsuitable because of limitations in output power. For instance, existing InP-based laser systems developed for fiber-based telecommunications cannot be extended to wavelengths longer than 2 μm. For emission wavelengths shorter than 3 μm, intersubband devices, such as infrared quantum cascade lasers, become inefficient due to band-offset limitations. To date, successfully demonstrated single-mode GaSb-based laser diodes emitting between 2 and 3 μm have employed lossy metal Bragg gratings for distributed-feedback coupling, which limits output power due to optical absorption.

By optimizing both the quantum well design and the grating fabrication process, index-coupled distributed-feedback 2.65-μm lasers capable of emitting in excess of 25 mW at room temperature have been demonstrated. Specifically, lasers at 3,777 cm^{-1} (2.65 μm) have been realized to interact with strong absorption lines of HDO and other isotopologues of H_2O. With minor modifications of the optical cavity and quantum well designs, lasers can be fabricated at any wavelength within the 2-to-3-μm spectral window with similar performance. At the time of this reporting, lasers with this output power and wavelength accuracy are not commercially available.

Monolithic ridge-waveguide GaSb lasers were fabricated that utilize second-order lateral Bragg gratings to generate