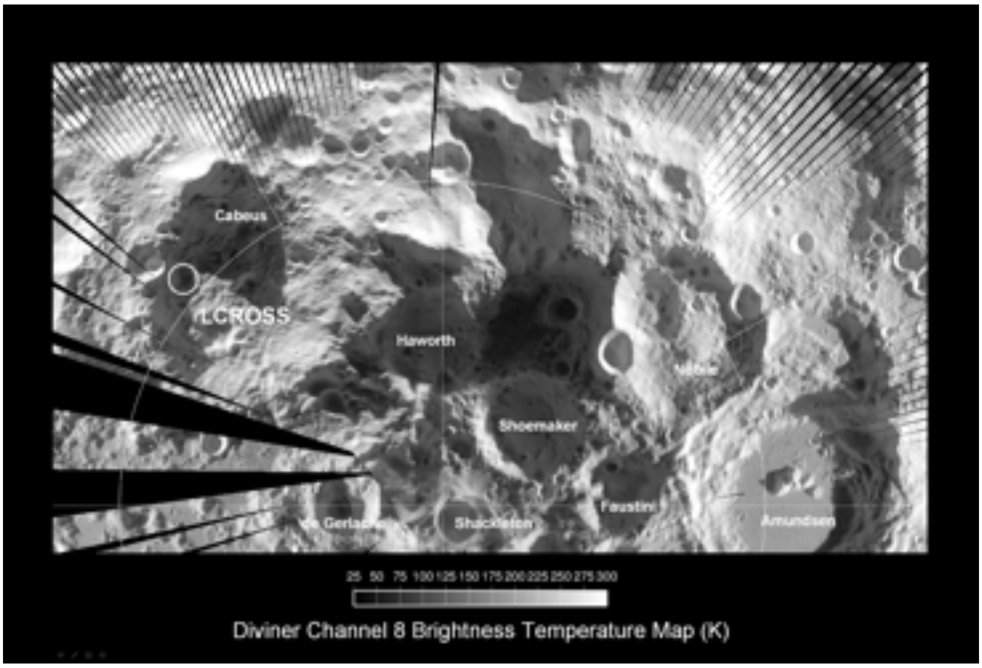
How Different Types of Radiation on the Moon Affect DNA and its General Structure

Holly Bale

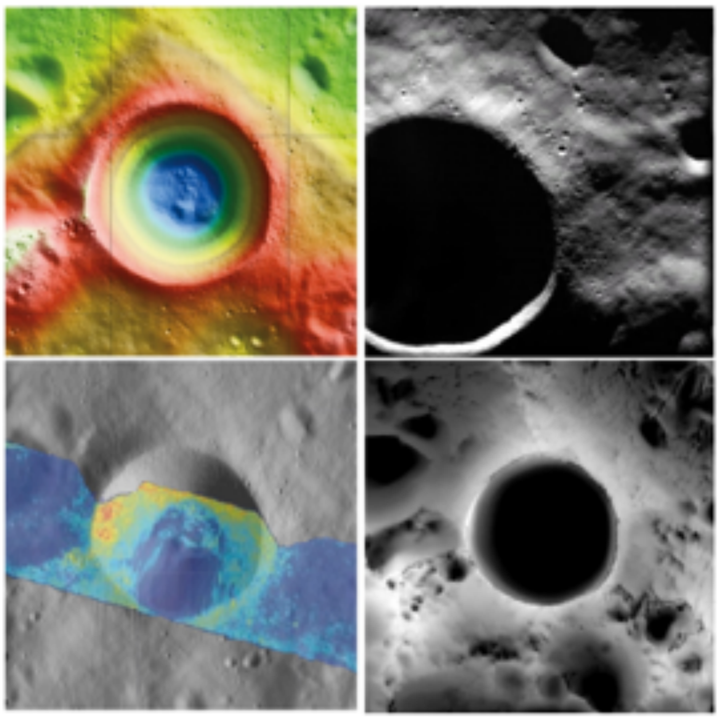
<u>An Introduction to Lunar Mission One</u>

The whole purpose of Lunar Mission One is to explore and investigate the moon. A robot will be sent up to the moon and this will then land on the Moon's South Pole; on the edge of the Shackleton Crater. From here we will then proceed to drill a hole 20-100m into the Moon's surface. We will then investigate the possibility of a future manned base; we will then collect samples from different stages of the bore hole and once this has been achieved we will then proceed to place an archive about the Life on Earth into the hole and we plan for this to last a billion years.

In December 2014, Lunar Mission One raised over $1million; this was raised by over 7,000 backers from 70 different countries. Due to this funding, Lunar Mission One has entered its first phase of development.



The diagram on the left shows the Shackleton crater as well as the other crates surrounding it. This way we can compare and discuss the landing site.



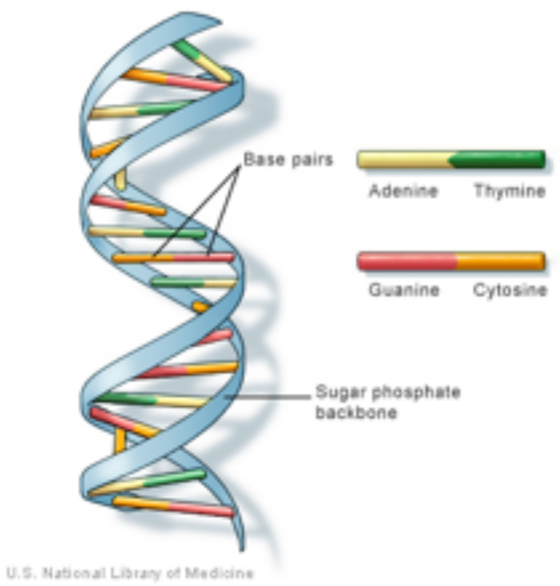
Introduction to my Investigation

In my report I am investigating how different types of radiation present on the moon affect DNA and its general structure. This is an extremely important investigation as we need to prevent the DNA from being damaged if we want to keep an archive for a billion years. One of the biggest factors that will affect the DNA that we will come across is radiation; the moon is full of many different types of DNA.

As a huge part of this mission is placing a time capsule into the hole we will create, we need to ensure that this archive is protected so it can be accessed in many years to come. Radiation is a huge factor to consider as it has the ability to mutate DNA and it exists in many forms on the moon; making it a huge problem to scientists.

<u>DNA</u>

DNA or Deoxyribonucleic Acid is a very important part in life. Most DNA is located in the cell nucleus however some is also located in the mitochondria. DNA is a code made of four nitrogenous bases, these are: Adenine, Cytosine, Guanine and Thymine. In DNA, the bases pair up with each other, Adenine with Thymine and Cytosine with Guanine. These bases are also attached to a phosphate molecule and a sugar molecule; these make up a nucleotide. These are then organised into two strands (Polynucleotide strands) that then form a spiral which is called a double helix.



One phosphate molecule from one strand is covalently bonded to a sugar molecule in the other strand. The phosphate molecules are bonded together by hydrogen bonds and it is these hydrogen bonds that cause the DNA strand to twist into the spiral. It is these bonds that are directly affected by the radiation on the moon.

Scientists have found that DNA can be stored for up to 50,000 years; however this is not long enough for what is needed for the archive and radiation will also be a factor which could decrease the storage time.

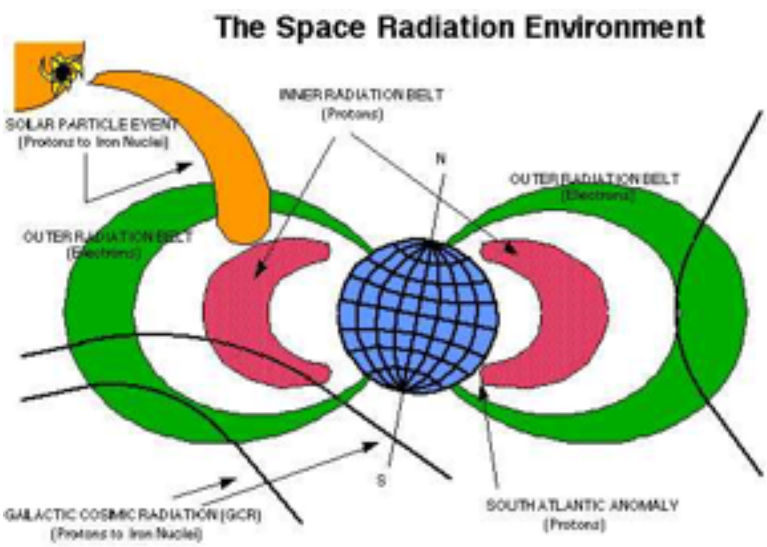
Radiation and Types on the Moon

Radiation can be defined as energy in transit in the form of high-speed particles and electromagnetic waves.

On Earth we experience radiation as x-rays or gamma rays; however radiation on the moon is completely different to this. The main form of space radiation is ionising radiation. This exists as high-energy, charged particles. The three main sources of space radiation are: Galactic cosmic radiation, trapped radiation and solar particle events. "Space radiation is compromised of atoms in which electrons have been stripped away as the atom accelerates in interstellar space to speeds approaching the speed of light" This then means that eventually only the nucleus of the atom remains.

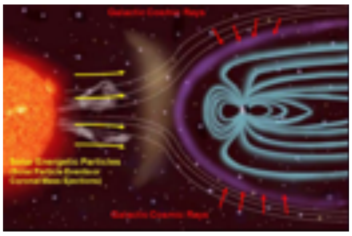
Trapped Radiation

Around the Earths core (this is molten iron) the rotation causes many electric currents; these produce magnetic field lines. The Van Allen belts are actually trapped radiation; there are inner and outer belts. The reason the radiation gets trapped in the Earth's magnetic field is because not all of the particles are deflected by the magnetosphere. The inner belt contains a stable population of protons. The outer belt mainly consists of electrons. As this radiation is not specifically on the moon it will not have as large affect on the DNA in the capsule; however as the shuttle is on its journey to the moon, this radiation will have a small affect on the DNA so we still need to ensure that the archive is well protected. The diagram above also shows the two other types of space radiation: Galactic Cosmic Radiation and Solar Particle Events. This very clearly shows where the 3 different types of radiation target and tell us how they will affective DNA in the archive.



Representation of the major sources of ionizing radiation of importance to manned missions in low-Earth orbit. Note the spatial distribution of the trapped radiation belts.

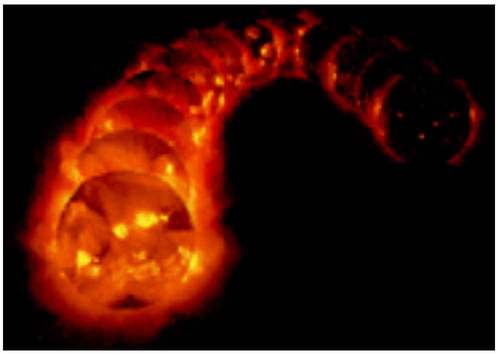
Galactic Cosmic Radiation



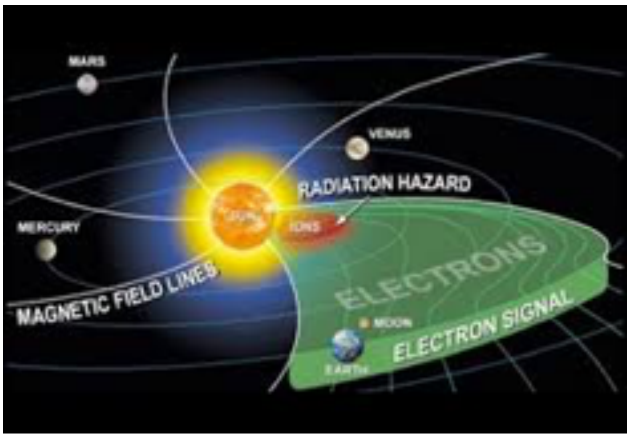
Galactic Cosmic Radiation consists of “ionised atoms ranging from a single proton up to an uranium nucleus. The rate of flow levels of these particles is very low.” However, because they travel extremely close to the speed of light, they will produce intense ionisation as they pass through matter.

The Earths magnetic field will provide shielding for the spacecraft against galactic cosmic radiation; however this radiation can have access which still causes a huge issue for the DNA in the archive.

Solar Particle Events



“Solar Particle Events are injections of energetic electrons, protons, alpha particles and heavier particles into interplanetary space.” The particles are then accelerated to “near relativistic speeds by the interplanetary shock waves.” These temporarily enhance the “radiation in interplanetary space around the magnetosphere. The Sun is made up of gas, this means that due to its magnetic field, different parts rotate and many different speeds. Due to this happening, the magnetic field gets all messed up; this means that parts of the magnetic field will break as too much energy has been built up. This then causes a small amount of gas to escape from the magnetic field; this seems pretty harmless, however in this gas there is a small amount of ionising radiation.

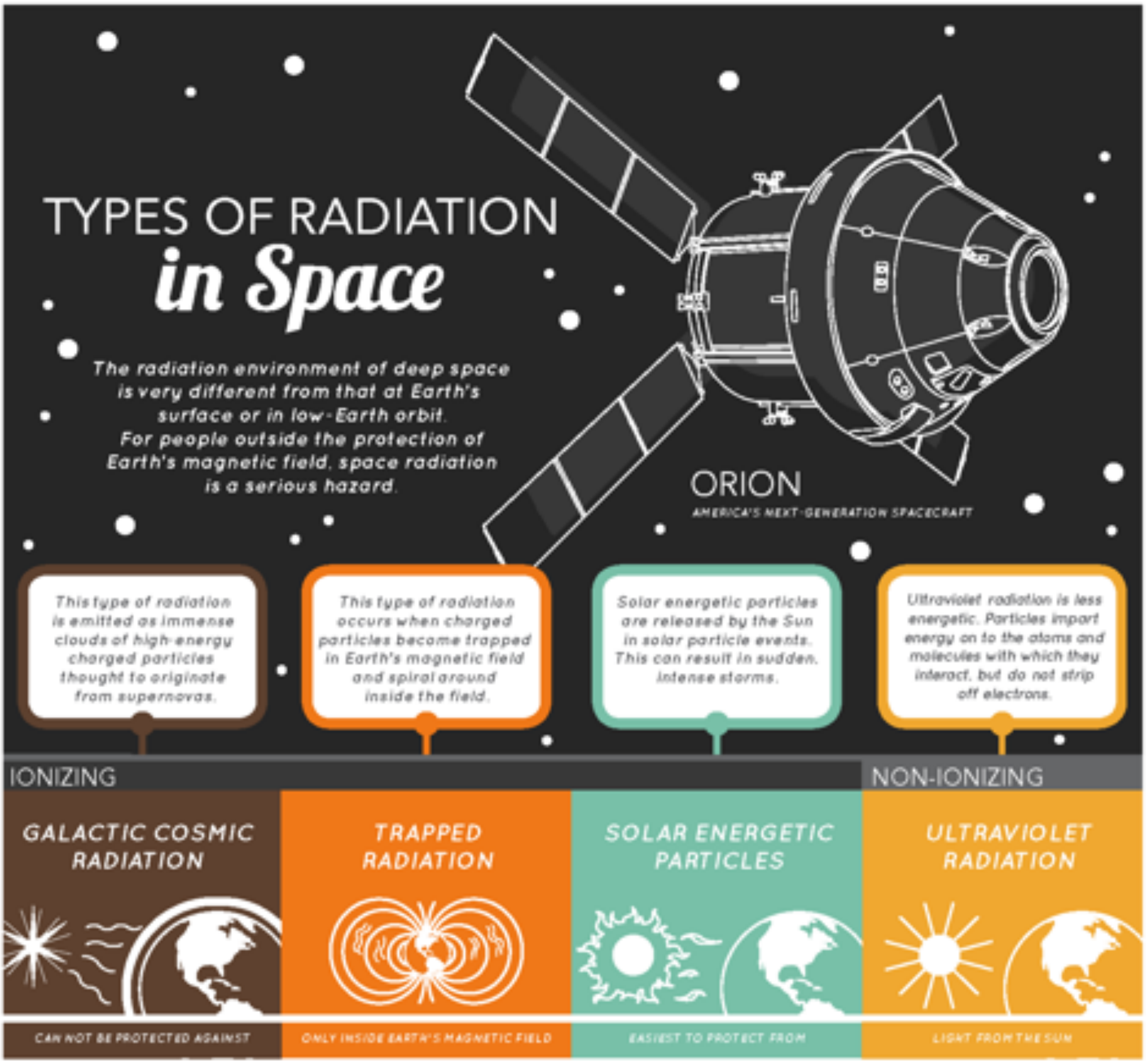


From the picture on the left you can see that right next to the sun there is a red disc; this is an area with a high density of ions which causes quite a large radiation hazard.

“The surface of the moon is baldy exposed to cosmic rays and solar flares; some of that radiation is very hard to stop with shielding.” This is because when the galactic cosmic rays collide with different particles on the lunar surface “they trigger little nuclear reactions that release radiation in the form of neutrons.” The lunar surface is essentially radioactive itself.

In the borehole there is also signs of rock radiation. From the studies carried out by NASA the archive should be buried deep enough so that it wont be affected from non-lunar ionising radiation, like cosmic radiation and solar flares. However there will be some radiation coming from the lunar rock itself.

This radiation will be very small but as the archive is planned to be there for a billion years the gradual build up of radiation attacking the archive will cause some problems and could degrade the archive's information.



http://www.jpl.nasa.gov/infographics/infographic.view.php?id=11188

How Different Types of Radiation on the Moon affect DNA

The main focus of my report was to investigate how different types of space radiation affect DNA. As many samples of DNA are going to be sent up to the moon in the archive we need to fully understand the possible problems we will encounter with trying to keep the DNA fully protected.

Space radiation can cause many problems to human DNA. These problems are either known as acute or chronic. Acute effects are when the radiation has an immediate impact on humans; whereas chronic effects are when radiation affects humans over a longer period of time.

“Acute Effects

Acute effects can be felt almost immediately when a large dose of radiation is accumulated in a short amount of time. These effects can include acute radiation syndrome, which causes nausea, vomiting and fatigue.

Chronic Effects

Chronic effects are the results of an accumulated dose of radiation over longer periods of time. Chronic effects include an increased risk of cancer, for example. The onset of these diseases can happen decades after the exposure to radiation occurs.”

When radiation interacts with living tissue there is either direct damage or indirect damage. Direct damage is when a proton hits the DNA and causes a double strand break. The radiation directly breaks one of both of the sugar phosphate backbones or it will break the base pairs of DNA. This is because the base pairs are only bonded together by weak hydrogen bonds.

Indirect damage is when radiation interacts with water, this causes free radicals to from; these free radicals cause free radical cascades which go on to cause heavy damage.

When this damage has occurred the DNA starts to repair itself. It does this by a process called excision. This happens in three steps.

-“Endonucleases cut out the damaged DNA

-Resynthesis of the original DNA by DNA Polymerase.

-Ligation whereby the sugar phosphate backbone is repaired.”

However as the DNA in the archive are just samples it might not be possible for it to carry out excision; hence why we need to make sure that the samples are completely protected.

Cosmic rays can seriously damage DNA, the exposure could increase the risks of cancer, cataracts and neurological disorders.

Methodology

The main focus of my investigation was to research how different types of radiation on the moon affect DNA. This meant that I did not have any experiments to carry out. One possibility of an experiment would be to test different types of radiation samples on some samples of DNA; however I do not have the resources available to carry this out. Another possibility of an experiment would be to test how different types of material protect DNA samples from different types of radiation, but again I do not have the resources available to carry this out.

Whilst researching I came across some papers about the Atomic Bomb; this made me think about whether scientists could compare the effects from the radiation produced from the bomb on some DNA samples. This could be extremely useful as they could look at some reports and see how they could protect the samples from these different types of DNA.

Different ways we can protect the DNA in the archive

One of the main materials currently used to protect against radiation is Lead. This is due to its density. This is because the denser a material is, the more atoms it has per unit. This means that there is a higher chance of the gamma ray photon colliding with an atom and expending its energy on the Lead, instead of expending it on your body. This works the same way with protecting the DNA in the archive.

Another reason is because lead has a very highly positively-charged nucleus. This is due to the electrons being able to absorb a large amount of energy; so when a gamma ray or x-ray hit the lead; the electrons around the nucleus absorb this energy.

Acknowledgments

I would just like to take the opportunity to say a few thank you’s; firstly i would like to thank the Nuffield Research Placement Scheme for allowing to take part in this project and allow me to broaden my knowledge, especially on a topic I did originally not know much about. I would like to say thank you to Sue for all her fantastic help and guidance throughout the entire programme and for always being there whenever I needed assistance. I would also like to thank Paul Bennett for again giving me guidance and for providing me with this research placement tin the first place. I would also like to thank the University of Bath for providing us with the equipment and facilities required for this scheme and for being such great hosts.

References

1. http://www.sciencedirect.com/science/article/pii/S0273117707005133
2. http://science.nasa.gov/science-news/science-at-nasa/2005/08sep_radioactivemoon/
3. http://genetics.thetech.org/ask/ask402
4. http://www.universetoday.com/10915/radiation-on-the-moon/
5. http://explorecuriocity.org/Explore/ArticleId/2212/radiation-effects-on-cells-dna-2212.aspx
6. http://genetics.thetech.org/ask/ask402
7. http://ibex.swri.edu/students/What_are_cosmic_rays.shtml
8. http://ocw.mit.edu/courses/nuclear-engineering/22-55j-principles-of-radiation-interactions-fall-2004/lecture-notes/ef_of_rad_on_dna.pdf
9. http://www.nasa.gov/mission_pages/ibex/IBEXDidYouKnow.html
10. http://www.ncbi.nlm.nih.gov/pubmed/16872898
11. https://www.youtube.com/watch?v=PQjL4ZDuq2o
12. http://www.nasa.gov/mission_pages/ibex/IBEXDidYouKnow.html
13. https://www.dnalc.org/view/15529-Radiation-can-cause-DNA-mutations-3D-animation-with-narration.html
14. http://science.nasa.gov/science-news/science-at-nasa/2005/08sep_radioactivemoon/

15. https://www.researchgate.net/publication/260605005_Lunar_surface_heat_flow_mapping_from_radioactive_elements_measured_by_Lunar_Prospector

16. https://www.researchgate.net/publication/6070138_Radioactivity_of_the_Lunar_Surface
17. http://science.howstuffworks.com/life/cellular-microscopic/dna1.htm
18. http://www.jpl.nasa.gov/infographics/infographic.view.php?id=11188
19. http://www.sepserver.eu/sepserver/news/SlidePublic1.html
20. http://quest.arc.nasa.gov/people/journals/space/smith/radiation10-07.html
21. http://teachnuclear.ca/all-things-nuclear/radiation/biological-effects-of-radiation/effects-of-ionizing-radiation-on-dna/
22. http://www.physlink.com/Education/Askexperts/ae590.cfm
23. http://www.thenakedscientists.com/HTML/questions/question/2490/