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Testimony of Brian Mullins, CEO of DAQRI
Senate Committee on Commerce, Science and Transportation
"Exploring Augmented Reality"

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Chairman Thune, Ranking Member Nelson, and members of the Committee, thank you for the opportunity to speak to you on this important topic.

My name is Brian Mullins. I am the founder and CEO of DAQRI, a Los Angeles-based technology company focused on empowering people in our everyday lives through Augmented Reality (AR). In these brief remarks, I will discuss the power of AR, how it is being applied today, and why it represents a shift in technology so significant as to rival that of the internet itself.

I first started working with AR technologies in 1997 when I started my career at the Department of Transportation (DOT) after graduating from the U.S. Merchant Marine Academy at Kings Point, New York. First at the DOT and later at the Space and Naval Warfare Systems Command, I worked with simulation and early mixed reality technologies that provided a glimpse of what AR would one day become. The technology was early, but I already knew then that it would become the best way to transfer knowledge while maintaining situational awareness.

When I left the government sector and moved into the field of Industrial Automation and Robotics, I learned firsthand how technology could dramatically increase workplace efficiency, but was dismayed to see workers left behind as factory floors were transformed. Drawing upon my earlier experiences, I realized that Augmented Reality could give people the ability to keep pace with the advancement of automation technologies and remain an invaluable part of the loop. We needed to leverage technology not just to optimize factories, but also to empower the human beings that ran them.

This year, much attention has been focused on AR in the entertainment sector. But behind the scenes – less covered by the media – practical and valuable applications of Augmented Reality that will positively influence American lives are already gaining momentum in other fields.

AR is similar to Virtual Reality (VR), but while VR is limited to interactions within a completely virtual world, AR mixes the real and the virtual together, allowing you to enhance what you see, without losing the connection to the world around you.

Today, AR technology allows you to overlay information into the real world and rapidly transfer knowledge that empowers people to make decisions that would not be possible without it. Augmented Reality devices will have a significant impact in the workplace. Gartner's 2016

forecast cites these business drivers for wearable head-up displays[1]: hands free worker productivity and safety, training in simulated environments, checklists for quality control, real-time training, and remote expert assistance and collaboration.

Industry leaders such as General Electric, Boeing, Intel, Huntington Ingalls, and countless others are applying Augmented Reality in training, maintenance, operations, construction, defense and manufacturing applications. The use of AR in the enterprise can also reduce errors, increase efficiency on complex tasks, and contribute to significant improvements in worker safety.

Imagine a worker who wants to transition to a new manufacturing facility that opened in her community, but lacks formal training for a highly skilled manufacturing role. Through the power of AR, she can be empowered to learn and execute complex tasks, improve productivity, and quickly gain new skills and knowledge even in environments where she has little experience through guided, step-by-step, augmented reality work instructions. On her first day at a new factory, using AR, she can look at the disassembled wing of an aircraft and see step by step instructions right on top of the components that she needs to put together.

This is not a hypothetical scenario. In 2015, Boeing and Iowa State University published a study[2] comparing the efficacy of traditional desktop work instructions with augmented reality work instructions for aircraft wingtip assembly. The team observed first-time trainees doing complex manufacturing tasks, and tracked a few key productivity stats. Major increases in efficiency, accuracy, speed, and worker satisfaction were found. Here are some highlights:

- **Accuracy:** Trainees utilizing AR instructions made fewer errors than those using desktop instructions by a factor of 16-to-1 on the trainees' first time completing a task. On the second time around, those using AR had perfect performance — zero errors. Overall, the AR work instructions improved first time quality by 94 percent.
- **Speed:** Trainees using AR instructions were able to complete tasks significantly faster than their counterparts, reducing job completion time by an average of 30 percent and, in some cases, as much as 50 percent.
- **Greater focus:** AR allowed workers to maintain focus on the task at hand. Trainees using AR looked at their instructions less frequently and for shorter periods of time, demonstrating that comprehension was happening rapidly. As the team put it, "The fewer number of looks meant that participants were not 'bouncing' back and forth between the instructions and the physical task."
- **Satisfied workers:** How did workers feel about the experience? A post-action survey asked participants if they would agree with the statement, "I would recommend work

[1] Gartner Forecast: Wearable Electronic Devices, Worldwide, 2016, Analyst(s): Angela McIntyre, Brian Blau, Michele Reitz

[2] Fusing Self-Reported and Sensor Data from Mixed-Reality Training, *(I/ITSEC) 2014, Trevor Richardson, Stephen Gilbert, Joseph Holub, Frederick Thompson, Anastacia MacAllister, Rafael Radkowski, Eliot Winer Iowa State University, Paul Davies, Scott Terry, The Boeing Company*

instructions like this to a friend." The answer was a resounding "Yes," at rates roughly 4 times higher than the median score for questions like this at more than 400 companies in 28 industries.

The AR instructions in this study enabled workers to complete tasks faster, more accurately and with greater enjoyment. Such results promise improved outcomes for industrial businesses, while also enhancing quality of life for workers.

Technology can take away jobs. It's true though that most times when it does, it creates new, even better jobs. But this doesn't happen overnight. It can take years, and an entire segment of workers can be left in the cold trying to re-skill when their industry or vocation is no longer relevant. Augmented Reality is a technology that helps people to learn and adapt to new technologies faster than ever before. It empowers workers with an entirely new tool that enables them to keep up with the accelerating pace of change in the modern world.

This year consumer awareness of AR is higher than ever thanks to the rise in gaming applications kicked off by the Pokémon Go phenomenon, however the adoption of AR has already been underway in the enterprise market for some time. Analysts predict that sales will grow from $2B today to over $100B by 2022 in combined hardware and software, across both consumer and enterprise markets.

Much like cellular phone technology, I expect AR to continue to develop in the enterprise market before it moves to consumers. And as it does, it will enter our day to day lives in a way that we haven't yet discussed. This hearing is timely because this transition to consumer use is already underway with AR Applications in cars.

Automotive Head-up Displays (HUD), a technology developed for fighter pilots to get the information they need in the cockpit without distracting them from their mission is finding itself on the road today.

DAQRI's own AR technology can already be found in hundreds of thousands of vehicles on the road today, providing drivers with critical information in the windscreen, reducing distraction and helping drivers to make decisions faster. At the current rate of growth, the market for AR in cars is expected to grow to over 10 million vehicles per year by 2022.

With a HUD you no longer have to look down to see your speedometer, that information is available at a glance, directly in your field of view. AR technology is making driving safer by providing information like turn by turn directions directly on top of the road. When information is in the space around us, it is more intuitive and easier to understand.

The use of HUD in automobiles has been studied extensively[3,4] and has been shown to have a number of significant safety benefits, the most important of which is enabling the driver of the vehicle to maintain their gaze on the road. This reduces the 'blind flight' time, which can equate to a significant distance when travelling at speed. Because of this, it is anticipated that the number of vehicles fitted with Head Up Displays at build time will increase significantly in the near future.

And now, as cars become more intelligent there is an even greater need for information to flow to the driver. A driver assist system can communicate to the driver that there is a hazard ahead they might not have seen, or perhaps a self-driving car will inform the passengers that it is aware of the truck that moved in front of them, and that it will be taking action accordingly. A visual connection between the vehicle and the driver using AR is one of the most powerful ways to improve safety on the road today.

From the beginning of my career, I knew there was something special about a technology that centered around people and allowing humans to adapt to changes in technology as quickly as computers. I am honored to stand before you and share the amazing possibilities that AR has to enhance the American worker and create new jobs and opportunities that will fundamentally make a positive impact on the world in years to come.

As AR continues to emerge as one of the most important technologies of the modern world, I ask the committee to consider the transformational impact that this technology has on our society. The use case with consumers will be materially different than the use case in the industrial environment and regulations to support that need to be tailored instead of painted with a broad brush.

I applaud the Commerce Committee for their foresight in holding this hearing now to begin to understand these issues and I look forward to partnering with the United States government to help support the emergence of this transformational technology.

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[3] N. J. Ward and A. Parkes, "Head-up displays and their automotive application: An overview of human factors issues affecting safety," *Accident Analysis & Prevention*, vol. 26, no. 6, pp. 703–717, 1994.
[4] R. J. Kiefer and A. W. Gellatly, "Quantifying t he Consequences of the 'Eyes-on-Road' Benefit Attributed to Head-Up Displays," p. 960946, Feb. 1996.

Figure 1: Augmented Reality Work Instructions

Figure 2: Automotive Augmented Reality