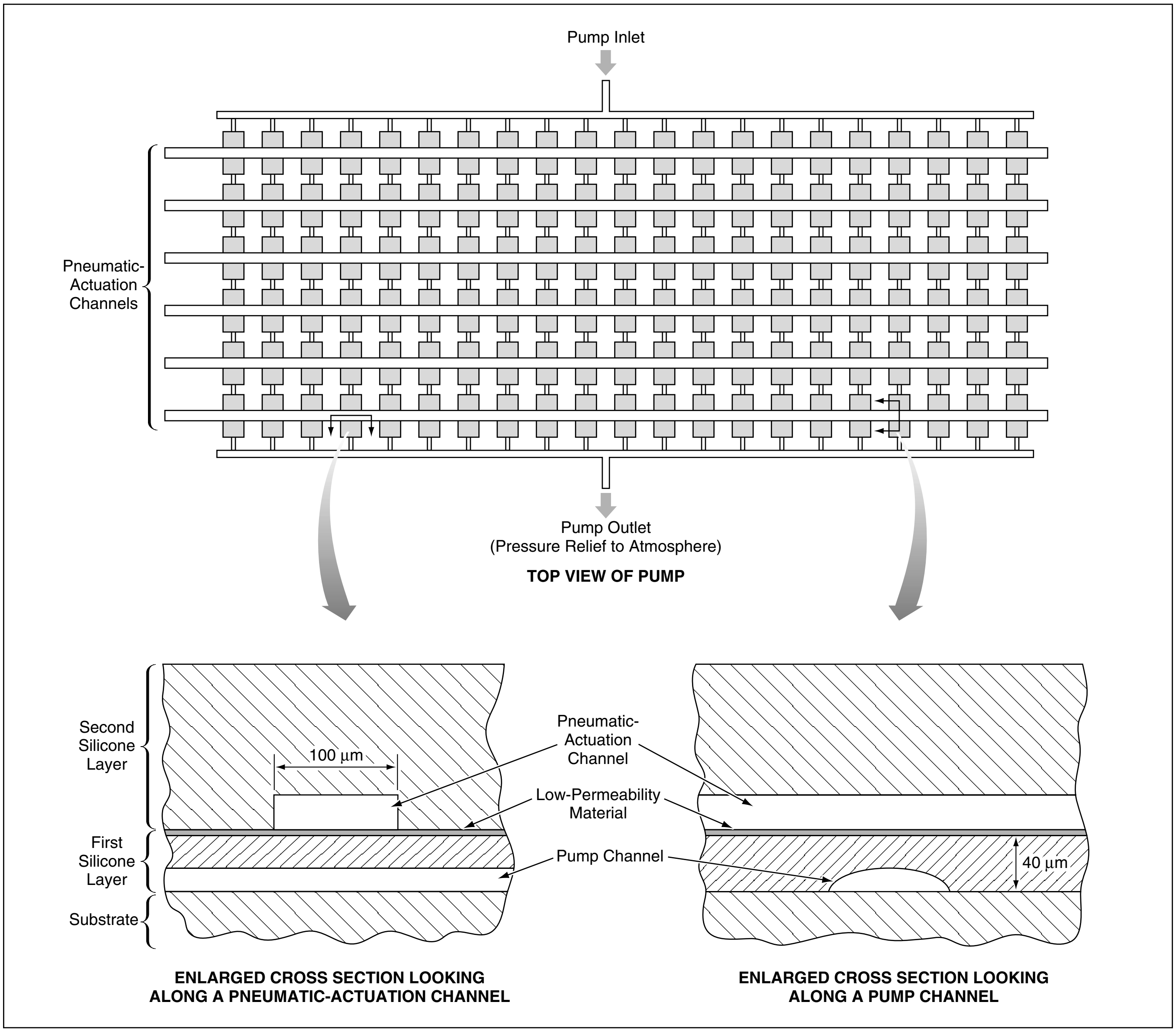
# Pneumatically Actuated Miniature Peristaltic Vacuum Pumps

Small, rugged, low-power pumps could be fabricated inexpensively.

*NASA's Jet Propulsion Laboratory, Pasadena, California*




**Pneumatic-Actuation Channels** would be alternately pressurized and depressurized to push down the silicone arches or allow them to spring back up, respectively. This action would create waves of opening and closing, equivalent to peristalsis, that would move gases along the pump channels. The dimensions shown here are exemplary, not exclusive.

Pneumatically actuated miniature peristaltic vacuum pumps have been proposed for incorporation into advanced miniature versions of scientific instruments that depend on vacuum for proper operation. These pumps are expected to be capable of reaching vacuum-side pressures in the torr to millitorr range (from ≈133 down to ≈0.13 Pa). Vacuum pumps that operate in this range are often denoted roughing pumps. In comparison with previously available roughing pumps, these pumps are expected to be an order of magnitude less massive and less power-hungry. In addition, they would be extremely robust, and would operate with little or no maintenance and without need for oil or other lubricants. Portable mass spectrometers are typical examples of instruments that could incorporate the proposed pumps. In addition, the proposed pumps could be used as roughing pumps in general laboratory applications in which low pumping rates could be tolerated.

The proposed pumps could be designed and fabricated in conventionally machined and micromachined versions. A typical micromachined version (see figure) would include a rigid glass, metal, or plastic substrate and two layers of silicone rubber. The bottom silicone layer would contain shallow pump channels covered by silicone arches that could be pushed down pneumatically to block the channels. The bottom silicone layer would be covered with a thin layer of material with very low gas permeability, and would be bonded to the substrate everywhere except in the channel areas. The top silicone layer would be attached to the bottom silicone layer and would contain pneumatic-actuation channels that would lie crosswise to the pump channels. This version is said to be micromachined because the two silicone layers containing the channels would be fabricated by casting silicone rubber on micromachined silicon molds.

The pneumatic-actuation channels would be alternately connected to a compressed gas and (depending on pump design) either to atmospheric pressure or to a partial vacuum source. The design would be such that the higher pneumatic pressure would be sufficient to push the silicone arches down onto the substrates, blocking the channels. Thus, by connecting pneumatic-actuation channels to the two pneumatic sources in spatial and temporal alternation, waves of opening and closing, equivalent to peristalsis, could be made to move along the pump channels.

A pump according to this concept could be manufactured inexpensively. Pneumatic sources (compressors and partial vacuum sources) similar those needed for actuation are commercially available; they typically have masses of ≈100 g and power demands of the order of several W. In a design-optimization effort, it should be possible to reduce masses and power demands below even these low levels and to integrate pneumatic sources along with the proposed pumps into miniature units with overall dimensions of no more than a few centimeters per side.

*This work was done by Sabrina Feldman, Jason Feldman, and Danielle Svehla of Caltech for* **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com***.
*NPO-30165*

# Miniature Gas-Turbine Power Generator

Energy density would greatly exceed that of a typical battery system.

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A proposed microelectromechanical system (MEMS) containing a closed-Brayton-cycle turbine would serve as a prototype of electric-power generators for special applications in which high energy densities are required and in which, heretofore, batteries have been used. The system would have a volume of about 6 $cm^3$ and would operate with a thermal efficiency >30 percent, generating up to 50 W of electrical power. The energy density of the proposed system would be about 10 times that of the best battery-based systems now available, and, as such, would be comparable to that of a fuel cell.

The working gas for the turbine would be Xe containing small quantities of $CO_2$, $O_2$, and $H_2O$ as gaseous lubricants. The gas would be contained in an enclosed circulation system, within which the pressure would typically range between 5 and 50 atm (between 0.5 and 5 MPa). The heat for the Brayton cycle could be supplied by any of a number of sources, including a solar concentrator or a combustor burning a hydrocarbon or other fuel. The system would include novel heat-transfer and heat-management components. The turbine would be connected to an electric power generator/starter motor.

The system would include a main rotor shaft with gas bearings; the bearing surfaces would be made of a ceramic material coated with nanocrystalline diamond. The shaft could withstand speed of 400,000 rpm or perhaps more, with bearing-wear rates less than $10^{-4}\times$ those of silicon bearings and 0.05 to 0.1× those of SiC bearings, and with a coefficient of friction about 0.1× that of Si or SiC bearings. The components of the system would be fabricated by a combination of (1) three-dimensional x-ray lithography and (2) highly precise injection molding of diamond-compatible metals and ceramic materials. The materials and fabrication techniques would be suitable for mass production.

The disadvantages of the proposed system are that unlike a battery-based system, it could generate a perceptible amount of sound, and, if it were to burn fuel, then it would also generate exhaust, similarly to other combustion-based power sources.

*This work was done by Dean Wiberg, Stephen Vargo, Victor White, and Kirill Shcheglov of Caltech and Philip Muntz of the University of Southern California for* **NASA's Jet Propulsion Laboratory**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com***.
*NPO-20933*