Combustion and propellants

Efforts to address the challenges of climate change, energy security, and energy-efficient high-speed propulsion brought significant progress in the development of next-generation low-carbon transportation fuels, advanced propulsion technologies, and experimental facilities for space exploration.

An Energy Frontier Research Center for Combustion Science has been established at Princeton University by the Dept. of Energy in an effort to advance fundamental understanding and quantitative modeling of renewable transportation fuels. The ultimate goal is to develop a validated, predictive, multiscale combustion modeling capability to optimize the design and operation of evolving fuels in advanced engines for transportation applications. The investigation will cover all the myriad time and length scales involved in combustion, from the scale of the electron to that of the largest turbulent motion in engines.

The center, funded at $4 million a year for five years, consists of 15 principal investigators from seven academic institutions (Cornell, MIT, Princeton, Stanford, and the universities of Connecticut, Minnesota, and Southern California) and the Sandia and Argonne national laboratories, with expertise in quantum chemistry, chemical kinetics, combustion theory and modeling, and corresponding experimentation.

At Princeton, a next-generation jet fuel project funded by NetJets has identified a sustainable pathway for synthesis of zero net carbon cycle transportation fuels from biomass and coal using carbon capture and storage and coproduction of low-emission electricity. Other activities include system analysis for energy conversion economics and carbon emissions; energy and policy analysis for sustainability; and combustion technology assessment of this and other means of producing renewable transportation fuels.

A DOD multiuniversity research initiative called “Fundamental Mechanisms, Predictive Modeling, and Novel Aerospace Applications of Plasma Assisted Combustion” was awarded to a research team from five universities (Ohio State, Princeton, Drexel, Georgia Tech, and Penn State) to study nonequilibrium plasma-assisted combustion for novel applications in scramjet and gas turbine engines. The objective is to investigate elementary reactions and nonequilibrium kinetic processes using advanced laser diagnostics and experimentation tools in plasma-assisted ignition, and stabilization of flames at extremely high air velocities and elevated pressures.

As the ISS nears completion, studies of fuel and material flammability have now begun on the station under the leadership of NASA Glenn. The goals are to improve fundamental understanding of combustion and enable improvements for fire safety in space and in terrestrial applications.

A multiuser facility, the combustion integrated rack (CIR), was installed on the ISS in Destiny, the U.S. laboratory module, in late 2008. This combustion facility provides a gas delivery system, cameras, and a 100-liter chamber into which a variety of experiments can be installed. It can be commanded remotely from a control center at NASA Glenn. Operations with the first CIR effort, the flame extinguishment experiment (FLEX), began early this year. FLEX is a direct successor to the droplet combustion experiment conducted on space shuttle missions in 1997 and 2003. Leading the multiuniversity FLEX research team is the University of California-San Diego. The objective is to evaluate the effectiveness of suppressants on microgravity flames in atmospheres under consideration for future spacecraft. CIR will also be used in ACME (advanced combustion via microgravity experiments) for studies of gaseous laminar diffusion flames.

Combustion research has also been initiated in the ISS microgravity science glovebox (MSG), a general-purpose facility enabling a variety of studies. Early this year, SPICE (smoke point in coflow experiment) became the first combustion experiment to be conducted in the MSG. More MSG investigations are planned for 2010, including studies of flame stability and solid fuel flammability.

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