What are The Future Prospects for Data Communications within Space Exploration?

A dissertation submitted in partial fulfilment of the requirements for the degree of Bachelor of Science (Honours) in Computing

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Declaration

I hereby declare that this dissertation entitled *What are The Future Prospects for Data Communications within Space Exploration* is entirely my own work, and it has never been submitted nor is it currently being submitted for any other degree.

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Abstract

This dissertation answers the question “What are the future prospects of data communications within space exploration?”, and is split into two sections. The first section of the project is intended to study the current methods of data communications within space exploration, researching the future possibilities and how they can be implemented in space. The second section is the development of a game and a website based on the research carried out in the first section with the idea of providing a fun learning opportunity suitable for all ages.

For the first section of the project, secondary data collection methods are utilised by collecting information from relevant literature. The project investigates different areas of the topic such as the history of communications and space exploration, the current methods that are used to communicate in space, security techniques, possible future developments, and limitations while communicating in space.

The second section of the project, which is the development of a game and website based on the secondary data collected in the first section, uses the primary data collection methods, in the form of questionnaires and testing to gather valuable information to create a functional game fit for purpose.
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1.0 Introduction

‘Communications’ is a term that is used to describe how information can be sent and received through speaking, writing and various other methods (Murray et al., 1961). Further developments within communications has led to the rise of the phenomenon of digital communications. This is the use of transmitting information electronically, usually through a computer processing unit (Kolimbiris, 2000).

Data communications within space exploration will be analysed in this dissertation project. This topic was chosen because there has been an increasingly strong interest in space exploration for many years. Probes, telescopes and rovers are being sent all over the solar system and beyond on a regular basis to perform scientific experiments to help us further our understanding of space.

This dissertation is a worthwhile investigation as it is apparent that there is a growing need to find out more about space. This urge to learn more is increasing on a global scale, for both personal and commercial use. Due to this topic of space being of keen interest to the public, an evaluation of communication within space exploration will be conducted. With that in mind, a question was coined to be answered within this dissertation project: “What are the future prospects for data communications within space exploration?”

This project has two main aims. The first is to carry out research in order to answer the question posed. This includes researching data communications within space exploration and the future prospects. The second aim of this project is to offer a suitable learning activity to the general public. This will involve displaying the findings of section one on a website and creating a game based on this knowledge.

The objectives are as follows:

- To understand the history of data communications and space exploration and how communications first developed.
- To identify the methods of how communications are possible in and around space.
- To evaluate the security behind communications that are sent to and from Earth.
- To assess how real life experiments (cases) such as rovers and probes communicate and send data back.
- To produce a game and website based on the findings to give a non-biased view of how communications in space are achieved in the form of a fun activity.

- To develop a game and website that is user friendly and is appropriate for all ages.

These objectives have been chosen after deciding the best method to approach this topic with the intention to examine various other topics within this overarching subject. Achieving the stated objectives will help answer the question that has been posed in greater detail. In addition to this, it provides an excellent opportunity to demonstrate the research findings on a website thus achieving the goal of creating a fun learning activity.

The first section of the project will be to carry out widespread research with regards to the topic in question. In order to complete the research, the project will evaluate data from relevant literature, sources that are known to be reliable by being published in journals, books and articles. Once the literature review has been completed, the second main section of the dissertation will be tackled via the production of a game and website based on the overall results found. As mentioned above, it will be essential for both the game and the website to be user friendly and suitable for all ages. In order for this to be done, suitable programming languages adequate for the game aims and objectives will be investigated.

The project will also have a detailed discussion into the methodology that has been adapted within the project. The discussion will also include the data collection methods and sampling discussing how the data can be obtained. Furthermore, this section will look at the development of the project along with the testing and feedback gained from the use of questionnaires. The last part of this section will evaluate and discuss the ethical issues and limitations behind the project.

The final section of the project will evaluate the results from both the literature that has been reviewed, and from the data that has been obtained through the questionnaires. The project will also look at the results of the development of the game and website before and after receiving feedback with regards to testing. This section will also include an analysis of the statistical data collected from the questionnaires. Once the results and findings of both sections of the project have been discussed, a summary of the project will be completed to provide an answer to the question that is being asked.
2.0 Literature review

A literature review has been conducted on data communications within space exploration, with a range of sources analysed to determine how communication has been possible in space, along with examining future prospects within this field. To begin, the literature review will be based on an overview of data communications and space exploration which will be followed by focussing on certain aspects of the subject, such as its use, evolution and the subsequent development of space exploration through the technology created to allow us to communicate in space.

2.1 Data communications

The term ‘data communications’ refers to the process of transferring data from one location to another (Cole, 1999). This transmission is achieved by converting the data (such as characters and numbers) into digital signals. These are also known as electrical or binary signals, which are composed of binary digits 1 and 0 (Cole, 1999). Historically, this began via the use of the telegraph which was a revolutionary moment where long distance communication became possible. The telegraph itself was a network of data communication where messages were converted into Morse code and transmitted as electrical signals. The receiving telegraph would decode the message back to its original state. The telegraph system comprises of dots and dashes where an electrical signal was either sent as a short burst of electrical current (dot) or as a longer burst of electrical current (dash). However, the use of the telegraph reduced substantially after the advent of the telephone (Cole, 1999).

A transducer which is a device that converts one form of energy into another form is required in all data communications e.g. talking into a microphone (Mirabito and Morgenstern, 2004). A transducer can produce a signal than can be processed, stored and transmitted by converting what we say, hear or see e.g. a camera.

Terrestrial network foundations are simply not capable of meeting the needs of activities that are required due to their physical limitations (Santamarta, 2014). Therefore, to enhance this, satellites are regularly designed and developed prior to launch into the Earth’s orbit. Satellite Communications (SATCOM) play an essential part in delivering an accessible worldwide telecommunications system (Santamarta, 2014). Satellite networks have become a growing market within many fields, an example of certain sectors are; Aerospace, Military and
Governments, Emergency services and finally the Media (there are others). Therefore, the data that is captured and created from them can be very vital.

2.2 Data Communication and Space Exploration History:

Throughout the early years of the 19th century, space exploration was a field that most nations wanted to be part of (Levine, 1994). Space exploration had always been a topic of debate throughout the first half of the 1900s, however, the main reason for the lack of exploration had been due to the amount of funding required. The funding granted by each nation was dependent on the political will of the nation because governments would analyse the expenditure and of course evaluate the interests of the state (Launius, 2004).

The 1950s brought about a revolution in terms of space exploration. The beginning of space exploration commenced because of Cold War rivalries between the United States and the now defunct Soviet Union (Levine, 1994). There had always been a contest between the two nations whether that was defence, economic strength or space exploration. Due to the competition between the United States and the Soviet Union, this created the ‘Space Race’. The Space Race showed the true ability and dominance of both nations within this field, demonstrating how far each nation has come in regards to advancement in technology (Mirabito and Morgenstern, 2004).

On October 4th 1957, the Soviet Union launched the world’s first artificial satellite named ‘Sputnik 1’. The aim and objectives of this experiment had been to record the sunrise and sunset variations in the Artificial Earth Satellite (AES) radio signals to provide information about the ionosphere (Kuznetsov, Sinelnikov and Alpert, 2015).

On April 12th 1961, the Soviet Union were perceived to be marching away from the U.S in the Space Race as they became the first nation to put a human being into space. After these successful missions from the Soviet Union, President John F.Kennedy promised the U.S would put a man on the moon (Mirabito and Morgenstern, 2004). July 20th 1969 was and remains the most pinnacle date in space exploration history. NASA’s Apollo 11 had successfully landed on the moon. At this point, it appeared that the Americans took control in the space race as they became the first nation to successfully land astronauts on the moon and return them to Earth safely (Mirabito and Morgenstern, 2004). However, only 2 years later on 19th April 1971,
the Soviet Union launched the first space station called Salyut 1, with the aim of conducting scientific experiments (Nssdc.gsfc.nasa.gov, n.d.). Despite this period of competition between the United States and the Soviet Union, a cooperative mission known as the Apollo-Soyuz Test Project (ASTP) was conducted on 15th July 1975, thus ending the infamous space race (Hall and Shayler, 2003).

Following the end of the space race, the development of exploration in space rocketed. Multiple missions were launched which included many milestones. On 17th February 1984, a mission involving the deployment of two communication satellites and the first untethered spacewalk was funded by NASA (Millbrooke, 1998). Five years later, the first astrometric satellite was launched on the 8th August 1989 and determined the accurate position of objects in space and allowed the precise mapping of space (Perryman, 2010). The first rover (Sojourner) to successfully function on Mars landed on the 4th July 1997 and was part of NASA’s Pathfinder mission (Jpl.nasa.gov, n.d.). Sojourner explored the terrain of Mars and retrieved chemical and atmospheric measurements that were transmitted back to Earth (Jpl.nasa.gov, n.d.).

Further cooperation between national space agencies over a decade of research resulted in the first international space station that was launched on 20th November 1998 (Hoang, 2011). In comparison to Salyut 1, this space station offered the potential for technological development in various aspects of science such as physics and astronomy, whilst also sharing the huge cost between five space agencies (Hoang, 2011).

Over ten years later, a space telescope called Kepler was launched by NASA on the 6th March 2009 in the search for Earth like planets in other solar systems within the Milky Way galaxy (Kepler.nasa.gov, n.d.). This was revolutionary in data communications due to its capabilities of transmitting information on a routine basis and from outside of the solar system. This has identified over 2000 planets to date and it continues to discover more (Kepler.nasa.gov, n.d.).

Another milestone in space exploration history occurred on the 12th November 2014 when the Philae Lander part of the Rosetta mission successfully landed on the comet known as 67P/Churyumov-Gerasimenko (67P) (Sci.esa.int, 2017). Development in space exploration is ongoing and with advancing technology, will only improve.
2.3. The methods for communicating in space

SATCOM’s can be divided into two crucial components, in space and on terrain (Santamarta, 2014). Within space they may consist of operations such as tracking and controlling the satellite, whereas on terrain, infrastructure is necessary to access the satellite from Earth.

One of the biggest issues within space communications is the issue of distance because communications are affected by the intensity of electromagnetic radiation (Vågberg, 2005). The further into space you reach, the lower the intensity of electromagnetic radiation, meaning signals sent from probes in deep space are often very weak by the stage in which they reach the Earth. On Earth, scientists and researchers are using large parabolic disc antennas to catch all signals that have been sent. These antennas have been designed in a way to attempt to collect all faint signals and as much data as possible from them. These parabolic dishes are an example of aperture antennas which increase in frequency capabilities the larger the size of the antenna dish (Haslett, 2008).

The method of communicating from one object to another is via radio waves (Vågberg, 2005). These radio waves travel at the speed of light from a source, such as the antenna, into space surrounding the source, provided there are certain conditions encountered in free space (Haslett, 2008). This includes either a vacuum or any clear air that provides a similar atmosphere. The speed of light can be calculated as 3.0 x 10⁸ metres per second, roughly 186,282 miles per second (Haslett, 2008). Radio waves travel from the transmitter to the receiver via different routes which include directly, diffraction, reflection or penetration. Therefore, the total amount of power (energy) that would be received by a transmitter would be a total of the propagation waves via all these routes.

Communicating directly to Earth when required can be somewhat difficult as radio waves cannot pass through solid objects like planets and asteroids (Vågberg, 2005). Therefore, when a spacecraft is orbiting the far side of a planet, communication may be lost between the spacecraft and Earth. Ideal conditions for communicating to Earth would be when the probe (or other transmitter) which is sending the signals has a free line of sight of the source. However, there can be a further potential delay as the receiving antenna for that spacecraft may be on the wrong side of the Earth. With that in mind, space agencies will look to utilise all the antennas that are orbiting the Earth to pick up the signals (Vågberg, 2005).
An antenna comprises of the interface between the guided wave and electromagnetic wave and they can receive and transmit a signal at the same time (Haslett, 2008). Depending on the antenna, it will measure the focus of the radiated energy (Vågberg, 2005). There are two different types of antennas currently in use, a low gain antenna and a high gain antenna. The low gain antenna will radiate in a wide range and the high gain antenna will radiate in a narrow beam (Vågberg, 2005). Spacecraft are usually fitted with high gain antennas to send large amounts of data that has been collected from experiments back to earth whilst also having the ability to receive instructions from earth. The only issue with this type of antenna is that they need to be setup correctly and the aiming must be precise. On the other hand, spacecraft are also fitted with low gain antennas as well as a high gain antenna. This is because the low gain antennas can capture signal from most directions due to its wide angle, which can work effectively if the high gain antennas are accurately pointing towards Earth. Spacecraft and probes require both antennas due to the various sizes of the data that are sent and received (Vågberg, 2005).

Satellites operate under a broad range of bands. This is because the lower frequency bands are becoming congested due to their extensive use across the globe (Koudelka, 2011). Lower frequency bands comprise of L, S, C and X bands (European Space Agency, 2017). Whereas, higher bands comprise of Ku, K and Ka waves which are predominantly used in space communication as demonstrated in the figure below (European Space Agency, 2017).
2.4 Security behind data communications

As the use of satellite technology increases so too does the demand for it use (Santamarta, 2014). However, while these are in operation there are known to be cyber criminals looking to attack these satellites when they know their vulnerabilities. A cyber attacker may attempt to hack into a satellite for many reasons such as they could be looking to interrupt or block communications or, if they can hack into the system in depth, they may be granted full access and take control of the satellite.

There are number of methods used to protect satellites while communicating. One method required is the use of encryption and decryption (Medawar, 2003). Encryption is several algorithms that are used to secure sensitive data that is being transmitted, whilst, decryption is the unlocking of the placed algorithms in order to ultimately access the sensitive data (Gollmann, 2011). With data from satellites being encrypted it would make it harder for a cybercriminal to access the information (Medawar, 2003). The encryption would also be required for the tracking and telemetry control links (TT&C links) and data links of the satellite.

High power Radio Frequency (RF) uplinks represents another security technique as they require large antennas to send a high-power signal from ground stations directly to the
satellite (Medawar, 2003). In an attempt to hijack the satellite, the attacker would require a power radio transmitter and large antennas.

2.5 Restrictions and vulnerabilities:

2.5.1 Noise

An electrical signal that is transmitted from one location to another comprises of the original intelligence (desirable) and noise, also known as electronic noise (undesirable; Hioki, 2001). Unfortunately, noise is present in all transmitted signals and potentially affects the quality of the data that is received by affecting the amplitude, frequency and phase of information (Kolimbiris, 2000). However, techniques such as encoding and decoding are applied to optimize recovery of signal. In addition to this, the use of filters and amplifiers are used to condition the signal (Hioki, 2001). Many mathematical tools have been successfully created to evaluate the effects that noise can have on a signal.

There are a variety of noises that can affect the signal at differing extremities which can be classified as either internal or external noise (Kolimbiris, 2000). It is of note that there are further noises than those mentioned within this review.

Internal noise is that which is generated by both the active and passive components within the communication system (Kolimbiris, 2000). Examples of internal noise include shot, popcorn, flicker and quantum noise.

External noise is that generated from terrestrial and extraterrestrial sources rather than the communication system itself (Kolimbiris, 2000). Examples include the atmosphere, sun, moon and the universe. All these sources may not be present at one time and their intensity will depend on the timing of the transmission of data. A satellite antenna will encounter an average noise temperature of 254 K and further noise is produced from the Earth atmosphere via lightning discharges and radiation absorption.

2.5.2 Space Suits

While astronauts explore in space, they require protective space suits to ensure their safety from any harmful environments. It is essential they are in constant communication with their crews and mission control back on Earth. Within these space suits, astronauts wear a
Communications Carrier Assembly (CCA) which is essentially a fabric hat that is tailored with microphones around the ear and boom microphones around the mouth area (Nasa.gov, 2017).

Although this equipment is functional, it has its potential issues. Astronauts require the availability of multiple cap sizes due to different head sizes (Nasa.gov, 2017). The caps cannot be adjusted once the astronauts have put their helmets on which can be a problem as the microphones may move out of place, decreasing the quality of sound or speech. The CCA also has some limitations to how the boom microphones have been designed as it’s likely to interfere with the feeding and drinking mechanisms built in for astronauts during space walks and maintenance. A potential issue materialises when an astronaut sweats as this can have an impact on the performance of the equipment. Therefore, NASA along with other space agencies are investing time and money into finding a better solution to remove these limitations.

Researching and testing the possibility of an integrated audio system within the space suits is taking place, thus removing all the separate components such as the earphones and microphones from the CCA (Nasa.gov, 2017). Researchers would be able to remove the current issues with the CCA as all external parts would be removed, thereby improving the functionality and quality of communication. The integrated audio system includes an array of microphones along with digital signal processing removing the loss of negative frequency and improving output. While testing the integrated audio system, researchers are also researching the plausibility of the Multi-Channel Noise Reduction (Nasa.gov, 2017).

2.5.3 Electromagnetic Radiation

Electromagnetic radiation has not got the ability to move quicker than the speed of light, and therefore, it is found that there are time lags within communications which makes real time communications impossible (Vågberg, 2005). For example, to communicate with space probes in the far reaches of the solar system, such as near Pluto, it can take over five hours for a signal from earth to communicate with the probe.
2.6 Real life cases (data communication + space exploration):

2.6.1 The Mars Express Mission and Beagle 2

The Mars Express mission was organised by the European Space Agency (ESA), and this worked in conjunction with the Beagle 2 (Mars lander) that had been built and operated by the National Space Centre within the UK (Chicarro, Martin and Trautner, 2004). This mission was a revolutionary moment for the ESA because it was the first time in history that the space agency had successfully visited another planet. The mission comprised of two key components, an orbiter which would orbit around Mars with the purpose of studying its interior, subsurface and atmosphere. Secondly, the lander (Beagle 2) which would be placed on the planets terrain to determine any traces of past or current life on Mars. The development and planning of this mission had taken a record five years before launch. The Mars Express mission started its journey on the 2\textsuperscript{nd} June 2003 when it was launched into space from Kazakhstan.

After six months travelling, on 20\textsuperscript{th} December 2003, the Mars Express orbiter had finally begun its orbit around Mars (Chicarro, Martin and Trautner, 2004). Prior to this, the Beagle 2 had been ejected from the orbiter on the 19\textsuperscript{th} December to start its descent. The lander was due to land on Mars on the 25\textsuperscript{th} December 2003. On entry into Mars, the Beagle 2 had successfully entered the Martian atmosphere but after that point of the mission, Beagle 2 was missing after communications had been lost. The UK Space Agency (who led the lander part of the mission) and ESA attempted on many occasions to communicate with Beagle 2, but to no avail (Sci.esa.int, 2017). They attempted to retrieve feedback via the Mars Express orbiter and NASA’s Mars Odyssey orbiter, yet neither received any signs of communication back. In February 2004, ESA declared the lander lost.

Although the Beagle 2 had been declared lost, the Mars Express continued its mission and still communicates with Earth to this day (Space.com, 2017). The Mars Express has made a number of discoveries such as the detection of water, ice and carbon dioxide ice at the southern pole of Mars. The orbiter also discovered methane within the atmosphere on Mars which must have originated from the surface due to methane not being naturally occurring in the planet’s atmosphere.
Twelve years after the Beagle 2 lander disappeared, scientist and space agencies made a breakthrough of the whereabouts of Beagle 2. NASA’s Mars Reconnaissance Orbiter discovered that Beagle 2 had actually successfully landed on Mars (Sci.esa.int, 2017). Images from the HiRISE camera built on the orbiter show clear footage of the lander, confirming it landed in one piece, however, did not fully open its instruments in order to communicate directly with the orbiters (Gov.uk, 2017).

2.6.2 Rosetta and Philae Mission

The Rosetta and Philae mission was designed and controlled by the European Space Agency (ESA) with the intention to orbit around the solar system and study the comet 67P/Churyumov-Gerasimenko (67P) and land Philae (lander module) on the comet (Sci.esa.int, 2017). The original plans for this mission had been discussed in the late 1970s but were only approved by the ESA’s Science Programme Committee in 1993. The idea had been to analyse the comet of 46P/Wirtanen which later changed to 67P due to the timing of the launch of the mission in 2004. After over a decade of mission planning, on the 2nd March 2004, Rosetta had been successfully launched into space. Throughout the mission the spacecraft had flown near a couple of asteroids such as 2867 Steins and 21 Lutetia. It was essential that the probe flew near Earth and Mars in order to get the gravity pushes required for its expedition. In total, four gravity assists had been performed (Sci.esa.int, 2017).

The primary aims and objectives behind this mission were to follow comet 67P through the solar system and attempt to detect the nucleus and coma of the comet from nearby (Sci.esa.int, 2017). Further objectives were to measure the comets position to the sun and to record all the changes detected while going through changes of season. After completion of the set out objectives, the spacecraft (Rosetta) would release its lander (Philae). Philae would help to measure the characterisation of the nucleus and evaluate all the activities that take place on the comet. In the case of Rosetta, it has orbited around the solar system, with the aim of examining the asteroids it passed by (Steins and Lutetia) and to observe Mars while it had the Mars gravity boost. The reasoning for the mission had been to collect scientific measurements and investigate how these comets are formed and whether they were formed from within the solar system or outside.
Although this had been an ESA mission, NASA had also provided aid in the research by providing instruments (ALICE, MIRO and IES) that would help discover more information about the comet, its nucleus and how it was formed (Sci.esa.int, 2017). NASA’s Deep Space Networks (DSN) had also been used by ESA to communicate with the orbiter, to track and help navigate.

After over a decade of orbiting comets, planets and objects around the solar system, Rosetta finally reached Comet 67 on 6th August 2014 (Rosetta.jpl.nasa.gov, 2017). Rosetta subsequently remained within the comet’s orbit performing manoeuvres and global mapping of the comet. On 12th November 2014, Philae was released and successfully completed the first ever landing on a comet.

Rosetta communicates via either a one-way or two-way radio communication (Sci.esa.int, 2017). The Radio Science Investigation (RSI) uses this to retrieve information. The one-way communication is produced by the ultra-stable oscillator (USO) that transmits back to Earth. Whereas the two-way communication is completed by a signal that is transmitted from Earth and sent directly to the spacecraft. Therefore, whichever communication is being used, the signals are being transmitted in the X-band or sometimes the S-band, depending on the data being sent. The RSI investigates nondispersive frequency shifts and dispersive frequency shifts, signal power and polarisation of radio carrier waves. Investigation into these particular parameters provides information on the spacecraft’s motion, perturbing forces acting on the spacecraft and the propagation medium. This information can provide valuable data on the comet that was not well understood before (Sci.esa.int, 2017).

2.6.3 The Curiosity Rover on Mars

The Curiosity rover was one of four rovers that have successfully touched down on the terrain of Mars (Messer, 2004). All successful rovers that have managed to reach Mars have been designed and controlled by the National Aeronautics and Space Administration (NASA). The first rover landing on Mars occurred in 1977 followed by the second and third rovers landing in 2004 (Messer, 2004). However, the fourth rover (Curiosity) landed on the 6th August 2012, and this proved to be NASA’s biggest test to date. John Grotzinger (mission leader) stated that the manoeuvres had to be precise particularly in their timing. He also mentioned that Mars is the Bermuda Triangle of the solar system, with two thirds of missions that are due to visit the
planet ending in failure. To add further pressure to NASA, the curiosity rover had been the most expensive and ambitious mission in history totalling $2.5 billion, powered by decaying plutonium rather than sunlight (McKee, 2011).

The objectives set out for the Curiosity Rover were to examine whether there was habitable life in the distant past on Mars and whether there is currently life preserved within its rocks (McKee, 2011). The reasoning for the high expense of this mission was due to the great amount of technology behind it such as the instruments that the rover is carrying in order to have the ability to perform certain tasks and to communicate to other objects.

The rover undertakes tasks and performs tests on samples that it is observing and collecting. However, it is fundamental that it is able to communicate with Earth and orbiters around Mars to aid with the sampling. The rover is fitted with X-band transmitters and receivers that have the capability to contact and communicate directly to the DSN’s on Earth (JPL, 2017). For the rover to communicate with the Mars orbiters, it has UHF Electra-Lite software-defined radio built in. The reasoning for using UHF Electra-Life technology is the speeds at which the data can be transmitted to Earth from the orbiter rather than the rover. The main form of communication of the rover is to the orbiter where it can send the data directly to them. The orbiter has been designed with larger antennas which provide more power allowing faster communication speeds and less restriction in terms of size of the data being sent back (JPL, 2017). The rover uses the UHF radios to relay the data to the orbiters, whereas the orbiter communicates directly to the DSN on Earth via X-band radio waves. The differences between the two forms of communication are very apparent (JPL, 2017).

The Mars Curiosity rover mission has been perceived a success due to the fact that it remains in continuous communications with its orbiter and Earth to date, in addition to performing the required tasks that it has been set out to do.

2.7 Future prospects

As more and more manned and unmanned exploration missions are being considered and planned, so too are the instruments in use for various sectors particularly with communication. We now know that the current communication methods from orbiters and other object to direct DSNs are through X-band radio waves, however, space agencies and
scientists are evaluating the possibility of using Ka-band radio waves for future deep space communications. The Ka-Band radio is currently being tested due to the difference in speeds and its larger capability of data sizes it offers in comparison to X-band (JPL, 2017). The Ka-Band frequency offers speeds of 32 gigahertz, whereas X-band is only capable of 8 gigahertz. The Ka-band can deliver frequency four times higher than X-band, and thus the Ka-band method is currently being tested out on the Mars Reconnaissance orbiter providing information for future missions (JPL, 2017).

While communications in space is in a growing need as more and more exploration missions are being set out, the idea to use other forms of communications are being investigated. Currently, scientist and space agencies are evaluating the use of laser communications. Laser communications is essentially the ability to communicate wirelessly through the atmosphere, working similarly to fibre optic links, the only difference being that with lasers, the beam is transmitted through free space (Sachdeva, 2008).

In an attempt to utilise lasers in space, systems are being created to achieve these greater speeds. In order for an object to transmit data via laser communication, it requires a modulator (Signal processing unit) and a laser diode in order to send the laser beam directly to another object. Whereas, for the other object to receive this data it would require a telescope also known as an Antenna, a photon sensor and a demodulator to capture the laser beam to retrieve the data (Baishnab, 2016). The laser diode works accordingly to the signal in use, whether that would be ON-OFF Keying (OOK), Pulse Width Modulation (PWM) or Pulsed Frequency Modulation (PFM).

In order for communication to work accordingly on terrain, the use of fibre optics and microwave radio waves are being used to provide the high speed connectivity allowing transmission of larger amounts of data such as 4k video’s in a short period of time. However, due to the installation and maintenance cost, fibre optics cannot be used for certain aspects in space, particularly with most satellite links as they do not have the ability to use it. However, laser communication can be operated at low cost, thus, it can be used in areas that fibre optics is unusable (Baishnab, 2016).
In comparison with microwave communication, which is most commonly used today, particularly in space, laser communication can have its advantages. Firstly, the beam width is narrower than microwave antennas allowing better accuracy. Secondly, the bandwidth is larger, and therefore allows more data to be transmitted at higher speeds. Thirdly, laser requires less power outage than microwave technologies. Finally, and most importantly, laser communications are known to be more secure with high intense security methods than microwave communication (Baishnab, 2016).

On the other hand, laser communications can have its drawbacks, depending on many aspects in space. These include solar radiation, physical objects causing obstructions, potential issues with weather or pollution and with atmosphere absorption. Although this can affect laser operations, these issues can be reduced by laser tuning and fitting more transmitters and filters (Baishnab, 2016).
3.0 Methodology

Once the research for data communications within space exploration was conducted, the project looked to carry out effective and extensive measures to evaluate the results and aimed to find an overall answer to the question that was being asked. Within this section of the project, the researcher evaluated the research philosophy that had been adopted. Subsequently, the approach to the project was discussed along with key research methods used including questionnaires and sampling. With the above in mind, the intention was to use these methods to the best of the researcher’s ability in order to accomplish all the aims and objectives of the project.

3.1 Research Philosophy

While coming up with an idea for this project it was important to realise what research philosophies were available and which were best suited for this project. A research philosophy means evaluating how data can be successfully gained, then evaluated in order to provide final results (Saunders, 2013). Research philosophies are also constructed by ontology and epistemology. Ontology can be defined as something that is believed to be real, whereas epistemology means the study of knowledge or understanding. After analysing all the available research philosophies, it was clear that this project would be based around the interpretivism philosophy. Interpretivism is a research approach that is based around the researcher’s knowledge and interest in a subject, allowing the researcher to use their interpretation of information that they have knowledge of from their research. There are variations within interpretivism, however the research within this project was completed using the variation known as phenomenology, which is providing understanding through experience of actions. This was suited to this particular research project as participants as well as the researcher would be using a website featuring a game, together with information about data communications within space and space exploration, which could then be used to answer the questions within the game (Dudovskiy, 2016). It is also important when embarking on the decision of which philosophy to apply to a research project to consider the ontological and epistemological approaches that different philosophies are based on. With regards to these approaches within the philosophy of interpretivism, a relativist ontology was applied within the approach allowing the researcher to see what they know as information that is commonly known about a topic area, and that any understanding that is gained
through research can be compared to this knowledge (Dudovskiy, 2016). The philosophy also makes use of subjectivist epistemology which allows the researcher to treat information gained from other sources in the same way that the researcher treats the knowledge that they personally have, using it to develop clear links between researcher, project and participant (Dudovskiy, 2016). The benefits of using this research philosophy lie in the fact that it allows the researcher to develop a depth of discussion that can add great value to a research project, whilst also making use of qualitative data collection and the use of qualitative data collection methods such as questionnaires as is the case within this project, with the information gathered having a greater likelihood of being correct, as is the case with the majority of primary data studies (Dudovskiy, 2016).

3.2 Research Approach

Throughout this project, the inductive research approach was used as there would be a number of questionnaires that would be completed from a variety of individuals to provide a final result from the data obtained. The Inductive research approach is usually a pattern that is followed where there is a research question to start off with while collecting primary and secondary data in order to create a theory and produce results (Russell, 2015). The inductive research approach is based on specific data followed by general data with the subsequent aim of producing theories. Alternatively, the deductive research approach works the opposite way, where initial information is general, and then comes to a specific conclusion (Russell, 2015). This project involved the collection of both primary and secondary data, in the form of literature from journals, books and articles. Once the data had been gathered, it was then used to further the development of the project. As the project developed, primary data was then collected in the form of a questionnaire, to evaluate whether the project developed was a good learning activity for those participants involved.

3.3 Data Collection

As a result of the project being split into two sections, the methods for data collection also varied. For the first section with regards to the research and theory behind the project, in order to complete the aims of the project and address the title question, there was a literature review which was conducted via secondary data collection. Secondary data collection is a method of data collection through published items such as articles, papers and books
(Dudovskiy, 2016). In order for the second section of the project to be completed, it was based on the secondary data that was collected within the first section. Once the second section (game and website) were completed, primary data collection was conducted via questionnaires in order for the project to be tested and to evaluate whether it had been a valuable experience for the user. The project was based around the qualitative data collection method with the intention to collect the data to meet the aims and objectives that had been set out. Qualitative data collection is a method that is used to gain feedback or acquire data from interviews and questionnaires (Dudovskiy, 2016). The project utilised qualitative data collection methods using questionnaires as stated earlier, which provided an understanding for the researcher with regards to the quality and usefulness of the game to a prospective future user, and resolved any issues within the game and website. The data collected from the user was carefully stored in a password contained computer environment, with no personal data required from participants, limiting the ethical and data protection ramifications of the project.

3.4 Sampling

Once the development of the project had been completed, it was essential for the game and the website to be used to see whether this research was clearly acknowledged and understood. For sampling, the chosen technique that was implemented by the project was convenience sampling. As suggested by its name, convenience sampling is a method of sampling that is used to gain data from participants who are conveniently available (Dudovskiy, 2016). This could mean gathering data by asking people within a busy shopping centre to stop and fill in a questionnaire or it could be family and friends who are available to add weight to the project, which was the case within this project. This type of sampling was chosen due to the time constraints of the project, and because it fitted hand in hand with the project as the participants were asked to take part in the testing of the game, and the game did not require any specific knowledge of space exploration or a level of computer literacy that could not be found within the majority of society. The game was uploaded to a website featuring other research from the project, which provided the user an opportunity to gain knowledge that was used within the game. As such, the game was created as a learning tool to help educate the general public on communications in space, with the information
gathered by this project playing a part in the background, and therefore the choice of participants was not necessarily of huge importance to the results of the testing.

3.5 Development

During the completion of the research within the literature review, it was essential to produce designs and ways of implementing these ideas within the overall project. From the very start, it was decided that in order to attempt to build a game based on the research, paper drawings would be created in an attempt to establish the functionality of these designs. Once the designs were produced, they were faithfully implemented, using the various languages that were to be used. (HTML, CSS and JavaScript).

Before the creation of the game, it was decided to do some research to see which language would be best suited for the game and of course for the user experience. As there were many programming languages capable of creating games, the choices were narrowed down to a small number of languages, namely; Adobe ActionScript 3, JavaScript and along with the possibility of using a game engine such as Unity.

Firstly, the possibility of using a game engine such as Unity which is usually developed within JavaScript or C# was explored. At first, this seemed like a possible option as there seemed to be a lot of support online along with ideas of how to implement certain functions. However, due to the nature of the game, it was decided that this game engine was not required as the game would not be including any stressful functions or high intensive graphics. Another reason why Unity was removed was due to the lack of knowledge for developing within C#. As there had been a large amount of support for C# within Unity, it may have been possible to develop the game. However, with limited time available, it was decided that it was best not to include Unity.

Secondly, the option of creating this game within Adobe ActionScript 3 was assessed as development for Adobe Flash has been around for many years (Aune, 2010). Many developers developed for Adobe Flash. However, after carefully evaluating the research, it was clear that many developers are utilising the use for JavaScript and HTML5. The reasoning behind the surge of developers using JavaScript is due to the vulnerabilities that Adobe Flash seems to have developed as a result of being an old multimedia platform (Us-cert.gov, 2015).
Lastly, the option of JavaScript was looked at. At the beginning, this was the preferred choice of language, given the researcher’s experience in developing with JavaScript in the past. While this is a language familiar to the researcher, there was also a lot of online support that came in handy along with many additional external libraries that could be added such as JQuery and EaselJS to help simplify the nature of the function that one is attempting to create. The development for JavaScript has increased within a short space of time as it seems to be an easier language to help create small and simple animations (Help.adobe.com, n.d.).

The principle behind the game was to have a website that could link directly to the game. However, in order to answer the questions in the game, the information would be provided on the website. Therefore, JavaScript was chosen for the reasons above. Furthermore, another reason why this programming language was chosen was the ease with which it incorporated JavaScript and HTML together.

In order to produce the game as required it was essential to decide how to implement its functionality while deciding the best way to code all functions. Within the HTML files, for the display, the game required the use of containers with buttons also being created. This formed valid links while the JavaScript worked out the calculations and answers. While the HTML files made use of sections and articles to display certain subheadings on the website, the bulk of the game functionality was developed under JavaScript, shown in Appendix C and D. The use of JQuery was also implemented in order for the ‘Start button’ to link directly to the game page. The website was a template that was downloaded from HTML5 Up (HTML5 UP, 2017). The template was heavily edited, unnecessary items were removed and new items were included within the template to make a custom design fit for the projects purpose. The reason for using a template will be discussed in greater detail in the limitations section of the report.

With these principle ideas in mind, it was essential to consider exactly what functions needed to be implemented within the JavaScript file. Those functions would include the ability to show each question every time, a function that could calculate the correct answer, another function to check if the selected choice was correct to clearly show the result on the game and, finally, another function to calculate the score for every right answer selected.
Furthermore, for the game to populate the questions within the container created, the questions had to be stored in a few arrays along with the choices offered and the correct answer within the JavaScript file. The need for a number of variables was created in order to assign it with a value. In order for many functions to work such as, the selection of answers, storing of results, calculating correct answer and assigning the score, the use of ‘If statements’ needed to be applied to determine whether statements were true or false. The use of innerHTML was also implemented within the JavaScript file in an attempt to manipulate the HTML file to change certain texts and displays without permanently coding into the HTML file. The use of another external library called t.min.js (Lips, 2017) was also implemented within the game, for the way the questions were displayed. The game would show the question being typed up as it appeared thanks to this external library.

As discussed in further detail below, once the results from the testing were finalised, certain improvements were added. These included the way the start button for the game displayed. Due to the game being developed on a 24” screen, some of the game features did not display correctly on smaller screens. Another improvement added thanks to the feedback given was the use of validation. Clicking the submit button would take the user to the next question even if the question had not been answered. With the implementation of the validation, a message box would now appear if no answer had been selected.

3.6 Questionnaires and Testing

Once the game and the website were completed, it was essential to get some feedback for testing purposes. Testing is an important stage while developing an application, therefore, it was essential that the testing be completed, to provide the best overall project possible. The testing method that this project adopted was the usability testing method. Thanks to the application of “usability testing” we were given the opportunity to not only collect and analyse data but also to be presented with dynamic data which would otherwise be difficult to capture (Moayeri, 2010). The aim was to use two participants and use the questionnaire created for their feedback in terms of testing. Initial testing showed that it was imperative that the feedback previously mentioned was incorporated to allow improvements to the project.
As mentioned above, the questionnaires were used for two different purposes. Firstly, the questionnaire was available to a small number of participants in order to find any faults within the testing phase of the development. Secondly, the questionnaire would again be available to all participants who used the application, to provide the primary data needed. To avoid ethical constraints, there was no requirement to gather personal data, thus allowing personal feedback with regards to the game and website.

3.7 Ethical Risks

Once the project direction had been planned, it was important to consider the ethical issues that could occur while conducting primary and secondary data collection. Although there are many ways of collecting data, it is imperative that rules regarding ethical issues are followed (Bryman, 2007). While considering the rules, the project took these into consideration when required.

When collecting primary data, it was essential to follow the Data Protection Act. Therefore, all results obtained were stored on computer that was password protected. In terms of personal data, there were no fields on the questionnaire that could be traced back to the participant, making sure they stayed anonymous. Another key issue that had to be considered, was the development of the website and game, ensuring that the development was suitable for use by people of all ages. While collecting data from questionnaires it was essential to know that these participants would give a fair representation of the results, making sure there was no bias.

During the collection of secondary data, at this level, it was vital to consider any ethical implications. Therefore, any information that was obtained through relevant literature in papers, books and articles has been fully credited to the original authors.

3.8 Project Limitations

As the research carried out for the project grew, so too did the limitations regarding certain areas of the topic. One limitation that occurred during the research was the limited number of sources that were easily accessible. Although there seemed to be a lot of websites that provided substantial information, due to the nature of the information, it was important to find reliable sources such as published articles, books and papers. Even though certain
websites provided information that looked to be reliable, there was a worry of bias while reading the information, particularly through websites that anyone could edit such as Wikipedia and forum based websites. One particular area that proved to be a limitation became apparent while researching the security behind satellites and how communication in space is secure. The idea of the research was to investigate the security of data communications being transmitted securely between satellites, rovers and other objects during transmission back to Earth. Finding the appropriate literature for this was difficult which is understandable due to the increasing amount of cyber-attacks that occur on a regular basis. Therefore, to tackle this problem, it was decided to discuss security as a whole, as some resources that were used discussed that security methods such as encryption and decryption had been utilised in space.

An additional limitation that occurred during the research of this project was the arrangement of interviews to commence the primary data collection. While in the process of starting this project, confirming its ethics approval, it was decided to do some research to see who would be appropriate for the interviews. After careful evaluation it was decided to focus on three individuals. All three had an academic background and were professors within their respective Universities. The reasoning for choosing these three individuals was due to their knowledge of the topic, with two of them taking part in the future ExoMars Rover mission (ESA) in 2020 and the other being part of the team that organised the Beagle 2 mission to Mars in 2003. An attempt was made to arrange an interview with all three individuals. However, none of them initially replied. After waiting for a month, it was decided to call them to see if they would respond, at which point one individual agreed to take part. As this individual was extremely busy at the time, he asked if he could be called back later on that month. A call was made accordingly but with no success. Subsequent emails also failed to elicit a response. As result of this, the interviews did not materialise and this course of enquiry was thus abandoned.

During the course of the development of this project, the idea was to create a question based game to give the user a learning experience of the research by making it fun. The idea was to give the user the chance to be able to play with the rocket while moving in space. However, due to the lack of time, it was decided to allow the rocket and objects in the game to move automatically and have the user to play the game by answering the questions.
Another limitation that developed during the project was with the involvement of the participants. The convenience sampling method was chosen, meaning that friends and family would be playing, helping in the collection of the data required. This was a limitation due to the bias that may have occurred while giving their personal opinions towards the project. An additional limitation that was found during the development was the design of the website. Due to time, the focus was on the development of the game. Therefore, a template was downloaded and restructured (HTML5 UP, 2017). However, as a result of the using this template, it was edited with idea that it needed to be user friendly allowing the user to play the game.
4.0 Research Findings and Results

Within this section, the discussion will involve the two parts of the project. One regarding the research that was conducted; reviewing the arguments and results from the research. The other section will discuss the decisions behind the game and the results that have been accumulated from the testing and questionnaires. The data that was obtained with the intention to provide an answer to the question will be discussed in further detail, along with valuable feedback in understanding whether the game has been a successful learning activity for those involved.

4.1 Collecting Secondary data from the Literature review

After an extensive amount of research was carried out, it was important to note that space exploration in regards to data communications has significantly improved in the last decade. Space exploration has been occurring since the 1950s when the race to send humans into space had commenced. However, in recent decades, probes and satellites have been launched into space with the aim of transmitting data back to Earth without the requirement of a human to be on board. This has included probes landing on comets (e.g. 67P/Churyumov-Gerasimenko; Sci.esa.int, 2017), rovers on Mars (e.g. Curiosity; Messer, 2004) and telescopes exploring beyond the solar system. The extent of space exploration and the data that can be retrieved has improved considerably in conjunction with technology advances on Earth. Examples previously mentioned in detail are the Rosetta probe and the Curiosity Rover which provided invaluable data of comet 67P/Churyumov-Gerasimenko and Mars, respectively. There have been slight disappointments such as the Beagle 2 which failed immediately upon reaching the atmosphere of Mars (Chicarro, Martin and Trautner, 2004). At present, there are telescopes and probes observing planetary bodies and their moons to determine the atmosphere and terrain of each.

Despite the successes of these instruments, the data received is still affected by issues such as noise, whether that is internal or external noise. Furthermore, a clear line between the transmitter and receiver is required in order to receive useful and reliable data. Therefore, obstructions such as planetary bodies and comets can affect the data that these probes transmit. At present, data communications with these instruments is predominantly via radio waves such as X-bands. However, these lower frequency waves are greatly affected by noise
such as electromagnetic radiation. Although, despite these limitations, the probes are capable of transmitting data back to satellite dishes (aperture antenna) from a great distance such as from Mars on a continuous basis with only a slight delay in transmission. However, in the grand scheme, a delay of a few hours is negligible.

In the case of security in place for data communications within space, a known method that is used is encryption and decryption. However, unfortunately, other methods were difficult to determine due to the secrecy of agencies such as NASA who are not willing to inform the public of security protocols in place. They believe that an understanding of the security measures in place will allow an opportunity for a cyber attacker to detect a vulnerability. Although, it is understood that encryption and decryption are used, the exact nature of the encryption could not be established for the above reasons.

A variety of bands of different frequencies are used by satellites, i.e. from S-band to Ka-bands. Recent research has been focused on utilising the Ka band for future endeavours involving probes and satellites. A further method which is being extensively researched and tested, especially by Space Agencies such as NASA, is laser communication. This provides several advantages in comparison to radio-waves such as speed, bandwidth and security is far greater. However, it must be noted that laser communication is also affected by noise such as atmospheric radiation, but this is likely to be a problem faced by all data communication within space.

Future space explorations seems to be focussed on releasing further probes and telescopes beyond the solar system in order to discover planetary bodies that are capable of sustaining life, very similar to Earth.

4.2 Design of the game

For this section, the project will be going into greater detail about how the design of the game came along, why certain areas of the game have been displayed as they are and what the reasoning was behind the implementation.

To begin with, before any development had commenced, it was vital to consider the design aspects of the game and to contemplate who exactly would be using it. As one of the aims of the project was to make a learning activity from the findings of the initial research in the
form of a game, the idea was to make it available to all ages. Therefore, it was essential to make the game as user friendly as possible, considering that it also needed to be appropriate for all ages. While it was imperative to design a game based on the research which was displayed on the website, the main principle behind it was to make it fun. Therefore, the use of animations and colourful fonts were introduced.

4.3 Low Fidelity Designs

Once the audience of the game had been considered it was important to understand how the layout of the game would appear. In order to get a true representation of the project idea, a few paper designs of different interfaces which could be considered were created. The use of the low fidelity designs acted as a springboard when it came to the development and implementation of the project. As shown below in Table 1, three designs were created based on the audience before the development. Each of the designs display different features and layouts.
Table 1 - Low Fidelity Game Designs

<table>
<thead>
<tr>
<th>Game Design 1</th>
<th>Game Design 2</th>
<th>Game Design 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design No. 1</td>
<td>Design No. 2</td>
<td>Design No. 3</td>
</tr>
</tbody>
</table>

**Game Design 1**

Design No. 1

![Image](path/to/image1)

Which year did humans first step foot on the moon?

- A. 1961
- B. 1962
- C. 1963
- D. 1969

**Game Design 2**

Design No. 2

![Image](path/to/image2)

Which year did humans first step foot on the moon?

- A. 1960
- B. 1965
- C. 1969
- D. 1970

**Game Design 3**

Design No. 3

![Image](path/to/image3)

Which year did humans first step foot on the moon?

- A. 1961
- B. 1965
- C. 1969
- D. 1969
- Submit
Looking at the designs in Table 1, they all show a clear indication of how the game would operate, with all three presenting a nice and clean user interface. After carefully evaluating all three designs it was decided that ‘Game Design 3’ would be best suited for the implementation of the game.

A very similar approach was executed for the website design. Low fidelity paper designs were created in order to give an impression of how the information would be displayed. Contrary to the game approach, to commence the process of designs other websites and templates were researched in an attempt to visualise the user interface of the website. As mentioned in section 3.8 of this report, due to time constraints, the website was created using a template and the majority of it was edited to fit the objectives. As shown in Table 2, the low fidelity designs were drawn to capture how the content would appear on the HTML website. Weighing up the three designs, ‘Website Design 3’ was chosen for its simplicity as well as the fact that the original design was based around a template (HTML5 UP, 2017).
| Table 2 - Low Fidelity Website Designs |

**Website Design 1**

*Design Website 1*

**Website Design 2**

*Design Website 2*

**Website Design 3**

*Design Website 3*
4.4 Results gathered from usability testing

Once the development was completed, it was vital to release the game and the website to a couple of participants with the intention to gather valuable feedback, seeking any improvements that may be required. The questionnaires that were created for the main data collection were used here to obtain valuable information about the functionality of the project and to identify any faults. This would allow for any faults found to be rectified.

As seen in Table 3, there were several issues that needed to be addressed in order to improve the project's functionality. While the project had been developed on a 24” screen, it became apparent from these results that both the game and website had issues with different screen sizes. It was essential to fix this issue as many users may not have access to this size of computer and therefore may use a device with a smaller screen. Thus, this change was vital because it ensured that both the website and the game were user-friendly and accessible to a wide range of people. With this feedback in mind, an adjustment was implemented to both the website and the game, resulting in the ability for the project to work on smaller screens.

Another important discovery from the results was that validation was not correctly implemented into the game (Table 3). This meant that the user did not need to answer the question in order to proceed, allowing them to click the submit button and be directed to the next question. Once this issue was noted, it was imperative to make this change to the game to ensure that the game was robust. While this was implemented, the use of validation was included with a message box now appearing to prompt the user to answer the question before clicking submit. Although the issues discussed were the main changes that were incorporated into the project to improve functionality, there were also some smaller or less important changes that were noted (Table 3). One minor change was to number the questions as they appeared. After careful consideration, this change was conducted because it gives the user an idea of which question they are on, also notifying them when the game has been reset to the first question. Another participant left feedback with regards to the font on the game (Table 3). When this problem was first picked up, the exact issue was not clear as a different type of font was implemented in the game. It was later discovered that the font that was implemented within the game wasn’t incorporated into the project. This was because it was only installed to the main device, rather than the server. This issue was soon repaired, with
the relevant font now included into the code of the game. Furthermore, with the aid of these participants, the project can be deemed as more robust and therefore offers a better experience for the user.

Table 3- Testing Results

<table>
<thead>
<tr>
<th>Participant</th>
<th>Testing – Suggested improvement</th>
<th>Implemented</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Allows me to click submit button even though I haven’t selected an answer + no clear indication of the question number.</td>
<td>✓</td>
</tr>
<tr>
<td>2</td>
<td>Screen resolution and size, start game button disabling the option the click on different screen size. Font also looks standard, would be good to use a professional font.</td>
<td>✓</td>
</tr>
</tbody>
</table>

4.5 Results Gathered from Questionnaires

As soon as all the feedback from the participants who took part within the testing phase was collected, the project was uploaded to the web hosting server allowing everyone to access it. Once the website and game were live, the purpose was to provide the questionnaire survey to all who visited the website. The use of the questionnaire would provide insight into whether the project met the aims and objectives, i.e. to produce a successful learning activity.

The data collected highlighted that the 22 participants were from all age groups (Figure 2). As one of the main objectives was to create a project that was suitable for all ages, it was essential to gather the opinions from participants of different age groups. Figure 2 shows that the majority of the users were between 18-30 along with a large portion of users under the age of 18. Table 4 shows the number of participants in each age group, showing a percentage of the total number of users who completed the survey.
Figure 2 - Question 1(Age)

![Bar chart showing age distribution](image)

Table 4 - Questionnaire, Question 1 Age

<table>
<thead>
<tr>
<th>Age</th>
<th>Percentage (%)</th>
<th>No. of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 18</td>
<td>31.82%</td>
<td>7</td>
</tr>
<tr>
<td>18-30</td>
<td>36.36%</td>
<td>8</td>
</tr>
<tr>
<td>31-40</td>
<td>9.09%</td>
<td>2</td>
</tr>
<tr>
<td>41-50</td>
<td>13.64%</td>
<td>3</td>
</tr>
<tr>
<td>50+</td>
<td>9.09%</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>22</strong></td>
</tr>
</tbody>
</table>

Figure 3 displays the gender of all the participants of the survey. The results show that the majority of users were men (16 individuals), however, there were a fair number of women (6 individuals) that also visited the website and tested out the game. While it was important to establish the age groups and the type of people that were using the website, the main aim of this survey was to find out the information discussed below.
In Figure 4, there is a clear indication that the website was successful and that the information on the website was clearly documented. All of the participants awarded the website with a score of six or above, suggesting that the website provided valuable and informative information. The majority of users (12 individuals) awarded the information on the website a score of eight out of ten, with a large amount (5 individuals) also rating the website a ten out of ten (Figure 4). From these results, one can deduce that it was a fun learning activity.
Following the evaluation of the website, the next step was to evaluate the game. Thus, the following question was implemented to establish how the user felt about the functionality of the game. As the graph in Figure 5 shows, once again the results have come back with high marks, with the largest portion of participants scoring the game as nine or ten out of ten. On the other hand, the results in this graph are interesting as one participant rated the game three out of ten. This score rating could have been for many reasons, which will be further discussed in the section below in regards to improvement comments.

The next question was based on the information provided within the game. The ratings have been totalled up as shown clearly in Figure 6. The results show a clear indication that participants involved again rated this question quite highly, with the majority scoring between eight and nine out of ten. Although, there seem to be a few lower scores with one participant rating the information provided on the game a three. However, other than this one participant, the graph shows that the rest of the participants scored a six or more out of ten with some participants even scoring this section a ten (Figure 6).
Figures 2 to 6 were the results of multiple choice questions. However, the last two questions were text based answers where the participant had the option to leave feedback if desired. This was an essential part of gathering data as it can help provide answers to some of the scoring that was left in the previous questions. The results from the comments have been displayed in a table (Table 5) to provide evidence of any improvement feedback that was mentioned. As shown in Table 5, many participants left comments that could be seen as very valuable. However, after careful analysis of the feedback, it is clear that many of the comments provided are very similar. A few individuals left comments suggesting that the questions appearing on screen were too slow and others requested the use of more animations and control.
In addition to leaving feedback for improvements, the participant had the possibility of leaving further comments with regards to the whole project. The results of all comments that were left are shown in Table 6. A small proportion of participants left valuable comments, with the majority regarding the functionality and information included. Both of these factors were already addressed in previous questions.

Table 6 - Questionnaire, Question 6 - Improvement Comments

<table>
<thead>
<tr>
<th>No:</th>
<th>Improvements Mentioned:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>“Website is great, nice layout and easy to navigate. Smooth animations and good typography, very easy to read. Game doesn’t work as there are no questions and when you select an answer and press submit, nothing happens.”</td>
</tr>
<tr>
<td>2.</td>
<td>“The game could have some input to the control of the rocket. This would make it more fun and would encourage better animations.”</td>
</tr>
<tr>
<td>3.</td>
<td>“speed up the questions”</td>
</tr>
<tr>
<td>4.</td>
<td>“Speed up questions”</td>
</tr>
<tr>
<td>5.</td>
<td>“None.”</td>
</tr>
<tr>
<td>6.</td>
<td>“No end screen on the game.”</td>
</tr>
<tr>
<td>7.</td>
<td>“More questions”</td>
</tr>
<tr>
<td>8.</td>
<td>“Make the correct/incorrect pop up on the game more obvious”</td>
</tr>
<tr>
<td>9.</td>
<td>“Increased speed of appearance of questions”</td>
</tr>
<tr>
<td>10.</td>
<td>“Great menu screen and the various sections with regards to history and future going forward was very nice. Would have made the answer for each question slightly more clear however”</td>
</tr>
<tr>
<td>11.</td>
<td>“Game could be more interactive.”</td>
</tr>
<tr>
<td>12.</td>
<td>“Bit slow in places, feedback could be more obviously given.”</td>
</tr>
<tr>
<td>13.</td>
<td>“Back button to previous page”</td>
</tr>
</tbody>
</table>
4.6 Summary of Results

The questionnaire was completed by people from various age groups and both genders, thus ensuring that the results were well rounded. Overall, both the website and the game were successful, as shown in the highly ranked results. In terms of the information included in both the website and the game, the information provided was very informative and useful. Furthermore, the game was perceived to be easy to use. Therefore, the aim to produce a fun learning activity in the form of a user friendly game and website has been fulfilled. In addition to this, based on the demographics of the participants, the website and game were appropriate for all ages. However, it is clear from the final two questions that there are improvements that could be made. Further improvements could include the use of more animations within the game in order to make it more interactive and therefore a more enjoyable experience.

Table 6 - Questionnaire, Question 7 (Further Comments)

<table>
<thead>
<tr>
<th>No:</th>
<th>Further Comments:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>“Very easy to use and extremely informative.”</td>
</tr>
<tr>
<td>2.</td>
<td>“Having read the website I have learned a lot more about data communication.”</td>
</tr>
<tr>
<td>3.</td>
<td>“The information is useful on the website.”</td>
</tr>
<tr>
<td>4.</td>
<td>“Website very good, although masses of text could do with being broken up with more use of images, maybe inclusion of some video for explanations.”</td>
</tr>
<tr>
<td>5.</td>
<td>“no”</td>
</tr>
<tr>
<td>6.</td>
<td>“Lots of interesting information about space”</td>
</tr>
<tr>
<td>7.</td>
<td>“A very informative website/game that proved easy to understand and interesting.”</td>
</tr>
</tbody>
</table>
5.0 Conclusion

In conclusion, the use of technology throughout recent decades has increased drastically. It has improved across all areas and has made it possible for humans to explore the solar system and beyond, making the impossible, possible. Within the space of fifty years, space exploration has grown exponentially, yet there is still an endless amount of possible discoveries to be made.

The project aims were to ultimately evaluate the future prospects of data communications within space exploration, as well as producing a game and a website with the idea of offering a fun learning opportunity for those who may be interested. With the use of secondary data, the project has involved an in-depth research of the history behind data communications, considering space exploration and how it has adapted throughout the ages. A thorough study into the methods that are known for communications was also undertaken. This included how they are currently used and evaluating the future possibilities for communications within space. One of the objectives of the project was to assess the security of methods of communication in space. This was completed by touching briefly on encryption and decryption. However, with the lack of access to information, which is understandable due to the growing use of the internet and the increasing number of cyber attackers, it was not possible to discuss this topic in greater detail. On the other hand, other objectives such as determining the methods of communications, evaluating the limitations of communicating and the history of data communications were fulfilled. Research based on real life cases allowed a comparison of the technology utilised on each case and whether they were a success.

After reviewing the current methods that are used for data communications in space, it is clear that current technology and instrumentation utilises radio-waves to transmit data on a regular basis. The use of microwave radio signals is continuously being supported, in particular for future scientific experiments with space agencies funding the trialling of Ka-Band frequency equipment. Although this technology has been around for a number of years, it was not previously used extensively in experiments which required sending and receiving data from long distances. However, with the advancement in this particular technology, the Ka-band frequency now seems to have the ability to transmit and receive data quickly over
long distances and without any problems. Space agencies and scientists are also exploring the possibility of laser communications instead of radio-wave technology. This could be a massive improvement in communicating in space due to the vast enhancement in speeds that it can offer when transferring data. Laser communication could soon be implemented and offering the opportunity to provide data that comprises of high definition images and also 4K video.

The second section of the project was to develop a game in an attempt to create a user friendly and also a fun learning activity (Appendix E). Primary data collection methods were used to gather feedback from the game. Questionnaires were used to gather the information whilst also assisting in terms of testing as it helped create a better functional game, example of the questionnaire can be seen in Appendix B. After carefully reviewing the graphs and tables, the results demonstrate that the project has successfully met its aim of producing a fun and useful learning activity as most questions were scored highly. Very few questionnaires returned with a low score and when this occurred, it was found that this was due to compatibility issues with the game being used in the Mozilla Firefox internet browser. Despite a flaw being detected, this would provide valuable information to improve the game in future.

Although it has been truly remarkable what humans have achieved in space with the current technology, it is clear that substantial advances are still to be made. By maintaining and updating the technology within microwave radio waves and implementing laser technologies, communications in space is only going to improve.
6.0 References:


44
7.0 Appendices

Appendix A – Ethics Form (Ethics approval No: 2016D04797)

When undertaking a research or enterprise project, Cardiff Met staff and students are obliged to complete this form in order that the ethics implications of that project may be considered.

If the project requires ethics approval from an external agency (e.g., NHS), you will not need to seek additional ethics approval from Cardiff Met. You should however complete Part One of this form and attach a copy of your ethics letter(s) of approval in order that your School has a record of the project.

The document Ethics application guidance notes will help you complete this form. It is available from the Cardiff Met website. The School or Unit in which you are based may also have produced some guidance documents, please consult your supervisor or School Ethics Coordinator.

Once you have completed the form, sign the declaration and forward to the appropriate person(s) in your School or Unit.

PLEASE NOTE:
Participant recruitment or data collection MUST NOT commence until ethics approval has been obtained.

PART ONE

<table>
<thead>
<tr>
<th>Name of applicant:</th>
<th>Jonathan Swanwick</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supervisor (if student project):</td>
<td>Dr Paul Angel</td>
</tr>
<tr>
<td>School / Unit:</td>
<td>Cardiff School of Management</td>
</tr>
<tr>
<td>Student number (if applicable):</td>
<td>st20066826</td>
</tr>
<tr>
<td>Programme enrolled on (if applicable):</td>
<td>BSc(Hons) Computing</td>
</tr>
<tr>
<td>Project Title:</td>
<td>What are the future prospects for data Communications within space exploration?</td>
</tr>
<tr>
<td>Expected start date of data collection:</td>
<td>23/01/2017</td>
</tr>
<tr>
<td>Approximate duration of data collection:</td>
<td>2 Months</td>
</tr>
<tr>
<td>Funding Body (if applicable):</td>
<td>N/A</td>
</tr>
<tr>
<td>Other researcher(s) working on the project:</td>
<td>N/A</td>
</tr>
<tr>
<td>Will the study involve NHS patients or staff?</td>
<td>No</td>
</tr>
<tr>
<td>Will the study involve human samples and/or human cell lines?</td>
<td>No</td>
</tr>
</tbody>
</table>
Does your project fall entirely within one of the following categories:

<table>
<thead>
<tr>
<th>Category</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper based, involving only documents in the public domain</td>
<td>No</td>
</tr>
<tr>
<td>Laboratory based, not involving human participants or human samples</td>
<td>No</td>
</tr>
<tr>
<td>Practice based not involving human participants (e.g., curatorial, practice audit)</td>
<td>No</td>
</tr>
<tr>
<td>Compulsory projects in professional practice (e.g., Initial Teacher Education)</td>
<td>No</td>
</tr>
<tr>
<td>A project for which external approval has been obtained (e.g., NHS)</td>
<td>No</td>
</tr>
</tbody>
</table>

If you have answered YES to any of these questions, expand on your answer in the non-technical summary. No further information regarding your project is required.

In no more than 150 words, give a non-technical summary of the project:

The design of this project will be based around the development of a game that will be question-based for the users and will look to provide the user with a learning opportunity regarding data communications in space.

In order for the user to be able to play this game, the questions will be based on the research that has been carried out. All research findings will be available on the website that the game is displayed on, allowing the user to learn and answer the appropriate questions. Not only would this be a learning activity for the user, it would be a good opportunity for the user to understand the history behind data communications in space along with possible future prospects.

DECLARATION:

I confirm that this project conforms with the Cardiff Met Research Governance Framework.

I confirm that I will abide by the Cardiff Met requirements regarding confidentiality and anonymity when conducting this project.

STUDENTS: I confirm that I will not disclose any information about this project without the prior approval of my supervisor.

Signature of the applicant: Date:
<table>
<thead>
<tr>
<th>Name of supervisor:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Paul Angel</td>
<td>21/03/17</td>
</tr>
</tbody>
</table>

**FOR STUDENT PROJECTS ONLY**

<table>
<thead>
<tr>
<th>Name of supervisor:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Paul Angel</td>
<td>21/03/17</td>
</tr>
</tbody>
</table>

**Signature of supervisor:**
P Angel
**Research Ethics Committee use only**

<table>
<thead>
<tr>
<th>Decision reached:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Project approved</td>
<td>☐</td>
</tr>
<tr>
<td>Project approved in principle</td>
<td>☐</td>
</tr>
<tr>
<td>Decision deferred</td>
<td>☐</td>
</tr>
<tr>
<td>Project not approved</td>
<td>☐</td>
</tr>
<tr>
<td>Project rejected</td>
<td>☐</td>
</tr>
</tbody>
</table>

Project reference number: 2016D04797

**Name:** Dr Hilary Berger

**Date:** [Click here to enter a date.]

**Signature:** [Signature]

**Details of any conditions upon which approval is dependant:**

N/A

### PART TWO

**A RESEARCH DESIGN**

<table>
<thead>
<tr>
<th>A1 Will you be using an approved protocol in your project?</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2 If yes, please state the name and code of the approved protocol to be used¹</td>
<td>N/A</td>
</tr>
<tr>
<td>A3 Describe the research design to be used in your project</td>
<td>The design of this project will be based around the development of a game that will be question-based for the users and will look to provide the user with a learning opportunity regarding data communications in space. For the ease of access to participants and to gather multiple opinions I will be using convenience sampling (Friends, family and fellow students at Cardiff Met). To aid with the development of this game, there will be a stage of testing involving participants who have experience using similar such software and who</td>
</tr>
</tbody>
</table>

¹ An Approved Protocol is one which has been approved by Cardiff Met to be used under supervision of designated members of staff; a list of approved protocols can be found on the Cardiff Met website [here](#)
will aid the development of the game as part of the project and will provide the project with qualitative data that will help with regards to the analysis of the game and provide information that can be used to aid the development of the game and the future development of the game. The data that is received from the participants will remain anonymous and will not be in any way traceable back to the participants. This will be done by storing the information securely in a password protected computer system. In order to provide me with background knowledge on the area of data communications in space, I will be completing my own research of secondary data which will help with the development of a theoretical understanding of the topic area, that will enable me to engage with the task of creating a game that will add value to the project. Once the secondary data has been researched and the game has been fully developed and tested, there will be a questionnaire given to those who have participated in the testing of the game, asking them for information regarding their experiences using the game which will allow me to come to conclusions which will help me reach the aims and objectives of the project. The project will make use of thematic analysis with regards to data analysis to make correct use of the information gained from testing and the questionnaires, as well as an interpretive research philosophy that is adapted to the qualitative data that will be obtained.

A4 Will the project involve deceptive or covert research?
No

A5 If yes, give a rationale for the use of deceptive or covert research
N/A

A6 Will the project have security sensitive implications?
No

A7 If yes, please explain what they are and the measures that are proposed to address them
N/A

B PREVIOUS EXPERIENCE

B1 What previous experience of research involving human participants relevant to this project do you have?
N/A

B2 Student project only
What previous experience of research involving human participants relevant to this project does your supervisor have?
Click here to enter text.
### C POTENTIAL RISKS

#### C1 What potential risks do you foresee?

1. Participants may be concerned about anonymity.
2. Participants may be concerned about the use of the data procured from the questionnaire.
3. Concerns over the timescale of the testing and research stages of the project.

#### C2 How will you deal with the potential risks?

1. Participants will be informed that the data collected will be anonymised and stored in a safe and secure manner.
2. Participants will have the option to withdraw from the research at any time without penalty. Any data collected from them will be destroyed.
3. A detailed time plan / Gantt Chart will be produced to give enough time to each section.

When submitting your application you **MUST** attach a copy of the following:

- All information sheets
- Consent/assent form(s)

An exemplar information sheet and participant consent form are available from the Research section of the Cardiff Met website.
Appendix B – Proposed Questionnaire

**Proposed Questionnaire**

1.) Age:
   - Under 18 □
   - 18-30 □
   - 31-40 □
   - 41-50 □
   - 50+ □

2.) Gender:
   - Male □
   - Female □

3.) On a scale of 1-10, 1 being irrelevant and 10 being useful, how would you rate the information on the website?
   
   1   2   3   4   5   6   7   8   9   10

4.) On a scale of 1-10, 1 being unusable and 10 being easy to use, how would you rate the game on the website?

   1   2   3   4   5   6   7   8   9   10

5.) On a scale of 1-10, 1 being irrelevant and 10 being understanding, how would you rate the information provided on the game?

   1   2   3   4   5   6   7   8   9   10

6.) Are there any improvements that you would like recommend for either the website or the game?

   ………………………………………………………………………………………………………………………………………………………………………
   ………………………………………………………………………………………………………………………………………………………………………
   ………………………………………………………………………………………………………………………………………………………………………

7.) Any other comments?

   ………………………………………………………………………………………………………………………………………………………………………
   ………………………………………………………………………………………………………………………………………………………………………
   ………………………………………………………………………………………………………………………………………………………………………

Thank you for completing this questionnaire.
Appendix C – JavaScript game functionality file (Code)

```javascript
1. var question = document.getElementById('question_box');
2. // creating jQuery variables.
3. var link1 = $('#q1');
4. var link2 = $('#q2');
5. var link3 = $('#q3');
6. var link4 = $('#q4');
7. var submit = $('#submitButton');
8. var score = document.getElementById('score');
9. var answerF = document.getElementById('answerF');

10. var span1 = document.getElementById('a1');
11. var span2 = document.getElementById('a2');
12. var span3 = document.getElementById('a3');
13. var span4 = document.getElementById('a4');
14. var qRight = 0;
15. var questionNow = 0;
16. var askQ = true;
17. var answerGiven = false;
18. var isClicked = false;
19. // creation of arrays and data stored
20. var questions = [{
23.   answer: 1969
24. }, {
25.   question: '2. How did it become possible for data communications to go long distance?',
26.   selection: ['Antennas', 'Via a Telegraph', 'Internet', 'Email'],
27.   answer: 'Via a Telegraph'
28. }, {
29.   question: '3. What is the calculation to measure the speed of light?',
30.   selection: ['$3.0x10^8$ $m/s$', '$2.8x10^8$ $m/s$', '$3.8x10^8$ $m/s$'],
31.   answer: '$3.0x10^8$ $m/s$'
32. }, {
33.   question: '4. What does DSN stand for?',
34.   selection: ['Deep Space Networks', 'Dual Signal Networks', 'Deep Signal Network', 'Dual Speed Networks'],
35.   answer: 'Deep Space Networks'
36. }, {
37.   question: '5. What is the name of the ROVER that landed on Mars in August 2012?',
38.   selection: ['Bagle 2', 'Rosetta', 'Curiosity', 'Odyssey'],
39.   answer: 'Curiosity'
40. }, {
41.   question: '6. What radio frequency equipment do most spacecrafts use to communicate?',
42.   selection: ['S-Band', 'X-Band', 'Ka-Band', 'Ku-Band'],
43.   answer: 'X-Band'
44. }, {
45.   question: '7. What was the first invention that inspired digital communication?',
46.   selection: ['Morse Code', 'Telephone', 'Email', 'Internet'],
47.   answer: 'Morse Code'
48. }, {
49.   question: '8. Which radio frequency can transmit data through speeds of up to 3 20GHz?',
50.   selection: ['S-Band', 'X-Band', 'Ka-Band', 'Ku-Band'],
51.   answer: 'Ka-Band'
52. }, {
53.   question: '9. What type of technology is currently being reviewed for future space communications?',
54.   selection: ['Laser', 'Wireless', 'Wired', 'Telegraphs'],
55.   answer: 'Laser'
56. ];
```
59. }, {
60.   question: "10. Noise can be an issue while communicating. Which one of the foilowing is an example of internal noise?",
61.   selection: ['Popcorn', 'Loud', 'TV', 'String'],
62.   answer: 'Popcorn'
63. });
64.
65. function askQuestion() {
66.   var choices = questions[questionNow].selection;
67.   $( '#question_box' ).text(question.innerHTML = questions[questionNow].question, {speed:70, speed_vary: true});
68.   span0.innerHTML = questions[questionNow].selection[0];
69.   span1.innerHTML = questions[questionNow].selection[1];
70.   span2.innerHTML = questions[questionNow].selection[2];
71.   span3.innerHTML = questions[questionNow].selection[3];
72. }
73.
74. function checkAnswer() {
75.   // Function to calculate if the answer is right or wrong.
76.   clicked = false;
77.   $('.textAnswers').removeClass('activeBackground');
78.   if (askQ) {
79.     askQ = false;
80.     if (answerGiven === questions[questionNow].answer) {
81.       qRight++;
82.       score.innerHTML = 'Score: ' + qRight;
83.       answerF.innerHTML = 'Answer: Correct!!!';
84.     } else {
85.       answerF.innerHTML = 'Answer: Wrong!!!';
86.     }
87.     askQ = true;
88.   }
89.   if (questionNow < questions.length - 1) {
90.     questionNow++;
91.     askQuestion();
92.   } else {
93.     showScore(); // end of game show score
94.   }
95.
96. }
97.
98. function clicked() {
99.   // Function for when button is clicked.
100.  var idOfThis = $( this ).attr("id");
101.  $('.textAnswers').removeClass('activeBackground');
102.  $(this).toggleClass('activeBackground');
103.  $(this).text($(this).text() == 'Yes' ? 'No': 'Yes');
104.  $(this).toggleClass('trueBackground');
105.  if (questionNow < questions.length - 1) {
106.    questionNow++;
107.    askQuestion();
108.  } else {
109.    if (questionNow < questions.length - 1) {
110.      questionNow++;
111.      askQuestion();
112.    }  
113.  }
114.  }
115.  
116.  if (idOfThis != 'thatButton') {
117.    answered = answered + 1;
118.    if (idOfThis == 'trueBackground') {
119.      answered++;  
120.    }  
121.  if (questionNow < questions.length - 1) {
122.    question.innerHTML = idOfThis;
if (idOfThis == "an1") {
    answerGiven = questions[questionNow].selection[0];
    isClicked = true;
} else if (idOfThis == "an2") {
    answerGiven = questions[questionNow].selection[1];
    isClicked = true;
} else if (idOfThis == "an3") {
    answerGiven = questions[questionNow].selection[2];
    isClicked = true;
} else if (idOfThis == "an4") {
    answerGiven = questions[questionNow].selection[3];
    isClicked = true;
}
}

window.addEventListener("load", askQ, false);
//submit.addEventListener("click", checkAnswer(), false);

$("#submitButton").click(function() { // submit button with validation for a message box to appear when no answer selected.
    if(isClicked) {
        checkAnswer();
    } else {
        alert('No answer selected. Please select and try again.');
    }
});

function resetValues() { //Function to reset for and answers
    questionNow = 0;
    qRight = 0;
    askQ = true;
    answerGiven = 0;
    score.innerHTML = 'Score';
    answerF.innerHTML = 'Answer';
    askQuestion();
}

function showScore() { //function to show score result and to play again
    var displayScore = $("#resultShown");
    var scoreNow = qRight;
    var noOfQuestions = questions.length;
    var scoreText = '<h3>Score</h3><p>You have a score of ' + scoreNow + ' out of ' + noOfQuestions + '. Game reset, play again!</p>'';
    displayScore.append(scoreText);
    resetValues();
    askQuestion();
}
Appendix D – Development HTML file Game (Game Structure)

```html
<!DOCTYPE html>
<html>
  <head>
    <title>Dissertation Game</title>
    <meta charset="utf-8" />
    <meta name="viewport" content="width=device-width; initial-scale=1, user-scalable=no" />
    <link rel="stylesheet" href="assets/css/main.css" type="text/css" />
    <link rel="stylesheet" href="https://fonts.googleapis.com/css?family=Indie+Flower|Permanent+Marker" rel="stylesheet" />
    <script src="assets/js/jquery-3.2.1.min.js"></script>
    <script src="assets/js/script.min.js"></script>
    <link rel="icon" type="image/png" href="assets/images/earthLogo.png" />
  </head>
  <body>
    <div id="quizStarter">
      <div id="startGame"><a id="StartButton" href="#">Start</a></div>
      <div id="mission">
        <br>
        <br>
        Houston, we have a problem..."<br>
        <br>
        "Communications have been lost! We need your help getting back to Earth... Are you ready?"<p>
      </div>
      <div id="instructions">
        <br>
        How to play:<br>
        <br>
        Read the question. <br>
        Click on the box with the right answer. <br>
        Click Submit.<br>
        <br>
        Thanks!!</p>
    </div>
    </div>

    <div id="container">
      <!-- created the animation pane -->
      <div id="leftPanel" class="inset-section">
        <div id="questionPane"></div>
        <div id="questionPane">
          <div id="answerButtons"></div>
          <div id="answerButtons">
            <div id="score">Score</div>
            <div id="answerC" >Answer</div>
          </div>
          <div id="rightPanel" class="inset-section">
            <ul id="answer_container">
              <li id="a1" onclick="clicked(this); class="textAnswers"
              <li id="a2" onclick="clicked(this); class="textAnswers"
              <li id="a3" onclick="clicked(this); class="textAnswers"
              <li id="a4" onclick="clicked(this); class="textAnswers"
              <li id="a5" onclick="clicked(this); class="textAnswers"
              <li id="a6" onclick="clicked(this); class="textAnswers"
              <li id="a7" onclick="clicked(this); class="textAnswers"
              <li id="a8" onclick="clicked(this); class="textAnswers"
            </ul>
            <div id="hint">
              To finish game, close the tab to go back to the website.</p>
            </div>
            <div id="resultShown"></div>
          </div>
        </div>
      </div>
    </div>
  
  </body>
</html>
```
Appendix E – Game and Website official screenshots

Final implementation of website and game can be found at:
www.jonathanswanwick.co.uk/dissertation

Website homepage:

Example of Menu Clicked:
Welcome screen on game:

Summary:
*Houston, we have a problem...*
Communications have been lost! We need your help getting back to Earth.
Are you ready?

How to play:
*Read the question.*
*Click on the box with the right answer.*
*Click Submit.*

SIMPLES!!

Final Game:

**To finish game, close the tab to go back to this website.**
**Score**
You have a score of 10 out of 10. Great score! Play again!
Appendix F – Participant Information Sheet

PARTICIPANT INFORMATION SHEET

Data Communications within Space Exploration

Project summary
The purpose of this research project is to establish the future prospects of data communications within space exploration. Your participation will enable the collection of data which will form part of a study being undertaken at Cardiff Metropolitan University.

Why have you been asked to participate?
You have been asked to participate because you fit the profile for the research of this project, to which I believe you will have better understanding of the proposed questions.

During the questionnaire, you will be asked questions about the website and game and about any improvements required.

Your participation is entirely voluntary and you may withdraw at any time.

Project risks
The research involves the completion of a questionnaire and participation in an interview and which will be recorded for later analysis. I am not seeking to collect any sensitive data on you; this study is only concerned with data communications in space. I do not think that there are any significant risks associated with this study. However, if you do feel that any of the questions are inappropriate then you can stop at any time. Furthermore, you can change your mind and withdraw from the study at any time, I will completely respect your decision.

How we protect your privacy
All the information you provide will be held in confidence. I have taken careful steps to make sure that you cannot be directly identified from the interview. Your personal details (e.g. signature on the consent form) and your interview answers will be kept in secure locations by the research team. When I have finished the study and analysed all the information, all the documentation used to gather the data will be destroyed. The recordings of the interview will also be held in a secure and confidential environment during the study and destroyed when it is complete.

YOU WILL BE OFFERED A COPY OF THIS INFORMATION SHEET TO KEEP

If you require any further information about this project, then please contact:

Jonathan Swanwick, Email: jonathanswanwick@gmail.com