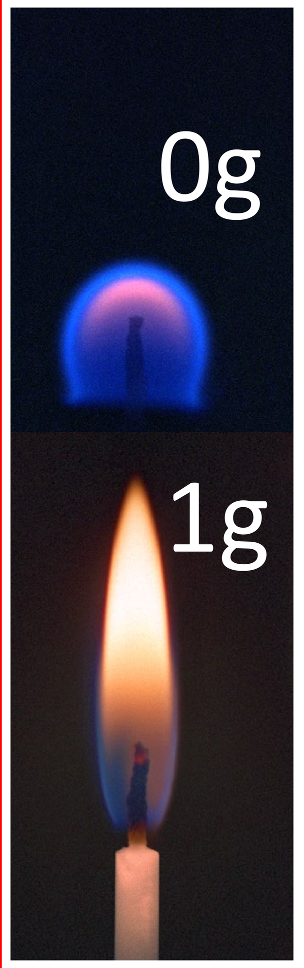


Space Science 101 – Combustion

Why is combustion research important to space exploration?

- Fire is a critical hazard for spaceflight.
  - Limited resources; escape opportunities; smoke and toxic gas production; and constrained post-fire recovery make fire a catastrophic hazard.
- Low-gravity research is needed to improve and validate fire prevention, detection, suppression, and post-fire cleanup strategies as gravity impacts all of these processes.

Why is space research important to combustion ?

- Laboratory flames on Earth are dominated by the effects of buoyancy.
- In space we can study other competing or controlling phenomena without the complications raised by buoyancy.
- This understanding can be directly applied to combustion in engines which are typically not controlled by buoyancy.

Why is combustion research important to Earth?

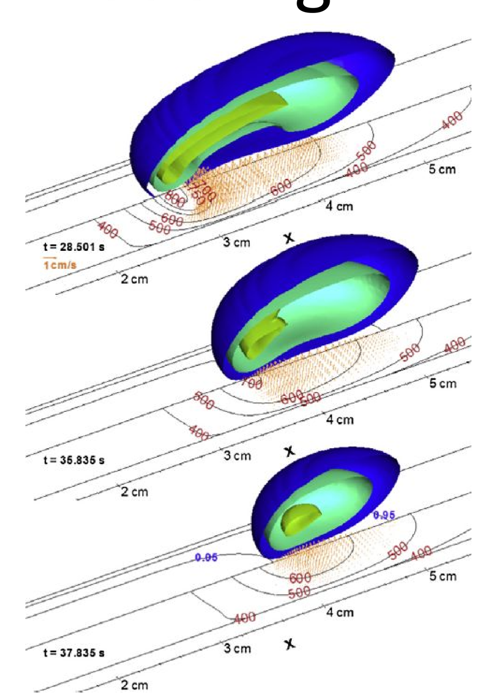
To enable critical technologies on Earth. Combustion affects our economy at all levels:

- 85% of our delivered energy comes from combustion
- Combustion is the primary source of air pollution
- Combustion processes are a dominant source of greenhouse gas release; we need to learn how to capture energy from fuels more efficiently
- Unwanted fires cause extensive loss of life and property
- Combustion is an essential element of the fabrication of numerous materials and an emerging source of novel material synthesis.

Important Questions – what do we need to know about combustion science and fire behavior to support space exploration?

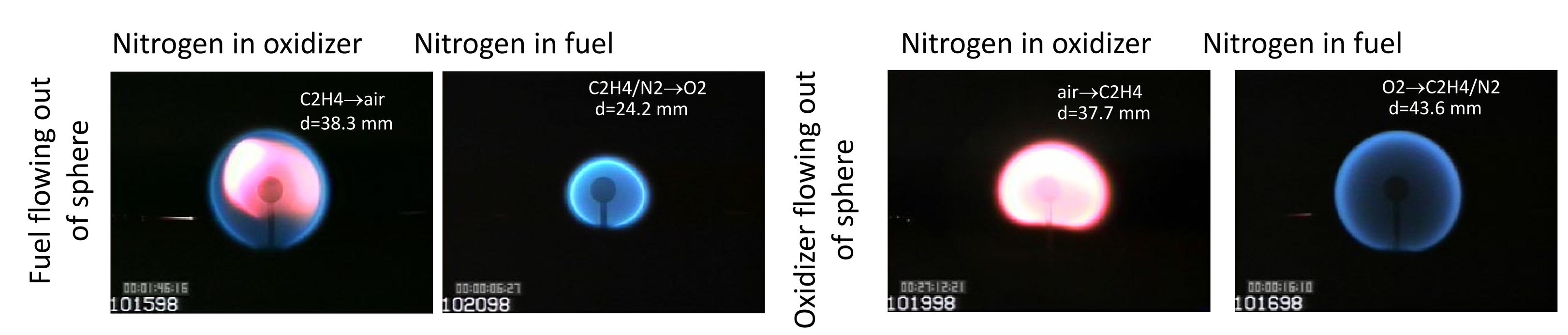
- Buoyant flows induced by combustion heat and 1-g are mitigated in partial-g environments and eliminated in microgravity. Controlling mechanisms change in reduced gravity resulting in different flame behavior e.g. different flame shapes and burning rates.
- The flammability limits of materials can change in low-gravity, some become more flammable than on Earth. A more complete assessment of the flammability of practical spacecraft materials is needed.
- The growth of fires and the transport of smoke in a spacecraft cabin is very different in low-gravity. Validating predictions of the entire fire scenario and the effectiveness of detection and suppression strategies in low-gravity is needed to ensure mission safety.

Fire Spread Modeling



Materials Flammability Screening

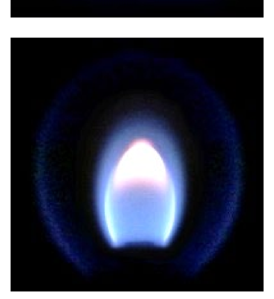
Demonstration of soot control in low-gravity



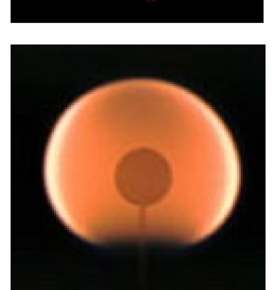
Wide Range of low-gravity flame structures


Emulation of solid fuel combustion

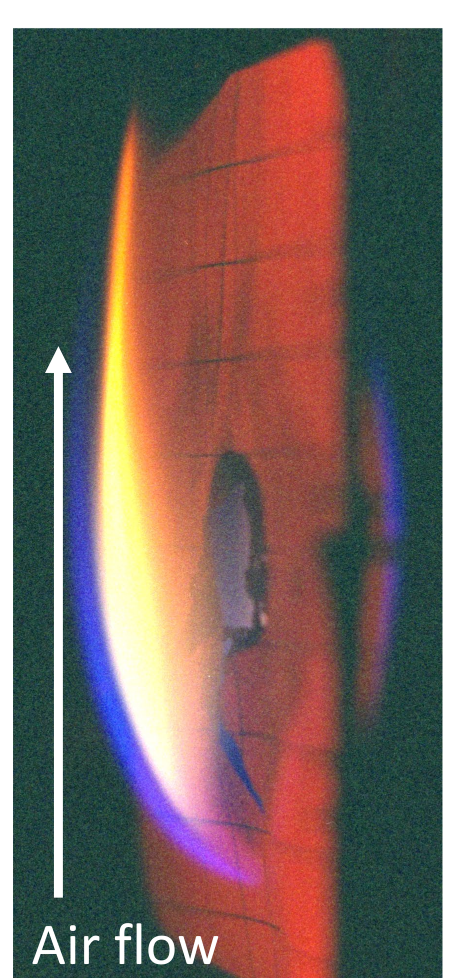

Coflow Laminar Diffusion Flame


Electric-Field Effects on Laminar Diffusion for stabilization


Flame Design for soot control

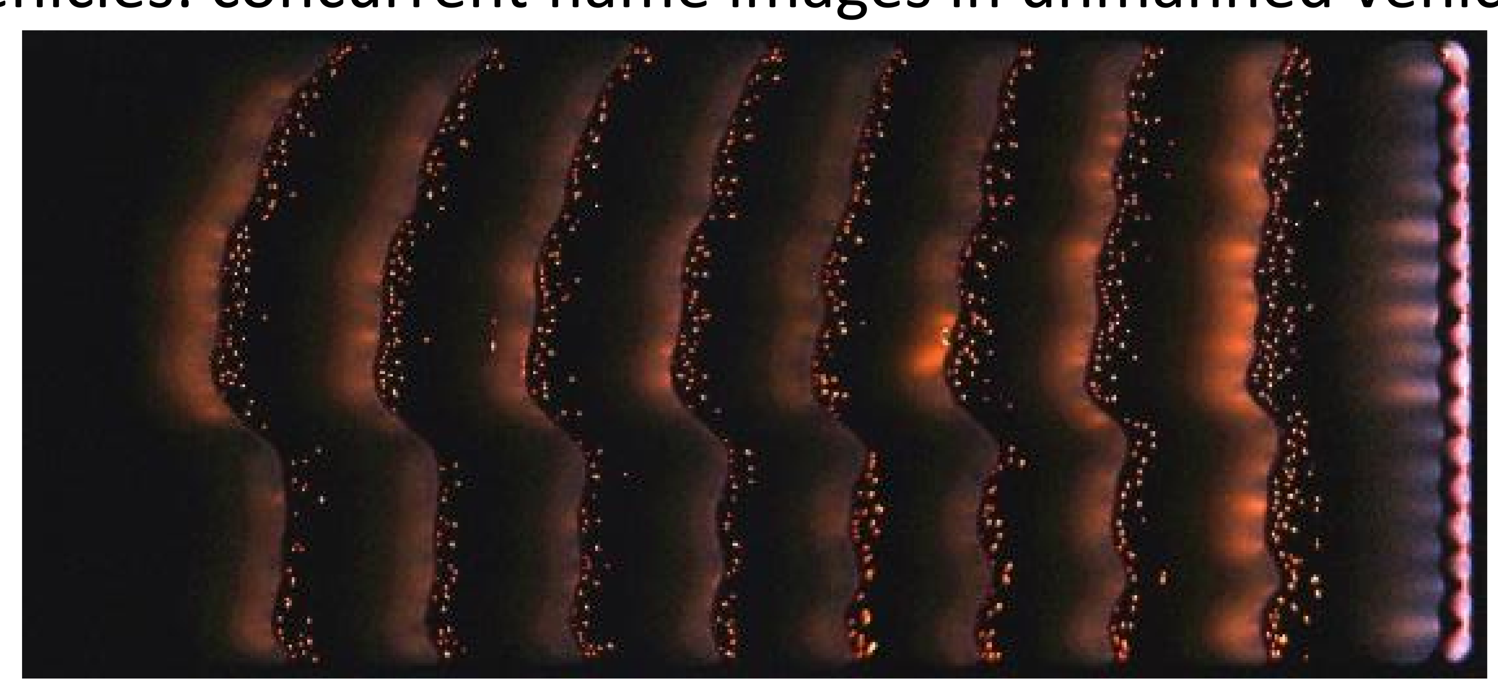

Spherical Diffusion Flames – flame structure and soot production

Flame Spread over surface in low-gravity



In low-gravity, flame spreads into the wind, contrary to normal-gravity

Large scale experiments are unsafe to conduct in manned vehicles: concurrent flame images in unmanned vehicle



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Selected Important Answers – what have we learned that could only be revealed in space?

Cool Flames (flames that have flame temperatures significantly below normal flame temperatures and are also typically unstable) were stabilized in low-gravity unexpectedly, providing a test of the chemical kinetics for engine knock and diesel ignition.

Radiative Extinction and absence of buoyant flows changed the heat loss mechanisms for flames bringing radiative heat loss forward as the dominant mechanism for extinction in low speed flows.

Flame Balls are formed in the absence of buoyancy and turbulence allowing diffusion of gaseous reactants to control their diameter. Modeling them provides good validation of fundamentals. They were predicted to exist 70 years ago but had never been demonstrated until the space experiments.

Unusual Flame Structures created by removing gravity allow interrogation of conditions that that cannot be studied in a 1-g lab.

Fire Risk exists in spacecraft as long as there is fuel, oxygen, and a potential source of heat. We reduce fire risk by understanding *material flammability, ignition sources, atmosphere effects* ***(O_2, P, flow),*** *fire modeling.*

Spacecraft Atmospheres Impact Fire Risks