

solenoid valve. This design also eliminates the need for many seals used with existing ball valve and globe valve designs, which commonly cause failure, too. This, coupled with the elimination of the valve stem and conventional valve actuator, improves valve reliability and seat life.

Other mechanical liftoff seats have been designed; however, they have only

resulted in increased cost, and incurred other reliability issues. With this novel design, the seat is lifted by simply removing the working fluid pressure that presses it against the seat and no external force is required.

By eliminating variables associated with existing ball and globe configurations that can have damaging effects upon a valve, this novel design reduces

downtime in rocket engine test schedules and maintenance costs.

*This work was done by Bruce Farnor of Stennis Space Center, (U.S. Patent #8,336,849), and is available for licensing. For more information contact the SSC Office of the Center Chief Technologist at (228) 688-1929 or by e-mail SSC-Technology@nasa.gov. Refer to SSC-00264.*

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## ⚙️ Impact-Actuated Digging Tool for Lunar Excavation

*John F. Kennedy Space Center, Florida*

NASA's plans for a lunar outpost require extensive excavation. The Lunar Surface Systems Project Office projects that thousands of tons of lunar soil will need to be moved. Conventional excavators dig through soil by brute force, and depend upon their substantial weight to react to the forces generated. This approach will not be feasible on the Moon for two reasons: (1) gravity is 1/6th that on Earth, which means that a kg on the Moon will supply 1/6 the down force that it does on Earth, and (2) transportation costs (at the time of this reporting) of \$50K to \$100K per kg make massive excavators economically unattractive.

A percussive excavation system was developed for use in vacuum or near-vacuum environments. It reduces the

down force needed for excavation by an order of magnitude by using percussion to assist in soil penetration and digging. The novelty of this excavator is that it incorporates a percussive mechanism suited to sustained operation in a vacuum environment.

A percussive digger breadboard was designed, built, and successfully tested under both ambient and vacuum conditions. The breadboard was run in vacuum to more than 2 times the lifetime of the Apollo Lunar Surface Drill, throughout which the mechanism performed and held up well. The percussive digger was demonstrated to reduce the force necessary for digging in lunar soil simulant by an order of magnitude, providing reductions as high as 45:1.

This is an enabling technology for lunar site preparation and ISRU (In Situ Resource Utilization) mining activities. At transportation costs of \$50K to \$100K per kg, reducing digging forces by an order of magnitude translates into billions of dollars saved by not launching heavier systems to accomplish excavation tasks necessary to the establishment of a lunar outpost. Applications on the lunar surface include excavation for habitats, construction of roads, landing pads, berms, foundations, habitat shielding, and ISRU.

*This work was done by Jack Wilson, Philip Chu, Jack Craft, Kris Zacny, and Chris Santoro of Honeybee Robotics Ltd. for Kennedy Space Center. For further information, contact the Kennedy Innovative Partnerships Program Office at (321) 861-7158. KSC-13398*

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## ⚙️ Flexible Mechanical Conveyors for Regolith Extraction and Transport

*John H. Glenn Research Center, Cleveland, Ohio*

A report describes flexible mechanical conveying systems for transporting fine cohesive regolith under microgravity and vacuum conditions. They are totally enclosed, virtually dust-free, and can include enough flexibility in the conveying path to enable an expanded range of extraction and transport scenarios, including nonlinear drill-holes and excavation of enlarged subsurface openings without large entry holes.

The design of the conveyors is a modification of conventional screw conveyors such that the central screw-shaft

and the outer housing or conveying-tube have a degree of bending flexibility, allowing the conveyors to become nonlinear conveying systems that can convey around gentle bends. The central flexible shaft is similar to those used in common tools like a "weed whacker," consisting of multiple layers of tightly wound wires around a central wire core.

Utilization of compliant components (screw blade or outer wall) increases the robustness of the conveying, allowing an occasional oversized particle to pass

though the conveyor without causing a jam or stoppage.

*This work was done by Otis R. Walton and Hubert J. Vollmer of Grainflow Dynamics Inc., and Ali Abdel-Hadi of Tuskegee University for Glenn Research Center. 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: Steven Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-19015-1.*