Part 1 Concept

Project Title: First Immersive Safety Technology **(FIST)**

Concept Approach: Web based GIS Virtual Reality (VR) / Augmented Reality (AR) application with speech /touch / gestural navigation.

Applicant Background: Contestant Knowledge, Skills, Capabilities:

Over 20 years' experience designing, developing and coding of virtual and augmented reality applications with:

- Walt Disney Imagineering Virtual Reality Lab,
- NCPC / ESRI (GIS developer) team designing location based Augmented Reality (AR) applications for urban environments.
- 3D modeling, GIS, CAD, game engines and other graphic applications.
- Coding in ActionScript, JavaScript, Arduino IDE, Grasshopper and Dynamo.
- Team member on PA 2040 Smart City (IoT) pilot which was part of the NIST Global City Teams Challenge in 2014-2016 (potential team building opportunity for phase 2)

Team Building

The concept (phase 1) submission is Individual Contestant with ESRI ArcGIS "Urban Product Alpha" team support, with the goal of team building using the 2018 Global City Teams Challenge (GCTC) as a starting point for phase two of the challenge. The GCTC has built an effective and efficient process for team building. The 2018 GCTC round will focus on developing smart and secure communities which align well with goals for the HUD Challenge. Participation in previous years of the GCTC has yielded successful outcomes. Initial partnership outreach has been made to the Verizon and Nvidia. Additionally, there's the possibility of support from US-Ignite, and the Federal Emerging Technology Community of Practice (COP) creating a rich innovation environment. There are also great opportunities for university involvement in the team building process. The previous GCTC challenge team included George Washington Univ. (GW), Georgetown and Howard. There is also the potential for a great deal of synergistic success in the two NIST challenge's (HUD and GCTC) which could lead to significant development possibilities for the FIST solution.

Project Summary

The FIST objective is the successful implementation of an HUD solution that will have a significant real-world impact. To lower development cost FIST will use Commercial off the Shelf (COTS) products with customization when possible, and applications that are common to most local, state and federal agencies. The product should facilitate the establishment of a universal standard that can be adopted across government. Open or near open source file formats will be recommended for data delivery within the immersive first responder environment. The FIST concept is based on using web services, and virtual / immersive technology systems to provide real-time data and visual enhancements to first responders in the field. The immersive system will be comprised of seven (7) key technologies:

1. User's geographic location. (GPS).
2. Situational awareness (Coordination Platform between first responders).
3. Redundant voice and touch interface controls (AI).
4. Building and geographic information model data (BIM and GIS).

5. First responder's database information. (Geo-database).
6. Internet of things (IoT) sensor technology. (Smart City IoT).
7. Redundant Networks (the cloud).

The HUD hardware goals would similarly allow for the use of COTS products with the potential to modify graphic cards, and any open source GUI element e.g. (Google Glassware, Amazon Alexa, and Ubers SDK's) or other open GUI's.

Part 2 Description

Proposed HUD Design Elements

- HUD GUI Web Services (ESRI, Google, Amazon,)
- Near-eye display
- Position Tracking
- VR/AR Browser
- Public Wi-Fi Mesh Network
- Web based 3D GIS with BIM Building Data

The Current State-of-the-Art in VR and Location Based Immersive Technology

VR has matured to the point where almost everyone has idea about what a VR experience is like. However there are still a number of challenges and limitations to mapping out a first responders VR solution without considering how an Augmented Reality (AR) or Mixed-Reality (MR) approach to the first responders HUD might evolve. VR limits the user to a static environment. An AR or MR solution could offer a more accurate scenario for the HUD concept development, with a VR elements serving as tools in the immersive scene.

Some of the limitations for immersive technologies are being addressed by users and developers world-wide. For the First Responders HUD challenge there are several key areas that the project will need to address to overcome come some of the VR world's shortcomings and limitations:

- **VR / AR Issues**
  Frame Rate, Update Rate, and Refresh Rate are equal to the time that it takes for a virtual view to redraw to a new view, and the time it takes the viewer to adjust their viewing position or direction. Delay's between action and reaction is called Latency, and the goal of most immersive experiences is to limit that lag time. There are different approaches and definitions for real-time refresh rates. A reasonable achievable refresh rate in a VR environment without any negative user impacts (motion sickness or dizziness) is 60 frames /second (fps) however, 90fps and higher has been easily achieved. In a cloud based environment where data rate could be impacted by network or other issues 60 fps would be a good standard for the FIST VR.

  It should be noted that because we are designing for a Location Based System (LBS) a different type of standard should be considered. Because the user position is changing, and not just their viewing position; using feet per second or meters per second could be a better standard to work with. In experience with urban scale AR where a refresh rate of three (3) meters per second worked well.
  The FIST methods for overcoming the frame rate issues could be addressed at the vector level by using lower polygon models or tessellating down the number of faces in a mesh that was acquired

outside of the FIST development environment. The solution could also be solved at the raster end of the data delivery pipeline by pre-rendering frames, compressing the file outputs, dropping frames or a combination of all three. This works in both the VR and AR environments. However, issues related to file cache storage arise when large numbers of raster files are created for the real-time experience, dropping frames could also result in motion sickness.

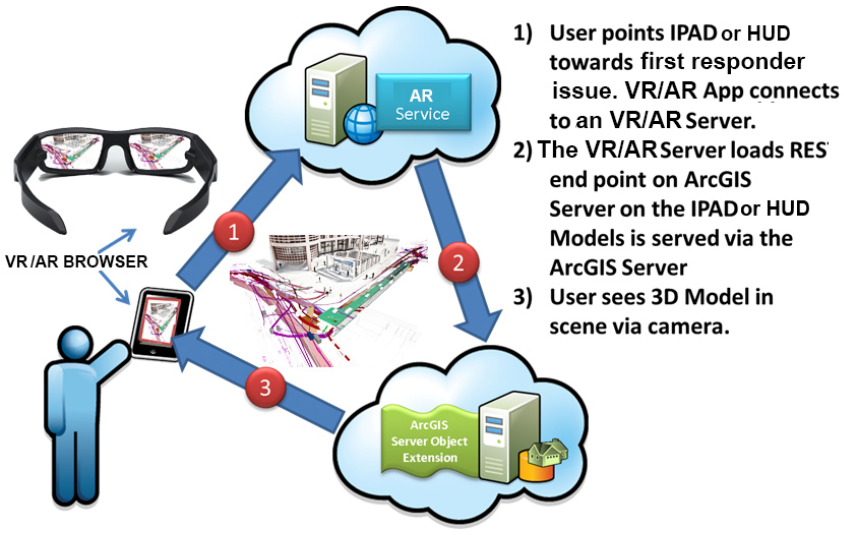
- **Data Networks**

  Satellite and Mesh Networks

  Because uninterrupted data transmission is required to first responders in the field, FIST will be designed to use a redundant network environment. The dual network system will provide a data delivery back-up if needed, and other first responder enhancements as required. The networks would use both satellite delivery of the virtual data, and delivery via public Wi-Fi (Mesh Network). The Mesh network will use a Light Sensory Network (LSN) that transforms street light fixtures into an application platforms.

  The number of obstacles that could impact the conveyance data of visual and text to the first responder in an immersive environment is vast. Dependent on the type of crisis the emergency situation itself could cause data transmission problems. The FIST concept would propose two networks for data delivery. The first a satellite based network.

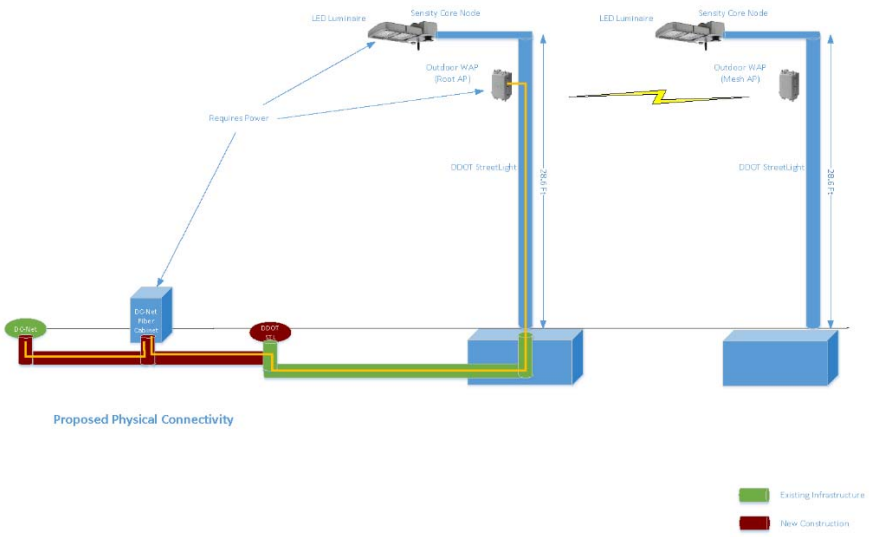
  This network would allow 3D Data (buildings, street furniture, trees etc.), and any associated reference data in a geodatabase to be served to the HUD, and geo-located within the limits of satellite triangulation. This Geo-database stores the location, orientation and attributes of the 3D data and associated text information related to each urban model. The 3D data is then delivered via a web service REpresentational State Transfer (REST) endpoint created by a GIS Server Object Extension. The first responder then travels to the site, looks in the direction(s) of the emergency with the FIST HUD and FIST VR/AR browser being projected. The 3D model + the data is fused into the scene.



A potential FIST satellite based network back-up data delivery

Note: One issue to overcome with this VR/AR application method is vertical geo-location. Ground level VR/AR will work perfectly but upper building floor/ vertical orientation will be an issue to be addressed in development.

The network would be based on a Mesh Network. The public Wi-Fi network would use smart LED streetlights that respond to activity. The network would serve to notify people in emergencies of potential problems, but also as a local delivery network for first responders. The network would mirror the satellite based network using a common database. This would allow for a more accurate method for a location based immersive application, while the satellite based network would serve as a back-up if the crisis impacts data transmission on the ground.



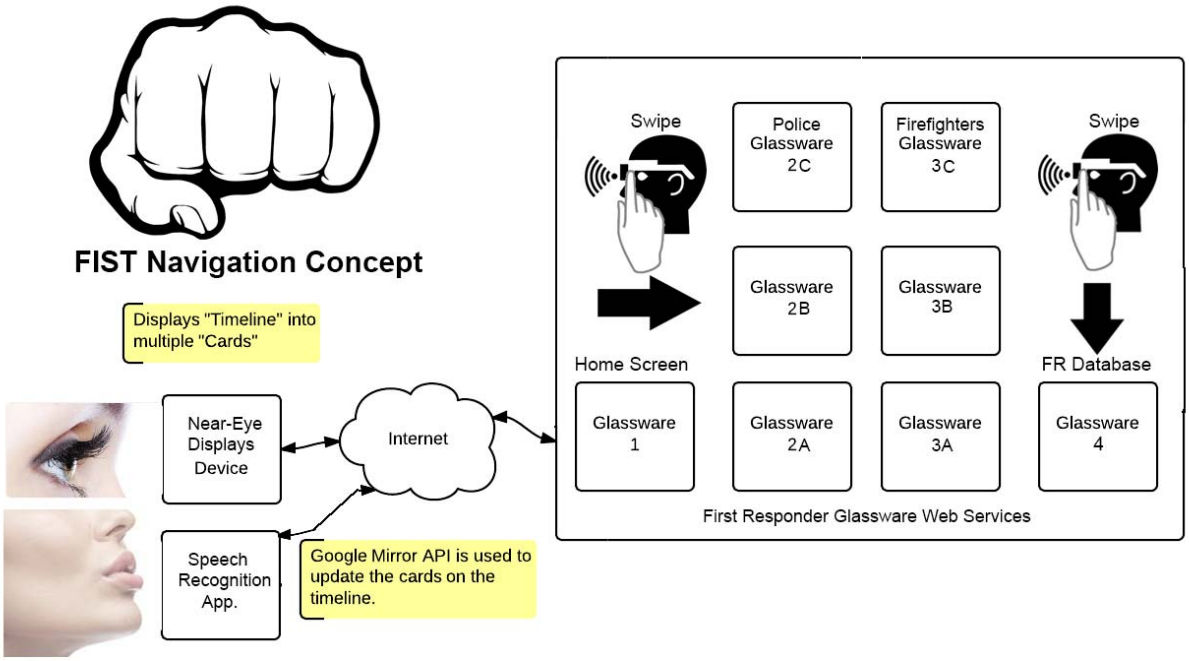
A Potential FIST Mesh Network primary data delivery

Note: The Satellite and Mesh network vary greatly in the accuracy of geo-location. The range of accuracy for the satellite could be plus or minus 3 to 6 meters; while the Mesh Network may be 6 inches to a foot. Geo-location accuracy can be an important element in the first responders HUD application. As an example for firefighters: In a smoke filled room, if the application is pulling 3D Building Information Model (BIM) data in IFC format for reference use in the HUD. This is depicted in the website header for the HUD Challenge. Accuracy of geo-location would be key for the firefighter to successfully navigate the space. An example in a police condition: If an officer is using the HUD to pinpoint the location of an active shooter using shot spotter (IoT sensors) triangulating the source of gunfire, and his relationship to the shooter, and fellow officer's geolocation accuracy is an important consideration.

Potential Integrated Technology Solutions

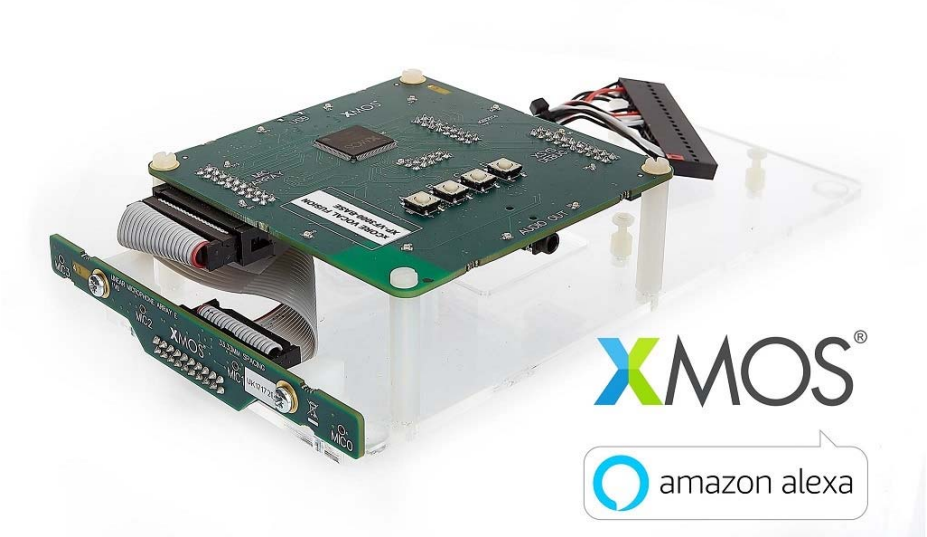
The market for immersive displays, speech recognition and gestural navigation technologies continues to mature, and there are several new display technologies that have made it possible to create a better-quality potential immersive environment for first responders. Some available technologies for the HUD include but are not limited to:

- The Glass Glassware Development Kit (SDK) Google Mirror API is an add-on to the Android SDK that lets you build Glassware that runs directly on Glass. The SDK allows for the design interfaces that use imagery, colloquial voice interactions, and natural gestures.

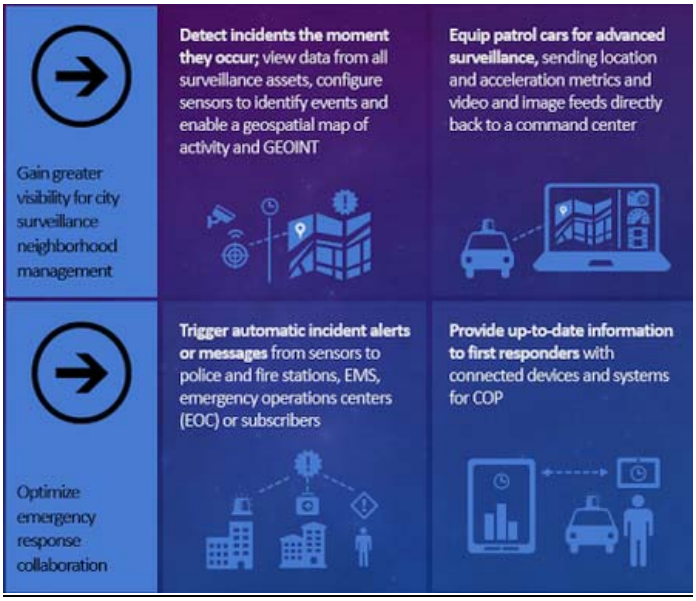


Google Glassware GDK allows for GUI's with voice interactions, and natural gestures

•The Alexa MOS captured voice signals are crystal clear even in noisy environments, enabling commands to be accurately captured from across the room for processing by the Alexa cloud-based speech recognition system. XMOS is the only solution that packs audio digital signal processing (DSP) and programmable I/O processing and control software into a single chip, enabling developers to significantly reduce their bill of materials, flexibly tailor their designs, and reduce costs.

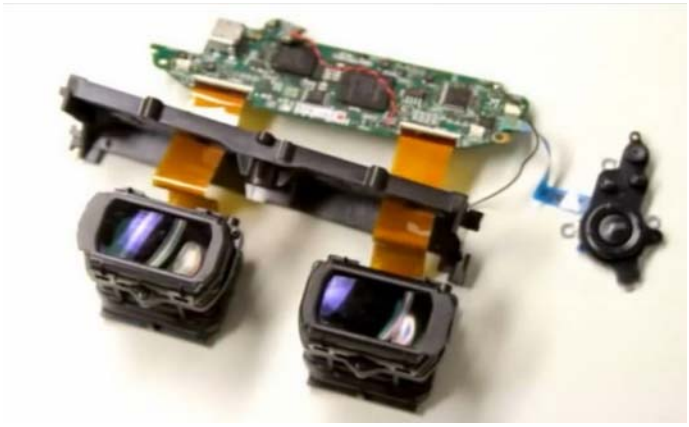


- Real-Time Geospatial Collaboration Platform - Leading up to and during critical situations within any community there is a universal need to coordinate the appropriate personnel and the appropriate information in order to realize the most efficient response. Combining real-time geospatial collaboration, Geospatial Information Systems, and easy Heads-Up Display. The Real-Time Geospatial Collaboration Platform for First Responders is previous GCTC pilot. It is designed to be a best-of-breed solution that improves the way in which first responders interact with and disseminate information for improved situational awareness across federal, state and local organizations. The proposal included analytical tools for improved analysis, like overlaid datasets, transparency of data sets, and lensing to focus attention to specific locations or relevant data, including demographic data and fusing feeds from connected devices/IoTGIS locations.



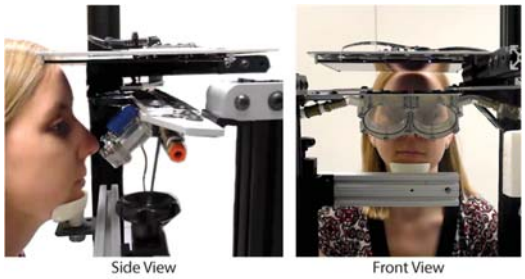
Real-time data via web service

- Near-eye displays (NEDs)- This new optical design that is simple, compact, varifocal (lens with variable focal length in which focus changes as focal length changes), and it provides a wide field of view with clear peripheral vision.



Prototype of Nvidia's NED

- *Deformable Membrane AR/VR*- Some of the fundamental limitations of (NEDs) are a limited field of view (FOV), low angular resolution, and fixed focal state. Optimizing a design to overcome one of these limitations typically leads to a trade-off in the others. Nivida has introduces an all-in-one solution: deformable beamsplitters. It is a new hybrid hardware design created by combining hyperbolic half-silvered mirrors and deformable membrane mirrors.



Prototype Nvidia Deformable Membrane

- Untethered VR and AR experience made for large-group interaction in the same physical and virtual space. Several organizations are working on technology that could be used for a multi-user immersive experiences.

Vuzix Blade Untethered AR Glasses, and the Intel Alloy Untethered VR Glasses

- **Physiological Concerns (eyestrain and motion sickness)** - As mentioned above motion sickness can be addressed by overcoming the frame rate issue. Overcoming visual data issue like parallel parallax is a greater challenge for the FIST VR world. There are several techniques for the delivery of a VR experience to a user. One approach is mono-spherical images (VR 360) single camera data collection. VR 360 relatively simple to produce in a digital environment, as they are shot under the same principle as in the physical world with a single camera rotating around fixed pivot point. Because VR 360 images are shot with a camera with its own pivot point, their view is that of a single eye looking in all directions. This is fixed pre-rendered video outputting two dimensional (2D) data. This can be great for a mock-up or prototype, but not recommended as an end choice for the First Responders FIST VR application.

Converged stereo consists of two images toed-in to focus on a single plane of space known as the Parallax Plane. This type of stereo configuration behaves the way our eyes do. However, the image is displayed on a flat surface, and the user will notice "Vertical Parallax" or the keystone

effect, which can cause eyestrain. The good solution is Parallel Parallax which is comprised of two slightly rotated parallel views to each other.

This configuration will eliminate the distortion/keystone issue but will require two images be rendered at slightly different angles. When displayed each user will need to adjust the HUD's viewing angle to match their physiological features. This also creates issues for any first responder that may have a sight issue in one eye. Parallax viewing requires stereo vision.

Note: For the final HUD stereo images would not likely be needed because of the LBS requirement. AR would be the best approach for a final LBS application.

Performance Metrics Goals

The development vision for FIST includes an immersive experience that delivers multiple first responder applications as web services in a heads-up display including real-time 3D visual data/text data overlays, IoT applications, situational awareness and other tools for the first responder. Additionally a prototype of a FIST Near-eye display to meet the needs of first responders will be developed. The final prototype will be completed for the GCTC 2018 development cycle comprising the following performance metrics goals:

1. Location based real-time immersive application with a GIS based geo-location web service. The VR data will be served via a REST endpoint created by a GIS Server Object Extension. The first responder then travels to the site, looks in the direction(s) of the emergency with the FIST HUD and the FIST AR/VR browser. The 3D model + the data is fused into the scene. The VR solution **KPI** rate of 60fps and an AR version of the application would deliver 3 meters per second update rate.
2. Using a Smart City IoT (Light Sensory Network / mesh network) use proximity sensors, smart cameras and first responder data to create citywide data platform between first responders application working with private, federal, local government and institutions to take advantage of the potential of new technologies transmitting fast data rates. **KPI** Ethernet frames at rates of 100 gigabits per second.
3. Development of the FIST GUI using a combination of Artificial Intelligence (AI) speech recognition voice controls, and multi-touch/ gestural interface GUI's (Google Glassware/Alexa). **KPI** a simple and intuitive user interface that would allow for significant control of the FIST tools with limited to no physical interaction.
4. Use the Uber SDK create a real-time situational awareness in web coordination platform for locating other first responders (friends vs. foes), visually triangulating gunshots, visual observation and analysis of spatial elements for emergency purposes. **KPI** Track the state of an emergency (estimated arrival/in progress), real-time incident briefing, IoT data tracking from neighboring sensors, friends vs. foes location and ID.
5. Stream geo-referenced building and geographic data in open formats (.OBJ, .KML, .KMZ, .SHP .IFC etc…) from existing local or federal government urban data models. **KPI** real-time streaming of 3D data 60fps VR and 3 meters/second AR environment.
6. Merge local first responder's database (police/fire) information, with real-time streaming of 3D data. **KPI** real-time visual and text data matching.
7. Development of a cloud based VR/AR browser. **KPI** Delivery real-time, multi user immersive experience.

FIST Concept Competitive Advantage

The competitive advantage offered by the FIST approach is in the team building process. With the ESRI ArcGIS Urban "Product Alpha project team on board; the team can be broadened in Phase 2. Using the Global City Teams Challenge as a starting point there's an opportunity to build a very diverse team across several sectors. Two example's are the Real-Time Geospatial Collaboration Platform for First Responders and PA 2040 both products of previous GCTC's. Additionally, the synergy created by two NIST challenges (HUD and GCTC) seeking similar goals tools and systems for safer more secure cities will create cross-pollination that lifts the outcomes of both challenges.

Taking advantage of the public private partnerships networks developed by NIST, the National Science Foundation (NSF) and US-Ignite in the GCTC creates increased, and unusual partnering opportunities. Mixing private companies, government organizations, and institutions increases the likelihood that successful implementation of a proposed solution is amplified; with the potential for significant real-world impacts. Because many of the private partners may have solutions in development currently improves the chances that a product will result in significant improvement to commercially available technology which will enable considerable progress toward the challenge goals.

Key Element Takeaways

- Web based GIS Virtual Reality / Augmented Reality application with speech /touch / gestural navigation.
- Opportunity to create new VR/AR and urban IoT standards using the both Virtual Reality Heads-Up-Display Navigation Challenge, and the Global City Teams Challenge.
- Build on existing Urban GIS AR platform (EyeSite AR) with the ESRI ArcGIS Urban "Product Alpha project team.
- Potential to work with local, and federal agencies for development and testing.
- Real-Time Geo-spatial First Responders Collaboration Platform.
- Twenty years VR and AR development experience.