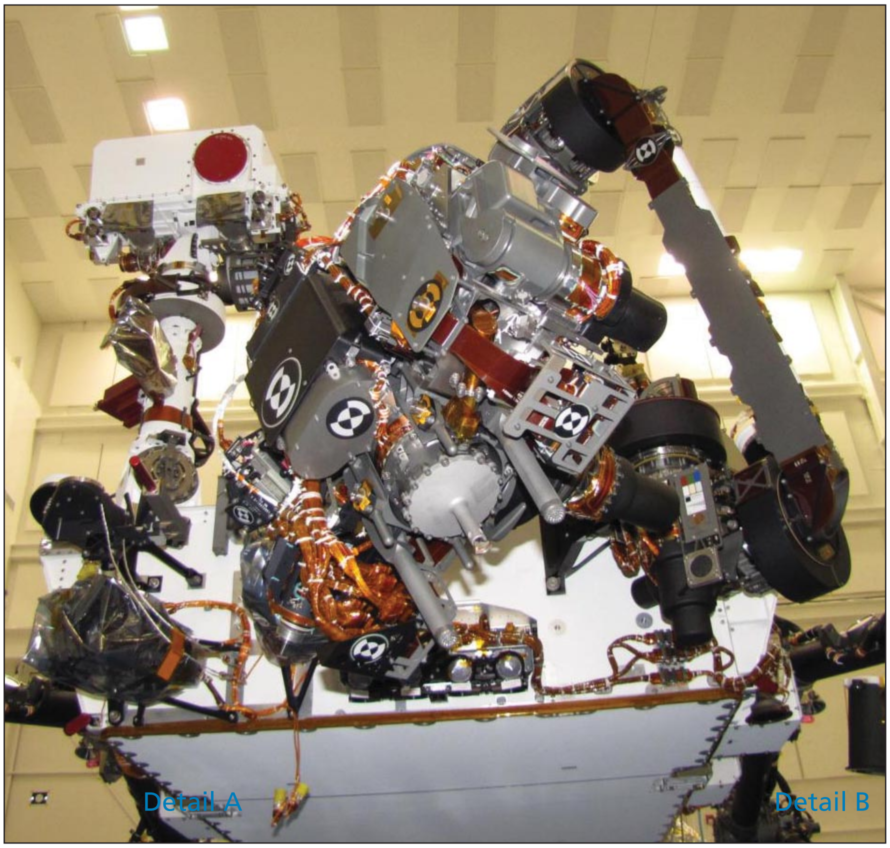


Figure 2. The flight **MSL Drill** undergoing system-level testing after it has been integrated at the end of the robotic arm on the MSL Rover.

shaft to permit the following functions: the transmission of the hammer blow directly onto the bit, the mating of a fresh bit, and release of the bit both in free space and under load.

The drill chuck mechanism (DCM), also residing within the chuck/spindle subassembly, enables the drill to release worn bits and take hold of fresh ones stored on the rover front panel. The design driver was not just to survive a worst-case load scenario — the complete slip of the rover on a Martian slope — but to release the bit while subjected to it.

The drill percussion mechanism (DPM) generates the impact needed to break the rock and the dynamic (vibration) environment required to move powdered sample through the DBA. The mechanism operates at 1,800 blows-per-minute and has variable impact energy levels that range from 0.05 to 0.8 Joules. The DPM is a functionally simple device consisting primarily of a hammer assembly, energy storage spring, and housing/linear bearing assembly. The DPM is actuated by a long-stroke voice coil that is operated using an open loop voltage drive method. Within the DPM is an array of reed switch sensors that provides coarse hammer position telemetry.

The drill translation mechanism (DTM) provides the linear motion of the bit, spindle, chuck, and percussion drill subassemblies for the following functions: maintaining 120 N weight-on-bit (WOB) during sample acquisition, generating the retraction force to extract the bit from the hole, and mating to a fresh bit in the bit box.

The dual-bridge force sensor is required to sense the low WOB because the nominal axial load is too low to be observed in the actuator current telemetry. The inner diameter of the force sensor is axially clamped to the ball nut. The force sensor outer diameter is axially constrained between two preloaded wave springs. The force sensor and wave springs are housed in a gimbal assembly, which couples the translation mechanism to the translation tube. The gimbal isolates the ball screw and force sensor from radial and bending loads.

*This work was done by Avi B. Okon, Kyle M. Brown, Paul L. McGrath, Kerry J. Klein, Ian W. Cady, Justin Y. Lin, and Frank E. Ramirez of Caltech, and Matt Haberland of MIT for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).* NPO-47523

# Ultra-Compact Motor Controller

## Applications include industrial robotic arms, industrial machinery, and automobiles.

*Lyndon B. Johnson Space Center, Houston, Texas*

This invention is an electronically commutated brushless motor controller that incorporates Hall-array sensing in a small, 42-gram package that provides 4096 absolute counts per motor revolution position sensing. The unit is the size of a miniature hockey puck, and is a 44-pin male connector that provides many I/O channels, including CANbus, RS-232 communications, general-purpose analog and digital I/O (GPIO), analog and digital Hall inputs, DC power input (18–90 VDC, 0–10 A), three-phase motor outputs, and a strain gauge amplifier.

This controller replaces air cooling with conduction cooling via a high-thermal-conductivity epoxy casting. A secondary advantage of the relatively good heat conductivity that comes with ultra-small size is that temperature differences within the controller become smaller, so that it is easier to measure the hottest temperature in the controller with fewer temperature sensors, or even one temperature sensor.

Another size-sensitive design feature is in the approach to electrical noise immunity. At a very small size, where conduction paths are much shorter than in conventional designs, the ground becomes essentially isopotential, and so certain (space-consuming) electrical noise control components become unnecessary, which helps make small size possible. One winding-current sensor, applied to all of the windings in fast sequence, is smaller and wastes less power than the two or more sensors conventionally used to sense and control winding currents. An unexpected benefit of using only one current sensor is that it actually improves the precision of current control by using the "same" sensors to read each of the three phases. Folding the encoder directly into the controller electronics eliminates a great deal of redundant electronics, packaging, connectors, and hook-up wiring. The reduction of wires and connectors subtracts substantial bulk and eliminates their role in behaving as EMI (electro-magnetic interference) antennas.

A shared knowledge by each motor controller of the state of all the motors in the system at 500 Hz also allows parallel processing of higher-level kinematic matrix calculations.

*This work was done by William T. Townsend, Adam Crowell, and Traveler Hauptman of Barrett Technology, Inc., and Gill Andrews Pratt of Olin College for Johnson Space Center. For further information, contact the JSC Innovation Partnerships Office at (281) 483-3809.*

*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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*Web site: www.barrett.com*

*Refer to MSC-23930-1, volume and number of this* NASA Tech Briefs *issue, and the page number.*

# A Reversible Thermally Driven Pump for Use in a Sub-Kelvin Magnetic Refrigerator

*Goddard Space Flight Center, Greenbelt, Maryland*

A document describes a continuous magnetic refrigerator that is suited for cooling astrophysics detectors. This refrigerator has the potential to provide efficient, continuous cooling to temperatures below 50 mK for detectors, and has the benefits over existing magnetic coolers of reduced mass because of faster cycle times, the ability to pump the cooled fluid to remote cooling locations away from the magnetic field created by the superconducting magnet, elimination of the added complexity and mass of heat switches, and elimination of the need for a thermal bus and single crystal paramagnetic materials due to the good thermal contact between the fluid and the paramagnetic material.

A reliable, thermodynamically efficient pump that will work at 1.8 K was needed to enable development of the new magnetic refrigerator. The pump consists of two canisters packed with pieces of gadolinium gallium garnet (GGG). The canisters are connected by a superleak (a porous piece of VYCOR® glass). A superconducting magnetic coil surrounds each of the canisters. The configuration enables driving of cyclic thermodynamic cycles (such as the sub-Kelvin Active Magnetic Regenerative Refrigerator) without using pistons or moving parts.

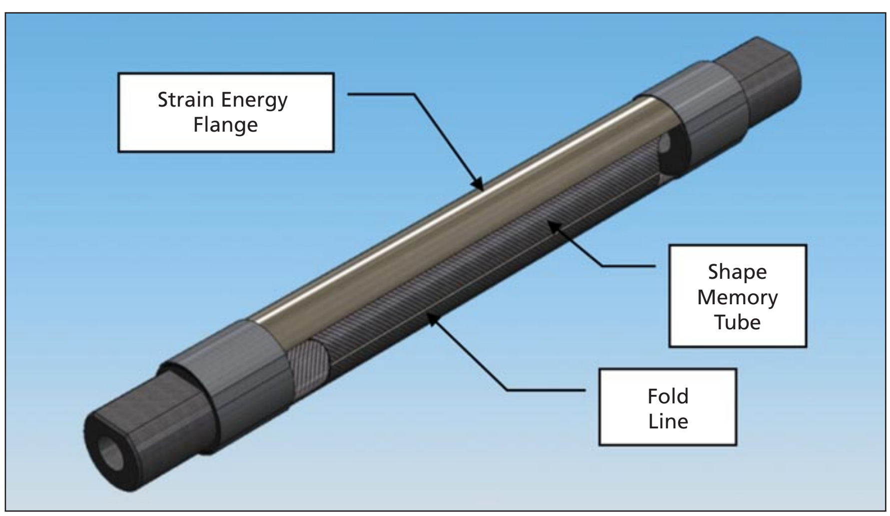
*This work was done by Franklin K. Miller of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15573-1*

# Shape Memory Composite Hybrid Hinge

## The hinge can be used for in-space deployment of antennas, reflectors, cameras, solar panels, and sunshields, as well as in any structure requiring hinges.

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

There are two conventional types of hinges for in-space deployment applications. The first type is mechanically deploying hinges. A typical mechanically deploying hinge is usually composed of several tens of components. It is complicated, heavy, and bulky. More components imply higher deployment failure probability. Due to the existence of relatively moving components among a mechanically deploying hinge, it unavoidably has microdynamic problems. The second type of conventional hinge relies on strain energy for deployment. A tape-spring hinge is a typical strain energy hinge. A fundamental problem of a strain energy hinge is that its deployment dynamic is uncontrollable. Usually, its deployment is associated with a large impact, which is unacceptable for many




The **Shape Memory Composite Hybrid Hinge** is composed of two strain energy flanges and one shape memory composite tube.