The Past, Present and Future of XR for Space Exploration

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ABSTRACT

XR (Virtual and Augmented Reality) Simulations have a long history at NASA, from mission rehearsal to mission design. This presentation will look back at what was and look forward to some novel VR/AR solutions that are just around the corner.

This presentation will include a quick history of VR at NASA, going back beyond some of the earliest VR systems in the 1990s, a quick snapshot of today's solutions and an in-depth look at VR and AR hardware solutions and novel use cases that are just years away.

- Could VR "holograms" (real time 3D captures of human models) be used to improve astronaut morale and mental health by creating more realistic, believable and human interactions with their friends and family back on earth?
- How close are we to building neutral a buoyant (water tank) VR system?
- Will microgravity cause any issues with tracking systems?
- Could XR relaxation training help with astronauts' sleep patterns, motion sickness and PTSD if there were an accident on the way to Mars?
- How useful is XR for treatment of pain?
- How could XR ensure better PR and support by allowing users on earth to experience VR tours of ISS and Mars?

These solutions also have earthbound applications for long duration, remote and isolated missions such as submarines and overseas deployment.

ABOUT THE AUTHORS

John E. Williamson Mr. Williamson began his work in Virtual Reality (VR) with a research grant from the Air Force Office of Scientific Research. That study led him to the Human Interface Technology Lab at the University of Washington working for Dr. Tom Furness on a wide range of VR projects. John then spent 20 years making commercial video games as a producer/designer/writer, shipping over two dozen games (*SAW, Spec Ops, America's Army, Hawken*) in nearly every genre (FPS, RTS, Survival Horror, Arcade, MOBA) on nearly every platform (iOS, Android, Wii, PC, Web, PS2, PS3, PS4, Xbox, Xbox 360). He is a frequent speaker on a wide range of topics and conferences from technology talks at the International Space Station R&D Conference and MODSIM World, to Narrative talks at the Seattle Film Festival and Emerald City Comic Con to Game Design talks at Game Developer Conferences such as GDC, PAX, and Geek Girl Con. He has recently returned to his origins, once again creating VR training apps for the U.S. Air Force, this time as a lead designer on the Pilot Training Next team.

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PAST

For this paper, we will use the most inclusive definition of XR, one that includes all Augmented and Virtual Reality devices.

We begin with Ivan Sutherland's 1968 HMD, the "Sword of Damocles" (see Figure 1). While there is no record use of the system being used by NASA, it is included in this paper because it illustrates that XR has been around far longer than most people recognize, over 50 years. The HMD could display simple, wire frame, cube rooms, but these spaces would rotate as the user turned their head using electromechanical sensors suspended from the ceiling above the user's head (hence the name).

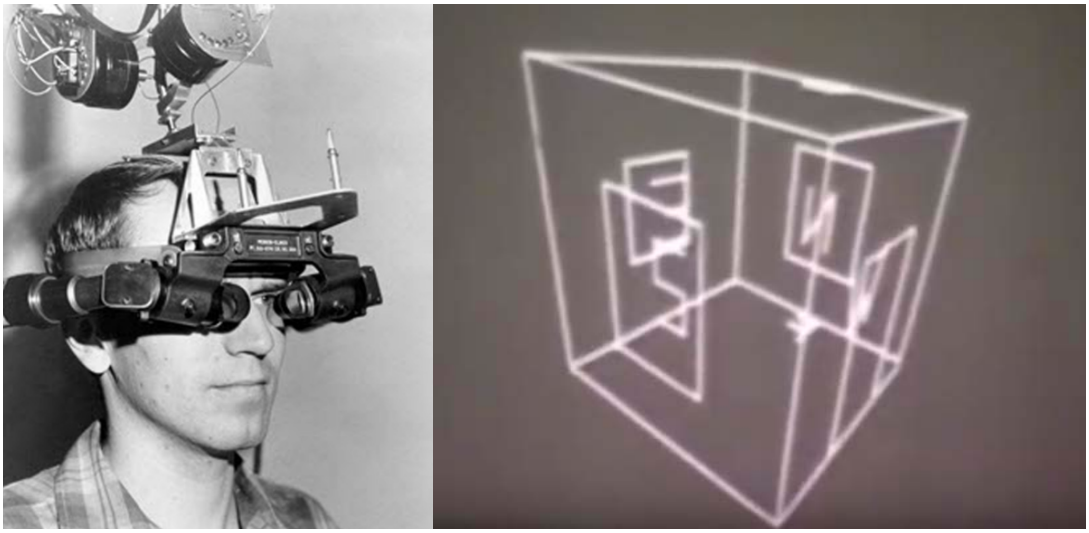

Figure 1. Sword of Damocles Hardware and Image Sample

The first use of an XR like system by NASA seems to be the 1962 Lunar Orbit and Landing Approach Simulator or LOLA (See Figure 2). Four very large-scale models and murals, some 30 feet in size, were used to represent the lunar surfaces from different altitudes. The model was fed, via closed-circuit TV, to an astronaut trainee who would then "fly" the cameras towards the large moon model, making course corrections based on the flickering images on his TV screens. In the end, while the device was labeled both "fun and quite aesthetic", it was dismantled because there was no reason to learn the landmarks of the moon to fly a lunar orbit. Rendezvousing with the LEM, which the device could not simulate, was the most important task. But the technical issues solved with LOLA were used to successfully train astronauts for Landing and Ascent for Apollo 11 and 12 in the Lunar Modula Simulator (LMS) which also featured very large modes (scale 1 to 2,000) and closed-circuit TV.

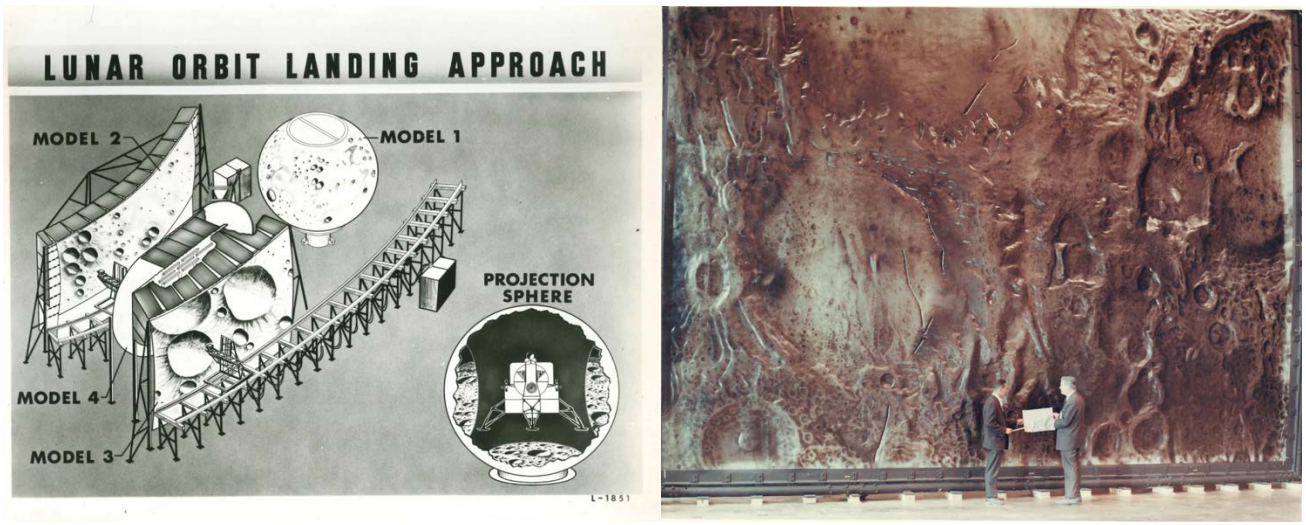

Figure 2. LOLA Schematic and Model with Worker for Scale

NASA built several motion flight sims as computers and projection technology advanced. A need made all the more important to allow the astronauts to rehearse for the landing of Space Shuttles. Thanks to laptops, astronauts could bring portable versions of their flight sims with them and practice the landing while in low earth orbit. The Mid 1990s saw an explosion of VR, both the higher end SGI powered systems from VPL, and 3 competing commercial systems were released for home PC: Virtual iO, Cybermax and Forte. NASA experimented with these systems and built their own. Though all came up well short in terms of performance and resolution (Figure 3.), they still served as valuable stepping stones and research platforms from mission rehearsal to visualization.

Figure 3. NASA 1990's HMDs

NASA Astronaut Terry W. Virts is shown using an XR system in 2015 (Figure 4) to train with the Simplified Aid For EVA Rescue (SAFER), that shows not only the out of the box problem solving prevalent in space exploration, but also the fact that there are solutions that work in low earth orbit (strapping a heavy metal frame and laptop to your head), that are not viable on Earth. SAFER is a jet pack designed to allow astronauts to return to the ISS if they are separated during a spacewalk.

Figure 4. Laptop as HMD onboard the ISS

PRESENT

Today, XR has been used successfully many times on the International Space Station (ISS). Current systems seemed to have behaved perfectly in space, showing no issues with zero gravity on hardware nor the astronauts using XR.

VR 360 Photography

NASA has always used stunning photographs taken with state of the art equipment to help sell the ISS and Space Exploration, from Hasselblads to IMAX. They have now moved to include 360 videos shot from the ISS by astronauts.

Situational Awareness

The Microsoft HoloLens (Figure 5) has been shown to be an effective tool to help astronauts convey exactly what they are seeing, and allow specific guidance and feedback from Mission Control in the aptly named “Project Sidekick.” Furthermore, AR assisted assembly overlays have been prototyped to help illustrate new solutions to astronauts before they perform them.

Figure 5. Microsoft HoloLens

Science Experiments

The Oculus Rift (Figure 6), with a modified InfraRed tracker, has been used on board the ISS to help determine how astronauts' perception adapts to low earth gravity.

Figure 6. Oculus Rift

FUTURE

The ability for XR to transform space travel is just around the corner with a new wave of technological advancements. Perfect timing, as Space Exploration looks to once again leave low earth orbit with trips to the Moon and Mars.

AR/AI Integration

In the near future AI will be able to recognize everything we see, allowing for complete AR integration, the perfect smart goggles -where everything you look at is identified and everything has its own built in instruction manual. The Microsoft HoloLens "Project Sidekick" has just begun to illustrate all that is possible.

Entertainment

Just as on Earth, XR is a wonderful distraction and source of entertainment. This entertainment could be used to help escape a sense of claustrophobia and help astronauts readapt to an 8 hour sleep cycle before going to bed.

Exercise

Astronauts must vigorously exercise 2 hours per day just to maintain a manageable level of bone and muscle loss. VR could help gamify the exercises making them an enjoyable, competitive and social experience.

Figure 7. Exercise on board the Space Station

Social and Family

Astronauts' lives are stressful and their families are often a key thing to help keep them happy and healthy. In the future, it may be that VR "holograms" can help with a more realistic rendering of that interaction. Microsoft has demonstrated the ability to capture real-time "holograms" and present them to users of the HoloLens (Figure 8).

Figure 8. Microsoft "Holograms" demonstration

Telepresence in Robonauts

NASA believes the future of space travel will include more robots, including robots on manned missions controlled by astronauts, or Robonauts (Figure 9). While it will still be decades before they are autonomous, controlling robots via telepresence with HMDs will soon become common. There is one on the ISS now. Having the astronauts on the mission perform the telepresence removes the lag caused by the vast distances in space travel. The Robonauts can perform functions too dangerous for humans and with less exertion.

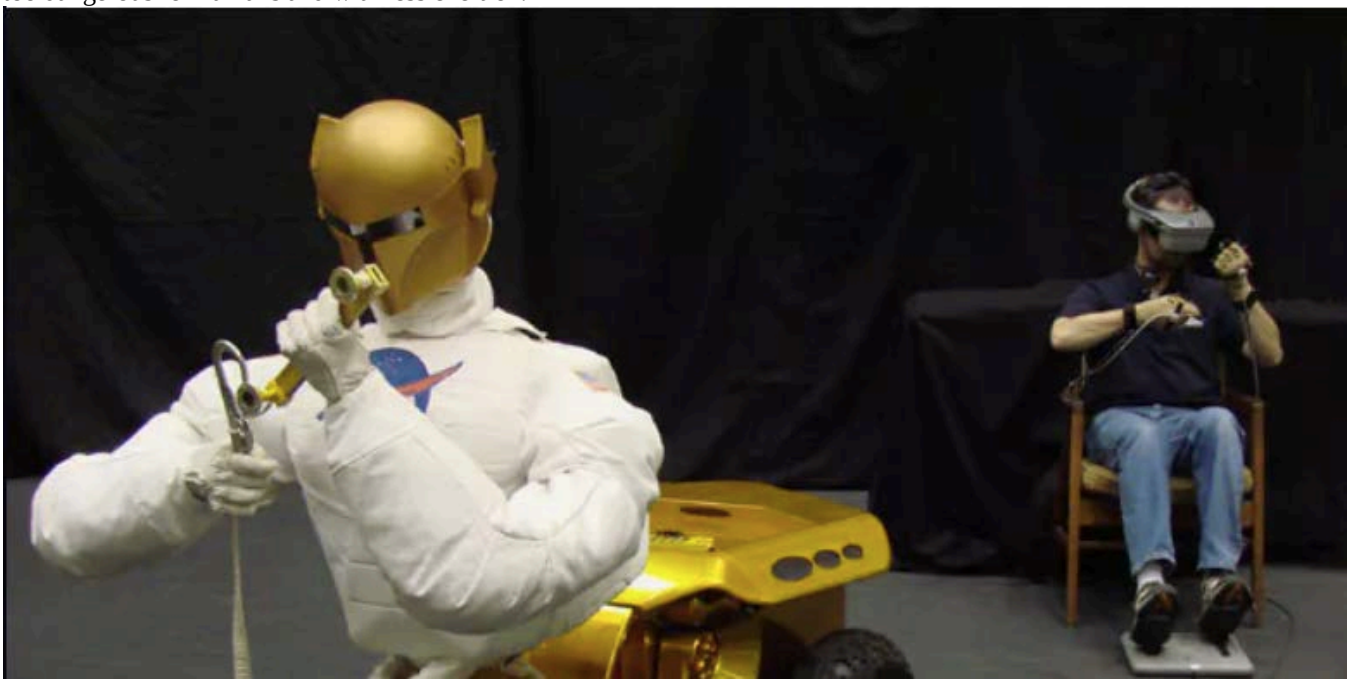

Figure 9. Robonaut

No "Buck Rogers" No Bucks/PR

Barring some shift in geopolitical power, a competitive Mars Race to rival the Cold War Space Race is unlikely. How then to engage the public and obtain and leverage their political and financial support? Why not let them experience space travel through XR? 360 Cameras have already recorded footage from space, there are several VR experiences that allow one to recreate the Apollo Moon landing and build your own solar systems.

Pain/Stress Relief

XR has been used for Pain and PTSD relief for decades now. Hunter Hoffman (Figure 10) showed how effective VR Pain Distraction could be in a series of studies with a VR app called "Snow World" that showed both with self-reports and MRI brain scans that patients would report and feel less pain if they were distracted by VR. Similar results have shown the effectiveness of VR to treat PTSD.

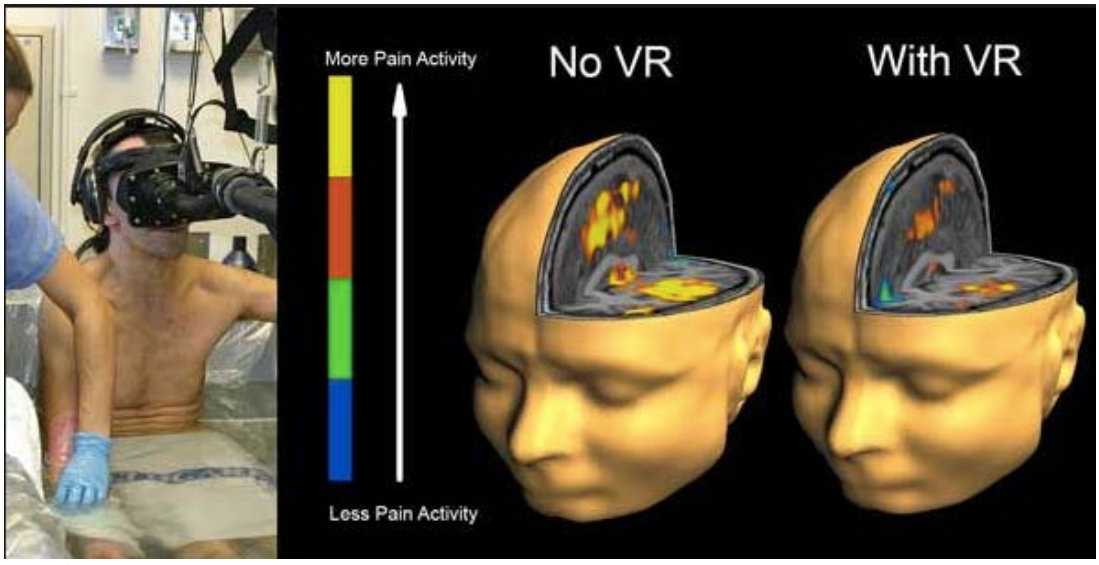

Figure 10. Brain Scan

On a multi-year trip to Mars, there are no "extra" crew members and there is no way to simply abort and return to Earth. If there is a traumatic event, the astronauts will need to return to duty as soon as possible. Instead of a long course of Opioids, XR Pain Distraction may prove to be a better solution for pain management. If an astronaut is unable to return to duty due to PTSD, XR therapy may prove a way to recovery.

"Overview Effect"

Many astronauts report a life altering change in perception of themselves and world when they first see the Earth from Space. Common themes include a desire to work together and fragility of life.

"When you're finally up at the moon looking back on Earth, all those differences and nationalistic traits are pretty well going to blend, and you're going to get a concept that maybe this really is one world and why the hell can't we learn to live together like decent people" -Frank Broman, Apollo astronaut.

"The first day or so we all pointed to our countries. The third or fourth day we were pointing at our continents. By the fifth day, we were aware of only one Earth." -Sultan bin Salman bin Abdul-Aziz Al Saud.

Perhaps one day, with better technology, we can all experience the Overview Effect simply by donning an HMD. (Author's note, once I read of the Overview Effect, I tried to experience it in Google Earth VR on a VIVE Pro, and I'm not sure if it was the resolution or gravity, but I did not experience the Overview Effect.)

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