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Heads-Up / Hands-Free Firefighting Solutions: Requirements, State of Technology Overview and Market Characterization

Michelle Royal
Mickayla McNamara
FirstLink Analytics

Prepared by:
FirstLink Analytics
1673 W. 8th Street, Suite B
Erie, (PA)
16505, USA

MOU: CAN/US CIPABS - Cooperation in Science and Technology for Critical Infrastructure Protection
and Border Security

Technical Authority: Gerry Doucette, DRDC – Centre for Security Science

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Defence Research and
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Defence Research and Development Canada

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The following study was completed by FirstLink. It represents the best efforts of the FirstLink team to gather, assimilate, and assess certain information pertaining to the topic at hand. It is recognized that this study analyzes certain economic conditions. As these conditions are in constant flux, neither FirstLink nor its members (Pittsburgh Gateways Corp.; AMTV, LLC or its affiliates) can be responsible for these conditions. Any decisions, actions or investment made on the subject covered are solely those of the client.

Abstract

The *Canadian Next Generation First Responder (CNG-IR)* initiative, a Canadian Safety and Security Program (CSSP) investment - CSSP-2016-TI-2226 - aims to better connect, protect and improve situational awareness capabilities for front-line police, fire fighters and paramedics through science and technology. The Program is led by Defence Research and Development Canada's Centre for Security Science (CSS), in partnership with Public Safety Canada.

Responder representative organizations such as the Canadian Association of Fire Chiefs have cast light on the need to make operating environments such as the fire ground safer for operators and the public. In keeping with insights and approaches cited from the National Fire Protection Association Research Foundation (NFPA RF), and in close collaboration with the U.S. Department of Homeland Security Science and Technology Directorate (DHS S&T) a Smart Firefighting (SFF) workshop was held in Ottawa, Ontario on January 30-31, 2018 in order to help frame requirements for improved situational awareness technology supports for fire fighters in a structural fire setting. This document served as background 'read-in' resource to get workshop participants situated beforehand.

Firefighters from Canada and the US – mostly at the captain rank or equivalent - joined DHS S&T program officials, representatives from the National Research Council Industrial Research Assistance Program, and the NFPA RF to focus attention on technology solutions which may position responders to operate on the fire ground in an integrated, 'heads-up / hands-free' (HU/HF) mode. The following document is the result of work undertaken by FirstLink Analytics, with generous assistance from DHS S&T, to support the workshop and frame future discussions between operators and potential SFF solution providers. This analysis was undertaken to support the workshop with a view to: generating HU/HF SFF requirements for consideration by solution providers; providing an overview of technologies in this problem space; and characterizing the market for industries that may be positioned to help.

The Canadian Safety and Security Program is a federally-funded program to strengthen Canada's ability to anticipate, prevent/mitigate, prepare for, respond to, and recover from natural disasters, serious accidents, crime and terrorism through the convergence of science and technology with policy, operations and intelligence.

Significance for Defence and Security

The primary clients for this initiative are civilian first responders serving in Canada, the United States and partner /allied countries. The results of this report are intended to contribute to the body of knowledge which will help responders and technology solution providers move towards relevant investments and development pathways such as those funded by the CSSP, Innovations Solutions Canada and investments that may be approved by partner countries.

Résumé

L'initiative *Canadian Next Generation First Responder (CNG-IR)*, un investissement du Programme canadien pour la sûreté et la sécurité (PCSS) – CSSP-2016-TI-2226 – vise à mieux connecter, protéger et améliorer les capacités de connaissance de la situation pour les agents de police, les pompiers et les ambulanciers de première ligne grâce à la science et la technologie. Le Centre des sciences pour la sécurité (CSS) de Recherche et développement pour la défense Canada, en partenariat avec Sécurité publique Canada, dirige le programme.

Les organismes représentant les intervenants, comme l'Association canadienne des chefs de pompiers, font ressortir le besoin de rendre l'environnement opérationnel, le lieu du sinistre par exemple, plus sûr pour les opérateurs et le public. Conformément aux idées et points de vue de la National Fire Protection Association Research Foundation (NFPA RF) et en étroite collaboration avec la direction des sciences et de la technologie du Département de la sécurité intérieure des États-Unis (DHS S&T), un atelier de lutte intelligente contre l'incendie (Smart Firefighting [SFF]) s'est déroulé à Ottawa (Ontario) les 30 et 31 janvier 2018 afin de cerner les exigences en matière de soutiens technologiques destinés à améliorer la connaissance de la situation pour les pompiers dans un feu de bâtiment. Ce document a servi de ressource pour établir le contexte afin que les participants de l'atelier aient une connaissance préalable de la situation.

Des pompiers du Canada et des États-Unis, ayant pour la plupart le grade de capitaine ou un équivalent, se sont joints aux officiels du programme du DHS S&T, aux représentants du Programme d'aide à la recherche industrielle du Conseil national de recherches du Canada et de la NFPA RF pour se concentrer sur les solutions technologiques qui pourraient permettre aux intervenants d'opérer sur le lieu de l'incendie en mode intégré « tête haute et mains libres ». Ce document est le résultat du travail entrepris par FirstLink Analytics, avec l'aide gracieuse du DHS S&T, pour soutenir l'atelier et cadrer les futures discussions entre les opérateurs et les éventuels fournisseurs de solutions SFF. Cette analyse a été entreprise pour soutenir l'atelier en vue de : cerner les exigences SFF « tête haute et mains libres » devant être prises en compte par les fournisseurs de solutions; fournir un aperçu des technologies dans cet espace de problème; et caractériser le marché pour les industries qui pourraient être en mesure d'aider.

Le Programme canadien pour la sûreté et la sécurité est un programme financé par le gouvernement fédéral visant à renforcer la capacité du Canada à réagir (anticipation, prévention/atténuation, préparation, intervention et rétablissement) aux catastrophes naturelles, aux accidents graves, aux actes criminels ou terroristes en jumelant la science et la technologie avec les domaines des politiques, des opérations et du renseignement.

Importance pour la défense et la sécurité

Les principaux clients de cette initiative sont les premiers intervenants civils qui servent le Canada, les États-Unis et les pays partenaires ou alliés. Les résultats du présent rapport sont destinés à contribuer à l'ensemble des connaissances qui aidera les intervenants et les fournisseurs de solutions technologiques à se tourner vers des investissements pertinents et des voies de développement tels que ceux financés par le PCSS, Solutions innovatrices Canada et des investissements qui pourraient être approuvés par des pays partenaires.

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Background

The Canadian Next Generation First Responder (CNG-1R) Initiative is managed by the Centre for Security Science, Defense Research and Development Canada (DRDC CSS). The intent of the CNG-1R program is to inform the development of science and technology requirements and investment planning for the Canadian Safety and Security Program (CSSP). The CSSP mission is to strengthen Canada's ability to anticipate, prevent, mitigate, prepare for, respond to, and recover from natural disasters, serious accidents, crime, and terrorism through the convergence of science and technology (S&T) with policy, operations, and intelligence.¹

The CNG-1R program has three primary objectives:

1. Identify capability needs for near-term CSSP investments;
2. Identify processes and mechanisms to guide future technology development efforts; and
3. Develop a framework for periodic re-assessment of capability needs.

In 2017, DRDC CSS completed a preliminary assessment of Canadian emergency response capability needs across Canada, with 12 needs identified as the highest priority for selected police, fire fighting and paramedic leadership. One of the outcomes of that assessment was initial support for innovative S&T solution development including 'Smart Firefighting' (SFF). This CSSP investment is intended to: contribute to the body of knowledge regarding first responder capability gaps; focus specifically on situational awareness challenges associated with structural fire suppression and rescue; support the development of science and technology (S&T) requirements leading to improvements in the overall solution space for Canadian and international program partners and stakeholders; envision what enhanced situational awareness technology solutions may look like; and develop preliminary SFF architecture options and models.

The International Forum to Advance First Responder Innovation (IFAFRI) is an organization of international government program leaders from 13 countries and the European Commission, focused on enhancing and expanding the development of new technology for first responders worldwide. IFAFRI does this by:

- Working with the global first responder community to define a list of common, high priority capability gaps;
- Providing a platform for international collaboration on innovative research and development (R&D) initiatives and solutions;
- Characterizing global first responder markets to inform and guide industry and academia to develop and produce innovative technology solutions at affordable prices; and
- Providing information about relevant and available first responder technologies to the first responder community.

¹ "Canadian Safety and Security Program," Defense Research and Development Canada, last modified December 21, 2016, http://www.science.gc.ca/eic/site/063.nsf/eng/h_D6358D2D.html

IFAFRI is supporting the development of this assessment. Elements of the requirements definition process used by IFAFRI to characterize selected capability gaps will be used in this treatment.

Problem Statement

Firefighters on the fire ground scene currently have limited access to rich sources of readily available information which could make their work safer and more operationally effective. . Land mobile radios (LMR) used by many responders provide primary voice communications and limited text capability (on some models). Many responders, including fire fighters often rely on personal smart phones for access to data, although these phones are often prohibited by their agencies, have network coverage issues, and are not built to operate in extreme and hazardous incident scenes. State-of-the-art personal protective equipment (PPE) masks integrated with a firefighter's self-contained breathing apparatus (SCBA) can provide an integrated thermal camera display capability, but this equipment has not yet been adopted by many fire service agencies due to considerations such as price and face piece compatibility restrictions.

In keeping with early discussions on SFF, responders want to obtain up-to-date information on threats and hazards and to understand the characteristics of the incident as it evolves. Responders believe that a heads-up / hands free (HU/HF) capability will support fire ground operations by providing situational awareness information and data that will improve their safety, effectiveness, and efficiency. In addition, receiving information in an HU/HF configuration may reduce the equipment load on an individual responder and free their hands to perform other operational tasks.

This document contains a description of the types of operational capability envisioned by responders, functional and non-functional requirements that define the capability, an overview of existing and emerging technology that may address the operational need, and a high-level assessment of the related markets.

Methodology

The study team used a three-step process in the development of this document:

Requirements

The first step was identification of draft operational requirements. This identification was accomplished by review of current literature to include emergency response capability assessments; research outcomes related to smart firefighting, wearable computing, head-mounted displays, and augmented reality; and specifications for available technologies. The study team developed a list of functional and non-functional requirements that serve the basis for the desired operational capability.

These requirements were discussed during a Smart Firefighting Requirements Development Workshop held in Ottawa, Ontario on January 30-31, 2018. Canadian and American firefighters discussed specific data needs related to structural firefighting, noted considerations for the development of a heads-up/hands-free (HU/HF) capability, and reviewed the draft operational requirements contained in this document and shared with those firefighters

State-of-Technology Overview

The second step involved a technology foraging process to identify existing and in-development products in the emergency response, defense, and commercial sectors. The team researched the specifications of these products, comparing them against the draft operational requirements. A table on pages 14-16 is an early attempt to map the requirements to existing products.

Market Characterization

The final step in the development of this treatment was the assessment of market factors for related solutions. The team defined and segmented the relevant markets to quantify the market size, review the competitive landscape, and identify dominant solutions. The intent of this assessment is to frame further discussions and incentivize researchers in academia and industry to develop affordable, innovative technology addressing the capability gap for responders.

This document contains the outcomes of this three-step process. The HU/HF operational requirements served as the basis for discussion among responders during the CNG-1R Smart Firefighting workshop, and are now intended to provide guidance to government agencies, industry, and academia interested in developing solutions to meet the needed operational capability.

Requirements

General Description of Operational Capability

The purpose of the CNG-1R effort is to provide innovative capabilities for fire service personnel that will improve safety, effectiveness, and efficiency while performing their mission. The intended outcome is development of detailed requirements that can be used by industry to develop novel solutions that provide greater situational awareness for firefighters during their operations.

Those requirements describe potential characteristics of a HU/HF capability that is integrated into existing personal protective equipment (PPE), possibly the mask of the firefighters' self-contained breathing apparatus (SCBA) or into interactive glasses. A HU/HF capability could allow a responder to view vital data and information, such as the status and function of personal protective equipment (PPE), fire conditions, threats and hazards, location of other responders, and incident scene characteristics, while maintaining their attention on the incident scene.

Viewing information in an HU/HF capability is thought to provide multiple benefits. First, it allows responders to maintain an eyes-on view of the incident scene. This means that a firefighter does not have to look down at a screen or other device to receive critical information, distracting his or her attention from their mission. Second, the HU/HF capability minimizes the number of additional devices that a responder must carry. An example is the thermal camera, which translates heat into light, allowing firefighters to "see" the hottest parts of a structure. By integrating a thermal camera feed into the SCBA mask, responders would have one less piece of equipment to carry, decreased weight load, and are able to use their hands for other functions. An additional benefit of the HU/HF capability is that it expands the amount of integrated information immediately available to responders, giving them greater situational awareness to support decision-making.

Responders would like an HU/HF configuration that provides communications, fire conditions, threat and hazard data, PPE status, and other information pertinent to the incident scene (e.g., weather data, structure data, and model projections). The HU/HF apparatus should accommodate persons of different sizes (e.g., accommodate varying inter-pupillary distance), present a field of view (FOV) sufficient to present information while retaining sufficient view of the incident scene, be user-configurable, be immersive, and be designed to minimize distraction and cognitive failure.² The HUD should incorporate visual, audible, and haptic alerts and alarms, and be ruggedized to withstand and operate in harsh emergency response environments. A detailed list of requirements is provided in the Operational Characteristics section of this document.

Operational Environment

The emergency response environment involves exposure to: extremes in temperature and humidity, water spray and runoff, precipitation and other weather elements, as well as air pollutants, dust, smoke, ash, etc. For firefighters inside a building, that environment can vary






² Interpupillary distance (IPD) is the distance between the centers of each pupil. It is used to determine the optical center of a lens.

based on fuel type and load (furniture, carpeting, etc.), interior finish, ventilation conditions, structure layout and construction, and the firefighting tactics employed.³ Equipment designed to support firefighting operations in particular must be able to withstand a significant thermal load. For example, pre-flashover firefighting environments have been measured at 300 °C and more severe firefighting environments include temperatures up to 700 °C.⁴ Furthermore, equipment must be designed to withstand and operate after extended exposure to high humidity and water spray.

Firefighters currently carry a large amount of equipment, resulting in a significant weight burden. It is estimated that basic protective garments and gear for firefighters weigh approximately 45 pounds, with additional equipment (e.g., radio, thermal camera) adding 20 or more pounds. Potential solutions for this capability need will need to minimize (or ideally reduce) any net gain in weight. Power source and operational period are two further considerations. Standard operational periods may be extended to 12 hours, especially during large incidents. During that time, firefighters may have limited access to a stable source of electricity, network connectivity, or back-up power sources. Equipment needs to function for the duration of the call for service and beyond.

Considerations for HU/HF Structural Firefighting Solutions

Canadian and American responders that participated in the DRDC CSS workshop used common structural firefighting scenarios to frame a discussion of specific data needs and operational considerations. The graphic below summarizes the outcomes of a discussion on the information that is commonly transmitted, requested, or required during firefighting operations currently and that which may be provided in the future.

					
	Responder	Structure	Utilities	Fire Conditions	Incident
CURRENT	<ul style="list-style-type: none"> • Responder location • SCBA tank volume • Time on task • PASS alarm status 	<ul style="list-style-type: none"> • Structure type • Construction type • Floor plans 	<ul style="list-style-type: none"> • Water source • Supply level • Utility status 	<ul style="list-style-type: none"> • External temperature • Thermal imaging 	<ul style="list-style-type: none"> • Wind speed • Wind direction • Temperature • Dispatch data • Gas meter data
DESIRED	<ul style="list-style-type: none"> • Responder geolocation • Physiological data • PPE status • Proximity to threats 	<ul style="list-style-type: none"> • 3D building model • Egress points • Location of known hazards 		<ul style="list-style-type: none"> • Heat map • Flares • Flow paths • Rate of rise 	<ul style="list-style-type: none"> • Decision-support for actions • Images/video

³ *Thermal Performance of Self-Contained Breathing Apparatus Face piece Lenses Exposed to Radiant Heat Flux*, U.S. Department of Commerce, National Institute of Standards and Technology, February 2013, p. 1. <http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1785.pdf>

⁴ Ibid

Draft Requirements

The following is a list of functional and non-functional requirements that describe a potential HUHf firefighting capability designed to provide communications and data to fire service personnel. This list is currently focused on requirements for structural firefighting, but workshop participants agreed that extension of potential solutions for other technical disciplines (e.g., confined space, hazardous materials) is desirable.

Data Requirements:

- Shall receive and transmit voice communications
- Shall receive and transmit text communications
- Shall receive and transmit data communications
- Shall display PPE status data
- Shall display threat and hazard sensor data (e.g., thermal radiation, the location of hostile forces, the location of hazard sensors)
- Shall display the location of fixed and mobile sensors
- Shall display the location of responders
- Shall display distance projections to items within field of view (FOV)
- Shall allow user to digitally mark items within FOV
- Shall use geographic information system (GIS) coordinates to mark the location of objects within view (as applicable)
- Shall display data using GIS-enabled maps or displays
- Shall be designed to indicate the sensitivity/criticality of data displayed
- Shall allow the user to configure the sensitivity/criticality of data
- Shall provide an indication that the data is current

Human Factors Requirements:

- Shall use standardized symbology to represent mission-specific data
- Shall allow the user to declutter the symbology and data present on the display
- Data and symbology shall be visible to the user from the design eye position (DEP)
- Data and symbology shall not degrade the FOV or the view of the outside visual scene
- Shall be designed with an FOV adequate for the user to perform all tasks and missions
- Shall convey correct spatial representation to the user
- Shall provide a usable display under operating and environmental lighting conditions
- Shall maintain luminescence/contrast sufficient to prevent confusion
- Shall be designed to minimize distraction and cognitive failure (i.e., the failure of the user to switch attention from the display to/from the outside visual scene when necessary)
- Shall be designed to minimize user memory load (e.g., key data should be on the display at the same time)
- Eyebow (three-dimensional volume from which all essential data and symbology is visible) shall be big enough for normal use
- Shall prevent the loss of data displayed due to change in head position
- Eyebow size shall not cause unreasonable concentration or fatigue

- Shall be designed to cover the interpupillary distance (IPD) for 95% of the potential market
- Shall be capable of performing most functions hands-free
- Shall be capable of being operated by a single gloved hand (as appropriate)
- Shall provide visual, audible, and haptic warnings to the user

Transmission Requirements:

- Shall securely transmit data to authorized personnel
- Shall transmit data in real time
- Shall securely cache data intended for recipients when connection to a communication network cannot be made
- Shall securely transmit cached data to recipients when connection to a communications network is restored
- Shall store data for post incident analysis

Configuration Requirements:

- Shall allow the user to configure the layout and data sources of the display
- Shall allow user to adjust brightness of the display
- Shall allow user to adjust contrast of the display
- Shall allow the user to switch between multiple FOVs
- Shall have a resolution of <x> x <x> at <x> frames per second (to be determined)
- Shall allow user to clear all non-critical symbology and data from the display
- Shall operate in conjunction with corrective lenses
- Shall be designed to accommodate near-sightedness, far-sightedness, and other visual problems
- Shall be integrated or compatible with other public safety equipment (e.g., SCBA)

Power Requirements:

- Shall be capable of operating for <12> hours (nominal)
- Shall operate using standard, inexpensive, and readily available batteries or on a non-proprietary power source

Robustness Requirements:

- Shall be ruggedized to withstand temperature ranges of -<x> degrees C (x degrees F) - 160 degrees C (320 degrees F) for <15> minutes (thermal class II) (to be determined)
- Shall be ruggedized to operate at temperature ranges of -<x> degrees C (x degrees F) - 60 degrees C (140 degrees F) (to be determined)
- Shall be ruggedized to function after immersion in <3> feet of water for <60> minutes
- Shall be ruggedized to function in humidity of up to <100>% for <12> hours
- Shall be ruggedized to function until a maximum thermal radiation threshold of <x>;
- Shall be ruggedized to resist air pollutants, dust, smoke, ash, and sand
- Shall be ruggedized to withstand decontamination processes using a hospital-grade disinfectant (where feasible)
- Shall be non-degradable due to hazard
- Shall be waterproof in all situations

- Shall be intrinsically safe as specified in ANSI/UL 913
- Shall be minimum weight, including batteries

State-of-Technology Overview

The study team conducted a technology foraging process to identify existing and in-development products in the emergency response, defense, and commercial sectors. Within these sectors, the following technologies were defined:

- **Head-Mounted Display (HMD)** – an HMD is a small display or projection technology that has been integrated into eyeglasses or mounted on a helmet or hat, to enable mobility and hands-free activities.⁵
- **Heads-Up Display (HUD)** – an HUD is a type of HMD that does not block the user's vision, but instead, superimposes the image on the user's view of the real world.⁶
- **Augmented Reality (AR)** – AR is the real-time use of information in the form of text, graphics, audio, and other virtual enhancement integrated with real-world objects.⁷ AR differs from virtual reality (VR) in its ability to integrate and add value to the user's interaction with the real world, rather than a simulation.⁸

Within the emergency response, defense, and commercial sectors, the aforementioned three categories of technologies, and in some instances a combination of these technologies, are often used to enhance a user's situational awareness and operational capabilities. In particular, product offerings in the commercial sector appear to offer unique and advanced characteristics that could be adopted and deployed within the emergency response sector to improve responder safety, efficiency, and effectiveness. Some of the available features among existing and in-development products within each of the sectors presented in this assessment are listed below:

Emergency Response

- ANT+/Bluetooth and Wi-Fi connectivity to iOS and Android devices;⁹
- Cylinder air pressure LED light indicators;
- Thermal imaging cameras; and
- Biometric sensors.

Defense

- Rugged design;
- ANT+/Bluetooth and Wi-Fi connectivity to iOS and Android devices;
- User configurable, HD stereoscopic displays with graphic overlays; and
- GIS mapping and tracking.

⁵ "Wearable Computer," Gartner, n.d. <https://www.gartner.com/it-glossary/wearable-computer/>

⁶ "Head-Mounted Displays (HMDs)," Gartner, n.d. <https://www.gartner.com/it-glossary/head-mounted-displays-hmd/>

⁷ "Augmented Reality (AR)," Gartner, n.d. <https://www.gartner.com/it-glossary/augmented-reality-ar/>

⁸ Ibid.

⁹ ANT+ is a wireless technology that allows monitoring devices to communicate with each other, allowing devices from multiple brands to work together. "ANT+ 101: What is ANT+," ANT+, viewed January 14, 2018, <https://www.thisisant.com/consumer/ant-101/what-is-ant/>

Commercial

- Intrinsically safe (ANSI Z87.1 certified) and rugged design (IP54 certified);
- ANT+/Bluetooth and Wi-Fi connectivity to iOS and Android devices;
- Sensor suite that includes multi-axis accelerometer, gyroscope, altimeter, barometer, and magnetometer;
- HD camera that enables image capture, video recording, and live remote viewing;
- Voice and gesture-controls; and
- Software Development Kits (SDK) to support custom applications and ecosystems.

The study team identified a total of 35 existing and in-development products within the emergency response, defense, and commercial sectors. The perceived intersection between these selected products and corresponding draft operational requirements is presented in Table 1. Additional characterization of these select products is provided in Appendix A of this assessment. The compilation of products in this assessment is not intended to be an exhaustive list nor an endorsement of any technology described herein. Rather, it is meant to provide useful information about current developments and capability maturity in the area of HU/HF technology.

Some of the key observations from Table 1 include:

- Most solutions appear to be powered by rechargeable lithium-ion batteries;
- Most solutions appear to offer at least four hours of battery life;
- Most solutions appear to offer ANT+/Bluetooth and Wi-Fi connectivity;
- Most solutions appear to be compatible with iOS and Android devices;
- ANT+/Bluetooth and Wi-Fi connectivity, along with iOS and Android compatibility, appears to enable features such as audio alert messaging, GPS navigation and image or video recording;
- Video recording is often provided in high definition (i.e., 1080p and 720p) display;
- Integrated sensor suite often includes an accelerometer, gyroscope, magnetometer, and compass; and
- Cost of solutions with integrated sensor suites can range from approximately \$500 USD (~\$625 CAD) to \$5,000 USD (~\$6,250 CAD).

Table 1: Correlation of Products and Requirements

* Indicates data does not appear to be publicly available.

- Emergency Response Sector
- Defense Sector
- Commercial Sector

Manufacturer	Product	Audio Alert Messaging	Battery Life	Cost	Connectivity	Device Compatibility	Dimensions and Weight	Field of View	Multi-Sensor Integration	Navigation	Power Source	Resolution	Rx Glasses Integration	Storage/Memory	User Configurable Display	Video Recording	Water Proof
Existing Products																	
Halo Thermal Imaging Ltd.	Halo™	None	10hrs	*	None	None	125D x 70W x 125H mm; 390g	37.5° V x 50° H	None	None	Rechargeable Li-ion bat.	160x120p	None	None	*	None	*
Halo Thermal Imaging Ltd.	SoloTI™	None	3hrs	*	None	None	390D x 285W X 350H mm; 2,900g	37.5° V x 50° H	None	None	Rechargeable LiPo bat.	160x120p	None	None	*	None	*
Laster Technologies	LASTER WAV3	*	*	*	Bluetooth, Wi-Fi	Smartphone	100g	*	9-axis accelerometer, gyroscope, magnetometer	*	*	800x480p	*	*	*	*	*
Recon Instruments	Recon Jet™ Pro	Yes	2-5hrs	\$599-699 USD (~\$750-875 CAD)	ANT+/Bluetooth, Wi-Fi, USB	iOS, Android	*	*	3D accelerometer, 3D gyroscope, 3D magnetometer, atmospheric pressure, infrared	GPS	Rechargeable Li-ion bat.	428x240	*	8GB, 1GB RAM	*	720p	Water Resistant
Rosenbauer International AG	C1	None	1.5hrs	*	None	None	155L x 61W x 91H mm; 427g	*	*	None	Rechargeable Li-ion bat.	384x288p	*	*	*	*	*
Scott Safety	Scott Sight	None	4hrs	\$1,500+ USD (~\$1,875+ CAD)	Bluetooth	iOS, Android	245g	*	*	*	4 AAA bat.	160x120p	*	*	*	In-development	*
Mistral Solutions Pvt. Ltd.	Mistral R7	*	*	*	Wi-Fi	*	*	30°	*	*	*	*	*	*	*	*	*
Six15 Technologies	Odin	*	*	*	*	*	102g	45°	*	*	*	800x600p	*	*	*	*	*
Six15 Technologies	Tac-Eye 2.0	*	*	\$3581.35 USD (~\$4,480 CAD)	*	*	51g	29.5°	*	*	*	800x600p	*	*	Yes	Yes	*
Vue Smart Glasses	Vue	Yes	*	\$229 USD (~\$375 CAD)	Bluetooth	iOS, Android	Varies per design; 28g	*	6-axis accelerometer and gyroscope, infrared	Yes	Rechargeable LiPo bat.	*	Yes	*	*	*	Water Resistant
DAQRI®	DAQRI Smart Glasses™	Yes	12hrs	\$4,995 USD (~\$6,250 CAD)	Bluetooth, Wi-Fi	*	335g	44°	“Suite of sensors”, including depth	*	Rechargeable Li-ion bat.	1360x768p	*	64GB	*	1080p	*
Epson America Inc.	Moverio Pro BT-2200	Yes	6hrs	\$2,999 USD (~\$3,750 CAD)	Bluetooth, Wi-Fi	Android	315g	*	Sensors for head tracking, voice, and gesture control	GPS	Rechargeable Li-Po bat.	960x540p	*	1-8GB	*	1080p	Water Resistant
Kopin Corporation	Golden-i 3.8D	*	*	*	Bluetooth, Wi-Fi	*	*	*	Sensors for voice and gesture control	GPS	*	*	*	*	*	*	*
Manufacturer	Product	Audio Alert Messaging	Battery Life	Cost	Connectivity	Device Compatibility	Dimensions and Weight	Field of	Multi-Sensor Integration	Navigation	Power Source	Resolution	Rx Glasses Integration	Storage/Memory	User Configurable	Video Recording	Water Proof

								View							Display		
Existing Products (cont)																	
ThirdEye Gen Inc.	X1 Smart Glasses™	Yes	8hrs	\$800-1,000 USD (~1,000-1,250 CAD)	Bluetooth, Wi-Fi	Android	218L x 181W x 53H mm; 255g	40°	3-axis accelerometer, compass, gyroscope, magnetometer, brightness, Digital Motion Processor, temperature	GPS	Rechargeable 2400 mAh bat.	1280x720	Interchangeable lenses	32GB, 3GB RAM	*	1080p or 720p	*
Optinvent	ORA-2	Yes	5hrs	~\$840 USD (~\$1,050 CAD)	Bluetooth, Wi-Fi, USB	Android	90g	*	9-axis accelerometer, compass, gyroscope, light	GPS	Rechargeable 1200 mAh bat.	42p/deg	Can be worn over most eyeglasses	*	Above, centered, below	Yes	*
Osterhout Design Group (ODG)	R-7HL	Yes	*	\$3,500 USD (~\$4,380 CAD)	Bluetooth, Wi-Fi	Android	183L x 155W x 53H mm; <227g	*	3-axis accelerometer, altitude, gyroscope, humidity, magnetometer	GNSS	Rechargeable LiPo bat.	*	*	64GB, 3GB RAM	*	Yes	Water Resistant
RealWear Inc.	HMT-1	Yes	9-10hrs	\$2,000 USD (~\$2,500 CAD)	Bluetooth, Wi-Fi	Android	380g	20°	3-axis accelerometer, gyroscope, magnetometer	GPS, GLONASS, BeiDou, Baidu A-GPS	Rechargeable Li-ion bat.	854x480p	*	16GB, 2GB RAM	Yes	1080p	Yes
Vuzix	M100	Yes	6hrs	\$999.99 USD (~\$1,200 CAD)	Bluetooth, Wi-Fi, USB	iOS, Android	*	15°	3-axis accelerometer, gyroscope, magnetometer, ambient light, compass, head tracking, proximity	GPS	Rechargeable Li-ion bat.	640x360p	Yes	5-32GB, 1GB RAM	Left or right eye	1080p	*
Vuzix	M300	Yes	2-12hrs	\$1,499 USD (~\$1,875 CAD)	Bluetooth, Wi-Fi, USB	iOS, Android	*	20°	3-axis accelerometer, gyroscope, magnetometer, compass, head tracking, proximity	GPS	Rechargeable Li-ion bat.	640x360p	*	64GB, 2GB RAM	Left or right eye	1080p	*
EverySight Ltd.	Raptor	Yes	8hrs	\$499-649 USD (~\$625-812 CAD)	ANT+/Bluetooth, Wi-Fi	iOS, Android	98g	*	Accelerometer, barometer, magnetometer, gyroscope, proximity	GPS, GLONASS	*	*	Rx adaptor (sold separately)	16-32GB, 2GB RAM	*	Yes	Water Resistant
Recon Instruments	Recon Jet™	Yes	4hrs	\$499 USD (~\$625 CAD)	ANT+/Bluetooth, Wi-Fi, USB	iOS, Android	*	*	3D accelerometer, gyroscope, magnetometer, infrared, pressure	GPS	Rechargeable Li-ion bat.	400x240p	Interchangeable lenses	8GB, 1GB RAM	*	Yes	Water Resistant

Manufacturer	Product	Audio Alert Messaging	Battery Life	Cost	Connectivity	Device Compatibility	Dimensions and Weight	Field of	Multi-Sensor Integration	Navigation	Power Source	Resolution	Rx Glasses Integration	Storage/Memory	User Configurable	Video Recording	Water Proof
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								View							Display		
In-Development Products																	
Swiss Federal Technology Institute (EPFL) and DariX	Vizir	Yes	*	*	*	*	*	*	Thermal imaging camera, depth	*	*	*	*	*	*	*	*
Georgia Institute of Technology	FireHUD	*	*	*	FireHUD web application	*	About the size of a cell phone	*	Sensors for biometric and environmental data	*	*	*	*	*	*	*	*
Six15 Technologies	DARWIN	Yes	*	*	USB	Android, Windows	<20g	20.3°	Sensors for biometric and facial recognition data	*	*	640x400p	Yes	*	Yes	Yes	*
Quake Technologies	C-THRU	*	*	*	*	*	Size of a deck of playing cards	*	Thermal imaging camera, air, biometric, toxicity	*	*	*	*	*	*	Yes	*
Applied Research Associates (ARA) Inc.	ARC4	*	*	*	Bluetooth, Wi-Fi, USB	*	119L x 38W x 33H mm; 170g	*	Accelerometer, barometer, gyroscope, magnetometer	GPS	*	640x480p	*	1-8GB	*	*	*
Benny Labs Ltd.	LinaTxt	*	*	*	Bluetooth	Smartphone	*	*	*	*	*	*	*	*	*	*	*
LAFORGE Optical	Shima	Yes	*	\$590-790 USD (~\$740-990 CAD)	Bluetooth, USB	iOS, Android	28g	*	*	GPS	*	*	Yes	*	*	Yes	*
Rokid Corporation Ltd.	RoKid Glass	*	*	*	Bluetooth, Wi-Fi, USB	Smartphone	*	40°	*	*	*	*	Can be worn over most eyeglasses	*	None	*	*
Vuzix	AR3000	*	*	*	Bluetooth, Wi-Fi, USB	Smartphone	*	*	*	*	*	*	*	*	None	*	*
GlassUp	F4	Yes	12hrs	*	3G, Bluetooth, Wi-Fi, USB	iOS (in-development), Android	100L x 180W x 100H mm	22°	Thermal imaging camera, 9-axis accelerometer and gyroscope, temperature	*	*	640x480p	*	8GB	None	Yes	*
Vuzix	M3000	Yes	2-12hrs	*	Bluetooth, Wi-Fi, USB	iOS, Android	*	20°	3-axis accelerometer, compass, gyroscope, head tracking	GPS	160mAH (internal), 860mAH (external)	854x480p	*	64GB, 2GB RAM	Left or right eye	1080p	*
X Development LLC	Glass Enterprise Edition	Yes	*	Varies per developer	ANT+/Bluetooth, Wi-Fi, USB	Android	42g (without frame), 48g (with frame)	*	Ambient light, barometer, capacitive head, digital compass, hinge, wink/blink	GPS, GLONASS	Rechargeable Li-ion bat.	640x360p	Yes	32GB, 2GB RAM	*	720p	*
Kopin Corporation SOLOS®	SOLOS®	Yes	5hrs	\$500 USD (~\$625 CAD)	ANT+/Bluetooth, USB	iOS, Android	160L x 180W x 50H mm; 65g	10.68°	Speed, cadence, heart rate, power zones, calories, distance, and elevation	GPS	Rechargeable Li-ion bat.	320x240p	Interchangeable lenses in-development	*	Repositionable display arm	*	*
SKULLY Systems Inc.	Skully AR-1	Yes	*	\$1,399 USD (~\$1,750 CAD)	Bluetooth	iOS, Android	Sizes S-XXL	*	*	GPS	*	*	*	*	*	*	*

Market Characteristics

In its *Research Roadmap for Smart Firefighting*, the U.S. National Institute of Standards and Technology (NIST) claims that there are significant opportunities in making use of HU/HF like capabilities for fire service applications. HU/HF technologies are an example of military technology that has gained much wider use after having been adapted for commercial use.¹⁰ NIST states that HU/HF capabilities - particularly in the form of wearable eyewear - will likely be the canvas on which various sensor data and graphical information are presented.¹¹ Based on this claim, this assessment uses the global smart glasses market to help quantify and further characterize the potential market space for smart firefighting wearable eyewear that provides heads-up/hands-free capabilities to fire service operators.

Market Figures

According to a BCC Research report, the “global market of smart glasses for augmented reality” is expected to grow from approximately \$340.4 million USD (\$425.7 CAD) in 2017 to almost \$20.0 billion USD (~\$25.0 billion CAD) by 2022, **at an estimated compound annual growth rate of 125.8%** during the forecast period of 2017 to 2022.¹² The following table presents the estimated revenue of the global market from 2017 to 2022.

Table 2: Global Market Size of Smart Glasses for Augmented Reality (in millions)							
	2017	2018	2019	2020	2021	2022	CAGR
USD	\$340.4	\$768.6	\$1,735.6	\$3,918.9	\$8,848.8	\$19,980.6	125.8%
CAD	\$425.7	\$961.3	\$2,170.7	\$4,901.3	\$11,067.2	\$24,989.8	125.8%
Note: The global market forecast period is 2017 to 2022 with market figures available for 2017 and 2022. The CAGR of 125.8% was used to estimate the revenue values for 2018 to 2021. Conversions were completed using the exchange rate \$1 USD = \$1.2507 CAD as of January 2, 2018.							

Market Phase

The global smart glasses market appears to be in its nascent stage of growth; it is a relatively new and rapidly developing market with limited standards and regulations. Purchases are predominantly being made by early adopter consumers. In addition, a large portion of the market appears to be composed of new smart glass companies and start-up vendors that used crowdfunding to support their research and development efforts. To maintain a competitive advantage against larger firms entering the market, small vendors will likely focus on developing cost-effective smart glasses for specific application segments, which could include fire services. Limited consumer awareness of smart glasses with AR capabilities and a lack of intuitive AR content will likely maintain the market’s nascent phase in the near term.¹³

¹⁰ NIST Special Publication 1191 *Research Roadmap for Smart Fire Fighting Summary Report*, U.S. Department of Commerce, National Institute of Standards and Technology, May 2015, p.50. <http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1191.pdf>

¹¹ Ibid.

¹² “The Global Market of Smart Glasses for Augmented Reality,” BCC Research, January 2018, https://www.bccresearch.com/index/advancedsearch?search_keyword=smart+glasses

¹³ “Global Smart Glasses Market 2016-2020,” Technavio, August 2016, <https://www.technavio.com/report/global-human-machine-interface-global-smart-glasses-market-2016-2020>

Market Factors

In 2015, the enterprise segment dominated the smart glasses market with more than 97% of the total market share.¹⁴ Consumers in the enterprise market segment have more diverse applications for the use of smart glasses, as well as greater purchasing power over individual consumers. Notably, vendors have targeted industrial, military, and defense sectors, which has led to the development of ruggedized smart glasses. The adoption and increased availability of ruggedized smart glasses will likely improve the development of similar solutions for fire service applications. In addition, rapid proliferation of Internet of Things (IoT) sensors and applications have the potential to connect assets and information that promise to enable users to work more efficiently and effectively in real time and in any location. This capability has fueled the adoption of IoT-compatible devices and technology across many market sectors, especially at the enterprise level. It is anticipated that smart glasses will serve as an effective means of relaying and interpreting IoT data and analysis in enterprise and other market sectors (e.g., oil and gas, public safety), which will in turn contribute to the advancement and overall growth of the global smart glasses market.¹⁵

In addition to IoT capabilities, the integration of new technologies in augmented reality (AR), such as simultaneous localization and mapping (SLAM) and depth-sensing cameras, will likely increase the demand for advanced smart glasses solutions and drive the overall growth of the market.¹⁶ SLAM is described as “an autonomous mapping and navigation technique” used in mobile robotics. The purpose of the technology is to create a map of an unknown environment, while simultaneously navigating through the environment.¹⁷ Once deployed, this feature will likely enhance operational capabilities in emergency response applications, especially fire services.

Table 3: Market Factors	
Market Opportunities	Market Barriers
<ul style="list-style-type: none">• Estimated \$768.6 million USD (\$961.3 million CAD) market revenue in 2018• Development of ruggedized smart glasses for the enterprise market segment (e.g., oil and gas, sports and fitness)• Advances in AR, app ecosystems, and operating systems• Investment in wearable technologies and Internet of Things (IoT)	<ul style="list-style-type: none">• Dependency on innovators and early adopters• Significant research and development costs• Design complexity and attractiveness• Increasing presence of large technology firms

¹⁴ Ibid.

¹⁵ “Smartglasses and IoT for a More Productive Work Day,” Microsoft, posted April 10, 2015.

<https://blogs.microsoft.com/iot/2015/04/10/smartglasses-and-iot-for-a-more-productive-workday/>

¹⁶ “Global Smart Glasses Market 2016-2020,” Technavio, August 2016, <https://www.technavio.com/report/global-human-machine-interface-global-smart-glasses-market-2016-2020>

¹⁷ “SLAM for Dummies: A Tutorial Approach to Simultaneous Localization and Mapping,” Massachusetts Institute of Technology, n.d. https://ocw.mit.edu/courses/aeronautics-and-astronautics/16-412j-cognitive-robotics-spring-2005/projects/1aslaml_blas_repo.pdf

Development and Procurement Considerations

There are two other factors that may impact planning, design, and development of solutions that correspond with many of the HU/HF requirements listed. The first is the convergence of related projects and data sources. The U.S. National Institute of Standards and Technology (NIST) *Research Roadmap for Smart Fire Fighting* describes how interconnected technologies, referred to as cyber-physical systems, can be integrated to improve fire-protection and firefighting capabilities. The document specifically discusses the integration of HU/HF solutions. Another effort, the [*First Responder Virtual Reality Heads-Up-Display Navigation Challenge*](#) issued in January 2018, also by NIST, offers a prize competition for the development of HU/HF solutions to support the public safety community. The challenge, focused on virtual reality and user interface design, with a view to awarding financial prizes in mid-2018. This challenge has the potential to generate additional relevant HU/HF solutions that align with the *Research Roadmap* and the capability needs described in the CNG-1R preliminary capability needs assessment.

Another key factor impacting the development of potential HU/HF solutions is the existence of standards and guidelines that can impact the design, testing, performance, and certification of products or solutions. These regulations and standards are in place to ensure minimum levels of protection, consistency in performance, uniform testing criteria, and the safety of responders and the public. A sample of related standards and guidelines include:

- National Fire Protection Administration (NFPA) 1981: Standard on Open-Circuit Self-Contained Breathing Apparatus
- National Institute for Occupational Safety and Health (NIOSH) 42CFR Part 84: Respiratory Protective Devices
- Underwriters Laboratories (UL) 913: Intrinsically Safe Apparatus
- International Electrotechnical Commission (IEC) Ingress Protection (IP) 66/67

Failure to recognize and comply with related standards and guidelines during S&T development pathways can significantly impact the ability for response agencies to acquire new solutions.

Conclusion

This study was completed as part of the Canadian Next Generation First Responder (CNG-1R) Smart Firefighter Project. One objective of this project is to work collaboratively with partners including the US Department of Homeland Security S&T Directorate and operators to identify innovative solutions to improve situational awareness during fire suppression and rescue operations. The outcomes of this study include:

- A description of the operational need for the development of a heads-up display (HUD) that provides data and information for use by fire service personnel;
- A list of draft requirements that may be used as the basis for the development of HUD products and solutions;
- An assessment of market factors that may impact technology development efforts; and

- The identification of 35 existing or in development solutions and an assessment of how they align with the draft requirements.

The outcomes of this study were intended to be used first as a background document for a CNG-IR responder workshop, in which participants review, discuss, and prioritize these requirements. The CNG-1R Smart Firefighting Workshop is to be held January 30-31, 2018 in Ottawa, Ontario. Participants will be asked to assess each of the requirements to determine those that are: 1) critical (minimum essential requirements); 2) important, but not crucial for initial iterations; or 3) ideal, but not vital. These requirements provide data that can be used to develop innovative solutions that could significantly increase the safety, effectiveness, and efficiency of firefighters involved in response operations.

The market factors and technology landscape also presented in this study are intended to provide participants in the workshop and CSSP program partners with an understanding of the state-of-the-art for products that are currently available and in development that address some of the smart firefighting HUD requirements. It is important for the participants to understand what is currently available or possible as they discuss the HU/HF requirements. Further, the market information herein is provided to offer technology solutions providers with additional information that may help inform development pathways for new products intended for first responders and other stakeholders who may benefit from these investments.

Appendix A: Technology Landscape

This section presents solutions that appear to be relevant in the area of HUD technology with the potential for use by fire services. The content was collected and reported from publicly-available product literature published by developers, manufacturers, distributors, and dealers. The study team did not assess the validity of any product claims. This section is not meant to be an exhaustive list nor an endorsement of any technology described herein. Rather, it is meant to provide useful information about current developments in the area of HUD technology.

Existing Solutions

Emergency Response

Halo Thermal Imaging Ltd.

Halo Thermal Imaging (United Kingdom) develops solutions to enhance night vision, situational awareness, personal safety, and threat-detection capabilities for fire service, marine, and industrial users.¹⁸

Halo™

Halo™ is a hands-free thermal imaging camera with a 2.5" high-definition (HD) screen display that can be mounted on multiple manufacturers' fire helmets. Halo™ features spot temperature measurement with four color maps, as well as a "snap shot" function with image freezing for situation assessment.¹⁹



Figure 1: Halo™

SoloTI™

SoloTI™ is a fire helmet that provides head protection, respiratory protection, and a communications interface in one system. SoloTI™ features a "fully integrated thermal imaging camera that displays the image inside the face mask using augmented reality viewing optics".²⁰ A battery indicator is also displayed using the augmented reality viewing optics. Video output is provided by a miniature Bayonet-Neill-Concelman (BNC) socket on the battery housing that can be combined with a wireless transmitter and receiver unit to enable dual operator and incident commander overview of the fire ground.²¹



Figure 2: SoloTI™

Laster Technologies

Laster Technologies (France) develops custom solutions for a variety of application areas including civil power (i.e., military and public security).²² Notably, Laster Technologies is the

¹⁸ "About," Halo Thermal Imaging, n.d. <http://www.halothealthimaging.co.uk/about/>

¹⁹ "Halo™ Datasheet," Halo Thermal Imaging, n.d. <http://www.halothealthimaging.co.uk/assets/ProductDatasheets/Halo-datasheet-the-halo.pdf>

²⁰ "SoloTI™ Datasheet," Halo Thermal Imaging, n.d. <http://www.halothealthimaging.co.uk/assets/ProductDatasheets/Halo-datasheet-soloTI.pdf>

²¹ Ibid.

²² "Application Areas," Laster Technologies, n.d. <http://www.laster.fr/en/application-areas/>

developer of *Enhanced View™* technology, which can present any type of information (e.g., text, image, video, 3D file, etc.) on a transparent lens. Laster Technology claims this technology enables the integration of optoelectronic modules in products such as eye level viewfinders and displays, informative eyewear, motor or fireman's helmets, ski goggles and other eye-use products.²³

LASTER WAVE

LASTER WAVE is described as a hands-free, head-mounted display solution that uses Enhanced View™ F25 optical technology to assist operations in industrial environments. LASTER WAVE has a light (100 g) design, comparable to regular eye glasses and can connect to a smartphone via Wi-Fi or Bluetooth. Options to integrate a camera, microphone, and/or bone conduction audio to the device is available.²⁴ Additional information

regarding cost and deployment within fire services does not appear to be publicly available.



Figure 3: Laster WAVE

Recon Instruments

Recon Instruments (Canada) claims to be a global leader in smart eyewear technology for sports and high-intensity environments. Recon Instruments has an extensive patent portfolio, which has supported the development of award-winning technology that integrates high-contrast displays with “state-of-the-art” computing platforms and sensor suites.²⁵ In 2015, Recon Instruments was acquired by [Intel Corporation](#) (United States).²⁶

Recon Jet™ Pro

Recon Jet™ Pro smart glasses claim to enable significant operational cost savings by delivering smartphone-class capabilities in a hands-free wearable device. Recon Jet™ Pro smart glasses are designed for use in logistics, maintenance, field service, and first responder industries and enable users to access mission-critical information. Recon Jet™ Pro smart glasses feature a rugged design, sunlight-readable display, swappable lenses for indoor and outdoor work, impact-resistant clear lens, and water-resistant components. Recon Jet™ Pro smart glasses can also access custom applications that have been built using Recon Instruments' Enterprise Development Kit.²⁷ Recon Jet™ Pro smart glasses are available in two variations: American National Standards Institute (ANSI) Z87.1 and ANSI Z87.1+, which are listed at \$599 USD (~\$750 CAD) and \$699 (~\$875 CAD) respectively.²⁸



Figure 4: Recon Jet Pro™

²³ “Technologies,” Laster Technologies, n.d. <http://www.laster.fr/en/technologies/>

²⁴ “Products,” Laster Technologies, n.d. <http://www.laster.fr/en/products/>

²⁵ “LinkedIn Profile,” Recon Instruments, n.d. <https://www.linkedin.com/company/recon-instruments/>

²⁶ “About Us,” Recon Instruments, n.d. <https://www.reconinstruments.com/company/about-us/>

²⁷ “Recon Jet™ Pro,” Recon Instruments, n.d. <https://www.reconinstruments.com/enterprise/jet-pro/>

²⁸ “Recon Jet™ Pro,” Recon Instruments, n.d. <http://store.reconinstruments.com/recon-jet-pro>

Rosenbauer (Austria) develops systems for firefighting and disaster. Rosenbauer offers vehicles, fire extinguishing systems, equipment, and telematics solutions for professional, industrial, plant, and volunteer fire services across the globe.²⁹

The C1 Thermal Imaging Camera (TIC) can be integrated on the HEROS-titan firefighting helmet via a click-attachment on the front shield of the helmet. The camera is composed of five components: control button, battery compartment, lens and high-power LED, moveable goose neck, and infrared display. In addition, the camera offers five color representations, which include search mode, white-hot mode, black-hot mode, full color mode, and green mode.³⁰



Figure 5: C1 TIC

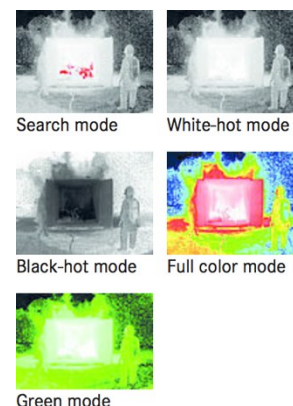


Figure 6: C1 TIC Color Modes

Scott Safety (United States) develops respiratory and personal protective equipment, as well as safety devices for emergency management, defense, and industrial applications. In the fire service domain, Scott Safety provides self-contained breathing apparatuses (SCBAs), supplied air and air-purifying respirators, gas and flame detection instruments, thermal imaging cameras (TICs), and communications and accountability devices.³¹

Scott Safety claims Scott Sight is the industry's first, hands-free, in-mask thermal imaging system. Scott Sight uses a mask-mounted thermal imaging camera to display the thermal image on an in-mask display (IMD) via a Bluetooth connection. At present, Scott Sight is only compatible with the Scott Safety AV3000HT piece.³²



Figure 7: Scott Sight

Scott Sight includes a mobile configuration application that is accessible on iOS and Android devices. The application enables the user to configure the IMD in terms of brightness, icon layouts, temperature displays, and display

²⁹ “Group Profile,” Rosenbauer International AG, n.d. <https://www.rosenbauer.com/en/svc/rosenbauer-group/company/group-profile>

³⁰ “Helmet-mounted C1 Thermal Imaging Camera,” Rosenbauer International AG, n.d. <https://www.rosenbauer.com/en/svc/rosenbauer-world/products/equipment/thermal-imaging-cameras/helmet-mounted-c1-thermal-imaging-camera>

³¹ "About Scott". Scott Safety, n.d.

³² "Scott Sight™ Frequently Asked Questions," Scott's Safety, https://www.scottsafety.com/en/7524B_EN_LoRes.pdf

Figure 8: Scott Sight Mobile Application

2011
i.d.

[Marketing/Product Literature and Catalogs/Questions and Answers/Scott Sight FAQ](#)

icons.³³ Additional features of Scott Sight include a one-touch, simultaneous power off button for both the IMD and TIC, as well as a one-touch standby mode for the TIC. According to Scott Safety, Scott Sight will offer a Thermal Video Recording (TVR) capability as an optional upgrade in late 2017.³⁴

The thermal image camera will be able to store up to four hours of video on a solid state random access memory (RAM). The video will be downloaded and saved as MP4 files, which can then be accessed on free viewers such as QuickTime® or RealPlayer®. The thermal image camera will automatically overwrite video that is not downloaded.³⁵

Scott Sight appears to meet all current National Fire Protection Agency (NFPA) and other regulatory standards, including NFPA 1981, 2013 ed, NIOSH 42CFR Part 84, UL 913 6th ed, ATEX, IECEx and IP 66/67.³⁶

Defense

Mistral Solutions Pvt. Ltd.

Mistral Solutions (India) is a product design and system engineering company that provides end-to-end services for product development and deployment among a variety of industries including defense and aerospace, consumer electronics, medical electronics, industrial applications, telecom and networking, and Homeland Security.³⁷

Mistral R7

The Mistral R7 is a wearable computer targeted for defense, paramilitary, law enforcement, and enterprise users. The device is described as a “fully integrated platform with ultra-transparent HD 3D stereoscopic displays, high-speed wireless connectivity and high performance positional sensors with 30° FoV [field of view]”.³⁸ Mistral Solutions states the device may be best suited for Armed Forces due to its rugged design and panoramic camera that enables a 360° operational view.³⁹



Figure 9: Mistral R7

Six15 Technologies

Six15 Technologies (United States) develops smart glasses and wearable displays for enterprise and military customers. The company holds a broad IP portfolio with over 20 patents in wearable optical displays, head tracking, and low power electronics.⁴⁰

³³ “Scott Sight,” Scott Safety, n.d. <https://www.scottsafety.com/en/us/Pages/ProductDetail.aspx?productdetail=Scott+Sight>

³⁴ “Scott Sight™ Frequently Asked Questions,” Scott Safety, n.d.

https://www.scottsafety.com/en/us/DocumentandMedia1/Marketing/ProductLiteratureandCatalogs/QuestionsandAnswers/Scott_Sight_FAQ_7524B_EN_LoRes.pdf

³⁵ Ibid.

³⁶ Ibid.

³⁷ “About Us,” Mistral Solutions Pvt. Ltd., n.d. <https://www.mistralsolutions.com/about-us/>

³⁸ “AR Glasses for Military,” Mistral Solutions Pvt. Ltd., n.d. <https://www.mistralsolutions.com/defense-solutions-page/defense-product-page/homeland-security-solutions/ar-glasses-military/>

³⁹ Ibid.

Odin

Odin is described as a “patented optical see through system that allows the user to simultaneously view the real world and relevant computer-generated information such as graphics, maps, and alerts” without compromising situational awareness.⁴¹ Odin can be coupled with hands-free technology for uses in a variety of applications in industrial, medical, commercial, and defense sectors.⁴²



Figure 10: Odin

Tac-Eye 2.0

The Tac-Eye 2.0 is a head-worn, hands-free display system for non-standard environments. The system includes a high-contrast super video graphics array (SVGA) display, ideal for displaying images from computers, IR imagers, camera systems, thermal weapon sights, or other video sources. The device can be mounted via a clip for glasses or a boom for helmets. The device's adjustable HMD module enables users to move the display out of the field of view or into a position ideal for the user. The list price for Tac-Eye 2.0 appears to be \$3,581.35 USD (~\$4,480 CAD) per unit.⁴³



Figure 11: Tac-Eye 2.0

Commercial

Consumer

Vue

Vue (United States) is a San Francisco-based start-up company that develops smart fashion eyewear for application in “everyday” activities. In 2016, Vue launched a crowdfunding campaign on Kickstarter, which raised approximately \$2.2 million USD (~\$2.75 million CAD) from 10,410 individual supporters. Vue has since raised an additional \$1.4 million USD (~\$1.75 million CAD) from 14,736 individual supporters through another crowdfunding platform, Backerkit.⁴⁴

Vue

Vue claims to be the world's first pair of smart glasses that are designed for everyday use. Vue smart glasses are offered in prescription, non-corrective (plano), and sunglasses. In addition, Vue frames are available in a variety of colors, textures, and shapes for personalized style. Vue smart



Figure 12: Vue

⁴⁰ “Company,” Six15 Technologies, n.d. <http://www.six-15.com/aboutus>

⁴¹ “Odin,” Six15 Technologies, n.d. <http://www.six-15.com/odin>

⁴² Ibid.

⁴³ “Tac-Eye 2.0,” Six15 Technologies, n.d. <http://www.six-15.com/tac-eye>

⁴⁴ “Vue: Your Everyday Smart Glasses,” Backerkit, n.d. https://vue.backerkit.com/hosted_preorders

glasses feature an ARM Cortex processor and a suite of sensors including a 6-axis accelerometer and gyroscope, infrared proximity and 5 field capacitive touch pad. Vue smart glasses are compatible with all devices via Bluetooth connectivity and compatible with iOS and Android applications.⁴⁵ Vue smart glasses are available for pre-order at a price of \$299 USD (~\$370 CAD) and are anticipated to ship by March 2018.⁴⁶

Enterprise

DAQRI®

DAQRI® (United States) develops AR solutions to enhance efficiency among professional consumers. DAQRI® offers a comprehensive AR platform composed of devices and extensions that are supported by its Visual Operating System™ (Vos). DAQRI® states its solutions deliver visualization of IoT and sensor data in real time and provide users with contextually-relevant and actionable information in multiple environments.⁴⁷⁴⁸

DAQRI Smart Glasses™

DAQRI Smart Glasses™ are described as portable, lightweight, powerful augmented reality wearables designed for professional workers. DAQRI Smart Glasses™ offer a wide 44-degree field of view, a 6th generation Intel® Core™ m7 Processor, and a suite of sensors to capture valuable information about a user's surrounding environment. DAQRI Smart Glasses™ also feature built-in apps, such as "Remote Expert" and "Camera" that enable experts to remotely assist workers through the user's point of view. In addition, through DAQRI's Unity Extension, developers can build custom applications for particular operational uses. DAQRI Smart Glasses™ are available to purchase at a price of \$4,995 USD (~\$6,250 CAD); this cost includes 1 DAQRI Smart Glasses™, 1 DAQRI Compute Pack with DAQRI Vos Installed, access to developer tools, over-the-air (OTA) updates, and Device Management for Enterprises.⁴⁹



Figure 13: DAQRI Smart Glasses™

Epson America Inc.

Epson (United States) claims to be a leading manufacturer in the printer, professional imaging, projector, scanner, system devices, and factory automation categories. Epson delivers its products for use in education, financial, healthcare, logistic, manufacturing, and retail industries. Among its enterprise solutions, Epson develops wearable devices, which include GPS watches and smart glasses.⁵⁰

⁴⁵ "Vue: Your Everyday Smart Glasses," Kickstarter, n.d. <https://www.kickstarter.com/projects/vue/vue-your-everyday-smart-glasses/description>

⁴⁶ "Vue: Your Everyday Smart Glasses," Backerkit, n.d. https://vue.backerkit.com/hosted_preorders

⁴⁷ "LinkedIn Profile," DAQRI®, n.d. <https://www.linkedin.com/company/daqri/>

⁴⁸ "About," DAQRI®, n.d. <https://daqri.com/about/>

⁴⁹ "DAQRI Smart Glasses™ - \$4,995*," DAQRI®, n.d. <https://shop.daqri.com>

⁵⁰ "About Epson – Our Vision, Team and Values," Epson America Inc., n.d. <https://epson.com/about-us>

Moverio Pro BT-2000 Smart Headset

Moverio Pro BT-2200 is a wearable device specifically built for the industrial workplace. Moverio Pro BT-2000 is safety-glass compliant (ANSI Z87.1), dust and waterproof (IP54 certified), and is capable of withstanding a 1.2m drop. The device offers hands-free operation with built-in voice commands and the option to create user interfaces based on head-tracking and

gesture-control. The device also includes a high-resolution, 5-megapixel front-facing camera that enables remote sharing of the user's point of view. In addition to GPS, the device includes an inertial measurement unit (IMU) for accurate positioning, even indoors. Moverio Pro BT-2200 is available to purchase for \$2,999.99 USD (~\$3,750 CAD) on Epson's official website.^{51,52}



Figure 14: Moverio Pro BT-2200 Smart Headset

Kopin Corporation

Kopin (United States) develops solutions that enhance the visual, verbal, audio, and head-gesture command capabilities of wearable headset products. The company has more than 200 patents and patents pending globally among its technology portfolio that includes ultra-small displays, optics, speech enhancement, head-gesture command, low-power application-specific integrated circuits (ASICs), packaging, and system reference designs.⁵³

Golden-i 3.8D

The Golden-i 3.8D headset system for industrial application is composed of a microprocessor, a display pod that provides an equivalent of a 15-inch screen, a 14-MP camera, a 9-axis motion sensor to track head motion, and wireless connections via Wi-Fi and Bluetooth. These system features enable hands-free operation with voice command and gesture control.⁵⁴

Golden-i 3.8D appears to be highly customizable, which may allow the device to adapt to a variety of applications, such as fire service and incident command.⁵⁵ For example, the headset system could utilize a fire service-specific wearable device application (e.g., [FirefighterLog](#)) to enhance the operator's safety, efficiency, and effectiveness at an incident scene.⁵⁶

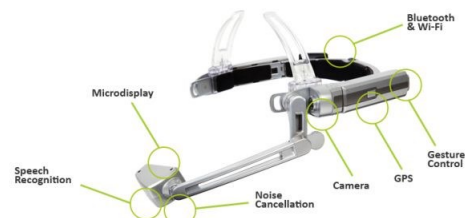


Figure 15: Golden-i 3.8D

⁵¹ "Moverio Pro BT-2000 Smart Headset," Epson America Inc., n.d. <https://epson.com/For-Work/Wearables/Smart-Glasses/Moverio-Pro-BT-2000-Smart-Headset/p/V11H725020>

⁵² "Moverio Pro BT-2200 Smart Headset," Epson America Inc., n.d. <https://epson.com/For-Work/Wearables/Smart-Glasses/Moverio-Pro-BT-2200-Smart-Headset/p/V11H853020>

⁵³ "About," Kopin Corporation, n.d. <http://www.kopin.com/about/default.aspx>

⁵⁴ "Headset Solutions," Kopin Corporation, n.d. <http://www.kopin.com/offerings/headset-solutions/>

⁵⁵ "Smart Glasses Just Got Smarter," Mistral Solutions Pvt. Ltd., June 2014. https://www.mistralsolutions.com/wp-content/uploads/2014/06/EFY_June14.pdf

⁵⁶ Ibid.

ThirdEye Gen Inc.

ThirdEye (United States) has historically developed inclusive augmented reality solutions (i.e., hardware and software platforms) for defense applications, such as AR scopes mounted onto rifles and AR HMDs for soldiers. More recently, ThirdEye has used its AR expertise to expand into enterprise and commercial markets.⁵⁷

X1 Smart Glasses™

X1 Smart Glasses™ are described as a military-based, hands-free mobile computing solution for enterprise consumers, such as engineers, doctors, and teachers. The solution uses ThirdEye's AR software to provide a full "Enterprise Augmented Reality" platform that includes live audio, video, and point-of-view AR data communication between remote users. In addition, the software enables a 3-screen interface that allows a user to have a clear field of view while rotating between AR screens via head-motion. A secure cloud-based architecture enables the entire session to be archived for later reference.^{58,59}

X1 Smart Glasses™ integrate a suite of sensors, which include GPS, a 3-axis gyroscope, a 3-axis accelerometer, a 3-axis compass, a magnetometer, a flashlight, a Digital Motion Processor (DMPTM), brightness sensor, and temperature sensor. In addition, X1 Smart Glasses™ sync with the ThirdEye App Store, which allows users to try out new AR/VR experiences; for example, an app that gives an AR tour of a city.⁶⁰ Cost is based on user and software needs, however, a "vanilla" set of X1 Smart Glasses™ may range between \$800 USD and \$1,000 USD (~\$1000 and \$1,250 CAD).⁶¹



Figure 16: X1 Smart Glasses

Optinvent

Optinvent (France) develops wearable technology solutions for commercial users. Optinvent is also the creator of "Clear-Vu", which is defined as a patented optical see-through near to eye display technology. Optinvent states Clear-Vu has a high see-through ratio, wide viewing angle, is light weight, shatter proof, power efficient, and enables the most cost effective and scalable approach for near to eye display products.⁶²

ORA-2

⁵⁷ "About Us," ThirdEye Gen Inc., n.d. <https://www.thirdeyegen.com/about/#1501226745808-02c1508f-29a2>

⁵⁸ "X1 Spec Sheet," ThirdEye Gen Inc., n.d. <https://www.thirdeyegen.com/wp-content/uploads/2017/06/X1Brochure.pdf>

⁵⁹ "ThirdEye displays award-winning X1 Augmented Reality Smart Glasses™ at CES 2018," Markets Insider, posted January 11, 2018. <http://markets.businessinsider.com/news/stocks/ThirdEye-displays-award-winning-X1-Augmented-Reality-Smart-Glasses-at-CES-2018-1012925916>

⁶⁰ X1 Spec Sheet," ThirdEye Gen Inc., n.d. <https://www.thirdeyegen.com/wp-content/uploads/2017/06/X1Brochure.pdf>

⁶¹ "ThirdEye's AR glasses come with massive swappable batteries," Engadget, posted January 7, 2018. <https://www.engadget.com/2018/01/07/thirdeye-x1-ar-smart-glasses-workplace/>

⁶² "About Us," Optinvent, n.d. <http://www.optinvent.com/the-company/>

ORA-2 is a wearable computing device that enables hands-free mobile computing and AR applications such as remote maintenance, logistics, remote training, and situational awareness. ORA-2 is equipped with a dual core processor with a graphics processing unit (GPU), camera, microphone, sound, inertial sensors, Wi-Fi, Bluetooth, GPS, ambient light sensor, and a high capacity rechargeable battery. Optinvent states that ORA-2 also includes its own flexible Android software development kit (SDK) in order to develop apps and customize the device based on user needs. ORA-2 is available to purchase for €699 (~\$840 USD/\$1,050 CAD).^{63,64}



Figure 17: ORA-2

Osterhout Design Group (ODG)

ODG (United States) develops mobile computing hardware platforms in the form of smart glasses and extended reality technologies. ODG designs and optimizes its products for a variety of users among industrial, enterprise, and business mobility professionals. The company's product line includes one of the first hazardous location-certified smart glasses, described further below.⁶⁵

R-7HL (Hazardous Location) Smart Glasses

R-7HL is described as a durable, hands-free, wearable computing platform for professionals in oil exploration and production, energy, mining, utilities, chemical products, and pharmaceuticals.⁶⁶ R-7HL enables heads-up, hands-free checklists, guided assistance tools, remote assistance support, and the delivery of real-time notifications and alerts for enhance safety and efficiency. In addition, the device is Zone 2 "Intrinsically Safe" certified for deployment in dangerous environments where volatile gases, vapors, or mists may be present.⁶⁷ The R-7HL smart glasses system costs \$3,500 USD (~\$4,380 CAD) per unit.⁶⁸



Figure 18: R-7HL

RealWear Inc.

RealWear (United States) develops hands-free and fully rugged head-mounted tablet solutions for connected industrial workers. RealWear currently offers HMT-1 (described further below) and will soon offer [HMT-1Z1](#), a similar, "intrinsically safe" solution that meets Class 1 Division 1

⁶³ "ORA-2," Optinvent, n.d. http://www.optinvent.com/our_products/ora-2/

⁶⁴ Conversions were completed using the exchange rate \$1 USD = €1.2050 EUR and \$1 CAD = €1.5082 EUR as of January 2, 2018.

⁶⁵ "About ODG," ODG, n.d. <https://www.osterhoutgroup.com/about/>

⁶⁶ "R-7HL (Hazardous Location)," ODG, n.d.

https://www.osterhoutgroup.com/pub/static/version1515626698/frontend/infotris/ultimo/en_US/pdf/R-7HL-TechSheet.pdf

⁶⁷ Ibid.

⁶⁸ "R-7HL Smart Glasses System," ODG, n.d. <https://www.osterhoutgroup.com/r-7-hl-smartglasses-system.html>

and ATEX Zone 1 certifications, meaning it presents no ignition risk where potentially explosive atmospheres exist in normal routine operations.^{69,70}

HMT-1

HMT-1 is described as a voice-driven, hands-free, head-mounted tablet designed for skilled technicians and engineers in field service, equipment inspection, maintenance, and complex manufacturing assembly. HMT-1 features an 854x480 pixel display, an adjustable boom arm, a 16-megapixel camera for hi-resolution photo capture and real-time video chat, as well as Bluetooth and Wi-Fi connectivity and GPS, gyroscope, and digital compass sensors.⁷¹ Additional information regarding cost does not appear to be publicly available.



Figure 19: HMT-1

Vuzix

Vuzix (United States) claims to be a leading supplier of smart glasses and AR technologies and products. The company has supported defense R&D for next-generation military display solutions and is now dedicated to advancing consumer and enterprise markets. The company's product line includes personal display and wearable computing devices that can access video and digital content, including movies, video games, computer data, and the Internet. Vuzix holds 59 patents with 42 additional patents pending, as well as numerous IP licenses in the near-eye display field.⁷²

M100 Smart Glasses

M100 Smart Glasses "provide the features and capabilities of a modern smartphone in a hands-free wearable device".⁷³ M100 Smart Glasses are available to purchase for \$999.99 USD (~\$1,200 CAD) and include many features. In particular, "it includes an HD camera for still picture and video capture and enables the user to store their content in expandable onboard memory or stream it live".⁷⁴ The device also integrates GPS, gyroscope, and compass systems for added environmental awareness. The key advantage of M100 Smart Glasses appears to be compatibility with existing Android apps and developer resources, which can enable the creation of custom apps to meet the need of any application.⁷⁵



Figure 20: M100 Smart Glasses



Figure 21: M300 Smart Glasses

⁶⁹ "Facebook Page," RealWear Inc., n.d. https://www.facebook.com/pg/RealWearInc/about/?ref=page_internal

⁷⁰ "HMT-1," RealWear Inc., n.d. <https://www.realwear.com/products>

⁷¹ "Home Page," RealWear Inc., n.d. <http://www.realwear.at/en>

⁷² "About," Vuzix, n.d. <https://www.vuzix.com/About>

⁷³ "M100 Product Sheet," Vuzix, n.d. <http://files.vuzix.com/Content/pdfs/Vuzix-M100-Product-Sheet-01-01-2016.pdf>

⁷⁴ Ibid.

⁷⁵ Ibid.

M300 Smart Glasses

Similar to the M100 series, M300 Smart Glasses features an Intel Atom processor for enhanced computing capabilities. M300 Smart Glasses are available to purchase for \$1,499 USD (~\$1,875 CAD).⁷⁶

Sports and Fitness

Every sight Ltd.

Every sight (Israel) is a spin-out company of [Elbit Systems Ltd.](#) (Israel), which is a global supplier of airborne, land, and naval systems and products for defense, homeland security, and commercial applications.⁷⁷ Every sight states it “brings the fighter jet pilot AR experience to regular consumers at a reasonable price, with an exclusive slim, streamlined design and advanced BEAM™ projection technology for convenient daily use.”⁷⁸ In 2017, Every sight launched Raptor, which is described further below.

Raptor

Raptor is a wearable eyewear device for cyclists, and ultimately other sports enthusiasts. Raptor directly links with a user’s smartphone via ANT+/Bluetooth Smart technology to track speed, cadence, power, and heart rate, as well as mobile notifications. Raptor is controlled using an integrated touchpad as well as voice control for recording videos, taking a picture, and adjusting volume/brightness.⁷⁹ Raptor is currently available to purchase by invitation only. Two storage sizes are offered: 16GB and 32GB, which are priced at \$499 USD (~\$625 CAD) and \$649 (~\$812 CAD) respectively. Orders are anticipated to be shipped by May 2018.⁸⁰



Figure 22: Raptor

Recon Instruments

Recon Instruments (Canada) claims to be a global leader in smart eyewear technology for sports and high-intensity environments. Recon Instruments has an extensive patent portfolio, which has supported the development of award-winning technology that integrates high-contrast displays with “state-of-the-art” computing platforms and sensor suites.⁸¹ In 2015, Recon Instruments was acquired by [Intel Corporation](#) (United States).⁸²

Recon Jet™

Recon Jet™ is described as a sports eyewear that delivers metrics, maps, and other data on a high-contrast display positioned just below an athlete’s right eye. Recon Jet™ features a smartphone-class processor that supports an onboard GPS and a comprehensive sensor suite: accelerometer, gyroscope,



Figure 23: Recon Jet

⁷⁶ “Vuzix M300 Smart Glasses,” Vuzix, n.d. <https://www.vuzix.com/Products/m300-smart-glasses>

⁷⁷ “About Us,” Elbit Systems Ltd., n.d. <http://elbitsystems.com/about-us-introduction/>

⁷⁸ “About Us,” Every sight Ltd., n.d. <https://eversight.com/about-eversight/>

⁷⁹ “About Raptor,” Every sight Ltd., n.d. <https://eversight.com/about-raptor/>

⁸⁰ “Raptor,” Every sight Ltd., n.d. <https://eversight.com/product/raptor/>

⁸¹ “LinkedIn Profile,” Recon Instruments, n.d. <https://www.linkedin.com/company/recon-instruments/>

⁸² “About Us,” Recon Instruments, n.d. <https://www.reconinstruments.com/company/about-us/>

altimeter, barometer, and magnetometer. In addition, Recon Jet™ features ANT+, Bluetooth Smart (Bluetooth 4.0), and Wi-Fi connectivity that enables caller ID, SMS notifications, and access to social media. Recon Jet™ is available to purchase for \$499 USD (~\$625 CAD) via Recon Instruments' official website.⁸³

In-Development Solutions

Emergency Response

Swiss Federal Technology Institute (EPFL) and DariX

EPFL (Switzerland) is an engineering college, primarily funded by the Swiss Confederation. EPFL emphasizes a focus on research, innovation and technology transfer.⁸⁴ EPFL funded preliminary efforts on the Vizir Project, which eventually lead to the spin-out of DariX, a company that is dedicated to advancing the safety and efficiency of fire service operators and industrial workers.⁸⁵

Vizir

In 2014, the Vizir Project aimed to develop a solution that would provide firefighters with thermal information on an AR display. Today, this initiative is continued by DariX. Engineers of the company claim to have successfully developed a proof of concept, which has been tested and validated by professional firefighters in Vaud Canton, Switzerland. The prototype currently uses AR glasses; however, the next phase of development will be to incorporate the screen in a firefighter oxygen mask and reduce bulk by eliminating some of the wires.^{86,87}



Figure 24: Vizir

Georgia Institute of Technology

Georgia Institute of Technology (United States) is a public college and research university. Its core research areas include: Bioengineering & Bioscience; Data Engineering & Science; Electronics & Nanotechnology; Energy & Sustainability; Manufacturing, Trade & Logistics; Materials; National Security; People & Technology; Public Service & Policy; Renewable Bioproducts; Robotics; and Systems.⁸⁸

FireHUD

FireHUD is a wearable device that claims to provide biometric and environmental data to firefighters in an in-mask HUD and relays this



Figure 25: FireHUD

⁸³ "Recon Jet™," Recon Instruments, n.d. <http://store.reconinstruments.com/Recon-Jet/>

⁸⁴ "Facts & Figures," École Polytechnique Fédérale de Lausanne, n.d. <https://information.epfl.ch/facts-figures>

⁸⁵ "Home Page," DariX, n.d. <http://www.darix.ch/#aboutus>

⁸⁶ "Augmented reality for firefighters," EPFL, n.d. <https://actu.epfl.ch/news/augmented-reality-for-firefighters>

⁸⁷ "Home Page," DariX, n.d. <http://www.darix.ch/#aboutus>

⁸⁸ "Research," Georgia Institute of Technology, n.d. <http://www.research.gatech.edu/areas/systems>

information to incident command via an application. FireHUD is roughly the size of a cell phone and attaches to a firefighter's mask to measure heart rate, respiratory rate, blood oxygen level, body temperature, external temperature, and other vital signs via a sensor placed in the responder's ear.⁸⁹

Six15 Technologies

Six15 Technologies (United States) develops smart glasses and wearable displays for enterprise and military customers. The company claims to have a broad IP portfolio with over 20 patents in wearable optical displays, head tracking, and low power electronics.⁹⁰

DARWIN Smart Glasses

The Six15 DARWIN Smart Glasses Platform is described as an augmented reality (AR) accessory platform that “leverages the battery and application processor from an Android or Windows host device to reduce size, weight, power, and cost over competing alternatives.”⁹¹

DARWIN can equip an industrial worker with heads-up, hands-free checklists, guided assistance tools, remote assistance support, and real-time notification and alerts. In the public safety domain, DARWIN can provide officers and first responders with facial recognition and biometric data to enhance situational awareness and effectiveness. In addition, the device's camera can supply a database of activity by combining video, audio, commentary, and other data points, as seen from the eyes of the public safety officer. Six15 Technologies is currently testing three tiers of potential DARWIN solutions: DARWIN Developer, DARWIN Assistant, and DARWIN Mentor.⁹²



Figure 26: DARWIN Smart Glasses

Quake Technologies

Quake Technologies (United States) is the developer of C-THRU, a next-generation smart solution for fire and rescue operators. Quake Technologies was co-founded by Omer Haciomeroglu, who worked closely with Sweden's Umea Firefighting Department to first develop the solution's concept and design.⁹³



Figure 27: C-THRU

C-THRU

C-THRU is described as a modular platform that provides real-time navigation through a transparent AR display placed directly within the firefighter's line of sight. C-THRU is the

⁸⁹ “Keeping Firefighters Safe,” Georgia Institute of Technology, posted April 4, 2016, <http://www.news.gatech.edu/2016/04/04/keeping-firefighters-safe>

⁹⁰ “Company,” Six15 Technologies, n.d. <http://www.six-15.com/aboutus>

⁹¹ “The DARWIN Smart Glasses Platform - Built for Enterprise,” Six15 Technologies, n.d.

⁹² “DARWIN Smart Glasses for Enterprise,” Six15 Technologies, n.d. <https://static1.squarespace.com/static/57dc111b414fb5bdb26a7ff6/t/59d7e4e4e4b0a4e4e4e4e4e4/ses+for+Enterprise.pdf>

⁹³ “Home Page,” Quake Technologies, n.d. <https://www.qwake.tech>



Figure 28: Smart Edge Detection

size of a deck of playing cards and claims to feature Smart Edge Detection, hot spot ID, fire event recording, and live streaming. Object recognition and flow path tracking features appear to be in development. Quake Technologies claims it has developed the first working prototype of C-THRU and is working to bring the product to market in 2018.⁹⁴

Defense

Applied Research Associates (ARA) Inc.

ARA (United States) provides science and engineering research, technical support services, specialty products, and integrated solutions to international government and enterprise consumers.⁹⁵

ARC4 – Tactical Augmented Reality (TAR)

ARC4 is described as an advanced AR technology for outdoor on-the-move applications. ARC4 incorporates advanced head tracking sensors and algorithms, network management software, and an intuitive user interface to overlay geo-spatial iconic information on a user's environment.⁹⁶ In addition, ARC4 is composed of on-board GPS, accelerometer, gyroscope, magnetometer, and barometric pressure sensors for added situational awareness. ARC4 appears to be deployable via daytime see-through displays and night-vision goggles. Notably, ARC4 software is currently being used to develop Tactical Augmented Reality (TAR) solutions for defense applications. TAR solutions aim to provide advanced situational awareness to



Figure 29: ARC4



Figure 30: TAR Technology

soldiers via one encompassing platform that features integrated blue-force and red-force tracking, mission-critical information displays, and communications.⁹⁷

Commercial

⁹⁴ Ibid.

⁹⁵ "Who We Are," Applied Research Associates (ARA) Inc., n.d. <https://www.ara.com/who-we-are>

⁹⁶ "ARC4: Heads-up on-the-move augmented reality technology," Applied Research Associates (ARA) Inc., n.d. <https://www.ara.com/projects/arc4-heads-move-augmented-reality-technology>

⁹⁷ "Heads up: Augmented reality prepares for the battlefield," Ars Technica, posted May 25, 2017. <https://arstechnica.com/information-technology/2017/05/heads-up-augmented-reality-prepares-for-the-battlefield/>

Consumer

Benny Labs Ltd.

Benny Labs (Israel) is a private start-up firm that is working to develop several new concepts for affordable wearable devices that enable an HUD and “layered reality” experience to commercial users.⁹⁸

LinaTxT

LinaTxT is a pair of HUD glasses that uses a narrow high definition (HD) liquid crystal display (LCD) screen and reflective technology to display text messages (including emoticons and other small graphics) one line at a time. LinaTxT connects to a user’s smartphone via Bluetooth

and pairs with an application to direct operation. The use of reflective technology improves the affordability and energy consumption of this device. It is expected that LinaTxT glasses will need to be charged once a week. Benny Labs claims it has successfully demonstrated proof of the concept’s feasibility and the product was expected to launch in early 2017.⁹⁹



Figure 31: LinaTxT

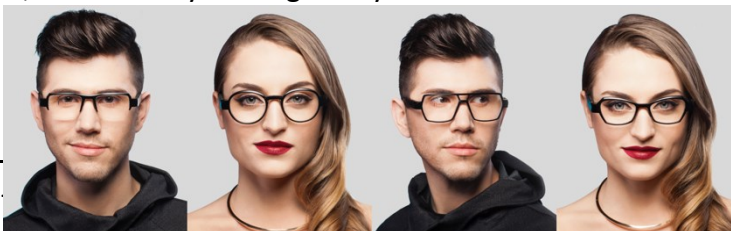
LAFORGE Optical

LAFORGE (United States) develops fashion eyewear with an embedded HUD system for application in “everyday” activities.¹⁰⁰

Shima

Shima is a line of digital eyewear with an embedded HUD system. According to LAFORGE, Shima runs mods that allow a user to see content on a Phantom Display™ and connect to iOS and Android devices. In addition, the company’s DNA™ software enables features for drive, normal, and active modes, which are further described below.¹⁰¹

- *Drive Mode* – use map app of choice; show turn-by-turn directions; estimate time of arrival; display current street; preview upcoming turns; and mute most other notifications.
- *Normal Mode* – view notifications; control and listen to music; view date and time; use 3rd Party Widgets; use teleprompter; view Caller ID; take pictures; and record short videos.
- *Active Mode* – view running and cycling routes; use step counter; view number of floors climbed; view miles ran or walked; view performance data from other wearables; and virtually race against yourself or friends.



⁹⁸ “Home Page,” Benny Labs Ltd., n.d.

⁹⁹ Ibid.

¹⁰⁰ “Company: About,” LAFORGE Optical, n.d. <https://laforgeoptical.com/pages/company>

¹⁰¹ “Meet Shima,” LAFORGE Optical, n.d. <https://laforgeoptical.com/pages/meet-shima>

Figure 32: Shima

Shima eyewear is lightweight (about 28 g) and is available in prescription lenses at no extra cost. LAFORGE offers Alpha, Beta, and “Beta Bold” prototype tiers of its eyewear to early adopters and developers. Shima Alpha is currently available for \$590 USD (~\$740 CAD), while Shima Beta and Beta Bold are expected to launch in 2018 at prices of \$590 USD and \$790 USD (~\$990 CAD) respectively.¹⁰²

Rokid Corporation Ltd.

Rokid (China) is a technology company that claims to specialize in robotics research and artificial intelligence (AI) development. The company’s core technologies include automatic speech recognition/natural language understanding (ASR/NLU), facial and gesture recognition, and sound and projection systems. In March 2016, Rokid established a research center in San Francisco, California.¹⁰³

Rokid Glass

Rokid Glass is a standalone headset with an internal processor and Bluetooth/Wi-Fi connectivity that enables communication with a user’s smartphone and access to the Internet. Rokid Glass features a monocular display that is projected using a 1080p embedded OLED (organic light-emitting diode) with a field of view of approximately 40 degrees. Most notably, Rokid Glass integrates an AI digital assistant, similar to that of Amazon’s Alexa or Google Assistant, that responds to gesture and voice controls. Rokid Glass debuted at CES 2018 and appears to also offer facial recognition capabilities.^{104,105}



Figure 33: Rokid Glass

Vuzix

Vuzix (United States) claims to be a leading supplier of smart glasses and AR technologies and products. The company has supported defense R&D for next-generation military display solutions and is now dedicated to advancing consumer and enterprise markets. The company’s product line includes personal display and wearable computing devices that can access video and digital content, including movies, video games, computer data, and the Internet. Vuzix holds 59 patents with 42 additional patents pending, as well as numerous IP licenses in the near-eye display field.¹⁰⁶

¹⁰² “About Alpha + Beta,” LAFORGE Optical, n.d. <https://laforgeoptical.com/pages/alpha-beta>

¹⁰³ “Our Story,” Rokid Corporation Ltd., n.d. <https://www.rokid.com/en/story.html>

¹⁰⁴ “Rokid Glass voice-activated smartglasses try to improve AR,” CNET, posted January 8, 2018. <https://www.cnet.com/news/rokid-glass-ar-smartglasses-add-voice-ai-ces/>

¹⁰⁵ “This startup’s mixed reality glasses offer a glimpse at the future – but AR is still in its infancy,” The Verge, posted January 8, 2018. <https://www.theverge.com/circuitbreaker/2018/1/8/16865534/rokid-glass-ar-glasses-augmented-reality-ces-2018>

¹⁰⁶ “About,” Vuzix, n.d. <https://www.vuzix.com/About>

AR3000 Smart Glasses

AR3000 Smart Glasses is Vuzix's latest binocular concept of an AR smart glasses viewer. AR3000 Smart Glasses will leverage Vuzix's see-through waveguide optics and will include dual ultra-slim 'Cobra' display engines, a touch pad, noise canceling mics, and two HD cameras, one of which will enable gesture support. In addition to Bluetooth and Wi-Fi connectivity that will enable various smartphone application features, AR3000 Smart Glasses will ultimately allow users to reach out, manipulate, and interact with virtual 3D objects overlaid in the real world.¹⁰⁷



Figure 34: AR3000 Smart Glasses

Enterprise

GlassUp

GlassUp (Italy) is a start-up company with a focus on augmented reality technology that is working to develop smart glasses for both commercial and industrial applications. Notably, GlassUp has received funding for its efforts from the European Union's Horizon 2020 & SME Instruments 2 research and innovation program under grant agreement No. 636302 and No. 778161.¹⁰⁸

GlassUp F4

GlassUp F4 is described as a hands-free wearable device designed for industrial, medical, logistical, and professional use. The device includes several pre-installed apps that compose a suite of features, however, customization is available to support enterprise, IoT platform, and software needs. GlassUp F4 offers video streaming and voice calling capabilities, as well as danger detection (e.g., man down, overheating, alert visualization) from on-machine sensors and Wi-Fi, Bluetooth, and 3G connectivity.¹⁰⁹



Figure 35: GlassUp F4

Vuzix

Vuzix (United States) claims to be a leading supplier of smart glasses and AR technologies and products. The company has supported defense R&D for next-generation military display solutions and is now dedicated to advancing consumer and enterprise markets. The company's product line includes personal display and wearable computing devices that can access video and digital content, including movies, video games, computer data, and the Internet. Vuzix holds 59 patents with 42 additional patents pending, as well as numerous IP licenses in the near-eye display field.¹¹⁰

¹⁰⁷ "AR3000 Series of Smart Glasses," Vuzix, n.d. <https://www.vuzix.com/Products/Series-3000-Smart-Glasses>

¹⁰⁸ "Company," GlassUp, n.d. <http://www.glassup.com/en/company/>

¹⁰⁹ "F4," GlassUp, n.d. <http://www.glassup.com/en/f4/#f4-valore>

¹¹⁰ "About," Vuzix, n.d. <https://www.vuzix.com/About>

M3000 Smart Glasses

M3000 Smart Glasses is described as an “ergonomically designed and rugged Android-based wearable computer, featuring the latest Vuzix 1.0 mm thin waveguide optics and custom WVGA [wide video graphics array] linear DLP [digital light processing] ‘Cobra’ display engine”.¹¹¹ In addition, M3000 Smart Glasses include a monocular display and onboard processor, built-in memory, camera recording features and wireless connectivity capabilities. Further, an integrated head tracking and GPS system supports apps that enhance a user’s situational awareness. Vuzix showcased its M3000 smart glasses at the International Consumer Electronics Show (CES) 2017.¹¹²



Figure 36: M3000 Smart Glasses

X Development LLC

X Development (United States), formerly Google X, is a research and development subsidiary of Alphabet Inc. composed of inventors and entrepreneurs that incubate “moonshot” or audacious ideas in order to bring innovative solutions to market within ten years.¹¹³

Glass Enterprise Edition

Glass Enterprise Edition or Glass, is the second iteration of Google’s smart eyewear solution, which specifically targets industrial users. Glass integrates a variety of sensors including an ambient light sensor, digital compass, wink sensor, blink sensor, barometer, capacitive head sensor, hinge sensor, and assisted GPS/GLONASS. Glass can connect to other smart devices via Wi-Fi and Bluetooth and can also support voice calling and video streaming. Glass is currently available for purchase and testing from a selection of developer companies known as Glass Partners. Glass Partners can provide a user with specialized software applications and ongoing support to build a custom end-to-end solution that meets the needs of the user.¹¹⁴



Figure 37: Glass Enterprise Edition

For example, Patrick Jackson, a U.S. firefighter of the Rocky Mount Fire Department, developed **FirefighterLog** for Android, iOS, Google Glass, and wearable devices. Information, such as type of emergency, address, map of incident, and known location of hydrants is sent to firefighters via the app when a 911 call is received. Future capabilities of the app and related features include occupancy information, building preplans, a CAD monitor on TVs for information at the fire house, wearable

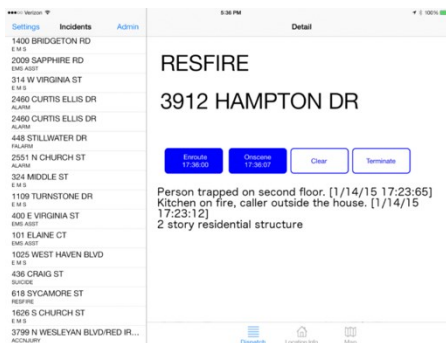


Figure 38: FirefighterLog

¹¹¹ “M3000 Smart Glasses,” Vuzix, n.d. <https://www.vuzix.com/Products/m3000-smart-glasses>

¹¹² “Vuzix Unveils Award-Winning M3000 Smart Glasses at CES 2017,” Vuzix, posted January releases/detail/1535/vuzix-unveils-award-winning-m3000-smart-glasses-at-ces-2017

¹¹³ “Google to be publicly traded under Alphabet Inc. in planned restructuring,” CBC/Radio-Canada, posted August 10, 2014. <http://www.cbc.ca/news/technology/google-to-be-publicly-traded-under-alphabet-inc-in-planned-restructuring-1.3186244>

¹¹⁴ “Google Glass Enterprise Edition: The Full Spec Sheet Revealed,” 9to5Google, posted July 24, 2017. <https://9to5google.com/2017/07/24/google-glass-enterprise-edition-specs/>

integration in Google Glass and Android Wear watches, and Android Auto integration for information access on a vehicle dashboard.¹¹⁵

Sports and Fitness

Kopin Corporation SOLOS®

Kopin Corporation SOLOS® (United States) is a division of Kopin Corporation (United States) that develops high-performance smart eyewear for cyclists and fitness enthusiasts.¹¹⁶ In 2016, the company launched a crowdfunding campaign on Kickstarter, which raised \$128,179 USD (~\$160,300 CAD) from 412 individual supporters in less than two months.¹¹⁷

SOLOS®

SOLOS® is a wearable eyewear device for cyclists that integrates a Vista™ micro-HUD, which is credited as the world's smallest optical module for mobile augmented reality smart glasses "that offers a high-resolution display for clear and readable performance in variant lighting conditions".¹¹⁸ SOLOS® is compatible with iOS and Android devices and supports ANT+/Bluetooth connectivity. In addition, SOLOS® can provide users with real-time data on speed, cadence, heart rate, power zones, calories, distance, and elevation, which can be easily shared through existing fitness and social media apps. SOLOS® also offers audio and visual cues for turn-by-turn GPS navigation. SOLOS® was developed in partnership with the U.S. Olympic Cycling team in preparation

for the 2016 Rio Games and appears to be in the final stages of development before commercial availability.¹¹⁹

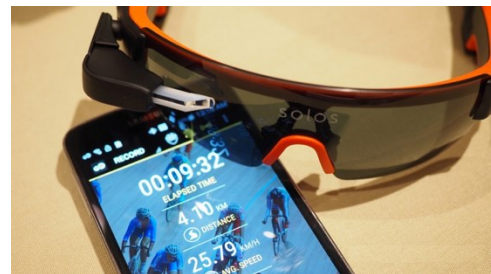


Figure 39: SOLOS®

SKULLY Systems Inc.

SKULLY Systems (United States) is a San Francisco-based start-up company that launched a crowdfunding campaign on Indiegogo for its smart motorcycle helmet. The campaign is cited as one of the fastest fully-funded campaigns on Indiegogo, raising \$1 million USD in about 45 hours, with an average contribution of \$1,425 USD.¹²⁰ In 2014, the Skully AR-1 prototype won the SXSW Accelerator Award in the wearable technology category and was distributed to select consumers for beta testing.¹²¹ However, according to its Indiegogo campaign page, Skully

¹¹⁵ "Home Page," FirefighterLog, n.d. <http://www.firefighterlog.com>

¹¹⁶ "Solos, High-Performance Smart Eyewear for Elite Cyclists Showcased at CES 2016," Kopin Corporation, posted January 6, 2016. <http://www.kopin.com/investors/news-events/press-releases/press-release-details/2016/Solos-High-Performance-Smart-Eyewear-for-Elite-Cyclists-Showcased-at-CES-2016/default.aspx>

¹¹⁷ "Solos Smart Cycling Glasses with Heads Up Micro-Display," Kickstarter, n.d. <https://www.kickstarter.com/projects/1101608300/solos-smart-cycling-glasses-with-heads-up-micro-di/posts/1754786>

¹¹⁸ "What is Solos: Product Specs," Solos Wearables™, n.d. <http://www.solos-wearables.com/what-is-solos/product-specs/>

¹¹⁹ "Solos Smart Cycling Glasses with Heads Up Micro-Display," Kickstarter, n.d. <https://www.kickstarter.com/projects/1101608300/solos-smart-cycling-glasses-with-heads-up-micro-di/description>

¹²⁰ "The Skully Smart Helmet is the Fastest Indiegogo Campaign to Hit \$1M," Oath Tech Network, posted August 14, 2014. <https://techcrunch.com/2014/08/14/the-skully-smart-helmet-is-the-fastest-funded-indiegogo-campaign-to-hit-1m/>

¹²¹ "Coming This Fall: The Augmented Reality Motorcycle Helmet," Popular Mechanics, posted May 28, 2014. <http://www.popularmechanics.com/cars/motorcycles/a10620/coming-this-fall-the-augmented-reality-motorcycle-helmet-16836594/>

Systems was forced to cease operations in 2016 due to a lack of additional capital and other “unforeseen challenges and circumstances”.¹²² The Skully AR-1 prototype is included in this assessment for awareness and information purposes.

Skully AR-1

Skully AR-1 is a motorcycle helmet with a high-speed microprocessor that enables “smart” features, such as Bluetooth connectivity and GPS navigation. Skully AR-1 includes HUD as well as an ultra-wide angle rear view camera for enhanced situational awareness. Skully AR-1 also features integrated audio, hands-free calling, and music streaming capabilities. A beta prototype of Skully AR-1 in sizes S-XXL, was available to purchase on the Indiegogo campaign page for a total of \$1,448 USD (~\$1,800 CAD).¹²³



Figure 40: SKULLY AR-1

¹²² “SKULLY AR-1 the World’s Smartest Motorcycle Helmet,” Indiegogo, n.d. https://www.indiegogo.com/projects/skully-ar-1-the-world-s-smartest-motorcycle-helmet#/

¹²³ Ibid.

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13. ABSTRACT/RÉSUMÉ (When available in the document, the French version of the abstract must be included here.)

The *Canadian Next Generation First Responder (CNG-IR)* initiative, a Canadian Safety and Security Program (CSSP) investment - CSSP-2016-TI-2226 - aims to better connect, protect and improve situational awareness capabilities for front-line police, fire fighters and paramedics through science and technology. The Program is led by Defence Research and Development Canada's Centre for Security Science (CSS), in partnership with Public Safety Canada.

Responder representative organizations such as the Canadian Association of Fire Chiefs have cast light on the need to make operating environments such as the fire ground safer for operators and the public. In keeping with insights and approaches cited from the National Fire Protection Association Research Foundation (NFPA RF), and in close collaboration with the U.S. Department of Homeland Security Science and Technology Directorate (DHS S&T) a Smart Firefighting (SFF) workshop was held in Ottawa, Ontario on January 30-31, 2018 in order to help frame requirements for improved situational awareness technology supports for fire fighters in a structural fire setting. This document served as background 'read-in' resource to get workshop participants situated beforehand.

Firefighters from Canada and the US – mostly at the captain rank or equivalent - joined DHS S&T program officials, representatives from the National Research Council Industrial Research Assistance Program, and the NFPA RF to focus attention on technology solutions which may position responders to operate on the fire ground in an integrated, 'heads-up / hands-free' (HU/HF) mode. The following document is the result of work undertaken by FirstLink Analytics, with generous assistance from DHS S&T, to support the workshop and frame future discussions between operators and potential SFF solution providers. This analysis was undertaken to support the workshop with a view to: generating HU/HF SFF requirements for consideration by solution providers; providing an overview of technologies in this problem space; and characterizing the market for industries that may be positioned to help.

The Canadian Safety and Security Program is a federally-funded program to strengthen Canada's ability to anticipate, prevent/mitigate, prepare for, respond to, and recover from natural disasters, serious accidents, crime and terrorism through the convergence of science and technology with policy, operations and intelligence.

L'initiative *Canadian Next Generation First Responder (CNG-IR)*, un investissement du Programme canadien pour la sûreté et la sécurité (PCSS) – CSSP-2016-TI-2226 – vise à mieux connecter, protéger et améliorer les capacités de connaissance de la situation pour les agents de police, les pompiers et les ambulanciers de première ligne grâce à la science et la technologie. Le Centre des sciences pour la sécurité (CSS) de Recherche et développement pour la défense Canada, en partenariat avec Sécurité publique Canada, dirige le programme.

Les organismes représentant les intervenants, comme l'Association canadienne des chefs de pompiers, font ressortir le besoin de rendre l'environnement opérationnel, le lieu du sinistre par exemple, plus sûr pour les opérateurs et le public. Conformément aux idées et points de vue de la National Fire Protection Association Research Foundation (NFPA RF) et en étroite collaboration avec la direction des sciences et de la technologie du Département de la sécurité intérieure des États-Unis (DHS S&T), un atelier de lutte intelligente contre l'incendie (Smart Firefighting [SFF]) s'est déroulé à Ottawa (Ontario) les 30 et 31 janvier 2018 afin de cerner les exigences en matière

de soutiens technologiques destinés à améliorer la connaissance de la situation pour les pompiers dans un feu de bâtiment. Ce document a servi de ressource pour établir le contexte afin que les participants de l'atelier aient une connaissance préalable de la situation.

Des pompiers du Canada et des États-Unis, ayant pour la plupart le grade de capitaine ou un équivalent, se sont joints aux officiels du programme du DHS S&T, aux représentants du Programme d'aide à la recherche industrielle du Conseil national de recherches du Canada et de la NFPA RF pour se concentrer sur les solutions technologiques qui pourraient permettre aux intervenants d'opérer sur le lieu de l'incendie en mode intégré « tête haute et mains libres ». Ce document est le résultat du travail entrepris par FirstLink Analytics, avec l'aide gracieuse du DHS S&T, pour soutenir l'atelier et cadrer les futures discussions entre les opérateurs et les éventuels fournisseurs de solutions SFF. Cette analyse a été entreprise pour soutenir l'atelier en vue de : cerner les exigences SFF « tête haute et mains libres » devant être prises en compte par les fournisseurs de solutions; fournir un aperçu des technologies dans cet espace de problème; et caractériser le marché pour les industries qui pourraient être en mesure d'aider.

Le Programme canadien pour la sûreté et la sécurité est un programme financé par le gouvernement fédéral visant à renforcer la capacité du Canada à réagir (anticipation, prévention/atténuation, préparation, intervention et rétablissement) aux catastrophes naturelles, aux accidents graves, aux actes criminels ou terroristes en jumelant la science et la technologie avec les domaines des politiques, des opérations et du renseignement.