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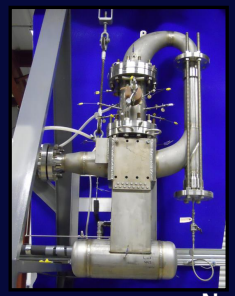
SIERRA LOBO®

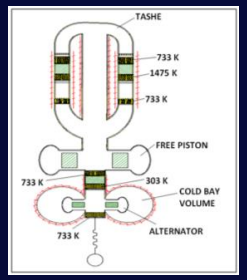
Thermoacoustic Stirling Heat Engine (TASHE) for Space Power and Cooling

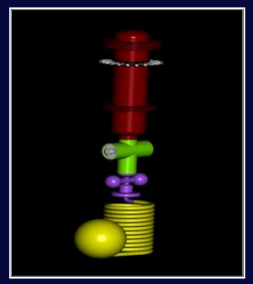
SBIR Phase 3

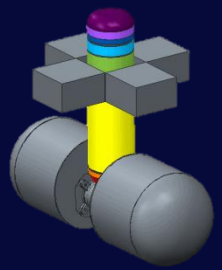
Presentation to:

Stirling Technical Interchange Meeting
NASA Glenn Research Center
June 29, 2015





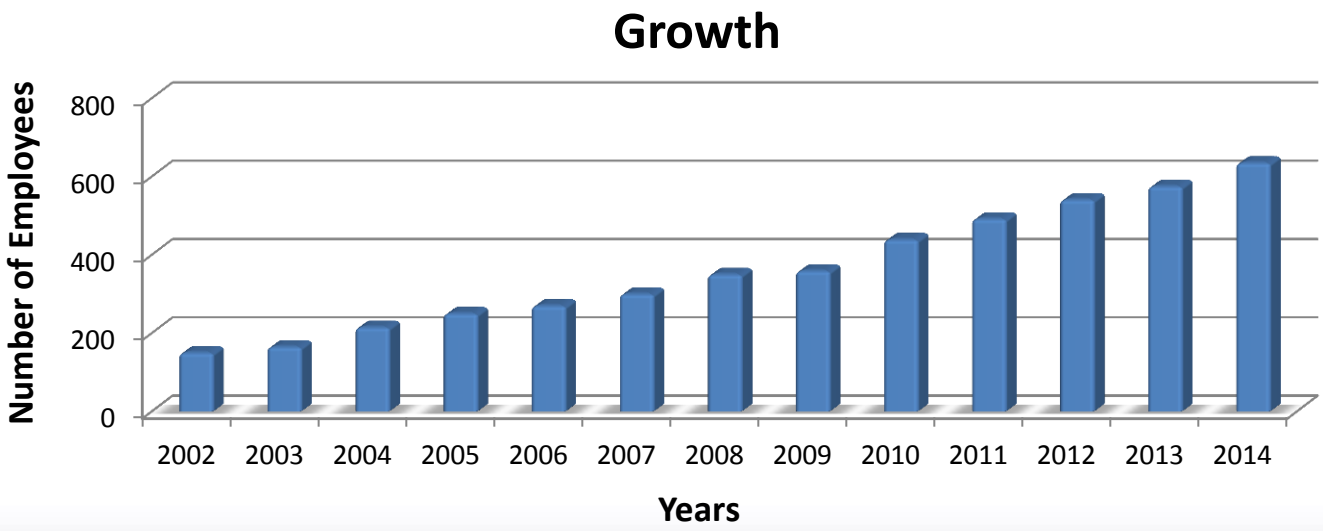




Non-Proprietary Information

Overview
Sierra Lobo, Inc.

- Focus on high-tech engineering services, innovative technologies, and reliable products
- More than 650 engineers, technicians, and administrative professionals
- Hispanic-American owned, small disadvantaged business, incorporated in 1993
- Customer focused with sustained performance in the “excellent” range on all contracts



Integrity, Trust, and Focus on Excellence

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Research and Technology Group
Overview

Primary Skills and Capabilities

- Research and development
- Design, simulation, and analysis
- Solid modeling
- Manufactured systems
- Fab and assembly of pressurized systems
- Systems integration
- Product assurance processes for flight
- Commercialization

Facilities and Infrastructure

- 35,000 sq. ft. engineering, manufacturing, and test facility
- Liquid hydrogen test capability

Our Goal is to Fly the "Wolf" in Space.

Technologies and Products

- Underwater vehicle energy systems
- Cryo-Tracker® Mass Gauging System
- CryoCube™ CubeSats
- Cryogenic storage systems
- Densified propellant management systems
- Cryocoolers
- Thermoacoustic Stirling Heat Engines

Applications

- Launch vehicle, missile, spacecraft, underwater vehicle, cryogenic fluid management
- Ground vehicles using alternative energy sources – LH_2 and NG
- Ground support equipment
- Laboratory and test facility
- Sensor cooling
- Aerospace power and propulsion

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TDEC
Technology Development and Engineering Center

TDEC Complex

- Engineering services complex
- Cradle to grave services
- IT infrastructure for virtual engineering
- Manufacturing and assembly complex
- Class 10,000 assembly area
- Secure research lab
- Bonded storage areas
- Hardware test and V&V capabilities of extreme pressure and temperature systems
- Cryogenic fuels and oxidizer testing complex – Sierra Lobo Test Facility (SLTF)
  - 1500 gallons of LH_2 storage and distribution
  - High and low speed DAQ, video and controls
  - Class I Group B, C, D electrical classification

TDEC, Milan, Ohio

SLTF – LH_2 dewar fill

Enhanced solutions resulting from the synergies between our services, technologies, and products.

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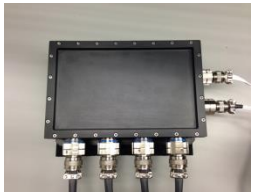
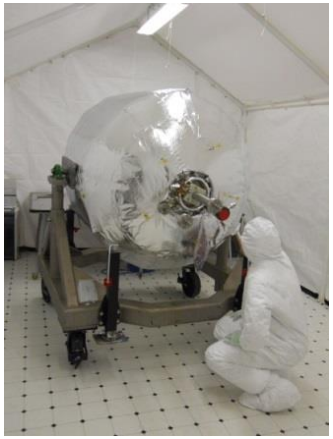
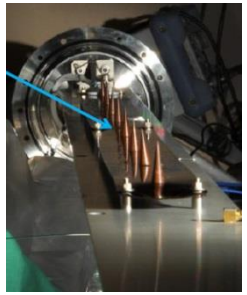
SLI Aerospace Critical Products

Processes Certified for Aerospace Critical Products

- **Quality Assurance Program - ISO9001/AS9100/CMMI Maturity Level 2 and Capability Level 3 in Risk Management**
- **Certified as "A Provider of Engineering and Technical Services, Including Hardware Fabrication and Testing, to the Aerospace and Transportation Industries."**
- **Configuration Management, Bonded Storage ESD Controls, FOD Management Program**
- **Aerospace Critical Products/Projects**
  - Cryo-Tracker® Sensor Systems
  - CryoCube™ CubeSat
  - Zero Boil-off Liquid Oxygen Demonstration Tank
- **Contracts with Aerospace Critical Tasks**
  - NASA Goddard – James Web Telescope
  - NASA Kennedy – Space Shuttle/SLS Flight Systems







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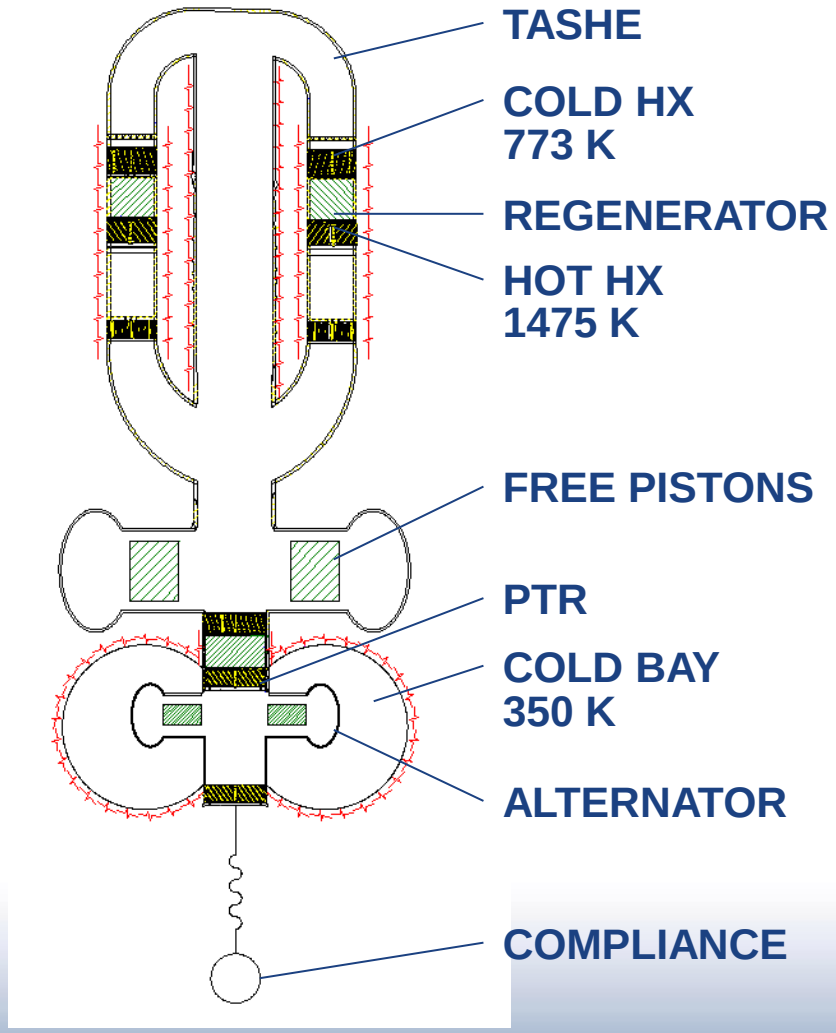
Problem Statement

- **NASA is planning to send a probe to study Venus in the 2020–2025 timeframe. Missions using a surface lander are desirable to maximize science return.**
- **Venus' environment is challenging: High surface temperature (500°C) and pressure (92 atm.), supercritical carbon-dioxide (CO_2)**
- **Maturation of technology enabling long-term operation of instrumentation, particularly a seismometer, on the surface of Venus was identified as a high priority in the Venus Flagship Mission Science and Technology Definition Team (STDT) report.**
- **NASA identified duplex technology for simultaneously cooling and electric power generation as a key technology for long-life mission operations on Venus when coupled with a radioisotope heat source.**

Duplex System Design Concept

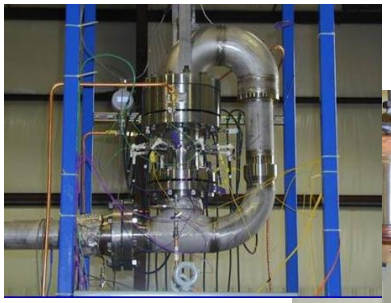


- Compact system for space applications
- Smaller annular radius on the Hot Heat Exchanger (HHX) can potentially transport heat from outside to inside through conduction
- Concentric Thermoacoustic Stirling Heat Engines (TASHEs) have been operated in the past
- Dual-opposed pistons reduce system vibration
- Linear alternator has high efficiency and operates inside the cold bay

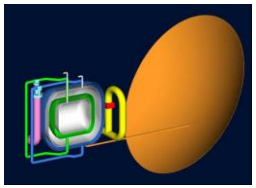
SLI TASHE Systems

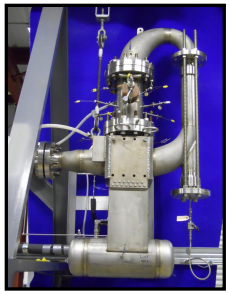
SLI has been Producing TASHE Systems for over 14 Years

- **NASA Space Launch Initiative - Densified Propellant Management System (2001 – 2003)**
  - Thermoacoustic densifier uses acoustic power to efficiently and simultaneously densify both hydrogen and oxygen propellants
  - Patented thermoacoustic densifier (U.S. Pat. Nos. 7,043,925 and 7,347,053)

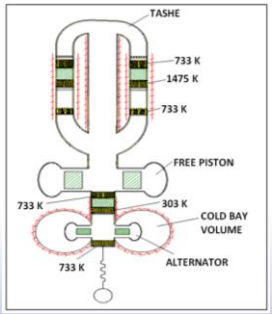


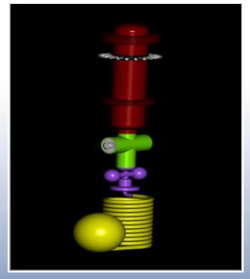
- **AFRL SBIR Phase I and II - Solar Powered Thermoacoustic Stirling Heat Engine Pulse Tube Cryocooler (2003 – 2009)**
  - TASHE Developed for LH2 Zero-Boil-off (ZBO) Propellant Storage in the Solar Orbital Transfer Vehicle (SOTV)
  - Developed with Los Alamos National Laboratory (LANL) via CRADA





- **Venus Duplex Trade Study and TASHE Testing (2010 – 2011)**
  - Conceptual design of the cooling and power system that is to be used to maintain the operability of the seismometer on the surface of Venus
- **NASA SBIR Phase I - Venus Duplex System Design (2013)**





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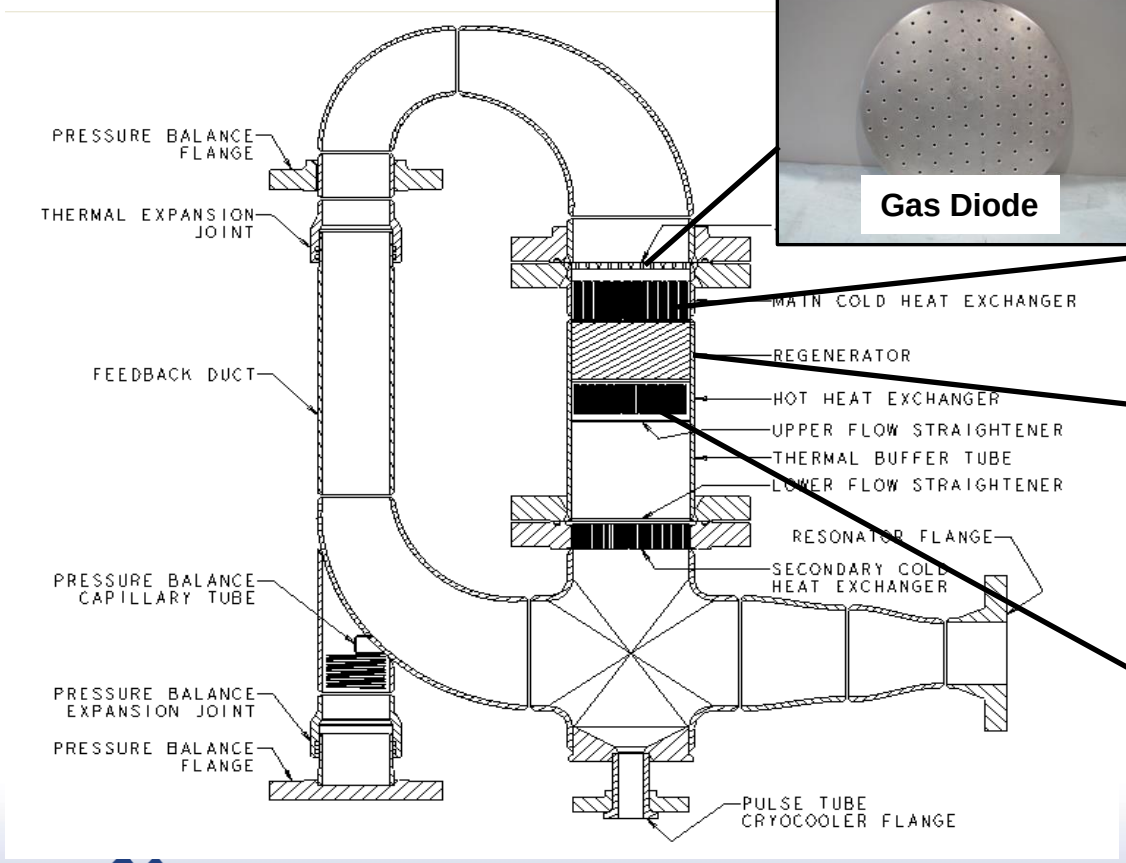
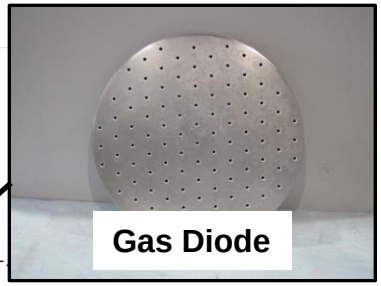
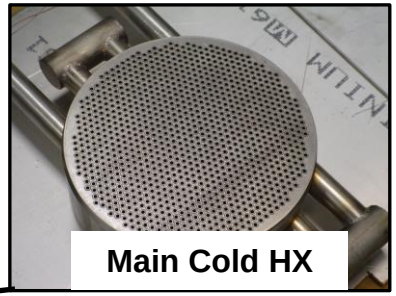
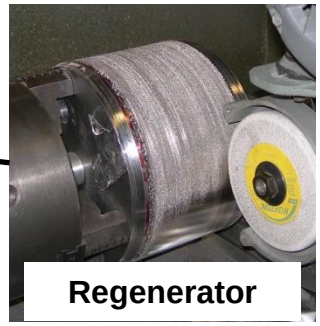
TASHE Construction Basics

- **12 kW TASHE Cross Sectional View**









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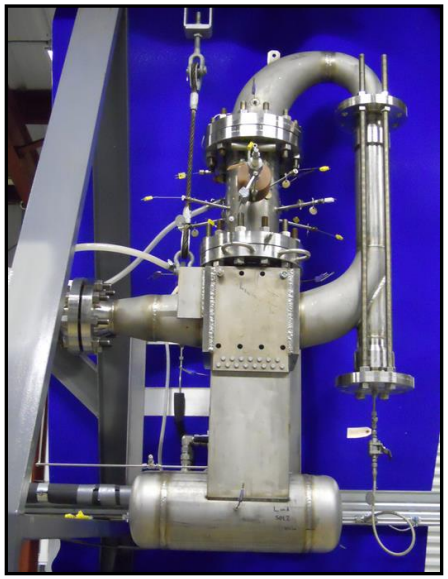
TASHE Performance

- **The system achieves <u>acoustic</u> power efficiencies at the design point of 36.4%.**
- **DeltaEC model predictions match test data within 10% validating model.**
- **Scaling TASHE power scales cross-sectional flow areas proportionally, roughly preserving component lengths, while minor scaling effects result in little to no change in efficiency.**

Parameters	**DeltaEC (12 kW)**	**Test**	**DeltaEC (TSPC)**
Frequency (Hz)	30	29.3	130
Hot Heat Exchanger Metal Temperature (K)	955	945	1000
Main Cold Heat Exchanger Metal Temperature (K)	296	287	300
TASHE Input Power at Hot Heat Exchanger (kW)	11.51	10.78	0.891
Pressure Amplitude at Load Inlet (psia)	62.5	62.4	49.7
PV Acoustic Power Output (kW)	4.51	3.92	0.3
TASHE Actual Efficiency (%) **Acoustic Efficiency**	39.1	36.4	33.7
Efficiency as Percent of Carnot (%), **Acoustic Power**	56	52	48



Sierra Lobo TASHE Technology is at TRL 4

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NASA Space Power Needs

- **NASA requires highly efficient and reliable power converters to conduct planetary exploration and space missions.**
- **High efficiency is necessary to reduce the number of GPHS units, decreasing the cost to the space program.**
- **Reliability is a necessity for mission success.**
- **The Sierra Lobo TASHE Space Power Converter has the potential to meet these requirements based on its inherent design features and mode of operation.**

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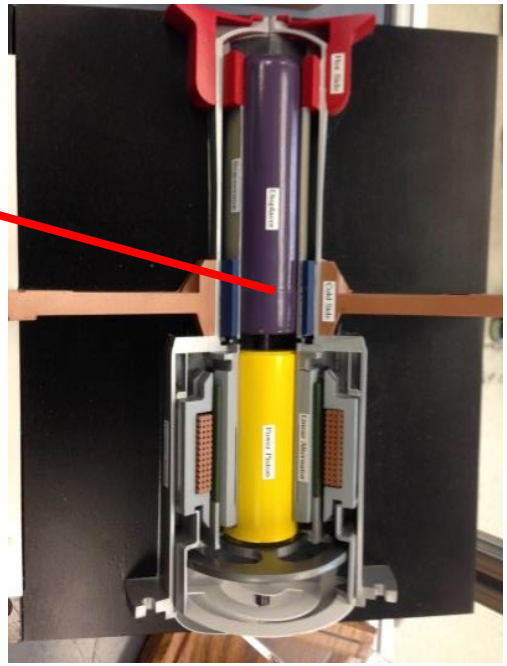
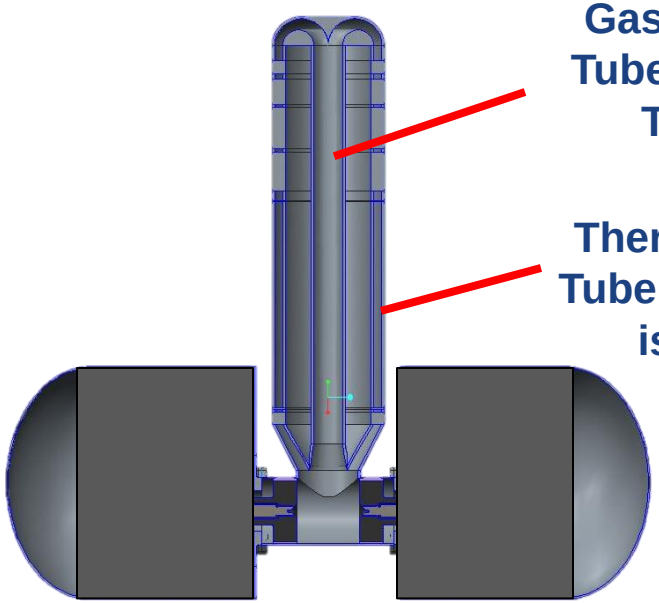
TASHE Advantage

- **TASHE Replaces Displacer Piston with Thermal Buffer Tube for Thermal Isolation and Gas Inertance Tube for Power Transfer**

Displacer



Advanced Stirling Converter



Gas Inertance Tube for Power Transfer

Thermal Buffer Tube for thermal isolation

200 W TASHE Space Power Converter

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Company Point-of-Contact

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