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 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 ºC.

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) benefits 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 favorable 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-
that extends from the gondola. Also outer end of a 0.8-m-long fiberglass boom sensor head is mounted at the
ated by other equipment, the magne-
sensor head from magnetic fields gener-
for as long as 24 hours.
supporting a load of as much as 15 kg
sure of 5 mb (500 Pa), that is capable of
a balloon, rated at a helium gauge pres-
columns housing outer-space-qualified
strumentation systems as aerobots for
scientific exploration of remote planets
and for diverse terrestrial purposes that
can include scientific exploration, map-
ing, and military surveillance. The un-
derlying concept of balloon-borne gon-
dolas 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 aer-
obot smaller, less expensive, and less
massive, relative to prior aerobots devel-
oped for similar purposes: Whereas the
gondola (including the instrumentation
system housed in it) of a typical prior aerobot has a mass of hundreds of kilo-
grams, the mass of the gondola (with in-
strumentation system) of a PAUSE aer-
obot is a few kilograms.

The figure schematically depicts a re-
cent PAUSE aerobot designed and built
for terrestrial demonstration and testing
in the development of a Mars-explo-
rerion 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
uspended from a 12-m-diameter helium
balloon, rated at a helium gauge pres-
sure 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 magneto-
tometer. To isolate the magnetometer
sensor head from magnetic fields gener-
ated by other equipment, the magneto-
tometer sensor head is mounted at the
outer end of a 0.8-m-long fiberglass boom
that extends from the gondola. Also
mounted on the boom are an external-
temperature sensor and a downward-
looking electronic camera containing a
complementary metal oxide/semi-
ductor (CMOS) image sensor.

The gondola houses the magnetome-
ter boards; two other CMOS imagers
(one aimed upward, the other aimed
horizontally); a spread-spectrum radio
transceiver operating at a nominal car-
rrier frequency of 900 MHz; a flash elec-
tronic memory having a capacity of 1GB;
a single-board computer; a pressure sen-
or; lithium primary batteries in one
configuration or solar photovoltaic pan-
els (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) re-
ceiver; and an inertial measurement unit
(IMU) that consists of accelerometers,
gyrosopes, 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 repeti-
tion rate of 4 Hz, and an average of four
successive readings is recorded every
second. The cameras are set to auto-
matically acquire images at intervals of
five minutes, but they can also be com-
manded to acquire images at any time.
The data (including digitized images)
are both stored in the flash memory
and transmitted via the radio trans-
ceiver 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 av-
erage power demand <4 W, with occa-
sional jumps to 7 W during transmis-
sion of data.

This work was done by Alberto Behar,
Carol A. Raymond, Jaret B. Mattheus, Fa-
 bien Nicaise, and Jack A. Jones of Caltech
for NASA’s Jet Propulsion Laboratory. Fur-
ther information is contained in a TSP (see
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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 in-
strumentation systems as aerobots for scientific exploration of remote planets and for diverse terrestrial purposes that
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