2016 Fire Service Technology Summit

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Cover Page

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Contents

Cover Photo: The Centennial Light at the Livermore-Pleasanton (CA) Fire Department is considered to be the world's longest-lasting light bulb. The fire department received it in 1901 and it has worked continuously, except for when it moved from different fire stations and one power outage. For more information about the Centennial Light and for a live view of the "Bulb Cam," visit www.centennialbulb.org.

Cover Photo Credit: Dick Jones

Abstract

The National Fallen Firefighters Foundation (NFFF) hosted the 2016 Fire Service Technology Summit July 24-26, 2016 in Oakland, California. The objectives of this meeting were to discuss the present and near-term use of technology in the fire service, and to suggest a path forward to improve firefighter health and safety. Members of the fire service and support agencies attended the meeting including firefighters, fire officers, researchers, scientists, and representatives of commercial interests ranging from start-up companies to large, industry-leading fire service technology manufacturers.

Subject matter experts opened the summit with presentations on the current state of the science regarding technology use in the fire service. To provide context, several speakers described the route we have collectively traveled to reach our current position, and hypothesized about the path forward. These experts then worked collaboratively with fire service attendees in a consensus-building framework to identify recommendations for technological needs and identify ways to transition new health and safety related technology to the fire service.

Attendees of the 2016 Fire Service Technology Summit were divided into five breakout groups, centered on the following topics: command and control; emergency operations; health, wellness, and occupational diseases; tools and equipment; and training. The first task for each group was to identify specific technological advancements that are viable in the next five years. This resulted in a list that complements the technology-related recommendations within the 2015 National Fire Service Research Agenda and other existing responder needs assessments, with an additional focus specifically on cancer-related concerns and the growth of the Smart Building sector. Critical technologies identified in most groups included physiological monitoring, accountability systems, command situational awareness, communications, personal protective equipment, and assistive devices, including unmanned aerial vehicles, robotics, and apparatus technology. Additional discussion addressed better collaboration between the fire service and research communities to help bring these and other technologies to the marketplace. Specific goals for transferring research to practice – from idea conception to product development to fire service training, along with fire service/technology collaboration and potential funding opportunities – were also identified.

Several key themes emerged in this meeting. First, fire service members recognized the need for stakeholders to be actively engaged throughout each step of the process. This could potentially include focused collaboration via existing mechanisms with federal partners, as well as resurrecting programs that have perhaps gone by the wayside. Also evident was the need to engage start-ups, academic research institutions, and early adopters of evolving technology. Suggestions for advancement include creating a known location where the technology industry can find information on the fire service, understand the applicable standards, interact with fire service experts who have a national perspective, and perhaps receive support, potentially in the forms of financial resources and/or honorary recognition.

This report presents an overview of the speaker's presentations and the specific recommendations identified within the work groups. The common reinforcing themes that evolved from the breakout sessions are gathered and summarized in detail in the pages that follow.

Section 1.

Significant (Key) Findings

A primary activity for participants was to identify specific technological advancements that are viable in the near-term (present to five years out). This discussion reinforced the need to examine technology in the fire service, and complements the technology-related recommendations from the 2015 National Fire Service Research Agenda and other existing responder needs assessments, with an additional focus specifically on cancer-related concerns and the growth of the Smart Building sector. Critical technologies identified in most groups included: physiological monitoring, accountability systems, command situational awareness, communications, personal protective equipment, and assistive devices, including unmanned aerial vehicles, robotics, and apparatus technology.

Key discussion focused on how the fire service and research communities can better work together to help bring these and other technologies to the marketplace. Specific goals for transferring research to practice—from idea conception to product development to fire service training – along with fire service/technology collaboration and potential funding opportunities were also identified.

In each of the identified goals, fire service members recognized the critical need for stakeholders to be actively engaged throughout each step of the process. These efforts could include focused collaboration via existing mechanisms with federal partners, as well as resurrecting programs that have perhaps gone by the wayside. Fire service membership took ownership of the need to advocate for solutions to their technological gaps in the marketplace that has already engaged end users from many different industries.

Finally, the need to engage start-ups, academic research institutions, and early adopters of evolving technology was identified. Suggestions for advancement in this area include creating a single, well-established location where the technology industry can find information on the fire service, understand the applicable standards, interact with fire service experts who have a national perspective, and perhaps receive support, potentially in the forms of financial resources and/or honorary recognition.

Translation of Findings

Fire service technology development has promised to reduce fireground injury through improved command and control. The key technologies that have been identified can improve an incident commander's situational awareness through location of operators on the fireground, physiological status monitoring, and the use of unmanned assist devices (unmanned aerial vehicles, robotics) to reduce physiological loads and improve communications.

The fire service marketplace has challenges due to relatively small size, limited budgets, and challenging purchasing requirements, so the need for industry-wide advocacy throughout the technology development cycle including through purchasing mechanisms was identified. The report from this summit will provide local firefighters, fire chiefs, and administrators with guidelines and a nationally relevant consensus document to reinforce these needs.

The findings of this project cannot immediately be applied to the workplace, but are relevant to developing future technological interventions that will improve the firefighter's workplace. The path to achieve marketplace success is challenging in the fire service, so this document is intended to support

the technologist as well as inform the fire service how to engage with technology development firms throughout the product development cycle.

Outcomes/Impact

The final report developed by this project and broadly distributed by the National Fallen Firefighters Foundation (one of the largest and most influential national-level fire service organizations in the U.S.) is focused on guiding future investigations and research into fire service technology. In particular, this effort focuses on technology aimed at improving firefighter health and safety. With the improved technology discussed at this summit, incident commanders will have improved awareness of fireground operations and capacity to maintain safety of those operating. Thus, communications and practices will eventually be improved throughout the industry. However, prior to implementing this technology, the current state of science and implementation must be improved with fire service partnerships throughout the process, and as such, this report provides a roadmap for how local fire departments can engage in the national effort to improve technology that is available. In some cases, this will include advocating for funding to develop technology, then purchasing these products. Other opportunities for involvement include engaging with technology funding agents (e.g. the Department of Homeland Security Science & Technology Directorate) to advocate for fire service needs or standards setting bodies (e.g. NFPA) to ensure technology can be integrated into the fireground in a safe and interoperable manner. The roadmap provided by this summit is an initial step in realizing the potential outcome of improved health and safety in the American fire service.

Section 2.

Background

The National Fallen Firefighters Foundation (NFFF) and the Everyone Goes Home® Program

In 1992, Congress created the NFFF to honor America's fallen firefighters and provide their survivors with the resources they need to rebuild their lives. In 2004, the NFFF expanded its mission to include the prevention of line-of-duty deaths and injuries by delivering firefighter health and safety training, resources, and advocacy under the Everyone Goes Home® program. The 16 Firefighter Life Safety Initiatives were created to support the Everyone Goes Home® program; each initiative focuses on a specific element of the fire service that impacts firefighter health and safety. This report addresses Firefighter Life Safety Initiative #8, which states: *Utilize available technology wherever it can produce higher levels of health and safety.* A complete list of the 16 Firefighter Life Safety Initiatives is included in Appendix A.

2014 Incident Command Operations and Accountability Conference

The first technology-related event in support of Firefighter Life Safety Initiative #8 took place in June 2014 in Monterey, California, at the Incident Command Operations and Accountability Conference. The goal of this meeting was to better understand the use of mobile devices for incident command operations and accountability on the fireground.

The final report from the conference included the findings from guided work sessions and recommendations from attendees regarding future needs in support of Firefighter Life Safety Initiative #8 (to view the report, click here). A key recommendation was that the NFFF should host a follow-up technology summit to more broadly address uses of technology to enhance firefighter safety. The report also described factors related to the challenges of implementing technology, and highlighted steps that can be taken to promote its successful implementation. It is recommended that readers review the Incident Command Operations and Accountability Conference final report as a companion piece to this report from the 2016 Fire Service Technology Summit.

2015 National Fire Service Research Agenda Symposium

Firefighter Life Safety Initiative #7 states: *Create a national research agenda and data collection system that relates to the initiatives*. In support of Initiative #7, the NFFF has hosted Research Agenda Symposia in 2005, 2011, and 2015. The most recent symposium was held outside Washington, D.C. in November 2015, and attended by approximately 100 stakeholders representing fire service organizations, researchers, academics, government agencies, corporate partners, and other interested entities. Technology and technology-related topics were included in 33 of the 54 recommendations developed by attendees, highlighting the importance and value of further examining technology in the fire service as a means to increase firefighter health and safety. A list of the technology-related recommendations from the 2015 National Fire Service Research Agenda Symposium can be found in Appendix B.

2016 Fire Service Technology Summit

The 2016 Fire Service Technology Summit took place in July in Oakland, California. Meeting attendees included representatives from fire departments, manufacturers, national fire service and research organizations, and select fire service-related partners. A complete list of summit attendees can be found in Appendix C.

Five primary goals guided the agenda and discussion at the 2016 Fire Service Technology Summit:

> **Goal #1**: Recommend technological advancements that the fire service can use to decrease the risk of firefighter injuries and fatalities.
>
> **Goal #2:** Create recommendations on transferring research into operations by outlining a pathway for fire service input from project/roadmap conception through adoption.
>
> **Goal #3:** Identify methods to inform, educate, and train firefighters in existing technologies.
>
> **Goal #4:** Identify mechanisms for the technology industry to collaborate with the fire service in the transfer of emerging technologies to fire service use.
>
> **Goal #5:** Establish potential diverse funding opportunities to meet the identified technological needs of the fire service

This report provides both an overview of the speakers' and panelists' guiding messages at the start of the 2016 Fire Service Technology Summit and a summary of the recommendations provided by attendees who participated in breakout groups.

Presentation Summaries

The Future American Firefighter
Casey C. Grant, P.E., Fire Protection Research Foundation, National Fire Protection Association

Casey Grant, Executive Director of the Fire Service Research Foundation, presented a compelling treatise on the 'Future American Firefighter.' Mr. Grant's vision included four elements that he believes will be essential to our country's firefighter of tomorrow:

- Technology development, networking, and outreach
- Standardization
- Training
- National data collection systems

Mr. Grant offered two key observations regarding technology development. The first was a belief that the fire service needs to seek partners that are currently working on related technology advancements versus the fire service reinventing the wheel with technology focused specifically on its relatively small market. Fire service research assets are at a premium and the service would do well to look for existing opportunities for partnership (e.g., Smart Cities) to take advantage of, rather than duplicate effort. His

second observation was that the greater challenge is not solving technology innovation, but rather addressing the legal, social, and cultural issues that are attached to technology solutions (e.g., data privacy, confidentiality, proprietary information, and competition).

Networking and outreach were noted as current challenges needing further resources. Solutions will require significant investments of time on the part of the American fire service, whose more comfortable operating principles revolve around rapid response, rapid resolution, and rapid return to service for the next event. Cultivating relationships must extend beyond single meetings, and will require extended time and effort. The fire service needs to look beyond its comfort zone, to find new partnerships and engage stakeholders in non-conventional venues.

Mr. Grant observed that the standardization infrastructure, an essential foundation for interoperability (i.e., mutual and automatic aid, disaster response, etc.) is being outpaced by new technology. In order to optimally prepare the future firefighter for the challenges of tomorrow, entrenched thinking cannot impair technological innovation. Today's fire service needs to be alert for new players and game-changing technologies that will allow the fire service to keep pace with its surroundings, and standards need to support this innovation within their domain.

Technology advances have great adaptation potential in the training discipline for the fire service, according to Mr. Grant. Declines in structure fires, as well as the exodus of the Baby Boomer generation of officers, are giving rise to an experience vacuum that gaming and simulation technologies may address. This is an important opportunity for the fire service to embrace technology as it seeks ways to keep future firefighters properly trained and prepared to handle emergencies.

With respect to national data collection systems, Mr. Grant suggested that current systems (e.g., National Fire Incident Reporting System, National EMS Information System) and yet to be fully developed/implemented resources (e.g., National Fire Operations Reporting System, National Fire Data System) need to be built to be able to share information across platforms. Credible national data is essential to support policy, programs, and funding for the fire service and related organizations. The time has long passed when fire departments were funded based on perceived and not quantified risk.

Department leadership will increasingly need to pull data from multiple sources quickly and reliably to keep pace with demands for justification. He also noted that as data collection becomes more automated, the data analytics will require careful packaging.

Mr. Grant concluded by offering resources to support his presentation. For additional information and detail, readers can visit www.nfpa.org/SmartFirefighting to download the report, Research Roadmap for Smart Firefighting.

Physiological Status Monitoring (PSM), Health Monitoring, and Location Monitoring for First Responders

Denise Smith, Ph.D., Skidmore College/Illinois Fire Service Institute
Maxim Batalin, Ph.D., University of California, Los Angeles Institute for Technology Advancement (via Skype®)

Dr. Denise Smith stated that the fundamental goals of personal monitoring are to reduce the risks associated with firefighting and to increase the safety of firefighters. She said, "We need data that is reasonable, feasible, and of real value to the fire service." The three types of monitoring – physiological, location, and environmental – can provide this useful data.

Physiological status monitoring (PSM) of firefighters has a wide variety of practical purposes including: measuring heart-related characteristics of individual responders, providing remote confirmation of a firefighter's viability, quantifying the difficulty of tasks, monitoring vitals during rehabilitation and recovery, monitoring sleep, and providing data for future research. Tracking the location of personnel can be used to help find lost firefighters or increase levels of safety during training. Environmental monitoring provides data that can be used to make decisions on the required levels of personal protection equipment, inform the choice of tactics, provide warnings related to the presence of specific particulates, and capture exposure-related data.

Dr. Smith gave three examples of fire service PSM research projects that have been funded. The first was a study during firefighting duty led by Skidmore College partnering with turnout gear manufacturer Globe, and funded by the DHS/FEMA's Assistance to Firefighters Grant Program. For four months, firefighters in Boston, Massachusetts and Oxnard, California wore a base layer with embedded physiological sensors for the duration of their 24-hour shift. To determine physiological and cardiovascular strain during all types of activity, sensors measured:

- Heart rate on a beat-to-beat level
- Heart rate variability
- Respiration rate
- Skin temperature
- Activity level

In this study, data was collected and analyzed over specific periods of interest, including the time from alarm response to post-response recovery, as well as during training, exercise, and sleep. Of the many interesting findings reported from this study, it was noted that pre-alarm heart rates were 20 beats per minute lower when alarms occurred during presumed sleep as opposed to during daytime hours, yet post-alarm heart rates did not differ based on time of day. The final report from this study can be found at this link.

At the same time, there exists significant product innovation in the PSM world including the development of the WASP™ (Wearable Advanced Sensor Platform) integrated system by a multi-disciplinary team again led by Globe, along with Zephyr Technology Corporation (physiological monitoring), TRX Systems (location tracking), Propel (textile development), and Skidmore College Health and Exercise Sciences (physiology science) with additional support from the U.S. Army. WASP™ addresses

two critical problems identified on the InterAgency Board's Research and Development Priority List: Emergency Responder Body-Worn Integrated Electronics System Development and 3D Tracking of Personnel.

Field trials of WASP™ provided invaluable firefighter feedback that was incorporated into all phases of development, design, and production. There were two phases to the testing—laboratory validation and field trials. In Phase I, WASP™ was worn during treadmill tests and heart rates were validated against criterion measures. WASP™ was similarly assessed when worn during firefighting activities (walk, search, and stair ascent/descent). In Phase II, WASP™ was worn during training drills of approximately four hours in duration. Firefighters rated the garment on fit, comfort, and function, and the design was modified prior to extended field trials. More information about WASP™ can be found here.

Dr. Maxim Batalin discussed the final example, Physiological Health Assessment System for Emergency Responders (PHASER), a tele-health system for the fire service. With funding from the Department of Homeland Security (DHS) Science and Technology Directorate (S&T), Dr. Batalin led the project development team at the University of California – Los Angeles. PHASER will capture data during firefighter activities providing monitoring of critical physiological variables and metrics that can be used to assess risk factors related to cardiovascular events and other health concerns, as well as fitness and aerobic capacity.

Ultimately, PHASER will capture data through state-of-the-art wearable sensor technology. An Android app is used to transmit the data, and a secure logon will maintain confidentiality. Data transmission via cloud computing will be used to provide secure and low-cost connectivity. The main functions of the network will be to acquire physiological data and to provide fitness assessments, analysis and reporting, and guidance for intervention. More information regarding PHASER can be found at this link.

Dr. Batalin discussed the two general categories of PSM technologies currently available:

1. Wearable sensors, which can measure heart rate, breathing rate, activity, body temperature (skin or communicate with ingestible pills for core temperature), and/or blood oximetry. They can also infer measurements regarding heart rate variability and resting heart rate, core temperature, posture, activity level, peak acceleration, speed, and distance. The benefit of wearable sensors is that they can be used 24/7.
2. Standalone sensors, which include blood pressure monitors, glucose monitors, pulse-oximeters, body weight and composition scales, and stationary 12-lead ECG, as well as sensors to monitor pulmonary function and aerobic performance. These can be used to establish baselines for periodic checkups, before and after training, and during rehab.

Drs. Batalin and Smith noted that there are critical limitations regarding these technologies. The current wearable/deployable sensor technology does not in general provide direct measurement of immediate risk. Sensor data generally lacks interpretation and actionable metrics. Radio reliability, bandwidth, and interconnectivity issues also exist.

Moving forward with physiological monitoring of firefighters presents multiple important challenges. Dr. Smith related the difficulty in matching what is happening physiologically with the data that can be reliably collected. For example, heart rate doesn't necessarily factor in risk, because the data may be more nuanced. Other questions related to data include how do we make sense of it? How much is

enough? Who interprets it, and when? Some yet unanswered questions relate to its practical applications, such as who will have access to this information? Will department administration and/or unions need to be involved? What are the industry and the individual departments' responsibilities in terms of privacy and liability?

My Journey with Technology in the Fire Service
Chief Alan Brunacini (ret.), Phoenix (AZ) Fire Department and Blue Card Command

Chief Alan Brunacini joined the Phoenix Fire Department in 1958 and served in every position, including Fire Chief from 1978 until his retirement in 2006. During his tenure, Phoenix adopted a number of technologies including the first computer-aided dispatch system and firefighter safety-related technologies such as the Personal Alert Safety System. Chief Brunacini discussed his experiences, and what he views as the benefits of embracing technology, the obstacles to address when adopting technology, and leadership's role in technological advancements.

Chief Brunacini spoke to the three fundamental components of the structure of a fire department organization: hardware (the tools and equipment of firefighting), software (the systems associated with firefighting), and 'liveware' (humans).

Chief Alan Brunacini: "The basic objective of technology is to make humans safer and more effective. We should empower the next generation's technological knowledge."

Chief Brunacini grouped hardware and software together because of their similarities in being tangible items that can be purchased, may have a 'shelf-life' and a limited usefulness, and are technical and non-emotional. However, the 'liveware,' the human aspects of the fire service, must be led by a person; oftentimes they have lifetime employment and human emotions are involved. He believes that leaders are much more effective managing the hardware and software of the fire service and less effective changing the habits of the 'liveware.' For leadership to be effective, Chief Brunacini said that "leadership needs to demonstrate functional boss behaviors" by letting firefighters know what's going on, including them in decision-making, and showing that they are cared for.

Today's fire service has a critical need for both safety and effectiveness, according to Chief Brunacini. The 'Performance Management Model' he encouraged attendees to consider demonstrates that safety and effectiveness can work together. As an example, he discussed firefighters arriving safely on scene when responding to a call. Without getting there safely, they would be unable to effectively work together on scene. As he points out, a number of firefighters die every year responding to or returning from a call. Safely responding and returning from a call requires hardware (the tools and equipment needed to respond), software (the process of getting the call and responding to the call), and 'liveware' (the firefighters responding to the call). All three of these must work in tandem to ensure the safety of the firefighters and the civilians who are in need of their assistance.

Chief Brunacini also elaborated on the need for strong leadership when looking at broadening the use of technology by the fire service. Fire service leaders can foster its growth by creating an environment where firefighters are empowered to be creative problem solvers when integrating new technology into the existing workplace.

Existing Technology and Improving Communications
Paul Steinberg, Motorola Solutions, Inc.

Paul Steinberg, Chief Technology Officer for Motorola Solutions, provided an informative presentation on existing technology and the process of improving communications within this framework. One of the prevailing themes in Mr. Steinberg's discussion was the importance of applying human factors principles to technology usage. He emphasized that the interface between a firefighter and fireground technology has myriad conflicting factors in two critical settings:

- Human performance limitations in firefighting due to the worn protection systems and the firefighting environment in which activities must take place; and
- Integrating advancing technologies in a manner that supports firefighting operations without further burdening the encapsulated firefighter.

Mr. Steinberg provided two examples of the complexities related to integrating technology and firefighting. The first related to a system Motorola engineers believed would enhance the job of a firefighter, and was developed without input from stakeholders. When the technology reached market, it was rejected. The second, and more successful example, was the Apex 7000XE radio. Motorola used knowledge transferred from a study of degradation of abilities firefighters experience during response (e.g., vision, dexterity, hearing, speech, etc., see Figure 1) to create the Apex 7000XE. These examples clearly illustrated that to achieve a commercially viable product, technological developments will need to incorporate input from the end users to promote success.

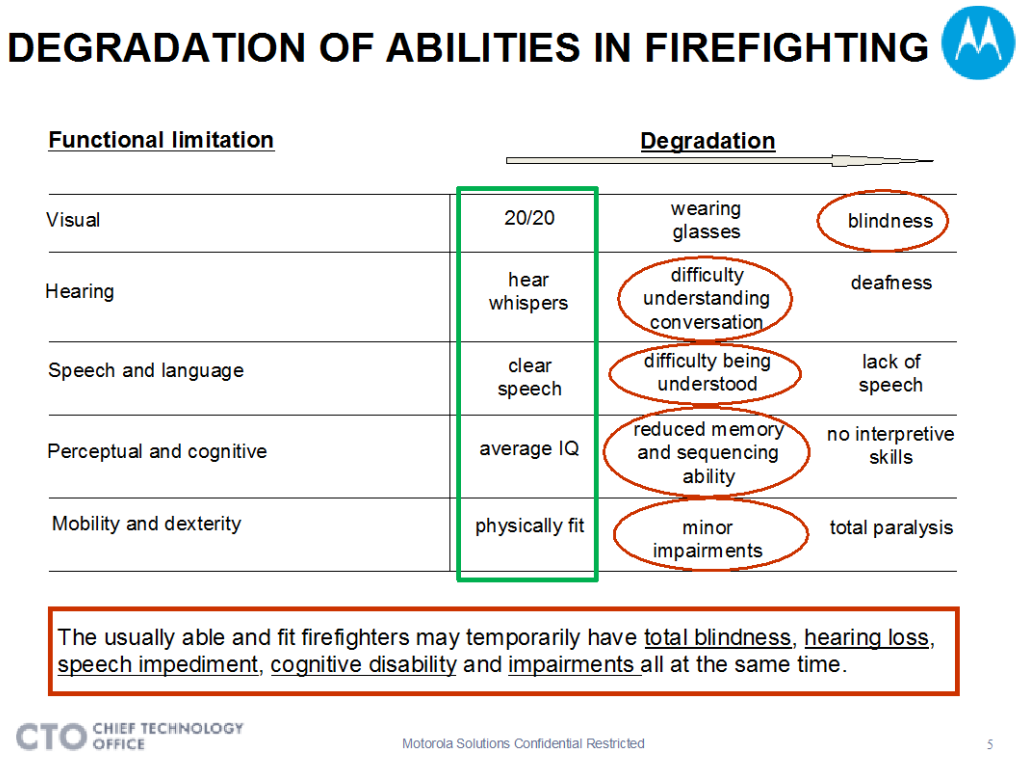

Figure 1. Courtesy Paul Steinberg, Motorola Solutions

Mr. Steinberg went on to discuss the importance of technology supporting the burgeoning nexus between mission critical ***communications*** and mission critical ***intelligence*** in the fire service. Motorola Solutions is working diligently to increase its understanding of the complexities of the fireground environment to find solutions to both communications and intelligence needs.

To illustrate where the technology is going, Mr. Steinberg displayed a vision of the 'Firefighter of the Future' (Figure 2). This slide points out the potential technologies that could be developed/implemented to bridge the mission critical communications and intelligence needs.

Each element of the 'Firefighter of the Future' supports the nexus between communicating information to command that will promote firefighter safety and providing commanders with real time intelligence to make decisions that will successfully mitigate emergencies. His observations echoed those of Casey Grant and Denise Smith in this regard.

For instance, Mr. Steinberg's presentation supported Mr. Grant's theory that gaming and simulation training are critical technologies for the future of the fire service. Ultimately, enhancing the human performance of firefighters is rooted in being able to gather and analyze intelligence and communicate with each other. Mr. Steinberg reinforced that interface systems currently used by firefighters will need to be constantly analyzed for effectiveness and the fire service must forge a strong partnership with technology companies to stay in step with the dynamic state of its operating environment.

Figure 2. Courtesy Paul Steinberg, Motorola Solutions

Technologies for Prevention and Suppression…Fast is Preferred!
Chief Shane Ray, President, National Fire Sprinkler Association (NFSA)

Chief Shane Ray, President of the NFSA, provided a unique perspective on fire service technology by discussing those currently being used for fire prevention and suppression. He described how the modern built environment and the current energy code are challenging traditional systems and approaches. Early warning sensors found in smoke alarms and carbon monoxide alarms and early suppression provided by fire sprinkler systems are monumentally important in protecting lives (civilian and firefighters) and property. Early warning and early suppression technology can minimize and sometimes stop losses caused by fire in residential and commercial structures. The challenge faced by industry and the fire service is ensuring that technology and tactics are keeping up with modern construction techniques and synthetic furnishings.

Chief Ray also presented the findings of burn studies completed by the National Institute of Standards and Technology and UL's Firefighter Safety Research Institute. These studies have resulted in a better understanding of how today's structure fires burn faster than in decades past due to evolving building materials and furnishings. He presented a video where NFSA also conducted tests in one of UL's modern homes that challenged the fire sprinkler system due to modern design, content, and requirements of current energy code. While the fire sprinkler system worked as designed and controlled the fire, the materials produced enough smoke to obscure visibility. This scientific research will help to advance the need for and the importance of early warning and early suppression technology.

Panel Discussion: Human Performance Factors Related to the Use of Technology

Gavin Horn, Ph.D., University of Illinois Fire Service Institute
Shawn Pruchnicki, The Ohio State University
Deputy Chief Thomas Riley, Fire Department of the City of New York (FDNY)
Paul Steinberg, Motorola Solutions, Inc.
Kevin Roche, Moderator

This robust panel discussion covered a variety of technology-related issues, after which attendees were invited to pose questions to the panel members. Key takeaways from the panel discussion included:

- Incorporating technology into existing systems: there is a need for the fire service to build confidence in new technology although it may seem to progress slowly at times. Chief Riley provided the example of FDNY's adoption of the Electronic Fireground Accountability System (EFAS). He also stressed the importance of thoroughly field-testing new technologies, to identify any potential issues, prior to wholesale adoption.
- Technology threshold: Mr. Pruchnicki suggested that overcoming a technology threshold is problematic in all domains, and the fire service is neither alone nor immune to this. The key areas he recommended that the fire service address first are 1) data overload and 2) the integration of multiple technologies and how they react together within the system. Mr. Pruchnicki recommended that this be accomplished by focusing on the complete life cycle of the technology (including evaluation, adaptation, and training), because it is critical to understand all

of the impacts of the integration of multiple technologies prior to its implementation.

- Fire service industry partnerships: Mr. Steinberg spoke of the value of fire service industry partners to better understand the needs of the fire service by working *with* the fire service and not just *for* the fire service. Mr. Steinberg likened the fire service to an ecosystem and identified that technology is part of the ecosystem. The use of Bluetooth® in products is an example of the market driving the direction of technology development. Mr. Steinberg said that multiple forces may facilitate the development of technological advancements including standards-driven research, interoperability testing, governmental agency guidance, and user groups.

Shawn Pruchnicki: "We are all trying to make the best decisions we can with the information we have. Decision-making is based on tasks, tools, and the environment. There are always unknowns and the unknowns are what gets us into trouble."

- The cost of adopting new technologies: the high cost of adopting new technologies is driven in part by the expenses related to research, development, and testing for the limited market of the fire service industry as a whole. Mr. Steinberg discussed strategies to reduce these expenses including overcoming regulatory obstacles, adapting technology solutions from other industries to the fire service, and looking toward the consumer market to leverage research funds.
- Technology and decision-making: one attendee asked the panel about the likelihood of data and technology replacing human decision-making abilities. The consensus of the panel was that this was highly unlikely and that data and technology will be utilized to better inform decision-making. Dr. Horn suggested that making technology adaptation palatable will help us to develop the 'lessons learned' to advance technology.
- Technology dependence: Chief Riley spoke to the balance of relying on technology along with relying on individual decision-making. He said, "We still need courage to do our job. If we get to the point we're relying on technology, people will die. You still need to practice your basic techniques." Mr. Pruchnicki added that new technologies expose new vulnerabilities in every industry. For example, firefighters may be increasingly involved in higher risk situations because bunker gear is being developed to handle higher temperatures.

In closing, each of the participants was asked to make a summary statement. Mr. Pruchnicki stressed the importance of knowing the limitations of technology, and understanding how it works within your department's system, both mechanically and organizationally. Dr. Horn concurred, stating that technology is among the many tools in the toolbox, and tools sometimes fail. It's important to have a backup, and training in the use of 'Plan B' systems or techniques. Chief Riley suggested that department leaders ask their members what they need and where they see gaps. Mr. Steinberg closed the discussion by saying that technology is there to help people be their best in the moments that matter. Technology doesn't make the decisions–it helps people to make better decisions that lead to a better outcome.

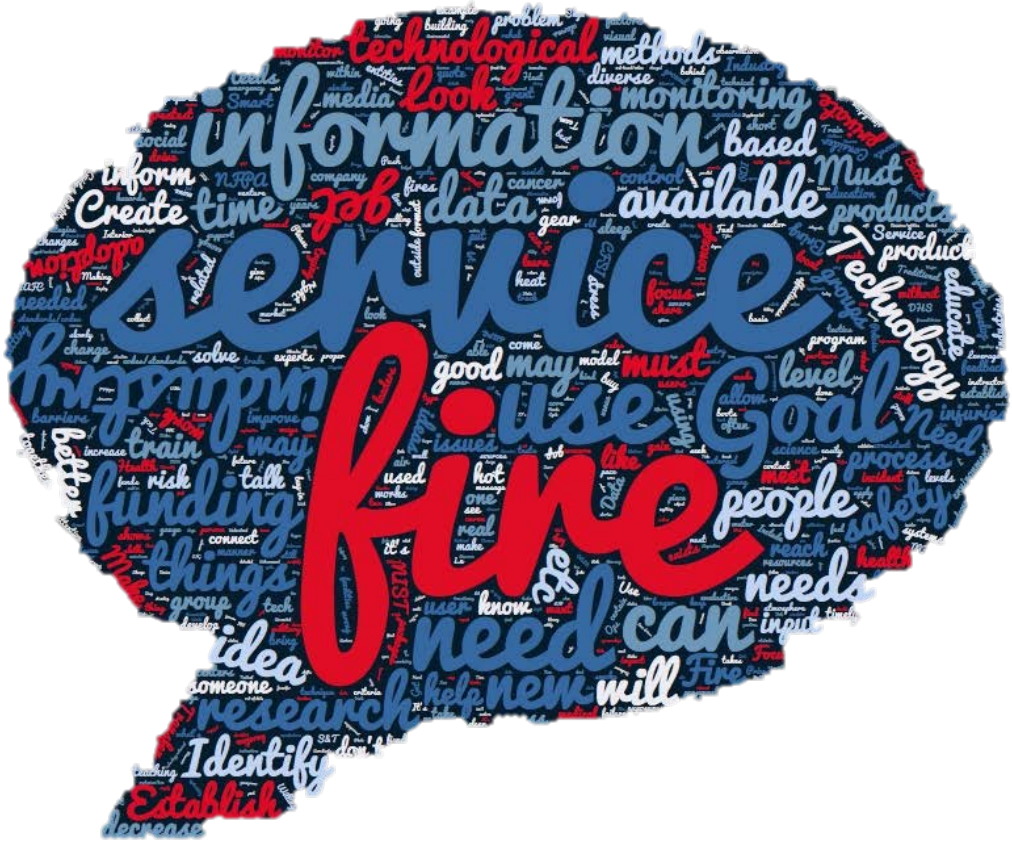

Figure 3: Word Cloud based on notes from the 2016 Fire Service Technology Summit

Recommendations

Attendees of the 2016 Fire Service Technology Summit were divided into five breakout groups and instructed to focus on one of the following topics: command and control; emergency operations; health, wellness, and occupational diseases; tools and equipment; and training. Each breakout session had a facilitator and a scribe. At the completion of the breakout sessions, each group was provided an opportunity to report out to all attendees on their recommendations for their topic, within the framework of the five goals of the summit. Because many of the recommendations overlapped, it was determined to report the recommendations based on the summit goals, rather than the topics of the five groups.

Goal #1: Technological Advancement Recommendations

The guidelines for discussing the first goal included asking attendees to identify specific technological advancements that are viable in the near-term, which was defined as technology that is currently available, or will be within the next five years. This discussion reinforced the need to examine technology in the fire service, and complements the technology-related recommendations from the 2015 National Fire Service Research Agenda and other existing responder needs assessments.

Physiological Monitoring

The need for improved physiological monitoring of fire personnel was discussed in detail in each of the five breakout groups, highlighting the far-reaching importance of physiological monitoring. In applications ranging from incident scene for firefighter safety to training scenarios for improved learning outcomes (and safety), the attendees were interested in more accurate and practical medical monitoring and temperature measurements (core temperature, skin temperature, and environmental temperature). Such technology would result in a better understanding of the limits of firefighters and would also help identify increased risks for individual operators on the fireground. This information was identified as critical for various roles within a fire department including individual emergency responders, safety officers, incident commanders, and training officers.

The information gathered from physiological monitoring needs to be provided in a timely and easily interpretable manner for the various roles in a fire department. In addition to the need for improved technology for the monitoring process, participants identified a specific need for a better means to use available health-related data and information in a visual format that can provide predictive capabilities.

The monitoring should be active in the three major segments of the event lifespan – 1) prior to and including alarm response, 2) throughout the incident itself, and 3) into rehab and recovery. There are important risks in each of these operational segments that can be quantified to provide immediate feedback and/or stored to provide a recall of events if medical response to an individual is needed. The physiological monitoring technology can be of further use in monitoring the quantity and quality of sleep, sleep apnea-related issues and elevated cardiac stress when toned. Using monitoring technology can provide an understanding of an individual's sleep-related concerns and also collect useful data for a broader understanding of sleep-related issues in the fire service.

Training scenarios provide a unique opportunity to use this technology to improve the learning outcomes for firefighters (e.g. "my heart rate is lower to do the same job if I use this technique…"). This type of

technology can also capture individual baseline levels for each firefighter while working in controlled training scenarios to help improve predictive capabilities. Employing a machine-learning approach may allow personalization of the system, making it easier to identify when a physiological response is outside the typical norms for that individual. At the same time, a community such as a fire station or fire department using physiological monitoring can have powerful motivational effects for the individual. This has been proven with step-tracking technologies assisting segments of the general population to take ownership of their health and oftentimes motivate those around them to do the same.

There are important legal and ethical issues that must be considered with any health monitoring technology. Of critical importance are privacy issues that can limit its use and effectiveness. At the same time, practical limitations of the technology that is available in the near term must be understood. For example, while the fire service has long asked for a system that can predict heart attacks prior to their occurrence, such technology does not exist, even in clinical settings.

Accountability Systems

The need for improved and even automated accountability systems for the fire service has been identified for many years, particularly after the events of September 11, 2001. Despite the well-documented demand and significant investment in this area, the need is still apparent. Firefighter tracking and location systems exist and are maturing in the prototype phase, as well as initial commercial offerings. However, consistent, ubiquitous use has not yet been achieved. The ergonomics of information delivery is critical to the success of these tools as is a detailed understanding of the use model, not only for incident command decision support, but also for the responding firefighter. In the latter, information should be delivered in an 'eyes up, hands free' manner to achieve the highest level of acceptance.

Command Situational Awareness

In addition to physiological monitoring and accountability systems, other improvements to incident command tools were identified. In general, these needs focused around improving the incident command's situational awareness on the scene. While the operational timeline of the identified needs focused mostly in the incident itself, significant improvements in situational awareness can be gleaned from pre-incident planning. Through properly developed building interfaces (e.g. tapping in to 'Smart Buildings,' supporting Firefighter Air Replenishment Systems), incident commanders can be better prepared for the firefight prior to any emergency response. Setting tactical and strategic benchmarks off of these pre-planned scenarios and capabilities can improve real-time decision making. Automated reminders of these benchmarks can be provided based on preplans and supplemented by the data from 'Smart Buildings.' As highlighted by the keynote speakers and panel discussion, this information should be provided as a ***decision support tool***, with the flexibility to support different command styles and needs.

Of particular interest, unmanned aerial vehicle (UAV) technology was highlighted as a relatively recent addition to the needs commonly identified by the fire service. UAVs can achieve a level – and view – of situational awareness that is not possible in the roughly 2-D point of reference that is presently available. These tools can provide a high-level overview for the incident commanders from above a scene, yet rapidly move to various locations in a way that would be difficult, time consuming and at times unsafe for humans. The systems may even be deployed ahead of response vehicles, providing reliable information and images while the responding units may be stuck in traffic or slowed in their ability to arrive. As the payload that can be feasibly carried by these tools increases, impressive additional capabilities appear promising. For example, one of the common themes in this meeting (as well as at the

2015 National Fire Service Research Agenda Symposium) was the need for improved exposure monitoring, including obtaining samples from plumes of smoke.

Reliable Communications Network

While improvements in communications technology have been numerous in the past 15 years, reliability can be inconsistent. Often these gaps in capabilities are tied to financial limitations of the fire departments and not in the technology itself. There are still departments that cannot afford reliable communications systems and/or do not have enough capabilities to safely outfit everyone working on the incident scene. Other limitations may be due to the obstacles encountered in the response area such as very tall buildings or below grade responses scenarios. The radios must work in the aggressive environment to which firefighters respond, yet radios and accessory equipment has been shown to fail at operationally relevant temperatures. The ability to communicate between those operating on the fireground and incident command is critical to support incident actions, but also as a first-line tool for personnel accountability and physiological status monitoring (verbal and qualitative…but often still effective).

Personal Protective Equipment

The ergonomics of firefighting personal protective equipment (PPE), through improved materials and garment design, has made remarkable strides in helping to reduce the biomechanical restrictions on the activities required to safely conduct firefighting operations as well as attempting to reduce the physiological strain of the same tasks. However, breakout groups identified some key areas where further PPE advancements can be made in the relative near term. Of particular interest is PPE that is more protective from the smoke, gasses, and particulate matter on the fireground. Concerns exist in the ability to protect interface areas where contamination may work its way into the PPE (e.g. between hood and coat, coat and pants and/or coat and gloves). While more comprehensive encapsulation may decrease these exposures, tradeoffs that may impact heat stress and range of motion of the firefighter must be understood. Additionally, technology that can identify when the PPE has been contaminated (and successfully decontaminated) can help to protect firefighters from secondary exposures to fireground by-products of combustion. Furthermore, sensors or other technology that can indicate when the gear may no longer provide protection would enhance the department's capacity regarding decision-making for cleaning and purchasing PPE.

Apparatus Technology

Modern fire apparatus manufacturers are continuously integrating some of the most impressive collections of modern technology into the fire service. In recent years, they have adopted many of the technologies from the commercial automotive industry to reduce the risk of injuries and fatalities associated with operating fire service vehicles. Two examples of this include audible and visual alarms when seatbelts are not used, and use of backup cameras. Anti-roll technologies in fire apparatus will further assist in reducing rollovers. As the automotive industry continues to develop accident and collision avoidance technology that may be adaptable to fire apparatus, these innovations may ultimately result in a decrease in firefighter injuries and fatalities. The fire service apparatus industry is highlighted as one area where rapid adoption of technology is ongoing and expected to continue into the near future.

As our knowledge of exposure to chemicals and contaminants in the fire service continues to evolve, the role that apparatus may contribute to the exposure risk that firefighters face is also becoming better

understood. The cabs themselves can become contaminated if doors and/or windows are left open on the incident scene, boots track contaminants back into the cab, or contaminated PPE is worn/stored in the cab. Technologies and/or materials for easy decontamination of the cab can assist in reducing this secondary exposure. The ability to verify that the cab is decontaminated is equally important. Finally, the ergonomics associated with diesel exhaust management systems should be studied to improve utilization and compliance.

Robotics

For some time, the promise of robotic technologies that can provide fireground support have been heralded for their potential to improve firefighter health and safety. While UAVs are likely poised to impact the fire service more rapidly than other assist devices, ground-based robots can be employed similar to bomb disposal or other emergency support units in related responder applications. Track-type robots have been used to apply water in structurally compromised fires during overhaul operations and appear to have more broad application internationally. Units that are being developed for carrying large payloads in military operations may have application in assisting in wildland response, hauling tools and air bottles in high-rise operations, or assisting in shoring of collapsed structures. Outfitted with the appropriate technology, small nimble units can provide a ground-based size up of structures or potentially even advanced location of trapped victims. While the development of these tools is rapid and ongoing, their impact on the fire service is likely to be understood more fully in the next five years.

Training-related Technology

Many of the technologies described above have obvious applications in training scenarios, to provide an increased level of safety for the firefighter and improve the ability of the instructor to teach critical skills and techniques. Training firefighters with the most recent technological advancements will help introduce the fire service to new tools as well as assist firefighters to understand and value their capabilities prior to purchase and application on the fireground. At the same time, manufacturers who support integration of their technology into training scenarios can gain valuable insight into how their tools are used (which may or may not be as originally designed) as well as potential failure points. The concept of integrating the training of technology with the technology of training allows both the industry and the end user to accelerate the product development cycle.

At the same time, there are important specific technological needs for the training industry. Development of training props that consistently replicate the modern fire environment (for training proper operations as well as learning through observation) are critical to improving the fidelity of the training scenarios and the learning outcomes for the firefighters. Technologies should be developed to provide feedback on and potentially control the environment within the training buildings to reduce risk to firefighters and instructors. Attendees identified a critical need to develop technology that can shorten the time curve of validated training materials. Finally, the development of adaptable decision-making tools and simulators connected to case studies was identified.

Summary

The key needs identified here are fairly consistent with those described in existing needs analyses of the fire service. The two most common high priority items (personnel location, physiological status monitoring) have been near the top of the fire service needs list for over a decade. The influence of

increased understanding of Smart Technologies was apparent in these recommendations. The increased connectivity of the fire service was mentioned repeatedly and the opportunity to which it can provide the fire service are tantalizing. The fire service has recently increased interest in both quantifying and reducing fireground chemical exposures, particularly those that may lead to occupational cancer and was discussed in all of the breakout groups.

Goal #2: Research into Practice Recommendations

Attendees of the breakout groups were charged with creating recommendations to support the transfer of research into operations in order for the fire service to have a role in the life cycle of technology from conception to adoption.

Increase Engagement of Fire Service in Technology Process

The key identified goals for gaining firefighter input into technology transfer are to increase the engagement of the fire service in the technology development process and increase the value that the fire service places on this activity. A specifically identified need is to continue bringing a group of firefighters and fire officers together more often to talk about specific needs. This group should also include product marketers, manufacturers, and design engineers along with representatives from national fire service organizations. This approach can create a strong collaborative voice for movement forward. Existing activities in this area are led by the Department of Homeland Security (DHS) Science and Technology Directorate (S&T). Programs such as the First Responders Resource Group are designed to engage responders in focusing S&T's efforts on the highest priority needs. On the other end of the technology development cycle, S&T also conducts operational field assessments. While these opportunities exist, it is suggested that broader involvement of the fire service, from individual responders to national organizations, would be beneficial and is warranted. Additional opportunities to provide an unbiased, yet globally relevant view directly to technology developers or those who can provide the solution should be actively sought through all segments of the fire service and technology industry.

It was recommended that a national fire service organization take the lead in creating a network of agencies committed to working with manufacturers, research and development entities, and start-up companies. Such a clearinghouse can support technologies from the creation of ideas, through the iterative design, build, test, revise process. This group would assist technologists to engage with influence leaders, training entities, trade shows, publications, the international fire service, and other industries.

Several manufacturers and organizations have found success in inviting stakeholders to participate in training burn scenarios in order to provide a simulated firefighting experience. This approach has had a powerful impact on political leaders to help them understand fire service needs. Engaging industry and product development leadership in a 'Fire Ops 101' type program, similar to that which the International Association of Fire Fighters manages, can allow technologists to gain a better understanding of the fire service operational environment early in the concept/design phase and for testing prototype units. Past experiences at fire service training institutions has shown this approach to be powerful for a broad range of commercial interests, from startup companies to well-established corporations with a long history of developing products for the fire service.

Oftentimes, ideas for new technology or tools for the fire service are generated organically within the fire service, yet they may not succeed due to lack of capital or commercial connections. It was recommended that the fire service encourage the support of crowdfunding projects and the kick-starter type model for

firefighting technology. This can be done by developing a lessons learned document to teach firefighters how to find sources of this type of funding and to spread the word on appropriate projects throughout the information sharing network that exists in each national fire service organization.

Feedback Loop

Further guidance on how the fire service can provide feedback useful to manufacturers could increase the value that those who develop technology gain from their interaction and partnership with fire departments. Anecdotally, it is commonplace for someone with a new idea to go to their local department and the support they receive can vary widely. Creating a standardized and openly available evaluation process for fire departments looking at new technology would be critical in broadening the acceptance of new technology. It was suggested that NFFF provide an algorithm or other form of guidance document to offer firefighters information on the transfer of Research into Practice. At the same time, guidelines for manufacturers to understand the pace of technology adoption in the fire service and recommendations on being solutions-oriented would help those who are looking to get feedback on a proposed technology. A checklist of items or suggestions on how to get feedback from the fire service during the development phase of creating a new product (from the conceptual phase to the roll-out phase) would be valuable.

Standards

The importance of identifying applicable standards for the technologists to consider and understand during their development process was highlighted by several breakout groups. It was noted that standards are often perceived roadblocks for getting technology to firefighters in a timely manner and that technology must be rugged enough to be evaluated against current codes and standards prior to adoption on the fireground. At the same time, small start-up companies may not have the resources to have their idea fully evaluated against the appropriate standard. In other cases, existing codes or standards could preclude a technology from reaching the marketplace and should be identified as early as possible.

NFFF Research Agenda Symposium

Needs analyses that combine input from the technology industry and participants of the fire service are critical to continuing the development and transfer of advanced technology. In particular, support for the NFFF Research Agenda Symposium was voiced as a model approach to bringing these stakeholders together, which in turn supports the collaboration to transfer technology.

Recognition

The powerful motivating role of award recognition was proposed as a means to actively promote engagement from the fire service in this process. The creation and support of an annual technology or innovation award for firefighters or fire departments who actively participate with technology development has potential to increase the attractiveness of this role. NFFF is currently bestowing a ‘Researcher of the Year’ award for those involved in academic research. The proposed recognition would be analogous for those in the fire service who are supporting development and adoption of new technology.

Goal #3: Existing Technology Outreach Recommendations

The third goal that attendees were charged with was to identify methods to inform, educate, and train firefighters in existing technologies.

Almost universally, the attendees suggested that a multi-media approach to fire service outreach is critical. The need to reach a population that has varying levels of comfort with technology requires a broad dissemination approach. In this day and age, social media (including YouTube®) dissemination would be expected for the younger generation in the fire service. At the same time, utilizing targeted legacy outreach approaches such as trade journals, conferences, and trade shows is more likely to engage the more seasoned firefighters and those who are later in their career. Suggestions were also made to approach training manual publishers about including information in their products.

Technology and product development companies have long worked with training organizations to provide rapid feedback on products due to the higher rate of tool usage than is common by responding fire departments. The reciprocal benefit to this activity is the ability to inform, educate, and sometimes train firefighters and instructors on these new technologies, in some cases even before they are released to the market. In a similar manner, the reciprocal benefit of a Fire Ops 101-type program to engage technologists in the fire domains informing, educating, and training firefighters on new and upcoming technology.

Participants also suggested updating the Fire & Emergency Training Network model, particularly using the currently available multimedia outlets, for teaching new technology. Using YouTube® or other video technology, daily or weekly news shows related to technology development could be produced and widely distributed. To supplement the video content, the development of a technology-focused blog site for open discussion between fire service and manufacturers was proposed.

Participants also suggested highlighting the benefits of advanced technology as part of the 'lessons-learned' outreach from actual fireground incidents. For example, adding a section to National Institute of Occupational Safety and Health's Fire Fighter Fatality Investigation Reports could highlight how incorporating technology may have had a positive effect on an incident. Simulations of incidents for training purposes that show how outcomes may be simulated with using different technologies can be powerful teaching tools. This approach is currently used to highlight the benefits of installed sprinklers, as demonstrated in Chief Ray's presentation to the attendees.

Goal #4: Fire Service and Technology Industry Collaboration Recommendations

The fourth goal of the summit was to have attendees identify mechanisms for the technology industry to collaborate with the fire service in the transfer of emerging technologies for the fire service to use.

Department of Homeland Security (DHS) Science and Technology Directorate (S&T)

The DHS S&T has multiple opportunities for collaboration between the fire service and the technology sector. Critical among the activities from S&T is the First Responder Group (FRG). Collaboration with the FRG to conduct 'operational field assessments' with a national view would be beneficial to ensure as wide of market applicability as possible and make the technology development visible to a broader segment of the fire service than a single local fire department. The fire service needs to increase their involvement and relationship with the FRG in particular and the S&T in general. The FRG represents first responders

from multiple disciplines, so it is critical that the fire service increase their presence and their voice amongst the other stakeholders and engage in a way to raise the priority of our needs and concern in order to receive the highest consideration for technology transfer.

Centers of Excellence

Centers of Excellence at Universities and research organizations have been created for the study of many different topics of interest to first responders. It would be of particular interest to develop a Center focused on the transfer of technology. The activities of S&T have set up much of the groundwork, though without specific focus on the fire service.

One of the critical aspects for a 'Firefighter Technology Transfer Center of Excellence' could be the focus to establishing accelerators and/or incubators for new technology focused on the fire service. Alternatively, providing a new (or focusing existing) funding stream that allows new technology to be integrated into existing technology accelerators would allow leveraging of technology transfer programs that already exist. Hosting 'hackathon' competitions concentrating on fire service needs could provide an avenue for untapped talent to study fire service problems and apply the most current research and technology to finding a solution. Young engineers are often interested in finding ways to connect their education with real world problems, particularly those of social interest such as reducing the impact of fires on the lives of citizens.

Technology Transfer Center's Emergency Response Technology Program

A recommendation was made for re-establishing a committee like the Technology Transfer Center's Emergency Response Technology Program, which included high-level collaboration between firefighters, military, scientists and manufacturers. The committee members of this program were charged with transferring military technologies to the fire service and historically resulted in important technological advances. To support such a committee, a stakeholders' group from different segments of the fire service could assist in providing the voice of the customer. In the past, the committee was managed by the National Science Foundation (NSF). If there is no longer interest from NSF, this would be a natural extension of a Firefighter Technology Transfer Center of Excellence.

Nontraditional Collaborations

Finally, collaborations from outside of the American fire service are critical to increasing information transfer into this stakeholder group. Beside the military, there are a multitude of other industries from which the fire service can mine developing ideas or adapt new applications for existing technologies if these partnerships are actively sought out. Additionally, while important differences exist with fire service operations in other countries, technology developed by international fire service organizations should be regularly evaluated with an open-minded view for innovative ideas. While existing technologies in other countries may not directly transfer due to differing standards and/or policies and procedures, the platform on which they are developed can provide a launching board for new capabilities in the American fire service.

Goal #5: Funding Opportunities Recommendations

Key to integration and adoption of new technologies is the establishment of diverse funding opportunities. Participants focused their responses on two broad areas: 1) those focusing on funding for technology development and 2) funding for the fire service to acquire this technology.

Technology Development Funding

For years, technologists have focused on several traditional avenues for procuring funding support for their efforts to develop applied solutions to critical problems. For example, federal grant programs exist specifically for this purpose. A sample of the opportunities that have some relevance for fire service related technology includes:

- DHS Homeland Security Advanced Research Projects Agency
- DHS-FEMA Fire Prevention & Safety (FP&S) Research and Development (R&D)
- Technical Support Working Group
- Department of Defense (DoD) Fire Service and related technologies

Continuing to tap into these funding sources will leverage coordination of federal stakeholders. However, important vulnerabilities exist within each of these avenues, and thus are only one potential pathway which may be considered.

The Fire Protection Research Foundation (FPRF) has funding sources which may provide potential financial assistance for research and development, specifically if the research can support the development of standards for fire service technology. While standards were identified by several breakout groups as both a guiding source and a potential roadblock for technology development, funding and research with FPRF may address some of these concerns for a specific project or standard.

Public/private partnerships have long been successful in assisting the development of technology, particularly if these private entities are the source of the product of interest. The FDNY Research & Development Unit has successfully worked with companies to develop technology in such a manner. Departments that provide the voice of the customer in project development, offer a sounding board for product development or assist in testing prototypes, often find the benefits in reduced cost or donated products once they are transitioned to market.

There are non-traditional methods to support funding for product development outside of the fire service and these approaches can be adopted within our industry. Funding for projects through crowdsourcing can help raise initial capital. While departments themselves may find it difficult to invest in such avenues, relationships within the fire service can be leveraged to generate funding for useful products. Maker Spaces, which are used to help incubate ideas as well as construct initial prototypes, are available in many larger communities and can be used to help move through the product development process.

Fire Service Technology Acquisition Funding

Equally important for the sustainment of technology integration into the fire service is the ability for end users to support the acquisition of the products that come to market. The fire service marketplace is relatively small and the purchasing process complex, so support for procurement of first responder-based technologies is critical for current and future technology development. In essence, the establishment of a successful fire service technology marketplace is critical for sustained investment in fire service technology development. Specific support for fire service purchase of new technology can be found from federal funding sources such as DHS through the Assistance to Firefighters Grants (AFG) program. AFG

provides funding for fire service agencies to purchase equipment that may not be feasibly acquired otherwise. In particular, AFG proposals are often scored highly if they can relate need, quantifiable impact, and cost benefit to the use of the requested technology. Guidelines should be developed and provided to assist local fire departments in acquiring AFG support. At the same time, those who are developing technology should keep an eye on the larger general public marketplace where transitions can be made. Some commercial entities have leveraged fire service applications in the advertising of a technology's capabilities as a marketing differentiator.

Summit attendees also identified local agency funding and in-kind support as potential resources for technology acquisition. For example, the San Diego (CA) Fire Department partnered with a local company to donate thermal imaging cameras. Other departments conducted fundraisers and specific community campaigns to raise money for thermal imaging cameras. This is another avenue where crowdsourcing funding campaigns may assist fire departments in technology acquisition. Where applicable, the fire service can look to related organizations to support technology purchase and integration. Attendees provided examples of working with law enforcement to help integrate funds used for mandatory NIMS training or other incident command activities into support of incident command technology purchases.

Other non-traditional partnerships, such as with medical industries and insurance companies, were identified, because they may have specific interest in firefighter health and safety technology. Often, non-fire service corporations use firefighters in their commercials and may be willing to donate a portion of profits to their local departments. The ability to host Fire Ops 101-type programs for business leaders in one's community and fire service industry partners was again cited as a means to engage these individuals in the fire service and help understand their needs first hand. In terms of justification for the purchase of new technology, it is often useful to demonstrate a return on investment for the community as it relates to increased safety and effectiveness of the local fire department and thus better serve their communities.

Resources

Report from Incident Command Operations and Accountability Conference
http://1rxflr7bsmg1aa7h24arae91.wpengine.netdna-cdn.com/wp-content/uploads/sites/2/2015/01/technology-report-2015.pdf

2015 National Fire Service Research Agenda
http://1rxflr7bsmg1aa7h24arae91.wpengine.netdna-cdn.com/wp-content/uploads/sites/2/2016/05/2015-Rearch-Agenda.pdf

Firefighter Life Safety Initiative #8 Resources and Research
http://www.everyonegoeshome.com/16-initiatives/8-technology/

Research Roadmap for Smart Fire Fighting, NIST Special Publication 1191
http://www.nfpa.org/SmartFirefighting

Publications

National Fallen Firefighters Foundation staff. [July 18, 2016] NFFF hosts summit to examine relationship between technology and firefighter health and safety. Available from https://www.everyonegoeshome.com/2016/07/18/tech-summit/.

National Fallen Firefighters Foundation staff. [August 22, 2016] Moving the fire service along the technology highway. Available from https://www.everyonegoeshome.com/2016/08/22/technology/.

FireRescue staff. [January 30, 2017] NFFF Releases 2016 Fire Service Technology Summit Report Can evolving technology improve safety and service?
Available from http://www.firerescuemagazine.com/articles/2017/01/nfff-releases-2016-fire-service-technology-summit-report.html.

List of Acronyms

Assistance to Firefighters Grants	AFG
Department of Homeland Security	DHS
Federal Emergency Management Agency	FEMA
Fire Prevention and Safety Directorate	FP&S
First Responder Group	FRG
National Fallen Firefighters Foundation	NFFF
National Fire Sprinkler Association	NFSA
National Science Foundation	NSF
Personal Protective Equipment	PPE
Physiological Status Monitoring	PSM
Science and Technology Directorate	S&T
Unmanned Aerial Vehicle	UAV
Wearable Advanced Sensor Platform	WASP™

Appendix A: 16 Firefighter Life Safety Initiatives

FLSI #1	Define and advocate the need for a cultural change within the fire service relating to safety; incorporating leadership, management, supervision, accountability and personal responsibility.
FLSI #2	Enhance the personal and organizational accountability for health and safety throughout the fire service.
FLSI #3	Focus greater attention on the integration of risk management with incident management at all levels, including strategic, tactical and planning responsibilities.
FLSI #4	All firefighters must be empowered to stop unsafe practices.
FLSI #5	Develop and implement national standards for training, qualifications, and certification (including regular recertification) that are equally applicable to all firefighters based on the duties they are expected to perform.
FLSI #6	Develop and implement national medical and physical fitness standards that are equally applicable to all firefighters, based on the duties they are expected to perform.
FLSI #7	Create a national research agenda and data collection system that relates to the initiatives.
FLSI #8	Utilize available technology wherever it can produce higher levels of health and safety.
FLSI #9	Thoroughly investigate all firefighter fatalities, injuries and near misses.
FLSI #10	Grant programs should support the implementation of safe practices and/or mandate safe practices as an eligibility requirement.
FLSI #11	National standards for emergency response policies and procedures should be developed and championed.
FLSI #12	National protocols for response to violent incidents should be developed and championed.
FLSI #13	Firefighters and their families must have access to counseling and psychological support.
FLSI #14	Public education must receive more resources and be championed as a critical fire and life safety program.
FLSI #15	Advocacy must be strengthened for the enforcement of codes and the installation of home fire sprinklers.
FLSI #16	Safety must be a primary consideration in the design of apparatus and equipment.

Appendix B: Technology-Related Recommendations from the 2015 Fire Service Research Agenda

RECOMMENDATIONS (in alphabetical order)	PRIORITY LEVEL
Assess the impact/influence of the adoption/enforcement of codes on the economic impact of wildland-urban interface fires. Consider the impact on both wildland to urban and urban to wildland fire transitions. Examine the impact on fire ignitions and loss. (#31)	Medium
Assess the reliability and performance characteristics of alternative smoke alarm technologies. (#14)	High
Conduct a study of the life span of PPE. (#16)	High
Conduct research based on fire dynamics to identify best practices at the strategic, tactical and task levels for firefighting operations in new and existing commercial and residential structures. The research should include the creation of on-scene risk assessment tools based on specific fire factors to assist company officers and incident commanders. (#17)	High
Conduct research into establishing safe and reliable aircraft operations in the wildland-urban interface. (#41)	Medium
Conduct research on cleaning methods for firefighter protective clothing, including potential impacts on the protective properties and useful life of the clothing, and determining effectiveness of removal of suspected carcinogens and other contaminants. (#33)	Medium
Conduct research on enhanced dermal protection provided by firefighter structural protective clothing, particularly as it relates to reducing exposures to known and suspected carcinogens. (#19)	High
Conduct research on how science can improve wildland firefighting training, tactics and response to reduce fatalities, injuries and unintended outcomes. (#20)	High
Conduct research on the effectiveness of alternative implementation strategies and policies for health and wellness programs. (#45)	Low
Conduct research to make improvements in the survivability of fire apparatus crashes. Conduct research related to anthropometric and ergonomic challenges in fire apparatus construction and arrangements that lead to frequent head and musculoskeletal injuries. (#50)	Medium
Continue progress toward the development and refinement of enhanced data systems (such as N-FORS) across all fire service domains. (#2)	High
Continue research into operational practices directed toward more effective tactics, improvements in firefighter safety and victim survivability and reductions in property losses. These studies should specifically address staffing and deployment, fire dynamics research and victim survivability. The focus should include high-rise residential and commercial buildings, private dwellings, multiple unit residential occupancies, strip malls, taxpayer buildings and warehouses. (#21)	High

Continue to employ fire modeling and full scale re-creations of specific incidents that resulted in firefighter injuries and deaths to identify contributing factors and recommended changes in strategy, tactics and tasks. (#47)	High
Determine the appropriate level of respiratory protection for use during overhaul operations including the use of air monitoring instruments to measure thresholds. (#35)	Medium
Determine the necessary components to be included in the educational process for incident commanders, taking into account risk management, tactics, operational concerns and an acceptable knowledge base. (#53)	Low
Develop a centralized data warehouse and common data elements to facilitate research related to wildland firefighting. (#3)	High
Develop a physical fitness risk assessment tool for wildland firefighters. (#46)	Low
Develop a user-friendly technological accountability system for use on the fireground. (#51)	Medium
Develop methods to evaluate and quantify the direct and indirect economic impacts of fire service response and operations on property, people and the environment. (#37)	Medium
Establish a center for best practices for data collection and analysis. Identify and catalog data sources and technology formats that are relevant and beneficial for the fire service. (#10)	Medium
Evaluate behavior modification strategies that will lead to lasting cultural changes resulting in improvements in data collection and use. (#5)	High
Evaluate existing ballistic protection options (including helmets) for firefighters and EMS responders. As indicated by findings, develop new options. (#52)	Medium
Evaluate the impact of modern and evolving building technology (i.e. green buildings, solar and battery storage systems) on fire service operations. Create a knowledge base for incident commanders, company officers and firefighters to support operational safely and proficiently. (#38)	Medium
Identify and develop methods to capture operational data on fireground performance, mental resiliency, effective communications and operational benchmarks. (#6)	High
Identify and make use of traditional and non-traditional data to supplement, update and enhance fire service programs, including fire suppression and emergency operations, public education, fire prevention and community risk reduction efforts. (#7)	High
Identify contributing factors to firefighter injuries and fatalities related to non-fireground events (i.e. EMS, special operations and roadway). (#39)	Medium
Identify respiratory contaminants and determine the potential adverse health outcomes associated with wildland and wildland-urban interface fire operations. Also, determine the adequate respiratory protection for wildland firefighters. (#25)	High
Improve local data collection in order to positively impact efficient service delivery, professional development and organizational health. (#8)	High
Measure the fire growth rate in new homes which are built to modern energy codes and specifications and furnished with contemporary fire loads. Simulate and evaluate escape times based on the realistic capabilities of individuals. (#44)	Low

Research the application of unmanned aerial vehicles for the fire service. (#54)	Low
Research the development of technology, tactics and response standards in the wildland-urban interface. Include PPE requirements for all responders. (#48)	High
Research the effectiveness of alternative learning mechanisms in order to identify and develop the best firefighter training delivery system(s) for strategic, tactical and task level operations. (#40)	Medium
Research the impact of communication failures with portable radio systems and devices as a contributing factor in firefighter injuries and fatalities. Address alternative radio system configurations to ensure reliable in-building radio communications. Also, examine potential improvements in radio construction, ergonomics and the ability to interface portable radios with other technologies to track firefighters in the fire environment. (#27)	High

High Priority: These recommendations have a significant impact on firefighter survivability because they relate to mission-critical job requirements. Research related to these recommendations is of the highest demonstrated priority.

Medium Priority: These recommendations have an important impact on firefighter safety and survivability and may support and reinforce existing efforts to reduce risks to personnel. Research on these recommendations is of a secondary priority.

Low Priority: These recommendations have an impact on firefighter health and safety. Research on these recommendations is needed and should be supported due to their often emerging nature.

Appendix C: Meeting Attendees

Name	Organization
Lisa Baker	International Association of Women in Fire & Emergency Services
	Oakland (CA) Fire Department
Seth Barker	Big Sky (MT) Fire Department
Maxim Batalin, Ph.D.	UCLA Engineering Institute for Technology Advancement
Chris Bennett	The Walsh Group
Tyler Boone	FireHUD, Inc.
Scott L Booth	Gig Harbor (WA) Fire & Medic One
Andy Bozzo	Tablet Command
	Contra Costa (CA) County Fire Protection District
Alan Brunacini	Blue Card Command
John Buckman, III	Indiana Department of Homeland Security
Thomas Calvert	Menlo Park (CA) Fire Protection District
Jennifer Chadwick	Everyone Goes Home® program Advocate
	San Antonio (TX) Fire Department
Amos Chalmers	Phoenix (AZ) Fire Department
Mark Charleston	Tualatin Valley (OR) Fire and Rescue
Dhiren Chauhan	Motorola Solutions, Inc.
Catalina Ciobanu	PBI Performance Products
Ronny Coleman	Rescue Air Systems
Kevin Conant	California State Fire Training
Brian Crandell	Fort Ellis (MT) Fire Department
Mark Duerr	City of Stockton (CA) Fire Department
Michael Dugan	Fire Department of the City of New York
Rick Dunn	South Carolina State Firefighters Association
Darian Edwards	Colerain (OH) Fire & EMS
David Eller	Fire Protection Publications-Oklahoma State University
Pat Fehling, Ph.D.	Skidmore College
Mike Gagliano	Rescue Air Systems
John Granby	The LION Group, FEMSA/FAMA
Casey Grant	Fire Protection Research Foundation
Debra Hall	Rescue Air Systems
Robert Halton	Pennwell Fire Group
J. Jafari Harris	San Diego (CA) Fire-Rescue Department
Richard Harris	The LION Group
Brad Harvey	Scott Safety
Scott Heiss	Denver (CO) Fire Department
Chad Hoefle	Stillman (IL) Fire Department
Tim Hopkins	International Association of Fire Chiefs
Gavin Horn, Ph.D.	University of Illinois Fire Service Institute
Brian Kazmierzak	International Society of Fire Safety Instructors
	Penn Township (OH) Fire Department
Robert Kmak	Denver (CO) Fire Department
Ed Mann	Provident
Rick Marshall	Renton (WA) Regional Fire Authority
Michael McAdams	National Fire Operations Reporting System
Stewart McGehee	Oakland (CA) Fire Department

Cyndie Montoya	Kidde Fire Safety
Mark Mordecai	Globe Manufacturing Company
Nathan Murphy	Ohio Fire Chiefs' Safety, Health and Wellness Committee
Manual Navarro	Menlo Park (CA) Fire Protection District.
Bill Parson	Scott Safety
Jakob Pelk	Central County (CA) Fire
Lawrence Petrick	International Association of Fire Fighters
Ryan Pietzsch	VFIS
Vickie Pritchett	National Fire Sprinkler Association
Shawn Pruchnicki	The Ohio State University
Eric Quinney	National Volunteer Fire Council
Shane Ray	National Fire Sprinkler Association
Jake Rhoades	International Association of Fire Chiefs Safety, Health, and Survival Section
David Rhodes	Rescue Air Systems
Allan Rice	Alabama Fire College North American Fire Training Directors
Richard Riley	Clearwater (FL) Fire & Rescue
Thomas Riley	Fire Department of the City of New York
Kevin Roche	National Fallen Firefighters Foundation
Lance Routson	Urbandale (IA) Fire Department
Derek Roy	Scott Safety
Jack Rupp	Ohio Fire Chiefs' Safety, Health and Wellness Committee
Tricia Sanborn	National Fallen Firefighters Foundation
Oscar Sepulveda	Pasadena (CA) Fire Department
Demond Simmons	International Association of Black Professional Fire Fighters Oakland (CA) Fire Department
Tyler Sisk	FireHUD, Inc.
Denise Smith, Ph.D.	Skidmore College University of Illinois Fire Service Institute
Elizabeth Snow	Wichita (KS) Fire Department
Victor Stagnaro	National Fallen Firefighters Foundation
Keith Stakes	UL - Firefighter Safety Research Institute
Paul Steinberg	Motorola Solutions, Inc.
Chris Tardif	East Hartford (CT) Fire Department
Skye Thompson	Tablet Command
Amy Tippett	National Fallen Firefighters Foundation
Eric Tomlinson	King County (WA) Fire Training Consortium
Mario Trevino	Rescue Air Systems
Robert Tutterow	Fire Industry Education Resource Organization
Christopher Walton	National Institute of Standards and Technology/ Public Safety Research Communications Program
Darin White	Oakland (CA) Fire Department
Michael Wieder	IFSTA/Fire Protection Publications
Ken Willette	National Fire Protection Agency
Joseph Willi	National Institute of Standards and Technology
Mike Worrell	FirstNet – U.S. Department of Commerce

NFFF Mission

Our mission is to honor and remember America's fallen fire heroes, to provide resources to assist their survivors in rebuilding their lives, and work within the fire service community to reduce firefighter deaths and injuries.

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