

U.S. Department of Energy's Advanced Natural Gas Reciprocating Engine Program

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**Reciprocating Engine
Peer Review**

April 23, 2002





Collaborative Advanced Engine Program

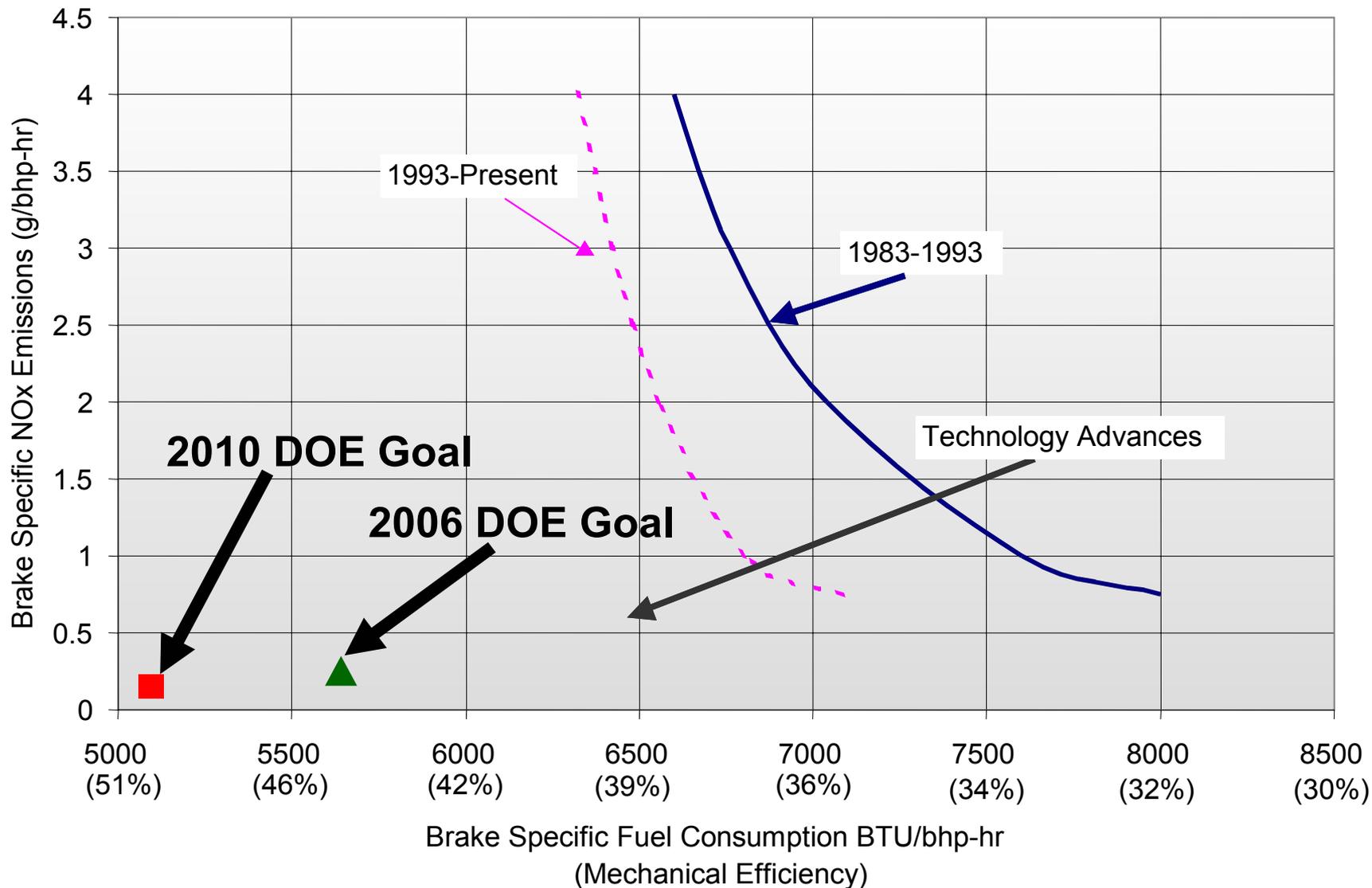


- **1999 - Joined SWRI study commissioned by ARES consortium to determine advanced technology roadmap**
- **Fall 1999 - Conducted DOE workshop to define reciprocating engine program goal and objectives**
- **Currently 7-year program (2000-2006)**
 - Initial program funding in FY2000

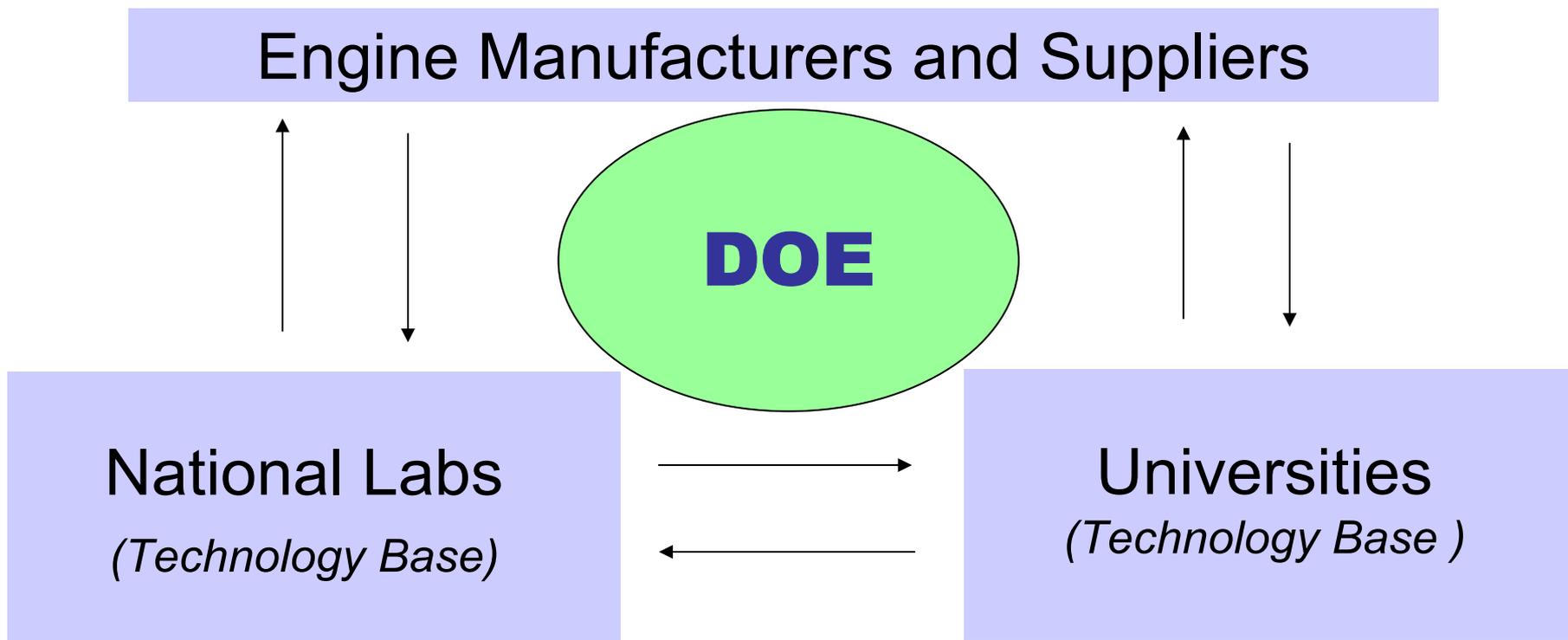
A Commercial Engine by 2010 with:

- **High Efficiency** - Fuel-to-electricity conversion efficiency of at least 50%
- **Environmental Superiority** - $\text{NO}_x < 0.1$ g/hp-hr (natural gas)
- **Reduced Cost of Power** – Energy costs, including O&M, at least 10% less than current state-of-the-art engines
- **Fuel Flexibility** – Adaptable to future firing with dual fuel capabilities, include further adaptation to hydrogen
- **Reliability and Maintainability** – Equivalent to current state-of-the-art engines

NO_x Emissions vs. Fuel Consumption



DOE's Strategy is Based on Partnerships



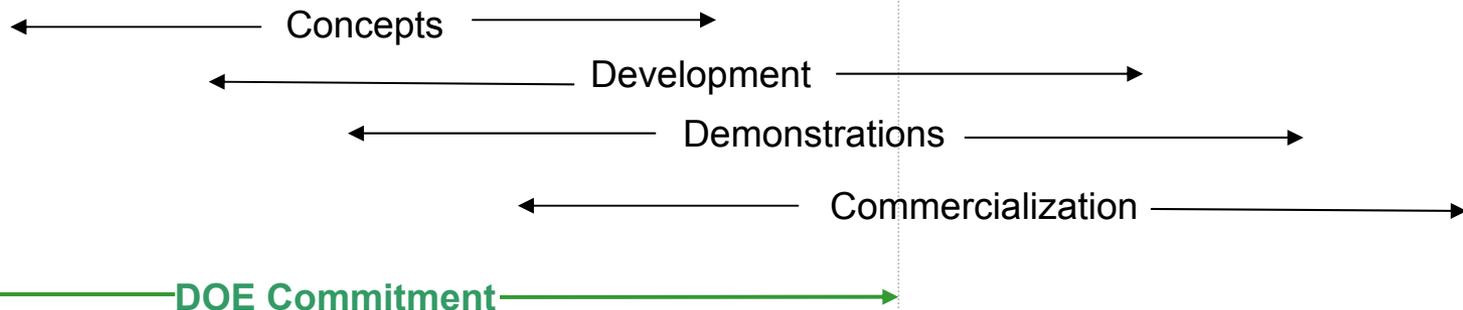
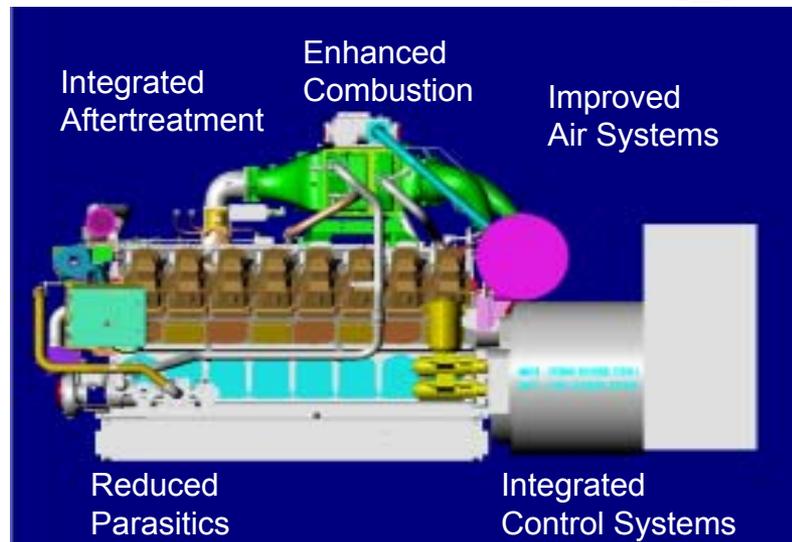
- **Leverage limited resources**
- **Reduce financial and technical risks**
- **Competitive solicitations**

Program Timeline

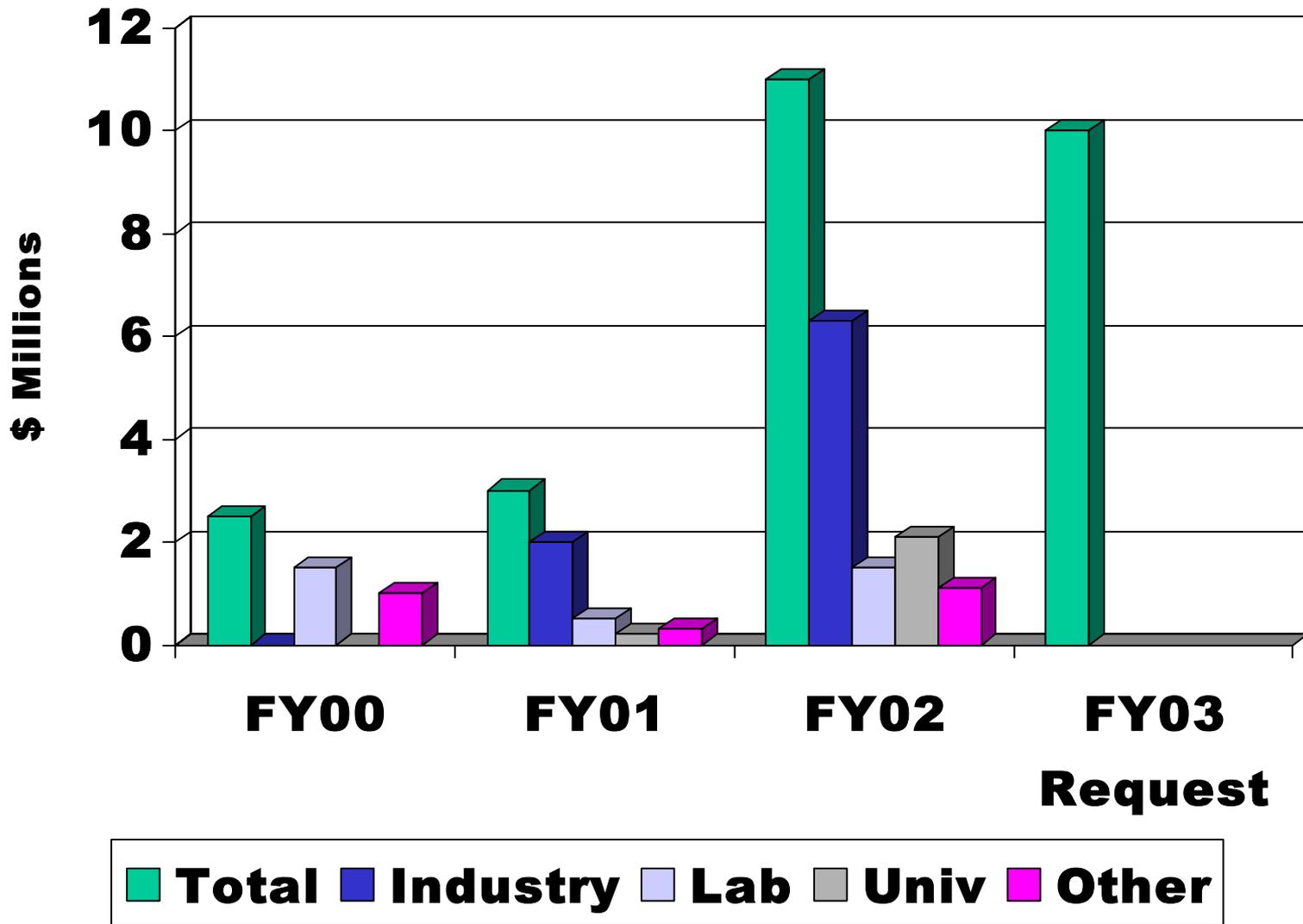
- DOE Workshop

- Industry Solicitation
- National Laboratory Call

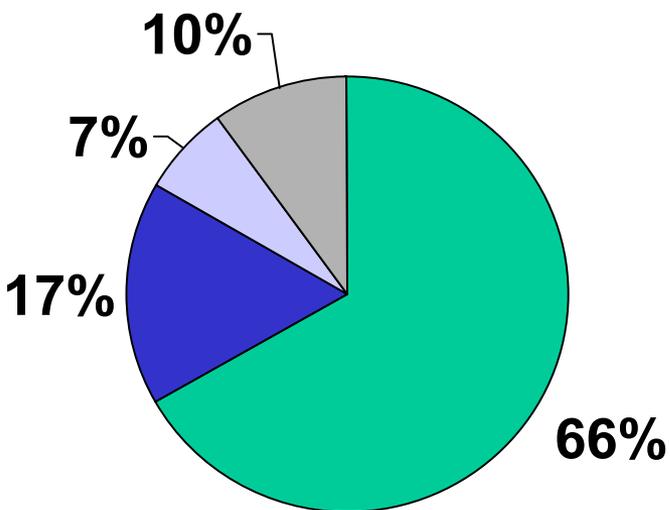
- Awards to Industry Partners
- University Solicitation
- Awards to Universities



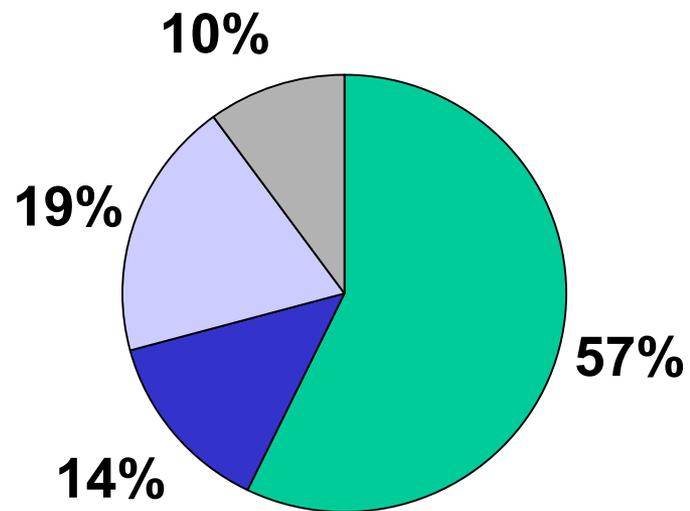
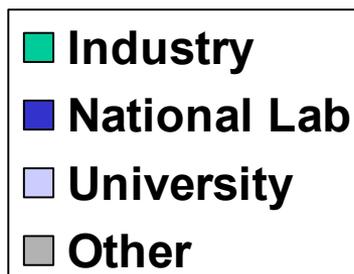
Program Funding



Budget Breakdown



FY 01

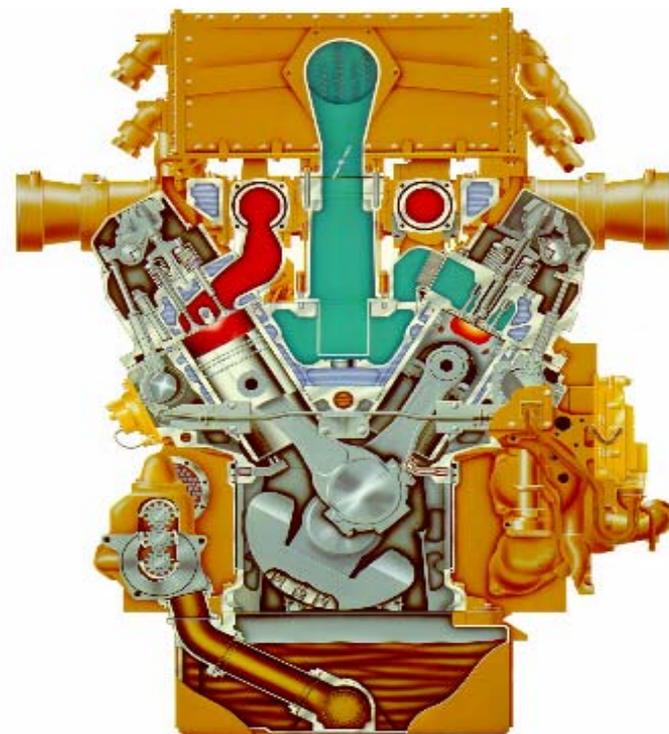


FY 02

- Focused on research, development, and testing of advanced natural gas reciprocating engines
- Three awards totaling at least \$15.0 million over 5 years:
 - Caterpillar, Inc. (Lafayette, Ind.)
 - Cummins Engine Company, Inc. (Columbus, Ind.)
 - Waukesha Engine Division, Dresser Inc. (Waukesha, Wis.)
- Average cost share over program 50% - staged over development: 30%, 45%, 60%
- Projects managed by Chicago Operations Office

Caterpillar ARES Program

- **Vision:** Develop and commercialize a 50% efficient natural gas fueled reciprocating engine system with a 95% reduction in NOx emissions with no increase in first cost by the year 2010.
- **Size Range:** Overall 0.5MW - 7.0MW, Initial Focus 2MW - 4MW
- **Partners:** Oak Ridge National Lab, Southwest Research Institute, Woodward Controls, Modine Heat Exchangers



Caterpillar G3500
series gas engine
cross-section

- **Overall Approach: Implement ARES Technology in Next Generation Natural Gas Quantum Series Products from 0.3 - 2.0 MW:**
 - 44% Brake Efficiencies
 - 0.1 gm NO_x/bhp-hr
 - 2005 First Product Launch
 - 2008 Second Round of Improvements, 47% Brake Efficiency
- **Partners; Westport Innovations, Colorado State University, Ricardo, ORNL, Southern California Gas Company, NICOR Energy Solutions**
- **Technologies:**
 - Combustion
 - Air Handling
 - Parasitics
 - Power Recovery
 - Next Generation After-treatment



- **Overall Program Approach:**
 - Further advance ARES technology findings
 - Demonstrate technology at customer sites
- **Partners: TRW, Winsert, Borg Warner, NICOR, MIT & CSU university**
- **Product: Engine/generator power plant (Modulator™) with high operating efficiency and low exhaust emissions:**
 - 2004: 0.25 NO_x, 45% BTE
 - 2007: 0.10 NO_x, 47% BTE
 - 2010: 0.10 NO_x, 50% BTE



APG2000 Modulator™

- **Focused on pre-competitive research activities that could have a significant impact in achieving the program goals**
- **Industry defined the topics for solicitation**
 - Environmental
 - Sensors and Controls
 - Knock Mitigation
 - Advanced Combustion
 - Ignition Systems
 - Tribology/Friction Reduction
 - Materials Research
- **Selected projects involving four national laboratories at \$3.0 million over 3 years**

- Argonne – Real Time Sensors for Combustion and Emission Control
- National Energy Technology Laboratory – Laser Ignition Development
- Oak Ridge – Development of Ultra Lean Burn Natural Gas Engine, Non-Linear Control
- Sandia – Rapid Combustion Linear Electric Generator
- Los Alamos – Ceramic Sensors for Emission Control

- University research projects focused on innovative/breakthrough technologies to address:
 - Ignition systems
 - Friction reduction
- 7 awards announced September 2000 - \$4.6 million over 3 years
- 20% cost share
- Project managed by NETL



Seven University Selections Made



Selection for Negotiation of Award

Applicant	Principal Investigator	Months	Project Title/Brief Description
Colorado State University collaborating with Waukesha Engine Dresser, Inc. and Woodward Governor Company	Dr. Bryan Willson 970-490-1418 bryan@enr.colostate.edu	24	<i>"Fundamental Studies of Ignition Processes in Large Natural Gas Engines Using Laser Spark Ignition"</i> Will use an existing laser ignition source to create data that will enhance the basic understanding of laser ignition, support related modeling efforts and demonstrate laser ignition as an effective, long-life ignition technique.
Massachusetts Institute of Technology collaborating with Waukesha Engine Dresser, Inc. and Colorado State University	Dr. Victor Wong 617-253-5231 vwong@mit.edu	24	<i>"Low Engine Friction Technology for Advanced Natural Gas Reciprocating Engines"</i> Will develop and use computer models to study lubrication conditions in ANGRE engines to develop concepts that reduce friction. Concepts stemming from the analyses will be tested in an actual ANGRE engine.
Michigan Technological University	Dr. Duane L. Abata 906-487-2151 duane@mtu.edu	24	<i>"Ignition Improvement of Lean Natural Gas Mixtures"</i> Will develop an on-board dimethyl ether reactor that creates DME from natural gas that is then used for pilot injection.
Purdue University with Caterpillar-Lafayette	Prof. Farshid Sadeghi 765-494-5719 sadeghi@ecn.purdue.edu	36	<i>"Advanced Natural Gas Reciprocating Engine: Parasitic Loss Control through Surface Modification"</i> Will develop several models to analyze the effects of patterned surface features on friction and lubrication conditions at an engine's piston ring cylinder liner. A bench-scale test will be designed to further investigate this area of research and to develop one comprehensive computer model that will design and analyze surface patterns.
University of Southern California collaborating with GEC Engineering Corporation	Prof. Paul D. Ronney 213-740-0490 ronney@usc.edu	36	<i>"Corona Discharge Ignition for Advanced Stationary Natural Gas Engines"</i> Will test corona discharge ignition in an effort to lower nitrogen oxides emissions without compromising thermal efficiency or, in one case, increasing thermal efficiency. The project will analyze leaner fuel mixtures, water injection and will minimize turbulence in engines by redesigning the intake port and piston shape.
University of Texas at Austin collaborating with Southwest Research Institute and John Crane Packing Company (AWARDED)	Prof. Ron Matthews 512-471-3108 rdmatt@mail.utexas.edu	36	<i>"Reduced Engine Friction and Wear"</i> Plans to rotate an engine's cylinder liners to reduce friction between the liners and piston rings and develop a model to not only enhance this concept, but to improve the design of piston assemblies as well.
University of Texas at Austin (AWARDED)	Prof. Ron Matthews 512-471-3108 rdmatt@mail.utexas.edu	36	<i>"Railplug Ignition System for Enhancing Engine Performance and Reduced Maintenance"</i> Will develop and test railplugs and driver-electronics for large-bore natural gas engines, and create an advanced 3-dimensional model to improve ignition-system designs. The model and the university's existing railplug model will be combined.



Examples of Program Coordination



External Coordination

- SWRI ARES consortium
- States (CEC, NYSERDA)
 - CEC ARICE program
- EPRI

Internal DOE

- Integrated Energy Systems (DER)
- CHP (DER)
- Interconnection (DER)
- Hydrogen (OPT)
- University program (FE/NETL)

Summary

- **Advanced natural gas reciprocating engines will play an important role in current and emerging DER markets**
- **Key technology challenges need to be overcome to meet aggressive program goals in efficiency, emissions and first cost**
- **Public/private partnerships with the reciprocating engine community have been established to meet joint program goals**
- **ARES technology will provide public benefits of improved energy efficiency and reduced emissions**



For Additional Information



Energy Efficiency and Renewable Energy Network (EREN) U.S. Department of Energy

The nation's electricity delivery system is straining in the face of [escalating demand for power](#). Electricity shortages, [power quality problems](#), rolling blackouts, and electricity price spikes are endemic.

To meet the country's need for high-quality, reliable electricity, [distributed energy resources](#) (DER) offer a faster, less expensive alternative to the construction of large, central power plants and high-voltage transmission lines.

The U.S. Department of Energy's Office of Distributed Energy Resources is working with industry stakeholders to streamline the integration of distributed energy systems with the electricity grid.

News & Events

New York to develop 280-acre clean energy technology park ([8/20/01 press release](#)).

[DOE DER conference](#) and peer review (Nov. 28-30) brings DER players together in Washington.

[Upcoming Events](#)

[Weekly Summary of Events](#)

www.eren.doe.gov/der

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