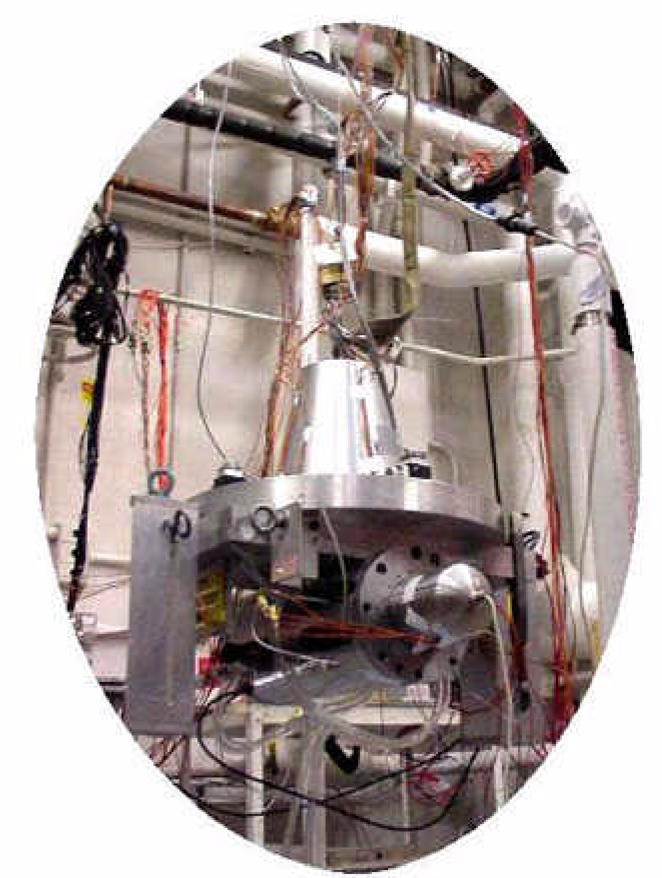
Understanding of the Dynamics of the Stirling Convertor Advanced by Structural Testing

The NASA Glenn Research Center, the U.S. Department of Energy, and the Stirling Technology Company (STC) are developing a highly efficient, long-life, free-piston Stirling convertor for use as an advanced spacecraft power system for future NASA missions, including deep-space and Mars surface applications. As part of this development, four structural dynamic test programs were recently performed on Stirling Technology Demonstration Convertors (TDC's) that were designed and built by STC under contract to the Department of Energy. This testing was performed in Glenn's Structural Dynamics Laboratory and Microgravity Emissions Laboratory.

The first test program, in November and December 1999, demonstrated that the Stirling TDC could withstand the harsh random vibration experienced during a typical spacecraft launch and survive with no structural damage or functional power performance degradation. This was a critical step in enabling the use of Stirling convertors for future spacecraft power systems. The most severe test was a 12.3g_{rms} random vibration test, with test durations of 3 min per axis. The random vibration test levels were chosen to simulate, with margin, the maximum anticipated launch vibration conditions.

The Microgravity Emissions Laboratory is typically used to measure the dynamics produced by operating space experiments and the resulting impact to the International Space Station's microgravity environment. For the second Stirling dynamic test program, performed in January 2001, the Microgravity Emissions Laboratory was used to characterize the structure-borne disturbances produced by the normal operation of a pair of Stirling convertors. The forces and moments produced by the normal operation of a Stirling system must be recognized and controlled, if necessary, so that other nearby spacecraft components, such as cameras, are not adversely affected. The Stirling convertor pair emitted relatively benign tonal forces at its operational frequency and associated harmonics. Therefore, Stirling power systems will not disturb spacecraft science experiments if minimal appropriate mounting efforts are made.



Dynamic emissions of a pair of Stirling convertors were measured in Glenn's Microgravity Emissions Laboratory.
Stirling convertors on the test stand. The dynamic emissions (degree of vibrational forces introduced into the structure by the operating hardware) are measured. Of interest is having a low amount of vibrational forces introduced into the host support structure because NASA is interested in how well the Stirling convertor would adapt for use onboard the International Space Station, where a continuous low-microgravity environment is important to scientific research.

The third test program, performed in February and May 2001, resulted in a modal characterization of a Stirling convertor. Since the deflection of the TDC piston rod, under vibration excitation, was of particular interest, the outer pressure shell was removed to allow access to the rod. Through this testing, the Stirling TDC's natural frequencies and modes were identified. This knowledge advanced our understanding of the successful 1999 vibration test and may be utilized to optimize the output power of future Stirling designs.

The fourth test program, in April 2001, was conducted to characterize the structural response of a pair of Stirling convertors, as a function of their mounting interface stiffness. The test results provide guidance for the Stirling power package interface design. Properly designed, the interface may lead to increased structural capability and power performance beyond what was demonstrated in the successful 1999 vibration test.

Dynamic testing performed to date at Glenn has shown that the Stirling convertors can withstand liftoff random vibration environments and meet "good neighbor" vibratory emission requirements. Furthermore, the future utilization of the information obtained during the tests will allow the corporation selected to be the Stirling system integrator to optimize their convertor and system interfaces designs. Glenn's Thermo-Mechanical Systems Branch provides Stirling technology expertise under a Space Act Agreement with the Department of Energy. Additional vibration testing by Glenn's Structural Systems Dynamics Branch is planned to continue to demonstrate the Stirling power system's vibration capability as its technology and flight system designs progress.

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Structural Dynamics Laboratory : http://facilities.grc.nasa.gov/sdl/
Microgravity Emissions Laboratory: http://www.grc.nasa.gov/WWW/MAEL/
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