

Developing Extended Reality Projects in Support of Design, Fabrication and Procedure

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Nomenclature

<i>MSFC</i>	=	Marshall Space Flight Center
<i>XRSpace</i>	=	Extended Reality Lab
<i>XR</i>	=	Extended Reality
<i>VR</i>	=	Virtual Reality
<i>AR</i>	=	Augmented Reality
<i>ECLSS</i>	=	Environmental Control and Life Support Systems
<i>4BCO2</i>	=	Four Bed Carbon Dioxide Scrubber
<i>PPSA</i>	=	Purge Pump and Separator Assembly
<i>EO23</i>	=	Crew Systems Engineering Branch
<i>AMO</i>	=	Autonomous Mission Operations
<i>JSC</i>	=	Johnson Space Center
<i>KSC</i>	=	Kennedy Space Center
<i>LaRC</i>	=	Langley Research Center
<i>JPL</i>	=	Jet Propulsion Laboratory

I. Introduction

The goal of this internship was to improve and create virtual reality simulations and visualizations for use in parallel with the design, fabrication, and analysis of flight ready hardware for areas like the Environmental Control and Life Support Systems (ECLSS) and also Space Systems. Specifically, my work was done in the XRSpace lab at Marshall Space Flight Center (MSFC) with assistance directly and indirectly from workers at KSC, JSC and LaRC. Led by David Reynolds, the XRSpace lab develops products for various entities at NASA. The work done in the XRSpace lab focuses on Extended Reality (XR) solutions for both simulations and visualization capabilities. The goal of the lab is to support the larger systems of NASA and to help find ways that XR technologies can streamline and optimize the design process.

Extended Reality is an umbrella term that encompasses Mixed Reality, Augmented Reality, and Virtual Reality. In this capacity, I was able to complete several elements in the design, building, testing, and deployment for a variety of immersive experiences, including a VR procedure simulation, visualization aids, and a 360-image capture tool.

II. Purpose of Research

The purpose of my research at XRSpace is to identify where Extended Reality (XR) can assist in improving efficiency, safety, and overall productivity at Marshall Space Flight Center and, ultimately, numerous centers at NASA. The XRSpace lab is in the process of developing capabilities for Extended Reality projects. The lab has recently focused on creating multiple Virtual Reality projects for Simulation, Design Tools, Visualization, and Education. During my internship here at MSFC, I have had the opportunity to advance previous work done by the lab, improve elements of existing projects, design new solutions for new projects and help widen the toolset for the XRSpace lab.

III. What is Extended Reality Technology

Extended Reality (XR) is an umbrella term given to numerous areas of immersive technology. According to Mann, "VR (Virtual Reality) replaces the real world with a simulated experience (virtual world). AR (Augmented Reality)

allows a virtual world to be experienced while also experiencing the real world at the same time. Mixed Reality provides blends that interpolate between real and virtual worlds in various proportions, along a “Virtuality” axis...(Mann 2018). It is the job of experience designers and creators to build these XR experiences. Plainly explained, while an engineer needs a digital tool to create a chair, an experience designer needs a digital tool to not only "create" a version of the chair, but also produce the experience of sitting in it. Some of the techniques in XR that are currently relevant are 360 photo/video, computer graphics, modeling, photogrammetry, game engine manipulation, light field captures, motion tracking, augmented reality, virtual reality and mixed reality.

IV. Overview of Extended Reality Technology at MSFC/ NASA

Extended Reality (XR) technology is not new to Marshall Space Flight Center (MSFC) and has been in development at Marshall Space Flight Center since 1989 (Hale 1995). Notably, works by Joseph P. Hale among the Crew Systems Engineering Branch (EO23) focused on hardware development, operations development and support, mission operations training, and science training. More recently, much work has been done throughout NASA using immersive technology. For example, recent work was done on Treadmill 2 Augmented Reality (T2 AR) ISS Flight Procedure for the Autonomous Mission Operations (AMO) project at Johnson Space Center (JSC) using Augmented Reality to repair and maintain an ISS treadmill. Also, work was recently completed at the Jet Propulsion Laboratory (JPL) Ops Lab

to simulate a walk on Mars using XR to provide a user with a view of the mars surface. The spectrum of immersive

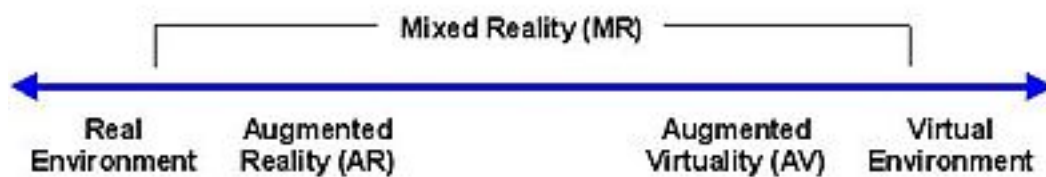


Figure 1 (Milgram 1994) Reality-virtuality continuum

technology uses is vast and mostly uncharted. Known as the Reality-Virtuality continuum and first identified by Paul Milgram (Milgram & Kishino 1994), the spectrum identifies areas of XR.

One of the XRSpace lab's goals is to continue the exploration of this spectrum and see where this technology belongs. It mainly attempts to find out how these technologies can currently be integrated within the existing processes at MSFC and NASA.

V. Areas of Applicability for Virtual Reality at MSFC

During my time as intern for the XRSpace, I worked with a variety of employees whose background with XR ranged from using an iPhone for AR applications, to participating in location based virtual reality. When explaining the capabilities of VR, it was readily apparent that a list of the pertinent and current XR areas at NASA could be useful tool to help communicate what is possible in XR. Below is a list of XR areas of research and what they could be used for. This list helped me to communicate better with those who have little experience with XR technologies and in turn help them to connect to the technology. If an engineer or designer wanted to know what types of XR experiences can be created, this list serves to show them how and where XR can be used.

- 1) Technology Demonstration - used to demonstrate the capabilities of a particular XR technology
- 2) Design Tool - used to place a designed product in the context of relevant elements or procedures
- 3) Assembly Simulation - used to recreate a physical process of assembly in XR. If there is an assembly procedure to mimic, this type of experience would be created.
- 4) Environmental Simulation - places user in a representation of another place
- 5) Instructional Simulation - teaches a user context and concepts. This can be used for certifications.
- 6) Workspace - used to enhance a workstation
- 7) Situational Simulation - used to place a user in a particular situation that they would typically not find themselves in, or in a place not often visited with emphasis on decision making
- 8) Visualization - creates a 3D representation of a difficult to imagine concept or element
- 9) Group Interaction - this is used to share group information with a user. Think of a group setting applied to any of these other areas.

- 10) Prototyping - used to set up a 1:1 duplication of the physical word and element to see how said element will behave
- 11) HUD - Used to layer CG elements into a user's POV
- 12) Teleconferencing - Used to network and link multiple users to a particular XR location
- 13) Robotic Avatar - Used to control a robotic avatar using a XR system
- 14) Multiplatform - Using a mixture of XR to interact with an environment. (i.e. using AR phone application with a VR system)

VI. Methods Used to Further Research

The research at XRSpace has been a combination of investigating and researching what some of the current workflows are for design here at MSFC and then identifying where in the design process XR technology would be most helpful. Most of the current XR projects at XRSpace are Virtual Reality Projects, so there is a workflow in creating the virtual reality experience. The workflow for creating a Virtual Reality experience, as defined by Jerald, and mostly used at MSFC, consists of the 1) Defined Stage, 2) Make Stage and 3) Learn Stage (Jerald 2015). The Defined Stage consists of the vision and goal of the project. It also encompasses the cost, risk and high-level design considerations of the project. The Make Stage consists of task analysis, prototypes and delivery. The Learn Stage contains the data analysis, scientific methods, communications and approaches. During my internship, I worked on a few projects. Each of these projects was at a different stage in the Virtual Reality workflow. This sheer number and variety of goals, projects, outcomes, expectations, people, departments, and problems to overcome gave me a chance to work with almost all the specific elements mentioned above.

This Practice-led design research has allowed me to identify a few critical areas by advancing and completing a variety of projects. As defined by Malins and Grey, Practice Led research involves the researcher as participant / observer ('reflective practitioner'). The research is collaborative, relying to some extent on the participation and feedback of [sic] architects, planners, and users (Malins and Grey 1995) The practice-led research I completed at MSFC has been a collaborative effort amongst many departments and projects.

VII. Simulation as a Design Tool

A. 4BCO2 Assembly Simulation

At MSFC there are ongoing efforts to improve CO2 removal on ISS. Not only for ISS, but for the Mars and other long-distance missions as well. These efforts are focused on producing an International Space Station flight demonstration of the next-generation four-bed molecular sieve system known as the 4BMS CO2 Scrubber (4BCO2) aka 4Bed. Currently in development, the rack will need to be installed on ISS scheduled for 2020 (Dankanich, J. W., & Morris, H. C. 2018). In order to help with identifying potential problems with the installation of 4BCO2 on ISS, a meeting was set up with a HFIT group from Johnson Space Center. The visitors came in to view a model mockup, inspect hardware items, and view a VR simulation of this Procedural Simulation. Here we see some screenshots of this VR project built at XRSpace to simulate this installation. I primarily worked to improve on the simulation. The simulation was made with Unity, ICE Creo, PiXYZ, Adobe Suite and Blender. In October, I performed a walkthrough of the VR simulation for the HFIT group and roughly 15 engineers, designers and management personnel who watched as I went from step to step installing the 4BCO2 rack. During the presentation, there was an increase in dialogue and discussions. Seeing the installation movements, issues that the group addressed prior were discussed in more detail. For example, in-depth discussion were had as to where the flight crew would actually grab the hardware to safely move it to the rack. Another topic discussed was the number of fasteners being used. When one performs a task, or sees someone else perform it, they start to get a more complete sense of what it will take to do an installation. Another issue addressed, was where to place the hardware in ISS to perform the unpacking of the rack. Finally, some design and manufacturing discussions took place while I was in the demo.

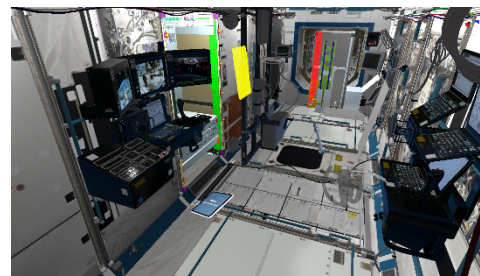


Figure 2 4BCO2 Simulation: XRSpace Lab

B. PCPA-PPSA Assembly Simulation

Yet another Assembly Simulation I worked on was the PCPA/PPSA removal and installation. This procedure involves the installation of the Purge Pump and Separator Assembly, or PPSA on ISS. The PPSA will be incorporated into the existing UPA, or Urine Processor Assembly, in place of the PCPA. This assembly will prove the purge capability of a scroll pump design concept on-orbit. In order for the PPSA to be installed, the existing PCPA will be removed (Dankanich, J. W., & Morris, H. C. 2018). The PCPA-PPSA simulation not only replicates the process for removal of PCPA, but also the installation of PPSA. For this simulation, I made an object triggering system that holds information on next steps, then shows next steps. I researched hoses, wire, and cables simulations in a virtual environment for use in the PCPA-PPSA simulation. This project was made with Unity, ICE Creo, PiXYZ and Blender.

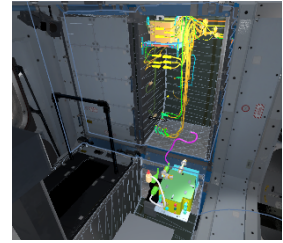


Figure 3 PCPA-PPSA Simulation: XRSpace

VIII. Virtual Reality Visualization

A. NEA Scout

The NEA, or Near-Earth Asteroid, Scout is a robotic reconnaissance mission that will be deployed to fly by and return data from an asteroid representative of NEAs that may one day be a human destination. It uses a solar sail and the current planned target is 1991VG (Johnson 2019). For this visualization, the designers wanted to have a practical mockup to get a sense of scale of the NEA Scout. Many designers are used to seeing their designed elements on 2D windowed displays, but this project shows the actual scale and size of the scout. The user has the option to pickup, move and also deploy the sails of the scout. This was made with Unity, ICE Creo, PiXYZ and Blender.

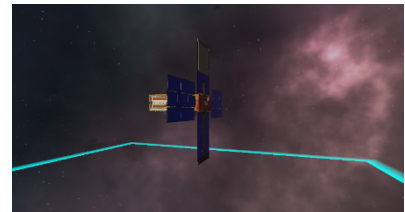


Figure 4 NEA Scout Simulation: XRSpace

B. Building 4487

Another visualization project was the rapid capture of 4487. As a possible tool for building design or historical record, this visualization is a walkthrough of rooms in building 4487. For this project I used a GoPro Fusion to capture numerous rooms and halls. I also used GIMP to change the photos and then built in some navigation in Unity.



Figure 5 Building 4487: XRSpace

IX. Integrating Existing Materials into XR

A. Tools and Labels in VR

Other critical elements in these simulations are labels and tools. Many NASA procedures have extensive labeling systems. Translating those instructions into simulations is helpful for XR Assembly Simulation building. For the 4BCO2 simulation, there was a need to not only label the actual part number, but also give it an on orbit, or OPNOM name.

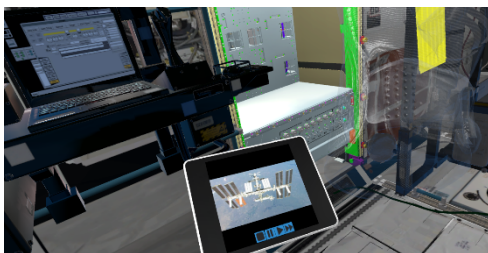


Figure 6 Tablet Tools, 4BCO2: XRSpace

Another often overlooked area of XR integration is the fact that existing materials like video instruction, pdfs, charts data and existing documentation can all be inserted into an XR simulation. Figure 6 shows this simulation's ability to also hold videos or instructions that are important for a NASA activity. Here I created a virtual tablet that contains a video play that can play video tutorials, documents and pdfs. The user can reference these while in the VR simulation.

B. Community Outreach

I was able to participate in some community outreach at the Racine Station Event held in September. I spent a few hours sharing the Mars Habitat VR simulation done by XRSpace lab. The event gave the lab an opportunity to share the experience of Mars with children and adults from the community.

C. PiXYZ - CAD in VR

I researched a program called PiXYZ Review which allows a user to pull in almost any CAD model to view. With a few minor tweaks, a designer or engineer who might not know how to script for a game engine or build a VR experience can view an object in VR. The tool can perform basic visualization, but its ability for manipulation, context, setting and multi object interaction is limited.

D. Development Task List

I was also able to implement a development task list for XRSpace projects. It is my hope that future groups will be able to develop a ticket system, or software solution like GitHub or Unity Collab to allow multiple individuals, like a programmer, modeler and a designer, to all work together on the project at the same time. This task list was just a first step toward towards that goal.

X. Conclusion

A look at the landscape of Extended Reality shows a variety of immersive tools that one can use to enhance goals at NASA. Much like picking the right tool for the job, future work at XRSpace will help to identify what types of XR experiences to build and where they will be most effectively implemented. These immersive tools have the potential to lower costs, improve safety and help enhance design at NASA. Continuation of practice led research needs to be continued to correctly identify the platforms, types of media, and the level of immersion that will be needed to best compliment areas of NASA work.

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