moves the drill axially into the surface while maintaining the proper WOB. The linear translation mechanism is composed of a ball screw and stepper motor that can translate a carriage with high precision and applied load. The carriage slides along rails using self-aligning linear bearings that correct any axial misalignment caused by bending and torsion. The carriage then compresses a series of springs that simultaneously transmit the load to the drill along the bit axis and act as a suspension that compensates for the vibration caused by percussive drilling.

The drill is a compacted, modified version of an off-the-shelf rotary percussive drill, which uses a custom carbide-tipped coring bit. By using rotary percussive drilling, the drill time is greatly reduced. The percussive action fractures the rock debris, which is removed during rotation. The final result is a 0.75-in. (≈1.9-cm) diameter hole and a preserved 0.5-in. (≈1.3-cm) diameter rock core.

This work extends microspine technology, making it applicable to astronaut missions to asteroids and a host of robotic sampling concepts. At the time of this reporting, it is the first instrument to be demonstrated using microspine anchors, and is the first self-contained drill/anchor system to be demonstrated that is capable of drilling in inverted configurations and would be capable of drilling in microgravity.

This work was done by Aaron Parness, Matthew A. Frost, and Jonathan P. King of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-48316, volume and number of this NASA Tech Briefs *issue, and the page number.*

Granular Media-Based Tunable Passive Vibration Suppressor

Potential applications include vehicle shock absorbers, earthquake protection systems, and explosion protection systems.

NASA's Jet Propulsion Laboratory, Pasadena, California

A complete, tested, and tunable shock and vibration suppression device is composed of statically compressed chains of spherical particles. The device superimposes a combination of dissipative damping and dispersive effects. The dissipative damping resulting from the elastic wave attenuation properties of the bulk material selected for the granular media is independent of particle geometry and periodicity, and can be accordingly designed based on the dissipative (or viscoelastic) properties of the material. For instance, a viscoelastic polymer might be selected where broadband damping is desired. In contrast, the dispersive effects result from the periodic arrangement and geometry of particles composing a linear granular chain. A uniform (monatomic) chain of statically compressed spherical particles will have a low-pass filter effect, with a cutoff frequency tunable as a function of particle mass, elastic modulus, Poisson's ratio, radius, and static compression. Elastic waves with frequency content above this cutoff frequency will exhibit an exponential decay in amplitude as a function of propagation distance.

System design targeting a specific application is conducted using a combination of theoretical, computational, and experimental techniques to appropriately select the particle radii, material (and thus elastic modulus and Poisson's ratio), and static compression to satisfy estimated requirements derived for shock and/or vibration protection needs under particular operational conditions. The selection of a chain of polymer spheres with an elastic modulus ≈3 provided the appropriate dispersive filtering effect for that exercise; however, different operational scenarios may require the use of other polymers, metals, ceramics, or a combination thereof, configured as an array of spherical particles.

The device is a linear array of spherical particles compressed in a container with a mechanism for attachment to the shock and/or vibration source, and a mechanism for attachment to the article requiring isolation (Figure 1). This configuration is referred to as a single-axis vibration suppressor. This invention also includes further designs for the integration of the single-axis vibration suppressor into a six-degree-of-freedom hexapod "Stewart" mounting configuration (Figure 2). By integrating each single-axis vibration suppressor into a hexapod formation, a payload will be protected in all six degrees of freedom from shock and/or vibration. Additionally, to further enable the application of this device to multiple operational scenarios, particularly in the case of high loads, the vibration suppressor devices can be used in parallel in any array configuration.

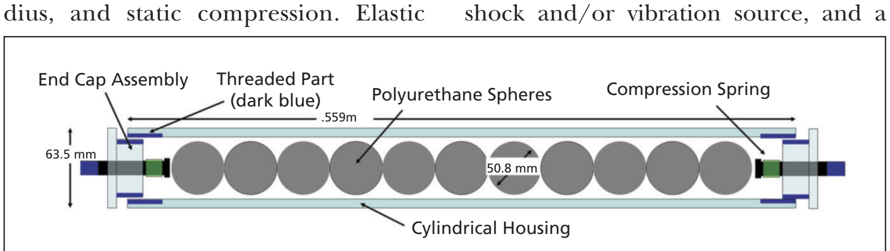

Figure 1. Initial schematic for the **Vibration Suppressor**. Pistons at each end of the cylinder make contact with the granular chain of spheres. Static compression of the granular chain is achieved through the use of soft springs located between the pistons and end caps, which screw onto the container.

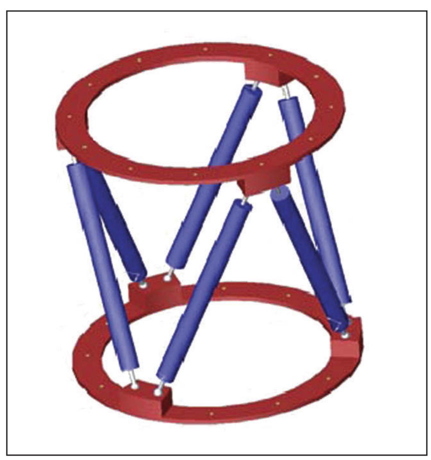

Figure 2. **Hexapod Configuration** for spacecraft mounting.

The parallel application of these devices divides the amplitude of the incident vibrations while preserving the frequency content and thus preserving the designed operation of the invention.

This invention includes the design of a novel, self-contained method for adjustably applying (and simply adjusting or tuning) static compression to the chain of spheres while still transmitting vibration through the dissipative and dispersive media. The dispersive filtering effect for this system only exists as predicted in the presence of static compression, which must be applied in application.

However, the mechanical method for applying this compression must be decoupled enough from the vibration source and payload such that vibrations are not primarily transmitted through the static compression mechanism and around the dissipative and dispersive media. This invention utilizes the solution of a soft spring-loaded casing for the chain of spherical particles, designed so that the first mode of the casing spring mass system is within the pass band of the dispersive filter. Attachment points are coupled directly to the first and last particle of the granular chain for simple attachment in between the payload and vibration source. The soft coupling and low-frequency first mode of the casing ensure the vibrations are transmitted primarily through the filtering media.

Performance of the invention was demonstrated using a prototype single-axis vibration suppressor constructed and tested under both high-amplitude simulated pyroshock and low-amplitude continuous broadband noise perturbations. The results show high attenuation with frequency response characteristics in accordance with the theoretical and numerical predictions. Two orders of magnitude reduction were observed in the shock response spectra at frequencies over 1 kHz, and over two orders of magnitude reduction in the peak accelerations for high-amplitude transient shocklike impacts. Approximately one order of magnitude reduction in the shock response spectra at frequencies below 1 kHz, which was attributed to the dissipative effects of the bulk polyurethane material, was observed.

This work was done by Robert P. Dillon, Gregory L. Davis, Andrew A. Shapiro, John Paul C. Borgonia, Daniel L. Kahn, Nicholas Boechler, and Chiara Daraio of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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Refer to NPO-47655, volume and number of this NASA Tech Briefs *issue, and the page number.*

Miga Aero Actuator and 2D Machined Mechanical Binary Latch

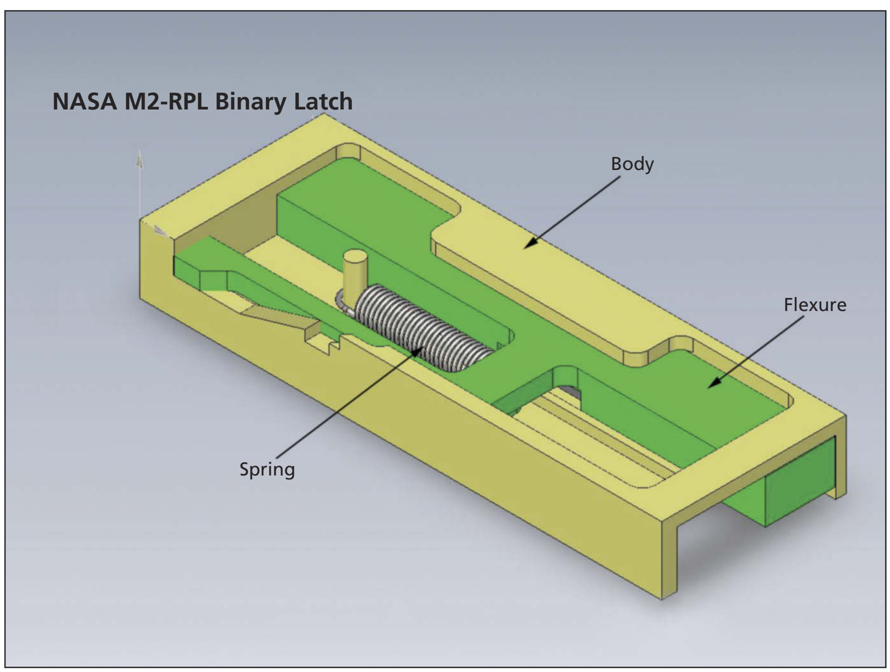
Applications include automobiles and deadbolts for windows or doors.

John H. Glenn Research Center, Cleveland, Ohio

Shape memory alloy (SMA) actuators provide the highest force-to-weight ratio of any known actuator. They can be designed for a wide variety of form factors from flat, thin packages, to form-matching packages for existing actuators. SMA actuators can be operated many thousands of times, so that ground testing is possible. Actuation speed can be accurately controlled from milliseconds to position and hold, and even electronic velocity-profile control is possible. SMA actuators provide a high degree of operational flexibility, and are truly smart actuators capable of being accurately controlled by onboard microprocessors across a wide range of voltages.

The Miga Aero actuator is a SMA actuator designed specifically for spaceflight applications. Providing 13 mm of stroke with either 20- or 40-N output force in two different models, the Aero actuator is made from low-outgassing PEEK (polyether ether ketone) plastic, stainless steel, and nickel-titanium SMA wires. The modular actuator weighs less than 28 grams. The dorsal output attachment allows the Aero to be used in either PUSH or PULL modes by inverting the mounting orientation.

The SPA1 actuator utilizes commercially available SMA actuator wire to provide 3/8-in. (≈1 cm) of stroke at a force of over 28 lb (≈125 N). The force is provided by a unique packaging of the single SMA wire that provides the output force of four SMA wires mechanically in parallel. The output load is shared by allowing the SMA wire to "slip" around the output attachment



A model of the machined **Mechanical Binary Latch**.