## Innovative Combustion Technology The plan for the Rising Sun Engine Initiative to Save the World

# Innovative Combustion Technology from Japan; the Trump Card to Save the Global Environment

Cars provide indispensable support to industry, society, and our personal lives, getting us from place to place quickly and comfortably. At the same time, the impact of vehicles on global warming calls for improvements in drivability, safety, and greater environmental performance. Innovative combustion technology (The Plan for the Rising Sun Engine Initiative to Save the World) aim to improve internal combustion thermal efficiency up to a maximum of 50 percent, reducing the impact of combustion engines on the environment. This cooperative research and development project between industry, academy, and government will contribute to the development of Japan's practical engineering capacity and the nation's ability to compete.



#### **Program Director**

Masanori Sugiyama

Toyota Motor Corporation Field General Manager, Advanced Power train Engineering Field

#### Profile-

Mr. Sugiyama joined Toyota Motors in 1984. He took over as project manager for new V6 engine development in 2002, and was subsequently named project general manager for renovation promotion of engine development in 2003. In 2007, Mr. Sugiyama took over as General Manager, New Engine Development Division. Mr. Sugiyama was named Executive General Manager, Field General Manager, Engine Engineering Field in 2013 and, in 2016, he was named Executive General Manager for Power Train Company and Field General Manager for Advanced Power train Engineering Field.

#### **Research and Development Topics**

#### 1. Research to improve gasoline engine thermal efficiency

Work towards elemental technologies for super lean burn, high boosted combustion, as well as combustion under high EGR volume, leading to thermal efficiency of up to 50 percent in comparison to today's maximum of 39 percent.

#### 2. Research to improve diesel engine thermal efficiency

Develop elemental technologies such as fast and quiet combustion and clean low temperature combustion that lead to thermal efficiency of up to 50 percent in comparison to today's maximum of 43 percent.

#### 3. Shared research for gasoline and diesel engines

Develop foundational technologies shared between gasoline and diesel engines, including modeling and control technologies for combustion, research into combustion analysis tools, and research into various types of loss reduction.

SPORT HYBRID i-MMD 2.0L DOHC i-VTEC

(Source: Honda R&D Co., Ltd.)

#### • Changes in the Thermal Efficiency of Automotive Internal Combustion Engines and SIP Goals

SIP Research Goals: Maximum Thermal Efficiency of 50%



### Create and popularize combustion technology that reduces CO<sub>2</sub> emission and strengthens Japan's competitive advantage

Offer fundamental technologies and development tools to society that reduce  $CO_2$  by 30 percent (vs. 2011). Leverage these results to improve fuel efficiency for the Japanese auto industry, strengthening the industry's competitive advantage and contributing to lower global  $CO_2$  levels.

#### 🗹 Create a sustainable multi-industry, multi-academic structure

A successful industry-academy cooperative research relationship will communicate common needs from industry, facilitate personnel exchange between industry and academy, grow the management capabilities of leader universities, and create new industries originating in university research. This new cooperative scheme will serve as a model to other industries, leading to a new development process that will contribute to a stronger Japan. Japan's Ministry of Economy, Trade and Industry and Ministry of Education, Culture, Sports, Science and Technology work together to study policies to create, over the next five years, a sustainable multi-industry, multi-academic cooperative research relationship that contributes to Japan's industrial competitiveness.

#### Create a strategy for a standard control model

Promote the standardization of control models and control/analysis software to reduce development costs and create new industries. At the same time, aim for international deployment by vendors, etc., including de facto standards.

#### **Team research framework**

As an expert in research management, the Japan Science and Technology Agency (JST) oversees the program as a whole. Approximately 80 participating laboratories and public research institutions have been divided into four teams covering the research fields of gasoline combustion, diesel combustion, control, and loss reduction, each led by a leader university. The **Research Association of Automotive Internal** Combustion Engines (AICE) has entered into a partnership agreement with the Japan Science and Technology Agency (JST) to support each research team, creating a research and development framework that brings together industry, academia and government agencies.



#### **Progress to Date**

# Steady Progress Through the Exchange of Knowledge

Industry-academia coordination utilizing open laboratories has led to the cross-linking and integration of research fields. This in turn has sparked an exchange of knowledge among researchers. As the result of steady progress, as of June of this year, the Gasoline Combustion Team and the Diesel Combustion Team have achieved indicated thermal efficiencies of 45 percent and 46.8 percent (single cylinder engine). The Loss Reduction Team has developed a technology in which low-friction materials are used to form a hardened surface on the engine piston, while the Controls Team is developing unique software for three-dimensional flow analysis. •Keio University SIP Engine Laboratory Inside the Ono Sokki Technical Center



### Program Director Masanori Sugiyama Interview

# Expectations for Deepened Multi-Industry, Multi-Academic Collaborations and Invigorated Automotive Engineering Over the Next Two Years

While electrification of the automobile continues, more than half of all vehicles are expected to still be using internal combustion engines 30 years from now. The program continues to make progress in improving the thermal efficiency of automotive internal combustion engines by combining specialized knowledge of control, combustion, and loss reduction.

#### Sparking an Exchange of Knowledge Among Researchers

Two years have passed since we set an ambitious goal for achieving a thermal efficiency of 50 percent for gasoline and diesel engines under industry-academia-government collaborative research. With approximately 80 laboratories and public research institutions participating, the scale of this joint research is unparalleled. Program Director Masanori Sugiyama sees a positive outcome from the deepening cooperation. "In the first year we were feeling our way around. Now, however, industry support of our academic research teams has resulted in mutual trust and smooth communications. Members from both the Japan Science and Technology Agency (JST) and Program Council managing the research and development have been visiting the universities frequently, offering advice and motivating teams to succeed."

To achieve these program goals, it is essential now to form

• Creation of Sustainable "Multi-Industry, Multi-Academy" Collaboration



new scientific theories, rather than reasoning by analogy based on past engine development experience and results. To this end, program researchers are combining a number of research fields, including chemical reactivity and basic combustion. Based on these results, research teams then work together to build larger integrated models. Academic research tends to drill deep into a particular field, having limited interchange with other fields. Through this joint research, however, a number of research fields have been cross-linked and integrated, encouraging active exchange of researcher knowledge.

### Progress Through Open Innovation

Under this program, open labs have been established at the four leader universities, equipped with state-of-the-art laboratory equipment and serving as forums for experiments, discussions, and data sharing among industry and academic researchers. The Keio University SIP Engine Laboratory in the Ono Sokki Technical Center was the first such open lab. This center is home to more than 100 registered researchers and student

> participants. Mr. Sugiyama spoke of his expectations for developing human resources, saying, "The experience of collaborative research with other laboratories and companies offers a great deal of opportunities for learning for students. Seeing that your own research can lead to large results increases motivation as well."

> A research environment that promotes this kind of open innovation leads to steady results. This June, the program delivered a success when the Gasoline Combustion Team and the Diesel Combustion Team achieved indicated thermal efficiencies of 45 percent and 46.8 percent (single cylinder engines). The Loss Reduction Team has developed a technology in which low-friction materials are used to form a hardened surface on the engine piston, while the Controls Team is developing unique software for three-dimensional flow analysis. One of the goals of this program is to develop standards from unique Japanese control models and analysis software, leading to future reductions in development costs.

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#### **Innovating Practical Engineering Research**

Regarding the current progress status of the program, Mr. Sugiyama states, "What I can say is that we're half-way up the mountain. However, the slope becomes only steeper at this point; we have no time to rest." In 40 years of effort, researchers finally broke the 40 percent barrier in thermal efficiency for automotive internal combustion engines, up from 30 percent. To gain another 10 percent in a span of five years is certainly a lofty goal.

To break through this wall, program participants are engaged in the scientific approach mentioned earlier. The ultimate goal is to elucidate the science behind combustion phenomena in theory. The next step is to turn this progress into general models, advancing development by motivating industry. This is an important element for achieving Society 5.0 as provided under the 5th Science and Technology Basic Plan, as well as an important initiative leading to highly competitive manufacturing for Japan."

"Model-based development will change approaches to automotive engineering in a significant way. As an SIP program, internal combustion engine research is gaining greater attention. We see an increase in the number of students aspiring to this field as well. Our aim is to incorporate new dynamics in the field to reinvigorate and innovate automotive engineering." (Sugiyama) We are accelerating open innovation to achieve ambitious goals.

#### **Future Plans**

Formulate technological concepts this year to achieve a thermal efficiency of 50 percent; perform tests using actual equipment in the second half of the year.



Our goal of increasing thermal efficiency to 50 percent has become not a dream, but very much a real possibility. Both automobile engines and automobile engineering will keep improving.