THE WALK OF LIFE

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EDITED BY AMIR A. ALIABADI

The Walk of Life

Biographical Essays in Science and Engineering

Volume 4

Edited by Amir A. Aliabadi

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The outside world is something independent from man, something absolute, and the quest for the laws which apply to this absolute appeared to me as the most sublime scientific pursuit in life.

—Max Planck

Dedication

Abbas Aliabadi

Preface

The essays in this volume result from the Fall 2019 offering of the course *Control of Atmospheric Particulates* (ENGG*4810) in the Environmental Engineering Program, University of Guelph, Canada. In this volume, students have written about Claude Elwood Shannon, Gottfried Wilhelm Leibniz, Max Karl Ernst Ludwig Planck, Rudolf Julius Emanuel Clausius, Jabir ibn Hayyan, and Wernher von Braun. Students have accessed valuable literature to write about these figures. I was pleased with their selections while compiling the essays, and I hope the readers will feel the same too.

Amir A. Aliabadi

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Amir A. Aliabadi

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1 Claude Elwood Shannon (1916-2001)

Father of the Information Age

By Aimen Siraj, Jordan Reeves, Quratulain Dar, and Shrishti Singh

Claude E. Shannon was a world-renowned mathematician and engineer responsible for the technology behind many communication devices used today. He graduated from Michigan State University and went on to achieve his Ph.D. at Massachusetts Institute of Technology (MIT) and Princeton University. Upon the completion of his schooling, he began working at Bell Laboratories where he developed many mathematical theories such as the theory of cryptography, theory of communications, and the information theory. At Bell, he also developed technologies capable of controlling firearms and machines capable of learning. He later returned to MIT as a professor where he shifted his focus toward the creation of toys. He continued to work as an inventor and engineer until his last paper was published in 1976.

1.1 Family

Claude E. Shannon, a mathematician, electronic engineer, and geneticist was born on April 30, 1916 in Petoskey, Michigan, and grew up in Gaylord, Michigan. He is best known for founding information theory, digital computer theory, and digital circuit theory (Golomb, 2001). His father, Claude Sr., was a self-made businessman and a judge of probate. As for his mother, Mabel Shannon, she was a language teacher and a principal. Although there was not much scientific influence from Shannon's parents, his grandfather, who was an inventor and a farmer, influenced him scientifically since he had much experience in the field. His inventions included the washing machine and various types of farming machinery (James, 2009). Shannon married Mary Elizabeth Moore and they had three children together: Robert James, Andrew Moore, and Margarita Catherine.

1.2 Education

Shannon's best subjects were always mathematics and science. His interests and curiosity were what led him to make huge impacts on the world. From a young age, he was fond of anything mechanical. He liked to construct model planes and radio-controlled boats. He also constructed a telegraph system to a friend's house, which was about half a mile away. He earned pocket money delivering telegrams and repairing radios. Shannon was educated in a public-school system and later went to the University of Michigan, from which he graduated in 1936 with a bachelor's degree in electrical engineering and mathematics (Gallager, 2003). His interest in both fields continued to influence the rest of his life. After he graduated, he received a research assistantship opportunity from the Massachusetts Institute of Technology (MIT) to work on a differential analyzer. During his research, he discovered that switching circuits can be described by the Boolean theory (Gallager, 2003). This work formed the scientific basis for the field of switching and it continues to grow in importance in today's digital world. During his Ph.D., he started to gain an interest in telecommunication and went to the University of Princeton to concentrate on this.

1.3 Innovations in Cryptography and Communication

In 1941, during World War II (WWII), he started to work on cryptography at Bell Laboratories, which was closely related to his work on telecommunication and wrote a paper called *A Mathematical Theory of Cryptography* in 1945, which established the principles of cryptography as they are known today (Gallager, 2003). During this time, his work on the mathematical theory of communication also started to come together and he published his most important paper, *A Mathematical Theory of Communication*, in 1948, described as one of humanity's proudest and rarest creations. This defined a mathematical notion, by which information could be quantified and demonstrated that information could be delivered reliably over imperfect communication channels like phone lines or wireless connections.

During the time of World War II (WWII), Shannon was in the process of developing fire-control systems, which could be used in anti-aircraft guns and cryptographic systems (James, 2009). During this period the weapons being fired were more dangerous than ever before, requiring a much higher target accuracy. This also meant that the messages being communicated were required to be sent with a high level of secrecy. To help with this, Shannon started developing the idea of cryptography while working at Bell Laboratories. Cryptography was closely related to information theory. For cryptography, Shannon realized that the basis was redundancy. He emphasized the fact that if a message has redundant elements, it would make it much easier to crack the message. Following this, all text messages would go through a transducer and the redundant parts of it would be removed. Most of the parts being removed would be vowels and any overlapping or repetitive elements.

Information theory was also being worked on in parallel with cryptography, which led to another important achievement of his in 1948, *A mathematical Theory of Communication*. Communication already existed before 1948 but the contributions made by Shannon played a very important role (Shannon, 1949). Before 1948, communication was thought to be an engineering discipline with no science behind it. Looking at the different modes of communication and the data that could be transferred, a connection between science and engineering could be seen, but no link was being developed. For example, Morse code as a model of transmitting information was complimentary to Shannon's later findings and so was Pulse-Code Modulation (PCM), which Shannon also explained in his theory later. Work was being performed in Bell Laboratories by different engineers and one such engineer Henry Nyquist developed the law

$$W = k \log(m), \tag{1.1}$$

which could be used to find the speed of transmission W using current values m and a constant k. This was not general enough but became a special case in Shannon's study. Another engineer, Ralph Hartley, tried to generalize this equation into

$$H = \log(S^n), \tag{1.2}$$

where S is the number of possible symbols and n would be the number of symbols in a transmission. However, there were still certain aspects missing which were brought together by Shannon. His theory could be divided into two main parts. The first would be information conceptualization and the second would be related to sending information, or how much can be sent at one time, and how noise would play a role. With the help of a Bush Diagram, Shannon could produce a general idea of the communication system. He had started to remove the extra layers to get to the root cause in the system. The effect of distortion on the signal was discussed along with the fundamentals of bandwidths and delays during communication. He then listed the parts of the system to be an information source, channel, transmitter, receiver, and destination. Further communication systems were divided into three types: discrete, mixed, and continuous. Discrete was recognized to be important not only in communication, but also in computers and telephones. Shannon defined the bit as being the smallest unit of information.

He finally went on to discover the two main theories of communication. The first one dealt with communication over noiseless channels and the second one dealt with communication in noisy environments. The idea behind the first theory was that the amount of information that can be transmitted depends on the entropy. This was important as it changed the older idea that maximum signal that could be transmitted depended on the different factors, one of them being frequency. The second theory proved that even in a noisy environment, information can be send using an encoding scheme. This also made it clear that after a certain level of noise it would no longer be possible to transmit the signal.

1.4 Creation of Smart Machines

While at Bell Laboratories in the 1950s, Shannon became more interested in building smart machines capable of learning. The most well-known example was an artificially intelligent machine he called Theseus. Theseus was a wooden mouse with an internal bar magnet and copper whiskers that could *learn* how to navigate a metal maze to find a piece of *cheese*, which was an electrical terminal attached to a bell. The mouse could turn clockwise 90 degrees at a time and move forward and backward. The machinery that controlled the mouse resided underneath the maze, where a series of electrical relays processed and *remembered* the locations the mouse visited, and a motorized electromagnet oriented and moved the mouse based on the information from the relays. Once it was placed, the mouse tripped a switch, which allowed the electromagnet to locate it. The copper whiskers acted as sensors to detect when the mouse faced a wall. The maze itself was built out of removable metal walls. This system was sophisticated enough that once a maze was solved, the mouse could remember the solution for the next trial. As well, if placed in an unfamiliar section in a previously solved maze, and if it returned to a familiar section, Theseus could solve the maze as if it *remembered* the path. If the maze was adjusted, Theseus could adapt to the change and find an eventual solution. Shannon presented this invention at the meeting for the National Academy of Sciences exhibit under Bell Laboratories.

1.5 Later Years

In 1956 Shannon became a visiting professor at MIT. He decided to join the University as a full-time professor in 1958. During these years he was awarded honorary degrees from Yale, Princeton, the University of Edinburgh, and many more. Throughout his time at MIT his focus shifted away from communications toward the creation of toys and problem-solving devices such as a computer that played chess, juggling machine, rocket-powered frisbee, motorized pogo stick, and a Rubik's cube solver. He was known for his enthusiasm, curiosity, and humour in approaching research and was an avid juggler, tinkerer, chess-player, and unicyclist. Shannon left the institute in 1978 and later entered a nursing home after contracting the Alzheimer's disease.

Claude E. Shannon was taken by the disease on February 24, 2001 at the age of 84 (James, 2009). He was a beloved professor, mathematician, and engineer who developed a wide range of theories and technologies. In his early years, he developed ground-breaking innovations that provided the tools that ushered in the information age (Gallager, 2003). Later in his life, he focused on the invention of toys and problem-solving devices. Shannon was an extraordinary scientist and left behind an influence on many devices used in everyday life today. From cell phones, to the cyber world, to high-definition TV, the world around us is filled with inventions made possible from the work of Claude E. Shannon.

2 Gottfried Wilhelm Leibniz (1646-1716)

A Man of Many Talents

By Rebecca Bar, Angela Lin, Warisha Ahmad, and Shina Ng

Gottfried Wilhelm Leibniz was without a doubt one of the greatest minds of the seventeenth and eighteenth centuries. It is impossible to solely call Leibniz a philosopher or mathematician as he was much more than that. He was primarily a philosopher and mathematician, but he was also a lawyer, physicist, historian, diplomat, linguist, logician, theologian, and librarian, among other things. Leibniz was a lawyer by profession, so his extraordinary intellectual activities and achievements were made during his spare time (Mates, 1989). His far-reaching interests have resulted in ground-breaking contributions in a variety of fields. This wide range often makes it difficult to decipher his career chronologically, but he is perhaps best known for his independent co-invention of differential and integral calculus. To this day, Leibniz' notation is used as the conventional expression of calculus (Mates, 1989).

2.1 Childhood and Early Years

Leibniz was born on July 1, 1646 in Leipzig, Germany, two years before the Peace of Westphalia, the end of the destructive Thirty Years' War (Mates, 1989). He was born into a noble and academic family. His father was a professor of Moral Philosophy and Registrar at the University of Leipzig, and his maternal grandfather was a professor of Law. He lost his father at the young age of six, leaving his mother in charge of his education (Ariew, 2006). Leibniz began his education at age seven and attended the Leipzig Nikolaischule, one of the best preparatory schools in the state from 1653 to 1661 (Antognazza, 2018). He was self-taught in Latin at ages seven to eight so that he could have access to his father's personal library. There, he took an early interest in history, poetry, and logic. These universal readings made him well-versed in almost every field at a young age (Ariew, 2006).

2.2 Education

Leibniz attended university between ages fourteen and 21. He was enrolled at the University of Leipzig in Saxony between 1661 and 1666, where he learned philosophy, language, literature, Greek, Latin, and Hebrew. At the age of seventeen, he obtained his bachelor's degree in Philosophy. He proceeded to temporarily study mathematics at the University of Jena and returned to Leipzig, to obtain a master's degree in Philosophy (Mates, 1989). At the time of Leibniz, *modern* philosophy of Descartes, Galileo, and others were still relatively new to German-speaking lands. Therefore, his philosophical education primarily consisted of Scholastic philosophy with elements of

Renaissance humanism (Antognazza, 2018).

Following his Philosophy degrees, after a year of legal studies, Leibniz was able to obtain a bachelor's degree in law. He wanted to pursue a license to practice law, but the committee at the University of Leipzig refused his candidacy, likely due to his youth (Ariew, 2006). Rather than waiting, Leibniz left Leipzig and attended the University of Altdorf in Nuremberg (1666-1667) and received his doctorate in law. The faculty at Altdorf were impressed and even offered him professorship but he declined their offer, as he knew he was headed in a different direction (Mates, 1989).

2.3 Career

Leibniz' career started with a modest job as a secretary to an alchemical society in Nuremberg. During his time in Nuremberg, Leibniz met a distinguished German politician named Johann Christian von Boyneburg, who hired Leibniz as his assistant. As von Boyneburg's assistant, Leibniz hoped to gain employment with the Elector of Mainz by dedicating an essay on law to the Elector. This strategy proved to be successful, and Leibniz was employed to assist in redrafting the legal code for the Electorate (Guhrauer and Mackie, 2007). In 1669, Lebniz became the assessor in the Court of Appeal and remained in this position until 1674 (Ariew, 2006).

Von Boyneburg advanced Leibniz' career by promoting his work to a great extent. Due to this, Leibniz' memoranda and letters started to garner attention. In 1672, Leibniz went to Paris upon the invitation of the French government to discuss the matters of European politics (Guhrauer and Mackie, 2007). Leibniz met the Dutch physicist, Christiaan Huygens, in Paris.

Upon their meeting, Leibniz realized that his knowledge of mathematics and physics was lacking and decided to enlist Huygens as his mentor. Under Huygens' mentorship, Leibniz made the most important contributions to mathematics in his career: the discovery of his version of differential and integral calculus.

Leibniz travelled to London in 1673 to discuss European politics with the English government. In London, he met with the Royal Society and quickly became a member as he revealed his invention: the first calculator that could perform the four basic mathematical operations. This mission came to an end several months after Leibniz arrived in London and with the death of the Elector as well as his two patrons, Leibniz was forced to find a new career path, so he travelled back to Paris after this ordeal (Guhrauer and Mackie, 2007).

In 1671, Leibniz began corresponding with the Duke of Hanover and, in 1673, was offered the position of counsellor by the Duke, which he accepted two years later. Leibniz was reluctant to travel to Hanover, however, after realizing that there was no other employment, he left Paris in 1676. In 1677, Leibniz was promoted to Privy Counsellor of Justice. He held this position for the rest of his life. In this position, Leibniz served as librarian of the Duke's library and political advisor and historian to three rulers of the House of Brunswick. The documents that were produced by Leibniz during his employment became an integral part of the historical records during this time. During his employment with the Brunswicks, Leibniz published his most important papers on calculus between 1682 and 1692. In 1691, he was appointed as the librarian of the Herzog August Library in Lower Saxony (Davis, 2011).

The most significant aspect of Leibniz' career was his dispute with Newton over who had discovered differential and integral calculus first. This dispute overshadowed many of Leibniz' other accomplishments and affected him till his death. A formal investigation was conducted by Newton's disciple, John Keill. Keill concluded that Leibniz had plagiarized Newton's work. This charge was upheld well after Leibniz' death and affected his life so much that few people attended his funeral. Since 1900, historians of mathematics have acquitted Leibniz of this charge by pointing out fundamental differences between Newton's and Leibniz' versions of calculus (Guhrauer and Mackie, 2007).

2.4 Overview of some of his Philosophical Works

Gottfried Leibniz is known as the last polymath and made various contributions to a wide number of fields but did not write any major works that could be considered as the embodiment of his thoughts. His *Catholic Demonstrations and Elements of Natural Law*, written between 1669 and 1671, were made with the efforts of achieving his lifelong dream to reconcile the Protestants and Catholics, which have yet to be fulfilled even today. Many of his essays on physics, mathematics, and epistemology were published in the *Acta Eruditorium* journal and he made his mark in the world of philosophy with his work *Discourse on Metaphysics*. The only book published during his lifetime was the *Theodicy* in 1710, and it was not until 1765 that his *New Essays Concerning Human Understanding* was published. Much of his work remain as unpublished manuscripts to date. In 1714, Leibniz wrote the *Monadology*, which broadly summarizes his philosophical views.

In 1686, the *Discourse on Metaphysics* was released following the controversy created over *Nicholas Malebranche's Treatise on Nature and Grace*, as a discussion between Leibniz and Arnauld. The latter was offended by Malebranche's thesis that God gave his care based on general laws of nature which went against Arnauld's belief that God's acts are purely based on divine care for human beings. Leibniz also disagreed to Malebranche's theories since he believed that the world we live in is the best God could have created and that the former was not fair in his judgment of the divine creation's inherent goodness. Having a common ground and in the pursuit of his lifelong dream, Leibniz sent a draft of his work to Arnauld who criticized his concept of God having a predetermined plan for every individual. Thus, Leibniz wrote the Discourse on Metaphysics, considered to be his first mature philosophical work, in response to Arnauld's criticisms (Jolley, 2005).

Another work, in the form of a dialogue, was Leibniz' *New Essays Concerning Human Understanding*, which was written with the aim to incite, through criticism, a response from John Locke concerning the latter's *An Essay Concerning Human Understanding*, which is recognized as a classic in empiricist philosophy. However, before Leibniz could publish his writings, Locke passed away, thus postponing the publication of the manuscript to much later. The New Essays has been an important piece of work, a classic that showcases the conflict between rationalist and empiricist ideas, and one in which Leibniz defended his immaterial theory of the mind (Jolley, 2005).

The *Theodicy*, a term invented by Leibniz, meaning 'the justice of God' was one of the pillars of his works that made him famous along with the *Monadology*. The former was based on his initial concern on reuniting many kinds of evils with the help of the good and compassionate almighty God, and mentions the idea of human freedom. While this publication was lengthy and scholarly, the *Monadology* was one of his greatest works, in which he defends his theory of 'monads'. He considers his theory to be the fundamental soul-like entity that makes up nature and shows God-like properties in that they can only be created or destroyed by preternatural forces. He states that there is a hierarchy to monads of which God is the leader and humans are lower down the chain and that they are monads that possess self-consciousness and the capability of reason. At the bottom of the hierarchy are 'bare monads', which have no consciousness and is the basis of inanimate objects. Based on his Law of Continuity, Leibniz makes his stance that all the additional positions in the monad hierarchy below God are occupied and argues that, throughout, it is the kind and not the quality of the monad that changes. Furthermore, based on his principle of Identity of Indiscernibles, no monad is identical, and each has their distinct perspective, which cannot be completely understood by other monads (Jolley, 2005).

Leibniz' works are numerous and about half of his writings and letters have yet to be published. This brief overview does not do justice to the name nor to the mind of Gottfried Wilhelm Leibniz. He has no masterpiece like other notable philosophers of that era, but his *Discourse on Metaphysics* and the *Monadology* are his most common work.

2.5 Personal Life

Gottfried Wilhelm Leibniz never married but had many friends and admirers from all over Europe that he met through his work. Most notably, he was good friends with German mathematician, scientist and philosopher, Ehrenfried Walther von Tschirnhaus. His professional duties in his career varied and caused him to travel widely, meeting many of the foremost intellectuals in Europe at the time. He has been described as charming, funny, well-mannered, and imaginative. He lived a relatively modest lifestyle but was never considered destitute, as his patrons, the Brunswicks always paid him well.

In addition to Leibniz being a religious man, he also considered himself both an optimist and rationalist. Since his father died young, Leibniz learned many of his moral and religious values from his mother, which would eventually play an important role in his life and philosophy. He believed strongly that our universe is the best possible one that God could have created and as such, any apparent flaws in our world must also be present in every other possible world. Leibniz identified as a Protestant, particularly a member of the Trinitarian Christian faith, but appreciated many aspects of Catholicism. Throughout his life and career, Gottfried was adamant that religion and philosophy cannot contradict each other given that reason and faith are both considered ‘gifts of God.’ One of Leibniz’ greatest ambitions during his career was to develop a basis of theology that would be pivotal in the reunion of the Church, which had been divided since the Reformation in the sixteenth century.

Leibniz’ curiosity and interests varied widely, and he expressed his views on science and theology through his hobbies in writing. He contributed significantly to the field of library science by completing various literary works on philosophy, politics, law, religion, history, and philology. Leibniz wrote in several languages but mostly restricted his craft to Latin, French, and German writings.

2.6 Reflection

Gottfried Wilhelm Leibniz led a rich and fulfilling life, both within and out of the academic community. From a young age, Leibniz was incredibly ambitious and keen to further himself professionally through education and networking. He was a man of many interests, skills and passions, and dedicated his life to advancing the science, mathematics, and philosophical ideas of his time. Furthermore, he was an incredibly dedicated writer and theologist and was often motivated by personal and religious ambitions, such as a strong hope to fuel the reunion of the Church through his work. Over the course of his career, Leibniz made countless contributions to a multitude of different fields in the seventeenth and eighteenth century. However, Gottfried Wilhelm Leibniz will be remembered most notably for his extensive work on differential and integral calculus.

3 Max Karl Ernst Ludwig Planck (1858-1947)

Perseverance for Science

By Hanna Bennett, Sam Bessai, Rizwan Shoukat, Harkrishan Punn, and Andres Leal

The following short biography describes the sublime pursuit of Max Planck, discovering the laws governing the absolute outside world that is independent from man, starting off in his early life and ending in his elderly age. Included are his major accomplishments and all the struggles that made Planck one of the most brilliant physicists we know today.

3.1 Early Developments

Max Planck was born in Kiel, Germany, in 1858, and was the sixth child of Wilhelm J. J. Plank and Emma Patzig (Aczel, 2002). His father was a professor of Law in Kiel, and his mother came from generations of pastors. Both parents kindled deeper thinking in Planck from a young age. They enjoyed vacationing and Planck received frequent exposure to the natural world. In addition, Planck also received musical exposure and became very talented at piano and cello.

Planck was enrolled in Maximilians Gymnasiumm, a school for those academically inclined, where a teacher, Hermann Müller, took special interest in Planck's mathematical gift (Weir, 2009). Müller taught Planck subjects which peaked Planck's interest such as astronomy and physics. In these classes was where Planck was first exposed to Clausius' first law of thermodynamics. The interest he took in this theory would later lead to some of Planck's greatest findings (Weir, 2009).

Planck demonstrated strong academic potential and became a very distinguished student graduating early at the age of sixteen. Planck then enrolled in the University of Munich for physics, a field which was regarded as insignificant by scientists at this time (Weir, 2009). Planck even had a professor that tried to sway his choice to study physics, saying there was not much left to discover in the field. Regardless of these persuasions to leave the field Planck persisted in physics all while still maintaining his other interest in history and music. These interests remained an integral part of his life. Planck played the piano frequently and enjoyed pieces by Brahms and Schubert.

3.2 Greatest Achievements

Planck transferred to Berlin's Friedrich Wilhelms University at age twenty, where he was taught by Helmholtz, and Kirchhoff (Planck, 2007). Planck recalled their lectures as somewhat dreary, yet he found their books fascinating to read and from this formed a fast friendship with both of his professors. In Berlin, Planck's natural mathematical talent became more recognizable through his focus on theoretical work in thermodynamics. His continued fascination with thermodynamics was what caused Planck to return to the university of Munich in 1879 where he then wrote his doctoral dissertation. One year later, Plank was granted privatdozent, which is a qualification that granted him permission to teach. At the age of 21, Planck received his Ph.D. in physics for a research paper outlining his findings regarding the theory of thermodynamics (Weir, 2009). However, due to the lack of interest in physics at the time, his first scientific papers were not even acknowledged by Helmholtz, Kirchhoff, and Clausius, the kind of men whose work had been the initial inspiration for Planck's interest in thermodynamics (Planck, 2007). Soon after, at the age of 21, Planck wrote a second paper on the characterizing of heat which granted him habilitation, the highest level of academic achievement (Weir, 2009).

Planck, after having multiple associate professor and professor positions at a variety of institutions, spent much of the rest of his career, from 1889 onward back at Berlin University as a professor. He remained there until retirement in 1926. Planck's major accomplishments included a paper that he published in 1900, in which he announced the revolutionary relationship between energy and frequency of radiation, and his two books in *Thermodynamics*, published in 1897, and the *Theory of the Photoelectric Effect*, published in 1906. These achievements were commemorated by his Nobel prize, won in 1919, and by naming the universal constant h, which he derived, as Planck's constant. Planck was awarded the Nobel prize for 'the services he rendered to the advancement of Physics by his discovery of energy quanta.'

3.3 Failing Forward

In his work and theoretical dwellings, Max Planck was not only a visionary but also a renown genius. Most engineers and scientists know his name from the famous Planck's constant used in the Planck-Einstein equation,

$$E = hv, \tag{3.1}$$

that relates the energy E carried by a photon to its frequency ν. The derivation of the constant was undoubtably a major success and feat, but many people do not know the difficult road that Max Planck endured to derive the equations practitioners simply input into their calculators.

Through his curiosity for thermodynamics, Planck developed a vision which was to prove the existence of thermal irreversibility. His area of theoretical research originated in radiation theory and slowly migrated towards the quantum realm (Badino, 2015). Planck was never particularly interested in radiation law as devised by Wein. He wanted to prove that electromagnetic radiation in an enclosed space reaches an irreversible form of stable thermal equilibrium (Badino, 2015). Planck used the knowledge of many other scientists to help him in this task. However, perhaps the most influential tool he was able to use was the oscillating dipole introduced by Heinrich Hertz at the end of the 1800s (Badino, 2015). Using the dipole, Planck was able to experiment with physical models involving controlled electromagnetic waves which was unheard of at the time. The theoretical knowledge he gained from these lab experiments provided him with enough evidence to write his first paper of the Pentalogy to the Prussian Academy of Science. Consequently, he explained his idea of irreversibility in two ways: "Firstly, the diffusion of energy is likely to reach a stationary state without the addition of external work; it is a spontaneous process. Secondly, the interaction between resonator and field should be such that a reverse process is excluded, so that the stationary state remains in place forever" (Badino, 2015).

Planck's breakthrough was magnificent, or so he thought. In his first paper, Planck used Maxwell's H distribution, a kinetic equivalent of the second law of thermodynamics, that states that heat always flows from a warmer body to a colder one until equilibrium is reached. The use of this fundamental equation intrigued the scientist Ludwig Boltzmann and he came to understand that this theory was fundamentally wrong. Boltzmann stated that, "If we suddenly reverse all directions of motion, leaving unchanged the remaining parameters, the system will still be described by Maxwell's distribution, but it will begin tracing back its own evolution until it has again reached the initial state of non-equilibrium from which it started. If entropy is a function of state, it cannot increase to a maximum and remain constant thereafter" (Badino, 2015).

Planck understood his defeat and accepted the challenge of Boltzmann to create a more fundamentally sound theory. He proceeded to finish his second and third installments of the Pentalogy attempting to prove and explain the underlying foundations of entropy. These installments mark the famous words laid out by Planck, "A stationary state is therefore a perfectly disordered one in which no special arrangement of the components produces constructive interferences" (Badino, 2015). Unfortunately, throughout his undying efforts, Boltzmann discredited his theories once again and left Planck hopeless. Planck was forced to give up his idea of proving irreversibility and a complete reorganization was necessary (Badino, 2015). In Planck's despair, he realized that Boltzmann's criticisms gave way for a different alternative; one that follows a kinetic theory more closely. Planck put all his effort into researching the proposed alternative and ended up proposing a theory called, "Hypothesis of Natural Radiation (HNR)" (Badino, 2015). In the years following, he completed his fourth and fifth installment of the Pentalogy explaining the newly-found theory. Without him realizing, Planck shifted his area of focus from radiation theories to mainly quantum mechanic dwellings. His future success in this field led him to discover the constant he is most known for, the Planck's constant h.

3.4 A Stance for Science

In the last few decades of his life, Planck continued to work and receive merits in the years prior to his retirement. The Royal Society elected him to Foreign Membership in 1926 and in 1928, awarded him the Copley Medal for "outstanding achievements in research in any branch of science." Planck was the president of the Kaiser Wilhelm Society from 1930 to 1937. He was granted a post-humous recognition when the Kaiser Wilhelm Society was succeeded by the "Max Plank Society" in 1948, the year after Planck's death.

Apart from being a powerful figure in German physics, Planck was also a patriot. The rise of Adolf Hitler and Nazism in 1933 and WWII were a tragic period in Planck's life. Despite being seventy-four upon Hitler's ascension, Planck fought for both his country and his beloved scientific field, by defending Einstein and his scientific work, both of which had been denounced due to Einstein's Jewish origins (Heilbron, 1986). In May 1933, Planck took perhaps the most powerful stance towards science over Nazi politics when he approached Adolf Hitler himself. He attempted to make Hitler understand the effect that the forced emigration of Jews would have on German science (Heilbron, 1986). Further action that showed his distaste for Nazi policies was his resignation from the presidency of the Prussian Academy of Sciences in 1938 upon its occupation by Nazis. Despite his distaste for the influence Hitler had on his country, Planck stayed in Germany to preserve what he could of his beloved field. Planck lived a life ailed not only by political tragedies, but also by the losses of family. He lost his first wife, whom he had known since childhood. Three of Planck's five children passed away in their earlier childhood leaving him with only two sons, one of whom was executed for an unsuccessful assassination attempt on Adolf Hitler. He died on October 4, 1947 due to his poor health.

As a physicist, Max Planck did justice to his field of pursuit by sharing his research that has forever left a mark on the very roots of classical physics. As a patriot and a rationalist, he stood for his country and for scientific proof and took painstaking steps to ensure that political troubles did not interfere with the progress of scientific work. As a family man, he stoically endured the tragedies that befell him. And as a teacher, he imparted not only scientific knowledge, but also words that resonated his passion and zeal for the field he dedicated his life to—physics.

"For if, while engaged in body and mind in patient and often modest individual endeavour, one thought strengthens and supports us, it is this, that we in physics work, not for the day only and for immediate results, but, so to speak, for eternity." — Max Planck

4 Rudolf Julius Emanuel Clausius (1822-1888)

Founder of the Second Law of Thermodynamics

By Alexander Harshaw, Corin Schneider, Dilraj Singh, Kyle Latter, and Tanis Sanders

4.1 Early Life Development

Rudolf Julius Emanuel Clausius was born in Köslin, Poland, on January 2, 1822. He was the sixth son of eighteen children. Clausius' family was successful, which allowed him to attend an elite private school and receive a prestigious education. Rudolf's father, Reverend C. E. G. Clausius, was a Protestant pastor and a councillor on the Royal Government School Board as a school inspector. Reverend C. E. G. Clausius founded a small private school and was its principle, resulting in Rudolf studying at the school his father founded for a few years. At sixteen years of age Rudolf left his family home to join his two elder brothers at Gymnasiumm in Stettin, now known as Szczecin, Poland, from which he graduated in 1840 when eighteen years old.

Clausius enrolled at the University of Berlin. He was among other students who later became notable scientists, including Gustav Magnus, Peter Gustav Lejeune Dirichlet, Jakob Steiner, and Leopold von Ranke. For a time, he was unsure at what he wanted to pursue throughout his life as he was extremely successful in multiple areas. He was very interested in possibly leaning towards a path in history, however, he eventually made the decision to go ahead and study mathematics and physics. He completed his degree in these fields during Easter of 1844 where he graduated and received his certificate from the prestigious University of Berlin.

4.2 Career Path

After receiving his teacher's certificate in 1844, Rudolf taught advanced classes in mathematics and physics at the Friedrich Werder Gymnasiumm in Berlin for a probationary period. He accomplished a degree of Doctor of Philosophy at University of Halle in 1847. His dissertation *De is atmosphere particulas quibus lumen reflectitur* was regarding to the study of the optical effects in the Earth's atmosphere. His thesis proposed that the multiple colours of the sky were from the refraction and reflection of light. Later, Lord Rayleigh would demonstrate that the multiple colours were because of scattering of light. Clausius used a far more mathematical approach than other scientists' attempts.

Clausius was appointed professor of physics at the Artillery and Engineering School at Berlin in September of 1850. He was also a Privatdozent at the University of Berlin where he gave an inaugural lecture pertaining to the paper he published titled *On the Moving Force of Heat and the Laws of Heat which May Be Deduced Therefrom*. His most famous statement written about the second law of thermodynamics was published in German in 1854, and in English in 1856.

Starting in 1855, Clausius became a professor of physics at Swiss Federal Institute of Technology in Zürich and stayed there for twelve years. He cared for his students' success and wrote fresh lectures for almost every year. In lecture, he conducted exercises and examinations in which he evaluated the performance of each individual pupil.

He was offered a position at the Polytechnic in Karlsruhe but turned it down in 1858 as well as a post at the Polytechnic in Brunswick, which he declined in 1862. In this career position, he was able to develop his research and scientific contributions. Rudolf moved and became a professor in Physics at the University of Würzburg in 1867, in the same year publishing *The Mechanical Theory of Heat—with its Applications to the Steam Engine and to Physical Properties of Bodies*. At Würzburg, he was supported by the Bavarian Government. In 1868, he was offered a post in Munich that he rejected, however, a year later he took the professor position at the University of Bonn to teach physics. Clausius organized an ambulance corps of Bonn students to serve in the Franco-Prussian War in 1870. He was a German patriot, and, although he was close to 50 years of age, he offered his services to his country. After a personal tragedy with his wife, he remained teaching, however, with the health issues and increased parenting responsibilities, did not have the time to continue his research.

4.3 Personal Life

Rudolf Clausius completed his studies in mathematics and physics and went on to get his doctorate on optical effects in the Earth's atmosphere at the University of Berlin in 1847. In 1855 he began working as a professor at the Swiss Federal Institute of Technology in Zürich until 1867. He then moved to Würzburg for a short stint of two years, until he finally settled in Bonn in 1867 where he would stay. During these years, he married Adelheid Rimpam in Zürich in November 1859. She was an orphan who was born in Brunswick.

In 1870, when the war of Franco-Prussian broke out, Clausius offered his services to his country being the German patriot he was. He conscripted as the leader of the ambulance corp that consisted of Bonn students. He, along with his students, helped carry the wounded soldiers from the battlefield and tend to their injuries most significantly through the two crucial battles of Vionville and Gravelotte. These two battles resulted in the retreat of France and as a result a victory for Germany at the cost of 20,000 men. Unfortunately, for Clausius, through all the war casualties, he did not come out unscathed. Clausius' leg had been wounded in the duration of one of the battles. This injury led to severe pain and disability which caused him constant pain and challenges through the rest of his life. From his patriotic contributions he was awarded the Iron Cross for his services at the battles of Vionville and Gravelotte.

In 1875, his wife, Adelheid, died in childbirth to add to his suffering. Of the six children Clausius had with his late wife, only four survived. With the death of his wife Clausius was left to raise his four children alone. These challenging circumstances of raising his children alone and the added pain of his battle wound shifted his focus from academics. He continued to teach but his research was left hindered as he no longer had the time. Clausius' doctor advised him to take up horse riding to help with the residual pain from the war and he soon became an expert horseman in 1878. In 1886 Clausius remarried with his second wife Sophie Stack from Essen. He would go on to have a son with her, the last of his kin. At this time, Clausius was the rector of the University of Bonn, and he continued to work his career and marriage until two years later, on August 24, 1888, he died in Bonn, Germany.

4.4 Awards and Accomplishments

One of Clausius' notable discoveries was involved in the Theory of Heat. In 1850, Clausius presented his paper titled *On the Motive Power of Heat and on the Laws Which Can Be Deduced from It for the Theory of Heat*, which James Clerk Maxwell praised, calling it the 'true theory'; this theory states that when work was performed by heat, one part of the heat was transformed into work. Clausius states two laws, with one being that there is a fixed relationship between the work performed by and the resultant heat generated, or by heat absorbed, and the resulting work produced. The second law states that whenever work is produced by heat, a quantity of heat that flows from a warmer to a colder body always results. Later on, in 1854, he continued building on this theory, describing that 'heat can never pass from a colder to a warmer body without some other change, connected therewith, occurring at the same time'. Claudius was able to show that the Carnot cycle, which provides an upper limit on the efficiency that any classic thermodynamic heat engine can achieve during the conversion of heat into work, corresponded to the integral around the engine

$$\int \frac{dQ}{T}, \tag{4.1}$$

where dQ is differential heat transferred and T is temperature. This shows that the resultant value is zero for an ideal or reversible process, and for real or irreversible processes the resulting value can only be positive.

Clausius was able to make important discoveries regarding the kinetic theory of gases. In 1857 and 1858, he wrote two papers that described the important notion of the mean free path of molecules. Clausius was able to calculate the average velocity of hydrogen molecules given normal temperature and pressure under the assumption that molecules move in a straight path. Additionally, in 1862, Clausius published a paper titled *On the Thermal Conductivity of Gaseous Bodies* where he was able to successfully derive from theoretical considerations the experimentally known data in question. Clausius, yet again, was praised by Maxwell by saying that he "gave us precise ideas about the motion and agitation of molecules." In 1862, he wrote another paper known as his sixth memoir which stated that it was "impossible practically to arrive at the absolute zero of temperature by any alteration of the condition of a body."

In 1865, one of his most important discoveries, stated in his ninth memoir, was the concept of Entropy. Clausius was able to use the concept of Entropy to describe that the energy of the universe is constant, and that the entropy of the universe tends to a maximum.

Clausius' accomplishments were recognized in his own time. The awards received by Clausius included being elected a Fellow of the Royal Society of London in 1868 and receiving its Copley Medal. This medal recognizes outstanding achievements in science, and alternates, annually, between physical and biological sciences. It is noteworthy that this award was established in 1731 and has recognized the achievements of such renown scientists as Albert Einstein and Charles Darwin. Nobel prizes were not awarded until 1901, which was after Clausius' time. Clausius additionally received the Huygens Medal in 1870, which is awarded for innovative research in mathematics, physics, or space sciences, and the Poncelet Prize of the French Academy of Sciences of 1882, for innovation in micro-encapsulation. These awards remain amongst the top distinctions in science to this day. He also received an honorary doctorate at the University of Würzburg in 1882, and the Clausius crater on the Moon was named in his honour.

4.5 Future Contributions

After his death in 1888, Clausius received the Pour le Mérite for Arts and Sciences, a German honour given for achievement in humanities, sciences, or arts. This is a major achievement to receive as a scientist, other notable physicists that have received this honour include Albert Einstein and Erwin Schrödinger. In 2009, Clausius had a memorial stone created in his memory, in front of Koszalin University of Technology in his hometown of Koszalin, Poland. Clausius' work in thermodynamics still holds a significant role today as it is taught worldwide in various applications.

5 Jabir ibn Hayyan (c.721-c.815)

The Father of Chemistry

By Robert Howard, Maximilian Ornat, William Raymond, Japjit Pawar, and Viktor Somers

5.1 Life and Accomplishments

The 5th to 10th centuries are often labelled as a time of little technological and scientific development by western historians. This viewpoint is myopic in that it fails to consider the hotbed of innovation and cultural development present in the eastern empires, also known as the Islamic Golden Age. One the foremost great thinkers of this era, was Jabir Ibn Hayyan. Hayyan is well known as renowned scholar of the Quran, alchemy, mathematics, philosophy, astronomy, and medicine. Widely regarded as the father of chemistry, Hayyan's most prominent work was the Jabirian Corpus, a collection of over 500 manuscripts detailing research on a variety of artistic and scientific topics. Some notable topics of the corpus included descriptions of chemical processes such as distillation, evaporation, and crystallization, as well as the discovery of sulfuric and hydrochloric acids. Hayyan's work had a strong focus on developing standardized procedures in the field of alchemy, and invented over twenty pieces of equipment which are considered standard lab equipment today.

Abu Musa Jabir Hayyan Al-Azdi is considered as one of the fathers of chemistry and one of the early founders of modern pharmacology. He was born in Tus, Iran, in 721 AD in a period of political instability. His father was a pharmacist and resided in Iraq during the rule of the Umayyads. Since Jabir's father supported the Abbasid Revolution during the Umayyads rule, he had to move to Iran where Jabir was eventually born. Jabir's family fled to Yemen after his father was caught and executed by the Umayyads.

The Umayyad Caliphate was the second Islamic State, which existed from 661 AD until 750 AD. As its name suggests, the caliphate was ruled by the Umayyad family. Both in area as in percentage of the world population the Umayyad Caliphate can be considered as one of the greatest empires in the history of the world. In 750 the Abbasids, which Jabir's father supported, would overthrow the Umayyad caliphate and form the third caliphate.

Hayyan studied in Yemen under Harbi Al-Himyari who taught him the Quran and basics of alchemy, pharmacy, philosophy, astronomy, and medicine. Certain works indicate that he may have been a student of the venerable Jafar Ibn Muhammad As-Sadiq, another renowned Muslim scholar based out of Medina. He was not able to return to his home city of Kufa in Persia until the rise of the Abassid Caliphate in 750 AD. Having sided with the Abassids during the Abassid revolution, for which his father had died, Hayyan found himself in the favour of the court. There is little documentation concerning Hayyan's life, with most of his writings focusing on scholarly work. As such, there are major gaps in what is known about Hayyan's life. His ethnic origin and identity are debated by historians.

What is known is that under the patronage of Caliph Harun al-Rashid, Hayyan was able to establish a career as a medical practitioner. This provided the framework for him to carry out his research and complete his writings. Throughout his time in Kufa, he eventually became close to the Iranian Barmakid Family. The Barmakids were wealthy and generous and were able to provide Hayyan with the resources to complete great works of research. In 803, the Barmakids expenditures and their careless handling of the Caliphate military caused them to lose favour in the eyes of al-Rashid. This led to the downfall of their house, for which Hayyan was imprisoned in his home until the end of his days in 815. Hayyan died at the age of approximately 94 years old in Kufa.

The exact number of books that Hayyan has written is unknown, but it is approximated that he as authored 300 books on philosophy, 1300 on mechanical devices, and many hundreds on alchemy. The corpus Jabirianum is a collection of over 300 books on chemistry and alchemy and is believed to include the works of his followers who wanted to associate themselves with Jabir. Some scholars even go to the lengths of denying him being a scientist or even denying his existence. It is a possibility that Jabir Ibn Hayyan should be seen as a pseudonym for scientists who wanted to work anonymously during the Islamic Golden Age.

In Western countries, Hayyan is sometimes referred to as 'Geber', a westernized form of Jabir. In the 13th century and 14th century a lot of Hayyan's work would be translated to Latin and republished under the name of Pseudo-Geber. As an interesting fact, the English word gibberish is thought to originate from Geber, since he would often write whole books in a code that would seem to make absolutely no sense.

In Europe, Hayyan is credited for several chemical processes in modern chemistry. These include crystallization, calcination, sublimation, evaporation, synthesis of acids, and distillation. Furthermore, Jabir is also acknowledged for the preparation of various metals, development of steel, dyeing of cloth, use of manganese dioxide in glass-making, rust prevention, and paint identification.

5.2 Standardization of Research

Alchemy is not considered a scientific field by most today, as it is based on several faulty propositions about the nature of matter in the universe. It is important to remember, however, that alchemy is the foundation upon which several important scientific discoveries are based. In fact, the primary field of revolutionary scientists such as Robert Boyle and Isaac Newton was alchemy (Nummedal, 2011). One of the main reasons that Jabir ibn Hayyan is widely considered the father of chemistry is his unique approach to the study of alchemy.

One of the reasons alchemy was still considered a viable field for so many years is the lack of clarity in experimental processes. This ultimately led to unrepeatable results, misinterpretations, and false discoveries. Hayyan began to bend the field towards the direction of modern chemistry with his dedication to rigorous experimental procedure. Hundreds of pages of the Jabirian Corpus are dedicated to detailed diagrams of experimental procedures, and schematics for the construction of specialized laboratory equipment (Amr and Tbakhi, 2007). This focus on the finer details of the experimental process allowed Hayyan to see past the vast muddled mess of previous alchemical research, and discern the true experimental results from the false. Hayyan's work heavily emphasized the importance of performing physical experimentation for the researcher, stating "Scientists delight not in abundance of material; they rejoice only in the excellence of their experimental methods" (Holmyard, 1923). This espoused an ideal, that one who publishes research should take ownership of it, not just by executing the experimentation, but by ensuring that the reader is able to follow, understand, and recreate this process. This provided a new challenge of accountability in a time where scientific understanding often lived and died with the original researcher.

5.3 Chemistry and the Scientific Method

As previously stated, Jabir Ibn Hayyan has been given the name "The Father of Chemistry", a significant nickname that carries much weight considering all contributors to the science of chemistry. Among Hayyan's many contributions to science he is credited with—the alembic, the processes of crystallization and distillation—one of his most significant contributions in modern science is perhaps the use of physical experimentation. In his time, the ideas behind science resembled mysticism and speculation rather than concrete data and reasoning. Jabir's work helped bridge the gap between speculation and scientific proof by using his instrumentation and methods to assist with the creation and identification of many 'commonly' known processes and substances.

Among Jabir's scientific inventions includes a framework for the classification of materials based on chemical characteristics. These include sublimation, liquefaction, crystallization, and distillation. Using these processes Hayyan was able to determine many basic compounds, as well as strong acids such as sulfuric acid (Khan, 2009). Of special importance is the alembic, which he created to be able to distill liquids. Using the alembic, Hayyan was able to separate liquids based on their boiling points efficiently. These discoveries were then used and built upon by later alchemists and scientists in both Europe and the Middle East.

While it may seem simple that there is a correlation between atomic structure and properties of a substance, one must acknowledge the ability and initiative of Jabir to break from the paradigm of mysticism in the pursuit of meaning behind characteristics of chemicals and metals (Nummedal, 2011). He has been credited with saying, "The first essential in chemistry is that you should perform practical work and conduct experiments, for he who performs not practical work nor makes experiments will never attain the least degree of mastery." Upon reading this quote, one can see just how similarly that quote resembles the scientific method: a technique used for developing and testing scientific theories. This method is in an important component of many scientific experiments both past and present, and helps to ensure a cogent hypothesis is formed. Even though this method is believed to have been formed in the mid-1800s, it is clear that Hayyan's techniques to ensure experiments can be both repeatable and systematic has helped to lay the base of the scientific method centuries earlier.

5.4 Alchemy

At the time of Hayyan's studies, alchemists were still using the Aristotelian elements of hotness, coldness, dryness and moistness. Hayyan took these elements one step further to declare that two of these elements are inside the material, while the other two are the elements that are shown. In this sense, each material has all four elements, just some are showing while others are not. As an alchemist, one of Hayyan's goals was to find a way to chemically turn base metals like lead or mercury into 'noble' metals like gold and silver. Hayyan hypothesized that there was a substance that could react with the lead and switch its elements so that it became gold. This theory was the basis for the philosophers' stone. The philosophers stone was thought to be a stone or material that could turn many materials to gold, heal any illness, and even prolong someone's life if they ingested a small portion of it (Nummedal, 2011). The philosophers' stone became the focus of many later alchemists, who would go on to spend their lives in search of this evasive substance (Burckhardt and Stoddart, 1997).

While the Philosophers' stone was a pseudo-scientific concept, the search for it would ultimately contribute greatly to our understanding of chemistry. One of the fundamental principles of the philosophers' stone was the ability to transmute one substance into another. The pursuit of this concept would go on to yield substantial discoveries in the field of physical chemistry. Believed to be key to unravelling the mystery of the philosophers' stone was the study of the way in which materials changed from one form to another. Observations of this process yielded new insight on chemical processes observed in nature, and the way specific materials could be combined and extracted.

6 Wernher von Braun (1912-1977)

A Prodigy of Rocket Science

By Sampurna Basu, Alexandra Laleva, Natasha Thompson, and Luke Foster

It is a controversial fact that the American space program, National Aeronautics and Space Administration (NASA), was supported by the contributions of a former Nazi SS officer, Wernher von Braun, a prodigy of rocket science. In addition to leading a team of intelligent German scientists in developing the first long-range ballistic missile, many condemn von Braun for his alleged aid in a large part of the slave labor of World War II (WWII)'s concentration camps. After speculation that von Braun was unfaithful to the Nazis and had a different ideology from the expected, he moved on to America where he led a team of NASA scientists in designing the Saturn V Rocket Vehicle that ultimately Apollo astronauts took to the moon. Despite his significant contributions to the most revolutionary piece of rocketry, historians continue to debate whether he was simply a political scientist who was limited by his choices of where to excel at a relatively young age: basically, to work under Adolf Hitler or to postpone his research indefinitely. Comparatively, others debate over the belief that he was a cunning opportunist who knowingly made a bargain with the 'devil' that lead the prolific World War II in order to pursue his own research and potentially create more prosperous opportunities in the future.

6.1 Early Strengths in Science

Baron Wernher Magnus Maximillian von Braun was born on March 23, 1912, to a wealthy, aristocratic Prussian family. The von Brauns belonged to a class of nobles who were not only a significant part of the Prussian military officer corps but also held a place in the office of civil services in the 19th and early 20th centuries. Being raised in a privileged and entitled environment ensured von Braun a certain quality of life that shaped him into a proud and cavalier young man (Garza, 2019).

Wernher von Braun became passionate about the idea and possibilities of space travel at the young age of thirteen when his mother gifted him a telescope for his birthday. Upon looking up at the moon and stars he was filled with aspirations and desire to travel into space and explore what lies beyond (Teitel, 2013). This obsession with spaceflight enhanced furthermore when he began reading Hermann Oberth's Die Rakete zu den Planetenrumen *Die Rakete zu den Planetenrumen* (*The Rocket into Interplanetary Space*), which fuelled his interest in subjects such as physics and mathematics, perpetually helping him understand the fundamentals of rocketry. Brilliant as he was in these subjects, it distracted him from his other subjects. His grades in these other subjects were only satisfactory, which was not proper in relation with his upbringing; however, he still managed to advance his studies and graduate high school a year early (Teitel, 2013).

In the late 1920s, von Braun joined the Berlin Institute of

Technology to study mechanical engineering. During that time, alongside other spaceflight enthusiasts just like himself, he launched primitive rockets located in an ammunition dump in suburban Berlin. Completing his undergraduate studies in 1932, von Braun was eager to further his knowledge on rocketry, so he enrolled in the University of Berlin to study physics. Thereafter, Germany had a drastic change when Adolf Hitler came to power in 1933. Von Braun had already caught Hitler's attention with his involvement in the ammunition dump testing, and further, he caught the attention of the German army (Garza, 2019). After university, von Braun went on to become the top civilian specialist at the Kummersdorf rocket station of the German Army, located south of Berlin. At the time von Braun was 21 and only partially aware of the changes he was beginning to help cause nationwide (Garza, 2019). He received his doctorate degree in Physics in 1934 at the age of 22 and joined the German army as a full civilian employee. While younger than most of his colleagues, von Braun was highly intelligent and was appointed to lead a team of scientists. By the following year, in 1935, he had successfully launched two rockets using liquid fuelled engines and thereby introducing the basis for modern spaceflight.

6.2 A Passion for Spaceflight, Resulting in Deadly Weapons

It was unheard of, at that time in Germany for anyone at the tender age of 25, to be in such an authoritative position as von Braun was. This paradox of a bold, starry-eyed, space cadet was one of the most ultra-conservative of engineers to exist. Von Braun's team looked up to another father of engineering and rocket propulsion, Robert Goddard. Goddard was responsible for building the very first liquid-fuelled rocket. Von Braun's team of dynamic students enhanced the engines of the rocket, which dramatically increased the power for the system, thus designing a larger and more powerful version of Goddard's rockets. Additionally, the team substituted a combination of alcohol and oxygen for the original gasoline as the rocket's main propellant. A significant amount of power from his design came from two turbo pump turbines that moved large volumes of fuel into the combustion chamber at high speeds every second. This design could thrust more than 25,000 kilograms, far more than Goddard's design could achieve (Hollingham, 2014).

6.3 Personal Conflict between War Efforts and Dedication to Engineering

Engineering is the science of human innovation and therefore cannot be performed in a vacuum; the human element intertwined with the quest for progress ultimately complicates the pursuit of it. The question of von Braun's loyalty was posed throughout his career by the many environments he found himself in. Up until the Spring of 1940, von Braun was able to avoid directly involving himself with the Nazi Party, but it eventually became unavoidable.

In 1937 he became the technical director of a new research centre on the northwest coast of Germany in the town of Peenemünde. This allowed him to continue to evolve his rocket designs, but their application outside of the facility was out of his control. However, the distance between his work and its application was shrinking and in April of 1940 von Braun was asked by Heinrich Himmler to join the SS. Initially he stated that he was too busy with work to become involved with politics and in his 1947 affidavit, it states he stalled for time to receive counsel from his superior, Col. Walter Dornberger; Dornberger insisted that he join to protect the program. Regardless of his displeasure to involve himself in the political spheres of the time, it is argued that this does not absolve him. The use of slave labour at the facility in Peenemünde was instrumental to the progress of the V-2 program.

Von Braun was aware that the facility was built using slave labour but was not directly involved with this decision. A letter to the Ministry of Armaments does however implicate him in the decision to use slave labour but does not prove it was his idea. He witnessed the horrific conditions of the Dora concentration camp which was located close to the facility but later remarked that he had no ability to help. Overall it is estimated that 3,000 people died from V-2 attacks compared to the 30,000 succumbing to the working conditions of the rocket production. There is no record of von Braun's interest in the fate of the workers, nor did the Gestapo or SS accuse of him of sympathizing when he was arrested in 1943. The primary reason for his arrest was revenge from Himmler for not aiding him in supplanting the army as overseers of the V-2 program. His recognition of this corruption plaguing the regime ultimately proved a real asset to his anti-Nazi image after the war (Neufeld, 2002).

6.4 Operation Paperclip and Pursuing Space

During a carefully orchestrated mission known as operation paperclip, von Braun and his team were taken from Germany to the US, along with other German scientists, engineers, and technicians. Von Braun was given the opportunity to demonstrate his weapon to the US army in New Mexico and was later transferred to Huntsville Alabama, eventually becoming the director of NASA's Marshall Space Flight Center. Even after fifteen years of working for the army, von Braun did not forget his original dream concerning rocketry, to send his design into space. Finally, in 1960 he received his chance to shoot for the stars; his team was assigned to the newly formed NASA. It was during this time that he developed the Saturn V Rocket. This famous rocket was used to send Neil Armstrong and Buzz Aldrin to the moon for the Apollo 11 mission.

The Saturn V was not only an incredible tool, but it divided the work of spaceflight into an elegant three stage system. The propulsion consisted of five separate engines, with four outer engines to control the direction of the rocket and a central engine to provide extra thrust. About 68 kilometers into the atmosphere, the first section would separate, and the second section would fire to carry the spacecraft to the edge of orbit. There, the second section would detach, and the third section would push the craft into orbit and to the moon. The design continues to be the most powerful single chamber liquid-fuelled rocket ever created. Von Braun went on to rise through the ranks of NASA and worked for multiple aerospace companies, and he was eventually awarded the National Medal of Science, not long before his death in 1977.

6.5 The Value of Testing

Even though Wernher von Braun tried to pursue a new life and focus on his skills of engineering in America, the burden of his war contributions never left him. In an interview, von Braun once said, "one good test is worth a thousand expert opinions." Von Braun was able to apply this philosophy, which originally referred to rocket tests, to his own life when considering the valuable experiences gained through the application of different hobbies and professions. Testing key ideas is an aspect often neglected in academic and professional projects; it is often tempting to reduce the testing phase, and rather rely on the opinions of team members and outside help. However, von Braun stressed that anyone can speculate what the result will be; it is often only a matter of opinion until the phenomenon is tested. Excelling from a young age in math and physics, to being forced to support unrealistic efforts and complete testing under constrained means, Wernher von Braun's contributions to society has greatly influenced rocket science through the first and most well-known piece of rocketry to enter space to this day.

6.6 Legacy and Reflection

Many contend that von Braun's passion was building rockets for the exploration of space. However, when the Nazis came to power in Germany this vision became blurred with political influence. His involvement with the Nazi Party is a stain on an otherwise successful engineering career and a reminder of the complexity of innovation. Wernher von Braun's work at NASA inspired an entire nation to achieve the unthinkable. Von

Braun never truly escaped his past and stands as an example of the close ties of engineering and ethics. Whether you consider him a villain, a visionary, or both, there is no disputing of his legacy, as von Braun turned the dreams of early 20th century rocket science, into reality. He once said “My friends, there was dancing here in the streets... when our first satellite orbited the earth, and there was dancing again when the first Americans landed on the moon, I would like to ask you, don’t hang up your dancing slippers.”

7 List of Contributions

Amir A. Aliabadi received his bachelor's and master's degrees in Mechanical Engineering, in 2006 and 2008 respectively, from University of Toronto, Toronto, Canada, and his doctoral degree in Mechanical Engineering in 2013 from University of British Columbia, Vancouver, Canada. He is an assistant professor of engineering in the Environmental Engineering program at the University of Guelph, Canada. He is specialized in applications of thermo-fluids in buildings and the environment. Prior to this position he was a visiting research fellow at Air Quality Research Division, Environment and Climate Change Canada from 2013 to 2015 in Toronto, Canada, and a research associate in Department of Architecture at the Massachusetts Institute of Technology (MIT) from 2015 to 2016 in Cambridge, U.S.A.

Reza Aliabadi graduated from University of Tehran, Tehran, Iran, in 1999 with a master's in Architecture, and founded the "Reza Aliabadi Building Workshop". After completing a post-professional master's of Architecture at McGill University, Montreal, Canada, in 2006 and obtaining the OAA license in 2010, the workshop was reestablished in Toronto as atelier Reza Aliabadi "rzlbd". He has established a strong reputation in both national and international architectural communities. Local and global media have published many of rzlbd's projects. He has been invited to install in Toronto Harbourfront Centre, sit at peer assessment committee of Canada Council for the Art, speak at CBC Radio, give lectures at art and architecture schools and colleges, be a guest reviewer at design studios, and mentor a handful of talented interns in the Greater Toronto Area. He also had a teaching position at the School of Fine Arts at the University of Tehran and was a guest lecturer in the doctoral program at the same university. Artifice has recently published Reza's first monograph "rzlbd hopscotch". He maintains an ongoing interest in architectural research in areas such as microarchitecture, housing ideas for the future, and other dimensions of urbanism such as compactness and intensification. Beside his architectural practice, Reza also publishes a periodical zine called rzlbdPOST.

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