INTRODUCING VIRTUAL REALITY TRAINING SOLUTIONS TO THE WATER SECTOR – WHERE DO WE GO FROM HERE?

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ABSTRACT

This paper explores the award-winning results of early trials of Virtual Reality (VR) technology for Safety in Design reviews, and its preliminary effect on the water sector. A key focal point is the adaptation of VR industry applications from defence and oil and gas projects.

Trials were developed for two water treatment facilities, identified by Melbourne Water as being ideally placed to benefit from VR in the design review process.

The outcomes of this point to the potential for VR and related technologies to make a step change in design, construction and operation of water assets.

INTRODUCTION

Despite being relatively unexplored in the water industry, Virtual Reality (VR) technology has been used for over a decade to improve design processes to consider safety, constructability, operability and maintainability in other industry sectors.

Melbourne Water has been a leading early adopter of this technology in the water sector, and following successful early trials have expanded the use of VR within their business.

The benefits of VR technology have now been demonstrated to directly benefit Occupational Health and Safety (OHS) performance, and can potentially provide a spectrum of improvements to efficiency in project delivery, training and empowerment of operators and facility users, and ongoing maintenance and operations.

This paper explores these benefits through specific applications on two of Melbourne Water's new water treatment plants, and points to the vast potential for further development and application in the water sector.

BACKGROUND

Virtual Reality as an industry tool

Virtual Reality (VR) and Augmented Reality (AR) technologies have experienced a leap forward in industry application in the last decade due to increasing ease of access and decreasing cost.

At the 'high end' common hardware and environments such as HTC Vive and Oculus Rift have capitalised on an exponential increase in computing power, motion sensing, positioning, and camera technology.

The VR capabilities of cheaper 'low end' platforms like tablets and mobile devices have also improved significantly with multiple vendors planning and releasing increasingly more powerful VR devices. This in turn presents such technologies as an increasingly cost effective industry tool.

At this stage the use of VR in engineering disciplines has been demonstrated to be reliable for:

- Early engagement of stakeholders with meaningful project information;
- Reducing costs by not requiring 'real world' versions of modelled assets to be constructed or used;
- Increased availability compared to limited physical resources, allowing more, and more frequent, opportunities to experience and interact with the simulated environment;
- Increasing safety by providing highly realistic environments and interactions with none of the physical risks;
- Providing consistency of simulation and training to all users;

As these technologies become more prevalent, studies investigating the psychology of the learning experience in VR have emerged. Results indicate that the brain responds to a VR experience in the same way as it would an actual experience (Bailenson, 2016), which is not replicated through other forms of simulation such as viewing a 3D model on a screen. As such, some studies point directly to AR and VR industry applications (Lateef, 2010), suggesting that "the time had arrived for enterprises to begin experimenting with the technologies" (Kaiser & Schatsky, 2017).

VR product continuum

A decade of 3D modelling, simulation and virtual training experience has highlighted 4 phases common to most VR projects. These are described in Table 1.

Table 1: VR Phases of Development

Phase	Description
Visualisation	The development of an early-stage model for visualisation and design review
Simulation	Further development and modifications based on final designs to produce a highly accurate simulation of the finished project for design and safety analysis and validation
Familiarisation	Use of the modelled environment to provide meaningful familiarisation to workers
Training	Adding interactions, assessments, learner management, higher detail and realism to specific areas of the model for task training

Tapping in to other industries

KBR has been active in the VR space for several years, primarily producing solutions for offshore, military, and infrastructure sectors. Defence applications such as the familiarisation and task training developed for the Australian Navy's Landing Helicopter Dock (LHD) vessels (Figure 4) progress through all phases of the continuum to the point of creating a training environment. It would be dangerous or expensive to provide the same level of immersion through conventional training techniques. Similarly the F35 Lightning Prototype (Figure 5) provides a familiarisation experience to the user prior to the experience of occupying the aircraft.

Due to the risk profile and expense of these projects in reality, these sectors have been the early industry leaders. As such, when the opportunity arises to develop an application specifically for a water project, the technology is brought forward from other industries more so than it is being innovated. This is important as it allows the water sector a base level of understanding and knowledge to draw from.

Melbourne Water and KBR have been early adopters of this technology in the water space through the use of VR in Safety in Design (SiD) meetings. SiD meetings serve the purpose of identifying potential safety issues in the configuration of the infrastructure during the design phase, mitigating the risk of OHS incidents or costly alterations in later phases.

WATER TREATMENT PLANT SIMULATIONS

Application to Water Treatment Plants

In late 2016, Melbourne Water identified opportunities for use of VR for a new water fluoridation plant (Figure 1 and Figure 2) which doses water from the Cardinia Reservoir (Emerald, VIC) as part of the treatment process for supply to Melbourne Water's transfer main network. At the time, the project had recently been awarded as a Design and Construct contract to the KBR – John Holland Joint Venture formed under Melbourne Water's Major Capital Works Framework agreement.

In early 2017, Melbourne Water also identified an opportunity to utilise VR for a new sodium hypochlorite disinfection facility within their Winneke treatment plant (Figure 3) which is supplied from the nearby Sugarloaf Reservoir (Christmas Hills, VIC). The Winneke treatment plant was within an earlier (functional) phase of design, and had been awarded to KBR under Melbourne Water's Technical Services Panel.

The scope of both facilities was similar. Both consisted of a new building housing a network of piping, pumps, tanks and process equipment to allow the controlled dosing of supply water with chemical, and an external piping network to bring carrier water to injection points on the nearby transfer mains. In addition, civil works including new roads, a waste tank and a bunded area for chemical delivery form the scope external to each new building.

In both cases, SiD meetings which were already scheduled in both projects were pinpointed as fitting opportunities to trial the VR technology.

Technology

The hardware used to create a virtual reality experience in this case was the HTC Vive Virtual Reality Kit. The kit is available to the public through many Australian retailers for approximately AU$1000, and includes the VR headset, as well as controllers and base stations which contribute to the VR experience.

Using a suitably sized room, the equipment is set up such that the base stations track the user, allowing them to walk around the treatment plant, while the use of hand controls can "teleport" users to another space in the model or raise/lower the virtual 'floor' to allow viewing of all aspects of the model from any height.

To provide the graphics and processing power required to seamlessly operate the VR equipment, and the portability to deliver the VR at any location, an Alienware laptop equipped with an Nvidia GTX1080 graphics card was selected.

3D models of both plants were created through the design process using the Autodesk suite of design and drafting software. As this was part of the base scope of the project, the only additional work that needed to be done was to port this to the Unity game engine for output to the HTC Vive environment.

Objects were rendered with basic surfaces and textures, however the technology used for this application is capable of more detailed rendering in future to further increase accuracy, and to immerse the user in a more real environment.

Safety in Design (SiD) meetings

SiD meetings often rely on review of design drawings, which do not lend to the same perception of space as in reality. As such, a high level of diligence goes in to these meetings to ensure that all parties gain an understanding of potential hazards and can mitigate accordingly.

The SiD meetings took place in the KBR office with between 10 and 20 people from Melbourne Water, John Holland (in the case of Cardinia), and KBR present. The meetings were structured so as to review a set of design drawings and identify hazards.

VR was used in these meetings as a supplementary tool to streamline this process and to provide an additional means of identifying potential hazards, rather than as a replacement to the current method.

During the SiD meetings, the user's view was projected on screen, allowing other attendees to guide the user to particular points identified on the drawings.

OUTCOMES

Use of VR simulations for chemical treatment plants

The VR experience transformed the abstract nature of SiD design drawings and processes into a consistent, immersive experience of the completed projects. This resulted in noticeably streamlined and improved efficiency in SiD meetings, and empowered operations staff to provide input to the infrastructure they will ultimately be the primary users of, without having to contextualise a set of 2D drawings. In turn, this created an opportunity for more staff to contribute.

In the case of the Winneke facility, an additional 20 safety issues were identified using the VR headset, significantly more than the six that were identified using traditional methods.

Notably, risks relating to space constraints (heights, constrained or awkward spaces) were easier to discern. Examples of specific risks identified in this case were:

- Relocating of safety showers to increase clearance to tanks
- Ventilation fans too high for maintenance
- Control panels placed too low for easy operation

These are all risks that are not immediately apparent through design drawings and models, however become obvious when the user is immersed in the environment.

Further to the safety risks identified, use of VR resulted in identification of clashes within the pipework and building. This contributed significantly to the proceeding Design and Construct phase of the project.

Industry Response

The application of VR on Melbourne Water projects has recently lead to Melbourne Water being awarded the 2017 Work Safe Victoria Award for Best Solution to a Specific Workplace Health and Safety Issue, citing that "Virtual Reality is now embedded in Melbourne Water's safety and hazard identification process" (WorkSafe Victoria, 2017).

FUTURE APPLICATIONS

Potential for Further development of WTP applications

The Cardinia and Winneke VR applications were developed to visualisation and basic simulation phases as they have produced a highly spatially accurate model which allows for design and safety analysis and validation.

Looking forward, these projects also provide a basis for further use as familiarisation and training tools. Future water sector projects, particularly for new treatment facilities, would be ideally placed to build on this through:

- Familiarising operators and other stakeholders with the new environment before construction has even commenced;

- Training operators in new or existing processes in the new facilities;
- Integration with existing asset management tools;
- Provision of 'virtual operation' functionality for appropriate equipment within the facilities.

Other 3D projects completed within KBR's defence and offshore sectors point to the potential for reusing engineering models for familiarisation and training applications.

KBR developed the 'LHD Ship Walkthrough Computer Model' (SWCM); a simulated version of the (then unbuilt) two new LHD vessels for the Australian Navy (Figure 4). This application was originally produced for desktop PC use. Two days of intensive familiarisation exercises using the desktop simulator equipped trainees with location-specific knowledge equivalent to having spent three months on the vessels. The extensive and detailed models used for this application are now being repurposed to provide VR training for costly and dangerous equipment and locations.

In 2015, KBR were engaged to provide 3D simulation of redesigned track and signal upgrades around the Hornsby train station. Utilising the latest 3D scanning technology and incorporating the redesign of track and signal work KBR TS produced a Virtual Signal Sighting (VSS) application for pre-construction engineering design. The excellent fidelity of the modelled environment allowed the application to be redeveloped as a training tool on PC, iPad and in VR (Figure 6).

Utilising a single, highly accurate virtual 3D environment for visualisation, design and safety evaluations, driver familiarisation and stakeholder engagement (drivers, unions, rail customers), is enabling unprecedented improvement in customer service by:

- reducing time and cost of construction;
- reducing interruptions to rail service during construction;
- allowing much earlier engagement with drivers to inform signal design and placement;
- reducing 'cost per driver' of familiarisation training; and
- Removing physical constraints (limited number of train simulators) on the number of drivers and time required to familiarise drivers with the upgrades.

Augmented Reality Vs Virtual Reality

An emerging tool for a similar set of uses is Augmented Reality (AR). As the name suggests, AR adds virtual elements to the user's view of the reality, rather than creating a reality. This can be implemented as a head mounted device (e.g. Hololens, Magic Leap), as with VR, but can also utilise simple technology such as a phone or tablet, where the devices camera captures the surrounding environment, interprets it, and adds information (a popular example being Pokemon Go).

AR does not supersede VR technology, as the characteristics of both of these lend to a different subset of uses. AR can provide supplementary information to real world tasks in real time, which is often more useful for manufacturing and construction. For example, Boeing engineers have trialled this technology as a replacement for assembly manuals, which resulted in a 25% decrease in wiring production time. (Kaiser & Schatsky, 2017).

VR environments can create a fully immersive world which does not necessarily have to be realistic. A recent initiative by the Victorian Government has seen the development of an interactive VR environment to simulate a bushfire, and allow users to make a choice to evacuate, stay and defend, or seek shelter (Oaten, 2018). The immersive experience created here is an excellent case in point for the advantages of VR.

VR as a subset of digital engineering

With the increased use of 4D visualisation for construction schedule and Building Information Modelling (BIM) to manage assets, a further opportunity is presented for VR to become a standard tool in the broader world of digital engineering.

Current technology at KBR's disposal is capable of integrating VR with an intelligent 3D model to view large infrastructure projects at various stages of construction. There is potential for this to be used as a tool in the water sector to assist the general public to grasp the short term effects of construction works. This may be particularly helpful in densely populated urban areas where water supply and sewage mains are to be rehabilitated or replaced.

Integration of VR in to BIM models would also pave the way for 'virtual rehearsals' of delicate or dangerous site operations (akin to the current military and rail training environments), or even remote operation of equipment in real time, in turn reducing the personnel required on site, and eliminating HSE risks.

CONCLUSION

This paper has demonstrated the capabilities for the application of virtual reality technology to various elements of the Water industry using standard and relatively inexpensive equipment. Specifically, this was able to demonstrate a measurable impact on safety outcomes and increased ability for operators to provide input to designs.

The future potential for VR and AR points to a broad spectrum of applications which will have an effect on cost, time and safety in the Water Sector. Some of these applications have already been demonstrated through KBR's Defence and Oil and Gas projects, while the true value of others are only just beginning to be understood. In any case, there is a bright future for VR and AR technologies going forward in developing the water sector in to a safer, more cost effective and customer centric industry.

LIMITATIONS

The findings, observations and conclusions expressed by KBR in this paper are not, and may not be considered, an advice for general public purposes or use. The data, findings, observations and conclusions are based solely upon specific circumstance in existence at the time of the investigations detailed in the paper and are not represented as relevant or applicable to any to other circumstances or facts. No warranty or guarantee, whether express or implied, is made with respect to the data reported or to the findings, observations and conclusions expressed in this paper and KBR/Melbourne Water shall assume no liability or responsibility to any person who may rely upon the information contained in this paper.

REFERENCES

Bailenson, J. (2016, July 22). Virtual reality works for games. But what about real life? (M. Lauren, Interviewer)

Bryden Wood Technology Limited. (2017). *Data Driven Infrastructure - From digital tools to manufactured components.* Lundon, United Kingdom.

Kaiser, R., & Schatsky, D. (2017). Signals for Strategists - For more companies, new ways of seeing. *Deloitte University Press*.

Lateef, F. (2010). Simulation-based learning: Just like the real thing. *Journal of Emergencies, Trauma, and Shock*.

Oaten, J. (2018, January 5). *ABC News.* Retrieved January 12, 2018, from http://www.abc.net.au/news/2018-01-05/virtual-reality-fire-emergency-program-rolls-out-in-victoria/9304948

WorkSafe Victoria. (2017). *WorkSafe Victoria Awards 2017*. Retrieved 01 10, 2017, from Work Safe Awards: https://www.worksafeawards.com.au/2017-worksafe-awards-finalists/best-solution-to-a-specific-workplace-health-and-safety-issue/melbourne-water/

Figure 1: Cardinia Treatment Plant – Outside (Visualisation, Simulation)

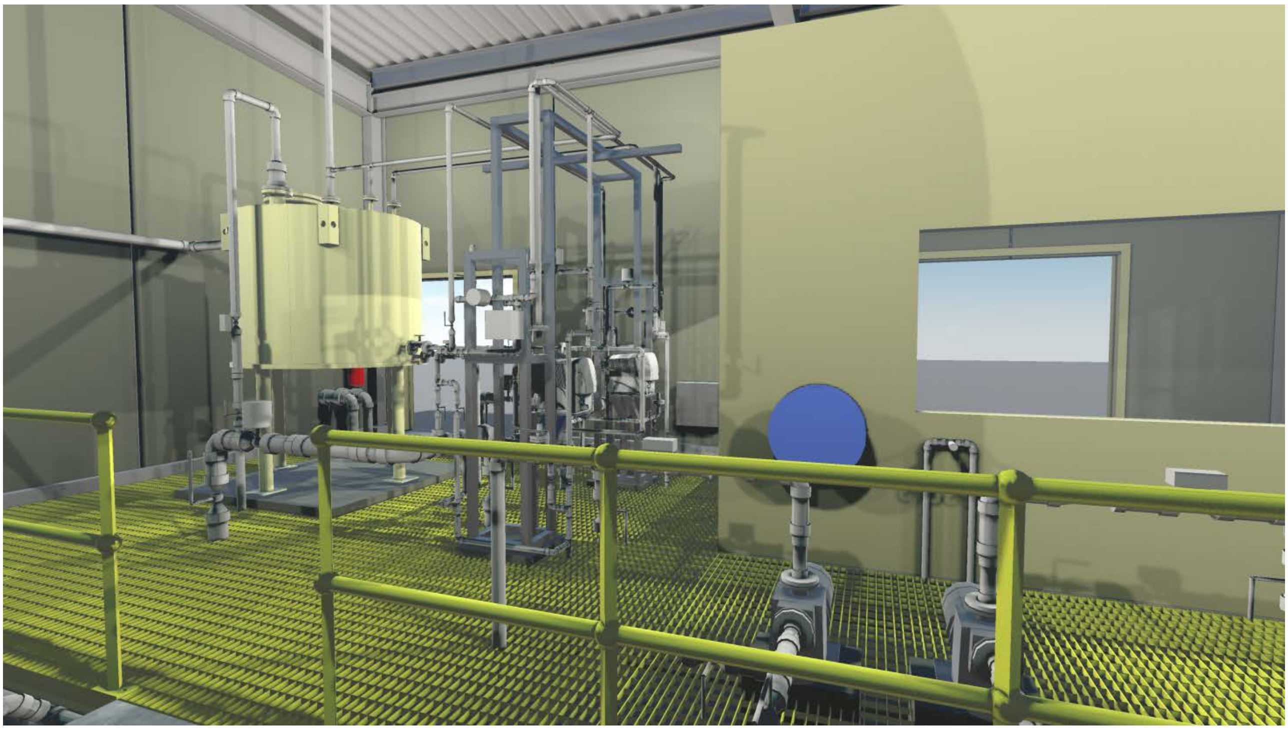

Figure 2: Cardinia Treatment Plant – Inside (Visualisation, Simulation)

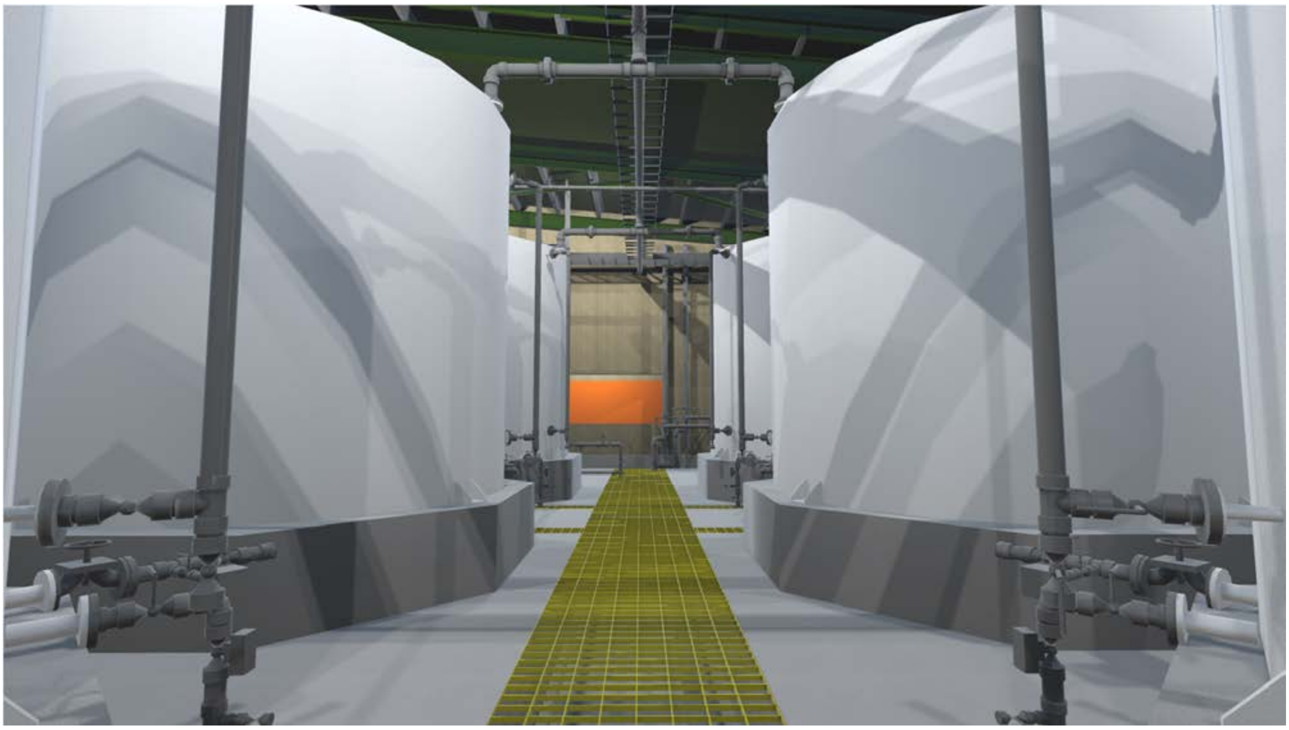

Figure 3: Inside of Winneke Treatment Plant (Visualisation, Simulation)

Figure 4: RAN, LHD Vessels (Visualisation, Simulation, Familiarisation, Training)

Figure 5: F35 Lightning Prototype (Visualisation, Simulation, Familiarisation)

Figure 6: Hornsby Junction Rail Station Driver Training Tool (Visualisation, Simulation, Familiarisation, Training)