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Applications for Augmented and Virtual Reality Technologies to Vehicle Maintenance Training

Developed by the Technology & Maintenance Council's (TMC)
Future Virtual/Augmented Training Task Force

ABSTRACT

Today, the trucking industry is challenged with the need to increase the efficiency and quality of repair and maintenance tasks. Additionally, the rapidly aging workforce threatens to exacerbate the need for faster, better repairs with technical resources whose skills, in some cases, may lean more toward the mechanical than the technological aspect of systems.

Advances in technical training, such as augmented reality, can be used to improve the effectiveness of training, both now and in the future. However, virtual/augmented simulations are not a panacea for the coming demographic change. This information report provides a glimpse into future training technologies: the good and the bad, the ready and the unready, the economically effective and the wasteful.

New training technologies have their place, to be sure; however, they are not a magic solution. Too often we see a fudged online video or a passing promo in an automotive commercial extolling the wonder of augmented reality. Too often these pronouncements are simply false. This information report will explore the value and challenges of widespread technological and demographic changes in the trucking industry.

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I. INTRODUCTION

"Augmented and virtual reality are often part of the same conversation, though there are significant differences between the two technologies. One provides textual, symbolic, or graphical information that holds a real-time relationship with a situation or surroundings, and the other provides a complete replacement to our visual world." [1] *— Steve Aukstakalnis*

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II. WORKFORCE CHALLENGES

In 2014, there were approximately 263,900 people working in truck maintenance and repair throughout the United States.[2] By 2024, there will be approximately 300,000 positions that need to be filled.

2014	263,900
2024	295,000
Increase:	31,000

Figure 1: Estimated Change in the Number of Workers in Truck Maintenance And Repair

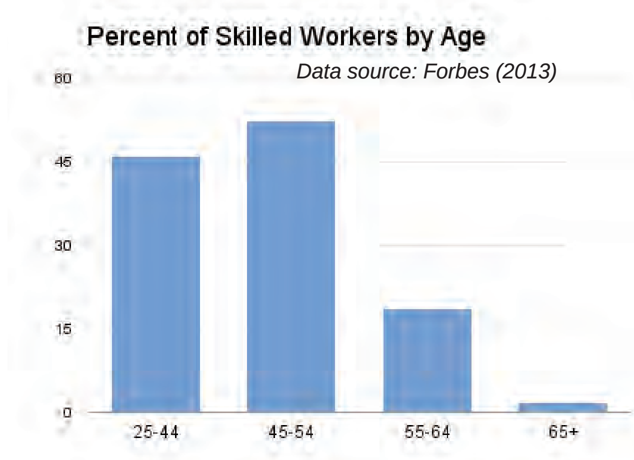

Figure 2: Percent of Skilled Workers by Age

However, these simple figures conceal the complexity of the growing problem. The entire workforce is aging rapidly — *very rapidly*. There is a skills gap across all trades. According to a ManpowerGroup 2012 survey, if you think skilled workers are hard to find now, just wait. In 2012, more than 53 percent of the skilled trades workforce were older than 45, with nearly 20 percent over the age of 55. As stated by Doug White, 2016-17 TMC General Chairman and Treasurer, "The technician shortage is going to get catastrophically worse."[3]

While there is a growing awareness of this huge deficit (see *http://profoundlydisconnected.com*), the educational system has not been able to fill this growing void. Between 2015-2025 there will be roughly three million manufacturing, maintenance and repair jobs, with a two million job shortfall.[4] The skills gap will become

1. Steve Aukstakalnis, "Practical Augmented Reality", Copyright 2017, Pearson Education
2. United States Department of Labor Statisics *http://www.bls.gov/ooh/installation-maintenance-and-repair/diesel-service-technicians-and-mechanics.htm*
3. http://fleetowner.com/fleet-management/technician-shortage-becoming-catastrophe
4. DeLoitte Touche Report Skills Gap Inforgraphic *http://www.mfgday.com*

700,000	New jobs based on expansion
+ 2,700,000	Retiring boomers
= 3,400,000	Jobs to fill
3,400,000	Jobs to fill
- 1,400,000	Filled jobs
= 2,000,000	Unfilled jobs

Source: 2015 Study from The Manufacturing Institute.

Figure 3: Projected Skilled Manufacturing Jobs Shortfall

a skills chasm as more baby boomers retire. As **Figure 3** indicates, there will be a massive shortfall. This nationwide labor tsunami will make the competition for quality employees more time consuming, more difficult and more expensive. In a job seeker's market, having a positive image to the trade skills will matter almost as much as the wage.

Further complicating this trend will be the continuing advances of technology and equipment improvements. As trucks become more complex, the skills needed will further restrict the pool of qualified applicants.

The thin talent pool guarantees that many new hires will have wide and deep skills deficiencies. **Table 1** shows skills deficiencies in new hires across the manufacturing industry by category. TMC believes it is reasonable to infer this same shortfall is represented within the transportation industry.[5]

These skills deficiencies will further exacerbate the skills problem as fleet owners will be forced to provide improved training to avoid losing business and/or valuable employees. "Technicians are now entering the realm of surgeons or doctors. We have guys that can fix any issue, but they have to be able to troubleshoot and find out the cause," said Allen Caldwell, Manager, FirstFleet, and past chairman of TMC's S.12 Onboard Vehicle Electronics Study Group.

TABLE 1: SKILLS IN WHICH EMPLOYEES ARE MOST DEFICIENT	
Technology/Computer	70%
Problem Solving	69%
Basic Technical Training	67%
Math Skills	60%

5. The Skills Gap in U.S. Manufacturing 2015 and Beyond, Deloitte and The Manufacturing Institute (2015).

In order to secure the best employees, fleet owners will need to develop and expand job attractiveness to truck technicians as well as provide new modes of learning and training for the growing crop of young truck engineers. An emphasis on the technological aspects of truck maintenance and repair will expand the candidate pool such as:

- Encouraging both formal and informal learning
- Embracing new ways to develop skills
- Expanding the candidate pool

III. TECHNOLOGY TO THE RESCUE?

Nearly everyone now swims in technological seas. The world of social media, instant communication and online resources are radically changing the lives of everyone in North America, if not the entire world. Simply put, the way we relate to information is changing. The ubiquity of smartphones, tablets and the internet has shifted the way most of us work and communicate.

The 25-year old prospective job candidate cannot imagine a world without smartphones and the internet. He or she typically expects instantaneous information and computer assistance for anything, from reading a map to even simple math calculations. In this vast ocean of information technology, older generation workers who have not chosen to remain "current" can only tread water, but the young generations appreciate speedboats.

Through most of known history, the skilled trades have been taught by demonstration and by apprenticeship. Before Gutenberg and widespread literacy, teaching was hands on—watch me, mimic me, learn. With increasing literacy, books became a primary hard drive of information. As complexity increased, literacy and fundamental math skills gained in importance.

With the mental impact of increasing fragments of stimulation, younger generations seem resistant to library drills. Fast-accessed information in the form of online searchable manuals greatly aid in providing original equipment manufacturer (OEM) specific information, and, unlike printed volumes, the electronic manual is easier to update and modify with new information or changes. Regardless of whether manuals have pictures and/or videos, manuals may not be the ideal training tool. Millennials do not engage, with any marked degree of success, with columns of text.[6]

The training solution can be found, instead, through the use of simulation, augmented reality (AR) and/or virtual reality (VR). As will be discussed, there are significant issues in the use of simulation and AR/VR. They are nothing more than a new set of tools to add to the tool chest. However, when paired with the correct need, a simulation or virtualization can become a phenomenally effective and ROI-efficient tool. In the following sections, this information report will explain the specific functions of virtual reality and simulation, providing example uses for each.

Virtual Reality

Since the purchase in 2014 of Oculus VR by Facebook for two billion dollars, there has been a huge uptick of head-mounted displays (HMDs) and related peripherals. While this is new for the mass market, head mounted displays have been around since the end of World War Two (wearable television was patented in 1945.) A wearable display paired with a computer was first shown in 1966. Now, virtual reality can be described as "a computer-generated, multi-sensory experience that simulates a user's experience and allows for meaningful interactions with objects and the environment using sight, sound, touch and even smell." [7]

Figures 4 and 5 illustrate two uses of virtual reality. **Figure 4** demonstrates the use of virtual reality in the design of the JSF-35. **Figure 5** was built for Northrop Grumman for training engineers on how to check for radiation leaks in a ship's compartment. This utilization highlights a significant aspect of virtual reality. In teaching the practical aspects of safety, a

Figure 4: Using a CAVE at Lockheed

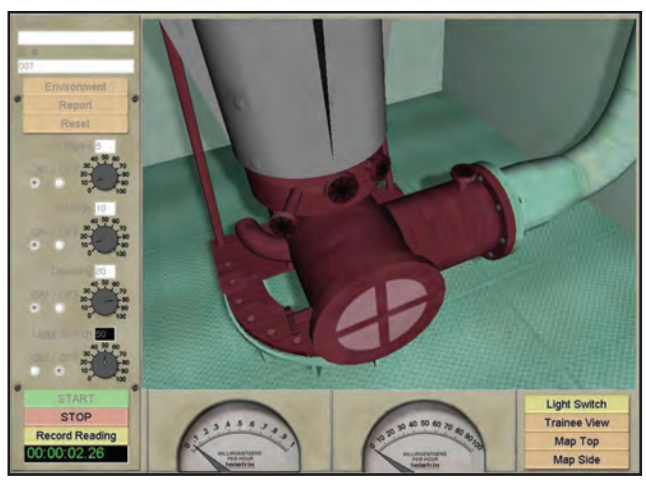

Figure 5: Virtual Reality Geiger Counter Training for Northrop Grumman.

6. *"Why digital natives prefer reading in print. Yes, you read that right" The Washington Post, February 2, 2015. An engaging discussion of millennial reading habits referencing Naomi Baron's Words Onscreen; The Fate of Reading in a Digital World.*
7. Wikipedia and MULTIsensory Interaction and Assistive Technology *dl.acm.org/citation.cfm?id=2835069*

Figure 6: Virtual Reality Welding Training

student can be safely "exposed" and tested in all manners of safety scenarios with no risk of injury or property damage. In 2006, one of the first practical virtual reality training products, the SimWelderTM, launched an industry of using virtual reality. The VRTEX® 360 is now the defacto standard in virtual welding training, with units in daily use in more than 161 countries (see **Figure 6**).

Augmented Reality

Unlike pure virtual manifestations, augmented reality (AR) uses one or more modes (e.g., Google Glass or smartphones) to superimpose a computer generated image or other sensory input on a user's view of the world. This composite sensory impression allows the integration of complex data onto a real world situation. Augmented reality is still in its infancy, given the difficulty of tagging a real-world location specific enough to be of use in the maintenance and repair environment. These highly technical constraints will inevitably give way to sustained development efforts during the next two to three years. Going forward, augmented reality solutions promise an immediacy and value proposition that demands development attention. Whether by phone, tablet or wearable display, augmented reality will be a game changer in aspects of maintenance and repair.

Work Instructions

Augmented reality holds great promise to revolutionize assembly maintenance and repair tasks. Intuitively simple, an augmented reality viewer would allow the user to see images or symbols superimposed over the real world. Both instructions and precise locations would allow for maintenance procedure to be followed on a step-by-step basis with accurate indicators of where the next part should be placed.

An AR device can present a technician with orderly work instructions in an utterly dead simple interface, walking him or her through a procedure. Simply put, the user is pushed through the process, step-by-step as the computer walks even an inexperienced user through the electronic manual. The manual could also be updated in real time, to better reflect any and all changes to parts or process.

This same technology set would allow for remote collaboration when faced with a particularly thorny problem. The maintenance tech can "phone a friend," who would be able to convey, through the augmented reality interface, the missing information to the exact spot. Despite its obvious utility, the real world implementations still represent a significant challenge (see below).

Simulation

Simulation is a large term that encompasses all aspects of training. Simulation has been a neglected means of training and testing, often because the implementations were grounded in rote formula or used "live problem solving"… which some find unpleasant. Research has shown that even simple interaction drastically expands both retention and understanding. Nowhere is the effect more pronounced than with millennials, who relate better to data that require interaction.[8]

Figure 7 illustrates a glass box training tool that teaches, through guided interaction, print reading in three dimensions. Further, this ex-

8. *https://www.uschamberfoundation.org/reports/millennial-generation-research-review*

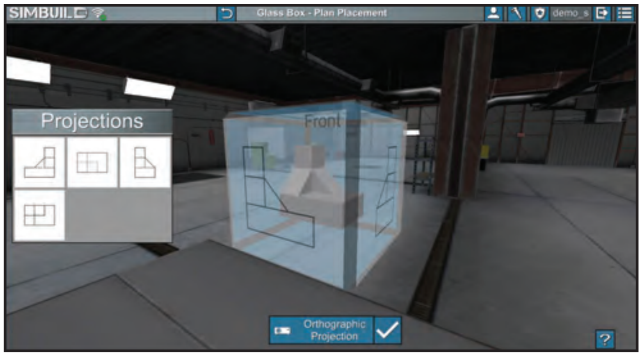

Figure 7: Print Reading and Orthographic Projections Taught Through a "Glass Box" Activity in SimBuild™ Industrial.

perimental trial and error encourages student engagement. Engagement leads to robust, repeatable learning.

The Other Shoe

All of these modern modes of communication are simply that. Each one has strengths and weaknesses and areas where the mode is the highest and best application.

As **Table 2** indicates, each of the communication modes has promise, and all of them require more resource from the fleet and/or educational program.

In order to modernize and improve training retention and testing, some measure of resourcing is required. There are numerous studies of specific implementations that promise aggressive and carefully tailored return on investment (ROI). In practical fact, these over-rich promises are unlikely to be met.

TABLE 2: ADVANTAGES, DISADVANTAGES AND THE SWEET SPOT OF DIFFERENT MODES OF TECHNOLOGY

Mode	Advantage	Disadvantage	Sweet Spot
Traditional	-Time tested -Instructor comfort and acceptance - Readily available	-Slow innovation -Limited by student/teacher ratio	-Technical knowledge -Basic skills
Sim	-Safe -Effective hands on learning with physical devices -Allows trial and error	-Broad distribution -Higher initial cost (but lower than AR/VR) -Instructor resistance	-Basic skills -Fine kinesthetic motions
VR	-Attractive, engaging, active experiences -Significantly enhanced feedback over traditional methods -Allows realtime trial and error -Safe practice of risky scenarios -Reduces material costs and set up and teardown time -Able to iteratively innovate	-Higher initial cost Instructor resistance -Limited applicability -Difficult to implement well -Limited haptic feedback -Limited motion tracking volume	-Kinesthetic involvement, especially with single tools -Safety -Tasks where materials are expensive or setup and teardown are time consuming
AR	-Integrates real and virtual worlds (e.g., overlays) -Able to iteratively innovate -Adaptable to changing OEM	-Higher initial cost -Instructor resistance -Tracking tech is still early and limited	-Knowledge acquisition -Repetitive or limited tasks needing realtime guides (e.g., environment awareness and alerts)

The primary obstacles are:

a. ***Hardware Costs***—Any implementation that utilizes an HMD or motion tracking will have significant hardware and maintenance costs. The average HMD alone is around $750. Durability, usability and connectivity are, and will remain, significant through the next two to three years. Within five years, hardware costs will substantially reduce. A significant exception to this are applications which utilize smartphones as a delivery mode. And while the implementation might lack a certain elegance, it will be cost free on the hardware side.

b. ***Application Costs***—Converting manuals to digital manuals and designing effective simulations are instructional design cost factors. Like all software, quality product requires sufficient time and resource. However, properly designed, these sorts of applications will be dynamic and allow near real-time modification.Provided OEMs accept the responsibility of supporting AR/VR efforts, OEM changes will, with only minimal involvement, be applied to the applications. However, it would seem that a standard must be written such that an OEM could publish changes in a manner that AR/VR systems created in support of the defined standards would then all be able to absorb and process the OEM changes. This will multiply the ROI over time, especially for systems that by their design are frequently modified. During the next three to five years, the process of transferring CAD (computer-aided design) models into a simulation platform will be increasingly automated and robust, with costs expected to decrease. Solid software design should be able to capture these cost savings.

c. ***Shared Framework and Private Data—***A significant cost in all training and certification programs is the development, maintenance and support costs of a learning structure. This includes a learning management system (LMS), courses and curriculum. While each OEM and fleet handler will have specific and often proprietary procedures and technologies, the core skills and academics (e.g., math, print reading and jobs skills) are all amenable to common treatment and certification. The same technologies that are needed for a robust training system can support multiple systems with a mixture of proprietary data. Opt-in association structures can allow independence while sharing burdensome costs, provided a common standard for sharing the desired and necessary information is developed and supported by the OEMs and the AR/VR vendors.

THE REQUIRED FUTURE

At the end of the day, virtual and simulation technologies will be part of the future — the means and ways in which a workforce is trained, developed and updated. The cost curve will continue to improve and the hurdles to implementation will lower. Within three to five years, simpler implementations will proliferate. Within 10 years, these methods will reduce, if not eliminate, manuals and textbooks.

A solid business case can be made for cautious, forward movement but always with the full understanding that the skills gap clock is running at an increasing rate. Those industries that have the least attractive and least effective training will suffer the most. Those companies and industries that hide behind stacks of textbooks and training manuals need to be reminded of what is well known in the education industry:

"Textbooks don't work well. Research shows that with rare exceptions they do not help improve student achievement much. They are not effective because effectiveness doesn't sell."— Jay Mathews, "Why Textbooks Don't Work and Hurt Schools." *The Washington Post*. February 25, 2012.