has been completed and the rotational-adjustment tools removed.

Optionally, the ball-and-socket assembly as described thus far could be used alone as a rotation-only stage. However, in the original application, the ball-and-socket assembly is mounted within a *z*-axis housing that, as its name suggests, enables translational adjustment along the *z* axis (focus adjustment). The socket is in threaded engagement with a focus-adjustment nut that can be turned about the *z* axis to make the adjustment. An anti-rotation pin that is free to translate along a *z*-oriented slot prevents undesired rotation of the socket about the *z* axis during focus adjustment. A focus-preload spring exerts a *z*-axis preload between the socket and the *z*-axis housing to prevent backlash in the focus adjustment.

Optionally, the *z*-axis-adjusting mechanism as described above could be used alone as a *z*-axis-translation stage. However, in the original application, it is mounted in an *x*–*y* translation stage that includes three flexural arms positioned at equal angular intervals on a circular frame. The radial position of the outer end of each flexural arm can be varied by means of a fine-pitch adjustment screw. Initially, all three adjustment screws are set at approximately the midpoints of their ranges, thereby placing all three flexural arms in tension and approximately centering the *z*-axis housing in the circle. Thereafter, the screws are turned, singly or in pairs as needed, to make fine adjustments to bring the optical component into *x* and *y* alignment. Care must be taken during these adjustments to maintain all three flexural arms in tension so as to prevent backlash. The *x*–*y* adjustment resolution is much finer than the thread pitch of the adjustment screws. Optionally, like the rotational and *z*-axis sub-stages, the *x*–*y* stage could be used by itself.

This work was done by Syed Shafaat and Daniel Chang of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). *NPO-45273*

Ultrasonic/Sonic Impacting Penetrators

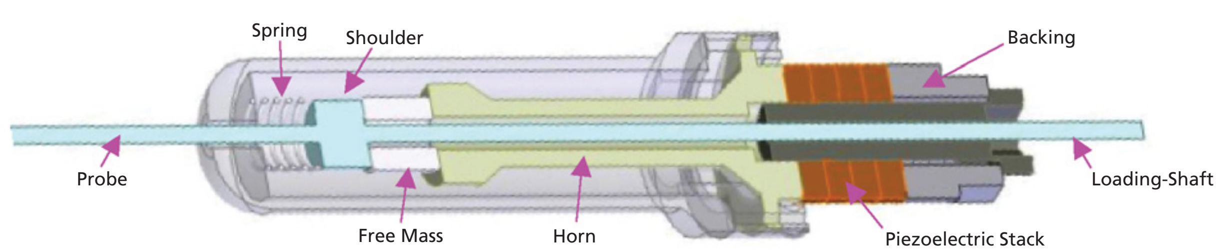
Soil can be probed relatively gently to a depth of several feet.

NASA's Jet Propulsion Laboratory, Pasadena, California

Ultrasonic/sonic impacting penetrators (USIPs) are recent additions to the series of apparatuses based on ultrasonic/sonic drill corers (USDCs). A USIP enables a rod probe to penetrate packed soil or another substance of similar consistency, without need to apply a large axial force that could result in buckling of the probe or in damage to some buried objects. USIPs were conceived for use in probing and analyzing soil to depths of tens of centimeters in the vicinity of buried barrels containing toxic waste, without causing rupture of the barrels. USIPs could also be used for other purposes, including, for example, searching for pipes, barrels, or other hard objects buried in soil; and detecting land mines.

USDCs and other apparatuses based on USDCs have been described in numerous previous *NASA Tech Briefs* articles. The ones reported previously were designed, variously, for boring into, and/or acquiring samples of, rock or other hard, brittle materials of geological interest. To recapitulate: A USDC can be characterized as a lightweight, low-power, piezoelectrically driven jackhammer in which ultrasonic and sonic vibrations are generated and coupled to a tool bit. As shown in the figure, a basic USDC includes a piezoelectric stack, a backing and a horn connected to the stack, a free mass ("free" in the sense that it can slide axially a short distance between the horn and the shoulder of tool bit), and a tool bit, i.e., probe for USIP. The piezoelectric stack is driven at the resonance frequency of the stack/horn/backing assembly to create ultrasonic vibrations that are mechanically amplified by the horn. To prevent fracture during operation, the piezoelectric stack is held in compression by a bolt. The bouncing of the free mass between the horn and the tool bit at sonic frequencies generates hammering actions to the bit that are more effective for drilling than is the micro-hammering action of ultrasonic vibrations in ordinary ultrasonic drills. The hammering actions are so effective that the axial force needed to make the tool bit advance into the material of interest is much smaller than in ordinary twist drilling, ultrasonic drilling, or ordinary steady pushing.

The differences between a USIP and a USDC-based apparatus described above lie in design details that make a USIP more suitable for penetrating packed soil. The piezoelectric stack in an experimental prototype USIP had a diameter of 1.0 in. (≈25 mm) and could be made to resonate at a frequency between 12 and 20 kHz, the exact value depending on the



The design of **Prototype USIP** shows key components.

specific design and operating conditions. The probe rod had a diameter of 1/8 in. (≈3 mm) and a length sufficient to enable penetration to a depth of 3 ft (≈91 cm). The piezoelectric stack was driven at a 20-percent duty cycle, with a combination of automatic and manual adjustments of the frequency of the driving signal to compensate for changes in the resonance frequency induced by changes in mechanical loading and by temperature rise during operation.

The design of the horn and a piezoelectric-stack-backing structure was optimized for coupling power from the stack to the horn and for amplification of the longitudinal displacement. The optimization was accomplished with the help of a computer program that numerically solved the governing equations to perform impact and vibration-mode analyses. The modal analysis was used to determine the dimensions of the horn and backing for a resonance frequency in the required range and to further adjust the dimensions of the horn so that the neutral plane matched the mounting plane to minimize adverse effects of transducer vibration on a supporting structure. The impact analysis, in which the focus was on the interaction between the free mass and the horn, was used to derive an optimal weight of the free mass.

In experiments, an axial force of 7 lb (≈31 N)] was found to be sufficient to cause the probe tip to reach a depth of 3 ft (≈91 cm) in a packed soil sample. In contrast, the axial force that would be needed to make an equivalent probe tip penetrate to the same depth by ordinary steady pushing has been estimated to be about 200 lb (≈890 N), which is large enough to easily cause buckling of the probe without a holding mechanism and to damage a buried barrel.

This work was done by Xiaoqi Bao, Yoseph Bar-Cohen, Zensheu Chang, Stewart Sherrit, and Randall A. Stark of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-41666

Miniature, Lightweight, One-Time-Opening Valve

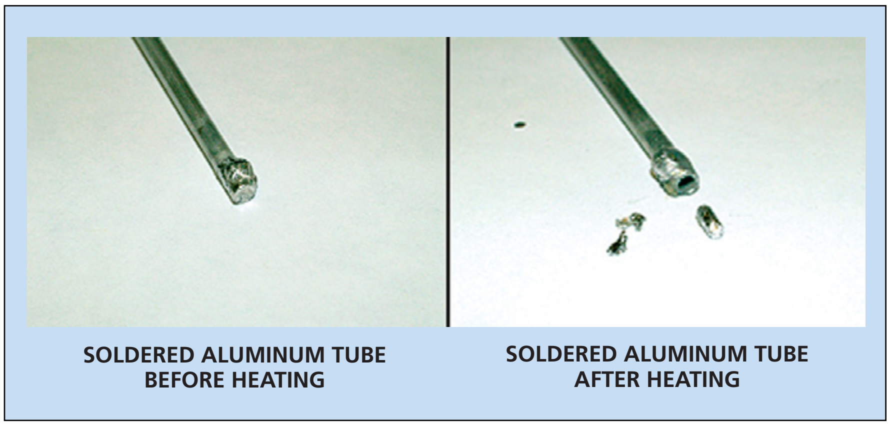
A small solder plug is melted to release a pressurized gas.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure depicts the main parts of a prototype miniature, lightweight, one-time-opening valve. Like some other miniature one-time-opening valves reported in previous issues of *NASA Tech Briefs*, this valve is opened by melting a material that blocks the flow path. This valve is designed to remain closed at some temperature between room temperature and cryogenic temperature until the time of opening.

The prototype valve includes a 1/8-in. (3-mm) aluminum tube, one end of which is plugged with a solder comprising about 37 weight percent of lead and 63 weight percent of tin. The tube and the solder both have a coefficient of thermal expansion of 23 micron/m-K at room temperature. Before plugging, the interior surface of the plug end of the tube is cleaned with a commercial flux paste developed specifically for preparing aluminum for bonding with lead/tin solder. The solder is then melted into the cleaned end of the tube, forming the plug.

In a test, the plugged tube was pressurized to 1,000 psi (6.9 MPa) with helium and leak-tested. It was then cooled to a temperature of 77 K (about –196 °C) and again leak-tested at the same pressure. Finally, at a lower pressure, the plugged end of the tube was heated to about 200 °C (the melting temperature of the solder is 183°C), causing the solder plug to be ejected (see figure). It has been estimated that in a subsequent version of the valve, the plug could be melted by electrical heating, using a nichrome wire having a mass of only 10 g.



The **Solder Plug Was Ejected** from the pressurized aluminum tube when the plugged end was heated to about 200 °C.

This work was done by Jack Jones, Juinn Jenq Wu, and Robert Leland of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-42236