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How Spaceflight was Born

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The pioneers and the ideas - from Peenemunde to the Jet Propulsion Laboratory.

Introduction

The initial movers and shakers who spirited manned and unmanned spacecraft into earth orbit, to the Moon and to the planets and beyond had a common characteristic. As adolescents each read science fiction books or viewed science fiction movies dealing with spaceflight and became inspired by its theme. They followed their dream and for the rest of their lives pursued technical endeavors advancing the cause of spaceflight.

They were visionaries with creative powers and technical prowess that moved them toward their goals. They were high achievers in science and math early on in school. The space pioneers harnessed their enormous enthusiasm and imagination to combine science and engineering at a high level. They worked relentlessly to produce innovations in the many technology disciplines required for spaceflight. Their love and enthusiasm for what they were doing drove them. Each shared this love with everyone around them. Their enthusiasm was contagious and continually created excitement around their work and the path to spaceflight was born.

Many engineers and scientists helped along the way contributing significant advances to eventually achieve spaceflight. Five have been considered key to creating technical breakthroughs coupled with generating a high level of excitement that helped the public become involved and to support public funding of space programs. Spanning three generations of accomplishments from 1923 to 1969, the most influential pioneers were: Goddard, Oberth, von Braun, Ehricke and Lally. Their burning desire or calling to achieve spaceflight inspired and drove them toward their dream. They spent their lives intoxicated primarily by their space work.

Goddard and Oberth were the first generation with von Braun and Ehricke second generation and Lally third. Goddard performed his work in America. Oberth, von Braun and Ehricke were German and combined their initial work in the German era of rocketry during World War II. The Germans chose to go to America not Russia after the war where they continued their work for the remainder of their lives. Lally an American emerged after World War II with fresh and innovative technical ideas for manned and unmanned space missions and related technical disciplines.

Their excitement and dreams frequently had to be internalized for long periods so their dreams did not get ahead of reality and hardware development, lest they be branded as out of touch or misguided. Each had their own frustrating trial periods before their accomplishments caught up to their imaginations at which time they could openly present their ideas without criticism.

The period between Russia's Sputnik first earth satellite launch (1957) to America's first Apollo manned landing on the Moon (1969) found Americans full of pride and consumed with interest in space. President Kennedy laid down the challenge to land men on the Moon and the elated environment in the country was likened to Camelot.

If you worked in the space business you were admired by the public and cheered on to reach exciting goals. The space pioneers discussed here were especially revered after Sputnik and constantly sought after to lecture and write about space. The country was in a euphoric state and of one mind during this period, united in purpose to beat Russia to the Moon to be followed by continued space exploration of the planets and beyond. It was a sweet spot in the history of America that may not be duplicated.

The following includes biographies of the five pioneers and how their path's crossed. Also presented is a timeline of related events: historical, World War II, post World War II, Cold War, post Sputnik and early spaceflight missions up to the first manned landing on the Moon. These events led to their dreams becoming reality and to the birth of spaceflight.

Biographies (Ref. 1)

Robert H. Goddard October 5, 1882 - August 10, 1945

Goddard was born in Worchester, Massachusetts. When his father showed him how to generate static electricity on the family carpet, the five-year-old's imagination was ignited. He developed a fascination with flight from kites and balloons. His interests merged at age 16 (1899) when he constructed a balloon using light weight aluminum for structure of the gondola that did not perform as he expected. After five weeks of hard work he abandoned the project but this first of many failures did not restrain his growing determination and enthusiasm of his goals.

The same year he read H.G. Wells's science fiction classic, "The War of the Worlds" and became interested in space. On October 19, 1899 at age 17 while climbing a cherry tree to cut off dead limbs he imagined, "How wonderful it would be to make some device which had even the possibility of ascending to Mars, and how it would look on a small scale, if sent up from the meadow at my feet". His dedication to pursuing rocketry became fixed that day and for the rest of his life he observed October 19 as "Anniversary Day", a private commemoration of the day of his greatest inspiration. From the very earliest he kept detailed journals to record his ideas, observations and comments.

A thin and frail boy, almost always in fragile health from tuberculosis, Goddard fell two years behind his school classmates. He became a voracious reader of library books on the physical sciences. Later he continued his formal schooling as an 18-year-old sophomore at South High School in Worcester, Massachusetts. His peers twice elected him class president. At the graduation ceremony in 1904, he gave his class oration as valedictorian. In his speech, Goddard included a phrase that would become emblematic of his life, “It has often proved true that the dream of yesterday is the hope of today and the reality of tomorrow”. He enrolled at Worcester Polytechnic Institute that fall and quickly impressed the head of the physics department who took him on as a laboratory assistant and tutor.

While still an undergraduate Goddard wrote a paper published in Scientific American about stabilizing aircraft in flight at the time breakthroughs in gyroscopes began. He graduated in 1908 and enrolled at Clark University where he received his M.A. and PhD in 1911.

His first writings on the possibilities of a liquid-fueled rocket came in February 1909. Goddard had begun to study ways of increasing a rocket’s energy efficiency using alternative methods from conventional powder or solid rockets. He wrote in his journal about an idea of using liquid hydrogen as a fuel with liquid oxygen as the oxidizer. In 1914 his first two landmark patents were issued, one describing a multi-stage rocket and the other fueling rocket engines with gasoline and liquid nitrous oxide. These patents became milestones in the history of rocketry. He followed by experimenting with ion thrusters which he envisioned could be used for propulsion at near vacuum conditions at high altitudes. By 1916 he was able to receive financial assistance from the Smithsonian Institute to help with his rocket research.

Goddard had many side interests unlike the German scientists to follow who concentrated on rocketry. Goddard like Lally, the other noted American who came later, had other productive peripheral interests. For example Goddard received a patent for a vacuum tube that operated like a cathode-ray tube. This was the first use of a vacuum tube to amplify a signal which marked the beginning of the electronic age. In 1916 he developed the idea of the bazooka rocket weapon that years later in World War II became the weapon of choice against armored vehicles.

In 1919 the Smithsonian Institute published Goddard’s groundbreaking book, “A Method of Reaching Extreme Altitudes”. It described his mathematical theories of rocket flight and his experiments with solid-fueled rocket engines burning high grade nitrocellulose “smokeless” powder. A critical breakthrough was the use of the steam turbine nozzle. This nozzle allowed the most efficient conversion of the energy of hot gases into forward motion. Using this nozzle he increased the efficiency of his rocket engine from 2% to 64% and obtained supersonic exhaust speeds of over Mach 7. This greatly reduced the amount of rocket fuel required to lift a given mass and thus made interplanetary travel feasible and not a fantasy. Modern rocketry was born.

His work attracted world wide attention and was both praised and ridiculed because it suggested a rocket theoretically could reach the Moon. He received scathing criticism in the press and began working in isolation to avoid publicity and became suspicious of others.

The New York Times was especially mocking of his work as were much of the media and other scientists. All of the five pioneers of spaceflight went through similar periods in their lives. The Times added more scorn saying, “after the rocket quits our air and really starts on its longer journey it will neither be accelerated nor maintained by the explosion of the charges it then might have left. To claim that would be to deny a fundamental law of dynamics, and only Dr. Einstein and his chosen few are licensed to do that". The Times also stated ….. Goddard, "only seems to lack the knowledge ladled out daily in high schools." Forty nine years afterwards, on July 17, 1969 the day after the launch of Apollo 11 to the Moon, the New York Times printed a short retraction of its 1920 editorial, "Further investigation and experimentation have confirmed the findings of Isaac Newton in the 17th century and it is now definitely established that a rocket can function in a vacuum as well as in an atmosphere. The Times regrets the error".

Goddard began experimenting with liquid-fueled rockets in September 1921. He bench tested his first engine in November 1923. The first launch of a liquid fueled rocket was March 16, 1926 in Auburn, Massachusetts. Goddard's engine used gasoline for fuel and liquid oxygen (LOX) for the oxidizer. His journal entry was an understatement: "The first flight of a rocket using liquid propellants was made yesterday at Aunt Effie's farm." The exact launch site is now a National Historic Landmark, the Goddard Rocket Launching Site, on the Pakochoag Golf Course between the first and ninth holes.

His first rocket dubbed "Nell" rose just 41 feet during a 2.5 second flight that ended in a cabbage field. The rocket burned 20 seconds before it burned off enough weight to equal the engine's thrust and lifted-off. His wife was using a movie camera but it ran out of film before the lift-off so no visible record is available of this historic event. This launch gained national attention and Charles Lindbergh took notice and looking past his aviation accomplishments met with Goddard. They immediately hit it off. Goddard was open with and trusted Lindbergh and they were friends the rest of his life. The stock market crash made it difficult for Lindbergh to help find backers for Goddard but eventually convinced the Guggenheim family to help out.

Goddard moved to Roswell, New Mexico in the 30's unrelated to the later alleged flying saucer crash there in 1947. He worked in near seclusion for years and developed gasoline and liquid oxygen engines pressurized with nitrogen and added a gyroscopic control system. In 1935 his A-5 successfully flew to 1.45 km altitude using his guidance system and achieved supersonic velocity.

In 1936 Goddard was visited by Frank Malina who was studying rocketry at the California Institute of Technology (Caltech). Goddard refused to discuss his work beyond what had been published. This secrecy troubled Theodore von Karman who was Malina's mentor. By 1939 von Karman's Guggenheim Aeronautical Laboratory at Caltech had received Army Air Corps funding to develop rockets to assist in aircraft take-off called Jet Assisted Take-Off (JATO). Within this framework, Aerojet Corp. a private company and the Jet Propulsion Laboratory managed by the California Institute of Technology were founded.

From 1940-1941 Goddard developed propellant turbo pumps for gasoline and LOX engines. He brought his work to the attention of the Army but was rebuffed as the Army failed to grasp the military application of rockets at the time. German intelligence kept an eye on Goddard's work and the spy Gustav Guellich gathered facts. In Nazi Germany von Braun took Goddard's plans from various published journals and with Guellich's reports incorporated the information to help design early prototypes of the V-2. After the Army declined Goddard's offer to develop rockets for them he gave up his rocket research to work on experimental aircraft for the U.S. Navy during World War II.

After the war ended Goddard was able to inspect captured German V-2s, many components of which he recognized from his own designs. Von Braun also stated that Goddard's early work was helpful in his development work in Germany of the V-2.

Hermann Oberth June 25, 1894 – December 28, 1989

Oberth was born in the Transylvanian city of Sighisoara, Romania to a Saxon family. Around the age of 11 he became fascinated with spaceflight through the writings of Jules Verne's, "From the Earth to the Moon" and "Around the Moon", rereading the books to the point of memorization. He constructed a model rocket as a student when 14 and conceived a multistage rocket.

He was drafted during World War I into a German infantry battalion and in 1915 was reassigned to a medical unit in a hospital where he conducted experiments concerning weightlessness. He later resumed his rocket designs. In 1919 after the war he moved to Germany to study physics. In 1922 his doctoral dissertation, "By Rocket into Planetary Space", was rejected as "utopian". He privately published it in 1923 and expanded the work to, "Ways to Spaceflight".

In 1929 Oberth became a scientific consultant in Berlin on the first movie to film scenes set in space, "The Woman in the Moon". His main task was to build and launch a rocket as a publicity stunt before the movie's premiere. He was teaching at the Technical University of Berlin and his students, one who was Wernher von Braun, helped with the rocket.

Oberth went to Peenemunde in 1941 to work for his ex-student von Braun then director of the rocket development center. Oberth worked on the V-2 and was awarded the War Merit Cross for courageous behavior during an Allied bombing on the center. He also worked on solid propellant anti-aircraft rockets at a different location.

After World War II, Oberth moved to Switzerland working as a consultant and writer. In 1953 he returned to Germany to publish his book, "Man in Space" in which he described his ideas for a space station, space suits and a space-based reflecting telescope.

In America he again joined his student at Huntsville, Alabama where von Baun was head of NASA's Marshall Space Flight Center. Oberth returned to Germany in 1958 where he published his ideas about a lunar exploration vehicle. In 1960 in the United States again, he went to work at Convair in San Diego where Krafft Ehricke also from the original Peenemunde team had settled in 1954. Oberth worked as a technical consultant on the Atlas rocket at Convair.

Oberth retired in 1962 at age 68. From 1965 to 1967 he was a member of the far right German National Democratic Party. In 1969 he returned to the U. S. to witness the launch of Saturn V that carried the Apollo crew to the first Moon landing. The 1973 energy crisis inspired Oberth to look at alternative energy sources including a plan for a wind power station utilizing the jet stream.

Oberth died in Nuremberg, Germany, December 28, 1989 at age 95.

Wernher von Braun March 23, 1912 – June 16, 1977

Born in Wirsitz, Province of Posen, German Empire. His father was minister of Agriculture in the Federal Cabinet during the Weimar Republic. Upon Lutheran confirmation his mother of medieval European royalty gave him a telescope and he became interested in astronomy and outer space. When Wirsitz was ceded to Poland in 1918 the family moved to Berlin.

At age 12, inspired by Fritz von Opel's rocket-powered race car, he fired off a toy wagon to which he attached a cluster of fireworks in a crowded street. He was taken into custody by police until his father came to collect him.

He did not do well in physics and math until he read Hermann Oberth's book, "The Rocket into Interplanetary Space". Space travel then became his inspiration and he applied himself to his studies to pursue his interest in rocketry. In 1929 he attended the Technical University of Berlin where Oberth taught and assisted in liquid-fueled rocket motor tests.

When Hitler came into power, rocketry soon became a national priority. Von Braun and his liquid propellant work were paired up with Walter Dornberger an expert in solid-fuel rocketry. They became highly interested in the American physicist Robert H. Goddard's liquid-fueled rocket work and contacted him directly. Goddard was uncooperative and referred them to his published papers. Von Braun used Goddard's plans from various public journals and incorporated them into the V-2.

A large facility was constructed at the village of Peenemunde in Northern Germany on the Baltic Sea to develop and test rockets. Dornberger became the military commander of Peenemunde with von Braun the technical director. In collaboration with the Luftwaffe, the German military air force, the Peenemunde group developed liquid fueled rocket engines for aircraft and jet-assisted takeoffs and developed the long range V-2 ballistic missile and the supersonic Wasserfall anti-aircraft missile. The V-2 used liquid oxygen as the oxidizer and an alcohol water mixture as the fuel.

After von Braun became technical director of the rocket center he was forced to join the National Socialist Party in 1937 and the SS in 1940. His refusal to join would have meant abandonment of his life's work he claimed. His memberships did not involve any political activities. This claim has been disputed as historical time lines note the SS had no interest in Peenemunde until after 1940.

On December 22, 1942, Adolf Hitler approved production of the V-2 as a "vengeance weapon" to target London. Toward the end of the war the V-2 was used against England and flew ballistic over the channel with inertial guidance along with the air breathing V-1 Buzz bombs, the first cruise missile. Both brought terror and death to the English and to other parts of Europe.

In March 1944, von Braun's loyalty to the Party was questioned and he was placed in a Gestapo cell for two weeks. He was a pilot with a government-provided airplane that could allow him to escape to England. He was released being deemed indispensible to continue his work on the V-2. Near the end of the war in the spring of 1945 with the

Soviet Army approaching Peenemunde, von Braun and his team decided it better to surrender to the Americans than the Soviets know for their cruelty to prisoners of war. On May 2, 1945 finding an American private on a bicycle, von Braun's brother approached the soldier and said, "My brother invented the V-2. We want to surrender".

The paper work the Americans used listing the German scientists had a paper clip on the pages of preferred scientists. The operation of selecting and sending them to America became known as Operation Paperclip. After several stops in the U.S. the selected group was transferred to their new home at Fort Bliss, Texas near White Sands Proving Grounds, New Mexico. Von Braun worked for the Army for fifteen years after World War II. While at Fort Bliss, von Braun and his staff trained military, industrial and university personnel in the design and operation of rockets and guided missiles. They also refurbished and launched a number of V-2s shipped from Germany to White Sands. Von Braun kept his interest in space travel alive and in 1948 coauthored "The Mars Project" with Krafft Ehricke a bright young rocket engineer also from the Peenemunde group.

In 1950 von Braun's team was transferred to the Redstone Arsenal in Huntsville, Alabama at the start of the Korean War. He worked there for 20 years as director. Between 1950 and 1956 he led the Army rocket development team. The Redstone Rocket developed there was used as the first nuclear ballistic missile test launch vehicle. Von Braun's early years in America were frustrating as the U. S. government was not much interested in his work and only provided low funding levels, while the Soviet Union plowed ahead with advanced rocket designs and the Sputnik program.

Von Braun and his team also developed the Jupiter-C, a modified Redstone Rocket which launched the Jet Propulsion Laboratory's Explorer 1 on January 31, 1957, United States' first man-made satellite that went into earth orbit four months after Russia's Sputnik.

While working the military side of rocketry where the funding was, as was the case in Germany, he continued his dream of rockets used for space exploration. In 1952 he first published his concept of a manned space station orbiting the earth in a series in Collier's Weekly magazine. The articles were beautifully illustrated by the space artist Chesley Bonestell. The articles and the artistry were influential in spreading ideas and public interest in spaceflight began to build.

Von Braun's proposed earth orbiting space station would be a toroid structure spinning around a docking hub to provide artificial gravity for the manned crew. Eugene F. Lally of the Jet Propulsion Laboratory later simplified the concept and reduced the cost. He employed two rotating spacecraft modules connected by a cable to simulate gravity for a manned crew. This concept was presented in Lally's paper "To Spin or Not to Spin" and was applied to manned Mars missions.

Von Braun became director of NASA's Marshall Space Flight Center which replaced the Redstone Arsenal. He was the chief architect of the Saturn V launch vehicle that propelled the Apollo spacecraft to the Moon fulfilling his life long dream.

Wernher von Braun died June 16, 1977.

Krafft A. Ehricke March 24, 1917 – December 11, 1984

Ehricke was born in Berlin, Germany. His father Arnold was a professor of dentistry and a medical doctor with a practice in dentistry and oral surgery. His mother Ruth was also a practicing dentist and oral surgeon in Germany and later, after the war, in Boston, Massachusetts. She is listed in Women of Achievement in the World. Her father, a Lutheran clergyman, was a chess champion of Germany. Krafft's parents divorced and he was brought up by his mother and saw his father on a regular basis.

He became a space enthusiast at age twelve when he was captivated by the movie "The Woman in the Moon" that Hermann Oberth consulted on for the space scenes in 1929. He watched the movie eleven times. Ehricke appreciated the technical detail that Oberth provided to make the movie realistic. He became fascinated looking at stars and planets through a telescope and studied the heavens. He gave lectures on the balcony of his mother's home with patients and friends attending. He then began giving lectures at the Berlin Observatory and gained a reputation of being a knowledgeable astronomer. He also founded a rocket society at that young age. His father was not pleased at his son's interest in space, calling him a dreamer and telling him to get his feet on the ground and go into dentistry. His mother on the other hand was supportive of her son's interests and encouraged him to continue and was a reassuring influence. (Ref. 2)

From this beginning Ehricke went on to became world famous for his contributions and his profound understanding of both the technology and philosophical meaning of space development.

Young Krafft was advanced in mathematics and physics going beyond what his school offered by finding outside help. He became acquainted with Russian work on proposed space rockets using hydrogen-oxygen. He also tracked Oberth's writings in his early teens. Ehricke graduated from Technical University in Berlin as an aeronautical engineer and did post graduate work in celestial mechanics and nuclear physics.

During World War II he was conscripted into the German army and sent to the western front. Later he served as a Panzer tank commander on the Russian front. He was wounded twice; the second time a Molotov cocktail was thrown into his tank. He was burned but climbed out and made his way toward the German lines where he collapsed, was found and then treated there. Later he was sent to Berlin for recovery. Walter Dornberger, military commander of Peenemunde happened to have Krafft's father for his dentist. During a dental appointment he learned that Krafft had been released from the hospital and was home on a rest leave. Dornberger knew of Krafft's technical background and made arrangements for him to go to Peenemunde in June 1942 to use his extraordinary technical skills on the rocket design work there. At that time his father began to understand his son's capabilities and worth to Germany.

Ehricke came under the strong influence at Peenemunde of Walter Thiel who was in charge of rocket development. Thiel shared Ehricke's desire to look beyond the work there and toward future possibilities in space and drew plans for testing rockets larger than any dreamed of. He talked Ehricke into resuming his earlier background and experiments with liquid hydrogen.

Experiments elsewhere in Germany with nuclear reactors using heavy water to power a steam turbine excited Thiel and he urged Ehricke to study the possibilities of using nuclear energy for rocket propulsion. They both concluded hydrogen as the best working fluid and believed it was the rocket fuel of the future. Theil was killed in the first British air raid on Peenemunde, August 1943. Ehricke continued on with their advanced work alone and with the primary work for von Braun on the V-2 rocket.

As the war was ending Ehricke helped move Peenemunde records into Bavaria to keep them out of Russian hands. He made his way to Berlin on foot where he found his wife and went into hiding until the Allies moved in. One day his wife Ingeborg answered the door and routinely said, "I don't know where he is." As she spoke, she recognized the insignia of a U.S. Army officer and immediately began screaming, "He's here! Krafft is here!" Ehricke was given a contract by the U.S. Army and sent to the United States to rejoin the von Braun team as part of Operation Paperclip.

In 1950 Ehricke moved with von Braun to Huntsville, Alabama, the Army's rocket development center but grew restless with both the climate and von Braun's conservative engineering. He then joined his old friend Walter Dornberger from Peenemunde at Bell Aircraft in 1952. Bell located in Buffalo, New York, was busy developing the Agena upper stage also proved unable to offer Ehricke the right environment for the breakthrough he was looking for.

K.J. Bossart, father of the Atlas ICBM at Convair in San Diego, California, convinced Ehricke in 1954 to come work on the new missile. While this also would be limiting to Ehricke's imagination, Bossart like Walter Theil at Peenemunde, encouraged Ehricke to think beyond the Atlas. Ehricke knew the Atlas missile could be used as a first stage launch vehicle for space exploration. To imaginative Ehricke, Bossart's attitude and kindred spirit plus living in Southern California were the beginning of a beautiful relationship and the start of his most productive years.

By 1956 Ehricke was conducting in-house studies of launch vehicles required for orbiting satellites. Space continued to be out of favor and he found few supporters in the various government agencies and military services. On the Monday following Sputnik's October 1957 flight, all the nay-sayers changed their minds and suddenly favored spaceflight and sought him out. The space race with Russia began.

Energized by the new interest, Ehricke contacted companies and government agencies to firm up a new rocket stage using liquid hydrogen and liquid oxygen. After six months, Convair now called General Dynamics Astronautics, was brought together with Pratt & Whitney by the Air Force and the Advanced Research Projects Agency (ARPA) to proceed with the development of Ehricke's Centaur stage, the first to use liquid hydrogen and liquid oxygen. Pratt & Whitney had been working on a secret contract for a new turbine driven pump that would fit into Ehricke's design of the Centaur stage. Ehricke also collaborated with the Jet Propulsion Laboratory where advances in liquid propellant rockets were on going.

The Centaur upper stage over decades of use made possible unmanned spacecraft probes with payloads managed by the Jet Propulsion Laboratory to reach across the solar system. They yielded our first detailed information about our neighboring planets.

During the 70s Ehricke led advanced studies at Rockwell International while working independently on a concept of space industrialization and commercialization. This led to a legacy of studies, designs, writings and paintings describing the colonization of the Moon and development of Earth-Moon space.

Perhaps his most influential work, currently awaiting translation to English from German – is “The Seventh Continent,” a culmination of decades of rigorous study for industrial development on the Moon. This is considered the zenith of his life’s work and addresses not only the framework for lunar development but also the philosophical impetus for humanity to become a multi-planet species. Ehricke is considered the quintessential philosopher of the space age.

Ehricke saw the exploration of space as based on an “Extraterrestrial Imperative”. For mankind to grow and develop, a new “open world” was needed, not limited to the confines of Earth. He wrote that such an effort was not voluntary, but mandatory because of growing world population and increasing standards of living would require new worlds and resources to explore and exploit. The alternative would be increasing shortages of strategic materials and energy sources, increasing geopolitical conflicts, wars and decreasing standard of living throughout the world.

Ehricke proposed a multi-decade program for lunar development. He described the Moon as earth’s Seventh Continent. Using nuclear fission power on a lunar base and employing the most advanced technologies, industrial activities on the Moon could become more productive than that on the Earth he proposed.

With thriving lunar industries, Ehricke described that mankind would no longer be limited to the resources of his home planet and would create the basis for the next steps in exploration, to Mars. Another book is to be published late 2008 by Marsha Freeman entitled “Krafft Ehricke’s Extraterrestrial Imperative”. It contains his biography and reprints of some of his papers, interviews, articles, space paintings etc.

Eugene Lally who worked with and studied under Ehricke remembered his high level of enthusiastic energy and charming grace. Ehricke’s enthusiasm for space travel was infectious and no one could listen to him speak on the subject without wanting to join the quest. His brilliant mind, warm personality and integrity combined to present a very unique scientist and human being. His contributions to spaceflight were unparalled.
He worked tirelessly until his last moments and was survived by his wife Ingeborg and three daughters who in 1985 founded the nonprofit Krafft A. Ehricke Institute for Space Development in San Diego, California.

The Institute prepared for the reintroduction of his influential works on space exploration and the Moon to the public. Over 60 cartons of material were shipped to the Air & Space Museum in Washington that included Ehricke’s research papers, space paintings and an unpublished novel. It is expected this material will eventually be made available to the public.

Ehricke was buried in space April 21, 1997 on the first such flight, “The Founders Flight”. An aircraft at 38,000 feet above Canary Island launched a modified Pegasus rocket which placed the remains into orbit. The orbit reached an apogee of 578 km (361 miles) and a perigee of 551 km (344 miles) with an orbital period of 96 minutes until reentry on May 20, 2002. Other remains on the flight were Gerald O'Neill space physicist, Gene Roddenberry creator of Star Trek and Timothy Leary writer.

Eugene F. Lally August 14, 1934 –

Lally was born in South Boston, Massachusetts, a rough-and-tumble Irish neighborhood. His father, Thomas, was well along to becoming an architect but left college during the depression to help support his large family of brothers and sisters. He was technically inclined and inquisitive with a bent toward inventing which were passed on to his first son Eugene, born in 1934.

Lally was the innovative space pioneer across all disciplines. He had a knack of coming up with several ideas simultaneously that broadened programs' scope leading to unexpected advances. His ideas would leap into new technical areas ahead of their time. His explosive creativity was admired by his support team to the point of them waiting for his "daily breakthrough" to help further their work. He was fun to work for because you knew every day would lead you into virgin territory of space exploration. His work formed the initial rationale to visit the planets backed by hardware concepts to accomplish the tasks.

He showed interest in technical areas at an early age. His grandmother gave him a Kodak box camera while baby sitting and photography turned into one of his life-long technical love affairs. He took classes in photography at age 8 in the South Boston Boy's Club during World War II. When color film first became available to consumers he modified a camera and solved the new "red eye" problem caused by flash photography. He sent the solution to a photography magazine at age 14 and it was published. The solution of moving the flash and the lens further apart is still the correct fix.

About the same time the South Boston Boy's Club also presented weekly movie shows where he watched the Flash Gordon serials of science fiction space adventures. He became bitten by the rocket and space travel bug. This became his most passionate interest and he launched his course toward the planets at the early age of 10.

He read everything he could find about rockets and space travel and followed German rocket advances during World War II. He was good at math and science and when it came time for college in the early 50s he chose electrical engineering at Northeastern University in Boston. Since there were no classes offered in anything related to rockets and space he felt this major plus a selection of extra class subjects in disciplines he expected to relate to spaceflight would provide a start toward his space exploration interests. In effect he made up a curriculum for his interests that would become a future undergraduate major called Aerospace Engineering.

He lived with his grandfather and aunts for two of his college years as their home was near the university. At one point the aunts phoned his mother and said they were worried about him. He had "strange pictures and art" hanging on the walls of his room of rockets, spaceships and planets. The aunts were troubled by this. His mother told them not to worry as he had something in mind that she assured them would be worthwhile.

Key to his early formation, Lally's parents were completely supportive and full of encouragement with whatever he wanted to explore. This gave him a sense of confidence early in life. He was unusually inquisitive and when very young listened to explanations of questions he asked but would say "How come"? several times to obtain more information. This would annoy some of his uncles and aunts but his patient parents would continue to answer as long as they had something to offer. His mother called him "projects" because he was always working on a new gadget to solve a problem. He was a self-starter continually coming up with an endless stream of new ideas to pursue.

Northeastern University was a co-op college where the students alternately went to school for three months then worked for three months in companies offering experience in their chosen field. Lally requested his work periods be at Fairchild Guided Missiles on Long Island, New York, because they were developing the Petrol missile, a Navy guided winged torpedo, and the Lark, a ground to air missile. He thrived in this environment and wrote his first technical paper as an undergraduate. The paper discussed ion engines to propel a space probe out of the solar system using solar cells to power the engines. He included new guidance and navigation ideas for his long duration solar system escape probe concept.

When he graduated in June 1957 the guided missile business was booming. Large launch vehicle rocket programs however were few but he did visit Martin Aircraft in Baltimore working on the Vanguard rocket. He was not impressed with the program. He received 24 offers for electrical engineering positions and chose Hughes Aircraft in California offering guided missile work hoping to move into the design of large rockets and spaceflight missions when funding became available.

Months after Lally arrived in California, Sputnik was launched by Russia in October 1957 and everything changed. Hughes did not have the work promised so he found a job launching and testing Nike missiles on a test range at Fort Churchill, Hudson Bay, Canada. He also helped there on high altitude rocket launches carrying scientific payloads as it was a test site for the International Geophysical Year. Lally continued post-graduate studies at UCLA to round out background in technical disciplines needed for his spaceflight mission designs.

He admired Krafft Ehricke's accomplishments and space mission concepts from boyhood and wanted to work with him. After publishing additional space exploratory mission concept papers Lally was hired by General Dynamics Astronautics in San Diego where Ehricke worked. The Atlas was moving through the development phase there as a long range intercontinental ballistic missile for the Air Force. Lally was assigned to compile rocket and guidance system hardware failure modes and was involved with launches at Cape Canaveral, Florida and Vandenberg Air Force Base in California. At that same time NASA's Man in Orbit program selected the Atlas to launch the Mercury astronauts. He was assigned to this program to design a system to signal the abort rocket to separate the manned capsule from the Atlas booster should it show signs of in-flight rocket or guidance and control safety problems.

Initial Atlas test launches for the Mercury program developed a concern because the manned capsule was considerably different in shape configuration from the nuclear war heads that the Atlas structure was designed to carry. Lally contacted Nikon to obtain a lens for a high-speed tracking movie camera to capture any structural failure on film of the test launch. The test flight exploded at high altitude as the different shape and weight distribution of the dummy Mercury capsule overstressed the thin stainless steel structural skin of the Atlas. The film captured the failure locating where on the outer structure the weakest point ruptured so that a fix could be designed into the structure.

Lally was teamed with “Deke” Slayton one of the original seven NASA Mercury astronauts to work out the details of the abort process during the launch phase and the landing sequence upon return from orbit and splash down. John Glenn later made the first orbital flight for the United States on the Atlas to help catch up with the Russian Yuri A. Garganin’s first manned orbital flight a year earlier.

Lally’s rocket guidance and navigation work resulted in his appointment to the American Rocket Society’s newly formed Guidance and Navigation Committee. Included on the committee with Lally were: Charles Stark Draper head of MIT’s Instrumentation Laboratory, plus the director of Northrop’s Inertial Guidance Division and also a former Peenemunde inertial navigation specialist. Lally was the youngster on the committee.

Ehricke was completing his book, “Space Flight” that became the premier reference book for orbital mechanics. The information in this book when combined with rocket engine performance specs could determine conceptual mission designs for earth orbiting, lunar and planetary missions. Ehricke felt Lally had his same unique enthusiasm and creative spark and a calling for space concepts. Ehricke taught Lally celestial mechanics and they became lifelong friends.

General Dynamics Astronautics won one of the studies for President Kennedy’s Man to the Moon program. Lally worked the guidance and navigation discipline of the study which half way through was named the “Apollo Program”. At that time Lally also thought further out and published papers about manned Mars missions with simulated gravity for the long duration. He also began working on an optical guidance and navigation concept and on other planetary missions.

The politics of winning the big budget Apollo prime contract by one of the study competitors did not look promising for Astronautics. North American Aviation appeared in the lead having successfully completed the X-15 program for NASA and gained much credibility. As the Apollo study was finishing up Lally presented a paper at the annual American Rocket Society’s conference in the Ambassador Hotel, Los Angeles. The concept dealt with launching, navigating and soft-landing multiple spacecraft at a lunar base. When he walked off the stage Jet Propulsion Laboratory managers approached him and made him an offer to work in their advanced conceptual design group of five people that would be hard to refuse.

Ehricke understood Lally’s potential and agreed to let him leave Astronautics for the purpose of broadening the country’s space exploration efforts. They agreed to part with Ehricke continuing to specialize on his goals of lunar surface manned missions while Lally would reach out to the planets primarily with unmanned missions.

At JPL Lally published, “Mosaic Guidance for Interplanetary Travel”, work he started at Astronautics. He was scheduled to present the paper at the 1961 annual American Rocket Society meeting in New York. His Guidance and Navigation Committee met and Charles Stark Draper, director of the prestigious MIT Instrumentation Laboratory did not want the paper presented. Draper being from the old school of inertial navigation was opposed to Lally’s optical concept which used a futuristic onboard optical camera system and minimum inertial components for proposed manned planetary missions. The politics quickly moved up to the heads of MIT and Caltech who managed JPL. William Pickering, Director of JPL, was convinced Lally's concept had merit and won the battle.

Lally presented the paper including a scheme to simulate gravity for the astronauts as well as his guidance and navigation concept using a camera with a mosaic photo-detector array that processed imagery in the digital domain, a breakthrough idea. This was the first concept of digital photography. Lally predicted hardware technology would catch up with the concept. That occurred in 1973 when research at Bell Labs was applied by Fairchild Semiconductor resulting in the first photo detector array of 100 x 100 pixels. This was given to Kodak where the first digital camera prototype was constructed.

Years later digital photography became a reality with the potential of advancing beyond the capabilities of film technology. Lally's design led to the digital camera revolution. In addition his concept of using images taken onboard spacecraft of celestial bodies during trajectories to planets, asteroids and comets to provide navigation and control information became useful for unmanned probes. Early applications relayed images back to ground controllers where trajectory correction maneuvers were calculated and transmitted back to the spacecraft.

The concept of using such images was applied onboard unmanned spacecraft including the Rosetta Spacecraft launched in 2004 by the European Space Agency (ESA) as it approached asteroid Steins in August 2008. The asteroid's orbit was known from ground based measurements but for the required close fly-by a more accurate location was needed. Photos from onboard cameras beginning at a distance of 24 million miles from the asteroid were transmitted down to and processed at ESA's ground Operation Center in Germany to refine the relative location of the spacecraft to the asteroid. Although not the original intent of the real-time onboard concept, the photos proved useful. Onboard corrective trajectory maneuvers were calculated on the ground and transmitted to the spacecraft for propulsion correction maneuvers.

His original real-time onboard navigation system based on using photos of celestial bodies eventually served NASA well. The system was adopted as conceived to save NASA massive new investments in deploying future missions. It was developed by JPL and called "Autonav" and became the central technology in the exploration of space from the late 1990s forward based on two fundamental issues.

First issue is bandwidth and the tracking antenna network's utilization as NASA replaced its failed doctrine of one costly, high-profile, fail-safe mission at a time in favor of smaller less expensive simultaneous missions. NASA's tracking antennas then needed to handle more spacecraft in different spatial locations simultaneously and the expanding ground controller labor costs required containment. Processing data and providing decisions onboard without the need of the up and down communication links and without ground controllers represented a less costly strategy. The second issue is based on sheer distance. Transmission time delays from distant spacecraft make it physically impossible to provide control for all requirements in a timely manner from the ground. Spacecraft needed to become more autonomous and solve navigation and other problems by themselves. Lally's real-time onboard navigation concept accommodated that and became the approach of choice in a cost conscious environment. It was first proven on the Deep Space 1 mission launched in 1998 opening a new era of lower cost unmanned spacecraft missions.

Lally was involved with a variety of special conceptual studies on a quick turn-around basis at JPL to assist NASA Headquarters with overall spaceflight mission selection and budget planning in the early phase of the space program. He presented concepts to NASA Headquarters and to von Braun at Huntsville's Marshall Space Flight Center for mission and launch vehicle planning considerations. While JPL primarily designed unmanned missions Lally was able to continue his manned Mars work there.

He worked with Caltech astronomers and also met Clyde Tombaugh of New Mexico State University who discovered the planet Pluto in 1930 at the Lowell Observatory. They found mutual areas of interest and communicated for the rest of Tombaugh's life. Tombaugh had Lally make an audio recording of his recollections of the lead up to and the moment when he viewed the two photographic plates that presented him with the discovery of Pluto. Tombaugh told Lally he then walked around outside the Lowell Observatory in the cold night air for 45 minutes pondering if he should wake up his boss and being the only person for those moments knowing there were nine not eight planets. The audio recording was made in the 80s, fifty years after Tombaugh's discovery but his excitement welled up as if it were yesterday.

At one point Lally was assigned a clandestine effort to convert the Surveyor lunar soft lander into a lunar orbiter. Development for JPL by Hughes Aircraft of the soft landing sequence was not testing well and he was flown cross-town by helicopter daily to Hughes' Culver City plant to study the problem. In reality he was designing a conversion of the Surveyor soft-lander into an orbiting Surveyor. It would carry an optical surface scanning camera that he was developing with a crash basis contract at Aerojet by their pioneer infrared and optical team of scientists. The lunar orbiting camera would assist in locating suitable landing locations for manned Apollo missions which was Surveyor's prime goal upon landing on the lunar surface. At a moment's notice the mission could have been redirected and the program salvaged. This effort had a happy ending as the Surveyor soft-landing problems were corrected in time and the surface camera scanning idea was useful in later planetary missions.

High level scientists left JPL and formed Space-General Corp. where they planned to obtain NASA contracts to build earth satellites and planetary probes. Lally had a backlog of creative ideas. They offered him Program Management at Space-General of study programs that he could obtain support from NASA for. He then could spend 40% of his time on space ideas he wanted to explore, funded by the company, knowing this would lead Lally to envision useful new space missions that would result in additional contracts.

Under these favorable terms Lally moved to Space-General Corp. and brought many new ideas to light. His body of work continued to expand as he generated initial concepts for spaceflight to explore planets and other celestial bodies. He won sole-source NASA study contracts and published papers in the American Rocket Society, American Institute of Aeronautics and Astronautics, IEEE, journals and magazines such as: Astronautics, Astronautia Acta, Design News, Aviation Weekly and national and local newspapers.

He proposed and won conceptual design study contracts for fly-by probes, orbiters and landers to Mercury, Venus and Mars. He added Jupiter and Saturn missions, comet and asteroid probes and landers. His detailed spacecraft designs and science payloads were illustrated by air-brush artists depicting various phases of the missions. Public interest in these missions and in hardware funding for the space program were helped by his exciting work which received widespread media coverage.

Aerojet Corp. makers of large solid propellant rockets also had a development contract for rocket engines to be powered by nuclear reactors under development at Westinghouse. Aerojet intent on broadening its space program base bought Space-General Corp. The Apollo manned landings on the Moon were progressing but the country became blasé about them and began to lose interest. The nuclear thermal propulsion work was directed toward manned Mars missions scheduled for the 70s. The ambitious program had technical difficulties but was making progress.

Lally was brought in to help Aerojet firm up the technical basis of nuclear reactor power in space. Ehricke a long-time proponent of nuclear thermal propulsion also spoke up from his position at General Dynamics Astronautics. When the Apollo program ended, NASA and the Nixon Administration favored the Shuttle program. Lally produced nuclear powered application studies including: rocket propulsion for manned Mars missions, electric power generation for a Lunar Base and for earth orbiting satellites offering high power communications. One concept developed for the latter application included transmitting large data rates from the earth up to a nuclear powered satellite and relaying broad bandwidth with high transmitter power television programming back to a large footprint on the earth and received by small home dish antennas as “Direct TV” later accomplished.

NASA decided to fund the Shuttle program and research and development of nuclear reactor power for space missions were stopped. The United States’ potential to land men on Mars by direct flight using efficient nuclear thermal propulsion rockets with faster and safer transit times ended. Unmanned spacecraft missions proposed by Lally did continue successfully to the planets, asteroids and comets with most of his concepts eventually accomplished.

Lally’s conceptual designs continue to have merit decades after publication. For example, his procedure for approaching and attaching a spacecraft to a small comet or asteroid having essentially no gravity was the design model used 50 years later on the European Space Agency’s Rosetta spacecraft scheduled to land on Comet 67P/Churyumov-Gerasimenko in 2014. The spacecraft’s lander Philae as it touches the comet will fire harpoons into the surface and reel itself in for secure attachment.

This same procedure could offer a method to affix a homing transponder onto an Earth threatening asteroid or comet to determine its orbit precisely. The procedure also could be used to deflect an asteroid confirmed as a threat to collide with Earth. A nuclear device delivered to the vicinity of the asteroid could be positioned at or above the surface. On command the device would vaporize a surface area resulting in a gas jet and debris changing the trajectory of the asteroid to avoid a disaster. Another possible deflection procedure, Gravity Tractor, where a spacecraft would rendezvous and follow a suspect asteroid or comet with their mutual gravity attraction used to change the asteroid’s trajectory, could be assisted by placing beacons where necessary on the asteroid’s surface to determine distances.

In the late 60s after Lally published many detailed conceptual spaceflight missions, an old scientist friend asked, “What will you do when you run out of planets”? Lally’s answer was, “We will have to find new planets around nearby stars”. At that time there was some skepticism that extrasolar planets existed.

He was frequently asked if he thought there was intelligent life elsewhere, answering the question “Are we alone”? He always responded, “No, we are not alone”, and referred to “Drake’s Equation” that explores this probability. When new planets were discovered orbiting nearby stars beginning in the 1990s, the question of determining if intelligent life existed elsewhere took on a new direction. While their distances preclude sending spacecraft there, Lally expected radio astronomy and other technologies to improve and develop new techniques to explore extrasolar planets and identify potentially habitable planets. He did not run out of planets.

Lally started his own company to continue his work and to develop innovative products for aerospace, commercial and consumer markets. Some products transferred technology from the space program others were unique from his out-of-the-box style of creative thinking. He created over 150 innovative products covering a variety of product areas.

He continued his photography interests throughout his life and developed concepts and products to improve the technology. He is an accomplished photographer specializing in outdoor scenic images. A collection of his “Southwest American Indian Pueblos and People” photographs were presented in a traveling exhibition for five years at museums, universities and libraries. Lally spent time in archaeology and published a series of twelve articles for the American Anthropological Association discussing Southwest American Indian culture coupled with application of the craft of photography as a tool for archaeology research. He became referred to as a “Photo Archaeologist”. His articles and photographic techniques were translated and used in European universities as teaching aids for archaeology research.

References

Ref. 1: Biographies were compiled and edited from various sources with additional details for von Braun, Ehricke and Lally provided for this paper by Lally from personal observations.

Ref. 2: A special thank you to Mrs. Ingeborg Ehricke and daughter Astrid for information of Krafft’s early years and family.

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Spaceflight Timeline…up to the first manned Apollo Moon landing.

Phases: Early historical events, World War II, post World War II, Cold War, post-Sputnik developments and early spaceflight missions.

Early History

300 BCE, China…….Religious mandarins threw ceremonial bamboo tubes packed with gunpowder (firecrackers) into ceremonial fires to drive off evil spirits.

1045 ACE, China….. Firecrackers developed into rockets, the sulphur, saltpeter and charcoal in gunpowder formed the earliest solid fuel for rockets. Gunpowder rockets were important weapons in China's military arsenal.

1232 ACE, China…….fire arrows were developed into explosive grenades to hold off Mongol invaders at the battle of Kai-fung-fu. Iron shrapnel and incendiary material demolished everything within half a mile.

1926, March 16, U.S. ……Robert H. Goddard associated with Clark University, launched the **FIRST** liquid-fueled rocket named "Nell" in Auburn, MA. It rose 41 feet during a 2.5 second flight.
Charles Lindbergh later helped Goddard obtain funding from the Guggenheim family.

1930s U.S. …Goddard eventually relocated in Roswell, NM long before the UFO craze. He brought his work to the attention of the U.S. Army but was rebuffed. He continued his work throughout the 1930s.

World War II

1930s Germany….Wernher von Braun took Goddard's plans from published journals and incorporated the ideas into his early prototypes of the A-1 and A2, later to become the A4 or V-2 that were launched at England the last two years of World War II. The German Intelligence Agency, the Abwehr, recruited a source who infiltrated Goddard's operation leaking discoveries to the Germans.

1936 U.S. ….Frank Malina studying rocketry at the California Institute of Technology visited Goddard who declined to pass along information other than what he published in "Liquid-Propellant Rocket Development". Theodore von Karman who was Malina's mentor at Caltech was troubled.

1937 Germany….Army Research Center Peenemunde, was founded under the Air Weapons Office (Heeres Waffenamt). Peenemunde is a village in western Germany on

Usedom Island. It is on the easternmost part of the German Baltic coast whose location permitted rocket test flights over water with monitoring along 200 miles of coastline. Dr. Wernher von Braun was the technical director and Dr. Walter Thiel deputy director. All required technical disciplines were made available and given priority by Hitler to support development and production of rockets and guided missiles.

1939 US…….von Karman's Guggenheim Aeronautical Laboratory at Caltech received Army Air Corps funding to develop rockets to assist aircraft take-off, Jet Assisted Take-Off (JATO). Goddard heard of this in 1940 and expressed displeasure and gave up his rocket work and turned to experimental aircraft for the U.S. Navy. Immediately after the war Goddard inspected captured German V-2s and noted many of the components were based on his designs. He died soon after from throat cancer in 1945.

1939 Germany….… Tests were conducted at Peenemunde of a flying bomb designated the V-1 flying bomb (buzz bomb), and the Messerschmitt Me 163 rocket-powered fighter aircraft.

1941, June, Germany……The V-1 (Buzz Bomb) entered combat. It was the **FIRST** operational cruise missile. Thousands were launched against Europe.

1943, August 17/18. Germany…..British Operation Crossbow conducted air raids over Peenemunde to target scientists, workshops and the experimental station at night. The raid killed 815 workers mostly foreign prisoners and Walter Theil the head of engine development.

1943, August 26, Germany……Albert Speer (Hitler's chief architect for aesthetically beautiful government buildings became Minister of Armaments during the war decided to move production of the V-2 to an underground factory in the Harz Mountains. In early September production machinery and personnel were moved to Mittelwerk.
The V-2 was the largest and most complex German missile. It carried one ton of explosive 150 miles in five minutes. It employed one rocket engine powered by alcohol and liquid oxygen. Near the war's end 700 V-2s were produced monthly in caverns by slave labor under unbearable conditions near Nordhausen.

September 1944 – March 1945 about 2700 V-2s were launched at England, Belgium and France from mobile launchers in Germany. 1100 V-2s hit southern England causing 2700 deaths and 6500 injuries. Even more were launched against the port of Antwerp, Belgium. Total kill was 7000 throughout Europe. Traveling four times the speed of sound and falling silently, the missile was a continuous terror threat as it struck at any moment without warning.

Post World War II

1945 U.S. …….. Captured V-2 missile parts were brought by the U.S. Army to White Sands Proving Ground, New Mexico for Project Hermes missile development program managed by General Electric. Werhner von Braun and his team of German scientists were housed in nearby Ft. Bliss, Texas.

The first launches were in 1946 using German components. Later American made components were substituted.

1945, October, U.S. ……White Sands. NM launched the first long range missile for the U.S. the WAC Corporal, a small aniline/nitric acid liquid rocket developed for the Army by the Jet Propulsion Laboratory, airframe by Douglas Aircraft and engine by Aerojet Engineering Corp. with a solid booster by JPL. Altitude reached 45 miles. It was the first U.S. ballistic missile to approach the capability of the German V-2.

1945 U.S. …… The **FIRST** two stage liquid propellant rocket came from the Army Bumper WAC program. A WAC Corporal was mated to the V-2 and reached an altitude of 234 miles. Later the Army started the Redstone, Juno and Jupiter as well as Nike Antiaircraft missile programs. Navy Aerobee and Viking sounding rockets also were developed.
The Air Force inherited from the Army various industry proposals for long range missiles, one the MX-774 program eventually led to the Atlas intercontinental ballistic missile from Convair in San Diego, CA.

1946 U.S. ….Navaho Program by North American Corp. took the V-2 rocket engine and made it more efficient and had a large influence on the development of large liquid-propellant rocket engine technology.

1949-1958 U.S. ……Viking U.S. Navy. Prime contractor Glen L. Martin Company of Baltimore, MD developed the alcohol/liquid oxygen Viking rocket as the first U. S. sounding rocket designed after V-2 tests were completed at White Sands.

COLD WAR

1953 U.S. …..U.S. weapon designers invented a way to make hydrogen bombs small and lightweight. The "Bravo" atomic test in the South Pacific in 1954 confirmed the feasibility of smaller H – bombs which enabled ICBMs on the design boards to deliver them in a combat role. The Cold War started in earnest as the Russians were at the same point.

1957, Oct. 4, USSR……Sputnik, **FIRST** man-made satellite placed in earth orbit. Reentered Jan. 4, 1958.

Post–Sputnik

1957, Nov. 3, USSR…..Sputnik 2, Dog Laika placed in earth orbit and dies a few hours later from heat exhaustion. Reentered April 13, 1958.

1957, Dec. 6, U.S….. U.S. first earth satellite attempt by the Navy's Vanguard rocket exploded on the launch pad and the satellite fell to the ground and bounced around.

1957, December, U.S. ….Jet Propulsion Laboratory of the California Institute of Technology given a launch window of 90 days to launch the first U. S. satellite before the next Vanguard was attempted which was losing credibility.

1958, January 31, U.S. …… The Jet Propulsion Laboratory with an Army Jupiter-C rocket from von Braun's team and two JPL upper stages successfully orbited the Explorer 1 with a James Van Allen experiment that discovered the Earth's radiation belt. This was the **FIRST** U. S. earth satellite.

1958, March 17, U.S. …..Vanguard 1 satellite was finally launched into orbit and transmitted for three years.

1958, May 15, USSR…..Sputnik 3 launched.

1958, Oct. 1, U.S. ……NASA founded.

1958, Oct. 11, U.S. ………Pioneer 1, International Geophysical Year launched to an altitude of 70,700 miles.

1959, Jan. 2, USSR.........Luna 1, **FIRST** man-made satellite to orbit the Moon.

1959, March 3, U.S. …..Pioneer space probe launched by Juno II achieved an earth-moon trajectory passing within 37,000 miles of the Moon resulting in a solar orbit, becoming the **FIRST** U.S. solar orbiter.

1959, Sept. 12, USSR……Luna 2 impacted the Moon on Sept, 13, being the **FIRST** man-made object to hit the Moon.

1959, Oct. 4, USSR……..Lunar 3 flew-by the Moon and photographed 70% of the far side.

1961, April 12, USSR……..Vostok 1 carried Cosmonaut Yuri A. Gargarin to become the **FIRST** man in orbit. One orbit.

1961, May 5, U.S. …….Mercury Freedom 7 carried Alan Shepard, the **FIRST** U.S. Astronaut into space, suborbital.

1961, Aug. 6, USSR….Vostok carrying Cosmonaut Gherman Titov orbited the earth for a day.

1962, Feb. 20, U.S. …..Mercury Friendship 7 lifts John H. Glenn to become the **FIRST** American in orbit. Three orbits.

1962, May 24, U.S. ……Mercury Aurora 7 places Scott Carpenter into three orbits.

1962, September 12, U.S…..President Kennedy's speech at Rice University set a goal to land men on the Moon by the end of the 60s.

1962, Dec. 14, U.S. ……JPL, Mariner 2, the **FIRST** successful planetary spacecraft flies past Venus and enters a solar orbit.

1963, June 16, USSR…..Vostok 6 carries Cosmonaut Valentina Tereskova, **FIRST** woman in space for 48 orbits.

1964, July 31, U.S. …….JPL Ranger 7 relays **FIRST** close-range photographs of the Moon's surface.

1965, March 18, USSR…….**FIRST** space walk. 12 minutes.

1965, March 23, U.S. …..**FIRST** two man capsule Gemini flight. Grissom and Young. 3 orbits.

1965, March 24, U.S. ……JPL Ranger 9 transmits high resolution images of the Moon shown LIVE in the **FIRST** TV space spectacular.

1965, June 3, U.S. …..Edward White makes the **FIRST** U.S. space walk from Gemini 4, 22 minutes.

1965, July 14, U.S. …..JPL Mariner 4 returns the first close-range images of Mars surface.

1965, Dec. 4, U.S. ….Gemini 7, Frank Borman and James Lovell make 206 orbits around earth proving a manned trip to the Moon is possible.

1965, Dec. 15, U.S. ….Gemini 6, Walter Schirra and Thomas Stafford make first space rendezvous with Gemini 7.

1966, Feb. 3, USSR……Luna 9, **FIRST** spacecraft to soft land on the moon.

1966, March 1, USSR…..Venera 3 impacts on Venus, **FIRST** spacecraft to reach another planet. No data returned.

1966, March, USSR……Luna 10, **FIRST** spacecraft to orbit the Moon.

1966, June 2, U.S. …….Surveyor 1, **FIRST** U.S. spacecraft to soft-land on the Moon.

1966, Aug. 14, U.S. ….. Lunar Orbiter 1 enters Moon orbit and takes the first picture of the Earth from the distance of the Moon.

1967, April 23, USSR …. Soyuz 1 launched killing Vladimir Komarov, **FIRST** spaceflight fatality.

1967, Oct. 18, USSR ….. Venera 4 sends a descent capsule into the Venusian atmosphere, returning data about its composition.

1968, Sept. 15, USSR …. Zond 5 **FIRST** spacecraft to orbit the Moon and return.

1968, Oct. 11, U.S. …. Apollo 7, orbited earth once with Walter M. Schirra, Donn F. Eisele and Walter Cunningham.

1968, Dec. 21, U.S. ….Apollo 8, first Apollo to use the Saturn V rocket, and the first manned spacecraft to orbit the Moon and return, making 10 orbits on a 6 day mission.

1969, January, USSR. …..Soyuz 4 & 5 perform the first Soviet spacecraft docking, transferring Cosmonauts between vehicles.

1969, July 31, U.S. ……. Apollo 11, Neil Armstrong and Edwin Aldrin, Jr. make the **FIRST** manned soft-landing on the Moon and the first Moonwalk. Return to the Command Module piloted in lunar orbit by Michael Collins and return to earth.

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