Cryobotics: Testing of Strainwave Gearboxes J. D. Smith[1], J. M. Schuler[2], A. J. Nick[3], [1]NASA Kennedy Space Center(Mail Code: UB-R1 Kennedy Space Center, Florida 32899, jonathan.d.smith@nasa.gov), [2]NASA Kennedy Space Center (Jason.m.schuler@nasa.gov), [3]NASA Kennedy Space Center (Andrew.j.nick@nasa.gov).

Introduction: Operating in the extreme Lunar environment has many challenges. One of these challenges includes cryogenic temperature conditions. Realistic performance testing on Earth is essential to designing sustainable hardware for the Lunar surface. Cryobotics is a technology focus area for robotic systems and rotating machinery that must operate at cryogenic temperatures in environments including Earth, low Earth orbit, Mars, Moon, asteroids, Solar orbit, planetary orbit, or those encountered during travel among these destinations. The heat transmission effects of these temperatures, as well as the large temperature differences (ΔT) and quick changes in temperatures (thermal transients), and thermal cycling must be understood by testing in relevant environments. The applications include mining equipment, spacecraft mechanisms, rotating machinery for superconducting power generation, cryofuel pumping systems, and so forth. Participating with science and industry partners in tribology research, dry lube technology, and material science in a collaborative way is a key facet of the focus area of cryobotics.

This abstract addresses the testing of an extreme cold environment test chamber and the initial testing of Harmonic Drive strainwave gear sets and Bulk Metallic Glass flexsplines in strainwave gear sets. This chamber was specifically designed for the testing of actuator subsystems such as planetary gearboxes, strainwave gear sets, and full actuators in vacuum and at approximately 100 kelvin (K) and below. The chamber's capabilities include life testing while under specific loads, gear efficiency, gear wear, temperature monitoring, and other operational parameters.

The test chamber was verified to accurately measure gearbox performance by testing known COTS gear sets in an ambient temperature and atmosphere environment. Once verified, the chamber was used to test a COTS Harmonic Drive and a Bulk Metallic Glass (BMG) Gear flexspline for a strainwave gear set at less than -200 degree Celcius, in medium vacuum, and a 33 N*m torque was applied. These gear sets were tested without the presence of any grease and were only burnished with moly disulfide.

The results of these tests proved the need more research in this Cryobotics area to advance heater less actuators. The COTS gear set ran without an input load for approximately 5000 input revolutions before failing. Figure 1 shows the flexspline worn teeth after the test was completed.

Figure 1. COTS Flexspline after test

The BMG gear set ran without input load for approximately 4500 input revolutions before failing. Figure 2 shows the broken BMG flexspline after the test. Also notice the lack of wear on the teeth.

Figure 2. BMG Flexspline after test

After further examination of the gear teeth wear and data crunching it seems that even though the BMG gear set failed before the COTS gear set, it may have performed better if it did not have a stress concentration from a manufacturing defect that caused it to shear the flexspline below the teeth. Future work will correct this manufacturing defect to continue the testing of strainwave and planetary gear sets and full actuator systems.