

Mars Interactive: Exploring the Immersive Potential of Browser Based Extended Reality

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Abstract

The Covid-19 pandemic has resulted in an increased demand for online collaborative tools, one such area which has seen a surge in interest has been in eXtended Reality (XR). Though tools such as Zoom and Skype have existed to simulate the environment of professional meetings there has been an absence of an online alternative to kinaesthetic tasks. Currently virtual reality has seen use in the training of medical students, specifically in the task of surgery, and as a rehabilitation method for those who are dealing with either psychological or physical trauma. These tools however have been limited by both a requirement for external construction of the scenarios and a dependence on offline mediums with local installations. The toolset described in this document aims to alleviate these problems with current training tools by allowing supervisors to construct training scenarios with modifiable parameters to vary the required training tasks. The scenario used for discussing the capabilities of the system is that of a Mars exploration team, used to showcase the flexibility of the toolset.

Declaration

I, Kyle Dick confirm that this work submitted for assessment is my own and is expressed in my own words. Any uses made within it of the works of other authors in any form (e.g., ideas, equations, figures, text, tables, programs) are properly acknowledged at any point of their use. A list of the references employed is included.

Signed: Kyle Dick

Date: DATE OF SUBMISSION.

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1. Introduction

In the past XR experiences have been limited mostly to systems which can support their installation and operations. Recently there has been a push to integrate this technology into web development such that similar experiences are accessible through a standard web browser. A forerunner in this regard was the WebVR API which is currently deprecated, replaced instead with WebXR that expands its focus from just Virtual Reality to the entire spectrum of Extended Reality [1]. Presently VR has been identified as a desirable solution to the problem of training students for practicing surgery in the medical field with benefits associated with the innate advantages of virtual environments and the improvement to real world abilities [2]. The problem presented with these applications however is the reliance on the systems which they run with VR applications sometimes requiring demanding hardware in order to support the rendering of their 3D assets. The strength of XR based training is the ability to construct scenarios which would be either dangerous or costly to implement in the real world and part of the identified benefits of this medium is the immersive capabilities innate to the technology which has shown positive results in current use [3].

The aim of this project is to engineer an immersive experience using the WebXR API for hardware integration into a web browser environment. The importance of this system would be in the benefits to real world training applications where immersive experiences are valuable in attaining experience while protecting trainees and providing a low cost alternative. One of the aspects of this project which would provide challenge is in the management of different aspects of XR as this encompasses both VR, AR and MR. The goal would be to explore the immersive capabilities of at least two of these technologies, namely VR and AR. A further breakdown of the objectives that were outlined to achieve the aim are included below. These were constructed with the explicit goal to answer the question of whether the web browser is a suitable environment for immersive extended reality experiences.

1.1 Objective A: Immersive VR

To explore the capabilities of web browser based VR this project will attempt to engineer an immersive experience modelled after the planet Mars. This virtual environment would allow for many demonstrations of how the technology could support immersive experiences.

An overview of the steps involved in this process are discussed below. This objective was developed using an Oculus Quest 2 headset.

- Objective A.1 Construct a 3D environment which supports a user's movement through the terrain.
 - Allow for the loading of 3D models to act as terrain.
 - A lighting system which mimics the presence of the Sun.
- Objective A.2 Implement a model of Mars' physics into the environment.
 - Basic capabilities for the user to pick up objects and put them back down in the environment.

- Objects in the environment move in a manner expected of the environment's gravity.
- Objective A.3 Attach correct textures to the environment that displays correctly while the viewpoint is moved.
- The viewpoint refers to the areas which are currently in view for the user.
 - Due to memory constraints for browser based applications this area must handle the ability to manipulate resolution such that the textures do not break immersion by being too low quality when the user is close but will also not cause problems with memory by loading high quality textures where the user cannot perceive them.
- Objective A.4 The addition of interactive elements to the environment.
- Small goal based objectives for the user to engage in within their surroundings.
 - This will involve interacting with the surroundings; picking up objects or other users.
- Objective A.5 Integrating internet related functions
- Allow for multiple users to inhabit the same environment and interact with the same objects.
 - A 'tag' system such that objects in the environment can offer to redirect the user to other locations within the web.

1.1 Objective B: Immersive AR

To explore the capability of browser based AR this project will remain with the theme of Mars and implement a virtual replica of a Mars Rover which users can place in their real world environment and control. When developing this objective the hardware involved is assumed to be a mobile phone with AR capabilities.

- Objective B.1 Implement the placing of virtual objects within the real world environment.
- In the early stages of this objective multiple objects should be loaded into the environment to determine the capabilities of different sizes
- Objective B.2 Implement the movement of an object in the real world environment.
- An object should be able to move around in the real world environment in a believable way.
 - This section will contribute to an immersive experience with accurately moving the Mars Rover in the following section.
- Objective B.3 Implement control of the Mars Rover through the web browser.
- Multiple forms of control should be explored which can include using on screen buttons or drawing a path through the camera.

2. Background

This section is dedicated to the discussion of the concepts underlying the solution to our aims. Within this section Extended Reality and the related areas will be further explored as this will aid in the discussion of the solutions later within this document.

2.1 Discussion of Extended Reality (XR)

XR is an umbrella term which encapsulates Virtual Reality, Augmented Reality, Mixed Reality and other forms of using rendered graphics to alter the perception of an individual's surroundings. The scope of the solutions discussed in this report refer primarily to the applications of Virtual Reality and Augmented Reality within the web browser however the other areas of Extended Reality are valuable to include due to the potential for future work based on the outcomes of this project to incorporate these other applications.

2.1.1 Virtual Reality (VR)

VR involves creating a virtual environment through entirely 3D rendered components that is displayed to the user through appropriate hardware, commonly known as visors. Most of these visors are paired with a set of controllers which will communicate with the WebXR API in this solution to interact with the virtual components of the environment. VR has seen a demand within fields in which training scenarios are either too dangerous or expensive to recreate in a real world case. The company VR-Interactive has already presented virtual reality solutions to the demands of industry for VR training tools, one such case being a crude oil burner simulation [4].

2.1.2 Augmented Reality (AR)

AR involves capturing the real world through devices such as the camera of a mobile phone and rendering virtual elements which are able to maintain a consistent position in the environment. These objects can persist within the environment when the camera is not currently pointing in its direction, using the real world surfaces and environment to track the positions of virtual objects. A popular example of this technology being used is the early implementations present within the Nintendo 3DS which used physical cards to initialise the virtual objects in the environment. Since then this technology has progressed such that the virtual objects no longer need any specialised real world objects to initialise the virtual elements, this can be seen in the recent google AR & VR experiments where AR is used to provide directions with google maps [5].

2.1.3 Mixed Reality (MR)

MR technology lies between the extremes of both VR and AR. While one method focuses on replacing the real world with a virtually rendered one and the other relies on rendered graphics which overlay the users surroundings, MR seeks to blend both in order to combine the virtual components with the real world. The Microsoft Hololens is an early adopter of this type of extended reality, a visor which resembles the hardware which is known to support

virtual reality however replacing a digital screen with a clear panel through which rendered graphics are drawn [6].

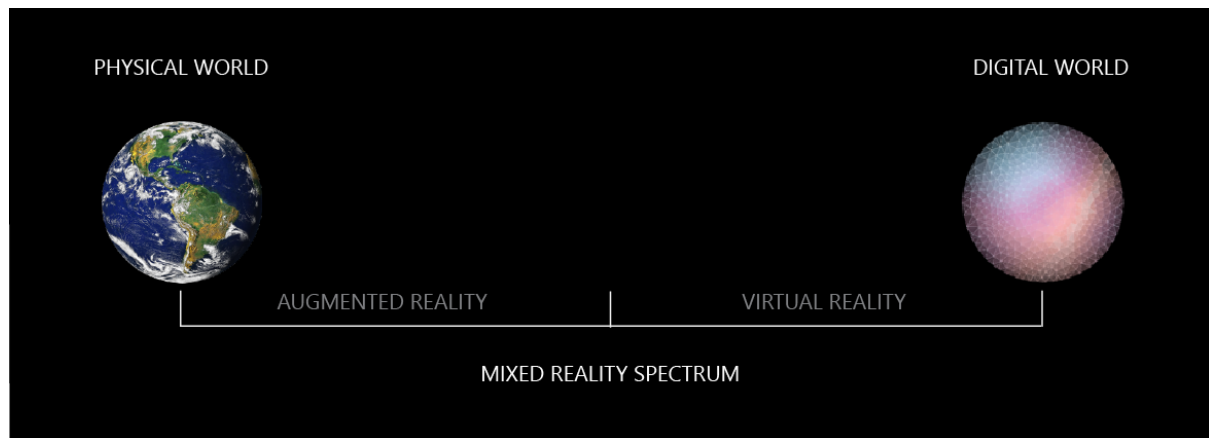


Figure 1: The Mixed Reality Spectrum [6]

3. Review of Related Literature

To assess the achievability of the objective given earlier in the introduction this section will examine similar work which deals with areas related to the aim. Through examining the conclusions that previous research has arrived at the stronger the case for the proposed aim will be. The literature which has been collated below has been organised into sections related to aspects of the development process.

3.1 Virtual Environments

Objective A which was outlined in an earlier section is rooted in the idea of engineering a virtual environment which the user is able to interact with through exploration and manipulation of objects. In the past there have been investigations into using virtual environments for a wide array of uses, one of which is its applications within education. Analysis of the applications of virtual environments has shown there to be a benefit to the ability of an individual to learn new skills which would normally require for a real world experience to develop naturally. The implementation of virtual reality for this has the additional benefit of decreasing the risk of damage to the individual and reducing costs associated[2][3]. The benefits of VR specifically have also shown benefits to the development of knowledge where practical kinesthetic learning methods would not traditionally be incorporated.

3.1.1 Collaborative Virtual Environments

Outside of training scenarios virtual reality and virtual worlds have seen popular use in the entertainment industry. One particular case is the social application VRChat which allows for users to assume the role of 3D avatars in a virtual world and interact with others users through the use of either VR hardware or a standard computer desktop configuration [6].



Figure 2: Virtual avatars greet a user within a virtual world through the application VRChat [6].

The application, while built for entertainment purposes, has relevance to our goals as it provides evidence that there are implementations for collaborative experiences within XR which are accessible through the use of internet access. The application itself requires an installation which is where the implementation differs from the stated goal of allowing the user to access from the web browser.

3.1.2 Immersive Experiences and XR

The strength of XR lies in the immersive potential that it contains which is an important role especially for any application which incorporates VR. The technical requirements of the engineered solution should be grounded in an attempt to create an immersive experience and as such the success that previous attempts with immersive systems have attained should be examined. A study which examined the effect that a Virtual Reality Learning Environment (VRLE) had on a students understanding of English paragraph structure found that the benefits that immersion was most suited as an exogenous variable in regards to how beneficial it showed to be in the outcome [7].

3.1.2 Interaction with Virtual Environments

A core component to the engineering of an immersive virtual experience is how the user is able to interact with the different objects present within the environment. A study was conducted to investigate how Fitts' Law applies to the 3D control methods of virtual reality [8].

Examples of Physics Engines with A Frame?

Realistic lighting Systems?

How have input devices been used with Extended Reality?

How have real world images been used in Extended Reality?

What past experience has there been with mode loading for web pages?

Goal Based Operations in VR?

Multiple User and Collaborative Based VR?

Uses of AR in the real world, examples of WebXR in AR?

Virtual Remote Control?

3.1 Hardware Devices

There is currently a large range of devices available both in research and to the public which allow for interacting with the virtual world. The devices can be separated by whether they are output devices or input devices.

3.1.1 Output Devices

Output devices are responsible for displaying the virtual elements of extended reality. They are available in a range of forms, each catering to a different section of the XR spectrum. In the objectives previously it was stated that the focus of this project would be in the realms of VR and AR. The main output devices that are concerned with these areas are those which are able to replace the real world environment with a virtual substitute and those which are able to capture the real world while rendering graphical components within that environment often overlaying the presence of real objects.

Virtual Reality Visors are the most common method of displaying VR to a user however there are concerns inherent to this medium, one notable example is the phenomenon of Virtual Reality Sickness. This is a form of motion sickness which an individual can experience through the use of VR visors, research was conducted which attempted to create an index for this form of motion sickness through the use of a VR motion sickness simulator.

3.3 Virtual Reality (VR)

The emergence of VR has coincided with research into the benefits this technology can have to different areas of data gathering due to its immersive capabilities. One such investigation of this was in the creation of R2VR, a package which allows for developing and performing VR experiments using R [7].

3.4 Virtual Objects in Real Environments

3.5 Defining an ‘Immersive Experience’

4. Requirements Analysis

Previously in the introduction the aim and objectives of this project were briefly outlined. This section will take an in depth analysis of those objectives and the steps taken to achieve them.

4.1 Aim and Objectives

The aim of this project which was defined earlier is to explore the immersive potential of extended reality within a web browser environment. The approach taken when creating the objectives set to achieve this aim was to define the manner in which immersion would be explored. For each of the two main objectives immersion was defined as being the ability for the user to interact with the rendered elements of the virtual world as if they were physical objects within the environment. Examples of this in practice would be the user picking up a virtual representation of a rock within the virtual world of Mars and tossing it into the air, they would observe the rock to leave their grip and travel in a trajectory expected of the Mars environment. A similar example which applies to the AR objective is the ability to remotely control the virtual rover through the use of the browser, similar to a remote control car.

4.1.1 Objective A

The main objective of this section is to construct a VR simulation of the planets Mars which users can visit through a standard web browser. As stated previously the experience should be immersive so when breaking down the steps involved to achieve this main objective, referred to as the sub-objectives in this context, a particular focus is situated on features which allow the user to interact with the virtual elements.

4.1.1.1 Objective A.1

This objective is centered on creating a generic 3D VR environment which will be accessible through the web browser. For the purposes of hosting it was decided that Github Pages would be the most optimal method for the purposes of achieving the aim, the extended reasons for this will be discussed in a later section. The main reason for this decision however is due to Github being used for version control of the project which made Github Pages an ideal solution compared to employing a paid service or creating a server which may detract time from the goals of the project.

The result of this objective should be for a featureless 3D VR environment in which the user can access through the web browser and explore through movement across the terrain. Within this environment will be several objects which exist as a means of testing the interactions between the user's movement and the environment. The terrain itself and the objects within it will primarily be objects imported into the environment which originate as assets developed specifically for this project or properly sourced assets located from third party sources. In the early stages of the project there were considerations made as to which framework would be

best suited for rendered the 3D graphics required for this project, the results of this comparison were that A-Frame would be the ideal choice due to its simplistic nature compared to the other available frameworks and it's relation to Three.js which would allow for a greater degree of control. A-Frame also contains the benefit of importing glTF models which will act as the objects in the virtual world [9].

Lighting is an important aspect to the virtual world as it allows for the objects present to be seen by the user. In the case of this objective the light should be present as a representation of the Sun, as is the case on the real Mars. The minimal requirement would be for a single static placement of the light source however the most ideal result would be a dynamic light source which moves through the environment as time progresses as this will result in a greater degree of immersion.

The virtual world is intended to be rendered through the use of a VR Visor which will be operated by the user and due to this there are unavoidable restrictions in how the movement system will operate in the system. The vast majority of users will have restrictions in regards to the available real world space in which they can inhabit, due to this it is inevitable that a user will try to move in the virtual world but will be prevented as a barrier in the real world prevents the movement. It is of great importance that an alternate movement option is available to the user, the proposed solution is for the user to have the ability to move their position in the world through the use of a placed marker to which they will be relocated. The exception to this would be users who are experiencing the virtual world through a computer screen in which case their movement is not limited.

The benefits this objective will contribute to the immersive experience will be observed in the movement capabilities of the user. The result of this object should allow the user to move freely within the environment and explore a featureless terrain.

4.1.1.2 Objective A.2

This objective will focus on improving the ways in which the user will be able to interact with the virtual environment. At this stage the interaction the user should have with the environment is restricted to movement around the virtual space which this objective will seek to expand.

The first step that will be taken in regards to expanding interaction is the implementation of features which will allow the user to use input devices such as touch controllers to manipulate objects in the environment. A simple example of this which was mentioned earlier is the ability to pick up a rock and toss it back out into the environment. In order for this to work however there must be a system in place to handle the physics of objects within the environment. Defined more exactly, this means that the system should handle the displacement of objects in the environment in such a way that it mimics how objects in our real world behave as a result of gravity. An additional effort should be made to model the way that the physics engine treats the objects to reflect the gravity of objects on Mars rather than Earth.

The benefits this objective will contribute to the immersive experience will be observed in the ability the user gains to manipulate the objects in the environment. The user will be able to gain an understanding for how their environment behaves and through such an immersive understanding of the Mars environment.

4.1.1.3 Objective A.3

At this stage the virtual world will consist of a generic VR environment with an implemented physics engine with which a user can enter into and interact with objects in the environment. The current environment will however reflect Mars in only the physics which this object seeks to remedy. This section will give an overview of how this environment will be transformed to more closely resemble the Mars surface.

The challenge of this section was in finding a way to provide the user with an accurate visual representation of the Mars surface while balancing the ability to interact with the environment. The initial plan for this section involved using images as a texture for the meshes which the 3D models would use, however this introduced a problem in which pictures for certain geography would feature objects which the user should expect to be able to interact with but would be unable. The solution that was devised to solve this problem was to select one of the quadrangles of Mars and instead model the environment to reflect this smaller area of Mars for the user to explore. The final decision was made to base the setting of the experience within the Jezero Crater due to this being the current location being surveyed as a part of NASA's Mars 2020 project [10].

The constraints which will affect the progress of this objective result from the web browsers limits on memory. This is in direct conflict with one of the ways that the project hopes to achieve its aim as memory will be important in displaying high resolution textures to the objects in the virtual environment. During this section care must be taken to allow the system to manipulate the resolutions at which textures appear such that the immersion is not broken for the user when faced with a low resolution image at a close distance, low resolution imagery however may find utility in allowing the rendering of vast distances without placing strain on the memory limits of the web browser.

The benefits this objective will contribute to the immersive experience will be observed in the users ability to recognise their surroundings as being on the planet Mars. Previously the terrain would be a bland textureless environment, with the addition of the contributions from this objective it should resemble the Mars environment closely.

4.1.1.4 Objective A.4

The current progress of the virtual world should provide the user with an environment which is recognisable as Mars with possibilities for interaction with the environment. This section aims to demonstrate the possible activities the user could partake in while within the virtual world. The method to be used to achieve this goal will be through the introduction of goal

based objectives for the user to complete. Each of these should reflect the previous efforts of the objectives until this point.

This stage of the project will also introduce the Mars Rover which will roam freely through the environment with the possibility available for the user to interact with the object. This will be encouraged through an objective to guide the object through the use of the controllers. The exact objectives will be determined after review of the previously implemented objectives to account for complications which may arise during the development process, however the following objectives should be included at a minimum:

1. An objective for the user to walk from one point within the virtual world to another. This may involve a change in altitude. This objective should also account for the different movement types (marker based relocation or free movement) and as such should include both variants in their completion conditions.
2. An objective to interact with an object in the environment. This could be with a simple rock on the surface or by guiding the rover to a point within the virtual world.

The benefits this objective will contribute to the immersive experience will be observed in the user having a greater understanding of the way the system allows them to have a degree of control over the environment they exist within.

4.1.1.5 Objective A.5

At this stage of development the virtual world should be completed with the user presented with opportunities to interact with their environment in ways which are perceived as being immersive. The system until this point has neglected the advantages to the experience which could be contributed as a result of the web browser environment that it is hosted within.

One of the main additions to the system that will be contributed within this objective will be the support to a collaborative experience. This will take the form of allowing users to share the same virtual world and interact with the environment simultaneously. This would require the avatars of each player to be visible to all others within the session with some form of unique identification for each player through the introduction of giving the user an identification string which they could change from within the experience.

The final addition which will be made in this section is the introduction of a 'tag' system in which attachments could be made to objects in the virtual world which can be interacted with to redirect the player to other locations on the web. There is a high risk for this addition to contradict with the players immersion however if they are pulled from the experience by a redirect which will require experimentation to find the best method of achieving a smooth transition with this system. The currently presented solution is for the 'tags' to instead open a new tab within the user's browser which will result in them staying present in the virtual world instead of being extracted from it.

4.1.2 Objective B

The main objective of this section is to explore the immersive potential of extended reality through the use of the WebXR API to support hardware which allows for AR experiences.

The resulting goal from the steps in this objective will be the creation of a virtual Mars rover which the user can pilot in the real world environment viewable from the camera of a device which supports AR content. The hardware used in the exploration of this objective would be a standard mobile phone which is able to support AR content.

4.1.2.1 Objective B.1

4.1.2.1 Objective B.2

4.1.2.1 Objective B.3

4.2. Textual Requirements

4.2.1 Requirements Key

This section details the requirements for the system. The following key is used to track the requirements with each requirement marked with either an A or B to indicate which objective the requirement encompasses. If a requirement lacks this indicator then the requirement is assumed to encompass both objectives.

ID	Requirement	Priority
FR(A/B)-U/S-No.	Textual description of the requirement.	MoSCoW priority of the requirement
NFR(A/B)-P/C/R/S/U-No.	Textual description of the requirement.	MoSCoW priority of the requirement

Functional Requirements (FR) are requirements which detail the system functionalities and how the function of the system will help achieve the overall goals. The types of functional requirements this system is concerned with are as follows:

1. User (U) - Requirements related to how the user interacts with the system.
2. System (S) - Requirements related to how the system behaves.

Nonfunctional Requirements (NFR) are requirements which detail issues related to the system's capabilities and its constraints. The types of nonfunctional requirements this system is concerned with are as follows:

1. Performance (P) - Requirements related to how the system is able to perform. This includes the ability to deliver a stable frame per second count when serving the graphical components.
2. Compatibility (C) - Requirements related to how well the system is able to perform when varying hardware, browser and the respective versions of both.

3. Reliability (R) - Requirements related to how prone the system is to both minor and critical failure.
4. Security (S) - Requirements related to the security of the system and the protections in place against malicious use. With the main focus of this system based within virtual reality this area will also concern itself with protecting users from malicious imagery being injected into the user's vision.
5. Usability (U) - Requirements related to how easy the user can operate the system and navigate its functions.

Both functional and nonfunctional requirements have been prioritized using the Moscow method. Therefore each requirement has exactly one of the following priorities:

- Must Have (M) - The requirements with the highest level of priority. These requirements are fundamental to the operation of the system.
- Should Have (S) - The requirements which are not as fundamental to the system as the previous category but ideally should be present in the final version of the system.
- Could Have (C) - The requirements which are not important to achieving the goals of the system but would be beneficial to the system.
- Won't Have (W) - The requirements which will not be present within the system. This is either due to them not fitting the scope of the system or being ill suited but still worth noting.

4.2.2 Functional Requirements

Below a collection of the functional requirements are given. The order in which each appears correlates to the timeline in the sense that earlier objectives which involve the presence of a requirement will result in a higher position on the below table.

ID	Requirement	Priority
FR-S-01	The system must be accessible through a standard web browser.	M
FR-S-02	The system must allow for the loading of 3D models which will act as objects in the environment	M
FR-S-03	The system must support 3D models imported through the format glTF (gl Transmission Format).	M
FR-S-04	The system must utilise the WebXR API to integrate the XR hardware into the web application.	M
FR-S-05	The system must be able to render 3D graphical objects in the environment.	M
FR-S-06	The system must include lighting which illuminates the environment such that the rendered objects are visible to the user.	M
FR-S-07	The system should allow for the use of a digital screen to act as	S

	the visual output in the absence of XR hardware.	
FR(A)-U-08	The user must be able to move in the real world while operating XR hardware and have this movement reflected by the system.	M
FR(A)-S-09	The system must support the placing of markers in the environment as an additional movement method	M
FR(A)-U-10	The user must be able to place markers in the environment which can be used to relocate their position.	M
FR(A)-S-11	The system must support a physics engine which handles the movement of objects in the virtual world which reflects the presence of gravity.	M
FR(A)-S-12	The system should resemble the gravity of the Mars environment in its application of the physics engine	S
FR(A)-U-13	The user must be able to interact with the surrounding environments by using controllers to pick up objects in the virtual world.	M
FR(A)-S-14	The system must process interactions made with the environmental objects to be handled with the physics engine.	M
FR(A)-S-15	The system should feature terrain which resembles the Jezero Crater geography.	S
FR(A)-S-16	The system must be able to display images in the environment as textures which are applied as meshes to the virtual objects.	M
FR(A)-S-17	The system must scale the resolution of textures in the virtual world with relation to the player's proximity.	M
FR(A)-S-18	The system should allow for the creation of objectives which will have a set of conditions for completion.	S
FR(A)-S-19	The system should display the current objective in an area which the user can view.	S
FR(A)-U-20	The user could be able to view the list of objectives in the environment on command.	C
FR(A)-S-21	The system should allow for objectives which have had their completion conditions reached to be archived as such.	S
FR(A)-U-22	The user could be able to reset an archived objective such that they could experience it once again.	C
FR(A)-S-23	The system should include the presence of a Mars Rover object in the environment.	S

FR(A)-S-24	The system should allow for the Mars Rover object to patrol the virtual environment along a set of predetermined paths.	S
FR(A)-S-25	The system could allow for the Mars Rover's movement patterns to reflect that of the Perseverance rover.	C
FR(A)-U-26	The user should be able to influence the movement of the Mars Rover through interaction with it.	S
FR(A)-U-27	The user should be able to use controllers to interact with the Mars Rover, ie. pushing buttons present on the object.	S
FR(A)-S-28	The system should allow for any interactions in the environment which require the presence of a physical controller such as an XR touch controller to be possible with a standard keyboard and mouse configuration.	S
FR(A)-S-29	The system must allow for users to join into the same session as other users.	M
FR(A)-S-30	The system must allow for the users to view the avatars of other users within their session.	M
FR(A)-U-31	The system should show a unique identifier for each user.	S
FR(A)-S-32	The user could be able to change their identifier.	C
FR(A)-U-33	The user could be able to create their own private sessions.	C
FR(A)-S-34	The system should allow for URL attachments to objects in the environment.	S
FR(A)-S-35	The system should be able to open a new tab within the user's browser when a URL attachment is interacted with.	S
FR(A)-U-36	The user could be able to disable URL attachments to prevent the opening of new tabs.	C

4.2.3 Non-Functional Requirements

ID	Requirement	Priority
NFR-P-01	The system must be able to render the environment while maintaining a stable fps (frames per second) count	M
NFR-S-02	The system must be	M

	protected from outside attacks which could affect the images displayed to users	
NFR-R-03	The system must not suffer critical failures during normal operation	M
NFR-U-04	The system controls should be easily understood by the user	S
NFR-C-05	The system should run on all the popular web browsers	S
NFR-C-06	The system should be able to fall back on the device screen in the absence of the appropriate hardware	S

5. Evaluation Strategy

5.1 Requirements Assessment

The main indicator of the progress of the project is the progress made in achieving the requirements laid out earlier within the document. Throughout the project the requirements will be assessed as each milestone of the project is reached.

6. Project Management

6.1. Project Timetable

6.2. Risk Analysis

6.2.1 Risk Classification

To manage the progress of this project efficiently it was important to identify possible risks that could prevent the realisation of the goals laid out earlier in this document. To aid in the identification of the risks the following key was used to classify the associated risks:

- People (P) - Risks which are the result of issues related to those individuals involved in the engineering of solutions.
- Technological (T) - Risks which result from the technology being used to engineer the solutions. This involves the software, hardware and frameworks used.
- Requirement (R) - Risks which result from changes to the requirements of the project. Examples of such being a requirement being dropped from the scope or a requirements priority undergoing a change.
- Estimation (E) - Risks which result from ill estimations of the project timing, capabilities of an individual or understanding of a certain technology.

ID	Risk	Risk Type	Description
R-P1	Textual Title of Risk	People	Textual Description of the Risk

7.2.2 Risk Identification

ID	Risk	Risk Type	Description
R-P1	Illness	People	Particularly important due to current events surrounding the Covid-19 pandemic. If an individual falls ill during the implementation of the solutions this could cause contributions to the project to cease temporarily.
R-P2	Conflict of Timing	People	Events within the personal lives of the contributors could cause a temporary cease in addition to the solutions. This could be due to requirements for other courses or personal emergencies.

R-P3	Lack of Experience	People	The technologies involved in the project may be unfamiliar to those involved in engineering the solutions. Time has been taken to familiarise the contributors with the tools however a lack of understanding could cause temporary problems in achieving objectives.
R-T1	Loss of Project Documents	Technology	Currently important documents pertaining to the project are being stored both locally and in multiple online cloud storage services. There is still a risk of some progress being lost even with the protections of version control however. This could range from either minor inconveniences to large setbacks.
R-T2	Service Downtime	Technology	The system currently relies on the services of Github for hosting the project. In the event of downtime with this service progress on the public web will be temporarily slowed.
R-R1	Requirement Changes	Requirements	The system as it is planned currently could undergo changes to its requirements set. This is a possibility in both the early and late stages of the project.
R-E1	Time Estimations	Estimations	The current planned timings for the project have a possibility to be found inaccurate. This can be beneficial to the project as areas may require less time to implement than intended however it is equally likely that not enough time is allocated. To counteract this the time given to each task is generous.

6.2.2 Analysis of the Risks

This section includes the analysis of the identified risks associated with the project.

Each requirement was assessed on three main criteria, these being:

1. Probability - The chance of a risk affecting the project at any stage.

- a. Very Unlikely
 - b. Unlikely
 - c. Possible
 - d. Likely
 - e. Very Likely
2. Consequence - The resulting impact on the project of this risk, assuming the worst.
 - a. Insignificant
 - b. Tolerable
 - c. Serious
 - d. Catastrophic
3. Priority - The importance of monitoring for this risk.
 - a. Low
 - b. Medium
 - c. High

ID	Risk	Probability	Effect	Priority
R-P1	Illness	Possible	Tolerable	Medium
R-P2	Conflict of Timing	Possible	Serious	High
R-P3	Lack of Experience	Unlikely	Serious	Medium
R-T1	Loss of Project Documents	Very Unlikely	Serious	Low
R-T2	Service Downtime	Very Unlikely	Catastrophic	Low
R-R1	Requirement Changes	Likely	Serious	Medium
R-E1	Time Estimations	Possible	Serious	Medium

6.2.2 Risk Planning

6.2.2 Risk Monitoring

6.3 Consideration of Professional, Legal, Ethical and Social Issues

6.3.1 Ethical Issues and Health Concerns

One of the identified risks associated with virtual reality specifically has been the ability it has to induce a form of motion sickness in the user. A study was conducted in an attempt to

create an index for levels of motion sickness experienced by those who used virtual reality equipment [8].

6.3.2 Legal Issues

The solution as it will be implemented showcases a demonstration of the system by constructing a replica of the Mars environment. In order for this to be achieved the use of 3D models is required and in the case of any included 3D model the correct copyright must be respected for any assets that were not created by those included in the creation of the solution.

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