



### **Patched Off-Axis Bending/Twisting Actuators for Thin Mirrors**

Two documents present updates on thin-shell, adjustable, curved mirrors now being developed for use in spaceborne imaging systems. These mirrors at an earlier stage of development were reported in “Nanolaminate Mirrors With Integral Figure-Control Actuators” (NPO-30221), *NASA Tech Briefs*, Vol. 26, No. 5 (May 2002), page 80. To recapitulate: These mirrors comprise metallic film reflectors on nanolaminate substrates that contain “in-plane” actuators for controlling surface figures with micron-level precision. The actuators are integral parts of the mirror structures, typically fabricated as patches that are bonded onto the rear (nonreflective) surfaces of the mirror shells. The current documents discuss mathematical modeling of mirror deflections caused by actuators arranged in unit cells distributed across the rear mirror surfaces. One of the documents emphasizes an actuator configuration in which a mirror surface is divided into hexagonal unit cells. Each unit cell contains four rectangular actua-

tor patches in an off-axis cruciform pattern to induce a combination of bending and twisting. For deflections to reduce certain optical aberrations, it is found that, relative to other configurations, this configuration involves a smaller areal density of actuators.

*This work was done by Gregory Hickey, Shyh-Shiuh Lih, and Horn-Sen Tzou of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).  
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### **Improving Control in a Joule-Thomson Refrigerator**

A report discusses a modified design of a Joule-Thomson (JT) refrigerator under development to be incorporated into scientific instrumentation aboard a spacecraft. In most other JT refrigerators (including common household refrigerators), the temperature of the evaporator (the cold stage) is kept within a desired narrow range by turning a compressor on and off as needed. This mode of control is inadequate for

the present refrigerator because a JT-refrigerator compressor performs poorly when the flow from its evaporator varies substantially, and this refrigerator is required to maintain adequate cooling power. The proposed design modifications include changes in the arrangement of heat exchangers, addition of a clamp that would afford a controlled heat leak from a warmer to a cooler stage to smooth out temperature fluctuations in the cooler stage, and incorporation of a proportional + integral + derivative (PID) control system that would regulate the heat leak to maintain the temperature of the evaporator within a desired narrow range while keeping the amount of liquid in the evaporator within a very narrow range in order to optimize the performance of the compressor. Novelty lies in combining the temperature- and cooling-power-regulating controls into a single control system.

*This work was done by James Borders, David Pearson, and Mauro Prina of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).  
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