Augmented Reality/Virtual Reality (AR/VR) Notional Requirements List for Procurements

Product of the Big City Fire Working Group

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FOREWORD

The mission of the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) is to develop and transition technologies and knowledge products that allow homeland security professionals — including emergency responders — to complete their missions effectively and safely. DHS S&T must obtain end-user input throughout its research, development, test, and evaluation (RDT&E) processes to accurately identify gaps and characterize requirements, enabling it to invest its RDT&E funds in projects that will improve the safety and effectiveness of emergency response operations.

DHS S&T leverages a volunteer group of emergency response and preparedness professionals to inform its research and development efforts. The First Responder Resource Group (FRRG), established in 2011, is an interagency working group comprising approximately 140 active and retired first responders. The members are drawn from a broad range of disciplines (e.g., law enforcement, fire service, emergency medical service, emergency management) and sectors (e.g., local, state, tribal, federal) and from all regions of the country.[1] FRRG members identify high priority capability needs and define operational requirements that technologies and knowledge products must meet to address those needs. FRRG members also help validate and evaluate solutions during development.

Figure 1-1 FRRG tasking

The Big City Fire Working Group (BCF) was established as a discipline-specific working group under the FRRG to addresses the unique needs of the fire service. BCF membership includes senior leaders across the fire service from large urban areas who identify capability needs and operational issues that are among the highest priorities to departmental leadership. Leveraging BCF's unified voice to understand the challenges of the fire service decreases DHS S&T investment risk because requirements are validated by leaders from agencies across the nation.

Twelve fire departments are represented on BCF: Atlanta, Chicago, Dallas, Denver, Las Vegas, Los Angeles, Los Angeles County, Miami, New York City, Philadelphia, St. Louis, and Seattle. These 12 fire departments comprise a combined total of approximately 909 fire houses and more than 37,000 fire service personnel (both uniform and civilian).

[1] "The First Responder Resource Group (FRRG) – An Emergency Response and Preparedness Think Tank," U.S. Department of Homeland Security, Science and Technology Directorate. Viewed on 12 March 2019. https://www.dhs.gov/sites/default/files/publications/First-Responder-Resource-Group_Fact-Sheet_v3-508.pdf

BACKGROUND

The continued development of augmented reality (AR) and virtual reality (VR) systems may have significant impacts on the fire service, from recruitment and retention to training and exercise. However, AR/VR applications for the fire service lag far behind those for other fields. Current limitations include the availability of scenarios, modules, algorithms, and peripheral equipment and the cost of acquisition, set up, and maintenance. The list is derived from AR/VR system requirements drawn from responder-identified needs and publicly available information.

PURPOSE

This document is a compilation of AR/VR system requirements providing fire departments with a set of non-proprietary specifications that can be used as a starting point for future requests for information (RFIs) and procurement activities. Moreover, this requirements list presents potential time and resource savings for resource-thin departments that do not have a large staff to easily develop similar documentation.

This list has been reviewed by BCF participating agencies and reflects specifications per the needs of their large urban departments. **Agencies are encouraged to adapt this document to fit their individual needs.**

REQUIREMENTS

These generalized requirements were developed by reviewing specifications, journal articles, and documentation from existing solution developers and removing proprietary elements. When a requirement involves a choice between multiple options, those options are listed in the "parameter" column. Agencies should choose the option that best fits their operational needs. Within a requirements category, items are indicated to be either standards-based (S) or operational (O) in the last column. Operational requirements relate to how the system is used or how the user interacts with the system. Standards-based requirements relate to standards that should be met by the system or a component of the system.

AR/VR SYSTEM REQUIREMENTS CATEGORIES

Click on a category below to jump to the corresponding notional requirements list.

STANDARDIZATION/REGULATORY REQUIREMENTS

1.0 Standardization/Regulatory Requirements		Parameter	Type
1.1	Virtual environments should be represented with a standardized data model and interface so that they can be generated for common use and exchanged between applications (e.g., Unity, Unreal)	N/A	O
1.2	Applications, components, systems, services, or specifications should be developed in accordance with: • ISO/IEC 18039 *Mixed and Augmented Reality (MAR) Reference Model* • ISO/IEC FDIS 18038 *Sensor Representation in Mixed and Augmented Reality* • ISO/IEC 18040 *Live Actor and Entity Representation in Mixed and Augmented Reality*	N/A	S
1.3	Real-world data should be imported, represented, simulated, and transmitted in accordance with ISO/IEC JTC 1/SC 24 *Computer graphics, image processing and environmental data representation*	N/A	S
1.4	Graphics should be represented in accordance with ISO/IEC JTC 1/SC 29 *Coding of audio, picture, multimedia and hypermedia information*	N/A	S
1.5	Knowledge databases for education and training should be creatable and manipulatable in accordance with ISO/IEC JTC 1/SC 29 *Information technology for learning, education and training*	N/A	S
1.6	Virtual environments should provide a standardized virtual three-dimensional (3D) space that can define and exchange education and training objects in heterogeneous computing environments according to: • ISO/IEC 14772 *Virtual Reality Modeling Language* (VRML) • ISO/IEC 14772-2 VRML97 *Functionality and External Authoring Interface* • ISO/IEC 19775-1 V3.3 *Extensible 3D* (X3D)	N/A	S
1.7	Humanoid models should be defined and managed within virtual environments in accordance with: • ISO/IEC 19774 *Humanoid Animation* (H-Anim) • ISO/IEC FDIS 19774-1 *Humanoid Animation (H-Anim) Part 1: Architecture* • ISO/IEC FDIS 19774-2 *Humanoid Animation (H-Anim) Part 2: Motion data animation*	N/A	S

1.0 Standardization/Regulatory Requirements		Parameter	Type
1.8	VR and AR information should be transmitted across heterogeneous computing environments in a seamless manner	N/A	O
1.9	A data dictionary shall be provided for geographical information in virtual environments	N/A	O

System Requirements

2.0 System Requirements		Parameter	Type
2.1	As necessary, manufacturer shall specify the graphics processing unit (GPU) minimum requirements	N/A	O
2.2	As necessary, manufacturer shall specify the controller minimum requirements	N/A	O
2.3	As necessary, manufacturer shall specify the operating system (OS) requirements	N/A	O
2.4	As necessary, manufacturer shall specify the central processing unit (CPU) minimum requirements	N/A	O
2.5	As necessary, manufacturer shall specify the random-access memory (RAM) minimum requirements	N/A	O
2.6	As necessary, manufacturer shall specify additional storage minimum requirements	N/A	O
2.7	As necessary, manufacturer shall specify the power source minimum requirements	N/A	O
2.8	As necessary, manufacturer shall specify the number and type of ports required for all system components	N/A	O

Head-Mounted Display (HMD) Requirements

3.0 Head-Mounted Display (HMD) Requirements		Parameter	Type
3.1	All HMD elements should demonstrate compliance with UL8200 *Standard for Virtual Reality, Augmented Reality and Mixed Reality Technology Equipment*	N/A	S
3.2	Manufacturer shall indicate the form factor of the HMD	Headset	O
		Goggles/Glasses	
		Mixed Reality	
		Other	

3.0 Head-Mounted Display (HMD) Requirements		Parameter	Type
3.3	Manufacturer shall indicate the HMD lens type	Fresnel	O
		Pancake	
		Other	
3.4	Manufacturer shall indicate whether the HMD features dioptic dials[2]	N/A	O
3.5	Manufacturer shall specify the HMD power source configuration	Integrated into HMD	O
		Body worn	
3.6	If not integrated into the HMD, manufacturer shall specify how the HMD is connected to the power source	N/A	O
3.7	Manufacturer shall specify whether the HMD power source is rechargeable	N/A	O
3.8	Manufacturer shall specify whether the data relay from the system to the HMD is wireless	N/A	O
3.9	The device shall be able to be worn while wearing required safety head gear (e.g., helmet)	N/A	O

CONTROLLER REQUIREMENTS

4.0 Controller Requirements		Parameter	Type
4.1	All controller elements should demonstrate compliance with UL8400 *Standard for Virtual Reality, Augmented Reality and Mixed Reality Technology Equipment*	N/A	S
4.2	Manufacturer shall indicate the number of controllers included with the station/platform	0	O
		1	
		2	
		Other	
4.3	Manufacturer shall indicate whether the platform allows hand tracking	N/A	O
4.4	Manufacturer shall indicate the number of hand gestures recognized by the platform	N/A	O

[2] Dioptic dials magnify the image of the virtual world seen through the lens it surrounds.

DISPLAY REQUIREMENTS

5.0 Display Requirements		Parameter	Type
5.1	Manufacturer shall specify type of light source used in the display	Organic Light-Emitting Diode (OLED)	O
		Liquid Crystal Display (LCD)	
		Active-Matrix Organic Light-Emitting Diode (AMOLED)	
		Other	
5.2	The display shall support full color	N/A	O
5.3	Manufacturer shall specify display resolution	N/A	O
5.4	Manufacturer shall specify refresh rate[3] in Hertz (Hz)	N/A	O
5.5	Manufacturer shall specify latency rate	N/A	O
5.6	Manufacturer shall specify field of view	N/A	O
5.7	Manufacturer shall specify how the system addresses the user's interpupillary distance (IPD)	Fixed IPD	O
		Manually-adjustable IPD	
		Automatic IPD adjustment	
5.8	If the system requires manual adjustment, manufacturer shall specify IPD in millimeters (mm)[4]	N/A	O
5.9	Manufacturer shall specify the number of pixels per degree (PPD)[5]	N/A	O

[3] Refresh rate means how many times per second the image on an electronic display is replaced by a new image (i.e., how often it is refreshed).

[4] Interpupillary distance (IPD) is the distance between the center of each eye when looking straight ahead. It is often measured in millimeters.

[5] Pixels per degree (PPD) means the number of pixels present in a horizontal line of the VR headset's display divided by its field of view. PPD is a measure of pixel density.

Peripheral Requirements

6.0 Peripheral Requirements		Parameter	Type
6.1	Manufacturer shall specify number and type of peripherals available	N/A	O
6.2	All peripheral elements should demonstrate compliance with UL8400 *Standard for Virtual Reality, Augmented Reality, and Mixed Reality Technology Equipment*	N/A	S
6.3	Manufacturer shall specify if peripheral accessories collect positional data about objects or user body movements	N/A	O
6.4	Manufacturer shall state deviance (e.g., size, shape, weight) of peripherals from real life equipment	N/A	O

Sensory Requirements

7.0 Sensory Requirements		Parameter	Type
7.1	Manufacturer shall describe all sensory elements present in the virtual environment	N/A	O
7.2	System shall enable user/learner to hear sounds from the virtual environment	N/A	O
7.3	Manufacturer shall specify whether device speakers are wired or wireless	N/A	O
7.4	System shall enable user/learner to speak to engage with virtual environment	N/A	O
7.5	If not connected to agency radios, the device microphone shall be wireless	N/A	O
7.6	The device microphone shall be directional (including jawbone, throat, and ear canal)	N/A	O
7.7	The device microphone shall have background noise cancelling	N/A	O
7.8	System shall produce haptic feedback	N/A	O

Sensor Integration Requirements

8.0 Sensor Integration Requirements		Parameter	Type
8.1	Real world information from sensors shall be represented in virtual environments	N/A	O

8.0 Sensor Integration Requirements		Parameter	Type
8.2	Manufacturer shall describe all sensor data elements present in the virtual environment	N/A	O
8.3	Sensor data shall be imported, represented, and simulated within scenarios	N/A	O
8.4	Sensor information shall be simulated visually and interactively in virtual environments	N/A	O

FACILITY/SITE REQUIREMENTS

9.0 Facility/Site Requirements		Parameter	Type
9.1	Manufacturer shall specify whether the system is portable or requires dedicated permanent space	N/A	O
9.2	If portable, manufacturer shall specify the estimated time required to set up portable components	N/A	O
9.3	If VR, manufacturer shall specify the movement range of the user/learner in feet (length x width x height)	N/A	O
9.4	Manufacturer shall indicate whether the system provides room-scale tracking	N/A	O
9.5	Manufacturer shall indicate whether beacons, base stations, or other accessories are used to determine user location and orientation	N/A	O
9.6	Manufacturer shall indicate whether the platform allows user teleportation within the module	N/A	O

SCENARIO/CONTENT REQUIREMENTS

10.0 Scenario/Content Requirements		Parameter	Type
10.1	System shall include realistic simulations of emergency response scenarios	N/A	O
10.2	System shall incorporate multiple scenarios to assess skills and decision-making	N/A	O
10.3	Manufacturer shall specify the expected rate of introduction of new scenarios	N/A	O
10.4	System shall accurately represent fire behavior	N/A	O
10.5	**OPTIONAL:** System shall allow customization based on jurisdiction-, incident-, and role-based variables	N/A	O

10.0 Scenario/Content Requirements		Parameter	Type
10.6	System shall integrate realistic audio and visual components (e.g., fire alarms, scene video)	N/A	O
10.7	**OPTIONAL:** System shall integrate agency-specific policies and protocols	N/A	O
10.8	**OPTIONAL:** System shall integrate digital twins of jurisdiction-specific tools and equipment	N/A	O
10.9	System shall integrate realistic incident conditions (e.g., crowd noise, weather)	N/A	O
10.10	System shall accurately reflect consequences of decisions	N/A	O
10.11	System shall accurately reflect circumstances or injects	N/A	O
10.12	System shall accurately reflect stress and chaos	N/A	O
10.13	Manufacturer shall specify whether the system allows for download of 3D structures from online repositories	N/A	O
10.14	Manufacturer shall specify whether the system includes a software and content generation tool	N/A	O
10.15	The software and content generation tool shall have a user interface that can be learned by non-software literate personnel (not a computer scientist or software engineer)	N/A	O
10.16	The software and content generation tool shall enable users to create accurate and comprehensive 3D renderings of building interiors and outdoor locations	N/A	O
10.17	The software and content generation tool shall support automatic generation of ultralight 3D models from engineering computer aided dispatch (CAD) drawings	N/A	O
10.18	The software and content generation tool shall store created renderings in a virtual library for reuse	N/A	O
10.19	The software and content generation tool shall allow the agency/owner to select the content storage mechanism	Local	O
		Server	
		Cloud	

SIMULATED TRAINING REQUIREMENTS

11.0 Simulated Training Requirements		Parameter	Type
11.1	Manufacturer shall specify the number of fire service-specific training scenarios currently available	N/A	O
11.2	Manufacturer shall specify the number of:	N/A	O

11.0 Simulated Training Requirements		Parameter	Type
	• operational skills training modules (e.g., pump panel) • communications focused modules • operational decision-making modules • command/management training modules		
11.3	Manufacturer shall specify the number of users/learners that the system can accommodate at one time	N/A	O
11.4	Manufacturer shall specify the number of roles available to users/learners	N/A	O
11.5	Manufacturer shall specify the number of roles that the system can accommodate at one time	N/A	O
11.6	Manufacturer shall specify whether mandated training requirements are met by existing training scenarios	N/A	O
11.7	Manufacturer shall map modules and outcomes to the NFPA Job Performance Requirements listed in latest edition of NFPA 1001 *Standard for Fire Fighter Professional Qualifications*	N/A	O
11.8	Manufacturer shall specify mechanisms for providing information to users/learners during training modules	N/A	O
11.9	All training elements shall be clearly defined for users/learners	N/A	O
11.10	All training element success metrics shall be clearly defined for users/learners	N/A	O
11.11	System shall provide a mechanism for users/learners to understand their success or failure in completing all training elements	N/A	O
11.12	System shall provide a mechanism for users/learners to view their results for a given training module	N/A	O
11.13	Users/learners shall be able to take a screenshot during training module	N/A	O
11.14	Users/learners shall be able to record video and audio during training module	N/A	O
11.15	Users/learners shall be able to obtain guidance from remote training staff members during module	N/A	O
11.16	Users/learners shall be able to receive notifications from the system or remote training staff members during module	N/A	O

11.0 Simulated Training Requirements		Parameter	Type
11.17	System shall include a “see what I see” functionality for training staff members to observe users/learners during training sessions	N/A	O
11.18	System shall assess leadership and command knowledge	N/A	O
11.19	System shall assess leadership and command skills	N/A	O
11.20	System shall assess decision-making	N/A	O
11.21	System shall identify skills that require improvement	N/A	O
11.22	System shall identify alternate outcomes based on specific decisions	N/A	O
11.23	System shall incorporate evolving challenges and scenarios	N/A	O

Simulated Exercise Requirements

12.0 Simulated Exercise Requirements		Parameter	Type
12.1	Manufacturer shall specify the number of fire service-specific exercise scenarios currently available	N/A	O
12.2	Manufacturer shall specify whether mandated exercise requirements met by existing exercise scenarios	N/A	O
12.3	Manufacturer shall specify mechanisms for providing information to users/learners during exercise modules	N/A	O
12.4	All exercise elements shall be clearly defined for users/learners	N/A	O
12.5	All exercise element success metrics shall be clearly defined for users/learners	N/A	O
12.6	Manufacturer shall specify the number of users/learners that are able to interact with and impact each other and their environment in real time	N/A	O
12.7	System shall provide a mechanism for users/learners to track their progress through each simulation	N/A	O
12.8	System shall provide a mechanism for users/learners to view their results for a given exercise module	N/A	O
12.9	System shall provide a mechanism for users/learners to know when they have completed the exercise module	N/A	O

12.0 Simulated Exercise Requirements		Parameter	Type
12.10	System shall provide a mechanism for users/learners to understand their success or failure in completing all exercise elements	N/A	O
12.11	Users/learners shall be able to take a screenshot during exercise module	N/A	O
12.12	Users/learners shall be able to record video and audio during exercise module	N/A	O
12.13	System shall allow users/learners to participate in exercise in different roles	N/A	O
12.14	System shall allow users/learners to participate solo or with a selected group	N/A	O
12.15	System shall specify number of unique roles that can be used simultaneously in each scenario by users/learners as well as the total number of users /learners that can participate	N/A	O

USER MOVEMENT AND HEALTH DATA REQUIREMENTS

13.0 User Movement and Health Data Requirements		Parameter	Type
13.1	Users/learners shall be able to move throughout the virtual environment in accordance with real life roles and missions	N/A	O
13.2	Users/learners shall be able to interact with specific objects within the simulation in accordance with real life roles and missions	N/A	O
13.3	Users/learners shall be able to pick up and manipulate specific objects within the simulation in accordance with real life roles and missions	N/A	O
13.4	Users/learners shall be able to move objects within the scenario	N/A	O
13.5	Users/learners shall be able to use objects to complete tasks within the scenario	N/A	O
13.6	Solution shall track movements along <…> degrees of freedom (DoF)[6]	3	O
		6	

[6] Degrees of freedom (DoF) refers to the number of axes of physical movement that can be tracked by a VR headset.

13.0 User Movement and Health Data Requirements		Parameter	Type
13.7	Manufacturer shall indicate tracking of user movements	Eye tracking	O
		Facial movement	
		Full body movement	
		3D positioning	
		User interactions	
		Biometrics	
13.8	Manufacturer shall indicate the number and placement of points on the body tracked by the platform	N/A	O
13.9	Manufacturer shall specify calibration methods and processes for users/learners	N/A	O
13.10	Manufacturer shall specify whether tracking elements are included in the HMD or need to be purchased as an accessory	N/A	O
13.11	Manufacturer shall specify outputs of user/learner movement tracking features	N/A	O

System Training Requirements

14.0 System Training Requirements		Parameter	Type
14.1	Manufacturer shall specify <…> requirements for initial system training upon purchase • In-person • Online • Virtual library	N/A	O
14.2	Manufacturer shall specify the number of hours of initial system training provided to agency/owner upon purchase	N/A	O
14.3	Manufacturer shall specify the mechanism for communicating new system features when released	N/A	O
14.4	Manufacturer shall provide training (as necessary) for new system features	N/A	O

System Warranty Requirements

15.0 Warranty Requirements		Parameter	Type
15.1	Manufacturer shall specify the warranty for: • System • HMD • Other display • Peripherals • System provided server- or cloud-based storage	N/A	O
15.2	Manufacturer shall provide a clear point of contact for warranty claims	N/A	O
15.3	Manufacturer shall define mechanisms for post-delivery services (as necessary)	N/A	O
15.4	Manufacturer shall notify agency/owner NLT180 days before existing features are discontinued	N/A	O

Compatibility Requirements

16.0 Compatibility Requirements		Parameter	Type
16.1	System shall comply with exchange standards for data transmission (e.g., NIEM)	N/A	O
16.2	System shall bi-directionally communicate with existing response-related software and systems (e.g., electronic situational awareness, responder geolocation)	N/A	O
16.3	Manufacturer shall specify whether the system supports the latest low power Bluetooth wireless connectivity standard	N/A	O
16.4	Manufacturer shall specify whether the system supports the latest low power Wi-Fi wireless 802.11 standard	N/A	O
16.5	Manufacturer shall specify whether the system supports the latest global system for mobile communications (GSM) cellular device standard	N/A	O
16.6	Manufacturer shall specify whether the system supports person to person communication during training or exercise activities	N/A	O

Security Requirements

17.0 Security Requirements		Parameter	Type
17.1	Manufacturer shall specify methods of malware detection and cybersecurity screening of software and firmware components	N/A	O
17.2	The device shall support memory storage encryption, for security of the content	N/A	O
17.3	System shall provide a dedicated login when the information provided to the user may be confidential	N/A	O
17.4	The system shall encrypt any data that can be tracked to a specific user/learner to include performance and biometric data (as applicable and in accordance with NIST Cybersecurity Framework 2.0 or other relevant standard)	N/A	O

Maintenance Requirements

18.0 Maintenance Requirements		Parameter	Type
18.1	System shall be modular to allow for upgrade and replacement of components	N/A	O
18.2	System shall maintain backwards compatibility after upgrade	N/A	O

Power Source Requirements

19.0 Power Source Requirements		Parameter	Type
19.1	Manufacturer shall specify how the system elements are powered	N/A	O
19.2	Manufacturer shall specify and document if power source relies on proprietary components	N/A	O
19.3	If powered by batteries, manufacturer shall specify whether the batteries are rechargeable	N/A	O
19.4	Manufacturer shall specify whether the battery can be “hot swapped” during virtual training or exercise activities	N/A	O
19.5	If rechargeable, manufacturer shall specify the shelf life of a single charge	N/A	O
19.6	Manufacturer shall specify how often the batteries need to be checked for integrity	N/A	O

19.0 Power Source Requirements		Parameter	Type
19.7	Manufacturer shall provide test data as evidence of battery duration during operations	N/A	O
19.8	Manufacturer shall list any parts/components that contain lithium-ion batteries	N/A	O

Environmental Requirements

20.0 Environmental Requirements		Parameter	Type
20.1	The device displays shall provide visible (easy to read) displays while in full ambient light conditions.	N/A	O
20.2	The device shall be able to auto adjust brightness from a full ambient light condition to a dark condition, and vice versa in <1> seconds.	N/A	O
20.3	The device shall work in environmental requirements documented in IP64F	N/A	O

Comfort Requirements

21.0 Comfort Requirements		Parameter	Type
21.1	Manufacturer shall specify the weight of the device worn on the head	N/A	O
21.2	The device external temperature shall not exceed 35°C against the user's skin	N/A	O
21.3	The device shall support the addition of prescription lenses or be usable with them	N/A	O

Data Requirements

22.0 Data Requirements		Parameter	Type
22.1	Manufacturer shall specify the amount of on-board memory storage	N/A	O
22.2	System shall track user data to include: • Decision points • Task completion success • Task completion rate • Milestones • Response rate	N/A	O

22.0 Data Requirements		Parameter	Type
22.3	System shall provide data for after-action reporting at individual or team level	N/A	O
22.4	System shall be able to export training data to learning resource management (LRM) system	N/A	O

Artificial Intelligence/Machine Learning Requirements

23.0 Artificial Intelligence/Machine Learning Requirements		Parameter	Type
23.1	System shall provide artificial intelligence (AI) avatars/non-player characters (NPCs) to support realistic training and exercise scenarios	N/A	O
23.2	Manufacturer shall describe how platform integrates AI/machine learning to augment user experience	N/A	O
23.3	System shall incorporate natural language processing (NLP) if voice recognition of user commands is an element of training or exercise modules	N/A	O
23.4	Manufacturer shall describe increased needs for system (e.g., processing power), HMD (e.g., weight), controllers, peripherals, etc. associated with optional AI augmentations	N/A	O
23.5	Manufacturer shall provide testing data as requested for algorithms used for fire behavior, plume dispersal, or other technical effects used to control module actions	N/A	O
23.6	System shall provide a personalized learning experience, allowing tracking of user progress across time and modules, suggestions for specific modules to improve weak areas, etc.	N/A	O

HELPFUL RESOURCES

Digital Manufacturing and Design Innovation Institute, "Augmented Reality Hardware Functional Requirements for Industrial Industry Use Cases," November 17, 2016. https://thearea.org/wp-content/uploads/2017/08/AR-Functional-Requirements-Hardware-rev1.pdf

Digital Manufacturing and Design Innovation Institute, "Augmented Reality Software & Content Generation Tools Functional Requirements for Industrial Industry Use Cases," November 17, 2016. https://thearea.org/wp-content/uploads/2017/08/AR-Functional-Requirements-Software-rev1.pdf

ISO/IEC JTC 1/VR AR for Education Ad Hoc Group, "Guidelines for Developing VR and AR Based Education and Training Systems," white paper. ISO/IEC, August 8, 2019. https://www.iso.org/files/live/sites/isoorg/files/developing_standards/who_develops_standards/docs/White_Paper_VRAR.pdf

UL Solutions, "Augmented, Virtual and Mixed Reality Equipment Safety," 2023. https://collateral-library-production.s3.amazonaws.com/uploads/asset_file/attachment/53450/AR_VR_MR_Equipment_Safety_Infosheet.pdf