Biographical Essays in Honor of the Centennial of Flight, 1903–2003

Realizing the Dream of Flight

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Wernher von Braun

A Visionary as Engineer and Manager

ANDREW J. DUNAR

DURING THE 1960S, AS NASA'S APOLLO PROGRAM PREPARED TO PLACE MEN ON THE MOON AND RETURN THEM SAFELY TO EARTH, WERNHER VON BRAUN WAS UNDOUBTEDLY the most well-known nonastronaut in the American space program. An immensely talented man, he had a rare combination of the vision to project the potential for human spaceflight in the 20th century, the engineering skills to develop the technology needed to make such dreams reality, and the managerial ability to direct accomplished scientists and engineers by motivating them, earning their loyalty,and organizing their energies into a cohesive enterprise that pressed the limits of new technology. In Germany during World War II, he developed the notorious V-2 rocket, which also became the first rocket to lift an object constructed by humans into space. After the war, von Braun helped stimulate interest in space travel in the United States and the West in the 1950s through articles in popular magazines, speeches, and appearances on television. He directed the development of the rocket that launched the

first American satellite, Explorer I, into space in January 1958 and the first American, Alan Shepard, into space on 5 May 1961. After the establishment of the National Aeronautics and Space Administration, he became the Director of one of its two largest Field Centers, the Marshall Space Flight Center in Huntsville, Alabama. There he directed development of the powerful Saturn rocket series that served as the launch vehicles for the Apollo program, the American program of lunar exploration.

Yet von Braun was a complex man whose critics never let him forget that his earliest notoriety came from his work on behalf of Hitler's Nazi regime, developing the V-2 missiles that fell on London during WWII; that he had been a member of the Nazi Party, and as was later discovered, of the SS; and, as the story developed in the late 1960s and early 1970s, that slave labor built the V-2 rockets. The German background was always present, for even in the United States von Braun built his team on a foundation of German engineering talent that had worked with him developing the V-2 in Peenemünde during WWII and accompanied him to the United States after the war ended. One of the reasons for his success was his ability to blend Germans and Americans into a successful organization, incorporating the best of contrasting approaches in engineering methodology, testing, and development.

SOCIETY FOR SPACE TRAVEL

Von Braun was born on 23 March 1912 in Wirsitz in Posen, a territory east of the Oder River; the town Wirsitz became part of Poland after WWI. His father was a government administrator, the equivalent of a county commissioner in Wirsitz, and later held positions in the German government in Berlin. Young Wernher was confirmed into the Lutheran church at the age of 13. His mother stimulated his first interest in space when she gave her son a telescope.[1] Wernher recalled an early experiment with rockets, in which he fastened skyrockets to a wagon—an unmanned vehicle, he remarked—and watched in fascination as it careened wildly about. "The police, who arrived late for the beginning of my experiment, but in time for the grand finale, were unappreciative," he recalled.[2]

During von Braun's adolescence, general interest in rocketry in Germany developed into a national fascination. Hermann Oberth, an ethnic German from Romania, became the focus of the rocket fad when he published *Die Rakete zu den Planetenraumen* (*The Rocket into Interplanetary Space*) in 1923. Unlike the more obscure works of the Russian

1 Ernst Stuhlinger and Frederick I. Ordway III, *Wernher von Braun: Crusader for Space* (Malabar, FL: Krieger Publishing Company, 1994), pp. 9–12.

2 Wernher von Braun, "Recollections of Childhood/Early Experiences in Rocketry" (1963), *http://history.msfc.nasa.gov/vonbraun/recall.html*.

Konstantin Tsiolkovsky and the more cautious publications of the American Robert Goddard, Oberth wrote in accessible prose, advocating liquid-fueled rockets for human spaceflight. An Austrian publicist and rocket enthusiast, Max Valier, publicized Oberth's ideas. Valier was among the charter members of an amateur rocket society founded by Johannes Winkler in 1927—the Society for Space Travel—that became known by its German acronym, VfR.[3] Oberth served as president of the society and also cooperated with the renowned film director Fritz Lang in the production of a science-fiction film, *Frau im Mond* (*Woman on the Moon*), that gave further publicity to the embryonic rocketry boom.[4]

Oberth's ideas stimulated the young von Braun. As a high school student at Ettersburg boarding school, Wernher sent Oberth a paper he had written on rockets. By the fall of 1929, having graduated from Ettersburg, von Braun had joined the VfR, which now had grown to 870 members. The following spring, he registered as an engineering student at the Technische Hochschule (Technical University) of Berlin Charlottenburg. There he met Oberth for the first time and helped him test a combustion chamber and nozzle that used gasoline and liquid oxygen as fuel.[5]

ROCKETRY IN THE GERMAN ARMY

By the late 1920s, the German army had developed interest in rockets. Lieutenant Colonel Dr. Karl Becker, chief of ballistics and ammunition for the Army Ordnance Office, was an artilleryman by trade, but the Versailles Treaty that ended WWI forbade the German army from developing heavy artillery, and rockets provided a possible alternative. In the winter of 1931–1932, Becker and two other army officers, Captain Dr. Walter Dornberger, who was responsible for powder rockets for the army, and Major Wolfram Ritter von Horstig, an ammunition expert, visited the amateur rocket experts of the VfR, including von Braun, who were experimenting at the Raketenflugplatz Reinickendorf, and invited them to Kummersdorf, where the army had begun experimenting with rockets. At Kummersdorf, the VfR amateurs set off a small rocket that flew 1,300 meters before crashing. Becker criticized the amateurish approach, particularly the lack of hard data, but offered von Braun a chance to work for the army.

Von Braun accepted, and, by early December 1932, he signed a contract to work on liquid-fueled rockets for the army at Kummersdorf. As von Braun's defenders point out,

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3 Hermann Oberth, *Die Rakete zu den Planetenräumen* (Nuremburg: Uni-Verlog, 1960 (reprint)); and Michael J. Neufeld, *The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era* (New York: Free Press, 1995), pp. 6–7.

4 Frederick I. Ordway III and Mitchell R. Sharpe, *The Rocket Team* (New York: Crowell, 1979), pp. 12–13.

5 Stuhlinger and Ordway, *Wernher von Braun*, pp. 15–17.

Photo occasioned by the certification of Hermann Oberth's liquid-fueled rocket engine in the 1930s. Left to right: Rudolf Nebel, Dr. Karl Ritter, Mr. Baermueller, Kurt Heinish, Klaus Riedel, Wernher von Braun, and unidentified person. (NASA Marshall Space Flight Center, negative number 6517791)

he went to work for the army two months before Hitler came to power. Von Braun was no admirer of the Nazis and indeed was frank (if perhaps unintentionally revealing) in explaining his decision to accept the army's offer: "Our feelings toward the army resembled those of the early aviation pioneers, who, in most countries, tried to milk the military purse for their own ends and who felt little moral scruples as to the possible future use of their brainchild." At the same time, the Technical University of Berlin accepted von Braun as a doctoral candidate. In a secret agreement with the army, he used the development of liquid-fueled rockets as the topic for his dissertation.[6]

Von Braun went to work under the military supervision of Dornberger, who assessed the young man as an energetic, shrewd, and temperamental student with an "astonishing" theoretical knowledge, whose ideas gushed forth in a "bubbling stream."[7] By 1934, von Braun and his team had designed their first rocket, the A-1 (Assembly-1 or Aggre-

6 Neufeld, *The Rocket and the Reich*, pp. 20–23.
7 Walter Dornberger, *V-2: The Nazi Rocket Weapon* (New York: Ballantine Books, 1954), pp. 33–34.

gate-1), a 4.6-foot-long tube 1 foot in diameter that developed 650 pounds of thrust. Its center of gravity was too far forward, however, and it blew up on the test stand. Von Braun modified its design, producing the A-2, and in December the group successfully fired its first liquid-propelled rocket.

While in Kummersdorf, Dornberger and von Braun never had unlimited funds and had to work with a small staff and be creative in getting needed materials. They began with only von Braun and a single mechanic. Dornberger and von Braun recruited others, and by the end of 1934 they had added Walter Riedel, a steady test engineer and designer, and Arthur Rudolph, who had already designed a liquid-propellant motor and who had become a member of the Nazi Party in 1931.

The solution to the financial problem came from an unexpected source. Herman Goering's recently established Luftwaffe threatened to disrupt the military missile program, but an alliance between the two services, fashioned by the Luftwaffe's Major Wolfram Freiher von Richthofen, brought them together. The Luftwaffe—brash, ambitious, and financially well heeled—challenged the hide-bound, bureaucratic, tightly budgeted army to act decisively. Indeed, when the Luftwaffe offered 5 million marks to initiate the alliance, General Becker more than matched the figure, offering 6 million—a 75-fold increase over the usual annual budget of only 80,000 marks![8]

PEENEMÜNDE

The operation began to outgrow its limited facilities, and Dornberger and von Braun began looking for a new location. Von Braun suggested Peenemünde on the wooded north end of the Baltic island Usedom, near where his grandfather had hunted ducks. Dornberger visited the site and agreed. The shift to Peenemünde took time, however, and during the transition operations were split between the new site and Kummersdorf. Thus when Hitler inspected the operation in 1939 for the first and only time, he came to Kummersdorf. Dornberger led the tour, but von Braun assisted and helped to present the technical progress to the Führer. Unlike most other visiting dignitaries, Hitler seemed strangely passive; although, he did ask about the range of the A-4, about how long it would take to make it operational, and whether steel could be used for the tank instead of aluminum. Without further ado, he said, "Well, that's grand," and departed.[9]

Peenemünde had several advantages, not the least of which was that test missiles could be fired over water. The remote location also offered secrecy, although nearby

8 Ordway and Sharpe, *The Rocket Team*, pp. 24–26.
9 Dornberger, *V-2*, p. 66.

summer beach resorts meant that isolation was limited. Furthermore, the site had room for expansion and allowed for the concentration of research, development, and production at one location, a concept that Dornberger called "everything under one roof." Von Braun at first resisted this approach, arguing that he lacked experience in production. Eventually he embraced it, and this "arsenal system" became one of the hallmarks of von Braun's approach to rocket development and a key to its success.[10]

At first, the imperative of secrecy allowed little cooperation with industry. Nor was there much incentive for industry to desire a role, since few had expertise in rocketry, and conventional arms contracts were more lucrative. Thus Dornberger and von Braun adopted the arsenal concept both by design and by default. As von Braun's colleague Ernst Stuhlinger recalled, Peenemünde used the arsenal system because nobody else could build rockets. "We had to develop it," he explained. "We did it in our Peenemünde laboratories and became the experts before anybody else was an expert."[11]

As operations at Peenemünde matured, von Braun sought closer relationships with industry and universities, but the in-house system was already in place. He contracted work to the universities and also recruited professors to Peenemünde, where many became lab directors. Although few of these recruits had worked in rocketry, they had expertise in disciplines such as physics, chemistry, and mechanical and electrical engineering, all of which had applications at Peenemünde. Many had advanced degrees, and many had worked in industry.[12] It was a substantial operation that, at its peak in 1943, employed 1,950 scientists, engineers, and technicians. At that time, Peenemünde had a budget of 112 million reichsmarks, or approximately $27 million.[13]

From 1938 to 1942, von Braun's research team conducted hundreds of test firings. They learned to profit from failure. Von Braun remembered that for a long time "our main objective was to make it more dangerous to be in the target area than to be with the launch crew."[14] They made progress in stability, propulsion, gas stream rudders used for steering, the wireless guidance communication system, and instruments to plot flight paths. Privately, among themselves, they discussed spaceflight.

The most memorable moment for veterans of rocket development at Peenemünde, and the pinnacle of von Braun's achievements in Germany, occurred on 3 October 1942. On

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10 Michael J. Neufeld, "Peenemünde-Ost: The State, the Military, and Technological Change in the Third Reich," paper presented at the International Congress of the History of Science, Hamburg, West Germany (2 August 1989), p. 3. Neufeld cites von Braun team member Gerhard Reisig in attributing the phrase to Dornberger.

11 Ibid., pp. 4–6, 10–11; and Ernst Stuhlinger, interview by Andrew J. Dunar and Stephen P. Waring (24 April 1989), Huntsville, AL.

12 Ernst Stuhlinger, interview by Dunar and Waring (24 April 1989), Huntsville, AL.

13 Tom D. Crouch, *Aiming for the Stars: The Dreamers and Doers of the Space Age* (Washington: Smithsonian Institution Press, 1999), p. 79.

14 Major General John B. Medaris with Arthur Gordon, *Countdown for Decision* (New York: G. P. Putnam's Sons, 1960), pp. 37–38.

that date, an A-4 rocket became the first human-engineered creation to penetrate space. The A-4 achieved an altitude of 53 miles (85 kilometers) during a 5-minute flight, traveling 118 miles (190 kilometers) downrange. Von Braun remembered Dornberger's joy and his comment, "Do you realize what we accomplished today? Today the spaceship has been born! But I warn you: our headaches are by no means over—they are just beginning!"[15]

By May 1943, British intelligence had determined that Peenemünde was a center for rocket development. In August, the British struck with a bomber attack that killed 732 or 735 people (according to accounts by Dornberger) and destroyed test stands and transportation facilities. V-2 production facilities suffered little damage, but the raid prompted a decision that no production would take place at Peenemünde.[16]

THE NAZI PARTY

Labor for production had become a problem in any case by 1943, and the solution has influenced interpretations of von Braun's early career. Arthur Rudolph, who was the chief engineer of the Peenemünde factory, sought concentration camp prisoners as a source of labor, helped gain approval for their transfer, and served there as a technical director. V-2 production facilities at Nordhausen and the nearby concentration camp at Dora witnessed the death of approximately 20,000 people through execution, starvation, and disease. The major production facility, Mittelwerk, was in an abandoned gypsum mine that afforded interlocking tunnels, where slave labor built a factory that extended a mile into the hillside. There is no dispute that conditions at Mittelwerk were harsh beyond belief; even the high-ranking Nazi Albert Speer described conditions as "barbarous" and "scandalous."[17] Unlike Rudolph, von Braun never had direct supervisory responsibility over Mittelwerk's slave labor. He visited on several occasions, for periods ranging from a couple of hours to two days. On occasion he observed slave labor, and colleagues recall that he reported that he had never seen a dead person there and was deeply disturbed by what he saw, but that when he suggested that conditions ought to be improved, Stuhlinger asserts that he was told to mind his own business or he would find himself wearing the striped shirt of the prisoners.[18] The historian Michael Neufeld, who has conducted the most thorough review of the Peenemünde-Mittelwerk nexus, concluded that von Braun "essentially made a pact with the devil in order to build large rockets" and that "there is no evidence that he ever stuck his neck out for the concentra-

15 Stuhlinger and Ordway, *Wernher von Braun*, p. 29.
16 Neufeld, *The Rocket and the Reich*, pp. 198–200.
17 Stuhlinger and Ordway, *Wernher von Braun*, p. 42.
18 Ibid., pp. 41–46.

tion camp prisoners before his arrest, nor did he show any obvious pangs of conscience about their fate until the 1960s and 1970s, when protests by French prisoner survivors forced him to confront the issue more directly."[19]

Von Braun's relationship with the Nazi Party likewise is laden with ambiguities that give both his defenders and his critics evidence to debate. Many German academics, scientists, and technicians joined the Nazi Party. To do so offered the prospect of grants, promotions, and other preferential treatment. To refuse to do so risked untold consequences. In May 1940, an SS colonel brought von Braun an order from Heinrich Himmler, chief of the notorious SS, urging von Braun to join and accept the rank of lieutenant in the SS. Von Braun accepted, but only after conferring with his colleagues who agreed that refusal might provoke Himmler's wrath. Von Braun's colleagues recall this and a promotion offered in 1943 as part of an attempt to lure him from the army to the SS.[20]

In March 1944, one of the strangest events in von Braun's years under the Third Reich occurred when the Gestapo arrested him. The arrest came in part because of competition within the Nazi bureaucracy for control of the Peenemünde project. Himmler made a bid to wrest control of rocket development from Armaments Minister Albert Speer. Himmler summoned von Braun in February. After suggesting that von Braun must realize that the A-4 was no longer a toy and that the German people were awaiting its deployment, Himmler dangled his bait. He sympathized with von Braun's dilemma, being enmeshed in the army bureaucracy, and suggested that von Braun ought to come over to the SS, which had direct access to Hitler and could cut through red tape. Von Braun responded that he had the best chief he could hope for in Dornberger and that it was technical difficulty rather than the bureaucracy that was slowing development. Himmler dismissed von Braun but began compiling a dossier on him and other members of his team.

Early in March, von Braun relaxed with colleagues, discussing space travel as they often did in their off-duty hours. Among them was a woman who was an agent of the SD, the security arm of the SS; she reported the conversation to her superiors, although her report only added to the charges already assembled. At 2 a.m. on a March morning—the precise date is disputed, but was most likely March 22—the Gestapo awakened von Braun, arrested him, and took him to Stettin, nominally under protective custody. Gestapo officers also arrested other members of his team, including Klaus Riedel and von Braun's brother Magnus. Dornberger soon learned of the arrests and that the charges were so serious that it might cost the prisoners their lives. They stood accused of sabo-

19 Neufeld, *The Rocket and the Reich*, pp. 278–279.

20 Christopher Simpson, *Blowback: America's Recruitment of Nazies and Its Effects on the Cold War* (New York: Weidenfeld & Nicholson, 1988), pp. 32–36; and Neufeld, *The Rocket and the Reich*, pp. 178–179. The comments of von Braun's colleagues come from Ernst Stuhlinger; see notes on a draft chapter of Dunar and Waring, *Power to Explore: A History of Marshall Space Flight Center, 1960–1990* (Washington, DC: NASA SP 4313, 1999).

taging the A-4 program and diverting their attention to space travel rather than devoting their energies to weapons development. The charges alleged that von Braun had a plane at his disposal that he could use to flee to Britain with the A-4 plans. Von Braun indeed had a plane that he used for business flights in Germany, and the allegation was impossible to prove or disprove. Dornberger claimed that he defended von Braun and Riedel without reservation, saying they were not working on space rockets but on war missiles, and ultimately won their release. The incident, as historian Michael Neufeld observed, proved to be "one of the most fortunate things that ever happened" to von Braun in the Third Reich, since "after the war his defenders were able to credit him with an anti-Nazi record he never had."[21]

SURRENDERING TO THE AMERICANS

By early 1945, little doubt remained that the allies would win the war. With the Russians advancing toward Peenemünde, the group began to evacuate late in January, destroying material that the Russians might seize. SS General Hans Klammer, who had taken charge of missile development even as it was collapsing, directed von Braun and his colleagues to the Harz Mountains, near the notorious Mittlewerk site. On 1 April, as the Americans neared the Harz Mountains, Kammler directed von Braun and approximately 500 key people to move to the Bavarian Alps. As allied forces advanced in April, von Braun's men moved to villages in the vicinity of Oberammergau. They moved crates of documents estimated at 14 tons to an abandoned mine and detonated dynamite at the entrance to seal the treasure. Von Braun and his colleagues later claimed that they discussed their situation and agreed that their future would be more promising if they could surrender to the Americans, who had not suffered the physical damage that other combatant nations had endured and whose economy would be most able to support rocket development. Only at the end, however, did they have much control over their destiny. Early in May, as the Americans advanced toward Oberammergau, von Braun's brother Magnus rode out on a bicycle to meet the troops and surrendered.[22]

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21 Neufeld, *The Rocket and the Reich*, pp. 214–220; Ordway and Sharpe, *The Rocket Team*, pp. 46–49; and Dornberger, *V-2*, pp. 178–184. Michael Neufeld elaborated on his investigation of von Braun's Nazi connections in an article in 2002, in which he concluded that "Wernher von Braun was neither an ideologically committed National Socialist nor an enthusiastic SS officer, but . . . like a great majority of Germans, he was enthusiastic about many of the 'accomplishments' of the 'Führer' during the late 1930s and early 1940s, and was correspondingly indifferent to the persecutions of the political opponents, Jews, and citizens of occupied countries. . . . Ultimately, it is not Wernher von Braun's membership in the SS nor his involvement in slave labor that is most bothersome. . . . It is his technocratic amorality, his single-minded obsession with his technical dreams, that is so disturbing." Michael J. Neufeld, "Wernher von Braun, the SS, and Concentration Camp Labor: Questions of Moral, Political, and Criminal Responsibility," *German Studies Review* 25/1 (2002): 72–73.

22 Ordway and Sharpe, *The Rocket Team*, pp. 261–267; Neufeld, *The Rocket and the Reich*, pp. 256–260, p. 265; Dunar and Waring, *Power to Explore*, p. 8; and Stuhlinger and Ordway, *Wernher von Braun*, pp. 58–61.

Von Braun (in cast) surrenders to U.S. Army counter-intelligence personnel of the 44th Infantry Division in Reutte, Tyrol, in April 1945. (NASA Marshall Space Flight Center, negative number 6517789)

The fate of the group now shifted out of the control of the dying Third Reich and into the crosscurrents of Soviet-American rivalry, the moral condemnation of Nazism, and the technological imperatives of the American military. Months before V-E Day, the Chief of the Rocket Branch of U.S. Army Ordnance, Colonel Gervais William Trichel, began taking steps that eventually led to the transfer of von Braun and more than 100 of his associates to the United States. In preparation for the U.S. Army's own rocket program, Trichel signed a contract with General Electric for the development of long-range missiles under Project Hermes. He hoped to use V-2 rockets in this research. In consultation with British intelligence, Major Robert Staver of Trichel's staff compiled a list of German rocket experts, ranked in order of significance, and von Braun's name was first on the list. Trichel directed Colonel Holger Toftoy, chief of Ordnance Technical Intelligence, to find 100 V-2 rockets and ship them to the Army's firing range in White Sands, New Mexico. When Toftoy learned about the allied discovery of Mittelwerk, he sent Major James P. Hamill to arrange for a shipment of V-2s to the United States. Staver meanwhile convinced von Braun's team to help locate the hidden Peenemünde documents and directed the shipment of 14 tons of documents just ahead of the British authorities who were closing access to the area.[23]

23 Dunar and Waring, *Power to Explore*, pp. 8–9.

In July 1945, the American Joint Chiefs of Staff established Project Paperclip (originally called Project Overcast), which gave authority to transfer German specialists who had expertise that might be of value to the military. Toftoy received permission to transfer about 120 members of the von Braun team to the United States, and, in September, von Braun and Major Hamill traveled to Fort Bliss in El Paso, Texas. There and in nearby White Sands, Toftoy planned Project Hermes, an effort to conduct rocketry research using V-2 rockets. By the spring of 1946, most of the Germans had arrived. In April, Project Hermes, assisted by the von Braun group, successfully fired the first V-2 to be launched from American soil. For the next several years, the von Braun group worked as consultants to the Army, Navy, and private contractors, including General Electric. Von Braun and his colleagues worked on a project of their own, designated Hermes B; it was a ramjet-powered second stage for the V-2. Among the accomplishments under Project Hermes was the launching of a Bumper-WAC (a modified V-2 first stage with a WAC Corporal second stage) from White Sands to an altitude of 250 miles.[24]

Perhaps as important as the rocket research conducted at Fort Bliss was the molding of a team under von Braun's leadership. The circumstances at Fort Bliss promoted the sense of group identity. Transferred to an unfamiliar country, separated from their families, united by professional interests, viewed with suspicion by citizens of El Paso (who had little interaction with them in any case), they naturally drew together. They hiked in the nearby mountains, played chess and ball games, and played pranks on one another. They were an elite group, and they knew it. One American described them as "a president and 124 vice presidents." There was no doubt who was the president; von Braun's leadership was never questioned. He negotiated for them and insisted on his prerogatives, sometimes sparring with Hamill, especially when Hamill made decisions affecting the group without working through him.

In October 1949, General Toftoy won approval to move Army rocket research to Huntsville, Alabama, site of Redstone Arsenal and the old Huntsville Arsenal, which the Army Chemical Corps wanted to sell. Toftoy moved the German team from Fort Bliss to Huntsville the following year, where they moved into leadership of the Ordnance Guided Missile Center. In 1952, the Army established the Ordnance Missile Laboratories at Redstone Arsenal, with von Braun as the Chief of the Guided Missile Development Division. Unlike their work at Fort Bliss, where they mainly worked as contractors for other groups' projects, in Huntsville von Braun's group had a project of their own: the development of the Redstone, a new surface-to-surface missile meant to augment the Army's Corporal and Hermes missiles.[25]

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24 Ordway and Sharpe, *The Rocket Team*, pp. 310–314, 346–349; Major General H. N. Toftoy and Colonel J. P. Hamill, "Historical Summary on the Von Braun Missile Team" (29 September 1959), University of Alabama, Huntsville, Library Saturn Collection; "What We Have Learned from V-2 Firings," *Aviation Week* (26 November 1951): 23ff; Crouch, *Aiming for the Stars*, pp. 110–111; and Neufeld, telephone conversation with Dunar (11 December 2003).

25 Dunar and Waring, *Power to Explore*, pp. 12–14.

Von Braun employed the arsenal system in development of the Redstone, and it became the hallmark of his approach to rocket development from Redstone through the Saturn rockets that powered the American lunar program in the 1960s and 1970s. The approach was not uniquely German. In fact, the U.S. Army had used the arsenal system as early as the mid-19th century at its arsenal and armory at Harper's Ferry, West Virginia. By the late 1950s, however, when an interservice debate over in-house vs. contractor development took shape between the U.S. Army and Air Force, the von Braun group had come to epitomize the arsenal in-house approach. Indeed, their German training complemented the Army's approach because, as one of von Braun's lab chiefs explained, in Germany "you are not admitted to any technical college or university if you do not have some practical time."[26] Furthermore, during WWII Germany had followed the older statist tradition in which the building of arms and munitions was controlled by the state.[27] Von Braun's commitment to in-house development was also a response to funding constraints on the Army's missile program, since things could often be done more cheaply in house than by contracting the work to outside firms. After receiving a contractor's bid of $75 thousand for the construction of a static test stand, von Braun's team built their own for $1 thousand worth of materials and fondly named it the "Poor Man's Test Stand."[28]

PROPHET OF HUMAN SPACEFLIGHT

The Army's missile development program received little attention in the early 1950s, but von Braun nonetheless began to acquire a national reputation as a visionary prophet of human spaceflight. In a series of richly illustrated articles in 1952 in the popular magazine *Collier's*, von Braun discussed the prospects for space travel, advocating the development of a space station and even suggested that a Moon landing could occur within the next quarter-century. In another *Collier's* article the following year, von Braun advocated the development of an unmanned satellite, and, in 1954, he made a bold proposal for the exploration of Mars.[29] In 1955, he appeared on the enormously popu-

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26 Karl Heimburg, oral history interview (OHI) by Dunar and Waring (2 April 1989), Huntsville, AL.

27 Neufeld, telephone conversation with Dunar (11 December 2003).

28 Heimburg OHI; David S. Akens, "Historical Origins of the George C. Marshall Space Flight Center," in *Marshall Space Flight Center Historical Monograph No. 1* (Huntsville: Marshall Space Flight Center (MSFC), 1960), p. 37; and Ordway and Sharpe, *The Rocket Team*, p. 372. Of course, as James Kingsbury, the former Director of Science and Engineering at MSFC, pointed out, the comparison is not entirely fair, since the $75,000 figure included labor costs, and the $1,000 figure did not. Kingsbury, undated note to Dunar and Waring on chapter draft of *Power to Explore*.

29 Wernher von Braun, "Man on the Moon: The Journey," *Collier's* (18 October 1952): 52–59. The space station article appeared on 27 June 1953. Other occasional articles by von Braun and other authorities on space travel appeared in 1953 and 1954.

lar television program *Disneyland*, where his authoritative German accent, charismatic enthusiasm, and ability to express complex concepts in understandable terms made him perhaps the most recognizable advocate for space exploration. A decade later, still one of the most effective spokespersons for the American space program, he began writing a monthly column in the magazine *Popular Science*, answering readers' questions about space.[30] He spoke to a wide range of audiences, from service clubs in Huntsville to industrial leaders around the nation.

Von Braun and his fellow Germans feared that they might encounter hostility in their new location, since, unlike their situation at Fort Bliss, they were living in the midst of a civilian population. The hostility never developed, and members of the team remarked that the green hills of Huntsville reminded them of Germany. The immigrants and their families had a dramatic impact on the city. The immigrants helped to start a symphony orchestra and contributed to the development of the city's public library. On 15 April 1955, von Braun, his wife Maria, and 40 members of his team became naturalized American citizens in a ceremony attended by 1,200 of their Huntsville neighbors and friends.[31]

Von Braun backed his public appeals with concrete proposals that might lead to the first steps toward spaceflight. In 1953, he argued that existing hardware could be used to launch a satellite into Earth orbit. The next year, the Army proposed an interservice satellite project, later the basis for the Army-Navy proposal Project Orbiter. The Air Force and the Naval Research Laboratories submitted similar proposals, and the Defense Department chose to support the Navy's Project Vanguard—in part, some suggested, because the department did not want to see the first American satellite launched by German rocket experts. Von Braun's dream, it appeared, would be executed by others.[32]

In 1956, the Army reorganized its missile development program, incorporating its Guided Missile Development Center and the Redstone project into the Army Ballistic Missile Agency (ABMA) at Redstone Arsenal under the command of General John B. Medaris. Von Braun's team received authorization to develop an Intermediate Range Ballistic Missile (IRBM) to be known as the Jupiter, a single-stage liquid-fuel rocket with a maximum range of 1,500 miles, a limitation designed to prevent competition with the Navy's Vanguard for the honor of launching the first artificial satellite. Von Braun chafed under the restriction, saying, "We at Huntsville knew that our rocket technology was fully capable of satellite applications and could quickly be implemented." The Defense

30 NASA MSFC Retiree Association, *50 Years of Rockets and Spacecraft in the Rocket City* (Paducah, KY: Turner Publishing Company, 2002), p. 69.

31 Stuhlinger and Ordway, *Wernher von Braun*, pp. 98–99; and Dunar and Waring, *Power to Explore*, pp. 14–16.

32 Wernher von Braun, "A Minimum Satellite Vehicle Based Upon Components Available from Missile Development of the Army Ordnance Corps"; Akens, "Historical Origins," pp. 38–39; and Ordway and Sharpe, *The Rocket Team*, p. 376.

Department even sent an observer to ensure that ABMA would not exceed its limits and orbit a booster by activating a dummy fourth stage.[33]

Despite the restrictions imposed on ABMA by the Defense Department, the greater altitude achieved by the new generation of missiles provided von Braun's team the opportunity to work on developments that had a bearing on spaceflight. One such challenge was the matter of how to deal with the tremendous heat developed during missile reentry into Earth's atmosphere. While the Air Force worked on a heat sink solution in which nosecone materials would absorb heat, the Huntsville team worked on an ablation system in which materials shielding the nosecone would melt and evaporate during reentry. Jupiter-C launches in 1956 and 1957 proved the viability of this system, and reentry studies gave ABMA's engineers experience in the technology of spaceflight.[34]

When Americans learned of the launch of the Russian satellite Sputnik on 4 October 1957, incoming Secretary of Defense Neil McElroy was visiting Redstone Arsenal. At dinner that evening, von Braun and Medaris sat on either side of McElroy and lobbied. Von Braun insisted that ABMA could launch a satellite into orbit in 60 days. Medaris, more cautious, said 90 days might be necessary. McElroy hesitated, but after the Soviet Union launched the 1,200-pound Sputnik II with the dog Laika aboard on 3 November, ABMA received approval, with 29 January designated as the launch date. ABMA worked in cooperation with the Jet Propulsion Laboratory (JPL) at the California Institute of Technology to develop the launch vehicle and its satellite. The launch vehicle combined a cluster of solid-propellant rockets designed and built by JPL with a Redstone rocket, which the von Braun team integrated into a new vehicle designated the Jupiter-C (sometimes called Juno I). Dr. William H. Pickering of JPL developed Explorer I, a 34-inch-long, 6-inch-diameter tube for that purpose. Weather delays postponed the launch until 31 January, but on that date Explorer I successfully achieved an orbit with an apogee of 1,594 miles.[35]

In the aftermath of the Sputnik launches, the Eisenhower administration conducted the first comprehensive review of American space policy. President Eisenhower, who wanted to avoid a space race with the Soviet Union, preferred a civilian space agency, and, on 29 July 1958, President Eisenhower signed the National Aeronautics and Space Act, which established the National Aeronautics and Space Administration (NASA).

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33 Kurt H. Debus, "From A4 to Explorer I," paper presented at 24th International Astronautical Congress, Baku, USSR (8 October 1973), Debus/1973/Redstone/Pershing/Jupiter Folder, NASA Headquarters Historical Reference Collection, Washington, DC, p. 33; and Medaris and Gordon, *Countdown for Decision*, p. 72.

34 Debus, "From A4," p. 36; Medaris and Gordon, *Countdown for Decision*, pp. 142–144; William Lucas, OHI by Dunar and Waring (19 June 1989), Huntsville, AL.

35 Patricia Yingling White, "The United States Enters Space, 1945–1958: A Study of National Priorities and the Decision-Making Process in the Artificial Satellite Program" (master's thesis, Ohio State University, 1969), p. 95; Medaris and Gordon, *Countdown for Decision*, pp. 151–190, 207–226; Ordway and Sharpe, *The Rocket Team*, pp. 382–386; Akens, "Historical Origins," pp. 44–47; Debus, "From A4," pp. 52–54; and Stuhlinger and Ordway, *Wernher von Braun*, pp. 134–140.

During the months between the launch of Explorer I and the establishment of NASA, von Braun continued to pursue his dream of spaceflight. The Defense Department had responded to Sputnik by establishing the Advanced Research Projects Agency (ARPA), which had authority to sanction space projects for a one-year period, subject to presidential approval. Both ABMA and the Air Force submitted plans to put a man in space (Project Adam and Man-in-Space-Soonest). Von Braun also continued work on the remaining launches in the Juno series of missiles. Explorer II failed when the fourth stage did not ignite, but Explorer III went into orbit in March 1958. By October, when the Juno series came to an end, ABMA had recorded three successful launches and three failures.[36]

The Space Act assigned to NASA the 8,000 personnel and three laboratories of the National Advisory Committee for Aeronautics, the Navy's Vanguard project, and several Air Force projects. The status of the von Braun team was uncertain; three of ABMA's satellite projects and two of its lunar probes went to NASA, and the new NASA Administrator T. Keith Glennan requested transfer of more than half of von Braun's group. But General Medaris fought to retain von Braun and his German colleagues in ABMA, and for the time being they remained with the Army. Von Braun worried about possible dispersal of his team and NASA's opposition to in-house development; he wondered whether NASA would be able to support Saturn; and, in any case, he had little choice but to insist on his loyalty to Medaris.[37]

Despite von Braun's reservations, he could not ignore NASA. In December 1958, while still firmly attached to ABMA, von Braun and two of his lieutenants made a pitch to Glennan that looked beyond NASA's early plans to put a man in space. Von Braun had his eyes set on the Moon, and he told Glennan that he knew how to get there. He explained his concept of rocket clusters that could provide such power and suggested that the Saturn, already on the drawing boards in Huntsville, could reach the Moon, perhaps as early as the spring of 1967. Furthermore, the Saturn fit well into NASA's plans, since it could be developed even as NASA took its first steps into human spaceflight. As aerospace historian William Burrows observed, "It was right off the pages of the *Collier's* series, with one step locked into the next."[38] Von Braun the visionary had inspired von Braun the engineer, and the hardware to achieve the lunar dream was already in development.

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36 Loyd S. Swenson, Jr., James M. Grimwood, and Charles C. Alexander, *This New Ocean: A History of Project Mercury* (Washington: NASA SP 4201, 1966), pp. 25–28; John M. Logsdon, *The Decision to Go to the Moon: Project Apollo and the National Interest* (Cambridge, MA: MIT Press, 1970), pp. 28–29; J. Boehm, H. J. Fichtner, and Otto A. Hoberg, "Explorer Satellites Launched by Juno and Juno 2 Vehicles," in *Peenemünde to Outer Space*, ed. Ernst Stuhlinger, et al. (Huntsville: Marshall Space Flight Center, 1962), pp. 163–165.

37 Richard L. Smoke, "Civil-Military Relations in the American Space Program, 1957–60" (bachelor's honors thesis, Harvard University, 1965), pp. 70–75; Medaris and Gordon, *Countdown for Decision*, pp. 242–245; Dunar and Waring, *Power to Explore*, p. 25; Jim G. Lucas, "Army Expects to Lose Von Braun," *New York World-Telegram & Sun* (31 October 1958); and "The Periscope," *Newsweek* (10 November 1958): 19.

38 William E. Burrows, *The New Ocean: The Story of the First Space Age* (New York: The Modern Library, 1999), pp. 286–287.

MANAGING AT MARSHALL

NASA's leaders wanted von Braun's expertise, but they had reservations about his way of doing business. From the start, suspicions about the German background were not far below the surface. Glennan's staff suggested that he should make it clear that he wanted "ABMA personnel and facilities, not the ABMA way of doing business."[39] NASA Deputy Administrator Hugh L. Dryden commented after reading an article by Walter Dornberger on the lessons of Peenemünde that "the general principles of the required management are well known; it seems difficult to get them adopted in a democracy."[40]

For a time, the relationship between ABMA and NASA was ambiguous. NASA contracted with ABMA to provide eight Redstone rockets for the early suborbital flights of Project Mercury, and ABMA continued the development work it had begun on the clustered Saturn booster, a powerful liquid-fueled vehicle that figured prominently in NASA's plans, but which promised to provide much more thrust than required for anything on the Army's drawing board. Indeed, the Saturn became the catalyst that enabled von Braun's contingent to transfer to NASA. To keep the Saturn in ABMA made little sense, despite Medaris's complaints about "project snatchers," and by October 1959—two years after Sputnik—the Army agreed to transfer von Braun's Development Operations Division of ABMA intact to NASA. The transfer required no physical move; instead, on 1 July 1960, a portion of Redstone Arsenal became the new George C. Marshall Space Flight Center with von Braun as Center Director.[41]

The year's delay in joining NASA had ramifications for von Braun's role in the new Agency. By the time the transfer took effect, NASA's culture had begun to form, shaped largely by a group of engineers from Langley Research Center that later transferred to Houston, where the group became the nucleus of the Manned Spacecraft Center (later renamed the Johnson Space Center). This group and the NASA Administrators in Washington would be at the center of planning for American human spaceflight and would harbor some suspicion of von Braun's approach at ABMA with its commitment to the arsenal system, engineering conservatism, and reliability testing, and its aversion to contracting out. Charles Murray and Catherine Bly Cox, in their account of the Apollo

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39 Memorandum from Walter T. Bonney to T. Keith Glennan (30 September 1958), NASA-Army (ABMA) Folder, NASA Headquarters Historical Reference Collection, Washington, DC.

40 Letter from Dryden to Lieutenant General Arthur G. Trudeau (25 February 1959), Krafft Ehricke—The Peenemünde Rocket Center Folder (vertical file), NASA Johnson Space Center Historical Reference Collection, Houston, TX.

41 Wernher von Braun, "The Redstone, Jupiter, and Juno," *Technology and Culture* 4 (Fall 1963); Roger E. Bilstein, *Stages to Saturn: A Technological History of Apollo/Saturn Launch Vehicles* (Washington, DC: NASA SP 4206, 1980), pp. 35–37; Dunar and Waring, *Power to Explore*, pp. 26–30; and Medaris and Gordon, *Countdown for Decision*, p. 266.

program, argued that von Braun's group "had missed their chance to run the whole mission when they had stayed with the Army for the first year after NASA was founded."[42]

Von Braun became the first Director of Marshall Space Flight Center, and under his leadership the Huntsville Center became the heart of NASA's propulsion expertise. The early NASA test flights and manned suborbital and orbital flights of Project Mercury relied on four rockets, including the Little Joe, Redstone, and the Atlas. The von Braun team also brought from ABMA the Juno II, which was used for unmanned space science launches. Thus two of NASA's early launch vehicles, the Redstone and Juno II, were products of the von Braun team at ABMA. Whatever reservations NASA Administrators may have had, von Braun's success gave him enough immunity from criticism that he was able to carry out his program with little modification.

The apogee of von Braun's accomplishments at Marshall was the development of the Saturn V, the propulsion system of the Apollo program, and it is on this monumental achievement that his reputation rightly rests. Von Braun had the vision to conceive the development of a propulsion system of unprecedented complexity that was powerful enough to propel to the Moon the fuel, equipment, and life-support systems necessary to sustain a crew and return it safely to Earth. But he also had the hard-headed pragmatism of an engineer that leavened his visionary conceptual approach to scientific inquiry. He had acquired the engineering experience, assembled the personnel, and developed the managerial skills that enabled him to undertake such a daunting project. That he was able to do so in a political environment that dictated a demanding schedule and required working with managers, peers, and politicians who scrutinized his motives, resented his popularity, and questioned his loyalty makes his record all the more remarkable.

The success of the Saturn rested on the concept of clustering engines in order to achieve the thrust required for the lunar program. Concepts for the Saturn dated back to 1957. Von Braun recalled the concept of clustered engines developing out of ABMA's work with the Defense Department's ARPA in the late 1950s. "I don't know whether we came forth with drawings of clustering rockets, or whether ARPA came to us," von Braun reflected.[43] Saturn relied on the clustering of powerful rocket engines that used liquid fuel, and thus the project demanded the development and testing of complex engines and cryogenic tanks that could carry the enormous quantities of fuel consumed by these engines.

The statistics of these rockets are staggering, even decades after the last Saturn flight. The Saturn V was a three-stage rocket. Its first stage, the S-1C stage, had five clustered

42 Charles Murray and Catherine Bly Cox, *Apollo: The Race to the Moon* (New York: Simon and Schuster, 1989), p. 136.

43 Glen E. Swanson, ed., "Before This Decade Is Out . . ." in *Personal Reflections on the Apollo Program* (Washington, DC: NASA SP-4223, 1999), p. 49.

F-1 engines, each standing 18.5 feet in height. The F-1 used liquid oxygen and RP-1 (kerosene) for fuel, and each provided 1.5 million pounds of thrust, for a total of 7.5 million pounds of thrust during the first 2½ minutes of launch. In its original design, the first stage had four clustered rockets; von Braun had said that the "great big hole in the center is crying for a fifth engine," and the weight requirements added over the months of development made the fifth engine a fortunate decision. The second stage, the S-2 stage, clustered five J-2 engines, each powered by liquid oxygen and liquid hydrogen, and each providing 200,000 pounds of thrust for 500 seconds. Finally, the third stage employed one J-2 engine. A fully assembled Saturn V stood 364 feet in height and weighed 5.8 million pounds.[44] It provided power equivalent to 85 Hoover Dams.[45]

Development of the huge F-1 engine required dealing with issues of size rather than new technology, since the F-1 mainly used technology that was already understood. The J-2, however, was another matter, since the technology of dealing with liquid hydrogen was less well developed. At -423°F, liquid hydrogen is 130° colder than liquid oxygen, making more complex the technology of dealing with cryogenic propellants. Development of the Saturn's engines required coordination with NASA's Lewis Research Center (now the Glenn Research Center) in Cleveland, which had expertise in the use of liquid hydrogen, and with the contractors Rocketdyne and Pratt and Whitney.

Despite official concerns about how von Braun's team operated, Marshall's organization bore the mark of Peenemünde and ABMA. The Center had the capacity to design, test, and manufacture rockets from concept to completion. Marshall's matrix organization rested on the strength of its eight laboratories, each with a technical specialization, and each with its own facilities.[46] The laboratories gave Marshall expertise that exceeded its reputation as a propulsion center, and, after the Apollo program, this strength would allow the Center to diversify into other areas. Project offices—such as the Saturn I and Saturn V offices—would draw on the labs and form interdisciplinary teams to accomplish specific tasks.

Von Braun and his Center also remained deeply committed to the arsenal system. Von Braun believed that the system improved quality, contained costs, and allowed direct contact between engineers and technicians. When Marshall did contract work to industry, von Braun's engineers prided themselves on understanding the technology better than

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44 Swanson, "Before This Decade," pp. 52–53; Roger E. Bilstein, *Stages to Saturn: A Technological History of the Apollo/Saturn Launch Vehicles* (Washington, DC: NASA SP-4206, 1980), pp. 110, 151; and William E. Burrows, *This New Ocean: The Story of the First Space Age* (New York: The Modern Library, 1998), p. 373.

45 *http://history.msfc.nasa.gov/rocketry/tl7.html*.

46 Marshall underwent periodic reorganizations, and the laboratories occasionally changed names, but the fundamental laboratory organization remained intact. The laboratory structure in 1963 included the following laboratories: Aeroastro-Dynamics, Astrionics, Computation, Manufacturing Engineering, Research Projects, Propulsion and Vehicle Engineering, Quality Assurance and Reliability, and Test.

the contractor; they believed they could "penetrate" the contractor, because the hands-on experience of Center engineers and technicians ensured that they could better monitor contractors and assist them in overcoming technical problems. They employed conservative engineering practices and tested beyond the usual requirements of industrial production. They remained committed to liquid fuel for propulsion, even as advocates of solid fuel stressed the cost savings of less-complex solid-rocket motors. Liquids suited the German research methodology; it allowed for component testing and provided a larger margin of safety since liquids could be shut down, whereas solids, once lit, could not.

While von Braun remained committed to conservative engineering practices, he came to appreciate the interaction with others—contractors, subcontractors, other NASA Centers, and NASA Administrators—inherent in the American system, which he once referred to as "a stock exchange of good ideas where we felt we picked the best things out."[47] Indeed the major contractors for the Saturn V (Boeing, McDonnell Douglas, IBM, North American Aviation Space Division, and North American Aviation Rocketdyne) used scores of subcontractors, spreading the space business around the nation, developing political support for the space program in the process.[48]

Von Braun insisted on open communication within the organization and devised managerial tools to ensure its practice. Among these practices were Marshall's "board meetings" and "weekly notes." The board meetings drew Center administrators, lab directors, project managers, and guests who provided outside expertise. Meetings included formal presentations, but participants remembered the freewheeling discussions and arguments over technical issues, policies, and problems. Two of von Braun's talents made these meetings particularly valuable. Participants often explained their point of view in complex scientific terminology. Von Braun would push experts to restate their argument in terms that everyone at the meeting could understand, and, if they were unable to do so, he would intervene and restate the issue in comprehensible terms himself. One participant recalled that specialists "would be talking almost like in unknown tongues," and that "finally von Braun would take over and explain what was being said in terms that everybody could understand." Von Braun also had the ability to summarize and to distill a consensus out of a contentious meeting. One of his engineers remembered the discussion of a technical point when von Braun interrupted, "Am I the only person at this meeting who doesn't understand this?" He looked around the room with a "quizzed look," stepped to the chalkboard, and made a diagram pertinent to the discussion.[49]

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47 Swanson, "Before This Decade," p. 59.

48 A full listing of all subcontractors runs for nine pages in "Appendix A—Saturn V Subcontractors," in *Saturn V News Reference* (1968), *http://history.msfc.nasa.gov/saturnV/Subcontractors.pdf*.

49 Ralph A. Burns, "An Engineer Remembers," in *50 Years of Rockets and Spacecraft in the Rocket City*, comp. NASA MSFC Retiree Association (Paducah, KY: Turner Publishing Company, 2002), p. 108.

The weekly notes were a von Braun innovation that allowed open airing of difficult issues across the Center. Lab directors and project managers submitted weekly a one-page summary of their progress and problems of the previous week. Von Braun wrote marginal comments and circulated the notes among lead personnel. The resulting cross-fertilization of ideas kept key personnel aware of the overall status of Marshall's projects, prompted cross-disciplinary discussion of the Center's engineering challenges, and led to solutions that might otherwise have been overlooked. Managers began to require that their subordinates submit "Friday notes" in preparation for their own "Monday notes," bringing the benefits of the system to lower levels of the organization.[50]

The weekly notes demonstrated another aspect of Marshall's organization under von Braun. The Center's structure was hierarchical, disciplined, and conservative. One Marshall engineer described it as "a very conservative overview in management technique which went through the whole organization."[51] Those who worked closely with von Braun over the years considered it a creative system and believed that it fostered a team spirit that permeated the Center.[52] Those who were lower in the organization's hierarchy had a different perception. One assessment suggested that the weekly notes aired "problems and bad things—very few good things got surfaced. . . . Nobody at the bottom really felt free to do anything unless he got it approved from the next level up, the next level up, the next level up."[53] Another lower-ranking subordinate concluded that the weekly notes created "an almost iron-like discipline of organizational communication."[54]

The formality that characterized relations at Marshall was unusual in the freewheeling world of NASA, and it stemmed from von Braun and his German colleagues. Once when NASA Deputy Director Robert Seamans visited Marshall, he questioned von Braun's Deputy Director Eberhard Rees about this formality. Seamans asked Rees if he had always addressed von Braun as "Dr. von Braun." Rees turned to Seamans and replied that he used to call him "Herr Dr. von Braun."[55]

But Marshall's formality was only one side of von Braun. Stories are legion among Marshall veterans about memorable personal interactions with the Center Director, and many of the recollections refer to his charisma. There was a disarming boyishness and spontaneity to von Braun that captivated Marshall's workers and won their unstinting loyalty. One remembered an incident in 1962:

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50 Dunar and Waring, *Power to Explore*, pp. 50–51.

51 Bob Marshall, OHI by Waring (29 August 1990), NASA Marshall Space Flight Center Historical Reference Collection, Huntsville, AL, p. 1.

52 Georg von Tiesenhausen, OHI by Dunar and Waring (29 November 1988), NASA Marshall Space Flight Center Historical Reference Collection, Huntsville, AL, p. 9.

53 Bob Marshall OHI, p. 1.

54 Phillip K. Tompkins, "Organization Metamorphosis in Space Research and Development," *Communication Monographs* 45 (June 1978): 116.

55 J. N. Foster, "Formality of the Von Braun Team," in *50 Years of Rockets*, pp. 129–130.

> I was sitting on the floor of the Recorder Room with my feet in a cable trench. Members of my crew were in the basement feeding long, black electrical cables up from below into the trench. The cables were stiff and heavy. I really needed someone to help with this end of the task. As I started to pull up another cable, I was aware of someone entering the room and taking hold of the end of the cable and pulling it across the room. The last cable seemed to be stuck. Without looking, I assumed that my helper was one of my crew, so I told him to get down in the trench and help. He dutifully complied. We broke the cable loose, and he pulled it across the floor. Still sitting in the trench trying to catch my breath, I heard my helper ask with a German accent, "Well, Mr. Weaver, what is the purpose of these cables?" I jumped out of the trench and faced the Center Director. As I searched for words, Dr. von Braun extended a hand, now very soiled by our task.[56]

TO THE MOON

Von Braun's central role in the American space program was well established when he became the Director of Marshall Space Flight Center, but the path that would lead to his primary achievement in aviation history began when President John F. Kennedy set the course for the American space program. Kennedy, in a speech in May 1961, announced a national goal of landing a man on the Moon and returning him safely to Earth by the end of the decade. Kennedy visited Marshall Space Flight Center twice. On his second visit, in May 1963, Kennedy asked von Braun about the prospects for achieving that goal. "Yes, Mr. President," von Braun replied, "we are going to meet your commitment of landing a man on the Moon, and we're going to do it within the time you set."[57]

Von Braun had a hand in many of the key decisions in the American lunar program in the 1960s. The decision to go to the Moon not only gave impetus and ample budget to Marshall's Saturn V program, it also touched off a debate among NASA leaders about the best way to reach the Moon, which in NASA parlance soon became known as the "mode decision." Each Center studied alternatives; Marshall examined "direct ascent," which would have required a rocket even more powerful than Saturn (called NOVA in the planning stages), and Earth Orbital Rendezvous (EOR), which stipulated launch to the Moon from a Saturn-launched vehicle in Earth orbit. EOR, which bore similarities to a von Braun concept in his *Collier's* articles, would have required two Saturn V vehicles; it became the Marshall favorite. Houston's Manned Spacecraft Center studied and preferred Lunar Orbital Rendezvous (LOR), which would have required one Saturn launch

56 Willie E. Weaver, "From Co-Op to Rocketeer," in *50 Years of Rockets*, p. 106.
57 Ed Buckbee, "JFK's Visit to Marshall," in *50 Years of Rockets*, p. 137.

of two spacecraft—one in lunar orbit, and a lunar lander that could take off and return to the lunar orbiter. Beyond practical applications, each Center had reason to back its own proposal; in Marshall's case, EOR would have taken the Center into new areas of future work in engineering and likely would have given Marshall new work at the end of the lunar program. The decision seemed to be one of numerous instances of Center rivalry that surfaced often between NASA's two principal Centers devoted to human spaceflight. The key meeting took place on 7 June 1962, with personnel from both Centers and Headquarters in attendance. At the end of the presentations, von Braun took the floor and announced, to the astonishment of all, that Marshall's position was to support LOR. Von Braun later explained that EOR was simply Marshall's study task, not its preference, and that LOR, with its single Saturn launch, offered the greatest chance for success within the decade. Von Braun's acceptance of the logic of LOR fostered the necessary cooperation for the success of the lunar program. Marshall, in what appears to have been something of a consolation prize, received designation as the Lead Center for a lunar rover.[58]

Wernher von Braun, Marshall Space Flight Center Director, greets President John F. Kennedy during a visit to the Center on 12 October 1962. (NASA Marshall Space Flight Center, negative number 9806978)

But there may have been more to it. In a curious way, the decision symbolized Marshall's culture. The Center under von Braun prided itself on teamwork, and, in confrontations with Houston, Marshall was more likely to be the team player, Houston the tenacious infighter. Von Braun was never reticent, always an eloquent spokesman for his Center and defender of its positions—but only to a point. He would back down rather than risk division, and he did so not only on EOR-LOR, but on other important decisions

58 Dunar and Waring, *Power to Explore*, pp. 54–58.

that affected the Center and its stake in NASA's programs. Other such moments included the decision to make Florida's Cape Canaveral, which had been Marshall's Launch Operations Directorate, an independent center and to accept the Air Force contracting system in a move away from Marshall's long commitment to the arsenal system.

The shadow of von Braun's German background affected his relationship with NASA Headquarters and other Centers. It was a subtle influence, seldom brought into the open, and it did decrease in frequency, but the issue came up too often to be incidental. Charles Sheldon, a senior staff member representing the White House on the National Aeronautics and Space Council in the early 1960s, remembered that people in Washington discounted rumors that von Braun might one day head NASA because "von Braun would never be given any political position. No one who had worked with Hitler and the Nazi government could be trusted." The Nazi issue came up often enough in public references to keep the matter alive. A film biography of von Braun produced in the early 1960s entitled *I Aim at the Stars* prompted one critic to add "but sometimes he hits London." Satirist Tom Lehrer, in one of his popular recordings in 1965, included a verse saying, "Once the rockets are up, who cares where they come down? 'That's not my department,' says Wernher von Braun."[59]

Jealousies at Headquarters compounded the problem. As one of von Braun's Huntsville associates noted, "When von Braun appeared at certain occasions—symposiums, meetings at Headquarters—he, rather than the upper Administrator, was the center of attention."[60] NASA Administrator James Webb, who served under Presidents Kennedy and Johnson, warned von Braun that his speeches contained overly optimistic projections of NASA's capabilities, creating unrealistic expectations. Webb, worried also about the propriety of von Braun making substantial profits from his speeches, restricted von Braun to four paid public appearances a year and required him to submit a list of intended speeches for approval. Thomas Paine, who followed Webb as NASA Administrator, said Webb wanted to keep von Braun out of Washington, saying, "I think Jim had the feeling that, well, the Jewish lobby would shoot him down or something—the feeling that basically you were dealing with the Nazi party here. And you could get away with it if he were a technician down in Huntsville building a rocket, but if you brought him up here . . . ."[61]

The issue lingered in relations with the Manned Spacecraft Center in Houston, too. Chris Kraft, who ran Houston's Mission Control during most of the Apollo flights, believed that "Wernher had a Teutonic arrogance that he'd honed to a fine edge. He saw himself as the number-one expert in the world on rockets and space travel, and had polished that self-image with magazine articles, books, lectures, and technical papers. He was famous. He was a NASA Center Director, equal to Bob Gilruth [Houston's Center

59 Ibid., pp. 154–155.
60 Georg von Tiesenhausen OHI.
61 Joseph J. Trento, *Prescription for Disaster* (New York: Crown Publishers, 1987), pp. 89–90.

Director], and probably trying to figure out ways to move Gilruth aside." Kraft remembered asking Gilruth over lunch one day what he thought of von Braun. "Gilruth looked up from his salad and gave me one of those looks that said 'this isn't a good subject.' But after a moment, he found the words to describe everything he felt about the German rocketmeister in one short sentence: 'Von Braun doesn't care what flag he fights for.'"[62]

In this atmosphere, von Braun, an extraordinarily self-confident person, realized that if he may have to give ground on occasion and exercise caution with outsiders, it would afford him the latitude to control his own domain in Huntsville. During the von Braun years, Marshall developed a reputation for secrecy that becomes understandable in this context. Engineer Bob Marshall remembered that von Braun's Center had a reputation as a "very good technical organization, but a poor management organization."[63] A 1968 study described von Braun as a model for the "reluctant supervisor" typical of the Huntsville Center, a man who wanted to keep his hands dirty and avoid red tape and committees.[64] Others saw it differently, and even von Braun's critics could not deny the record of success produced by the rocket team. NASA Administrator James Webb was not one to lavish praise on his subordinates, but when he visited Marshall Space Flight Center in 1965, he commented, "I saw here one of the most sophisticated forms of organized human effort that I have ever seen anywhere!"[65]

Furthermore, if questions arose about the management style at Marshall, von Braun had his own concerns about working with Headquarters. In the early 1960s, NASA's lunar program suffered the usual growing pangs of an organization experiencing rapid growth, and in 1963 von Braun complained to his associates that relations between the Centers and Headquarters had become "terribly complicated." He lamented "it is almost impossible to obtain a guideline, let alone a decision." Von Braun and the other Center Directors, Robert Gilruth in Houston and former von Braun team member Kurt Debus at Cape Canaveral, asked that one man at Headquarters be placed in charge of the Saturn-Apollo program. Webb concurred and appointed George Mueller as NASA's Director of the Office of Manned Space Flight.

The Mueller-von Braun relationship was critical and worked to the benefit of both men. Mueller came to his post sharing the prevalent Washington perspective that the NASA Centers preferred to operate as independent fiefdoms that desired contact with Headquarters only to receive money, but otherwise wanted to be left alone to do their work. Indeed, von Braun contributed to that perception, for he often quipped, "All we need is a rich uncle in Washington who sends the money but does not interfere with our

62 Chris Kraft, *Flight: My Life in Mission Control* (New York: Dutton, 2001), pp. 83, 103.
63 Bob Marshall OHI, p. 4.
64 Tompkins, "Organization Metamorphosis," p. 116.
65 Stuhlinger and Ordway, *Wernher von Braun*, p. 197.

work." Mueller told the Center Directors that things would not operate that way, and Debus and von Braun quickly came around. "Wernher turned out to be one of the strongest supporters," Mueller remembered. The relationship worked both ways, for Mueller became one of Marshall's protectors at Headquarters in the infighting among Centers and between Centers and Headquarters.[66]

At no point was the von Braun-Mueller collaboration more important than on another of the turning points in the Saturn program, a decision nearly as significant as the EOR-LOR debate. In November 1963, Mueller proposed that Saturn testing proceed with a compressed schedule in which the first Saturn IB flight and the first Saturn V flight would be conducted with all live stages rather than in incremental stage-by-stage tests—"all-up testing" in the NASA vernacular. The savings in money would be significant, and, in Mueller's view, it was the only way NASA could meet the schedule of landing on the Moon by the end of the decade. It meant that the first manned launch in each sequence would be on the third flight rather than the seventh. The concept went against Marshall conservative engineering practice, and von Braun's senior staff vehemently objected. Von Braun nonetheless decided to share the risk with Mueller and endorsed the concept despite continuing resistance from trusted subordinates. All-up testing proved to be a key to the success of Apollo.[67]

But all-up testing should not obscure the rigorous testing that went into the development of Saturn's components. Four years passed between the time von Braun accepted Mueller's proposal and the first Saturn V launch on 9 November 1967. During that crucial period, tests proceeded in the labs and on the test stands at Marshall Space Flight Center; without that program, Saturn would not have compiled its incredible record of reliability. Von Braun explained Saturn's dependability, insisting that

> Saturn V was not overdesigned in the sense that everything was made needlessly strong and heavy. But great care was devoted to identifying the real environment in which each part was to work—and "environment" included accelerations, vibrations, stresses, fatigue loads, pressures, temperatures, humidity, corrosion, and test cycles prior to launch. Test programs were then conducted against somewhat more severe conditions than were expected. A methodology was created to assess each part with a demonstrated reliability figure, such as 0.9999998. Total rocket reliability would then be the product of all these parts reliabilities and had to remain above the figure of 0.990, or 99 percent. Redundant parts were used whenever necessary to attain this reliability goal.[68]

66 Ibid., 196–197.

67 Bilstein, *Stages to Saturn*, pp. 348–351.

68 Wernher von Braun, "Saturn the Giant," in *Apollo Expeditions to the Moon*, ed. Edgar M. Cortright (NASA Scientific and Technical Information Office, NASA SP-350, 1975), *http://history.msfc.nasa.gov/special/pogo.html.*

Despite all of the testing, a serious problem developed on the second Saturn V flight. A longitudinal vibration developed in all three stages that von Braun described as similar to a concertina. As von Braun explained, the oscillation, which came to be known as the "Pogo effect," "was caused by resonance coupling between the springlike elastic structure of the tankage and the rocket engines' propellant-feed systems." Once the source of the problem was understood, a damping system minimized the Pogo effect, and Saturn flights continued with little interruption.

The next flight was one of the triumphant successes of the lunar program. Apollo 8, commanded by Frank Borman, reached lunar orbit during the Christmas season of 1968. The sixth flight of the Saturn V carried Apollo 11 to the Moon. In July 1969, Neil Armstrong became the first person to set foot on the Moon.

Altogether, NASA and its contractors produced 17 of the mammoth rockets. One was a dynamic test vehicle intended for testing rather than launch; 2 launched unmanned Apollo missions; 10 carried manned Apollo missions; 1 launched Skylab, the first American space station in 1973; and 3 became museum pieces, 1 in Huntsville, 1 in Houston, and 1 at Kennedy Space Center in Florida. "The Saturn V's track record of successful launches remains a marvel of technology," reflected Chris Kraft, often a von Braun critic. "In the 21st century, I still find it hard to believe that von Braun did so much in the 1960s. The world has nothing like a Saturn V today."[69]

AVIATION AND AEROSPACE PIONEER

Even as the peak achievements of the Apollo program captured the world's attention in the late 1960s, von Braun faced more mundane but nonetheless challenging problems in his role as Director of Marshall Space Flight Center. Pressured by the Kennedy and Johnson administrations to hire African Americans to counter the otherwise negative image of Alabama in civil rights, von Braun worked with local leaders in Huntsville to improve race relations in the city. Although he was never entirely successful—it was, after all, hard to convince African American engineers to come to Alabama—he helped to facilitate a more positive approach to race relations in north Alabama, and Huntsville never experienced the violent clashes that marked the civil rights struggle in Birmingham, Selma, or Montgomery. He was instrumental in establishing a university in Huntsville that became part of the University of Alabama system; it has collaborated with Marshall ever since.

One of his biggest challenges was managing the cutbacks at Marshall that began after the development of Saturn, particularly because these decisions were beyond his control. Cutbacks in spending and mandated personnel reductions in force came in waves, and

69 Kraft, *Flight: My Life*, p. 351.

Von Braun and Dr. Eberhard Rees during the launch of the Saturn A-6 on 28 May 1964. (NASA Marshall Space Flight Center, negative number 6673878)

the Center went through difficult readjustments even as its accomplishments in propulsion won worldwide praise.

The completion of Saturn V development posed questions about the future of Marshall Space Flight Center. Without a major propulsion project, and with the days of unlimited funding and abundant staffing fading, the future of the Center looked dim. Von Braun began to investigate other possible activities for the Center. Anticipating the decline, he formed a Future Projects Office in 1964 and directed the Research Projects Laboratory to conduct studies for space science projects. Between them, these two groups investigated possibilities that later became major NASA projects, including Skylab, the High Energy Astronomy Observatories, the Large Space Telescope, the Apollo Telescope Mount, lunar rover, and lunar science studies. These proposals became the basis for Marshall's diversification into fields other than propulsion, particularly space science. They also encouraged new space science for NASA.[70]

On 1 March 1970, von Braun left his position as Director of Marshall Space Flight Center to accept a position at NASA Headquarters as Deputy Associate Administrator for Planning, the fourth-ranking position in the Agency. Dr. Eberhard Rees, his long-time

70 Dunar and Waring, *Power to Explore*, pp. 137–138.

Deputy, succeeded him as Center Director. Five thousand Huntsville residents turned out on a drizzly day to bid "Huntsville's First Citizen" farewell. The *Huntsville Times* concluded "Dr. von Braun leaves this community bigger and better than he found it."[71]

In Washington, von Braun and his staff of 20 worked to develop long-term plans for NASA and to work out an approach for presenting the Space Shuttle to Congress.[72] Feeling marginalized and frustrated, von Braun left NASA after two years and four months at Headquarters. He accepted a position at Fairchild Industries in Germantown, Maryland. He died in Alexandria, Virginia, on 16 June 1977.[73]

Twenty-six years to the day after his death, the magazine *Aviation Week & Space Technology* announced at the Paris Air Show its list of the top 100 aviation pioneers. Von Braun's name was second on the list, behind only Orville and Wilbur Wright.[74] It was a fitting tribute to a man with the imagination to envision human space travel in the 1920s and the engineering expertise and managerial skills to make it a reality in the 1960s. His three milestone achievements—developing the first human-launched vehicle to reach space, the launch system that put the first American satellite in orbit around the Earth, and the Saturn V rocket that powered the American lunar program—represent a remarkable lifetime of achievement. That he was among the foremost individuals to popularize space travel adds luster to his record and demonstrates the range of his abilities. That his name is not free of its association with the Nazi Third Reich demonstrates that not even the loftiest of achievements can entirely escape the disturbing political undercurrents of the 20th century. He never escaped the charge of amoral opportunism or the stain of the concentration camps.

Not all of von Braun's ideas have reached fulfillment. NASA rejected the arsenal system of an all-in-one research and development organization. The Agency also rejected the conservative engineering approach that was the hallmark of the von Braun team, with its mission of step-by-step testing from component to subsystem, to system, to flight article, to test flight.

Other von Braun visionary concepts, such as a mission to Mars, remain unfulfilled. The dreams of a visionary are not always accomplished in one lifetime, and von Braun may yet speak to future generations.

ENDNOTE

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71 Ibid., pp. 152–153.

72 Jay Foster, "Dr. von Braun in Washington," in *The Marshall Retiree Report* (September 2003).

73 "Dr. Wernher von Braun: First Center Director, July 1, 1960–January 27, 1970," *http://history.msfc.nasa.gov/vonbraun/bio.html*.

74 Ed Buckbee, "Von Braun Honored," in *The Marshall Retiree Report* (September 2003).