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Choosing the Most Suitable AR-enabled Wearable for Industrial Use

Roland Richards
Portland State University

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Roland Richards
Instructor: Dr. Ramin Neshati

Abstract

This study seeks to provide guidance in choosing the most suitable augmented reality enabled industrial wearable for use in the high-tech production and support environment. New development breakthroughs are coming to light every month in the world of VR (virtual reality), AR (augmented reality), and MR (mixed reality). The research data provided can be used to assist fab production and support personnel choose the AR-enabled wearable headsets. Many factors and agents are responsible for bringing cutting edge technology into use. Multiple criteria decision modeling was used to assist in the selection process for hardware for an augmented reality pilot and implementation across multiple sites.

First, subject matters experts were identified. Second, interviews and product tests were conducted in participation with a functioning use case, Third, a hierarchical decision model was used and validated with a one site pilot program and an option selected with the highest level of agreement on specifications, Head Mounted Display (HMD) type, and overall inclusive cost.

The study produced for ETM coincided with a project that I am heading internally at Intel of the same result. The only limitation on the internal study was the budget to purchase testing hardware. Procedurally the HDM tool with its acknowledged flaws was an obvious hurdle which necessitated more pre-work and hand holding. In person sessions to walk through the HDM tool alleviated frustration and reluctance to complete the model.

Index:

A modern semiconductor factory costs upwards of $7,000,000,000.00 to construct. Shortly put that makes floor space inside a current production high tech fabrication facility extremely expensive. An average commercial building costs $16.00 to $20.00 per square foot. Space in a highly technical environment such as silicon production is $5 or more per square centimeter or $3,000.00 a square foot. [1]. Once only held in the cannons of science fiction, augmented reality holds amazing experiential possibilities. Creating virtual spaces within a fabrication plant would revolutionize space utilization. An ambitious goal would be to create augmented reality installations to facilitate factory functionality and reduce space usage. The first stage goal is to utilize AR to provide augmented experiences in the factory. The principle outcome of this study is find the best Head Mounted Display (HMD) unit for AR utilization. Using AR/MR in the factory environment, while exciting, has additional hurdles such as PPE requirements following IOSH 1910.133 and the need for prolonged use such as a battery pack attached to a helmet.

Apple's Tim Cook said about AR, "I think it is profound. I am so excited about it, I just want to yell out and scream." [2] Now that VR and AR technologies have made their way out of the gaming arena and into industry, their real-world practical applications should now be clear. Being able to layer digital information on top of the real world has enormous benefits in industries such as manufacturing, engineering, and maintenance, especially in training or the carrying out of sensitive or dangerous tasks. Via a pair of smart glasses (HMD), industrial workers can be fed a steady stream of task-related information, without them needing to carry around paper-based manuals and reference materials. Already in use at Boeing and in GE's Aviation, Healthcare and Renewable Energy divisions, as well as at other companies including automotive company Toyota, airline Delta, third-party logistics (3PL) company Ryder and metals and mining company Rio Tinto. [3]

"These active learning methods use sight, sound and touch, codifying learning," Vincent Higgins, director of technology and innovation, Honeywell Connected Plant, told HR Dive in an email. "We are finding that Honeywell's Skills Insight Immersive Competency, which uses augmented and virtual reality, really boosts retention rates," he said. "Technical staff are better prepared to face the challenges of a constantly changing work environment. AR can be critical to help human beings process all of this information in real time and in context." [4] Current projections indicate that augmented reality will generate $120 billion in revenue by 2020

WHAT IS AR?

Augmented Reality Research Data

The optimal details of a head mounted display and the experience created has a field of view 94 ° of vision straight ahead. The user needs the ability to rotate head comfortably 30 ° degrees to the side with a max of 50 ° to either side. Any user experience created past 20m loses depth and anything closer than .5m the user can lose the ability to focus.

What are the components of an AR system?

An AR system contains the following components: [4]

- Tracking: Via sensors and camera, the system tracks the user's viewpoint.
- Registration: Virtual objects must be spatially registered or anchored in the real world.
- Visualization: Based on current location and viewpoint, the visualization of virtual objects has to be adjusted.
- Spatial Model: This consists of both the real world and the virtual world. Both must be registered in the same coordinate system.

For AR to work, virtual objects must be placed accurately in the real world. We can identify the following essentials: [4]

- *Visual Keypoint Matching*: Also referred to as Marker Detection, this requires image processing, feature extraction and marker detection. The marker's surface is determined so that virtual objects can be placed on the surface.
- *Spatial Mapping*: The idea is to map the real world to a virtual model. Depth sensing is involved. The virtual model can be used to detect surfaces (walls,

floors, tabletops). When virtual objects are placed, occlusion becomes important.

- *Sensing*: Viewer becomes the anchor of the virual space and content. Viewpoints are adjusted based on inputs coming from sensors: GPS, accelerometer, gyroscope, etc. Since sensing accuracy may be limited, this can be combined with visual tracking.

A typical AR wearable would need sufficient processing power and memory, wireless connectivity and GPS. Sensors may include accelerometer, gyroscope and magnetometer to detect movements and thereby adjust the views of virtual objects. Some devices use mirrors to assist in aligning images to the viewer's eye. Augmented reality proliferation in our walking around lives is a set of four big stages: mobile AR software, mobile AR hardware, tethered smart glasses and standalone smar tglasses. These four stages could drive AR from tens of millions of users and $1.2 billion last year, to more than a billion users and $83 billion by 2021. [8]

HEAD MOUNTED DISPLAY UNITS CHOSEN FOR COMPARISON (OUTCOMES LAYER):

Google Glass: Monocular Head-mounted AR (or Monocular Smart glasses) A single visual data view - out of your line of sight, letting you focus on the task at hand, but keeps the display available to get glanceable information)

Figure 1: Google Glass Enterprise Edition [https://x.company/glass/]

ODG R-8: Binocular Head-mounted AR (or Binocular Smart glasses) or stereoscopic view. A thin translucent monitor on each glass lens that the user looks through.

Figure 2: ODG Smart Glasses [https://www.osterhoutgroup.com/r-8-smartglasses]

Microsoft HoloLens Mixed Reality HMD an all-in-one fully-inclusive standalone system. The highest quality display and the ability to render 3D on-board, depth sensors that make sense of the environment to correctly overlay objects, so they seem “fixed” in the real world. The projected holograms can appear life-like and can

Figure 3: Microsoft HoloLens [https://www.microsoft.com/en-ca/hololens]

move, be shaped, and change according to interaction with the user or the physical environment. Gestures, gaze and voice commands can be used to navigate and control the presented content.

Magic Leap: **Mixed Reality Photon Projection** – Device projects photons directly into your eye - largest field of view (FOV) Least known about – N.D.A. signed for testing. Limited Testing in the field.

Figure 4: Magic Leap [https://www.magicleap.com/]

Methodology Overview:

This section details the research methodology used for the study and the pilot program. This research involved the development of a decision model for evaluating several potential augmented reality head mounted displays, both those that are currently available and future ones (Magic Leap). The decision model was developed based on the Hierarchical Decision Modeling (HDM) methodology. The model considers four major dimensions the level one perspectives are ***AR Implementation, Specifications, HDM Types, and Cost***, and their related criteria and sub-criteria. The model was designed and developed by the author, and its elements' validation and evaluation were done by experts in the field of software, hardware, IoT, marketing, and EHS engineering. The decision model was applied in evaluating the best possible AR headsets: Magic Leap, Microsoft HoloLens, Google Glass, and ODG R-8.

1. ***Research was conducted to narrow down the top four HMD units.***

   Multiple companies, including the final four were interviewed and put through criteria of needs and usage models.

2. ***Subject Matter Experts were solicited for input and feedback on the HDM and the AR-headsets.***

   SMEs invited to provide input from the project teams and business units engaged in VR/AR/MR development and deployment.

3. ***Select initial set of options, top-level perspectives and sub-criteria.***

   Build out the Hierarchical Decision Model with the goal to refine it into a specific set of outcomes, set of perspectives, and criteria.

4. ***Validate HDM model with SMEs***

   Make updates and edits to the model based on feedback towards the goal of selecting the most appropriate VR Headsets.

Intel AR Pilot

An environmental health and safety training class was selected as a pilot AR training environment; used for entry level energy rated technicians. Custom training development accompanied with Intel instructional design experts created the content over a two-month period. Over two weeks 40 technicians and 14 Intel senior leaders were put through the training. All four of the selected headsets were used at 3-day intervals and responses were gathered based on each. ***Microsoft HoloLens*** came out on top with the technicians and 6 of the leaders. 8 leaders chose ***Google Glass*** however feedback appeared to be possibly biased toward Google Glass in their responses due to name recognition and eagerness to use the unit. Hillsboro, Oregon Ronler Acers campus is the location of the pilot due to the large amount of research and development teams. once success criteria is met and a plan is ratified throughout TMG / CCG / NTG Folsom, California and Leixlip, Ireland are the next sites to receive the pilot. At present the bottleneck is in content development. While the breadth of AR applications is growing – the internal develop community is small but growing.

A second phase of testing took place in an EGEN or Emergency Generator building. This site was chosen because a skilled technician has to read 14 gauges per unit many times throughout the week to ensure the fabrication plant generators are operational at all times. A simple AR interface was engineered to display IOT cloud fed data. Google Glass and Microsoft HoloLens were tested. Google Glass won out on comfort only because of its light design, however it lost in all other aspects. The HoloLens arguably had an unfair advantage because it is the industry leader in worksite industrial AR headsets. They've recently released a hard hat attachable HMD unit that is perfect for Intel's fabrication plant usage and likely any other OHSA safety focused industrial - technology forward AR implementations.

HDM and the SMEs

The Portland State University HDM tool is known to have flaws and it shown in the confusion of my experts. Multiple explanations back and forth needed to be done to ensure the categorization was done on the same intent and choosing plane. For the research 6 experts were selected; 2 Internet of Things engineers that are engaged in AR/MR development, 2 CCG Software Development engineers, 1 Environmental Health and Safety engineer, 1 one technical marketing engineer.

SELECTING & VALIDATING HDM PERSPECTIVES AND CRITERIA

Level 1 – Perspectives.

Knowing that emerging yet established hardware had to be chosen we used the manufacturers information as leading criteria of feature, accessibility, and performance. The level one perspectives are AR Implementation, Specifications, HDM Types, and Cost.

Perspective #1 - AR Implementation

Criteria #1: Marker-based augmented reality (also called Image Recognition) uses a camera and some type of visual marker, such as a QR/2D code, to produce a result only when the marker is sensed by a reader. Marker based applications use a camera on the device to distinguish a marker from any other real world object. Distinct, but simple patterns (such as a QR code) are used as the markers, because they can be easily recognized and do not require a lot of processing power to read. The position and orientation is also calculated, in which some type of content and/or information is then overlaid the marker. [5]

Criteria #2: Markerless (also called location-based, position-based, or GPS) augmented reality, uses a GPS, digital compass, velocity meter, or accelerometer which is embedded in the device to provide data based on your location. A strong force behind markerless augmented reality technology is the wide availability of smartphones and location detection features they provide. It is most commonly used for mapping directions, finding nearby businesses, and other location-centric mobile applications. [5]

Criteria #3: Projection based augmented reality works by projecting artificial light onto real world surfaces. Projection based augmented reality applications allow for human interaction by sending light onto a real world surface and then sensing the human interaction (i.e. touch) of that projected light. Detecting the user's interaction is done by differentiating between an expected (or known) projection and the altered projection (caused by the user's interaction). Another interesting application of projection based augmented reality utilizes laser plasma technology to project a three-dimensional (3D) interactive hologram into mid-air. [5]

Criteria #4: Superimposition based augmented reality either partially or fully replaces the original view of an object with a newly augmented view of that same object. By downloading an app and scanning selected pages in their printed or digital catalogue, users can place virtual ikea furniture in their own home with the help of augmented reality. [5]

Through initial discussion with 3 SME engineers the AR Implementation perspective was removed. The user experience interface used for implementation while very valuable in deciding how best to create engaging and valuable experiences was irrelevant in selecting the appropriate headset. All the headsets could view any of the methods of AR deployment.

Perspective #2 - Specifications:

Criteria #1: Field of View as defined by the usable range of view that a user can see while looking through the AR head mounted display. When a VR UX is placed in front of the user's eyes, the real world can be seen without loss of the eye's natural field-of-view (FOV), while the digitally rendered virtual content appears through the use of reflections. The human eye's FOV is 200° horizontally and 135° vertically (both eyes). [6] As shown, earlier research states that the optimal viewing range is 94°of vision straight ahead. The user needs the ability to rotate head comfortably 30° degrees to the side with a max of 50° to either side.

Criteria #2: Power - Battery Life is a very important consideration for all mobile devices. A balance must be struck between rich features, battery size, battery duration and charging time. Battery technology seems to be the toughest problem for engineers to crack. An HMD is worthless if its power has been drained when you want to experience AR. [7]

Criteria #3: Comfort - Design is important in all personal technology and has been the key to success for companies. Users must be able to wear the device for an extended period of time without excess pressure on the nose bridge, ears or neck. Device should be entirely self-contained. [7]

Criteria #4: Focal Plane significant role in providing a true AR experience. The richest AR applications will recognize surfaces and objects in three dimensions and overlay information and images that take into account the context of one's surroundings. Depth sensing cameras pulse-illuminate the area and an optical lens to focus the reflected light onto an image sensor at speeds up to 100 Hz. Logic circuits then interpret the reflected light as depth. [7]

Perspective #3: HDM Types

Criteria #1: Monocular Head Mounted - A single visual data view - out of your line of sight, letting you focus on the task at hand, but keeps the display available to get glanceable information

Criteria #2: Binocular Head Mounted or stereoscopic view. A thin translucent monitor on each glass lens that the user looks through. Tethered to smart phone and lack 3D depth. Cheaper.

Criteria #3: Mixed Reality HMD depth sensors that make sense of your environment to correctly overlay these objects, so they seem “fixed” in the real world. Stand alone system, better visual experience than competitors, powerful 3D rendering.

Criteria #4: Mixed Reality Photon Projection – The technology is exclusive to Magic Leap however it was included because the focal plan shifting is life like. MR Photon Projection provides a massive field of view – the largest in the product class. The ability to shift focus naturally, as you do in real life. However, to the likely negatively skewed response rate of its selection the product is under a strict non-disclosure agreement with no announced release date.

Perspective #3: Cost

Criteria #1: Initial investments – The cost of a system to purchase. In order of cost research concluded in order of most expensive to least Magic Leap, Microsoft HoloLens, Google Glass and lastly ODG R-8.

Criteria #2: Maintenance – How much time is spent keeping the system up and running and issue resolution in order based on manufacturers call center feedback form least amount of down time to greatest – Microsoft HoloLens, Google Glass, ODG R-8, and Magic Leap.

Criteria #3: Ongoing cost – The financial impact of continual upkeep, updates, and hardware ecosystem costs.

Criteria #4: Time to Break Even – the value of the product in conjunction with the value of usage and impact over time until the value of the experience and service is greater than the initial costs and associated cost of ownership.

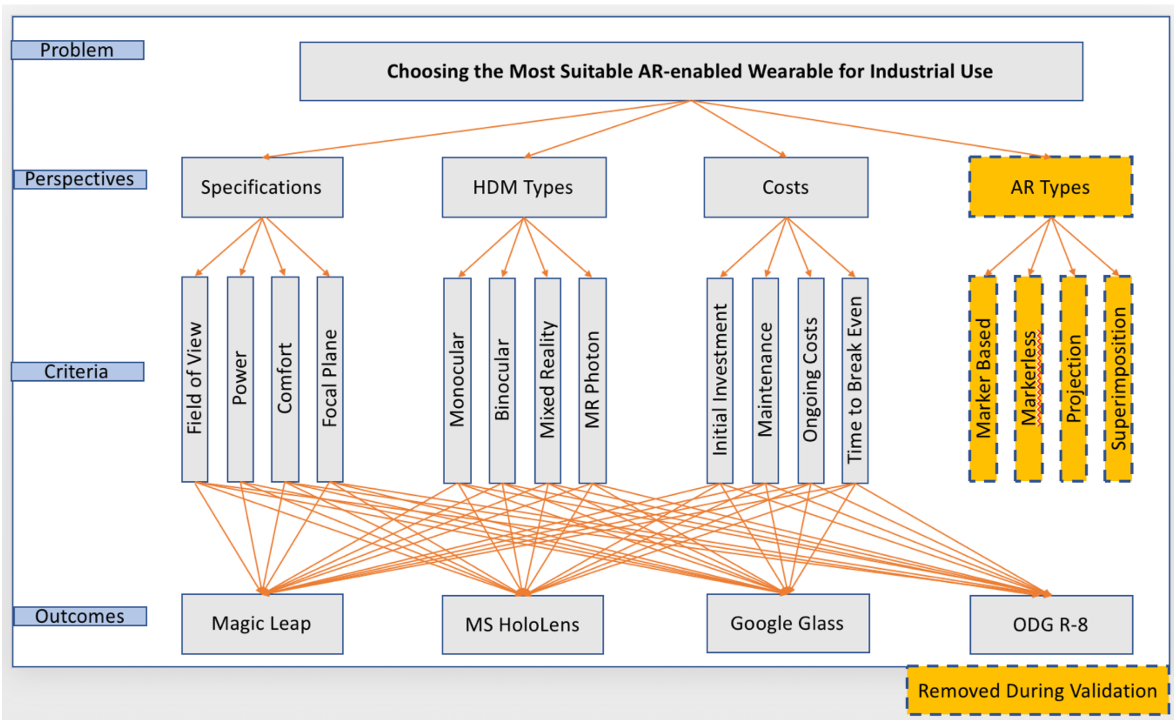


Figure 5: HDM Model - AR HDM

The visual strength of the HDM Model, is that it shows in a single view all the interconnections a choosing option has. The demarked layers show the viewer or user how each criteria and sub criteria relate via a relative weight to each other based on a 2- option choice. The orange outlined data above is the perspective of "AR Types" that once validated through the first phase of SMEs was shown to be inconsequential to the desired outcome. In addition to the removed node there were several other sub criteria that came out after the HDM model was run – based on SME interviews of the results.

In reference to the system abilities; CPU, GPU, and RAM came up.

- **A CPU** or microprocessor with a minimum of two cores. The latest generation of smart phones have eight cores and sophisticated HMDs will also need this amount of power for the demands that AR will place upon them. [7]
- **A GPU** (graphics processing unit) is needed to process and display 3d images with minimal latency. Originally developed to support the demands of gaming, GPUs are indispensable for state of the art AR HMDs. [7]
- **RAM** is also built into the SoC. Todays units have 1 or 2 GB of RAM to handle temporary storage of data. Look for this to soon go up to 4 GB for the state of the art HMDs. [7]

In reference to radio communication or how the AR HMD responds to its environment WiFi, Bluetooth, and NFC were raised:

- **WiFi** is key to connecting the HMD to networks.
- **Bluetooth** is the ideal protocol for connecting the HMD to peripheral devices. The latest standards version uses less energy and has a greater range than its predecessors.
- **Near Field Communications** technology enables devices to establish radio communication with each other by touching them together or bringing them into close proximity.

While both of these areas of focus would provide valuable additional data, the author had to draw a line at certain criteria, because adding in too many additional items could potentially water down the overall data with too many data points.

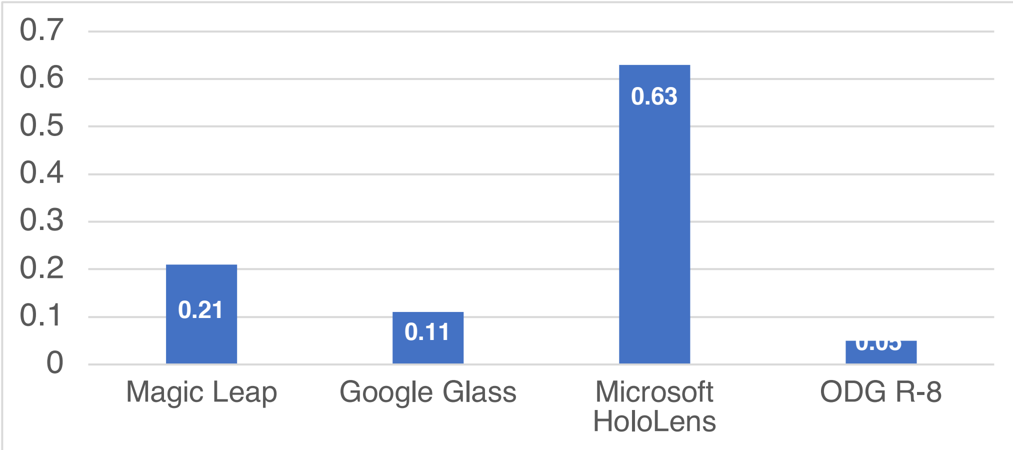
PSU's HDM Data Feedback

SME Engineers were supplied with the link to the online HDM tool along with a job aid that walked through explanation of how to use the tool in a 1:1 choice. Each criteria was explained and told to make their best assumption of outcome.

Head Mounted Display (HMD) for Manufacturing AR Implementation	Magic Leap	Microsoft Hololens	Google Glass	ODG R-7	Inconsistency
Mechanical Engineer 1	0.08	0.7	0.16	0.06	0.16
Mechanical Engineer 2	0.24	0.63	0.1	0.03	0.21
Mechanical Engineer 3	0.25	0.63	0.09	0.03	0.21
Mechanical Engineer 4	0.25	0.61	0.1	0.05	0.24
Mechanical Engineer 5	0.23	0.63	0.1	0.05	0.21
Mechanical Engineer 6	0.23	0.6	0.12	0.05	0.2
Mean	**0.21**	**0.63**	**0.11**	**0.05**	

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	1.26	3	.419	**197.5**
Between Conditions:	0.00	5	0.000	
Residual:	0.03	15	0.002	
Total:	**1.29**	**23**		

Analysis and Key Findings



The final results show the Microsoft Hololens as the clear winner at .63 with a large margin then to the Magic Leap at .21, followed by Google Glass at .11 and the ODG R-8. The Magic Leap, while scoring second could be a misleading selection. The outcomes on paper were desirable for the device however the future of the product is still so much under wraps. Beta tested demo units provided a fundamental understanding of what the product will potentially be capable of.

Inconsistency

SME	Level 1 Perspectives	Level 3 Options
1	0.0	.16
2	0.16	.21
3	0.12	.21
4	.13	.24
5	.11	.21
6	.09	.20

The data graph above shows the inconsistency rankings from the level 1 perspectives and an evenly weighted level of inconsistency on the outcomes. The author spent time with the SME group to discuss the results of the information and answer questions about the HDM tool. There were three instances where values of options were chosen based on a different interpretation of intent. A future study of new leading-edge technology could have a greater in depth job aid created for the HDM model usage.

Inconsistency Explanations and Acceptance

There is a larger amount of inconsistency however the author feels this is acceptable based on the understanding that head mounted augmented reality equipment is a brand-new field. There are technology biases that can work in favor and against new technology. Magic Leap while proposing a very promising solution is 50% hearsay at present because of the intense secrecy. Even with the limited practical testing and knowledge to share the SMEs were excited at the prospects. Conversely Google Glass has had a mixed release over the past few years. Even with that head start in usage the SMEs seemed to view the product as marginal or unimpressive – not exactly future minded. That and the coupled monocular configuration of the project place it in an interesting but marginal at best. The form factor of having the camera along one arm of the unit, while streamlined, has finite capacity for compute power. The bulk of the one arm design has become a satirical comment on its quasi-star trek look yet not quite science fiction capabilities.

The ODG R8 headset was interesting however felt like an early version of 3D glasses. The unit was light and performed satisfactorily but the product felt cheaper and less engineered than the other units; certainly not industrial quality grade. The Microsoft HoloLens physically fit and felt the most solid and professional. Especially expecting the industrial teams to adopt technology there is an expectation of top grade engineering. The fact that the HoloLens attaches to a hard hat is a game changer in itself. While it seems to be nothing important to non-industrial professionals researching AR headsets – this alone makes the Microsoft unit stand out. The OHSA safety rated glass coupled with the hard hat integration are far better suited to be pitched across organizations like Intel across the globe. The development ecosystem detailed below was a secondary decision criteria but sets Microsoft far above the other units

Additional Research

The goal of the study was to select the best AR Head Mounted Display. It was evident from the start that the Microsoft HoloLens was the instant front runner. The greatest usefulness from the study was that each of the four options were validated against each other and being sensitive to any biases the Microsoft HoloLens won out in nearly every category. The Microsoft VR HDM is purpose built for what could be utilized within a semi-conductor fabrication plant. Additionally the use case pilot validated the short comings of competitor headsets and brought a fair amount of certainty to the selection process.

I researched **Lorraine Bardeen**, GM Studio Manager, Mixed Reality and the HoloLens at Microsoft to ask a few follow up questions around industrial implantation. **How do you see the overall ecosystem of early adopters?** "The best part of my job is seeing what people around the world are doing with mixed reality. The innovation and development we see on the platform inspires us to create the software and tools needed to bring the potential of mixed reality to life. Over the first six weeks of 2018, we have seen some really great work from our partners and customers." **What do you see that can elevate industrial site VR usage?** "[MS HoloLens is] a mixed-reality solution that improves coordination by combining models from multiple stakeholders such as structural, mechanical and electrical trade partners. The solution provides for precise alignment of holographic data on a 1:1 scale on the job site" What is coming next? Trimble's Hard Hat Solution for Microsoft HoloLens extends the benefits of HoloLens mixed reality into areas where increased safety requirements are mandated, such as construction sites, offshore facilities, and mining projects. The solution, which is ANSI-approved, integrates the HoloLens holographic computer with an industry-standard hard hat. [9] And that's the true differentiator with new technology; the robust ecosystem. We're not only selecting and purchasing a headset we're looking for the workflow, creation, and the highest level of support structure in place. As of May 7, 2018 Microsoft released new software that enables field support efficiencies "We asked ourselves, "How can we help Firstline Workers share what they see with an expert while staying hands-on to solve problems and complete tasks together, faster.” [9]

- Workers and experts can annotate their shared view with mixed-reality ink and arrows, or insert images into their view, to pinpoint and solve problems efficiently.
- The ability to control access to remote communications with industry-leading identity and security measures.
- With mixed-reality annotations, live streaming, and video capture, we can enable Firstline Workers and experts to identify and address issues accurately the first time. This can help customers eliminate travel and expedite troubleshooting, increasing employees’ efficiency.

Microsoft Layout is an exciting application that should prove to be invaluable for our industrial space planners “With Microsoft Layout our goal was to build an app that would help people use HoloLens to bring designs from concept to completion using some of the superpowers mixed reality makes possible. With Microsoft Layout customers can import 3-D models to easily create and edit room layouts in real-world scale. Further, you can experience designs as high-quality holograms in physical space or in virtual reality and share and edit with stakeholders in real time. [9]

Next Steps

The PSU HDM tool provides a practical environment to value (A) against (B) and calculate the overall weights for a set of outcomes. However, the user interface and on-screen instructions of the model used for this study caused more issues than helped. Live user sessions helped greatly but took away from the original intent to have experts go through the tool with unbiased instruction. Time was spent adding detailed explanations to the HDM creation and these tips were near impossible for the user to find. A supplemental hand out was made to walk people through what they had to do step by step – even so far as the appropriate places on the hierarchy to click to proceed. One SME responded "I wasn't sure what to do at the end. I was afraid to close the window for fear of losing all the work. I left the screen open for a day before I heard back that – the save button would submit everything I needed to do." Dr. Neshati has reassured graduate students that there is a PSU HDM tool replacement in the works – which should solve that very high hurdle.

The luxury of being part of an organization with influence in high-tech provides opportunities to consult industry experts. It is far easier with a major brand name behind a research initiative to get to the right engineering experts. Having deeper access compounds development advancements and enriches the overall VR/AR/MR landscape. The field of augmented reality and mixed reality are set to revolutionize how we experience our waking world. The projects are 2023 that AR enabled smart headsets will replace the ever present cell phones clutched in everyone’s hands.

Research the required ecosystem of AR/MR development specific to enterprise usage. Microsoft HoloLens was the only solution that had a robust app development and true enterprise ecosystem to accompany their product. As augmented reality UX / software development matures more forms of marker/markerless interactive environments will become available. Deeper research will yield exciting possibilities into the goal of creating “magic” virtual spaces in expensive high-tech factory space. The holy grail of next level experience design would be being able to have a solid headset that accompanies an on-demand 4D space that a person could “walk into” and ultimately trigger events in the real world. In terms of job site collaboration as of May, 2018 two or more headsets can view the same experience. Having multiple users see visual data the same way will expand the usage possibilities. The new knowledge and experience will come from knowing what data to visualize and how not to overwhelm the senses and visual plane. Cloud based IOT solutions providing faster visual data will enrich the experience as well. Currently the interfaces are fairly simple. When we can create interfaces and visual data expressions that replicate what we’ve dreamed in science fiction we’ll have achieved something astounding.

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Figure 6: Google Glass Enterprise Edition [https://x.company/glass/]

Figure 2: ODG Smart Glasses [https://www.osterhoutgroup.com/r-8-smartglasses]

Figure 3: Microsoft HoloLens [https://www.microsoft.com/en-ca/hololens]

Figure 4: Magic Leap [https://www.magicleap.com/]

Figure 7: HDM Model - AR HDM