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by

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1. Propulsion
2. Space Physics
3. Moon Base Feasibility
4. Launch Systems

Abstract

This project is designed to study the topic of space exploration. We took an in depth look at propulsion, space physics, moon base feasibility, and launch systems. We determined that for launch the best way to reach space would be rocket propulsion and then when in space a combination of plasma thrusters and solar sail. This project would best be used as a resource and a starting point for others who are interested in the colonization of space.

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Executive Summary

The problem that is addressed in this project is one of understanding space exploration. The problem was narrowed down to propulsion in space, spacecraft launches, launch systems, re-entry, moon base feasibility, and space physics. Investigation into the space environment was also necessary in order to understand the Van Allen belts and other cosmic phenomena. All of these aspects are important things to understand in order to be able to evaluate the feasibility of colonizing space.

We accomplished a comprehensive look at propulsion. Rocket physics were discussed in length as that is what we currently use. This covered single and multiple stage rockets with the benefit of using a multiple stage rocket over a single stage rocket. We took a look at various types of propulsion beyond rockets from nuclear to tachyon drives. This left many options open for propulsion and even let us explore the strictly theoretical idea of tachyon particles.

We were able to also look at launch considerations to help build an understanding of just what it takes to get ready for space and how to get there. This understanding ultimately gave us an insightful look into how non-cost effective a launch by current methods is. We also looked into the six degrees of freedom equations in order to understand how re-entry into the atmosphere works.

We then looked into how a moon base could work and made a suggestion on how to sustain an efficient supply chain. This would allow us to slowly colonize the moon inside of a base. Also, we built an understanding of cosmic radiation and the Van Allen belts in order to see what needs to be done in ways of protection requirements. With all of this information covered, we feel like we've accomplished our goal of setting up a foundation of information for understanding space exploration and moon base feasibility.

Introduction

Space has always been a wonder to mankind. From the dawn of time men and women have gazed up at the sky and marveled at what they saw. When early civilizations could not explain what was happening in the heavens above them, they created gods to explain what they couldn't understand. As humanity developed its technology, it kept an eye to the stars. When Galileo separated space and religion, it kept its mystery and intrigue. What is it that draws the human race to space?

This project will explore the importance and meaning of space through the course of history, and will attempt to make some inferences about the current ability to colonize space. Over the years space has been connected to religion, technology, economy, and national defense. Through an understanding of the myths and stories from ancient cultures as well as the research and technologies employed to explore space, this project aims to determine whether or not humans could potentially colonize space.

Through the discussion of the topics covered in this project, the project group has determined that travel to and from a colony by using chemical rockets to escape the gravity of the Earth and plasma thrusters while in space. The chemical rockets seem to be the best choice for escaping gravity, as the other propulsion systems discussed do not offer a high enough thrust. Once free from gravity, plasma thrusters would be more efficient, and more effective, as more of the energy in the system is used to move the craft, and the top speed of the engine is higher. The idea is feasible and may come to pass in the next decade.

Matthew Brown – Matthew chose this topic due to his personal interest in space, aeronautics, and technology. As an electrical engineering major, he has a background that allows for more in depth discussion about certain types of propulsion. As an avid fan of flying and airplanes, he was particularly interested the six degrees of freedom equations used in the flight of the shuttle.

Thomas MacDonald – Tom chose this project over all others because he's always had an interest in space ever since he was young. He went to space camp when he was in 5th grade and always had a desire to go into space. With this ambition, the project fit his wants and desires for knowledge about space. It also just happened to be about something that he would like to be a part of, the colonization of space.

Barry Kosherick – Barry chose this topic as a result of his interest in space, which he has since he was a young child. He also feels that space exploration and colonization will be essential to battle the ongoing problem of overpopulation. He thinks that with space exploration, new scientific discoveries can be made that can further the human race.

Matthew Goon – Matthew chose this project because of his curious interest in what is beyond the home we call earth. He has always had an interest to explore the large unknown we call space. He feels that the space race will either directly or indirectly help out mankind with research for things that will make life more convenient and easier.

Chapter 1 – Space Mythology

Space in Greek Mythology

Thomas MacDonald

As many know, the Greeks and Romans believed in various Gods and these beliefs even extended into space. Helios was the God who rode a chariot across the sky. He was in fact the sun. He is often confused with Apollo who is known for radiant purity and was then interpreted as a Sun God. Apollo and Helios could be the same being just different interpretations. (“Helios”, Encyclopedia Britannica)

However, the other Gods feared Apollo and couldn’t be in his presence. Only his parents Leto and Zeus could withstand being near him. During the time of Homer and after, Apollo was seen as a God who emphasized divine distance. He was able to make men able to see their own guilt and was able to cleanse them of it. It is easy to see how Apollo could be associated with the sun as the sun can be seen as a purifying celestial body just like Apollo. (“Apollo”, Britannica)

Daedalus was a very gifted sculptor and architect in Greek mythology. Some of his crowning achievements include building the labyrinth for King Minos. Unfortunately for Daedalus he was imprisoned by King Minos after losing considerable support. He made wings of wax for himself and for his son. He flew to Sicily while his son, Icarus, flew too close to the sun and his wings melted. Icarus fell into the sea and drowned a victim of the sun. ("Daedalus", Britannica)

Corvus is a constellation in our sky that is named after a crow. In Greek mythology, this crow was a raven instead. Anyway, the crow was sent to fetch water for Apollo in his cup. However, the crow spent time doing other things and infuriated the God. In order to cover his own tail, the crow grabbed a water snake and blamed his tardiness on the snake. Apollo would have none of this and cast the cup, the crow, and the snake into the sky and made them into stars. However, the bird would forever suffer thirst as it is not allowed to drink from the cup. (Dibon-Smith, “Corvus”)

Orion is another constellation that takes its back story from Greek Mythology. Orion was a human that fell in love with Merope. Merope was the daughter of Oenopion, the King of Chios. Orion tried many times in winning Merope’s hand in marriage. Orion once had a lot to drink and attacked Merope. With this attack, Oenopion had Orion blinded. (“Oenopion”, Mythical) However, the most interesting and disputed fact is Orion’s death. After his death, he was put up into the sky and became a star constellation. He can be differentiated by his club, his sword, and most widely his belt. It is also very interesting to see that the Greeks saw being put into the stars as a reward and as a punishment. (“Orion”, Britannica)

All of our planets, even our recently demoted planet Pluto, take their name from Roman Gods who have Greek equivalents. Mercury’s equivalent is Hermes while Venus is Aphrodite just for some example. Each planet bares a Roman God’s name except for Earth. Each planet’s name has a lot of mythology that surrounds it since Roman and Greek mythology is very closely related. We tend to think we’re past the days of superstition with our vast sciences but why do we rely on mythology to name our planets? Could there be something more to mythology or do we just like the names? (“Planet”, Encyclopedia Britannica)

Middle Eastern Historical View of Space

Barry Kosherick

One of the first stories of people trying to get to space is the Tower of Babel. In this story the people of the city of Babel were trying to get into space by building a tower. The main interpretation of this is that the people of Babel were very pompous and thought they were better than god, and they wanted to prove it. This angered god, so when they were nearing what they thought was completion, god made everyone speak different languages thus causing too much confusion to complete the tower (Eytz Hayim, 11:1-9). This shows the basic view of space in the Middle East during the biblical age; god is in heaven of space and people are on earth. In this time when people saw things like comets, meteor shows and shooting stars they thought it was a message from god. Many times when prophets preached they said that god spoke to them from the heavens, or that a messenger of god came from the sky. Almost every blessing in Judaism starts with blessed is God, king of the universe. Stating universe implies that god is the ruler of not only the earth, but everything outside of earth, including space. There is even a Jewish blessing for seeing a comet or shooting star.

One of the best stories of a human going to the heavens is that of Elijah, in which he does not die, but gets taken up to the heavens in a chariot of fire instead (Eytz Hayim, 2:8-9). He is the only person who went to heaven without first dying. The story of Jacob also mentions the heavens in which while Jacob is sleeping he dreams of a ladder leading to heaven with angels ascending and descending between earth and heaven (Eytz Hayim, 28:11-19). These points illustrate that early Jewish thought touched on the topic of there be more to the universe than just the earth.

Islam goes further into depth by touching on the size of space. In the Qur'an there is a verse that says "With the power and the skill did We (Allah) construct the firmaments: for it is We who created the vastness of space". This implies that there is more to the universe than earth and the sky above it. The Muslim story of creation goes into much more detail of Allah creating space than the Jewish and Christian ones do. The Qur'an lists Allah specifically created the stars and the moon, while the Torah just says that God created the heavens and earth. Islam also mentions the topic of a human voyage to heaven. It is said that Muhammad took a trip overnight from Medina to Jerusalem, where he went to heaven, from the rock now inside the Dome of The Rock. In heaven Muhammad talked to Moses and was given the Islamic prayers (Muhammad).

Chinese Myths of the Sky

Matthew Goon

The Chinese have always been fascinated by the skies and what they contain. Flight and exploration of space and its constellations have always been a large part of Chinese mythology. The Chinese have always been interested in the creatures that roam the skies. Most of the creatures in Chinese mythology were usually flying creatures, from birds to dragons; these creatures heavily influence the lives of humans.

Birds have always been a large part of Chinese mythology and are influential to Chinese culture. One of the most well known birds in Chinese mythology is the Fenghuang. The Fenghuang are the mythological birds, similar to another mythological creature the phoenix, that rule over all other birds.

The fenghuang is made up from 8 different animals, and its body symbolizes the six celestial bodies. The head represents the sky, the eyes represent the sun and other stars, the back represents the moon, the wings represent wind, the feet represent the earth, and the tail represents the planets. The fenghuang can symbolize virtue and grace, and the union of yin and yang (appears in peaceful and prosperous times but hides in the face of danger). The fenghuang was also used to symbolize the Empress of China who is paired with the dragon that symbolizes the Emperor. The fenghuang can be used to decorate a home to symbolize loyalty, honesty, and the lack of darkness and corruption in the people that live in the home. Once referred to Feng (male) and Huang (female), the fenghuang was combined into a feminine creature as a supplement to Chinese dragon (usually male). The fenghuang can also be used to decorate weddings and royalty, because it complements the dragon as a symbolic relationship of blissful relations between husband and wife. (Fenghuang)

Other birds like Jian, Jingwei, and Peng have major roles in Chinese mythology. Jian is a mythical bird that has only one eye and only one wing, so that when a pair come together depend on each other. The pairing of the Jian, and their dependence on each other, symbolizes the inseparability and bond of a husband and wife. Jingwei is another mythological bird that is influential to Chinese culture, known for taking revenge on the ocean by bringing stones and twigs to fill the East Sea. Jingwei started out as the daughter of an emperor that dies in the East Sea, and then assumes the shape of a bird to fill the sea so that it will never swallow others. Jingwei has become a major symbol in Chinese culture as the embodiment of dogged determination and perseverance. Peng are giant birds that are transformed from giant mysterious fish called Kun. It is said that when there is a storm in the northern sea, the Peng flies to the southern sea. The Peng’s massive wings are referred to large colorful clouds in the sky. Peng, in its mighty glory, symbolizes high ambitions and great accomplishments, making it very popular to use in nomenclature. (Chinese Mythology)

Dragons have been a major part of Chinese mythology and culture for centuries. (Chinese Dragon) Starting with the four Dragon Kings, these dragons are the divine rulers of the four seas who live in crystal palaces. These Dragon Kings have been known to manipulate the clouds and rain along with their respective seas. There are different dragons that serve their own purpose in Chinese mythology and way of life. Starting with the Fucanglong, these mighty dragons guard the underworld and the buried treasures hidden in the underworld. The Shenlong dragon is a spiritual entity, which is referred to as the Eternal Dragon of Earth that controls the wind and rain. The Dilong is referred to as the Earth dragon because there exists evidence of a feathered dinosaur called the Dilong paradoxus (paradoxical emperor dragon). The last of the well known dragons is the Tianlong, who are servants and defenders of heaven. The Tianlong are celestial dragons that are believed to pull the chariots and defend the palaces of the gods. (Dragon King)

More than half of the mythical creatures in Chinese mythology have the ability to fly. The Chinese have always had an interest in the beings that roam the sky, creating two of the most well known mythological creatures of flight: the Fenghuang (phoenix) and the dragon. These creatures are a large part of Chinese mythology but have also spread their popularity out to the western cultures. The phoenix and dragons are still heavily influential to Chinese culture and tradition.

The Heavens in Norse Mythology

Matthew Brown

Viking Myths

The creation of the world began with a void. To the north of the void was Niflheim, a realm of ice and cold. Muspelheim, a land of fire, lay across the gap. The mixing of the two created the ice giant Ymir and the giant cow Auðumbla. The cow licked the ice, uncovering the first of the gods, through which Odin and his brothers were born (Norse Mythology). Odin and his brothers killed Ymir and used his body to form the world, called Midgard. His body became the earth, his blood the rivers, and his hair the trees. Odin then set the top of Ymir's skull above the earth, held by the dwarves North, South, East, and West. The stars were made by collecting sparks from Muspelheim and placing them in the new sky (Ymir).

The structure of the universe in this mythology consists of nine worlds, centered on Midgard. The earth was shaped like a disc and settled in the branches of Yggdrasil. The home of the gods, Asgard, was located in the center. Between Asgard and Niflheim lay Midgard, the land of men. The tree was fed by three springs, one in the Asgard, one in Jotunheim, and one in Hel (Norse Mythology). The wind was caused by an eagle placed by Odin at the ends of the earth, and the clouds were the brains of Ymir, scattered to the winds (Ymir).

The Norse believed that the sun was the goddess Sol traveling in her chariot across the sky. Her carriage was pulled by the horses Arvak and Alsvid, and she was constantly running from the wolf Skoll. A solar eclipse was Skoll closing in on Sol's chariot, and she would eventually be eaten, though her daughter. The light from the sun was given off not by the sun, but by the manes of the horses pulling the chariot. The earth was protected from the heat of the sun by Svalin, who would stand between the two and block it with his body. Sol's brother was named Mani, also chased by a wolf named Hati. Hati will also succeed, during Ragnarok, the end of the world (Norse Mythology).

To explain thunder, the Norse believed in the god Thor. Son of Odin, he was often portrayed as the most powerful of the gods. Thor was the sworn enemy of the giants, and used his war hammer Mjolnir to fight them. To wield his mighty weapon, Thor has special iron gloves and a strength giving belt named Megingjord. When Mjolnir was thrown, a clap of thunder would be heard, and it would then return to its master. It was said that when Thor's chariot, pulled by the goats Tanngrisnir and Tanngnjóstr, traveled through an area, the ground would be scorched and mountains would crack. Thor is often compared to Jupiter or Zeus in Greco-Roman mythology (Thor).

Neighbors in the North – Finnish Mythology

The Norse mythology differs greatly from its northern friend, Finland. Although many of the countries in the region are grouped together, Finland actually differs quite a bit from those around it, especially in terms of mythology. The structure of the world was seen as either an exploded egg, or a large tent. A pole held up the dome, directly under the North Star. The dome spun on this pole, facilitating the movement of the stars. The spinning of the pole caused a storm through which the dead could reach Tuonela, the underworld.

Birds feature prominently in Finnish mythology. Lintukoto was at the edge of the earth, and it was a warm place the birds lived in during the winter. The Milky Way was called Linnunrata, or the Path of the Birds, because the birds would theoretically fly along Linnunrata to get to Lintukoto (Finnish Mythology).

The Finnish had a god they referred to as ylijumala, or “the high god.” He was the god of things above, the sky, the weather, and most natural things above ground. A conglomerate of Odin and Thor of the Norse myths, Ukko was the most significant god in the pantheon, and could create thunderbolts with his weapon Ukonvasara, which is described to be an axe, hammer, or a sword. The acts of riding his chariot through the skies or mating with his wife Akka caused thunderstorms (Ukko). He is often compared to the Hindu god Indra (Jumala).

Chapter 2 - History

Early Flight

Barry Kosherick

The first records and tales of human flight involve the use of gliders and kites. The first record was with the Muslim Moors Armen Firman and Abbas Qasim Ibn Firnas in the ninth century. Armen Firman used a wing like cape to slow his descent off of a tower in Spain; however the cape acted more like a parachute than a glider. Firnas jumped off of a mountain using a glider. His main downside is that he did not account for the landing and injured his back. Firnas is viewed as the first person to take a scientific approach to flying (Aviation History).

Eilmer of Malmesbury took inspiration from the Greek fable of Daedalus and Icarus, and Firnas's design. Eilmer made a glider with wings similar to that of a bird. He jumped off of a tower in his abbey. He glided a distance of over 220 yards. However he suffered an injury to his legs. After his glide, he realized that with the addition of a tail, he could make landing more controllable, but the abbot forbid him from risking his life on further experiments (Aviation History).

In the 15th century Leonardo da Vinci designed a glider that was constructed in modern times using only materials that were available to da Vinci. This design was fully functional as the prototype flew. Da Vinci also had designs for a helicopter, but this design was much less successful than his glider; it could not fly. Glider development continued through the 19th century by leaps and bounds done by changes in wing shape and pilot placement (Aviation History).

A notable design was that of Sir George Cayley. This design featured the pilot suspended below the center of gravity to improve the stability and a separately tail used to control the glider. Over years of experimentation Cayley invented the majority of basic aerodynamics including ideas such as lift and drag. Cayley started his research with small scale models, but moved up full size in 1849 when his design was first flown unmanned and manned in 1853 (Aviation History).

All of the preceding examples of flight were technically only gliding because the highest point was the point of the departure. This changed in 1856 when Jean-Marie Le Bris had his glider "*L'Albatros Artificiel*" pulled by a horse on a beach and reached a height of 100 meters with a glide distance of 200 meters (Aviation History).

Many think that the only method for human flight was with gliders; this could not be farther from the truth. In the 18th and 19th centuries hot air balloons were hugely popular with the royalty and upper class of Europe. The first manned hot air balloon was made Josef and Etienne Montgolfier and was flown on November 21st 1783. King Louis XVI degreed that the first pilots were condemned pilots, showing his support for the idea. However a physicist Pilatre de Rozier and the Marquis Francois d'Ardelandes successfully petitioned for this honor. The early hot air balloons were basically giant cloth bags with a wood fire on a grill attached to the bottom. They resulted in almost all of the hot air balloons catching aflame upon its landing. These hot air balloons could not be controlled and went wherever the wind took it (Aviation History).

In 1852 Henri Giffard flew fifteen miles in an air balloon powered by a steam engine. This was seen as the first powered, controlled sustained lighter-than-air flight. This airship was able to be controlled, but it had issues navigating in wind. The first fully controllable free-flight was done in an electrically powered airship named "La France". Both of these designed proved that controllable light than air travel was possible, but they did it at the cost of reuse. In order to make these airships fly, they had to be very frail; the best example being the Hindenburg (Aviation History).

In the late 1800's many people looked at powering the early gliders. One such person was Sir Hiram Maxim. He built a 7000-pound design with a wingspan of 105 feet that was powered by two low weight steam engines. He built this design not try to fly, but to research and experiment with the problems associated with construction power. He did not include controls in his design, to keep it safe he had an 1800 foot track built for the design to fly in. this worked when it was at 2/3 power, however when all three boilers were turned on, this design created so much lift that it broke free of the track (Aviation History).

Samuel Pierpont Langley with the Aerodrome No 5 accomplished the first fully successful flight of a powered heavier than air on May 6 1896. This flew twice with flights of length of 3300 and 2300 feet. This design was a small-scale design, when Langley tried to scale the design to full size he overlooked some details. The full size model was too heavy to hold itself up (Aviation History).

The first full scale, fully powered, sustained heavier-than-air flight was done on December 17 1903 by the Wright brothers. Of the main reasons for the Wright brothers' success was due to their concern for safety. This led them to a rear heavy design, and using low power. One of the main elements of their design was using a technique called "wing warping". What this design entails is being able to control the bend of the wings in flight. The Wright brothers are remembered as the first people to achieve controlled powered human flight because they were able to provide good documentation. There are numerous reports of other people achieving this goal before the Wright brothers but due to a lack of documentation they are not credited.

The History of Skylab

Thomas MacDonald

Skylab was a space station that was sent into space on May 14th 1973. Skylab was used to conduct various experiments specifically to record the effects of zero gravity on the human body. Skylab had a short life, as the last mission was performed in 1974 and it lasted three months. Skylab circled the Earth with a gradually decaying orbit until it re-entered Earth's atmosphere July 11th 1979. (Bredeson, pp 29)

Skylab was meant to stay in orbit until 1983; however it fell out of orbit prematurely despite the efforts to keep it up. The plan was to possibly send up the brand new space shuttle. (De Pree, Axelrod, pp. 143) There were three manned missions for Skylab. The first mission, hosted three astronauts, Charles Conrad Jr., Paul J. Weitz, and Joseph P. Kerwin who repaired Skylab, performed three-hundred ninety two hours of experiments, and performed three EVAs. (Angelo, pp. 377) An EVA is an abbreviation for extravehicular activity. ("EVA", Merriam-Webster) Specifically an EVA is what people would probably call a "space walk". This is a term used by the general public; however astronauts don't walk in space they float. (Irvine, "EVA Space Walks")

During launch, atmospheric drag acted on the solar/meteoroid shield that was equipped on Skylab. The shield tore away at approximately thirty-six seconds in. This shield protected the workshop from tiny particles and from the Sun's extreme heat. The shield, on its way off, grabbed onto a solar panel. When the rocket stage of the Saturn V rocket started, it tore away the partially opened solar panel. NASA had to postpone the first manned mission of Skylab in order to buy time to be able to make a solar parasol. The astronauts were launched by a Saturn IB rocket to conduct their mission. (Angelo, pp. 377)

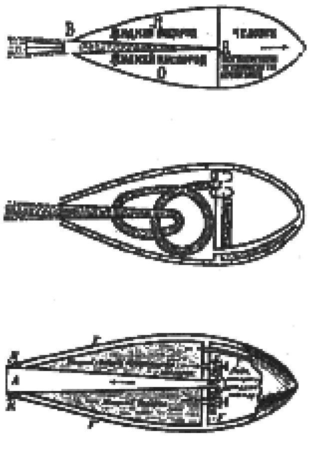
These astronauts first had to repair the Skylab docking mechanism. They then went through a space access hatch and erected a Mylar solar parasol. As soon as this was done, the workshops' temperatures dropped and it soon became habitable without a space suit. Unfortunately, many of the experiments that were planned had to be postponed because they required more power than the four remaining solar panels could provide. The other solar panel was fixed by using tools such as long-handled pruning shears and a crowbar. This enabled Skylab to be able to complete its scientific missions. This was all completed in twenty-eight days with almost four hundred hours of experiments performed. (Angelo, pp. 377-378)

The second crew of Skylab was launched on July 28th 1973 in a Saturn IB rocket. The members of this crew were Alan Bean, Jack Lousma, and Dr. Owen Garriott. They performed maintenance on the space station and also performed one thousand eighty-one hours of experiments. They returned to Earth after spending fifty-nine days in orbit. The third crew of Skylab was launched on November 16th, 1973. This would be the last crew of Skylab. The members of this crew were Gerald Carr, William Pogue, and Dr. Edward Gibson. This crew observed Comet Kohoutek and performed four EVAs. They stayed on the ship for about eighty-four days. (Angelo, pp. 377-378)

Design History of Spacecraft

Barry Kosherick

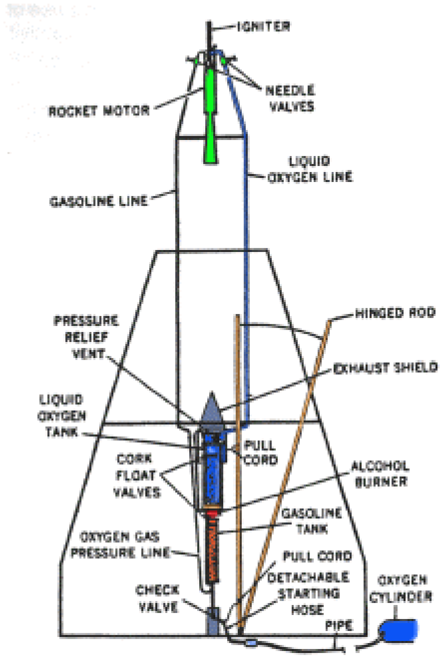
The first person to think of space exploration by use of a rocket was Konstantin Tsiolkovsky in 1903. He had the idea to use liquid propellants to power a rocket in order to obtain a greater range. Tsiolkovsky stated that the velocity and range of a rocket was only limited by the velocity of the exhaust gasses escaping, in what is now known as the Tsoilkovsky rocket equation, $\Delta V = -v_e \ln\left(\frac{M+P}{P}\right)$. Below are some of the drawings of his design of a rocket (fiu.edu, Rocket History).



Tsiolkovsky Rocket Designs

1 Tsoilkovsky Rocket Designs

Although Tsoilkovsky first thought of the idea of rocket propulsion for space travel, Robert Goddard is thought of as the father of modern rocketry, because he was the first to be able to successfully launch a liquid filled rocket on March 16 1926 (pictured below). Goddard's notable work started fourteen years earlier when he mathematically proved that rocket propulsion could reach high altitudes and possibly the moon. He later went on to prove that a multi stage rocket could achieve higher altitudes than a single stage rocket with the same amount of fuel (NASA.gov, Robert H. Goddard: American Rocket Pioneer).



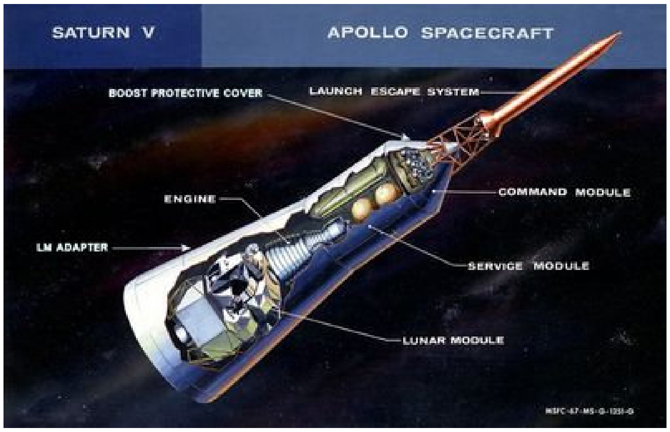
Dr. Goddard's 1926 Rocket

2 Goddard's 1926 Rocket

Following Goddard's work, rocketry grew by leaps and bounds as many small rocket societies sprung up around the world. The early rockets started off with barrel shaped bodies like Vostok from 1960 pictured below. These early rockets were meant to collect data from a low earth orbit (fiu.edu, Rocket History).

3 1960 Vostok Rocket

In the 1960's manned spacecraft started to have conical shapes as to improve aerodynamics, such as the Apollo shown below, which had to not only provide a safe journey for the astronauts, it also had to retain the data the astronauts collected fiu.edu, Rocket History).



4 Apollo Rocket

As moon exploration decreased severely, the design of manned spacecraft changed greatly to reflect on its new purpose; a vehicle meant to leave earth's atmosphere, orbit earth, and reenter the earth's atmosphere without posing any threat to the astronauts inside. Its new design resembled a modern airplane, as the space shuttle depicted below is transported by a Boeing 747 (Wikipedia, Spacecraft).

5 Space Shuttle transported by a 747

Currently manned spacecraft have been appearing very similar to planes out of science fiction. One such example is Spaceship One, which was the first commercially flown manned vessel to leave the Earth's atmosphere, shown below.

6 Spaceship One

In the future we may see a return to previous design ideas as the idea of going to the moon is becoming more and more popular as is the case with the Orion, NASA's replacement for the space shuttle in 2010. The Orion's crew area looks very similar to the conical shaped shuttles of earlier moon exploration, depicted below (Wikipedia, Spacecraft).

7 Orion

While the entire shuttle, shown below, would use a current multi stage rocket for the major propulsion; this allows it to reach higher altitudes.

8 Orion with Multi Stage Rocket Booster

Mistakes and Disasters in Space

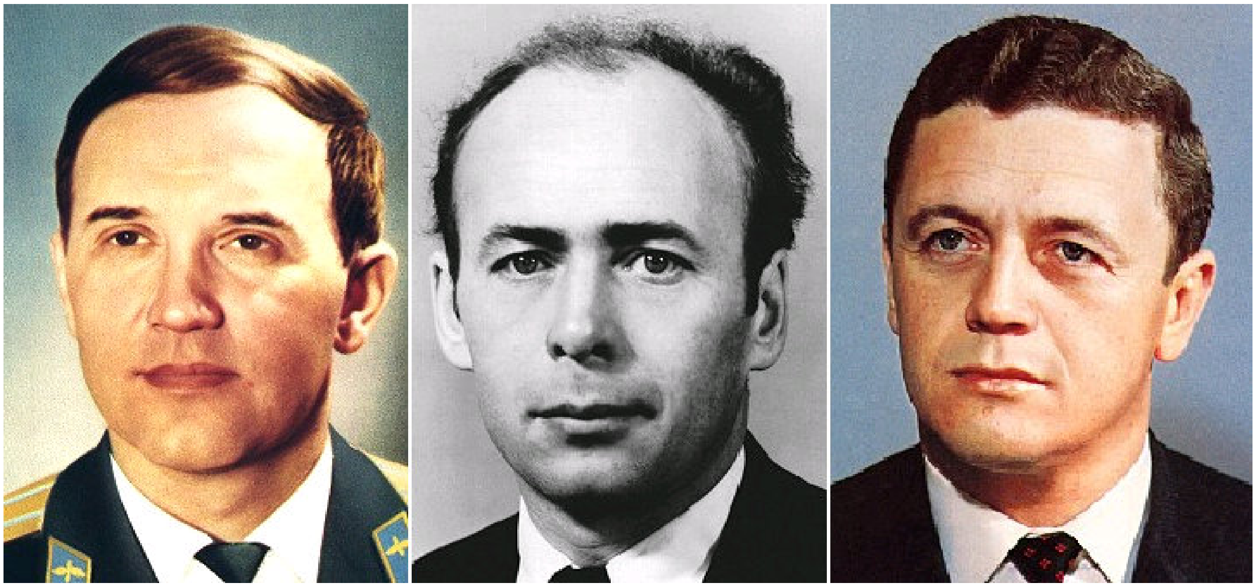
Matthew Goon

With every excursion into new territory comes risk and peril for those who are unprepared. There are many risk factors that take into account even in the most routine and mundane situations. As we venture into space, the risk of danger increases with the parameters of the journey. From the Challenger to the Columbia, new problems arise with the intricacies of the spacecrafts. Fortunately there have only been two major disasters in the decades that NASA (National Aeronautical and Space Administration) has been in existence.

April 24, 1967 marks the first in-flight fatality, killing Russian cosmonaut Vladimir Mikhailovich Komarov on board the Soyuz 1. Komarov is the first person to die during spaceflight when the main parachute would not deploy. The drag parachute deployed allowing a successful reentry into the earth's atmosphere; but the main parachute failed and the backup parachute tangled with the drag parachute. The descent module could not decelerate its chaotic descent with the tangled parachutes resulting in a crash landing in a field. Large retro-rockets, that were meant to help with the deceleration, did not activate until the crash causing an explosion and an inferno around the module. (Wade, Soyuz 1)

Vladimir Komarov (left) and the crash site of the Soyuz 1(right) was the first in-flight disaster of the space race.

The Soviet space campaign suffered another major disaster killing the crew of the Soyuz 11. June 30, 1971 the crew of the Soyuz 11 would not survive the undocking from space station Salyut 1. The crew consisted of pilot Georgi Doborovolsky, engineer Viktor Patsayev, and engineer Vladislav Volkov. The Soyuz 11 crew members are pictured on the next page.

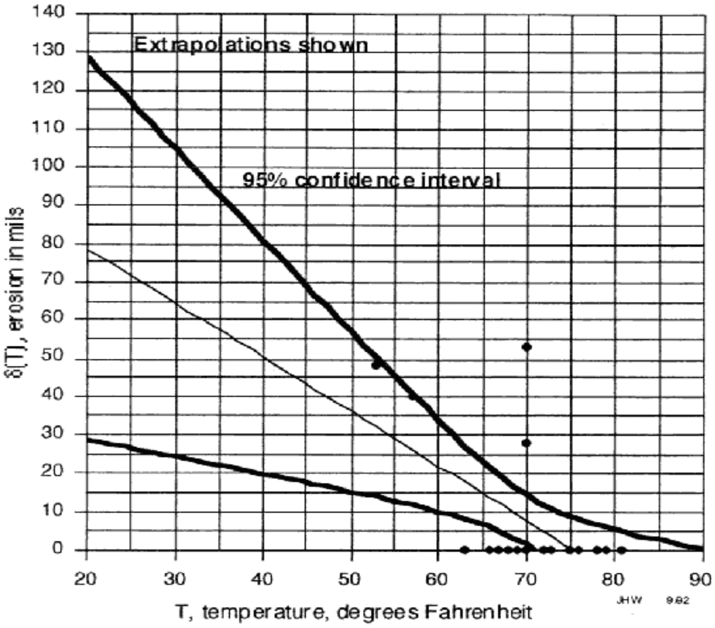


Soyuz 11 crew: Georgi Doborovolsky (left), Viktor Patsayev (center), and Vladislav Volkov (right)

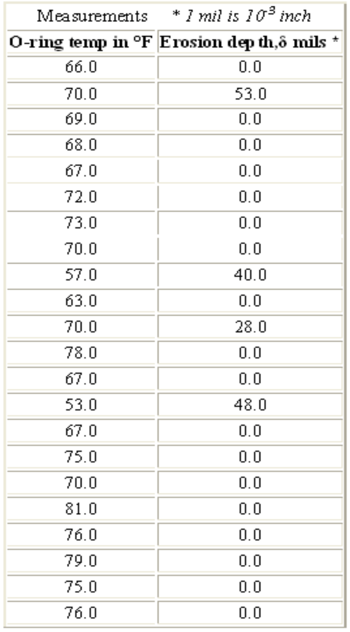
The disaster started after undocking from the space station Salyut 1. During the reentry into the atmosphere, a pressure equalization valve was broken open causing the cabin to depressurizing and releasing the air supply into space. The recovery team discovered the bodies of the doomed crew members, and later equipped the Soyuz with spacesuits that the Soyuz 11 crew did not have the luxury of possessing. (Wade, Soyuz 11)

On January 28, 1986 would go down as the first United States space race disaster; claiming the lives of seven Americans. The crew of the Challenger was unfortunately a part of the first in-flight catastrophe of NASA. The crew consisted of pilot Michael Smith, pilot Dick Scobee, physicist Ronald McNair, engineer Ellison Onizuka, teacher Christa McAuliffe, engineer Gregory Jarvis, and engineer Judith Resnik. 73 seconds after the launch at Kennedy Space Center in Florida, Challenger seemed to “explode” in midair killing all seven astronauts inside. Even more disturbing was the fact that, NASA allowed the launch of the Challenger after days of delays due to weather and the inability of the crew to eject from the spacecraft in case of an emergency. (Greene)

President Reagan appointed former Secretary of State William Rogers, to head a commission, in charge of investigating what cause the Challenger disaster. The cause of the failure of the Challenger was a faulty O-ring seal. The O-ring seal failed cause a hot gas leak, from the solid rocket booster that spread to the external fuel tank. The Challenger was torn apart when liquid hydrogen and liquid oxygen was mixed and ignited by the hot gas leak. Below are the O-Ring analysis and the values of the elastomeric erosion due to temperature. (Wujek)

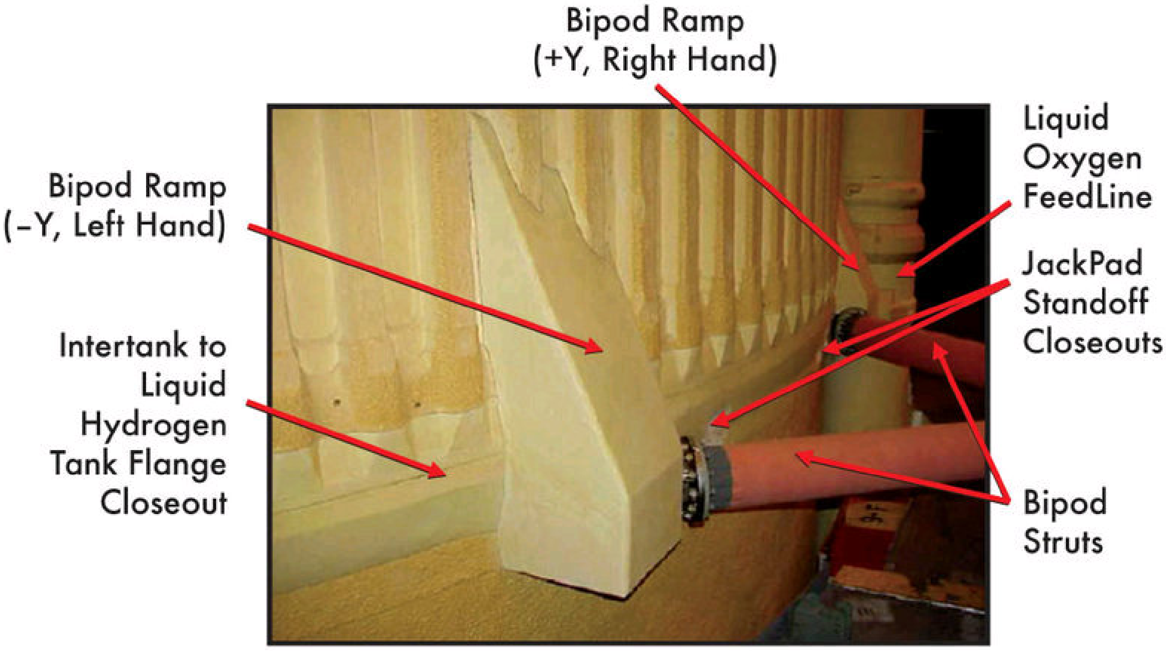


$\delta(T) = 107 - 1.41T$, for $53 \leq T \leq 81$;
with T in Fahrenheit, $\delta(T)$ in mils (0.001 inch)
Correlation coefficient: $r = -0.56$



Measurements	* *1 mil is 10^{3} inch*
O-ring temp in °F	**Erosion depth,δ mils ***
66.0	0.0
70.0	53.0
69.0	0.0
68.0	0.0
67.0	0.0
72.0	0.0
73.0	0.0
70.0	0.0
57.0	40.0
63.0	0.0
70.0	28.0
78.0	0.0
67.0	0.0
53.0	48.0
67.0	0.0
75.0	0.0
70.0	0.0
81.0	0.0
76.0	0.0
79.0	0.0
75.0	0.0
76.0	0.0

On February 1, 2003, the spaceship Columbia was destroyed during the reentry of the Earth's atmosphere. After investigation, the Columbia was damaged when the main propellant tank was broken off. The foam insulation that was supposed to prevent debris from affecting the propellant tank was not taken in to account and left to break off in the harsh conditions.



A view of the foam Bipod Ramp, a piece of the insulation broke off and struck the wing causing the disaster.

A piece of the foam from the insulation broke off and struck the wing of the spacecraft, taking out the heat shielding panels. The hole inside the wing was penetrated by hot gases destroyed the spaceship by breaking the support structure. The more disturbing part of the events that occurred is that, NASA ignored the launch safety protocol by not researching the insulating foam. If NASA had done more research with the structural integrity of all the parts of the ship the minor things might not leads to big disasters like the Challenger and Columbia. (Space Shuttle Challenger Disaster, Space Shuttle Columbia Disaster)

Chapter 3 - Satellites

Global Positioning Systems

Matthew Goon

Global Positioning System (GPS) is used as a navigation system that is run by sets of satellites. These satellites (over 24) orbit around the earth and broadcast radio signals that contain precise timing. This allows a GPS receiver (GPSr) to pick up the signal and determine the location of an object by giving the coordinates and altitude. These satellites orbit around in different paths so they can pick up signals all over the earth, regardless of the weather or lighting conditions. GPS is used all over the world and made usable for the public consumer.

The GPS is based off a ground-based radio navigation system that was developed during World War II and the idea of using satellites, like *Sputnik* in 1957, which have a Doppler effect to transmit frequencies. The first satellites that were used by the military for the purpose of navigation were developed during the 1960s.

> The first satellite navigation system, *Transit*, used by the United States Navy, was first successfully tested in 1960. Using a constellation of five satellites, it could provide a navigational fix approximately once per hour. In 1967, the U.S. Navy developed the *Timation* satellite which proved the ability to place accurate clocks in space, a technology the GPS system relies upon. (Global Positioning System)

During the 1970s, a ground-based navigation (OMEGA Radionavigation) system used phase comparisons of a signal to become the first world-wide radio navigation system. “The OMEGA Radionavigation System, developed by the United States Navy for military aviation users, was approved for full implementation in 1968 and promised a true worldwide oceanic coverage capability and the ability to achieve a four mile accuracy when fixing a position.” (Proc)

The original application of GPS was created by the military as a navigation system, but now GPS is integrated into parts of military weapons. GPS is used around the world to; navigate cars, planes, or ships, aids people who travel through nature, help glider pilots during races. “GPS allows accurate targeting of various military weapons including cruise missiles and precision-guided munitions, as well as improved command and control of forces through improved location awareness. The satellites also carry nuclear detonation detectors, which form a major portion of the US Nuclear Detonation Detection System.” This system of satellites is set up to overlap each other so that if a satellite were to be destroyed or compromised, it would be covered by neighboring satellites. (Global Positioning System: Military)

There are many applications for the Global Positioning System other than its original use for the military. The uses range from emergency services, locating position in the air, surveying, agriculture, geology, a precise time reference, and even location-based games. GPS can be used to locate cell phones, by the emergency services, so they can locate where the call is coming from accurately. Some GPS units can be used by passengers on a flight, to locate the position of the plane mid-flight. "More costly and precise receivers are used by land surveyors to locate boundaries, structures, and survey markers, and for road construction. There is also a growing demand for machine guidance such as automatic grade control systems that use GPS positions and 3D site plans to automatically control the blades and buckets of construction equipment." (Global Positioning System: Machine Guidance) GPS is also used in large agricultural machines, to control traffic and row crop operations. Operations that depend on synchronized timing in computer systems can use GPS as a reference for time code generators or Network Time Protocol (NTP) clocks. Another use for the GPS unit is to play location-based games, like Geocaching. "Geocaching is the widely popular, high-tech game of treasure hunting." (Geocaching Garmin-Style)

Communications Satellites

Barry Kosherick

The first satellite that had a use for communication was Sputnik 1, which was equipped with a radio transmitter, and was launched in 1957. The Americans followed up with the launch of Project SCORE, which was used to send a Christmas greeting from President Eisenhower to the world. The active, direct relay satellite was the Telstar. It was the product of collaboration from AT&T, Bell Telephone Labs, NASA, the British General Post Office and the French National Post Office. Telstar was also the first privately funded launch. These early communication satellites paved the way for more modern technology (Wikipedia, Communications Satellites).

The idea of geostationary orbiting satellites provided a path for many current satellite uses. A geostationary satellite orbits over the earth in a constant speed with a one day rotation, thus making it appear that the satellite is always over the same area on earth. The idea credited to Arthur C. Clarke who thought that if the receiver could easily find the satellites in the sky it would eliminate the need for expensive tracking equipment. The easiest way for a satellite to be found is for it to be above a certain area all the time, and the receivers would just need to be pointed at it, without having to follow it (Wikipedia, Geostationary Orbit).

However maintaining the exact same location above earth is a costly process. A less expensive way of achieving the same ease of use as a geostationary orbiting satellite, is use multiple satellites that always travel over the same area, so there is always a satellite above the receiver, but each does not have to be kept at the same orbital speed as earth. These satellites fall into the categories of either Low-Earth-Orbiting Satellite or Molniya Satellites. The main difference between these two types of satellites is the orbit's elevation. Low-Earth-Orbiting satellite's orbit has a fairly low elevation, as it requires less signal strength for a signal to travel a smaller distance. Molniya satellites which were developed in the USSR, orbit at significantly higher elevations than Low-Earth-Orbit satellites. The advantages of using a Molniya satellite are that it requires far fewer satellites to maintain constant contact, and it will still be in contact of areas in high altitudes such as Siberia and the Himalayas (Wikipedia, Communications Satellites).

The tradeoff between these two technologies is that for geostationary satellites, only one is needed for uninterrupted coverage of an area, but the cost and difficulty to keep them at the exact same orbital speed as the earth is fairly high. While Molniya and Low-Earth-Orbiting satellites require multiple satellites orbiting at a higher rotation speed than earth to maintain constant contact, these satellites are less expensive to design, build and launch. This concludes that neither is the definitive best choice for all communication satellite needs, but that the best choice is situational depending on the needs and technologies available (Wikipedia, Communications Satellites).

The most common use for communication satellites is international and intercontinental telephone, television and other important forms of communication. The way that this is done is that someone from one country for example the United States, wanted to message someone elsewhere on the globe for example Japan. The person in New York would send their message from their phone or television studio to a central point somewhere in the United States. From there it would be sent to the satellite currently orbiting above the central United States station, which would then be sent to the satellite currently in contact with the Japanese central station. Finally it would be sent from the central Japanese station to the person in Tokyo.

Television and Radio are other areas of high use for communication satellites. Cable Television for example, if it is a network that covers more than one viewing area will have one signal sent to a satellite which sends it to the receiving station for each broadcast area. The signal is then sent through the cable into people's televisions. Satellite TV is sent very similarly, but instead of having the signal being sent to a receiving station, each satellite television set picks up the signal. Satellite radio is another large user of communication satellites. This technology however was designed to be portable, so it uses GPS to redirect the antenna on the receiver to the closest satellite. This is the same method that some airlines are using to have TV or radio available on their flights (Wikipedia, Communications Satellites).

Communication satellites seem to have a very bright future as technology progress. They are currently the most effective method of intercontinental communication, and with developing technology, they might replace any sort of physical connection requiring method of communication such as telephone lines or networks (Wikipedia, Communications Satellites).

Defense Satellites

Matthew Brown

Defense Satellite Communications System

The Defense Satellite Communications System (DSCS) is a sophisticated system operated by the United States Air Force. The DSCS program began in 1966 with the launch of IDSCS 1. The current group of DSCS satellites is known as Phase III, of which there are nine. As the name suggest, they are used to allow data and voice data to be moved from one place to another securely. They have six channels for normal high data rate transfer, and one used for emergency and to give directions to nuclear-capable units. The satellites are launched using Atlas II rockets and an expendable launch vehicle. The propulsion system is a hydrazine thruster system. These propulsion systems are very efficient for a satellite, as it takes a small amount of hydrazine to create a large amount of gas. This system keeps them in a geo-synchronous orbit at 22,230 miles above the Earth's surface. See Appendix A for launch facts from the third and most recent DSCS series.

General Characteristics

Primary Function: Worldwide, long-haul communications
Primary Contractor: Lockheed Martin Missiles and Space
Weight: 2,716 pounds (1,232 kilograms)
Power Plant: Solar arrays generating average of 1,500 watts
Orbit Altitude: 22,230 miles (35,887 kilometers)
Dimensions: Rectangular body is 6 feet long (1.8 meters), 6 feet high (1.8 meters), and 7 feet wide (2.1 meters); 38-foot span (11.5 meters) with solar arrays deployed
Launch Vehicle: Atlas II and Evolved Expendable Launch Vehicle
Unit Cost: $200 million
Inventory: 9
(United States Air Force, 2006)

DSCS III Launch Data

Country of Origin	United States
Customer/User	USAF
Manufacturer(s)	GE Astro Space
Size	2.1 x 1.9 x 2.0 m bus, 11.5 m solar array span
Orbit	Geosynchronous
Design Life	10 years

Launch Facts

Name	**Int'l Desig.**	**Date**	**Site**	**Vehicle**	**Orbit**	**Mass(kg)**
Notes						
DSCS 3 F1	1982-106B	10/30/82	ESMC	Titan 34D IUS	GEO	
Defense Satellite Communications System						
DSCS 3 F2 (USA 11)	1985-092C ?	10/3/85	ESMC	STS 51J	GEO	
Defense Satellite Communications System; released from STS 51J 10/4/85; boosted into orbit with DSCS 3 F3 on single IUS booster						
DSCS 3 F3 (USA 12)	1985-092D ?	10/3/85	ESMC	STS 51J	GEO	
Defense Satellite Communications System; released from STS 51J 10/4/85; boosted into orbit with DSCS 3 F2 on single IUS booster						
DSCS 3 F4 (USA 44)	1989-069B	9/4/89	ESMC	Titan 34D	GEO	
Defense Satellite Communications System						
DSCS 3 F7 (USA 93)	1993-046A	7/19/93	ESMC	Atlas 2	GEO	2615
Defense Satellite Communications System						
DSCS 3 F8 (USA 97)	1993-074A	11/28/93	ESMC	Atlas 2	GEO	2615
Defense Satellite Communications System						
DSCS 3 F9 (USA 113)	1995-038A	7/31/95	ESMC	Atlas 2A	GEO	2610
Defense Satellite Communications System						

Point of Contact
Air Force Space Command, Public Affairs Office; 150 Vandenberg St., Suite 1105; Peterson AFB, CO 80914-4500; DSN 692-3731 or (719) 554-3731.

(DSCS)

Defense Meteorological Satellites Program

The Defense Meteorological Satellites Program (DMSP) is a system of polar, sun-synchronous satellites the Air Force is using to monitor weather conditions. It is used to plan military movements. The information from the satellites is used by the military, but it also shared with civilian organizations to allow tracking of weather systems. As well as weather on Earth, the satellites keep track of space weather, as well. At NASA's website for the DMSP(High Energy Astrophysics Mission, 2006), one can find data from selected missions that show the X-ray and gamma-ray emissions picked up by the satellites. The data from multiple satellites over the course of a day are combined and added to the archive which is shipped to several civilian and military destinations.(Goddard Space Flight Center/Smithsonian Astrophysical Observatory, 2003)

General Characteristics

Primary Function: Collect terrestrial, space environment and Earth surface data
Primary contractor: Northrop Grumman/Lockheed Martin Missiles and Space
Weight: 2,545 pounds (1154.4 kilograms), including 592-pound (268.5 kilogram) sensor payload
Orbit altitude: Approximately 450 nautical miles (nominal
Dimensions: 14.1 feet long (4.29 meters) without solar panels deployed
Power plant: 10 panels, generating 2,200 watts of power
Launch vehicle: Evolved Expendable Launch Vehicle - Medium
Date deployed: August 1962

Point of Contact
Air Force Space Command, Public Affairs Office; 150 Vandenberg St., Suite 1105; Peterson AFB, CO 80914-4500; DSN 692-3731 or (719) 554-3731.

(United States Air Force, 2006)

Near Field Infrared Experiment (NFIRE)

The NFIRE program is a program headed by the Missile Defense Agency. It consists of a low-orbit satellite with sensors that are designed to study the exhaust plume of a missile in flight. Integrated with the satellite is a deployable interceptor, termed the NFIRE Kill Vehicle. It is designed to be able to intercept a ballistic missile in flight. There is a great deal of controversy over this, as many feel it will lead to the deployment of weapons in space. A Department of Defense official projects that an experimental constellation of missile defense satellites may be launched by 2012.

Generally, the military does not develop its defense satellites itself, but contracts out to several Department of Defense contractors. Lockheed Martin Missiles and Space is the heavyweight in this field, along with Northrop Grumman and The Aerospace Corporation. The Aerospace Corporation is a Federally Funded Research and Development Center, or FFDRC. As well as working with Lockheed

Martin on the DSCS and DMSP systems, Aerospace also supports the Defense Support Program (DSP). This is a network of twenty-three missile detection satellites, although they are soon to be replaced with newer technology.

(Singer, 2004)

(Near Field Infrared Experiment)

Chapter 4 - Thrust

Aircraft Propeller

Matthew Brown

Thrust is the force that moves an aircraft through the air, creating lift. A propeller aircraft uses an engine to spin the blades of the propeller with push air in the direction opposite of where the plane wants to go. The spinning propeller acts like a wing, creating high pressure behind the propeller and low pressure in front. This causes the plane to move forward. This forward motion caused a pressure differential around the wings of the aircraft, which creates lift.

There are two major forms of propeller drive engines, internal combustion engines and jet engines.

Internal combustion engines mix fuel with air to create controlled explosions which move pistons up and down. This movement acts on a drive shaft which spins. This shaft causes rotation in its drive element, whether the wheel of a car or an aircraft propeller. In World War I, many propeller planes used a rotary engine, which were commonly built with the piston arrayed in a radial fashion.

Thrust Equations for propeller (F is the force of the thrust; V_e indicates the velocity of the exhaust; V_0 indicates initial velocity of the air in the free stream in front of the propeller; p is pressure either at t_0, time the air is in the free stream, or t_e, time when it is in the exhaust stream; ρ is the density of the air)

$$F = A \text{ x } \Delta p$$

$$\Delta p = pt_e - pt_0$$

$$\Delta p = .5\rho(V_e^2 - V_0^2)$$

So the thrust is

$$F = .5\rho A(V_e^2 - V_0^2)$$

(Benson, Propeller Thrust, 2006)

A jet engine powered propeller engine is referred to as a turboprop. This type of engine uses the energy of the jet engine to turn a propeller instead of using exhaust to push against the air. The core of the engine is a gas turbine, basically the same as an ordinary turbojet.

Thrust Equations for turboprop (F is the force of the thrust; ${}_0$ is mass flow rate where 0 indicates initial position in the free stream, ${}_e$ is the mass flow rate of the exhaust, and ${}_c$ indicates mass flow rate in the core of the engine; V_0 is the velocity in the free stream, V_1 is the velocity after the propeller blades, and V_e is the velocity of the exhaust after both propeller and jet engine)

$$F = \dot{m}_0 V_1 - \dot{m}_0 V_0 + \dot{m}_e V_e - \dot{m}_c V_1$$

Mass Flow

$$\dot{m}_0 > \dot{m}_c$$

$$\dot{m}_e \approx \dot{m}_c$$

So the thrust is

$$F = \dot{m}_0 (V_1 - V_0) + \dot{m}_e (V_e - V_1)$$

(Benson, Turboprop Thrust, 2006)

A variation of the turboprop is the turbofan, using a fan as opposed to the more traditional propeller. The air either travels into the burner of the jet core, or is pushed around the core by the fan. The core acts like a regular jet engine, and the fan works as a propeller, both creating thrust.

Thrust Equations for Turbofan ($_0$ is mass flow rate where 0 indicates initial position in the free stream, $_e$ is the mass flow rate of the exhaust, and $_f$ indicates mass flow rate of the air after the fan blades, $_c$ is the mass flow rate of the air in the core; V_0 is velocity of the air where 0 indicates initial position in the free stream, V_e is the velocity of the exhaust, $_c$ is the velocity of the air in the core, and V_f indicates velocity of the air after the fan blades)

$$F = \dot{m}_f V_f - \dot{m}_f V_0 + \dot{m}_e V_e - \dot{m}_c V_0$$

Mass Flow

$$\dot{m}_0 = \dot{m}_f + \dot{m}_c$$

Bypass Ratio (bpr: the ratio of air that bypasses the core)

$$bpr = \frac{\dot{m}_f}{\dot{m}_c}$$

So the thrust equation is

$$F = \dot{m}_e V_e - \dot{m}_0 V_0 + bpr \text{ x } \dot{m}_c V_f$$

(Benson, Turbofan Thrust, 2006)

Understanding the Gas-Turbine Jet Engine and the Brayton Cycle

Thomas MacDonald

A jet engine is a specific class of internal combustion engine that is used to thrust an aircraft forward by forcing a rear expulsion of a fluid. This fluid is usually burning exhaust gases that was created by burning fuel mixed with air being pulled in. ("jet engine", Encyclopedia Britannica) Jet engines were invented in the 1930s. (Lane, Jaffe, pp.113) The main force behind almost all jet engines is a gas turbine. In the core of the gas turbine, hydrocarbon fuel is burned to produce energy that is converted to mechanical energy. This mechanical energy takes the form of a stream of air that is not only highly pressurized but also extremely hot. This energy is then used by the propulsor in order to create thrust. ("Jet engine", Encyclopedia Britannica)

Gas turbines are known for their long life, low maintenance, clean-burning, and minimal vibration. This makes them ideal for jet engines since gas turbines can vary from a few hundred horsepower to thousands of horsepower. The Brayton cycle, also known as the Joule cycle, is the foundation for how gas turbines operate. They either operate on an open cycle or a closed cycle. It is much more likely to run into an open cycle gas turbine rather than a closed cycle gas turbine. (Patches, pp. 1)

There are some advantages when working with closed Brayton cycle gas-turbines, some are: that it has the ability to work with various fuels, it also has the ability to be able to control output by changing the fluid density and pressure, and is able to use clean working fluids. While some of the disadvantages are: the system needs cooling before fluid re-enters, cost from the combustion equipment and ducting, and temperature limitations because of the system's heat exchanges. (Patches, pp. 1)

Now a specific form of the gas-turbine is one that better suits itself closer to the jet engine is the aeroderivative gas turbine. Specific defining characteristics of the gas-turbine are: the use of light and also thin alloys for the outer turbine and compressor cases, a high thermal efficiency for simple cycle, pressure ratios are usually above 15:1 and low moment of inertia that allows for quick acceleration. (Patches, pp. 2)

$$Q_{in} = \dot{m}c_p(T_3 - T_2)$$

Equation 1 – Heat Input of the Ideal Cycle during State Changes (Patches, pp. 3)

$$Q_{out} = \dot{m}c_p(T_4 - T_1)$$

Equation 2 – Heat Output of the Ideal Cycle during State Changes (Patches, pp. 3)

In Equation 1, $\dot{m}$ is the mass flow rate while c_p is the specific heat, T_3-T_2 is the corresponding change of temperature between states. While Equation 2 uses the same variables, however it substitutes out for the change between state four and state one. To understand this further, it is important to understand the states of the Brayton cycle. Stage one is air entering into the compressor. Stage two is where the air leaves the compressor and enters into the combustion chamber. Stage three directly follows stage two and introduces heat into the system. Stage three also introduces the new energy into the turbine. Stage four is the end result from the turbine spinning and expels exhaust gases.

Stage four then goes back to stage one giving the temperature change for the heat output of the system. (Patches, pp. 1-3)

$$W = Q_{in} - Q_{out} = \dot{m}[c_p(T_3 - T_2) - c_p(T_4 - T_1)]$$

Equation 3 – A work equation substituting terms in for Q_{in} and Q_{out} (Patches, pp. 3)

$$\eta_{Brayton} = \frac{(Q_{in} - Q_{out})}{Q_{in}} = \frac{c_p(T_3 - T_2) - c_p(T_4 - T_1)}{c_p(T_3 - T_2)} = 1 - \frac{(T_4 - T_1)}{(T_3 - T_2)}$$

Equation 4 – Solving for the ideal thermal efficiency (Patches, pp. 3)

$$\eta_{Brayton} = 1 - (\frac{v_1}{v_2})^{1-k}$$

Equation 5 – Using volumes to solve for ideal thermal efficiency (Patches, pp. 3)

However, the ideal Brayton cycle is slightly dissimilar to what happens in a gas-turbine engine because there are things that cannot be reversed in the compressor and turbine. Examples of where there are losses are in the bearings because of friction and because of a fall of pressure in the combustion chamber. The Brayton cycle also requires a lot of work done by the compressor when compared to the turbine which does anywhere from 40 to 80 percent. Efficiency of the entire system will decrease quickly when either the efficiency of the compressor or turbine drop. (Patches, pp. 3)

Essentially jet engines boil down to a series of rotors that are capable of spinning very rapidly that are held inside a shroud that prevents air from exiting once it enters the engine. At stage two and three of the Brayton cycle, the compressed air is exposed to a fuel that is usually kerosene in a specific ratio. This mixture then enters the combustion chamber where a sparkplug ignites the mixture and causes an explosion. The explosion is then funneled out as part of stages three and four. This produces thrust because of Newton's second law that states for every action there is an equal and opposite reaction. (Lane, Jaffe, pp. 296)

A scramjet is a jet engine that does not have any moving parts. With the use of a scramjet, air travels through the engine at a supersonic speed. While air travels through the engine, it is mixed with fuel and that mixture is burned in order to generate thrust. It's been theorize that the scramjet will be able to push future aircraft to speeds of around two miles per second. That equates to over 7,000 miles per hour. (Lane, Jaffe, pp. 295 – 296) However, since this uses air to propel itself forward this would not lend itself to be usable in space since there is not a medium to be compressed and pushed through the system.

Solar Sails

Barry Kosherick

One of the main problems associated with current space propulsion methods is that ninety five percent of the weight is the fuel. However an object propelled by solar sails would have no weight associated with fuel. This is the result of its unique method of propulsion; a solar sail uses energy from sunlight to provide propulsion, whereas all other forms of propulsion require a chemical reaction. Solar sails provide thrust by reflecting protons in sunlight. There are about nine Newtons of force produced by this method across the entirety of the sail. This is much smaller than the 1.67 million Newtons produced at liftoff and 2.1 million produced in a vacuum by rockets. Even though the amount of force produced by a solar sail is very small, it is continuous; this means that a solar sail can reach higher speeds than a rocket because eventually a rocket's fuel will diminish while a solar sail can keep going as long as there is light. The solar sail will even function when it is far away from any star by pointing a stationary laser or microwave at the sail, providing it with light when natural light will not provide enough thrust.

A real advantage of using a solar sail is that it is constantly accelerating because light would always be shining on it, whereas a chemical rocket is propelled by a series of instantaneous explosions. This means long distance travel would be much faster with solar sails. For example it would take roughly five years for a solar sail launched from Earth's orbit to reach Pluto whereas it would take a chemical rocket eight years to travel the same distance. The use of a laser or microwave in addition to sunlight can quicken the sail; it could reach almost one tenth the speed of light. The top possible speed a solar sail could reach is 56 miles per second where as a chemical rocket can only reach a speed of 5 miles per second.

At a distance of one astronomical unit, or the distance from the earth to the sun, the force applied to the sail by the sun is

$$F = \frac{2(PA)}{c}$$

Where P is the Power of sunlight which is 1,400 watts/m^2, A is the area of the sail, and c is the speed of light which is 3x10^8 m/s. The acceleration is

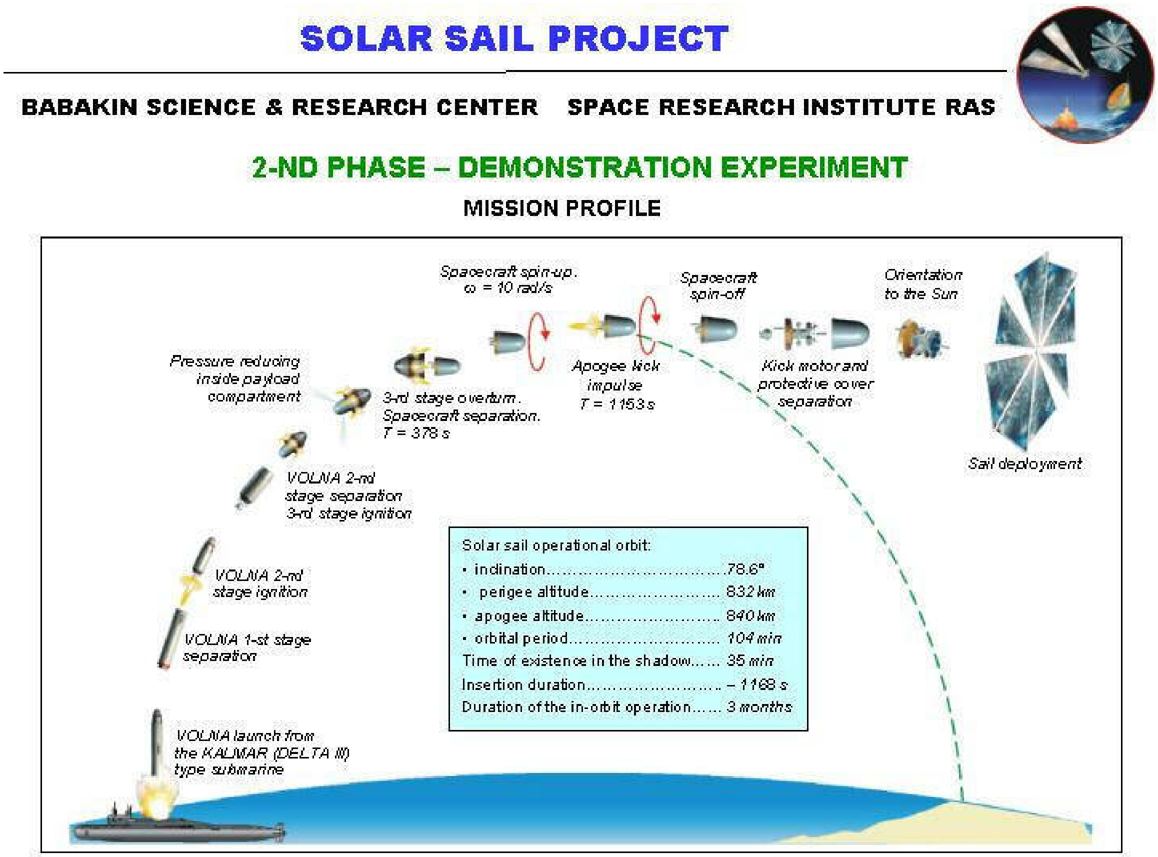
$$a = \frac{F}{M}$$

Where F is the force found in the previous equation, and M is the mass of the solar sail and the craft connected to it. With a craft with a mass of 1 kg, and a sail with area of 1 million m^2, the force would be about 9 N, and the acceleration would be about 9 m/s^2 (Kevin Bonsor, How Solar Sails Work)

One of the main issues with solar sails is that they cannot be launched from the ground, they only work in space. Therefore a secondary shuttle is needed to launch the sail into space. One of the ways that is being considered is using an intercontinental ballistic missile to launch the sail past the earth's gravitational field. Another method is to use a space shuttle with the sail as the payload. This would only be beneficial for long distance trips as a result of the large quantity of fuel used to launch the shuttle (Wikipedia, Solar Sails).

There a few different designs that are being considered for a solar sail. The first is a square sail that is composed of four triangles. This design needs support booms in order to support the sail material. A second design idea is heliogyro sail. This design has the same appearance of helicopter blades. Just like helicopter blades, it needs to be constantly rotated to maintain stability. A third design is a disc sail, which entails a series of trapezoids arranged in a circle. This design has to be controlled by changed the center of center of mass in relation to the center of pressure. All of the designs have one common thread, that being the material that the sails are made of. Each sail is made up of 5 micron thick film of aluminized Mylar or Kapton with a 100 nanometer aluminum film on one, forming a mirrored side with 90% reflectivity (NASA.gov, Solar Sail Technology Development).

The first attempt at using a solar sail, the Cosmos 1, was a joint effort between the Russian Academy of Science, The Planetary Society and Cosmos Studios. It was intended to just prove whether or solar sailing is possible. The Cosmos 1 never made it to orbit as a result of failure associated with the intercontinental ballistic missile used to launch it. Even though it failed to achieve orbit, it has paved the way for further steps to be taken on the road to solar sails. Currently there are other missions aimed at proving that solar sailing is possible. Below is the flight path the Cosmos 1 was supposed to take (The Planetary Society, Solar Sailing).



Solar sail operational orbit:
- inclination………………………………78.6°
- perigee altitude…………………… 832 km
- apogee altitude……………………… 840 km
- orbital period………………………… 104 min

Time of existence in the shadow…… 35 min
Insertion duration…………………… – 1168 s
Duration of the in-orbit operation…… 3 months

Plasma Thrusters

Matthew Brown

In the category of electrical rocket engines, there has been a great deal of advancement, allowing for some very interesting thruster designs. Plasma engines have been a focus of research in recent years but have existed for decades, and hold great potential for improved space flight. Rockets operate on the principle of conserved momentum. As the gas created in the engine leaves through the exhaust nozzle, it expands and increases in velocity. The momentum of the rocket changes to compensates for the increased momentum of the gas to keep the momentum of the system in balance. Therefore, the faster the gas moves, the faster the rocket will move. In an attempt to speed up the particles, engineers focused on electric and magnetic fields.

Plasma consists of an ionized gas. By adding or subtracting electrons, atoms can be given a charge, either positive or negative. Considered the fourth stage of matter (solid, liquid, gas, plasma), plasma is electrically neutral, although its constituent molecules are charged. Because the molecules in plasma are charged, it conducts electricity and reacts strongly to electric and magnetic fields. (Wilson, 2006) Plasma is the basis for electrical thrusters. These thrusters come in many varieties, but all work on the same principle. An electrical or magnetic field is used to accelerate the charged plasma and push it out the exhaust nozzle of an engine.

NASA is currently using a technology called PPT, or pulsed plasma thrusters. The legacy of these engines extends back to 1964, when the Soviet Zond 2 was the first spacecraft with a PPT. These thrusters operate with a low power electrical system that controls the thruster. Usually powered by solar cells, a capacitor is charged to high voltages and is allowed to arc across the igniter. This produces the initial plasma, which works on the fuel rod, a solid propellant, to produce the propellant plasma. By utilizing the Lorentz forces, the propellant plasma is accelerated and leaves the thruster as exhaust. The Lorentz force defines the force on a charged particle created by an electromagnetic field. On NASA's Earth Observing 1 (EO-1), plasma thrusters had a capacity to produce an exhaust velocity of 13,700 meters per second. Without interference from an atmosphere, the engine could achieve a velocity twice that of a space shuttle which travels at 18,000 miles per hour. This thruster only uses 70 watts of power. (Wilson, 2006)

Another prominent design is the Australian National University's (ANU) Helicon Double Layer Thruster (HDLT). The plasma is created by charging noble gas particles in a tube with a radio antenna. An electric field, created by solenoids, compresses the plasma to a high density. This creates a double layer of plasma, a standing shock wave which creates an electric field. This is a natural property of plasma, and is what cause auroras in the sky. The electric field produced by the double layer accelerates the plasma particles out of the end of the tube as high velocity exhaust. ANU estimates that the coils used to create the magnetic field that creates the dense plasma could be cooled in space application, lowering their resistance, and yielding power consumption in the 10s of watts. (PRL - How does the HDLT work?, 2004)

Plasma thrusters are one of the up and coming technologies to be used in the attempts at interplanetary travel. They are highly efficient and produce a thrust to fuel ratio which is much greater than conventional rocket engines. With a legacy spanning 40 years, the plasma thrusters may be the best solution to allow spacecraft to travel to other planets in the solar system.

Nuclear Propulsion

Matthew Goon

Nuclear propulsion is the idea of using a nuclear reaction as a primary power source for propulsion. Nuclear reactions come in different types and there are also many ways to utilize these types of nuclear reactions. The two very different types of nuclear reactions are fusion and fission. Some of the concepts that utilize nuclear fusion are nuclear pulses, Bussard ramjets, microwave-induced, and antimatter catalyzed nuclear pulses. Fission reactions are used in the following rockets: fission-fragments, fission sails, and gas core reactors. Other methods of nuclear propulsion use radioisotope thermoelectric generators, nuclear thermal and nuclear photonic rockets. (Nuclear Propulsion)

Nuclear fusion is the combining of nuclei to form a heavy nucleus resulting in a release of energy. A fusion reaction would create a very large specific impulse, because it would increase the change in momentum divided by mass of the propellant. Nuclear pulse propulsion is a method of using nuclear explosions to create thrust. During the late 1950s, NASA experimented with an engineering design study (Project Orion) of nuclear pulse propulsion. The Bussard Interstellar Ramjet utilizes what is in space, “where the hydrogen would be scooped and compress to temperatures where it would ignite in a fusion reaction, providing huge amounts of thrust.” The Bussard Ramjet was never put into production because of its calculated inefficiencies with regard to thrust and drag. (Bussard Interstellar Ramjet, 2006)

Microwave-induced fusion propulsion utilizes microwaves to start a fusion reaction of hydrogen isotopes, heating them up to at least 100 million Kelvin. Plasma is created from the stripped isotopes, depending on the temperature and density, hydrogen nuclei fuse releasing neutrons and large amounts of energy. (Microwave-Induced Fusion Propulsion) A type of nuclear fusion propulsion that is being actively investigated is the utilizing the destruction of a matter & antimatter mixture. The energy output is best described by Einstein’s mass-energy equation (**$E = mc^2$**). Research has taken place for the study of creating matter & antimatter mixtures at NASA’s Marshall Space Flight Center in Huntsville, Alabama. (Antimatter Propulsion)

Nuclear fission is the opposite of fusion, where the heavy nucleus splits up into smaller fragments and neutrons causing a chain reaction of dividing nuclei. The fission-fragment rocket is an engine that creates thrust directly from releasing the fission byproducts. Individual atoms are used to provide thrust by extracting the atoms that undergo fusion, to harness the energy before it dissipates into the fuel. (Fission-Fragment Rocket) Fission sails have the same concept of the fission-fragment, but the energy is used to move a large solar sail for thrusting instead of the direct expulsion of the fission byproducts. Though it is a fission reaction, fission sails do not use a nuclear reactor as an engine but depends on a radioactive decay for energy. (Fission Sail) Gas core reactor rockets used the exhausted coolant of a fission reactor to create thrust. They are a conceptual type of rocket that can use a gaseous fission reactor with vapor, gas, or plasma as a fuel source. “Due to the much higher temperatures achievable by the gaseous core design, it can deliver higher specific impulse and thrust than most other conventional nuclear designs.” (Gas Core Reactor Rocket)

On the mission to explore the mysterious red planet we call Mars, a chemical rocket was used to travel from Earth. In his article provided by Astrodigital, Blair P. Bromley took the information about the performance of the chemical rockets and compared them to the performance of a nuclear thermal rocket. In the tables on the next page, Bromley displays the comparison of the performances of chemical rockets versus nuclear thermal rockets. (Bromley, 2001)

Nuclear reactions do not only limit themselves to fusion and fission. The radioisotope thermoelectric generator uses the decay of a radioactive element as an energy source for heating a fuel. (Mission of Daring: The General-Purpose Heat Source Radioisotope Thermoelectric Generator) Nuclear thermal propulsion works by a propellant flowing through coolant channels of a nuclear reactor to heat up and exhaust through a nozzle. (Why Thermonuclear Propulsion?) Nuclear photonic rocket utilizes radiation from a nuclear reactor to generate high temperatures from the reactor to create thrust. (Nuclear Photonic Rocket) These methods are effective for converting energy and creating a high specific impulse but not effective enough to escape Earth's gravitational pull. Nuclear is the way of the future and steps are taken to use fusion and fission to allow the transport of humans into space.

Table 1: Types of Propulsion Systems

Type	Isp	T/W
Chemical (H2/O2)	400 - 500 s	50-75
NTR - Solid Core	500 - 1000 s	1-20
NTR - Gas Core	1000 - 6000 s	1-10
NEP - Ion Thruster	2000 - 10000 s	<< 1
NEP - Hall Thruster	1000 - 5000 s	<< 1
NEP - MPD Thruster	1000 - 8000 s	<< 1

Table 2: Mars Mission Comparison - Round Trip

Parameter	Chemical (H2/O2)	NTR - Solid Core
Payload Mass	100 tonnes	100 tonnes
Travel Time	1 year	1 year
Mission Delta-V	7.7 km/s	7.7 km/s
Isp	500 s	1000 s
Mass Ratio	4.806	2.192
Structural Mass	25 tonnes (⍰=0.05)	15 tonnes (⍰=0.10)
Propellant Mass	475 tonnes	137 tonnes
Total Initial Mass in LEO	600 tonnes	252 tonnes
Payload Fraction	0.167	0.397

(Bromley, 2001)

Understanding Kepler's Second Law and Gravitational Assist

Thomas MacDonald

The use of Kepler's second law in order to reach a greater speed is often referred to by people as the slingshot effect while NASA calls it a gravitational assist. This is usually used to be able to reach the outer planets Jupiter and Saturn. (Johnson, "Slingshot Effect") Cassini-Huygens used four gravitational assists in order to reach Saturn. The first happened on April 26th, 1996 and it was a close trajectory around Venus. The second happened on June 24th, 1999 with another round trip around Venus. On August 18th, 1999 the Cassini-Huygens entered Earth's gravitational force and was flung out towards Jupiter. On the fourth, December 20th 2000, the NASA spacecraft entered Jupiter's gravitational force and was sent on its way to its destination, Saturn. ("ESA-Portal – Let Gravity Assist You…")

This works because planets have a lot of angular momentum. When a space craft enters the gravitational field of a planet and gets close enough, the space craft itself exerts a gravitational force on the planet. By doing this, the space craft insignificantly decreases the angular momentum of the planet. This invokes a conservation of momentum, and therefore the space craft has to increase in velocity to conserve the momentum that is being lost by the planet. NASA explains this as throwing a ping pong ball at an electric fan. When the ball hits the fan, it should bounce off at a speed faster than when it went in while the blades would actually be moving slightly slower at the moment of impact. However, it is important that the motor for the electric fan is not on since that would defeat the conservation principle. Also for this to work, friction would have to be ignored so that the blades would constantly spin at the same speed. ("Cassini-Huygens: Operations-Gravity Assists")

Johannes Kepler (1571-1630 AD) published his first two of his laws in 1609 and the third was published in 1619. Kepler's laws of planetary motion are direct consequences of Newton's laws of motion. Kepler's second law is usually written this way: "as each planet moves around the sun, a line drawn from the planet to the sun sweeps out equal areas in equal times". (Taylor, pp. 91-93) Even though Kepler's laws were written for planets and the sun, they also apply to satellites. In our case, the satellite would be a space ship that entered into an orbit around one of the planets. (Nave, "Kepler's Laws")

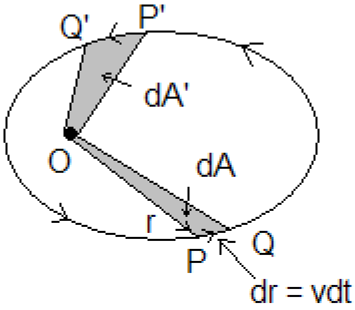


Figure 1 – This is a figure explaining Kepler's second law visually. (Taylor, pp. 92)

In **Figure 1**, there are two sets of points *P*, *Q* and *P´*, *Q´*. It is important to remember that they are separated by equal time intervals so that means that *dt* = *dt´*. Since that is true, then using Kepler's second law it is easy to see that *dA* and *dA´* are equal. *dA* is the change in area as a function of time while *dt* is the time increment that this example uses. The velocity is v while the change in the distance covered is represented as *dr* because it is a change in radius. (Taylor, pp. 92)

To further explain, for this example we will assume that the black dot is the sun and that it is stationary. It is also important to note that the sun is a point referred to as *O*. Now we select the points *P* and *Q* somewhere in space. Now we take the line *O P* and sweep it out until *O Q*. This forms the area *dA.* It is important to remember that *dt* is the time elapsed between the P and Q. Now, using Kepler's second law we can choose any other two points, which is denoted above as *P´* and *Q´*. Now it is important to remember that the points are separated by the same interval *dt´* therefore has to equal *dt´*. Based on this, we can fully understand that *dA* is indeed equal to *dA.´* (Taylor, pp. 92)

Taylor goes on to further prove his result by noting that the line *O P* is just the position vector **r**. He then goes on to say that *P Q* is just the displacement of ***dr*** = **v***dt*. He then goes into using a property that when we use a cross product we can figure out the area of a triangle if we know two of the vectors. He refers to the two vectors as **a** and **b**. (Taylor, pp. 92)

$$A = \frac{1}{2}[\vec{a} \times \vec{b}]$$

Equation 1 – Initial Area of a Triangle (Taylor, pp. 93)

$$dA = \frac{1}{2}[\vec{r} \times \vec{v}dt]$$

Equation 2 – Applying our variables into the above equation. (Taylor, pp. 93)

Taylor then goes in and replaces **v** with **p**/m. It is important to remember that **p** is linear momentum. He also divides both sides by *dt*. (Taylor, pp. 93)

$$\frac{dA}{dt} = \frac{1}{2m}[\vec{r} \times \vec{p}] = \frac{1}{2m}\ell$$

Equation 3 – The above formula while exchanging **v** with **p**/m. (Taylor, pp. 93)

Now it is important to note that ℓ is the magnitude of the angular momentum. This is because **r** x **p** is equal to ℓ . Now because angular momentum in this case is conserved, this brings the conclusion that *dA/dt* is constant. This is consistent with Kepler's second law. Now when we pull in closer to the planet, we can see that the object must speed up in order to cover the same amount of area it would when looked upon externally. (Taylor, pp. 93)

This is all well in good, if we make the assumption that it's only the planet and the spacecraft. That is what Kepler's laws were designed for, however we have to make adjustments to Kepler's laws in order to understand what truly happens during gravitational assist. With this case, we'll make some assumptions and simplifications in order to explain this topic. A sphere of influence is when the force of gravity coming from a planet on a space ship is greater than that of the sun's gravity on the ship. Of course, when the ship leaves the sphere of influence of the planet, it'll be once again attracted to the sun. (Bogan, "Orbits – Gravitational Assist from Planets")

$$r_{in} = D(\frac{m_p}{m_{sun}})^{\frac{2}{5}}$$

Equation 4 – Laplace's formula for finding the radius of the sphere of influence. (Bogan)

For Laplace's formula, m_p is the mass of the planet, m_{sun} is the mass of the sun, *D* is the distance between the sun and the planet, and r_{in} is the radius for the sphere of influence. We then have to find the relative velocity between the space craft and the planet in order to make calculations. The spacecraft will enter into a hyperbolic orbit around the planet because it enters the planet's sphere of influence with an inward velocity. The spacecraft will also have a relative velocity greater than the necessary escape velocity. (Bogan)

$$r = a\frac{(e^2 - 1)}{(e\cos(\phi) + 1}$$

Equation 5 – Used to calculate fly-by orbit radius with reference to the angle ϕ (Bogan)

With equation 5, we have a few variables to explain. ϕ is the angle relative to the perihelion. The perihelion is dependent on the orbit; however it is the point where the spacecraft comes closest to the planet during its orbit. There is r, which is the radius for a given ϕ. e is the eccentricity of the spacecraft's orbit and a is the semi-major axis in an elliptical orbit. The semi-major axis is how far the closest approach is to the crossing of hyperbolic orbits. (Bogan)

$$b = (\frac{Gm_p}{v^2})\cot(\theta)$$

Equation 6 – Gives the equation for the impact parameter. (Bogan)

The impact parameter, b, is used in order to be able to find the deflection angle, 2θ. It is also the distance from the planet that the probe would be at if the spacecraft just moved along a straight line while inside the sphere of influence. G is the universal gravitation constant which is equal to 6.67 x 10^{-11} N kg^2/m^2. The maximum angle that the spacecraft can enter into the planets sphere of influence is equal to $\frac{\pi}{2} + \theta$. Calculating gravitational assist trajectories is a difficult process; however the gain can be enough energy to escape the sun's gravitational effects. (Bogan)

$$v_{esc} = (2\frac{Gm_p}{r_{in}})^{1/2}$$

Equation 7 – Formula for escape velocity. (Bogan, "Velocity Transform…")

From equation 7, we can see the escape velocity necessary in order to escape a planet's sphere of influence. This is a fact that we can use in many other calculations when we set up orbits for gravitational assist. The normal case is that our relative velocity to the planet is greater than the needed escape velocity. However, we can capitalize on the planet's gravitational force in order to accelerate us even further. (Bogan)

$$C = \frac{a_p}{a} + 2 * \cos(i) * (\frac{a}{a_p}(1 - e^2))^{1/2}$$

Equation 8 – Formula for Tisserand's Parameter (Bogan, "Conservation…")

There are also limitations on gravitational assist orbits known as Tisserand's criteria. These stem from the conservation of angular momentum and energy, thus only allowing certain orbits. In equation

8, C is Tisserand's Parameter, i is the inclination of the orbit when compared to the planet's orbit, and a_p is the semi-major axis of the planets orbit when the orbit is assumed to be circular. (Bogan)

$$\frac{1}{a_1} + 2 * \cos(i_1) * (a_1(1-e_1^2))^{\frac{1}{2}} = \frac{1}{a_2} + 2 * \cos(i_2) * (a_2(1-e_2^2))^{\frac{1}{2}}$$

Equation 9 – Tisserand's Criteria (Tolsen)

Tisserand's Criteria dictates that initial Tisserand Parameter must be equal or within acceptable levels of error in order to be a valid orbit. (Tolsen) This stems from the conservation of energy and momentum. It assures us that laws of physics are being obeyed and that we can actually implement the orbit that is being suggested. All of these factors make gravitational assist a very thought out process of calculations although the rewards for this method are tremendous. (Bogan)

Rocket Propulsion

Matthew Goon

Rocket propulsion is used to increase the velocity of a spacecraft or satellite and is a heavily researched topic. Some of the more recent spacecrafts use rocket engines which derive their power by heating a fuel and allowing it to flow out the back of the vehicle. There are many types of methods to achieve acceleration (change in velocity). Most of the current spacecrafts use chemical rocket or air-breathing engines to achieve launch. Most of the current satellites use simple but very reliable resistojet rockets.

Rocket propulsion is very important because it is not only used for launch, but also for moving and maintaining a specific orbit. Satellites use rocket propulsion to move from one orbit to another, and once a satellite has used up its ability to accelerate into different orbits it's considered a danger. Propulsion is also required to move a spacecraft after it has escaped Earth's gravitational pull. An equation for this attraction of gravity is given below, where m1 and m2 are the 2 masses in comparison, G is a gravitational constant, and r is the distance between the 2 masses.

$$g = G\frac{m_1 * m_2}{r^2}$$

Force of gravity

$$\Delta V = -V_e \, \ln\left(\frac{M+P}{P}\right)$$

Tsiolkovsky's rocket equation

Listed above is Tsiolkovsky's rocket equation, where ve is exhaust velocity, M is the reaction mass, and P is the payload of the mass. Exhaust velocity is defined by multiplying the specific impulse of the rocket by the gravitational acceleration at sea level. The Tsiolkovsky's rocket equation is used to determine the change of velocity of the spacecraft in a straight line in free space. This equation is derived from integrating the equation for the conservation of momentum, m *dv* = ve *dm*.

Most rocket engines are internal combustions heat engines that use a high temperature reaction mass by combusting a solid, liquid, or gaseous fuel. "This exothermal reaction of a fuel with an oxidizer creates gases of high temperature and pressure, which are permitted to expand. The defining feature of an internal combustion engine is that useful work is performed by the expanding hot gases acting directly to cause movement, for example by acting on pistons, rotors, or even by pressing on and moving the entire engine itself." (Internal Cumbustion Engine) The gases, created by the reaction with the oxidizer, are allowed to escape through a high-expansion ratio nozzle. The high-expansion nozzle is used to accelerate the mass, which increases thrust (converting most of the thermal energy into kinetic energy).

There are many different types of rocket engines that use different heating methods of providing propulsion, including chemical, solar, nuclear, and electrical. The types of rocket engines that use chemical heating are: solid, hybrid, monopropellant, bipropellant, tripropellant, and dual mode propulsion rockets. A solar thermal rocket utilizes solar power to directly heat the reaction mass to create thrust. There are 2 types of basic solar thermal propulsion concepts, varying in the method of using the solar power.

> Indirect solar heating involves pumping the propellant through passages in a heat exchanger that is heated by solar radiation. The windowless heat exchanger cavity concept is a design taking this radiation absorption approach.
>
> Direct solar heating involves exposing the propellant directly to solar radiation. The rotating bed concept is one of the preferred concepts for direct solar radiation absorption; it offers higher specific impulse than other direct heating designs by using a retained seed (tantalum carbide or hafnium carbide) approach. The propellant flows through the porous walls of a rotating cylinder, picking up heat from the seeds, which are retained on the walls by centrifugal force. The carbides are stable at high temperatures and have excellent heat transfer properties. (Rocket Engine)

The nuclear rocket consists of many different types of rockets based on reaction type: nuclear thermal, radioisotope, antimatter catalyzed nuclear pulse propulsion, gas core reactor, fission-fragment, fission sail, nuclear salt-water, nuclear pulse propulsion, fusion and antimatter rockets. The last type of rockets is electrical like the pulsed plasma thruster, resistojet, arcjet rockets.

Understanding Rocket Physics

Matthew Brown, Barry Kosherick, Matthew Goon, Thomas MacDonald

Based on "Lecture Notes on Mathematical Modeling" by Mayer Humi

Single Stage Rocket Physics:

The motion of a rocket is determined by many different things. In the article provided by Professor Humi, they made many simplifications in order to make the problem easier and to introduce an advanced rocket topic at an undergraduate level. The simplifications made were: the flight of the rocket is straight up, the atmosphere does not exist, the Earth does not rotate, ignore the ignition stage of the rocket, stability of the rocket, neglect the gravitational effects of the Sun and moon, and the assumption that the Earth is a perfect sphere. When these topics are neglected, some of the issues that are avoided are the coriolis force and quadratic air resistance. The model used is a rocket that continually ejects a constant stream of gases that propel the rocket upwards. This stream of gases is considered by this model to be constant except for at ignition which has been neglected. They define the velocity of the escaping gases as u . This serves as an approximation.

Now when drawing a free body diagram, one would see that the only external force being applied to the system is now the force of gravity exerted on the rocket by the Earth. They then use the conservation of momentum in order to set up an equality in order to be able to calculate the final velocity of the rocket. The momentum of the gases with the addition to the momentum of the rocket minus the momentum of the rocket before is equal to the momentum imparted by gravitational field.

What makes the rocket actually leave the ground is the fact that there is a conservation of momentum. This is because the mass of the rocket decreases and escapes out of the bottom. This movement of mass means that the rocket cannot stay stationary it has to start to move the other way because of Newton's second law. Newton's second law states that for every action there is an equal and yet opposite reaction. Now with the understanding of the physics of the situation we set up the assumption that v(t) is the changing velocity and m(t) is the changing mass of the rocket in the following equation.

$$[-\frac{dm}{dt}\Delta t](v(t)-u)+m(t+\Delta t)v(t+\Delta t)-m(t)v(t)=-m(t)g(h(t))\Delta t$$

Equation 1 – Setting up the momentum equation of each portion

Now it is important to understand that h(t) is the changing altitude of the rocket at time *t*. The source then goes on by dividing by Δt -> 0. This simplifies the equation further.

$$\frac{d}{dt}(m(t)v(t))=\frac{dm}{dt}(v(t)-u)-m(t)g(h(t))$$

Equation 2 – This is Equation 1 divided by Δt -> 0

Even though gravity changes as a rocket goes up into the air and gets further away from the Earth. The source ends up setting g(h(t)) to be a constant since the gravity function will go constant since it is build around a change in height. This yields the next equation.

$$\frac{dv}{dt}=-u\frac{1}{m}\frac{dm}{dt}-g$$

Equation 3 – This is the equation that sets g(h(t)) to be a constant

$$v=v_0+u\ln\frac{m_0}{m(t)}-gt$$

Equation 4 – This is the equation after being integrated with respect to *t*

In Equation 4, m_0 is the initial mass of the rocket at launch. The initial velocity is represented by v_0. However, if you set *u* to approximately 3000 m/sec and the rockets flight is short, then the last term of gravity becomes insignificant.

$$v=v_0+u\ln\frac{m_0}{m(t)}$$

Equation 5 – This is the simplified Equation 4 with the approximation that *u* is greater than 3000 m/sec.

Now in a one stage rocket, the mass of the payload in addition to the final mass and the mass of the engines is equal to the initial mass. The payload mass will is denoted as m_p while the initial mass of the fuel is m_f. The mass of the engine and fuel containers that are ejected during the final seconds of the one stage rocket is m_s.

$$m_0 = m_p + m_f + m_s$$

Equation 6 – The equality of the masses involved in a single stage rocket.

$$v_F = v_0 + u \ln \frac{m_0}{m_p + m_s}$$

Equation 7 – Equation for the final velocity.

The final velocity is found by assuming that all of the fuel has been burnt up and the engines and fuel containers have not been disengaged from the ship. For the most part the ratio of mass of the engines and fuel containers and the initial mass is approximately $\frac{1}{10}$. The author then makes the argument that even if m_p is equal to zero and the effect of gravity is neglected the final velocity will be approximately 7200 m/sec. This assumes that the initial velocity is zero and that the velocity of gases escaping is equal to 3000 m/s.

Multi Stage Rocket Physics:

The presuppositions set in the single stage rocket hold in the multi stage rocket approximation. The flight of the rocket is still straight up, the atmosphere continues to not exist, the Earth again does not rotate, they continue ignore the ignition stage of the rocket, the stability of the rocket is still omitted, the gravitational effects of the Sun and moon are neglected, and the assumption that the Earth is a perfect sphere still holds. The multi stage rocket was developed in an attempt to bridge the gap between a single stage rocket and the physically impossible ideal rocket.

The ideal rocket consumes weight and fuel in a way such that the ratio of these two is constant, therefore allowing for the most efficient thrust. The loss of fuel creates dead weight in empty fuel tanks, thus offsetting the ratio. The ideal rocket losses the weight of the tanks at a rate which balances the loss of fuel.

$$\frac{m_f(t+\Delta t)}{m_s(t+\Delta t)} = \frac{m_f(t) - \Delta m_f(t)}{m_s(t) - \Delta m_s(t)} = \frac{1-\lambda}{\lambda}$$

Equation 8 – Payload ratio

The symbol λ represents a number such that the payload ratio is always constant in the ideal rocket. This ratio defines the rate at which the weight is lost in relation to the fuel consumed.

$$m(t)v(t) = m(t+\Delta t)v(t+\Delta t) - \lambda \frac{dm}{dt}\Delta t v(t) - (1-\lambda)\frac{dm}{dt}\Delta t(v(t) - u)$$

Equation 9 – Equation for conservation of momentum with payload ratio

$$m\frac{dv}{dt} = -(1-\lambda)u\frac{dm}{dt}$$

Equation 10 – Conservation of momentum divided by Δt and Δ goes to zero

$$v_f = (1-\lambda)u \ln \frac{m_o}{m_p}$$

Equation 11 – Equation for Final Velocity

As the ideal rocket is physically impossible, as it would require tanks that can change in mass in a controlled manner, the multi stage rocket was developed. When a tank becomes empty, the tank is jettisoned from the system to eliminate dead weight, effectively reducing the mass of the system. This allows for an approximation of the ideal rocket. While the efficiency drops from the ideal to the multi stage, due to the fact that a tank must be emptied entirely before jettisoned, it is more efficient than the single stage rocket. As the number of stages increases, the efficiency increases as the stages can be jettisoned more regularly. To maximize the efficiency, the effort must be to increase the number of stages, that is, to reduce Δstage to as small as possible, as in a Riemann sum.

$$m_t = m_p + m_1 + m_2 + m_3$$

Equation 12 –Equation for the Total Mass of a Rocket

Just like the single stage rocket, the final velocity for the first stage can be easily calculated in a similar fashion.

$$v_1 = u \ln \frac{m_0}{m_p + \lambda m_1 + m_2 + m_3}$$

Equation 13 – Equation for maximum velocity of stage one

$$v_2 = v_1 + u \ln \frac{m_p + m_2 + m_3}{m_p + \lambda m_2 + m_3}$$

Equation 14 – Equation for maximum velocity of stage two

$$v_F = v_3 = v_2 + u \ln \frac{m_p + m_3}{m_p + \lambda m_3}$$

Equation 15 – Equation for maximum velocity of stage three

This is the logical progression of velocities as each one should include the one before it and also incorporate the changes of the changes of its own section. All of these equations can be compressed down to a smaller easier to use equation.

$$\frac{v_F}{U} = \ln(\frac{m_0}{m_p + \lambda m_1 + m_2 + m_3})(\frac{m_p + m_2 + m_3}{m_p + \lambda m_2 + m_3})(\frac{m_p + m_3}{m_p + \lambda m_3})$$

Equation 16 – Combining the results of Equations 14 – 16

Based on the fact that this is a very bulky equation, it is preferable to condense them into a smaller much easier format to work with. The source attempts to compress the equation into something much smaller by introducing new variables.

$$x_1 = \frac{m_0}{m_p + m_2 + m_3}$$

$$x_2 = \frac{m_p + m_2 + m_3}{m_p + m_3}$$

$$x_3 = \frac{m_p + m_3}{m_p}$$

Equation 17-19 – The introduction of new variables

$$\frac{v_f}{u} = \ln\{(\frac{x_1}{1 + \lambda(x_1 - 1)})(\frac{x_2}{1 + \lambda(x_2 - 1)})(\frac{x_3}{1 + \lambda(x_3 - 1)})\}$$

Equation 20 – Plugging in the new variables in order to simplify matters.

The author writes about how m_p appears in all of the denominators in Equation 21 that our goal is to minimize the values of these variables. This is in order to see what the maximum payload ratio is. Since there is symmetry in this problem, the source sets $x_1 = x_2 = x_3 = x$.

$$\frac{v_F}{u} = \ln(\frac{x}{1 + \lambda(x - 1)})^3$$

Equation 21 – Equation after the variables are minimized

$$x = \frac{1 - \lambda}{p - \lambda}$$

Equation 22 – Solving for x when p = exp($-v_f/3u$)

$$\frac{m_0}{m_p} = x_1 x_2 x_3 = (\frac{1-\lambda}{p-\lambda})^3$$

Equation 23 – The final mass equation

From equation 24, when the values of λ, *u*, and v_f which were used previously, the payload ratio can be calculated to approximately 77. That means that the original mass is seventy-seven times larger than the payload itself.

Tachyon Particle Propulsion: Fact and Fiction

Thomas MacDonald

A tachyon particle is a particle that travels faster than the speed of light. However, a photon is a massless particle that travels at the speed of light. To further explain this, I have provided in figure 1 a plot of E = +/-p. E is energy and p is momentum. (Chase, "Tachyons")

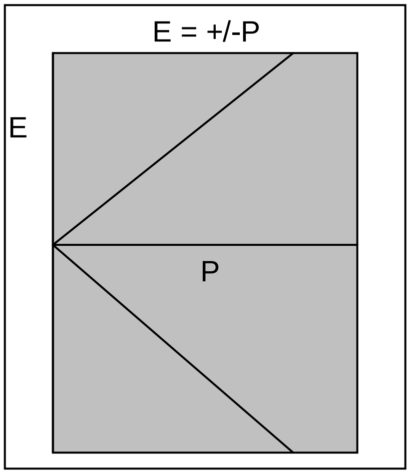


Figure 1 – Drawing of the "light cone" (Chase, "Tachyons")

In the figure above, this is a graph of the formula E= +/- p. The lines are a representation of a "light cone" despite this being shown in two dimensions. The source sets this up as a 1+1 dimensional space-time that is now comprised of two regions. He explains that above and below the lines are "time-like" quadrants while the lines to the left and right are "space-like" quadrants. (Chase, "Tachyons")

The next argument is based off of the equation that $E^2 - p^2 = m^2$. In this article, c=1 for simplicity reasons. The original equation is $E^2 = p^2c^2 + m^2c^4$. C is the speed of light, however if we set it equal to one, the equations become much more malleable. Now a photon, which is a massless particle has $E^2 = p^2$. That allows the massless particle to satisfy the equation and would mean that it travels at the speed of light. Now the author goes further with the introduction of a very important formula. This formula is $E = m*[1-(v/c)^2]^{-1/2}$, which is the total energy of a particle traveling at a specific speed. So when one looks at a particle traveling faster than the speed of light, the square root in the equation will have a negative inside. That'll produce an imaginary square root. That means E is then imaginary. (Chase, "Tachyons")

The next process is that if one takes the rest mass to be imaginary, then they would exhibit negative energy. Based on this preliminary knowledge of tachyon particles, one can deduce interesting properties of the tachyon. As the momentum increases, the energy will go down as a result. Also if a tachyon has zero energy, it moves infinitely fast. The author then goes on to suppose that if the tachyon particles were electrically charged that in a vacuum they would emit Cherenkov radiation. Creating this radiation would actually lower their energy and accelerate the particle further. (Chase, “Tachyons”) Cherenkov radiation is emitted when a charged particle goes through matter with a velocity that exceeds the speed of light inside of the medium. (Rudolf, “Cherenkov Radiation”)

So let’s deal with the actual problem of using tachyons for propulsion. We would have to make sure that the momentum is conserved. Let’s assume that our spacecraft is capable of firing tachyon particles in a controlled fashion. Now with the conservation of momentum, if a particle is fired out the exhaust then the ship would have to move ahead to conserve the momentum. However, if we use the assumption above where the tachyon has imaginary mass, which means there would be an imaginary component to be able to be equal and opposite. This imaginary component could be absorbed by the velocity or mass. However, since the mass of our starship is not imaginary, this conservation of momentum seems to hit a wall. This would mean that the ship would have to have an imaginary velocity.

Chapter 5 – Space Flight

Space: The Mission has to Start Somewhere and that's the Launch

Thomas MacDonald

In order to get a shuttle into space to do its mission, the shuttle has to be launched somehow. The shuttle sometimes lands in California but mainly lands in Florida. When the shuttle lands in California, NASA gives the space shuttle a ride on a modified 747 classified as a Shuttle Carrier Aircraft (SCA). The SCA with the shuttle riding piggy-back will sometimes takes off from Edwards Air Force Base in California and fly to Kennedy Space Center in Florida. (Nemiroff, Bonnell, "…Shuttle Ferry…") An interesting fact is that the 747 needs to be weighed down by gravel and iron because the shuttle itself is very rear heavy. This is because of the rocket boosters that the shuttle has are where most of the weight is located. (Creech)

Once it has landed, the shuttle is brought to the vehicle assembly building (VAB). This building will add on the additional parts necessary to get the shuttle into space. The VAB was originally made for the Apollo and Saturn projects. However, it has been modified in order to meet the requirements for the space shuttle. It has four high bay areas. High bays 1 and 3 are used for stacking the complete space shuttle and the incorporation that is necessary to reach that point. High bay 2 is used to store the external tank (ET) and as an unforeseen event storage area for orbiters. High bay 4 is also used for a very similar aspect however it will also be used to store the SRBs on a contingency basis. (Dumoulin)

There is also a low bay area. This area is used to maintain the space shuttle's main engines and also a holding area for SRB assemblies. When the shuttle is actually built, it is done in stages. The SRBs go into a check out facilities and are hoisted onto a Mobile Launcher Platform (MLP) in high bays 1 and 3. After that the external tank is inspected and checked out from either high bay area 2 or 4 and it is attached to the SRBs that are already set up. The orbiter itself is moved from the Orbiter Processing Facility to the VAB and raised into a vertical position. It is then lowered onto the MLP and attached to the external tank. Once everything has been checked over, the crawler comes in and picks up the MLP to bring it to the launch pad. (Dumoulin)

The crawler that takes it from the VAB to the correct launch pad is the largest tracked vehicle. The top speed of the crawler when fully loaded is less than two kilometers per hour even when it boasts over 5,000 horsepower. This isn't an easy vehicle to drive; in fact it takes eleven people to be able to drive the crawler. The crawler has been able to consistently keep its passenger crafts upright. The trip takes a little over six hours from the VAB to the launch pad. (Nemiroff, Bonnell, "…the Shuttle Crawler Transporter.")

Let's take a closer look at the components in a space shuttle launch. Let's start with the orbiter. This piece of equipment is the space shuttle specifically. It has all of the experiments, equipment, and everything else that is important to the mission. The space shuttle itself is used as a space laboratory. This is where the astronauts live and work. It is the first vehicle that was capable of going to and returning from space. (Angelo, pp. 298) The space shuttle has a bay that can transport up to 65,000 pounds of cargo. However, on the return flight it can only bring back 32,000 pounds of cargo. The orbiter normally carries four crew members and three passengers. ("About United Space Alliance – Orbiter")

The external tank is a large tank that contains additional fuel for the three main engines of the orbiter. The external tank during a launch will sustain the force of 28,560 kilonewtons. This force comes from the main engines of the orbiter and from the SRBs. The three main components of the external an oxygen tank, a hydrogen tank, and an interconnect tank that combines the two tanks together and provides an attachment structure. The external tank is jettisoned at approximately an altitude of seventy miles. (Angelo, pp. 129) It is important to remember that it is liquid oxygen and liquid hydrogen tanks that are used as rocket fuel. (“About United Space Alliance – External Tank”)

Last but not least are the solid rocket boosters. The SRBs create a force of 11,790 kilonewtons at launch. The SRB internal supply is separated as such: 70% is ammonium perchlorate (an oxidizer), 16% powdered aluminum (the fuel), and the rest is iron oxide (a catalyst). The solid propellant actually looks and feels like a hard rubber eraser. These rockets are jettisoned at 44 miles high and parachute downwards to be recollected later. (Angelo, pp. 382) The SRBs provide about 71.4% of the thrust at lift off. Although the SRBs are not ignited until the three main engines of the shuttles have been confirmed to be burning. (“About United Space Alliance – Orbiter”)

Launch Systems

Thomas MacDonald, Barry Kosherick

Basic Launch Considerations

When looking at a space launch system, it is important to remember that a space launch system operates uniquely compared to other vehicles. It is the only vehicle that constantly accelerates through its entire performance envelope. The most important aspect about achieving orbital velocity is the propulsion efficiency, the vehicles weight, and the drag exhibited on the vehicle. It’s important to understand all of the forces that are acting upon the launch vehicle. The weight, W, of the space craft acts upon the center of gravity. Weight is defined as being mass multiplied by gravity. The mass in question would be the mass of the total system in order to calculate the weight. The forces of lift, L, and drag, D, however act in a different spot. This spot is called the center of pressure. When designing a space launch system, it is important that the center of gravity precedes the center of pressure. That makes the system stable because the lift and drag will create restoring torques at the center of gravity. In an ideal sense the thrust will act on a straight line through the center of the vehicle. The flight plan angle, , is measured from the local horizon. While the angle of attack, α, is measured from the centerline that is created by the thrust. (Larson, Wertz, pp.720-721)

$$a_x = g[\frac{T}{W} - \sin(\phi - \alpha) - \frac{D}{W}\cos(\alpha) + \frac{L}{W}\sin(\alpha)]$$

Equation 1 – Formula for solving for acceleration along the x axis (Larson, Wertz, pp.721)

$$a_z = g[-\cos(\phi - \alpha) + \frac{D}{W}\sin(\alpha) + \frac{L}{W}\cos(\alpha)]$$

Equation 2 – Formula for solving acceleration along the z axis (Larson, Wertz, pp.721)

Equation 1 and 2 are formulas for solving for specific acceleration components of a space launch vehicle. This is assuming $\hat{x}$ is to the right and $\hat{z}$ is up. Now in order to calculate the velocity that the launch vehicle has to provide, one can just add the basic velocities. (Larson, Wertz, pp.721)

$$\Delta V_{design} = \Delta V_{burnout} + \Delta V_{gravity} + \Delta V_{drag}$$

Equation 3 – Basic velocity necessary for a launch vehicle (Larson, Wertz, pp.721)

When dealing with equation 3 it is important to understand the variables. ΔV_{design} is what the design ultimately requires while $\Delta V_{burnout}$ is the velocity that is necessary in order to put the system into orbit. $\Delta V_{gravity}$ and ΔV_{drag} are the losses caused by gravity and drag respectively. There are other losses caused thrust vector control which is used for trajectory shaping and performance variables. All of these losses are susceptible to the initial thrust-to-weight ratio T/W_0. That is with T being thrust and W_0 being the initial weight of the entire launch vehicle. When using a low thrust-to-weight ratio this causes the losses of gravity to be much higher since the craft will be under the effects of gravity for much longer. While a high thrust-to-weight ratio will cause drag losses because of quadratic air resistance which depends on velocity. (Larson, Wertz, pp.721-722)

Now if there was no atmosphere or topographical variations, the best way to launch the vehicle would be thrusting normally to the radius vector, this would minimize gravity losses. However, in order to calculate gravity losses a person needs to know the time of flight and the ascent profile. When launching a large launch any losses due to gravity will range from 750 and 1,500 m/s. With all of this, it is easy to see why designing a launch vehicle even on the most basic level is still a very complicated task. (Larson, Wertz, pp.723)

Launch System Selection Process

This section will discuss the process that determines how a launch will take place. There are many procedures that help choose the best launch system for a particular mission. One of the most important steps is establishing the mission needs and objectives. This happens first as performance and trajectory heavily dictate the how the craft will be launched, both of which can be determined from the mission needs and objectives. This needs to be stated very clearly as any ambiguity could alter the mission. Usually in the mission needs and goals are the primary objective of the mission, the areas that the craft will travel, and the timeframe. One example of this would be the directive John F. Kennedy made to put a man on the moon within a decade. (Larson, Wertz, pp.723)

Another important issue is whether the craft will be launched alone or with another craft in the payload of the launch vehicle. This is an important consideration because if the craft is launched with a shared launch vehicle, the cost is greatly reduced, however the two craft could interfere with each other, such as if one was to be launched a lower altitude than the other, that it could cause both to be launched there. (Larson, Wertz, pp.723)

One the mission needs have been established, specific requirements are determined. These usually include the flight path specifics such as orbit altitude, inclination, and right ascension of the ascending node. Also included are the physical requirements of the craft such as estimated payload weight and dimensions. Other parameters come into play now; these include number of spacecraft, anticipated lifespan, replacement strategies and methods for data retrieval and management. (Larson, Wertz, pp.723)

After requirements have been set, they get split between ones that the payload must accomplish, and ones that must be done by the launch vehicle. These often include propulsion, guidance, navigation and control. The most common situation is if the launch vehicle can achieve the desired orbit, or must the craft climb to a higher altitude than the launch vehicle can reach. One way that the desired altitude can be reached is with adding additional stages of boosters. This drives the cost up greatly as the cost of each stage is quite expensive. The other way to achieve the desired altitude is to have a propulsion system on the craft that can reach its target altitude. This adds complexity to the craft that might put the craft in danger. The tradeoff that must occur is between cost of additional stages and complexity of the craft. (Larson, Wertz, pp.723-724)

Propulsion is not the only area where tradeoffs are made; other major areas are navigation, guidance and control. Currently it is possible to have the craft control and navigate both the craft and the launch vehicle. This means that the integration between the two is very complex, and that it is difficult to manage the interface between the craft and launch vehicle. However it is the norm now to have the launch vehicle and the craft as independent as possible as it avoid any unnecessary complex interfacing and programming. This also allows the craft to be compatible with several launch systems. This helps to keep more viable options open. (Larson, Wertz, pp.724)

The launch system has a few criteria that must be met for a mission to be possible. These include the capability to boost the necessary weight to the desired altitude, availability of the launch system on the desired date, spacecraft to launch vehicle compatibility and the cost of launch. The launch system's performance must exceed the projected boosted weight. The difference of launch system performance minus the spacecraft boosted weight is known as the performance margin, which is something that unless kept in mind can ruin a mission. This is something that usually starts as a small positive number which means that the craft weights just what the launch system can place into orbit. As the design of the craft progresses, the performance margin sometimes grows which if they exceed a certain point a new launch system must be chosen, which causes a lot of lost time. (Larson, Wertz, pp. 724-725)

Time is another criterion that must be included in the mission plan, as launch vehicles and sites are not available all the time, so the completion of the project must be done so in order to use the desired launch vehicle and site. Not only does the launch pad need to be available on the day of launch, the weather and surrounding area must also be as such that a launch can happen.

$$A = 1 - \left[\frac{L(1-R)T_d}{\left(1 - \frac{1}{S}\right)} \right]$$

Equation 4- Expected Launch Availability

A is the expected launch availability, measured in percent of the time the launch system is available. R is the reliability, the nominal or planned launch rate is L, measured in flights per year, T_d is the estimated or demonstrated down time after a failure in units of years and S is the surge-rate capacity. The surge rate capacity is how much the craft's actual rate of launches can change from L, and is normally from 1.15 and 1.5. If A comes to be negative then the system will probably not be available when needed. This equation must be used carefully because if S is 1, then the equation will not work. (Larson, Wertz, pp. 726)

Space Craft Design Envelope and Environments

This section will discuss picking operating environments and determining the design envelope after the launch system has been selected. Operating environments are important for keeping the people safe and also for keeping the payload in a safe state. When thinking about the payload it is important to make sure the payload is in the correct storage environment from when it leaves the vendor and until its mission is completed. One of the ways of protecting a piece of equipment is by putting it in a fairing. However, the fairing has to fit inside the launch system. When examining the space shuttle, its cargo bay is so large that it can often store multiple payloads. (Larson, Wertz, pp.735)

The space shuttle's bay is split up into four sections. This is done in order to assist with planning. Each of these sections will provide the necessary electricity, cooling, and telemetry for the payloads. If a payload is exceptionally large then it will use multiple sectors in order to meet its needs. Typical fairings protect from temperature, electromagnetic, contamination, venting, acceleration, vibration, acoustics, and shock. Typical values of thermal protection range from 10 to 35 degrees Celsius while the pad provides 188 BTU·ft^2/hr. Typical acceleration protection is 5-7g while acoustics have to protect from 140dB. (Larson, Wertz, pp.735-736)

During the early portion of the design process, a payloads interface to the launch system has to be clearly identified. The example given by this author is if a payload adapter is attached to the launch vehicle and the payload is attached to that adapter. The payload itself may need additional support even though it is clearly attached to the launch vehicle. Manufacturers have to provide the separation mechanisms from the launch vehicle. It is extremely important that these systems have high reliability. (Larson, Wertz, pp.736)

Moon Base: Getting There and Lunar Landing

Thomas MacDonald

Understanding how to land on the moon will allow us to be able to create a spaceship that can land consistently on the moon. Once the vehicle has delivered its payload, then it will have to be able to return back to the Earth. This requires being able to reach the moon and to reach the Earth from the moon. The first manned mission to land on the moon was performed by Apollo 11's crew: Michael Collins, Edwin "Buzz" Aldrin, and Neil Armstrong. ("Apollo 11", Thinkquest)

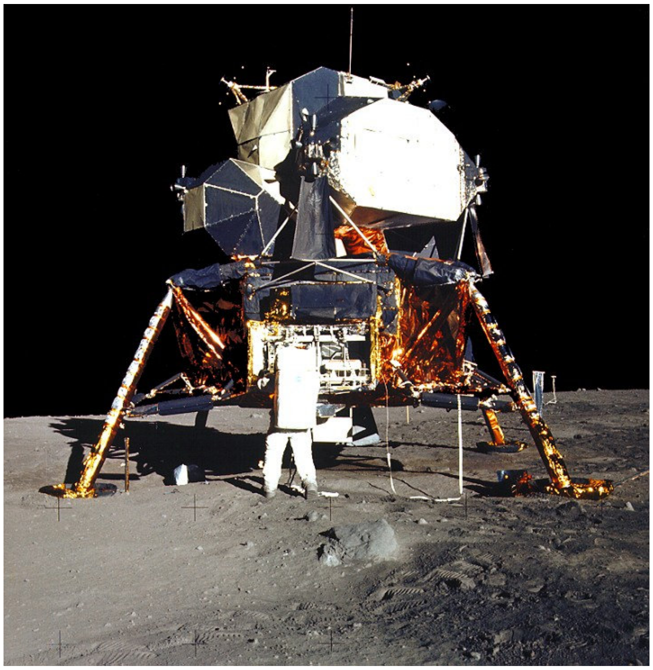


Figure 1 – This is a picture of Apollo 11 spacecraft on the moon. (Kipp, “Apollo 11 Image Gallery”)

Apollo 11 was launched from Kennedy Space Center Launch Complex 39A on July 16th, 1969. It landed on the moon in Mare Tranquillitatis. (“Apollo 11 Home”) Mare Tranquillitatis was chosen as the landing spot because it was a pretty smooth landing spot, however it had plenty of craters to serve as an obstacle. During the last few seconds of the landing, Neil Armstrong had to land the craft manually in order to avoid a crater. (“Apollo 11 Landing Site”) By examining Figure 1, the general idea behind it is a vertical landing. There are four landing legs that have to sustain the impact of landing.

There are thrusters that allow the landing module to be able to slow its decent onto the moon. This lessens the stress on the landing gear caused by impact. The thrusters also would allow the craft to maneuver as is the case in the Apollo 11 mission. Specifically the Apollo 11 space craft had three parts: the command module “Columbia”, service module, and the lunar module “Eagle”. The lunar module is the part shown in Figure 1. The lunar module splits into two parts, one would stay on the moon and the other half lifted off to rejoin “Columbia”. (“Apollo 11”, The History Place)

A space shuttle requires a runway to land as it was designed to be reusable. However, the space shuttle relies on an atmosphere to be able to glide in using lift. This would mean if a space shuttle was going to be designed to land on the moon; it would have to have maneuvering thrusters spread out in the front and sides of the shuttle. Slowing down would be a problem. The shuttle releases parachutes when landing and uses air brakes also. A possible work around could be the steel cables that airplanes use on cruisers. This would assume that one would be able to actually pilot the craft in, have enough maneuverability from thrusters, and be able to slow down to a speed that wouldn’t snap the steel cables.

It is also important to note that the ship would need radiation shielding. That is because to get to the moon the ship has to pass through the Van Allen radiation belts. (Braeunig, “the Moon Hoax Debate”) The Van Allen belt is a donut shaped area where electrons and protons get stuck in Earth’s magnetic field. Now the amount of flux experienced in an area is due to how much energy the particles possess. The amount of flux is generally less when the energy is high while when the amount of flux is high when it is a lower energy. Low energy particles cannot particle the covering of the space craft let alone pierce human skin. Electrons up to 1 MeV are unlikely to be dangerous as are protons under 10 MeV. ("MAD Scientist: the Van Allen Belts and Travel to the Moon")

When Apollo was first proposed, a major concern was the radiation of this belt. However, the flight plan of the Apollo space craft was able to cut through this belt in an hour both to and back from the moon. During that time the astronauts were exposed to about 1-2 rem of radiation. However, this belt isn't located around the entire Earth so if we had a different launch site we would be able to avoid it. This is because the belt is twenty degrees above and below the equator coving a span of forty degrees. (Braeunig, "The Moon Hoax Debate")

In order to understand what it takes to get to the moon and back, let's take a closer look at a concept called mission velocity. Mission velocity is the magnitude of energy that a space vehicle needs in order to achieve its mission. This is defined as the sum of all the flight velocities during the entire space mission that are necessary in order to achieve success. When dealing with this summation it is important to understand that any retro-active thrust has its absolute value taken and then summed. So even if the force being applied is negative, the amount of thrust that had to be produced is still positive. When dealing with the sum it is important to remember that because of the Earth's rotation an initial velocity is given to the ship. This velocity varies from 464 m/s at the Earth's equator to 408 m/s at a launch site whose longitude is 28.5 degrees. In order to be able to complete a mission, the thruster system has to be able to provide an equal amount of energy as the mission velocity requires. (Sutton, pp. 130)

Ideal Satellite Velocity	7790 m/s
Δu to overcome gravity losses	1220 m/s
Δu to turn the flight path from the vertical	360 m/s
Δu to counteract aerodynamic drag	118 m/s
Orbit injection	145 m/s
Deorbit maneuver to re-enter atmosphere and aerodynamic braking	60 m/s
Correction maneuvers and velocity adjustments	62 m/s
Initial velocity provided by the earth's rotation at 28.5 degrees latitude	-408 m/s
Total required mission velocity	9347 m/s

Table 1 – Incremental Flight Velocities for a Space Shuttle (Sutton, pp. 130)

Δu is the amount of velocity in order to overcome the loss from other forces. These have to be overcome in order to complete a mission. As discussed in the launch system paper, gravity and aerodynamic drag are two elements of a launch that are always planned for. Let's examine what these velocities actually mean. The ideal satellite velocity is the ideal velocity to establish an orbit around the Earth. The Δu losses are self-explanatory. Orbit injection is the process of pushing a space craft into the desired orbit. Deorbit maneuver and correction maneuvers are self-explanatory. Rotational maneuvers are not included in the flight velocities budget although the designer does have to take these into account. Also the velocities necessary to keep a satellite in orbit are not usually apart of the mission velocity. (Sutton, pp. 130-131)

Mission	Ideal Velocity (km/s)	Actual Velocity (1000 m/s)
Satellite orbit around Earth (no return)	7.9-10	9.1-12.5
Escape from Earth (no return)	11.2	12.9
Escape from the moon	2.3	2.6
Earth to moon (soft landing on the moon, no return)	13.1	15.2
Earth to Mars (soft landing)	17.5	20
Earth to Venus (soft landing)	22	25
Earth to the moon (landing on the moon, assumes air braking within the atmosphere, and return to Earth)	15.9	17.7
Earth to Mars (landing on Mars, assumes air braking within the atmosphere, and return to Earth	22.9	27

Table 2 – Mission Velocities for Various Space Missions (Sutton, pp. 131)

Mission	Relative Payload (%) (555.6 km earth orbit is 100% reference)
Earth Satellite	100
Earth escape	35-45
Earth 24-hr orbit	10-25
Moon landing (hard)	35-45
Moon landing (soft)	10-20
Moon circumnavigation (single fly-by)	30-42
Moon satellite	20-30
Moon landing and return	1-4
Moon satellite and return	8-15
Mars flyby	20-30
Mars satellite	10-18
Mars landing	0.5-3

Table 3 – Relative Payloads related to High Energy Chemical Multi-Stage Rocket Launch Vehicles (Sutton, pp. 132)

Table 2 deals specifically with ideal mission velocities and compares them to approximate actual values. The moon's actual values are only at 2600 m/s. This assumes a takeoff specifically from the moon itself and does not include leaving the Earth's orbit. (Sutton, pp. 131) It is important to remember that the moon has one sixth the gravity of the Earth and does not have an atmosphere. The moon is also significantly smaller than the Earth. (Russell, "The Earth's Moon") Table 3 gives the relative amount of the fuel that would be used on a few special missions. Most of the fuel is used on the insertion into space although a hard moon landing would have the same amount of fuel as the launch. (Sutton, pp. 131-132)

With this knowledge, now we can deal with the actual problem of landing on the moon. In order to escape into a satellite orbit around the Earth we need to reach a velocity of 7,300 m/s and to shift this orbit requires another 2,900 m/s. Now, in order to slow the vehicle down and to set the space craft on a trajectory for the moon, the vessel has to be prepared for another 1,000 m/s. An additional 1,600 m/s is required to land on the moon. In order to escape the gravity of the moon and enter an Earth re-entry orbit requires another 2,400 m/s. (Sutton, pp. 131)

Based on this information, it might be worthwhile to ship up as much equipment as possible to a space station and then have the space station host space cabs. These cabs would make the journey between the space station and the moon. These cabs could be refueled at the space station and would have to be able to make multiple landings on the moon. Supplies could be filtered from the space station to the moon and robots could assemble the basic facilities there. Designing the space crafts for this could be a challenge, however perhaps the International Space Station could add a module that would be able to sustain these space cabs.

Moon Base

Barry Kosherick

Many people feel that developing a base on the moon would help further space exploration. The most common proposed use for a moon base is as layover for missions to Mars. Having a base on the moon would allow for the astronauts to stop at the moon to refuel and rest before venturing towards Mars. Many hurdles must be crossed before this idea becomes reality.

One of the first hurdles was finding a possible place for the base to be located. The ideal base would be in constant sunlight which would allow solar arrays to provide power. Power is not the only thing that constant sunlight would provide, but stable temperatures as well. As some areas of the moon can have temperatures that fluctuate between 100^{o} Celsius during the day and -173^{o} Celsius at night. Power and temperature are not enough to dictate a possible site for a moon base. The base would have to be close to an ice cap which could be melted into drinking water or broken down into hydrogen and oxygen used as propellants in space crafts. There would also have to be a large flat area suitable for arrivals and departures of shuttles. With all of these considerations taken into account, the best places for a base would be either the North or South poles. These places are the best because they get near constant sunlight as a result of the moon’s rotation around the axis of the poles. Both of the poles also have ice caps surrounding them. Currently the site chosen is the Shackleton crater near the south pole, as it has a 300 acre flat surface. NASA's exploration systems chief, Doug Cooke feels that there may even be ice from comets in this area (Perlman, Permanent Moon Base Planned).

After a site for the base has been chosen, one of the next big hurdles is protection against the elements. Moon dust is one of the most damaging things to a space suit. The dust consists of small razor sharp pieces of moon rock. Not only can these rip right through a space suit, they can cause machinery to lock up and prevent the use of any machinery utilizing ball bearings. This is a hurdle that has not been fully overcome; scientists and engineers are still trying to find a viable solution to the problem posed by moon dust. The most recent idea is to microwave the area around the site so that the ground gets compacted. This would hopefully reduce the amount of moon dust affecting the astronauts and the base.

Another issue with a moon base is the construction of it. This is a problem because the lack of gravity makes current construction equipment unusable, as most construction equipment uses the weight of the tool to create the necessary force. Kriss Kennedy, the master architect at NASA's Johnson Space Center, may have the key to building a base in such conditions; an inflatable one. This would alleviate the need for construction equipment, as the base would be already build, it would just need to be inflated. Similar structures are already in use in both the Arctic and Antarctic regions for scientific use. The Bush administration stated a goal of having astronauts go back to the moon starting in 2020. If this goal is met, it would not be long after that the idea of a moon base would be realized (Gugliotta, U.S. Planning Base on Moon to Prepare for Trip to Mars).

Once a moon base is established, it will have to fulfill some sort of functionality. There are a few proposed ideas for the use of a moon base; research, commerce, defense and as a stepping stone to further exploration. The base could be used to conduct experiments as it would be an excellent place for telescopes to be placed. This is the result of the moon having a very slow rotation. The moon also has a much smaller amount of mechanical disturbances when compared to the Earth, which would allow radio and interferometric telescopes to function at much higher levels of resolution than on earth (Schactman, Moon Base: NASA's Recurring Dream).

Another major possible reason for having a moon base is that it is much easier to launch a space craft from the moon than from earth, because the moon has no atmosphere and much less gravity. This would allow for further space exploration to become much easier, as the Earth's atmosphere and gravity cause the lift requirements to be greatly increased (Wikipedia, Colonization of the moon).

Using the moon for national defense has been a topic of many science fiction movies and books. The idea has some merit though, because from the moon it is possible to monitor a larger area of Earth for things like missile launches and army movements. However the ideas of using the moon to fire rockets or missiles is seen as unpractical as the time for it to be detected is much higher than a missile fired from the Earth(BBC News, US plans for Moon Base).

After a moon base has been successfully established, it would not be long before it was used for commercial purposes. One of the biggest commercial ideas for the moon is the development of new materials, such as foaming metals. This process involves injecting gas into the metal while it is still molten. This allows for the molecules of the metal to align themselves in the strongest possible combinations. This process is not possible in places with a higher gravitational force because it would cause the gas bubbles to rise to the top of the material and burst. The low gravity would also make the manufacture of nanotechnology items much easier (Wikipedia, Colonization of the Moon).

Another major commercial use for the moon is a source of resources. Many scientists believe that the minerals found in the moon could help replace depleting natural resources from Earth. Scientists also believe that resources not easily available on Earth would be more easily harvested from the moon; such resources include Helium-3, a possible fuel for fusion reactors (Schactman, Moon Base: NASA's Recurring Dream).

As the possibility of moon base becomes more of a reality; the likelihood of each use becomes more apparent. After a base is fully established, the chances of similar bases being developed increases, and eventually the moon may be able to be fully colonized and not just an outpost in the vastness of space.

Re-entry

Matthew Brown

The re-entry of an orbiting spacecraft poses many problems, and can easily be seen as the most dangerous part of a mission. The craft must lose most of this speed before landing. If the shuttle is moving too fast or too slow, it will crash. There are three methods which can be used to slow modern spacecraft and allow for successfully re-entry and landing.

Method 1 Powered Deceleration

Powered deceleration is the reverse of launch. The shuttle would use jets to slow its descent. While effective, this would require the craft to carry twice as much fuel during launch. This must take place, however, just outside the atmosphere to break orbit and position the craft to prepare for re-entry.

Method 2 Mass Shedding

Mass shedding would involve a landing vehicle that would be jettisoned before landing. Most of the energy of the system would be in the larger mass of the craft, while the landing vehicle would lose most of the velocity. This does not allow for reuse of the spacecraft, however, as most of it would crash and be rendered useless.

Method 3 Energy Dissipation

The most feasible method of slowing the spacecraft is energy dissipation. By entering the atmosphere at a certain angle, the profile of the shuttle increases the drag force and much of the energy of the craft is converted to heat. This is currently the method used for modern space vehicles. (The Physics of Space Shuttle Re-Entry, 2006)

There are some equations than can help predict the parameters for re-entry.

Drag Equation

$$D = \frac{1}{2}\frac{\rho V_r^2 S_{ref} C_D}{m g_0}$$

Where ρ is the air density, V_r is the velocity of the shuttle, S_{ref} is the reference surface area of the shuttle, C_D is the drag coefficient, and g_0 is the force of gravity. (Lift and Drag Equations, 2005)

Six Degrees of Freedom Equations for Re-Entry

$$\dot{r}_C = V_r \sin\gamma$$

$$\dot{\Theta} = \frac{V_r \cos \gamma \sin \Psi}{r_c \cos \Phi}$$

$$\dot{\Phi} = \frac{V_r \cos\gamma \cos\Psi}{r_c}$$

$$\dot{V}_r = -D - \left(\frac{\sin\gamma}{r_c^2}\right) + \omega^2 r_c \cos\Phi \left(\sin\gamma\cos\Phi - \cos\gamma\sin\Phi\cos\Psi\right)$$

$$\dot{\gamma} = \frac{1}{V_r}\left[L\cos\sigma + \left(V_r^2 - \frac{1}{r_c}\right)\left(\frac{\cos\gamma}{r_c}\right) + 2\omega V_r \cos\Phi\sin\Psi + \omega^2 r_c \cos\Phi\left(\cos\gamma\cos\Phi - \sin\gamma\cos\Psi\sin\Phi\right)\right]$$

$$\dot{\Psi} = \frac{1}{V_r}\left[\frac{L\sin\sigma}{\cos\gamma} + \frac{V_r^2}{r_c}\cos\gamma\sin\Psi\tan\Phi - 2\omega V_r\left(\tan\gamma\cos\Psi\cos\Phi - \sin\Phi\right) + \frac{\omega^2}{\cos\gamma}\sin\Psi\sin\Phi\cos\Phi\right]$$

Where r_c is the distance from the center of the earth to the vehicle center of gravity (ft), Θ is the geodetic longitude, Φ is the geodetic latitude, V_r is the earth's relative velocity (ft/sec), γ is the flight path angle (degrees), Ψ is the velocity azimuth angle (degrees), ω is the earth's rotation rate (degrees/sec), and σ is the vehicle bank angle (degrees). These equations are used to plot the course for the re-entry, by finding the values of γ and σ. (Six Degrees of Freedom Reentry Equations, 2005)

Six Degree-Of-Freedom Equations

Matthew Goon

The six degree-of-freedom equations deal with the translational and rotational motion of an object, in this case it is a spacecraft shuttle. Steady flight angle (γ gamma) is determined by a simple equation $\gamma = \theta - \alpha$. Here we see that the steady flight angle is altitude (θ theta) minus the incidence (α alpha). (Cook, 2000)

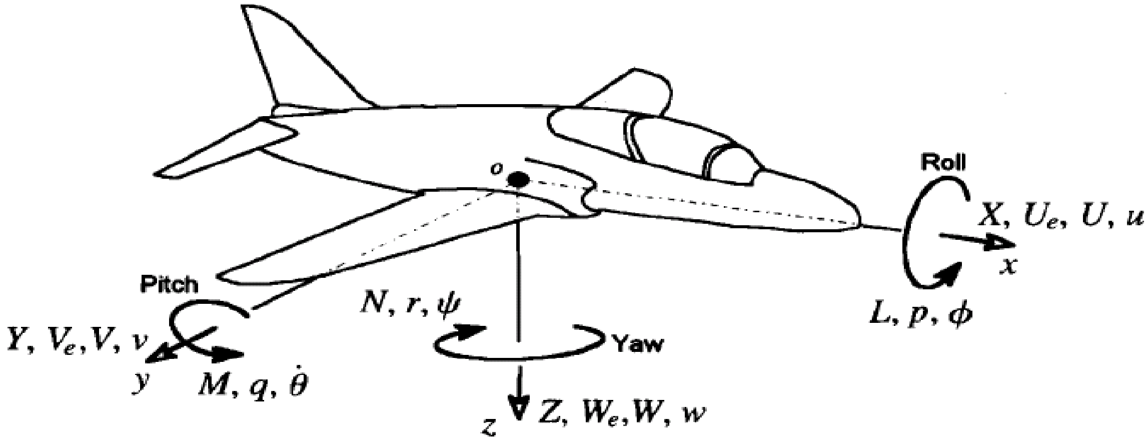


Figure 2.4 Motion variables notation

Another set of angles that determine how an object will move though space are called Euler angles. Euler angles are used to figure out the 3 rotational orientations (yaw, pitch, and roll) determining 3 of the 6 degrees of freedom. The other 3 degrees of freedom are used to determine position on a Cartesian coordinate system. (Euler Angles)

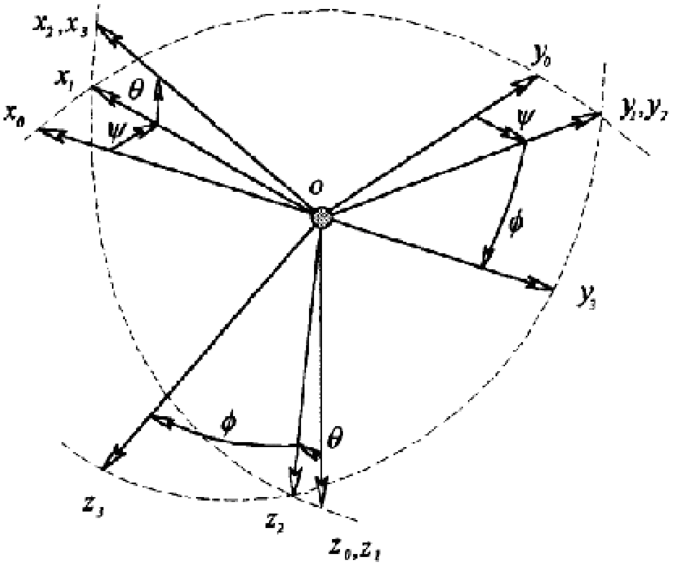
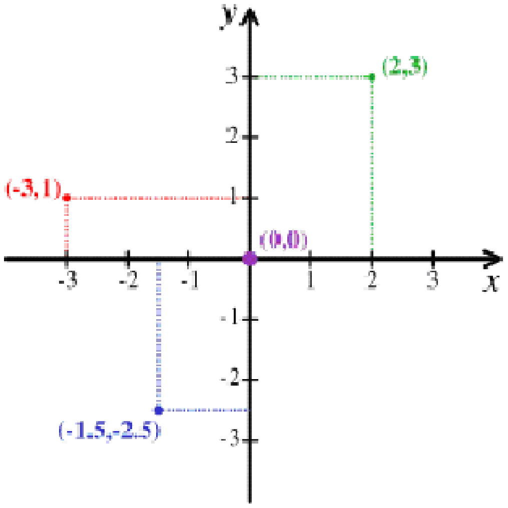


Figure 2.6 The Euler angles



Cartesian Coordinate System

Graphic Analysis of the Six Degrees of Freedom Equations

Matthew Brown

The Six Degrees of Freedom equations dictate movement in three-dimensional space. They can be written in many forms, ranging from state-space, to vector, to the specialized version used in this model. All movement in three dimensions can be described as movement in any of the lateral directions (left ↔ right, up ↔ down, forward ↔ reverse) as well as rotation along three axes (pitch, yaw, and roll). In this case, Earth oriented axes will be used. This model neglects many variables in an effort to simplify the problem, but still allows for an understanding of the complexity of flight and the movements of a space shuttle.

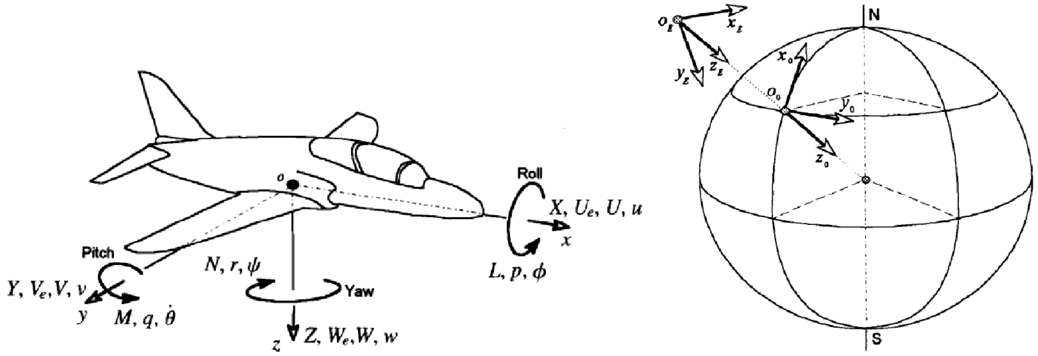


Fig. In 1 – Definition of Directional Motion in Three-space and Earth Oriented Axes (Cook, 2000)

Equations

The equations used for this model are as follows:

$$L = \frac{1}{2}\frac{\rho V_r^2 S_{ref} C_L}{m g_0}$$

$$D = \frac{1}{2}\frac{\rho V_r^2 S_{ref} C_D}{m g_0}$$

$$\dot{r}_C = V_r \sin\gamma$$

$$\dot{\Theta} = \frac{V_r \cos\gamma \sin\Psi}{r_c \cos\Phi}$$

$$\dot{\Phi} = \frac{V_r \cos\gamma \cos\Psi}{r_c}$$

$$\dot{V}_r = -D - \left(\frac{\sin\gamma}{r_c^2}\right) + \omega^2 r_c \cos\Phi\,(\sin\gamma\cos\Phi - \cos\gamma\sin\Phi\cos\Psi)$$

$$\dot{\gamma} = \frac{1}{V_r}\left[L\cos\sigma + \left(V_r^2 - \frac{1}{r_c}\right)\left(\frac{\cos\gamma}{r_c}\right) + 2\omega V_r \cos\Phi\sin\Psi + \omega^2 r_c \cos\Phi\,(\cos\gamma\cos\Phi - \sin\gamma\cos\Psi\sin\Phi)\right]$$

$$\dot{\Psi} = \frac{1}{V_r}\left[\frac{L\sin\sigma}{\cos\gamma} + \frac{V_r^2}{r_c}\cos\gamma\sin\Psi\tan\Phi - 2\omega V_r(\tan\gamma\cos\Psi\cos\Phi - \sin\Phi) + \frac{\omega^2}{\cos\gamma}\sin\Psi\sin\Phi\cos\Phi\right]$$

In this system:

L is lift,

D is drag,

r_C is the distance between the center of the Earth and the center of gravity of the vehicle,

Θ is the geodetic longitude* of the vehicle,

Φ is the geodetic latitude* of the vehicle,

V_r is the relative velocity of the Earth,

γ is the flight path angle,

Ψ is the velocity azimuth angle,**

ω is the Earth's rotational velocity,

σ is the vehicle bank angle.

(Six Degrees of Freedom Reentry Equations, 2005)

(Lift and Drag Equations, 2005)

*Geodetic latitude and longitude are what one generally refers to simply as latitude or longitude. There are many types of longitudes and latitudes, but geodetic is the most common, used mostly in GPS applications and navigation.

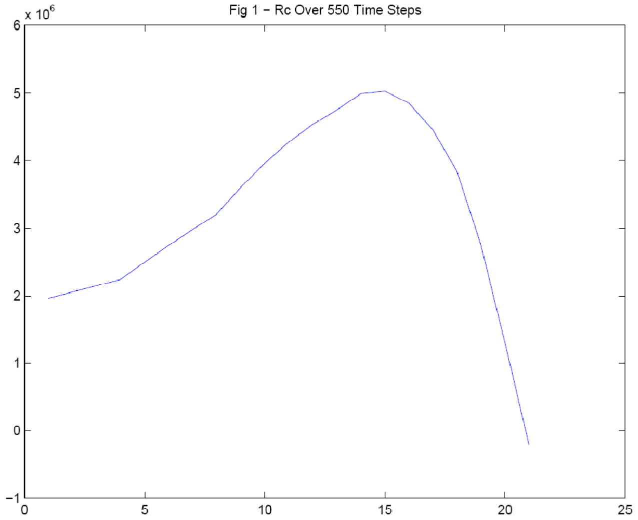
**The velocity azimuth angle is the vertical component of the three dimensional velocity.

Graphical Analysis

Using MathWorks MATLAB software to numerically integrate the equations, the following graphs were obtained:

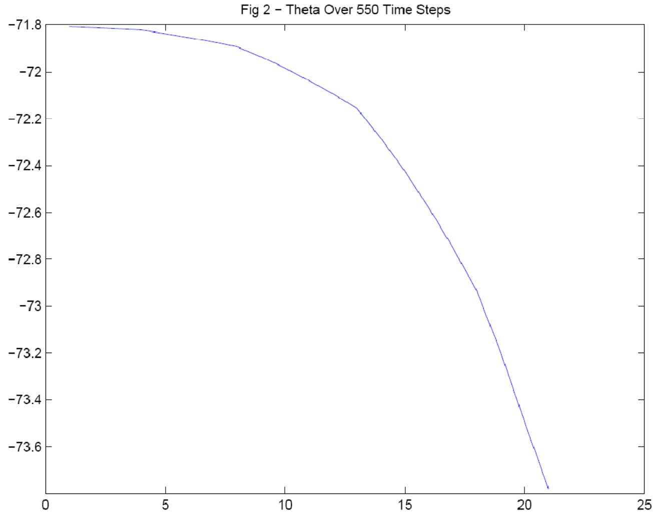
r_C

Figure 1 is the graph of the integrated variable r_C, the distance between the Earth and the center of gravity of the shuttle, over 550 time steps. The distance has been normalized so that 0 on the graph is approximately sea level, where the shuttle would theoretically land. This graph shows an unexpected ascent early in the model and then an abrupt dive. This is the closest the model could come to a decent landing, for reasons that will be discussed in the error section. Because of the errors, the model has a tendency to either ascend quickly, back out into space, or to plummet to Earth. If a human pilot where controlling the craft instead of formulae, they would likely be able to correct these issues.



Θ

Figure 2 plots how the value of Θ, the geodetic longitude, changes over 550 time steps. The initial values for longitude and latitude were chosen so that the shuttle would enter the Earth's atmosphere directly over WPI. The shuttle is moving almost directly west as it descends. There would, however, appear to be a slight turning.



Φ

Figure 3 illustrates the change in Φ over time, in this case, 550 time steps. Φ is the counterpart for Θ, being latitude. The change in latitude is very slight, changing only by a few hundredths. Figure 3a shows the approximate landing place for the shuttle based on this model. Obviously, the outcome is not realistic in any manner, as an actual shuttle landing generally takes much longer than this model predicts, as well as requiring a much larger distance. Again, these errors will be addressed in the error portion of this report.

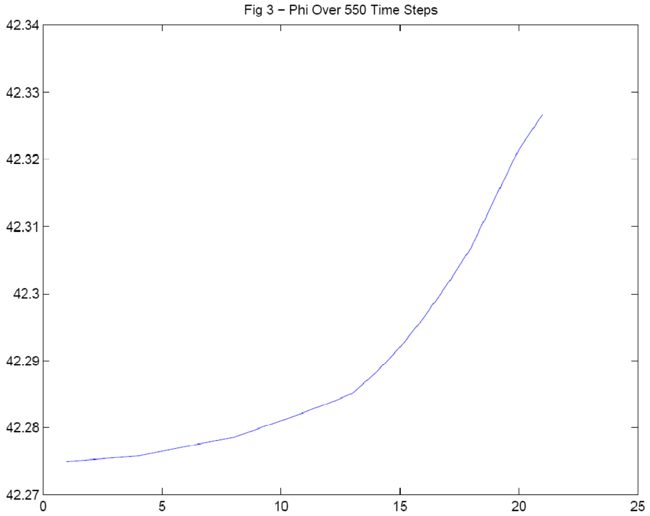
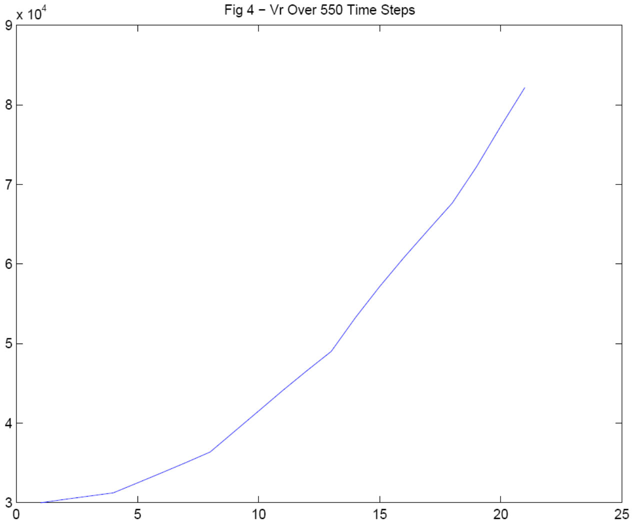


Figure 3a – Map Showing Worcester and Approximate Landing Place (Mapquest)

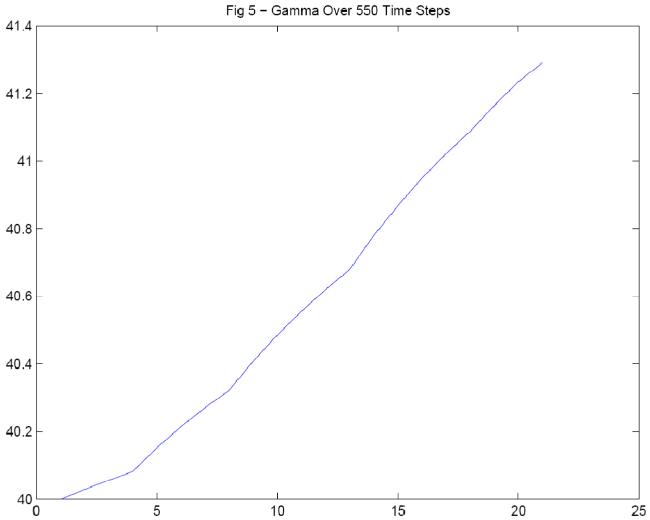
V_r

Figure 4 shows the relative velocity of the Earth in reference to the shuttle. As the shuttle turns slightly, the relative velocity of the Earth gets larger, as the difference in the directions of the velocity of the Earth and that of the shuttle increases. The shuttle is initially traveling 25,405 feet per second, the speed of the orbit just before entering the atmosphere.



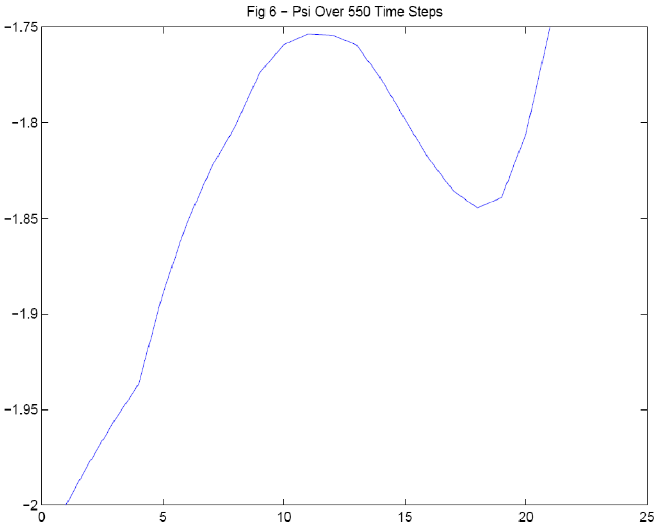
γ

Figure 5 shows the change in γ, being the flight path angle. There is very little change in the flight path angle in this model. This would generally be considered desirable. One would not want quick changes in flight path that might destabilize the craft. As to whether or not this plot is realistic is difficult to determine, but it would seem to be within the realm of possibility.



Ψ

Figure 6 shows the change in the velocity azimuth angle. There is a relatively small change, which seems to be a reasonable outcome.



Issues and Sources of Error

The model conducted for this report had several issues. The largest of these was that the assumptions made to simplify the equations made it much less able to predict realistic events. First, life and drag are, in this case, quadratic equations based on several factors. The gas density of the atmosphere was assumed to be constant to simplify the problem. This means that the atmosphere in the model acts more like a liquid than it does a gas. This would change the lift and drag, causing error. Some assumptions were also made in the initial conditions which were chosen in a way to be convenient. Things like the point at which the shuttle entered the atmosphere were chosen to be easy to work with and familiar to the reader. They would not make a likely place for an actual shuttle to re-enter. While these simplifications reduce the accuracy of the model, a general idea of the complexity and planning of a shuttle re-entry are demonstrated, as well as a possible, if unlikely flight path.

Applications of the Six Degrees of Freedom in Gaming

Matthew Goon

Technology, over the past couple decades, has evolved exponentially and also to the point where a child has the access to a gaming console inconceivably more powerful than the technology of his/her parents. These days, video game makers have pushed beyond the limits of the laws that men are bound to for the everyday consumer. Where 3-dimensional gaming is almost the normal, some games take the 6 degrees of motion beyond the imagination of the masses, allowing a figure to move in inhumanly surreal maneuvers that expand with our imaginations.

Over the years, the imagination of man can be projected onto an application with some mind boggling results for the gaming industry. Below, are pictures of an Atari game Pong, which takes a 2-dimensional game similar to the basic idea of soccer and brings it homes of consumers worldwide during late 1970's.

Screenshot (left) of Pong, Control (center), and Console (right) for the Atari 2600 circa 1977

(Top Video Games), (Atari 2600), (Atari 2600)

The third generation of video game consoles was a major improvement allowing the user to move in two dimensions. The Nintendo and Sega blew away the consumers with new movements of characters like Donkey Kong, Mario & Luigi (for Nintendo) and Alex Kidd (for Sega) shown below. This is a breakthrough in gaming because it evolved from moving just up/down and forward/backwards moving characters into two degrees of freedom.

Donkey Kong (Nintendo 1981), Mario Brothers (Nintendo 1983), Alex Kidd in Miracle World (Sega 1986)

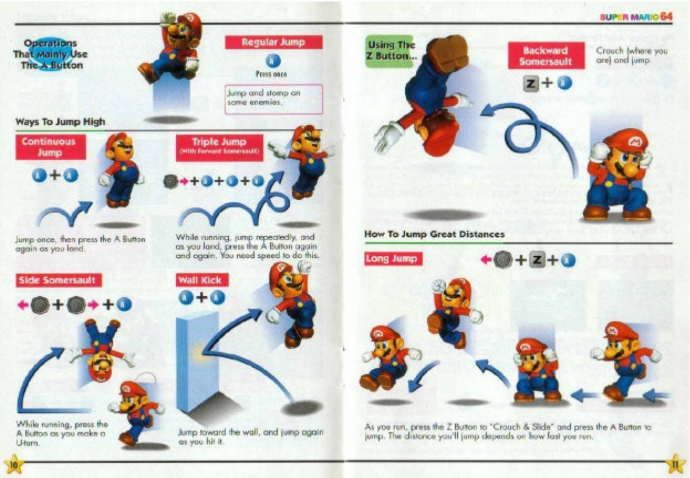
(Super Mario Bros.), (Donkey Kong), (Alex Kidd in Miracle World)

The first use of 3-dimensional figures and all of the 6 degrees of freedom comes from the first person shooter game called Descent. This was the first game to now only move in 3 dimensions but also allowed you to rotate along the 3 axes. Shown below are a couple screenshots of the vehicle that you are in charge of attacking with. Motion is entirely controlled by the keyboard so it took gamers some time to adjust from a controller to your everyday keyboard. A nice feature is the 3D map, which allows the gamer to retrace his/her steps if the gamer is smart enough to understand how the 3D map works.

Screenshots from computer game Descent, one of the first games that allows the player to move the 6 degrees of freedom

(Descent)

The fifth generation of video game consoles expanded to 32-bit (Sega Saturn & Sony PlayStation both in 1994) and 64-bit (Nintendo-64 in 1996) of CPU size. These consoles brought a new set of 3-dimensional games like Virtua Fighter 2 (Sega Saturn 1995), Gran Turismo (Sony PlayStation 1998), and Super Mario 64 (Nintendo-64 1996) shown below. (4)



Operations That Mainly Use The A Button

Regular Jump

Press once

Jump and stomp on some enemies.

Ways To Jump High

Continuous Jump

Jump once, then press the A Button again as you land.

Triple Jump (With Forward Somersault)

While running, jump repeatedly, and as you land, press the A Button again and again. You need speed to do this.

Side Somersault

While running, press the A Button as you make a U-turn.

Wall Kick

Jump toward the wall, and jump again as you hit it.

Using The Z Button...

Backward Somersault

Crouch (where you are) and jump.

How To Jump Great Distances

Long Jump

As you run, press the Z Button to "Crouch & Slide" and press the A Button to jump. The distance you'll jump depends on how fast you run.

Sega's Virtua Fighter (top left) bring the arcade game to the home

Sony's Gran Turismo (bottom left) allows you to leave your friends in the dust

Nintendo's Super Mario 64 (right) shows a couple new degrees of freedom that Mario can enjoy using to get from place to place, in compensation for gravity.

(Virtua Fighter), (Gran Turismo), (Super Mario 64)

Currently game developers are in the seventh generation of video gaming consoles. The 3 main producers of video game consoles are: Microsoft with the Xbox 360 (2005), Sony with the PlayStation 3 (2006), and a new type of gaming console from Nintendo with the Wii (2006). (5)

7th generation video game consoles: Microsoft's XBox 360 (left), Sony's PlayStation3 (center), and Nintendo's Wii (right)

(History of Video Game Consoles (Seventh Generation))

Although Microsoft and Sony worked on improving the graphics, Nintendo went in a different direction with the Wiimotes (Wii remote and nunchuk). Nintendo changed the face of gaming by adding a motion sensing capability, that involves point the Wii remote to the sensor and moving your arm instead of just pushing buttons.

The technology of gaming had changed exponentially over the past couple decades. With the changes of machinery comes the evolution of the game. Who knows what the future holds for future gaming consumers, but with the evolution of parts inside these consoles for everyday use comes the evolution of parts that can be used to make robots and lunar vehicles.

The Van Allen Belts and Radiation in Space

Thomas MacDonald

When looking to the stars, a very specific consideration to think about is space radiation. Surrounding the Earth we have the Van Allen Belts, which traps radiation. The belt is comprised of radiation that includes protons with energies of 800 MeV and electrons with energies of 1 MeV. (Licari, pp. 236) The inner belt is the region where the proton flux is the greatest. They were discovered by the Explorer 1 spacecraft. (Hyder, pp. 61, 159)

Electron Flux	Proton Flux

Inner belt	
99% between 10 and 600 keV	1% between 10 and 800 MeV
2 * 10^9 electrons/(cm^2)(sec), E > 20 keV	2 * 10^4 protons/(cm^2)(sec), E > 40 MeV
Outer belt	
10^8-10^{11} electrons/(cm^2)(sec), E> 20 keV	10^2 protons/(cm^2)(sec), E > 60 MeV
10^8 electrons/(cm^2)(sec), E> 200 keV	
10^6 electrons/(cm^2)(sec), E>2.5 MeV	

Table 1 – Estimated Values for Various Fluxes in the Van Allen Belts (Licari, pp. 236)

The Van Allen Belts are named after James Van Allen who designed the first instruments that were used in order to discover this space phenomenon. The shape of the radiation belts are defined by Earth's magnetosphere. Each of these belts can be looked at as a series of concentric shells. With the increasing altitude of each shell, the magnetic flux decreases. The shells are called L shells and are given a dimensionless less number that is given in units of the Earth radii. The shells extend the farthest at the magnetic equator, which is 11 degrees above the Earth's equator. The shells then fall in towards the magnetic North Pole and magnetic South Pole. (Chang, pp. 4188)

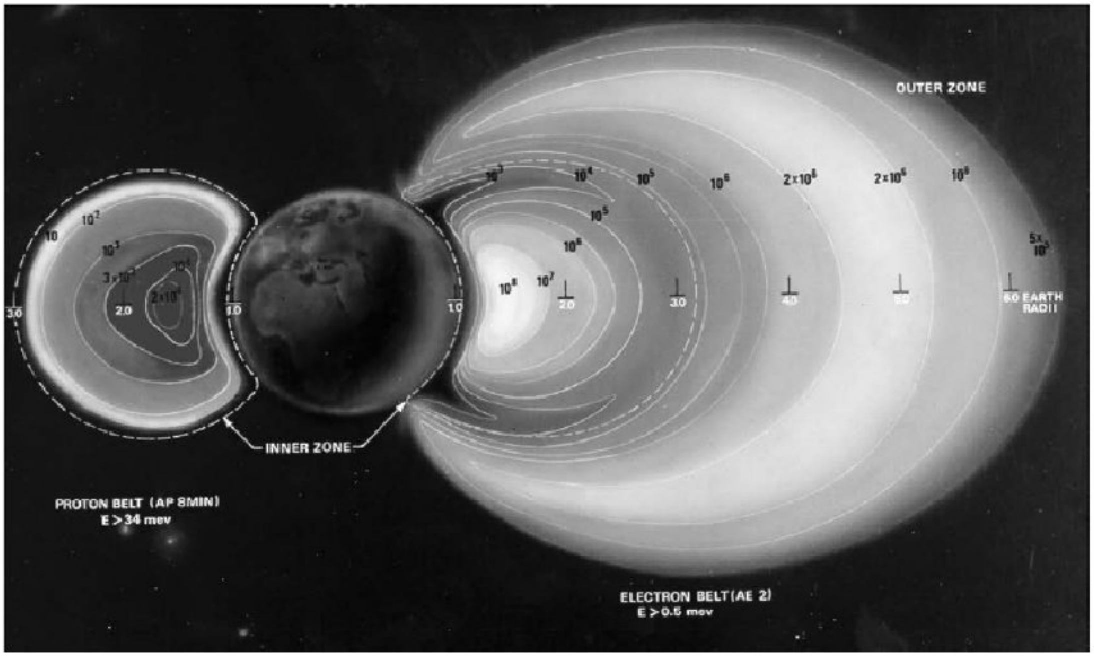


Figure 2 – Visual Representation of the Van Allen Belts (Chang, pp. 4188)

First, when considering what is depicted in Figure 2, it is important to realize that the shells are actually toroidal. The artist separated them in order to make them easy to understand. The belts start at an altitude of approximately 1,000 km. The proton belt peaks at 5,000 km and extends out to about 18,000 km. There are two electron belts. The inner electron belt peaks at 4,800 km and extends out to

9,600 km. On the other hand, the outer electron belt spans from 11,500 km to 70,000 km. Low orbit space craft will encounter both electron and proton belts while geosynchronous space craft will usually only experience the outer belt. The peak of this radiation is experienced at 17,500 which is half the geosynchronous orbit of 35,775. (Chang, pp. 4188-4189)

There is another radiation area that is important to consider when dealing with spacecraft is the South Atlantic Anomaly (SAA). This anomaly is caused by a dip in the magnetosphere towards the Earth. The region causes an increased proton flux. The region itself actually will dip as low as 500 km and the proton flux of particles that have energies greater than 30 MeV is 10^4 times greater at 1000 km in this region than at any other region at this altitude. At other regions the magnetosphere is more uniform and the energies will usually depend on the L levels. (Chang, pp. 4189)

Other sources of radiation in space are galactic cosmic rays (GCRs) and solar flares. Galactic cosmic rays originate from outside of the solar system and propagate throughout all of space. A GCR's composition is usually 85% protons, 14% electrons, and 1% heavy nuclei. These rays are very important to understand in order to be able to build a space ship that will be able to withstand the radiation. Solar flares are a lot like GCRs, they are high fluxes of protons, electrons, and heavy nuclei just like GCRs. (Chang, pp. 4189)

Solar flares, on the other hand, can last anywhere from hours to even days. However, these solar flare fluxes are orders of magnitude greater than galactic cosmic rays and the steady state radiation of the Van Allen belts. Solar flares are usually one of the main causes of the peak failure rates of a satellite. During a solar flare, proton flux can increase to 10^{10} protons/cm^2 and the energies can exceed well over 100 MeV. (Chang, pp. 4189) It is important to understand that electrons up to 1 MeV are unlikely to be dangerous as are protons up to 10 MeV. ("MAD Scientist: the Van Allen Belts and Travel to the Moon")

Based on this understanding of the Van Allen belts and radiation in general, it is easy to see why we put things in a low-Earth orbit. As explained in Figure 1, the electron energies of the inner electron belt only vary from 10 to 600 keV. This is below the 1 MeV that is unlikely to be dangerous. The proton energies are between 10 and 800 MeV, however they only make up 1% of the inner belt. So without proper protection the astronauts and the space crafts equipment would experience radiation that could be potentially harmful. However, if things were put in a geosynchronous orbit, they would be exposed to electrons of much higher energies.

Impact of Space Exploration on Humanity

Barry Kosherick, Matthew Goon

Humanity has been greatly impacted by exploration of space. The act of space exploration requires many technological advances. One of the most noticeable areas of impact is around the house; many of these conveniences were developed for missions to space. Innovations include wireless and satellite communication. These were developed so that the control center on Earth could keep in contact with the astronauts in space during a mission. Now they are also used for television, telecommunication, and global data transfers. Another huge use of satellites is Global Positioning Satellites (GPS). Currently there are many GPS systems used in cars to help people find their way around in areas unfamiliar to them and around traffic. Originally satellites were just used by scientists to relay data across the globe, now satellites are used by everyone in both home and business. Many companies have offices located around the world, satellites allow these offices to all communicate with each other in a matter of seconds, not weeks or days, this allows businesses to work more efficiently, and thus goods and services can be supplied much faster (DeLombard, 2006). The average time that a 8 inch by 10 inch image can be sent globally is now two minutes. Before the use of satellite communications it would take up to twenty two hours (Kim).

Another use for satellites is discovery of natural resources. This is done by using the imaging capabilities of GPS to analyze the color of the ocean along with the concentration of a chemical called SST. These allow scientists to determine whether or not there are nutrients vital for fish survival in a certain area. Once nutrients have been found, the scientists can determine what fish would most likely be in that areas by taking into account the water surface temperature, the salinity, turbidity and other factors. This is how a large new tuna crop was found off the coast of eastern Asia (Shattri Mansor, 2001). Recently this technology became available to a much broader portion of humanity, when XM satellite weather released a new service package. The cost of the service package is one hundred dollars a month, which allows any recreational angler to be able to locate certain fish, and not just have this technology available to scientists or huge commercial fisheries (Danielle Keeton, 2007). This technology along with acoustic detection is also being used to locate and study endangered species such as North Pacific Right Whales. The satellite tracking allows for a general area to be located rather easily, while acoustic detection is used to actually pinpoint each whale (Paul Wade, 2006). This technology allows for fish to be found easier, thus increasing the possible amount of food available to humanity, which helps combat the problem of feeding a rapidly increasing populous.

Fish is not the only resource that satellites can find, oil is another. When there marine oil deposit, there are oil drops and gas bubbles that reach the surface of the water, forming linear streaks that flow with the current and wind. These are called oil slicks, and can be seen using satellite systems. Using this method, more oil sources can be found, usually they are much larger than oil deposits found inland. A recent example of such a find is the deposit found in the Gulf of Mexico. Finding more sources of oil reduces the cost, which reduces the price of gasoline paid at the pump. Although new discoveries are decreasing the use of oil, it is still the largest fuel source, and will remain there until new technologies allow for a new energy source to be the standard. (Gulf of Mexico Saturated with Oil?)

Another big innovation is with electronics. Weight is very important concern in space missions, because the less weight that is needed for the mission, the easier and less cost effective it is to launch it. This need required electronic circuits to be shrunk down, often having to be redesigned and new technologies invented. Examples of this are flat screen televisions, quartz timing used in watches and many other devices where exact oscillations are needed. Televisions used to be big and bulky, often weighing up to fifty pounds and having a depth of up to two feet, now televisions are only a few inches thick, and the average weight is less than thirty pounds. The idea of compacting trash came from a space mission's requirement for waste to use as little area on the vessel as possible, and now there are trash compacters now common in the household. (DeLombard, 2006)

Medicine is another area with innovations that are a direct result of space exploration. Pacemakers stem from the same technology as the signals being sent from orbital satellites. Pacemakers were created to help the doctor control the heart rate of the patient, and with current technology, able to be adjusted without surgery. In America there are about 2.2 million people who now benefit from this technology (Arrhythmias Originating in the Atria). Another invention, which has been created as a result from space exploration, is the programmable implantable medication system (P.I.M.S.) for the insulin delivery in diabetics. The P.I.M.S. is a surgically implanted insulin pump that is attached to the diabetic's abdomen that was created by the Applied Physics Laboratory at Johns Hopkins University working with

Goddard and MiniMed Technologies. Lasers that were once used for satellite-based atmospheric studies are now used to destroy blockages in coronary arteries and treat atherosclerosis. The concept of using a laser to vaporize blockages in the coronary without damaging walls of the artery was developed by Advanced Interventional Systems. This angioplasty system has been a major breakthrough in treating atherosclerosis and coronary diseases which can reduce the number one cause of death in the United States in heart disease. Another medical technological advance is in the world of digital signaling processing, to view certain areas of the body. Computer-aided tomography (CAT scans) is used to taking slice-like pictures and forming a picture from multiple views of bones. Magnetic Resonance Imaging (MRI), is more versatile and used throughout the body to view muscles, ligaments, and tendons. MRI's use magnetic fields and radio waves instead of X-rays to create images. (Woodfill, 2000)

Household medicine has also increased greatly, with items such as toothpaste and infrared thermometers. These were developed originally to help keep astronauts healthy and allow for early diagnosis of potential problems, now they are used by the majority of people in the world for the same reasons. Toothpaste was invented because in space it is much harder to prevent cavities when all of the food is freeze dried, a process that was invented to allow astronauts to be able to keep food from rotting. This process is done by freezing the product while pressure causes all the liquid in it to sublimate. This process is now used to keep food good for hikers and other people who are away from refrigeration for long periods of time. This process is most used however by pharmaceutical companies to increase the shelf life of their product by many years. (Harris)

These are just some of the important impacts that space exploration has had on humanity. The majority of things that people take for granted today is somehow the result of space exploration. The reason for this is that space travel and colonization provide much more challenging problems then what exist within the Earth's atmosphere, and therefore new technological advances must be made to conquer them. Once the technology is available, all it takes is someone realizing that there are other uses for it, for a much greater impact to be used.

Recommendations For Future Projects

Some of the areas that were not covered by this report of interest: mythology, satellites, and some propulsion methods. Mythology was briefly covered from areas of our interest, but certain civilizations and regions were not covered that might be if interest. Eastern and Western Europe, Rome, and tribes in Africa were not covered in this project. Some new types of satellites are under research and development to improve life. Biosatellites, solar power, Earth observation are some of the new technologies that satellites can be applied to. Some propulsions methods that were covered but not thoroughly studied were nuclear propulsion, laser brooms, and ion thrusters. Nuclear propulsion is under research currently as an efficient method of providing thrust and hazardous waste. Laser brooms, solar sails, ion thrusters and other methods of providing propulsion are also under research.

Mythology was a method of many cultures to explain supernatural events of humanity and surrounding environment. All cultures and groups of similar heritage and/or religion, pass down stories to either carry on tradition or convey certain beliefs and ideals. It is these stories that keep humanity in a state of wonder and feeds curiosity. Myths are not only to entertain but given a symbolic meaning that make cultures unique and strong. Our quest for knowledge and the satiation of our curiosity, paves new roads for the improvement of the survival of humanity. Common beliefs and ideals can heavily influence a society, and with the application of science and knowledge comes immense power.

Technology is the application of science and engineering for adapting to our surroundings and improving the chances of survival. Satellites are one of the most commonly used pieces of technology that has spawned from the space race. From defensive measurement, to observe the environment, to you every day cell phone, satellites heavily influence our lives. Currently under research and development, are new uses for satellites like biosatellites for growing organisms in space, solar power satellites as a power source, and Earth observation satellites to monitor the environment/weather.

The search for knowledge and truth does not occur without positive and negative repercussions. Research, for the great beyond called space, has also indirectly aided humanity with new technology. It is the balance of belief and reason with some curiosity, which allows humanity to surpass natural selection. As children, most dream of exploring foreign territory and reaching for the stars. This project explores the benefits that come from the quest for knowledge and enlightenment. Space provides many wonders that can span far beyond the imagination of humans and into a world of amazing discoveries that could be used for the improvement of mankind.

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