A Zero-Gravity Cup for Drinking Beverages in Microgravity

This spill-resistant cup can be used by commuters for general beverage consumption on-the-go.

Lyndon B. Johnson Space Center, Houston, Texas

To date, the method for astronauts to drink liquids in microgravity or weightless environments is to suck the liquid from a bag or pouch through a straw. A new beverage cup works in microgravity and allows astronauts to drink liquids from a cup in a manner consistent with that on Earth.

The cup is capable of holding beverages with an angled channel running along the wall from the bottom to the lip. In microgravity, a beverage is placed into the cup using the galley dispenser. The angled channel acts as an open passage that contains only two sides where capillary forces move the liquid along the channel until it reaches the top lip where the forces reach an equilibrium and the flow stops. When one sips the liquid at the lip of the channel, the capillary force equilibrium is upset and more liquid flows to the lip from the reservoir at the bottom to re-establish the equilibrium. This sipping process can continue until the total liquid contents of the cup is consumed, leaving only a few residual drops — about the same quantity as in a ceramic cup when it is drunk dry on Earth.

Figure 1. **Astronaut Don Pettit Moves the 0 G Cup** about the cabin without spillage while Steve Bowen takes a sip of tea.

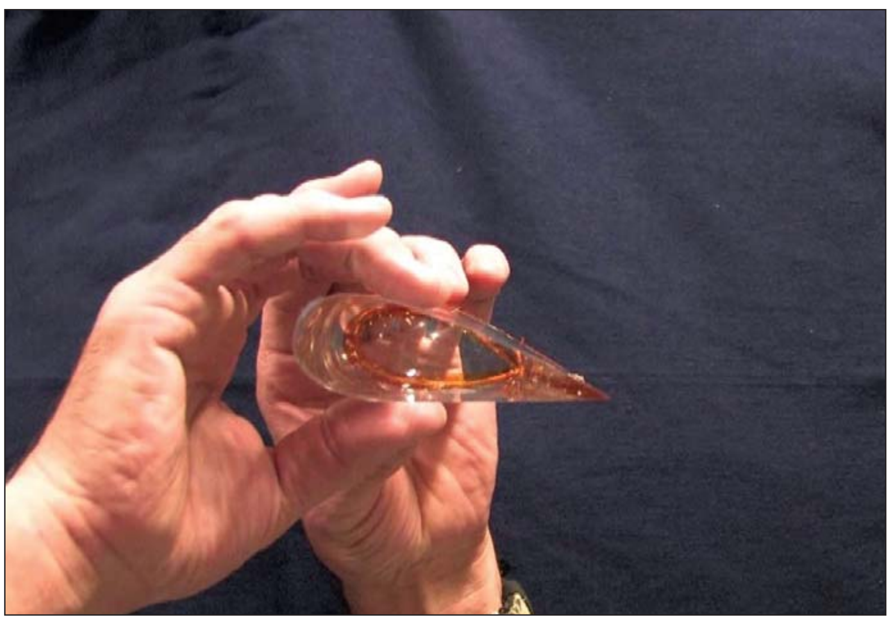

Figure 2. **Top View of the 0 G Cup** showing the cup profile and the liquid channel at the rim.

The free surface profile, governed by surface tension forces, was sufficient to keep the water from spilling during normal cup motions, thus allowing for the cup to be moved about like one would normally do for drinking beverages during a meal. Unlike on Earth, the cup could not be set on a table, but it could be parked on a wall and when desired, picked "up" for a sip.

Flexible walls functioning as a default handle proved to be a highly desirable feature. After the prototype cup was used with coffee where the remaining few drops were allowed to dry, the coffee residue as a contaminant altered the contact angle properties such that when refilled, the coffee was reluctant to move up the channel. A few gentle squeezes of the channel, reducing the angle to a value near zero degrees, increased the effect of capillary motion and quickly moved the coffee to the lip where thereafter the squeezing was unnecessary and the coffee could be sipped normally. As the cup begins to empty, again, gently squeezing the channel walls together, decreasing the angle to a near zero value, helps move the last few drops to the lip. Having a flexible channel is thus useful in initially priming of the fluid if the walls are contaminated from a prior use and in drinking the last few drops.

The main body of the cup could be made from a material optimized for overall cup design, with a specialized coating applied to the inside region of the channel. An example would be a stainless steel cup with an enamel or ceramic coating applied to the inside of the channel. Such a coating could have low contact angles, those closer to glass than metal or plastic, and not pose a breakage safety hazard.

This work was done by Donald R. Pettit of Johnson Space Center, Mark Weislogel of Portland State University, and Paul Concus and Robert Finn, independent consultants. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.

This is the invention of a NASA employee, and a patent application has been filed. Inquiries concerning license for its commercial development may be addressed to the inventor:

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Refer to MSC-24558-1.

Co-Flow Hollow Cathode Technology

NASA's Jet Propulsion Laboratory, Pasadena, California

Hall thrusters utilize identical hollow cathode technology as ion thrusters, yet must operate at much higher mass flow rates in order to efficiently couple to the bulk plasma discharge. Higher flow rates are necessary in order to provide enough neutral collisions to transport electrons across magnetic fields so that they can reach the discharge. This higher flow rate, however, has potential life-limiting implications for the operation of the cathode.

A solution to the problem involves splitting the mass flow into the hollow cathode into two streams, the internal and external flows. The internal flow is fixed and set such that the neutral pressure in the cathode allows for a high utilization of the emitter surface area. The external flow is variable depending on the flow rate through the anode of the Hall thruster, but also has a minimum in order to suppress high-energy ion generation.

In the co-flow hollow cathode, the cathode assembly is mounted on thruster centerline, inside the inner magnetic core of the thruster. An annular gas plenum is placed at the base of the cathode and propellant is fed throughout to produce an azimuthally symmetric flow of gas that evenly expands around the cathode keeper. This configuration maximizes propellant utilization and is not subject to erosion processes.

External gas feeds have been considered in the past for ion thruster applications, but usually in the context of eliminating high energy ion production. This approach is adapted specifically for the Hall thruster and exploits the geometry of a Hall thruster to feed and focus the external flow without introducing significant new complexity to the thruster design.

This work was done by Richard R. Hofer and Dan M. Goebel of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-47901

Programmable Aperture With MEMS Microshutter Arrays

Goddard Space Flight Center, Greenbelt, Maryland

A microshutter array (MSA) has been developed for use as an aperture array for multi-object selections in James Webb Space Telescope (JWST) technology. Light shields, molybdenum nitride (MoN) coating on shutters, and aluminum/aluminum oxide coatings on interior walls are put on each shutter for light leak prevention, and to enhance optical contrast. Individual shutters are patterned with a torsion flexure that permits shutters to open 90° with a minimized mechanical stress concentration. The shutters are actuated magnetically, latched, and addressed electrostatically. Also, micromechanical features are tailored onto individual shutters to prevent stiction.

An individual shutter consists of a torsion hinge, a shutter blade, a front electrode that is coated on the shutter blade, a backside electrode that is coated on the interior walls, and a magnetic cobalt-iron coating. The magnetic coating is patterned into stripes on microshutters so that shutters can respond to an external magnetic field for the magnetic actuation. A set of column electrodes is placed on top of shutters, and a set of row electrodes on sidewalls is underneath the shutters so that they can be electrostatically latched open.

A linear permanent magnet is aligned with the shutter rows and is positioned above a flipped upside-down array, and sweeps across the array in a direction parallel to shutter columns. As the magnet sweeps across the array, sequential rows of shutters are rotated from their natural horizontal orientation to a vertical open position, where they approach vertical electrodes on the sidewalls. When the electrodes are biased with a sufficient electrostatic force to overcome the mechanical restoring force of torsion bars, shutters remain latched to vertical electrodes in their open state. When the bias is removed, or is insufficient, the shutters return to their horizontal, closed positions. To release a shutter, both the electrode on the shutter and the one on the back wall where the shutter sits are grounded. The shutters with one or both ungrounded electrodes are held open. Sub-micron bumps underneath light shields and silicon ribs on back walls are the two features to prevent stiction.

These features ensure that the microshutter array functions properly in mechanical motions. The MSA technology can be used primarily in multi-object imaging and spectroscopy, photomask generation, light switches, and in the stepper equipment used to make integrated circuits and MEMS (microelectromechanical systems) devices.

This work was done by Samuel Moseley, Mary Li, and Alexander Kutyrev of the University of Maryland, College Park; Gunther Kletetschka of the Catholic University of America; and Rainer Fettig of Raytheon Company for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15998-1