

Human and Engineering Perspective of Lunar Landings

Report for the Winston Churchill Memorial Trust

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Context.

We will soon be approaching the 40th anniversary of the first landing on the Moon. For those of us who remember the event it is hard to believe that it is over 36 years since the last man stood on the Moon. The lunar landings took place in a very short period of time. It was all over in the blink of an eye. The twelve men who walked on the moon did so in the space of just over forty months. If you had questioned the general public at that time many would have said that trips to the Moon or Mars would now be common place, a matter of routine. Although NASA has said it intends to return to the moon we are unlikely to see such a mission take place before 2015.

In the late 1960's the technical challenge of putting a man on the moon was not really explained to the general public. The BBC had James Burke and Patrick Moore covering each mission but they did little in terms of explaining how the various Apollo systems worked, were constructed or flown. The whole event was treated as if it was beyond the grasp of the general public and we were left to believe that the missions were being stage managed by rocket scientists.

Project Apollo had little to do with rocket science; it was an engineering problem that a great many people worked hard to resolve. Joe Shea, who managed the project for many years, is recorded as saying that when broken down into a number of parts the project was very simple to understand.

At the time of the Apollo 11 landing on the moon I was 13 years old and was very interested in each successive and more complex mission to the lunar surface. I have retained an interest since then in spaceflight, both manned and robotic, and marvel at some of the recent space probe results from the Mars rovers and the Cassini mission to Saturn. For the past twenty nine years I have been a teacher and Head of Design and Technology at a leading Independent School in the Midlands, The Royal Grammar School Worcester and Alice Ottley School (RGSAO). The subject I teach revolves around the solving of engineering problems and I began to wonder what similarities there are between the enormous undertaking of putting a man on the moon and the activities and design processes that pupils who study my subject undertake.

For my study I decided to concentrate on one aspect of the Apollo missions, the Lunar Module. My aim was to look at the engineering and human aspects of building and flying the lunar module. I chose the Lunar Module for a number of reasons:

- It is the only manned spacecraft that has been designed and built without the need to consider aerodynamics. It would only ever fly in earth orbit or around the moon and could be made whatever shape the designers and engineers wished. This was in direct contrast to any other spacecraft, such as the Gemini and Mercury capsules, which had to be conical in shape to be launched on a rocket and survive the re-entry through the Earth's atmosphere.
- The Lunar Module is the only manned spacecraft that has been designed to land on another world in the solar system. The engineers were faced with a difficult problem because little was known about the lunar surface when they set about designing the landing gear.
- The designers were faced with building two spacecraft in one. One section would land on the moon and a second section would have to take off from the surface and return the two astronauts to the command module in lunar orbit.
- The total weight of the spacecraft needed to be carefully controlled. The Saturn V rocket could only accelerate a specific weight towards the moon. If the Lunar Module exceeded the weight specification the success of the whole Apollo programme would be in doubt.

Aims of the study.

- Initially my aim was to create a case study that could be used by D&T teachers to illustrate the design process.
- To produce educational material that explained the materials used to construct the Lunar Module and the systems that made it operate.
- To produce material that explained what it was like to live and work in the Lunar Module for up to three days.
- I hope that some of the material I produce will be made available through the internet and also by being published in one of the many engineering and design publications sent out to schools.
- Prior to planning my trip I had read a considerable amount of material on the Apollo missions and the engineering problems that had to be resolved.
- To broaden my horizons and help to get my work, life balance in order.

Itinerary. What, Where and When?

My trip to America took place during the months of June and July 2008.

3rd June I flew to New York to study at the Cradle of Aviation Museum on Long Island.

11th June I travelled to Washington.

18th June I flew to Orlando to work at the Kennedy Space Centre.

27th June I flew to Houston, Texas to visit the Manned Spaceflight Centre.

The Kennedy Space Centre (KSC) in Florida is known around the world as the launch station for the Space Shuttle and the Apollo missions to the moon. The majority of people think KSC is where all the flight hardware, the rockets and lunar spaceships, were manufactured but nothing could be further from the truth. KSC was responsible for testing the hardware and assembling the various parts of the Saturn V rocket and Apollo spacecraft and launching it. However, there were no manufacturing facilities at the Cape which remains the case today. Parts were made all over America and the Lunar Module itself was built at the Grumman Aircraft factory on Long Island, New York. I spent my first week at a museum not far from the factory. The Cradle of Aviation Museum has many important artefacts from the Apollo era. Joshua Stoff, curator of the museum, and his staff were very helpful giving me total access to all the archive material they have on the Apollo project. A number of people who worked on the Lunar Module now volunteer to spend some time in the museum each week. All of them are well past retirement age but they do an excellent job of explaining what some of the complex Apollo artefacts on display are. These include the engines, landing gear design and a range of simulators that were used to train the astronauts. By far the most impressive is the display of the Lunar Module scheduled to land on the moon with Apollo 18. This mission was cancelled due to budget cuts in the early 1970's and the Lunar Module was donated to the museum. It is a complete, ready to fly spacecraft and has recently been stripped back to the basic engineering framework and refurbished. Joshua Stoff and his team have done a superb job of placing this spacecraft on a display that mimics exactly the landing of the first men on the moon. Using photographs from the Apollo 11 mission they have faithfully recreated the lunar surface to match the boulders and craters that Neil Armstrong and Buzz Aldrin landed amongst. The Lunar Module is tilted at the correct angle to match exactly how Armstrong and Aldrin landed. At the bottom of the ladder is an accurate mannequin of Neil Armstrong making his first step onto the lunar surface.

The main illumination is provided by a single spot light placed in the same position in which the sun would have been above the horizon on the moon. When you walk in the room where this display is set up it is breathtaking. It is like being transported to the Sea of Tranquillity on the moon to witness the event live. Joshua Stoff and his assistants deserve great credit for preserving this important artefact from the 1960's in such good order.



Neil Armstrong takes his first step onto the lunar surface at the Cradle of Aviation museum.

In addition the museum houses the engineering prototype of the Lunar Module. This was used for structural testing to determine if the lunar module would survive landing on the moon. It is possible to get very close to this lunar module and to inspect the engineering skills that went into its construction. The lunar modules were made and assembled by hand. It was impossible to machine the parts to shape because the material used was so thin. Studying this display, you realise how brave the Apollo astronauts were. The Lunar Module is an incredibly lightweight structure; the thickness of the pressurised cabin wall is only a fraction of a millimetre.



Engineering test article with model technicians hard at work!

I met three people who worked on the Lunar Module and it was fascinating to hear their stories about how hard they worked to meet the deadline of putting a man on the moon prior to the end of the 1960's.

Towards the end of my time at the museum I asked Josh if it would be possible to gain access to the Lunar Module simulator. This is the simulator used by the Apollo astronauts to train to land on the moon. Josh made a dream come true for me when, after the museum closed, we removed a large glass screen and I was able to stand where Neil Armstrong trained. I think the smile on my face in the picture below says it all. It also made me realise how incredibly confined the cabin of the Lunar Module is.



Front half of LM simulator used by astronauts for training.

A number of days were spent visiting the major tourist attractions in New York. The site of the World Trade Centre disaster is now clear and construction well underway on the new Freedom tower which it is hoped will be complete by 2012. Tours of Brooklyn, Ellis Island, Central Park and Harlem all proved very memorable.

I spent the second week in Washington working at the Smithsonian Air and Space museum. It took me three days to tour the museum and view the incredible range of artefacts on display. These range from small samples of Moon rock to the enormous Skylab 2 space station. The museum has an excellent display of Apollo artefacts including some of the moon suits worn by the Apollo astronauts on the surface of the moon. I was also able to study the design of many of the tools used on the lunar surface and how they had been adapted so they could be used by astronauts wearing thick spacesuit gloves. The battery powered drills and power tools that many of us now use in the garden and for DIY projects owe much of their design to the power tools developed for use on the lunar surface.

The Lunar Module display at the Smithsonian looks quite tired with parts of the foil covering on the spacecraft peeling away. It is sad to see a 50 million dollar spacecraft and a very important artefact from the Apollo era mounted on poorly painted sheets of plywood and set on display outside the fast food hall.

When you plan a trip like this you never know what is going to make the most impression on you. I found the museum district in Washington a fascinating area. The Korean and Vietnam War memorials are both very sombre and moving places to visit. The list of names on the black marble face of the Vietnam Memorial is in a very small font and this drives home how many young lives were lost in this terrible conflict. The average age of those listed was only nineteen years.

I was also able to collect some educational material for the textiles and art departments at my school. I spent time in the North American Indian museum which was hosting a display of dresses created by Indian women. I also spent time in the sculpture garden of the Art museum photographing all of the displays for the art and design department. Visits to the botanical gardens, Lincoln Memorial and the White House completed my time in Washington.

I then flew to Florida to work at the Kennedy Space Centre. I was able to use some of the resources in the education centre as well as touring the facilities that were used to launch the Saturn V and Apollo spacecraft to the moon. The two crawler vehicles used to move the moon rocket from the vehicle assembly building to the launch pad are still in use today for launching the Space Shuttle. I had hoped to be able to get behind the scenes a little at KSC and job shadow someone who currently works on the shuttle programme. However with the International Space Station now almost complete, the Shuttle will no longer be required to transport sections to orbit. As a result the Shuttle programme will come to an end in 2010. The mood at KSC is not good. While I was there, KSC workers were holding a demonstration concerning job losses from the Shuttle programme. Even with the introduction of the new Orion Project to return men to the moon, over 3000 workers will be made redundant. This will have a big impact on the surrounding area and service industries. Given the security issues and employment problems, my contact at KSC was unable to fulfil her promise of a behind the scenes tour. However, with the amount of information that I had been able to collect while in New York and Washington, I had more than sufficient notes to start to produce some educational material for use in schools. However, touring the KSC facilities and the Saturn V centre kept me busy for several days.



Saturn V exhibition at KSC

The recently opened Saturn V centre is a superb facility. Until a few years ago the Saturn V rocket had been on display outside the vertical assembly building exposed to the salty humid air and tropical Cape weather. It had deteriorated considerably and a decision was made to refurbish the giant rocket and house it in a new building together with the launch control centre. If you ever have the opportunity to visit KSC you must visit this centre. The entrance to the rocket display is carefully controlled and you must first experience the simulated launch of a Saturn V prior to entering the rocket hanger just under the five mammoth engines. It is quite incredible how all three hundred and sixty five feet of the Saturn V managed to take off from the launch pad. It is an enormous machine and a very complex piece of engineering. Once launched it's operational life was only a few hours and all parts of it were discarded into the Atlantic Ocean or deep space. Every Saturn V launched on an Apollo mission worked successfully, hurling the fifty ton spacecraft and three astronauts towards the moon with outstanding precision and at a speed of almost seven miles per second.

On the final day in Florida I went on a half day Kayak tour around the mangrove swamps of the everglades. Together with Merritt Island, on which the KSC stands, the everglades form an important conservation area. While I was in Florida it was announced that even more of the area is to be designated as a wild life preserve. Our guide on the tour was excellent. We managed to see manatees, dolphins and a wide variety of birds which use the area as a staging post on their migratory flights. We also got quite close to a horseshoe crab. It was an excellent way in which to complete the time in Florida.

KSC in Florida has the responsibility of assembling and launching rockets and the Manned Spaceflight Centre (MSFC) in Houston has the responsibility of training the astronauts and running the missions. So Houston was my final destination to complete the research into my study and it did not disappoint. The facilities at MSFC have been added to considerably over the years with most of the buildings and workers now supporting the International Space Station and Shuttle missions. The Apollo mission control room has been preserved and is a fascinating stop on one of the many tours that are offered. The control systems from the 1960's look very dated with each console equipped with an old fashioned ring dial telephone. Our guide highlighted the limited technology available to the controllers in that many used slide rules to do calculations! Hand held calculators were not available in the 1960's. The level 9 tour of the facilities was fascinating with the opportunity to go into the mission control centre for the International Space Station and observe astronauts train for missions in the space shuttle. A very large water tank is used to provide neutral buoyancy, as close to weightlessness as you can get on earth, for the astronauts to train for space walks and assembly of the International Space Station. We were privileged to see astronauts training for the final Hubble Space Telescope repair mission.



Shuttle and International Space Station Training Facility

A trip to Galveston proved to be very worthwhile. At Moody Gardens there was an exhibition of artefacts raised from the wreck of the Titanic. My study was now extending itself to reach the limits of mans exploration under the oceans as well as outer space. From travelling a quarter of a million miles out into space to reach the Moon to the technology required for raising objects from two and a half miles down on the seabed of the Atlantic. Possessions of people who travelled on the Titanic have been well preserved in the cold depths of the Atlantic Ocean.

I visited Houston zoo and the Natural History museum where there was an excellent display of the Shell wildlife photographs of the year. My time in Houston and the study came to an end on July 4th when I was able to join many Americans in a local park to enjoy the celebrations of their independence.

At the end of the five weeks of the study, my partner, Sue, flew out from England and we met in Las Vegas. From there we spent a week touring the north and south rims of the Grand Canyon. We then spent a week in San Francisco prior to returning to England. These final two weeks were not funded by the trust but contributed immensely to this once in a lifetime trip. We visited the Hoover Dam, cycled across the Golden Gate Bridge and marvelled at the 270 feet high giant redwood trees of Muir Wood.

Outcome of the study.

The aim of my study was to look for parallels between the Apollo program and the design work that I carry out with pupils in school. I found the similarities were numerous but obviously on a much greater scale. I obtained a wealth of material that will assist me in teaching and the preparation of a number of reports for educational and engineering magazines. These include:

- Photographs of models of the lunar module both scale and full size.
- A range of factual detail about the construction phase and the problems that had to be overcome.
- Visual material that will help me to prepare a number of posters for use in the department to promote design and engineering. I hope these will appeal to the pupils in the school and help promote engineering and design as a career.
- I also obtained a range of useful material for the textile and art departments at RGSAO.

I have written a number of reports on the Lunar Module and I hope they will be used by the Science Museum in London and the Space Centre in Leicester.

These are entitled:

1. Living in the Lunar Module.
2. Building the Lunar Module.
3. Flying the Lunar Module.
4. Walking on the moon.

These will also be published on the web to add to the growing bank of information on the Lunar Module for researchers and educators to use.

A number of articles are to be featured in the TEP magazine for schools that showcases important engineering achievements.

On a personal level I learned much from the trip. A large number of the pupils I teach take a gap year either prior to or during their university course. I have already given a number of talks at school to promote the work of the Trust and to encourage pupils to travel.

I believe I have returned more confident and relaxed about my approach to teaching since my return and I am less stressed out about the pursuit of excellence. I always felt that if anything was worth doing it should be done 100%. Perhaps all those i's don't need to dotted and all the t's crossed after all. It certainly gives you a better perspective on your work life balance.

Other benefits:

It has given me a perspective on an important historical event.

I had the opportunity to work with a group of very dedicated people at the Cradle of Aviation Museum.

On my return to school pupils and colleagues have asked me what was the most memorable part of the trip? I often recount my experience in Washington when the temperature was almost 40 C and I decided, one afternoon, to seek the cool air conditioned atmosphere of the Holocaust museum.

The internal decoration of this building is very stark, no plaster on the walls, all the brickwork is on display. There is extensive use of stainless steel to create a very harsh and cold environment. The way in which the Nazis attempted to systematically exterminate the Jewish population is set out in very graphic detail as you follow a route through three floors of the museum. No photography is allowed. We silently followed the route, shocked by the information on display, wondering how men, women and children survived for days as they were moved around Europe packed into cattle wagons. Towards the end of the route was a display that reduced me to tears. It was a very large area covered in shoes of all sizes from children to adults. They had been collected from one of the concentration camps and obviously represented only a fraction of the total that must have been left on the ground as people undressed to enter the gas chambers. Visitors to the museum looked on in silence and anguish at this very moving and upsetting display.

On the wall above the shoes are a few lines from a poem by a Yiddish poet:

We are the shoes, we are the last witnesses.
We are the shoes from grandchildren and grandfathers
From Prague, Paris and Amsterdam
And because we are only made of stuff and leather
And not of blood and flesh, each one of us avoided the hellfire.

These are the words that made the greatest impact on me during my trip and that have also brought silence to the morning assemblies during which I have recounted my trip.

Acknowledgments.

I would like to thank my partner Sue van Meeuwen for all her love, support and encouragement and giving me the belief that I could apply for a fellowship and undertake the study and trip of a lifetime.

For help in producing the various articles my thanks go to Joshua Stoff and his assistants at the Cradle of Aviation museum in Bethpage NY State.

I am also in debt to my colleagues at school who covered for my absence from school and taught my classes. I must also thank the Headmaster and Governors of the school for allowing me time off to undertake the study.

Last, but by no means least, a big thank you to all at the Winston Churchill Memorial Trust for their assistance, efficiency and advice in helping to organise the study.

Itinerary.

3 rd June 2008.	Departed UK to fly to JFK airport New York.
4 th to 10 th June	Work at Cradle of Aviation Museum and tours of NY
11 th June	Travel from NY to Washington.
12 th to 17 th June	Continue to carry out study at Smithsonian Air and Space Museum. Tours of Washington and visits to a number of other important museums.
18 th June	Fly from Washington to Florida.
19 th to 26 th June	Work at educational centre at KSC. Tours of KSC. Visit Florida Everglades.
27 th June	Fly from Washington to Houston, Texas.
28 th June to 4 th August.	Continue to carry out study at MSFC Houston. Tours of Houston and local area.

Contact:

If you would like copies of any of the reports I have produced then please do not hesitate to contact me. Email: djc@rgsw.org.uk