Cardiovascular & Chemical Exposure Risks on Today's Fireground

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Project Team

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Funding

This project was also made possible through a partnership with the CDC Foundation and received additional support through interagency agreement between the National Institute for Occupational Safety and Health and the National Institute of Environmental Health Sciences (AES15002-001) as a collaborative National Toxicology Program research activity. *The findings and conclusions in this presentation are those of the author(s) and do not necessarily represent the views of the National Institute for Occupational Safety and Health. Mention of any company name or product does not constitute endorsement by NIOSH.*

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FDIC Workshop Tentative Schedule

- Introduction and Motivation
  - *Break*
- Measurements and Initial Results
  - *Break*
- Recommendations and Tactical Considerations

Ask questions at any time!!!

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Project Objectives

- Better understand how operating in today's fire environment is related to the two leading health issues facing firefighters
  - Cardiovascular events
  - Chemical exposures related to carcinogenic risk

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Project Goals

- We investigated the impact of
  - Tactics (traditional interior vs transitional attack)
  - Firefighting location/assignment (interior ops, outside ops, outside command, overhaul)
  - Hygiene measures (skin cleaning, gross on-scene decon)

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Study Components

Fire Dynamics

Cardiovascular Strain

Chemical Exposures

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Fire Dynamics

- Greater understanding of the development, propagation and dangers of today's residential fires
- Significant advances in understanding the hazards associated with firefighting.
- Important tactical guidance that may potentially increase firefighter effectiveness while decreasing risk.
- Often the focus is placed on acute risks…

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Firefighter Health & Safety Risks

- Cardiac events are the leading cause of duty-related deaths and are far more likely to occur after fire suppression activity.
  - Firefighting leads to significant cardiovascular strain.
- Firefighters have an increased risk for several types of cancer.
  - Fires produce hundreds of toxic compounds. Some are carcinogenic.

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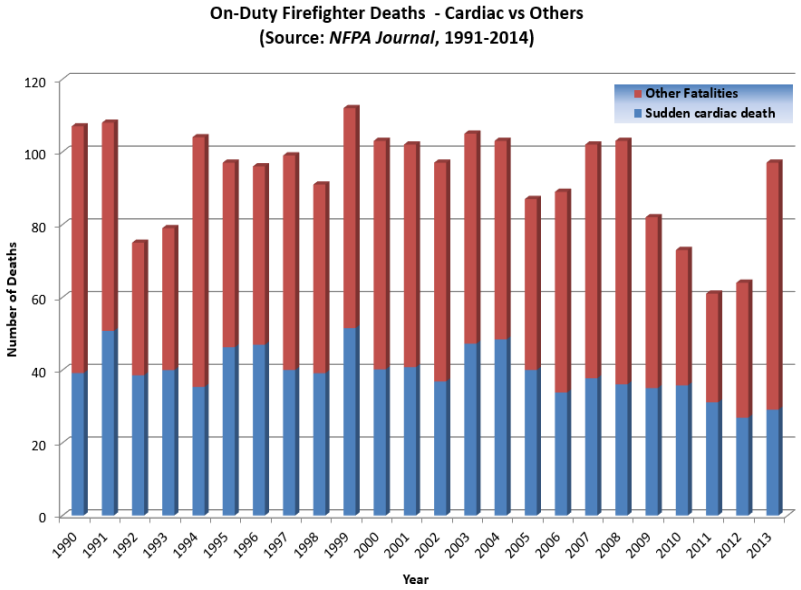
Sudden Cardiac Events



- Sudden cardiac events account for approximately 45% of all LODDs each year
  - Firefighting is associated with a 10-100x greater risk of suffering sudden cardiac death compared to non-emergency duties
  - 20-25 non-fatal cardiac events in the line of duty for every fatality

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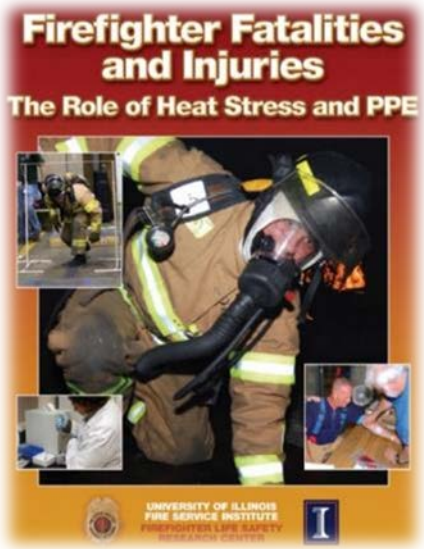
Cardiovascular Strain of Firefighting



- History of cardiac, vascular, hemostasis studies at IFSI
- Important questions remain
  - Clinically relevant responses (EKG, blood clotting) of firefighters exposed to today's fire scenarios
  - How do fires with common household furnishings & tactics affect firefighters' cardiovascular system

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Linking CV Strain of Firefighting with Sudden Cardiac Events

Theoretical models that guide research

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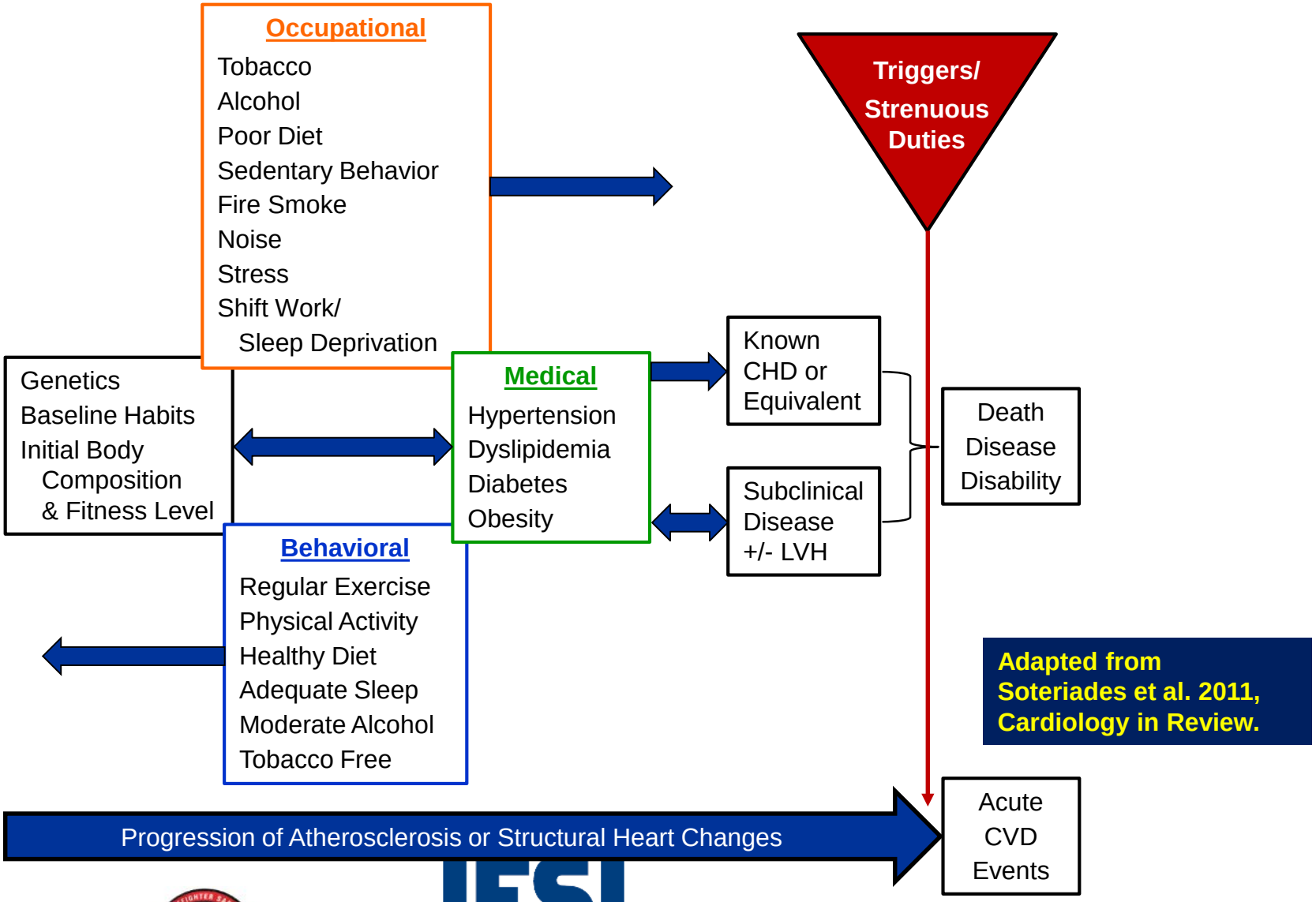
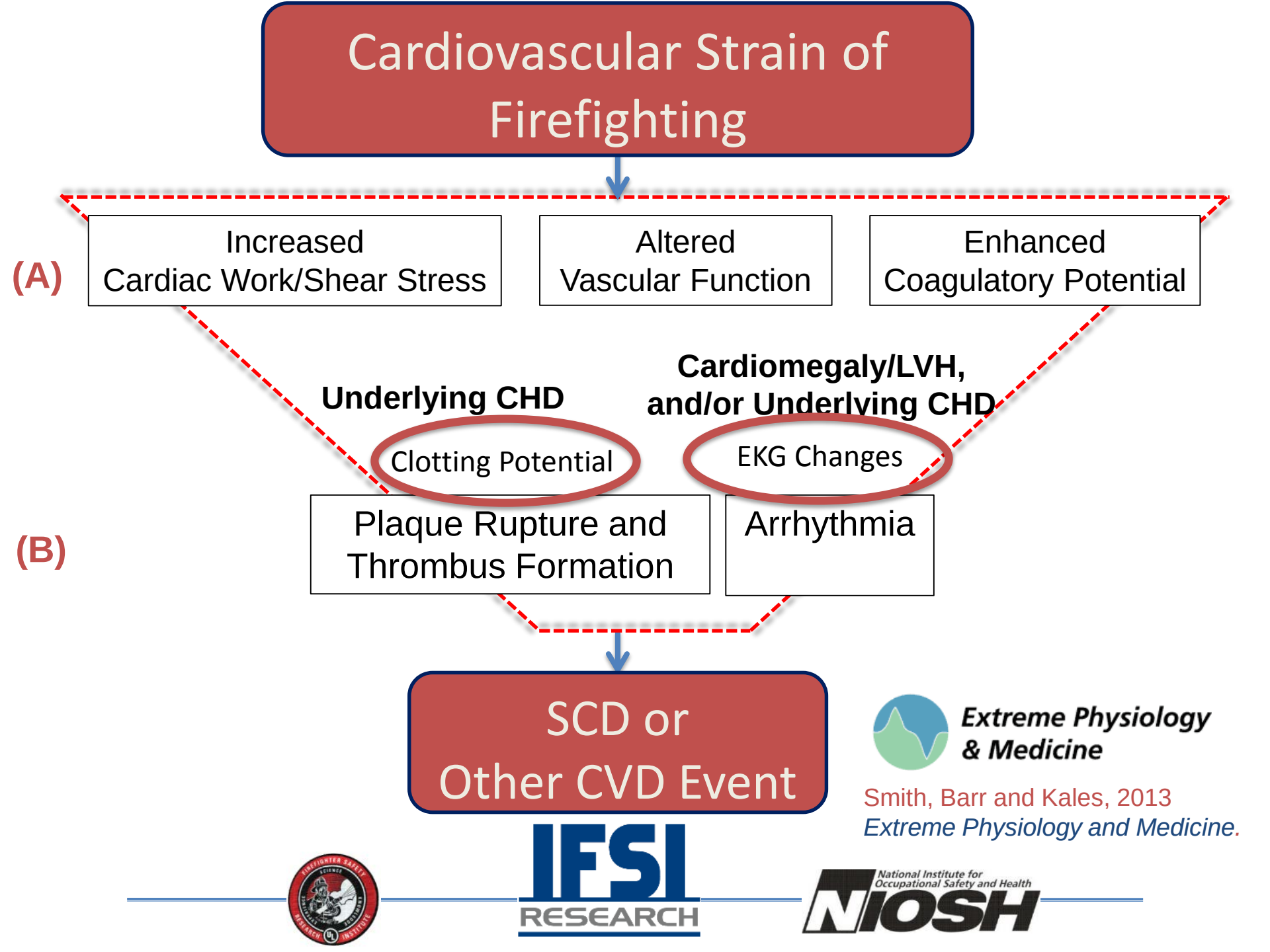
Model of CVE in Fire Service Cardiac





Extreme Physiology & Medicine

Smith, Barr and Kales, 2013
Extreme Physiology and Medicine.

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Complex Exposure Pathways

- Source: where the chemicals originate
- Composition: makeup and physical state of the chemicals
- Transport / contact: how the chemicals come into contact with the firefighter
- Intensity: exposure concentration
- Duration: length of the exposure time
- Absorption route: how the chemicals enter the firefighter's body (inhalation, dermal absorption, or ingestion)
- Dose: amount of chemical deposited in the firefighter's body

Potential Sources of Exposure

Residential fire (photo by IAFF.org)

Dumpster fire (public domain)

Vegetation fire (photo by Physics.org)

Industrial fire (photo by Eastern Daily Express)

Car fire (photo by NIOSH)

Training fire (photo by NIOSH)

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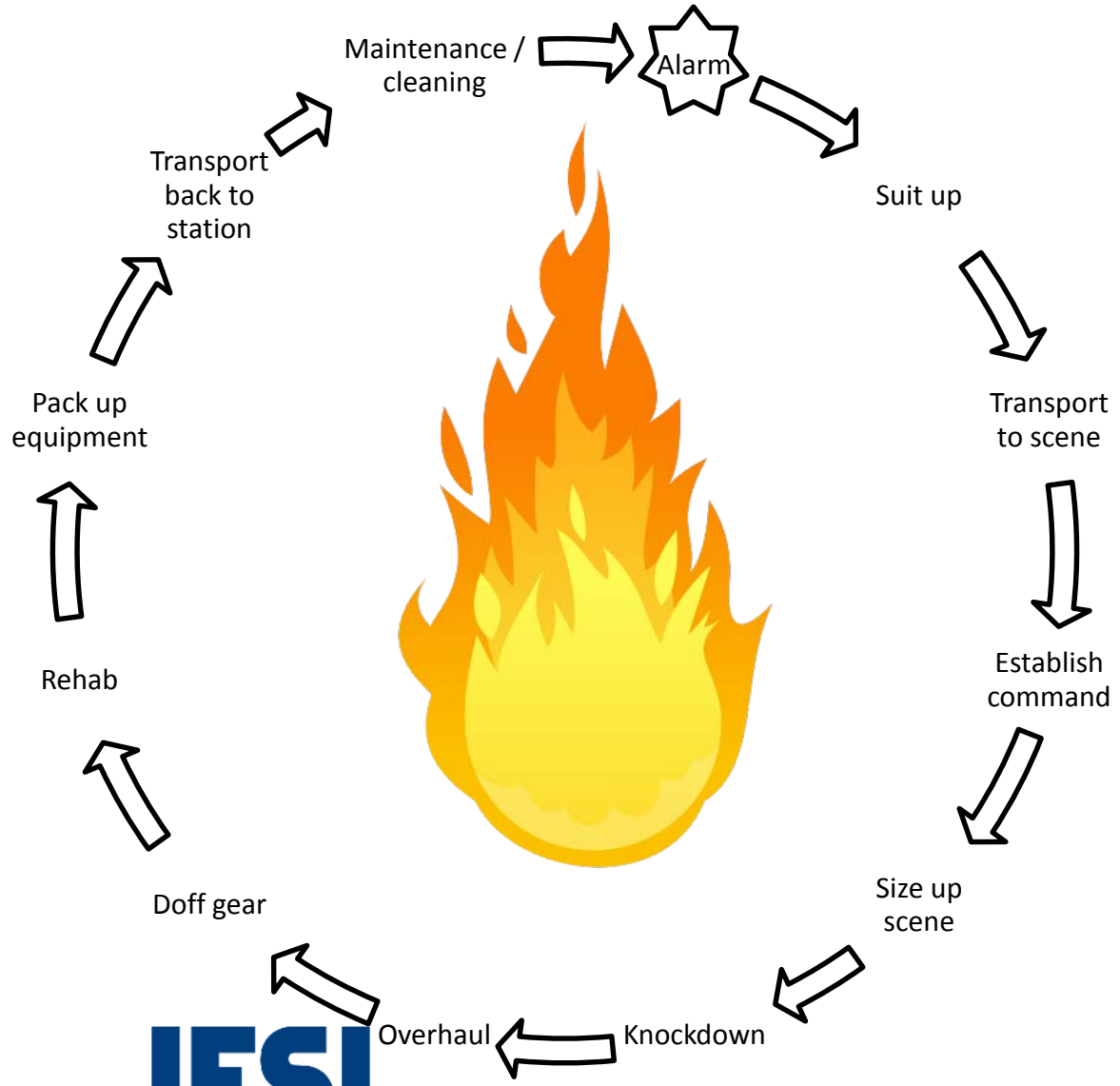
Composition of Smoke

- Respiratory irritants (acrolein, acids, sulfur dioxide)
- Respiratory sensitizers (isocyanates, aldehydes)
- Chemical asphyxiants (CO, HCN)
- Cardiotoxicants (fine particulate, chemical asphyxiants)
- Carcinogens:
  - Single-ring aromatic hydrocarbons (benzene)
  - Polycyclic aromatic hydrocarbons (benzo[a]pyrene)
  - Aldehydes (formaldehyde)
  - Halogenated compounds (vinyl chloride, PCBs, dioxins)
  - Diesel exhaust

Potential for Chemical Contact



*** Also during live-fire and simulated smoke training**

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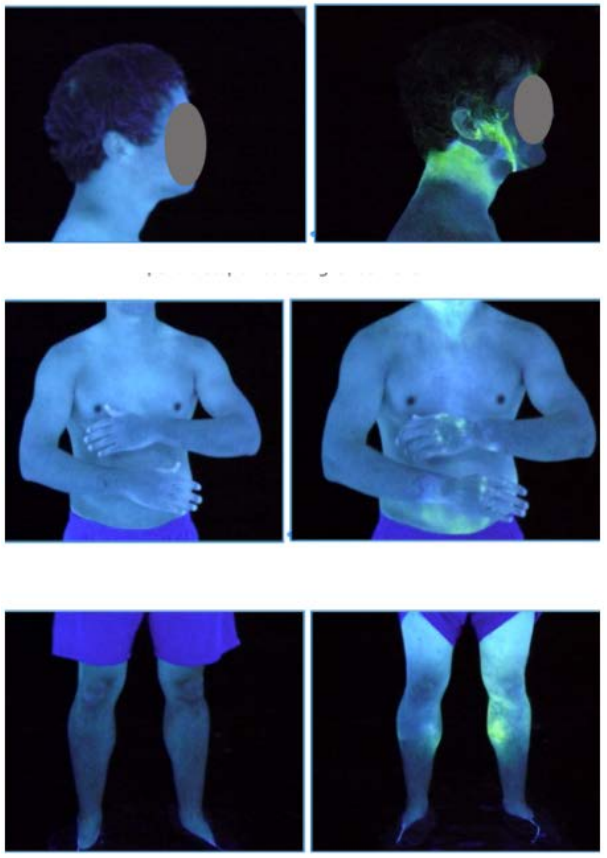
Dermal Exposures during Knockdown

- PAH contamination on wrist, neck, forehead, and back[1]
- Neck may be especially vulnerable
  - Significantly higher PAH levels on neck after firefighting[2]



Jeff Stull, RTI study commissioned by IAFF

1. Presentation by Dr. McCarry, McMaster University (2013)
2. NIOSH Report 2010-0156 (2013)

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Dermal Exposures during Knockdown (cont'd)

- Particles/soot that contact the skin can be absorbed[1]
- Some vapors (e.g., benzene) can also be absorbed[2]
- Chemicals absorb faster through thinner skin (e.g., neck)
- Dermal absorption may increase with increasing:
  - Concentration, ambient temperatures, skin temperatures, humidity, and sweat[3]

Hydrocortisone relative absorption[4]

Plantar foot arch	1
Lateral ankle	3
Palm	6
Ventral forearm	7
Back	12
Scalp	25
Forehead	43
Jaw angle	93
Scrotum	300

1. VanRooij et al. (1993)
2. Bader et al. (2008), Piotrowski (1967, 1971), Weschler and Nazaroff (2012)
3. Franz (1984), Jones et al. (2003)
4. Feldmann & Maibach (1967)

Exposures during Overhaul

- Levels of exposure will depend on:
  - Time-lapse from suppression to the next activity
  - Amount of natural or mechanical ventilation
  - If materials are still smoldering
  - If there are any dead-air spaces
- Inhalation exposure possible if respiratory protection is not worn
  - Compounds > short-term exposure or ceiling limits: Acrolein, CO, formaldehyde, glutaraldehyde, benzene, NO_2, SO_2, PAHs[1,2]
- Dermal exposure possible if protective clothing is not worn

1. Bolstad-Johnson et al. (2000)
2. NIOSH Report 2010-0156 (2013)

Fireground Exposures

- Sizing up the fire without SCBA
- Exterior operations without SCBA
- Diesel exhaust exposure – Group 1 human carcinogen[1]

* Currently lacking reliable data on fireground exposure levels

1. IARC (2012)

Contaminated Gear & Equipment

- PAHs, phthalates, metals, and flame retardants on turnout gear[1,2]
- Hose and other equipment contaminated
- Hands especially vulnerable and any body parts touched by the hands
- Contaminated dust in fire stations[3]

Photo Courtesy of Anderson Career and Technology Center

* These exposure pathways have not been well characterize.

* Baby wipes should help to remove skin contamination and lessen absorption, but we do not have quantitative data to support this.

1. UL Firefighter Exposure to Smoke Particulates (2010)
2. Huston et al. (2014)
3. Shen et al. (2015)

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Off-Gassing Gear

- Volatile compounds will off-gas from gear and can be inhaled
  - Benzene, toluene, ethylbenzene, xylenes, styrene, and HCN have been measured at elevated levels (compared to background)
  - Well below short-term exposure limits, but yet another source of exposure[1,2]

* Semi-volatile compounds can off-gas for weeks, months, or even years, but this exposure pathway has not been well characterized.

1. Fent et al. (2015)
2. Kirk et al. (2015)

Training and Other Fires

- Simulated smoke: High levels (above short-term exposure limits) of mineral oil mist and/or glycols[1]
- Simulated smoke and propane burners: High levels of formaldehyde and acrolein[1]
- Vehicle fires: High levels of formaldehyde, acrolein, carbon monoxide, and isocyanates[2]

* Even Class A fuels (pallet and straw) may produce high levels of PAHs, aldehydes, HCN, and CO[3,4]

Simulated smoke training

1. NIOSH Report 2012-0028 (2013)
2. NIOSH Report 2008-0241 (2010)
3. UL Firefighter Exposure to Smoke Particulates (2010)
4. Kirk and Logan (2015)
5. Feunekes et al. (1997)

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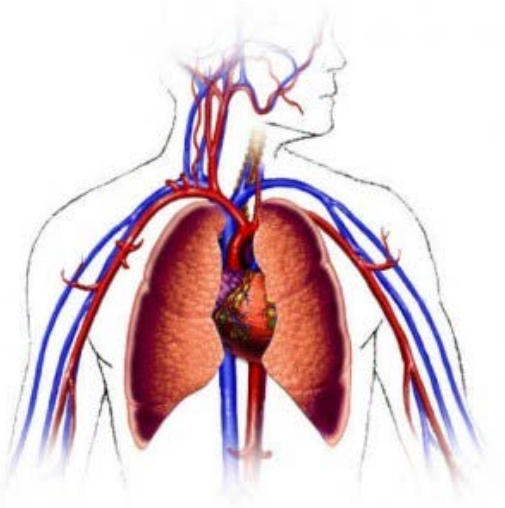
Exposure Duration

- Initial exposure period is typically short
- High intensity, short duration exposures may be more hazardous
  - Respiratory irritants, sensitizers, and asphyxiants – can overwhelm the respiratory system
  - Carcinogens – may present greater risk of cancer[1]
  - Particles – can precipitate cardiovascular events[2]
- Can extend beyond the fireground (contaminated gear and equipment)



1. Kodell et al. (1987), Chen et al. (1988), Murdoch et al. (1992), Halmes et al. (2000)
2. Brook et al. (2004)

Biological Absorption

- Several studies have found elevated levels of contaminants in the body after firefighting (despite use of turnout gear and SCBA)[1,2]
- We found that urinary PAHs and exhaled breath levels of benzene increased with increasing air concentrations of PAHs (in firefighters who wore SCBA throughout the response)[3]
- Dermal absorption was hypothesized as the primary route of entry[3]
- Systemic exposure levels generally similar to occupational groups with low exposures.

1. Caux et al. (2002)
2. Laitinen et al. (2009)
3. NIOSH Report 2010-0156 (2013), Fent et al. (2014)

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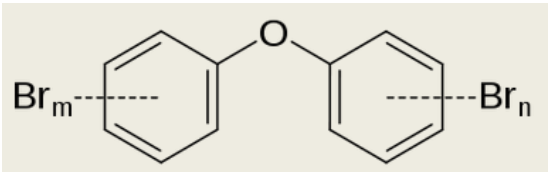
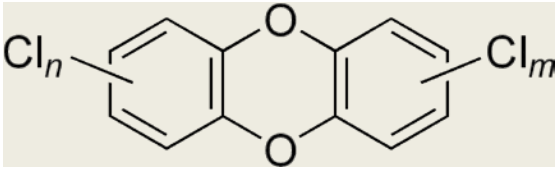
Biological Absorption (cont'd)

- Two studies have found elevated levels of flame retardants in blood of California Firefighters (compared to general population)[1,2]
- Dioxins and furans (some of which are carcinogenic) were also detected[1]
- Routine cleaning of turnout gear was associated with reduced levels[2]
- Interior fire suppression within the last month was associated with elevated levels[2]



Polybrominated diphenyl ethers



Dioxins

Source → Composition → Transport / contact → Intensity → Duration → Absorption route → Dose

1. Shaw et al. (2013)
2. Park et al. (2015)

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Excess Cancer Risk[1]

Outcome	Obs	Mortality SMR[3] (95% CI)	Obs	Incidence SIR[4] (95% CI)
All mortality	12,028	0.99 (0.97, 1.01)	NA	NA
All Cancers	3,285	1.14 (1.10, 1.18)	4,461	1.09 (1.06, 1.12)
Esophagus	113	1.39 (1.14, 1.67)	90	1.62 (1.31, 2.00)
Intestine	326	1.30 (1.16, 1.44)	398	1.21 (1.09, 1.33)
Lung	1,046	1.10 (1.04, 1.17)	716	1.12 (1.04, 1.21)
Kidney	94	1.29 (1.05, 1.58)	166	1.27 (1.09, 1.48)
Oral cavity[2]	94	1.40 (1.13, 1.72)	174	1.39 (1.19, 1.62)
Mesothelioma	12	2.00 (1.03, 3.49)	35	2.29 (1.60, 3.19)

1. Cancers with statistically significant excesses in mortality and incidence with U.S rates referent (Daniels et al. Occup Environ Med 2014; 71(6): 388-397).
2. Oral cavity includes lip (excluding skin of the lip), tongue, salivary glands, gum, mouth, pharynx, oropharynx, nasopharynx, and hypopharynx
3. SMR = standardized mortality ratio
4. SIR = standardized incidence ratio

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Cancer Risk: Comparison with Other Studies

NIOSH Study[1]	Nordic Study[2]	Australian study[3]	California Study[4]
all cancers	all cancers	all cancers	melanoma
esophagus	prostate*	prostate	myeloma
intestine	melanoma*	melanoma	leukemia (AML)
lung	myeloma#		esophagus
kidney	lung#		prostate
oral cavity	mesothelioma#		brain
mesothelioma			kidney
prostate*			
bladder*			

* At younger ages.
# At older ages.
Australian study results restricted to career firefighters.
References: 1. Daniels et al. Occup Environ Med 2014; 71(6): 388-392. 2. Pukkala et al. Occup Environ Med 2014;71:398-404. 3. http://www.coeh.monash.org/downloads/finalreport2014.pdf 4. Tsai et al. Am J Ind Med 2015; 58: 715-729.

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What We Don't Know

- Production of flame retardants and dioxins during residential fires
  - Deposition of these compounds onto turnout gear
  - Biological uptake of these compounds in responding firefighters
- Fire-ground exposure levels
- Effect of attack methods and position on exposure
- Effectiveness of decontaminating turnout gear and its relationship with systemic exposure
- Effectiveness of skin cleaning and its relationship with systemic exposure
- Systemic exposure from routine training fires

Break

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Study Overview

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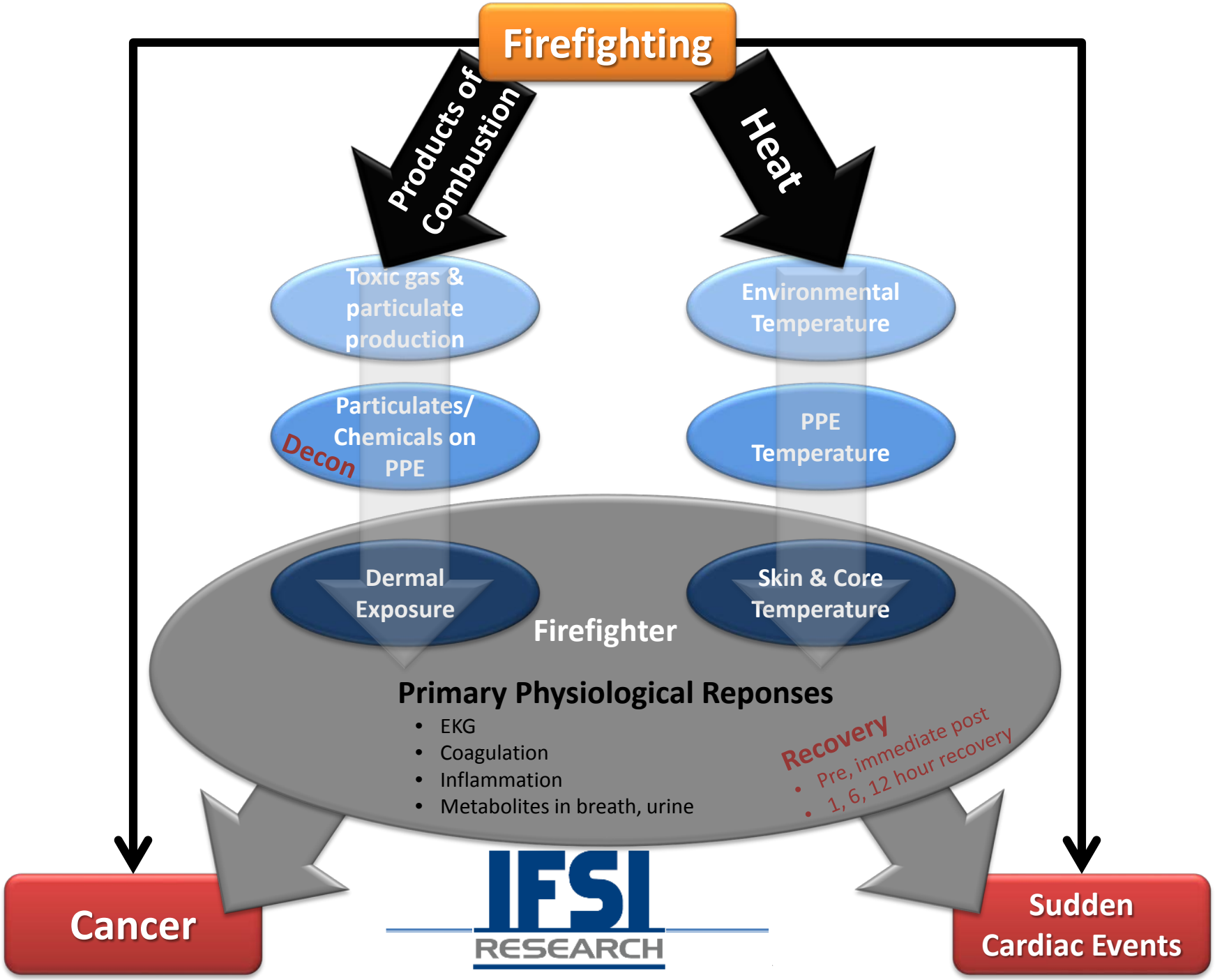
Firefighting
Products of Combustion
Heat
Toxic gas & particulate production
Environmental Temperature
Particulates/ Chemicals on PPE
Decon
PPE Temperature
Dermal Exposure
Skin & Core Temperature
Firefighter
Primary Physiological Reponses
• EKG
• Coagulation
• Inflammation
• Metabolites in breath, urine
Recovery
• Pre, immediate post
• 1, 6, 12 hour recovery
Cancer
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Sudden Cardiac Events

Recruitment	6-12 hr pre	1 hr pre	30 min pre	Live Fire Response	Immediately Post FF	*PPE swab	*PPE off gassing	1 hr, 3 hr, 6 hr, 12 hr Post-FF
*Informed Consent *Health History	*Ingest GI Pill	*Skin swab (neck, arm) *Urine sample *Breath sample *Venous Blood Draw * Vascular Function *Electrocardiogram (EKG)	*Fit PSM *Fit Particle monitor *Fit Gas monitor ***PPE swab**	**Continuously monitor:** • Core Temp, HR, EKG • Gases, Particles	*Skin swab (neck, arm) *Urine sample *Breath sample *Venous Blood Draw * Vascular Function *Electrocardiogram (EKG)			*Urine sample *Breath sample *Venous Blood Draw * Vascular Function *Electrocardiogram (EKG)

Fire Involvement
Room & Contents
Multiple Rooms

Firefighting Tactics
Interior Only
Transitional Attack

Response Units
Engine 1
Truck 1
Engine 2

PPE Cleaning Measures*
None
Spray down with hose
Hose and brush

*after initial off-gassing data is collected from these samples, they will be professionally laundered and swab/off-gassing measures repeated

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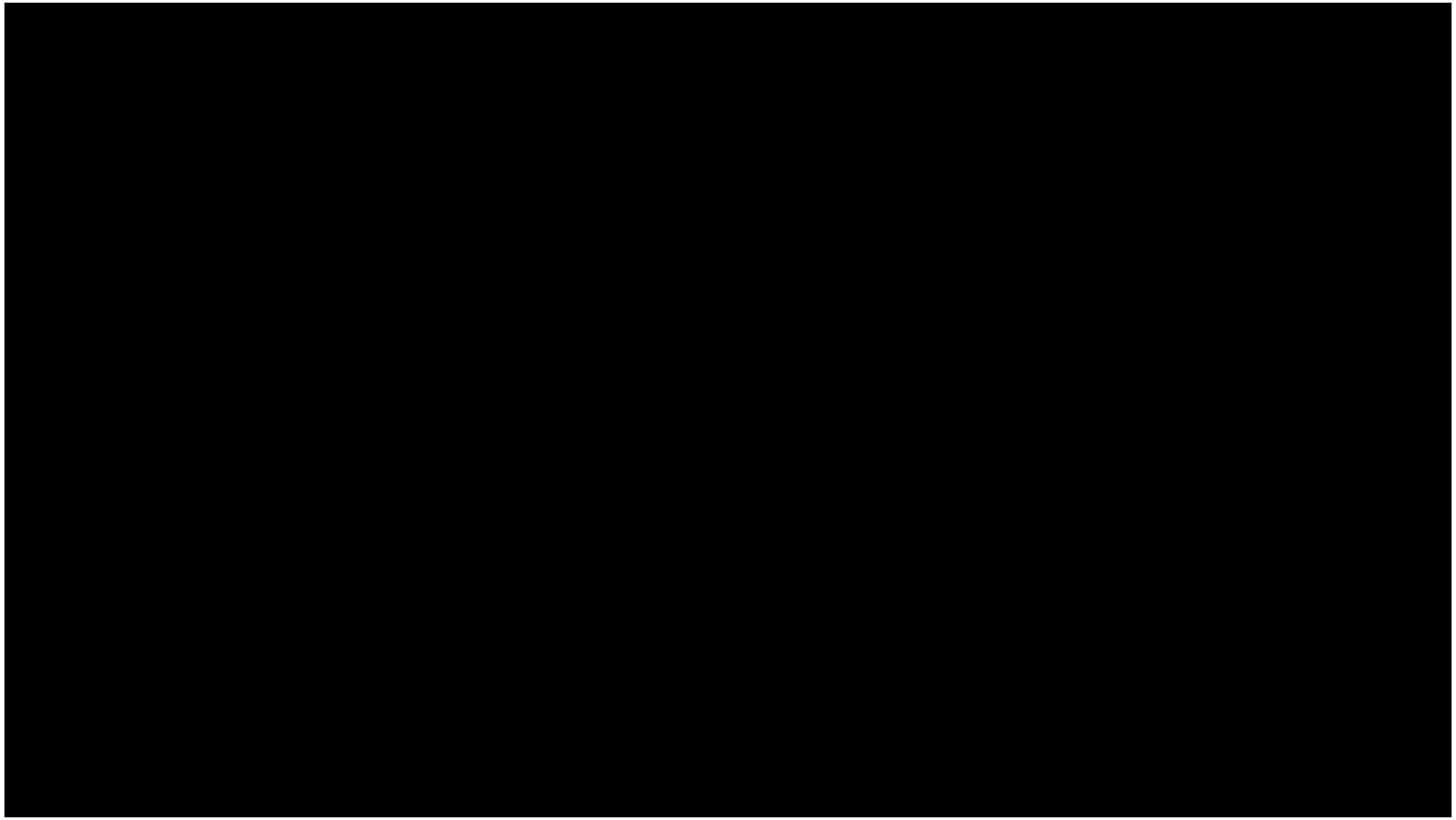

https://www.youtube.com/watch?v=uZO3GO1Nd-E

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Participants

- 40 firefighters recruited from across the country
  - Between the ages of 18 and 55 years old
  - Not a smoker or other tobacco user
  - Have no known cardiovascular diseases, history of any neurological disorders or digestive complications
  - Have completed an NFPA 1582 based physical in the past year

- Canton (IL)
- Cleveland (OH)
- Cobb County (GA)
- Corn Belt FPD (IL)
- Danville (IL)
- Decatur (IL)
- Hanover Park (IL)
- IAFF Local 4416 (IN)
- IAFF Local 1147 (IL)
- Kenosha (WI)
- Lafayette (IN)
- Milwaukee (WI)
- Mt Carmel (IL)
- Oakwood (IL)
- Savoy (IL)
- Sioux Falls (SD)
- Springfield (IL)
- Streamwood (IL)
- Wayne Township (IN)
- West Lafayette (IN)

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Participant Safety

- IRB approval from Illinois, NIOSH & DHS
- Emergency action plan, IAP and ALS ambulance
- Briefing and walk through
- Interior video, temperature, heat flux measurements continuously monitored
- Interior safety officers with each crew
- Backup line and RIT firefighters throughout scenario
- Interior deluge suppression system

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Fireground Roles

- The teams were separated into pairs that completed specific tasks.
  - Compliment of 4 firefighters arriving every 1 minute
  - Engine 1 –
    - A - **Interior** firefighters; fire suppression
    - B - **Exterior** firefighters; command &pump operator.
  - Truck 1 –
    - A - **Interior** firefighters; forcible entry then search &rescue
    - B – **Exterior** firefighters; ventilation (horizontal and vertical).
  - Engine 2
    - A – Back-up line, supported the first-in engine then **overhaul**
    - B - Rapid intervention team (RIT) then transitioned to **overhaul** operations after the fire was suppressed.

Fire Suppression Tactics

- Traditional interior- first line through the front door

- Transitional attack – hit from exterior then transition through front door

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Comprehensive Study

- We sought to answer multiple questions: grouped by
  - Temperature/gas exposure (for FF and victim)
  - Cardiovascular strain
  - Chemical exposure – especially related to carcinogenic risk (for FF and victim)

Instrumentation & Preliminary Results

Fire Dynamics

Cardiovascular Strain

Chemical Exposures

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Fire Dynamics

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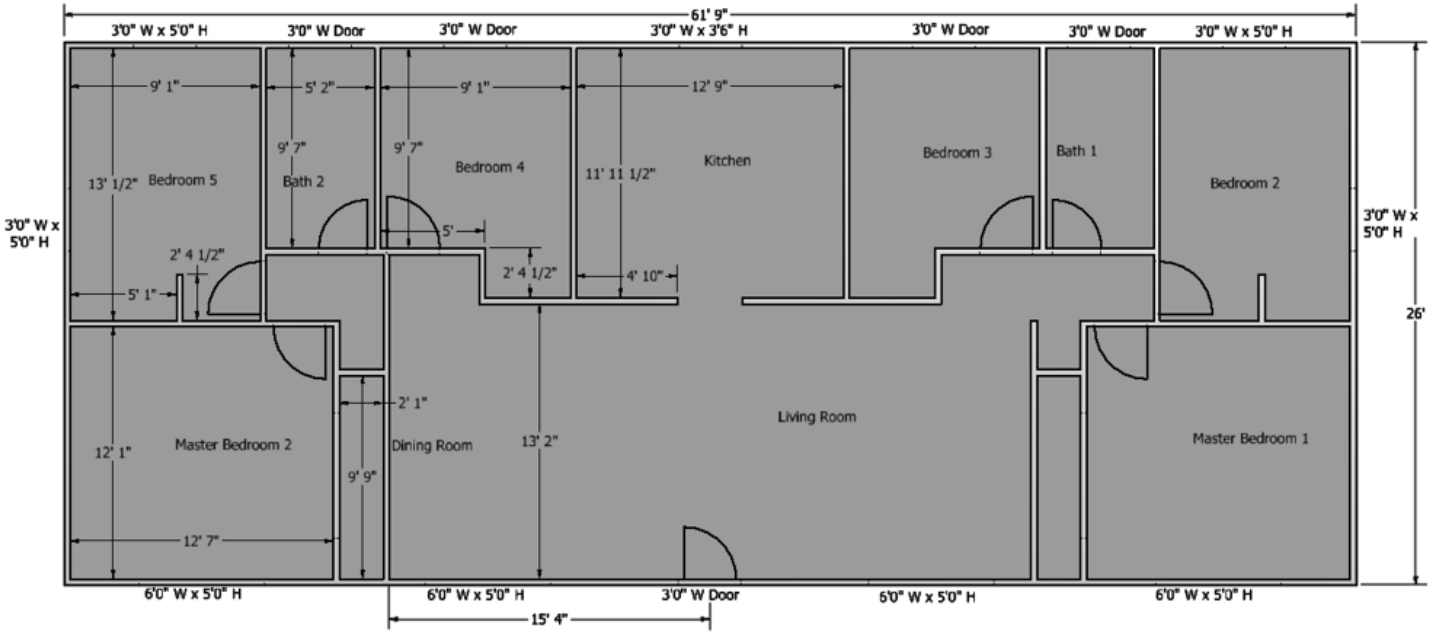
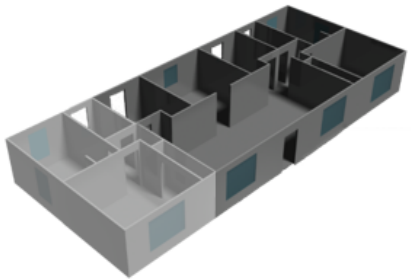
New Research Burn Structure





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Structure Views

Overhead View & Apparatus layout

Side A (North)

Side B (East)

Side C (from Southeast Corner)

Side D (West)

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Fuel Load

Living Room

Kitchen

Bedroom 1/6

Bedroom 2/5

Bedroom 3/4

Dining Room

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Building Instrumentation

Symbol	Measurement
	Differential Pressure
	Gas Concentration
	Thermocouple Array
	Heat Flux
	Video Camera

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Typical Response Timeline

Time (mm:ss)	Description
00:00	Ignition BR 6/1
02:00	Ignition BR 5/2
04:30	FD Dispatch
06:39	Water in BR 6/1 Window Start
06:54	Water in BR 6/1 Window Stop
07:01	Water in BR 5/2 Window Start
07:17	Water in BR 5/2 Window Stop
07:56	Front Door Open
09:12	Nozzle FF Reaches Hallway
09:27	BR 6/1 Window Cleared
09:34	BR 5/2 Rear Window Open
11:28	Victim 1 Out
16:12	Victim 2 Out
19:34	Living Room Right Window Open
19:39	Living Room Left Window Open
20:33	Kitchen Window Open
35:32	End of Experiment
08:12	Fire Attack Enters
18:17	Fire Attack Exits
08:30	Search Enters
18:02	Search Exits
19:58	Overhaul Enters
35:38	Overhaul E2A Exits
35:42	Overhaul E2B Exits

Conditions at dispatch

Attack Team deploying transitional attack

Attack Team transitions to front door as Search Team forced door prop

Attack Team makes entry followed by Search Team

Backup line is deployed as outside ventilation is taking place

Roof is ventilated as fire is suppressed

Simulated occupant is rescued by Search Team

Overhaul Teams remove debris and drywall from fire rooms

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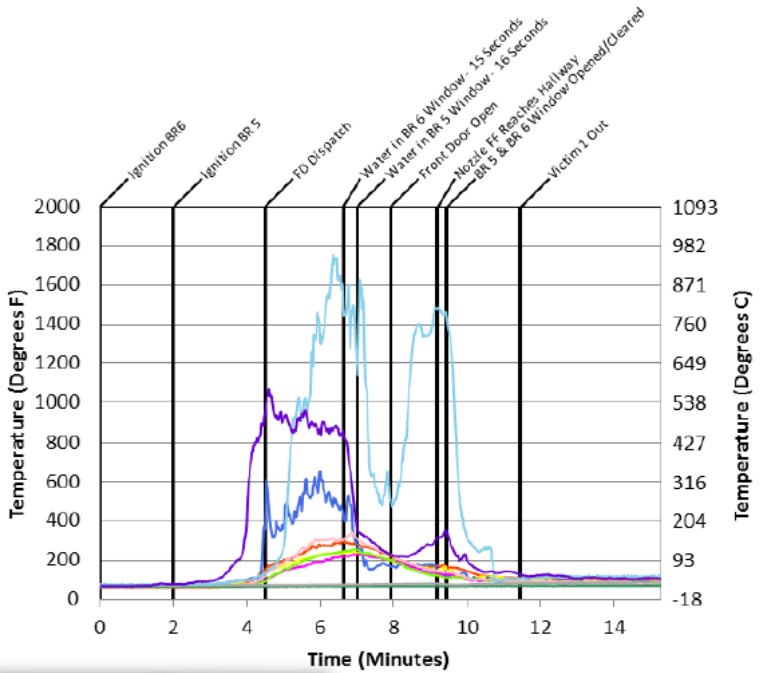
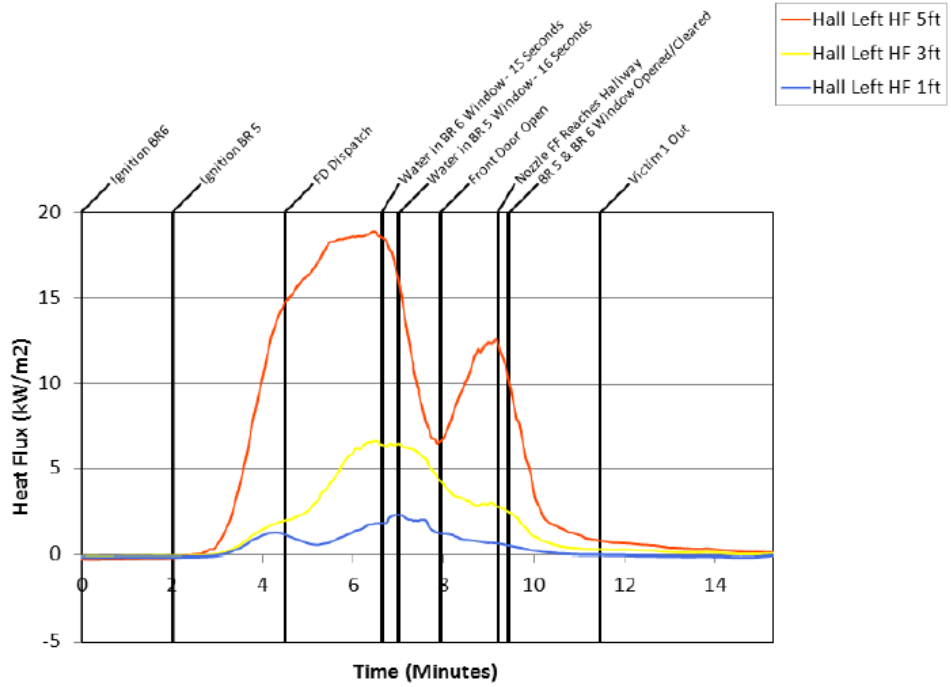
Building Temperature & Heat Flux





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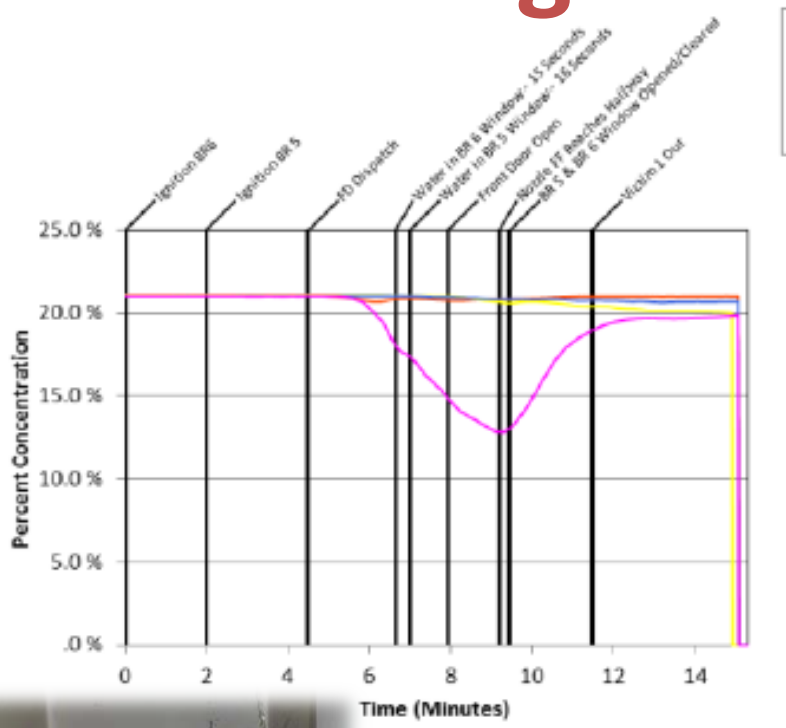
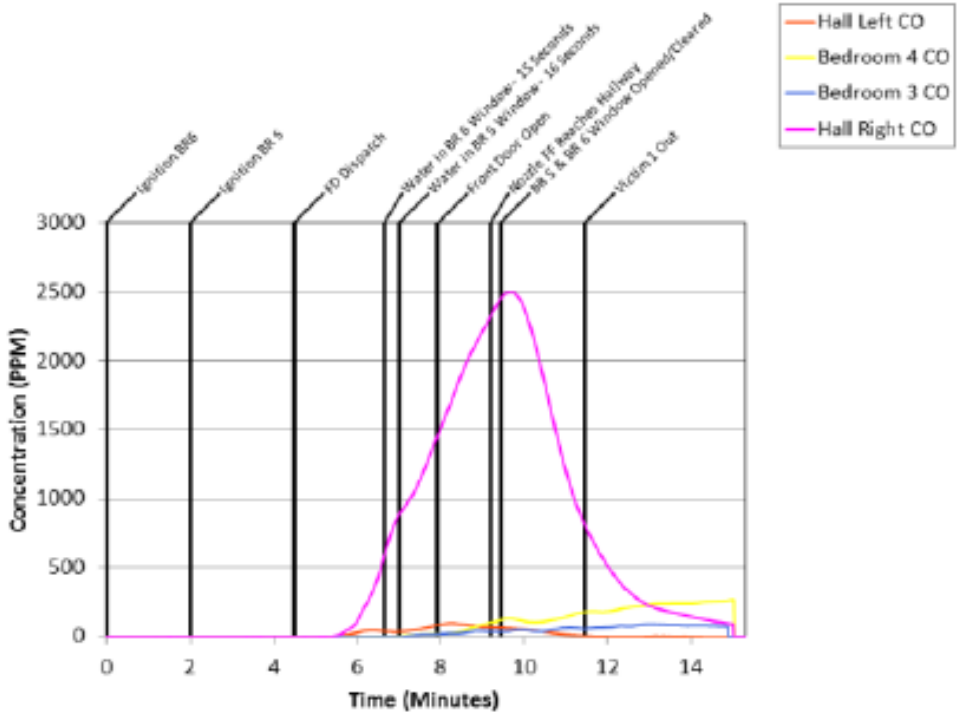
Building Gas Concentrations





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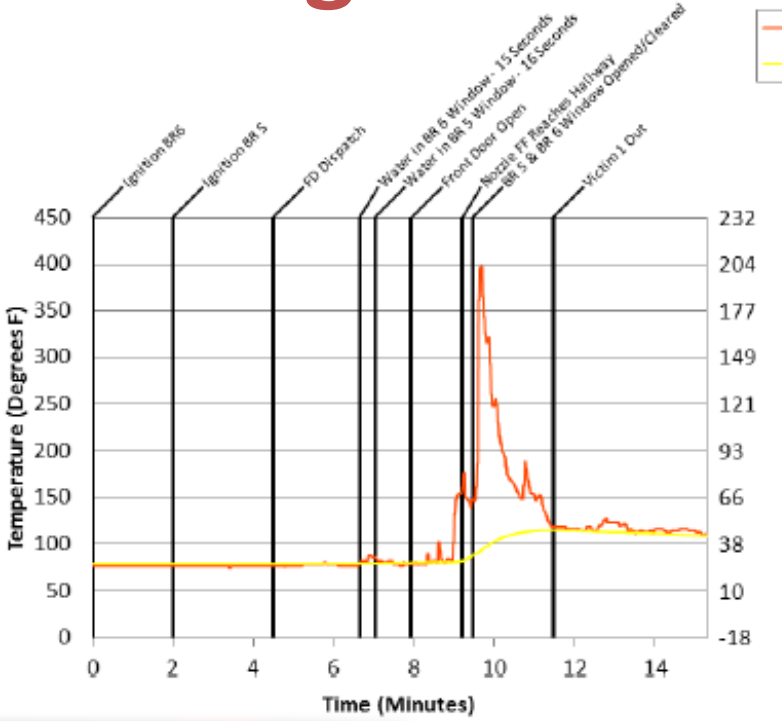
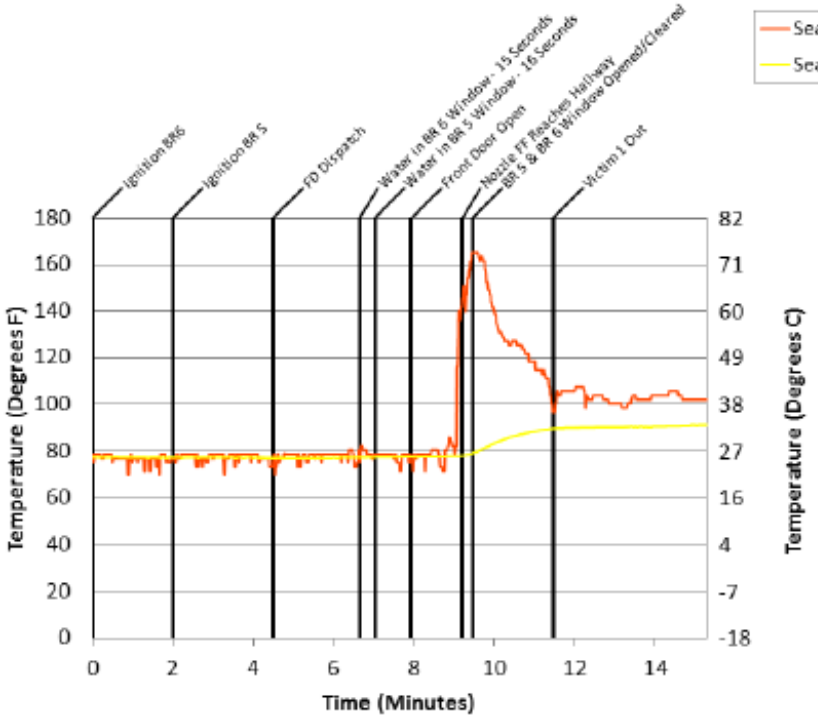
Firefighter Helmet Mounted Temps





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Heat Stress & Cardiovascular Strain

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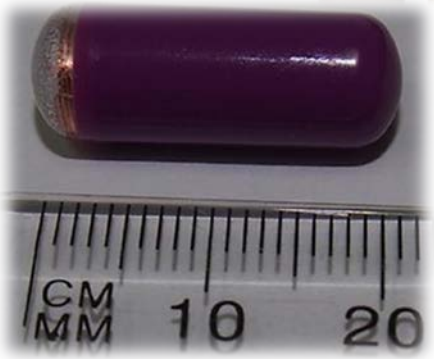
Core & Skin Temperature

- Ingestible core temperature pills
- Dermal patches
- Wireless transmission to continuous data recording



Cardiovascular Function

- Electrical function (EKG)
  - Portable Holter Monitor
  - Up to 12 hour recovery

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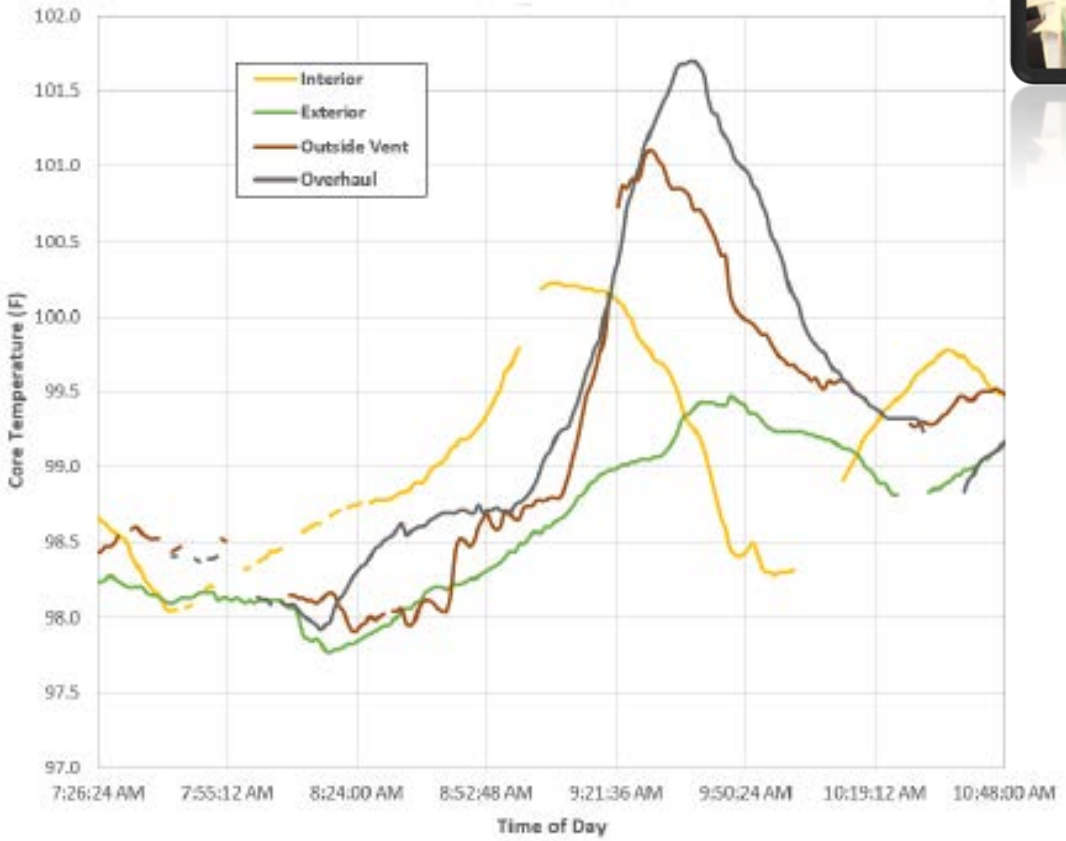
Cardiovascular Function

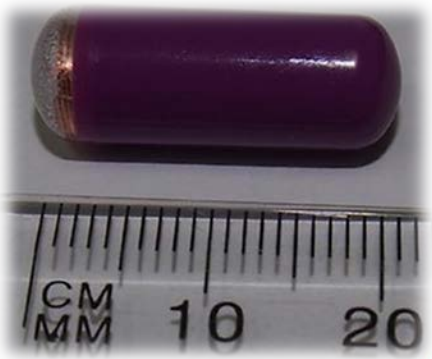
- Vascular function
  - Mobil-O-Graph PWA
  - Pulse wave monitoring,
    - Peripheral blood pressure
    - Central hemodynamics
    - Arterial stiffness

Blood Parameters

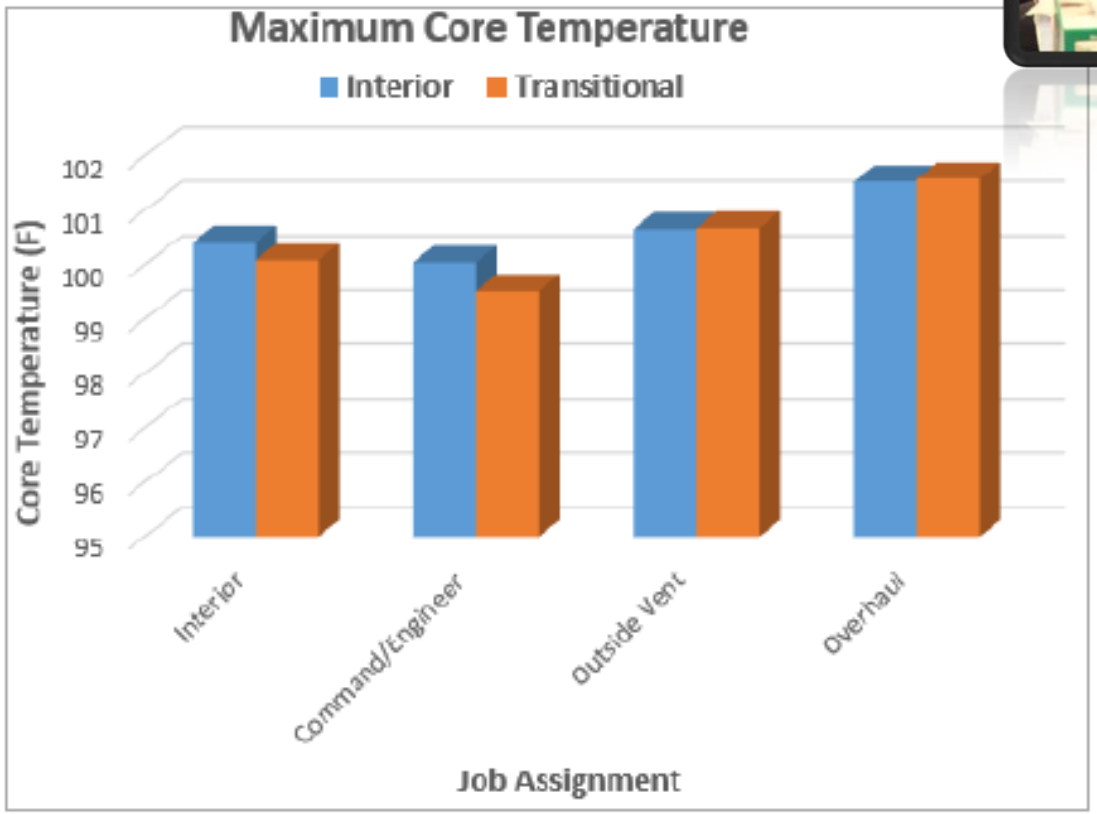
- CBC
  - Blood count
- Platelet function
  - Platelet activity (measured as platelet closure time)
- Coagulatory factors
  - aPTT

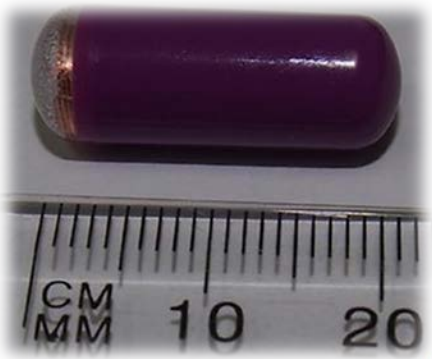
Core Temperatures





Maximum Core Temperatures





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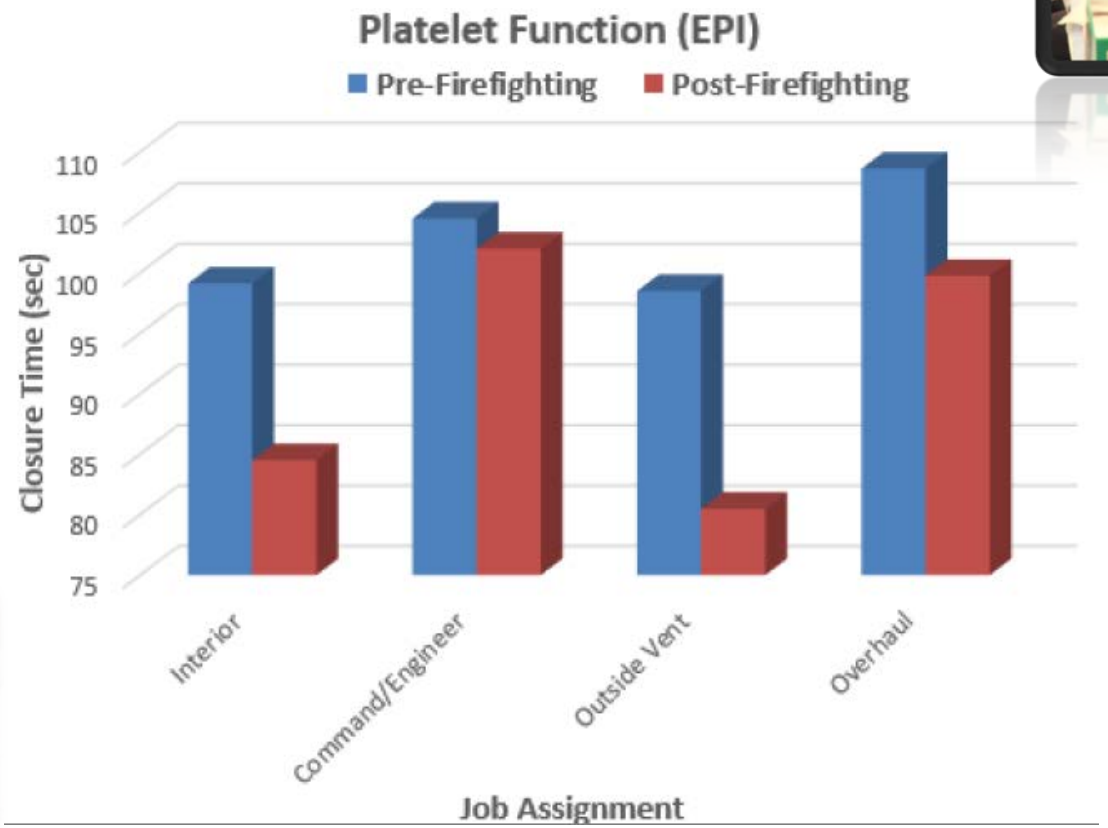
Platelet Function



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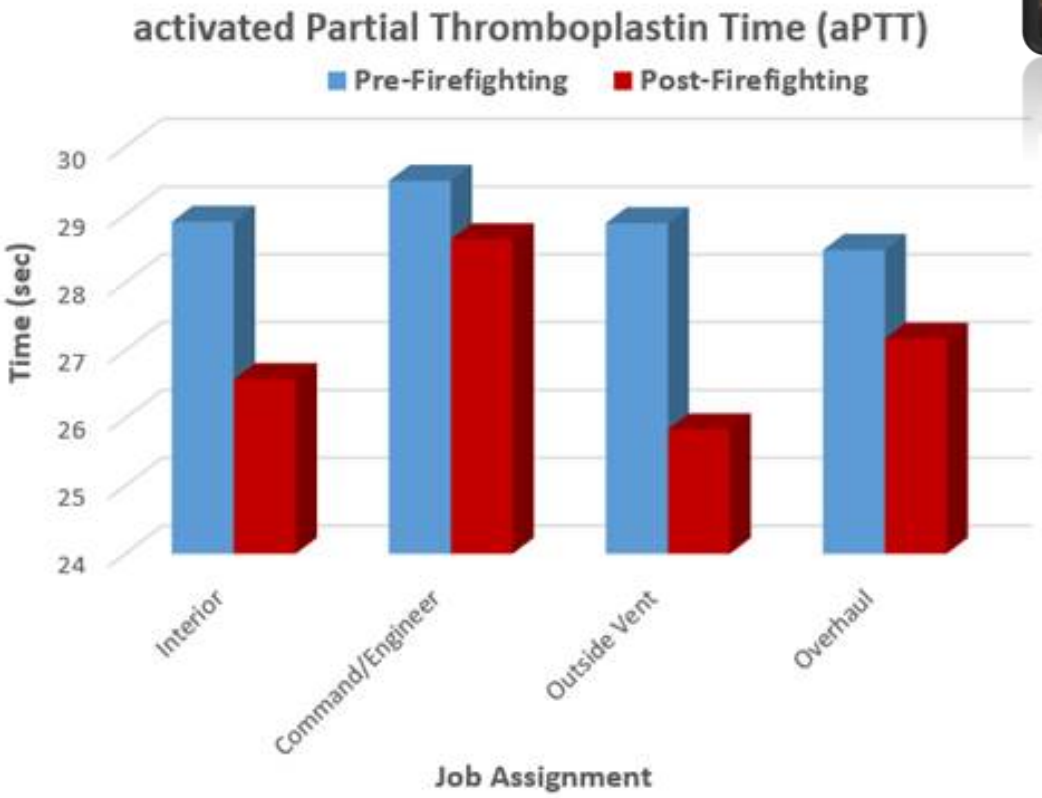
aPTT



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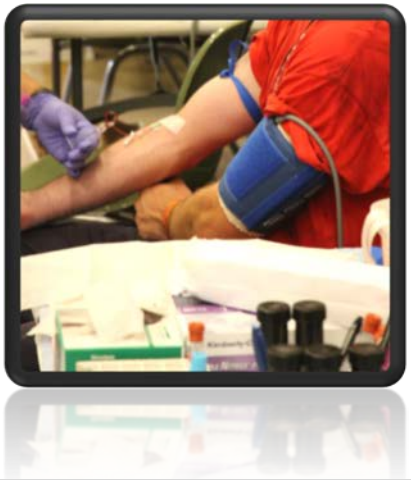
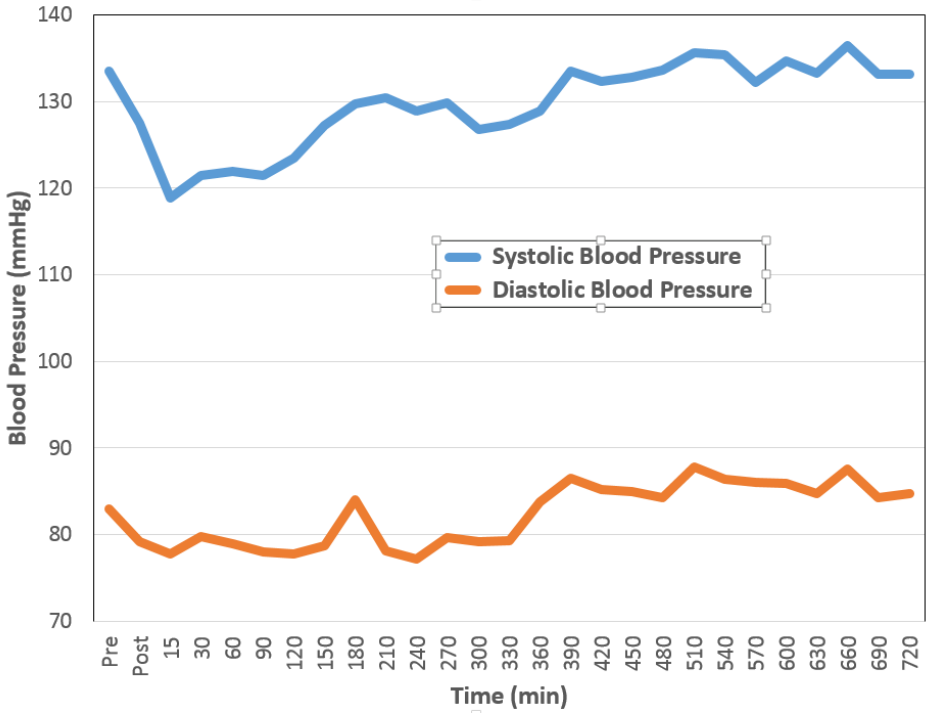
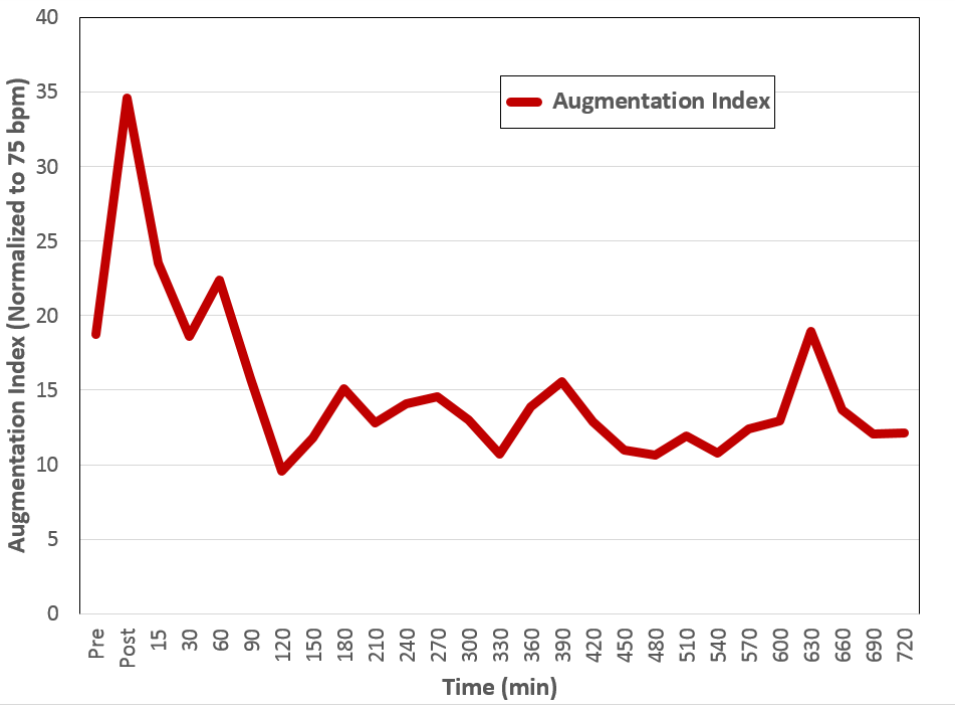
Blood Pressure & Augmentation Index







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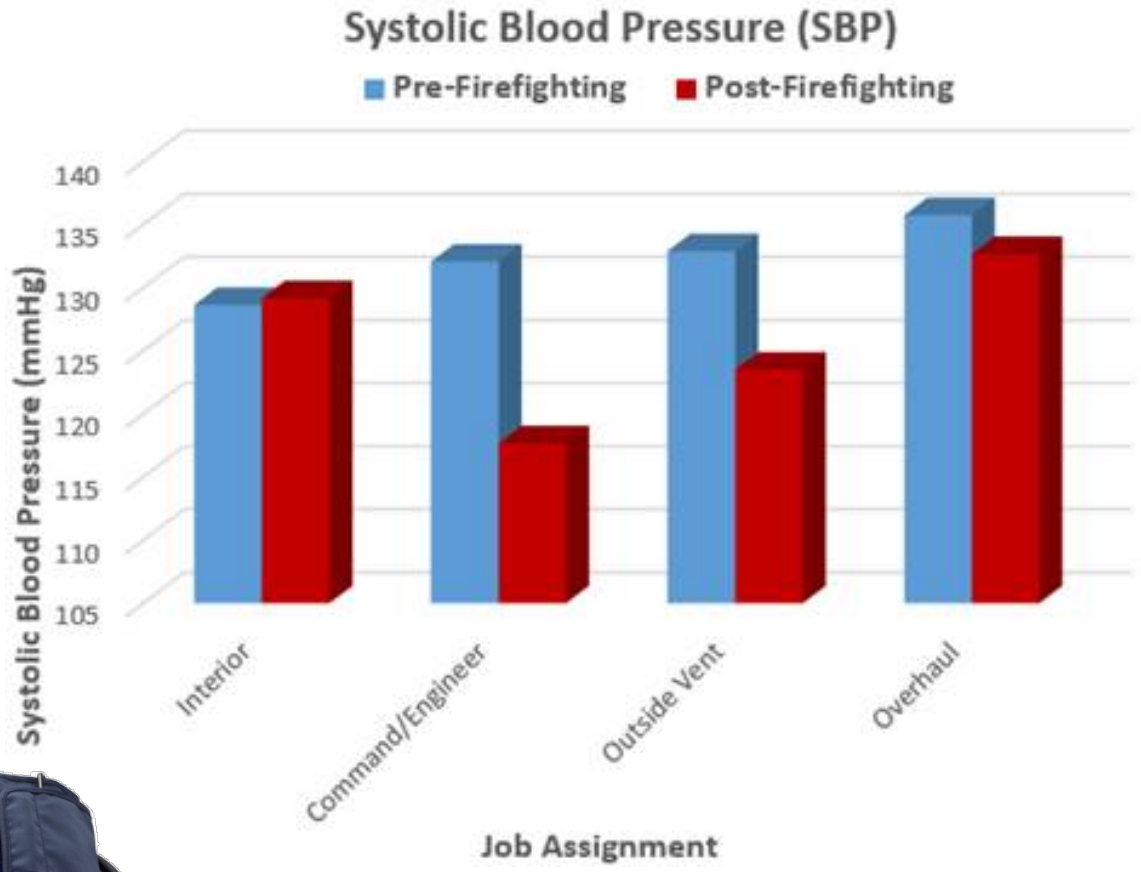
Blood Pressures



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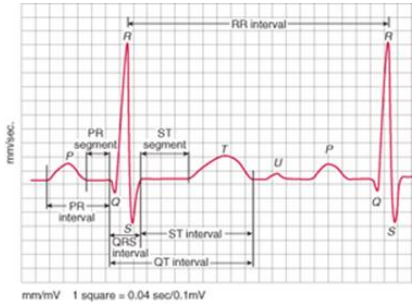
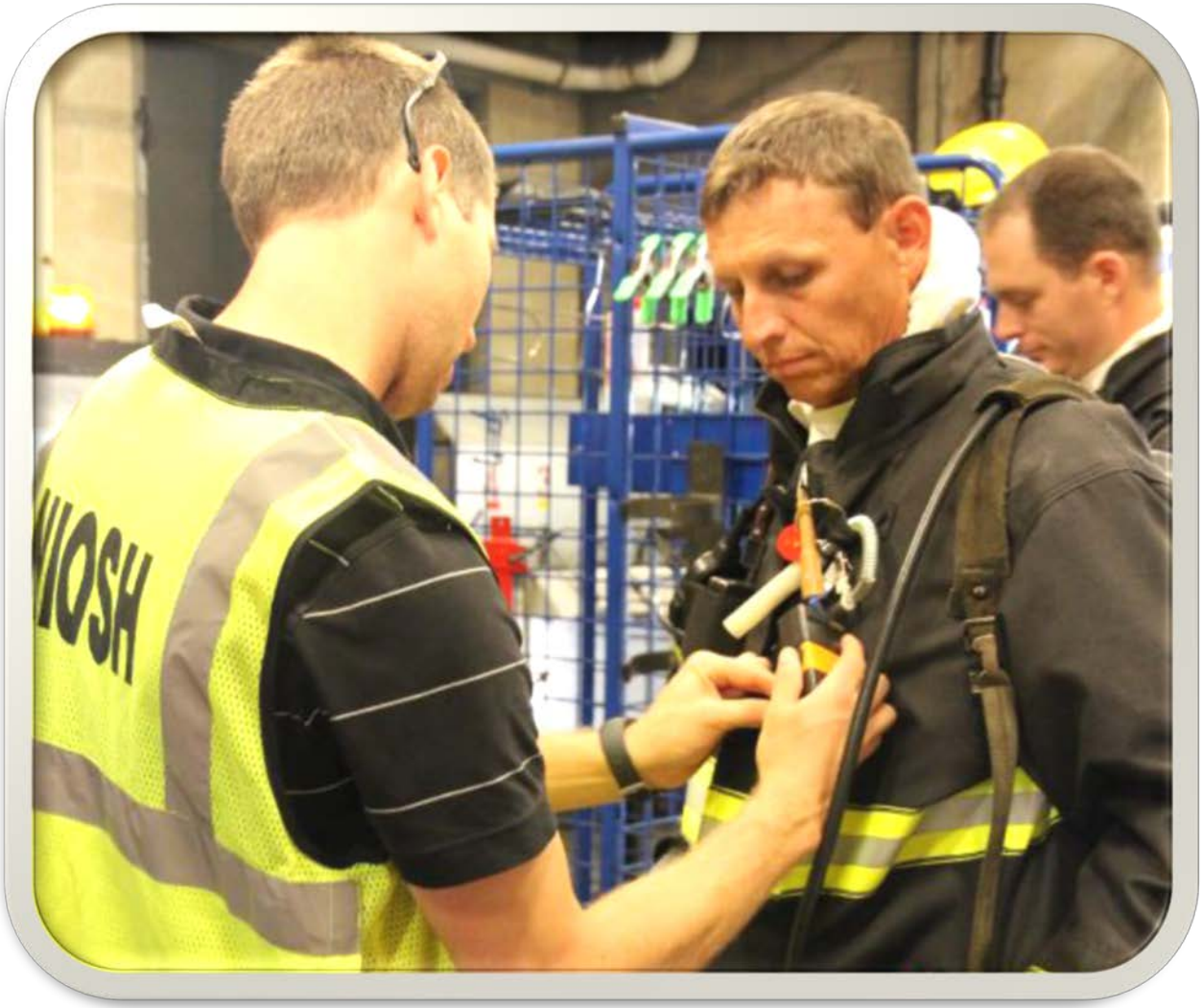
Cardiac Electrical Function



Chemical Exposures



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Exposure Monitoring Component

- Bulk sampling of fuel package for flame retardants
- Air sampling from within the structure for flame retardants, HCN, and VOCs
- Air sampling for VOCs and particulate in the fireground
- Testing surfaces of turnout gear for flame retardants and PAHs (before and after decon)
- Sampling HCN and VOCs off-gassing from used turnout gear

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Personal & Biological Monitoring

- **Personal air sampling**
  - PAH's, VOCs (Benzene, Toluene, etc.), HCN
- **Skin wipes** (Pre and Post-FF)
  - PAHs
- **Biological** (Pre and Post-FF)
  - Urine
    - PAHs, Benzene, Organophosphate FRs
  - Exhaled Breath
    - VOCs (Benzene, Toluene, etc.)
  - Blood
    - Brominated FRs, perfluorinated compounds (PFCs), HCN

** Results are still pending and will not be discussed here*

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Concentrations of flame retardants (µg/g)* in bulk samples of the burn room furnishings

Compound measured	Carpet padding (n = 3)	Curtain liner (n = 1)	Foam from inner spring mattress (n = 2)	Foam topper for bed (n = 2)	Head-board padding (n = 1)	Chair cushion (n = 2)	Liner for chair cushion (n = 1)	Flat screen TV plastic (n = 1)
Polybrominated diphenyl ethers								
BDE 47	< 0.1 - 0.41	0.19	< 0.1	< 0.1 - 0.74	5,600	< 0.1 - 4.1	< 0.1	< 0.1
BDE 85	< 0.1	< 0.1	< 0.1	< 0.1	840	< 0.1 - 1.6	< 0.1	< 0.1
BDE 99	0.11 - 0.56	0.25	< 0.1 - 0.44	< 0.1 - 2.9	15,000	< 0.1 - 25	< 0.1	< 0.1
BDE 100	< 0.1	< 0.1	< 0.1	< 0.1 - 0.6	2,500	< 0.1 - 3.8	< 0.1	< 0.1
BDE 153	< 0.1 - 5.6	< 0.1	< 0.1	< 0.1 - 2.0	2,000	< 0.1 - 13	< 0.1	< 0.1
BDE 154	< 0.1	< 0.1	< 0.1	< 0.1 - 0.69	1,400	< 0.1 - 5.0	< 0.1	< 0.1
BDE 183	< 0.1 - 1.1	< 0.1	< 0.1	< 0.1 - 2.0	67	< 0.1	< 0.1	< 0.1
BDE 206	< 0.1 - 14	2.8	< 0.1 - 6.3	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
BDE 209	0.41 - 102	440	< 0.1 - 61	< 0.1	< 0.1	< 0.1 - 0.68	< 0.1	< 0.1
Other brominated flame retardants								
TBBPA	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
TBB	0.38 - 3.2	910	< 0.1 - 0.5	< 0.1 - 7.5	< 0.1	18,500 - 26,750	68.5	< 0.1
TBPH	0.22 - 5.7	340	< 0.1 - 1.2	< 0.1 - 3.7	< 0.1	5,800 - 6,380	19.6	< 0.1
DBDPE	< 0.1 - 0.53	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Organophosphate flame retardants								
TCEP	< 0.1	1.4	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
TCPP	59 - 630	5.4	< 0.1	< 0.1	8.4	< 0.1 - 1.3	< 0.1	< 0.1
TDCPP	240 - 9,100	1.2	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
TPP	0.43 - 3.8	4.0	0.16 - 0.23	< 0.1 - 1.3	1,690	1,400 - 7,380	22.6	19
TCP	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1

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Flame retardant air concentrations (µg/m^3) measured from living room during active fire and from initial burn room (bedroom) during overhaul on 6/25/2015.

Compound measured	Fire period	Overhaul period
BDE 47	9.6	< 0.04
BDE 85	< 0.17	< 0.04
BDE 99	7.4	< 0.04
BDE 100	< 0.17	< 0.04
BDE 153	< 0.17	< 0.04
BDE 154	8.7	< 0.04
BDE 183	< 0.17	< 0.04
BDE 206	< 0.17	< 0.04
BDE 209	14	< 0.04
TBBPA	12	< 0.04
TBB	9.2	< 0.04
TBPH	1.2	< 0.04
DBDPE	< 0.17	< 0.04
TCEP	< 0.25	< 0.06
TCPP	< 0.25	< 0.06
TDCPP	< 0.25	< 0.06
TPP	2000	14
TCP	220	1.9

Photo by NIST

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HCN and VOC air concentrations (ppm) measured from within living room during active fire and from within initial burn room (bedroom) during overhaul on 6/25/2015

Compound measured	Fire period		Overhaul period
HCN	340	IDLH	1.2
Benzene	15	> STEL	0.17
Toluene	0.069		0.0038
Ethyl benzene	< 0.0004		0.0014
Xylenes	< 0.0008		0.0038

Above 8-hr NIOSH REL (0.1 ppm)
Below NIOSH STEL (1 ppm)

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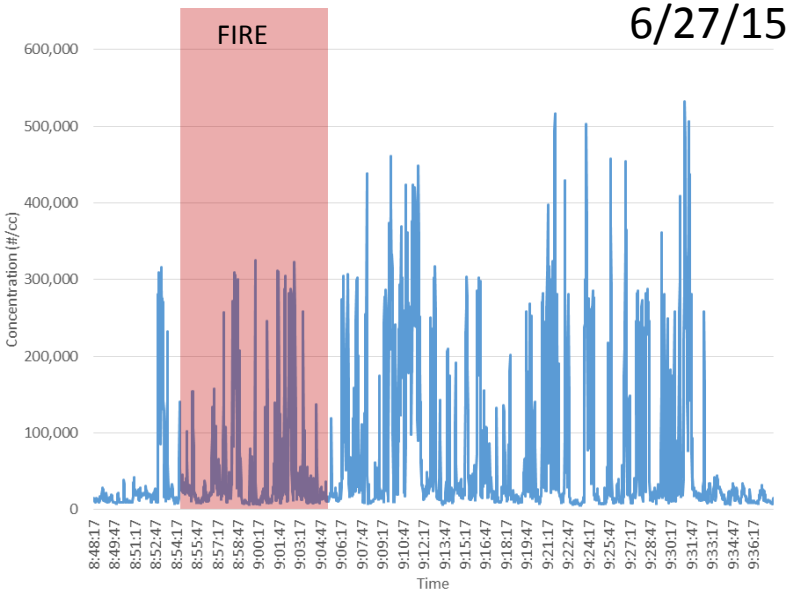
Air concentrations of VOCs (ppm) measured in the fireground (south of Engine 1) on 6/27/2015 and 6/30/2015.

Compound measured	6/27/2015	6/30/2015
Benzene	0.029	0.060
Toluene	0.0034	0.0061
Ethyl benzene	< 0.0004	0.0012
Xylenes	< 0.0008	0.0032

Below applicable short-term exposure limits

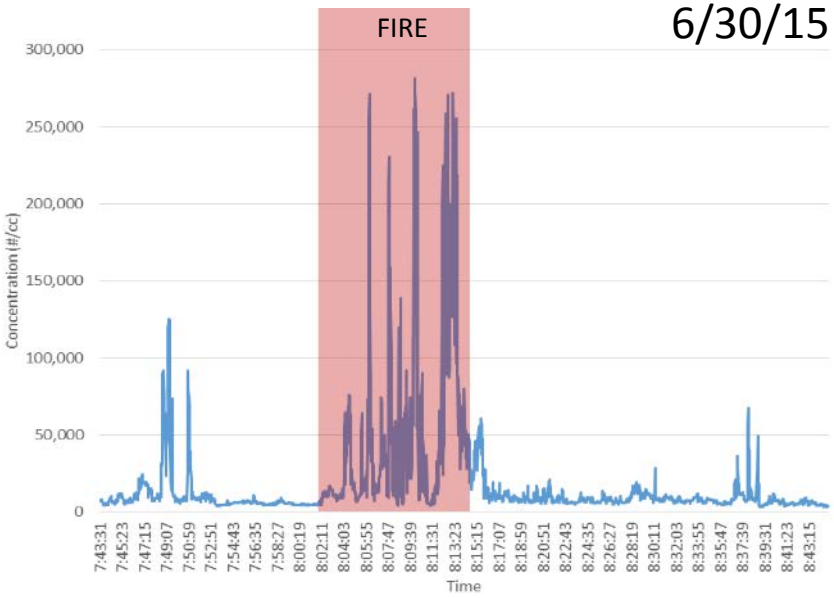
Downwind of diesel exhaust

6/27/15



Downwind of smoke plume

6/30/15



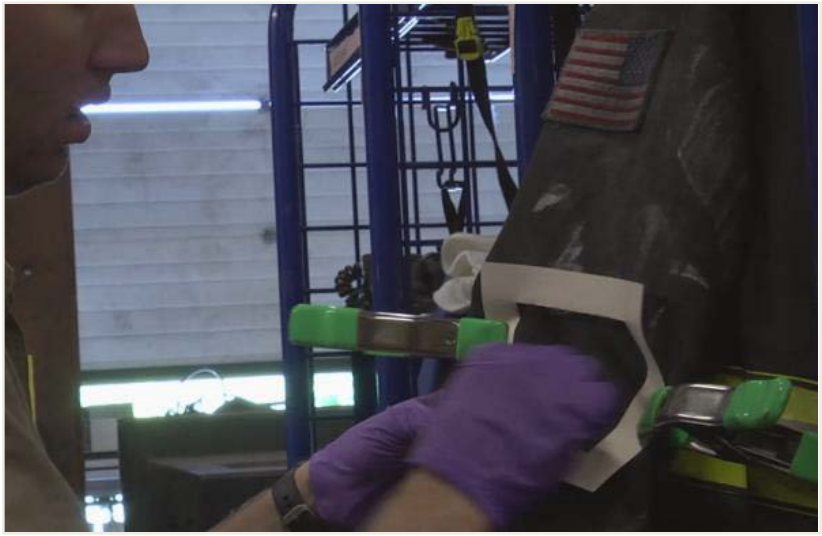
Water, detergent, and scrubbing

Surface contamination levels (ng/100 cm^2) of total PAHs measured from "green" turnout jacket worn by search during crew's first scenario on 6/22/2015

Pre-fire	Post-fire	Post-decon
< 300*	3,800†	< 300*

* Based on limit of detection for fluoranthene.

† Sum of 15 PAHs; PAH measurements below their limit of detection were assigned zero values.



Surface contamination levels (ng/100 cm^2) of flame retardants from "red" turnout gear worn by search during crew's last scenario on 6/30/2015.

Compound Measured	Post-fire (jacket)*	Post fire (right glove)
BDE 47	48	35
BDE 85	< 1	< 1
BDE 99	< 1	40
BDE 100	< 1	12
BDE 153	< 1	< 1
BDE 154	< 1	< 1
BDE 183	< 1	< 1
BDE 206	< 1	< 1
BDE 209	1,200	1,200
TBBPA	< 1	30
TBB	22	30
TBPH	11	14
DBDPE	140	290
TCEP	5.5	< 1.5
TCPP	< 1.5	200
TDCPP	190	460
TPP	2	3,100
TCP	< 0.2	360

* Quality control samples were 60–80% less than expected, so measurements may be underestimated.

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Air concentrations of VOCs (ppb) measured off-gassing from green (wet decon) and red (no decon) gear pre-fire, post-fire, and post-decon during the first scenario (6/22/2015) for crew C.

Compound Measured	Green (wet decon)			Red (no decon/control)		
	Pre-fire	Post-fire*	Post-decon	Pre-fire	Post-fire*	Post-decon
Benzene	< 0.6	75	< 0.6	< 0.6	66	0.84
Toluene	< 0.5	19	< 0.5	< 0.5	16	< 0.5
Ethyl benzene	< 0.4	3.3	< 0.4	< 0.4	2.8	< 0.4
Xylenes	< 0.4	2.2	< 0.4	< 0.4	2.1	< 0.4
Styrene†	< 0.4	120	0.42	< 0.4	98	0.95

Well below applicable short-term exposure limits

* Quality control samples were 50% less than expected, so measurements may be underestimated.

† Results based on calibration curve for toluene.

Air concentrations of HCN (ppb) measured off-gassing from green (wet decon) and red (no decon) gear pre-fire, post-fire, and post-decon during first and last scenarios for crew C.

Scenario	Green (wet decon)			Red (no decon/control)		
	Pre-fire	Post-fire	Post-decon	Pre-fire	Post-fire	Post-decon
First (6/22/2015)	< 20	140	71	42	130	49
Last (6/30/2015)	< 20	120	< 20	< 20	120	< 20

Same approximate volume as apparatus cabin

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Break

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Summary of Prelim Findings – Fire Dynamics

- Conditions improved throughout the structure after water application
  - Water into Bedrooms resulted in no apparent increase in heat flux in the hallway
- Survivable victims were found behind closed doors in each scenario
  - Low O2, high CO in hallway & living room through which victims were ‘rescued’
- The time to get both victims out of the house varied twofold
- Suppression team had more severe exposure than search and rescue team

Summary of Prelim Findings - Cardiovascular

- Significant elevation of core temperature
  - Fireground position dependent
- Significant elevation of skin temperature
  - Suppression tactic dependent(?)
- Significant cardiovascular strain
  - Evidence by heart rate changes, blood pressure changes, coagulatory changes
  - Effected by fireground position, possibly tactic dependent

Summary of Prelim Findings - Exposure

- 17 of 18 flame retardants tested were found in the fuel package
- Many of these compounds were released into the air during the fire and a few persisted during overhaul
- PAHs and flame retardants were measured on turnout gear
  - Studies suggest that PAHs and certain flame retardants can be absorbed through skin[1-3]
- Wet decon (water, detergent, and scrubbing) removed PAH contamination

1. VanRooij et al. (1993)
2. Abdallah et al. (2015)
3. Hughes et al. (2001)

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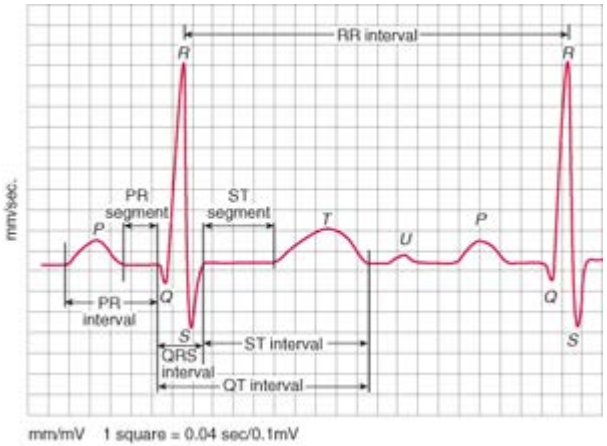
Summary of Prelim Findings - Exposure (cont'd)

- Benzene and HCN were present at hazardous levels in the structure during the fire
- Fire-ground levels of VOCs were above background but below short-term exposure limits
- Firegound particulate levels were much greater than background
  - Contribution from both diesel exhaust and smoke plume
- VOCs and HCN were measured off-gassing from turnout gear
  - Off-gas levels immediately after use were below applicable short-term exposure limits
  - Off-gas levels returned to background within the testing period (~45 min) regardless of decon

Next Steps

- Obtain remaining data from the lab
- Thorough statistical review
- Integration between components of study
- Update/compare with training fire data (Summer 2016)
- EKG
  - Arrythmias post-fire event
  - Compare to 12 hour baseline



- Heat stress, skin temperature, hemostasis
  - Did the response vary by position and/or tactic for entire group?
  - Statistical significant vs clinical significance

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Next Steps

- Dermal sampling results
  - Did firefighters get PAHs on their skin?
  - Did the levels vary by position, tactic, and use of deconned PPE?
  - How effective were baby wipes at removing this contamination?
- Biological monitoring results
  - Did firefighters absorb PAH, VOCs, flame retardants, and dioxins and furans into their bodies?
  - Did the levels vary by position, tactic, use of deconned PPE, and skin cleaning?

Once we have all the data, we can run statistical tests to determine the significance of our findings

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Interim Recommendations

- In depth analysis still ongoing
- Based on current knowledge, some actions should be taken now to protect firefighters from
  - Heat stress
  - Chemical exposures
  - Cardiovascular strain

  to lessen risk of cardiovascular disease, cancer, and other illnesses or injuries.

Interim Recommendations – Fire Dynamics

To translate research to tactics:

- Apply water to the fire rapidly.
  - Conditions improved throughout the structure after application
- Train on coordinated attack for successful response.
  - The time to get both victims out of the house varied from 6:02 to 11:42.
- Stress the importance of closed doors to the public and firefighters.
  - Survivable victims found behind closed doors in each scenario

Interim Recommendations – CV Risk

To decrease the risk of a sudden cardiac event:

- NFPA 1582 physical performed by knowledgeable physician
- Physical fitness
- Incident scene rehab
- Smoking cessation

Interim Recommendations - Exposure

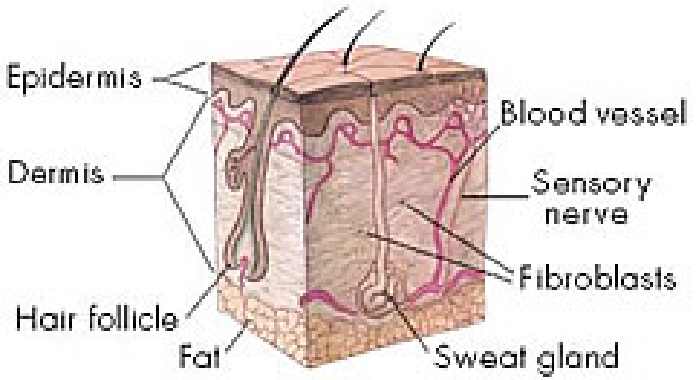
- To minimize inhalation of contaminants during fire response
  - Wear SCBA during knockdown, overhaul, and other activities where exposure to combustion products is possible
  - Remain upwind of fires if not directly involved in attack
    - If this cannot be done, wear SCBA
  - Remain upwind of apparatus diesel exhaust

Interim Recommendations – Exposure (cont'd)

- To minimize inhalation of contaminants off-gassing from gear
  - Doff gear before entering rehab area
  - Do not store or wear gear inside apparatus during ride back to station
  - Do not store gear in personal vehicles or living areas

Interim Recommendations – Exposure (cont'd)

- To minimize skin absorption of contaminants
  - Decon and/or launder turnout gear, fire hoods, and other equipment
  - Do not take gear/equipment home
  - Wash hand and neck skin immediately and shower ASAP after a fire response




Interim Report
Cardiovascular & Chemical Exposure Risks in Modern Firefighting
Cardiovascular & Chemical Exposure Risks in Modern Firefighting
Interim Report – Summary
Full Report can be downloaded from:
https://www.fsi.illinois.edu/documents/research/CardioChemRisksModernFF_InterimReport2015.p
Purposes of the Study
Motivation for Study
https://www.fsi.illinois.edu/content/research/
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Cardiovascular & Chemical Exposure Risks on Today's Fireground

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