mounted in a "saddlebag" configuration on either side. Two counter-rotating bucket drum digging implements are held by a rotating cantilever mechanism at the fore and aft ends of the mobility platform. The cantilever arms are raised and lowered to engage the bucket drum into the soil or regolith. A variable cutting depth is possible by controlling the angles of the cantilever arms.

The unit has three modes of operation: load, haul, and dump. During loading, the bucket drums will excavate soil/regolith by using a rotational motion whereby scoops mounted on the drum's exteriors sequentially take multiple cuts of soil/regolith while rotating at approximately 20 revolutions per minute. During hauling, the bucket drums are raised by rotating the arms to provide a clearance with the surface being excavated. The mobility platform can then proceed to move while the soil/regolith remains in the raised bucket drums. Finally, when the excavator reaches the end-user or dump location, the bucket drums are commanded to reverse their direction of rotation to the opposite spin from digging, causing the gathered materials to be expelled out of each successive scoop. It can also stand up in a vertical mode to deliver regolith over the edge of a hopper container.

The RASSOR can operate with either side up in a reversible mode and it can flip itself over. This means the unit can drive directly off of the deck of a lander to deploy in low gravity, eliminating a deployment mechanism, which saves mass and increases reliability due to decreased complexity. The RASSOR system is scaleable and may be mounted on mobility platforms of various sizes, and has control equipment — wireless signal router, computer, joystick, E-stop, and associated software.

*This work was done by Robert P. Mueller, Jonathan D. Smith, Tom Ebert, Rachel Cox, Laila Rahmatian, and James Wood of Kennedy Space Center; Jason Schuler of EASI; and Andrew Nick of Sierra Lobo. For more information, contact the Kennedy Space Center Innovative Partnerships Office at 321-867-5033. Refer to KSC-13664.*

# Magnetically Actuated Seal

## Design replaces existing pressure-actuated lift-off seals in turbopumps and eliminates low pressure drains, thereby increasing overall efficiency.

*Marshall Space Flight Center, Alabama*

This invention is a magnetically actuated seal in which either a single electromagnet, or multiple electromagnets, are used to control the seal's position. This system can either be an open/close type of system or an actively controlled system.

A lift-off seal (LOS) is a type of shaft seal used in a turbopump that does not allow propellants to enter the turbine during pre-start operations, such as when a cryogenic turbopump is being chilled-in or when the pump is being primed prior to start. Typically, lift-off seals are pressure activated and a low constant pressure in the seal's secondary seal cavity is needed to provide the delta-P necessary for the seal to open. This is typically accomplished with an overboard drain cavity. The LOS must remain closed during pre-start operations. This prevents cryogenic liquid from chilling-in the turbine, which would result in excessive thermal shock, and subsequent turbine blade cracking. During the start-transient, the LOS must open to prevent propellant gasification and sometimes to provide coolant to the turbine disk. If it opens too soon, however, the turbine pressure can be higher than the pump pressure, and result in hot gas ingestion into the pump or bearings. If it opens too late, the seal surface speed becomes excessive, and results in excessive wear and premature failure of the seal.

The magnetically actuated LOS is more reliable and requires no low-pressure secondary seal cavity or overboard drain (thereby improving efficiency). An electromagnet is used to open and close the seal at an exact prescribed instant during the transient. Additionally, with the magnetically actuated seal, the particular instant can be different between the start transient and shut-down transient. This allows for more desirable and predictable transient performance of the turbopump as well as more certain wear performance of the seal.

*This work was done by Alex Pinera of Florida Turbine Technologies, Inc. for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32979-1.*

# Hybrid Electrostatic/Flextensional Mirror for Lightweight, Large-Aperture, and Cryogenic Space Telescopes

## A much lighter-weight structure with higher correction range uses polymer-based membrane mirror technology.

*Marshall Space Flight Center, Alabama*

A lightweight, cryogenically capable, scalable, deformable mirror has been developed for space telescopes. This innovation makes use of polymer-based membrane mirror technology to enable large-aperture mirrors that can be easily launched and deployed. The key component of this innovation is a lightweight, large-stroke, cryogenic actuator array that combines the high degree of mirror figure control needed with a large actuator influence function. The latter aspect of the innovation allows membrane mirror figure correction with a relatively low actuator density, preserving the lightweight attributes of the system.

The principal components of this technology are lightweight, low-profile, high-stroke, cryogenic-capable piezoelectric actuators based on PMN-PT (piezoelectric lead magnesium niobate-lead titanate) single-crystal configured in a flextensional actuator format; high-quality, low-thermal-expansion polymer membrane mirror materials developed by NeXolve; and electrostatic coupling between the membrane mirror and the piezoelectric actuator assembly to minimize problems such as actuator print-through. PMN-PT single-crystal material provides a piezoelectric driver that delivers appreciable strain from above room temperature to less than 20 K. The combination of a polymer membrane material for the mirror and the flextensional actuator design results in a very lightweight structure with a large range of aberration correction.

The membrane mirror is a low-stiffness component that requires relatively low actuator force. The flextensional actuator design is a low-force, high-displacement (>400 microns), lightweight piezoelectric positioning technology. The combination of the two results in a much lighter-weight structure with higher correction range than can be achieved with conventional piston-style actuators and glass face sheets. To combat actuator print-through and to lessen actuator density, a hybrid piezoelectric-electrostatic actuation approach was developed. The actuators push on an electrode plate held at a high voltage. The plate is coupled to the mirror through the electrostatic field established by the applied voltage, but does not make direct mechanical contact with the mirror. As the actuators move the electrode plate, the mirror is stretched or relaxed as needed. This allows a high degree of figure control with a relatively small actuator density. Control can be further enhanced by including multiple actuators for each electrode plate, allowing both piston and tip/tilt motion.

*This work was done by Brian Patrick and James Moore of ManTech NeXolve Corp., and Wesley Hackenberger and Xiaoning Jiang of TRS Technologies, Inc. for Marshall Space Flight Center. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32878-1.*