withstand both the impact of the initial drop, as well as the impact of the different obstacles it would encounter while traversing the surface of Mars. This polymer should not deteriorate with the 100 K daily temperature swings on Mars. The inner layer should consist of a very light gas such as nitrogen or helium. In terms of maneuvering, six very light weights placed at strategic locations would give moballs the ability to turn, or even hop, over hazardous (e.g., sharp) obstacles, or even initiate a movement (before getting more help from the wind to be carried around) when stuck. Maneuvering would be necessary in order to get closer to objects of interest. If the weights would be allowed to move freely, they could also be used to generate energy.

To deploy the moballs, NASA Standard Initiators (NSIs) would carry a light gas in the middle, and a few NSIs in the outer layer would carry the liquid form of a selected polymer. As soon as the moballs would get released by the deployer, the inner capsule would be exploded and the gas would fill out the inner layer of the moball, making it round. The NSI capsules containing the special polymer would then be broken, releasing the polymer that fills out the outer layer. In this manner, hundreds or even thousands of deflated moballs could be compacted inside the deployer and inflated just after the deployment and before their initial drop.

For the inner sphere of the moball, three principal (*XYZ*) axes with movable weights inside them would be constructed. The movable weights could be used to balance the motion of the moball. In this manner, the trajectory of the sphere could be corrected with a motorized controller that sits in the center of the sphere and that would control the distance of each weight from the center. This system of weights could be used to deflect the trajectory of the moball. If the weights would be magnet, they could generate power while tumbling around too.

The design described here (in terms of the inner and outer layer, and the three principal axes with controllable weights) would be novel. No pump would be required to deflate or inflate the moballs, saving power, and also reducing the risk of failure. However, it is emphasized that the novelty in this design would make the "hopping" movement of the moball much easier than earlier methods. Previous techniques for making a spherically-shaped robot hop over an object on Mars have assumed that the initial condition of the robot was stationary, i.e., the robot would hop from a position of complete stillness. This would be difficult to do on Mars, since the gravity is around 1/3 of the gravity of Earth, making the reaction force much less than what one would expect. However, since the moballs proposed here would be in a wind-driven (or downward rolling) movement already, they would have an "initial velocity," which would make hopping all the more easy. This is believed to be the most possible way of hopping over a hazardous object on Mars.

This work was done by Faranak Davoodi of Caltech and Farhooman Davoudi, Technical Consultant, for NASA's Jet Propulsion Laboratory.. For more information, contact iaoffice@jpl.nasa.gov.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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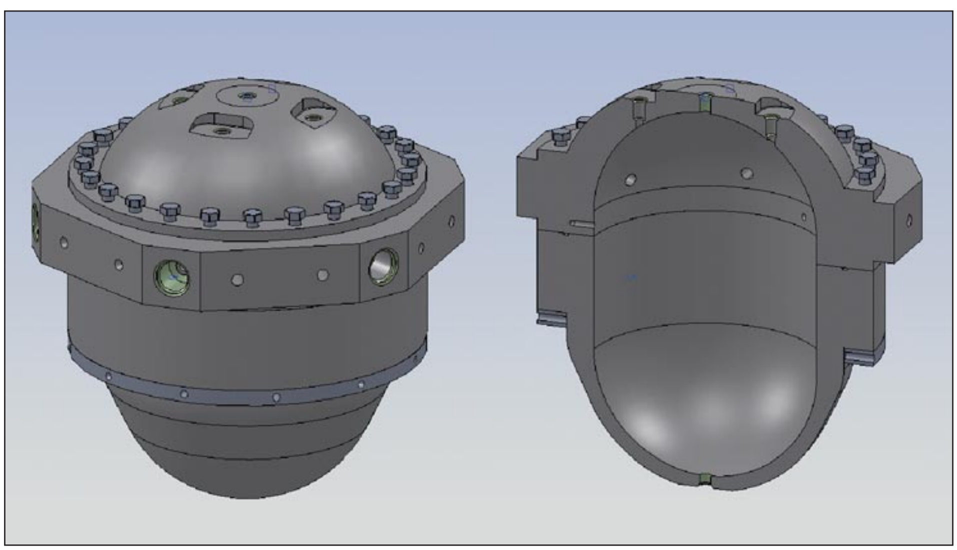
Refer to NPO-48643, volume and number of this NASA Tech Briefs *issue, and the page number.*

Pressure Dome for High-Pressure Electrolyzer

External gas pressure permits higher pressure and more versatile electrolyzer.

John H. Glenn Research Center, Cleveland, Ohio

A high-strength, low-weight pressure vessel dome was designed specifically to house a high-pressure [2,000 psi (≈13.8 MPa)] electrolyzer. In operation, the dome is filled with an inert gas pressurized to roughly 100 psi (≈690 kPa) above the high, balanced pressure product oxygen and hydrogen gas streams. The inert gas acts to reduce the clamping load on electrolyzer stack tie bolts since the dome pressure acting axially inward helps offset the outward axial forces from the stack gas pressure. Likewise, radial and circumferential stresses on electrolyzer frames are minimized. Because the dome is operated at a higher pressure than the electrolyzer product gas, any external electrolyzer leak prevents oxygen or hydrogen from



The **Pressure Dome** consists of two machined segments. An O-ring is placed in a groove in the flange of the bottom segment and is trapped by the flange on the top dome segment when these components are bolted together with high-strength bolts.

leaking into the dome. Instead the affected stack gas stream pressure rises detectably, thereby enabling a system shutdown. All electrical and fluid connections to the stack are made inside the pressure dome and require special plumbing and electrical dome interfaces for this to be accomplished. Further benefits of the dome are that it can act as a containment shield in the unlikely event of a catastrophic failure.

Studies indicate that, for a given active area (and hence, cell ID), frame outside diameter must become ever larger to support stresses at higher operating pressures. This can lead to a large footprint and increased costs associated with thicker and/or larger diameter endplates, tie-rods, and the frames themselves. One solution is to employ rings that fit snugly around the frame. This complicates stack assembly and is sometimes difficult to achieve in practice, as its success is strongly dependent on frame and ring tolerances, gas pressure, and operating temperature. A pressure dome permits an otherwise low-pressure stack to operate at higher pressures without growing the electrolyzer hardware.

The pressure dome consists of two machined segments. An O-ring is placed in an O-ring groove in the flange of the bottom segment and is trapped by the flange on the top dome segment when these components are bolted together with high-strength bolts. The pressure dome has several unique features. It is made (to ASME Pressure Vessel guidelines) in a high-strength aluminum alloy with the strength of stainless steel and the weight benefits of aluminum. The flange of the upper dome portion contains specially machined flats for mounting the dome, and other flats dedicated to the special feedthroughs for electrical connections. A pressure dome can be increased in length to house larger stacks (more cells) of the same diameter with the simple addition of a cylindrical segment.

To aid in dome assembly, two stainless steel rings are employed. One is used beneath the heads of the high-strength bolts in lieu of individual hardened washers, and another is used instead of individual nuts. Like electrolyzers could be operated at low or high pressures simply by operating the electrolyzer outside or inside a pressurized dome.

This work was done by Timothy Norman and Edwin Schmitt of Giner Electrochemical Systems, LLC for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18772-1.

Cascading Tesla Oscillating Flow Diode for Stirling Engine Gas Bearings

John H. Glenn Research Center, Cleveland, Ohio

Replacing the mechanical check-valve in a Stirling engine with a micromachined, non-moving-part flow diode eliminates moving parts and reduces the risk of microparticle clogging.

At very small scales, helium gas has sufficient mass momentum that it can act as a flow controller in a similar way as a transistor can redirect electrical signals with a smaller bias signal. The innovation here forces helium gas to flow in predominantly one direction by offering a clear, straight-path microchannel in one direction of flow, but then through a sophisticated geometry, the reversed flow is forced through a tortuous path. This redirection is achieved by using microfluid channel flow to force the much larger main flow into this tortuous path.

While microdiodes have been developed in the past, this innovation cascades Tesla diodes to create a much higher pressure in the gas bearing supply plenum. In addition, the special shape of the leaves captures loose particles that would otherwise clog the microchannel of the gas bearing pads.

This work was done by Rodger Dyson for Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18862-1.

Compact, Low-Force, Low-Noise Linear Actuator

This actuator has potential uses in military and automotive applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

Actuators are critical to all the robotic and manipulation mechanisms that are used in current and future NASA missions, and are also needed for many other industrial, aeronautical, and space activities. There are many types of actuators that were designed to operate as linear or rotary motors, but there is still a need for low-force, low-noise linear actuators for specialized applications, and the disclosed mechanism addresses this need.

A simpler implementation of a rotary actuator was developed where the end effector controls the motion of a brush for cleaning a thermal sensor. The mechanism uses a SMA (shape-memory alloy) wire for low force, and low noise. The linear implementation of the actuator incorporates a set of springs and mechanical hard-stops for resetting and fault tolerance to mechanical resistance. The actuator can be designed to work in a pull or push mode, or both. Depending on the volume envelope criteria, the actuator can be configured for scaling its volume down to 4×2×1 cm^3. The actuator design