Flight Hardware Fabricated for Combustion Science in Space

In January 2004, President George W. Bush outlined an exciting new space exploration vision. The exploration programs will seek profound answers to questions of our origins, whether life exists beyond Earth, and how we could live in other worlds. In support of this vision, NASA's microgravity combustion research program is being realigned to support major milestones such as a human Moon landing and establishment of a lunar exploration testbed. The design and operation of exploration spacecraft and partial-gravity habitats presents new challenges for fire safety, waste incineration, and power generation. A major goal of NASA's microgravity combustion program is to address these challenges by gaining increased understanding and insight into the behaviors of microgravity and partial-gravity flames.

Engineering models of the Fluids and Combustion Facility. The Combustion Integrated Rack (CIR) is shown on the left; the Fluids Integrated Rack is shown on the right.

The Fluids and Combustion Facility, a facility-class payload planned for the International Space Station (ISS), will support the study of fluid physics and combustion science in a long-duration, microgravity environment(see the preceding photographs). 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: the Combustion Integrated Rack (CIR) and the Fluids Integrated Rack. 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, and stowage. The facility is being designed to accommodate 5 to 15 experiments during the lifetime of the Fluids and Combustion Facility.

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 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 Destiny. The CIR provides a bifold door with upper and lower halves, and the passive rack isolation system attenuates on-orbit vibrations transmitted from Destiny 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 airflow, and diagnostics can 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 access to the chamber. The experiment mounting structure is mounted on guide rails in the chamber. This structure supports internal components, such as a burner, a sample holder, diagnostic sensors, a flow tunnel, and interface hardware. Electrical, vacuum, gas, and other connections are made through an interface resource ring. The chamber has eight interchangeable windows and a maximum design pressure differential of 827 kPa (120 psig).

The diagnostics measurement systems measure the required and desired 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 provided by the CIR include pressure measurements; visible, ultraviolet, and near-infrared imaging; gas composition; and acceleration.

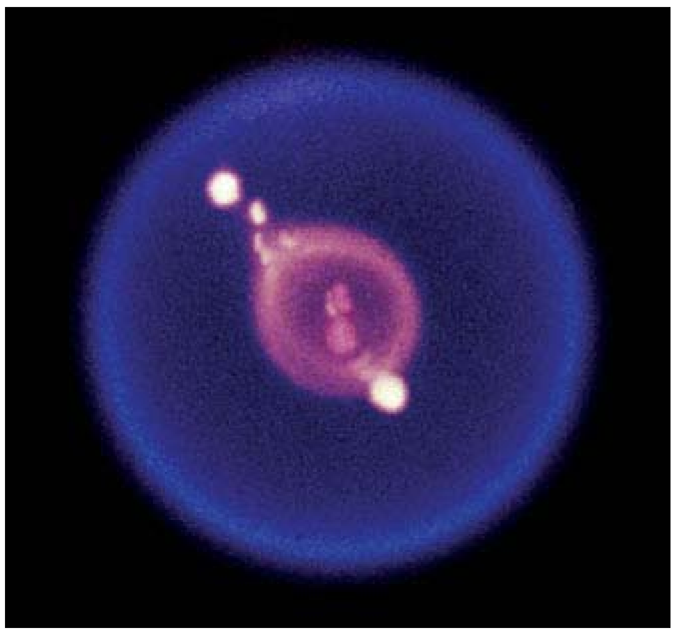
The Fuel/Oxidizer Management Assembly provides gaseous fuels, oxidizers, and diluents to the combustion chamber, sampling and analysis of the chamber contents, and venting to space through the ISS vacuum exhaust system. It contains gas supply bottles, valves, pressure regulators and switches, and mass flow controllers. The gas bottles may be either 1.0, 2.25, or 3.8 liters and are replaceable by the crew.

The electrical power system performs electrical power distribution, conversion, control, management, and fault protection. The system provides 120 Vdc or converts the ISS 120 Vdc to the 28 Vdc needed for most loads. The environmental control systems remove waste thermal energy, detect smoke and fire, and provide access to the ISS-provided nitrogen and to the vent system.

The command and data management system consists of an input-output processor, the Fuel/Oxidizer Management Assembly control unit, a laptop computer, and image-processing pack-ages. The input-output processor provides commanding and controls, data acquisition and processing, data management and checking, and communications to the crew and ground operators.

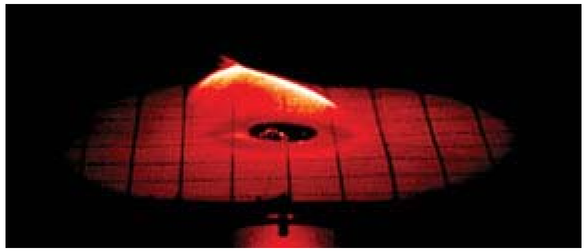
The combustion areas that can be studied in the CIR include, but are not limited to, fire prevention, detection, and suppression; incineration of solid wastes; power generation; flame spread; soot and polycyclic aromatic hydrocarbons; and materials synthesis. Near-term experiments will support the exploration vision.

When possible, similar investigations will be flown at the same time to increase the use of common hardware and diagnostics. A set of multiuser chamber inserts is being designed to support experiments in droplets, solid fuels, and gaseous fuels. Commercial and international investigations will provide their own chamber inserts or other resources instead of using a NASA insert.



Flame image of an isolated droplet burning in microgravity.

The candidate initial investigations will study the combustion of small, spherical, individual fuel droplets (see the preceding image). They will demonstrate the use of the CIR and will use a common experiment insert and similar measurements. They will determine the flammability of a fuel droplet in limiting atmospheres of oxygen. Solid fuel experiments will focus on the quantification of material flammability in low-pressure, increased-oxygen atmospheres (see the following image). The fuels include wire insulation, advanced composites, packing foam, and materials for inflatable structures. Gaseous fuel experiments will determine the effectiveness of various extinguishing agents.



Flame image of a thin sheet of paper burning in microgravity.

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 flight hardware fabrication phase and is moving toward flight hardware testing at the package and system levels. Launch of the CIR is currently scheduled for 2006.

Find out more about this research:
Microgravity combustion research at Glenn at
http://microgravity.grc.nasa.gov/combustion/

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