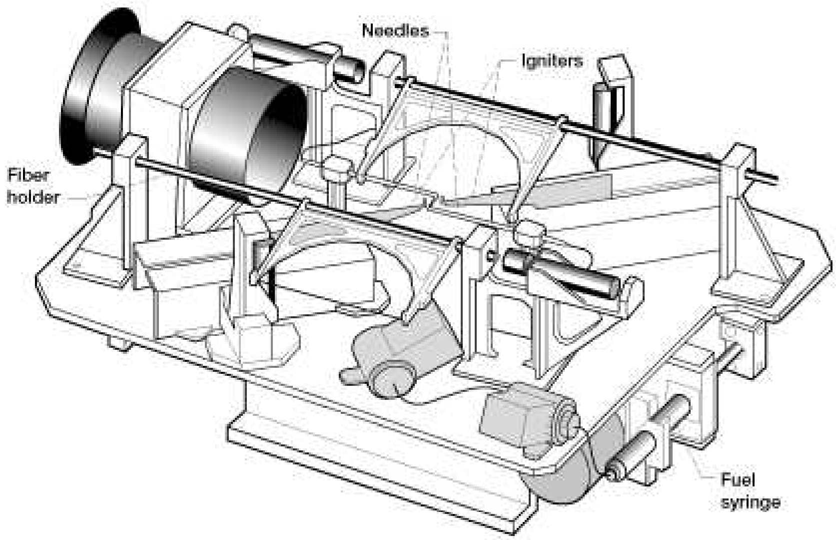
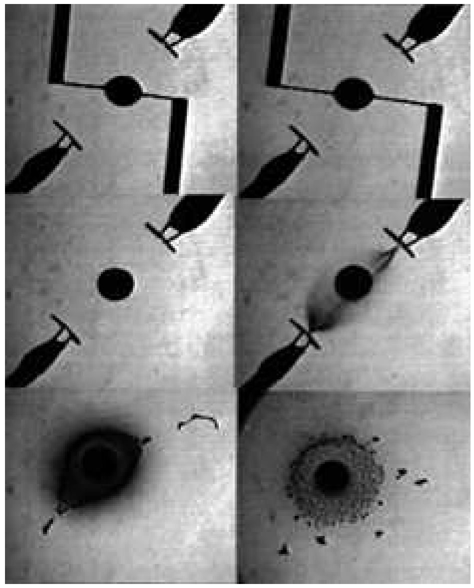
Droplet Combustion Experiment

Liquid fuel combustion provides a major portion of the world's energy supply. In most practical combustion devices, liquid burns after being separated into a droplet spray. Essential to the design of efficient combustion systems is a knowledge of droplet combustion behavior. The microgravity environment aboard spacecraft provides an opportunity to investigate the complex interactions between the physical and chemical combustion processes involved in droplet combustion without the complications of natural buoyancy.

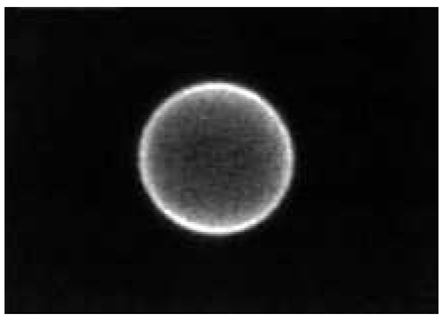


DCE internal apparatus.

Launched on STS-83 and STS-94 (April 4 and July 1, 1997), the Droplet Combustion Experiment (DCE) investigated the fundamentals of droplet combustion under a range of pressures (0.25 to 1 atm), oxygen mole fractions (<0.5), and droplet sizes (1.5 to 5 mm). Principal DCE flight hardware features were a chamber to supply selected test environments, the use of crew-inserted bottles, and a vent system to remove unwanted gaseous combustion products. The illustration above shows the internal apparatus located inside the test chamber. The internal apparatus contained the droplet deployment and ignition mechanisms to burn single, freely deployed droplets in microgravity. Diagnostics systems included a 35-mm high-speed motion picture camera (see the following sequence of photos) with a backlight to photograph burning droplets and a camcorder to monitor experiment operations. Additional diagnostics included an ultraviolet-light-sensitive CCD (charge couple discharge) camera to obtain flame radiation from hydroxyl radicals (see the final figure) and a 35-mm SLR (single-lens-reflex) camera to obtain color still photographs of the flames.



Droplet growth, deployment, and burning sequence from a 35-mm high-speed camera.



Hydroxyl radical chemiluminescence obtained from an ultraviolet camera for an n-heptane droplet burning in a 30 vol % oxygen - 70 vol % helium environment at 1-atm pressure.

The DCE experiments, which were carried out during the Microgravity Science Laboratory (MSL-1) mission in Spacelab, burned n-heptane droplets in helium-oxygen test gases and identified three regimes of droplet combustion. Droplets burned for as long as 20 seconds, much too long a time to be studied in Earth-bound facilities. The first regime was the quasi-steady regime, a fairly well documented regime in which the droplets and flames decrease linearly with time until extinction. The extinction size can be related to the chemical kinetics of combustion. A much less well documented regime (flame radiation) occurred when sufficiently large droplets and low oxygen levels were used.

Extinction occurred soon after ignition because of the large radiation heat losses from the flames. Finally, another less well documented regime (droplet disappearance) occurred when oxygen levels were sufficiently high. A flame would persist for a short time after the droplet had completely vaporized and would extinguish at a nonzero flame radius. This regime leaves behind a small vapor cloud that might be responsible for combustion inefficiencies in practical combustion systems.

Professor Forman A. Williams of the University of California, San Diego, and Professor

Frederick L. Dryer of Princeton University served as the principal investigator and coinvestigator, respectively, for the DCE experiments. The DCE hardware was designed and built at the NASA Lewis Research Center.

The experiment results will aid in reducing air pollution, conserving fuel energy sources, and improving fire safety. Extinction and soot-generation phenomena will help researchers to determine the best way to build fire protection systems as well as help designers to design efficient combustion systems for space that are low in unwanted combustion product pollutants.

Lewis contacts: Dr. Vedha Nayagam (Project Scientist) (216) 433-8702, Vedha.Nayagam@grc.nasa.gov, and John Haggard (Project Manager), (216) 433-2832, John.B.Haggard@grc.nasa.gov
Author: Dr. Vedha Nayagam
Headquarters program office: OLMSA
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