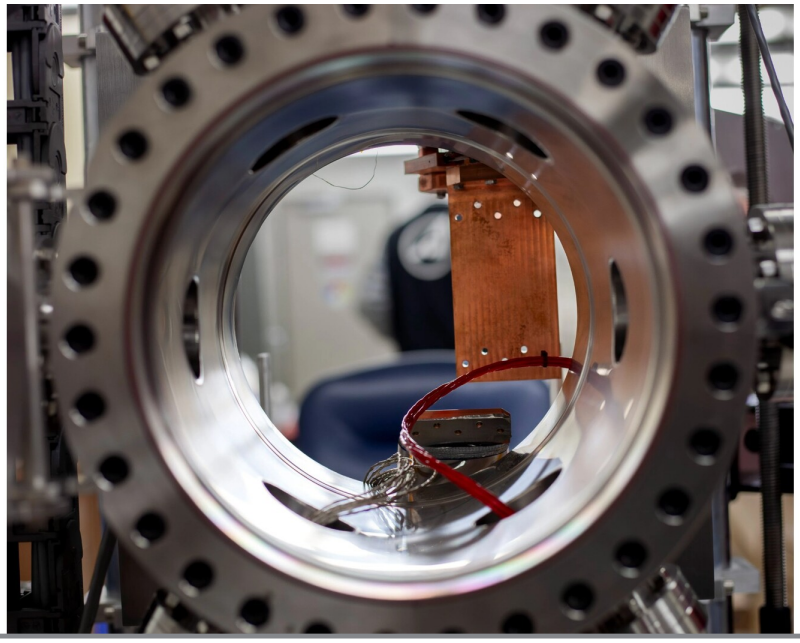


National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Mechanical and Fluid Systems

Lunar Environment Structural Test Rig (LESTR)

A Low-Temperature Shape-Memory Alloy Mechanical Cyclical Testing Apparatus

The rapid acceleration of space exploration has created an increased demand for space environment testing of metal materials. All materials being used to manufacture flight hardware, electronics, and other products for government and commercial space require controlled replication of extreme temperature and vacuum conditions around mechanically loaded specimens to generate data that reflects in-service behavior.

Developed at Glenn Research Center, the Lunar Environment Structural Test Rig (LESTR) introduces a dry, cryogen-free approach to environmental testing that brings lunar-relevant cryogenic-vacuum testing into ordinary labs by integrating with existing universal testing machines. This technology was developed for Glenn researchers to evaluate materials and shape memory alloy mechanisms used in lunar mobility. LESTR simulates environments with vacuum and very low temperatures, such as permanently shadowed lunar regions. It addresses long-standing problems of conventional environmental testing methods by removing consumable cryogens and their associated logistics, improving safety, and overcoming the limitations of air/gas cooling that cannot achieve vacuum or the coldest required setpoints. The result is a practical path to representative, mission-relevant structural data under extended cyclic conditions, helping teams reduce operational burden and make faster, more confident qualification decisions for cold environment applications.

BENEFITS

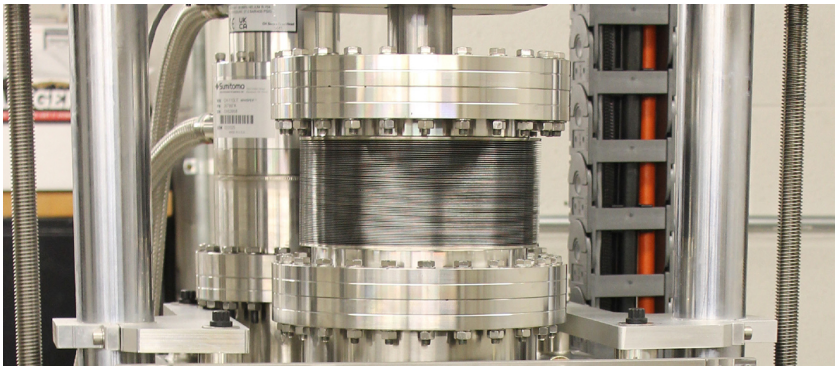
- Dry, Cryogen-free Operation: Eliminates consumable handling, lowering costs and safety overhead.
- Adjustable Temperature Control: Variable temperature to match mission relevant profiles.
- Endurance-ready Testing: Supports long, continuous cyclic runs for reliable durability data.
- Better Measurement Quality: Optical access enables non-contact strain measurement for accurate results.
- Scalable and Integrable: Modular architecture mates with commercial load frames and expands with program needs.

THE TECHNOLOGY

LESTR is a unique mechanical test rig that doesn't use cryogenic fluids to chill the materials, flight hardware, or electronics during testing. Instead, it uses a high powered refrigerator called a cryocooler to remove heat in a completely dry vacuum. This makes LESTR safer and more affordable than traditional methods for testing at temperatures as low as 40 Kelvin, or about -388 degrees Fahrenheit.

LESTR encloses standard tensile and four-point bending fixtures inside a high-vacuum chamber and mates with commercial universal testing machines for stress- or strain-controlled cyclic evaluation. Using off the shelf components makes it more affordable and easier to run, and it allows larger samples with a high-power camera for pre-marked samples. Inside the chamber, a closed cycle cryocooler couples to the load train through flexible thermal straps with integrated heaters, allowing operators to adjust the temperature to cryogenic setpoints without liquid cryogens. Dedicated optical access supports non-contact strain measurement (e.g., digital image correlation), enabling high-fidelity tracking of deformation and functional stability across long cyclic runs.

The concept of operations uses a roughing pump to achieve soft vacuum followed by a turbo pump for hard vacuum. A pressure transducer is used for pump-down, and the cryocooler then lifts heat from the load train and cold box through the thermal straps to the cold head, establishing stable low-temperature, high-vacuum conditions. Loads are applied through the load head and fixtures, measured at the load cell, and grounded through the static base, while electrical feedthroughs carry heater power and sensor signals. LESTR provides a unique, true dry cryogenic mechanical test environment with adjustable temperature, long-duration cyclic capability, and vacuum integrity that mirrors relevant lunar conditions. Because it integrates with existing test frames and eliminates consumables, LESTR simplifies operations, enhances safety, and delivers more representative structural data for cold-environment mechanisms and materials, accelerating qualification with synchronized thermo-mechanical profiles. This technology is assessed at Technology Readiness Level (TRL) 7 and is available for patent licensing.



APPLICATIONS

The technology has several potential applications:

- Cryogenic Materials and Durability: Fatigue, fracture, and lifecycle testing for materials used in extreme cold.
- Electronics for Mobility Systems: Low-frequency vibration qualification for components used in rovers and other mobility platforms.
- Mobility Stems and Drivetrain: Evaluation of shock absorbers, wheel materials, springs, and textiles for cold-environment vehicles.
- Textiles: Assessment of fabrics and composites for lunar habitats and EVA suits.
- MRI – Healthcare – new generation of magnets can be tested using this technology.
- Cryogenic Welding
- Quantum Computers

PUBLICATIONS

Patent Pending

https://ntrs.nasa.gov/citations/20260005630

More Information

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Agency Licensing Concierge

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LEW-20642-1, LEW-TOPS-197