National Aeronautics and Space Administration

**Glenn Research Center**
Cleveland, Ohio

# *Combustion Research in the Fluids and Combustion Facility*

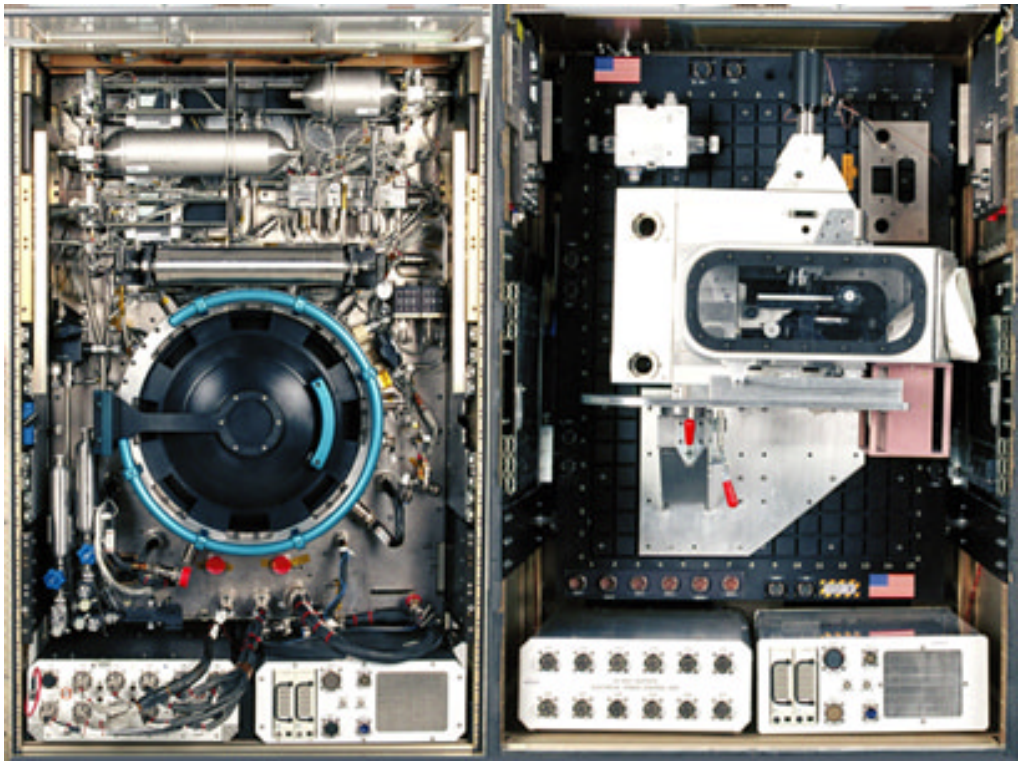
### *Combustion Science in Space*

Combustion is a major part of life for most people. We use it for electrical power generation, heating and cooking, transportation, and in manufacturing processes. Yet there is much about combustion that is not sufficiently understood, including the knowledge needed to address important issues such as pollutant and particulate formation, combustion efficiency, waste incineration, fire prevention and suppression, and global change. Many combustion phenomena are complicated by gravity-induced buoyant flows, thus making it difficult for the combustion researcher to isolate and understand the different processes and interactions occurring in flames. A major goal of NASA's microgravity combustion program is to simplify the study of combustion phenomena so as to gain increased understanding and insight needed for practical benefits both on Earth and in space.

### *FCF Overview*

The Fluids and Combustion Facility (FCF) is a facility-class payload planned for the International Space Station (ISS) and will support the study of fluid physics and combustion science in a long-duration, microgravity environment. The facility is a system of on-orbit and ground hardware, software, experiment operations, and planning designed to accommodate a wide variety of investigations. The majority of the on-orbit hardware will remain there and be used by many investigations. Each investigation will customize the facility with a small amount of hardware and software. The facility will be adaptable and modular so that it can be upgraded with new hardware and software as needed.

The facility comprises two powered racks called the Combustion Integrated Rack (CIR) and the Fluids Integrated Rack (FIR): these will be located adjacent to each other in the U.S. Laboratory Module "Destiny." The two racks share common features and perform the functions of structural hardware, power control and distribution, environmental controls, command and data management, communications, stowage, and acceleration isolation. The facility is being designed to accommodate 5 to 15 combustion experiments and a similar number of fluid physics experiments each year of the 10-year lifetime of the FCF.



*Combustion Integrated Rack* *Fluids Integrated Rack*

### *CIR Elements*

The CIR contains the hardware and software necessary for conducting combustion science experiments. It is designed to accommodate a range of combustion experiments while meeting the ISS requirements and limitations such as safety, power and energy, cooling, mass, crew time, stowage, resupply flights, and downlink.

The *International Standard Payload Rack* provides the supporting and mounting elements for the CIR subsystems and mechanical connections to the U.S. Laboratory Module. CIR provides a bifold door with upper and lower halves. The passive rack isolation system (PaRIS) provides attenuation of on-orbit vibrations transmitted from the U.S. Laboratory Module to the rack.

The *optics bench* provides structural support, electrical connections, and mounting locations. It spans two-thirds of the rack vertically and can be slid out from the rack and folded down for access to both sides. It contains the wiring and cooling air flow, and diagnostics may be interchanged via a quick-latch mechanism at any of eight universal mounting locations around the chamber.

The *combustion chamber* has a volume of 100 liters (0.40 m in diameter and 0.90 m in length). The front lid opens for on-orbit access to the inside of the chamber. The experiment mounting structure is mounted on guide rails in the chamber. This structure is a framework for the mounting of internal components such as a burner, a nozzle, or a sample holder, diagnostic sensors, flow tunnel, and interface hardware. Electrical, vacuum, gas, and other resource connections are made through an interface resource ring. The chamber has eight interchangeable windows, and has a maximum design pressure differential of 827 kPa (120 psig).

The *diagnostics* measurement systems perform the required and desired measurements of the combustion phenomena. Many of these are imaging systems that include the imaging device, an illumination source, and an image-processing package. Digital imaging systems are used for data fidelity and ease in data transfer and storage. The diagnostic measurements are segmented into two categories. One set is provided entirely by the CIR, including the measurement device, power, control, and data collection and storage. These include pressure measurements; visible, ultraviolet, and near-infrared imaging; gas composition; and accelerometry. The other set of diagnostics is provided jointly by the experiment team and the CIR. The diagnostics may include temperature measurements, soot volume fraction, soot temperature, soot particle collection, flame radiation, and velocity measurements.

The *Fuel/Oxidizer Management Assembly* (FOMA) provides gaseous fuels, oxidizers, and diluents to the combustion chamber, sampling and analysis of the chamber contents, and venting to space through the ISS vacuum exhaust system. It contains gas supply bottles, valves, pressure regulators and switches, and mass flow controllers. The gas bottles may be either 1.0, 2.25, or 3.8 liters and are replaceable by the crew. On-orbit gas mixing is done by partial pressure or by dynamic mixing. A gas chromatograph analyzes the chamber contents. Filter cartridges remove particulates, water, and other contaminants from the gas prior to venting.

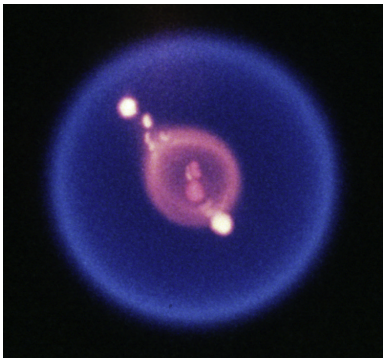
The *electrical power system* performs electrical power distribution, conversion, control, management, and fault protection. The system provides 120 volts dc power or converts the ISS 120 volts dc power to the 28 volts dc power needed for most FCF loads.

The *environmental control systems* remove waste thermal energy, detect smoke and fire, and provide access to ISS-provided nitrogen and the vent system.

The *command and data management* system consists of an input-output processor (IOP), FOMA control unit, laptop computer, and image processing packages. The IOP provides commanding and controls, data acquisition and processing, data management and checking, and communications to the crew and ground operators. A facility laptop is mounted to the front of the CIR and provides the crew interface command and data display.

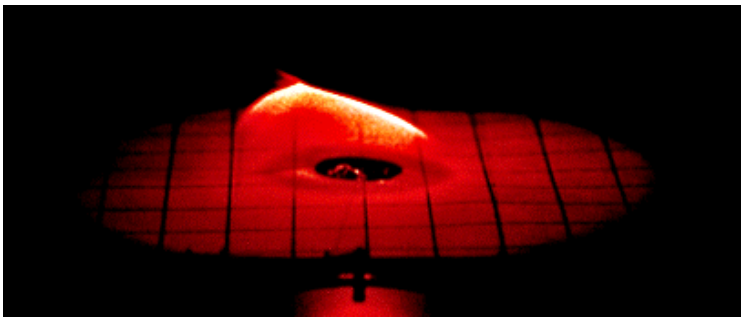
### *Combustion Science Utilization*

The combustion areas that may be studied in the FCF include but are not limited to laminar flames, reaction kinetics, droplet and spray combustion, flame spread, fire and fire suppressants, condensed phase organic fuel combustion, turbulent combustion, soot and polycyclic aromatic hydrocarbons, and materials synthesis.



*Burning droplet of heptane in microgravity. Image was acquired on MSL–1 flight of the Droplet Combustion Experiment.*

When possible, similar investigations will be flown at the same time to increase the use of common hardware and diagnostics. A set of three multiuser chamber inserts is being designed to support broad classes of experiments in droplets, solid fuels, and gaseous fuels. Inserts for investigations having requirements not met by the multiuser inserts will be developed as resources permit. Commercial and international investigations will provide their own chamber inserts or other resources in exchange for using a multiuser insert. Fifteen flight and flight-definition investigations supported by the microgravity science program and one or more commercial investigations are currently planning to use the CIR over the first few years of operation. Several international investigations are at the conceptual stage.



*Radiatively ignited flame spread over cellulose with opposed flow.*

The two initial investigations will study the combustion of small, spherical, individual droplets. They will demonstrate the use of the FCF and will use a common experiment insert and similar measurements. The first investigation will further explore new behaviors observed on its initial space flight. Radiative extinction of large-diameter droplets and extinction diameters of droplets are of interest. The other investigation will explore the behavior of bi-component droplet combustion.

Subsequent investigations will study additional aspects of droplet combustion, the combustion of solid fuels, and premixed and nonpremixed gaseous fuel combustion.

### *Development Status*

The Fluids and Combustion Facility is being developed at the NASA Glenn Research Center in Cleveland, Ohio under a prime contract with Northrop Grumman Information Technology. The overall system has concluded its critical design phase and is moving towards development and testing of flight hardware. Launch of the CIR is currently scheduled for 2004.

***For more information, visit the***

**NASA Glenn Microgravity Science Web Site** at
http://microgravity.grc.nasa.gov/

or the **FCF Web Site** at
http://fcf.grc.nasa.gov

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M–0723–05
Apr 03