National Aeronautics and Space Administration

Glenn Research Center
Cleveland, Ohio

Combustion Module-2 (STS–107) Studying Fire in the Sky

Light a candle and it quickly forms the familiar teardrop shape, which is caused by hot air rising and cold air flowing in behind to keep the fire going. This airflow obscures many of the fundamental combustion processes we need to understand so that we can learn how to

- Burn fuels more efficiently
- Improve fire safety
- Reduce pollution

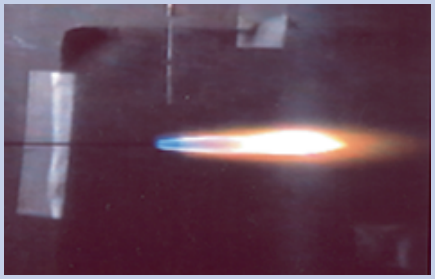
Conducting combustion experiments in the microgravity environment of orbit eliminates gravitational effects and slows many combustion processes so they become easier to study. Professor Gerard Faeth of the University of Michigan—the Laminar Soot Processes Principal Investigator—has said that gravity has impeded the development of combustion science much as the atmosphere has impeded astronomy.

We use a Combustion Module (CM), which is a state-of-the-art, complex laboratory, to study combustion in space. This reusable, modular combustion facility was first flown on the Microgravity Sciences Laboratory-1 and 1R (STS–83 and STS–94) in 1997. The forthcoming STS–107 shuttle mission will fly an updated version of the CM, known as CM–2. The three experiments that will be conducted are Laminar Soot Processes (LSP–2), Structure of Flame Balls at Low Lewis number (SOFBALL–2), and Water Mist Fire Suppression Experiment (Mist). CM–2 will complete the primary science plan for these investigations, and help set the stage for expanded, long-term experiments aboard the International Space Station.

Members of the CM–2 team—a systems engineer and a software engineer—inspecting the CM–2.

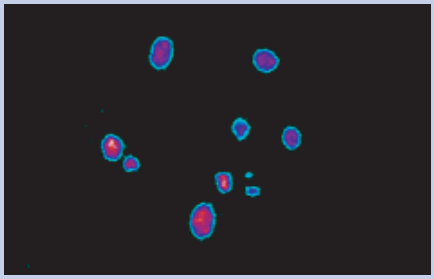
LSP–2 Experiment

Objectives: Evaluate and predict flame shape and internal structures; determine the nature of the soot emission process; validate new universal equations for soot and temperature in a flame; and investigate the soot-bursting hypothesis. Results will improve our understanding of turbulent flames found in many combustion devices on



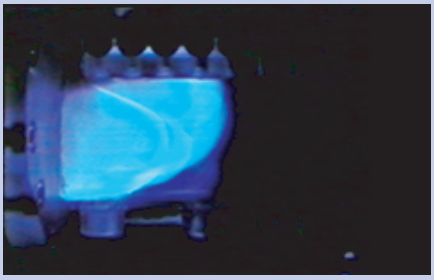
SOFBALL–2 Experiment

Objectives: Improve our understanding of the flame ball phenomenon and lean (low fuel) burning combustion; determine the conditions under which they can exist; test predictions of duration; and derive better data for critical model comparison. Results will lead to improvements in engine efficiency, reduced emissions, and fire safety.



Mist Experiment

Objectives: Measure the effectiveness of fine water mists to extinguish a flame propagating inside a tube to gain a better understanding of the water mist fire-suppression phenomenon. What is learned will help us design and build more effective mist fire-suppression systems for use on Earth, as well as in space.



Ann Over, Project Manager
NASA Glenn Research Center
Ann.Over@grc.nasa.gov
216–433–6535

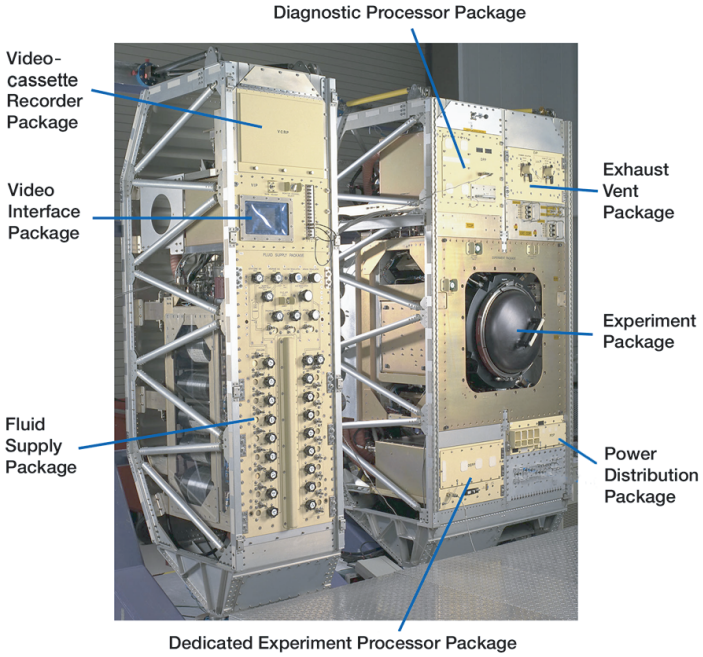
David Frate, Deputy Project Manager
NASA Glenn Research Center
David.Frate@grc.nasa.gov
216–433–8329

Dr. David Urban, CM–2 Science Contact
NASA Glenn Research Center
David.Urban@grc.nasa.gov
216–433–2835

For more information, please see the
NASA Glenn Microgravity Combustion Web Site at
http://microgravity.grc.nasa.gov/combustion/

CM–2 Subsystems

The *Experiment Package* is a 90-liter combustion chamber with six ports for three intensified near-infrared cameras, one color camera, and three black and white cameras; a gas chromatograph; crew switches; and thermistors. The *Fluid Supply Package* is a complex gas control and distribution system containing 20 composite, over-wrapped bottles. The *Videocassette Recorder Package* consists of four Hi-8 video recorders. The *Exhaust Vent Package* includes a blower, canister, and other fluid components for cleanup and evacuation of chamber gases. The *Dedicated Experiment Processor Package* is the main processor for experiment command and control, and connects to the crew laptop (the CM–2 human interface). The *Video Interface Package* is the primary video interface for switching, routing, and display. The *Diagnostic Processor Package* is the video frame grabber and storage system for digital data. The *Power Distribution Package* controls and conditions the power from the Shuttle/SPACEHAB for all CM–2 packages. Finally, the *Experiment Mounting Structures* (EMS) are experiment-unique chamber inserts. Each contains an ignition system and special sensors; the Mist EMS also contains test gases, a water mist generator, and a canister to remove water and carbon monoxide after each test.



CM–2 and its eight major components.

CM–2 Flight Operations

Although the flight crew is in the spotlight for shuttle missions, there is a team of engineers, scientists, and other support personnel who are on the ground making it all possible. The CM–2 Team, comprising almost 40 engineers and scientists, will work side-by-side with the Johnson Space Center Mission Control Team in Houston, Texas. For STS–107, 16 days of around-the-clock operations are conducted to ensure safety and mission success. The CM–2 experiments timeline spans the entire mission.

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Launch/CM–2 setup	—	—	—													
LSP–2 operations				—	—	—	—									
SOFBALL–2 operations							—	—	—	—	—	—				
Mist operations												—	—	—	—	
CM–2 Teardown/landing																—

CM–2 experiments timeline.

CM–2 Statistics

Size:	Main racks—7 ft tall by 5 ft wide by 3 ft deep
Weight:	Main racks—1840 lb; Other CM–2 hardware—355 lb
Subsystems:	Eight rack-mounted components and three chamber inserts
Power Usage:	Average—419 W (dc); Peak—543 W (dc)
Chamber Size:	16 in. (40 cm) diameter by 30 in. (76 cm) long; 24 gallons empty
Cameras:	Seven—one color, three intensified near-infrared, three black and white
Lasers:	Two sets of low-power beams for LSP and Mist measurements
Sensors:	Dozens of pressure, temperature, and radiation sensors
Gas Analysis:	Gas chromatograph determines percent of each kind of gas
Gas Bottle Sizes:	Total of 21—three 10 liter, nine 3.8 liter, eight .7 liter, one .4 liter
Gas Bottle Usage:	Fourteen SOFBALL mixes, two air, two LSP fuel, three chromatograph
Software:	Three computers, ~35,000 lines of code, 25-MHz clock speed
Video:	Four VCR's, frame grabber, and two-channel downlink capability; 6-in. diagonal screen onboard
Data:	13.3 gigabytes storage (20 hard drives/flash memory cartridges)
Crew Time:	86 hours

Astronaut Janice Voss services the LSP EMS, partially withdrawn from the combustion chamber, during the MSL–1 mission in 1997.