# Laminar Soot Processes-2 (STS-107)
# Studying Fire in the Sky

## Soot: The Good, the Bad, and the Ugly

Soot is a scourge. It looks and smells bad, and it's a health hazard. It's also wasted energy, which is a paradox since soot forms in a flame's hottest regions, where you would expect complete combustion and no waste.

The causes of soot production are among the most important unresolved problems of combustion science. This is because gravity's effect on the combustion process has impeded the development of combustion science, much as the atmosphere has impeded the development of astronomy.

The Laminar Soot Processes (LSP-2) experiment will use the microgravity environment of space to eliminate buoyancy effects and thus slow the reactions inside a laminar jet diffusion flame so they can be more easily studied. These flames are similar to candle flames *except* the fuel is supplied by a gas jet rather than by evaporation from a wick. The effect is similiar to that of a butane lighter and the flames approximate the combustion that takes place in diesel engines, aircraft jet engines, furnaces, water heaters, and other devices.

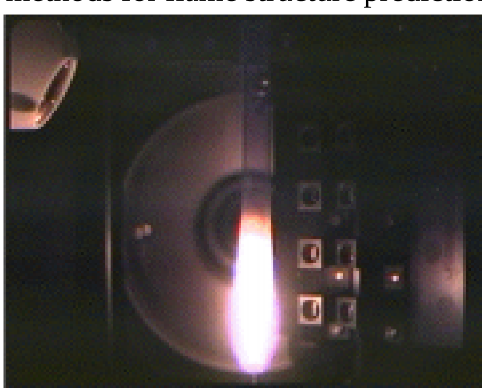
**Areas Affected by the Study of Soot Processes**

**Transportation**: Internal combustion engines on aircraft (jet and piston), rail, ships, trucks, buses
**Industry**: Power plants, manufacturing plants that use combustion heating
**Consumer**: Home heating and cooking; and gas-fired heat pumps

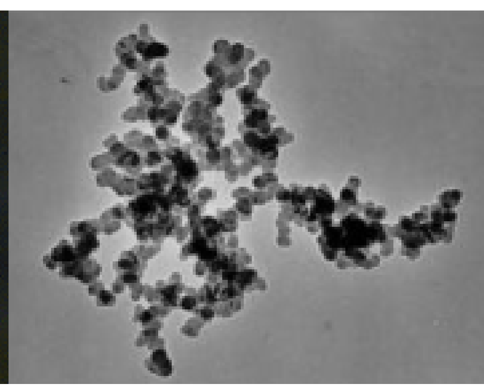
LSP-2 will explore the provocative results of LSP-1, which was flown in 1997. The data suggest the existence of universal state relationships—called the "soot paradigm"—that, if proven, will be used to model and develop more efficient combustion systems on Earth.

## Science Objectives

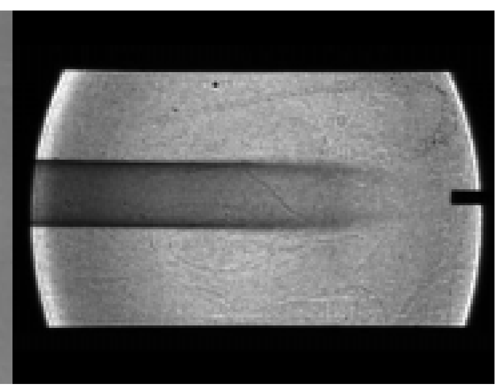
The primary objectives of LSP-2 are to evaluate flame shape predictions, determine the nature of the soot emission process, assess the soot state relationship concept, investigate the soot bursting hypothesis, and develop methods for flame structure predictions.



LSP uses a small jet burner—similar to a butane lighter—that produces flames up to 60 mm (2.3 in) long.



Individual soot particles from MSL-1 experiments are 10-60 nanometers wide; aggregates are 1,000 nm (1 micron) wide.



This laser image shows the soot produced by an LSP flame.

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For more information, please visit the NASA-Glenn Microgravity Combustion web site: **http://microgravity.grc.nasa.gov/combustion/**

## LSP-1 Results

LSP-1, which flew in 1997, yielded a number of surprises. A new mechanism of flame extinction caused by radiation from soot was discovered. The mechanism is unusual because the flame quenches near its tip, unlike a buoyant flame which quenches near its base. The LSP-1 team also made the first observations of steady, soot-containing nonbuoyant flames (with and without soot emissions).

## LSP-2 Hardware

LSP-2 experiments will be conducted inside the Combustion Module-2 (CM-2) facility. CM-2 consists of a rack that holds the Fluid Supply Package and video support equipment, and a double rack that includes the Experiment Package, computer, and mechanical support equipment.

The Experiment Package is a forged, aluminum combustion chamber (40 cm in diameter and 76 cm long) and diagnostic equipment. Six windows let external diagnostic instruments view and measure events inside the chamber. Diagnostics include a color camera, a soot volume fraction system (which measures soot by shining a laser through the flame), and a soot temperature measurement system.

The LSP-2 Experiment Mounting Structure (EMS)—which consists of experiment-specific equipment—has a large central volume in which the laminar flames will be formed. A series of soot samplers snap through the flame to capture particles for post-flight analysis.

## Operations In Space

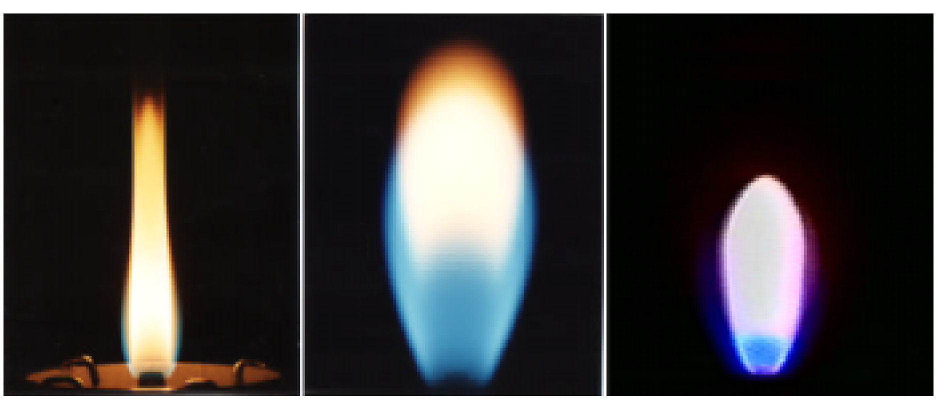
LSP-2 is operated by the flight crew through a laptop computer connected to CM-2. During flight, the crew will install the EMS, fill the chamber with fresh air, ignite the flame, adjust the fuel flow rate to get the right smoke height, adjust the camera exposure time to get the best possible images, end the test run, and vent the chamber for the next test.

A CM-2 engineer inspecting the Combustion Module-2, which consists of the Fluids Supply Rack (left) and the Experiment Rack (right).

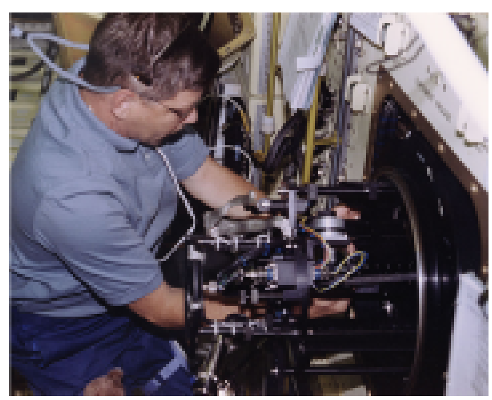
**Benefits of Studying Soot**

Better burner design and operation will:

- Reduce soot production in combustion processes.
- Reduce radiative heat transfer from soot that damages engines and furnaces.
- Improve combustion models for designing new, optimized systems and retrofitting existing systems.



In buoyant flames (left), soot mainly nucleates at the outer boundary of the soot production region, moving inward before approaching the flame sheet near the flame tip. In nonbuoyant, or microgravity, flames (center and right), soot mainly nucleates near the inner boundary of the soot production region, and is then drawn toward the flame sheet.



Dr. Roger Crouch, a payload specialist on 1997's MSL-1 mission, inserting the LSP-1 Experiment Mounting Structure (EMS) into Combustion Module-1 during flight.