Compartment Fire Modeling of a Crew Cabin in 1-g and Lunar-g

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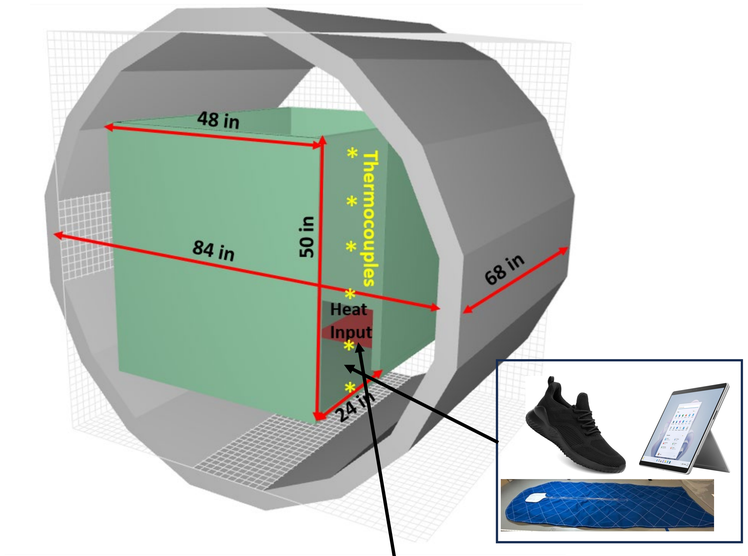
Introduction

- A fire on a spacecraft poses a catastrophic risk
- Large-scale fire growth tests were performed to inform the decision regarding cabin atmosphere for the Artemis 3 mission
- Data from these tests was used to develop a model to determine the habitability inside a crew cabin
- The profile from the top thermocouple at the door was used as the heat input of the model and the magnitude of the heat input was calibrated until the model matched the experiment
- Other thermocouples at the door were used to validate the model
- Model was simulated in lunar-g to determine the effect of gravity



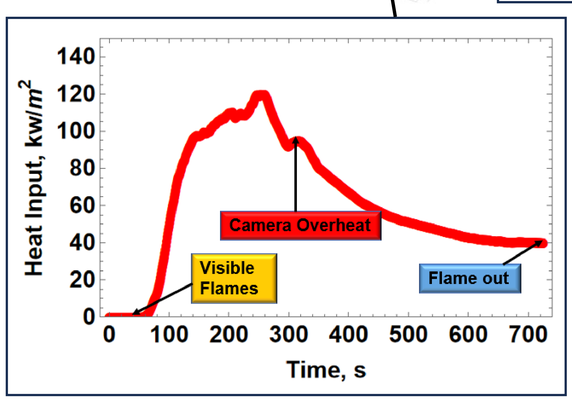


Figure 1: Geometry of model with Heat Input Parameter. The model shows and open pressure chamber in gray to visualize the crew cabin, despite being a closed pressure chamber during the experiment and simulation.

Objectives

- Use data from tests to estimate heat input into crew cabin
- Validate numerical model in 1-g using test data
- Use model in lunar-g to estimate the effect of gravity on the habitability inside the crew cabin

Experimental Conditions

Nine tests were performed on partial crew quarters mockups at White Sands Test Facility to observe fire growth in exploration atmospheres

- O_2 from 24% to 37%
- Pressure from 8.2 to 12.44 psia

Ignition from chemical igniter or Surface Pro (lithium-ion battery thermal runaway via patch heater)

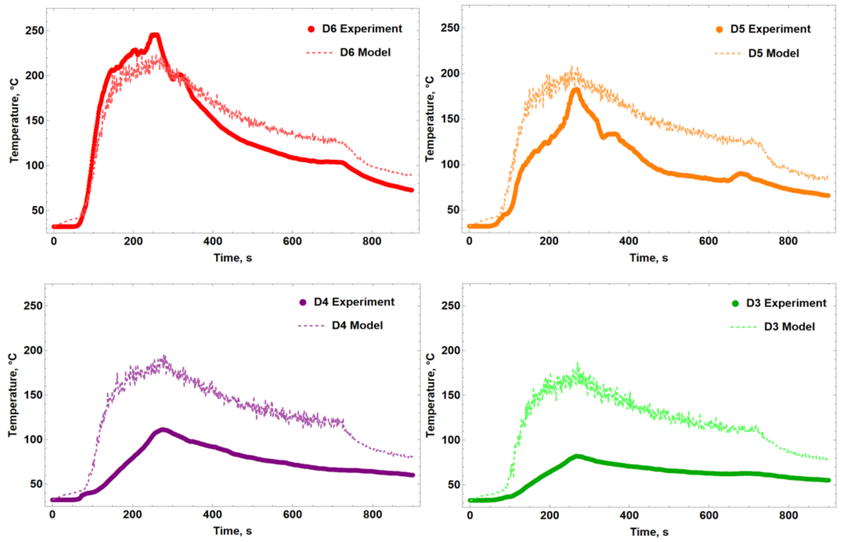


Figure 2: Experimental and simulated temperature profiles at the door for Test 4 (24% O_2, 12.4 psia and chemical igniter). Thermocouples were 9.2 inches apart, with D6 at the top and D1 at the bottom.

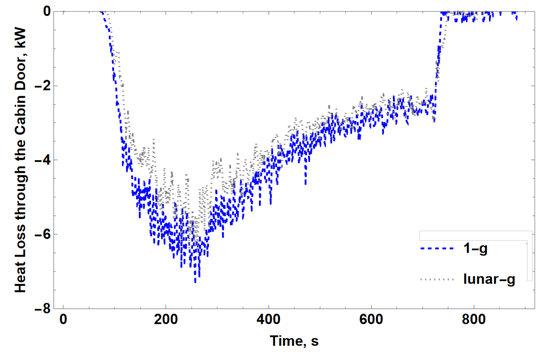


Figure 4: Heat loss through the door of the crew cabin for 1-g and Lunar-g simulations calculated

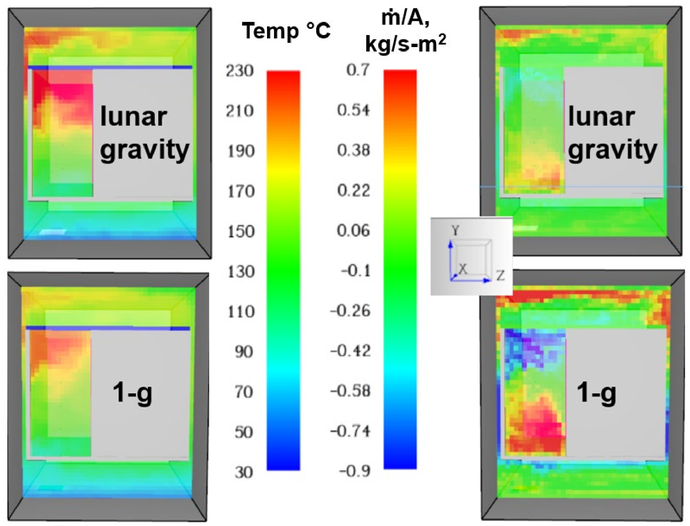


Figure 5: Temperature and mass flow rate at the door of the crew cabin for lunar-g and 1-g simulations. The darker red in the top of the lunar-g simulation temperature contour on the left indicate a higher temperature. The darker blue at the top of the mass flow contour for the 1-g simulation shows more hot mass exiting the top, while the dark red in the bottom of the mass flow contour shows more cold air entering from the bottom when compared to the lunar-g simulation.

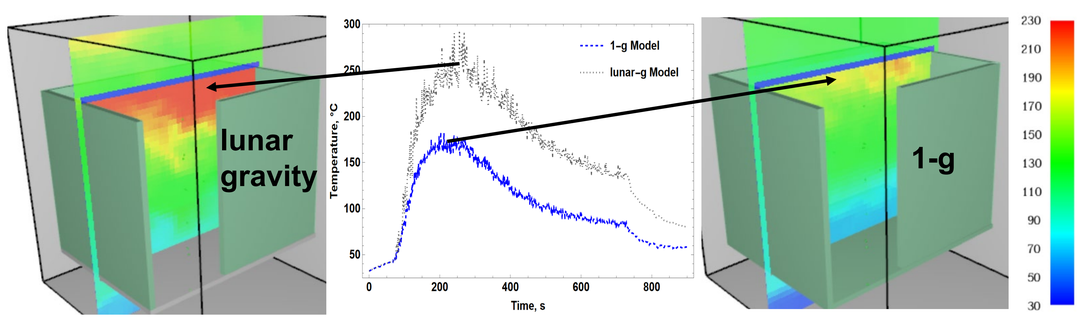


Figure 3: Midplane of crew cabin temperature contours for lunar-g and 1-g simulations at 250 s. Lunar-g simulation is noticeable hotter.

Conclusions

- A test campaign was completed at WSTF in order to test fire growth and fire propagation properties at exploration atmospheres
- Data from the test campaign was used to validate a model in 1-g that generated a heat input to match the atmospheric temperature
- The model was simulated in Lunar-g to determine the effect of gravity on habitability
- Air temperature in the lunar-g simulation was substantially higher than in 1-g showing buoyant transport significantly affects habitability

Acknowledgements

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