

Fed. funding:	\$2.5M
Length	36 mo.

Single-Cylinder Two-Stroke Free-Piston Internal Combustion Generator

Aerodyne Research, Inc., Kurt Annen, PI

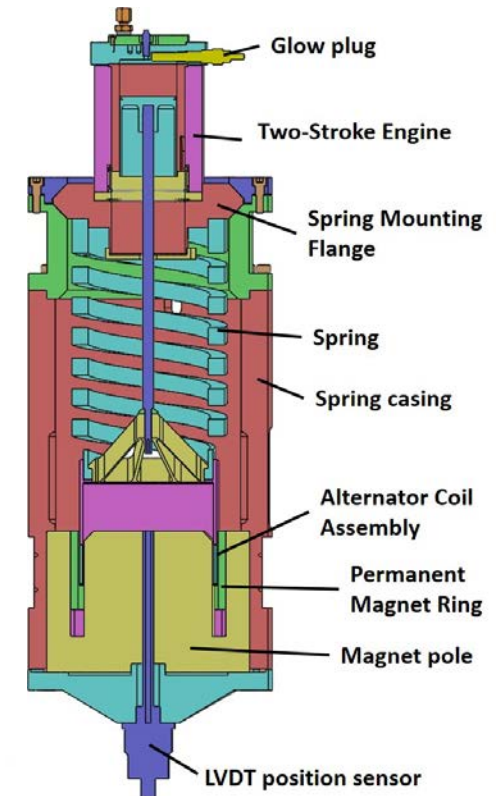
Stony Brook University, Precision Combustion, Inc, C-K Engineering

Project Goal:

Develop a low-cost free-piston engine generator CHP system having 40% fuel-electrical efficiency

Current Technical Status

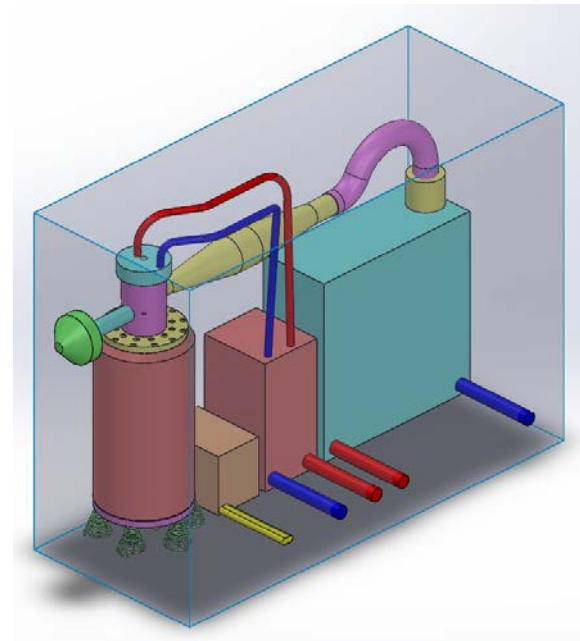
Demonstrated glow-plug assisted natural gas combustion with indicated efficiency ~ 40% with significantly higher efficiency achievable from improved control algorithm/electronics



Free-Piston MICE Generator CHP System

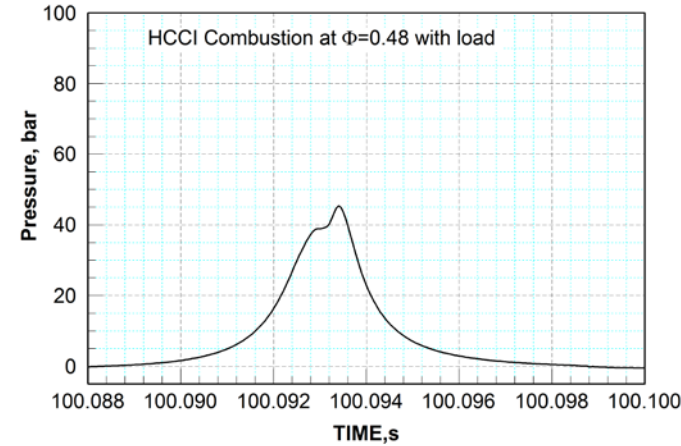
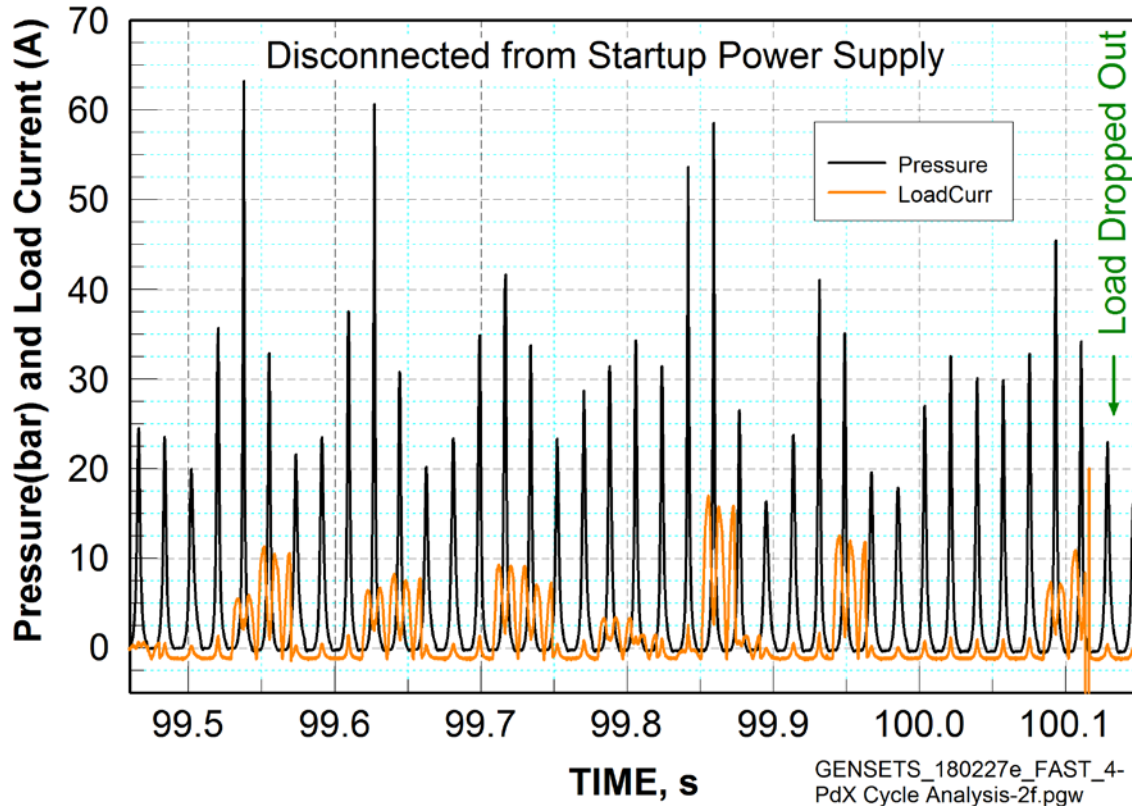
Unique Features

- Free-piston design for adjustable compression ratio to accommodate fuel variations
- HCCI combustion with glow-plug assist for high efficiency and low emissions
- Resonant multiple helix spring for high cycle frequency, low parasitic loss, cycle-to-cycle energy storage, and easy startup
- Moving coil linear permanent magnet alternator for low active mass and high efficiency
- Direct lubricant injection at low feed rate



Data from Combustion Test with Natural Gas

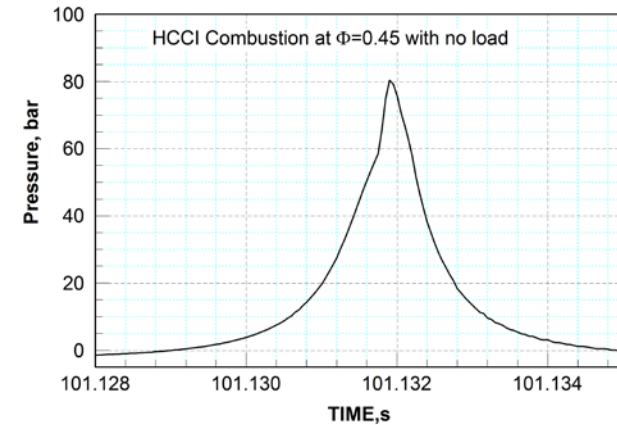
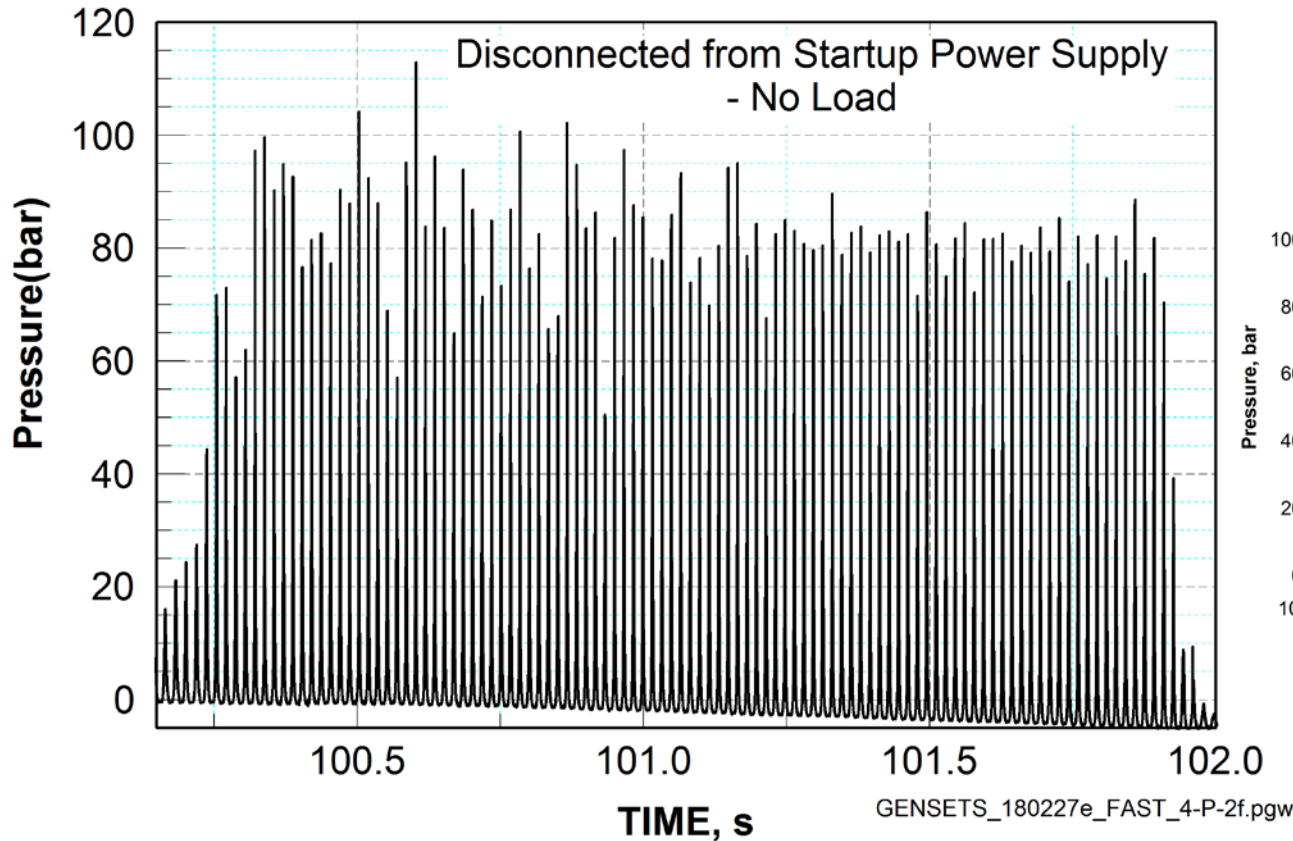
Low Power Operation with Digital Control



- Load controls piston stroke within acceptable limits, though in cyclic manner due to nonoptimal control parameters
- Occasional HCCI combustion cycles with operation at low compression ratio with catalytic glow plug

Data from Combustion Test with Natural Gas

High Power HCCI Combustion Operation



- Consistent HCCI combustion occurs at 60 Hz and $\Phi=0.45$ after load dropped out – better performance achievable with good load control
- Cycle analysis suggests indicated efficiency of ~ 40%

Tech-to-Market Strategy

- **Vision:** a GENSETS in every home with natural gas service
- **Market:** > B\$/year; can justify large investment (corporate or VC) unlike military or other small markets
- **IP strategy:** patent the hardware; keep control software code as trade secret
- Prefer joint-development-and-license deal with a partner in the market
- Complete product development with the partner (total cost: tens of millions of \$)
- Aim for gradual introduction to “early adopters” at low unit production rates (thousands per year) to build up market recognition and acceptance
- **OPTION:** go into military markets first (small, but early adopters by nature) then CHP
- Eventually achieve unit sales ~ millions per year
- ARI will need support over the entire transition time post-ARPA-E GENSETS program (either from the partner or third parties)

Details on Envisioned Product Offering

Metric	Program Target	Current Status	Envisioned Product offering
Device Application	Residential CHP	Residential CHP	Integrated with new water heaters
Power (kWe)	1	1	1
Fuel-to elec. eff. (%)	40		36
System cost (\$)	3,000	NA	~ 2,000
O&M cost (\$/kWh)	≤0.005	NA	~ 0.01
Capacity factor (%)	99.9	NA	~ 99.9
System Life (years)	≥10	NA	>10
System Noise (dB(A) at 3 feet away)	≤55	70 est	< 55
System Mass (kg)	≤150	100 est	< 75

Challenges - Resolved

“Resolved” Challenges

- **Design for low lubrication usage**
- **HCCI combustion at original design cycle frequency**
- **High spring fatigue life**

Desirable Partnerships

- **ABILITY TO FIND MONEY (OUTSIDE/INSIDE/COMBINATION)**
- **MARKETING**
 - **MARKET PRESENCE**
 - **FOR R&D FUNDING**
 - **FOR SALE OF FINAL PRODUCT (MIGHT BE PART OF A SYSTEM)**
 - **PRODUCT DEFINITION (REQ'TS / SPECS)**
- **PRODUCT ENGINEERING**
 - **MECHANICAL “TO-SPECS”**
 - **TO COST**
 - **RELIABILITY, MAINTAINABILITY, SAFETY, ETC**
 - **SYSTEM CONTROL FIRMWARE AND ELECTRONICS HARDWARE DESIGN**
 - **TO-SPECS, ETC**
 - **TESTING CAPABILITY (IN-HOUSE AND FIELD)**
 - **ENGINEERING-CHANGE SYSTEMS (BEYOND FIRST-RELEASE)**
- **PRODUCTION**
- **SALES (TO THE ULTIMATE USER)**
- **INSTALLATION AND PRODUCT SERVICE / SUPPORT**