Thermoacoustic Duplex Technology for Cooling and Powering a Venus Lander. A. R. Walker[1], M. S. Haberbusch[1], and J. Sasson[1], [1]Sierra Lobo, Inc. 11401 Hoover Road, Milan, Ohio 44846

Sierra Lobo is developing a Thermoacoustic Stirling Heat Engine (TASHE) to drive a Pulse Tube Refrigerator (PTR) and linear alternator for instrument electronics cooling and power generation on a Venus lander and for other power generation and cooling applications. The proposed technology significantly improves energy conversion efficiency for space power systems and enables a unique capability of simultaneously generating electrical power and refrigeration. The TASHE that has been designed suits the need of a long-lived Venus lander. However, any space power program that requires the generation of electrical power from solar or nuclear sources will be able to transition to this technology to accommodate the energy source. Space Systems will be able to take advantage of the high-reliability of the TASHE driver with no moving parts at the hot end and high energy conversion efficiency.

The TASHE is directly coupled to a PTR in a duplex configuration for the Venus Lander. A linear alternator, also directly coupled, generates electricity. This configuration reduces the number of energy conversion processes and thus maximizes efficiency. The PTR cools a space called the coldbay that houses the linear alternator and scientific instruments. There are no moving parts in the TASHE, thus increasing the reliability of the heat engine. The only moving parts in the system are free pistons that tune the resonant frequency, which operate at Venus-ambient temperature, and the linear alternators that operate near Earth-ambient temperature. The linear alternators consist of magnets and coils that are not suitable operating at Venus-ambient temperature (500°C). The free pistons and linear alternators are arranged in a dual-opposed configuration to minimize system vibration.

The innovative feature of this Venus Duplex System is the use of the supercritical carbon dioxide (CO2) from the Venus atmosphere as the working fluid. This provides two key advantages: (1) The system can make the transit to Venus in a low-pressure state, which significantly decreases system mass, and (2) the effect of leakage during operation is minimized, providing confidence in long mission lifetime.

An innovative development approach is proposed to develop the system near Earth ambient conditions. This approach utilizes similitude of a supercritical CO_2 system with a supercritical N_2 system. Components of the two systems are identical in size, but keeping the relevant thermoacoustic physics equivalent scales other factors of the design. This scaling results in a Similitude Duplex System that operates at 46.1 percent of the maximum pressure and 41.5 percent of the maximum operating temperature thus enabling the manufacture and testing of Similitude Duplex System hardware for validating the thermoacoustic models without the need for exotic high temperature materials.

The system is designed by modeling the thermoacoustic physics of the Venus Duplex System with DeltaEC. The initial detailed thermoacoustic model indicates that a TASHE working at 23 percent efficiency and a PTR operating at 23.7 percent efficiency can effectively produce 20 W of electrical power and 154 W of cooling at an operating temperature of 350°C using the heat from 15 General Purpose Heat Sources (GPHS). CAD models of the resulting Similitude Duplex System hardware configuration have been developed. These CAD models provide insight into manufacturability and enable design iteration with the thermoacoustic models for further optimization and updates based on selection of final component selection.

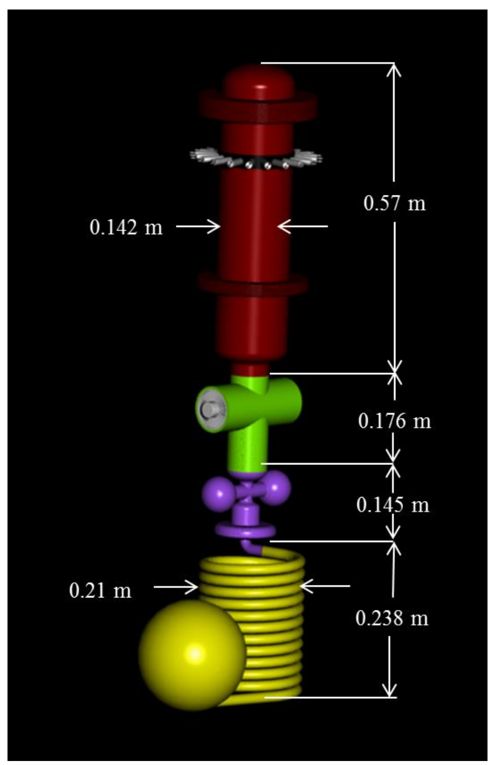

Figure 1 – Similitude Duplex System Solid Model