APPENDIX 3.F – What We Know About Particulates Resulting from Fires

George Mulholland, Building and Fire Research Laboratory, NIST

The smoke aerosol is described in more detail in this presentation. Particulates may be either solid particles or liquid droplets. Flaming results in large agglomerates of primary spheres that are roughly 30 nm in diameter, and smoldering results in liquid droplets about 2 µm in diameter. Information on smoke yield and particle size from various fuels is presented. Deposition in the lungs is a strong function of particle diameter. Non-flaming smoke scatters more than 90 % of light. Its composition is related to the fuel, and gases may adsorb to its surface. This raises the question of what materials would be appropriate for a standard smolder smoke.

What We know About Particulates Resulting from Fires

George W. Mulholland
University of Maryland
and NIST

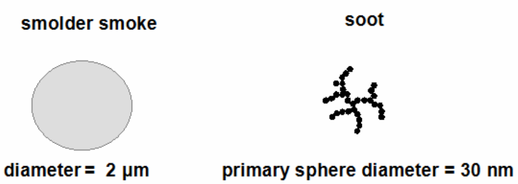
Workshop on Real-Time Particulate Monitoring: Respiratory Threats for First Responders
May 3, 2007

Overview of Non-flaming Smoke Aerosol Properties

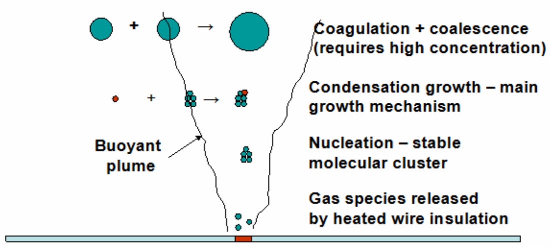
- **Terminology**
- **Demonstration of non-flaming smoke aerosol**
- **Production of smoke**
- **Light transmission through smoke**
- **Size and shape of smoke**
- **Size Distribution of smoke**
- **Smoke deposition in the respiratory system**
- **Chemistry of smoke**

Terminology

- Smoke aerosol – the condensed phase component (solid and liquid) of the products of combustion. In this presentation the smoke aerosol will be simply referred to as smoke.
- Particulate matter – either solid particles or liquid droplets.



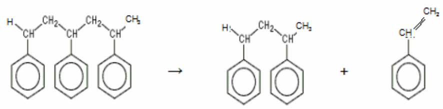
Mechanism of Smoke Formation and Growth



Insulated wire with a short resulting in a hot spot

Generation of Non-flaming Smoke

- Evaporation and condensation – candle wax
- Pyrolysis – fuel molecule undergoes reaction when heated.
  Example: pyrolysis of polystyrene



- Smolder – enough heat release via oxidation for the process to be self-propagating without external heat.
  Examples: newspaper, polyurethane foam cushion, pile of rubble with wood or paper.

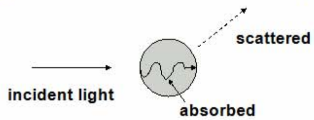
Smoke Yield

Smoke yield = mass of smoke produced per mass loss of fuel

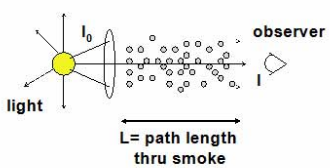
Fuel	Yield
Cellulose (paper)	0.06
Douglas fir – low flux - high flux	0.03 0.15
Polyurethane foam	0.15
PVC	0.12
Polypropylene	0.12

K.M. Butler and G.W. Mulholland, *Fire Tech.*, 40, 149-177(2004)

Light Transmission Through Smoke



For non-flaming smoke, more than 90 % of the light is scattered. For there to be significant scattering, $\pi D_m/\Lambda > 1$.



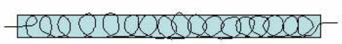
Transmitted Intensity

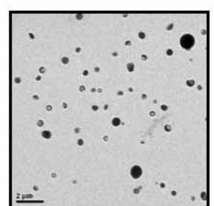
$I/I_0 = \exp(-\sigma m L)$

σ(avg) = 4.4 m^2/g for white light; Range from 2.5 m^2/g to 8 m^2/g.

TEM Images of Non-flaming Smoke

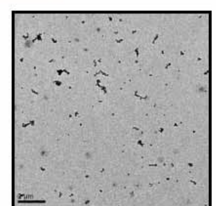
Cylinders of various materials were heated with a coiled tungsten wire. The voltage to the wire was controlled so each test was run at a fixed temperature.





B3-6-4-LLa

Lamp-wick smoke



B1-6-2-LLa

Kapton smoke

TEM photos by NASA Glenn Research Center

Size Distribution of Non-flaming Smoke: Lognormal Parameters

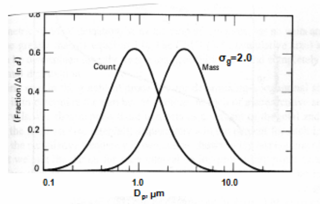
Fuel	D_{gm}, µm	σ_g
Cellulose	2-3	
Douglas Fir	0.8 – 1.8	1.9
PU foam	1.1 – 1.6	2.0
PVC	1.5	1.6
PP	2.1	1.8
Range	1 - 3	1.6-2.0

Geometric mass median diameter

$$\ln D_{gm} = \frac{\sum m_i \ln D_i}{m_t}$$

Geometric standard deviation

$$\ln \sigma_g = \left(\frac{\sum m_i (\ln D_i - \ln D_{gm})^2}{m_t} \right)^{1/2}$$

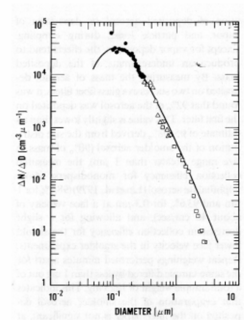


Count and mass distributions (logarithmic size scale).

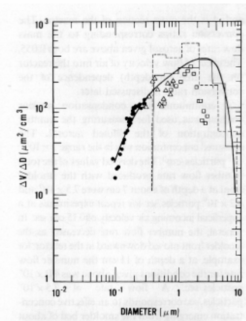
From *Aerosol Technology*, W. C. Hinds

Size Distribution of Cellulose Smoke

- Broad size distribution from < 0.09 µm to 5 µm
- Requires 2 instruments to obtain both number and volume dist.



Number distribution with optical particle counter (OPC)

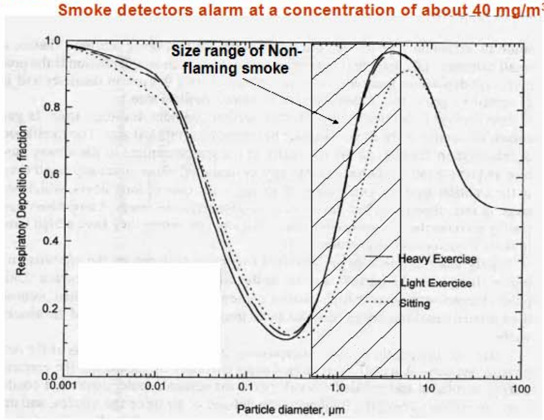


Volume distribution with OPC and 2 impactors (solid and dashed lines)

G.W.Mulholland and T.J. Ohlemiller, Aer. Sci. Tech., 1, 59 (1982).

Total Respiratory Deposition

Note: OSHA 8 hour exposure limit = 5 mg/m³ for nuisance particulate. Smoke detectors alarm at a concentration of about 40 mg/m³.

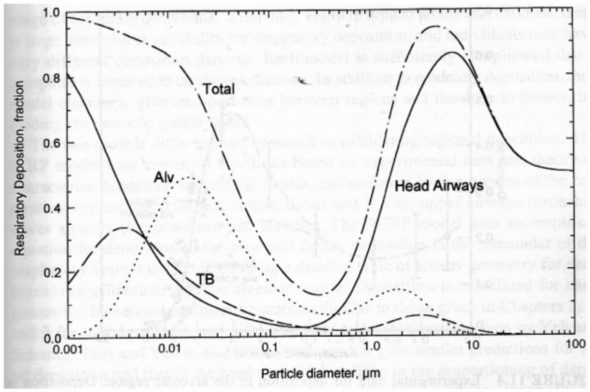


From *Aerosol Technology*, W. C. Hinds

Chemistry of Non-flaming Smoke Aerosol

- Related to fuel – each with its own set of pyrolysis products
- Possibility of adsorbed gases such as HCl from PVC
- Other materials could generate particulate from prolonged exposure to heat:
  a. metals such as lead and mercury
  b. Transformer fluids
  c. Asbestos from tiles and insulation
- Acute toxicity tests performed at NIST on a range of materials found in buildings for exposure to both particulate and gases; indication that particulate produced by pyrolyzing Teflon may be highly toxic.
- Key Question – What should be the exposure limit to non-flaming smoke aerosol?

Total and Regional Deposition for Light Exercise (nose breathing) based on ICRP Model



From *Aerosol Technology*, W. C. Hinds

Respiratory System

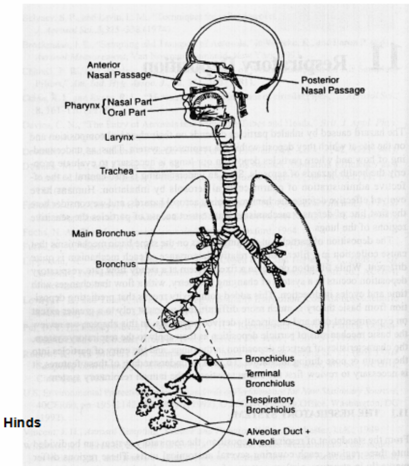


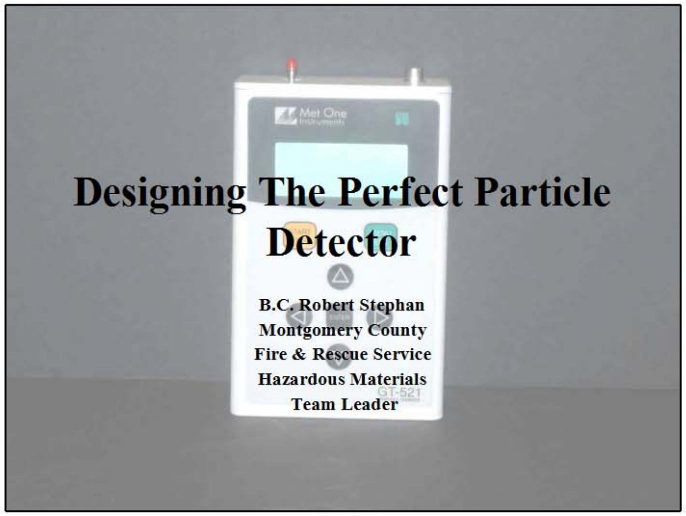
FIGURE 11.1 The respiratory system. Adapted from International Commission on Radiological Protection (1994).

From *Aerosol Technology*, W. C. Hinds

APPENDIX 3.G – The Ideal Detector for the Fire Service

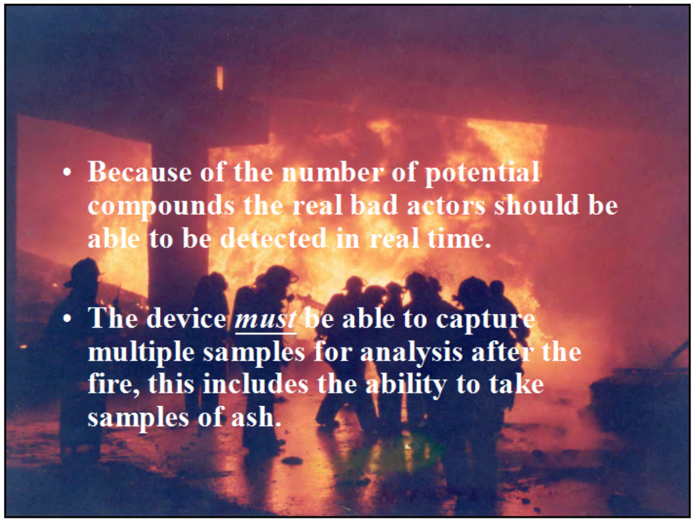
Robert Stephan, Montgomery County Maryland Fire and Rescue Service

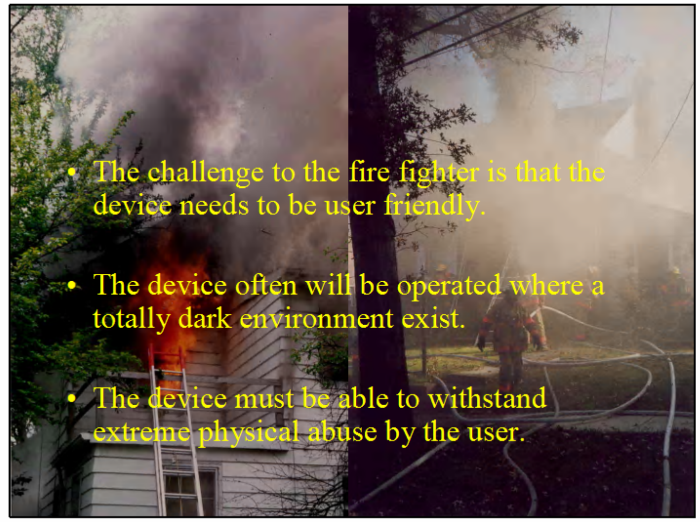
The fire environment is a highly hazardous environment that contains hundreds of unknown vapors and gases and particles of unknown size distribution and toxic composition. The ideal detector for the fire service must be functional in both high and low temperature extremes. It must be lightweight and durable, and must be operable by a user wearing heavy gloves and in the dark. It should not need frequent cleaning or be easily clogged. The detector must be able to function in the significant amounts of steam produced by firefighting. The most dangerous compounds should be detectable in real time. The device must capture multiple samples for analysis after the fire. Skin samples and nose swabs are alternative methods for getting more exposure data after firefighting. Particles can affect the respiratory tract, skin, eyes, and digestive system, although absorption of typical fire contaminants through the skin is not currently considered by the fire service.



The Issues

- Sampling air inside of a fire environment presents a tremendously hazardous environment which is wrought with unknown dangers.
- Inside of a fire environment you will encounter hundreds of unknown vapors and gases in addition to particles made up of toxic compounds.





What To Do With The DATA!

- Particles of combustion can effect the respiratory tract, skin, eyes, and digestive system.

- The synergistic affect of these suspended particles are much more dangerous than most of the elements and compound when they stand alone.

Summary

- An effectively designed particle detector is years away.
- Presently we should be drawing air samples during and after a fire to analyze and determine the most common toxic particles.

APPENDIX 3.H – NIST Fire Fighter Technology Program Overview

Nelson Bryner, Building and Fire Research Laboratory, NIST

The Advanced Fire Service Technologies (AFST) Program objectives are to

- Provide the science and performance metrics for development and implementation of new technology,
- Enable an information-rich environment, firefighter training tools, and application of innovative new technologies,
- Improve effectiveness and safety of first responders, and
- Support Fire Loss Reduction Goal and facilitate the development and transfer of BFRL research to the fire service.

Funding is prioritized to improve equipment where no current metrics or standards exist and to improve existing metrics and standards, to integrate emerging technology with the biggest impact, and to transfer technology to the fire service through firefighting simulators and training programs. Projects in this program include the characterization of firefighter respirators using computer modeling and experiments, hose stream effectiveness, standards for thermal imaging cameras, PASS device audibility, structural collapse prediction, emergency responder and occupant locator technology, and tactical decision aids, among many others.

Workshop on Real-Time Particulate Monitoring: Respiratory Threats for First Responders 2007

Advanced Fire Service Technologies Program

Francine Amon, Rodney Bryant, **Nelson Bryner**, Kathy Butler, Joannie Chin, William Davis, Glenn Forney, Jeff Gilman, Anthony Hamins, Steve Kerber, Randy Lawson, Jack Lee, Alan Lytle, Dan Madrzykowski, Jay McElroy, Roy McLane, Nader Moayeri, Mike Molloy, Marc Nyden, Mike Selepak, David Stroup, and Robert Vettori

May 3 - 4, 2007
Gaithersburg, MD

NIST National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Overview

- Introduction
  - Technology without Standards
- AFST Program
  - Objectives
  - Approach
- Projects
- Summary

Why Invest in Advanced Fire Service Technologies ?

- Firefighter Fatalities –
  - 117 in 2004 (USFA)
- Total Injuries –
  - 80,800 in 2004 (NFPA)
  - Fireground – 37,976 injuries

- Magnitude of U.S. Annual Losses ~ $200 billion total cost

Issues- Technology without Standards

- Existing & new technology is being used without adequate metrics or standards to evaluate the performance
- Fire service is learning to exploit
  - existing technologies
    - thermal imaging, positive pressure ventilation
    - performance evaluated in a scientifically sound method
    - technology transferred to the fire service through training programs and fire fighting simulators.
  - developing technologies
    - tactical decision aids, training simulators, improved protective clothing, and real-time particulate monitors.
    - look ahead to developing innovative technologies and how new technologies can be effectively integrated into existing equipment

AFST Program Objectives

- Provide the science and performance metrics for development and implementation of new technology
- Enable an information rich information environment, fire fighter training tools, and application of innovative new technologies.
- Improve effectiveness and safety of first responders
- Support *Fire Loss Reduction Goal*,
  - facilitate the development & transfer of BFRL research
    - science, metrics, and technology
    - fire fighters, incident commanders, and other first responders.

AFST Program Approach

- Funding does not allow development of performance metrics and testing protocols for all emergency responder equipment
- FY07 funds are prioritized
  - equipment where there are currently no metrics or standards and/or at improving existing metrics and standards **50%**
    - thermal imagers
    - hose streams/nozzles
    - respirators
  - emerging technology with biggest impact is integrated first **40%**
    - National Fire Research Agenda Symposium - 50 organizations, including the fire service, IAFC, IAFF, and NVFC, manufacturers, DHS, & USFA
    - fire responder locators
    - tactical decision aids
    - respirator performance
    - improved protective clothing
  - fire fighting simulators and training programs to insure that the above science and technology to transfer to the fire service **10%**

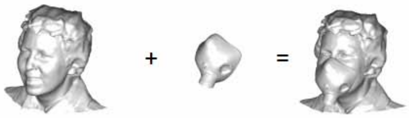
AFST Program Projects

Project	PI
• Thermal Imager Technology	Amon / Bryner
• Characterization of Fire Fighter Respirators	Butler / Bryant
• Fire Fighter Protective Clothing	Gilman / Chin
• Hose Stream Effectiveness	Stroup / Amon
• Research on Hydrogen and Alternate Fuel Hazards to First Responders	Kerber / Bryner
• Monitoring and Metrology Technology for Field Scale Validation Experiments	Stroup / Kerber
• Emergency Responder and Occupant Locator Technology	Bryner / Davis Lytle / Moayeri
• Tactical Decision Aids	Bryner / Davis
• Virtual Fire Fighter Trainer	Forney

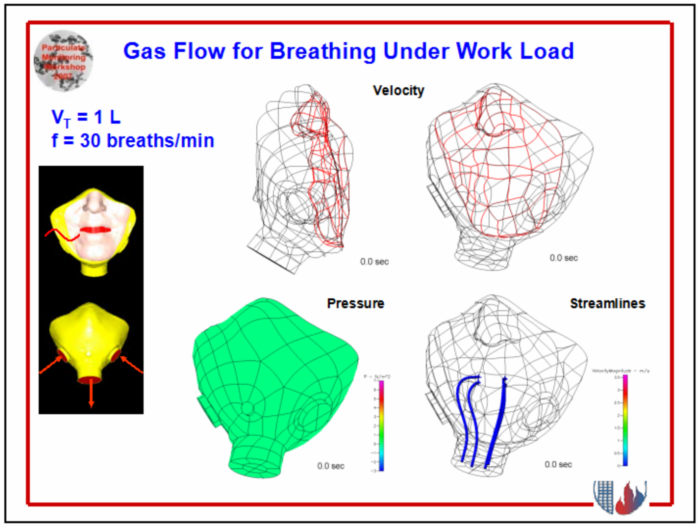
Characterization of Fire Fighter Respirators

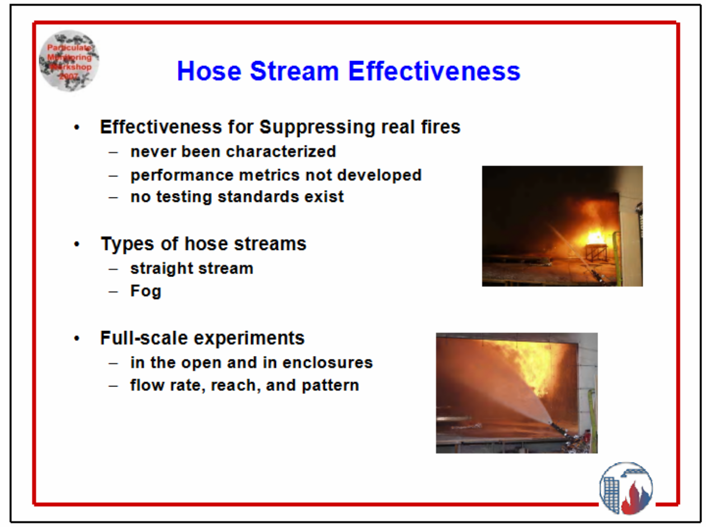
- **SCBA, Closed-Circuit SCBA, PAPR**
- **Standards do exist, but based on USAF data from 1960s**
- **Using computational fluid dynamic models to characterize flow in, out, and around respirator face pieces**
- **Use laser-based scanner to input**
  - **Head geometry**
  - **Respirator geometry**

Laser Scanner

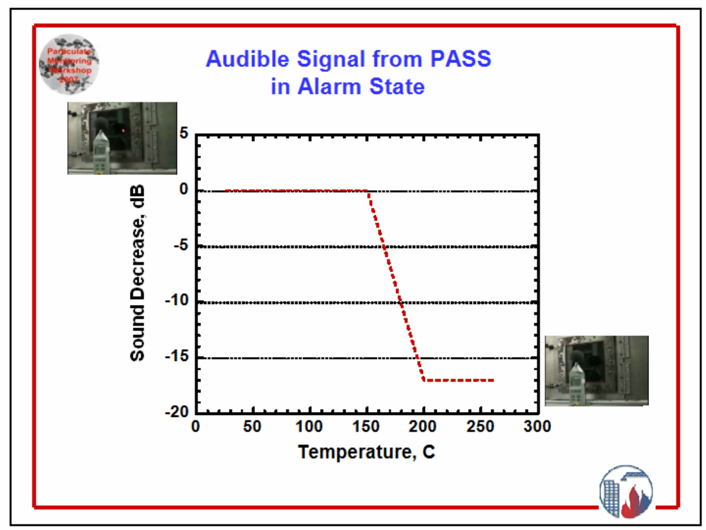


Head Scan + **Mask Scan** = **Head & Mask Scan**


Gas Flow for Breathing Under Work Load
V_T = 1 L
f = 30 breaths/min
Velocity
Pressure
Streamlines
0.0 sec


Hose Stream Effectiveness
• Effectiveness for Suppressing real fires
– never been characterized
– performance metrics not developed
– no testing standards exist
• Types of hose streams
– straight stream
– Fog
• Full-scale experiments
– in the open and in enclosures
– flow rate, reach, and pattern


Thermal Exposure Standards for First Responder Devices
Davis, Donnelly, Selepak, & Lawson
Firefighter Equipment Evaluator (FEE)
• Survey exposure limits for electronic equipment used by firefighters.
• Define exposure conditions encountered by first responders.
•Test a number of devices for degradation of performance based on thermal and humidity criteria.
•Expose radios, gas analyzers, PASS equipment to realistic conditions
DANGER
HOT


Audible Signal from PASS in Alarm State
Sound Decrease, dB
5
0
-5
-10
-15
-20
0
50
100
150
200
250
300
Temperature, C

Structural Collapse Prediction

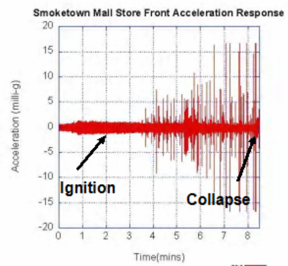
Stroup, Bryner, Madrzykowski

•Provide adequate warning to fire fighters of impending collapse
•Portable, quick, and easy to install

•Evaluated thermal imagers/cameras - unsuccessful
•Examined laser mappers - unsuccessful

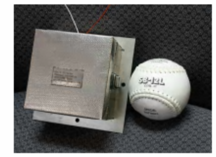
Duron - Harvey Mudd College
•Adapt acoustic sensors for detecting leaks in hydroelectric dams

Field tested prototype
- Single family home
- Industrial warehouse
- Strip shopping mall



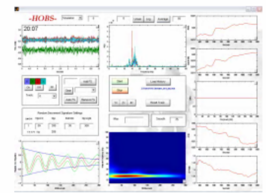
Structural Collapse Prediction

Health of Burning Structures (HOBS)



- A real-time acquisition and analysis capability
- The HOBS Panel provides real-time capabilities for
  - Multiple sensor data acquisition and storage
  - Signal processing
  - Collapse Index Analyses and Parameter adjustments
  - Fire-induced vibration and collapse index monitoring

- HOBS Indicators include
  - Root Mean Squared (RMS)
  - Power Spectral Density (PSD)
  - Frequency Bandwidth (FreqBand)
  - Shock Response Spectrum (SRS)
  - Random Decrement (RD)
  - Damping
  - Intensity



Emergency Responder and Occupant Locator Technology

- Fire fighter / occupant locator systems track first responders and occupants inside structures
- Technology must meet the performance needs
  - First responders
    - Rescue
    - Tactical
  - Public / building occupants No Performance Standards or Testing Protocols
- Technology must operate
  - Different building types
  - Different thermal conditions
- Develop Standards & testing protocols
  - Insure technology consistently performs as needed
  - Technology neutral and unbiased standards/protocols

Emergency Responder and Occupant Locator Technology

- *Precision Indoor Personnel Location and Tracking for Emergency Responders Workshop, August 2006*

WPI

Location Resolution under "severe" conditions = 3 foot

Fire Fighter "severe" conditions

Locating & Tracking - where or what building type ?

- Type I or Fire-Resistive (NFPA)
  - High rise office, shopping centers, or residential units
  - Reinforced concrete, structural steel (protected)
- Type II or Noncombustible
  - Office buildings, warehouses, auto repair shops
  - Metal frame with metal walls, metal frame with masonry walls, masonry walls with metal roof
- Type III or Ordinary
  - Office buildings, retail stores, mixed occupancy, apartment buildings
  - Noncombustible bearing walls and combustible roofs
  - Most buildings are of this type
- Type IV or Heavy Timber
  - Exterior noncombustible or limited combustible, masonry
  - Interior structural members, walls, columns, floors and roofs are large timbers
  - Common in the New England area
- Type V or Wood Frame
  - Single family dwelling, restaurants, retail stores
  - Log, post & beam, balloon, platform, and plank & beam
  - Structural members are wood and exterior walls are combustible

Under what conditions ?

Thermal Class	Maximum Time (min)	Maximum Temperature	Maximum Flux (kW/m^2)
I	25	100 C / 212 F	1
II	15	160 C / 320 F	2
III	5	260 C / 500 F	10
IV	<1	>260 C / 500 F	>10

Location & Tracking – Resolution

Residential Scenario

Resolution meters	Location		Escape	
	X-Y Direction	Z Direction	X-Y Direction	Z Direction
100	City Block +/-	10 floors +/-		
10	Front or rear of house	3 floors +/-	Structure +/- (Townhouse)	Floor +/-
1	Room	Floor +/-	Correct Wall	Window or Door
0.1	Location in Room	Correct Floor	Location on wall	Height of window or door

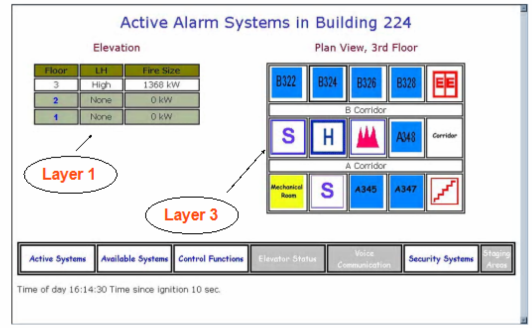
Location and Tracking Performance Standards

- Roles of NIST
  - Fundamental Science
    - Measurement or metrology (working with DHS)
    - Signal penetration (working with DHS)
    - Sensor design
    - Combustion Science
  - Building performance
  - Fire Environment
  - Performance Standards and Testing Protocols
    - Signal quality (working with DHS)
    - Sensor interfaces/performance (working with DHS)
    - Thermal exposure testing (working with DHS)
    - Network design (working with DHS)
  - Develop new technology where expertise exists

Tactical Decision Aids

- Provide fire fighters with tactical information
  - before arrival - more informed first responders
  - better and safer response to emergencies in buildings
- Information Rich Environment
  - Building sensors – data available at fire panel
  - Wireless transfer of floor plans and alarms on apparatus display
- Standards
  - What is being measured
  - How reported to fire panel – fire fighter
    - NFAC Task Group: 2002 NFPA 72 Annex Graphics Annunciator Panel Standard with Icons adopted
- Training tools
  - How to deploy search and suppression teams

Tactical Decision Aids



Display standard was published as NEMA SB30-2005 to provide standardization of displays for emergency personnel. This display standard was to be included in NFPA 72 at the June 2006 meeting

Tactical Decision Aids

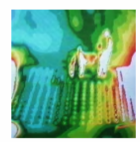
Commercial Implementation (Siemens Fire Finder)

Available Systems

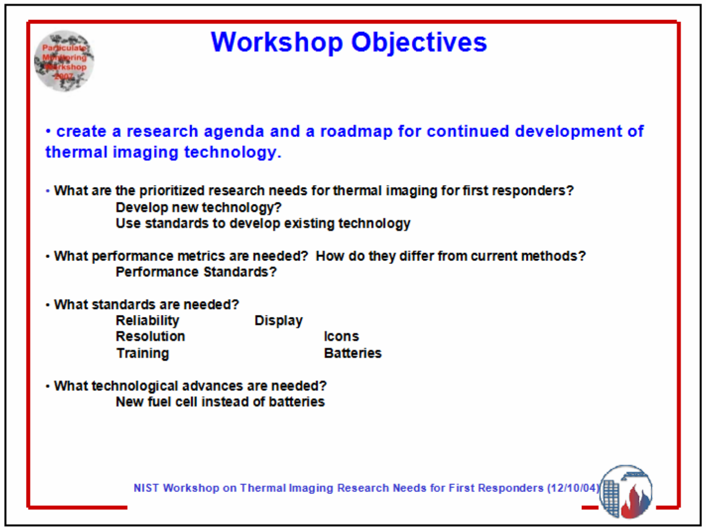
Active Systems

Evaluating the Performance of Thermal Imagers and Infrared Cameras

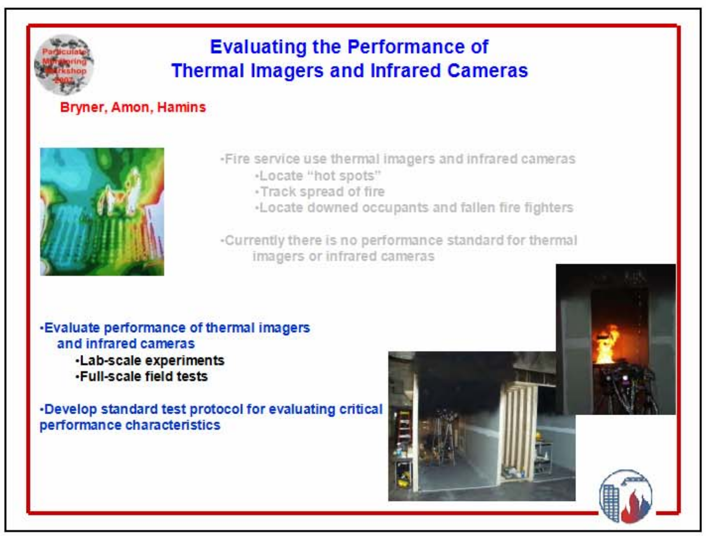
Bryner, Amon, Hamins

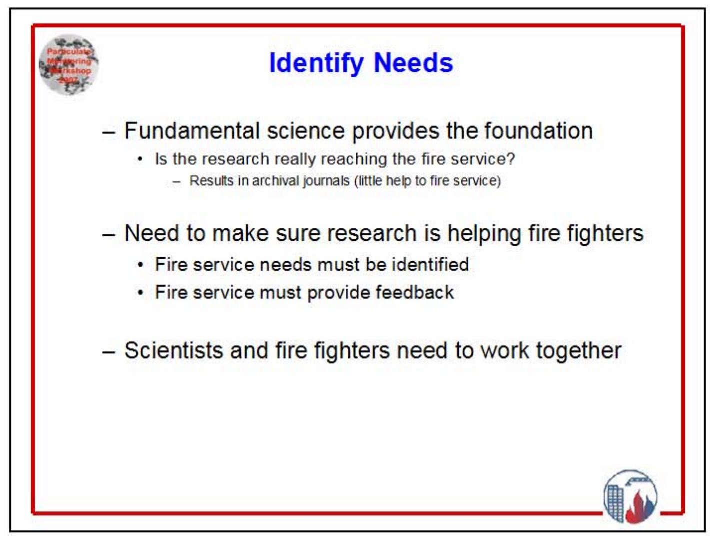


- Fire service use thermal imagers and infrared cameras
  - Locate "hot spots"
  - Track spread of fire
  - Locate downed occupants and fallen fire fighters
- Currently there is no performance standard for thermal imagers or infrared cameras


Workshop Objectives
• create a research agenda and a roadmap for continued development of thermal imaging technology.
• What are the prioritized research needs for thermal imaging for first responders?
Develop new technology?
Use standards to develop existing technology
• What performance metrics are needed? How do they differ from current methods?
Performance Standards?
• What standards are needed?
Reliability
Display
Resolution
Icons
Training
Batteries
• What technological advances are needed?
New fuel cell instead of batteries
NIST Workshop on Thermal Imaging Research Needs for First Responders (12/10/04)


Standards – Performance & Testing
• A standard will be developed
• Science based
• Ad-hoc ....arbitrary?
• Science based standard –
Capture, identify, address underlying issues
Product Neutral
Fosters the development of better equipment
improvement of currently available
new technology & materials
NIST Workshop on Thermal Imaging Research Needs for First Responders (12/10/04)


Evaluating the Performance of
Thermal Imagers and Infrared Cameras
Bryner, Amon, Hamins
•Fire service use thermal imagers and infrared cameras
•Locate "hot spots"
•Track spread of fire
•Locate downed occupants and fallen fire fighters
•Currently there is no performance standard for thermal imagers or infrared cameras
•Evaluate performance of thermal imagers and infrared cameras
•Lab-scale experiments
•Full-scale field tests
•Develop standard test protocol for evaluating critical performance characteristics


Identify Needs
– Fundamental science provides the foundation
• Is the research really reaching the fire service?
– Results in archival journals (little help to fire service)
– Need to make sure research is helping fire fighters
• Fire service needs must be identified
• Fire service must provide feedback
– Scientists and fire fighters need to work together

Identify and Prioritize Needs

- National Fallen Firefighters Foundation and NIST funded a National Fire Service Research Agenda Symposium - June 2005
- Workshop –
  - Priorities for performance
  - Priorities for research
  - Exposure to new tools and methods to improve safety
  - Opportunities to expand the applications of available technology
  - Sharing of ideas and future collaborations
- Potential funding sponsors can use this prioritized list in funding decisions.

Related Projects

- **Grants**

Structural Collapse	Harvey Mudd
Fire Fighter Interface	U Texas San Antonio
Positive Pressure Ventilation	U Texas Austin

- **Other Agency Funding**

PASS Devices	USFA
IR Camera Standards	USFA
Burn Pattern Analysis	OLES & DHS
Passive Cooling Systems	DHS
RFID Performance Standards	DHS
RF Linked PASS Devices	DHS
Technology Transfer	USFA
Structural Collapse	OLES
Locator/Tracker	ATP

Summary

AFST Program

- **Gets BFRL research directly into hands of**
  - Fire service
  - Fire protection engineers
  - Fire equipment manufacturers
- **Critical role in providing science-based**
  - Performance metrics
  - Standard testing protocols
- **Plays a leadership role**
  - Technology and standards for transfer of emergency information from buildings to fire service
- **Improve the safety and effectiveness of fire fighters**
  - Reduction of fire related fatalities and injuries
  - Both fire fighters and building occupants

Fire Research Division - 2007

Fire Fighting Technology Group
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Fire Metrology Group
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Analysis & Prediction Group
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Integrated Performance Group
thomas.cleary@nist.gov
301-975-6858

Materials and Products
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301-975-6573

Fire Fighting Technology Group - 2007

Project Leaders -

Dan Madrzykowski- (daniel.madrzykowski@nist.gov)
- Fire Fighter Safety Simulation
- Recreation of Fire Patterns
- Sim. Fire Burn Patterns w/Computer Models
- NFA Training Program
- Heat Transfer Model

Nelson Bryner (nelson.bryner@nist.gov)
- Equipment Standards for First Responders
- Fire Safety and Preparedness
- Fire Fighter Locator
- IR Camera Performance
- Structural Collapse Prediction
- Advanced PASS Devices

Fire Fighting Technology Group - 2007

Project Leaders -

David Stroup – (david.stroup@nist.gov)
- Structural Collapse Prediction
- Fire Performance of Building Design
- Hose Stream Effectiveness
- Method of Fire Resistance Determination

Robert Vettori – (robert.vettori@nist.gov)
- Heat Transfer Model
- Sprinkler Activation under Sloped Ceiling
- WTC Investigation

Francine Amon – (francine.amon@nist.gov)
- Thermal Imagers
- Thermal Imager Performance

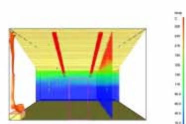
Fire Fighting Technology Group - 2007

Project Leaders -

Doug Walton – (william.walton@nist.gov)
- In-Situ Burning of Oil Spills
- Fire Reconstruction/Recreation

Randy Lawson –(james.lawson@nist.gov)
- Fire Service Technologies and Guidelines
- Firefighter Protective Clothing
- Fire Codes & Standards
- Heat Transfer Model

Stephen Kerber – (stephen.kerber@nist.gov)
- Positive Pressure Ventilation
- RI Fire Investigation



Contact Fire at NIST ?

Website - **http://fire.nist.gov**

FireDOC - on web

Gaithersburg, MD
Paul Reneke 301-975-6696

Fire Data - pubs/web
Models - pubs/web
Videos - call or e-mail

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NIST At A Glance

"Nation's Oldest Federal Physical Sciences Laboratory"

National Bureau of Standards (1901 – 1988)

National Institute of Standards and Technology (1988 – present)

- 2,800 employees
- 1,800 guest researchers
- 1,500 field agents
- 850 users of facilities
- NIST Laboratories

- Advanced Technology Program
- Hollings Manufacturing Extension Partnership Program
- Baldrige National Quality Program

Boulder Colorado

Gaithersburg Maryland

Where We are in NIST

- Advanced Technology Program
- Manufacturing Extension Partnership
- Malcolm Baldridge National Quality Award
- **Measurement & Standards Laboratories**
  - Information Technology
  - Manufacturing Engineering
  - Chemical Science & Technology
  - Electronics & Electrical Engrg.
  - Material Science & Engrg.
  - Physics
  - **Building & Fire Research Lab**
    - Materials & Construction Division 861
    - Building Environment Division 863
    - Fire Research Division 866

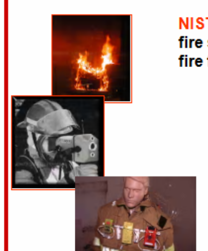
Fire Research at NIST

- **Building and Fire Research Lab**
  - created by Fire Act of 1974
- **Budget - $44 M**
  - STRS (Congress) - $27 M ($9 M)
  - Outside - $17 M ($6 M)

- **160 staff (57 Fire)**
- **Large Fire Facility**

NIST Fire Research Mission

To conduct basic and applied fire research for the purposes of understanding fundamental fire behavior and to reduce losses from fire. *[Federal Fire Prevention and Control Act of 1974]*



NIST Fire Loss Reduction Program - to enable engineered fire safety for people, products, and facilities; and enhance fire fighter effectiveness.

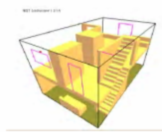
- Advanced Measurement & Predictive Methods
- Reduced Risk of Fire Spread
- Safety of Threaten Buildings
- Advanced Fire Service Technology

Fire Loss Reduction

I. Advanced Measurements and Predictive Methods

Current Projects

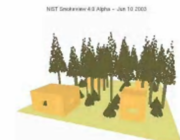
- CFAST, FDS/Smokeview Research and Development
- Smokeview and Computer Visualization
- Underventilated Comp. Fire Measurements
- HRR Uncertainty in Large Scale Fire Meas.
- Gas Velocity Measurements
- Large Fire Laboratory Operations
- Validation of Bench Scale Smoke Toxicity
- Experimental Data for Sub-Grid Fire Growth



Fire Loss Reduction

II. Reduced Risk of Fire Spread

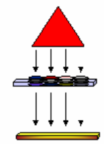
Current Projects



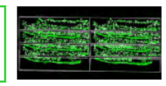
Site Specific Fire Model: quantitative planning & training tool

- Sprinkler Decision Tool for Communities
- Fire Suppression Test Method Development
- Community Fire Spread
- Fire Growth and Spread on Real Objects
- Mass Pyrolysis and Degradation of Flam. Objects
- Fault-Free Detection Test Methods and Standards
- Nanoadditive Flame Retardants for PU Foam
- Modeling Melt Flow Using Particle Methods
- Fire Retarded Polyurethane Foam Flammability

Home smoke alarm evaluation



High throughput screening methods for fire retarded nano-composites



Fire Loss Reduction

III. Safety of Threatened Buildings

Current Projects

- Standard Test Methods for Eval. Fire Resistance of Structural Steel
- Prevention of Progressive Structural Collapse
- Fire Resistance Design and Rehabilitation of Struct.
- Complex System Failure Analysis
- Building Information for Emergency Responders
- Occupant Behavior and Egress
- Experimental Investigation of the Performance of Structural Comp. Exposed to Real Fires
- Emergency Use of Elevators and Firefighter Lifts
- Implement WTC Recommendations

Fire Loss Reduction

IV. Advanced Fire Service Technologies

Current Projects

- Computer Modeling of Respirators
- Thermal Exposure Standards for First Responder Devices
- Thermal Imaging Technology
- Emergency Responder and Occupant Locator Tech.
- Hose Stream Effectiveness
- Fire Safety and Preparedness
- Field Validation Experiments
- Fire Fighter Protective Clothing – advanced materials
- Tactical Decision Aids for First Responders
- Fire Fighter Protective Clothing – Heat Transfer Model
- Virtual Fire Fighter Trainer

Fire Division Synergism

Location & Tracking - Resolution

Industrial Scenario -

Resolution meters	Location		Escape	
	X-Y Direction	Z Direction	X-Y Direction	Z Direction
100	Building +/-	10 floors +/-		
10	Section of Bldg	3 floors +/-	Section of Bldg	Floor +/-
1	Room	Floor +/-	Correct Wall	Window or Door
0.1	Location in Room	Correct Floor	Location on wall	Height of window or door

Thermal Imager Technology

- •Fire service use thermal imagers and infrared cameras
  - •Locate "hot spots" or track spread of fire
  - •Locate downed occupants and fallen fire fighters
- •Currently there is no performance standard for thermal imagers or infrared cameras

- •Evaluate performance of thermal imagers and infrared cameras
  - •Lab-scale experiments
  - •Full-scale field tests
- •Develop standard test protocol for evaluating critical performance characteristics
- •Draft Standard submitted to NFPA ESE Committee