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National Aeronautics and
Space Administration
John H. Glenn Research Center

Fire Prevention, Detection, and Suppression

Research Plan for Fire Signatures and Detection

Strategic Research to Enable NASA's Exploration Missions

June 22 - 23, 2004
Marriott Downtown at Key Center
Cleveland, Ohio USA

Fire Prevention, Detection, and Suppression Sub-Element Products

3. Advanced fire detection system for gaseous and particulate pre-fire and fire signatures
   a. Quantification of pre-fire pyrolysis products in microgravity
   b. Suite of gas and particulate sensors
   c. Reduced gravity evaluation of candidate detector technologies
   d. Reduced gravity verification of advanced fire detection system
   e. Validated database of fire and pre-fire signatures in low and partial gravity
4. Verified models of fire precursor transport in low and partial gravity
   a. Development of LES models for large-scale transport in reduced gravity
   b. Validated CFD simulations of transport of fire precursors
   c. Evaluation of the effect of scale on transport and reduced gravity fires

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FPDS Organizing Questions

Fire Signatures and Detection

1. What is the background particulate and chemical species loading in a spacecraft and how does it vary with time?
2. What are the appropriate pre-fire and fire signatures for fire detection in low and partial gravity?
3. Is there a normal gravity analog to quantify low and partial gravity fire signatures?
4. What type or suite of sensors minimize the time to alarm and yet eliminate nuisance alarms?
5. Where should fire detectors be placed to minimize the time for a detection system to alarm?
6. How much warning time will the crew get with a particular fire detection system?

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Signatures, Sensors, and Simulations

- **Quantification of fire and pre-fire signatures**
- **Development and characterization of sensors**
  - Electronic nose
  - MEMS gas sensors
  - Particulate sensors
  - IR absorption spectrometer
- **Simulations tools to determine the transport of smoke, fire precursors, and contaminants**
  - Where sensors should be located
  - Time to alarm

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Quantification of Fire and Pre-Fire Signatures

- Effect of microgravity on size distribution of pre-fire and fire particulates
- Effect of microgravity on combustion products and concentrations

  - Flames are often cooler and less radiant
  - Average size and range of soot particle sizes are greater
  - Combustion-product nature and quantities are altered

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SMOKE

Characterization of Smoke from Microgravity Fires for Improved Spacecraft Fire Detection

PI: Urban, NASA-GRC; co-I: Mulholland, Cleary, and Yang, NIST; Yuan, NCMR

- Experiment to be conducted in the Microgravity Science Glovebox
  - quantify the size distribution of liquid smokes from silicon rubber, cotton, Teflon, and DBT

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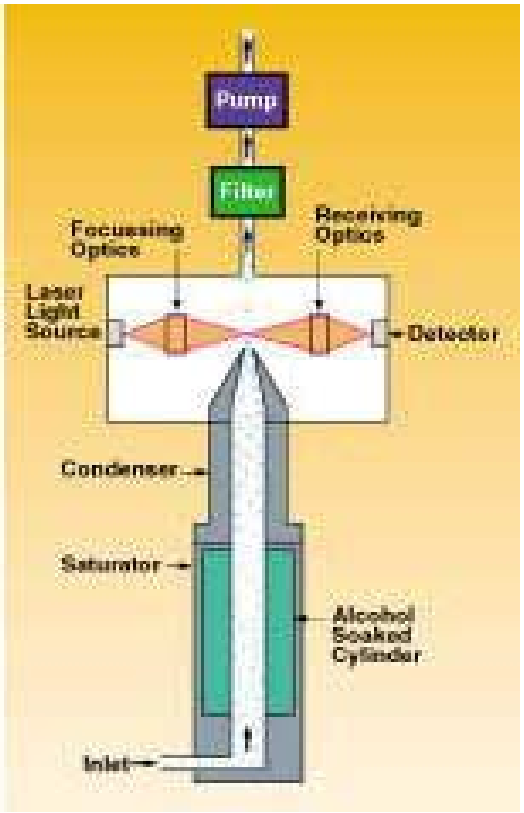
Quantification of Fire and Pre-Fire Signatures

➢ Background particulate loading

- ***D***ust and ***A***erosol measurement ***F***easibility ***T***est (DAFT)
- Risk mitigation experiment for Smoke to evaluate the performance of the TSI P-Trak in microgravity
  - Commercially available condensation nuclei counter in microgravity
  - Manifested for Progress Flight 16P (Nov 2004)



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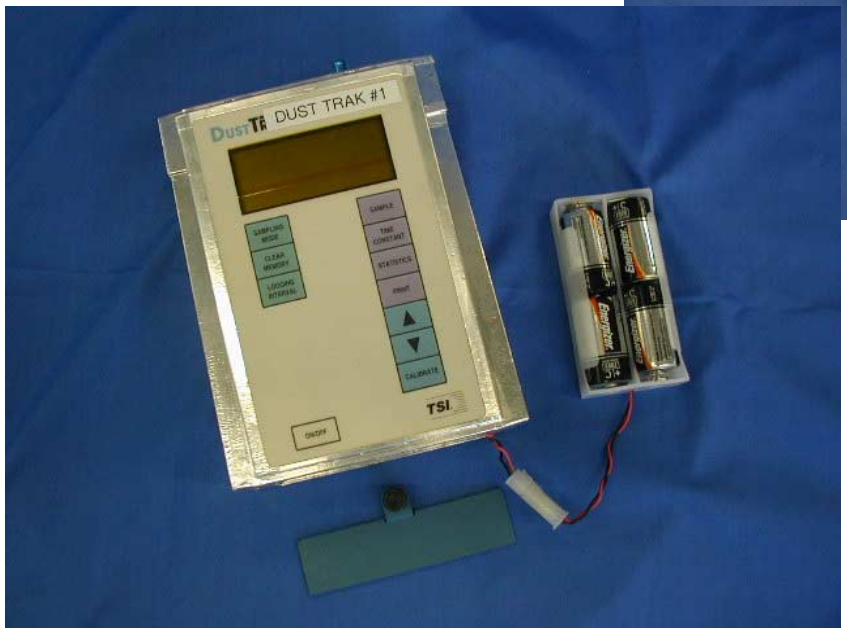
DAFT Hardware

P-Trak, Alcohol Wick (w/Container) and Batteries



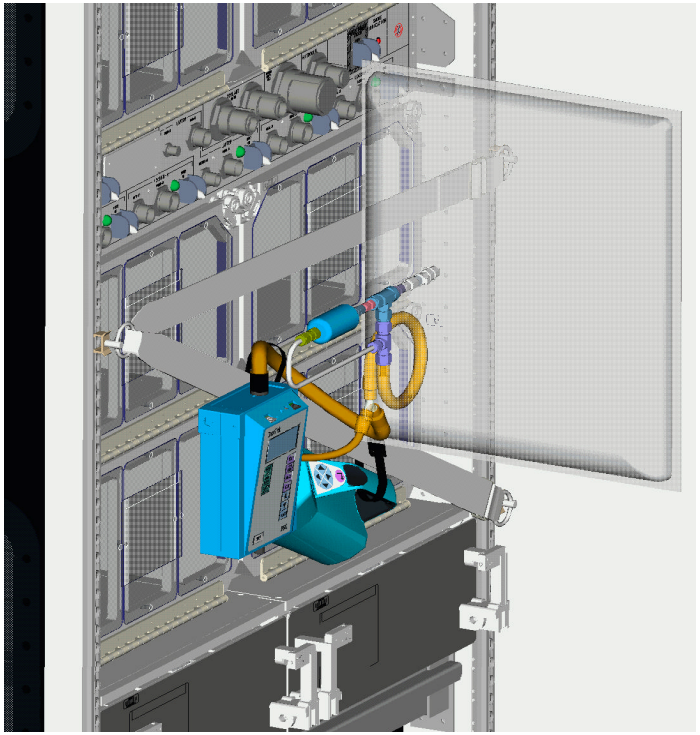
DustTrak and Batteries

Note: Engineering hardware shown without flight labels and Velcro.

Additional Benefits of DAFT

- During DAFT experiment operations, measurements of the ISS cabin atmosphere will be taken with the P-Trak and DustTrak instruments

- P-Trak measures particle counts per unit volume
- DustTrak measures particle mass concentration per unit volume
- Currently lacking air quality measurements aboard the ISS
- DAFT will operate in front of EXPRESS Rack 5 but can acquire samples at various locations within ISS as requested by ECLSS personnel



DAFT-3 in front of EXPRESS Rack

Quantification of Fire and Pre-Fire Signatures

Quantification of Fire Signatures for Practical Spacecraft Materials

Dr. Randy Vander Wal, National Center for Microgravity Research

- measure the time history of various fire signatures of typical spacecraft materials in 1-g at varying heating rates, temperatures, convective velocities, and oxygen concentrations,
- conduct tests in the Zero-Gravity Facility at NASA John H. Glenn Research Center to investigate the manner that a microgravity environment alters the fire signature,
- compare 0-g and 1-g time histories and determine if 0-g data exhibits the same dependence on the test parameters as experienced in 1-g

Development and characterization of sensors

➢ Concurrent development of candidate technologies

- **Electronic nose**
  - JPL: Advanced Environmental Monitoring and Control
  - KSC: 2002 NRA (HRI)

    Advanced Fire Detection Using Machine Olfaction

    B. Linnell, ASRC Aerospace
- **MEMS gas and particulate sensors**
  - GRC: Jointly funded with the Aviation Safety Program

    Development of a MEMS Spacecraft Fire Detector

    G. Hunter and P. Greenberg, GRC
- **IR absorption spectrometer**
  - JPL: Space Physics
  - Southwest Sciences, Inc. (SBIR)

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Development and characterization of sensors

- **Evaluate prototype detectors as part of the fire signature quantification effort**
  - Requires a secondary measurement capability and procedure
  - Normal-gravity and ground-based micro-g testing as appropriate
- **Evaluate suite of species and particulate sensors**
  - Conceptually similar to testing on the NIST Fire Emulator/Detector Evaluator
- **Reduced gravity verification of advanced fire detection system**
  - Hardware and software

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Simulation of the Transport of Smoke and Fire Precursors

02 NRA (Human Research Initiative)

- Fire Suppression and Safety in Reduced Gravity
  PI: K. Kailasanath, NRL

- Engineering Tool for Fire System Safety Placement
  PI: R. Roby, Combustion Science and Engineering

- Large-Scale Fire Dynamics in Spacecraft in Reduced Gravity
  PI: G. Linteris, NIST

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Questions

- Are the questions relevant and posed correctly?
- What should be added?
  - **Expand Smoke experiment to other materials**
    - Further examine overheating electrical components and circuit boards
    - Evaluate other fire signatures (radiation, temperature, ...)
    - Are the research and technology development efforts appropriate?
  - End-to-end MEMS fire detector for evaluation of low-g fire signatures
    - Incorporate capability into MSG Smoke+ experiment
- Are there technologies and/or research groups that should be included?