Numerical Analysis of Smoke Transport in Reduced Gravity

Bjoern Bingham[1,2], Salix Bair[1,2], Matthew Claassen[1,2], Alita Regi[2], Xiaoliang Wang[1,2], Judith C. Chow[2], John G. Watson[2], W. P. Arnott[1], Marit E. Myer[3], and Claire Fortenberry[4]

[1]University of Nevada, Reno, NV
[2]Desert Research Institute, Reno, NV
[3]NASA Glenn Research Center, Cleveland, OH
[4]Universities Space Research Association, Cleveland, OH

- Contact information:

  Bjoern Bingham (M.S. student): bjoernb@nevada.unr.edu, (707) 362-0940
  Xiaoliang Wang (thesis advisor): xiaoliang.wang@dri.edu, (775) 674-7177

- Statement of proposition/hypothesis: Smoke transport in reduced gravity behaves differently than on Earth.

Abstract:

Fires are catastrophic to space activities. In the confined space of a spacecraft, toxic gases, and particles can increase to dangerous concentrations much faster than in most terrestrial situations, and as missions increase in length, the risk of fire increases. Therefore, improving the understanding of the transport of fire emissions is critical for the placement of smoke detectors, ventilation, and safety procedures. The goal of this project is to effectively model the transport of smoke from a sample of PTFE by utilizing the NIST Fire Dynamics Simulator (FDS). Specific objectives are to 1) learn to use FDS and SMV; 2) Simulate smoke emissions and transport in the Orion Spacecraft under different gravities using experimentally collected emission factors; and 3) model multiple ventilation orientations in FDS.

Smoke emission and transport vary with gravity. Under normal gravity (1 g = 9.81 m/s2) on Earth, terrestrial fires are dominated by the buoyant transport of both oxidizers and combustion products. In contrast, under the micro-gravity (near 0 g) of the International Space Station, smoke lingers near the fire source, and smoke transport is mainly driven by the ventilation flow.

Computational Fluid Dynamics (CFD) simulations have become a powerful tool to study fire behaviors for both terrestrial and space fires. CFD simulations provide useful insights into the optimization of smoke detector locations and ventilation arrangements for quickly purging smoke out of the spacecraft. As NASA plans to return astronauts to the Moon and further leap forward onto Mars, studying smoke emission and transport under lunar (1/6 g = 1.62 m/s2) and Mars (0.38 g = 3.71 m/s2) gravities is of critical importance in designing the spacecraft ventilation and smoke detection systems. Results presented here provide a visual representation of gaseous and particulate emission transport as well as modeled concentrations at multiple locations.