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# Chapter 1

# Arthur Rudolph and the Rocket That Took Us to the Moon*

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## Abstract

For hundreds of years, writers imaginatively transported people to the Moon by angels, dreams, and cannon fire. Space pioneer Arthur Rudolph managed the rocket program that allowed humans, for the first time, to set foot on the lunar surface.

Rudolph's management of the Saturn V rocket program was the culmination of a 40-year career in space technology development, which he began at the age of 24, working alongside rocket enthusiast Max Valier. After Valier's death in 1930, Rudolph designed his own, improved liquid rocket engine. He was one of the first men hired by the German Army to work on rocket experiments, based on the innovations he had made. Following his work on the World War II A-4 rocket, Rudolph came to the United States, working for the U.S. Army on the earliest intermediate range intercontinental ballistic missiles, including as manager of the Pershing I project.

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Following U.S. President John F. Kennedy's 1961 commitment to land a human on the Moon, Arthur Rudolph was given the responsibility of managing the rocket program to carry out Kennedy's mandate. The Saturn V rocket program was the most complex engineering, manufacturing, and management task in history.

While most people with such a lifetime of accomplishment are able to retire and enjoy their later years, Arthur Rudolph was subjected, in the early 1980s, to a "Nazi-hunting" witch hunt by the U.S. Department of Justice. Driven from the United States, Rudolph was later exonerated by the German government, but was never able to return to his adopted country. But Arthur Rudolph will be remembered in the history of astronautics for his early contributions and for the success of the rocket that took humans to the Moon.

**Figure 1:** Arthur Rudolph (1906–1996), the man who managed the Saturn V Moon rocket. This 1960 photograph was taken before his transfer to NASA. Credit: Arthur Rudolph.

## Modest Beginnings

Arthur Rudolph was born on 9 November 1906 in the small village of Stepfershausen (Figure 1). His parents were farmers—something he decided, at a young age, he would not be. From childhood, Rudolph expressed an interest in and passion for things mechanical and used every opportunity to examine how agricultural implements and other equipment in his small world functioned.[1]

Arthur Rudolph's father died in 1915 during World War I, leaving Arthur and his younger brother Walter the responsibility, and the chores, of the farm. After attending his village school, he attended the equivalent of a high school for three years and then left for Bremen, where he worked in the silver-working industry and underwent training in metal working and forging.

But he longed to be in a big city with new opportunities. In 1926, he had read, in a newspaper, an article with a picture of the Moon, advertising a novel by Otto Gail, about a flight to Venus. He was intrigued.

Arriving in Berlin in 1928, Rudolph was a toolmaker at the R. Stock and Company machine tool factory and later continued his studies, graduating in 1930 with an equivalent bachelor's degree in mechanical engineering.[2]

Rudolph reported that he was a heavy smoker, and one day, a pack of cigarettes he bought had a picture of Robert Goddard and his rocket on it! When a student, he read Hermann Oberth's 1929 book, *Wege zur Raumschiffahrt*, as soon as it was published.[3] And, being in Berlin, gave him the opportunity that same year to see *Frau im Mond*, the popular movie that convinced young men, such as Rudolph and Krafft Ehricke, that making space travel a reality was what they wanted to do with the rest of their lives.

On 1 May 1930, Rudolph started a new job at a manufacturing plant, owned by Dr. Paul Heylandt, which produced compressed liquid gases, including liquid oxygen, for German industry. During a tour of the plant on his first day, "we walked through the halls and also the machine shop, and I was not very impressed with that, because I had seen better ones before," Rudolph recalled in an interview in 1992.[4] "But finally we went into the backyard, and there I saw a strange contraption. "What is that?" Rudolph asked. "That is the test stand of Max Valier," the fellow giving the tour replied. "And when he said, 'Max Valier,' my ears picked up," Rudolph reported.

After quitting time on the second day of his job at Heylandt, Arthur Rudolph, "heard this loud noise, and I ran outside to see what it was." Max Valier and his assistant Walter Riedel were testing a small, liquid-fuel rocket engine. Rudolph asked Valier if he could use another assistant to conduct his experiments. He replied that "he could use all the help he could get," Rudolph recalled.[5]

Just two weeks later, on 17 May, Max Valier would die in Arthur Rudolph's arms. During the test of the rocket engine on a Saturday at the Heylandt works, as the pressure was turned higher in the engine, which was about a foot long and four or five inches in diameter, it exploded, shooting metal shrapnel in all directions. Valier died within minutes, and Riedel and Rudolph were lucky to escape with their lives.[6]

Happily, neither amateur rocket experimenter was about to give up, and Rudolph took on the challenge of moving rocket technology forward by improving Valier's rocket engine design.

## The Lampshade Engine

Max Valier's rocket engine used a "sprinkling can" type of injection system, where the fuel was delivered through small holes and in all directions. The holes were difficult to drill, according to Rudolph, which led to an uneven distribution of propellant and uneven combustion. The liquid oxygen flowed along the walls of the combustion chamber, but the inlet areas were not well controlled.

The rocket was prone to overheat, and glowing red spots and burn-throughs developed on the wall of the combustion chamber. This caused spikes in pressure, which in turn, created severe explosive jolts in the engine.

Rudolph replaced the "sprinkling can" with a lampshade-type injection system for the fuel and oxygen through ring slots, which could be more easily manufactured (Figure 2).

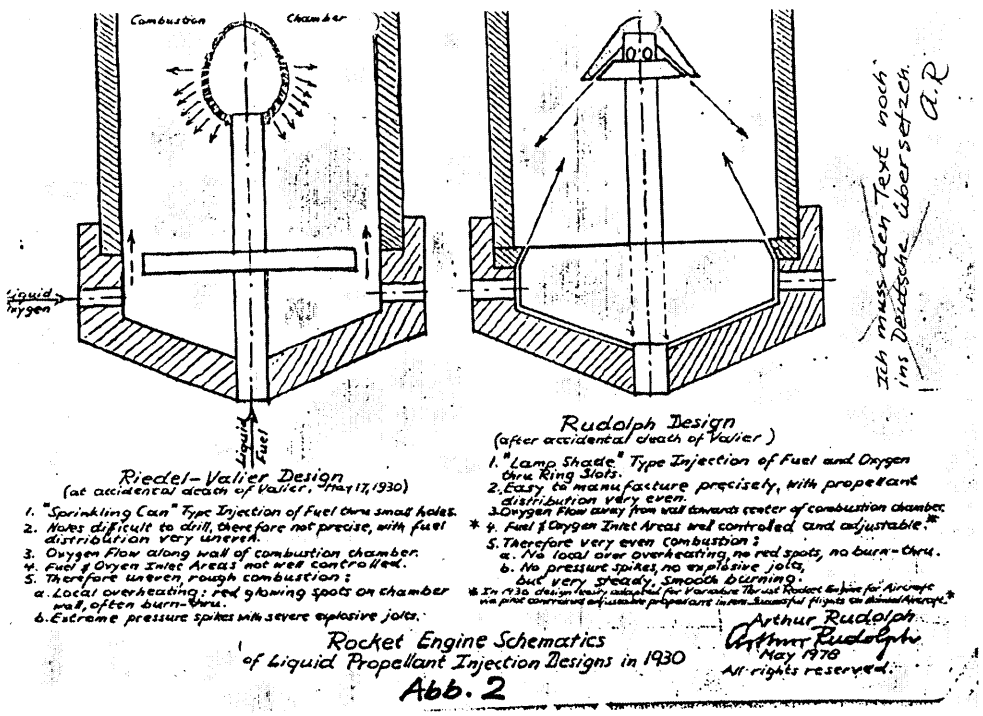


**Figure 2:** Arthur Rudolph's 1930 rocket engine design, as compared to Max Valier's. Credit: Arthur Rudolph.

With his new design, Rudolph was able to obtain a smooth, controlled burn. The propellant distribution was even, and the inlets were adjustable.[7] Now, he was ready for some real experiments.

Arthur Rudolph, Walter Riedel, and their boss at Heylandt, Alfons Pietsch, continued in Valier's footsteps and even got so far as a public demonstration of a rocket car at Tempelhof Airport in the spring of 1931.

With Pietsch behind the wheel, the crew tried to start the engine. No ignition. Arthur Rudolph reported: "I took a cigarette and threw it into the combustion chamber through the nozzle, and yelled, 'Full power. Ignition.' and Pietsch started the engine."

The automobile began to move at good speed, and the demonstration was a success. Rudolph remembered years later that "the applause was good, but the net income was equal to zero," considering what they had spent to prepare it. The money from the few paying observers did not even pay for the cost of the fuel.[8]

Meanwhile, Wernher von Braun and a band of unemployed machinists, engineers, and rocket enthusiasts, under the auspices of the German Society for Space Travel, were carrying out their own amateur experiments in the Berlin suburb of Reinickendorf, and Arthur Rudolph decided to see if they were faring any better than he.

The observation that Rudolph made about these early efforts was similar to that of Walter Dornberger, then directing the research for the German Army on rocket technology. There were no instruments to measure the thrust of the rocket engine, and von Braun explained that instead, they were doing theoretical calculations! Rudolph went back to his own experiments.

In May 1932, deep into the Depression, both Arthur Rudolph and Alfons Pietsch became unemployed. Determined to continue their rocket engine development work, Pietsch approached various industrial firms for support, but "nobody had a penny for our ideas," Rudolph reported.[9]

Finally, the German Army, under the guidance of (later) General Walter Dornberger, did provide the intrepid team with 100 marks for the construction and testing for its new engine and the establishment of a small laboratory. But it was far from smooth sailing.

When Rudolph and Pietsch were half finished, the money had run out. Arthur's future wife, Martha, contributed the funds she had squirreled away, which helped but was not enough. Finally, Dornberger threw in an additional 300 marks, and the project was completed in August 1934.[10]

During this time, Arthur Rudolph made trips each day to the patent office and "read all he could find about rockets and space travel" (Figure 3). He also entered a patent for his engine design.[11]

**Figure 3:** In 1932, when this photograph was taken, Arthur Rudolph was living in Berlin, working as an amateur rocket experimenter. Credit: Arthur Rudolph.

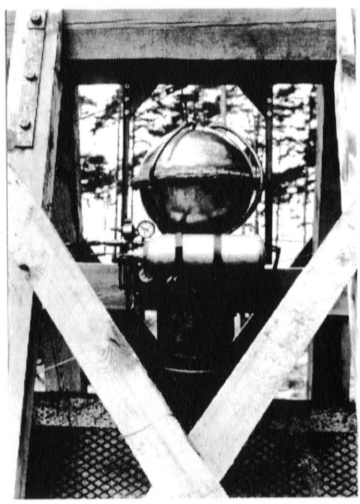

**Figure 4:** The rocket engine designed by Arthur Rudolph was the heart of the A-1 rocket, built by the German Army at its experimental station in Kummersdorf. This photograph of the engine on a test stand was taken in 1934. Credit: Deutsches Museum.

Von Braun reported that Rudolph was hired by the Army as a civilian, like himself, when he showed up with the "complete alcohol-oxygen rocket power-plant" that he had designed, "which made two wholly successful static runs at first trial."[12]

By 1934, the Army had established the experimental rocket research and test station at Kummersdorf, and, after the successful tests of the Rudolph rocket engine, it was finally time to also design the rocket. The entire assembly was to be called an Aggregate. The Aggregate-1, or A-1, rocket was built but never flight tested, due to a lack of available methods for guiding and controlling rockets. Arthur Rudolph's engine, the heart of the A-1, worked fine, but there was no ability to stabilize the assembly in flight (Figure 4).

Finally, two successful tests of the A-2, outfitted with a gyroscope for stability, brought the German rocket program into its own.[13]

To move on to the larger A-3, Arthur Rudolph was given the task of completing the test stand, which had been designed by Walter Riedel, ordering the equipment, and hiring more people for the project.[14] This early management experience would serve him well in later years.

On 4 December 1937, the A-3 performed its first flight, and while the propulsion system performed to specification, again the lack of adequate guidance and control plagued the system.

A year before that, it had become clear to Dornberger that a larger, more remote rocket test station was needed, and, at von Braun's suggestion, the site chosen was at Peenemünde along the Pomeranian coast. In May 1937, Arthur and Martha Rudolph moved to the nearby town of Zinnowitz, and their daughter Marianne was born there on 26 November (Figure 5).

**Figure 5:** In May 1937 Arthur and Martha Rudolph moved to the town of Zinnowitz, near the experimental rocket station at Peenemünde. In November of that year, Marianne was born. This photo shows the family in 1938. Credit: Arthur Rudolph.

## Rockets and Retaliation

General Dornberger may have convinced the military brass to finance the establishment of the premier rocket research and development facility in the world, but in return, the Army wanted results. The design specification for the next rocket in the series, the A-4, was to be the first designed to carry a warhead.

Following the decision to move forward, Arthur Rudolph was responsible for outfitting the new research center at Peenemünde and started ordering the machinery. "I wrote out my requirements, wrote it myself," he reported, "for hundreds of machine tools. Then I went to [the Luftwaffe,] and they ordered what I wanted without any question. It was fantastic; fantastic. And that made it possible to establish that marvelous place, Peenemünde."[15]

But Arthur Rudolph's life would take a turn for the worse after the 17–18 August 1943 British air raids on the Peenemünde center. The Nazi military Schutzstaffel (SS) was now running the A-4 production program, which had been propagandistically been renamed the V-2, for "Vergeltung" or "retaliation," for the carpet bombing that was underway of German cities.[16]

The underground rocket manufacturing facility, Mittelwerk in the Harz Mountains, was run by the SS. Arthur Rudolph recalled: "I had the overpowering, awful feeling that I was trapped in a cage like an animal, and that I was caught in the claws of the SS system."[17]

Those among the forced laborers who raised questions or objections to the hideous conditions in the tunnels were hanged. Those among the German workers or technical managers, like Arthur Rudolph, were threatened with being sent to concentration camps, and some were. When Arthur Rudolph began work in the tunnels, he weighed 180 pounds. By the time the war was nearing its end, and production stopped in the tunnels, he weighed 126 pounds. His wife, Martha, believed that if he had continued in those conditions for six more months, he would he died there.[18]

Finally, the war was over. Some members of the von Braun team, including Arthur Rudolph, were, in August 1945, deployed to Cuxhaven to participate in Operation Backfire, firing V-2s for the British. And then, finally, they were off to the United States.

## Building America's Arsenal

In November 1945 Arthur Rudolph left for Paris, France, and then by ship, to the United States. The von Braun team worked in El Paso, Texas, at Fort Bliss and at White Sands, New Mexico, testing rockets they already knew how to fly.

In 1950, Arthur Rudolph and the von Braun team were transferred to the Redstone Arsenal in Huntsville, Alabama, to finally start some real work. The U.S. Army established the Ordnance Guided Missile Center at the arsenal, under Major James Hamill, with von Braun as technical director, and Rudolph was made technical director of the A-4-derived Redstone rocket.[19]

During his work on the Redstone rocket, Rudolph took a top management course to hone his skills for guiding large projects. He commented later about his observations on what needed to be changed in the management of the system of military procurement. "According to my experience, all of the U.S. weapons systems were accompanied by guidance and control failures. I proposed that they only order [components] from such firms that had shown themselves to be superior." This proposal was rejected, on the basis of money, as the military looked for a cheaper variant, "which would undoubtedly show the same series of failures."[20]

The German space pioneers in Huntsville knew that for military requirements and to ever get into space, larger, more capable rockets than the war-time V-2 were required. In March 1956, Arthur Rudolph put together a plan for the mass production of the Redstone missile by industry. His job was to crack down on the contractors and try to keep the program on schedule. He related that he went to visit the Chrysler plant in Detroit, to find out why their work on the Redstone had been delayed. He was told that there was a part missing, which turned out to be a detergent! "That a rocket, on account of a piece of washing soap could not be completed, was the absolute negative height in the breakdown-rich history of the U.S. rocket work," he reported. Eventually, the design of the Redstone was standardized, which required that Rudolph "untangle various functions and still have them all work."[21]

In 1958, the Redstones were deployed as mobile missiles, backing up NATO forces in Europe, and were replaced by the first multi-state rocket, the Jupiter, developed in Huntsville, by 1960. The Jupiter missiles were designed for an intermediate range of 1,500 miles and were developed in facilities at the newly established Army Ballistic Missile Agency (ABMA) under General John Medaris. The Jupiter rocket obtained its place in history, when, at the end of January 1958, it lofted America's first satellite, *Explorer 1*, into Earth orbit.

In 1956, the decision was made that the U.S. Army needed a "shoot and scoot" mobile missile, which meant it had to be solid-fueled. This was the Pershing program. Rudolph was made the project director, with $500 million for its development. He assembled a team and took bids. He visited the potential contractors in person, and, knowing the guidance system was critical, chose the Bendix plant in New Jersey for the job. After inspecting the facilities, he noted that it

had the best precision machine tools for the job, which were made in Germany! "That was the firm for us!" he decided.[22] The creed that Rudolph developed to manage the Pershing rocket was that "nothing could fall through the cracks." Research and development laboratories were expanded for testing vibration, hearing, and other conditions that would face the rocket in flight.[23]

Following the uproar after the Soviet launch of *Sputnik* in November 1957, the National Aeronautics and Space Administration (NASA) was established. The heart of the new civilian space program would be rockets, and the von Braun team—all but Arthur Rudolph—was transferred from the Army. He was considered irreplaceable on the Pershing program (Figure 6).

**Figure 6:** Key members of the rocket team under General John Medaris at the Army Ballistic Missile Agency in Huntsville, Alabama, posed for this photograph, shortly before the general retired from the Army in fall 1959. Arthur Rudolph is in the light-colored jacket. Credit: NASA, Marshall Space Flight Center.

In 1960, Arthur Rudolph, for his management of the Pershing missile program, received the Exceptional Civilian Service award, the highest civilian award in the Army. During 1960, the Pershing project director made trips for the Army to Italy, France, and West Germany, to promote the purchase of the missiles for air defense in Europe. But his goal was to rejoin his friends and colleagues to get the United States into space.[24] Finally, in 1961, Arthur Rudolph did so, when he transferred to NASA. President Kennedy had challenged the United States to land a human on the Moon.

## The Moon Rocket

Providing the transportation to take astronauts to the Moon would require the greatest mobilization of engineering power and technical and manufacturing capability in U.S. history. Arthur Rudolph's job was to manage the Saturn V rocket program to make sure they got there safely and on the President's timetable.

In 1962, at a meeting at NASA headquarters in Washington, DC, Rudolph put forward his list of basic requirements for the Apollo rocket and a mission plan that was based on his experience managing the Pershing program. In 1963, he was named the program manager for the Saturn V. He quickly examined the problems that NASA's Jet Propulsion Laboratory (JPL) was having with the robotic Ranger lunar program, to see what lessons could be learned. He reported later that JPL had complained that the design, engineering, and testing demands at NASA's Marshall Space Flight Center (MSFC) in Huntsville were "too strict" in comparison to the way JPL was carrying out its effort.

Arthur Rudolph responded: "I was so angry that I jumped up and said, 'you still don't seem to have understood that if there is the slightest doubt about the ability of the system to function, you must, through long and repeated improvements and tests, make sure that no flight failure will occur. If you don't introduce this principle in the Ranger project, it will remain a failure.'"[25]

Arthur Rudolph's management of the massive Saturn V rocket program involved his personal tracking of all aspects of the system. He had a chart in his office showing all the components, large and small, to be able to immediately see their progress. This made the entire program transparent and provided an overview of the massive coordination. Every problem was dealt with, in excruciating detail, by the program manager and his staff.[26] The goal of the Saturn V program was a rocket system with 99 percent reliability. This required a meticulous attention to detail, extensive testing, stringent quality control, and management techniques to coordinate and supervise more than 20,000 industrial contractors and 7,000 civil service NASA employees (Figure 7).

NASA's official history of the Saturn V program reports that even NASA Administrator, James Webb, who "prided himself on managerial techniques and skills," was impressed with MSFC organization of the Moon rocket effort. "Given the diversity of the prime contractors and their armies of subcontractors and vendors ... the clockwork efficiency and the reliability of the Saturn vehicles were remarkable." NASA history also reports that "even after the Saturn V program was over, MSFC still received many requests from businesses and managers asking, 'how did you do it?'"[27]

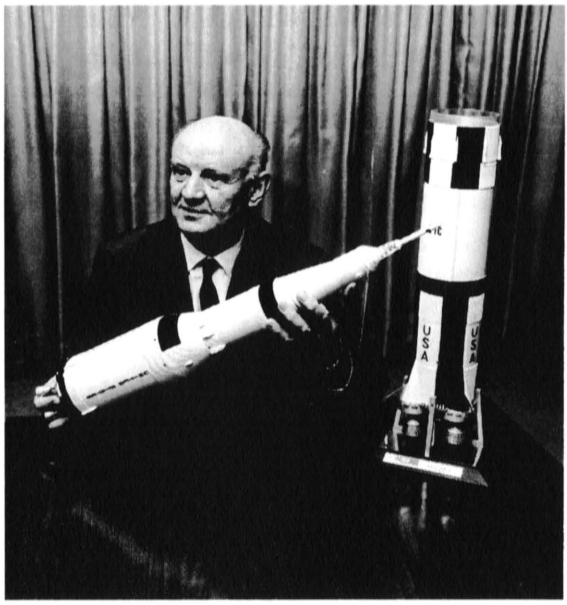


**Figure 7:** As manager of the Saturn V rocket program, Arthur Rudolph was responsible for supervising the work of more than 20,000 industrial contractors and more than 7,000 civil service employees. For his accomplishments, he received the Exceptional Service Medal and Distinguished Service Medal by NASA. Credit: Arthur Rudolph.

The proof of the pudding was in the results: a total of 32 Saturn launches, including 9 human lunar missions, the first humans to orbit the Moon, and the first people to land there. For Arthur Rudolph, personally, the successful test flights of the Saturn V were proof that his program was a success. On his 61st birthday, in November 1967, he informed NASA he would retire the following year. When *Apollo 8* orbited the Moon during Christmas 1968, Rudolph knew he had done his job.[28] For his management of the Saturn V program, Arthur Rudolph received both the Exceptional Service Medal and the Distinguished Service Medal from NASA. His job of developing and producing the rocket to take humans to the Moon completed, Arthur Rudolph retired from the space agency and from rocket research on 1 January 1969.

On 20 July 1969, Neil Armstrong and Buzz Aldrin took humankind's first steps on the Moon. They could not have done it without Arthur Rudolph's Saturn V. When Arthur Rudolph retired from federal service, his Congressman, Robert Jones, entered a tribute to him into the *Congressional Record.* He concluded with: "I commend him on his outstanding achievements in our Nation's missile and space programs, and I wish Dr. Rudolph and his family every happiness in their future years."[29] Unfortunately, not many of Arthur Rudolph's remaining years would be happy ones.

## A Travesty of Justice

While living quietly in retirement in California, Arthur Rudolph received a letter, in September 1982, from the Office of Special Investigations (OSI), of the U.S. Department of Justice. The letter asked if he would meet with the OSI and answer some questions about his activities during World War II. Knowing he had nothing to hide, and foolishly trusting the honesty and integrity of representatives of the U.S. government, he agreed to the meeting, without a lawyer present.

Thus began a battle between the "Nazi-hunting" OSI and the Rudolph family to counter charges that Arthur Rudolph was guilty of war crimes. The tactics used by the OSI, of threats, intimation, and charges without evidence, would be repeated more than a decade later in the effort to frame computer scientist Dr. Wen Ho Lee, on equally bogus charges of nuclear spying for the People's Republic of China.

In secret, Arthur Rudolph, then ill and 77 years old, signed an agreement with the Department of Justice on 28 November 1983 to leave the United States to avoid prosecution for war crimes. Arthur and Martha Rudolph left for West Germany on 27 March 1984. When the news of his having left for Germany became public late that year, a political mobilization began on the part of not mainly his former colleagues in the German rocket team, who were, themselves, under surveillance and possible threat, but by his American military and civilian colleagues[30] (Figure 8).

**Figure 8:** The author with Arthur Rudolph at his home in Hamburg, Germany, during an interview in 1992. Although he was not exonerated during his lifetime, Rudolph's place in history is secure, as the man who built the rockets that took humans to the Moon.
Credit: William Jones.

Rudolph applied for German citizenship after he arrived, and on 19 July 1984, the German government formally asked the OSI for the evidence it had against him. Nearly one year later, the OSI finally responded to the request. The German government, after an extensive investigation, determined in March 1987 that there was no basis for prosecuting him, and Arthur Rudolph was granted West German citizenship.

Arthur Rudolph passed away on 1 January 1996 without being exonerated by the U.S. government in this travesty of justice. But on 5 September 2003 some justice was served in this case that is a stain on the American democratic principle of fairness. The newspaper *Forward* reported that Neal Sher, the former chief of staff in the Washington office of the International Commission on Holocaust Era Insurance Claims, had been disbarred. Sher had been investigated for misappropriating funds for personal use. Neal Sher was one of the OSI officials who interrogated Arthur Rudolph in a California hotel room in 1982.

Arthur Clarke observed that the 20th century will be remembered, not for the world wars or other horrible events, but for the first human landing on the Moon. Arthur Rudolph will be remembered by history as the man who managed the Saturn V rocket program that took humans to the Moon.

## Notes

[1] Thomas Franklin, *An American in Exile* (Huntsville, Alabama: Christopher Kaylor Company, 1987), p. 7.

[2] Franz Kurowski, *Raketenpionier Arthur Rudolph* (Inning, Germany: Vowinckel Verlag, 2001), p. 18.

[3] Kurowski, *Raketenpionier,* p. 18.

[4] Interview with by the author with Arthur Rudolph, 1992.

[5] Franklin, *An American*, p. 17.

[6] Franklin, *An American*, pp. 17–18.

[7] Rudolph interview.

[8] Kurowski, *Raketenpionier*, p. 22.

[9] Kurowski, *Raketenpionier*, p. 24.

[10] Kurowski, *Raketenpionier*, p. 24.

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[12] Marsha Freeman, *How We Got to the Moon: The Story of the Germany Space Pioneers* (Washington, DC: 21st Century Science Associates, 1993).

[13] Freeman, *How We Got to the Moon*, p. 91.

[14] Kurowski, *Raketenpionier*, p. 27.

[15] Franklin, *An American*, p. 48.

[16] Freeman, *How We Got to the Moon*, p. 124.

[17] Franklin, *An American*, p. 76.

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[19] Freeman, *How We Got to the Moon*, p. 185.

[20] Kurowski, *Raketenpionier*, p. 145.

[21] Kurowski, *Raketenpionier*, p. 148.

[22] Kurowski, *Raketenpionier*, p. 150.

[23] Kurowski, *Raketenpionier*, p. 151.

[24] Kurowski, *Raketenpionier*, p. 158.

[25] Kurowski, *Raketenpionier*, pp. 161–162.

[26] Kurowski, *Raketenpionier*, p. 168.

[27] Roger Bilstein, *Stages to Saturn* (Washington, DC: NASA, SP-4206, 1980), p. 399.

[28] Kurowski, *Raketenpionier*, p. 174.

[29] Franklin, *An American*, p. 123.

[30] William E. Winterstein, *Gestapo USA* (San Francisco: Robert D. Reed, 2002). Freeman, *How We Got to the Moon*.