Microgravity Drill and Anchor System

This system has applications in rock-climbing and cave exploration, as well as in drilling into rock on the sea floor.

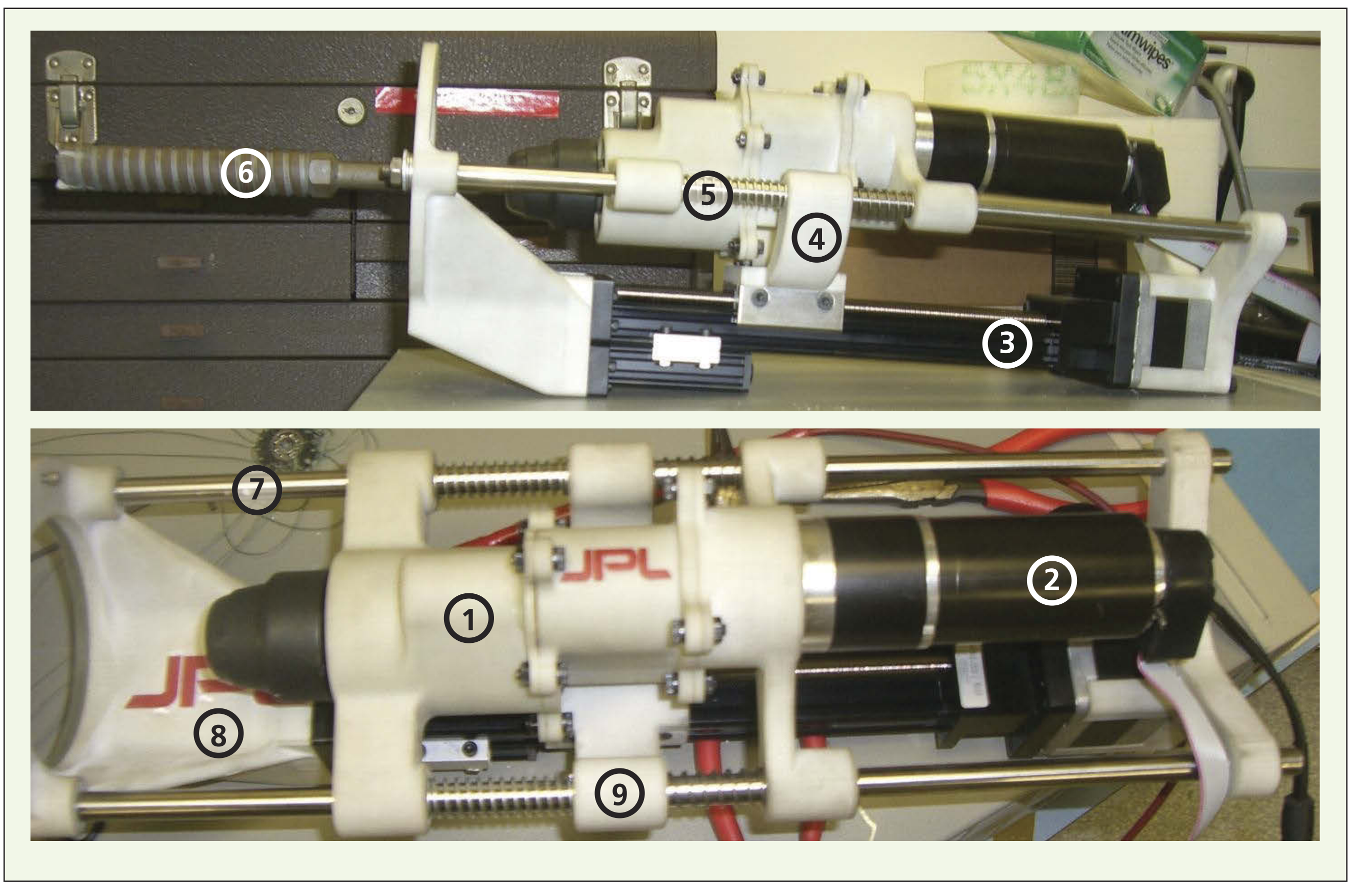
NASA's Jet Propulsion Laboratory, Pasadena, California

This work is a method to drill into a rock surface regardless of the gravitational field or orientation. The required weight-on-bit (WOB) is supplied by a self-contained anchoring mechanism. The system includes a rotary percussive coring drill, forming a complete sampling instrument usable by robot or human. This method of *in situ* sample acquisition using microspine anchoring technology enables several NASA mission concepts not currently possible with existing technology, including sampling from consolidated rock on asteroids, providing a bolt network for astronauts visiting a near-Earth asteroid, and sampling from the ceilings or vertical walls of lava tubes and cliff faces on Mars.

One of the most fundamental parameters of drilling is the WOB; essentially, the load applied to the bit that allows it to cut, creating a reaction force normal to the surface. In every drilling application, there is a minimum WOB that must be maintained for the system to function properly. In microgravity (asteroids and comets), even a small WOB could not be supported conventionally by the weight of the robot or astronaut. An anchoring mechanism would be needed to resist the reactions, or the robot or astronaut would push themselves off the surface and into space.

The ability of the system to anchor itself to a surface creates potential applications that reach beyond use in low gravity. The use of these anchoring mechanisms as end effectors on climbing robots has the potential of vastly expanding the scope of what is considered accessible terrain. Further, because the drill is supported by its own anchor rather than by a robotic arm, the workspace is not constrained by the reach of such an arm. Yet, if the drill is on a robotic arm, it has the benefit of not reflecting the forces of drilling back to the arm's joints. Combining the drill with the anchoring feet will create a highly mobile, highly stable, and highly reliable system.

The drilling system's anchor uses hundreds of microspine toes that independently find holes and ledges on a rock to create an anchor. Once the system is anchored, a linear translation mechanism



The top and side views of the assembled **Microgravity Drill** showing (1) the housing, (2) drive motor, (3) linear translation mechanism, (4) slide carriage, (5) compression springs ×4, (6) bit, (7) guide rails ×2, (8) mounting plate, and (9) housed linear bearings ×6.

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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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.

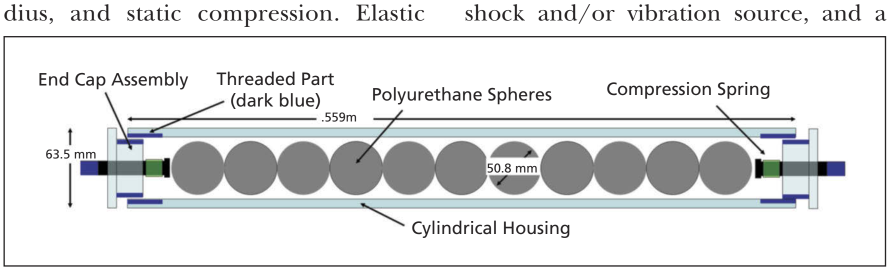

Figure 1. Initial schematic for the **Vibration Suppressor**. Pistons at each end of the cylinder make contact with the granular chain of spheres. Static compression of the granular chain is achieved through the use of soft springs located between the pistons and end caps, which screw onto the container.

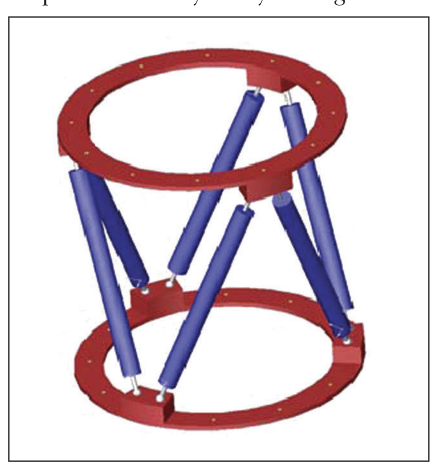

Figure 2. **Hexapod Configuration** for spacecraft mounting.