heat to the condenser sections (walls and/or floors). The temperature could be easily controlled, providing a comfortable and affordable living environment. Investigating the appropriate materials and working fluids is needed to determine this application's potential success and usage.

This work was done by Marc Gibson, James Sanzi, and Ivan Locci of 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-18900-1.

Apparatus for Pumping a Fluid

There are no rotating or moving parts apart from bellows.

Marshall Space Flight Center, Alabama

A fluid pump has been developed for mechanically pumped fluid loops for spacecraft thermal control. Lynntech's technology utilizes a proprietary electrochemically driven pumping mechanism. Conventional rotodynamic and displacement pumps typically do not meet the stringent power and operational reliability requirements of space applications. Lynntech's developmental pump is a highly efficient solid-state pump with essentially no rotating or moving components (apart from metal bellows).

Figure 1 schematically illustrates the electrochemically-driven actuator. The conversion of electrical energy to mechanical work is achieved by transporting hydrogen across an electrochemical cell. Hydrogen is dissociated at the anode; protons that are formed from the dissociation are driven across the membrane by an applied potential, while electrons are conducted through an external circuit; protons and electrons recombine at the cathode to form hydrogen. The transport of hydrogen into and out of the attached bellows results in a pressure variation that is used to actuate the fluid pumping diaphragms. Each electrochemical cell is made up of a proton exchange membrane, typically Nafion®, with platinum catalyzed electrodes on either side, called a membrane electrode assembly (MEA). The use of hydrogen and its low oxidation and reduction potentials results in high electric-to-mechanical work conversion efficiency.

For size and convenience, a plurality of individual MEAs is used to transport the hydrogen, rather than a single electrochemical cell. The MEAs are connected electrically in series and fluidically in parallel. The stack of MEAs is sandwiched between two current collectors, and a voltage is applied across the stack, driving hydrogen gas from one

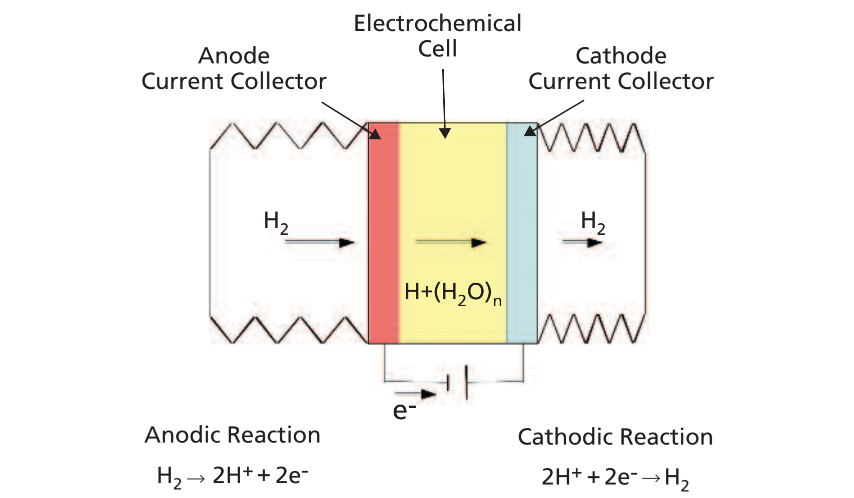


Figure 1. **Hydrogen** is dissociated at the anode; protons formed from the dissociation are conducted through the membrane, while electrons are conducted through an external circuit; protons and electrons recombine at the cathode to form hydrogen.

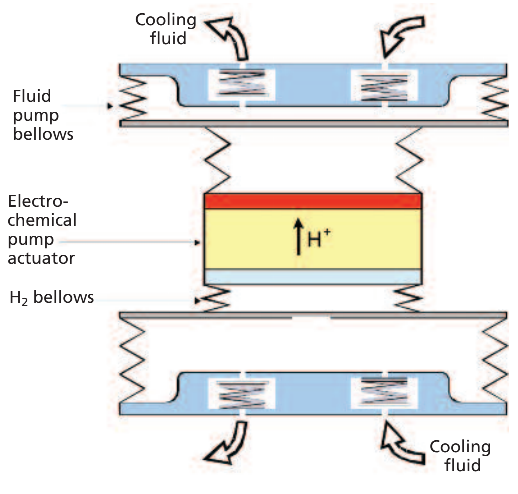


Figure 2. The **Smaller Hydrogen-Filled Bellows** actuates the second larger set of bellows, which displace fluid in the pump heads. Fluid is expelled from one pump head while being drawn into the other.

bellows to the other. The hydrogen flow rate through the actuator is directly proportional to the applied current. The hydrogen-filled bellows are used to actuate a second set of bellows, which displace the fluid in the pump head, as shown schematically in Figure 2. To further reduce the pump power requirements, a stroke-volume multiplier is utilized wherein a smaller-volume hydrogen filled bellows actuates a larger-volume fluid bellows. The stroke volume multiplier also allows the pump frequency to be reduced below audible frequency while maintaining adequate flow.

The largest factor affecting the lifetime and reliability of the pump is expected to be loss of hydrogen from the electrochemical actuator. The electrochemical actuator is hermetically sealed; however, permeation of hydrogen is expected to eventually result in loss of hydrogen. The lifetime of the pump is extended by generating hydrogen onboard the pump. The onboard hydrogen generation also allows the hydrogen pressure and pump performance to be optimized for varying operating temperatures.

The prototype pump is expected to operate with a power consumption of 2.4 W at a flow rate of 0.76 L/min and pressure rise of 27.6 kPa. The pump will operate at temperatures between 0 and 100 °C and survive temperatures between –60 to 110 °C. The prototype occupies a volume of ≈600 cm^3.

This work was done by Robert Van Boeyen and Jonathan Reeh of Lynntech, Inc. for Marshall Space Flight Center. For more information, contact Sammy A. Nabors, MSFC Commercialization Assistance Lead, at Sammy.a.nabors@nasa.gov. Refer to MFS-32760-1.

Cobra Fiber-Optic Positioner Upgrade

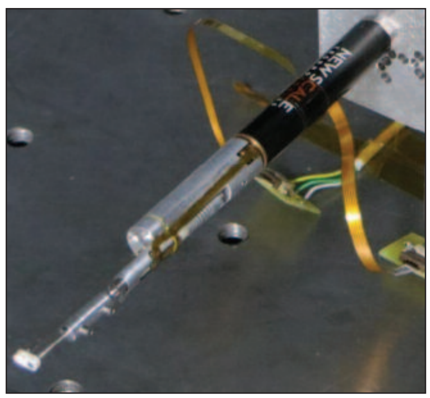
This technology could be used for applications requiring precise location of a small object within a small circular area, such as in medical lasers.

NASA's Jet Propulsion Laboratory, Pasadena, California

A prime focus spectrometer (PFS), along with corrective optics, will mount in place of the secondary mirror of the Subaru telescope on Mauna Kea, Hawaii. This will allow simultaneous observations of cosmologic targets. It will enable large-scale galactic archeology and dark energy surveys to help unlock the secrets of the universe.

To perform these cosmologic surveys, an array of 2,400 optical fibers needs to be independently positioned within the 498-mm-diameter focal plane of the PFS instrument to collect light from galaxies and stars for spectrographic analyses. To allow for independent re-positioning of the fibers, a very small positioner (7.7 mm in diameter) is required. One hundred percent coverage of the focal plane is also required, so these small actuators need to cover a patrol region of 9.5 mm in diameter. To optimize the amount of light that can be collected, the fibers need to be placed within 5 micrometers of their intended target (either a star or galaxy).

The Cobra Fiber Positioner was designed to meet the size and accuracy requirements stated above. Cobra is a two-degrees-of-freedom mechanism that can position an optical fiber in the focal plane of the PFS instrument to a precision of 5 micrometers. It is a theta-phi style positioner containing two rotary piezo tube motors with one offset from the other, which enables the optic fibers to be placed anywhere in a small circular patrol region. The patrol region of the actuator is such that the array of 2,400 positioners allows for full coverage of the instrument focal plane by overlapping the patrol areas.



The **Prime Focus Spectrometer** (PFS) installed on the Subaru Telescope.

A second-generation Cobra positioner was designed based on lessons learned from the original prototype built in 2009. Improvements were made to the precision of the ceramic motor parts, and hard stops were redesigned to minimize friction and prevent jamming. These changes resulted in reducing the number of move iterations required to position the optical fiber within 5 micrometers of its target. At the time of this reporting, there are still many tests to be performed that will validate system level performance, but on an individual level, the Cobra positioner demonstrates excellent performance and will enable the PFS instrument to make unprecedented measurements of the universe.

What is unique about the upgrades made to the Cobra positioner is the improved performance due to the design changes in the hard stops and the ceramic end caps of the motors. Other changes were made to reduce the unit cost of a Cobra positioner without affecting the performance, since thousands of these devices will have to be built for the PFS instrument.

This work was done by Charles D. Fisher, David F. Braun, and Joel V. Kaluzny of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-48751