Mechanics/Machinery

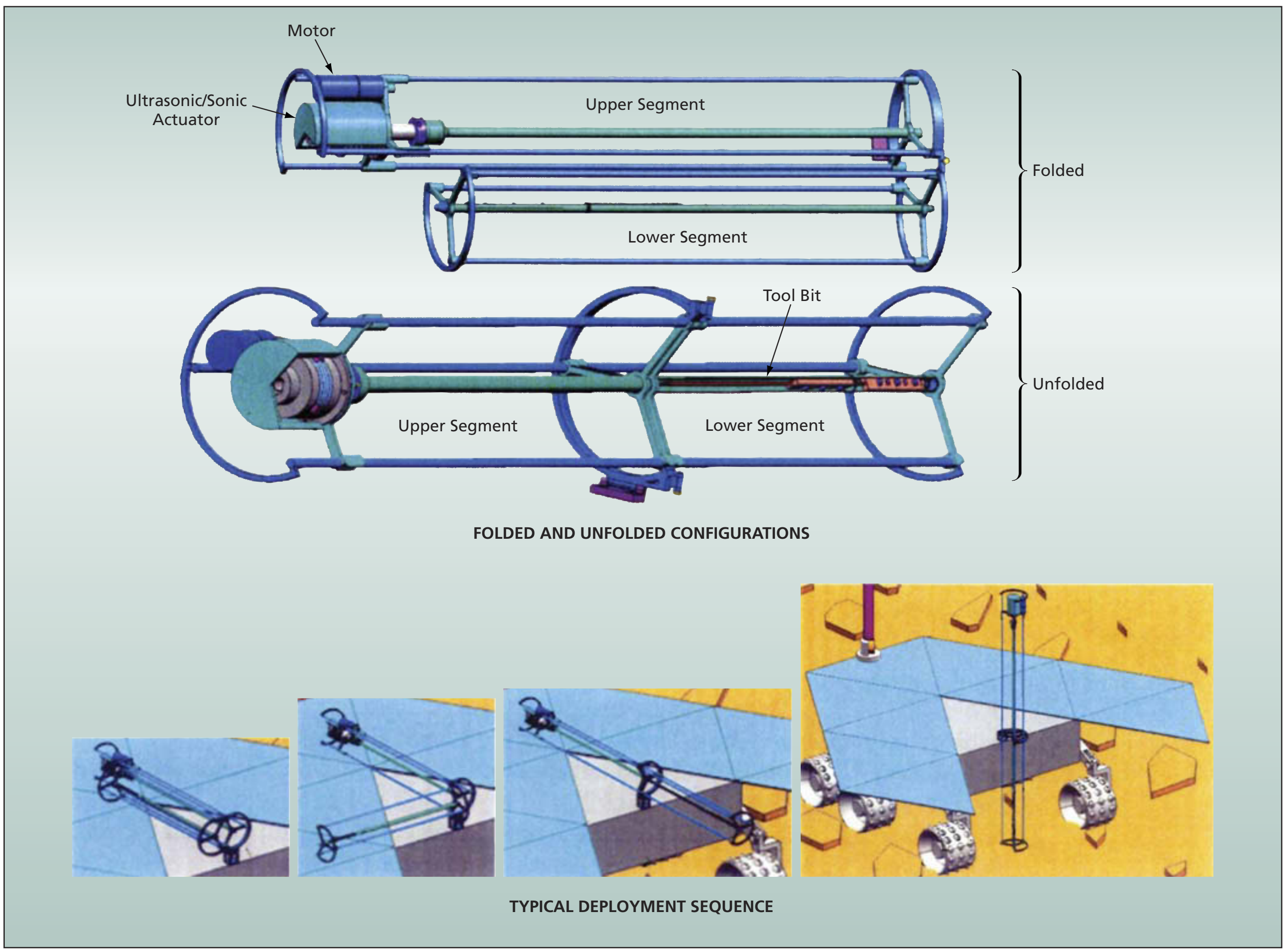
Foldable Instrumented Bits for Ultrasonic/Sonic Penetrators

These bits are stowed compactly, then extended to full length when needed.

NASA's Jet Propulsion Laboratory, Pasadena, California

Long tool bits are undergoing development that can be stowed compactly until used as rock- or ground-penetrating probes actuated by ultrasonic/sonic mechanisms. These bits are designed to be folded or rolled into compact form for transport to exploration sites, where they are to be connected to their ultrasonic/sonic actuation mechanisms and unfolded or unrolled to their full lengths for penetrating ground or rock to relatively large depths. These bits can be designed to acquire rock or soil samples and/or to be equipped with sensors for measuring properties of rock or soil *in situ*. These bits can also be designed to be withdrawn from the ground, restowed, and transported for reuse at different exploration sites.

Apparatuses based on the concept of a probe actuated by an ultrasonic/sonic mechanism have been described in numerous prior *NASA Tech Briefs* articles, the most recent and relevant being "Ultrasonic/Sonic Impacting Penetra-tors" (NPO-41666) *NASA Tech Briefs*, Vol. 32, No. 4 (April 2008), page 58. All of those apparatuses are variations on the basic theme of the earliest ones, denoted ultrasonic/sonic drill corers (USDCs). To recapitulate: An apparatus of this type includes a lightweight, low-power, piezoelectrically driven actuator in which ultrasonic and sonic vibrations are generated and coupled to a tool bit. The combination of ultrasonic and sonic vibrations gives rise to a hammering action (and a resulting chiseling action at the tip of the tool bit) that is more effective for drilling than is the microhammering action of ultrasonic vibrations alone. The hammering and chiseling actions are so effective that the size of the axial force needed to make the tool bit advance into soil, rock, or another mate-



Hinged Lower and Upper Segments of a tool bit and supporting structure are unfolded at the hinges and locked in axial alignment. The resulting assembly is then positioned with the lower end of the tool bit in contact with the ground. The lower views show a conceptual sequence for deployment from an exploratory robotic vehicle, but this sequence is also typical of deployment in other settings.

rial of interest is much smaller than in ordinary twist drilling, ordinary hammering, or ordinary steady pushing.

Examples of properties that could be measured by use of an instrumented tool bit include electrical conductivity, permittivity, magnetic field, magnetic permeability, temperature, and any other properties that can be measured by fiber-optic sensors. The problem of instrumenting a probe of this type is simplified, relative to the problem of attaching electrodes in a rotating drill bit, in two ways:

(1) Unlike a rotating drill bit, a bit of this type does not have flutes, which would compound the problem of ensuring contact between sensors and the side wall of a hole; and (2) there is no need for slip rings for electrical contact between sensor electronic circuitry and external circuitry because, unlike a rotating drill, a tool bit of this type is not rotated continuously during operation.

One design for a tool bit of the present type is a segmented bit with a segmented, hinged support structure (see figure). The bit and its ultrasonic/sonic actuator are supported by a slider/guiding fixture, and its displacement and preload are controlled by a motor. For deployment from the folded configuration, a spring-loaded mechanism rotates the lower segment about the hinges, causing the lower segment to become axially aligned with the upper segment. A latching mechanism then locks the segments of the bit and the corresponding segments of the slider/guiding fixture. Then the entire resulting assembly is maneuvered into position for drilling into the ground.

Another design provides for a bit comprising multiple tubular segments with an inner alignment string, similar to a foldable tent pole comprising multiple tubular segments with an inner elastic cable connecting the two ends. At the beginning of deployment, all segments except the first (lowermost) one remain folded, and the ultrasonic/sonic actuator is clamped to the top of the lowermost segment and used to drive this segment into the ground. When the first segment has penetrated to a specified depth, the second segment is connected to the upper end of the first segment to form a longer rigid tubular bit and the actuator is moved to the upper end of the second segment. The process as described thus far is repeated, adding segments until the desired depth of penetration has been attained.

Yet other designs provide for bits in the form of bistable circular- or rectangular-cross-section tubes that can be stowed compactly like rolls of flat tape and become rigidified upon extension to full length, in a manner partly similar to that of a common steel tape measure. Albeit not marketed for use in tool bits, a bistable reeled composite product that transforms itself from a flat coil to a rigid tube of circular cross section when unrolled, is commercially available under the trade name RolaTube™ and serves as a model for the further development of tool bits of this subtype.

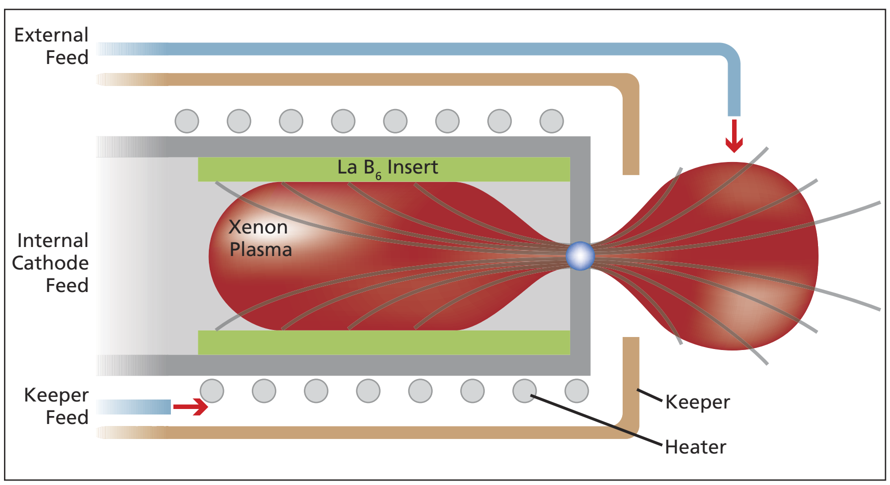
This work was done by Yoseph Bar-Cohen, Mircea Badescu, Theodore Iskenderian, Stewart Sherrit, Xiaoqi Bao, and Randel Lindemann of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-45289

Compact Rare Earth Emitter Hollow Cathode

This rare earth insert for ion and Hall thrusters has longer life and resistance to poisoning.

NASA's Jet Propulsion Laboratory, Pasadena, California

A compact, high-current, hollow cathode utilizing a lanthanum hexaboride (LaB_6) thermionic electron emitter has been developed for use with high-power Hall thrusters and ion thrusters. LaB_6 cathodes are being investigated due to their long life, high current capabilities, and less stringent xenon purity and handling requirements compared to conventional barium oxide (BaO) dispenser cathodes. The new cathode features a much smaller diameter than previously developed versions that permit it to be mounted on axis of a Hall thruster ("internally mounted"), as opposed to the conventional side-mount position external to the outer magnetic circuit ("externally mounted"). The cathode has also been reconfigured to be capable of surviving vibrational loads during launch and is designed to solve the significant heater and materials compatibility problems associated with the use of this emitter material. This has been accomplished in a compact design with the capability of high-emission current (10 to 60 A). The compact, high-current design has a keeper diameter that allows the cathode to be mounted on the centerline of a 6-kW Hall thruster, inside the iron core of the inner electromagnetic coil.



A **Schematic of the Hollow Cathode** with external gas feeds either directly into the cathode plume or into the cathode keeper gap, both of which feed gas into the plasma exterior to the insert region.

Although designed for electric propulsion thrusters in spacecraft station-keeping, orbit transfer, and interplanetary applications, the LaB_6 cathodes are applicable to the plasma processing industry in applications such as optical coatings and semiconductor processing where reactive gases are used. Where current electrical propulsion thrusters with BaO emitters have limited