History of Rocketry and Astronautics

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Chapter 4

From Vahrenwald via the Moon to Dresden*

Konrad K. Dannenberg

Early Interest in Rocketry

This is the story of *my* involvement in rocket technology, which started when I became interested in space exploration in high school. I took part in many early military and most manned space flight programs; I am still active in the field, because of my Space Camp lectures at the Alabama Space and Rocket Center. I believe my story is to a large part the history of space flight. It all started when Max Valier talked in the mid-1920s in my home-town about space travel and rocketry. This triggered my curiosity, which increased in June 1928, when Fritz von Opel conducted tests of a rocket driven railroad car at Burgwedel near Hannover. This interest was shared by a few friends and school-mates, and we began to experiment with solid propellant rockets, which could be bought commercially as New Year's fireworks. By bundling these small units, or by "re-manufacturing" them into larger elements, we improved their performance.

Still dissatisfied, we studied Hermann Oberth's books, *Die Rakete zu den Planetenräumen* [The Rocket into Interplanetary Space][1] and, later, *Wege Zur Raumschiffahrt* [Means for Space Travel].[2]

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This built the necessary foundation for our simple and straightforward ideas and designs. We also studied serious and science fiction books written by Ganswindt, Hohmann, Sanders, Sänger, Valier, and others. This provided the theories and excellent reasons to switch from solid to liquid propellants. Static firing tests with our primitive designs demonstrated early on that more work had to be done, but there was really no functioning hardware available.

This recognition, and an increase in public interest, led Albert Püllenberg, in November 1931, to establish the Gesellschaft für Raketenforschung ([Society for Rocket Research] GEFRA), of which I became a member. This organization was one of several pre-Peenemünde groups of rocket amateurs located across Europe. An excellent description of these early groups is provided in Frank Winter's *Prelude to the Space Age.*[3]

Rocket Tests in Vahrenwald

Our group had obtained possession of a former ammunition storage bunker on an Army Base in the Vahrenwalder Heide, just north of Hannover. It was located close to today's airport in Langenhagen. Earthen storage bunkers provided safety for our static test firings of liquid propellant rocket engines. Our projects included postal rockets to carry mail; propulsion systems for sailplanes; and simple liquid fueled rockets for public displays and demonstration purposes to earn some badly needed funds to support our activities and plans for the future.

In conducting these early firings, we found out very early that all the formulas and performance data given in the available literature were probably suitable for future space flight calculations, but they did not help us in the design and construction of our early and primitive rockets. Our big problem was to make a rocket work at all. They often malfunctioned at the very beginning, at the moment of motor ignition. We encountered many blow-ups and explosions.

Whenever we had succeeded in making our engines run, we did not get the expected performance. We blamed this on incomplete combustion, inefficient propellant injection, poor manufacture due to unsatisfactory tools in our home workshops, and similar problems. We had a particularly hard time obtaining the desired materials, having adequate welding and soldering done, and gaining the basic knowledge in the manifold areas of manufacturing procedures and methods.

The biggest problem was, however, that we could never raise the needed funds to tackle the problem on a satisfactory basis. One of the reasons for this situation was that the general public and officials in a position to help our efforts had not been convinced of the benefits of rocket propulsion, of space travel, and of space exploration. In other words, we had then the same problems that space programs still encounter today!

Preparing for a Career in Rockets

Although I was aware of the need of well performing rocket systems, I decided not to waste my time with further fruitless experimentation without proper tools and facilities. That is why I practically withdrew, in 1934, from further participation in Albert Püllenberg's experiments and entered the Technical University in Hannover. I was still convinced of the value and the future of space travel, and I would have liked to enter studies in this field, but there were no courses on this subject. I had learned from our amateur tests that we had to know much more about proper fuel injection and atomization and their effect on the combustion process. This lesson led me to enter the field of combustion engineering, specializing in the field of fuel injection into Diesel engines under high internal pressure conditions, which are similar to the fuel injection into rocket motors. I also wanted to learn more about correct machining and manufacturing processes and proper test procedures. I therefore volunteered for 2 years as assistant to my professor of combustion engineering, Dr. Ing. Kurt Neuman. During those years we modified, with a group of students, a Daimler Phaeton vehicle of 1904 vintage to use propane gas instead of gasoline. Fuel shortages in Germany at that time had generated high interest in the use of alternate fuels for automobiles.

In order to learn more about instruments and measuring techniques, I joined the VDO Tachometer AG in Frankfurt/Main, who had also made an excellent offer of employment. Half a year later the war started. I was drafted into the German army and served during the French campaign in an anti-tank unit. In early 1940, the VDO managed to get me released from army duty, since they were working on war materials and had a dire need for qualified engineers to set up the new production lines, and to prepare the plant realignment from automotive instrumentation to wartime products. Once I was back at the VDO, it was rather easy to arrange for a call to duty in Peenemünde—a "Dienstverpflichtung." My friend, Albert Püllenberg, had informed me "between the lines" in our continuing correspondence that in Peenemünde work was going on that would interest me. The plant also needed workers, and if I had any interest, the military could call me to duty in that facility. In my initial interview with Dr. Walter Thiel, I learned in greater detail about the ongoing rocket activities at that site. I agreed to be called—to be "dienstverpflichtet"—and moved, in mid-1940, to my new work location in Peenemünde on the Island of Usedom on the Baltic Sea.

The Days in Peenemünde

My first assignment in Peenemünde was to improve the propellant injection systems which were in use at that time for several combustion chamber designs. We had not obtained the targeted exhaust velocities, and we believed that we had to obtain a more even propellant distribution over the individual injection units. That was my first assignment. Initial testing was done with smaller units, which had been designed for this specific purpose, resulting in a 1.4-ton combustion chamber. By clustering 18 of these sub-elements, one would obtain the needed thrust of the A-4 combustion chamber, or Heizbehälter, as it was called. In our tests we could improve the combustion efficiency dramatically, at the same time also introducing manufacturing simplifications of the fuel injection system.

The next development step utilized a 3-unit combustion chamber, which would yield a thrust of 4.2-tons. During these tests we found that the interaction of these 3 elements with one another helped to improve the combustion efficiency. But it was still not sufficient to obtain an exhaust velocity of the combustion gases of 2,000 m/sec. This was required to assure that the V-2 could obtain its promised range. Parallel to these tests we also tested similar improvements on a 1-ton unit, which was being developed as an assist unit for aircraft take-offs. It was never used operationally, since another similar unit, using only hydrogen-peroxide, was simpler in its operation and was ready for use somewhat earlier in time.

When our proposed modifications and changes were finally introduced into the actual 25.4-ton combustion chamber with an 18-element cluster, we fortunately met this requirement without having to introduce any further special measures. Apparently the additional mixing of the combustion gases from the 18 elements provided sufficient improvements of the combustion efficiency to the desired values.

Other problems plagued the development. The double-walled cooling jacket led to many burn-throughs and chamber failures. Additional wall cooling had to be introduced, which complicated the manufacture and decreased the combustion efficiency. The fuel lines had to wrapped around the chamber to provide enough flexibility for the expansion of the chamber length during firing. Other problems with valves and measuring devices kept the development work always a step behind. Therefore, the technical people in Peenemünde would have liked to have another year for further testing and the approval of necessary changes. But army headquarters and the political situation forced an early deployment before all these problems had been solved.

The First V-2 Launch

Because of all these prevailing problems, the launch of the first A-4 on June 13, 1942, was unsuccessful. So was the second one. Only the third missile, on October 3, 1942, traveled most of the promised range and was considered a success. This vehicle had penetrated space. Wernher von Braun and the entire rocket team were delighted about this major step ahead in space travel. General Dornberger said at that time: ". . . Wir haben mit unserer Rakete in den Weltraum gegriffen. . . . Dieser 3. Oktober 1942 ist der erste Tag eines Zeitalters neuer Verkehrstechnik, dem der Raumschiffahrt! . . ." **This is the beginning of the Space Age.**[4,5]

When I came to Peenemünde, the basic design of the chamber had been completed. The above-discussed improvements finally led to a chamber which was ready for longer duration runs, and which should have been usable. The major problem was the ignition of the combustion chamber. We tried many igniter designs: we tried hypergolic liquids (zinc-diethyl); built-in igniters; systems which could be inserted from the end of the chamber; etc., etc. The problem was finally solved by an experimental approach, which inserted a spinning swastika-shaped 4-solid-propellant rocket assembly into the chamber. It was positioned close to the upper chamber wall.

A gradual step-wise opening of the propellant valves turned out to be particularly helpful. We developed a "pre-stage" valve design, where the main propellant valves opened before the turbine was activated. After the turbine had been started by opening the hydrogen-peroxide valve, the gradually increasing turbine pressure opened the valve slowly to its fully open position. We did not realize at that time that under the old procedure an unduly large amount of propellants might accumulate prior to full burning. This large amount would immediately generate a very high combustion chamber pressure that often destroyed the chamber. The gradual increase of propellant flow by step-wise opening of the main fuel and Lox valves solved this problem.

Although the above statements may appear to imply that I was the one who solved all these problems, I would like to emphasize here that all these operations, the tests, the evaluation and appraisal of test results derived from the work of a team of people. Not only Army employees of many departments participated, but much of this work was supported by universities and contractors, who all participated in the tests and their evaluation. They were always given an important say in final decisions.

The V-2 in Mass Production

When the production finally got under way, a design freeze was imposed, and only "mandatory" changes, which affected the operability, were accepted. A Change Board, which consisted, besides the designers, of production personnel, planners, quality control people and cost estimators, had to agree that the change was mandatory, that it could be implemented in time, and that needed resources were available. The Change Board had also to determine the missile serial number which would be affected by the change and the need for rework, and modification of missiles which had been manufactured and had been completed in the meantime. You can imagine that the introduction of changes had become very difficult, and mere product improvements were not acceptable at all. Only mandatory changes were being considered, and either the designer or the development engineer had to certify, by his signature, the need for the change to the Change Board.

In preparation of mass production, a "Nachbau-Direktion" planned to redesign many components for ease of manufacture and improved producibility, but test results with many of these changed components showed that they did not meet functional requirements. Many missile malfunctions resulted. Therefore this effort was soon stopped, and a directive was issued to mass-produce all missiles in accordance with the original research and development design to assure operational success. A rather large number of changes was necessary again towards the end of the war, when many materials became unavailable. Functioning missile components had often to be changed for the use of wartime "Ersatz-Materials." In the end, about 65,000 changes had been required to get the A-4 to its final deployment status.

In the early days of the war, several study efforts had been under way. One project studied the possibility of increasing the range of the A-4 by coasting on wings to a much more remote target. It was estimated that the range could be extended to more than 500 km by the addition of delta-wings on the sides of the A-4. Also, a manned version had been studied. An A-10 two-stage design would have increased the range to an intercontinental distance by the use of a large 200-ton recoverable first-stage liquid propelled booster. Although these proposals had been of interest in the beginning, they were frowned upon towards the end of the war, when all personnel were required to concentrate all efforts toward the completion of the A-4 development, its deployment and its fieldworthiness. At the time of its actual troop use, the A-4 was given by Hitler's propaganda minister, Joseph Göbbels, the name V-2, for "Vergeltungswaffe 2," or "Vengeance Weapon 2."

Two other developments in Peenemünde at the end of WWII were an anti-aircraft missile, the Wasserfall, and a Taifun project, which used a 24-unit cluster of long, small-diameter liquid-fueled rockets to hit enemy area targets. They operated without a guidance system. Also, all other guided and/or controlled missiles under development in Germany at that time were being test-fired in Peenemünde, such as the Natter, the Rheinbote and the Rheintochter, the Schmetterling, and others.

When I joined this Army research facility, it was the Heeres Versuchsanstalt Peenemünde, or HVP. Later on, it was also known as Heimat Artillerie Park [Home Artillery Park], or HAP. The military contingent had been organized in the Versuchskommando-Nord [Research Command-North], or VKN. In 1943, the facility had grown to such an extent, that it was decided—partially for political reasons—to form a private company, named the Electro-Mechanische Werke, or EW. It was under the technical management of Professor Wernher von Braun. Located just north of the Army Research Center was an Air Force facility, named "Werk West," while the Army area was also known as "Werk Ost."

Post War Rocket Activities

At the end of the war, all Allied Forces wanted to learn about the operation, the handling, and the launching of missiles. The British had captured, in the Northern part of Germany, many V-2's, including items of firing and launching equipment, Meillerwagen transporters and other ground equipment. They used captured German soldiers, who had served in the missile firing units, to conduct the firings. They also brought a few former Peenemünde engineers and technicians to Cuxhaven. These were to provide technical advice, to supervise pre-launch testing and firing preparations of the captured V-2's. They had to approve the final missile assembly and flight procedures. I was part of this British-controlled team. Only a small number of German rocket engineers stayed with the British missile program.

The Russians re-activated the Mittelwerk facility and assembled V-2's at that site, but they relocated these activities, eventually, to a new assembly line near Moscow. The Russians already had their own active development program under way, and they proceeded with their missile developments without any direct participation of the captured German engineers and technicians. The French eventually hired a large number of former Peenemünde and Mittelwerk workers, and they initiated their own missile development program soon after the war ended. A number of these personnel finally went to Egypt and developed military systems under then-president, Nasser. Many of these operations are mentioned in *Unternehmen Paperclip* by Franz Kurowski.[6]

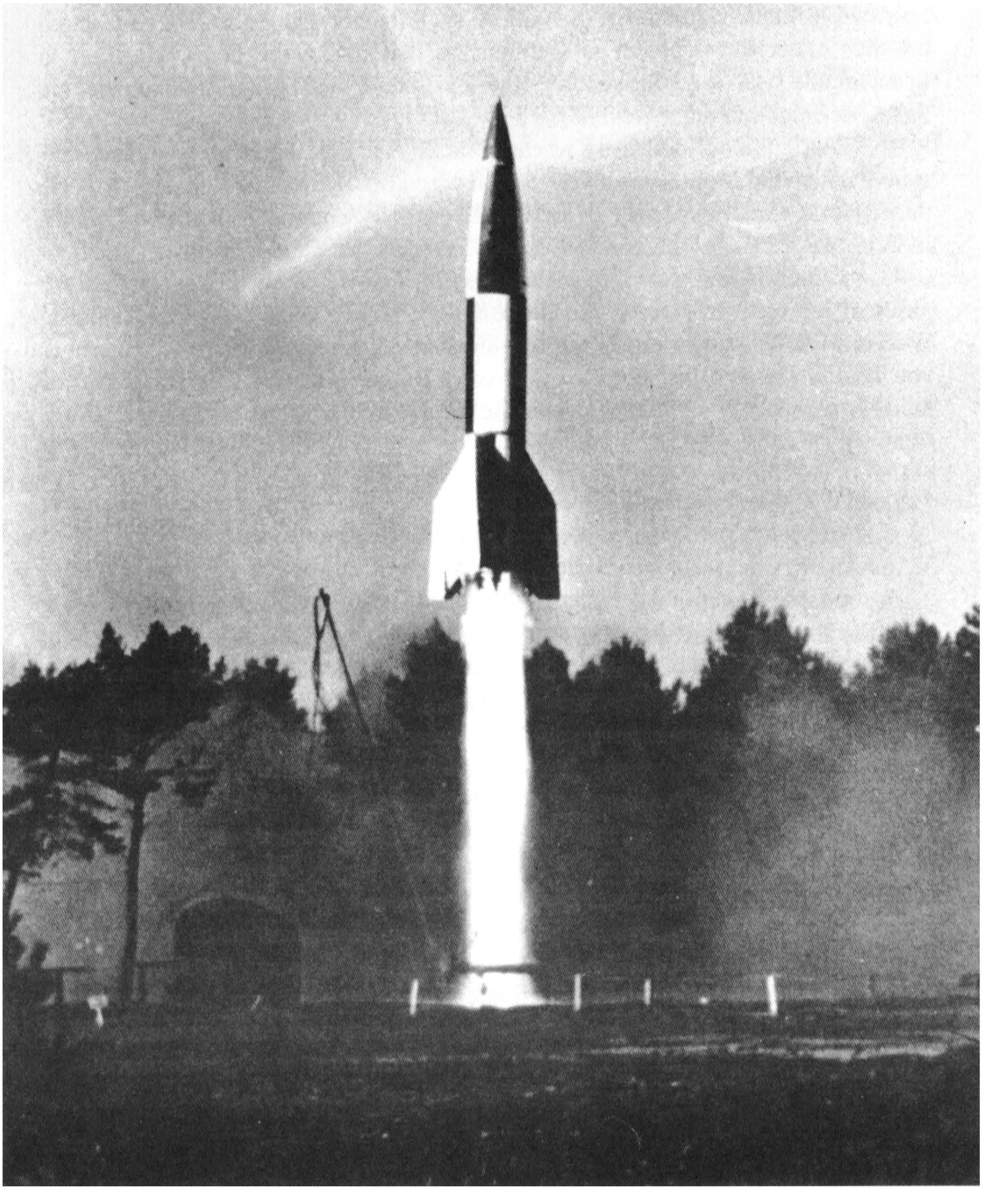

Figure 1 Post war firing of a V-2 rocket.

Operation Paperclip

The United States also became interested in learning more about the technical capabilities of this new weapon system. A team of American scientists was dispatched to Europe on August 14, 1945, to collect information and equipment related to German rocket programs. As a result, components for approximately 100 V-2 missiles were shipped to the United States and stored at the Army's White Sands Proving Ground in New Mexico. In October 1945, the Secretary of War approved a plan to bring the top German scientists to the United States to aid military research and development. Beginning at the end of that year, Wernher von Braun, and finally another 117 scientists and specialists, came under Operation Paperclip to this country.[7] I had the good fortune to be one of them!

After a short stay in Fort Strong, MA, the group moved to Fort Bliss, TX, and started work immediately. The primary task was to check out stored parts and components of the V-2s, which had been shipped separately to the White Sands Proving Ground across the border in New Mexico. There these items had to be assembled into complete vehicles; some of these were being subjected to a "static firing" prior to launch. About 66 of these V-2's were finally launched. Eight of them had been modified into the world's first liquid-propelled two-stage vehicles. The JPL-developed WAC-Corporal had been mounted on a V-2 as a second stage. This combination demonstrated the advantages of staging.

The first V-2 launch at the White Sands Proving Ground in New Mexico, took place on April 16, 1946, and it was a flop. It went only 3.5 miles up and exploded. The first successful launch occurred on May 10, 1946, and it reached an altitude of 71 miles. This was the beginning of the Space Age for the United States! An altitude record for one stage rockets of 130 miles was set by a V-2 on August 22, 1951, while a 2-stage "Bumper WAC" obtained a height of 244 miles on February 24, 1949. Two of the eight Bumper-WAC's were taken to a Naval Air Station in Florida for launch. These first 2 launches from Cape Canaveral, on July 24, 1950, opened up what is now known as the Eastern Test Range of the U.S. Air Force, and/or NASA's Kennedy Space Center.

A primary task at Fort Bliss was to be available for interrogations by scientists and engineers of American aerospace companies and for consultation regarding their projects and advanced ideas. Other tasks were studies of advanced launch vehicles. One of these projects was the proposal for a new and powerful missile to replace the V-2. Another study added a ramjet upper stage to the V-2, which would increase its range to about 500 miles. It was even decided to start work on the actual design and manufacture of such a unit for an early launch. Testing of ramjet combustion units was conducted at South Lake in California. Later on, however, the project was canceled.

The Move to Redstone Arsenal

These Fort Bliss studies and test firings at White Sands evidently convinced the Army to start a full-scale missile research and development program. It was decided to relocate this activity to the Redstone Arsenal near Huntsville, Alabama. The wartime mission of this facility had been completed, and the arsenal was for sale until the Army decided to modify it into a missile and rocket development center. To implement this decision, Dr. Wernher von Braun and almost all members of his team, as well as many American military and industrial personnel, left Fort Bliss in the Summer of 1950, and moved to Huntsville. At that time, several original team members departed and joined private industry, where they eventually took leading positions at such aerospace contractors as the Aerojet Corporation, General Dynamics/Convair, Lockheed, and North American Aviation. Another small group had worked on the Loki (Taifun) project. They moved north to continue this development for the Bendix Corporation.

An immediate task at the new location was the continuation of the ramjet work, which had been started at Fort Bliss. But the Army soon put greater priority on the development of a mid-range ballistic missile, which later was named the Redstone. It could carry a very large payload, which could be separated from the booster for re-entry in order to overcome one of the major problems of the V-2 at re-entry, causing "air-bursts." It had about the same range as the V-2, and it was principally based on V-2 technology. It used ethyl alcohol as fuel; it had a double-walled combustion chamber and used a turbopump driven by a supply of hydrogen-peroxide, almost identical to similar systems on the V-2. Advances were made in the injection system for the propellants and the catalytic steam generator for the decomposition of the hydrogen-peroxide. The guidance system was similar to the "stabilized platform" developed for the V-2, but not ready in time for operational use. The control system for both missiles consisted of graphite jet vanes, which protruded into the exhaust jet of the rocket engine. Only a little over 100 Redstone units were manufactured. The U.S. Army deployed them in Europe for several years as the first medium range ballistic missile (MRBM) available for troop use. These military accomplishments, however, were not as important as the many scientific research and development missions to which the Redstone missile was finally adapted. Due to its high reliability, its dependability, and its availability, it could finally play a most important role in early space exploration efforts by this country.

Launch of the Explorer Satellite

In accordance with agreements made in preparation for an International Geophysical Year (IGY), the United States and Russia had agreed to sponsor a satellite project for the study of the Earth's environment. The Army proposed a "Project Orbiter," a modified Redstone vehicle, to fulfill U.S. obligations. But President Eisenhower decided against the use of a military weapon system for that purpose, and he ordered that an entirely new Vanguard project be developed for the IGY satellite launches.

In the meantime, the Russians demonstrated the availability of their ICBM by a launch in the summer of 1957. To meet their part of the IGY agreement, they utilized this vehicle and launched their Sputnik satellite, surprising the world, on October 4, 1957. A second Russian missile carried the dog Laika into orbit on November 3, 1957. This demonstrated the survivability of living beings in space under "zero-gravity" conditions, and it indicated to American scientists that the Russians were preparing for early manned missions into space.

Contrary to these two Russian successes, the first U.S.-IGY launch attempt, on December 6, 1957, with the Vanguard was a dismal failure. This new launch vehicle just had not undergone sufficient testing and development time to perform adequately. After this Vanguard mishap, the U.S. Army Ballistic Missile Agency (ABMA) was finally given approval to launch a modified Redstone missile for the IGY satellite. A suitable vehicle assembly had been in storage for several years. It had originally been prepared for test launches of ablative nose cones to demonstrate the survivability of re-entry from space. Several launches of this type had already been conducted, using the Redstone as a first stage booster and adding solid propellant upper stages, developed by the Army's Jet Propulsion Laboratory (JPL). These launches were to demonstrate the suitability of the Jupiter/IRBM ablative nose cone design, which was being developed at that time. It was just necessary to add another, last and final fourth, solid propellant stage to improve the performance from a 3,000 mile ballistic missile to an Earth orbital mission. This could *not* be done earlier because strict orders had been issued by the Army *not* to put a fourth stage on these vehicles for an unapproved launch.

The successful Explorer satellite launch, on January 31, 1958, put Huntsville, Alabama, "on the map!" And bigger things were still to come: To demonstrate U.S. capabilities in space flight, and particularly the survivability and safe re-entry, two monkeys had been carried inside a modified Jupiter nose cone. They both survived the ballistic 2,700 mile flight and showed that the ablative heat protection for nose cone re-entry would be safe. It would, accordingly, also support the return of living creatures from space. President Eisenhower showed the recovered nosecone on public television to demonstrate to the world that the U.S. was not lagging behind Russian missilry. The recovery from space was a first, since the Russians had killed the dog Laika in orbit and did not recover that nosecone.

Based on these experiences, the Redstone vehicle, now known as "Old Reliable," was called upon again, to carry Alan Shepard on May 5, 1961, and Gus Grissom on July 21, 1961, as the first two U.S. astronauts into space on top of a Redstone-Mercury configuration. The Russians had launched cosmonaut Yuri Gagarin, already on April 12, 1961. He orbited the Earth, using again the Russian ICBM, while the one-stage Redstone could carry Alan Shepard and "Gus" Grissom only to a 118-mile altitude, providing a space environment and zero-gravity for just about 5 minutes out of a total flight time of 15 minutes and 22 seconds. The United States was finally able to demonstrate manned orbital capabilities with John Glenn's flight on February 20, 1962, using a modified Atlas/ICBM as the Atlas-Mercury version. He flew 3 orbits around the globe in about 5 hours.

The Saturn/Apollo Program

These Explorer and Redstone-Mercury missions opened the door for the von Braun team to participate in much more ambitious missions of the future. The basis for this was laid by President Eisenhower's Executive Order of October 21, 1959, which transferred personnel from the Development Operations Division of ABMA to the National Aeronautics and Space Administration (NASA), as well as the Saturn launch vehicle program of large rocket boosters. This transfer initially met strong political resistance, but Wernher von Braun finally recognized the situation and said in a December 1959 speech: ". . . We will no longer be charged with developing long-range missiles for defense. We will be charged with providing the transportation system to carry forward the national space exploration program. For us, this is the realization of a dream that dates back to the inception of our rocket development efforts in Europe many years ago. . . ." He expressed the feeling of all team members. We had now the chance to do what we had always wanted to do: build and launch vehicles for the exploration of space!

This transfer finally led to the establishment of NASA's George C. Marshall Space Flight Center, located at the Army's Redstone Arsenal at Huntsville, Alabama. It also laid the foundation for the design, development and launching of the Saturn series of large launchers. When President Kennedy announced the plan to land men on the Moon and bring them back safely, he called on the Marshall Space Flight Center to provide the transportation for such a mission.

The Center staff now included thousands of American technicians, engineers and scientists, besides the core of former Germans, most of them transferred from the Development Operations of ABMA. An excellent summary of all these activities is given in the book *The Rocket Team*.[8]

The first test vehicle in the development of the Saturn series consisted of a cluster of eight modified Jupiter engines, eight Redstone tanks arranged in a circle around a central Jupiter tank. Its design and construction had been started to provide a first stage booster for a powerful multi-stage vehicle for ambitious space missions. This test vehicle became, finally, the Saturn I booster.

Since doubts existed about the reliability and dependability of such an eight-engine cluster, it was decided to also develop a new, powerful single engine to replace the eight-engine cluster. It was named the F-1 engine, and it later became the main propulsion element of the first stage of the Saturn V booster for the lunar missions. The Saturn I had a second stage using six RL-10 hydrogen engines. It was contemplated to replace these by a more powerful single unit, the J-2 hydrogen engine, which could be used in the second and third stages of the Saturn V. Without all these early activities, the lunar landing would most likely not have taken place in the decade of the sixties, as President Kennedy had asked for.

The Lunar Landing

While these new developments went on, the Saturn I was utilized for a series of early test flights to demonstrate the feasibility and safety of the clustering principle; to measure micro-meteoroid dangers, radiation levels in planned orbits, solar effects, and other still unknown factors of space flight. The Saturn I used liquid hydrogen in the second stage, a first for the Peenemünde group. Fortunately, Krafft Ehricke, another original team member, had left the group and developed, at General Dynamics/Convair, together with Pratt and Whitney, the RL-10 liquid hydrogen engine for use in a second stage of the Atlas/Centaur space vehicle. The efficiency of hydrogen combustion was required to permit travel to the Moon with a large payload, such as the Apollo capsule, the command module, and the lunar lander and ascent stage.

In order to try out the newly developed liquid hydrogen and liquid oxygen J-2 engine, it was decided to replace the second stage of the Saturn I (the S-IV stage) with a more powerful unit (the S-IVB stage) by using a single J-2 engine as the propulsive system. Thus the Saturn IB was created. This configuration found extensive use in several demanding pre-lunar missions. It permitted testing of all systems required for the lunar landing, except that all of these preliminary tests had to be conducted in Earth orbits, and not in lunar orbits. This permitted the program to proceed with the utmost assurance that all components performed well and that no major design flaws existed.

After completion of the lunar landings, the Saturn IB was also used for three manned Skylab missions and for the launch of the American portion of the rendezvous equipment for the Apollo-Soyuz Test Project. All Saturn IB flights were successful and did not reveal any problem areas of the tested hardware items. Therefore, the design and the construction of the Saturn V for the actual lunar landings could proceed to meet a very tight schedule. The Saturn V second stage used a cluster of five of the new hydrogen-oxygen J-2 engines. The successful and timely launch of Apollo XI on July 16, 1969, is the most impressive accomplishment of the German-American team of rocket engineers and space scientists, and it will remain a milestone in the annals of human history forever.

Conclusion

During the earlier phases of the Apollo Program, I was Deputy Manager of the Saturn portion of the program. At the time of the lunar landing I had been assigned to a space station project, which von Braun had hoped would be started right after the end of the lunar landings. This was the reason for the development of the Skylab program, which was actually the world's first space station. Von Braun had hoped that a larger unit, utilizing S-II (Saturn V second stage) tanks with a 10 meter diameter, would become a follow-on. This is one of very few projects for which he did not succeed in convincing the decision makers in NASA and in Congress. Since such post-Apollo projects as the Space Shuttle, the Space Station, the lunar base and a Mars expedition are not history yet, I will end my narrative here.

To conclude my report, I would like to relay to you my evaluation of the impact that Wernher von Braun and his Rocket Team has had on developments in rocket technology, space exploration, and the world economy. I have concluded that this effect has been tremendous. Wernher's charisma, his vision, his technical and managerial skills were the driving force behind all the related activities. Wernher von Braun could convince his superiors that his ideas were realistic, deserving of support, and should be implemented as proposed. He convinced individual members to stay with the team, although they all could have improved their salary level and standard of living by joining private industry, as some of them finally did! Wernher always gave credit to his team members for their ideas and contributions. And he is the one who molded and shaped all of the major accomplishments which I have outlined above. I am grateful to him for the roles he assigned to me at various periods. I had more fun and satisfaction than I ever would have expected from merely doing a job. I enjoyed every minute of it, and that is why I am still working with young people in Space Camp. I hope I can relay to them some of my enthusiasm about space exploration.

I would now like to give you my answer to the age-old question about the benefits to mankind from our space ventures. As you all have experienced, we are quite often asked to cite our justification for the support of space exploration. Many quoted benefits from space appear to me quite far-fetched: Teflon frying pans, perfectly round ball bearings, computer science advances and other "minor" benefits.

Instead, I would like to highlight to you here the tremendous impact that rocketry has had on all military technologies around the world. All armies have been geared to the use of missiles and spacecraft. The military balance on both sides of potential enemies has finally led to the conclusion, by all parties, that there is no way to win a war where ballistic missiles and atomic warheads are being employed. This recognition is now leading to disarmament talks, which are expected to lead to a "Peace Dividend" on all sides. Without our space and missile developments—and the availability of atomic warheads—none of this would have happened!

My other point may be even more important: Our satellite communications technology has brought about the fact that any "Wall" or other kind of barrier has become meaningless. That is the principal reason for recent developments all over Eastern Europe. There exists no artificial barrier which can enable any national government to hide the information coming in from the rest of the world. It seems now to be accepted that a free economy, a free press, and freedom in general terms will always perform better than any centrally controlled economy. This recognition is strictly based on open communications, and it is the driving factor behind all the recent events in the East. I myself am fully convinced that the new cooperation will provide a tremendous uplift to economies around the world, although immediate difficulties may overshadow these long-term benefits and may hide them!

Our cosmonauts and astronauts have seen our Mother Earth as a global community. We are no longer subject to neighborhood events or news from City Hall. The occurrences in other countries and nations have a tremendous impact on the way we live our lives and plan our future.

I also propose to pursue actively a permanent settlement on the lunar surface and a manned mission to Mars. We should redirect the "Peace Dividend" into these directions to avoid massive unemployment and embitterment. These forward-looking missions will, in my opinion, be the best way to bring all of mankind together, so we can join hands in the most ambitious venture of history. I am only sorry that I will probably not be the one to report about these events, which have been my boyhood dream from the beginning.

In conclusion, I present to all of you here the rhetorical question—"Are these not the greatest and the most important benefits that any of us can get from a viable and efficient space program?" **These are the real benefits from space!**

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