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A Path to Space: From Tsiolkovsky to Armstrong

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ABSTRACT

The United Soviet Socialist Republic (USSR) and the United States (US) led the Space Race during the 20th century at the height of the Cold War. These adversaries raced to be the first to achieve spaceflight capabilities. The concept of space travel would provide an unprecedented experience and political might. Due to events in history at that time, military technologies aided advancements. The innovation resulted in creative ways to address fundamental questions, yet more importantly, would prove one nation dominate. Many extraordinary people pioneered this venture, including physicist and engineer Robert Goddard from the United States and Hermann Oberth, an Austro-Hungarian-born German physicist and engineer. In 1962, the United States achieved the first interplanetary flyby when Mariner 2 sped past Venus. Soon after, the Soviets sent the first woman into space, Valentina Tereshkova, in 1963. Additionally, other nations launched their rockets and satellites, including Canada in 1962, France in 1965, and Japan and China in 1970. The Russians led the race from Sputnik to the first Moon landing on July 16, 1969, when US astronauts Neil Armstrong and Erwin "Buzz" Aldrin touched down on the Moon's surface. Each nation made incredible advancements. Hard work and great focus brought the dreams of space travel to reality.

KEYWORDS: ***Third Reich**: Nazi Germany was officially known as the German Reich from 1933 until 1943; **The Great Depression:** severe worldwide economic depression during the 1930s; **The Treaty of Versailles:** the peace treaties that brought an end to World War I; **Ballistic:** relating to projectiles or their flight or moving under the force of gravity; **Publicity Stunt:** planned event designed to attract the public's attention; **NASA:** National Aeronautics and Space Administration, independent U.S. federal government agency*

This paper reviews the origins of the two modern space programs: Russian and American. In the first section, we will look at the scientific research and ideas that would eventually form the basis for the programs, beginning with the Russian theorist Konstantin Tsiolkovsky. We will then discuss the contribution of the French researcher Robert Goddard and that of the German physicist Hermann Oberth. We will then proceed to the first large-scale implementation of rocket technology by the Third Reich military forces and their contribution to the relevant research and development. Next, we will examine the scramble for the Nazi technology that followed the fall of the Third Reich. Finally, the third section will review the first successes of the Soviet and American space programs, ending with the first Moon landing.

THE BEGINNINGS OF MODERN ROCKET SCIENCE: FROM TSIOLKOVSKY TO THE THIRD REICH

Although a prototype of a rocket was designed in 1812, rocket research only truly began in the twentieth century.[1] At the beginning, rocket research was primarily developed by individual scientists and enthusiastic individuals. Of these, three are commonly believed to have been the founders of modern rocketry: the Russian educator Konstantin Tsiolkovsky, the American scientist Robert Goddard, and the German physicist Hermann Oberth.[2]

Born on September 17, 1857, Konstantin Eduardovich Tsiolkovsky is publicly acknowledged as the first man to develop the main principles of a rocket capable of spaceflight.[3] In 1903, Tsiolkovsky's paper "Exploration of the universe with reaction machines" explained various key aspects of space flight, and in the following decade, Tsiolkovsky would release many similar papers with illustrations of the rockets he conceptualized, though he never physically created one within his lifetime. Despite his achievements, his work remained buried in obscure Russian journals in Czarist

1 Catledge, Burton "Ernie," et al. Space History. Air University Press, 2009, pp. 1, AU-18 Space Primer.

2 Pendray, G. Edward. "Pioneer Rocket Development in the United States." Technology and Culture, vol. 4, no. 4, 1963, pp. 384–385.

3 Chakrabarti, Bhupati. "One Hundred and Fifty Years of a Dreamer and Fifty Years of Realization of His Dream: Konstantin Eduardovitch Tsiolkovsky and the Sputnik 1." Current Science, vol. 93, no. 6, 2007, pp. 862–863.

Russia and failed to achieve much recognition in his lifetime. However, while his work was not well known during his time, Tsiolkovsky supposedly did communicate with Sergei Pavolovich Korolev, a student that would later become the leader of the Soviet space program and be responsible for many of Russia's first spaceflight achievements in the future.

American scientist Robert Goddard is considered by many as a father of modern rocketry for his many achievements in the field, such as being the first to research liquid-propellant rockets in 1909, and for proving that rockets could work in space three years later.[4] Goddard's ideas were conceived on his own, as Tsiolkovsky's work was still untranslated at the time. In 1919, Dr. Goddard published his book, "A Method of Reaching Extreme Altitudes",[5] which discussed many concepts critical to spaceflight and that would be used in the future US space missions. Despite his achievements, Goddard was mocked by the press. A New York Times editorial claimed that Goddard "(seemed) to lack the knowledge ladled out daily in high schools.'' [6] Dr. Goddard orchestrated the first liquid-fueled rocket launch in Auburn, Massachusetts in March 1926, and launched a revised version in 1929. However, Goddard's experimental rockets exploded that summer, and the backlash of the public - who questioned his sanity - caused Goddard to escape to New Mexico, where he continued to work on his inventions with funding from Charles Lindbergh and the Guggenheim Foundation until his death in 1945. A few of Goddard's inventions include gyro control guidance systems, variable-thrust rocket engines, small high-speed centrifugal pumps, and gimbaled nozzles, all of which are used in modern rockets.

Ultimately, Dr. Goddard's influence on rocket development was less significant than one might have expected. While he was the first to invent many major rocket components, Goddard's negative experience with the press caused him to become secretive about his work, which resulted in little to no attention from the government.[7] The statements made by The New York Times were retracted, but only long after Goddard's death.[8] However, in Germany, scientists were soon achieving similar results. Their work led to the V-1 and V-2 rockets that were used by the Nazis during their air raids on London and later throughout WWII.[9]

In 1923, German physicist Hermann Oberth published his book "The Rocket into Interplanetary Space," which marked the beginning of the fascination with space in Germany.

This fascination lasted up until the early 1930s, when the Great Depression and its many economic and political difficulties pushed space-related topics into the background.[10] In the years following Oberth's publication, many other technical works were published in Germany that discussed the feasibility and attractiveness of spaceflight. Specifically, Oberth collaborated with Max Valier, an engineer, on various rocket stunts meant to increase public interest in space. In 1927, the first spaceflight society was founded: the Verein für Raumschiffahrt, "Society for Space Travel."[11] After the release of the large spaceflight movie *Frau im Mond* in late 1929, space interest in Germany reached its peak. Rocket experiments continued the trend into the early 1930s, but interest dwindled as the Great Depression continued.

One major problem that all these independent space enthusiasts faced was resources. Regardless of how feasible their ideas were, they simply couldn't sponsor their implementation.[12] This was not a problem that the German military had to face. As they searched for weapons that were not restricted by the Treaty of Versailles, their funds were incomparable to the individual scientists' pockets.[13] Arthur C. Clarke noted that "All Goddard's initial pioneering work was financed by a grant of some $11,000, but the German War Department sank £35,000,000 into the building of Peenemunde," the German military's research facility.[14]

The German efforts to develop a rocket began in the early 1930s, around when the space fad was dying in the public eye. However, the army was not knowledgeable about rocketry at the time. In one instance, research in liquid-fuel rockets, which would have a longer range than any other kind of rocket, almost stopped when a branch chief accidentally

4 Catledge, Burton "Ernie," et al. *Space History*. Air University Press, 2009, pp. 1–28, *AU-18 Space Primer*.
5 Smithsonian Institution, Miscellaneous Collections, Vol. 71, No. 21 (1919).
6 Kuntz, Tom. "150Th Anniversary: 1851-2001; the Facts That Got Away." The New York Times, The New York Times, 14 Nov. 2001.
7 Catledge, Burton "Ernie," et al. Space History. Air University Press, 2009, pp. 1–28, AU-18 Space Primer.
8 Simberg, Rand. "The Return of the Space Visionaries." The New Atlantis, no. 56, 2018, pp. 52.
9 Dornberger, Walter R. "The German V-2." Technology and Culture, vol. 4, no. 4, 1963, pp. 406.
10 Neufeld, Michael J. "Weimar Culture and Futuristic Technology: The Rocketry and Spaceflight Fad in Germany, 1923-1933." Technology and Culture, vol. 31, no. 4, 1990, pp. 725.
11 Simberg, Rand. "The Return of the Space Visionaries." The New Atlantis, no. 56, 2018, pp. 53.
12 Dornberger, Walter R. "The German V-2." Technology and Culture, vol. 4, no. 4, 1963, pp. 393–409.
13 Ibid., pp 394.
14 Carter, Paula. "ROCKETS TO THE MOON 1919-1944: A Dialogue between Fiction and Reality." American Studies, vol. 15, no. 1, 1974, pp. 33.

reported flawed test results. The chaos in the military was eventually stopped when Major General Karl Becker, chief of the development department in the Army Board of Ordnance, concentrated the military's efforts. Initial work began soon after in a corner of Kummersdorf, an army testing ground near Berlin, after the military realized that they would have to rely on themselves to achieve the results they were looking for, instead of relying on industry or inventors who were mainly interested in publicity stunts.[15]

The original German rocketry team consisted of four men: student Wernher von Braun, technician Walter Rziedel, foreman Heinrich Grunow, and Walter R. Dornberger, Captain in the German Board of Ordnance and assistant in the ballistics branch. Without any concrete requirements for their rockets, the team was forced to come up with many aspects of their project on their own, and by December 1934, had achieved two successful launches of their A-2 rocket, the second of the aggregate or "A" series after the first experienced many failures.[16]

Primarily funded by General Becker, the team moved to Peenemuende, a small fishing village on an island in the Baltic Sea, in May of 1937, where they would be able to build the facilities, they knew would be necessary to seriously develop large operational missiles. However, as research continued, the team, which had grown to around 300 men by then, began to require more funding than what they had received. To be supplied with the funding they required, the team had to prove that their rockets had military value. Hence the development of the experimental rocket A-3, which they hoped would be capable of breaking the sonic barrier.

This rocket later became the A4, which would be successfully launched in October of 1942, becoming the first man-made object to reach the edge of space.[17]

Hitler was not involved in rocket development up until July of 1943. When Dornberge was recounting his experiences, he noted that, despite Hitler's scrutiny of the technical details of guns and other weapons, he was completely disinterested in the German missile program. In fact, as Hitler had not supplied any manpower or materials for the program, the team had to pull 4,000 soldiers from the Chief of the German Army High Command, which the Reich could not touch, for their research. By the time Hitler began to support the missile program in 1943, he had supposedly said to Dornberger: "Why didn't I believe in the success of your work? If we had had this weapon in 1939, we never would have had this war."[18]

15 Dornberger, Walter R. "The German V-2." Technology and Culture, vol. 4, no. 4, 1963, pp. 395.
16 Ibid, pp. 397-398.
17 Ibid, pp. 400-403.
18 Ibid., pp 397-401.

By 1943, the Nazi rocketry team had moved the production of their most important weapons to Mittelwerk, an underground facility in Nordhausen, Thuringia, and with Hitler's support, mass production of the A-4 rocket--which Hitler would later name Vengeance Weapon 2 (V-2) --became possible. Various slave labor camps, such as Dora and Mittelbau, provided manpower for rocket production, composed of around 60,000 Soviet, Polish, and French prisoners, with up to twenty-five dying per day due to harsh conditions. From September 8 of 1944 to March 27 of 1945, 1,359 V-2 were launched against London, with 1,190 successful contacts. Of those that succeeded, the V-2's caused significant damage to thousands of buildings, killing 2,724 civilians and severely injuring 6,467. Though the damages were minimal compared to the total casualties of WWII, the missile threat seriously hurt morale of the Allies. Eisenhower stated that "Soldiers at the front began again to worry about friends and loved ones at home, and many American soldiers asked me in worried tones whether I could give them any news about particular towns where they had previously been stationed in southern England."[19]

Ultimately, despite the power of the V-2 missile technology, the weapon came out too late in the war to succeed in defeating the Allies. By 1944, the war no longer could be won simply with the amount of V-2s the Germans had. Without enough support from the German leaders to win the war in Western Europe prior to the US involvement, the German missile program ultimately was not enough to change the course of the war. However, in General Eisenhower's memoir "Crusade in Europe", he wrote that, had the V-2 weapon been in action six months earlier, the Normandy landing would have been nearly impossible.[20]

POST-WAR SCRAMBLE FOR THE GERMAN TECHNOLOGY[21]

After the war, the Soviets and the Americans scrambled to find the rocket technology the Germans had developed. After dividing the German territory, the Allies set off to inspect their slice to find any materials, scientists, or documents of note to bring back to their countries.[22]

19 Baucom, Donald R. "Eisenhower and Ballistic Missile Defense: The Formative Years, 1944-1961." Air Power History, vol. 51, no. 4, 2004, pp. 6.
20 Dornberger, Walter R. "The German V-2." Technology and Culture, vol. 4, no. 4, 1963, pp. 407
21 Ibid., pp. 400. As Walter Dornberger has elaborated, the Germans never saw Goddard's work, therefore it is fair to call the V-2 technology German.
22 Catledge, Burton "Ernie," et al. Space History. Air University Press, 2009, pp. 4, AU-18 Space Primer.

Thousands of American representatives scoured through various German facilities, including Peenemunde and Mittelwerk. With vaguely named programs such as "Overcast" and "Paperclip," the representatives secretly transported large quantities of German hardware, research, and scientists.[23] Of these, the most well known was the immigration of Wernher von.

Braun and his rocket team, which would later be absorbed by NASA in 1960 after the organization's formation. The rockets created by this team would later appear in nearly all of America's accomplishments in space during the space race: America's first satellite, America's first astronaut, and the first Moon landing.[24]

After the war, the Soviets began to demand reparations from defeated countries, mainly Germany and Japan but also Korea, Hungary, Finland, and Romania. Through 1945-1946, various Soviet teams composed of scientists, industrial managers, soldiers, and party representatives, called "trophy brigades," travelled across Europe and Asia to track and collect massive amounts of materials to send to the Soviet Union. Equipment from 4,786 German and Japanese enterprises were sent back to the USSR, with 655 of explicitly military nature. By 1948, around $2.68 billion worth of material had been sent to Russia.[25]

The major Soviet industrial commissariats had planned on collecting reparations from abandoned factories from areas Germany had occupied in the war. As they had lost around $872 million from the war, the NKAP (Commissariat of Aviation Industry) compiled a list of nearly 200 factories to inspect. Following the Yalta agreements, the Soviets were able to access over half of the German aviation industry by July of 1945: around 600 facilities. [26]

From April 28 to August 1, 1945, eighty-eight "experts" commissioned by Nikolai Petrov, the director of the Scientific-Research Institute for Aircraft Equipment, delved into over various aeronautic facilities, finding models of planes, winged missiles, full technical reports, and aircrafts belonging to various companies. Some of Petrov's team went to Peenemunde as well, where they mainly found damaged German liquid fuel rockets and equipment, as most resources had been taken. In February of that year, around 500 of the original Nazi rocket team had fled south with fourteen tons of documents encompassing over a decade of work and had destroyed what remained with dynamite. Though largely unimpressed with their findings in Peenemuende, the Soviet teams believed that far more valuable resources would be found in the Mittelwerk facility. [27]

Despite their plans, however, the teams only managed to communicate their needs to the Commissariat on May 11, while the US had already begun accessing the facility in April. As a result, the Soviets would have to wait until the US had left to access the area, which would take two months. Throughout June of 1945, the Soviets and the American forces would engage in many competitions over the Nazi resources, with borders changing overnight. Soviet teams ransacked twenty-one industrial factories near Berlin just before they were to be handed over to the Americans, and similarly, the Americans were still in Mittelwerk hours before the Soviets arrived in the area.[28]

The Americans took some equipment, all the technical documentation that the Germans had left from both Peenemunde and Mittelwerk, as well as over one hundred of the best scientists and engineers who had worked on the V-2. By the time of the Soviet's arrival, they had found a decent amount of equipment still remaining and were assisted by the prisoners that remained after the Americans had freed and hired some. In a town near Mittelwerk, the Soviets discovered over fifty new rocket engine combustion chambers, fifteen railway wagons that contained V-2 engines, tankers that would transport liquid oxygen, carriages that would transport missiles, and flatcars that would hold ground equipment. The Soviets also found key Germans who worked at the facility, and because of these findings, the leader of the search teams reported that, with sufficient resources, the Soviet engineers could have at least five of the V-2 rocket engines ready by early August, within a week.[29]

In this way, the two major powers benefited from the pre-war and wartime German research. The V-2 technology, taken from the defeated Germany, opened the possibilities of space exploration, which would later be unlocked via revolutionary militarization.

DISSEMINATION OF THE EARLY IDEAS AMONG THE TWO ORIGINAL SPACE-RACING NATIONS: THE USSR AND THE US

Between May and August of 1945, the Soviet forces had spread throughout Soviet-occupied Germany, completed evaluations on the state of German reactive weapons, and had begun to send what they considered valuable back to the Soviet Union.

23 Ibid., pp. 6.
24 von Braun, Wernher. "The Redstone, Jupiter, and Juno." Technology and Culture, vol. 4, no. 4, [The Johns Hopkins University Press, Society for the History of Technology], 1963, pp. 452-53
25 Siddiqi, Asif A. "Russians in Germany: Founding the Post-War Missile Programme." Europe-Asia Studies, vol. 56, no. 8, 2004, pp. 1144.
26 Ibid., pp. 1134.
27 Ibid., pp. 1136-37.
28 Ibid., pp. 1137-38.
29 Ibid., pp. 1138.

Despite the lack of any technical documentation, the Soviets had managed to glean a large amount of information on German developments of reactive technology, and near the end of August, the official military printing press had even issued a secret seventy-page monograph that would detail every major system of the V-2 missile, its capabilities, and the operational procedures. [30]

After the initial scramble for German resources, the Soviets faced many problems with rocket development. Despite having knowledge of German technology nine months prior, the official beginning of the Soviet missile and space program would only be in May of 1946. This delay was primarily caused by three factors: Stalin's disinterest in the technology, the appearance of atomic bombs, and the demilitarization of the economy.[31]

Arguably the most important factor for the nine-month delay was Stalin's disinterest in German long-range missiles, at least in the time following the war. Unlike advocates of nuclear, aviation, and jet technology, those who supported long-ranged rockets had failed to meet Stalin even once to argue their case in 1945, and though Stalin signed many decrees on taking German reactive equipment back to Russia, he had never approved any long-range plans of action. Stalin's sentiments regarding long-ranged rockets were echoed among mid-level aviation engineers in 1945, with an engineer from the NII-1 aviation institute being told by his boss: "Nobody needs the V-2. We need jet aviation, as fast as possible."[32]

The bombing of Hiroshima and Nagasaki in August of 1945 was another major factor for the delay, shifting the power dynamic between the United States and Soviet Union nearly overnight. Within two weeks of the news, Stalin had signed into law a secret decree prioritizing atomic weapon development above all else. Vannikov, who was supposed to be responsible for the long-range missile program, was instead sent on a secret Committee to work on atomic weapon development.[33]

The third reason for the delay was the demilitarization of the economy, which dramatically slowed military research laboratories, testing facilities, and other crucial establishments. This caused massive problems, with many appearing in the long-ranged missile program, as it was considered of low strategic importance. Though the program had access to much of the material taken from Germany, Vannikov's only existing missile center had effectively no staff during the first quarter of 1946, with many engineers still in scattered German outposts. Adding onto these difficulties, many expert aviation leaders Vannikov had planned on using were sent to labour camps after being caught up in an elaborate plot.[34]

During this time, Commissar of Armaments Dmitrii Ustinov, who had provided guns and artillery for the Soviet war effort, was looking for new weapons to manufacture. After massive arrests during the Great Purges and the patronage of Andrei Zhdanov, the Leningrad party secretary, Ustinov became the director of the Bolshevik steel factory in Leningrad in 1937. In 1941, two weeks before the Nazi invasion, Ustinov was sent to Kremlin and was given control of the Commissariat of Armaments, controlling many large and famous Soviet plants despite being the youngest defense manager in the Soviet war effort. However, after World War II, military contracts for weapon development had declined, and the demilitarization order caused many problems for Ustinov's commissariat. With a large hole in the commissariat after the war, Ustinov looked for new technologies to invest in and for ways to maintain his strong relationship with the military. To this end, Ustinov looked to one of his wartime military customers, Artillery Marshal Yakovlev, who was supportive of the study of German long-range rockets. This caused Ustinov to send a deputy to visit engineer work in Germany.[35]

In the time since the initial scramble for German technology, the Soviet researchers who remained in Germany had drastically changed operations. Under Sergei Korolev, the researchers had integrated a more innovative approach to work on the long-ranged missiles, impressing Ustinov's deputy. After being informed of this, Ustinov was convinced to take control of the long-range missile program. After a report to Stalin on April 17 of 1946, compiling the current conditions and prospects of the program and a meeting that took place shortly after, Stalin signed a document prepared by Vannikov, Yakovlev, and Beryia, the head of the secret police. This decree, "The Question of Reactive Armaments," would lay the foundations for post-war Soviet missile and space programmes.[36]

After his return to Russia in 1946, Korolev was made the Chief Designer of long-range ballistic missiles. Under Korolev's bureau, the R7, an intercontinental ballistic missile, was successful on 21 August 1957, after three failed attempts. Six weeks after this launch, the Sputnik-1, the first human satellite, was put into orbit in October 4of 1957, using the same missile to launch. In 1958 and 1959, Korolev and his staff increased the Sputnik carrier rocket to a three-stage launch vehicle, Vostok, as opposed to the two stage one that had been used previously. With the new design, the

30 Ibid., pp. 1143.
31 Ibid., pp. 1144-45.
32 Ibid., pp. 1144.
33 Ibid., pp. 1144.
34 Ibid., pp. 1144-45.
35 Ibid., pp. 1146.
36 Ibid., pp. 1147-49.

orbit capability of the vehicle was increased from 1400 to 4,500 kilos. Korolev and his team also designed the Vostok spacecraft, which would be used with the Vostok launch vehicle to send Yuri Gagarin into orbit on April 12 of 1961, making Gagarin the first human to both travel in space, and the first to circle the Earth.[37]

In the time since the initial scramble for German technology, the US had done little in long-ranged missile research. US focus on the field prior to the 1950s had been primarily on the concept of intercepting missiles with other missiles to defend against potential ballistic missile threats. The two main programs that the US focused to this end were Project Wizard, and Thumper. However, these projects never saw much growth beyond the conceptual stage prior to the second half of the 1950s, and Thumper was even cancelled in 1948, as America's leaders at the time didn't see ballistic missiles as a major threat.[38]

However, development on the Redstone missile, the first large ballistic missile developed in the US, began in July 1950 for use in the Korean War as a 500-mile rocket weapon. A German group of about 120 who had previously worked on the V-2 were sent to Huntsville, Alabama for development of this weapon, Wernher von Braun among them. The test flight program ended in late 1958, and the Redstone was fired for the first time by Army troops in that year.[39]

During the test program, two forms of the Redstone missile were developed: Jupiter A and Jupiter C. Jupiter A was a modified Redstone missile which was used to assist in the development of the Jupiter IRBM (intermediate-range ballistic missile) project. Jupiter C, however, was far more significant. In the spring of 1955, Wernher von Braun and his team of rocket engineers and scientists submitted a proposal for orbiting an earth satellite, titled "A Minimum Satellite Vehicle Based Upon Components Available from Missile Development of the Army Ordnance Corps," to the Department of Defense. This initial proposal was later formulated into a joint proposal called "Project Orbiter," though it was ultimately shelved in favor of Project Vanguard.[40]

Despite having the idea shelved, von Braun's team was unwilling to scrap their idea, and the work they had accomplished in satellites later became the basis for Jupiter C (Composite Re-entry Test Vehicle). After becoming a part of the ABMA (Army Ballistic Missile Agency), the team worked with the JPL (Jet Propulsion Laboratory) on developing the Jupiter C. On September 20 of 1956, the first Jupiter C was launched, with the three-stage rocket performing well on all three stages and establishing a distance record that was only beaten after the ICBM (Intercontinental ballistic missile) was developed.[41]

After the development of the Jupiter C, a four-stage Jupiter C called Juno I was created, and following the launch of Sputnik on October 4, 1957, the Department of Defense ordered the ABMA to launch a satellite with a Jupiter C, on November 8, 1957. On January 31, 1958, the Explorer I, an eighteen-pound satellite, was sent into orbit by the Juno I. The US then sent the Explorer III and Explorer IV on March 26 and July 26 respectively, both using the Juno I boosters.[42]

One week after the formation of the National Aeronautics and Space Administration (NASA) on October 1, 1958, the organization approved a manned satellite mission, soon named Project Mercury. As NASA only accepted Redstone and would not admit any Jupiter C vehicles, the Wernher von Braun team developed Mercury-Redstone vehicles, which were used in various test flights, such as one on January 31, 1961, which allowed for the safe recovery of a thirty-seven-pound chimpanzee passenger, and another on March 24, 1961, as the flight in January had deviated from the expected trajectory.[43]

On May 5 of 1961, after ensuring the reliability of the Mercury-Redstone vehicles, Alan Shepard became the first American to fly in space, three weeks after Yuri Gagarin. On July 21, of 1961, another flight was carried out, with Virgil Grissom's flight almost identical to Shepard's, though the loss of the capsule used caused NASA to cancel a third manned flight they had planned. With two successful launches, however, the Mercury-Redstone program ended in the summer of 1961, its objectives completed. The next step in the US space flight program would be orbital flight, which required a more powerful vehicle.[44]

In March 1958, a request following the Explorer successes with Juno I started development for the Juno II, which was based on the completed Jupiter IRBM. The Juno II was a quick and cheap vehicle capable of launching payloads over three times compared to the Juno I. Over the course of the program, ten Juno II vehicles were used, with some sending deep space probes such as Pioneers III and IV, as well as heavy satellites such as Explorers VII, VIII, and XI. Of the ten Juno II missions, four were complete successes.

37 Prasad, M. Y. S., and K. R. Sridhara Murthy. "'Soviet Rockets Must Conquer Space' – Contributions of S. P. Korolev to the Soviet Space Research." Current Science, vol. 76, no. 1, 1999, pp. 100.
38 Baucom, Donald R. "Eisenhower and Ballistic Missile Defense: The Formative Years, 1944-1961." Air Power History, vol. 51, no. 4, 2004, pp. 7-8.
39 Von Braun, Wernher. "The Redstone, Jupiter, and Juno." Technology and Culture, vol. 4, no. 4, 1963, pp. 453-455.
40 Ibid., pp. 456.
41 Ibid., pp. 456-458.
42 Ibid., pp. 458-459.
43 Ibid., pp. 459-460.
44 Ibid., pp. 460-461.

After the development of the Juno vehicles were the Saturn launch vehicles. The Saturn I, a two-stage launch vehicle, was first tested on October 27, 1961. The vehicle would later experience nine successful launches, and an upgraded version, the Saturn IB, would be used for the Apollo missions of 1966-1968. Another Saturn vehicle developed was the three-stage Saturn V, which was designed for crewed Apollo lunar flights. First launched on November 9 of 1967, the vehicle was used for ten US-crewed Apollo missions, Apollo 8-17, from 1968-1972. The most notable of these missions was Apollo 11, on July 16 of 1969, where American astronauts Neil Armstrong and Edwin Aldrin stepped on the Moon for the first time in human history.[45]

45 "Apollo 11, July 1969: First Men on the Moon." Air Power History, vol. 36, no. 2, 1989, pp. 31

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