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Fire Suppression and Response

Strategic Research to Enable NASA's Exploration Missions
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Fire Prevention, Detection, and Suppression

Overview

- Organizing Questions
- Programmatic Background
- Experimental Concepts
- Discussion

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Fire Prevention, Detection, and Suppression

Organizing Questions for Research in Fire Suppression and Response

Background

- Limited research to date directed toward extinguishment of existing fires
  - Venting extinguishment testing (Skylab and KC-135)
  - CO_2 extinguishment testing (KC-135)
  - Thin-fuel Flammability limit testing (drop towers and KC-135)
- Testing has been limited to partially developed small fires
- Development of a reliable extinguishment system will require testing of extinguishment of a variety types of fires in a range of geometries, including well established fires

Organizing Questions

1. **What is the relative effectiveness of candidate suppressants to extinguish a representative fire in reduced gravity, including high-O_2 mole fraction, low-pressure environments?**
2. **What are the relative advantages and disadvantages of physically-acting and chemically-acting agents in spacecraft fire suppression?**
3. **What are the O_2 mole fraction and absolute pressure below which a fire cannot exist?**
4. **What effect does gas-phase radiation play in the overall fire and post-fire environments?**
5. **Are the candidate suppressants effective to extinguish fires on practical solid fuels?**
6. **What is required to suppress non-flaming fires (smoldering and deep-seated fires) in reduced gravity?**
7. **How can idealized space experiment results be applied to a practical fire scenario?**
8. **What is the optimal agent deployment strategy for space fire suppression?**

1. What is the relative effectiveness of candidate suppressants to extinguish a representative fire in reduced gravity, including high-O_2 mole fraction, low-pressure environments?

- CO_2, N_2, He, water mist, microencapsulated water, ...
- What metric do you use for effectiveness when evaluating different suppressants?
- What test configuration (or range of configurations) should be used?

2. What are the relative advantages and disadvantages of physically-acting and chemically -acting agents in spacecraft fire suppression?

- Chemical suppressants may be effective at concentrations below SMAC values
- Are chemical suppressants equally effective in reduced gravity?
- What metric do you use for effectiveness when evaluating different suppressants?
- What test configuration (or range of configurations) should be used?

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3. What are the O_2 mole fraction and absolute pressure below which a fire cannot exist?

- Provides a lower limit for design of a suppression delivery system
- Presume a physically-acting extinguishing agent
- Value will depend on configuration, fuel, and diluent
  - Testing with μg droplet combustion has shown the limiting oxygen index (LOI) for droplet combustion to be substantially (~4 mol %) below that for solids or normal gravity droplet testing.

4. What effect does radiative absorption in the gas phase play in the overall fire and post-fire environments?

- Prior work with radiatively participating gases indicate that extinguishing CO_2 concentrations in oxidizing environments might result in broader flammability limits due to radiative feedback from the CO_2 rich ambient.
- Effect is minimized in normal gravity because of buoyancy.

5. Are the candidate suppressants effective to extinguish fires on practical solid fuels?

- Evaluating agent effectiveness may require a simple geometry
- How is the connection made to a practical solid fuel?
- Is a space flight verification test required?

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6. What is required to suppress non-flaming fires (smoldering and deep-seated fires) in reduced gravity?

- NFPA Standard 12 requires a 20-minute holding time with CO_2
- Smoldering combustion is one of the most probable spacecraft fire scenarios (cable overheat, trash and bio-matter storage) yet holding times are unknown
- Deep seated fires (i.e., fires that can re-ignite after suppression of the gas-phase flame) have not been addressed for microgravity conditions
- Competition between heat loss (diffusion) and oxidant diffusion timescales
- Geometry can be either smoldering or dispersed solid (e.g. crib or trash fire)
- Testing will first establish whether re-ignition can occur and then extinguishment criteria will be established

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7. How can idealized space experiment results be applied to a practical fire scenario?

- Real fire geometries are complex and involve radiative interaction between burning solids.
- Model development concurrent with small scale extinguishment tests will build framework for large scale tests.
- Model validation with large scale testing will ultimately be required to assure extinguishment effectiveness

8. What is the optimal agent deployment strategy for space fire suppression?

- Normal gravity buoyant pumping of agent into fire is absent in μg (in both flooding and targeted application of agent)
- Fire brand transport and flammability must be considered in the design of hand-held extinguishers
- Fire brands released by agent deployment will not settle as in 1-g
- Flooding applications must be validated by computational modeling of agent deployment combined with experimental understanding of local extinguishment
- Data from the prior questions should be able to help address this issue

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Programmatic Background

- The Combustion Integrated Rack is currently scheduled for launch on ULF-2 in October 2006
- In March, a proposal was made at HQ to move the CIR launch to ULF-1.1 in June 2005
- What experiment can be run that supports the exploration mission?
  - Existing hardware → MDCA or MGFA inserts
- Two concepts were developed for rapid deployment
- The proposal was not accepted but the concepts remain relevant

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Brainstorming

- Fire Suppression
  - Carriers
    - ISS Glovebox
    - CIR new insert
    - FEANICS
  - Experiments
    - GBEX (cup burner)
    - FLEX (MDCA hardware)
    - Porous plate/cylinder
- Backward Facing Step
- Real Materials
- Smoldering Materials