

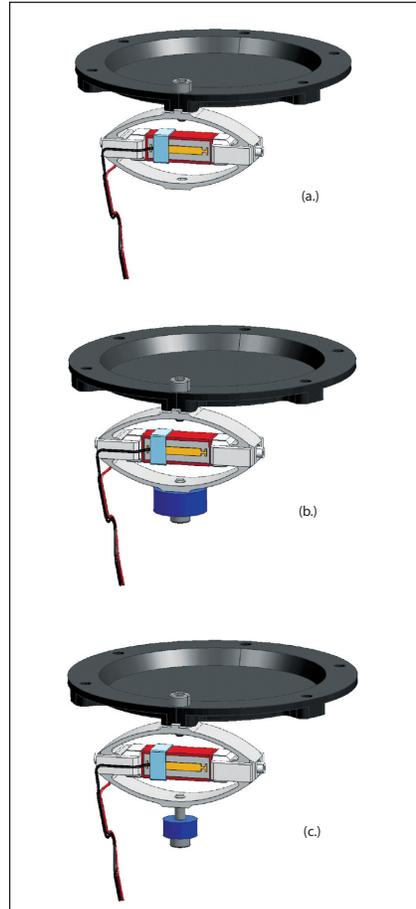
## ⚙️ Miniature Piezoelectric Shaker for Distribution of Unconsolidated Samples to Instrument Cells

This design could be applicable for handling powders in the pharmaceutical industry.

NASA's Jet Propulsion Laboratory, Pasadena, California

The planned Mars Science Laboratory mission requires inlet funnels for channeling unconsolidated powdered samples from the sampling and sieving mechanisms into instrument test cells, which are required to reduce cross-contamination of the samples and to minimize residue left in the funnels after each sample transport. To these ends, a solid-state shaking mechanism has been created that requires low power and is lightweight, but is sturdy enough to survive launch vibration.

The funnel mechanism is driven by asymmetrically mounted, piezoelectric flexure actuators that are out of the load path so that they do not support the funnel mass. Each actuator is a titanium, flextensional piezoelectric device driven by a piezoelectric stack. The stack has Invar endcaps with a half-spherical recess. The Invar is used to counteract the change in stress as the actuators are cooled to Mars' ambient temperatures. A ball screw is threaded through the actuator frame into the recess to apply pre-stress, and to trap the piezoelectric stack and endcaps in flexure. During the vibration cycle of the flextensional actuator frame, the compression in the piezoelectric stack may decrease to the point that it is unstressed; however, because the ball joint cannot pull, tension in the piezoelectric stack cannot be produced. The actuators are offset at 120°. In this flight design, redundancy is required, so three



A graphic of the **Actuator Mechanism** mounted on the funnel rim out of the load path. The other end of the flexure can be modified to (a) be free, (b) drive a fixed mass, or (c) drive a free mass at low resonance and produce impacts.

actuators are used though only one is needed to assist in the movement.

The funnel is supported at three contact points offset to the hexapod support contacts. The actuator surface that does not contact the ring is free to expand. Two other configurations can be used to mechanically tune the vibration. The free end can be designed to drive a fixed mass, or can be used to drive a free mass to excite impacts (see figure). Tests on this funnel mechanism show a high density of resonance modes between 1 and 20 kHz. A subset of these between 9 and 12 kHz was used to drive the CheMin actuators at 7 V peak to peak. These actuators could be driven by a single resonance, or swept through a frequency range to decrease the possibility that a portion of the funnel surface was not coincident with a nodal line (line of no displacement).

The frequency of actuation can be electrically controlled and monitored and can also be mechanically tuned by the addition of tuning mass on the free end of the actuator. The devices are solid-state and can be designed with no macroscopically moving parts. This design has been tested in a vacuum at both Mars and Earth ambient temperatures ranging from -30 to 25 °C.

*This work was done by Stewart Sherrit; Curtis E Tucker, Jr.; John Frankovich, and Xiaoqi Bao of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-45856*

## ⚙️ Lunar Soil Particle Separator

John H. Glenn Research Center, Cleveland, Ohio

The Lunar Soil Particle Separator (LSPS) beneficiates soil prior to *in situ* resource utilization (ISRU). It can improve ISRU oxygen yield by boosting the concentration of ilmenite, or other iron-oxide-bearing materials found in lunar soils, which can substantially reduce hydrogen reduction reactor size, as well as drastically decreasing the power input required for soil heating. LSPS particle size separations can be performed to "de-dust" regolith, and to

improve ISRU reactor flow dynamics. LSPS mineral separations can be used to alter the sintering characteristics of lunar soil, and can also be used to separate and concentrate lunar materials useful for manufacture of structural materials, glass, and chemicals.

An initial centrifugal particle size separation is integrated by the LSPS and is followed by magnetic, gravity, and/or electrostatic separations. LSPS hardware for each unit operation exhibits favor-

able properties of low mass and low power requirements. A single feeder delivers soil to the system where sorted particles cascade by gravity to the next unit operation, or to product collection bins. The centrifugal particle separator avoids the use of heavy, eccentric drives that require high power input, and does not require the use of screens that can plug with near-size particles. The magnetic separator uses high-strength, permanent magnets and requires power only to ro-

tate the separation drum. The electrostatic separator uses a high-voltage power module that generates an electrostatic field with very low power consumption. Small vibrators and smooth surfaces placed at appropriate angles are used to avoid particle hang-up.

This system is amenable to testing and operation in vacuum, and the operating parameters and hardware configurations can also be adjusted for testing and evaluation in reduced gravity.

*This work was done by Mark Berggren of Pioneer Astronautics for Glenn Research Cen-*

*ter. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18515-1.*

## ⚙️ Advanced Aerobots for Scientific Exploration

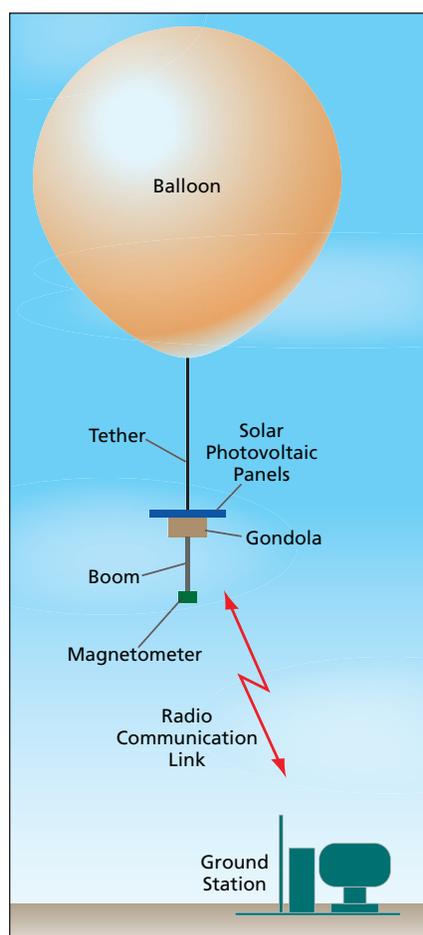
**Relative to prior such aerobots, these are much less massive.**

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

The Picosat and Uninhabited Aerial Vehicle Systems Engineering (PAUSE) project is developing balloon-borne instrumentation systems as aerobots for scientific exploration of remote planets and for diverse terrestrial purposes that can include scientific exploration, mapping, and military surveillance. The underlying concept of balloon-borne gondolas housing outer-space-qualified scientific instruments and associated data-processing and radio-communication equipment is not new. Instead, the novelty lies in numerous design details that, taken together, make a PAUSE aerobot smaller, less expensive, and less massive, relative to prior aerobots developed for similar purposes: Whereas the gondola (including the instrumentation system housed in it) of a typical prior aerobot has a mass of hundreds of kilograms, the mass of the gondola (with instrumentation system) of a PAUSE aerobot is a few kilograms.

The figure schematically depicts a recent PAUSE aerobot designed and built for terrestrial demonstration and testing in the development of a Mars-exploration aerobot. This aerobot includes a gondola with instrumentation system having a total mass <5 kg, the exact mass depending on which of two alternative configurations is chosen. The gondola is suspended from a 12-m-diameter helium balloon, rated at a helium gauge pressure of 5 mb (500 Pa), that is capable of supporting a load of as much as 15 kg for as long as 24 hours.

One of the instruments is a magnetometer. To isolate the magnetometer sensor head from magnetic fields generated by other equipment, the magnetometer sensor head is mounted at the outer end of 0.8-m-long fiberglass boom that extends from the gondola. Also



This **Aerobot** is a prototype of planetary-exploration and terrestrial aerobots having masses of only a few kilograms.

mounted on the boom are an external-temperature sensor and a downward-looking electronic camera containing a complementary metal oxide/semiconductor (CMOS) image sensor.

The gondola houses the magnetometer boards; two other CMOS imagers (one aimed upward, the other aimed

horizontally); a spread-spectrum radio transceiver operating at a nominal carrier frequency of 900 MHz; a flash electronic memory having a capacity of 1GB; a single-board computer; a pressure sensor; lithium primary batteries in one configuration or solar photovoltaic panels (on top of the gondola) and lithium-ion rechargeable batteries in the other configuration; a battery-current sensor; a serial multiplexer; voltage converters; a Global Positioning System (GPS) receiver; and an inertial measurement unit (IMU) that consists of accelerometers, gyroscopes, and magnetometers for all three coordinate axes.

The single-board computer takes temperature, pressure, IMU, battery current and voltage, and GPS readings at time intervals of one second. The magnetometer data are read at a repetition rate of 4 Hz, and an average of four successive readings is recorded every second. The cameras are set to automatically acquire images at intervals of five minutes, but they can also be commanded to acquire images at any time. The data (including digitized images) are both stored in the flash memory and transmitted via the radio transceiver to a ground station. The data transmissions are programmed to take place at set intervals; in addition, data transmissions can also be commanded at any time from the ground station. The instrumentation system has an average power demand <4 W, with occasional jumps to 7 W during transmission of data.

*This work was done by Alberto Behar, Carol A. Raymond, Jaret B. Matthews, Fabien Nicaise, and Jack A. Jones of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-42737*