INTRODUCTION
Training is a critical part of the fire service. As new technological innovation applications (e.g., virtual reality, augmented reality, artificial intelligence, machine learning, robotics, etc.) emerge and are proven in other arenas, fire service training academies must investigate these to see their impact on the skills, safety, and wellness of firefighter trainees.

This ROADMAP is a summary of the deliverables from a project addressing the application of immersive learning on firefighter skills, health, and safety during training. This effort seeks to leverage the immersive learning technologies that have proven to be beneficial in other high-risk occupations, such as military, law enforcement, health care, and identify the value of application of immersive learning for firefighter training.

This project is funded by a DHS FEMA Assistance to Firefighters Grant (AFG) FP&S Program (Award No.: EMW-2020-FP-00866) to the Fire Protection Research Foundation (FPRF) and North American Fire Training Directors (NAFTD) as the principal project partners.

This two-year effort consists of four primary components, each providing a separate report and/or project deliverable:

(I) Focus Group. Targeted focus group meetings with key types of NAFTD representative fire academies (e.g., large, small, community college based, etc.) to gain insight about the distinct training delivery systems of fire training academies.

(II) Literature Review. Literature review to develop baseline content and material that summarize the current landscape of immersive learning in fire service training and education.

(III) Summit. Stakeholder Summit to present, review, and evaluate the overall state of immersive learning technology in fire service training and develop a firefighter immersive learning environment (FILE) roadmap to provide guidance to fire training academies and others in support of future implementation of immersive learning.

(IV) Knowledge Base. A web-based knowledge base summary of the literature and available information on an interactive, living website.

PROJECT GOAL
The overall goal of this project is to identify, assess, and summarize the available and emerging technological tools, techniques, and innovations, to support the application of immersive learning environments in fire service training and address its impact on firefighter skills, health, and safety during training.

This ROADMAP provides the capstone document that demonstrates how this goal has been met.

I. FOCUS GROUP SUMMARY
The Focus Group Summary describes the present landscape of immersive learning in today’s fire service, and summarizes the understanding, desires, and concerns from the different stakeholders involved with fire service training.

Five separate focus group meetings were held, with three in-person meetings (New England, South Carolina, and Utah) and two virtual meetings. Each meeting specifically
targeted key stakeholders, including administrators, fire chiefs, instructors, new recruit students, in-service students, content providers, technology providers, and others. The final focus group report consolidates all input and discussions.

A key deliverable from the focus groups has been the development of a SWOT Analysis that indicates the strengths, weaknesses, opportunities, and threats involving immersive learning for fire service training. This addresses the attributes and characteristics of fire service immersive learning from the perspective of each of the impacted stakeholders, with consideration of the present strengths and weaknesses as well as the future opportunities and threats.

II. LITERATURE REVIEW

The literature review report summarizes the current landscape on immersive learning in fire service training and education. This is based on a comprehensive review of available information from published literature, ongoing research studies, and current practices implemented by the fire service and similar professions, which are using and/or considering immersive learning techniques and approaches.

The baseline information of the literature review report was a fundamental discussion and review item considered by the project Summit (a subsequent deliverable from this project). The literature review report includes future needs analysis for fire service training:

- Use the NFPA Job Performance Requirements (JPRs) as a starting point for a detailed needs analysis specifying the skills and concepts that firefighters need to know, along with performance metrics.
- Determine what methods/tools/technologies are best for teaching and practicing each skill or concept.
- Map those that are suitable for VR or AR (if any) into a needs requirement for the software to be developed or procured to support that element of the training.
- Determine the instructor’s role and the software’s role in teaching and practicing each skill, including the training delivery system, and training authoring system.
- Identify what level of sophistication is required for the underlying simulation for each task (e.g., 360° video, full 3D-model with high-fidelity simulation...).

- Integrate cost into the analysis to determine which needs may be more cost-effectively addressed by VR vs. non-VR methods.

Gap analysis:

- Task/training needs analysis: Which tasks (from those among the NFPA JPRs) will be best represented / improved with VR support?
- VR/AR training expertise: There is a scarcity of experts who can develop research-based VR / AR training.
- General-purpose software: There is a scarcity of training software suited for general-purpose use.
- Training deployment expertise: For existing software, there is often a lack of expertise as regards the best practices for deployment. Instructors need to be trained before they can train others.
- Underlying simulations: There need to be good, real-time underlying fire models with realistic evolution and smoke, based on the firefighters’ interactions with them.
- 3D models: While there are many 3D models of environments and structures, more – and more specific options are needed.
- Special-purpose hardware: There is a lack of hardware created specifically for firefighting tasks, which may be needed to optimize simulation of particular conditions.
- Performance data analysis tools: There need to be tools for analyzing the performance data that comes from the training system, to measure effectiveness and highlight areas for improvement.

III. SUMMIT PROCEEDINGS

The Summit Proceedings are a primary project deliverable and is titled “Firefighter Immersive Learning Environment (FILE) Summit”. The summit was conducted in-person on February 7 & 8, 2023, and was hosted at Illinois Fire Service Institute, Champaign, IL. The Summit reviewed baseline information, further refined all the other project deliverables, and supported networking dialogue and discussions on adopting and adapting immersive learning approaches in fire service training.

Summit Takeaways

The primary summary observations from the FILE Summit, and for this overall FILE project, are the following. These are the guideposts for all involved on this topic, with the
intent that they provide direction for future needs, concerns, and issues as fire service immersive learning is implemented.

1) Applications
a. **Applications:** Immersive learning has great promise for application to all levels of fire fighter and fire officer training. While it is currently used for pump operations, live fire attack skills enhancement and increasing situational awareness, it should be leveraged for hazmat, tech rescue, EMS training, and firefighter recruitment and retention.

b. **High-Risk Incidents:** Address low-frequency high-risk events (e.g., confined space, extrication, tanker rollover, drug lab, swift water, under ice, etc.)

c. **Live Fire Training:** The use of immersive learning should serve as a complement to in-person live fire training and not replace it.

d. **Parallel Professions:** Learn from immersive learning applications in other safety critical professions, including commercial aviation, aircraft maintenance technology, construction, healthcare, military, maritime, nuclear power, oil & gas, manufacturing, mining, etc.

e. **Introducing Skills & Maintaining Proficiency:** Immersive learning technologies can be effectively used to introduce skills and maintain proficiencies of the 1 million plus firefighters in the US. Emerging issues (e.g., replacement firefighting foams, battery energy storage systems (BESS), etc.) require retraining across the entire fire service.

2) Key Features
a. **Immersive Learning Technologies:** These emerging technologies are tools that must be: (i) aligned with validated curriculum and learning objectives (the JPR’s); (ii) able to deliver high quality training outcomes that support fire and emergency services; (iii) founded on a continued dialogue between developers, integrators, curriculum designers, instructors, fire academies, researchers, funders, and governmental agencies; and (iv) based on uniform evaluation methods that measure the ability of the technologies to achieve learning.

b. **Multi-Users:** Support cross discipline usage and promote team learning environments.

c. **Common Documentation Platforms:** Provide common standardized dashboards to facilitate documentation that is needed from different organizations (e.g., national, state, local, etc.).

d. **Adaptable to hybrid/blended training:** Immersive learning environments are recommended as a very important part of hybrid/blended learning and should, as technology continues to develop, evolve into a more important role.

e. **Minimize Risk:** Minimize risk during training by creating a safe environment for learning; and enhancing skills to prepare firefighters for operations in IDLH and similar environments.

3) Learning Experience
a. **Learning Environments:** Provide immersive learning environments customizable to local conditions and response needs, that are experiential, safe, engaging, memorable, and provide a sense of presence.

b. **Layered Content:** Supports development of wholistic curriculums that utilize training content in a layered manner resulting in achieving desired training outcomes.

c. **Job Performance Requirements:** Integrate use of JPRs as performance metrics and produce documentation that can be used for skills, validation, and certification.

d. **Inclusion and Equity:** Provide equitable training opportunities to the broad fire service population inclusive of all generations, genders, and races; adaptable to help influence firefighters to address acceptance of immersive learning.

e. **Muscle Memory Development:** Provide opportunity for repeatable skills performance at varied locations maintaining alignment with established curriculums and learning objectives.

4) Policy
a. **Single Voice:** Facilitate a unified, single voice of the fire service on immersive learning and the associated supporting technologies.

b. **Standardization:** Generate language in applicable NFPA standards to address immersive learning environments (& update NFPA 1451 Annex C). Consider a separate standard for immersive learning technology.
c. **Direct & Indirect Costs:** Identify all direct and indirect costs as part of a full cost benefit analysis, including value propositions. Address specific approaches, such as leases, regional-shared programs, and public/private partnerships. Quantify intangible costs, such as health & safety benefits, infrastructure support costs, etc.

d. **Managing the Evolution:** This is an evolutionary process that needs to be well-managed, and it is not a revolution. Immersive learning technologies are being implemented in numerous safety-critical professions, and the fire service should embrace this technology and maximize the advantages it provides.

**Stakeholder Perspectives**
Throughout this project, there has been a detailed focus on the perspectives of key stakeholders involved with this topic. For convenience, the following are the key summary observations for four of the primary stakeholders involved with fire service immersive learning:

**A) Administrators (@ Training Academies and Fire Departments)**

**Primary Focus Issue**
- **Direct & Indirect Costs:** Identify all direct and indirect costs as part of a full cost benefit analysis, including value propositions. Address specific approaches, such as leases, regional-shared programs, and public/private partnerships. Quantify intangible costs, such as health & safety benefits, infrastructure support costs, etc. (Summary Observation 4c)

**Other Key Focus Issues**
- **High-Risk Incidents:** Address low-frequency high-risk events (e.g., confined space, extrication, tanker rollover, drug lab, swift water, under ice, etc.) (Summary Observation 1b)
- **Introducing Skills & Maintaining Proficiency:** Immersive learning technologies can be effectively used to introduce skills and maintain proficiencies of the 1 million plus firefighters in the US. Emerging issues (e.g., replacement firefighting foams, battery energy storage systems (BESS), etc.) require retraining across the entire fire service. (Summary Observation 1e)
- **Multi-Users:** Support cross discipline usage and promote team learning environments. (Summary Observation 2b)
- **Adaptable to hybrid/blended training:** Immersive learning environments are recommended as a very important part of hybrid/blended learning and should, as technology continues to develop, evolve into a more important role. (Summary Observation 2d)
- **Job Performance Requirements:** Integrate use of JPRs as performance metrics and produce documentation that can be used for skills, validation, and certification. (Summary Observation 3c)
- **Inclusion and Equity:** Provide equitable training opportunities to the broad fire service population inclusive of all generations, genders, and races; adaptable to help influence firefighters to address acceptance of immersive learning. (Summary Observation 3d)

**B) Learners (Including Recruits and In-Service)**

**Primary Focus Issue**
- **Learning Environments:** Provide immersive learning environments customizable to local conditions and response needs, that are experiential, safe, engaging, memorable, and provide a sense of presence. (Summary Observation 3a)

**Other Key Focus Issues**
- **Applications:** Immersive learning has great promise for application to all levels of fire fighter and fire officer training. While it is currently used for pump operations, live fire attack skills enhancement and increasing situational awareness, it should be leveraged for hazmat, tech rescue, EMS training, and firefighter recruitment and retention. (Summary Observation 1a)
- **Introducing Skills & Maintaining Proficiency:** Immersive learning technologies can be effectively used to introduce skills and maintain proficiencies of the 1 million plus firefighters in the US. Emerging issues (e.g., replacement firefighting foams, battery energy storage systems (BESS), etc.) require retraining across the entire fire service. (Summary Observation 1e)
- **Multi-Users:** Support cross discipline usage and promote team learning environments. (Summary Observation 2b)
- **Adaptable to hybrid/blended training:** Immersive learning environments are recommended as a very important part of hybrid/blended learning and should, as technology continues to develop, evolve into a more important role. (Summary Observation 2d)
Firefighter Immersive Learning Environment (FILE) Roadmap

- **Learning Environments**: Provide immersive learning environments customizable to local conditions and response needs, that are experiential, safe, engaging, memorable, and provide a sense of presence. (Summary Observation 3a)
- **Muscle Memory Development**: Provide opportunity for repeatable skills performance at varied locations maintaining alignment with established curriculums and learning objectives. (Summary Observation 3e)
- **Managing the Evolution**: This is an evolutionary process that needs to be well-managed, and it is not a revolution. Immersive learning technologies are being implemented in numerous safety-critical professions, and the fire service should embrace this technology and maximize the advantages it provides. (Summary Observation 4d)

**C) Instructors**

**Primary Focus Issue**
- **Live Fire Training**: The use of immersive learning should serve as a complement to in-person live fire training and not replace it. (Summary Observation 1c)

**Other Key Focus Issues**
- **Applications**: Immersive learning has great promise for application to all levels of fire fighter and fire officer training. While it is currently used for pump operations, live fire attack skills enhancement and increasing situational awareness, it should be leveraged for hazmat, tech rescue, EMS training, and firefighter recruitment and retention. (Summary Observation 1a)
- **Common Documentation Platforms**: Provide common standardized dashboards to facilitate documentation that is needed from different organizations (e.g., national, state, local, etc.). (Summary Observation 2c)
- **Adaptable to hybrid/blended training**: Immersive learning environments are recommended as a very important part of hybrid/blended learning and should, as technology continues to develop, evolve into a more important role. (Summary Observation 2d)
- **Layered Content**: Supports development of wholistic curriculums that utilize training content in a layered manner resulting in achieving desired training outcomes. (Summary Observation 3b)
- **Job Performance Requirements**: Integrate use of JPRs as performance metrics and produce documentation that can be used for skills, validation, and certification. (Summary Observation 3c)
- **Standardization**: Generate language in applicable NFPA standards to address immersive learning environments (update NFPA 1451 Annex C). Consider a separate standard for immersive learning technology. (Summary Observation 4b)

**D) Providers & Supporters (including Content and Technology)**

**Primary Focus Issue**
- **Immersive Learning Technologies**: These emerging technologies are tools that must be: (i) aligned with validated curriculum and learning objectives (the JPR’s); (ii) able to deliver high quality training outcomes that support fire and emergency services; (iii) founded on a continued dialogue between developers, integrators, curriculum designers, instructors, fire academies, researchers, funders, and governmental agencies; and (iv) based on uniform evaluation methods that measure the ability of the technologies to achieve learning. (Summary Observation 2a)

**Other Key Focus Issues**
- **Applications**: Immersive learning has great promise for application to all levels of fire fighter and fire officer training. While it is currently used for pump operations, live fire attack skills enhancement and increasing situational awareness, it should be leveraged for hazmat, tech rescue, EMS training, and firefighter recruitment and retention. (Summary Observation 1a)
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- **Multi-Users**: Support cross discipline usage and promote team learning environments. (Summary Observation 2b)
- **Learning Environments**: Provide immersive learning environments customizable to local conditions and response needs, that are experiential, safe, engaging, memorable, and provide a sense of presence. (Summary Observation 3a)
• **Layered Content:** Supports development of holistic curriculums that utilize training content in a layered manner resulting in achieving desired training outcomes. (Summary Observation 3b)
• **Standardization:** Generate language in applicable NFPA standards to address immersive learning environments (& update NFPA 1451 Annex C). Consider a separate standard for immersive learning technology. (Summary Observation 4b)
• **Direct & Indirect Costs:** Identify all direct and indirect costs as part of a full cost benefit analysis, including value propositions. Address specific approaches, such as leases, regional-shared programs, and public/private partnerships. Quantify intangible costs, such as health & safety benefits, infrastructure support costs, etc. (Summary Observation 4c)

### IV. Knowledge Base

The immersive learning knowledge base is an online immersive learning knowledge base, for use by fire service community and innovators. Identify, the known providers of technological tools, techniques and software for immersive learning environment that can be applied to fire service training and fire academies, including those who are actively addressing similar technology applications in parallel professions. This can be accessed at: https://nafld.org/resources

### Path Forward

As a result of the input/data we received from this effort, the following are the actionable items for consideration as a path forward:

• **Networking and Engagement:** Continue providing opportunities for those engaged in fire service immersive learning (state training academies, technology developers and integrators, accreditation bodies, curriculum developers, federal agencies, researchers, and the fire service at large) to meet and collaborate on developing immersive learning tools for the fire service.
• **Focused Analysis:** Provide a more focused analysis of specific immersive learning applications currently used by the fire service, including consideration of the following: (a) current use & applications by training academies, metro, volunteer/on-call fire departments; (b) openness of fire service learners to use immersive learning training & factors influencing acceptance by the fire service; (c) identify if learner performance checklists/assessments sufficiently capture the transfer of knowledge, skills from a simulator to real-world.
• **Evaluation:** Consider the development of an evaluation mechanism or tool for immersive learning by leveraging critical theories from human factors psychology, as well as best practices for fire service training & learning.
• **Training Ecosystem:** Define a comprehensive training framework for supporting the cognitive evaluation of situational awareness, within the context of the FS training ecosystem, by clearly outlining stages for introducing immersive learning-based training in the fire service training continuum.
• **Standards:** Assess NFPA and other Standards, creating an inventory of applicable Standards that address, or could address, Immersive Learning Technologies. Purchasing authorities often are neither curriculum specialists nor trainers, they’re executives and would benefit by having guidance as they consider which immersive learning tool to invest in.
• **Knowledge Base:** Continue the Immersive Learning Knowledge Base to provide a central repository of information that will help the fire service when researching/considering the implementation of Immersive Learning Technologies.
• **Outreach:** Continue to share the results of this AFG FILE project through blogs, podcasts, articles, and presentations, to enhance fire service awareness and continue building a community to support the adoption of Immersive Learning Technologies by the fire service.

The future successful implementation of concepts described by this effort are critically dependent on providers of Immersive Learning Technologies meeting the needs of today’s Fire Service. These emerging technologies must support Fire Service curricula as tools that must be aligned with validated curriculum and learning objectives (the JPR’s); able to deliver high quality training outcomes that provide positive impact on firefighter health, safety and wellness; and based on uniform evaluation methods that measure the ability of the technologies to achieve learning.
Summary
This two-year research project has reached its goal of identifying, assessing, and summarizing the available and emerging technological tools, techniques, and innovations, to support the application of immersive learning environments in fire service training and address its impact on firefighter skills, health, and safety during training. The effort has four primary outcomes, each providing a separate report and/or project deliverable:

1) **Focus Group Summary.** Targeted focus group meetings with key types of NAFTD representative fire academies (e.g., large, small, community college based, etc.) to gain insight about the distinct training delivery systems of fire training academies; and

2) **Literature Review.** Literature review to develop baseline content and material that summarize the current landscape of immersive learning in fire service training and education.

3) **Summit Proceedings.** Stakeholder Summit to present, review, and evaluate the overall state of immersive learning technology in fire service training and develop a firefighter immersive learning environment (FILE) roadmap to provide guidance to fire training academies and others in support of future implementation of immersive learning.

4) **Knowledge Base.** A web-based knowledge base summary of the literature and available information on an interactive, living website.

Other safety critical professions, notably aviation, medical, and military, have embraced immersive learning technologies with great success. These other professions have enabled certain advantageous learning activities that are not yet well implemented for the fire service but could be as the fire service training programs utilize new immersive learning approaches (e.g., similar to the military training with multi-users on large scale interactive drills). The experiences of these other professions illustrate a path forward for the fire service, utilizing technologies that are proliferating throughout modern society.

Deliverables
All the project deliverables and outreach materials are available on the project website at:
https://www.nfpa.org/flimmersivelearning.

Additionally, during this project, there has been considerable outreach which is still available. Further information on this topic is available at:
- NFPA Journal article "Full Immersion." (Spring 2022)
- NFPA Journal article "Beyond Training", (Spring 2022)
- NFPA Learn Something New "Using Virtual Reality to Train Firefighters". (January 2022)
- Webinar (May 2023) - https://bcove.video/3nqkZa6P
- NFPA C&E Presentation (June 2023) - https://nfpa.confex.com/nfpa/2023/meetingapp.cgi/Session/3732

Disclaimer
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