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# *Workshop Summary Report*
## March 24-25, 2014
## Arlington, Virginia

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THE FIRE PROTECTION RESEARCH FOUNDATION
*Research in support of the NFPA mission*

NIST
National Institute of Standards and Technology
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# Abstract

This report summarizes the results of the Smart Firefighting Workshop held on March 24 and 25, 2014, in Arlington, Virginia and sponsored by the National Institute of Standards and Technology (NIST). The Workshop provided a forum to help identify and understand the R&D needs for implementation of smart firefighting, highlighting use of existing technologies, development and deployment of emerging technologies including cyber-physical systems (CPS), and use of standards for data collection, exchange, and situational awareness tools. The workshop brought together experts from various industry, educational, and governmental organizations involved in the cyber physical systems and firefighting areas. This report summarizes the workshop findings including prioritization of research needs according to those that have the greatest potential to enhance the safety and effectiveness of fire protection and the fire service. Small groups in each breakout session selected a high-priority task and completed detailed implementation plans for them.

# Acknowledgements

This report summarizes the results of the *Smart Firefighting Workshop* held on March 24 and 25, 2014, in Arlington, Virginia. The workshop was sponsored by the National Institute of Standards and Technology (NIST). Thanks go to Energetics Incorporated's workshop team members Laurie Aldape, Mauricio Justiniano, Rebecca Massello, Shawna McQueen, and Walt Zalis for their assistance in facilitating the workshop and preparing this report. The Workshop and this report would not have been possible without the specialized knowledge and insight contributed by the participants, representing recognized experts in various aspects of firefighting and cyber-physical systems. These experts took time from their busy schedules to participate in the Workshop and share their insight, which forms the basis for the workshop results. The Workshop participants are listed in Appendix A.

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# 1 Workshop Overview

## 1.1 Challenges and Opportunities for Cyber-Physical Systems, the Fire Service, and Fire Protection

In 2012, the fire departments in the United States responded to more than 480,000[1] structure fires. These fires resulted in approximately 2,470 civilian fatalities, 14,700 injuries, and property losses of approximately $10 billion dollars. In addition, more than 31,000[2] firefighters were injured on the fire ground.[3] New opportunities to fuse emerging sensor and computing technologies with building control systems and firefighting equipment and apparatus are emerging. The resulting cyber-physical systems will revolutionize firefighting by collecting data globally, processing the information centrally, and distributing the results locally. Engineering, developing, and deploying these systems will require new measurement tools and standards among other technology developments. This project focuses on the needed tools and standards in three areas: smart building and robotic sensor technologies, smart firefighter equipment and robotic mapping technologies, and smart fire department apparatus and equipment. The results of this project will help (1) mitigate total social costs of fires in communities and buildings and (2) integrate cyber-physical systems (CPS) to realize innovative fire protection technologies.

Firefighters operate in an ever increasing sensor-rich environment that is generating vast quantities of data, the majority of which goes unused. There is ongoing research and development (R&D) to create technologies that can better exploit the collected data and relay relevant information to emergency first responders. The "smart firefighting" of tomorrow is envisioned as fully processing collected information and transmitting germane information in a timely manner to improve the safety and functionality of every firefighter. Behind the advances in sensor performance and equipment-enhanced firefighting are profound questions of how best to enable effective use of this data deluge. The burgeoning area of CPS is an area of study that will help bridge this gap and promises to revolutionize fire protection and the field of firefighting.

This workshop is part of a collaborative effort between the National Institute of Standards and Technology (NIST) and The Fire Protection Research Foundation, (the research affiliate for the National Fire Protection Association - NFPA) to develop a research roadmap for smart firefighting. The workshop focused on addressing the most effective use of the immense quantity of data available from buildings, communities, and the fire ground; the computational power to compute and communicate that data; the knowledge base and algorithms to most effectively process the data; conversion of data into significant knowledge/beneficial decision tools; and effective communication of the information to those who need it, when they need it - on the fire ground and elsewhere.

## 1.2 Workshop Scope, Objectives, Goals, and Outcomes

The *Smart Firefighting Workshop* was held on March 24 and 25, 2014, in Arlington, Virginia, providing a forum to help identify and understand the R&D needs for implementation of smart firefighting. Implementation shall be achieved through greater use of existing technologies; development and deployment of emerging technologies including CPS; and use of standards for data collection, exchange, and situational awareness tools. Furthermore, this technical area is consistent with NIST Strategic

1. NFPA, "Fire Loss in the United States During 2012," M. J. Karter, Jr., Quincy, MA, 02169-7471, September 2012, www.nfpa.org.
2. NFPA, "Firefighter Injuries in the United States," M. J. Karter, Jr. and J. L. Molis, Quincy, MA, 02169-7471, October 2013, www.nfpa.org.
3. In 2012, firefighter injuries totaled 69,400, of which 31,490 or 45 % occurred on the fire ground.

Roadmap for Innovative Fire Protection[4]. As a part of that roadmap, NIST identified smart firefighting as a research area with significant potential for enhancing the safety and effectiveness of fire protection and the fire service. This workshop complements the overarching fire research roadmap.

The following were the workshop goals:

1. Establish dialogue among subject matter experts familiar with the unique characteristics of firefighting, fire protection and CPS,
2. Promote a better understanding of data opportunities available for fire protection and the fire service, and
3. Begin to galvanize a collective vision among stakeholders for a Smart Firefighting Research Roadmap.

## 1.3 Workshop Format

The workshop brought together experts from various industry, educational, and governmental organizations involved in the cyber physical systems and firefighting areas. The workshop opened with several presentations discussing firefighting topics including integrating CPS, addressing state-of-the-art technology and techniques, and clarifying challenges. After these general presentations, participants moved into one of five smaller breakout groups to discuss various questions specific to each breakout topic. Two of the breakout groups were cross-cutting, addressing data gathering, data processing and decision making for both structural and non-structural firefighting (e.g., wildland and wildland-urban interface firefighting). The five breakout groups were as follows:

- Group I: Data Gathering
- Group II: Data Processing
- Group III: Decision Making
- Group IV: Structural Firefighting (Cross-Cutting)
- Group V: Non-Structural Firefighting (Cross-Cutting)

The specific questions addressed by each breakout session are presented in Sections 2 and 3 of this report. After brainstorming sessions, the workshop participants prioritized the previously identified research needs according to those that have the greatest potential to enhance the safety and effectiveness of fire protection and the fire service. Small groups in each breakout session selected a high-priority task and completed detailed implementation plans for them.

## 1.4 Workshop Report

This report follows the organization of the workshop. The present section provides an overview; Section 2 presents the results of Groups I, II, and III; and Section 3 presents the results of Groups IV and V. Section 4 comprises worksheets that reflect the different questions and topics addressed by each group. Section 5 provides a brief summary of the workshop. The appendices provide additional information on the workshop, including the list of participants, a list of helpful acronyms, the workshop agenda, and copies of the overview briefings provided at the opening of the workshop.

4. NIST, "Reduced Risk of Fire in Buildings and Communities: A Strategic Roadmap to Prioritize and Guide Research," NIST Special Publication 1130, April 2012.

# 2 Integrating CPS into Fire Protection and the Fire Service

This Section presents the results of Groups I, II, and III and addresses integrating CPS into fire protection and the fire service. The focus is on data with separate subsections on data gathering, data processing and data utilization for decision making.

## 2.1 Data Gathering

The Data Gathering breakout session focused on issues surrounding the identification, collection, and communication of data related to firefighting prediction, detection, and prevention. Discussion topics included:

- Current data gathering methodologies
- Additional types of data, data repositories, emerging data collection technologies, novel communication modes, media, protocols, and/or information standards needed to enhance safety and effectiveness
- Development of research projects and standards related to the ideas identified in the previous two bullets

These topics were discussed within the context of the four temporal phases of firefighting:

- Before arriving at the fire ground
- Before entering the fire ground
- While on the fire ground
- After leaving the fire ground

These ideas were then prioritized and fleshed out into development plans provided in Section 4 of this report.

### 2.1.1 Overview and Importance of CPS for Fire Protection and the Fire Service

Data are generated and needed throughout the temporal stages of a fire event. Access to the data could provide information to reduce the risk of fire, help firefighters assess the situation before arriving to the fire scene, detect vital changes while at the scene, and enable the compilation of lessons learned and best practices after leaving the scene. The advancement and integration of CPS can enable critical improvements in data gathering for fire protection and firefighters, which should ultimately help save lives, minimize damage, and reduce risks to firefighters.

### 2.1.2 State of the Art and Shortcomings

Many data gathering technologies and approaches are currently in use by firefighters or could be adapted for future use by firefighters. However, each technology or approach has its own shortcomings. Group I identified data gathering technologies and approaches, and their shortcomings, at the four temporal stages of the fire (noted above). For example, before arriving to the fire ground, firefighters might respond to a fire alarm or a Good Samaritan call, not knowing whether it is a false alarm or whether there are any inhabitants in the building. While on the fire ground, radio communications can provide information in real time, but they are often hindered by lack of reception and incomplete transmission. After leaving the fire ground, loss estimates are carried out, but they are not based on real data and rely on subjective information, often rendering them inaccurate. The following tables list the technologies and approaches identified during the workshop.

### TABLE 2-1: DATA GATHERING TECHNOLOGY STATUS: BEFORE ARRIVING TO THE FIRE GROUND

| Data Identification | Data Collection | Data Communication |
|---|---|---|
| **Home smoke detectors**<br>• Shortcomings:<br>○ Prone to nuisance/false alarms<br>○ Battery replacement needed<br>○ Hard to stop<br>○ Annoying sound<br>○ Retrofit interconnectivity is expensive | **Google maps**<br>• Advantage:<br>○ Building foot print provided<br>• Shortcoming:<br>○ Not real-time data<br>○ Resolution limited | **Information from 911 caller**<br>• Shortcoming:<br>○ Not always coherent or accurate |
| **Global positioning system (GPS)**<br>• Shortcoming:<br>○ GPS not on all apparatuses | **Building environment data (e.g., temperature, $CO_2$, humidity)**<br>• Shortcoming:<br>○ Available data trapped within building systems | **Computer Aided Dispatch (CAD) mobile data computer (MDC)**<br>• Shortcomings:<br>○ Attention diverted to paper chart<br>○ Pop-up screens |
| **Building real-time occupancy information**<br>• Shortcoming:<br>○ High costs<br>○ Technology available in few buildings because of cost | **Smoke alarm data**<br>• Shortcomings:<br>○ Difficult to identify location of first alarm<br>○ Obstacles in accessing the alarm location | **Building fire system data**<br>• Shortcomings:<br>○ Non-standard delivery mechanisms<br>○ Non-standard display formats |
| **Good Samaritan calls**<br>• Shortcomings:<br>○ Unspecified receiver of information<br>○ Information often incomplete or difficult to act upon | **Large database**<br>• Shortcomings:<br>○ Difficult to integrate multiple databases<br>○ Expensive to populate<br>○ Difficult to change structure once implemented | **Emergency situation user training**<br>• Shortcomings:<br>○ Inconsistent quality<br>○ Non-standard frequency |
| **False alarm management (aligned with environmental events)**<br>• Shortcomings<br>○ Response required for all calls | | **Vehicle crash data**<br>• Shortcomings:<br>○ Data privacy issues<br>○ Transmit format compatibility |
| **Fire alarm - before entering**<br>• Shortcoming:<br>○ Lack of information about scene<br>▪ building occupants inside<br>▪ building profile/size/height<br>▪ construction hazards<br>▪ location of hydrants | | |
| **Demographic data**<br>• Shortcomings:<br>○ Need to specify number of inhabitants<br>○ Need to specify age of inhabitants<br>○ Need to specify disabilities of inhabitants<br>○ Undefined source databases that are accessible in real time | | |

### TABLE 2-2: DATA GATHERING TECHNOLOGY STATUS: BEFORE ENTERING THE FIRE GROUND

| Data Collection | Data Identification | Data Communication |
|---|---|---|
| **Building history**<br>• Shortcoming:<br>○ Data usually not current | **Alarm detector data (e.g., temperature, carbon monoxide [CO], motion, by location)**<br>• Shortcomings:<br>○ Need to protect proprietary data and privacy (single family)<br>○ Undefined means of access | **Commercial high-rise**<br>• Shortcomings:<br>○ Lack of fire panel integration with building management system (i.e., cannot be read on route)<br>○ Data accuracy of alarm information (e.g., zone, floor, number of alarms) |
| ***In situ* sensors**<br>• Shortcomings:<br>○ Information versus data<br>○ Undefined performance standards<br>○ Common syntax not specified<br>○ Non-existent interface standards | **Data hierarchy**<br>• Shortcoming:<br>○ Unclear how to prioritize | |
| **Equipment status (e.g., condition of communications, sensors, and building equipment)**<br>• Shortcomings:<br>○ Building retrofit for enhanced CPS not economical<br>○ System overloaded | | |
| **360º assessment**<br>• Shortcoming:<br>○ Physical obstruction hazards | | |

### TABLE 2-3: DATA GATHERING TECHNOLOGY STATUS: WHILE ON THE FIRE GROUND

| Data Identification | Data Collection | Data Communication |
|---|---|---|
| **Visual inspection**<br>• Shortcoming:<br>○ Incomplete information collected<br>○ Poor level of accuracy | **Bystanders/victims**<br>• Shortcoming:<br>○ Difficult to interpret data | **Electronic communications**<br>• Shortcomings:<br>○ Lack of interoperability<br>○ Lack of operation (reception transmission) |
| **Threat sensing (e.g., smoke/heat detection, bio/chemical attack, active shooter)**<br>• Shortcomings:<br>○ Difficult to integrate existing data<br>○ Unable to predict | **Physiological robust sensors and wireless communications**<br>• Shortcomings:<br>○ Inadequate sensors<br>○ Unable to determine firefighter location<br>○ Need wireless communications<br>○ Need to improve environmental hazard identification | **Voice communications**<br>• Advantage:<br>○ Able to convey information in real time<br>• Shortcomings:<br>○ Incomplete transmission |
| **Rapid intervention team (RIT)**<br>• Shortcoming:<br>○ Difficult to locate firefighter<br>○ Lack of tools for personal protective equipment (PPE) selection and use for multi-hazard response | **Web-based data communications**<br>• Shortcomings:<br>○ Access not available in remote areas<br>○ Difficult to protect data<br>○ No access during widespread power outage | |
| | **Command chart**<br>• Shortcomings:<br>○ User-generated<br>○ Unit/firefighter accountability | |
| | **Firefighter physiological monitoring**<br>• Shortcomings:<br>○ High cost<br>○ Need to protect information/privacy | |
| | **Infrared camera and thermal imaging**<br>• Shortcomings:<br>○ Limited information provided<br>○ Information often misunderstood | |

### TABLE 2-4: DATA GATHERING TECHNOLOGY STATUS: AFTER LEAVING FIRE GROUND

| Data Identification | Data Collection | Data Communication |
|---|---|---|
| **Loss estimates**<br>• Shortcomings:<br>○ Subjective<br>○ Inaccurate<br>○ Not based on data | **Fire reports**<br>• Shortcoming:<br>○ Inconsistent and missing data | **Lessons learned in digital format**<br>• Shortcomings:<br>○ Limit dissemination<br>○ Not usually a priority |

### 2.1.3 Development Areas

One of the most critical data gathering needs before arriving to the fire ground is the ability to obtain more accurate real-time information about the alarm/situation. Critical information could include the building's layout, contents, and number of occupants, as well as standards for fire system data delivery, information display, data integration, and testing. While standardization increases the likelihood of technology adoption, it must be done thoughtfully so as to not restrict innovation and creativity.

Before entering the fire ground, it would be beneficial to have data from a 360° autonomous situation assessment. Various technology applications could address this need including possibly unmanned vehicles.

While on the fire ground, key developments could include wireless, wearable, rugged, and robust environmental sensors. These sensors could be used to track firefighters at the incident site, providing real-time locations of responders and critical information during firefighter-down events, including data on the building's thermal environment.

After leaving the fire ground, there is a need for operational databases that provide automated data management and reporting systems such as the National Fire Operations Reporting System (N-FORS), which is currently under development. N-FORS is used to manage the National Fire Plan, a mandated program begun in 2001 to provide accountability for hazardous fuels reduction, burned area rehabilitation projects, and community assistance activities.[5]

Additional concepts are presented in Tables 2-5 to 2-8.

[5] National Fire Plan Operations & Reporting System - http://www.doi.gov/pmb/owf/nfpors.cfm.

### TABLE 2-5: DATA GATHERING DEVELOPMENT AREAS: BEFORE ARRIVING TO THE FIRE GROUND[6]

| Additional Data Needs | Desired Data Collection Technologies | Desired Novel Collection Modes/Information Standards |
|---|---|---|
| • More real-time information about situation (e.g., sensors, live video) ●●●●●●●●●●●<br>• More information about building contents<br>• Data/sensors in residential dwelling units versus commercial units (e.g., cost, privacy)<br>• Estimates of staffing needs for large-scale events in terms of workload/rehabilitation to estimate appropriate operational periods | • Improved decision making (automatic or assisted) to alleviate valuable time lost as data are gathered (e.g., location of the fire) and firefighting strategy is developed ●<br>• Development of real-time notification of out-of-service system (e.g., alarm, sprinkler, standpipe, smoke control) | • Development of standards for fire system data delivery and information display ●●●●●●<br>• Integration and testing of protocols and standards ●●●●<br>• Standard emergency application for centralized/standardized information gathering (i.e., people report from the field with text, audio, images, etc.) ●<br>• Ability to quickly identify vehicle propulsion system (i.e., fuel) on scene<br>• Development of building design for fire safety ●●<br>• Enforcement of existing technology (e.g., sprinklers) |

### TABLE 2-6: DATA GATHERING DEVELOPMENT AREAS: BEFORE ENTERING THE FIRE GROUND

| Additional Data Needs | Desired Data Collection Technologies | Desired Novel Collection Modes/Information Standards |
|---|---|---|
| • Develop risk-benefits analysis based on occupancy type, building age, construction type, hazards, fire conditions | • Improve sensor accuracy completeness ●<br>  ○ Affordable<br>  ○ Rugged<br>• Build 360⁰ autonomous situation assessment with unmanned aerial vehicle ●<br>• Improve building occupant sensors for residential/ commercial units | • None provided |

[6] *Note: In this and subsequent tables, each colored dot represents a participant-identified CPS priority with the greatest potential to benefit the fire service.*

*● Blue represents a CPS participant vote.*

*● Green represents a firefighter participant vote.*

*● Orange represents an industry participant vote.*

*● Red represents a government participant vote.*

*● Yellow represents a research participant vote.*

**TABLE 2-7: DATA GATHERING DEVELOPMENT AREAS: WHILE ON THE FIRE GROUND**

| Additional Data Needs | Desired Data Collection Technologies | Desired Novel Collection Modes/Information Standards |
|---|---|---|
| • People tracking, site incident tracking (e.g., real-time location of responders, man-down events) ●●●●●●<br>• Vertical and horizontal geo-location for radios to track firefighters ●●●●●<br>• Sensors for key task, data capture ●<br>  ○ Working on fire (WoF)<br>  ○ Victim requirements<br>  ○ Vent<br>• Sensors/data capture<br>  ○ Vehicle<br>  ○ Pump engaged<br>  ○ Water flowing/not flowing<br>• Asset tracking (e.g., fire respondent equipment)<br>  ○ Correlation to individual user<br>  ○ Real-time location notification<br>  ○ Open standards base ●●● | • Wireless, wearable, and robust environmental sensors ●●●●●●●●●●<br>• Algorithms for translating sensor data into useable information, validation of data ●●●●<br>• Real-time and recorded knowledge of firefighter thermal environment ●●● | • Standards development<br>  ○ Allow for innovation before premature standardization<br>  ○ Define interoperability versus reliability while considering proprietary technology ●●●●●●<br>• Development of nationwide reliable emergency wireless data communications infrastructure ●● |

**TABLE 2-8: DATA GATHERING DEVELOPMENT AREAS: AFTER LEAVING FIRE GROUND**

| Additional Data Needs | Desired Data Collection Technologies | Desired Novel Collection Modes/Information Standards |
|---|---|---|
| • Ability to detect whether firefighter's PPE needs attention/ cleaning ●●<br>• Ability to detect whether PPE is contaminant-free after cleaning | • Expand N-FORS approach<br>  ○ Integrate other systems such as Department of Homeland Security (DHS)/ Federal Emergency Management Agency (FEMA)<br>  ○ Increase automatic capture of operational data ●●●●●●●<br>• Appropriate data density | • Improved interoperability of data systems ●●●● |

### *2.1.4 Other Research Needs*

The integration of data gathering CPS in smart firefighting is hindered by a lack of standards (Table 2-9). The most critical standards needs are for data sharing. Other important standards needs include wireless sensor protocols to connect wireless sensor networks, operational data about fire department performance metrics, and a common fire panel protocol. When arriving at the fire ground, firefighters could benefit from information about a building or residence, such as the number of occupants and any mobility issues. Standards are also needed to protect the privacy of personal information.

**TABLE 2-9: DATA GATHERING: STANDARDS NEEDS**

| Areas of Development |
|---|
| • Data sharing standards ●●●●●●●●●● <br>• Wireless sensor protocols for connecting wireless sensor networks ●●● <br>• Operational data (e.g., fire department performance metrics) ●● <br>• Common fire panel protocol including physical connection ● <br>• Networked sensor performance standards <br>• Hygiene and structural standards of fire stations to improve response time <br>• Fire data communications equipment standards <br>• Privacy of personal/home data and security standards <br>• Fire department capability standards |

### *2.1.5 Priorities*

Of the identified needs for data gathering in Tables 2-5 to 2-9, the following eight were identified as the most important. The items in italics were selected for further elucidation as part of the program plans discussed in Section 4.

- *Real-time situational sensors with video*
- *Wearable, wireless, robust environmental sensors*
- *People tracking efforts at the incident site*
- *Asset tracking*
- Data sharing standards
- Improvements to N-FORS: DHS/FEMA; operational data
- Standard for fire system data delivery and information display
- Standards development for data gathering

## 2.2 Data Processing

The Data Processing session focused on issues surrounding the handling of data collected for firefighting prediction, detection, and prevention. Discussion topics included:

- Current data processing methodologies for translation, sensor fusion, data preparation, and data analytics
- Needs in data translation, sensor fusion, data preparation, and data analytics to augment firefighter response to an event
- Development of research projects and standards related to the ideas identified in the previous two bullets

The topics above were discussed within the context of the four phases of data processing:

- Protocol translation
- Sensor fusion
- Data preparation
- Data analytics

These ideas were then prioritized and fleshed out into development plans.

### *2.2.1 Overview and Importance for CPS and Fire Service*

The integration and accurate analysis of data could provide invaluable information to firefighters to enhance overall operations, incident response, and safety. Sensor data from equipment (e.g., PPE, unmanned vehicles, fire trucks) could assist the coordination of manpower and equipment location, improve real-time decision making, and simplify operations and maintenance. Comprehensive pre-planning could be enhanced with advance information provided to firefighters and incident commanders. Detailed analysis of the collected data could also improve predictive abilities (e.g., likely fire events, active fire path and spread rate, and medical issues with firefighters).

### 2.2.2 State of the Art and Shortcomings

Currently, a significant amount of data are gathered and processed by individual systems/equipment, creating processing "silos." Though this works for a specific application, it often presents difficulties when attempting to communicate/work with disparate systems. This limitation can restrict operations on the fire ground where data are usually processed by the firefighter in real time, resulting in many dead-end data points. Integrating the data into a data stream could improve decision making, incident management, or post-event analysis.

Equipment interoperability is also complicated by receiving outputs in both digital and analog formats within a single firehouse, fire district, or region. Since most firehouse and emergency dispatch communications systems grew out of CAD-based systems, CAD is the backbone of most systems and is the primary platform for protocol translation. Some issues with the traditional hardware used for data processing include filtering out noise in the data and developing devices that are rugged enough to reliably transmit data in and out of harsh environments. Both development and enforcement of codes and standards heavily influence the technology that is developed and implemented.

Additional state of the art of data processing concepts and their shortcomings are presented in Tables 2-10.

**TABLE 2-10: DATA PROCESSING TECHNOLOGY STATUS: STATE OF THE ART**

| Interoperability | Protocol Translation | Data Accuracy |
|---|---|---|
| • Much of the equipment has limited interoperability.<br>• There are many "dead end" data points—useful data that are not getting streamed anywhere.<br>• A combination of both digital and analog outputs exists.<br>• Implementation of technology is building-code driven.<br>• Much of the data are processed at the human level (on site at the fire). | • Legacy systems are often used—CAD is the backbone of most systems.<br>• Data are processed in silos, not toward solving a specific problem.<br>• Pre-processing could be done ahead of time but is scenario-driven. | • Building information (e.g., interior schematics) is often out of date.<br>• Better data are needed on explosive limits and temperatures. |

### 2.2.3 Development Areas

The primary goal of data processing for smart firefighting should be producing *actionable intelligence before, during, and after* an incident. This means that data must be compiled, processed, and communicated in such a way that they are accessible, understandable, and actionable at various operating levels (e.g., firefighter, chief, incident commander, dispatchers) and phases (e.g., before the fire, on the fire ground, after the fire). Since firefighting events are scenario-driven, this will require the development of use case models as a framework for data analysis, providing frameworks to process data in the context of solving problems rather than in silos.

Producing *meta models* that integrate data and provide equipment and system interconnectivity and interoperability will require common data communication languages, standard formats for reporting and storing data, and a comprehensive data dictionary. While standardization and open-source tools are desired from a data processing standpoint, care must be taken not to inhibit technology innovation or violate data privacy concerns. Data processing frameworks must also incorporate systems to verify the validity and authenticity of the data, since the reliability and trustworthiness of the inputs and outputs is crucial to firefighting operations. Table 2-11 identifies other development needs.

**TABLE 2-11: DATA PROCESSING DEVELOPMENT NEEDS AND OTHER REQUIREMENTS**

| Use Case Models | Data Standardization | Research | Other Requirements |
|---|---|---|---|
| • Produce "actionable intelligence"<br>• Identify key indicators for dashboards or command boards<br>• Make data "consumable" at various levels (e.g., chief, firefighter)<br>• Define minimum cut sets of data type and reliability needed to inform IC decisions based on scenario<br>• Develop use models as framework for data analysis<br>• Define relevant data for event type<br>• Explore options and consequences | • Define standard data and format<br>• Investigate pre-event data needs (e.g., common language, reporting, and storage protocols)<br>• Develop data management (e.g., data dictionaries and standards/protocols)<br>• Define an approach to standardize the input and output of the data protocols and databases<br>• Define plain text non-proprietary data formats<br>• Establish common formats to address location accuracy (e.g., national grid) | • Create a "Center for Fire Fighting Excellence" as a central resource<br>  ○ Develop standardized, shared analytical tools<br>  ○ Conduct analysis of post-fire data and lessons learned<br>• Develop models that are self-configurable<br>• Develop technology for tracking and allocating assets (e.g., across region, state) | • On fire ground, identify data communication improvement areas (e.g., need for better, more rugged on-firefighter devices)<br>• Leverage common, open-source (e.g., 9-pin, 25-pin) hardware/ software platforms or data analytics<br>• Ensure data are accurate and trustworthy<br>• Incorporate scenario-based pre-processing to fit data streams to response actions<br>• Develop tools to facilitate collection of fuller sets of fire scene documentation (photos, video, type of construction, etc.)<br>• Develop standard models of the capabilities of all sensor equipment and other devices that need to communicate<br>• Improve access to data<br>• Design automated intelligent feedback from sensor (model) to actuator model to the device<br>• Incorporate geo-locating data pieces<br>  ○ Develop open data for National Fire Incident Reporting System (NFIRS)/other systems to enable private and academic development<br>• Consolidate all data sources for analysis<br>• Investigate people consuming data versus software using data<br>• Study computing power/resources<br>• Examine cloud data versus real-time data<br>• Collect data from firefighters after shift |

### 2.2.4 Priorities

Of the identified needs for data processing in Table 2-11, the following six were identified as the most important. Those fleshed out into program plans later in Section 4 are in italics.

- *Use case models*
- *Data standardization for data processing*
- *Center for firefighting excellence*
- On fire ground, identify data communication improvement areas (e.g., need for better, more rugged on-firefighter devices)
- Leverage common, open-source (e.g., 9-pin, 25-pin) hardware/ software platforms or data analytics
- Ensure data is accurate and trustworthy

## 2.3 Decision Making

The Decision Making breakout session focused on issues surrounding the people, technology, and data involved in executing an action or behavior before and during an incident and in post-incident evaluation. Discussion topics included:

- Identification of the types of required decisions, decision makers, and input data for the first three temporal phases below
- Decision making development needs to advance firefighting techniques in the first three temporal phases below
- Identification of current and future capabilities needed to capture all fire-related events that transpired on the fire ground for after-action evaluation and training purposes

Discussion of the topics above was initially intended to cover the four temporal phases of firefighting:

- Before arriving to the fire ground
- Before entering the fire ground
- While on the fire ground
- After leaving the fire ground

However, after considering relevance to the incident commander versus individual firefighters, the discussion topics were adjusted to the needs for decision making in firefighting in general.

The collected ideas were then prioritized and fleshed out into development plans.

### 2.3.1 Overview and Importance for CPS and Fire Service

Good decision making in firefighting is crucial to safe and effective firefighting efforts—it could be the difference between safe and dangerous operations. Decision making is affected by many factors, including the data available to decision makers, effectiveness of decision protocols, and expertise of decision makers.

### 2.3.2 State of the Art and Shortcomings

The crucial elements—the types of decisions that must be made, who makes them, and the data that are needed to make decisions—currently used in fire-incident decision making were identified (Table 2-12). Many of these ideas possess limitation in their ability to contribute to effective decision making during a fire event.

**TABLE 2-12: DECISION MAKING ELEMENTS**

| In General | Incident Commander | Firefighter |
|---|---|---|
| • Constant updating of fire ground incident information to all responding parties<br>• Natural focus on firefighting activity<br>○ Alarm<br>○ On-scene<br>○ Suppression<br>○ Information overload<br>• Pre-response planning needs to be in place to focus on<br>○ Preplan<br>○ Demographics<br>○ Construction<br>○ Route | • C.O.A.L. W.A.S. W.E.A.L.T.H. - majority of fireground considerations for each event<br>○ Construction<br>○ Occupancy<br>○ Apparatus<br>○ Life hazard<br>○ Water supply<br>○ Aux appliances<br>○ Street conditions<br>○ Weather<br>○ Exposures<br>○ Area (square feet)/height<br>○ Location / extent of fire<br>○ Time<br>○ Hazardous materials response (HAZMAT)<br>• Who is responding?<br>• What is the need?<br>• Fuel load type, amount, location<br>• Location of fire in structure, likely spread<br>• Resource allocation and availability, type, capacity<br>• Hydrant locations<br>• Means of travel to fireground<br>• Nature of Emergency - fire, emergency medical services (EMS), HAZMAT<br>• Path to incident, mapping<br>• Location of team(s)<br>• Reception of sensor-detector signals | • Determination of the need for additional resources<br>• Fire spread—characterization of the potential for rapid fire movement and follow-up action<br>• Training in assessment and responses to different fire conditions |

### 2.3.3 Development Areas

The primary goal of decision making is determining needed actions before and during an incident based on the collection and analysis of available data. The development needs for improving decision making include developing opportunities for providing richer, more comprehensive information to existing data collection methods. For example, enhanced capabilities to determine topography or ventilation conditions during an incident could enhance safety and effectiveness of firefighting efforts. Table 2-13 identifies the types of information that needs collection in order to augment decision making during fire incidents.

**TABLE 2-13: DEVELOPMENT NEEDS IN DECISION MAKING FOR FIREFIGHTING**

| General Development Needs | | | |
|---|---|---|---|
| • Accountability<br>• Determination of floor plan or topography<br>• Threat identification<br>• Education of a new generation of firefighters<br>• Effective and timely use of gathered data<br>• Clearly defined communication networks, including points of contact<br>• Identification of unseen hazards<br>• Improvement of all levels of communications on the fireground | • Ventilation conditions<br>• Performance of risk assessments to determine what or who is at risk<br>• Safety of firefighters, fire team, fire ground<br>• Development of toxicant sensors to make a decision when to remove self-contained breathing apparatus (SCBA) during overhaul<br>• Establishment of data, cues, and expectations that support offensive versus defensive fire fighting<br>• Integrated simplicity<br>• Resource management<br>• Determine the human computer interface (HCI) to present right data at right time in right format to make right decision | • Qualification of alarm priority (buzzer/lights)<br>• Reliability and cost<br>• Identification of resources to deal with incident<br>  ○ Constant re-evaluation of the causes<br>  ○ Automatic updates to the fire ground/on-site resources<br>• Victim location<br>• Local and remote firefighter current health and prediction<br>• Certainty that firefighters are prepared to safely perform firefighting tasks<br>  ○ Medical heath<br>  ○ Physical heath<br>  ○ Safety training<br>• Identify similarities in operations requirements analysis and geographical differences<br>• Communication of scene/ building information to responders<br>• Use of crowd-sourced data reporting for prevention and better inspection | • Critical factors-based decision making |

### 2.3.4 Other Research Needs

After a fire event is complete, evaluation of the incident helps to identify lessons learned. Some capabilities exist to capture the relevant fire-related events and actions. Yet numerous other ones need development to support comprehensive after-action evaluation for incident review and training purposes. Table 2-14 identifies those capabilities currently available and development needs for a better understanding of the fire incident.

**TABLE 2-14: POST-EVENT DEVELOPMENT NEEDS FOR DECISION MAKING**

| Available Now | Development Needed |
|---|---|
| • Google Earth<br>• Reports from the fire scene<br>• Log of all alarms, data exchanges, tracker (current technology needs further development) • | • Data gathering black box data •••••••<br>• Video capabilities for on the ground (incident review) •<br>• Realistic training simulators<br>○ Simulation for incident commanders can be designed now •••<br>○ Simulation for firefighters will take significantly more computing power<br>• Provide feedback from reports (e.g., lessons learned now, simulations in the future)<br>• Current building target hazard<br>○ Occupancy and configuration<br>○ Contents<br>• Criteria to determine firefighter fitness for service •<br>○ Physical health<br>○ Resource allocation<br>○ Medical health monitoring post-event<br>○ Physiology<br>○ Safety<br>• Building and incident-centric data<br>• Incident simulations • |

### 2.3.5 Priorities

Of the identified needs for decision making in Tables 2-13 to 2-14, the following eight were identified as the most important. Those fleshed out into program plans in Section 4 are noted in italics.

- *Data gathering black box (like an airplane)*
- *Effective and timely use of collected data*
- *All levels of communication on the fire ground*
- *Automatic updates to fire ground and on-site resources*
- *Firefighters prepared to safely perform tasks*
- *Enhanced scene and building information*
- *Accountability*
- *Reliability and cost*

# 3 Structural and Non-Structural Cross-Cutting Topics

This Section presents the results of Groups IV and V. These groups considered integrating CPS into fire protection and the fire service from a cross-cutting perspective associated with both structural and non-structural firefighting approaches.

## 3.1 Cross-Cutting Structural Firefighting Issues

The Structural Firefighting breakout session focused on the shared CPS requirements to advance firefighting effectiveness on buildings and other constructions. The participants discussed and identified ideas related to the following focus topics:

- Common CPS development needs for firefighting in commercial versus urban residential buildings and new versus retrofitted (existing) buildings
- Issues with CPS integration into structural firefighting techniques with respect to codes and standards, software technologies, feasibility demonstration, and implementation strategies
- Non-technical issues (e.g., training, economic issues, standards and codes processes, market trends, behavioral issues) that affect successful integration of CPS into structural firefighting capabilities

The collected ideas were then prioritized and fleshed out into development plans provided in Section 4 of this report.

### *3.1.1 Overview and Importance for CPS and Fire Services in Structure Fires*

Whereas residential structural fires account for 25 % of fires in the United States, 83 % of civilian fire deaths are due to fires within a residential structure. In addition, 77 % of fire injuries and 64 % of direct dollar losses are also due to fires within residential structures.[7] In total, structural fires (both residential and commercial) account for only 35 % of reported U.S. fires,[8] but the human and property losses associated with these events make development of smart firefighting techniques in building structures an important area of attention. As firefighting and CPS leaders determine how best to effectively use the immense quantity of data available concerning and from building structures, a focus must be given to enriching such a typically information-poor environment as a structural fire. Through targeted CPS technologies, firefighters can take advantage of previously non-existent opportunities, tracking data on characteristics such as thermal and smoke conditions within a structure during a fire, to better inform the firefighting decision making process. While significant research issues remain, exploiting CPS in structural firefighting strategies remains a major focus of upcoming research and practice.

### *3.1.2 Common CPS Development Needs*

Table 3-1 displays the CPS needs across different types of building structures during a fire event. The requirements for a specific building type are also presented.

[7] U.S. Fire Administration, "Residential Structure and Building Fires," October 2008, https://www.usfa.fema.gov/downloads/pdf/statistics/Residential_Structure_and_Building_Fires.pdf.
[8] NFPA, "Fire Loss in the United States During 2012," M. J. Karter, Jr., Quincy, MA, September 2013, http://www.nfpa.org/~/media/Files/Research/NFPA%20reports/Overall%20Fire%20Statistics/osfireloss.pdf.

**TABLE 3-1: CROSS-CUTTING STRUCTURAL ISSUES: CPS DEVELOPMENT NEEDS ACROSS BUILDING STRUCTURES**

| Building Type | CPS Development Needs |
|---|---|
| Structural Cross-Cutting Needs | • Improve the understanding of structures and fire<br>• Gather data to rectify the lack of existing information available in older infrastructure<br>• Establish communications networks between firefighter and building<br>• Enhance the limited ability for building owners to invest in new systems<br>• Increase knowledge on building populations<br>• Build models to predict fires in structures based on their conditions<br>• Develop a building information model with easy access via mobile devices<br>• Eliminate barriers to indoor communication and location determination (lack of connection)<br>• Improve sensors in PPE to sense environment<br>• Remove reliance on human uploading data to network database infrastructure<br>• Develop software to help people see through smoke to egress paths<br>• Develop method to monitor exits - all aspects<br>• Provide real-time access to private or protected information within building structure<br>• Improve interoperability of different systems<br>• Present and disseminate clear information<br>• Integrate sensor electronics/hardware in firefighter PPE, considering sensor weight and cost<br>• Develop tampered/unbiased sensors<br>• Piggyback communications and standalone network<br>• Develop self-learning networks to provide reliable data after an incident and provide redundancy<br>• Provide rapid, sufficient data download for firefighter incident communication<br>• Update training and education using CPS in firefighting strategies |
| Commercial Building Needs | • Evacuation (residential) versus relocation (commercial)<br>• Provide simultaneous location and mapping<br>• Design radios that work to support commercial infrastructure |
| Residential Building Needs | • Resolve privacy and monitoring requirements, which vary per building, especially in residential structures<br>• Address the lack of oversight or maintenance requirements |
| New Building Needs | • Advance sustainable design for safety monitoring of new buildings<br>• Implement smart size-up from the start |
| Retrofitted Building Needs | • Address the lack of buy-in on sprinkler retrofit side<br>• Document capabilities of additional sensor and CPS systems<br>• Close off areas for retrofit adaptation<br>• Provide consistent building information updates |

### 3.1.3 CPS Integration Needs

Even if the common CPS needs identified in Table 3-1 are designed and fully developed, the technology will need technical integration with existing operations equipment to ensure that the enhanced firefighting techniques are effective. Specific integration challenges are detailed below in Table 3-2.

### TABLE 3-2: CROSS-CUTTING STRUCTURAL ISSUES: CPS INTEGRATION NEEDS

| Codes and Standards | Software and Hardware Technologies | Feasibility Demonstration | Implementation Strategies |
|---|---|---|---|
| • Develop standard protocol inter-connective of communication devices and systems<br>• Define code and standard characteristics:<br>  ○ Communication open and interpretable<br>  ○ Data representation<br>  ○ Data exchange<br>• Develop integrated and automated life safety systems and building management<br>• Require buildings to have integrated systems<br>• Improve speed of code/standards development<br>• Develop standards to improve firefighter education to provide redundancy to the system<br>• Identify protocol for human-robot interaction<br>• Define common concepts across all fire departments<br>• Develop communication protocols<br>• Pass telemetry data standards<br>• Develop interoperable equipment | • Select hardware and software for optimized architecture that can command, compile, and communicate fire ground intelligence<br>• Develop situational awareness technologies at all levels<br>• Understand dynamic software upgrades and differences between upgrades<br>• Develop platforms and software<br>  ○ Middleware platforms on- and off-site<br>  ○ Cloud computing (scalable platform)<br>  ○ Mobile applications<br>  ○ Open-source platforms to minimize cost<br>• Broaden technology and user input in constrained input environment<br>• Identify data needed for human location technologies including those in wearable mobile devices<br>• Widen mass notification systems that inform public at large<br>• Generate formulas and software regulations<br>• Perform maintenance and development from within<br>• Provide certification for equipment and firefighters<br>• Manage software quality measures including sustainability and reliability<br>• Provide real-time access to private or protected information<br>• Enrich formal methods of software building<br>• Develop fast models to predict fires based on conditions | • Measure performance (e.g., acceptable return on investment)<br>• Demonstrate credible proof of concept (test beds) using the National Incident Management System (NIMS)<br>• Use interconnected test beds<br>• Ensure validation metrics are true/real<br>• Evaluate human cognition under stress<br>• Understand characteristic current fire environment to ensure appropriate hazards for demo<br>• Identify user needs/use characteristics<br>• Integrate CPS into firefighter training to enhance human trust in CPS<br>• Foster trusted sharing with dynamic, evolving organizations<br>• Initiate technology challenge shout-outs (crowd sourcing for concepts and prototype)<br>• Develop fire prevention "intelligence" (e.g., Department of Defense (DOD) lessons learned in IC?)<br>• Estimate use of CPS technologies and capacity | • Implement training and education<br>• Initiate technology implementation challenge<br>• Develop virtual environments and serious games for firefighting<br>• Develop ad hoc network versus full coverage<br>• Encourage insurance incentives to perform building mapping and add new sensors |

### 3.1.4 Non-Technical Issues

In addition to the shared CPS needs and the integration challenges previously identified, there are general issues that should be taken into consideration to successfully implement the CPS technologies into the fire service. The non-technical needs—policy issues, economic issues, vendor issues, market trends, and cultural/behavioral issues—are detailed in Table 3-3.

**TABLE 3-3: CROSS-CUTTING STRUCTURAL ISSUES: NON-TECHNICAL CPS NEEDS**

| General Needs |
| --- |
| • Develop methods to evaluate the measurement of performance •<br>• Address cost savings concerns of elected officials and executives •<br>• Answer "What is in it for me?" question for users and decision makers ••<br>• Broadcast positive media support<br>• Leverage DHS, law enforcement, and military databases<br>• Provide more event analysis post-incident<br>• Include evaluation of adaptability to CPS/smart firefighting strategies in recruitment process of future firefighters<br>• Address issues with proprietary data ••<br>• Determine liability issues for CPS • |

### 3.1.5 Priorities

Of the identified needs for data processing in Tables 3-2 to 3-3, the following six were identified as the most important. Those fleshed out into program plans in Section 4 are noted in italics.

- *Standard protocol inter-connectivity of communication devices and systems*
- *Situational awareness technologies at all levels*
- Training and education
- Program architecture allowing easy transition of data
- Performance measurement
- Interconnected test beds for smart structural firefighting pilots

## 3.2 Non-Structural Cross-Cutting Issues

The Non-structural Firefighting breakout session focused on the shared CPS requirements to advance the effectiveness of firefighting in all situations that do not involve structures (e.g., vehicles; emergency services, EMS; wildland-urban interface, WUI; hazardous materials, HAZMAT). The topics discussed focused on:

- CPS development needs for firefighting in the WUI, EMS, HAZMAT, or other first responder applications
- CPS integration in WUI or EMS/HAZMAT/first responder applications with respect to codes and standards, software technologies, feasibility demonstrations, and implementation strategies
- Non-technical issues (e.g., training, economic issues, standards and codes processes, market trends, behavioral issues) that affect successful integration of CPS into WUI and EMS/HAZMAT/ first responder applications

The collected ideas were then prioritized and fleshed out into development plans.

### 3.2.1 Overview and Importance for CPS and Fire Services

The WUI encompasses housing and other structures that are either collocated with or abut wildland vegetation and forest. Communities in these areas are susceptible to fires, which may be caused by the increasing number of structures, long-term drought, climate change, or build-up of wildland fuel. When a fire or emergency occurs, first responders, EMS, and HAZMAT personnel are on the scene to address the incident and ensure public safety. The more information that these responders have available for a given situation, the better they can assess and respond. However, responders often may not have all the information for a particular incident until they arrive on scene, requiring quick assessment, decision, and response.

New and existing technologies are providing benefits to the fire service in this area and will continue to provide benefits as CPS offers more data with the increased use of sensors, as well as new capabilities. These data could potentially help first responders, EMS, and HAZMAT personnel assess a situation before they arrive on scene, better make decisions on how to address a situation, and keep firefighters and the public safe from harm.[9]

### 3.2.2 Common CPS Development Needs

As CPS continues to develop and be integrated into WUI, EMS, HAZMAT, and first responder applications, a number of issues and developmental needs must be considered. Information provided by CPS can help the fire service dynamically track fires, incidents, and firefighting personnel, as well as improve prioritization of risks and responses. However, new CPS tools and techniques should have minimal impact on existing capabilities and functions and should provide for interoperability and ease of use. Additional developmental needs and considerations are provided in the Table 3-4.

[9] NIST, "Wildland-Urban Interface Fire Research Needs: Workshop Summary Report," NIST Special Publication 1150, May 2013.

**TABLE 3-4: NON-STRUCTURAL CROSS-CUTTING: DEVELOPMENT NEEDS**

| WUI | Both WUI- and EMS-Related Needs | EMS/HAZMAT/ First Responder |
|---|---|---|
| • Consider how to implement using current radio technology without affecting communications capability<br>• Organize the data into higher-level concepts for human system interaction<br>• Develop better, more efficient and effective/cost-effective communications and technologies<br>• Adopt Blue Force Tracking:<br>  ○ Support firefighting personnel safety by employing cheap, simple, effective tracking technology to locate active firefighters at all times<br>  ○ Design more effective/robust communications to provide needed safety information<br>• Provide evacuation notification<br>• Develop weather models<br>• Improve situational awareness resource allocation<br>• Use autonomous field-deployed forest fire sensors<br>• Update mapping of wildland-urban incidents dynamically | • Organize data according to operational and safety risks<br>• Account for distributed sensing and uncertain inputs for processing and data management<br>• Integrate data from multiple sensors to support on-scene decision making<br>• Integrate existing information and guidance into new products (i.e., Department of Transportation guidebook on 16 lifesaving initiatives)<br>• Develop architecture standards to allow open access and transmission of data<br>• Develop data sharing and interoperability standards:<br>  ○ Develop standard information models<br>  ○ Integrate with existing standards<br>  ○ Ensure PPE applications are the same<br>• Develop consistent interface standards to improve interoperability for data and hardware<br>• Develop common training and standards<br>• Improve situational awareness with unmanned aerial vehicle (UAVs)/ unmanned aircraft system (UASs)/ unmanned ground vehicle (UGV) support<br>• Integrate information from social media<br>• Develop new and improved fire behavior modelling<br>• Deploy autonomous field personnel and equipment tracking systems (e.g., spot messenger) | • Identify HAZMAT location, type (i.e., materials), and vehicle needed for accident response<br>• Embed analysis in current PPE and tools<br>• Use through-the-wall sensing to identify personnel on the ground |

### 3.2.3 CPS Integration Needs

As noted above, a number of technical developmental needs must be considered in CPS development and integration. For example, new technologies should provide for interoperability and common data models and platforms, while providing simple and easy-to-use interfaces. Testbeds and metrics will be needed to demonstrate the feasibility of new technologies and applications. Additionally, the fire service will need appropriate training for these technologies. Table 3-5 below provides a list of technical developmental needs and considerations.

### TABLE 3-5: NON-STRUCTURAL CROSS-CUTTING: INTEGRATION NEEDS

| Topic Area | WUI | Both WUI- and EMS-Related Needs | EMS/ HAZMAT/ First Responders |
|---|---|---|---|
| Codes and Standards | • None provided | • Interface standard and hardware/software common data models and formats ●●●●●<br>• Aim for open standard, interoperable, non-proprietary ●●●<br>• Keep expectations realistic during the preliminary stages ●●<br>• Define data type, format, quality ●<br>• Consider local systems' need for technology that integrates with larger systems without interfering with operations<br>• Integrate standards into the decision making process to reduce human error<br>• Address privacy standards and concerns<br>• Support remote sensing for WUI standards compliance, insurance as driver | • None provided |
| Software Technologies | • Ensure models are realistic and have feasible expectations while being validated ● | • Develop new algorithms with artificial intelligence that are capable of dealing with uncertainty ●●●<br>• Build simple and intuitive user interface/user experience (UI/UX) ●●●<br>• Adapt to future use of cloud computing ●●<br>• Develop adaptive algorithms for dynamic situations<br>• Address security, reliability, and robustness<br>• Incorporate scalability of users and system<br>• Develop new data model for modeling the emergency scene | • None provided |
| Feasibility Demonstrations | • None provided | • Develop full-scale testbed for sensor integration through user demonstration and testing<br>  ○ Develop realistic testbeds and scenario for feasibility demonstration ●●●●●●<br>• Define metrics to determine success or failure in feasibility demonstrations ●●●●●●●<br>• Focus on pre-demonstration training to ensure effective CPS deployment<br>• Introduce a level of complexity that will be helpful in determining feasibility<br>• Establish better forums to demonstrate new capabilities, bringing users together with vendors/ government/academia<br>• Implement comparative analysis strategy (control versus test) | • None provided |
| Implementation Strategies | • None provided | • Remember the work environment and available resources ●●<br>• Link implementation to incident complexity ●●<br>• Integrate into tools and equipment without degradation of capabilities ●<br>• Improve approach to technology transfer in the Forest Service (no roadmap)<br>• Provide consistency with some flexibility<br>• Define training requirements and models, including who needs training and how and when it should be delivered<br>• Provide ongoing support for sustainability and upgradeability | • Make a compelling case/value-add to both the agency and the public about the value of these action items<br>• Obtain stakeholder buy-in, do public outreach |
| Other | • None provided | • Deploy training for use of systems and quality assurance (QA) standards for data input into systems<br>• Better connections between relevant research fields and industry<br>• Determine how data quality is evaluated<br>• Determine deployment methods, including who carries specific equipment along with its priority needs ● | • Integrate systems into the decision making process<br>• Reduce human error |

### 3.2.4 Non-Technical Issues

Non-technical needs also arise when attempting to integrate new CPS technology into existing WUI, EMS, HAZMAT, and first responder applications (e.g., determining funding organization and technology owner, developing new cost-effective technologies, and convincing the fire service of the advantages and dependability of the technologies). Additional non-technical developmental needs and considerations are provided in Table 3-6.

**TABLE 3-6: NON-STRUCTURAL CROSS-CUTTING: NON-TECHNICAL ISSUES**

| Policy | Economics | Cultural and Behavioral |
|---|---|---|
| • Obtain policymaker buy-in ●●●●●●●●●●● | • Address resource constraints<br>• Address budget and competing priorities ●●●●<br>• Consider affordability of software/hardware ●●<br>• Improve the business case for integrating CPS into firefighting equipment ●<br>• Consider cost-effectiveness of implementations | • Determine funding source and owner of technology (e.g., local, federal, county, state, public-private) ●●●●●<br>• Consider behavioral issues, i.e., how do you improve the human factor? ●●●<br>• Consider turf, competing priorities, and agenda ●<br>• Incorporate fire prevention into issues ●<br>• Consider privacy concerns<br>• Convince users that the technology can be trusted |
| **Education/Training** | **Sustainability** | **Other** |
| • Provide education on benefit and outreach to firefighting community ●<br>• Understand the learning curve of new technology<br>• Provide tiered training (e.g., user, manager, administrator)<br>• Define clearly the range of application<br>• Provide support that is easy to access and understand<br>• Ensure training includes common sense approaches and does not rely solely on technologies and experience | • Incorporate sustainability (e.g., life cycle cost) ●<br>• Provide contingency solutions should technology fail ●<br>• Ensure flexibility for equipment updates and retrofits.<br>• Provide continuous training or validation (i.e., educational sustainability)<br>• Consider need to sustain data accuracy | • Ensure operation and interpretation of technology is intuitive ●●●<br>• Provide firefighters with appropriate and timely information during a fire event<br>• Ensure seamless integration of CPS with firefighters<br>• Demonstrate benefits and develop strategy to support technology transfer ●<br>• Develop strategy to implement technology in remote areas<br>• Generate and document uncertainty/accuracy of output |

### 3.2.5 Priorities

Of the identified needs for data processing in Tables 3-4 to 3-6, the following eight were identified as the most important. Those fleshed out into possible program plans in Section 4 are noted in italics.

- *Feasibility demonstrations and testbeds*
- *Interface standards for hardware, software, and data exchange models*
- *User interface*
- *Algorithms for uncertainty*
- Policymaker buy-in
- Metrics that determine success or failure in feasibility demonstrations
- Budgets (i.e., who pays for and owns the technologies: local, federal, county, state, public-private)
- Address budget and competing priorities

# 4 Prioritization Worksheets

The previous sections provided a list of the priority topics for smart firefighting from each breakout session. Of those topics, specific priorities that have the greatest potential in enhancing fire service safety and effectiveness were expanded into development plans by identifying specific tasks, milestones, performance targets, challenges, and potential stakeholders. A summary of all the priority topics from each breakout are presented in Table 4-1. Figures 4-1 through 4-19 provide the results of the expansion of selected topics (**in bold text**).[10]

[10] Text generated during the workshop sessions was formatted and placed within Figure 4-1 through Figure 4-19 within Section 4. The text, which describes possible implementation plans, was a product of workshop participants working in small groups. Text was not edited for consistency between different breakout groups.

### TABLE 4-1: IDENTIFIED PRIORITIES FOR SMART FIREFIGHTING

| Breakout | Priority | Votes |
|---|---|---|
| **Data Gathering** | **Real-time situational sensors with video (Figure 4-1)** | (11) |
| | **Wearable, wireless, robust environmental sensors (Figure 4-2)** | (10) |
| | Data-sharing standards | (9) |
| | Improvements to N-FORS: DHS/FEMA; operational data | (7) |
| | Standard for fire system data delivery and information display | (6) |
| | **People tracking efforts at the incident site (Figure 4-3)** | (6) |
| | Standards development for data gathering | (6) |
| | **Asset tracking (Figure 4-4)** | (3) |
| **Data Processing** | **Use case models (Figure 4-5)** | (12) |
| | **Data standardization for data processing (Figure 4-6)** | (11) |
| | Identification of data communication improvement areas on fire ground (e.g., need for better, more rugged on-firefighter devices) | (10) |
| | Leveraging of common, open-source (e.g., 9-pin, 25-pin) hardware/software platforms or data analytics | (8) |
| | Accurate and trustworthy data | (7) |
| | **Center for firefighting excellence (Figure 4-7)** | (7) |
| **Decision Making** | **All levels of communication on the fire ground (Figure 4-8)** | (12) |
| | **Data gathering black box[11] (Figure 4-9)** | (7) |
| | **Effective and timely use of collected data[10] (Figure 4-9)** | (6) |
| | **Automatic update to fire ground and on-site resources (Figure 4-10)** | (7) |
| | **Firefighters prepared to safely perform tasks (Figure 4-11)** | (6) |
| | Accountability | (6) |
| | Cost and reliability | (6) |
| | **Enhanced scene and building information (Figure 4-12)** | (5) |
| **Cross-cutting: Structural Firefighting** | **Standard protocol inter-connectivity of communications devices and systems (Figure 4-13)** | (10) |
| | **Implement training and education (Figure 4-14)** | (8) |
| | Program architecture allowing easy transition of data | (7) |
| | Performance measurement | (6) |
| | Interconnected testbeds for smart structural firefighting pilots | (5) |
| | **Develop situational awareness technologies at all levels (Figure 4-14 and Figure 4-15)** | (5) |
| **Cross-cutting: Non-Structural Firefighting** | Policy maker buy-in | (11) |
| | Defined metrics to determine success or failure in feasibility demonstrations | (7) |
| | **Develop full-scale testbed for sensor integration through user demonstration and testing (Figure 4-16)** | (6) |
| | **Interface standards for hardware, software, common data models, and formats (Figure 4-17)** | (5) |
| | Determination of funding source and owner of technology (e.g., local, federal, county, state, public-private) | (5) |
| | Consideration of budget and competing priorities | (4) |
| | **New algorithms, with artificial intelligence, that are capable of dealing with uncertainty and change (Figure 4-18)** | (3) |
| | **Simple and intuitive user interface (Figure 4-19)** | (3) |

[11] These two topics were combined into one prioritization worksheet.

## 4.1 Data Gathering

The Data Gathering topics selected for program development is presented below and expanded in Figures 4-1 to 4-4.

- **Figure 4-1: Real-time situational sensors with video**
- **Figure 4-2: Wearable, wireless, robust environmental sensors**
- **Figure 4-3: People tracking efforts at the incident site**
- **Figure 4-4: Asset tracking**

## FIGURE 4-1: REAL-TIME SITUATIONAL SENSORS WITH VIDEO

**Brief Description:**
Remote control devices or drone robots could be used to collect additional situational information, including video, prior to human intervention in an incident. The building data, electronically transferred to the incident commander (IC) at an electronic control board, could include the number of occupants, location of occupants, structural status, and IC

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Gather qualitative information on sensor specifics and environmental thresholds for operation<br>• Coordinate stakeholders for development of plan and timeline<br>• Develop prototype, field test product, and validate production/implementation | • 0-3 years: Gather qualitative information and plan with timeline<br>• 3-5 years: Develop prototype and perform lab and field tests<br>• 5+ years: Produce and implement sensors | • Accuracy prioritized over precision<br>• Must operate in IDLH (immediately dangerous to life and health) environment<br>• Must operate in high thermal environment<br>• Wireless operation must work<br>• Must operate when wet | • Incident commander and firefighter still need to think and reason through situation<br>• Acceptance by fire service, training and implementation required<br>• May only work in newer built environments |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • Continuous updates in accordance with technology<br>• Apply a visionary mindset - What is possible? | • Cost<br>• Different needs for keeping current for each building<br>• Fire service training<br>• Maintenance of system, including testing |

### CHALLENGES

- **Communications technology:** Feasibility of wireless technology; new environments could be wired; selection of radio spectrum; interoperability
- **Sensor**: High costs; severe environments; must be reliable; must be easy to deploy, use, and replace
- **Data collection:** Concerns with buy-in and privacy issues; need to determine who collects data and data storage location (e.g., cloud); need simple format for information and video
- **Existing databases:** Incompatibility with new technology; coordination of upgrades; inconsistent data elements collected (currently consistent for monitoring company)

### STAKEHOLDER ROLES AND RESPONSIBILITIES

- **Fire Service**: Meet requirements generated from firefighters and officers; provide continuous input and testing
- **Government:** Provide funding (e.g., science and technology grants, NIST, DHS)
- **CPS experts**: Develop user-friendly products; continuously improve products consistent with technology
- **Vendors/manufacturers**: Produce product

## FIGURE 4-2: WEARABLE, WIRELESS, ROBUST ENVIRONMENTAL SENSORS

**Brief Description:**
Environmental sensors should be developed and integrated in firefighting PPE. Sensors would provide firefighters and IC with real-time data indicating environmental conditions and potential hazards faced by a firefighter.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Develop sensors<br>• Develop algorithms<br>• Integrate sensors with PPE<br>• Ensure stakeholders have input in the development of CPS components during the entire design cycle<br>• Develop standards for the sensors | • 0-3 years: Define existing sensor technologies<br>• 3-5 years:<br>○ Demonstrate wearable system<br>○ Conduct field trials/testing | • Meets defined criteria for durability and reliability<br>• Provides accuracy while being cost-effective<br>• Is easy to maintain<br>• Is ergonomic/lightweight | • None provided |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • Quantification of exposure environment<br>• Adaptation to future medical research, PPE, and other equipment | • Privacy/confidentiality of data generated<br>• Cost<br>• Maintenance |

| CHALLENGES | STAKEHOLDER ROLES AND RESPONSIBILITIES |
|---|---|
| • **Communications technology**: Must function in and out of structures<br>• **Sensor**: Must have high thermal and chemical particulate tolerances; must tolerate radioactive flux; must measure metabolic/physiological changes<br>• **Data collection**: Determine the longevity need of the data during the fire incident | • **Fire Service**: Perform trial testing<br>• **R&D**: Apply existing technology<br>• **Standards:** Establish NFPA/Underwriters Laboratory certifications |

## FIGURE 4-3: PEOPLE TRACKING AT THE INCIDENT SITE

**Brief Description:**
Location and tracking of responders will enable better situational awareness for IC. Incident commanders can then see whether resources are deployed as expected and respond rapidly in the event of rescue need.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Determine state-of-the-art tracking technology and methodology<br>• Review requirements and further develop business models<br>• Develop technology in order of prioritized use cases<br>• Iteratively test technology<br>• Pilot and deploy technology and methodology | • Establish steering committee and working groups<br>• List state-of-the-art technology and additional requirements<br>• Define viable business model<br>• Demonstrate progress for each technical element via component testing in relevant environment<br>• Draft standards<br>• Integrate testing and piloting | • Locate personnel within established tolerances as defined by incident commanders<br>• Achieve minimal deployment latency<br>• Display minimal data latency<br>• Meet cost requirements and document value added | • Must be cost-affordable<br>• Limited fire ground size |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • Indoor location technology breakthroughs<br>• Mandates for product use | • A means of preventing overwhelming the incident commander during large-scale events<br>• Data delivery mechanisms in radio frequency-challenged environments |

| CHALLENGES | STAKEHOLDER ROLES AND RESPONSIBILITIES |
|---|---|
| • **Communications technology:** Compliance with standard formats; functioning in a fire environment; structures where radio frequency has difficulty<br>• **Sensors**: Functioning in a fire environment; adapting to human needs (e.g., sensor weight, comfort)<br>• **Data collection**: Transmitting large-scale fire event telemetry data volume<br>• **Existing databases**: Possible need for new data formats | • **Major city Fire Service**: Provide user requirements and testbed (International Association of Fire Chiefs [IAFC], International Association of Fire Fighters [IAFF], and National Volunteer Fire Council [NVFC])<br>• **Manufacturers**: Develop tracking technology display and situation awareness technology<br>• **International Code Council (ICC) / International Building Code (IBC), NFPA**: Develop standards and regulations<br>• **Government:** Provide funding |

## FIGURE 4-4: ASSET TRACKING

**Brief Description:**
Asset and compliance tracking is enabled by placing small button-sized sensors, battery-operated or energy-harvested, on assets. The sensors enable digital recordkeeping for compliance and automation of particular equipment before, during, and after a fire event. Asset tracking enables geo-location of fire fighter assets, age tracking, maintenance, repair tracking, and pairing of assets.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Identify current program for tracking (e.g., manual or automated process, time and cost expended currently)<br>• Identify profile of assets, listing relationship to individuals<br>• Develop a scalable program based on department and size<br>• Develop an easy and intuitive process for deleting or adding new assets and monitoring battery life replacement (mobile console)<br>• Build robust sensors that last a minimum of five years and manage water intrusion, vibration/shock, abrasion, and chemical and thermal extremes<br>• Identify costs per site | • <u>0-3 years:</u><br>  ○ Test current wireless sensor network radio frequency performance<br>  ○ Test durability in fire environments<br>  ○ Identify beta test sites (e.g., small, medium, large)<br>  ○ Conduct voice-of-customer interviews | • Accuracy of device sensors (i.e., they always work)<br>• Self-test and check-in of devices once movement is detected (e.g., sleep state depending on use case)<br>• Fault tolerance diagnostics<br>• Radio frequency performance in fire environments<br>• Implementation of voice-of-customer changes | • Radio frequency range limits<br>• Temperature limits<br>• Robust sensors that last a minimum of five years and manage water intrusion, vibration/shock, abrasion, and chemical and thermal extremes |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • Asset tracking enables new software and workflow management | • Security (ensuring encryption)<br>• Training<br>• Maintenance |

### CHALLENGES

- **Communications technology:** Ensuring radio frequency bands are not saturated
- **Sensors:** Connecting to a personal area network (PAN) or local area network (LAN) environment
- **Data collection:** Managing and setting up the business rules for data collection and storage over time
- **Existing Databases:** Addressing need for a cloud integration, which entails support for a wireless (cellular) device for monitoring assets in the field

### STAKEHOLDER ROLES AND RESPONSIBILITIES

- **Resource management/logistics organizations**
- **Individual firefighters**

## 4.2 Data Processing

The Data Processing topics selected for program development is presented below and expanded in Figures 4-5 to 4-7.

- **Figure 4-5: Use case models**
- **Figure 4-6: Data standardization/ Base platform for data interoperability**
- **Figure 4-7: Center for firefighting excellence/ Fire Service CPS Integration R&D and Support Center**

## FIGURE 4-5: USE CASE MODELS

**Brief Description:**
A technical framework is needed for delivering "actionable intelligence," including risk-based profiles, predictive scenarios, and use and test cases. The framework will facilitate smart firefighting across a broad spectrum of activities, from analysis of building data for pre-event planning and response to post-event processing. The framework should extract patterns, allow for machine learning, and learn from device behavior. (For example, the system accepts the firefighter's verbal input, provides instantaneous feedback from multiple sensors, and provides actionable intelligence for firefighter's decisions.)

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Provide guidance for abstraction of actionable intelligence needs for development of design scenario (e.g., use cases, test cases, risk profiling)<br>• Develop base case scenarios for decision making and response (e.g., determine the information needed for each set of conditions)<br>• Define the environments for expected device behavior (i.e., behavior in the set of conditions defined above)<br>• Build a set of actionable intelligence engines based on data and processing needs (e.g., Fire Department City of New York [FDNY]-type analytics, fire ground decision making, event scenarios for compacting/ deciding data needs)<br>• Expand to multi-platform interaction and communication<br>• Conduct verification and validation | • None provided | • Develop scenario guidelines within 3 years<br>• Develop and test realistic scenarios (e.g., 10 each emergency and non-emergency) within 5 years<br>• Develop actionable intelligence engines within 10 years<br>• Expand to multi-platform within 15 years<br>• Wide-scale rollout within 20 years | • Amount of data that firefighter can process during an event<br>• Reliability of data relative to informing reliable/intelligent decisions<br>• Getting all stakeholders to work well together for the common good (e.g., business, technology) |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • None provided | • None provided |

### CHALLENGES

- **Hardware:** Ensuring interoperability; filtering of noise/ transmission of data; communications network reliability
- **Software:** Defining a common language; ensuring software heterogeneity; defining engine and model semantics; performing verification/validation; interpreting results
- **Overall:** Satisfying compatibility, integration, and interoperability needs

### STAKEHOLDER ROLES AND RESPONSIBILITIES

- **Operational firefighter**: End of hose and IC - to provide knowledge of actions and data needs
- **FF analytics personnel**: Knowledgeable in fire, building, other data
- **Data processing expertise**
- **Human-machine interface expertise**
- **Textual and environmental context expertise**
- **Building owner/manager**
- **Technology developers**
- **Modeling/simulation expertise**

## FIGURE 4-6: DATA STANDARDIZATION/ BASE PLATFORM FOR DATA INTEROPERABILITY

**Brief Description:**
Interoperability is important for the smart data usage for pre-planning, fire incident management, and post-incident analysis. Interoperability in this worksheet focuses on common interfaces for accessing the payload data and formats for the data to be universally read, manipulated, and stored.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Define data interoperability goals and scope<br>• Analyze data source and streams and identify applicable industry and related standards<br>• Identify and evaluate existing best practices from other fields<br>• Synthesize and specify best practices as applied to smart firefighting | • None provided | • Early industry involvement in working groups<br>• Early industry adoption<br>• Availability of devices and systems to enable comprehensive pre-planning, real-time incident management, and efficient post-incident analysis | • None provided |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • The Internet of Things (IOT) will heavily influence CPS and smart firefighting direction | • None provided |

### CHALLENGES

- Business case for civic authorities, insurance industry, and manufacturers
- Privacy concerns
- Ownership of standards development; cross-cutting concerns from communications to data format to equipment certification
- Expense and adoption by the fire protection services
- Intellectual property rights
- Technology hurdles: hardware, software, compatibility and integration for new and existing systems

### STAKEHOLDER ROLES AND RESPONSIBILITIES

- **Fire Service**
- **Standards development organizations**
- **Industry**
- **Academia and research centers**

# FIGURE 4-7: CENTER FOR FIREFIGHTING EXCELLENCE/ FIRE SERVICE CPS INTEGRATION R&D AND SUPPORT CENTER

**Brief Description:**
The center will become an entity for establishing and sharing information, guidelines, and recommendations for smart firefighting. It will be accessible to all fire services and industry members seeking to learn and develop CPS solutions for smart firefighting. This resource center would establish guidelines, recommendations, industry standards, etc. for areas related to data processing, utilization, and evaluation.

## PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Develop a business model and structure for establishing a center for shared knowledge and information<br>• Strategize methods for increased integration of CPS into fire services<br>• Establish interoperability and data standards, guidelines, and recommendations<br>• Identify common data utilization requirements and needs across fire services<br>• Develop a repository of use scenarios and models<br>• Develop lessons learned and best practices globally<br>• Act as first point of contact for fire services for CPS components and use models | • 0-1 years: Develop a business model and budget<br>• 2-3 years: Establish funding and governance<br>• 3-5 years: Build the center<br>• 5-6 years: Collect practices and build a resource base of information and standards for fire services | • Baseline of costs and sources of income for the organization<br>• Maximize reach of the center to fire services— target number of members, number of fire services affected | • None provided |

## FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • None provided | • None provided |

## CHALLENGES

- **Organizational:** Securing funding, developing the center, securing leadership, and developing the organization
- **Costs:** Ensuring data and resource access are cost-neutral to the fire services
- **Integration:** Identifying a strategy for integrating with other services (e.g., police, military, EMS, public works); obtaining early stakeholder buy-in to lessen disruption to current practices

## STAKEHOLDER ROLES AND RESPONSIBILITIES

- **Fire Services**
- **Industry members**
- **CPS experts**
- **Academic partners**
- **Standards organizations**
- **Government and non-government organization (NGO) entities** (the National Institute of Standards and Technology, National Fire Protection Association, Institution of Fire Engineers, Center for Public Safety Excellence, Inc., etc.)

## 4.3 Decision Making

The Decision Making topics selected for program development is presented below and expanded in Figures 4-8 to 4-12.

- **Figure 4-8: All levels of communication on the fire ground**
- **Figure 4-9: Timely utilization of gathered data / Data Gathering Block Box/**
- **Figure 4-10: Automatic updates to fire ground and on-site resources**
- **Figure 4-11: Firefighters prepared to safely perform tasks**
- **Figure 4-12: Enhanced scene and building information**

## FIGURE 4-8: ALL LEVELS OF COMMUNICATION ON THE FIRE GROUND

**Brief Description:**
Communications can be described as the fundamental core of the fire service, starting with building inspection and pre-planning to fire ground operations through post-fire critiques and investigations. Communication is accomplished through several vehicles: hand, verbal, electronic (e.g., wireless), and written.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Develop methods to gather and filter all data elements to ensure functionality to the fire service at all levels<br>• Investigate building history and floor plans<br>• Provide constantly updated incident information (verbal or electronic)<br>  ○ Responding: traffic, weather<br>  ○ On-scene: conditions, actions, needs, accountability, progress, biometric sensing<br>  ○ Post-incident reporting | • 3-5 years:<br>  ○ Periodic evaluation and rework to improve the constantly evolving process | • Develop a usable product for the fire service<br>• Develop customizable solutions | • One size does not fit all<br>• Every municipality is unique |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • Technology developed as the application becomes more widely accepted<br>• Standards developed to regulate technology without restricting advancements in technology | • Functionality and cost leading to cultural acceptance |

| CHALLENGES | STAKEHOLDER ROLES AND RESPONSIBILITIES |
|---|---|
| • **Pre-emergency and post-event:** Gathering appropriate information to use as a resource<br>• **During event:** Transmitting and receiving the information in a timely fashion with good quality<br>• **Non-firefighter data user applications:** Handling applicability of building information to all public service agencies (e.g., EMS, police, building and core enforcement)<br>• **User interface delivery methods:** Ease of information delivery to communications devices (e.g., radios, data terminals) | • **Fire service:** Identify needs and process<br>• **Technology developers:** Develop and deliver the information in a functional format via a usable medium |

## FIGURE 4-9: TIMELY UTILIZATION OF GATHERED DATA/ DATA GATHERING BLACK BOX

**Brief Description:**
A key challenge for smart firefighting is ensuring that all the data being generated are actually used. This requires best practices and technology for data integration that respect the real day-to-day needs of firefighters, across multiple dimensions. Solutions must be sensitive to limited fire service budgets, which may not be able to implement an all-or-nothing approach.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Identify fire departments that are interested in participating in pilots<br>• Inventory and integrate existing technology<br>• Explore sensor, communications, and imaging technology in other industries<br>• Share results with planners and builders<br>• Through pilots, identify the most essential and effective ways to improve situational awareness<br>• Break down best practices along the axes of data type (or data source), data prioritization, and data usage (or type of analysis) | • 0-1 year: Establish a data integration pilot<br>• 3-5 years: Complete end-to-end demonstration with data integration, black box, etc. for variety of situations<br>• 5+ years: Build a set of recommendations for best practices for fire departments to implement, partially or fully, for data management | • Integration of existing alarm systems, building information, SCBA, PPE<br>• Measureable impact on reducing firefighter and civilian injury over an established period of time | • Fire departments should not need to implement a full integrated system to get value from these recommendations and technology |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • None provided | • None provided |

| CHALLENGES | STAKEHOLDER ROLES AND RESPONSIBILITIES |
|---|---|
| • **Pre-emergency and post-event:** None provided<br>• **During event:** None provided<br>• **Non-fire fighter data user applications:** None provided<br>• **User interface delivery methods:** None provided | • **Firefighters:** Identifying critical data for tactical responses and personal safety<br>• **Incident commanders:** Identifying data needed for strategy, post-analysis, and situational awareness of entire scene<br>• **Technology developers:** Hardware and software experts to define what is feasible and develop analytical algorithms |

# FIGURE 4-10: AUTOMATIC UPDATE TO FIRE GROUND AND ON-SITE RESOURCES

**Brief Description:**
Fire scenes are fluid environments where conditions, personnel, and resources are constantly changing. In order to respond to the dynamic nature of the fire scene, incident commanders require continuous information updates to make informed decisions and re-evaluate incident action plans (IAPs). CPS would gather, organize, and prioritize information in the background. The incident commander could access information, alerts, and prompts at any time, and/or the system could provide hazardous condition alerts.

## PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Identity needs, system of priorities, and alerts/prompts points<br>• Develop sensors and communications networks for fire ground information-gathering from apparatus, firefighters, building, weather, and equipment<br>• Develop analytical and verification modules for information processing<br>• Develop interface to display processed information<br>• Conduct full-scale testing under fire conditions or actual operational use | • 0-3 years:<br>○ Needs, priorities, and alerts/prompts established through consensus process<br>○ Current sensor technologies identified and adapted to needs<br>• 3-5 years:<br>○ Future needs for specific sensor technologies identified and associated research initiated<br>○ Prototype analytical and verification modules and display interfaces available for testing<br>• 5+ years: Prototype systems evaluated during field burns | • Collection of temperature, thermal flux, and gas concentrations to identify IDLH for firefighter and fire teams<br>• Personal tracking of firefighters and fire teams on scene<br>• IDLH and location information available to incident commander as needed and in response to alerts/prompts | • Data/sensory overload potential for incident commander—may not be able to process all data<br>• Compressed window decision making ability to prioritize/filter information |

## FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • Equipment needs to be smaller and lighter than current technology<br>• Information needs to be targeted to specific fire teams | • Security - possibility of someone else looking at data<br>• System reliability - more important than security |

## CHALLENGES

- **Pre-emergency and post-event:** Getting all the fire service on same page and buy-in
- **During event:** Compressed window for decision making reliability of data, communication and display of information
- **Non-fire fighter data user applications:** Many law enforcement agencies (more important for security), military
- **User interface delivery methods:** Visual (limited audible applications), intermediate hand-held display for officer, monitor touch screen 15"-19" for incident command firefighter, series of lights (e.g., red, yellow, green)

## STAKEHOLDER ROLES AND RESPONSIBILITIES

- **Fire service (IC/operational personnel):** Develop priority alerts/prompts and ensure project maintains focus on fire service needs (e.g., cost-effective, simple, reliable)
- **Engineers:** Identify reliable measurement science to collect required information from fire ground including from apparatus, firefighters, building, weather and equipment
- **CPS**: Develop methodologies to collect, verify, process, report, and display information; develop interfaces, software, and analytics

## FIGURE 4-11: FIREFIGHTERS PREPARED TO SAFELY PERFORM TASKS

**Brief Description:**
Physiological monitoring should connect, interface, or supplement medical and fitness programs to ensure firefighters can safely perform work (i.e., they are medically fit). Data can be collected at baseline fitness training and during past incidents to monitor and improve health and safety.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Assemble, coordinate, and adopt current technology<br>• Human-computer interface must be emphasized with firefighters and be deeply involved in design<br>• Explore additional sensors (e.g., physiological or exposure) for relevant parameters (e.g., electrocardiogram, blood pressure, carbon monoxide, toxins) | • Offer commercially available methodology<br>• Document adoption<br>• Develop use model/ competition to draw in large participation. | • Seamless technology to support excellent medical, physical, cognitive, and behavioral performance<br>• Foster competition and collaboration within and between departments and stations | • Appropriate feedback provided on key hazards<br>• Not a stand-alone technology, will require human analysis and decision making |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • Vitals monitoring provides enormous potential for data mining to supplement on-going research<br>• Technology would support/enhance adoption or implementation of standard | • Union/administration issue<br>• Privacy issue (e.g., Health Insurance Portability and Accountability Act [HIPAA])<br>• What information when/where/to whom |

| CHALLENGES | STAKEHOLDER ROLES AND RESPONSIBILITIES |
|---|---|
| • **Pre-emergency and post-event:** model for Americans (e.g., heroes)**;** Compatibility with advances in medical and fitness<br>• **During event**: Most challenging time; some data may be useful to collect (e.g., exposure, events) for post-event (e.g., rehabilitation); most data are not actionable during events; at the scene, firefighter assumed to be medically and physically fit to do job; connects with current telemedicine - widely applicable<br>• **Non-fire fighter data user applications:** Many law enforcement agencies, military<br>• **User interface**: Delivery methods | • **Fire service:** Firefighters, firefighters' families, and fire departments<br>• **Medical providers**<br>• **Commercial partners**: FitBit, Zepher |

## FIGURE 4-12: ENHANCED SCENE AND BUILDING INFORMATION

**Brief Description:**
There are several critical factors that must be identified in order to determine an IAP. These include physical layout (e.g., occupancy, configuration, contents), topography, weather, and visual data.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Develop approach for digitizing, archiving, uploading, and retrieving building floor plans of publicly occupied/ inspected properties<br>• Develop the ability to retrieve current and expected weather data as geographic information system (GIS) layer<br>• Expand the ability to retrieve video feeds from public cameras<br>• Assimilate real-time WUI fire prediction data as GIS layer | • Create a repository housing the digital layout of all commercial and inspected structures<br>• Generate topographical maps for all response areas<br>• Design user interface layers for digitized data | • Standardized format of digitized GIS layer data based on open architecture<br>• Appropriate client side mobile data computer (MDC) display | • Indication of uncertainty in accuracy of data |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • Increased investment in real-time data | • None provided |

### CHALLENGES

- **Pre-emergency and post-event:** None provided
- **During event:** None provided
- **Non-firefighter data user applications:** None provided
- **User interface delivery methods:** None provided

### STAKEHOLDER ROLES AND RESPONSIBILITIES

- **GIS professionals**
- **Building officials**
- **Transportation departments**

## 4.4 Structural Cross-Cutting

The Structural Cross-Cutting topics selected for program development is presented below and expanded in Figures 4-13 to 4-15.

- **Figure 4-13: Standard protocol inter-connectivity of communication devices and systems**
- **Figure 4-14: Situational awareness technologies and training**
- **Figure 4-15: Situational awareness technologies education and standards**

Additional information was provided about the needs for situational awareness technologies and related training, education, and standards (Table 4-2). This additional information is applicable to Figure 4-15.

## FIGURE 4-13: STANDARD PROTOCOL INTER-CONNECTIVITY OF COMMUNICATION DEVICES AND SYSTEMS

**Brief Description:**
Intelligent interoperable systems are needed to most efficiently use resources and effectively respond to incidents. The ideal system would include many features: clear voice communication in all conditions, resistance to different environmental conditions, local thresholding for digital data, and a standardized dashboard.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Identify data sets that are most important for fire service<br>• Detail data sets and key metrics<br>• Develop the sensor(s) needed and standardize output<br>• Deliver strategy | • List top 10 data sets<br>• Develop standards-based sensors to stream data in real time<br>• Build testbeds that can test interoperability<br>• Standardize protocol | • Deploy first of 5 data sets within 2 years | • Sensor detection to response deployment time is less than 60 seconds<br>• Reliability within +/- 5% |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • None provided | • Trust of data |

### CHALLENGES

- **Communications:** Accessing sensor data
- **Computation:** Determining data storage and processing location
- **Targeted decision making:** Preventing overload of information for the users
- **Technology limitations:** Ensuring serviceability of equipment
- **Pre-emergency:** Identifying appropriate level of monitoring
- **During event:** Developing ability to interpret, receive, and rely on data
- **Post-event:** Analyzing systems' performance, feeding outcomes back into the process

### STAKEHOLDER ROLES AND RESPONSIBILITIES

- **Fire service:** Define data sets or points
- **Manufacturers:** Provide solutions
- **Third parties:** Test and certify

## FIGURE 4-14: SITUATIONAL AWARENESS TECHNOLOGIES AND TRAINING

**Brief Description:**
For effective and safe firefighting, it is essential to know the occupation, location, and health of firefighters; understand the dynamic fire environment; and receive an individualized information flow according to the role.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Identify gaps in training and close them<br>• Develop trusted means to identify and locate live occupants<br>• Develop trusted means to identify and locate fire ground responders<br>• Develop/identify key environmental data to measure and means to aggregate and analyze those data to make them actionable | • 0-3 years:<br>○ Conduct proof-of-concept demonstration of training exercises<br>○ Investigate/support locator for Americans with Disabilities Act (ADA) occupants<br>○ Create/support technology challenges/demonstrations<br>○ Workshop with FF/developers to identify environmental data<br>• 3-5 years:<br>○ Create/support technology challenges for civilian locator<br>○ Review existing DOD technologies<br>○ Identify performance metrics<br>○ Use developed sensor technology in demonstration | • General acceptance/test/ openness to new technology<br>• Pre/past measurement of unoccupied entry/ occupant recovery<br>• Integration/fielding of sensors in a percentage of targeted users | • None provided |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • None provided | • Privacy issues |

### CHALLENGES

- **Communications**: Data gathering
- **Computation:** Identifying best methods to analyze data to extract useful information
- **Targeted decision making:** Reaching all participants of fire grade
- **Technology Limitations:** Facilitating location (e.g., ability to reliably locate humans within a structure)
- **Communications pipeline**

### STAKEHOLDER ROLES AND RESPONSIBILITIES

- **NIMS experts:** Slice data to appropriate levels (of fire grade personnel)
- **Training and cognition experts**: Pre-event planning
- **Fire service:** Post-event feedback

## FIGURE 4-15: SITUATIONAL AWARENESS TECHNOLOGIES EDUCATION AND STANDARDS

**Brief Description:**
Enhanced situational awareness could improve the ability of the fire service at all levels (e.g., firefighter, incident commander) to understand the structural fire environment. Greater understanding would enable these personnel to use a wide range of sensor data to increase FF effectiveness and safety.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Develop curricula that reflect the current understanding of fire dynamics, building construction, suppression and ventilation, and technology's caps and limitations<br>• Develop a national/public-private partnership for disseminating the educational information<br>• Develop a current or new standard information package for sensing/communication technologies<br>• Develop data needs for each level of fire response (see Table 4-2) | • Revision of NFPA 1001 standard with respect to development of new firefighting educational standards<br>• Size-up decision making enabled by situational awareness technology<br>• Integration of physics-based situational awareness with situational awareness technology-based sensor data<br>• Reduced cost in collecting and maintaining pre-plan data, risk reduction, reduced incident costs | • Recertification of firefighters/fire officers with 5-year standard program<br>• Adoption by local government to deliver situational awareness technology infrastructure (within 10 years) | • Cost and timing constraints<br>• Reliability, sustainability, and maintainability |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • Research- and service-based firefighter education to provide a foundation for the use of situational awareness technology<br>• Design data delivery protocol and system based on needs (e.g., firefighter versus fire officer versus fire chief) | • Lack of desire to adopt<br>• Data overload of incident commander<br>• Recognition of CPS failure or damage |

| CHALLENGES | STAKEHOLDER ROLES AND RESPONSIBILITIES |
|---|---|
| • **Communications:** Getting data out of the building to the apparatus<br>• **Computation:** Maintaining or increasing speed (key en route to the incident and onsite)<br>• **Targeted decision making:** Integrating situational awareness sensor<br>• **Technology limitations:** Meeting need for national/local networks or simulators and technology testbeds<br>• **Pre-emergency:** Addressing limited time and funding to support education<br>• **During event:** Developing an automatic and prioritized method to recognize system failure and data overload<br>• **Post-event:** Developing and sharing post-event reports as another data set | • **Primary emergency responder organizations** |

### TABLE 4-2: DATA NEEDS FOR EACH LEVEL OF FIRE RESPONSE

| | Pre-Incident | Priority I En Route | During Incident | Post-Incident |
|---|---|---|---|---|
| **Situational Awareness Needs** | Duration: months to days<br>(standards exist, easy to implement) | Duration: 3-5 minutes<br>(maximum impact) | Duration: 30 minutes to many hours<br>(improve operation) | Duration: days |
| **Firefighter** | • Pre-plans for built infrastructure<br>• Drills and education<br>• Material safety data sheet (MSDS) information | • Apparatus<br>• Check of personnel monitoring systems (operational)<br>• Equipment for HAZMAT | • Current localized sensor information<br>• Entry/egress information<br>• Live personal data (e.g., biometrics, location, proximity)<br>• Ongoing hazard information in structure | • Level of exposure |
| **Company Officer** (first arriving captain, initial incident commander) | • Pre-plans for built infrastructure<br>• Access to CPS information<br>• Define entry and access to incident<br>• MSDS information | • Site specifics of indent (e.g., HAZMAT)<br>• Building real-time systems data to truck (e.g., alarm panel data)<br>• Current occupancy and usage<br>• Existing data<br>• Contact information | • Ongoing hazard in and near structure<br>• Severity assessment<br>• Technology assessment<br>• Crew integrity (i.e., group cohesiveness)<br>• Localized sensor information and special 360-degree view for fire fighters (e.g., alerts for those in danger)<br>• Location of fire and rate of change<br>• Perimeter set-up<br>• Command post set-up (e.g., building and event data)<br>• Recognition failure levels of CPS system<br>• Ongoing hazard information around incident<br>• Determination of additional monitoring to be done (e.g., facilitate set-up for new sensing) | • Identification of the characteristics of arson and provision of evidence to law enforcement for investigation |
| **Chief Officer** (for larger incidents) | • Pre-plans for built infrastructure<br>• Access to CPS info<br>• Occupancy and usage<br>• MSDS information | • Evaluation status<br>• Site specifics of incident (e.g. HAZMAT)<br>• Building real-time systems data to truck (alarm panel data)<br>• Current occupancy and usage<br>• Existing data<br>• Contact information | | |
| **Offsite Entities** (emergency operations center, dispatch, department of operations center) | • Emergency contacts for offsite consequences (e.g., city, county, officials)<br>• MSDS information<br>• External data sources (e.g., weather)<br>• Occupancy and usage<br>• CPS-related information for region | • Building-specific CPS information gathered and assimilated at dispatch time for delivery to responders, company officers, and chief officers<br>• Volumes of 911 calls<br>• Determination of provenance of data | • Status monitoring and determination of incident support needs<br>• Mutual aid specialty resources<br>• Notifications to public and other entities | • Status monitoring |

## 4.5 Non-Structural Cross-Cutting

The Non-structural Cross-cutting topics selected for program development is presented below and expanded in Figures 4-16 to 4-19.

- **Figure 4-16: Full-scale testbeds**
- **Figure 4-17: Interface standards in hardware, software, common data models, and formats**
- **Figure 4-18: New algorithms for uncertainty**
- **Figure 4-19: Simple and intuitive user interface**

## FIGURE 4-16: FULL-SCALE TESTBEDS

**Brief Description:**
The application of new technologies to the fire service mission requires a process to demonstrate the application and the benefits derived from the technology. Having clear metrics and testbeds for feasibility demonstrations allows end users to make accurate comparisons between products, communicate their needs, influence industry-recognized criteria, and measure operational improvements.

### PROGRAM APPROACH

#### Major Tasks

- Establish CPS advisory group to "own" the process
- Perform gap/needs analysis
- Identify key federal agencies and funding
- Solicit R&D proposals from industry

#### Major Milestones

- 0-3 years:
  - Conduct gap/needs analysis
  - Identify current best practices in military and other industry
- 3-5 years:
  - Develop prototype and beta test
  - Develop standard and guidance for manufacturers and users
- 5+ years:
  - Develop user community support system to sustain the process

#### Performance Targets

- Consensus on standards
- Scalable product that addresses rural, suburban, and urban fire service needs

#### Limits

- Tools not a replacement for common sense and experience
- Interoperability in multi-vendor environment

### FUTURE

#### Future Changes

- Field deployment and user feedback
- Active R&D program
- Increased R&D and decreased costs as capabilities move to market

#### Future Operations or CPS Issues

- Information overloads for users
- Security and privacy

### CHALLENGES

- **Communications:** None provided
- **Computation:** None provided
- **Targeted decision making:** None provided
- **Technology limitations:** None provided
- **Pre-emergency:** None provided
- **During event:** None provided
- **Post-event:** None provided

### STAKEHOLDER ROLES AND RESPONSIBILITIES

- **Researchers:** Provide gap analysis of existing standards and community stakeholder needs
- **Standards developer:** Produce industry standards
- **Responder community:** Develop awareness and provide testbed and demonstration sites
- **Manufacturers:** Commence R&D activities

## FIGURE 4-17: INTERFACE STANDARDS FOR HARDWARE, SOFTWARE, COMMON DATA MODELS, AND FORMATS

**Brief Description:**
Interoperability standards for firefighting CPS need to be developed to improve efficiency of the systems and firefighting efforts.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Develop universal standards for data exchange through interconnection nodes through the CPS<br>• Develop interoperability and scalability standards for universal hardware application<br>• Develop software standards that meet data exchange interoperability standards<br>• Develop standards for the HMI experience | • 0-3 years:<br>  ○ Human interface standard for fire service<br>• 3-5 years:<br>  ○ Interconnection standards<br>  ○ Software standards data exchange<br>• 5-7 years:<br>  ○ Interoperability and scalability standards | • Standards adoption by consensus among manufacturers and end-users | • Budget constraints (cost performance)<br>• Perceived cost/benefit for new technology |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • Improved training standards<br>• Interoperable equipment<br>• Paradigm shift from conventional to smart firefighting | • Culture<br>• Trust<br>• System dependency |

### CHALLENGES

- **Communications:** Identifying the useful data and types of data
- **Computation:** Developing capability to handle data volume and speed
- **Targeted decision making:** Managing reliability and trustworthiness (uncertainty)
- **Technology limitations:** Managing interoperability and scalability
- **Pre-emergency:** None provided
- **During event:** Prioritizing information to complement decision making
- **Post-event:** Using lessons learned to revise and improve standards

### STAKEHOLDER ROLES AND RESPONSIBILITIES

- **Standards developing organizations**
- **Policymaking organizations/agencies**
- **Manufacturers**
- **End users (e.g., emergency response community)**

## FIGURE 4-18: NEW ALGORITHMS FOR UNCERTAINTY

**Brief Description:**
In the non-structural firefighter response environment, multiple unknown variables exist that would affect accuracy of CPS solutions. Algorithms must be developed to account for these unknowns.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Create knowledge base by adequately describing the firefighting domain<br>• Identify past events that could be used as training<br>• Assemble ideas into a decision support tool incorporating human factors<br>• Develop user interface | • Conduct critical review of past incidents and technology (1-2 years)<br>• Identify needs and gaps that create uncertainty<br>• Invent coding adaptive algorithms<br>• Complete field testing | • A critical review of models and incidents to better understand factors that affect fire behavior<br>• Development of software | • Ability to quantify uncertainty<br>• Limited by number of inputs from existing technology |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • Framework to account for uncertainty | • Culture of integrating decision support tool<br>• Trust of technology over human decision making |

| CHALLENGES | STAKEHOLDER ROLES AND RESPONSIBILITIES |
|---|---|
| • **Communications:** Only as good as data input<br>• **Computation:** Importance of speed (scalability) | • **Computer scientists**<br>• **Fire subject matter experts**<br>• **Funding agency:** e.g., FEMA, FISP, Joint Fire Sciences Working Group |

## FIGURE 4-19: SIMPLE AND INTUITIVE USER INTERFACE

**Brief Description:**
A well-designed user interface should provide the user with access to relevant technology and data using appropriate PPE.

### PROGRAM APPROACH

| Major Tasks | Major Milestones | Performance Targets | Limits |
|---|---|---|---|
| • Go through development process (e.g., testing, beta release, final release)<br>• Work with users to determine final product<br>• Use successful products as examples<br>• Involve the experts (e.g., Google, Apple, etc.) | • Upgrade and improve existing user interfaces<br>• Evaluate feedback on beta and final releases | • Broad use and added value to fire service groups<br>• Mode of user interface utilization by fire service groups<br>• Functions with existing and new technology | • Well-defined (and realistic) tool required<br>• Realistic goals defined |

### FUTURE

| Future Changes | Future Operations or CPS Issues |
|---|---|
| • Safer, more effective work<br>• Better use of resources | • Loss of "hands-on" experience and problem-solving skills<br>• Overreliance on the technology |

### CHALLENGES

- **Communications:** Additional use on the job for feedback without interrupting or distracting firefighters
- **Computation:** Decision needed regarding client/server or client-only cloud
- **Targeted decision making:** Creation of a well-defined application scope
- **Technology limitations:** Inoperable touch screen with gloves; interference of background noise with voice interface
- **Pre-emergency:** Undefined data needs during an event
- **During event:** User interface may or may not be different; undefined method to provide relevant information in a timely manner
- **Post event:** Undefined beginning of post event; after-action review

### STAKEHOLDER ROLES AND RESPONSIBILITIES

- **Software vendors**
- **Users**
- **Industry regulatory bodies**

# 5 Summary

Incorporation of CPS capabilities into the fire service could provide significant enhancements to improve the safety and effectiveness of fire protection and firefighting. In an effort to galvanize stakeholder attention on this topic the *Smart Firefighting Workshop* was held on March 24-25, 2014, in Arlington, Virginia. This meeting assembled members of the fire service, CPS, and fire protection communities to identify key development areas—technical and non-technical—that are needed to take advantage of the volumes of data generated during all phases of a fire incident. The most beneficial concepts as identified by the workshop participants were prioritized and then expanded into potential program plans. Several common themes emerged including the following:

- Use of sensors on the fire ground to assist in situational awareness and personnel location
- Increased collection and utilization of data before the incident to aid in effective use of personnel and equipment
- Enhance interoperability between data systems
- Develop intelligent systems to assist with decision making

This report summarizes the results of the workshop and will serve to guide the development of a research roadmap on smart firefighting providing guidance for the research community as they consider developing programs focused on providing the science and standards needed to enable safer and more effective fire protection and firefighting. The material contained in this report will aid both the public and private sectors in development of policy, R&D, and other firefighting related decision making.

# Appendix A: Contributors

Contributors listed alphabetically

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# Appendix B: Acronyms

| | |
|---|---|
| CAD | Computer Aided Dispatch |
| CPS | cyber-physical system |
| DHS | Department of Homeland Security |
| DOD | Department of Defense |
| EL | Engineering Laboratory |
| EMS | Emergency Medical Service |
| FDNY | Fire Department City of New York |
| FEMA | Federal Emergency Management Agency |
| FF | firefighter |
| FIERO | Fire Industry Equipment Research Organization |
| FPRF | Fire Protection Research Foundation |
| GPS | Global Positioning System |
| GIS | geographic information system |
| HAZMAT | Hazardous Materials Response |
| HCI | human-computer interface |
| HIPAA | Health Insurance Portability and Accountability Act of 1996 |
| IAFC | International Association of Fire Chiefs |
| IAFF | International Association of Fire Fighters |
| IAP | incident action plan |
| IBC | International Building Code |
| IC | Incident Commander |
| ICC | International Code Council |
| IDLH | immediately dangerous to life or health |
| IFMA | International Fire Marshals Association |
| IOT | internet of things |
| LAN | local area network |
| MDC | mobile data computer |
| MSDS | Material Safety Data Sheet |
| NFIRS | National Fire Incident Reporting System |
| N-FORS | National Fire Operations Reporting System |
| NFPA | National Fire Protection Association |
| NGO | non-government organization |

| | |
|---|---|
| NIMS | National Incident Management System |
| NIST | National Institute of Standards and Technology |
| NVFC | National Volunteer Fire Council |
| PAN | personal area network |
| PPE | personal protective equipment |
| QA | quality assurance |
| SCBA | self-contained breathing apparatus |
| UAS | unmanned aircraft system |
| UAV | unmanned aerial vehicle |
| UGV | unmanned ground vehicle |
| UI/UX | user interface/user experience |
| WoF | working on fire |
| WUI | Wildland-Urban Interface |

# Appendix C: Workshop Agenda

**Monday - Tuesday, 24-25 March 2014**

**Sheraton Crystal City Hotel**

1800 Jefferson Davis Hwy, Arlington, VA (Phone: 703-486-1111)

Agenda last updated: 12 March 2014

***A one and one-half-day interactive workshop in support of the project to***

***"Develop a Research Roadmap for Smart Fire Fighting"***

## BACKGROUND:

The fire service and other emergency first responders are currently benefiting from enhanced-existing and newly-developed electronic technologies. Firefighters are now operating in an ever increasing sensor rich environment that is creating vast amounts of potentially useful data. The "Smart" firefighting of tomorrow is envisioned as being able to fully exploit select data to perform work tasks in a highly effective and efficient manner. Behind the advances of the new sensor and tool enhanced firefighter of tomorrow are profound questions of how to best enable effective use of this deluge of valuable information. This is an area that is informed by the field of "cyber-physical systems" and which promises to change the world of firefighting as we know it.

This workshop is being held to support a NIST funded research project to develop a "Research Roadmap for Smart Fire Fighting". This is focused on addressing how best to effectively use the immense quantity of data available from buildings, communities and on the fire ground, the computational power to compute and communicate that data, the knowledge base and algorithms to most effectively process the data, converting it into significant knowledge/beneficial decision tools, and effectively communicate the information to those who need it, when they need it --- on the fire ground and elsewhere.

## WORKSHOP GOALS AND ANTICIPATED OUTCOMES:

The goals and outcomes from this workshop are:

(a) Establish dialogue among subject matter experts familiar with the unique characteristics of firefighting and cyber physical systems.
(b) Promote a better understanding of data opportunities available to the fire service.
(c) Clarify the collective vision of the ultimate research roadmap expected as deliverables for this project.

## PLANNED AGENDA (24-25 MARCH 2014):

| | | |
|---|---|---|
| 8:00 am | ***Introductory Remarks***: Workshop Overview | Casey Grant, FPRF |
| 8:10 am | ***Welcoming Remarks***: The NIST Vision | Howard Harary, NIST |
| 8:20 am | ***Welcoming Remarks***: Overview of Smart Fire Fighting and Cyber Physical Systems | Anthony Hamins, NIST |
| 8:30 am | ***Presentation***: Federal Government Vision for Integrating Cyber Physical Systems with the Fire Service | Richard Voyles, OSTP |
| 8:50 am | ***Presentation***: Our Changing World from a Fire Fighting Perspective:<br>(a) Addressing State-of-the-Art; (b) Defining the Problem; (c) Clarifying the Challenges; (d) Prioritizing the Details | Glenn Gaines, USFA |
| 9:10 am | ***Presentation***: Our Changing World from a Cyber Physical Systems Perspective: (a) Addressing State-of-the-Art; (b) Defining the Problem; (c) Clarifying the Challenges; (d) Prioritizing the Details | Sokwoo Rhee, NIST |
| 9:30 am | ***Presentation***: Cyber Physical Systems and the Fire Service - the FDNY Perspective | Jeff Roth & Jeff Chen, FDNY Analytics |
| 9:50 am | Networking Break | |
| 10:10 am | ***Panel Discussion***:<br>Bringing Cyber Physical Systems to the Fire Service - Review of Experience, Applications and Opportunities | *Moderator*: Al Jones (NIST);<br>*Panelists*:<br>Glenn Gaines (USFA),<br>Eric Nickel (Palo Alto FD),<br>Patrick Jackson<br>(Rocky Mount FD),<br>Michael May (DoD),<br>Jeff Chen (FDNY Analytics),<br>Nalini Venkatasubramanian<br>(UC-Irvine) |
| 11:40 am | ***Presentation***: Road mapping Vision and Chapter Outline | Nelson Bryner, NIST |
| 12:00 pm | ***Breakout Group Introduction***: Breakout Group Assignment Review<br>● Breakout Group I: Data Gathering<br>● Breakout Group II: Data Processing<br>● Breakout Group III: Decision Making<br>● Breakout Group IV: Cross-Cutting (Structural)<br>● Breakout Group V: Cross-Cutting (Non-Structural) | Casey Grant, FPRF |
| 12:10 pm | Working Lunch | |
| 1:10 pm | ***Breakout Session Preview***: Introductions and Agenda Review | Energetics- Plenary |
| 1:25 pm | ***Breakout Session 1***: State of the Art | Workshop Groups |

| | | |
|---|---|---|
| 2:10 pm | ***Breakout Session 2***: Development Needs | Workshop Groups |
| 3:00 pm | ***Breakout Session 3***: Other Requirements | Workshop Groups |
| 3:30 pm | ***Breakout Session Prioritization*** | Workshop Groups |
| 3:45 pm | Break | |
| 4:00 pm | ***Breakout Group Presentations*** | Plenary |
| 4:50 pm | ***Day One Closing Remarks and Day Two Instructions*** | NIST & Energetics |
| 5:00 pm | Adjourn Day One | |

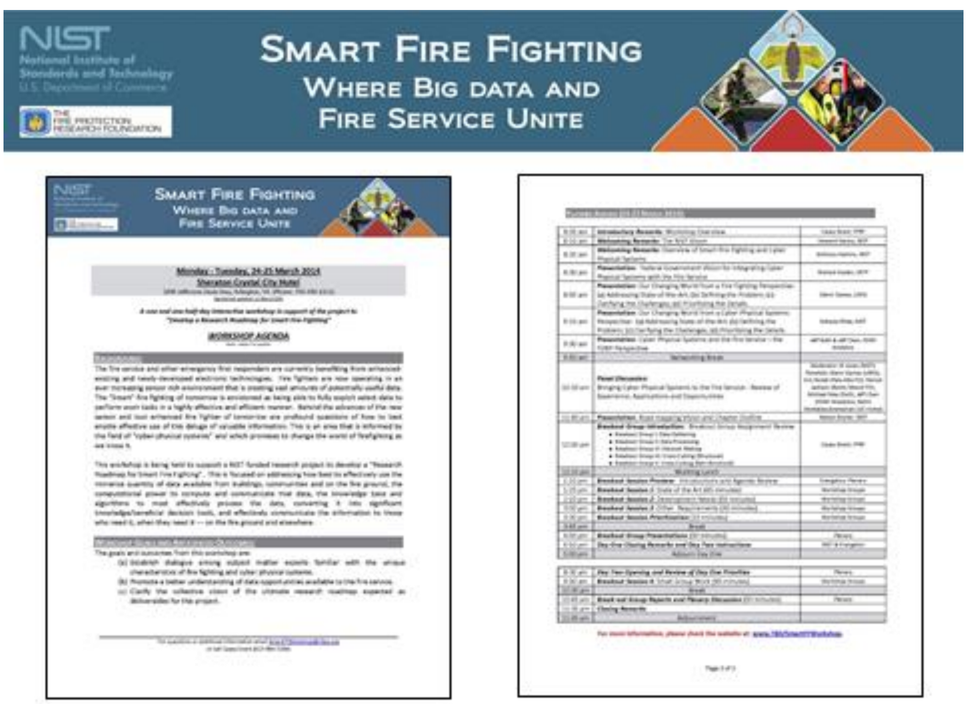
| | | |
|---|---|---|
| 8:30 am | ***Day Two Opening and Review of Day One Priorities*** | Plenary |
| 9:00 am | ***Breakout Session 4***: Small Group Work | Workshop Groups |
| 10:30 am | Break | |
| 10:45 am | ***Break-out Group Reports and Plenary Discussion*** | Plenary |
| 11:35 am | ***Closing Remarks*** | |
| 11:45 am | Adjournment | |

# Appendix D: Overview Briefings

Several presentations were given at the beginning of the workshop to set the stage for the discussions. Those presentations, provided in this appendix, are as follows:

- Introductory Remarks: Workshop Overview, *Casey Grant, FPRF*
- Welcoming Remarks: The NIST Vision, *Howard Harary, NIST*
- Welcoming Remarks: Overview of Smart Fire Fighting and Cyber Physical Systems, *Anthony Hamins, NIST*
- Federal Government Vision for Integrating Cyber Physical Systems with the Fire Service, *Richard Voyles, OSTP*
- Our Changing World from a Fire Fighting Perspective, *Glenn Gaines, USFA*
- Our Changing World from a Cyber Physical Systems Perspective, *Sokwoo Rhee, NIST*
- Cyber Physical Systems and the Fire Service - the FDNY Perspective, *Jeff Roth & Jeff Chen, FDNY Analytics*


NIST
National Institute of Standards and Technology
U.S. Department of Commerce
THE FIRE PROTECTION RESEARCH FOUNDATION
SMART FIRE FIGHTING
WHERE BIG DATA AND
FIRE SERVICE UNITE
24 - 25 MARCH 2014 ARLINGTON, VA
Casey C. Grant, Research Director
Fire Protection Research Foundation
Quincy, Massachusetts USA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SMART FIRE FIGHTING
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SMART FIRE FIGHTING
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Monday - Tuesday, 24-25 March 2014
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WORKSHOP AGENDA


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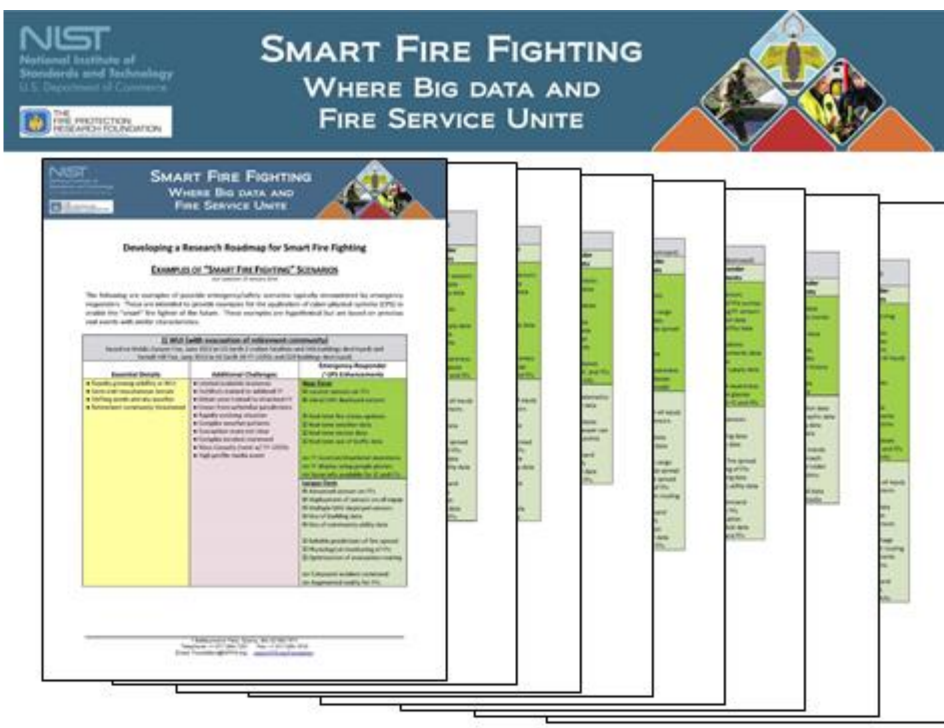
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WHERE BIG DATA AND
FIRE SERVICE UNITE
Developing a Research Roadmap for Smart Fire Fighting

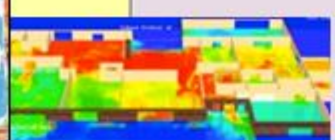
**1) WUI (with evacuation of retirement community)**
based on Waldo Canyon Fire, June 2012 in CO (with 2 civilian fatalities and 346 buildings destroyed) and
Yarnell Hill Fire, June 2013 in AZ (with 19 FF LODDs and 129 buildings destroyed)

| Essential Details | Additional Challenges | Emergency-Responder / CPS Enhancements |
|---|---|---|
| • Rapidly growing wildfire at WUI<br>• Semi-arid mountainous terrain<br>• Shifting winds and dry weather<br>• Retirement community threatened | • Limited available resources<br>• HotShots trained to wildland FF<br>• Urban crew trained to structural FF<br>• Crews from unfamiliar jurisdictions<br>• Rapidly evolving situation<br>• Complex weather patterns<br>• Evacuation route not clear<br>• Complex incident command<br>• Mass Casualty Event w/ FF LODDs<br>• High profile media event | **Near-Term**<br>⊖ Locator sensors on FFs<br>⊖ Initial UAV deployed sensors<br><br>Ξ Real-time fire status updates<br>Ξ Real-time weather data<br>Ξ Real-time terrain data<br>Ξ Real-time use of traffic data<br><br>⇔ FF location/situational awareness<br>⇔ FF display using google glasses<br>⇔ Same info available for IC and FFs<br>**Longer-Term**<br>⊖ Advanced sensors on FFs<br>⊖ Deployment of sensors on all equip<br>⊖ Multiple UAV deployed sensors<br>⊖ Use of building data<br>⊖ Use of community utility data<br><br>Ξ Reliable predictions of fire spread<br>Ξ Physiological monitoring of FFs<br>Ξ Optimization of evacuation routing<br><br>⇔ Enhanced incident command<br>⇔ Augmented reality for FFs |

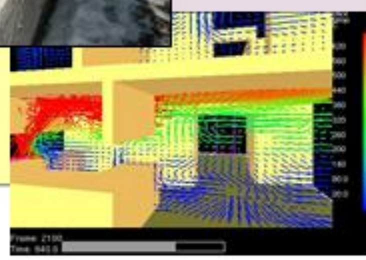


**2) Residential Structure Fire (wind driven fire)**
based on Marsh Overlook Structure Fire, April 2007 in Prince William County VA (with 1 FF LODD) and
Houston Residential Fire, April 2009 in Houston TX (with 2 FF LODDs) and
Pittsburgh House Fire, February 1995 in Pittsburgh PA (with 3 FF LODD)

| Essential Details | Additional Challenges | Emergency-Responder / CPS Enhancements |
|---|---|---|
| • Large modern single family home<br>• Heavy synthetic fuel load<br>• Open interior wood-frame building<br>• Located on hillside: 1 to 3 stories<br>• Fire starts externally from grill<br>• Fire spreads rapidly with high wind<br>• Well staffed urban FD | • Fire at early morning hours<br>• Cars in driveway<br>• Location of occupants unknown<br>• Heavy fire on arrival<br>• Rapid spread of fire to interior<br>• Initial search crews trapped<br>• RIT implemented | **Near-Term**<br>⊖ Coordination of existing FF sensors<br>⊖ Coordination of dispatch data<br>⊖ Initial use of building utility data<br><br>Ξ Real-time fire status updates<br>Ξ Real-time weather data<br>Ξ Real-time use of water supply data<br>Ξ Real-time use of traffic data<br>Ξ Real-time use of terrain data<br><br>⇔ FF location/situational awareness<br>⇔ FF display using google glasses<br>⇔ Same info available for IC and FFs<br>**Longer-Term**<br>⊖ Advanced sensors on FFs<br>⊖ Deployment of sensors on all equip<br>⊖ Multiple UAV deployed sensors<br>⊖ Use of building data<br>⊖ Use of community utility data<br><br>Ξ Reliable predictions of fire spread<br>Ξ Physiological monitoring of FFs<br>Ξ Advanced use of building data<br>Ξ Advanced use of public utility data<br><br>⇔ Enhanced incident command<br>⇔ Augmented reality for FFs<br>⇔ Coordination of FF location<br>⇔ Advanced use of medical data<br>⇔ Advanced info for IC and FFs |


| 3) Hi-Rise Apartment Fire (wind driven fire)<br>based on Vandella Ave 10-Story Apartment Fire, December 1998 in NYC (with 3 FF LODDs) | | |
|---|---|---|
| **Essential Details** | **Additional Challenges** | **Emergency-Responder / CPS Enhancements** |
| • 15 story brick apartment<br>• Building approximately 40 years old<br>• Unit on 12th floor fully involved<br>• High wind conditions<br>• Fire on up-wind side of building<br>• FD well-staffed metro department | • Most occupants are elderly<br>• Occupants trapped in rooms<br>• During FF windows break<br>• Fire rapidly intensities<br>• Wheelchair occupants on fire floor<br>• Wheelchair occupants elsewhere | <u>**Near-Term**</u><br>⊖ Coordination of existing FF sensors<br>⊖ Coordination of dispatch data<br>⊖ Initial use of building utility data<br><br>⌛ Real-time fire status updates<br>⌛ Real-time weather data<br>⌛ Real-time use of water supply data<br>⌛ Real-time use of traffic data<br>⌛ Real-time use of terrain data<br><br>⇔ FF location/situational awareness<br>⇔ FF display using google glasses<br>⇔ Same info available for IC and FFs |
| | | <u>**Longer-Term**</u><br>⊖ Advanced sensors on FFs<br>⊖ Deployment of sensors on all equip<br>⊖ Multiple UAV deployed sensors<br>⊖ Use of building data<br>⊖ Use of community utility data<br><br>⌛ Reliable predictions of fire spread<br>⌛ Physiological monitoring of FFs<br>⌛ Advanced use of building data<br>⌛ Advanced use of public utility data<br><br>⇔ Enhanced incident command<br>⇔ Augmented reality for FFs<br>⇔ Coordination of FF location<br>⇔ Advanced use of medical data<br>⇔ Advanced info for IC and FFs |



| 4) Vehicle Crash (ICEV and EV with entrapment)<br>based on NFPA statistics of U.S., with 17 vehicle fire per hour and 287,000 vehicle fires per year | | |
|---|---|---|
| **Essential Details** | **Additional Challenges** | **Emergency-Responder / CPS Enhancements** |
| • Two car MVA with electric pole<br>• Open two-lane roadway<br>• Daytime rainy weather<br>• Rush hour<br>• Mid-sized suburban FD | • One vehicle is an ICE<br>• One is EV with entrapment<br>• ICE vehicle smoking, fire threat<br>• Wires down in vicinity | <u>**Near-Term**</u><br>⊖ Initial use of vehicle telematics<br>⊖ Coordination of dispatch data<br><br>⌛ Real-time crash status updates<br>⌛ Real-time weather data<br>⌛ Real-time use of traffic data<br>⌛ Real-time use of terrain data<br>⌛ Clarify electric utility power<br>⌛ Clarify extrication cut-points<br><br>⇔ FF display using google glasses<br>⇔ Same info available for IC and FFs<br>⇔ Access personal medical info |
| | | <u>**Longer-Term**</u><br>⊖ Advanced use of vehicle telematics<br>⊖ Advanced use of dispatch data<br><br>⌛ Advanced crash status updates<br>⌛ Advanced electric utility power use<br>⌛ Update of extrication cut-points<br><br>⇔ Enhanced incident command<br>⇔ Augmented reality for FFs<br>⇔ Advanced use of medical data<br>⇔ Advanced info for IC and FFs |


**5) Train Derailment (with fire and toxic hazmat)**
based on Lac-Mégantic Train Derailment, June 2012 in Quebec (with 47 civilian fatalities and 30 buildings destroyed)

| Essential Details | Additional Challenges | Emergency-Responder / CPS Enhancements |
|---|---|---|
| • Freight train derailment w/ hazmat<br>• Three petroleum cars on fire<br>• Another car releasing toxic gas<br>• Type of gas (green) unknown<br>• In center of small rural town | • Immediate evacuation required<br>• Train crew location unknown<br>• Occupants nearby not known<br>• Volunteer FD w/ limited resources<br>• Mass Casualty Event<br>• High profile media event | **Near-Term**<br>⊖ Locator sensors on FFs<br>⊖ Initial UAV deployed sensors<br><br>Ξ Real-time analysis of train cargo<br>Ξ Real-time fire status updates<br>Ξ Predictions of fire/toxic-gas spread<br>Ξ Real-time weather data<br>Ξ Real-time terrain data<br>Ξ Real-time use of traffic data<br><br>⇔ FF location/situational awareness<br>⇔ FF display using google glasses<br>⇔ Basic use of evacuation model |
| | | **Longer-Term**<br>⊖ Advanced sensors on FFs<br>⊖ Deployment of sensors on all equip<br>⊖ Multiple UAV deployed sensors<br>⊖ Use of building data<br>⊖ Use of community utility data<br>⊖ Advanced environmental data<br><br>Ξ Real-time analysis of train cargo<br>Ξ Predictions of fire/toxic-gas spread<br>Ξ Reliable predictions of fire spread<br>Ξ Physiological monitoring of FFs<br>Ξ Optimization of evacuation routing<br><br>⇔ Enhanced incident command<br>⇔ Augmented reality for FFs<br>⇔ Coordination of FF location<br>⇔ Advanced use of medical data<br>⇔ Advanced info for IC and FFs |

**6) Hi-Challenge Warehouse**
based on Food Product Warehouse, December 2007 in Hemingway SC (with 2-day fire and warehouse destroyed)

| Essential Details | Additional Challenges | Emergency-Responder / CPS Enhancements |
|---|---|---|
| • Industrial warehouse fire<br>• Storage of general housewares<br>• Automatic retrieval system<br>• On-site industrial fire brigade<br>• Back-up by large metro FD | • Very high ceilings (125 ft)<br>• Very narrow aisles (5 ft)<br>• Large building footprint (100'x500')<br>• Full in-rack & ceiling sprinklers<br>• Fire at high level in back section<br>• Unable to pinpoint fire location | **Near-Term**<br>⊖ Field deployment of sensors<br>⊖ Real-time monitoring of fire pumps<br>⊖ Coordination of existing FF sensors<br>⊖ Coordination of dispatch data<br>⊖ Initial use of building utility data<br><br>Ξ Real-time fire status updates<br>Ξ Real-time use of bldg contents data<br>Ξ Real-time weather data<br>Ξ Real-time use of water supply data<br><br>⇔ FF location/situational awareness<br>⇔ FF display using google glasses<br>⇔ Same info available for IC and FFs |
| | | **Longer-Term**<br>⊖ Advanced use of field sensors<br>⊖ Use of interior UAVs<br>⊖ Advanced use of building data<br>⊖ Advanced use of utility data<br><br>Ξ Reliable predictions of fire spread<br>Ξ Physiological monitoring of FFs<br>Ξ Advanced use of building data<br>Ξ Advanced use of public utility data<br><br>⇔ Enhanced incident command<br>⇔ Augmented reality for FFs<br>⇔ Coordination of FF location<br>⇔ Advanced use of medical data<br>⇔ Advanced info for IC and FFs |

| 7) Night Club Code Compliance<br>based on Happyland Social Club Fire, March 1990 in NYC (with 87 civilian fatalities) and<br>Station Nightclub Fire, February 2003 in West Warwick RI (with 100 civilian fatalities) | | |
|---|---|---|
| **Essential Details** | **Additional Challenges** | **Emergency-Responder / CPS Enhancements** |
| • Large influx of refugee population<br>• Closed illegal dance clubs 3 times<br>• Each time illegally opens elsewhere<br>• Different people involved<br>• Inner neighborhood in major city | • Refugees ignore authority (via fear)<br>• Not understanding of building laws<br>• Lack of appreciation for safety<br>• Mass Casualty Event<br>• High profile media event | **Near-Term**<br>⊖ Initial use of population data<br>⊖ Initial use of demographic trends<br>⊖ Use of building data<br>⊖ Use of community utility data<br><br>Ξ Basic model of code trends<br>Ξ Initial access to latest codes<br>Ξ Use of code enforcement history<br><br>⇔ Portable access of all data<br>⇔ Initial use of social media |
| | | **Longer-Term**<br>⊖ Advanced use of population data<br>⊖ Advanced use of demographic data<br>⊖ Advanced use of building data<br>⊖ Advanced use of utility data<br><br>Ξ Advanced model of code trends<br>Ξ Optimization of best approach<br>Ξ Advanced access to latest codes<br>Ξ Advanced use of code history<br><br>⇔ Portable processing of all data<br>⇔ Advanced use of social media |


| 8) Tornado<br>based on Joplin Tornado, May 2011 in Joplin MO (with 158 civilian fatalities and ~$2.8 billion loss) and<br>Moore Tornado, May 2013 in Moore OK (with 25 civilian fatalities and ~$2.0 billion loss) | | |
|---|---|---|
| **Essential Details** | **Additional Challenges** | **Emergency-Responder / CPS Enhancements** |
| • F-4 Tornado strikes mid-sized city<br>• Occurs at 3 am<br>• Well staffed FD | • Hits residential area<br>• Directly hits hospital<br>• Little warning<br>• Damage significant<br>• Mass Casualty Event<br>• High profile media event | **Near-Term**<br>⊖ Early mass notification warning<br>⊖ Locator sensors on FFs<br>⊖ Initial UAV deployed sensors<br>⊖ Monitoring of public utilities<br>⊖ Field deployment of sensors<br>⊖ Deployment of sensors on all equip<br>⊖ Initial use of UAV sensors<br><br>Ξ Real-time fire status updates<br>Ξ Real-time weather data<br>Ξ Real-time terrain data<br>Ξ Real-time use of traffic data<br>Ξ Real-time damage assessments<br>Ξ Identify & track missing victims<br><br>⇔ FF display using google glasses<br>⇔ Same info available for IC and FFs<br>⇔ Access personal medical info |
| | | **Longer-Term**<br>⊖ Advanced sensors on FFs<br>⊖ Deployment of sensors on all equip<br>⊖ Multiple UAV deployed sensors<br>⊖ Use of building data<br>⊖ Use of community utility data<br>⊖ Advanced mass notification<br>⊖ Multiple UAV deployed sensors<br><br>Ξ Reliable predictions of damage<br>Ξ Optimization of evacuation routing<br>Ξ Advanced damage assessments<br>Ξ Advanced tracking of victims<br><br>⇔ Enhanced incident command<br>⇔ Augmented reality for FFs<br>⇔ Access personal medical info |

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**FPRF Website: www.nfpa.org/foundation**


THE
FIRE PROTECTION
RESEARCH FOUNDATION


engineering laboratory
Cyber-Physical Systems and Fire Research at the National Institute of Standards and Technology (NIST)
Smart Fire Fighting Workshop
March 24, 2014
Howard Harary, Acting Director
Engineering Laboratory


NIST: Basic Stats and Facts
A non-regulatory agency within the Dept. of Commerce
2800 federal employees, 2600 associates & facilities users/yr
Composed of four labs and three centers:
– Physical Measurement Laboratory
– Material Measurement Laboratory
– Engineering Laboratory
– Information Technology Laboratory
– Center for Nanoscale Science and Technology
– Center for Neutron Research
– Center for Advanced Communications
Gaithersburg, MD
Boulder, CO


NIST's Engineering Laboratory (EL) Mission
To promote U.S. innovation and industrial competitiveness in areas of critical national priority by anticipating and meeting the measurement science and standards needs for technology-intensive manufacturing, construction, and cyber-physical systems in ways that enhance economic prosperity and improve the quality of life.
Expanded National Fire Research Lab
Site photo (Feb. 2014)


EL Strategic Goals
Measurement Science and Standards for:
1. Smart Manufacturing, Construction and Cyber-Physical Systems
2. Sustainable and Energy-Efficient Manufacturing, Materials and Infrastructure
3. Disaster-Resilient Buildings, Infrastructure and Communities
CPS
Fire Fighting & Fire Protection Engineering
Smart Firefighting


What are Cyber-Physical Systems?
Massive integrated wireless networks, advanced sensors, 3D simulations, and cloud services that enable a new generation of Smart Systems

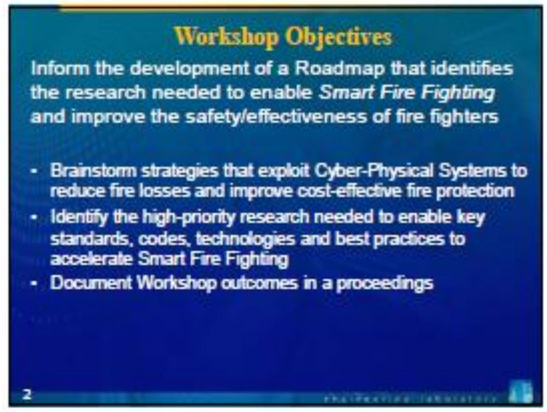

A Little Historical Perspective
Physical Systems
Cyber Systems
Cyber Physical Systems
Industrial Revolution
Internet Revolution
Industrial Internet Revolution
1700
1750
1800
1950
2000
Year


NIST is invested in CPS
Smart Grid - linking information technologies with the electric power grid - to provide "electricity with a brain"
Smart Grid Interoperability Panel (SGIP)
13 Smart Grid projects including:
– Smart Grid Communication Networks Precision Timing
– Smart Grid Systems
– Smart Grid System Testbed Facility


NIST is Invested in Fire Research
Fire research at NIST began in1904 with standardization of fire hose couplings
Today, 2 major programs and 20+ projects are working to Reduce the Risk of Fire in Buildings and Communities


Thank You
For Your Participation!


engineering laboratory
Cyber-Physical Systems (CPS) and Fire Fighting
Smart Fire Fighting Workshop
March 24-25, 2014
Anthony Hamins, Nelson Bryner, Chris Overholt, Dan Madrzykowski, Craig Weinschenk
National Institute of Standards and Technology (NIST)

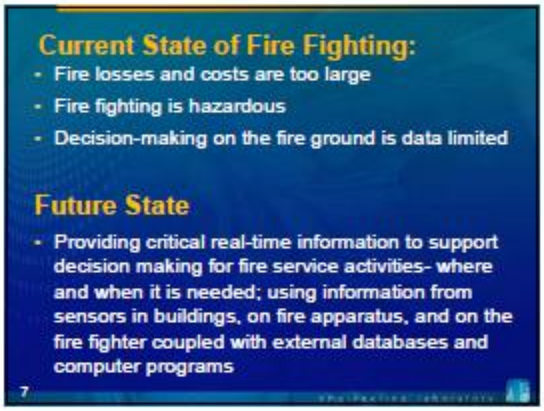

Workshop Objectives
Inform the development of a Roadmap that identifies the research needed to enable Smart Fire Fighting and improve the safety/effectiveness of fire fighters
Brainstorm strategies that exploit Cyber-Physical Systems to reduce fire losses and improve cost-effective fire protection
Identify the high-priority research needed to enable key standards, codes, technologies and best practices to accelerate Smart Fire Fighting
Document Workshop outcomes in a proceedings
2

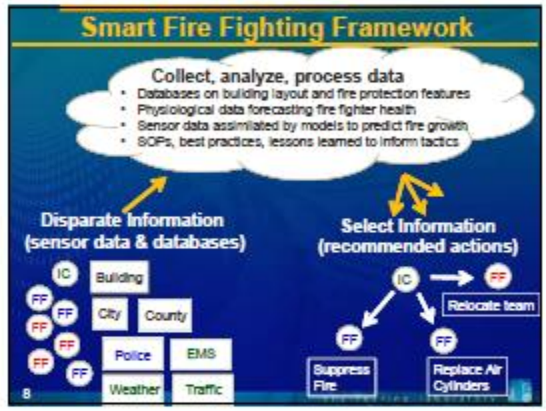

Penn
Palantir
SKIDMORE
IAFC
DARPA
SIEMENS
NIOSH
NOTIFIER
The National Association of STATE FIRE MARSHALS
UNIVERSITY OF MARYLAND
WPI
VT
NASA
ESRI
UMBC
NIST
3


Response to the 2007 Witch Creek Fire
San Diego, CA
4


Response to a residential fire
October 2012, East St. Louis, IL
FIREVIDEOS.NET
5

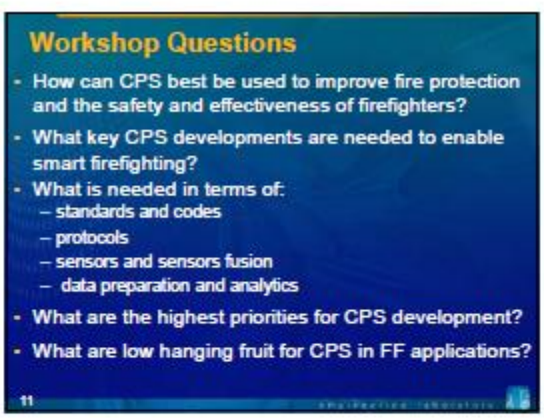

Existing Independent Systems
Firefighter
Radio
PASS alarms
Thermal imaging cameras
SCBA cylinder pressure and alarm
Firefighter locators
Health monitoring
Accountability systems
Building
Fire detection
Fire suppression
CO monitoring
Building energy
Activity sensors
BIM
Fire Apparatus
Computer aided dispatch
Building preplans
Resource management
GPS routing, maps
Nearest hospital
Nearest hydrant
There are lots of different systems, but are they interoperable?
How can we make them work better together?
6


Current State of Fire Fighting:
Fire losses and costs are too large
Fire fighting is hazardous
Decision-making on the fire ground is data limited
Future State
Providing critical real-time information to support decision making for fire service activities- where and when it is needed; using information from sensors in buildings, on fire apparatus, and on the fire fighter coupled with external databases and computer programs
7

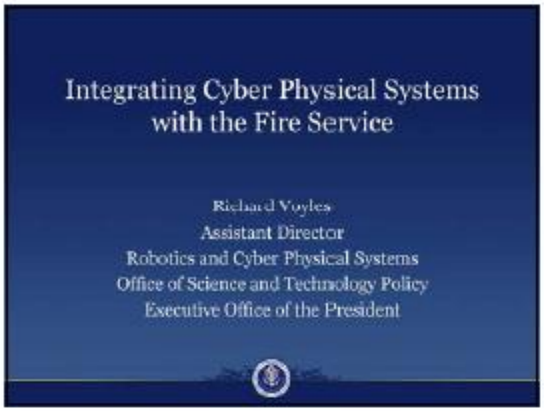

Smart Fire Fighting Framework
Collect, analyze, process data
Databases on building layout and fire protection features
Physiological data forecasting fire fighter health
Sensor data assimilated by models to predict fire growth
SOPs, best practices, lessons learned to inform tactics
Disparate Information (sensor data & databases)
Select Information (recommended actions)
IC
FF
Building
City
County
Police
EMS
Weather
Traffic
Relocate team
Suppress Fire
Replace Air Cylinders
8


Traditional Smart Fire Fighting Paradigm Shift
From:
To:
Information-limited decision making
Global information-rich decision making
Lack of awareness
Situational Awareness
Untapped/unavailable data
Data collection, analysis & communication
Tradition-based tactics
Data-driven physics-based tactics
Isolated equipment and building elements
Interconnected equipment and building monitoring, data, and control systems
Human operations
Human controlled & automated operations
9

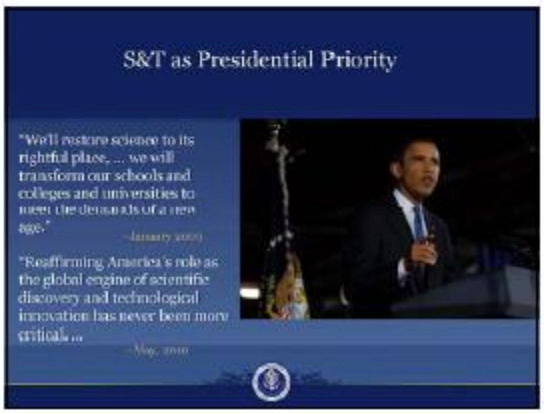

Emerging Technologies and Fire Fighting
Smart Clothing
Information-enriched reality
Google glasses
Situational Awareness
Autonomous vehicles
Real-time data from distributed sources
Robotics
Smartphone Apps
NY 311 Noise Map
Satellite information
UAVs
"Urban Science" Big Data analytics
Fully interoperable equipment
BACnet
10


Workshop Questions
How can CPS best be used to improve fire protection and the safety and effectiveness of firefighters?
What key CPS developments are needed to enable smart firefighting?
What is needed in terms of:
– standards and codes
– protocols
– sensors and sensors fusion
– data preparation and analytics
What are the highest priorities for CPS development?
What are low hanging fruit for CPS in FF applications?
11


engineering laboratory
Thank You
NIST
12

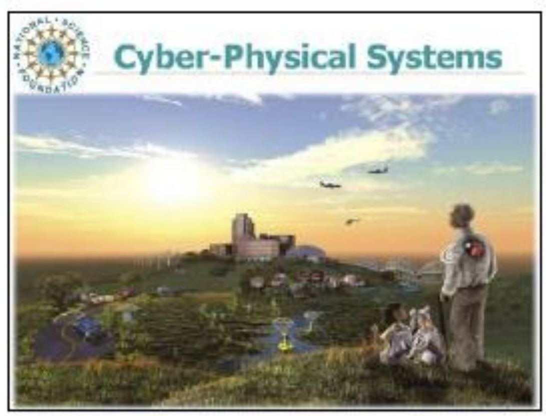

Integrating Cyber Physical Systems with the Fire Service
Richard Voyles
Assistant Director
Robotics and Cyber Physical Systems
Office of Science and Technology Policy
Executive Office of the President


White House
Office of Science and Technology Policy
PCAST Co-Chairs with POTUS
John P. Holdren
• Science and technology for policy
• Policy for science and technology

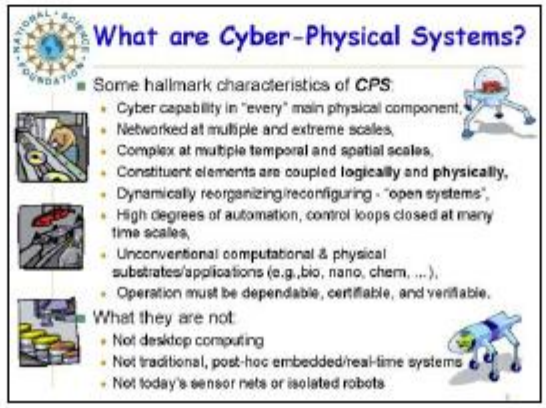

S&T as Presidential Priority
"We'll restore science to its rightful place, ... we will transform our schools and colleges and universities to meet the demands of a new age."
"Reaffirming America's role as the global engine of scientific discovery and technological innovation has never been more critical, ...

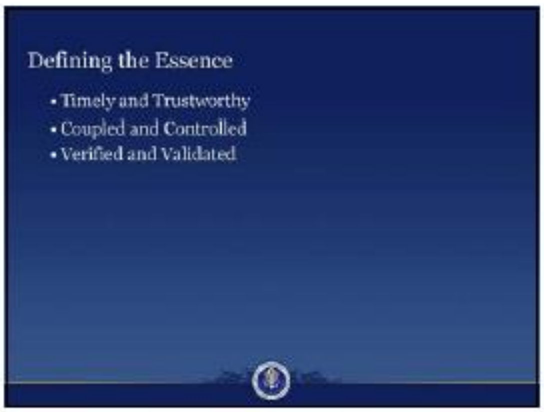

PCAST Report 2007
NIT SYSTEMS CONNECTED WITH THE PHYSICAL WORLD


Recent OSTP led R&D Initiatives
• Advanced Manufacturing
• Robotics
• US IGNITE
• Big Data
• STEM Education
• Open Data
• Materials Genome
• Grand Challenges
• Prizes
CPS inside

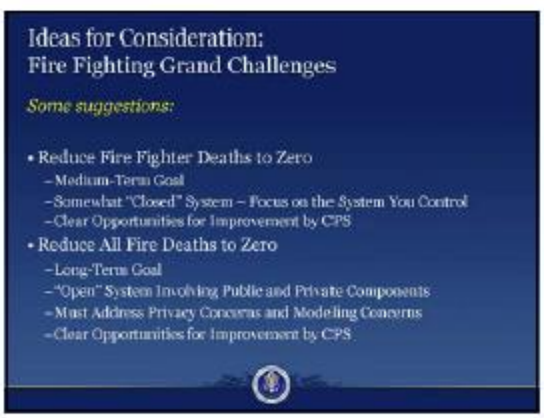

Cyber-Physical Systems


What are Cyber-Physical Systems?
Cyber – computation, communication, and control that are discrete, logical, and switched
Physical – natural and human-made systems governed by the laws of physics and operating in continuous time
Cyber-Physical Systems – systems in which the cyber and physical are tightly integrated at all scales and levels
Change from cyber, which is merely appliquéd on physical
Change from physical, with COTS "computing as parts" mindset
Change from ad hoc to grounded, assured development


What are Cyber-Physical Systems?
Some hallmark characteristics of CPS:
Cyber capability in "every" main physical component,
Networked at multiple and extreme scales,
Complex at multiple temporal and spatial scales,
Constituent elements are coupled logically and physically,
Dynamically reorganizing/reconfiguring - "open systems",
High degrees of automation, control loops closed at many time scales,
Unconventional computational & physical substrates/applications (e.g.,bio, nano, chem, ...),
Operation must be dependable, certifiable, and verifiable.
What they are not:
Not desktop computing
Not traditional, post-hoc embedded/real-time systems
Not today's sensor nets or isolated robots

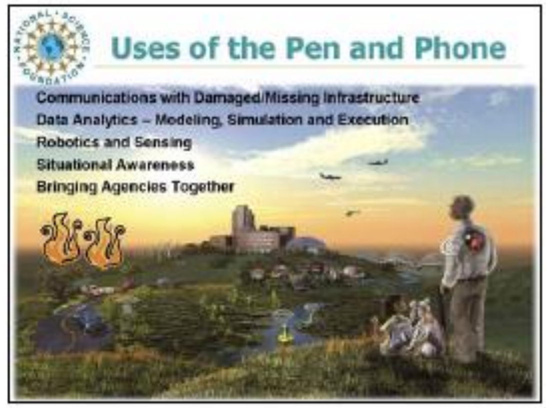

Defining the Essence
• Timely and Trustworthy
• Coupled and Controlled
• Verified and Validated


Systems at Multiple Scales
A BMW is "now actually a network of computers"
Autonomous Cars
Smart Infrastructure
Cars as nodes in a network
Lampson's Grand Challenge:
Reduce traffic deaths to zero


Ideas for Consideration:
Fire Fighting Grand Challenges
Some suggestions:
• Reduce Fire Fighter Deaths to Zero
– Medium-Term Goal
– Somewhat "Closed" System – Focus on the System You Control
– Clear Opportunities for Improvement by CPS
• Reduce All Fire Deaths to Zero
– Long-Term Goal
– "Open" System Involving Public and Private Components
– Must Address Privacy Concerns and Modeling Concerns
– Clear Opportunities for Improvement by CPS


Forbes
The Industrial Internet: Like Facebook For Things


Challenges for the CPS community
(Applicable to this FF Workshop, too)
CPS inside
• Better communicate challenges
• Develop strategy and mechanisms for university-industry partnership
• Develop technology roadmap
• Identify challenges and prizes


Uses of the Pen and Phone
Communications with Damaged/Missing Infrastructure
Data Analytics – Modeling, Simulation and Execution
Robotics and Sensing
Situational Awareness
Bringing Agencies Together


Other OSTP Staff interested in CPS
• Cristin Dorgelo, Assistant Director, Challenges
• Alex Slocum, Assistant Director, Advanced Manufacturing
• Nick Maynard, Senior Advisor, Small Business
• Tom Kalil, Deputy Director


National Institute of Standards and Technology
NIST
Smart Fire Fighting
"Where Big Data and Fire Service Unite"
NFPA
National Fire Protection Association
The authority on fire, electrical, and building safety

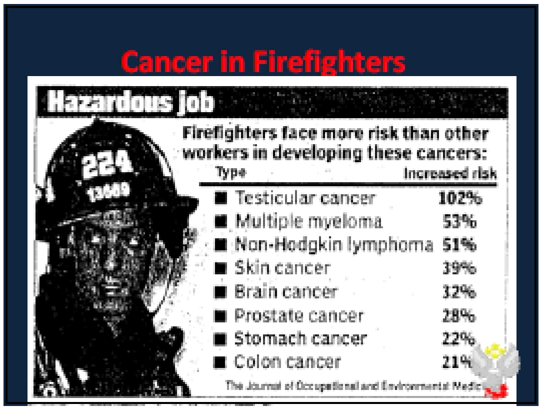

Where Are We Now
Where Are We Going?
FEMA

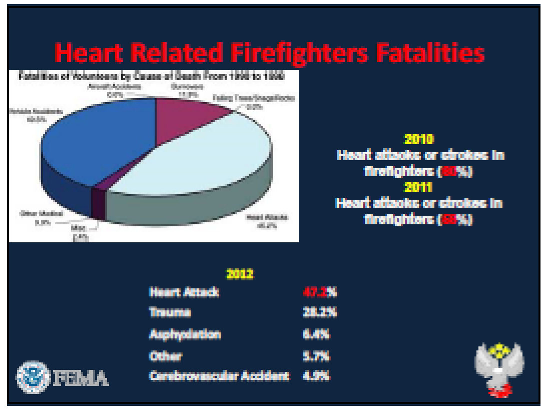

Now
It's Complicated
WARNING
CONTENTS OF THIS HELMET IS UNDER EXTREME PRESSURE!
FEMA

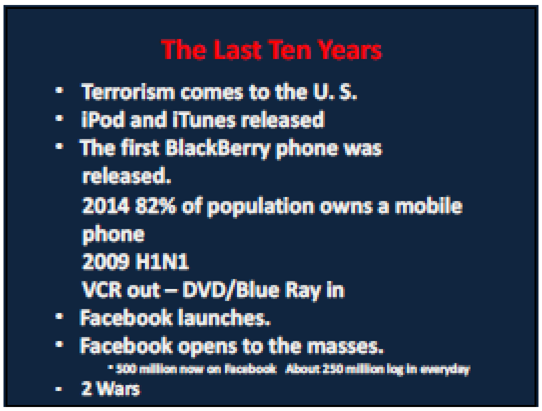

Climate Change
Social Media
The Boomers Are Coming
Cyber Intrusions
Active Shooter
Firefighter
Cancer
Flashovers
Loss of volunteer firefighters
Firefighter Health Risks
Sleep Deprivation
Emotional Issues
Substance Abuse
Infectious Disease
The New "Normal"
Substance Abuse
Bed Bugs
Lack of Capital Investments
Heart Related Firefighters Fatalities
FEMA

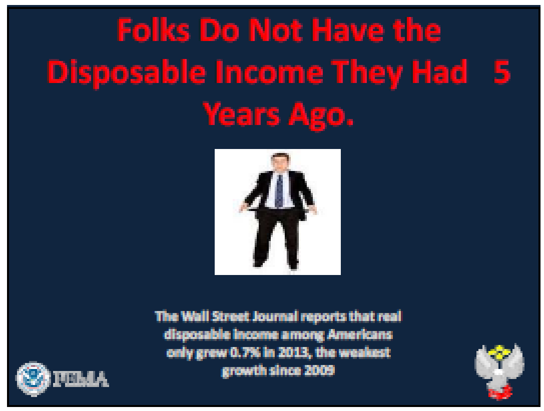

Active Shooter
More than 900 people died in mass shootings in the past 7 years.
A majority of them were killed by people they knew,
USA TODAY analysis.
FEMA


New Norm?
4 firefighters shot, 2 killed at Webster, N.Y
Police: Man killed after taking firefighters hostage in suburban Atlanta
FEMA


Cancer in Firefighters
Hazardous job
Firefighters face more risk than other workers in developing these cancers:
Type Increased risk
Testicular cancer 102%
Multiple myeloma 53%
Non-Hodgkin lymphoma 51%
Skin cancer 39%
Brain cancer 32%
Prostate cancer 28%
Stomach cancer 22%
Colon cancer 21%
The Journal of Occupational and Environmental Medic

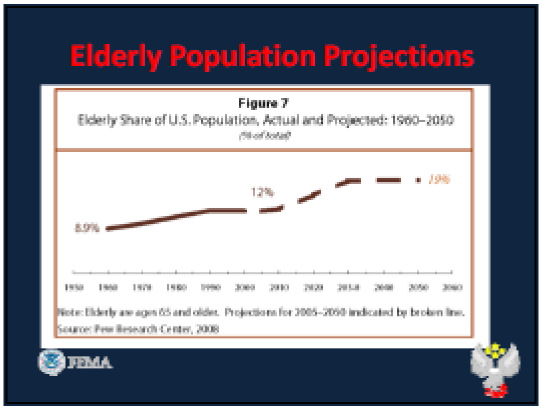

Heart Related Firefighters Fatalities
2010
Heart attacks or strokes in firefighters
2011
Heart attacks or strokes in firefighters
2012
Heart Attack 47.2%
Trauma 28.2%
Asphyxiation 6.4%
Other 5.7%
Cerebrovascular Accident 4.9%
FEMA

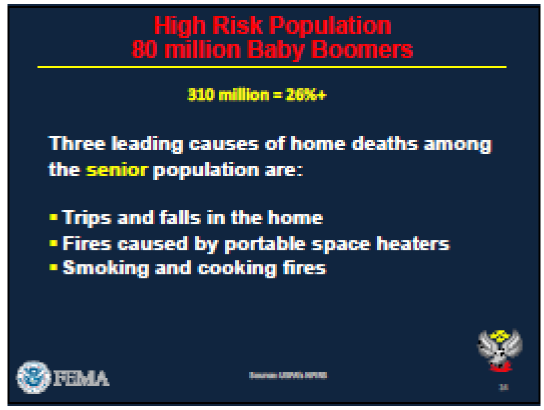

The Last Ten Years
Terrorism comes to the U. S.
iPod and iTunes released
The first BlackBerry phone was released.
2014 82% of population owns a mobile phone
2009 H1N1
VCR out – DVD/Blue Ray in
Facebook launches.
Facebook opens to the masses.
500 million now on Facebook About 250 million log in everyday
2 Wars

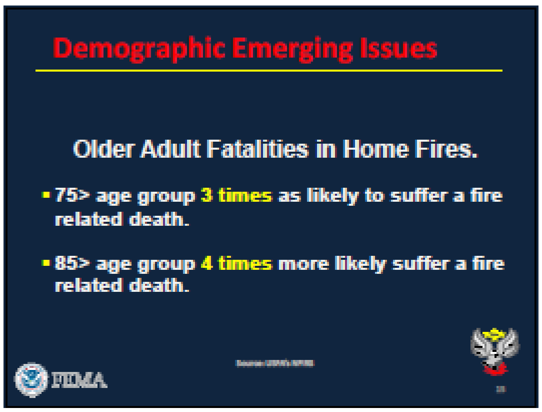

Folks Do Not Have the Disposable Income They Had 5 Years Ago.
The Wall Street Journal reports that real disposable income among Americans only grew 0.7% in 2013, the weakest growth since 2009
FEMA


There's no longer an "Average American."
FEMA


Boomers
FEMA


Elderly Population Projections
Figure 7
Elderly Share of U.S. Population, Actual and Projected: 1960–2050
8.9%
12%
19%
Note: Elderly are ages 65 and older. Projections for 2005–2050 indicated by broken line.
Source: Pew Research Center, 2008
FEMA


High Risk Population
80 million Baby Boomers
310 million = 26%+
Three leading causes of home deaths among the senior population are:
Trips and falls in the home
Fires caused by portable space heaters
Smoking and cooking fires
FEMA


Demographic Emerging Issues
Older Adult Fatalities in Home Fires.
75> age group 3 times as likely to suffer a fire related death.
85> age group 4 times more likely suffer a fire related death.
FEMA


Future
FEMA


Forward to the Future
Forecasting –– It Isn't Easy
The Future
Wilbur Wright, co-inventor of the airplane, quoted in 1901
"Man will not fly for 50 years."
Orville and Wilbur First Successful Flight
December 17, 1903

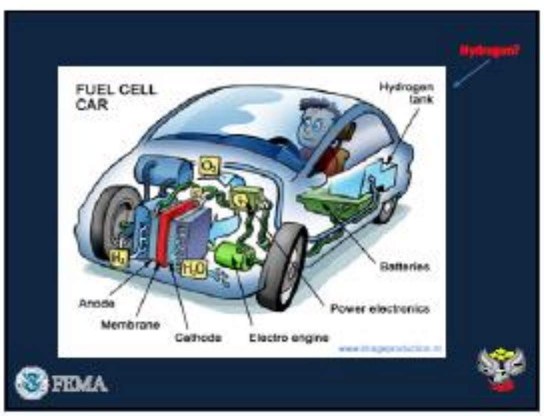

Green Energy
FEMA


Wind Turbines
FEMA

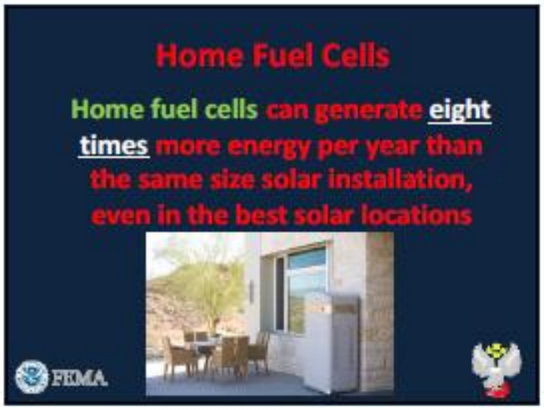

As of March 2014, there are more than 16 plug-in models available in the American market.
FEMA
http://www.evsafetytraining.org/


Driverless (Autonomous Vehicles)
Promise Seniors Independence
DC, FL, NV, CA,
Enacted pilot legislation
Other in committee etc.
Soon cars will drive themselves, greatly cutting accidents, traffic problems, fuel use, driving offences and highway costs.
FEMA

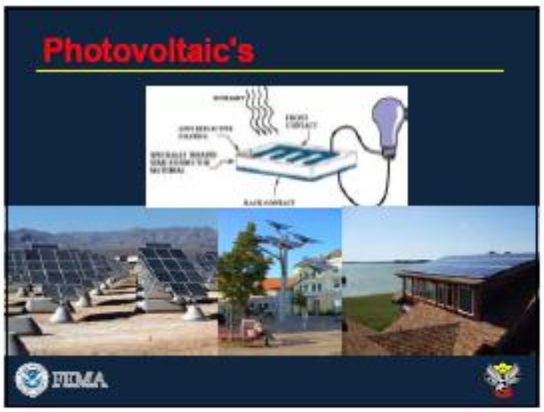

Fuel Cell Technology
It is not coming.
It is here.
FEMA


Hydrogen?
FUEL CELL CAR
Hydrogen tank
Batteries
Power electronics
Electro engine
Cathode
Membrane
Anode
FEMA

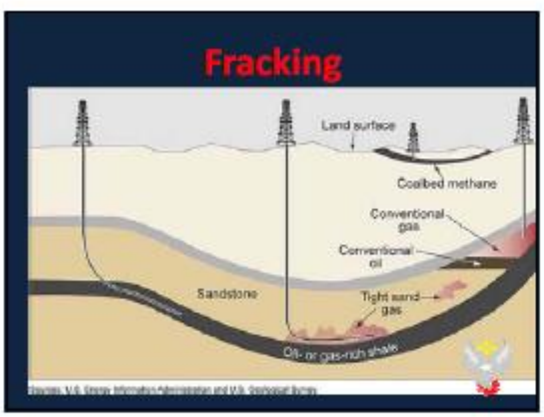

GSA Fuel Cell Powered Vehicles Currently on the Road in California
May 28, 2013
Berkley 150
City of LA 1388
Fremont 17
Long Beach 216
Oakland 187
Orange County 987
Riverside 39
Sacramento 876
San Bernardino 38
San Francisco 677
San Jose 68
Ventura 33
Total 4672
FUEL CELL
FEMA

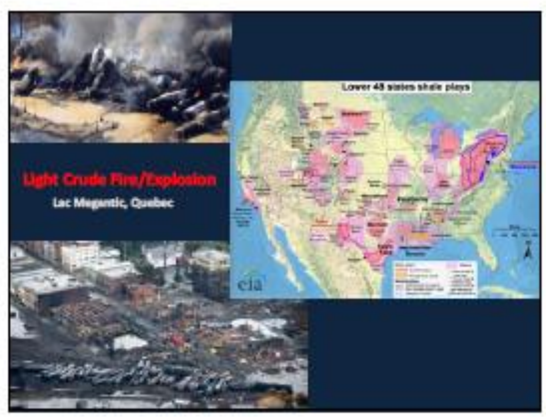

Home Fuel Cells
Home fuel cells can generate eight times more energy per year than the same size solar installation, even in the best solar locations
FEMA


HYDROGEN FACILITIES
Type of Facility
FEMA


Photovoltaic's
FEMA


Photovoltaic' s
Standards
NFPA
ICC

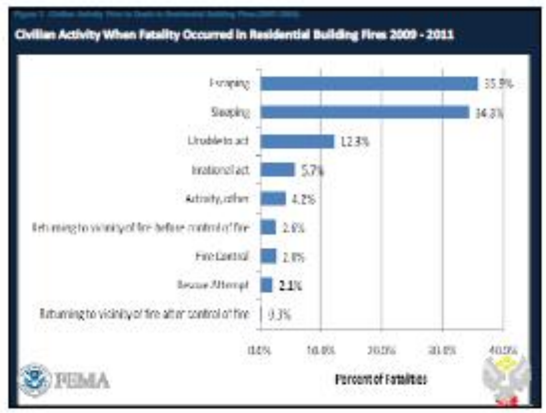

Fracking
Land surface
Coalbed methane
Conventional gas
Conventional oil
Sandstone
Tight sand gas
Oil- or gas-rich shale


Light Crude Fire/Explosion
Lac Megantic, Quebec
Lower 48 states shale plays
eia


Residential Fires Are Changing
Larger Homes
Open Home Geometries
Increased Fuel Loads
New Construction Materials
Faster fire propagation
Shorter time to flashover
Rapid changes in fire dynamics
Shorter escape times
Shorter time to collapse

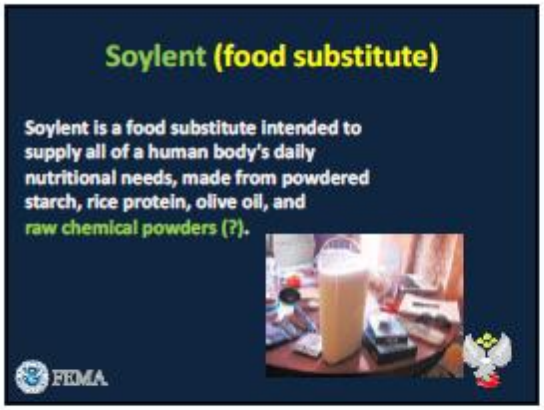

Rapid Fire Growth and Behavior in Occupied Buildings


Flashover Video


Civilian Activity When Fatality Occurred in Residential Building Fires 2009 - 2011
Sleeping
Fire Control
Rescue Attempt
12.3%
5.7%
4.2%
2.1%
FEMA
Percent of Fatalities


Drones
SHERIFF

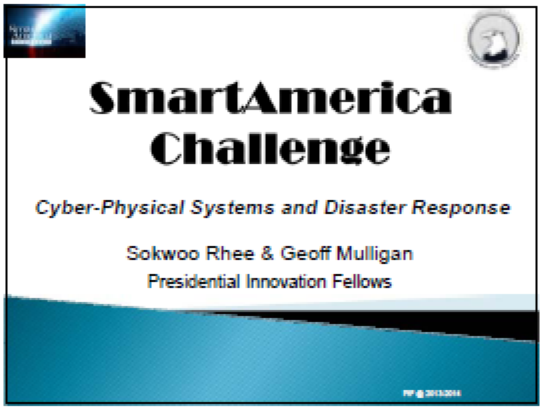

Swarm Robotics
Swarm Robotics is a multi robot system which consists of a large number of simple, physical autonomous robots.
FEMA

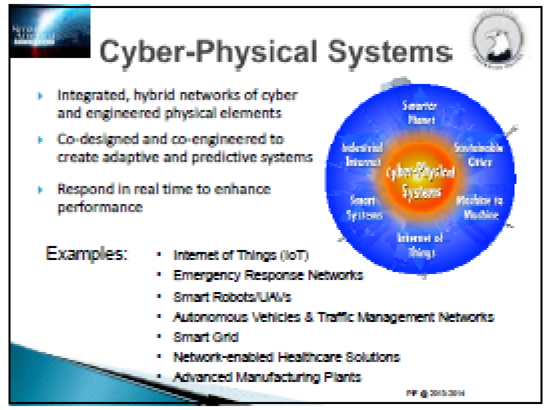

Soylent (food substitute)
Soylent is a food substitute intended to supply all of a human body's daily nutritional needs, made from powdered starch, rice protein, olive oil, and raw chemical powders (?).
FEMA

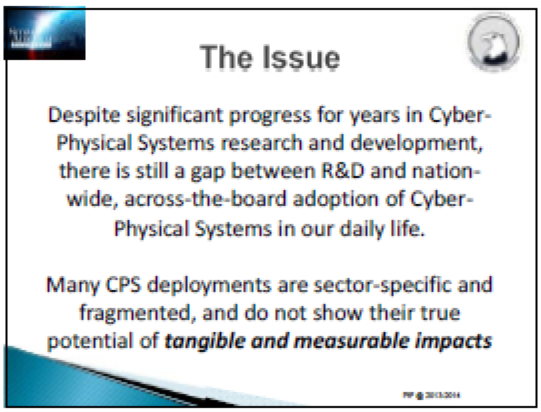

Organized in
Thought
Vision
Preparation
FEMA

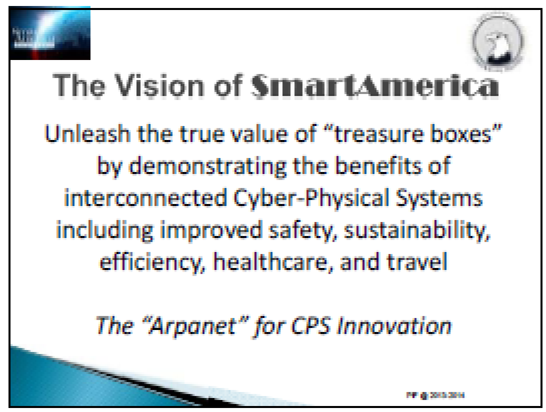

Stay Tuned
"When it comes to the future, there are three kinds of people:
• those who let it happen
• those who make it happen and
• those who wonder what happened."
John M. Richardson, Jr.
Professor, American University
FEMA

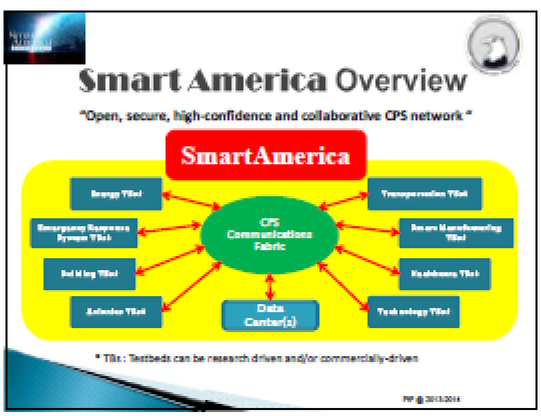

Thank You

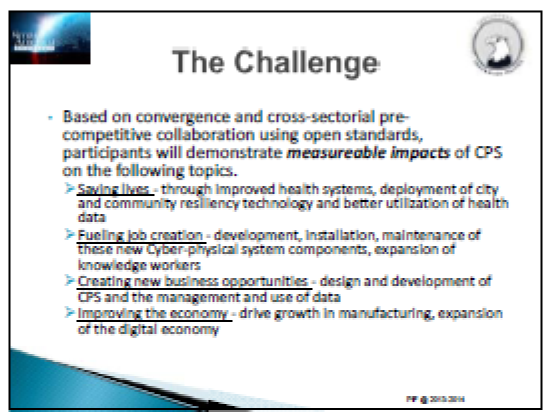

SmartAmerica Challenge
Cyber-Physical Systems and Disaster Response
Sokwoo Rhee & Geoff Mulligan
Presidential Innovation Fellows

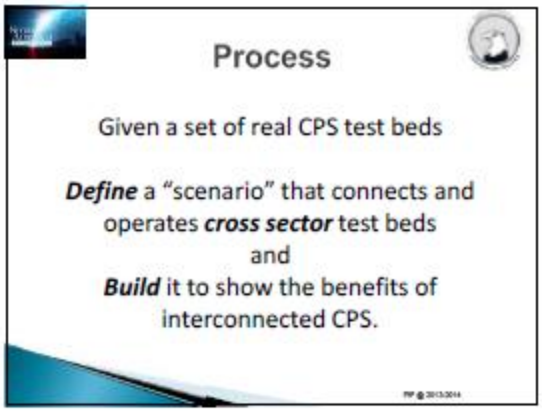

Cyber-Physical Systems
Integrated, hybrid networks of cyber and engineered physical elements
Co-designed and co-engineered to create adaptive and predictive systems
Respond in real time to enhance performance
Cyber-Physical Systems
Examples:
Internet of Things (IoT)
Emergency Response Networks
Smart Robots/UAVs
Autonomous Vehicles & Traffic Management Networks
Smart Grid
Network-enabled Healthcare Solutions
Advanced Manufacturing Plants


The Issue
Despite significant progress for years in Cyber-Physical Systems research and development, there is still a gap between R&D and nation-wide, across-the-board adoption of Cyber-Physical Systems in our daily life.
Many CPS deployments are sector-specific and fragmented, and do not show their true potential of tangible and measurable impacts


The Vision of SmartAmerica
Unleash the true value of "treasure boxes" by demonstrating the benefits of interconnected Cyber-Physical Systems including improved safety, sustainability, efficiency, healthcare, and travel
The "Arpanet" for CPS Innovation


Smart America Overview
"Open, secure, high-confidence and collaborative CPS network"
SmartAmerica
CPS Communications Fabric
Data Center(s)
* TBs : Testbeds can be research driven and/or commercially-driven

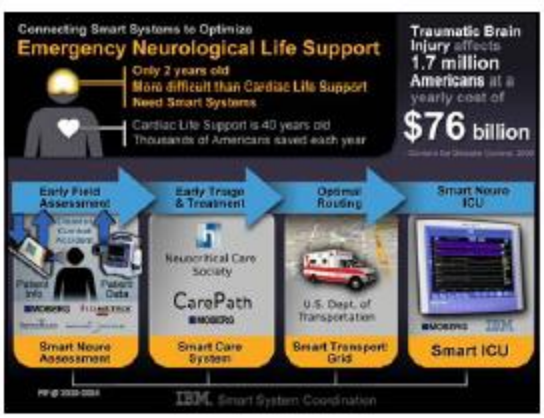

The Challenge
Based on convergence and cross-sectorial pre-competitive collaboration using open standards, participants will demonstrate measureable impacts of CPS on the following topics.
Saving lives - through improved health systems, deployment of city and community resiliency technology and better utilization of health data
Fueling job creation - development, installation, maintenance of these new Cyber-physical system components, expansion of knowledge workers
Creating new business opportunities - design and development of CPS and the management and use of data
Improving the economy - drive growth in manufacturing, expansion of the digital economy

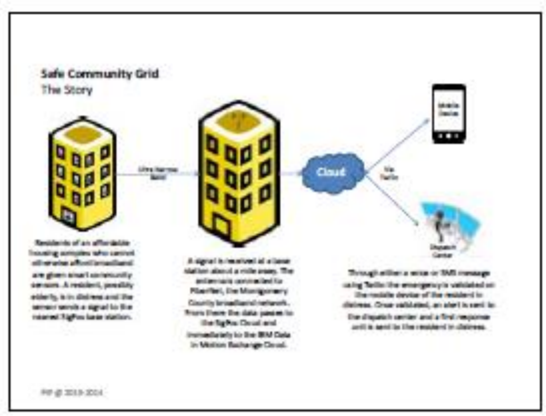

Process
Given a set of real CPS test beds
Define a "scenario" that connects and operates cross sector test beds
and
Build it to show the benefits of interconnected CPS.


Stakeholders
More than 100 organizations are currently participating in the Challenge
Multi Industry
– Auto, Health, Energy, Buildings, …
Multi Agency
– NIST, DoT, DoD, DHS, HHS, DoE, …
Key functions:
– First responders – e.g. Emergency Response, Robotics, Event Management
– Healthcare – e.g. Smart Hospitals
– Transportation – e.g. V2V and V2I, Autonomous Vehicles
– Utilities – e.g. Smart Grid
– Manufacturing – e.g. Smart manufacturing


Teams
23 team projects are currently running. Examples include:
Smart Emergency Response Systems
Emergency Neurological Life Support
Event Management for Smart Cities
Smart Roads
Public Safety for Smart Communities
Closed Loop HealthCare
Autonomous Vehicles working with hospital system
Transactive Energy
Smart Vehicle Communication
Smart Manufacturing
Smart Building Rooftops

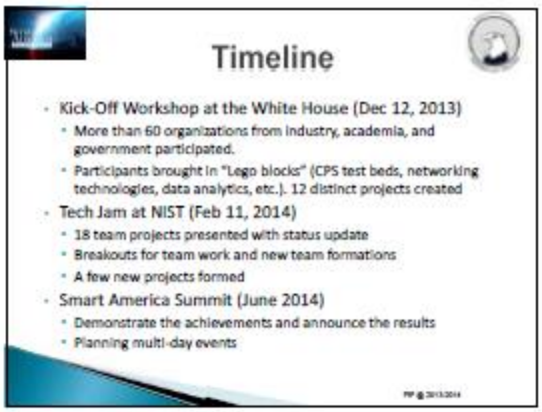

Smart Emergency Response Saves Lives
Mission Command
MathWorks


Connecting Smart Systems to Optimize
Emergency Neurological Life Support
Only 2 years old
More difficult than Cardiac Life Support
Need Smart Systems
Cardiac Life Support is 40 years old
Thousands of Americans saved each year
Traumatic Brain Injury affects 1.7 million Americans at a yearly cost of
$76 billion
Early Field Assessment
Early Triage & Treatment
Optimal Routing
Smart Neuro ICU
Neurocritical Care Society
CarePath
U.S. Dept. of Transportation
Smart Neuro Assessment
Smart Care System
Smart Transport Grid
Smart ICU
IBM Smart System Coordination


Safe Community Grid
The Story
Cloud


Closed Loop Healthcare:
Home to Hospital to Home
Patient data stored in the cloud
Family member accesses patient data from the cloud, sees reason to check in or seek medical treatment
Hospital accesses data from the cloud & adverse events are prevented using smarter technology in an integrated clinical environment (ICE)


SmartRoads
FORCES
mobile millennium
University of California, Berkeley
Vanderbilt University
Complex and interconnected road networks
World's largest traffic jam: 100+ Km/10+ days
Communication and Control:
Connected Corridors
High fidelity simulation software (C2WT)
Global web of critical IT infrastructure
Cyber vulnerabilities


Timeline
Kick-Off Workshop at the White House (Dec 12, 2013)
More than 60 organizations from industry, academia, and government participated.
Participants brought in "Lego blocks" (CPS test beds, networking technologies, data analytics, etc.). 12 distinct projects created
Tech Jam at NIST (Feb 11, 2014)
18 team projects presented with status update
Breakouts for team work and new team formations
A few new projects formed
Smart America Summit (June 2014)
Demonstrate the achievements and announce the results
Planning multi-day events

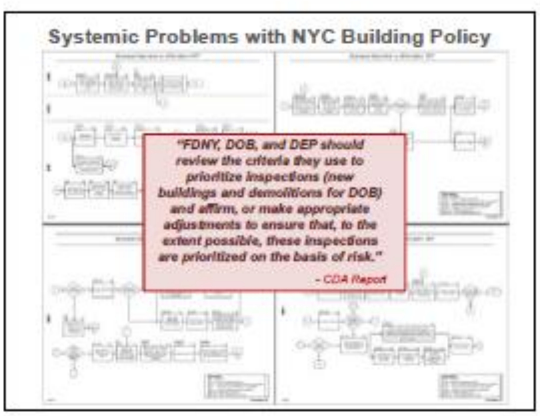

Contact Info
White House Presidential Innovation Fellows
Geoff Mulligan (geoff.mulligan@nist.gov)
Sokwoo Rhee (sokwoo.rhee@nist.gov)
SmartAmerica Challenge website
http://www.nist.gov/el/smartamerica.cfm
http://www.smartamerica.org/challenge/wiki

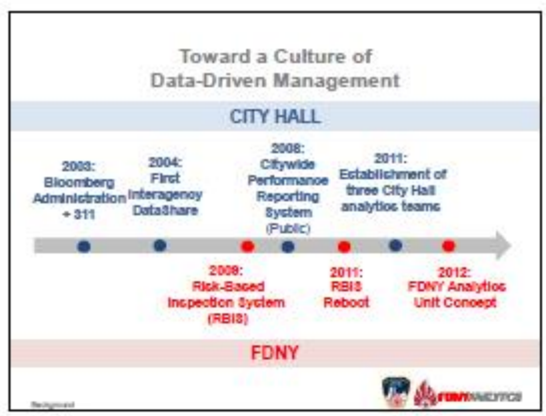

FireCast
Leveraging Data Science for Smart Fire Risk Mitigation
Fire Department of New York (FDNY)
Joe Woznica, Deputy Assistant Chief, Fire Prevention
Jeff Roth, Assistant Commissioner for Management Initiatives
Jeff Chen, Director of Analytics
Smart Fire Fighting Workshop
Washington, D.C.
March 24, 2014
FDNY ANALYTICS


ROAD MAP
• Overview
• Fire Risk + Operations
• Problem
• Implementation
FDNY ANALYTICS


Toward data-driven policy
FDNY ANALYTICS


The Deutsche Bank Fire (2007)
• In 2007 the Deutsche Bank building was in the process of being remediated and demolished
• Fire engulfed the building killing two firefighters
Overview
FDNY ANALYTICS


Systemic Problems with NYC Building Policy
"FDNY, DOB, and DEP should review the criteria they use to prioritize inspections (new buildings and demolitions for DOB) and affirm, or make appropriate adjustments to ensure that, to the extent possible, these inspections are prioritized on the basis of risk."
- CDA Report

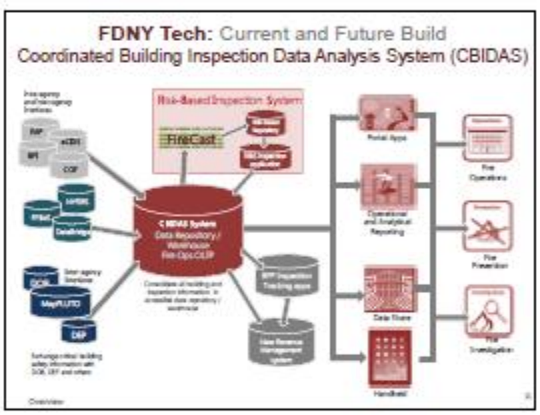

Toward a Culture of Data-Driven Management
CITY HALL
2003: Bloomberg Administration + 311
2004: First Interagency DataShare
2008: Citywide Performance Reporting System (Public)
2011: Establishment of three City Hall analytics teams
2009: Risk-Based Inspection System (RBIS)
2011: RBIS Reboot
2012: FDNY Analytics Unit Concept
FDNY
Background
FDNY ANALYTICS

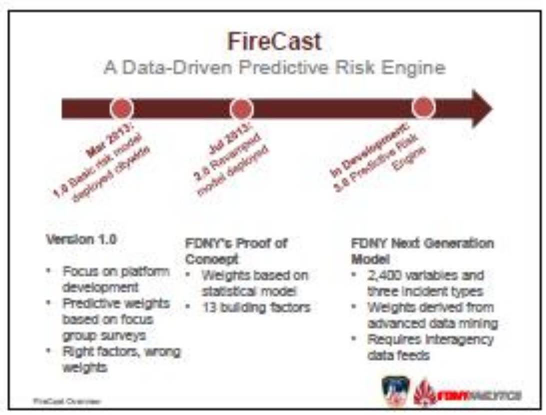

Leadership +Tech + Data = Opportunity
Organizational Change (Management Initiatives)
Modern Tech Platforms for Effective Ops
Cutting Edge Data-Driven Research (FDNY Analytics Unit)
Comprehensive and inclusive approach to driving performance
FDNY ANALYTICS

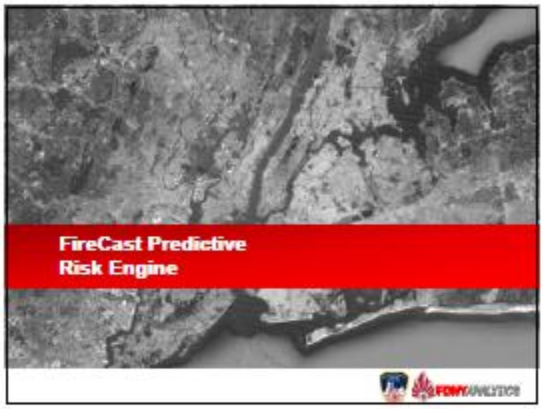

Risk Mitigation Philosophy
Fires will happen. It's just a matter of time. We need to get our units to inspect the buildings of highest risk so they're ready.
Overview
FDNY ANALYTICS

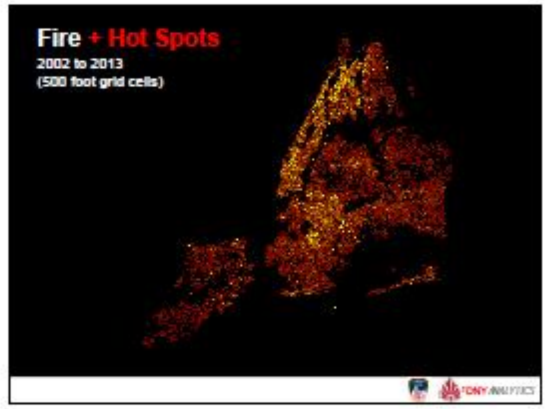

Considerations for Inspection Activities
330,000
# of buildings in inspection portfolio
10%
Expected proportion that will be inspected per year
3x3
Each company performs 3 hours of building inspections, 3 times per week
493,000
# of fire incidents per year (# of times an emergency could cut into building inspection time)
105
Heat index value at which inspection operations are suspended
Overview
FDNY ANALYTICS

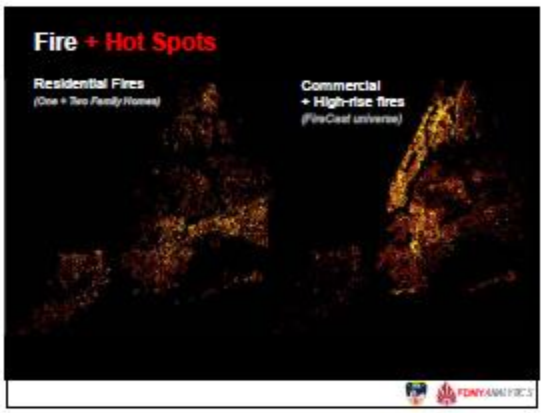

FDNY Tech
Pre-March 2013
Overview
FDNY ANALYTICS

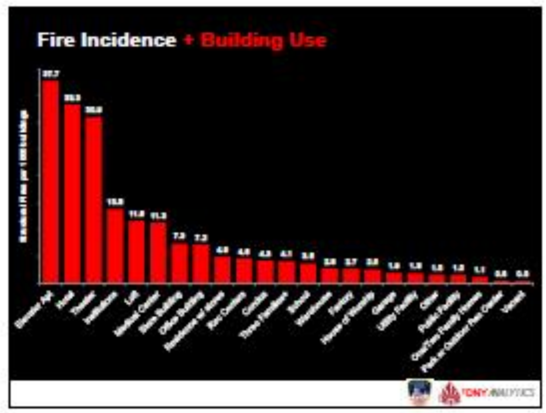

FDNY Tech: Current and Future Build
Coordinated Building Inspection Data Analysis System (CBIDAS)
Risk-Based Inspection System
FireCast
Portal Apps
Fire Operations
Operational and Analytical Reporting
Fire Prevention
Data Share
Handheld
Fire Investigation
Overview

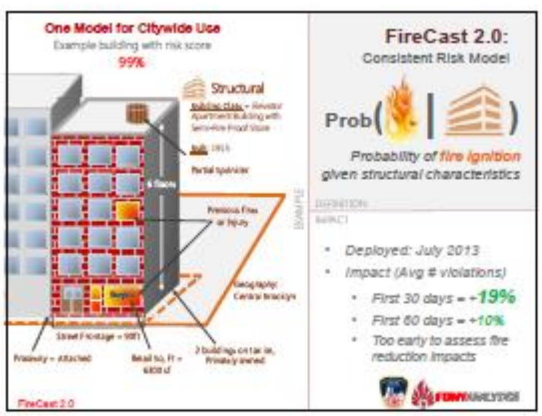

FireCast
A Data-Driven Predictive Risk Engine
Mar 2013: 1.0 Basic risk model deployed citywide
Jul 2013: 2.0 Revamped model deployed
In Development: 3.0 Predictive Risk Engine
Version 1.0
• Focus on platform development
• Predictive weights based on focus group surveys
• Right factors, wrong weights
FDNY's Proof of Concept
• Weights based on statistical model
• 13 building factors
FDNY Next Generation Model
• 2,400 variables and three incident types
• Weights derived from advanced data mining
• Requires interagency data feeds
FireCast Overview
FDNY ANALYTICS

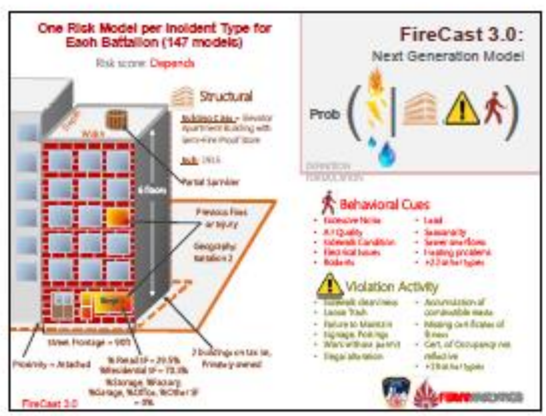

FireCast Predictive
Risk Engine

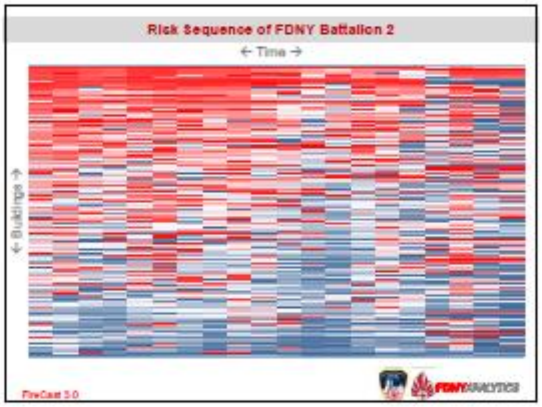

Fire + Hot Spots
2002 to 2013
(500 foot grid cells)


Fire + Hot Spots
Residential Fires
Commercial
+ High-rise fires


Fire Incidence + Building Use


One Model for Citywide Use
Example building with risk score
99%
Structural
FireCast 2.0:
Consistent Risk Model
Prob
Probability of fire ignition
given structural characteristics
Deployed: July 2013
Impact (Avg # violations)
First 30 days = +19%
First 60 days = +10%
Too early to assess fire reduction impacts
FireCast 2.0


One Risk Model per Incident Type for
Each Battalion (147 models)
Risk score: Depends
Structural
FireCast 3.0:
Next Generation Model
Prob
Behavioral Cues
Violation Activity
FireCast 3.0


Risk Sequence of FDNY Battalion 2
← Time →
← Buildings →
FireCast 3.0


Questions?
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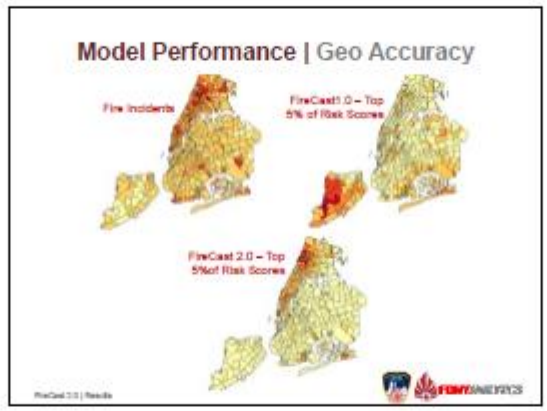
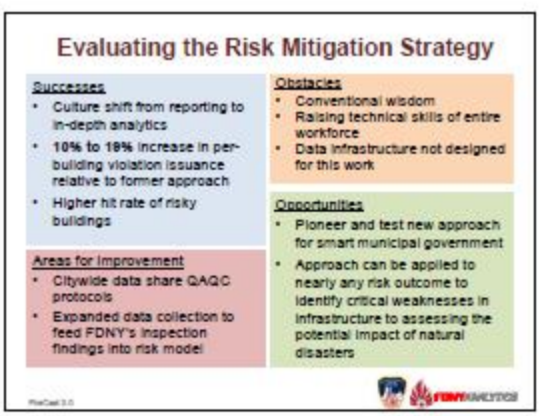
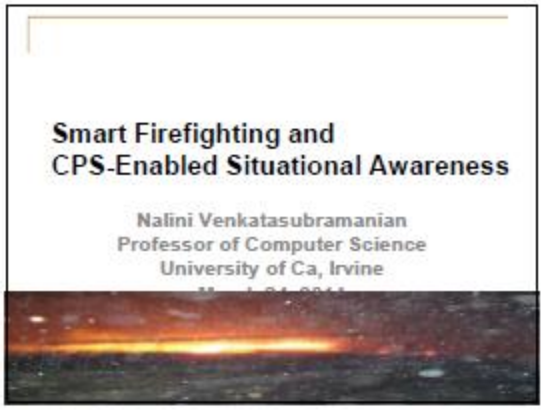
Joseph.Woznica@fdny.nyc.gov
Jeff Roth
Jeffrey.Roth@fdny.nyc.gov
Jeff Chen
Jeff.Chen@fdny.nyc.gov


Appendix


Model Performance | Geo Accuracy
Fire Incidents
FireCast1.0 – Top 5% of Risk Scores
FireCast 2.0 – Top 5%of Risk Scores

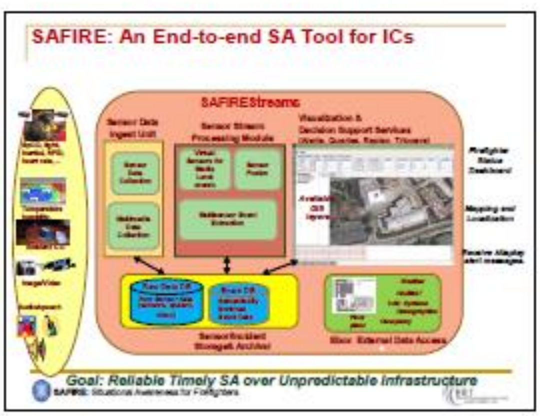

Evaluating the Risk Mitigation Strategy
Successes
Culture shift from reporting to in-depth analytics
10% to 19% increase in per-building violation issuance relative to former approach
Higher hit rate of risky buildings
Obstacles
Conventional wisdom
Raising technical skills of entire workforce
Data infrastructure not designed for this work
Areas for Improvement
Citywide data share QA/QC protocols
Expanded data collection to feed FDNY's inspection findings into risk model
Opportunities
Pioneer and test new approach for smart municipal government
Approach can be applied to nearly any risk outcome to identify critical weaknesses in infrastructure to assessing the potential impact of natural disasters

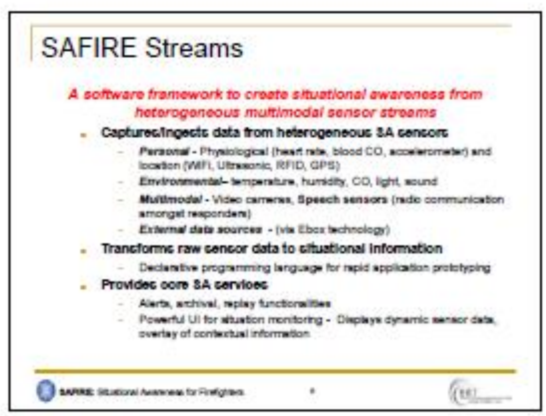

Smart Firefighting and
CPS-Enabled Situational Awareness
Nalini Venkatasubramanian
Professor of Computer Science
University of Ca, Irvine


The Team and Collaborators (over the years)
UC Irvine
SRI Inc.
Carolyn Talcott,Grit Denker, Minyoung Kim, Mark-Oliver Stehr, Murat Akbacak
UC San Diego
Ramesh Rao, B.S Manoj, Babak Jafarian, Ganz Chockalingam
Univ. of Bologna
Paolo Bellavista, Antonio Corradi, Luca Ioannaro
Caltech
Mani Chandy, Julian Bunn
ICSI
Nokia Research Labs
Deutsche Telecom Research
National Tsinghua University
Imagecat Inc
Paul Amyx, Charlie Huyck, Ron Eguchi
Deltin Corporation
Ron Cabrera
Government Agencies
County of LA Fire Dept.
Newport Beach Fire
Orange County Fire Authority
City of Ontario
City of Los Angeles
State of CA OES
US Department of Homeland Security
Federal Emergency Management Agency
US AirForce
US Marine Corps
rescue
SAFIRE: Situational Awareness for Firefighters
CYPRESS


Irvine-Sensorium – An Instrumented CyberPhysical Space
Campus-wide infrastructure to instrument, experiments, monitor, disaster drills & to validate technologies
sensing, communicating, storage & computing infrastructure
Software for real-time collection, analysis, and processing of sensor information
used to create real time information awareness & post-drill analysis

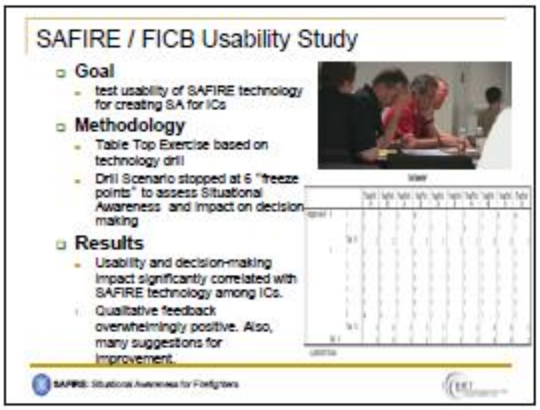

SAFIRE (Situational awareness for Firefighters) Project
Improve the safety of firefighters by providing decision makers with greatly improved situational awareness during response activities.
Incident Site
Incident Command Post
Dispatch / Operations Centers
SAFIRE System
SAFIRE: Situational Awareness for Firefighters

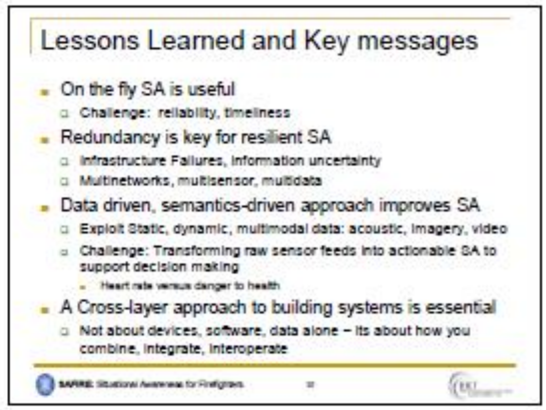

SAFIRE: An End-to-end SA Tool for ICs
SAFIREStreams
Goal: Reliable Timely SA over Unpredictable Infrastructure
SAFIRE: Situational Awareness for Firefighters

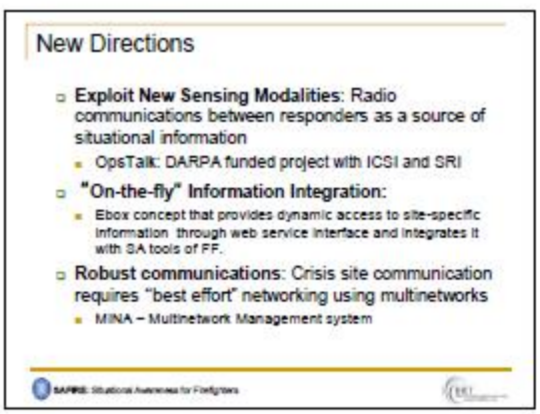

SAFIRE Streams
A software framework to create situational awareness from heterogeneous multimodal sensor streams
Captures/ingests data from heterogeneous SA sensors
Personal - Physiological (heart rate, blood CO, accelerometer) and location (WiFi, Ultrasonic, RFID, GPS)
Environmental– temperature, humidity, CO, light, sound
Multimodal - Video cameras, Speech sensors (radio communication amongst responders)
External data sources - (via Ebox technology)
Transforms raw sensor data to situational information
Declarative programming language for rapid application prototyping
Provides core SA services
Alerts, archival, replay functionalities
Powerful UI for situation monitoring - Displays dynamic sensor data, overlay of contextual information
SAFIRE: Situational Awareness for Firefighters

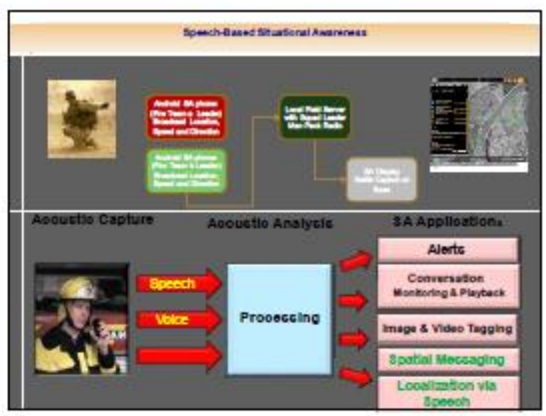

The Fire Incident Command Board - FICB
Firefighter Status Dashboard
Available GIS layers
Receive and display alert messages.
Mapping and Localization
SAFIRE: Situational Awareness for Firefighters


Drills & Experiments to Validate role of Sensors in Creating SA at Crisis Site
HazMat, casualties, First Response drill and SAFIRE Deployment (16 SEP 08)
Live Burn & CO Sensing Study: OCFA, LA County Fire (23 FEB 09)
HazMat drill (with multiple casualties) and SA Study (12 MAY 09)
Tabletop exercise IC Usability Experiment (15 MAY 09) to determine role of sensor based awareness for decision making
Analysis of in-field data collected to determine reliability of sensor data capture at crisis sites (IEEE PERNEMS 2010, IEEE IQ2S 2010, EMWS 2009)
SAFIRE: Situational Awareness for Firefighters


SAFIRE / FICB Usability Study
Goal
test usability of SAFIRE technology for creating SA for ICs
Methodology
Table Top Exercise based on technology drill
Drill Scenario stopped at 6 "freeze points" to assess Situational Awareness and impact on decision making
Results
Usability and decision-making impact significantly correlated with SAFIRE technology among ICs.
Qualitative feedback overwhelmingly positive. Also, many suggestions for improvement.
SAFIRE: Situational Awareness for Firefighters


Lessons Learned and Key messages
On the fly SA is useful
Challenge: reliability, timeliness
Redundancy is key for resilient SA
Infrastructure Failures, information uncertainty
Multinetworks, multisensor, multidata
Data driven, semantics-driven approach improves SA
Exploit Static, dynamic, multimodal data: acoustic, imagery, video
Challenge: Transforming raw sensor feeds into actionable SA to support decision making
Heart rate versus danger to health
A Cross-layer approach to building systems is essential
Not about devices, software, data alone – its about how you combine, integrate, interoperate
SAFIRE: Situational Awareness for Firefighters


New Directions
Exploit New Sensing Modalities: Radio communications between responders as a source of situational information
OpsTalk: DARPA funded project with ICSI and SRI
"On-the-fly" Information Integration:
Ebox concept that provides dynamic access to site-specific information through web service interface and integrates it with SA tools of FF.
Robust communications: Crisis site communication requires "best effort" networking using multinetworks
MINA – Multinetwork Management system
SAFIRE: Situational Awareness for Firefighters


Speech-Based Situational Awareness
Acoustic Capture
Acoustic Analysis
SA Applications
Speech
Voice
Processing
Alerts
Conversation Monitoring & Playback
Image & Video Tagging
Spatial Messaging
Localization via Speech

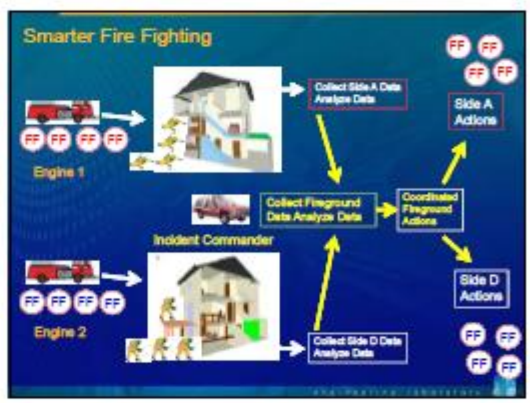

Roadmapping Vision and Chapter Outline
Nelson Bryner
Fire Research Division
Engineering Laboratory
March 24, 2014
Smart Fire Fighting Workshop
Crystal City, VA

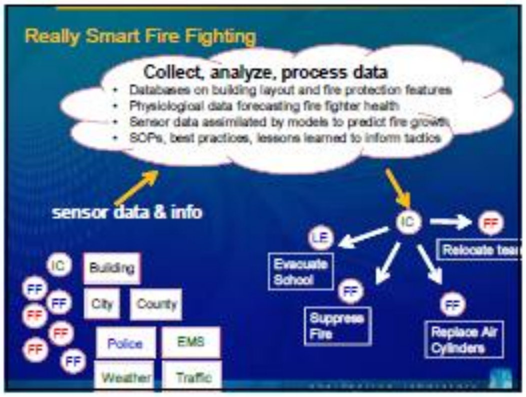

Roadmap for Smart Fire Fighting
Addressing "New Norm" of the Fire Service
– Technical Solutions
• Better equipment, personal protective equipment, information
• Policies and protocols
– Adaptive/Predictive Approaches
• Critical thinking
• Risk assessment
• Decision making skills
• Collaborative methods

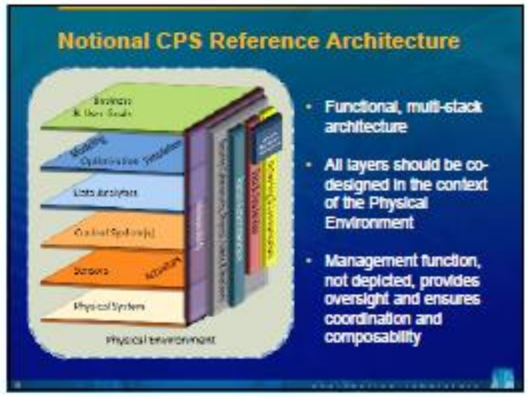

Roadmap for Smart Fire Fighting
• Framework for implementation
• Research needs – identify and prioritize
• How to move CPS R&D to real world
• Workshop begins this process
• Roadmap builds on output & collaboration


Challenges and Opportunities
Fire Fighting
• "New Norm"
• Safety
• Situational awareness
• Effectiveness
• Tactics
Cyber Physical Systems
• "Treasure Boxes"
• Sensors
• Data Integration
• Data Analytics
• Optimization
Smart Fire Fighting


Non-Smart Fire Fighting
Engine 1
Side A Exposure
Collect Side A Data Analyze Data
Side A Actions
Side D Exposure
Engine 2
Side D Actions
Collect Side D Data Analyze Data


Smarter Fire Fighting
Engine 1
Collect Side A Data Analyze Data
Side A Actions
Collect Fireground Data Analyze Data
Coordinated Fireground Actions
Incident Commander
Engine 2
Side D Actions
Collect Side D Data Analyze Data


Really Smart Fire Fighting
Collect, analyze, process data
• Databases on building layout and fire protection features
• Physiological data forecasting fire fighter health
• Sensor data assimilated by models to predict fire growth
• SOPs, best practices, lessons learned to inform tactics
sensor data & info
IC
Building
FF
City
County
Police
EMS
Weather
Traffic
LE
IC
FF
Relocate team
Evacuate School
Suppress Fire
Replace Air Cylinders


Notional CPS Reference Architecture
Physical System
Physical Environment
• Functional, multi-stack architecture
• All layers should be co-designed in the context of the Physical Environment
• Management function, not depicted, provides oversight and ensures coordination and composability


Challenges and Opportunities
Fire Fighting
• "New Norm"
• Safety
• Situational awareness
• Effectiveness
• Tactics
Cyber Physical Systems
• "Treasure Boxes"
• Sensors
• Data Integration
• Data Analytics
• Optimization
Communication – Gathering of Data
Computation – Processing of Data
Targeted Decision Making – Use of Data

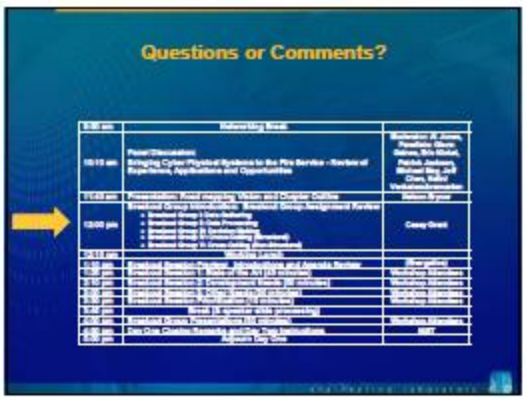

Research Roadmap - Outline
• Background - Where we are now
• Communication – Gathering of Data
• Computation – Processing of Data
• Targeted Decision Making – Use of Data
• Implementation Plan – Where we are going

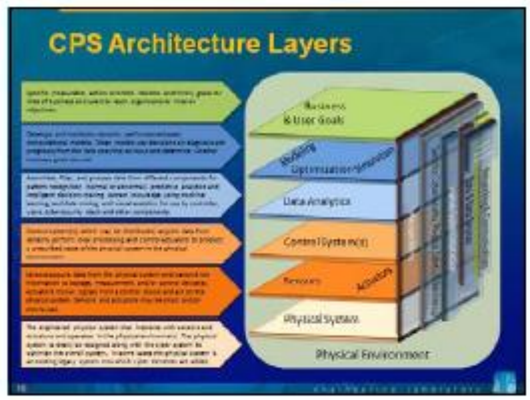

Research Roadmap - Outline
Communication – Gathering of Data
Fire Fighting
• Communication Technology & Delivery Methods
• Sensors
• PPE
• Mobile
• Stationary
• Data Collections
• Existing Databases
• Future
Cyber Physical Systems
• Control Systems
• Sensors
• Physical systems
• Interoperability
• Security
• Human-System Interaction

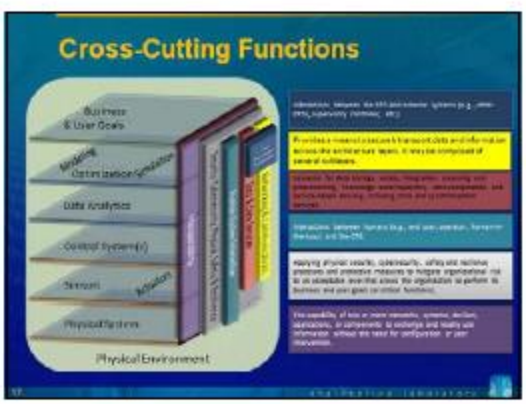

Research Roadmap - Outline
Computation – Processing of Data
Fire Fighting
• Hardware/Software
• Compatibility, Integration, &
• Interoperability
• Data Analytics
• Real-time
• Risk management
Cyber Physical Systems
• Optimization
• Interoperability
• Security
• Networking
• Data Integration


Research Roadmap - Outline
Targeted Decision Making – Use of Data
Fire Fighting
Cyber Physical Systems
Fire Service Data User
Pre Emergency and Post Event
Event
Non Fire Service Data User
Call processing centers
Primary & Secondary Receivers
Public and Building Occupants
Governments
User Interface Delivery Methods
Hand-held devices
Heads-up display
Augmented reality
Business & User Goals
Interoperability
Security
Human System Integration
Networking
Data Integration


Roadmap for Smart Fire Fighting
Addressing Changing Needs of Fire Service
– Technical Solutions
Better equipment, personal protective equipment, innovation
Policies and protocols
– Adaptive/Predictive Approaches
Global data
Central analytics
Risk assessment
Informed & targeted decision making
Smart Fire Fighting


Questions or Comments?


CPS Architecture Layers
Business & User Goals
Modeling
Optimization/Simulation
Data Analytics
Control System(s)
Sensors
Actuators
Physical Systems
Physical Environment


Cross-Cutting Functions
Business & User Goals
Modeling
Optimization/Simulation
Data Analytics
Control System(s)
Sensors
Actuators
Physical Systems
Physical Environment


Historical Perspective
Physical Systems
Cyber Systems
Cyber Physical Systems
Industrial Revolution
Internet Revolution
Industrial Internet Revolution
1700
1750
1800
1950
2000
Year