National Aeronautics and Space Administration

advanced combustion via microgravity experiments

Advanced Combustion via Microgravity Experiments (ACME)

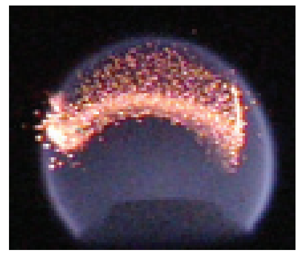
PURPOSE: ACME is focused on advanced combustion technology via fundamental microgravity research. The primary goal is to improve efficiency and reduce pollutant emission in practical terrestrial combustion. A secondary objective is fire prevention, especially for spacecraft.

RESEARCH: ACME includes five independent experiments investigating laminar, gaseous, nonpremixed flames. They will be conducted with a single set of modular hardware in the Combustion Integrated Rack (CIR) on the International Space Station (ISS). An ACME precursor, the Structure and Liftoff In Combustion Experiment (SLICE), was conducted on ISS in 2012.

STATUS: ZIN Technologies, under the direction of the NASA Glenn Research Center, has completed the design and is now fabricating the space flight hardware. On-orbit testing is expected to begin in 2017 and continue for a few years.

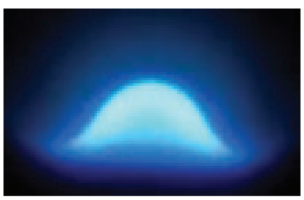
WEB SITE: http://spaceflightsystems.grc.nasa.gov/acme/

Burning Rate Emulator (BRE)



- Objective: Fire Safety—To improve our fundamental understanding of materials flammability, such as extinction behavior and the conditions needed for sustained combustion, and to assess the relevance of existing flammability test methods for low- and partial-gravity environments.
- Flame/Burner: Flat perforated disk fed with gaseous fuel to simulate the burning of solid and liquid fuels, where measurements are made of the thermal feedback upon which the vaporization of such fuels depend.
- Investigators: Profs. James G. Quintiere and Peter B. Sunderland, University of Maryland; and Dr. John L. deRis, FM Global (retired)

Coflow Laminar Diffusion Flame (CLD Flame)

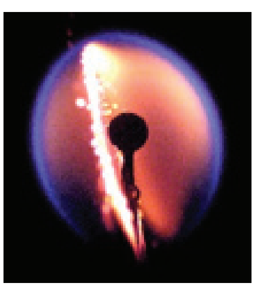


- Objective: Energy and Environment—To extend the range of flame conditions that can be accurately predicted by computational models, especially for highly dilute and heavily sooting conditions.
- Flame/Burner: Coflow flame where the gaseous fuel issues from an inner tube, which is centered within a much larger outer tube, where an oxygen/nitrogen mixture issues from the annulus.
- Investigators: Profs. Marshall B. Long and Mitchell D. Smooke, Yale University

Electric-Field Effects on Laminar Diffusion Flames (E-FIELD Flames)

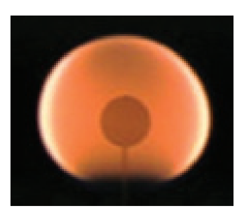
- Objective: Energy and Environment—To gain an improved understanding of ion production in flames and investigate how an electric field can be used to control flames through the ion-driven wind.
- Flame/Burner: Gas-jet flame, where (1) the gaseous fuel issues from a small circular tube into a still atmosphere and (2) a high-voltage electric field is established between the burner and a disk-shaped copper mesh located a few centimeters downstream of the burner.
- Investigator: Prof. Derek Dunn-Rankin, University of California, Irvine

Flame Design



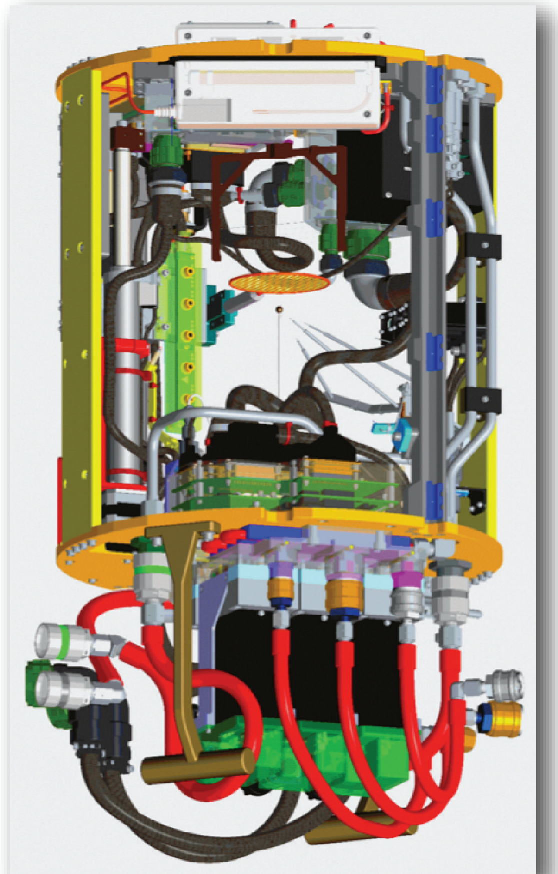
- Objective: Energy and Environment—To improve our understanding of soot inception and control in order to enable (1) the "design" of nonpremixed flames that are both robust and soot free and (2) the optimization of oxygen-enriched combustion.
- Flame/Burner: Spherical flame where the burner gas issues from a porous spherical burner. Tests are planned for both (1) normal flames, where the fuel flows into an oxygen/inert atmosphere and (2) inverse flames, where an oxygen/inert mixture flows into a fuel atmosphere.
- Investigators: Prof. Richard L. Axelbaum, Washington University in St. Louis; Prof. Beei-Huan Chao, University of Hawaii; Prof. Peter B. Sunderland, University of Maryland; and Dr. David L. Urban, NASA Glenn Research Center

Structure and Response of Spherical Diffusion Flames (s-Flame)



- Objective: Energy and Environment—To advance our ability to predict the structure and dynamics, including extinction, of both soot-free and sooty flames.
- Flame/Burner: Spherical flame—which is only possible in microgravity—where the gaseous fuel (fed through a small tube) issues from a porous spherical burner into a still oxygen/inert atmosphere.
- Investigators: Prof. C.K. Law, Princeton University; Prof. Stephen D. Tse, Rutgers University; and Dr. Kurt R. Sacksteder, NASA Glenn Research Center

ACME Hardware



ACME chamber insert

Mass Flow Controllers (MFCs)
- Three MFCs for the delivery of fuel, oxidizer, and/or nitrogen to the burner (and chamber for filling)
- Capable of on-orbit dilution of fuel or oxidizer (but not both at once), coflow flames, inverse flames, and premixed flames

Igniter
- Resistively heated, retracting with stepper-motor drive for precise positioning, with an exchangeable tip and arm

High-Voltage Supply and Electrode Mesh—for E-FIELD Flames
- –10 to +10 kV to crew-removable mesh downstream of burner where the ion current between mesh and burner is determined from the voltage drop across a known resistor

Thermocouples (TCs)
- Six far-field TCs to measure the thermal field spread, where two versions of a four-TC rake allow varied proximity to the burner

Radiometers (specifically thermopile detectors)
- One fixed wide-view sensor plus a crew-exchangeable array with up to five additional radiometers, where all sensors are sensitive from 0.2 to 11 microns

Photomultiplier Tube (PMT) Modules
- Three wide-view PMTs: (1) broadband, 230 to 700 nm, (2) OH* emission, 310-nm filter, and (3) CH* emission, 430-nm filter

Analog Color Camera (*hidden from view*)
- Downlinked in near real time to support operations, with an array of light-emitting diodes (LEDs) to illuminate the burner position, etc.

OH* Camera (*not shown*)
- Intensified monochrome camera, 310-nm filter, 30 frames per second binned at 512×512

Digital Color Camera (*not shown*)
- 12-bit, up to 30 frames per second at 1360×1024
- Motorized lens with independent control of zoom, iris, and focus
- Four filters: (1) clear for color imaging, (2) blue-green filter to balance color planes for pyrometry and soot volume fraction measurements, and (3-4) 430- and 450-nm filters for CH* imaging, where the combination enables subtraction of interfering soot emission

Color-Ratio Soot and Thin Filament Pyrometry
- (1) Compare color planes of digital color camera (*see above*) and/or (2) compare frames from a second monochrome camera (*not shown*) equipped with a liquid-crystal tunable filter, 30 frames per second binned at 512×512
- Translating array of five silicon carbide fibers (5 mm apart) with alternate arrays for absolute light calibration

Soot Volume Fraction
- Determined from (1) digital color camera (*see above*) using pyrometry results and absolute light calibration and/or (2) light extinction using a third monochrome camera (*not shown*), 30 frames per second at 1024×1024, and a light source with two fiber-coupled laser diodes

Gas Chromatograph (GC)
- Pre- and post-test analysis of chamber atmosphere for oxygen, nitrogen, carbon dioxide, carbon monoxide, and fuel gases

ACME Operations

- ACME experiments are constant volume, with ~85 liters free, where tests are typically 0.5 to 2 minutes long to limit the pressure rise
- Tests manually set up by ISS crew and then remotely commanded from the NASA Glenn Research Center (Cleveland, OH)
- Tests conducted in (1) a nominally automated mode using preprogrammed scripts and/or (2) a “manual” mode where changes can be made, for example, to flow(s) in response to video downlink and telemetry (e.g., to approach a soot or stability limit)

ACME Contacts

Project Manager: J. Mark Hickman, 216–977–7105
john.m.hickman@nasa.gov

Deputy Project Manager: Andrew C. Suttles, 216–433–8328
andrew.c.suttles@nasa.gov

Project Scientist: Dennis P. Stocker, 216–433–2166
dennis.p.stocker@nasa.gov

Deputy Project Scientist: Dr. Fumiaki Takahashi, 216–433–3778
fumiaki.takahashi-1@nasa.gov

National Aeronautics and Space Administration

Glenn Research Center
21000 Brookpark Road
Cleveland, Ohio 44135

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