2017

# Public Safety User Interface R&D Summit Report

CTL Communications Technology Laboratory

NIST

PSCR

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# Executive Summary

The Public Safety Communications Research Program (PSCR) convened over 40 stakeholders at the Department of Commerce Boulder, CO campus to build on the findings presented in the *Public Safety User Interface R&D Roadmap report*[1]. The Public Safety User Interface Summit – held July 18-19, 2017 – served to socialize the Roadmap with a broader stakeholder base and determine the core technology challenges inhibiting public safety's effective and expanded use of user interfaces in daily operations.

The Summit resulted in a list of seven clearly defined user interface technology research and development (R&D) focus areas that align with public safety needs and requirements. Each of these seven focus areas were prioritized against PSCR's investment criteria and attendees developed specific problem statements relating to the user interface challenges within each area. To close the Summit, attendees also described specific requirements, standards, measurement capabilities and technology capabilities that need to be developed if public safety intends to integrate these user interface capabilities effectively into day-to-day operations. In addition, attendees brainstormed potential R&D project opportunities for research organizations supporting public safety technology to consider going forward.

The User Interface Summit represents the culmination of three years of PSCR R&D roadmapping and planning. To assist in planning for public safety communications research and optimize the allocation of the $300 million apportioned to NIST from the AWS-3 spectrum auction, which concluded in January 2015, PSCR developed technology roadmaps and convened R&D summits focused on Location-Based Services (2015), Analytics (2016), and User Interface (2017). PSCR will use the information presented in these roadmaps and summit reports to better inform its research investment decisions supporting the public safety community. The methodology used to evaluate and characterize user interface challenges and opportunities remains consistent with that used for Location-Based Services and Analytics research planning.

1 http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1961.pdf

# Purpose of the User Interface Summit

The User Interface R&D Summit took place over two days. Day 1 was intended to evaluate and prioritize the user interface technology areas that would provide greatest impact and value to public safety against the research investment criteria established by PSCR and FirstNet in 2013. Day 2 asked participants to characterize specific challenges, research opportunities, and measurement considerations within each of the seven priority user interface topic areas.

The detailed agenda for the User Interface R&D Summit is provided below:

**Day 1 (8:00am - 4:30pm MT)**

Tuesday, July 18

**8:00am** Registration
**9:00am** Introduction, Roadmap Overview, Q&A
**9:30am** User Interface and Public Safety's Operational Reality (Panel)
**10:00am** Prioritizing UI for Discipline-specific Scenarios (Breakout #1)
**11:30am** Report Results from Breakout #1 (Plenary Session)
- o **Output:** Prioritized list of user interface paradigms for discrete response tasks

**1:30pm** Rank UI Capabilities vs. PSCR Investment Criteria (Breakout #2)
- o **Output:** Top 6 Priority UI Capabilities per breakout group

**3:30pm** Criteria Ranking report-out and discussion (Plenary Session)
**4:15pm** Day 1 Closeout

**Day 2 (8:30am - 4:30pm MT)**

Wednesday, July 19

**8:30am** Problem Statement Development (Breakout #3)
- o **Output:** List of problem statements affecting the priority User Interface research areas

**10:20am** Problem Statement R&D Characterization (Breakout #4)
- o **Output:** Measurement Capabilities, Technology Capabilities, Standards, Requirements, and R&D opportunities to consider per problem statement

**1:30pm** Measurement Capabilities Discussion (Plenary Session)
- o **Output:** Key Performance Indicators, Measurement Approaches, Testing Methodologies, and Challenges associated with evaluating UI effectiveness

**4:00pm** User Interface Summit Hotwash / Closeout

# User Interface Paradigms Under Consideration

During Day 1, attendees were instructed to evaluate the 12 User Interface paradigms / capability areas defined below. While in the Location-Based Services and Data Analytics Summits participants were asked to prioritize specific technology gaps listed in the roadmap, PSCR found that the gaps presented in the Public Safety User Interface R&D Roadmap were too narrowly defined to effectively prioritize. As a result, PSCR decided to invite participants to provide thoughts on the 12 capability areas presented in the Public Safety User Interface R&D Roadmap using the descriptions on the following page:

1. **Vocal Command -** *Natural voice interaction could streamline access to data and information and make data retrieval more intuitive to responders in action. Vocal commands could greatly reduce physical cognitive requirements for operating communications devices and allow responders to focus on the task at hand.*
2. **Gesture Recognition -** *Gesture recognition represents an attractive alternative to traditional user controls because it would reduce the cognition and dexterity required to operate devices such as computer interfaces and in-vehicle dashboard controls.*
3. **Eye-gaze input command / Eye Tracking -** *Many tasks within emergency response scenarios require full use of device operators' hands and cognitive capacity. Eye-gaze input commands that automatically track responders' field of vision present a hands-free, potentially subconscious method to operate user interface devices supporting the completion of these physically and mentally-demanding tasks.*
4. **Additional Biometric Input mediums (heart rate, tongue gesture) -** *These include biometric sensors, heart rate monitors, and subvocal input commands, among others. Given the extreme environmental conditions inherent to many emergency scenarios, these non-vocal input commands will help responders communicate with others on scene or trigger specific support services when experiencing high noise, low visibility, limited dexterity, or physical impairment.*
5. **Haptic feedback and responsive physical displays -** *Touchscreens represent one of the most common user interface technologies used today and will become more responsive to touch, resistance, and motion with and without gloves going forward. Other types of haptic displays such as haptic belts and harnesses will provide tactile feedback to help responders "feel their way" or navigate through extreme conditions during response.*
6. **Ruggedized devices and sensors -** *Typical emerging device technologies increase in fragility as they increase in complexity, but through ruggedization, public safety's 'devices of tomorrow' will allow responders to enter hazardous and variable environments with all of the same technology interfaces as a worker in a modern office. Specific ruggedized capabilities for public safety devices may include safeguards against extreme temperatures, emissions of flammable gases, chemicals that may be present in hazardous environments, fluids on the skin (e.g., sweat, salt), and dustproofing for desert environments.*
7. **Wearables and devices/sensors in clothing -** *Future public safety users may be equipped with wearable interfaces that measure physiological factors such as heart rate, electrical activity from muscles, and body temperature. This performance data may lead to more informed resource allocation and operational decision making. Other wearables such as personal accountability tags may enhance responder situational awareness and user experience while yielding more precise location tracking and route optimization.*
8. **Augmented reality (AR) interfaces -** *AR technology "enables users to interact with their physical environment through the overlay of digital information." The ability to overlay contextual information and background knowledge on an AR headset would increase the operator's awareness in the field. This may provide a series of visual cues that alert a responder to hazardous materials or resources within a scene as he or she moves between environments.*
9. **Virtual reality (VR) systems -** *VR systems will be used to train public safety and conduct controlled equipment and interface testing. The ability to completely virtualize the operational environment from the safety of a controlled, indoor location will reduce risk to the lives of first responders, costs of training staff, and difficulty in testing equipment for operational suitability.*
10. **Smart suit interfaces and cooperative devices/sensors -** *"Smart Suits" present the opportunity for public safety to integrate multiple user interface capabilities into an integrated product design. The smart suit technology for public safety looks to incorporate data, communications, sensors, displays, and cameras supporting improved situational awareness with the protective layer of the operational uniform.*
11. **Remote operation of unmanned ground and aerial vehicles -** *Higher prevalence of drones will enable virtualized public safety operations to be conducted from remote locations. Remote operations can be thought of as a separation between the human operator and the physical execution of public safety tasks where control is maintained via a virtualized interface.*
12. **Human-machine interaction (HMI) and co-participation -** *Public safety may eventually gain the ability to interact with robots as co-participants during response. These machines may be able to process commands within the context of a scenario's mood, uncertainty, risk factors, etc. in real time and notice deviations from standard operating procedure. Responders may interact with 'cobots' to retrieve or transmit data on-scene.*

# R&D Investment Criteria

On Day 1 of the Summit, attendees were asked to rank the user interface paradigms that most effectively met the definition of each criterion defined below. The original intent of this exercise was to characterize the highest-scoring user interface paradigms across all criteria on Day 2 of the Summit.

This criteria was developed in close collaboration with FirstNet and the Public Safety Advisory Committee (PSAC) in 2013. The blue text assigned to each criterion served as the discussion prompt for each breakout group's prioritization exercise. The full User Interface Capabilities List can be found at the bottom of the User Interface Summit Wiki Page: https://sites.google.com/a/corneralliance.com/pscr-user-interface-roadmap-wiki/2017-user-interface-r-d-summit

PSCR has used this criteria to evaluate R&D opportunities during the Location-Based Services R&D Summit in 2015[1] and the Analytics R&D Summit[2] in 2016.

1. **Leverage -** Create the ability to realize a return in multiple technology applications and/or public safety disciplines by investing in the underlying technology capability

   *Of these capabilities, which has broadest applicability to public safety's fundamental technology needs? Advancing which capability will impact the greatest number of technology areas?*

2. **Feasibility -** The probability of a successful return on investment in light of current or anticipated technology enablers

   *Which capabilities have highest likelihood of success? (with PSCR R&D funds)? Which user interfaces can most realistically be used in public safety operational settings?*

3. **Impact on Public Safety Processes** - The transformational and wide-ranging positive effects a new technology capability would have on public safety operations

   *Which capabilities have highest likelihood of success? (with PSCR R&D funds)? Which user interfaces can most realistically be used in public safety operational settings?*

4. **Rewards/Results -** The outcomes public safety could expect from the application of a new technology capability in relation to common good, cost effectiveness, increased safety, and job effectiveness

   *If realized, which user interface capabilities would lead to the greatest rewards/results?*

5. **Unique to Public Safety -** A technology gap will not receive significant non-governmental R&D investment because of a lack of a clear commercial application

   *Which user interface capabilities will most likely only be addressed by NIST Public Safety R&D funds?*

# User Interface Capability Prioritization Results

1 http://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.1914.pdf
2 http://ws680.nist.gov/publication/get_pdf.cfm?pub_id=922350

To identify the highest-priority technology areas going forward, all participants were organized into six breakout groups and prioritized the top three highest-performing capabilities within each criteria. PSCR aggregated the prioritization scores across all breakout groups and then facilitated a discussion around the following results:

1. Augmented Reality (**highest** priority User Interface Capability)
2. Voice Command
3. Unmanned Vehicles / Drones
4. Ruggedized Devices / Sensors
5. SmartSuit
6. Human-Machine Interaction / Co-Participation
7. Biometric Input
8. Wearables
9. Virtual Reality
10. Eye Gaze / Tracking
11. Haptic
12. Gesture Recognition (**lowest** priority User Interface Capability)

Participants were invited to react and provide feedback on these results to conclude Day 1. Many participants felt strongly that these 12 areas could be consolidated into 7 R&D topic areas based on significant areas of similarity and overlap between many of the interface paradigms and to more accurately capture the breadth of interface capabilities within PSCR's research scope.

# Problem Statement Development for Prioritized User Interface Capabilities

PSCR analyzed prioritization results within the context of feedback from participants and the laboratory's research scope. Rather than eliminating half of the user interface capability areas through the prioritization exercise as was originally intended, PSCR concurred with the feedback from participants and consolidated the full list into seven categories. This enabled Summit participants to characterize as many R&D topic areas as possible on Day 2.

As a result, the seven user interface paradigms that served as the focus for Day 2 discussion are listed below in rank-order from highest to lowest priority. This list derived from stakeholder input collected during the criteria prioritization breakout exercise concluded Day 1.

1. Augmented Reality (**highest** priority User Interface Capability)
2. Voice Command / Audio Intake
3. Unmanned Vehicles / Human-Machine Interaction
4. Biometrics / Wearables / Smart Suit
5. Haptic
6. Virtual Reality
7. Gesture Recognition / Eye-Gaze (**lowest** priority User Interface Capability)

Participants decided to remove the Ruggedized Devices / Sensors paradigm from this final list of topic areas because ruggedization was viewed as an attribute or characteristic that could be applied to a user interface technology, rather than a standalone technology area. Participants remained in the same six breakout groups, and each group was asked to develop R&D Problem Statements for at least one of the seven R&D Topic Areas.

Instructions for developing Problem Statements within each of these seven topic areas were as follows: Write a series of 1-3 sentence descriptions explaining a specific technology problem you want solved within your UI area and why this is important. What result or outcome will this provide to public safety? To begin the exercise, each group was asked to **describe the ideal** (<USER INTERFACE> will enable Public Safety to do what?) and then **describe reality** (What are the current technology gaps/barriers/obstacles that prevent <USER INTERFACE> from doing these things?). After brainstorming ideal and reality conditions affecting each R&D topic area, the groups developed the series of problem statements presented in the table below:

| R&D TOPIC AREA | PROBLEM STATEMENTS |
|---|---|
| Augmented Reality | **Hardware -** Public safety AR operators require a fully customizable visual delivery mechanism that seamlessly integrates into protective equipment / uniform.<br><br>**Software / Analytics -** AR operators have disparate information / data needs that are unique to each public safety discipline and role within the public safety agency. Therefore, situational awareness information that is presented on an AR display must be customized (through analytics, algorithms, data science, etc.) to the unique requirements of the event, task, and role. Software must be scalable based the capabilities / trust of the end-user. AR software must be interoperable across jurisdictions and disciplines. AR software must triage, analyze, and transmit mission critical situational awareness data from all data streams stored at the Public Safety Answering Point (PSAP). Augmented reality interfaces must feature an interactive display that the user can adjust while on-duty through hands-free controls such as voice, eye gaze, gesture.<br><br>**Command-Control / Improved Broadband Infrastructure -** AR operators need an improved command-control and broadband infrastructure to deliver situational awareness data to an AR display / operator at the right time. |

| R&D TOPIC AREA | PROBLEM STATEMENTS |
| --- | --- |
| Voice Command / Audio Intake | **Hardware -** To function within typical public safety environments, vocal command hardware (microphones, audio filters) and software (signal processing algorithms) need to more effectively parse vocal inputs (signal) from environmental noise. More effectively differentiating between surrounding noise and command / audio input will increase responders' trust of relying on vocal commands during operations. Audio interfaces need to function as a 2-way communications device that 1) receives incoming vocal commands from user and 2) collects additional audio data from the scene to support improved situational awareness. Audio interface hardware must be inconspicuous and seamlessly integrated with protective equipment / uniform.<br><br>**Software -** Public safety audio interface operators require the flexibility to provide vocal commands through a variety of regional dialects, speech patterns, and discipline/agency-specific nomenclature. Specific areas to improve include 1) improved accuracy of general speech intake / analysis and 2) more accurate recognition of public safety-specific commands. Software supporting improved speech analysis and natural language processing will enable audio interface operators to receive / transmit data, communicate with other resources via specialized vernacular (regional dialect, social media slang, disparate operational codes), enhanced filtration and interpretation of background noise, and command machines via voice in a greater variety of environments.<br><br>**Training -** Voice represents a ubiquitous form of communication and therefore would serve as an attractive bridge interface / easy learning curve for Public Safety to use to operate emerging technologies. Need to integrate vocal command capabilities with other user interfaces used during operations.<br><br>The public safety environment has loud, unusual, and unpredictable audio but it is not all noise. The system needs to adapt and train systems to research and collect unique audio information from public safety audio tasks. |
| Unmanned Vehicles / Human-Machine Interaction | Public safety requires/would benefit from increased situational awareness but public safety operates in harsh, unpredictable physical environments where existing unmanned vehicle operation is unreliable and the appropriate level of machine autonomy is unknown.<br><br>Unmanned Aerial Vehicles (UAV) /HMI technology would greatly increase public safety's situational awareness, but limitations on power prevent existing UAV technology from being a mission critical resource/tool. Public Safety also has not defined the appropriate level of autonomy required to deploy and manage these technologies effectively during incident response. Existing technology is highly vulnerable to adverse weather conditions, does not meet inherent latency/delay requirements, and the reliability of current technologies is suspect since it's being driven primarily from commercial market demand. |

| R&D TOPIC AREA | PROBLEM STATEMENTS |
|---|---|
| Biometrics / Wearables / Smart Suit | Leadership needs to have the ability to monitor the internal and external location, health, remaining capability, and the status of each first responder on scene. Public safety needs to identify the methods for collecting relevant data and presenting it in a way that enhances situational awareness through a single, integrated system that does not interfere with external systems and is identifiable to the individual end user.<br><br>In order to develop wearable technologies, the research community supporting public safety needs to have an in-depth understanding of the range of end user sizes, clothing, and protective gear. This community needs to develop human anthropometric models representing the diversity of first responders in order to communicate requirements to technology developers.<br><br>Lack of physiological situational awareness prevents public safety from understanding fellow responders' health status during operations. Situational awareness information available today is limited to the location of a resource and information that the resource communicates to other team members. Research organizations need to develop physiological sensors and interfaces that automatically capture and transmit biometric data to central command and/or other resources on-scene in real-time. |
| Haptic | Need to improve adoption, accessibility, and integration of haptic sensors with equipment, and develop a standardized 'language' of haptic commands.<br><br>The appropriate modality of presentation must adapt to public safety's various environments and users' varying stress levels during response. Adaptive algorithms for dynamic response environments or public safety use cases do not exist today. |
| Virtual Reality | Agencies using different VR sets are not compatible because of how scenarios are ingested and rendered by VR sets. Public safety needs interoperable VR testing systems across a variety of different scenarios.<br><br>Public safety has not yet defined the desired outcomes for Virtual Reality systems and lacks the ability to measure outcomes/results of the VR experience. VR researchers need to define what public safety agencies will measure and/or test in VR environments. |

| R&D TOPIC AREA | PROBLEM STATEMENTS |
|---|---|
| Gesture Recognition / Eye-Gaze | Public safety will require next generation gesture and eye-gaze recognition capabilities to command devices, trigger officer action or data presentation to improve situational awareness, and signal for aid or other resources during response. These capabilities need to feature hands-free and multi-modal operation.<br><br>Current Gesture Recognition and Eye-Gaze Interfaces cannot reach this ideal state because hands are busy during response and continuous gesture tracking requires significant data bandwidth and backhaul compared with other user interface paradigms. |

# Research & Development Characterization for each User Interface Capability

After developing problem statements for each user interface research area, participants were asked to describe specific requirements, capabilities, and potential opportunities within these seven areas for PSCR to consider in its R&D planning. Participants described each user interface research area according to five attributes: 1) Measurement Approaches/Metrics, 2) Technologies to Develop, 3) Standards, 4) Requirements, and 5) R&D Project Opportunities. In addition, PSCR asked participants to describe specific tasks in which the given user interface capability could be used and identify Key Performance Indicators to measure whether a user interface technology is effective in supporting the described task.

Given that participants provided input across each of the seven user interface topic areas, there is some inconsistency regarding the level of detail of how each capability was characterized. As a result, readers will notice high variance in the length, style, and granularity of the input provided in this section. The PSCR staff leading the User Interface Portfolio believed that capturing stakeholder input directly was more desirable than categorizing or otherwise altering stakeholder input to create greater consistency across the data. Highlights from participants' input across the seven user interface research areas are described in the tables below:

| Augmented Reality | |
|---|---|
| Measurement Approaches/Metrics | • Geolocation mapping capabilities, z-axis, teammate location positioning accuracy<br>• Airflow oxygen left / floor damage<br>• Field testing<br>• Time required to access pertinent information<br>• Measure cognitive load (how much information a user can process during various response tasks)<br>• Measure visibility of display in various environments<br>• Optimization of information location and display in different environments and hardware<br>• Current time to complete tasks with current technologies vs. time to complete tasks while using AR<br>• Reliability of connection<br>• Durability of interface for mission<br>• Ease of use |
| Technologies to Develop | • Algorithms to customize situational awareness data based on shifting tasks and requirements during operations<br>• Data mining and artificial intelligence capabilities for predictive situational awareness<br>• Improved voice interpretation accuracy<br>• Real time spatial / geolocation tagging in real environments and ability to share geolocation information with distributed personnel<br>• Heads-up display that meets public safety ruggedization standards<br>• Contact lens displays<br>• Improved integrated navigation<br>• Optimization of display materials for ruggedization in extreme environments<br>• Spatial visualization within protective envelope (i.e. tango / in Face Piece) |
| Standards | • Training standards for all users (law enforcement, fire, emergency medical services (EMS))<br>• Health Insurance Portability and Accountability Act (HIPAA) privacy standards<br>• Minimum cybersecurity standards, storage capabilities and requirements<br>• Minimum storage capabilities and requirements<br>• Interoperability<br>• Usability<br>• Standardize Augmented Reality data visualization dashboard layout for discipline-specific tasks and scenarios |

| Augmented Reality | |
|---|---|
| Requirements | ● AR software and hardware to be specifically tailored to the following delivery modes:<br>○ Police -- patrol, tactical (SWAT), Bomb Squad, Undercover (plain clothes), Marine / Air. In-vehicle compatibility for all modes<br>○ Fire/EMS -- Personal Protective Equipment effects, Hazmat, Technical Search & Rescue<br>● Data visualization on AR displays must automatically alter brightness, coloration, and contrast depending on shifting light conditions experienced during use<br>● Swap requirements for different end-users<br>● Information needs to be only visible to designated recipient to protect sensitive data, mission requirements<br>● Secure data and redundant data streams<br>● Minimal cost of ownership<br>● Availability of user- / department- / jurisdiction-defined information streams<br>● Legibility of information overlay on real world (brightness, contrast)<br>● Minimal latency rate to provide realistic augmented reality rendering (10 milliseconds for 5G, commercial networks)<br>● Heads-up display / AR visual delivery mechanism must be ruggedized to withstand 400 degrees Fahrenheit, cyanides, and other toxic gases in fire environments |
| R&D Project Opportunities / Ideas | ● Partnership with Department of Homeland Security, Science and Technology Directorate's First Responder Group/ Project Responder Series<br>● Develop prototype heads-up display that's integrated with fire mask<br>● Adapt the AR design ideas found in first-person video games into public safety training environments and operations<br>● Research into contextual awareness (how to determine environment / contextual information)<br>● Develop a display format that can be utilized in all environments (bright sunlight, smoke, night, etc.)<br>● Identify likely command signals and observations for different end-users<br>● Engage first responders to identify vital data and timing<br>● Analysis of alternative exploring if calculations and analytics are local, “fog” networks, or processed in a centralized location<br>● Research how to redesign PSAP architecture to best meet network performance requirements associated with using augmented reality systems |

## Augmented Reality

| | |
|---|---|
| Task Descriptions / KPI's | Task #1: Driverless cars w/ augmented reality capabilities that projects map / navigation data directly on windshield/road<br>● KPIs:<br>○ Error Rate, time to destination<br>Task #2: Law enforcement officer's augmented reality contact lenses reads and displays license plate, driver facial recognition, etc. upon traffic stop<br>● KPI:<br>○ False positive rate of matching facial recognition vs. driver's license info, vehicle registration, criminal history |

## Voice Command / Audio Intake

| | |
|---|---|
| Measurement Approaches/Metrics | ● Identify what level of vocal recognition fidelity is attainable in emergency environments (80%? 95%?)<br>● Monitor consumer voice / audio market R&D with respect to public safety<br>● Measure the number of words that can be recognized by audio intake platforms (vocabulary bandwidth)<br>● Locations and sounds of public safety audio environment<br>● Accuracy of speech-to-text voice transcription<br>● Speed of the translation<br>● 360-degree data on the microphone sensors to have a complete picture<br>● Anechoic chamber availability<br>● Characterization of current time to complete task - used to quantify audio improvement<br>● Consider length of time that it takes to relay command and device acts / provides information |

| Voice Command / Audio Intake | |
|---|---|
| Technologies to Develop | • Ability to override vocal commands through other input mediums when device cannot understand what is said<br>• Open software interfaces to correlate to voice output with databases (i.e. directory look up)<br>• Testing framework to evaluate public safety specific voice recognition audio and cues<br>• Artificial intelligence or machine learned certification process<br>• Audio test range and curated data sets<br>• Algorithms identify key events from background noise (i.e. respirator stops breathing, building collapses, gun fire, car crash, car backfire, glass break, etc.)<br>• Remove noise from Self-Contained Breathing Apparatus (SCBA) or airpatch speech and extract respiration rate from the sound/pressure to monitor other vitals<br>• Embed pressure sensor within air pack detecting rate of breathing to help with voice signal extraction<br>• Alternative listening (proactive response) |
| Standards | • Lowest common denominator of public safety common taxonomy<br>• Acceptable ear safety standards for humans<br>• Standards that use frequency response of mics to normalize all audio<br>• American National Standards Institute (ANSI) accredited training |
| Requirements | • Voice recognition accuracy rate / reliability of 99.9999%<br>• Ability to distinguish between voice commands and outside noise<br>• Gesture requirements like lip reading<br>• Device in mask<br>• Translation and identification<br>• Lateral quality<br>• Swap requirements for places microphones can be placed (mostly exists)<br>• Monitor radio traffic and extract unit status (en route, on scene, scene size up)<br>• Accommodate regional accents |

| Voice Command / Audio Intake | |
|---|---|
| R&D Project Opportunities / Ideas | ● Initiatives to collect more specific technical requirements related to voice command:<br>○ End-user survey on what 'future' voice commercial mobile devices (CMDs) should be focused on / prioritized<br>○ Acceptability criteria for human-human, human-bot, bot-bot voice interactions<br>○ Graceful degradation dialogues<br>○ Determine the vocabulary used in all law enforcement, EMS, fire, and search and rescue incidents<br>○ Requirements and analysis of alternatives for public safety specific audio co-processor<br>● Successfully address issue of background sound that is noise vs usable for situational awareness:<br>○ Sound identification<br>○ Sound isolation (removal and amplification)<br>○ Mobile testbed, go collect on-scene background noises - it would have multiple microphones, different distances, and different microphone types.<br>● Audio testbed to generate public safety direct background sounds<br>● Demonstrate capability to categorize discrete emotion state given the audio (more than voice) input<br>● Develop public safety autonomous CMD capability<br>● Characterize expected audio database given public safety incidents<br>● Pilot the use of in-vehicle voice commands to reduce public safety cognitive demands and distractions while driving |

| Voice Command / Audio Intake | |
|---|---|
| Task Descriptions / KPI's | Tasks:<br>• Emergency assistance<br>• Basic keyword-driven task ("Change status to on-scene")<br>• Query on free text<br>• Operate basic radio controls (channel, volume up, volume down, etc.)<br>• Log-in via voice authentication<br>• Query a plate number or name<br>• Voice transcription or speech to text messaging<br>KPI's Applicable to all Tasks<br>• Measure capability in clear environment<br>• Measure capability in noisy environment<br>• Measure capability under stress<br>• Time to accomplish<br>• Error rate<br>• Number of repeats<br>• Speed of translation (delay)<br>• Percentage of user aborts for another interface<br>• Response to different voice problems |

| Unmanned Vehicles / Human-Machine Interaction | |
|---|---|
| Measurement Approaches/Metrics | • Situational awareness (real time)<br>• Cognitive workload<br>• Usability<br>• Deviation from standard operating procedure when using UAVs<br>• Technology acceptance/adoption<br>• Perceived usefulness/intent to use |

| Unmanned Vehicles / Human-Machine Interaction | |
|---|---|
| Technologies to Develop | • Swarms<br>• Video format/size<br>• Audio format/size<br>• Autonomy<br>• Data sharing<br>• Jamming deterrence technology<br>• Concentrating data collected from multiple input sources (drones, sensors, cameras) into one clear operational picture<br>• Real-time spatial mapping and processing sent to remote and individual (visualization)<br>• Algorithm to automatically switch between based on environment, line-of-sight, situational awareness, weather, Global Positioning System (GPS), etc.<br>• Algorithm to adjust task handoff between unmanned vehicle and human operator |
| Standards | • Cybersecurity<br>• Control interference<br>• Cargo container<br>• Hardware security (remote destruction in case of interception)<br>• Improve handoff between non-line of sight network nodes<br>• Shared user interface - intelligent middleware platform based on open standards to control drones within an agency or jurisdiction |
| Requirements | • Geographic Information System (GIS) layering<br>• Updating of GIS with higher resolution<br>• Operation range<br>• Ruggedization<br>• Field repairable<br>• Adaptability to environment<br>• Over-the-Air (OTA) programming and system updates<br>• Real time data aggregation, analysis, and delivery of actionable into to incident command |
| R&D Project Opportunities / Ideas | • Deep machine learning<br>• Interwork UAV with personal assistant used by incident control centers |

| Unmanned Vehicles / Human-Machine Interaction | |
|---|---|
| Task Descriptions / KPI's | Task #1: Delivery of tangible or physical equipment and resources<br>● KPIs:<br>○ Time to completion<br>○ Accuracy Percentage<br>Task #2: Video Monitoring and Surveillance<br>● KPIs:<br>○ Monitoring Time<br>○ Location Stability<br>○ Moving Target Stability<br>○ Centered in Frame<br>○ Zoom Level |

| Biometrics / Wearables / Smart Suit | |
|---|---|
| Measurement Approaches/Metrics | ● Usability, efficiency, effectiveness, user satisfaction<br>● Location accuracy for location based services<br>● Incoming notification time to acknowledgment by recipient, including a corresponding action/response<br>● Truth biometric data set for test and evaluation (T&E)<br>● Biometric measurement accuracy<br>● Body tracking measurements to quantify how sensors affect movement<br>● Partner with industry to test and measure prototypes, including a model to test in a controlled environment<br>● Leverage usability test results to develop system/technology requirements |

| Biometrics / Wearables / Smart Suit | |
|---|---|
| Technologies to Develop | • High accuracy, indoor location tracking sensor including z-axis measurements<br>• Safe and efficient battery power supply<br>• Non-invasive monitoring of vitals<br>• Wearable device with situational awareness<br>• Light solutions with low size, weight, and power<br>• User calibration and testing device<br>• Standards based personal-area network (PAN) technology to easily connect diverse sets of sensors, including management platform<br>• Sensors with removable double-sided hypoallergenic adhesive |
| Standards | • Wireless wide area access connectivity standard (3GPP LTE)<br>• Develop Federal Communications Commission (FCC) Radio Frequency (RF) Telemedicine and personal area network (PAN) interoperability standards<br>• Recommend new or updated standards for the National Fire Protection Agency (NFPA), Occupational Safety & Health Administration (OSHA), ANSI accreditation, HIPAA, Committee on the Use of Humans as Experimental Subjects (COUHES), and the Food & Drug Administration (FDA)<br>• Hazardous location certification standards to monitor Smart Suit location and status<br>• Wireless personal area access connectivity (Bluetooth 5.0)<br>• Usability benchmarks for effectiveness, efficiency, and user satisfaction<br>• Ingress protection<br>• Biometric data format and exchange<br>• Location data format and exchange |
| Requirements | • Test results easy to read and updated in real time<br>• Smart Suit components are easy to wear, apply, and remove<br>• Integrated with existing systems and interoperable with other technologies across disciplines and jurisdictions<br>• Easy to maintain (washable, cost effective, network updates based on daily roster available to command laptop users)<br>• Inductively charged, efficient power supply<br>• Locally generated programming and coding for use (Alphanumeric alias)<br>• Sealed and waterproof<br>• Continuation of use into a hospital environment, incorporates the ability to monitor patients in mass casualty events |

| Biometrics / Wearables / Smart Suit | |
|---|---|
| R&D Project Opportunities / Ideas | • How to measure usability metrics, i.e. effectiveness, efficiency, and user satisfaction<br>• Evaluate the operational viability and cost effectiveness of fully-integrated suit/system versus a system consisting of individual components<br>• Resilient and secure PAN technology, including dense areas with a lot of users<br>• High accuracy X, Y, Z location tracking sensor<br>• Biometric testbed to collect and annotate data sets<br>• Analysis of utility for different biometrics<br>• Develop ingestible sensors<br>• Develop stand-off sensors<br>• Advances textiles |
| Task Descriptions / KPI's | Task 1: EMS places a patch sensor on a patient to automatically pull all medical information and monitor the patient's vitals<br>• KPI 1.1: Data is successfully collected, in real-time and displayed on a monitor for responders and pushed to the receiving hospital<br>• KPI 1.2: The speed of the data transfer<br>Task 2: Track the location of an asset<br>• KPI: Real-time location accuracy for indoor environments |

| Haptic | |
|---|---|
| Measurement Approaches/Metrics | • Effectiveness of user recognition of different vibration frequencies<br>• Pressure sensitivity required for device operation<br>• Error rate associated with operating interface with and without wearing protective equipment and/or uniform |

| Haptic | |
|---|---|
| Technologies to Develop | • Situationally aware haptic sensors that adjust pressure sensitivity based on changing equipment or environmental conditions<br>• Ruggedized Touchscreen / Glove hardware suite for firefighters<br>• Middleware to integrate haptic and gesture recognition sensors to ensure input commands are received when wearing gloves, unable to apply pressure<br>• More flexible and responsive glove materials<br>• Situationally aware haptic sensors that alert responders when other responding units, targets, or other resources are in close proximity<br>• Haptic alerts to assist in navigation<br>• Haptic feedback to alert device operators upon receiving an important message to assist communication in low visibility, high-noise environments<br>• Haptic input / output sensors embedded with shoe soles<br>• Sensors that can recognize changes in air pressure, muscle stretching, muscle compression |
| Standards | • Define haptic cues / standards to signify warnings to hazards commonly experienced by responders in the field (dangerous temperatures, toxins, evacuation route changes)<br>• Consistent haptic input command language |
| Requirements | • Ability to integrate haptic sensors with voice and gesture interfaces |
| R&D Project Opportunities / Ideas | • Cognitive study to determine whether responders can mentally process haptic commands while on-duty<br>• Pressure sensitivity study to determine whether haptic alerts are recognized or ignored in high-stress situations experienced by first responders<br>• Measure the effectiveness of operating different haptic input controls with gloves<br>• Evaluate the feasibility of using haptic input/output interfaces to communicate in scenarios in which responder audio, motion, and/or visibility may be impaired<br>• Identify the areas in which haptic alerts are most likely to be recognized and integrate these alerts with Smart Suit or personal protective equipment<br>• Translate audio / visual communications to haptic input and output<br>• Develop touchscreens that first responders can command while wearing personal protective equipment<br>• Integrate haptic command "fallback" with other user interface paradigms to improve device resiliency |

| Haptic | |
|---|---|
| Task Descriptions / KPI's | Task 1: Communicate critical alerts to distributed team<br>● Time to transmit and receive various types of information<br>● Time to act on alert<br>● Accuracy of alert transmitted<br>Task 2: Navigating through environments such as in-building, wildfire, perimeter, or to a target<br>● Obstacle near miss and avoidance<br>● Efficiency of path to target<br>Task 3: Alert device operator without alerting those around them<br>● Volume of haptic vibration |

| Virtual Reality | |
|---|---|
| Measurement Approaches/Metrics | ● Target recognition versus victim recognition<br>● Quality of function (e.g. are CPR compressions deep enough?)<br>● In VR scenarios, does casualty rate rise or fall based on the usage of different user interfaces?<br>● Accuracy/granularity of spatial movement<br>● Recording the person within VR from multiple angles using cameras that are in the VR environment<br>● How to measure cognitive load - when/where is too much input?<br>● Integrate biometric sensors to measure blood pressure, heart rate, sweating, etc. to map to training tasks<br>● Eye tracking to map what users are seeing in VR environments to how they react<br>● Individual vs. group training experience<br>● Capture/test learning objectives of VR modules for certification<br>● Human perception per sensor and type |

| Virtual Reality | |
|---|---|
| Technologies to Develop | • Virtual smart suit/sensor for temperature control with three-dimensional printed material<br>• Public safety add-on applications to possibly leverage within VR infrastructure<br>• Sensors and technologies required to recreate a real public safety environment for fire, police, EMS (i.e. sensory-based technology to produce sound, odors, smoke, etc.)<br>• Physical sensory feedback while engaging VR environments<br>• Ability to monitor the physiological effects climbing (i.e. heart rate increase)<br>• Three-dimensional audio<br>• Interactive devices that mimic real environmental conditions (i.e. resistance picking up an object)<br>• Technology platform to integrate measurement and map them all in time against a task<br>• Real world environment aware VR hardware, with adaptable VR environments to match<br>• Algorithms to translate perception in VR to real world |
| Standards | • Interoperable scenarios<br>• Compatibility of hardware<br>• Conformance<br>• Standards supporting integration of the National Incident Management System (NIMS) with other Incident Command Systems (ICS)<br>• Interoperability<br>• Develop standard processes for development of public safety VR modules<br>• Public safety industry standard VR hardware and software<br>• Scene and object descriptors<br>• Minimum equivalency standard between head-mounted displays (HMDs) |

| Virtual Reality | |
|---|---|
| Requirements | <ul><li>VR systems must accommodate the following public safety scenario parameters:<ul><li>High Noise (alarms/sirens)</li><li>Lighting (dark, smoky, flashing lights, low visibility)</li><li>Hot</li><li>Wet</li><li>Cold</li><li>Ability to raise heart rate, adrenaline</li><li>Spotlights</li><li>Ability to lift ladders, hoses, etc.</li></ul></li><li>Affordability / Cost of Investment / Cost of Ownership must align with agency budgets</li><li>Develop requirements specific to the responder community and identify core requirements that cross the 3 categories for:<ul><li>Police</li><li>Fire</li><li>EMS</li></ul></li><li>Provide training on the radio and wireless devices used by law enforcement, fire service, and EMS to account for high noise, loss of coverage in a building, and changing zones or channels during response.</li><li>Communications Unit training for Communications Unit Leaders (COML) and All-Hazards Communications Technicians (COMT)</li><li>Interactive with other remote users</li><li>Effectively simulate indoor/outdoor, day/night, rain/fog/snow, high/low elevation environments</li><li>Must be able to portray or duplicate the environment associated with scenarios (heat, cold, stress, heart rate)</li><li>Must utilize current or specific departmental equipment (i.e. the VR scenario that uses a fire hose should have the same type of nozzle that is used on truck)</li><li>Minimal latency to improve user experience</li><li>Interoperability with consumer VR equipment</li><li>Portability</li><li>Common framework or “Internet of Everything” (IOE) module development</li></ul> |

| Virtual Reality | |
|---|---|
| R&D Project Opportunities / Ideas | • Evaluate feasibility of leveraging current gaming industry infrastructure (Microsoft Xbox, etc.)<br>• Evaluate cognitive demands of completing various tasks<br>• Determine most effective method for measuring cognitive load<br>• Scenario development with environmental factors of real life operations<br>• Development of high power computers in small form factor to run the elaborate scenarios<br>• Use VR as predictive analytics to identify possible behavior and outcomes on given situation for planning of future incidents<br>• Training teams in VR and separate teams in traditional methods and comparing results with a controlled real-world scenario<br>• Efficient time of immersion to accomplish learning goals |
| Task Descriptions / KPI's | Task #1: Searching a house<br>• KPI:<br>○ Completeness of room search<br>○ Time of the search<br>○ Completeness of the search (all victims removed)<br>○ Error - officer got lost<br>Task #2: Putting out a fire<br>• KPI:<br>○ Establish water supply<br>○ Select the appropriate fire hose<br>○ Put out the fire with minimal impact of water (price/usage) |

| Gesture Recognition / Eye-Gaze | |
|---|---|
| Measurement Approaches/Metrics | • High resolution body tracking<br>• Limb tracking<br>• Reaching for equipment (handcuffs, Tasers, etc.) |

| Gesture Recognition / Eye-Gaze | |
|---|---|
| Technologies to Develop | • Fingertip tracking or finger wearable sensors<br>• Deployable, low swamp gesture sensors<br>• Gesture/pose test range for T&E |
| Standards | • Data standards to represent discrete gestures<br>• Diagnostics to determine false alarms or verify functionality |
| Requirements | • Swap of gesture observing sensors<br>• Acceptability criteria (percentage of false positive to negative ratio)<br>• No false executions of commander due to job performance (police focus down weapon sites)<br>• Public perception of gestures (what does it looks like on video)<br>• Data encryption and privacy requirements associated with tracking biometric data<br>• Ability to report data to dispatch/nearby officers |
| R&D Project Opportunities / Ideas | • User survey to identify common gestures and poses in priorities<br>• Robot capability to understand and act upon gesture/pose<br>• Identity existing tech or quip to integrate with<br>• Identify how to leverage exoskeleton technology<br>• Demonstrate modular gesture sensor evaluate tradeoffs of components<br>• Analysis of alternative technology transitions of Department of Defense gesture recognition technology to the public safety workforce<br>• Evaluate potential of gestures as part of multimodal systems<br>• Identify likely interoperable and not interceptable gestures |
| Task Descriptions / KPI's | Task #1: Alert to an officer struggle / "officer down" status<br>• KPIs:<br>  ○ Successful recognition and timely ability to alert dispatch / nearby officers<br>  ○ False positive detection<br>Task #2: Turning on/off body camera via hand gesture<br>• KPIs:<br>  ○ Accuracy of detection |

# Next Steps

PSCR will evaluate the specific problem statements, measurement approaches, technology needs, operational requirements, R&D opportunities, and standards for each of the seven R&D topic areas outlined in this report as it transitions from R&D project planning to project launch. Initial NIST R&D project planning related to the User Interface Portfolio is currently underway. PSCR also recently announced a Notice of Funding Opportunity (NOFO) titled NIST Public Safety Innovation Accelerator Program -- User Interface (PSIAP-UI). This opportunity will focus on improving user interface technology capabilities for public safety through VR and AR systems. The scope and objectives of this program were informed by input collected during the User Interface Summit. More details regarding PSCR's User Interface research activities can be found on the program website (https://www.nist.gov/ctl/pscr/research-portfolios/user-interface-portfolio), and full details regarding the PSIAP-UI FY18 NOFO can be found at https://www.nist.gov/sites/default/files/pscr_psiap-ui.pdf.

For more details on the 2017 User Interface R&D Summit please contact Scott Ledgerwood (scott.ledgerwood@nist.gov) or Marc Leh (mleh@corneralliance.com).