History of
Rockerty and Astronautics

Proceedings of the Twentieth and Twenty-First History Symposia
of the International Academy of Astronautics

Innsbruck, Austria, 1986

Brighton, United Kingdom, 1987

Lloyd H. Cornett, Jr., Volume Editor

R. Cargill Hall, Series Editor

AAS History Series, Volume 15

A Supplement to Advances in the Astronautical Sciences

IAA History Symposia, Volume 9

AAS Publications Office
P.O. Box 28130
San Diego, California 92198

Affiliated with the American Association for the Advancement of Science
Member of the International Astronautical Federation

First Printing 1993

ISSN 0730-3564

ISBN 0-87703-376-5 (Hard Cover)
ISBN 0-87703-377-3 (Soft Cover)

Published for the American Astronautical Society
by Univelt, Incorporated, P.O. Box 28130, San Diego, California 92198

Printed and Bound in the U.S.A.

Chapter 25

BRENNSCHLUSS OVER THE DESERT: V-2 OPERATIONS AT WHITE SANDS MISSILE RANGE, 1946-1952[*]

John R. London III[†]

The German-designed V-2 missile and White Sands Proving Ground, New Mexico, are forever linked in the annals of space history. From 1946 to 1952, V-2 operations at this remote site in the southwestern United States contributed significantly to the advancement of knowledge in a number of engineering and scientific disciplines. The V-2 provided training in the handling and firing of large missiles, acted as a test-bed for missile research and development, and served as a means to carry experiments and test equipment into, and beyond, the upper atmosphere. When the last V-2 was launched in 1952, American missile and atmospheric science programs had advanced significantly.

V-2 ORIGINS

The V-2, or A-4 as it was originally designated by the Germans, was recognized by its designers as a potential high altitude research vehicle long before the end of World War II. In fact, two missiles were launched vertically to peak altitudes of 107 miles (172 km) in studies by the German Rocket Research Laboratories at Peenemünde. These flights demonstrated the V-2 had altitude capabilities greater than any other missile in the world at that time. A number of high altitude research instruments were developed for the V-2 by Professor Regener, Director of the Research Institute for Stratosphere Physics at Friedrichshafen. Unfortunately, as the war situation grew critical for Germany, the necessary priorities to continue such long range research work could not be obtained [1].

As the Allied armies moved across western Europe, thousands of V-2 components were encountered in forward staging areas as well as in the underground Mittelwerk complex. Many Allied leaders already understood the military implications of this weapon, and the Americans mounted an extensive effort to capture and ship large quantities of V-2 components back to the United States for

---

[*] Presented at the Twenty-First History Symposium of the International Academy of Astronautics, Brighton, United Kingdom, 1987.

[†] John R. London, III, at the time of the presentation, was a major in the U.S. Air Force attending the Florida Institute of Technology at White Sands Missile Range, New Mexico.

study. This was the beginning of a journey for these V-2s that would ultimately lead to the desert environment of White Sands, far from their country of origin.

BACKGROUND

White Sands Proving Ground (Figure 1) was formally activated by the Chief of the Army Service Forces on July 9, 1945, exactly one week before the world's first atomic bomb was detonated on the Proving Ground's northern tier. However, testing of a much different sort would quickly become the primary activity at White Sands. The area had many characteristics that made it ideal as a test site for the new and burgeoning field of rockets and missiles: extraordinarily clear weather throughout most of the year; expansive and uninhabited terrain over which launches could occur; and, accessibility to rail and electrical power facilities and major military installations [2].

Figure 1 White Sands Proving Ground, 1945.

The main post area of the Proving Ground was located at the foot of the eastern side of the Organ Mountains. This area, known then as the "Cantonment

Area," provided the technical and administrative facilities needed for support of missile preparation, launch, tracking, and recovery activities. A large Quonset-style building was constructed in this area in July 1945, which became known as Missile Assembly Building One. By February 1946, a second building had been constructed, called the Mills Building. This building was used for assembly of major V-2 subassemblies, and it became more commonly known, in the late 1940s, as "the V-2 shop." Contained in this main shop were electrical, welding, sheet metal, and machine shops to support V-2 activities. Both of these buildings are still in use today [3].

Approximately seven miles (eleven km) due east of the Cantonment Area the first launch site for large missiles was constructed. Centerpiece of the launch area was the blockhouse, a building designed to contain the firing controls, communications equipment, and support personnel needed for missile launchings. Constructed to withstand the direct impact of a V-2 class missile for altitude, the blockhouse had walls of ten-feet (three meters) thick, reinforced concrete with a 27-feet (eight meters) thick roof [4].

Initially, access to various levels of the V-2, once it had been erected for launch, was provided by Meilerwagon work platforms and fire ladders (Figure 2). It quickly became obvious that a more effective means of access was required, and a powered trolley gantry crane was constructed. Built in late 1946, the gantry was designed to accommodate a variety of missiles, but it primarily supported V-2 operations during the late 1940s and early 1950s. The blockhouse and gantry today are national historic landmarks [5].

A static test stand was constructed to allow full-duration tests of a V-2 propulsion system. The stand was built into the side of a cliff, two miles (3.2 km) south of the Cantonment Area. The design was strongly influenced by the Germans, and it was based on their development and test experience with the V-2. Contracts were awarded on October 26, 1945, for the construction of the 90,000 pounds (400,000 N) -rated test stand, and work was completed in time for the first static test on March 15, 1946 [6].

Organizations and Personnel

Overall management and responsibility of the V-2 project at White Sands was under the United States Army Ordnance Department. The main post and proving ground were also under the Ordinance Department. Personnel from "C" Battery, 69th Anti-Aircraft Battalion, were assigned, on August 10, 1945, to support the Ordnance Department in initial guided missile activities at White Sands.

The 1st Guided Missile Support Battalion, Army Ground Forces, was activated at the Proving Ground on October 11, 1945, and it supported launches during the entire period of V-2 operations. The Battalion was the primary beneficiary of training in the handling of large missiles, provided first by the German technical team, and later, the General Electric (GE) Company. The last five V-2 launches at White Sands were conducted totally by the Battalion, establishing themselves as the first American all-military team to launch a large ballistic missile [7].

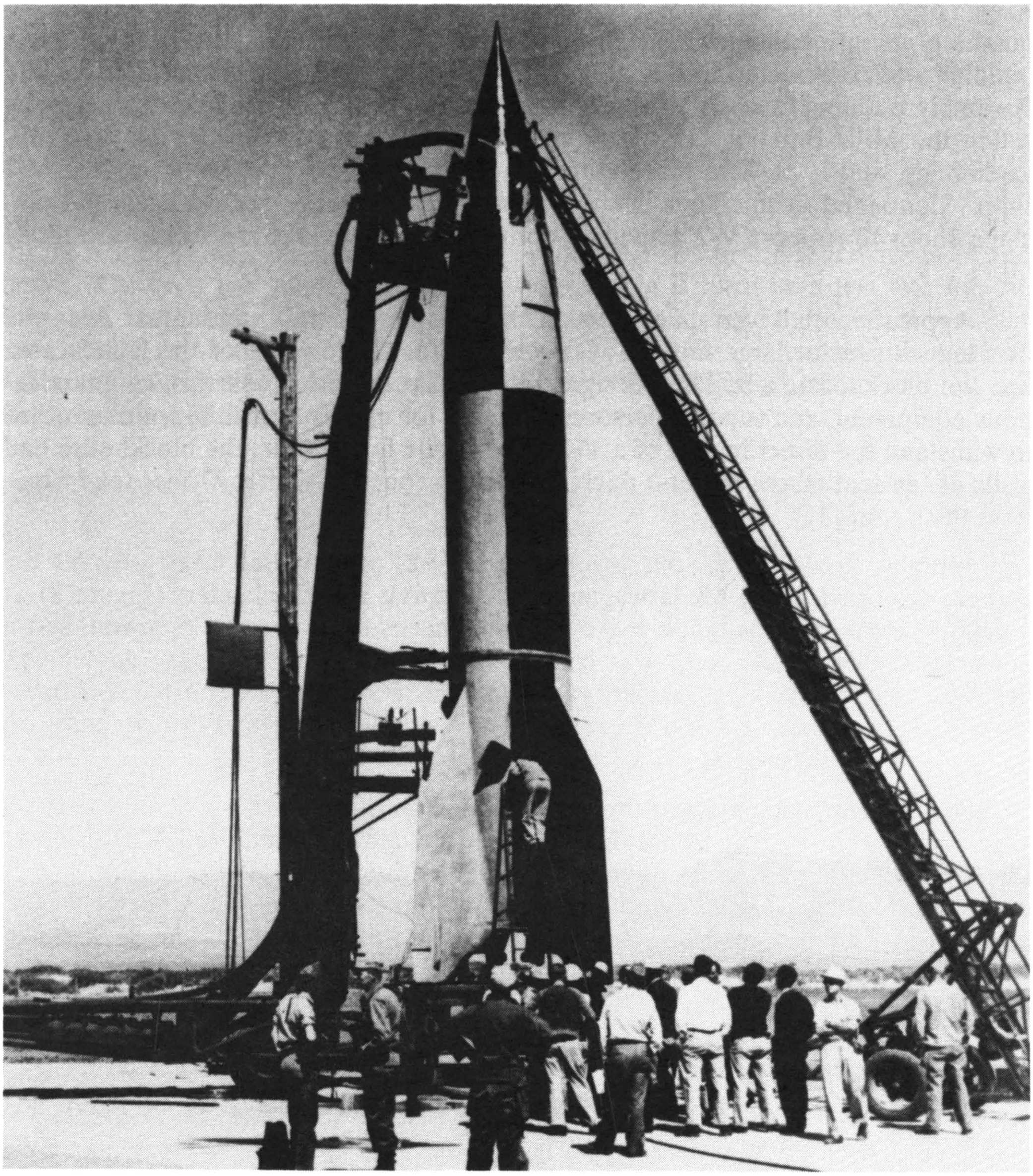

Figure 2 Early V-2 with Meilerwagon and fire ladders.

Members of the German "Paperclip" team were assigned to White Sands to provide technical consultation, training, and support for the V-2 project. The German personnel assigned at the Proving Ground were only a part of the entire "Paperclip" team, and their numbers peaked at 39 in March of 1946. The German team worked primarily with General Electric personnel, and the GE team gradually took over more and more of the launch preparation and firing activities, as their expertise increased. The German technical specialists continued to contribute to the Army's missile programs, and ultimately filled many key roles in America's satellite and manned spaceflight efforts of the 1950s and 1960s [8].

On November 15, 1944, the Ordnance Department established Project Hermes. General Electric Company received a contract to develop, fabricate, and test a series of surface-to-surface tactical missiles. GE personnel had been involved in the V-2 component round-up in Europe, and they were subsequently contracted to support V-2 activities at White Sands through an expansion of the already existing Project Hermes. This direct involvement in the V-2 project lasted until June 30, 1951, when General Electric's participation in this aspect of Hermes was terminated by agreement. Responsibility for the V-2 project shifted to the 1st Guided Missile Support Battalion at this time, but a transition period occurred after June 30, to allow GE personnel to transfer spare parts, testing equipment, and technical drawings to the Army organization. Additionally, GE provided training and consultation during this transition period to assist the Battalion in the initiation of their responsibilities [9].

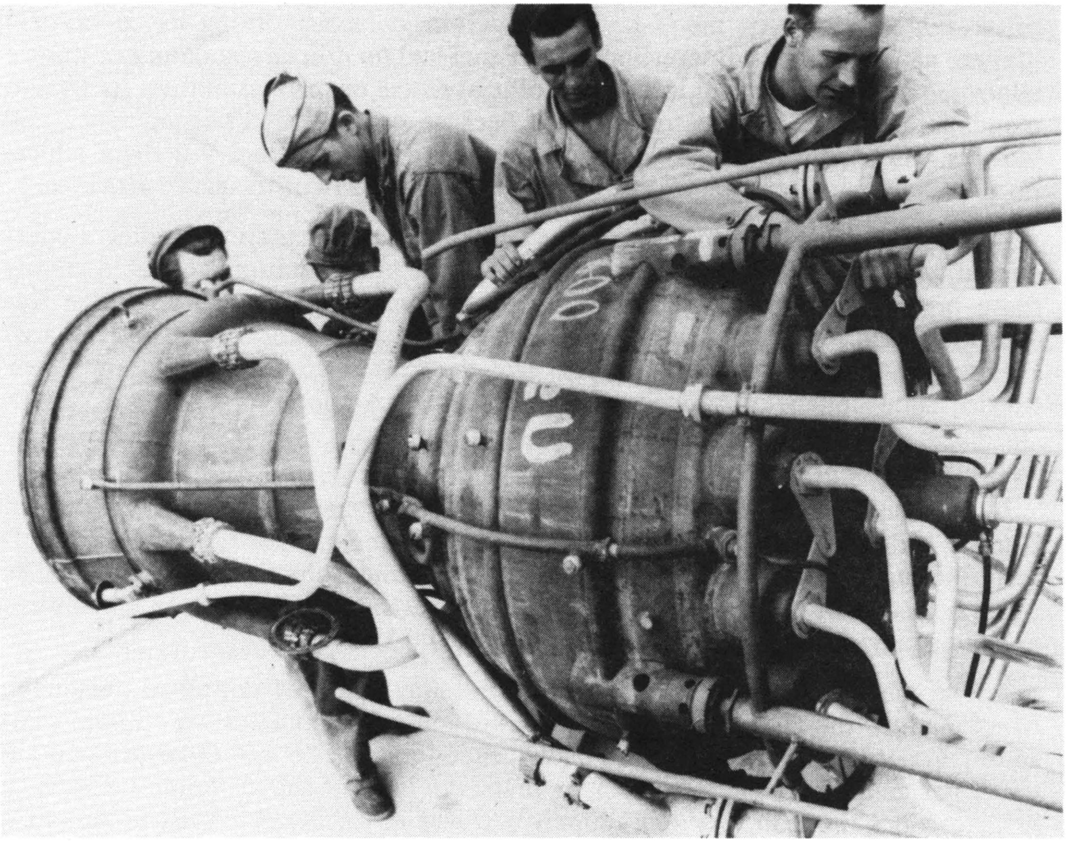

Figure 3 V-2 engine undergoing refurbishment.

When the Ordnance Department began making plans to refurbish (Figure 3) and test the captured V-2 components, the simultaneous opportunity to use the V-2 as a scientific instrument carrier was recognized. Credit for appreciating the possibilities of, and facilitating, the V-2 high-altitude research program, goes primarily to Ernst H. Krause of the Naval Research Laboratory (NRL), and Col. Holger N.

Toftoy and Lt. Col. James G. Bain of the Ordnance Department. The Army issued a formal invitation to government agencies and universities to participate in high-altitude research using the V-2. A meeting was held on January 16, 1946, at the Naval Research Laboratory with all interested organizations. As a result of this preliminary discussion, scientists representing various government and university groups held an organizational meeting at Princeton University on February 27, 1946, to form what would become the V-2 Upper Atmosphere Research Panel. Krause was elected the Panel's first chairman. James A. Van Allen of the Applied Physics Laboratory, Johns Hopkins University, and charter member of the Panel, was elected chairman in December 1947, when Krause left for employment with industry. Van Allen continued as chairman until the Panel ceased to be a visible entity upon the formation of the National Aeronautics and Space Administration [10].

In March 1948, the Panel was renamed the Upper Atmosphere Rocket Research Panel to reflect the growing diversity of rocket carriers being used for scientific research. However, the V-2 was the dominant carrier during its operational lifetime at White Sands. Interestingly, the Panel had no official regulatory or missile allocation authority, nor did it have any official duties or responsibilities. Its recommendations to the Army carried weight because of the Panel's competence and fairness. The Army essentially delegated authority for individual V-2 flight allocations to the Panel for all flights not already dedicated to Army research activities.

Several other government and university organizations played significant operational and support roles during the White Sands V-2 operations. Notable among these organizations were the University of Michigan, Air Force Cambridge Research Laboratory, Army Signal Corps Engineering Laboratory, Ballistic Research Laboratory/Aberdeen Proving Ground, and the Physical Science Laboratory/New Mexico State College of Agriculture and Mechanical Arts [11].

Logistics - V-2 Components

The condition of the V-2 components brought to the New Mexico desert from Europe varied greatly. Many parts had been subjected to German demolition efforts, looting of storage areas, and weather. Of the total shipment, only two missiles could be reconstructed from originally matched parts. Overall, however, there were enough components to assemble approximately 100 V-2s.

The missile parts had been gathered, in many cases, by untrained personnel. Consequently, the distribution of components and sub-assemblies were uneven, resulting in periodic hunts to procure badly needed items. The British government, in particular, helped provide various parts that were in short supply. Some items, such as gyroscopes, were in very short supply and had to be manufactured in America, since German industry was not yet allowed to produce war-related material [12].

In August 1945, approximately 300 railroad freight cars arrived in New Mexico, filled with the technological spoils from the most advanced ballistic missile in existence. The freight cars were unloaded at a rate of about fifteen cars per day, and a fleet of flatbed trucks hauled the cargo from the railroad yard in Las Cruces across the Organ Mountains to White Sands [13].

In addition to V-2 components, launch support equipment was also captured and shipped to the United States. This equipment included launching platforms, alcohol and oxygen tankers, peroxide tankers, road transport vehicles, and missile erection vehicles. Unfortunately, the overseas voyage and rough handling methods had made many of the missile parts, and some launch support equipment, unserviceable. This, coupled with the generally deteriorated condition of many parts when they were captured, dictated the start of a stripping and reconditioning effort immediately. Ultimately, enough parts and equipment were made available to conduct a successful test program, with reliability statistics comparable to German operational experience.

RESEARCH GOALS

Army Goals

Although the Army had a full agenda of goals for the V-2 program in America, all of these goals could be broadly summarized under a single one: to gain knowledge and experience that would be helpful in the design, development, and handling of future guided missiles. Through the pursuit of this overall goal, new goals and opportunities were developed with military applications.

Specifically, the Army pursued knowledge and experience in the following areas: training for both contractor and military personnel in the handling and firing of large missiles; experiments directly concerned with design of future missiles, including aerodynamic data such as heat transfer, boundary-layer transition, and drag; operational tests of future missile components, especially in the area of ramjets; ballistics data to better understand trajectories and the factors affecting them; radar detecting, tracking, and plotting; telemetry systems to provide real-time missile performance data; other tracking and range safety systems for missile testing activities; and, testing of prototype staged, or step rockets. The V-2 program provided information in these areas and others as well, and the Army's decision to allow scientific research to be conducted on V-2 flights ultimately resulted in much data that had direct or indirect military applications [14].

Scientific Goals

Offered the unique opportunity to participate in scientific research with the V-2, the various government agencies and universities established their own goals. The major areas of scientific research conducted with the V-2 flights were: measurement of cosmic radiation at different altitudes; measurement of the solar spectrum at high altitudes; measurement of atmospheric temperature and pressure at various altitudes; measurement of ionic density of high altitudes; radio frequency propagation and absorption measurements in the ionosphere; propagation studies of sound and shock waves; biological studies using plant and animal specimens; atmospheric composition studies using sampling bottles and mass spectrometers; measurements of the Earth's magnetic field; parachute design experiments; atmospheric meteor content studies; aerial photography; and meteorology studies. Results of this scientific research provided insights into many areas heretofore unexplored [15].

Interaction/Teamwork

The success of the V-2 program in America was due largely to the teamwork and cooperation between all parties, but especially between the Army and the V-2 Upper Atmosphere Research Panel. The Panel was essentially a self-constituted body, and it consisted of representatives with a detailed, day-to-day awareness of the technical and operational problems of their research groups. Although the Panel had no authority over the Army, it still was able to equitably distribute missiles to all research interests involved, including government agencies pursuing military-related studies.

LAUNCH AND RANGE OPERATIONS

Launch Preparations

The procedures for preparing a V-2 for launch are well documented, and they will not be discussed in detail here. However, activities unique to White Sands V-2 operations will be highlighted, to emphasize differences with standard wartime launch preparations.

Figure 4 V-2 components in Missile Assembly Building #1.

Assembly of the V-2's major components took place in the Cantonment Area's "V-2 shop" with the missile in a horizontal position (Figure 4). Most scientific equipment was also installed in the shop, so an essentially completed V-2 could be delivered to the launch site. The missile was weighed to establish its center of gravity, then loaded onto a Meilerwagon, using the shop's overhead five-ton (4500 kg) electric trolley crane for transportation to the launch area seven miles (eleven km) away [16].

The Meilerwagon, one of the significant pieces of ground handling equipment captured in Europe, served a number of functions, including horizontal work platform, transporter, verticator, and vertical access tower. It was basically a trailer with a large cradle and clamps for holding and securing the V-2. A hydraulic lifting system raised the missile to a vertical position and set it down on the launching platform.

Transport of the V-2 to the pad area normally took place about two days prior to the planned launch time, although this varied depending on the amount of launch site checkout and equipment installation required. After installation of the V-2 on its launch platform, the Meilerwagon was detached and withdrawn, and then the gantry crane was rolled into place, providing access to the entire missile Figure 5).

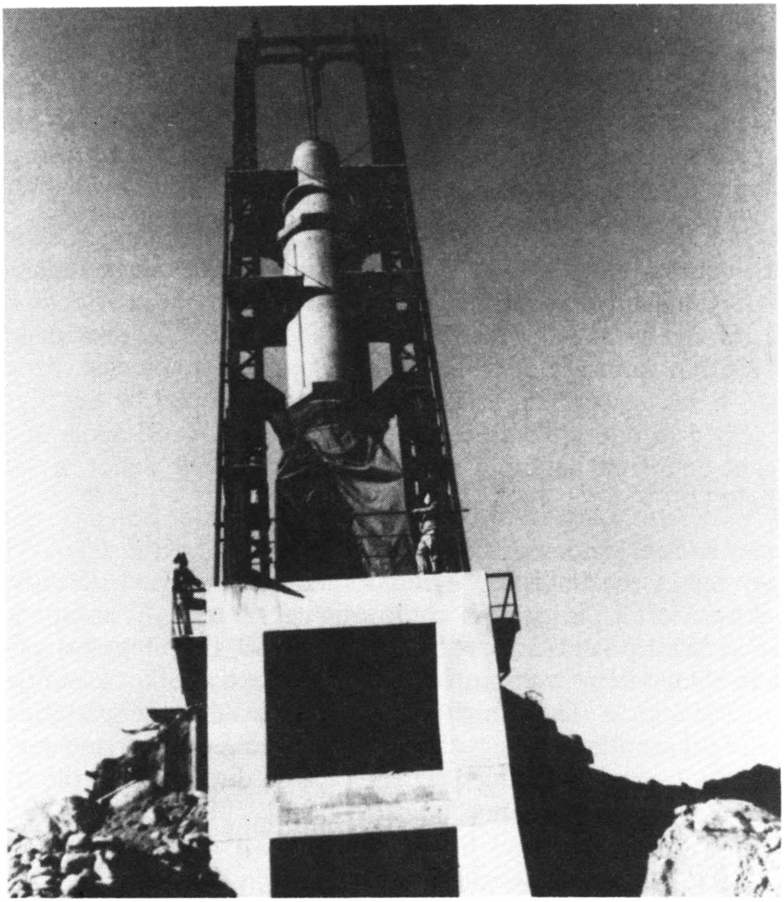

Figure 5 V-2 and gantry crane.

The count-down for a typical V-2 launch at White Sands began at X-360 minutes, when final checks of the scientific equipment and instrumentation began. At X-180 minutes, a weather status was requested from the Air Force Aerological Unit at White Sands to verify favorable launch conditions. Alcohol loading began at X-150 minutes, and took 25 minutes to accomplish. Liquid oxygen (LOX) loading began at X-105 minutes, and took 35 minutes. Immediately after LOX loading was completed, sodium permanganate and concentrated hydrogen peroxide loading began. These chemicals provided steam to drive the propellant turbomachinery. Explosive device detonators were installed at X-50 minutes, and five minutes later roadblocks were set up to close U.S. Route 70, a highway which diagonally crosses the range. At X-40 minutes, the loading of steam plant chemicals was completed. Control gyros were activated at X-35 minutes, and the gantry crane was rolled back at X-25 minutes. Over the next twenty minutes, the radar beacon, Doppler system, and telemetry equipment were turned on. At X-2 minutes, the vehicle was switched to internal battery power. Two minutes later the "fire" signals for primary and main stage ignition were sent [17].

Range Support During Flight

During the flight of a V-2, much of the data was gathered in a "remote" fashion. Devices on the ground interacted with the vehicle and provided a variety of data for real-time and post-flight analysis. This particular area of technology experienced significant advances in America during the late 1940s, partially because of the impetus provided by V-2 operations. With the array of range instrumentation available, a typical V-2 test conductor was provided with a relatively detailed picture of vehicle and payload performance.

Key information during a V-2's flight was provided by range radar. Operated by the U.S. Army Signal Corps Engineering Laboratory, radar provided bearing and distance data throughout most of the flight. The sheet steel V-2 provided a substantial radar target, but to insure a strong return signal, most vehicles carried a radar beacon. This S-band beacon and its antenna were developed by the Signal Corps, and were designed to operate with the ground-based SCR-584 radar system. Integration of radar data from multiple radar stations provided a plot of the missile's location in flight [18].

A Doppler system was used to determine velocity of an in-flight V-2. Developed and operated by the Ballistic Research Laboratory of the U.S. Army, the system operated on a principle similar to the original German "Verdoppler" system. The Doppler at White Sands was known as DOVAP, for Doppler, velocity, and position. Radio signals were transmitted to the vehicle and other ground stations at a frequency of 36.94 hertz. The vehicle's on-board DOVAP equipment doubled the frequency and retransmitted the signal. At the receiving ground stations this signal then beat with the frequency-doubled signal received directly from the transmitting station. The resulting beat frequency indicated missile speed, and the distance from the transmitter to the missile and to the receiver. Missile position could also be computed by use of multiple receiving stations.

Optical instruments were used during V-2 flights to provide photographic documentation and tracking data. A fixed motion picture camera photographed the missile during the early stages of flight, providing coverage up to 34 miles (55 km). Above 0.6 miles (one km), photo-theodolites recorded the missile at four frames per second. Photo-theodolites were the mainstay of V-2 optical tracking equipment, but they were somewhat altitude-limited. For high-altitude tracking, special tracking telescopes were used, including a twin ten inch (25.3 cm) Cassegrain reflector and a 16 inch (40 cm) Newtonian reflector nicknamed Big Bright Eyes. The Cassegrain had an effective range of up to 80 miles (130 km), and the Newtonian, mounted on a 90 mm anti-aircraft gunbase, was effective to 100 miles (160 km). Multiple optical stations, primarily photo-theodolites, used triangulation methods to plot a V-2's flight path. Optical instrument tracking was coordinated by the Ballistic Research Laboratory [19].

To aid optical tracking, many paint schemes were tried in an attempt to establish the optimum pattern. Black and white flat-color paint provided the highest visibility, gave the greatest contrast, and avoided reflections which could confuse optical tracking stations. A proper paint scheme maximized the tracking opportunities for ground optical systems, and provided reference points on the missile body to observe vehicle orientation during flight. Although no particular pattern dominated, a white V-2 with alternating black and white fins and broad, diagonal black stripes were typical. Fluorescent paint was sometimes used for stripes on the missile body, but this was primarily to aid the spotting of crashed missiles from the air [20].

Multiple tracking systems were used to support each V-2 launch, because each system had unique advantages and shortcomings. Taken collectively, they provided a reasonably comprehensive picture of a V-2's performance. All of these different systems had to be carefully coordinated, and they were dependent on a central time standard to work in an orchestrated fashion. In addition to tracking, however, other ground systems were required to gather vital data on the vehicle and payload.

The concept of data telemetry was not pioneered by the White Sands V-2 flights, but the program's success was largely attributable to it. By sending on-board data back to ground stations via radio during flight, various vehicle operating functions and payload information could be recorded. In the case of evaluating the missile's performance, telemetered data proved invaluable, especially when something went wrong. In-flight combustion chamber pressures, turbine speed, vehicle speed and acceleration, and angular positions of the carbon control vanes, could be captured and evaluated on the ground. Additionally, the use of telemetry allowed certain payload data to be recorded during flight, such as atmospheric pressure and temperature and cosmic radiation. Telemetry systems eliminated the need for many on-board recording devices, an important feature because of the uncertainty of post-flight vehicle recovery [21].

The V-2 telemetry system was developed by the Naval Research Laboratory. The system was capable of a transmission accuracy of two percent over line-of-sight ranges in excess of 100 miles (160 km), and it automatically transmitted a calibrating signal every minute. The telemetry transmitter package was built by the Raytheon Manufacturing Company. Data reduction of telemetry and photo-theodolite records was provided by the Physical Science Laboratory.

Before the first V-2 was launched at White Sands, the need for an emergency flight termination capability was recognized. An emergency cutoff system was developed by the Naval Research Laboratory to provide the ground controller with an engine shutdown capability anytime during the burn phase. The system consisted of an ARW-17 five-channel radio control system. A signal was required on at least three channels to accomplish a shutdown, thus limiting the possibility of an unintentional shutdown due to interference. The value of this system was demonstrated during the very first V-2 flight at White Sands [22].

Flight Characteristics

On a typical flight, the on-board guidance program placed the V-2 in a northerly trajectory of between 7 and 10.5 degrees from vertical immediately after lift-off. This allowed a high altitude to be attained, while moving the missile's impact point northward and away from the main post and launch facilities. Since the launch site was at the southern end of the Proving Ground, virtually the entire 125-mile (200 km) length of the Proving Ground was available as an impact area.

The duration of main stage burning was approximately 69 seconds to Brennschluss, or "end of burning." Acceleration during burn ranged from 1.64 g at lift-off to about 6 g at burn-out. At burn-out, the vehicle was traveling approximately 3500 miles (5600 km) per hour [23].

Several methods were used to shut down the engine, the simplest being to allow it to operate until propellant exhaustion. This approach normally provided the greatest altitude, and was used more than any other technique. Other shutdown methods included an on-board timer, activated at lift-off by a push-to-open tail switch, an integrating accelerometer that activated at a pre-set acceleration, and unplanned contingencies, such as radio emergency cut-off commands, turbine overspeed trips, and explosions.

One of the limitations of the V-2 as a payload carrier was its lack of stability after powered flight. At burn-out, the V-2's inertia carried it to apogee, but in the rarefied upper atmosphere the fins and control surfaces were useless. Any residual angular momentum at burn-out, plus the effects of high altitude winds, could impart roll, pitch, and yaw motions into the vehicle and adversely affect its orientation. Obviously, this lack of stability limited the V-2's usefulness as a measurement platform, since much scientific data gathering was required during the uncontrolled flight phase. To improve stability, efforts were made by the Naval Research Laboratory to impart a spin to the V-2 and therefore establish some amount of spin stabilization. NRL attempted to spin missiles by the deflection of the trim tabs and graphite vanes I and III, and by mounting small solid propellant rockets in the V-2's midsection. Neither of these methods provided satisfactory results.

As the V-2 descended from apogee into the denser atmosphere, the fins once again became effective. The V-2 normally fell from apogee tail first, and when the fins gained control, the vehicle tended to snap over to a nose-down attitude. This attitude was the most streamlined, and allowed the V-2 to maximize its descent speed. The velocity peaked at about 5,000 feet (1,524 m) per second, and dropped to approximately 3,600 feet (1,100 m) per second at impact. Although the V-2s at White Sands carried no explosive warhead, the kinetic energy of the vehicle at impact was enormous. A typical V-2 impact would create a crater 75 feet (23 m) across and 35 feet (11 m) deep [24].

FLIGHT PROGRAM - MISSILE EXPERIENCE AND RESEARCH

Early Flights

The V-2 program in America was inaugurated on March 15, 1946, when a full-duration static test of an entire missile was conducted. This static test was considered "Round #1" in the V-2 program, although no flight occurred (Figure 6). (The numbering of individual missiles in the V-2 program was neither sequential nor consistently applied.)

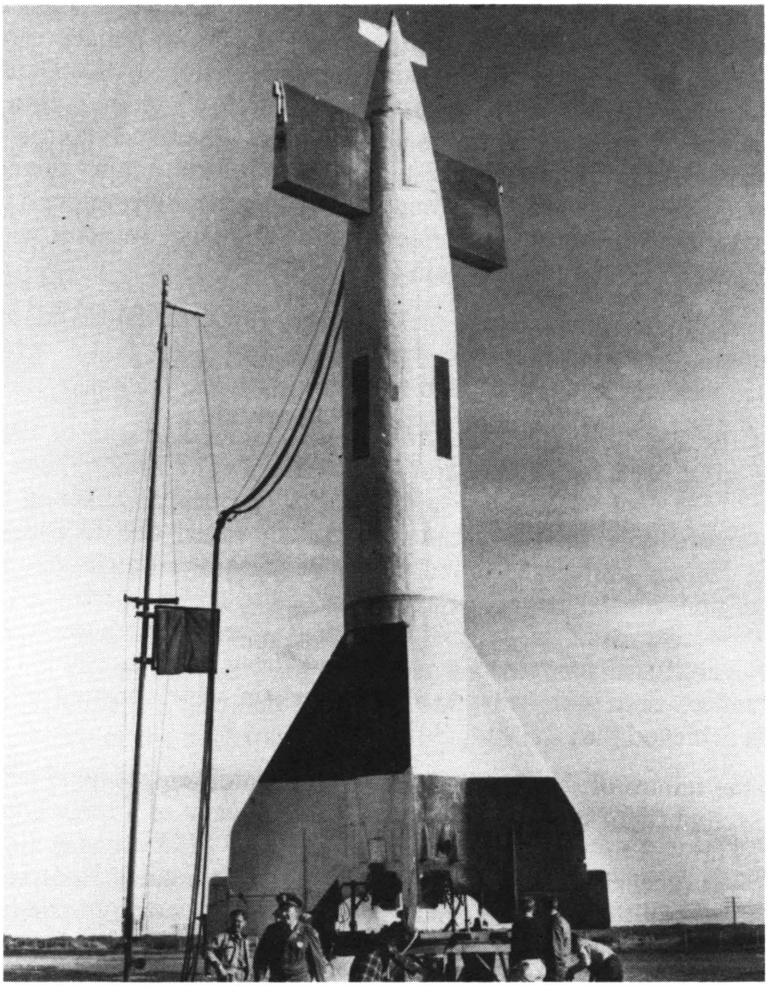

Figure 6 V-2 #1 on static test stand.

The March 1946 static test consisted of the entire compliment of propulsion components that made up V-2 #1, including the alcohol and oxygen tanks. The test article was a complete V-2 airframe, except for the warhead. Therefore, no ground propellant tanks were required to feed the engine during test. The newly constructed test stand was used, with the V-2 held in place by a steel structure housing an array of thrust measuring instruments. The engine fired for 57 seconds and was shut down by command. The force of the engine's thrust ripped loose the heavy steel plates that lined the exhaust duct. The plates, heated by the exhaust plume, were blown out over the surrounding area and ignited bushes and grass out to 250 yards (230 m) from the test stand. The static test was considered a success, paving the way for a flight attempt only a month later. Additional V-2 static firings, using the static test stand, were conducted until 1949 [25].

The first flight of a V-2 in America, known as Round #2, initiated the program in a rather inauspicious manner. The vehicle lifted off its launch mount at 1447 Mountain Standard Time (MST) on April 16, 1946, and almost immediately it began to roll, eventually spinning violently. A moderate wind caused the missile to turn in an easterly direction. As soon as the missile began to behave erratically, a decision was made to terminate flight using the emergency cut-off system developed by NRL. The cut-off command was not sent until 19 seconds into powered flight to allow the vehicle to clear the launch area. Four seconds prior to the command's transmission, fin number IV tore off the vehicle, taking the radar beacon antenna and emergency cut-off antenna with it. Fortunately, enough of the coaxial center conductor in the cable connecting the emergency receiver with the antenna was exposed to allow sufficient gain for the cut-off signal.

The first V-2 reached an altitude of 18,000 feet (5500 m) and landed 5.3 miles (8.5 km) from the launching point. At impact, the propellant tanks were approximately two-thirds full, and they exploded with a loud report.

Cause of the vehicle's erratic behavior was attributed to one of the graphite exhaust vanes suffering damage very early in the flight. The broken vane deflected fully and caused the vehicle to spin. Fin number IV, probably weakened by its trim tab trying to compensate for the failed vane, finally failed due to excess aerodynamic loading. The graphite vane failed, either because of an undetected defect in the vane itself, or from the impact of a portion of the engine igniter assembly. To avoid a future occurrence of this type of failure, all vanes were routinely X-rayed to inspect their overall structure, load tested, dried in an oven at 320°F (160°C) for three hours, and covered with heavy cardboard jackets, which burned off only after full thrust was achieved [26].

Despite the failure of the first flight, the Army boldly went ahead with plans to conduct the second flight attempt (Round #3) in full view of a large contingent of invited press. The V-2 lifted off its launch stand at 1415 MST on May 10, 1946, and fortunately it was successful from most every aspect. The peak altitude reached was 70 miles (113 km), and impact occurred 31 miles (50 km) north of the launch site. Engine cut-off was accomplished by the on-board integrating accelerometer. The launch angle was 4° steeper than programmed, but otherwise the vehicle's performance was excellent.

Small planes and a ground crew of three jeeps and a radio truck were immediately dispatched to locate the impact site. Preliminary impact predictions had already been telephoned in from the radar station, and the planes located the actual site first. Radioing directions, the planes vectored the convoy to the correct location. Upon arrival, the ground crew found a very large crater created by Round #3 impacting in a streamlined fashion, nosedown, from altitude. A two hour search of the area located only about 50 pounds (23 kg) of V-2 debris. It was clear that future on-board instrumentation would have very little chance of surviving or being recovered from an impact of this type [27].

A number of news reports resulted from the press coverage of Round #3, most notably the May 27, 1946 article in *Life* magazine. For the balance of the V-2 firings in New Mexico, the American press would continue to provide periodic information, fascinated by the sight of missiles lifting off into the upper reaches of the atmosphere. Despite this fascination, mention was also made in the May 1946 *Life* article of the military significance of long-range missiles and their potential ability to carry an atomic warhead.

Significant Flights

As the firings progressed, the scientific experimentation packages increased in number and complexity. However, the Army had an aggressive test agenda of their own. Early milestones included the first night launching, which occurred at 2212 MST on December 17, 1946. On this flight, Round #17 achieved an altitude of 116 miles (187 km), the highest of the Hermes Project launches. The carbon jet vanes were heated to a red incandescence by the engine's exhaust, and they were visible at a very high altitude.

The first completely successful operation of an on-board telemetry system occurred on January 23, 1947, with Round #19. This vehicle also was equipped with an automatic pilot system developed by General Electric. The system had a steering capability, which could vary the attitude of the vehicle in flight, and which was a forerunner of the remote-controlled missile. Testing was considered successful despite the somewhat poor flight performance of the V-2 [28].

V-2 #27, launched on October 9, 1947, carried instrumentation to investigate supersonic convective heat transfer. It was important to understand the thermal environment at different locations on the missile's airframe during various phases of the flight, and thermometers were placed at six locations on the V-2's skin. Data from the thermometers, correlated with on-board pressure measurements, provided a detailed picture of the heat transference at high Mach numbers.

Significant Failures

The V-2 flight failures were much more valuable than the successes in providing important vehicle experience and future design information. Anomalies were generally split between propulsion system problems and steering system problems.

A series of failures occurred during the Bumper and Blossom flights, that were apparently directly related to the vehicle structural modifications accomplished to support these projects. Explosions in the tail sections of one of the Bumper flights, and three of the last five Blossom flights, pointed to a common cause. These flights represented some of the most drastic airframe modifications and heaviest launch weights of the entire V-2 project. The explosion resulted from alcohol leaking into the tail section from breaks in the alcohol system. The major structural modifications likely caused overstress conditions during flight, resulting in the failures [29].

Ramjet Research

The V-2, because of its size and engine power, represented a potential test-bed for in-flight evaluation of new missile components being developed to support military programs. In particular, the V-2 could act as a flying wind tunnel for tests requiring supersonic speeds in the atmosphere. The Army's interest in developing longer range missiles included studies on ramjet technology and applications. Hence the marriage of the V-2 with ramjet test articles became a reality at White Sands.

The testing of ramjet diffusers were loosely categorized under the Hermes B program, with the most significant flight test occurring on November 18, 1949. This flight was designated Round #44, and it included a cylindrical experimental ramjet diffuser mounted on the top of the V-2's nose. The odd-looking configuration was nicknamed "The Flying Stovepipe." The V-2 attained an altitude of 90 miles (145 km), providing valuable ramjet performance data over a wide spectrum of flight conditions [30].

A separate, but related, ramjet technology program was designated Hermes II, and was largely influenced by the von Braun research and development group at nearby Fort Bliss, Texas. The Hermes II vehicle was envisioned to be a prototype for the development of long range missiles combining conventional rocket propulsion with ramjet technology. Hermes II consisted of a modified V-2 first stage and a ramjet-powered second stage, designated Organ. The second stage was 214 inches (5.5 m) in length and slightly more than 50 inches (1.3 m) in diameter at its widest point. Its wingspan was 183.86 inches (4.7 m), rudder span 58.87 inches (1.5 m), and elevator span 59.35 inches (1.51 m). Power was to be provided by two ramjet motors with rectangular cells using hydrocarbon fuel. The ram openings were to be placed at the leading edge of the wings. The flight profile called for the V-2 to carry its second stage to 12.5 miles (20 km) altitude, at which time pressurized pistons would separate Organ. The ramjets were designed to burn for 400 seconds at 2,948 pounds (13,113 N) of thrust. Maximum velocity was to be 3,180 feet (969 m) per second [31].

The unusual configuration of the Hermes II vehicle required enlargement of the stabilization fins of the V-2 first stage. Gyroscopes on board Organ provided guidance for the entire vehicle. The ramjet's own aerodynamic control surfaces supported overall vehicle control.

Although four flight tests of the Hermes II vehicle were conducted, none involved a fully-functional ramjet second stage. The flights were intended to test the aerodynamic stability of the entire vehicle, the integrated guidance and control system, and techniques for second stage separation. A dummy ram wing was mounted on the nose of the modified V-2. These tests were not considered part of the formal General Electric Hermes V-2 program, so the first flight was designated Hermes II, Round #0. GE was responsible for all fabrication and modification work supporting Hermes II. Despite the fact that #0 varied significantly from the basic V-2 configuration, its flight became probably the most famous of all the V-2s launched at White Sands.

Round #0 was launched on May 29, 1947, on what was planned to be a relatively short, low altitude flight. Control problems four seconds into the flight caused the vehicle to deviate from its planned trajectory, and a delayed emergency cut-off command allowed it to attain 49.3 miles (79.3 km) altitude and impact 47 miles (76 km) south of the launch site. Unfortunately, this down-range distance carried it across the international border into Mexico, landing it south of the city of Juarez. Although the political ramifications of this flight are remembered most often, the impact also had profound effects in the area of range safety. Many of the changes made to prevent a similar accident from happening again were carried forward to future missile system launch procedures, and the psychological effects of the incident influence range safety policies to this day [32].

After the Round #0 mishap, V-2 flights were halted until improved range safety practices could be put in place. The next V-2 flight did not occur until July 10, 1947. In the interim, a complex and effective safety system was installed. The system used radar data, integrated into automatic plotting boards, to provide real-time information on a missile's position in-flight. Backing up the radar plotting boards were: an impact computer designed to provide continuous impact location predictions; and, a sky screen which used visual observations to insure the ascending vehicle stayed within safe flight limits [33].

The next Hermes II launch occurred at 1326 MST on January 13, 1949, when Round #1 flew (Figure 7). Two more Hermes II flights occurred from White Sands; Round #2 on October 6, 1949, and Round #2A on November 11, 1950. The limited goals of the Hermes II program were accomplished over the course of the four operations, with the November 1950 flight being the most successful. After the last flight, Hermes II was discontinued as a tactical missile, but work continued within the program on ramjet development. The ramjet activities under Hermes B were folded into Hermes II, and ground testing continued at other research sites, until all Army ramjet work was terminated at the end of 1953.

Bumper Project

While the V-2 program in America was still in its infancy, Colonel H. N. Toftoy, Chief of the Research and Development Division, Office of the Chief of Ordnance, suggested the idea of combining the V-2 with a WAC Corporal to form a two-stage launch vehicle. The project was code named Bumper, and it was officially inaugurated in October 1946. Primary purposes of the project were to investigate launching techniques of a two-stage missile, study the separation of two stages at high velocity, conduct limited investigation of high-speed and high-altitude phenomena, and attain velocities and altitudes greater than ever before reached.

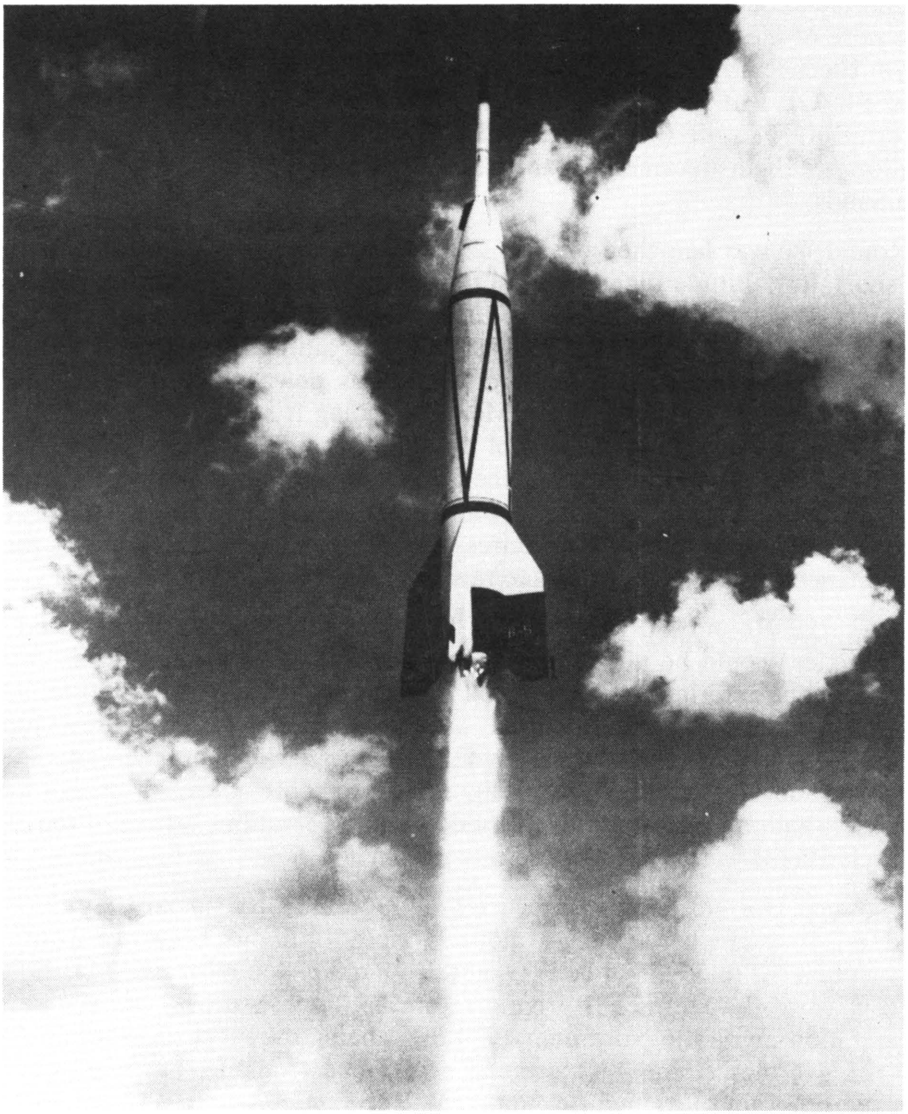

Figure 7 Hermes II #1, launched January 13, 1949.

The design of the two-missile configuration called for a minimum-length second stage that would fit as deeply as possible into the V-2, while still leaving room in the V-2 instrument compartment for the guidance system. This compartment also housed the guide rails for launching the WAC Corporal.

The WAC Corporal had been designed by the California Institute of Technology's Jet Propulsion Laboratory as a liquid propellant sounding rocket, using red fuming nitric acid as an oxidizer and aniline as a fuel. However, for the first two Bumper flights, the WAC used a six-second-burn solid-propellant motor designed to fire at V-2 cut-off, since the primary purpose of these two flights was to test the separation of a staged rocket.

Round #1 of the Bumper project was launched at 0643 MST on May 13, 1948. The performance of the V-2 first stage was nominal, and the WAC second stage separated as planned. The test was a complete success, and enthusiasm for the project grew.

Round #2 was launched on August 19, 1948. The V-2's turbine experienced an overspeed condition, and the overspeed trip occurred 33 seconds into the flight. This resulted in the V-2 not achieving the required speed of 4,150 feet (1,256 m) per second to fire the WAC motor. An integrating accelerometer would have shut down the V-2 and fired the WAC motor, if the proper speed had been reached. The unfired WAC separated from the V-2 immediately after shut down due to the dynamic pressure differential between the V-2 and WAC. Although the second stage did not fire, the flight was considered partially successful because of the valuable data obtained on the flight characteristics of the two-stage configuration.

Bumper #3 was the first to use a WAC Corporal with a liquid propulsion system. The propulsion system was of standard WAC design, except the propellant charge was decreased to provide only 32 seconds of burning time instead of the normal 45 seconds. The launch occurred at 0830 MST on September 30, 1948. The operation of the V-2 was nominal, and 59.5 seconds into the flight, the WAC ignition signal was given. The WAC propulsion system ignited, but it did not develop sufficient thrust to effect separation. The V-2 nose was explosively separated at 40 miles (64.4 km) altitude to make the V-2 main body unstable, and the tail section of the WAC was found still housed in the V-2's nose at impact.

The goals for Bumper #4 were essentially the same as Bumper #3. The WAC propulsion system was tanked for a 32-second burn. Overall vehicle configuration for #4 was virtually identical to #3. Bumper #4's flight began at 0724 MST on November 1, 1948, and hopes were high for a successful flight of the WAC second stage. Unfortunately, at 28.5 seconds into the flight, the steering began to be erratic, the exhaust jet brightened, and telemetry indicated propulsion system disturbances. A second later, the vehicle began to pitch south. The severe turning broke the WAC nose off, and a fraction of a second later the rest of the WAC fell away from the now burning V-2. Impact occurred 1.2 miles (2 km) southeast of the blockhouse, 130.5 seconds after launch. Cause of the failure was attributed to the alcohol feedline breaking and leaking, due to excessive dynamic loads created by the vehicle's modified airframe.

Bumper #5 was launched at 1522 MST on February 24, 1949 (Figure 8), beginning what would become one of the most successful flights of the entire American V-2 program. The WAC propulsion system had been loaded for a full-duration, 45-second burn. The V-2 booster operation was nominal, and at 62.8 seconds into the flight, the integrating accelerometer commanded the 25-ton (222,410 N) thrust valve closed, effectively reducing the V-2 thrust from 25 tones to 8 tons (71,171 N). At 65.2 seconds, the V-2 velocity had increased slightly, and the integrating accelerometer commanded the WAC engine to ignite. The WAC engine's ignition fused a wire which caused the 8-ton thrust valve to close, shutting down the V-2 engine. The WAC's engine had reached maximum thrust at this point, and separation from the V-2 was accomplished. Altitude at separation was 96,813 feet (29,509 m). Each of the Bumper WACs had been modified by installing four tail fins, instead of the normal three, set at an angle to impart spin to the WAC as it separated. Two small spin rockets, mounted in the WAC mid-section, fired about 0.25 seconds after separation, providing 420 revolutions per minute to the WAC. The V-2 booster continued upward to a peak altitude of 62.64 miles (100 km), and it impacted 21.5 miles (34.6 km) north of the launch area. The WAC second stage had a full-duration burn, and reached an altitude of 244 miles (393 km). This was more than double the altitude of any previously known flight, and the concept and benefit of staging had been dramatically demonstrated. The WAC missile proved so difficult to locate, that over a year passed before the smashed body section was found.

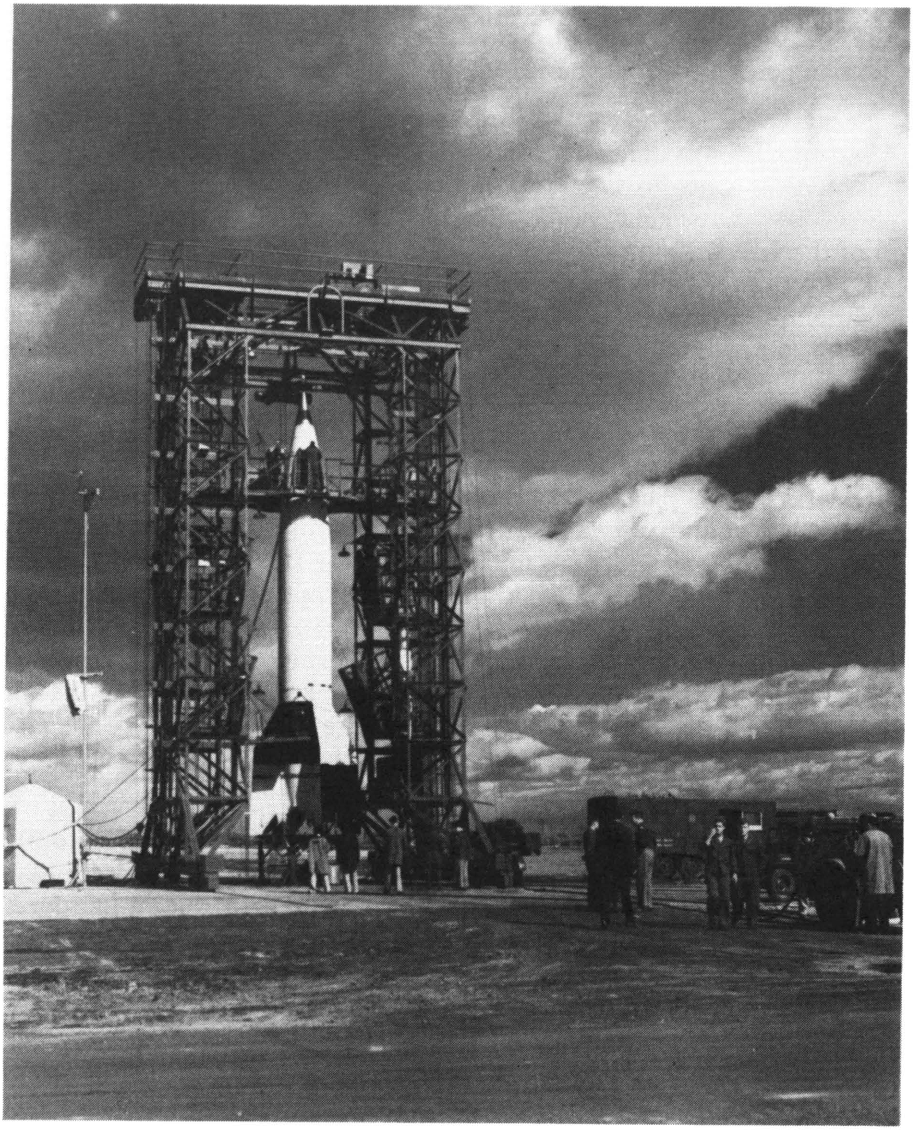

Figure 8 Bumper #5, launched February 24, 1949.

The last of the Bumper series to fly from White Sands was Bumper #6, launched on April 21, 1949, at 1717 MST. The second-stage WAC was tanked for a full-duration, 45-second burn. The flight appeared normal up to 48 seconds, at which time the cut-off command was given. Since the required acceleration had not been attained, the WAC never ignited. The WAC gradually separated from the V-2, and both crashed, leaving large craters. Cause of the premature shutdown command was never absolutely determined, but excessive vibration, induced by a previously-mentioned unique Bumper airframe configuration, was blamed for this failure, as well as the Bumpers 2 and 4 failures [34].

Bumper #6 ended the Bumper program at White Sands, and despite the failures, the overall program goals had been met. This was not the end of the Bumper program, however. Bumpers #7 and #8 were launched in July, 1950, from what would become the Cape Canaveral Air Force Station in Florida, with Bumper #7's WAC second stage attaining the highest sustained velocity in the atmosphere up to that time. In addition to Bumpers #7 and #8, one other V-2 was launched away from White Sands proper. On September 6, 1947, a V-2 was launched from the aircraft carrier U.S.S. *Midway*. Code-named Operation Sandy, the test proved that a large missile could be fueled and launched from a ship at sea. Two other fully fueled V-2s were intentionally toppled and detonated on-board the *Midway*. Called Operation Pushover, the tests demonstrated the effects of a large missile accident at sea. The tests were dramatic enough to influence the decision to use strictly solid propellant missiles for future American fleet ballistic missile submarines. An Operation Pushover test was also conducted on land at White Sands, on December 3, 1948 [35].

FLIGHT PROGRAM - ATMOSPHERE AND SCIENTIFIC RESEARCH

Scientific Applications

Although the Army's activities with the V-2 yielded significant missile handling experience and research data, the information derived from the numerous scientific investigations using the V-2 was at least equally important. Scientific packages normally were flown on a non-interference basis, whenever the Army had the primary mission objectives on a particular flight. Although the different scientific research efforts were diverse, the overall program will be examined by concentrating on both the general payload-carrying characteristics of the V-2, as well as a number of specific flights.

V-2 Benefits

The V-2 was used as a scientific research tool, because it was available at the right place and right time, not because it was designed for that role. Consequently, its design was not optimized for scientific research, and this fact created both benefits and limitations. On the plus side, the V-2 was larger and had a higher payload capacity than a pure research rocket of that day would have had. More payload volume and weight capacity allowed multiple experiments to be carried on a single flight. This was particularly important, given the general lack of electronic miniaturization in the late 1940s which is commonplace today. The V-2s at White Sands were also "spoils of war," and the development costs of the vehicle itself did not have to be shouldered by the research community. Additionally, the V-2's potential as a weapon caused the Army to provide most of the refurbishment, launch preparation, and flight support costs, creating an unprecedented opportunity to do high altitude scientific research.

V-2 Limitations

In addition to its lack of controllability after engine cut-off, another limitation of the V-2 was the tremendous logistical support required to prepare and launch the vehicle. The V-2 was a large and complex missile for its day, requiring a large team of support and launch personnel to bring about a successful mission. This was affordable to the scientific community only because the Army was paying for most of the costs in support of its own goals with the V-2.

The V-2, designed for the high performance requirements of its wartime mission, was "over qualified" for many scientific missions. This meant that the complexity of the V-2 was not always justified, yet it was this same complexity that resulted in the loss of a number of vehicles. From a scientific research standpoint, a much simpler and more reliable launch vehicle was desirable. The "pure" research vehicle of that era was realized with the development of the Aerobee sounding rocket. First flown in 1947, the Aerobee was operational until 1985, testimony to its utility as a research tool [36].

V-2 Warhead

The payload section at the front end of the V-2 was referred to as the "warhead." During the V-2's wartime existence, the warhead was actually just what its name implied, carrying over 1.5 tons (1361 kg) of Amatol high explosive. The original V-2 warhead casing proved unsatisfactory for research work, and it was replaced by American manufactured versions after the launching of Rounds #2 and #3.

The Naval Research Laboratory designed a new 0.374 inch (9.5 mm) thick cast steel warhead that retained the original warhead dimensions, but which had multiple ports for improved access. Built by the Naval Gun Factory, the warhead could be sealed at ground level and maintain pressure throughout the flight. This avoided electrical arc-over and glow discharge problems, that could arise when ambient pressure dropped and the insulating qualities of the air broke down. Another NRL warhead design had two sections that could be separately instrumented and pressurized, with the upper section made of 0.12 inch (3 mm) thick aluminum and the lower section made of 0.75 inch (1.9 cm) thick pressed steel. As the flight program progressed, warhead variations continued, driven by ever-changing payload requirements. The most significant variations were seen with the large volume warheads of the Air Force Blossom Project [37].

One problem experienced with early payloads was that they lacked the overall density of a warhead full of Amatol. Consequently, lead weights were added to keep the center of gravity in front of the center of pressure, maintaining aerodynamic stability. As the warheads and payloads became larger and heavier, the requirement for lead ballast diminished. Toward the end of the program, all V-2s were flying with significant enlargements to the forward airframe, including the warhead [38].

Equipment and Data Recovery

As discussed earlier, the kinetic energy of a V-2 impacting from altitude in a streamlined fashion destroyed the vehicle to the point that little was intact or recoverable. This created obvious problems for experimenters wanting to recover data recorded in flight. Four schools of thought developed on how best to secure data obtained during a mission. The first was to simply armor-plate certain instruments, such as film cassettes, so they would survive even the worst impact. This approach proved unsatisfactory, because the armored container had to be found, even if it did survive. In most instances, the containers were either scattered or buried, making container survivability of no benefit. A second approach was to telemeter data back during flight, making recovery of the instrumentation not an absolute necessity. This method was very efficient for certain applications, but was unacceptable for others. Sampling and data rates were limited, and experiments such as cosmic ray cloud chamber recorders, spectrography, and photography required physical recovery of the instrument packages. A third concept was to eject equipment containers at altitude and deploy a parachute or other speed retardation device. A number of experiment efforts, notably during the Blossom Project, attempted this method of data recovery. The results were mixed, with problems usually associated with the ejection and parachute deployment sequence. Equipment had to be designed to withstand the forces of parachute deployment, and parachutes had to be designed to withstand atmospheric heating effects.

The fourth method of in-flight data recovery proved to be the most effective, and consequently it was used most often. This method was the artificially-induced air breakup, more commonly referred to as warhead blow-off. On the downward leg of the V-2's trajectory, explosive charges in the control compartment were detonated, blowing the warhead and control compartment off the rest of the vehicle. This caused the lower section of the V-2, containing the propellant tanks, propulsion system, and fins, to become aerodynamically unstable. The instability induced tumbling, which greatly reduced the lower section's speed, and allowed it to impact without destroying itself. The warhead usually received more damage from the separation charge and impact than the lower section, but it still managed to survive sufficiently to provide some usefulness. The control compartment was usually completely destroyed by the separation charge [39].

The need to make the V-2 unstable during its descent was recognized very early in the program, but many in-flight trial-and-error tests were required before a satisfactory approach was developed. Early attempts focused on separating the aft section, containing the propulsion system and fins, from the rest of the vehicle. This method involved placing explosive charges just aft of the liquid oxygen tank, but flight results showed it was very difficult to cleanly and consistently separate this aft section. Attempts to separate the warhead were more successful, with various placements of the TNT charges tested. The placement and quantity of explosives found to be most ideal used two 0.5 pound (0.227 kg) blocks of TNT, located adjacent to each of the four main longerons at the forward end of the control compartment, directly below the warhead. Using this configuration, the warhead was always separated relatively intact, although it was not always found. The control compartment was always destroyed. Later flights moved the location of the TNT charges to just aft of the control compartment, resulting in the warhead and some portions of the control compartment being routinely recovered. The warhead was usually coated with a high visibility paint to aid in spotting it from the air.

The explosive separation charges were detonated above 40 miles (64.4 km) altitude on the V-2's downward leg. Detonation was normally accomplished by a timer that was set to activate at five minutes after lift-off. If the V-2 failed to go as high as calculated, resulting in a shorter flight time, an ARW-17 radio command was sent to detonate the explosives before the V-2 went below 40 miles (64.4 km) altitude.

Because of the severe nature of warhead blow-off, experiment package placement evolved to maximize the likelihood of data recovery. Packages requiring physical recovery were usually placed either in the mid-section between the propellant tanks, or in the aft section, notably on the fins. Packages, either telemetering their data during flight or ejecting containers at altitude, were usually placed in the warhead or control compartment.

The next-to-the-last V-2 launch conducted under the Hermes Project sustained a failure directly attributable to the warhead blow-off system. Round #55 was erected and fueled on June 14, 1951. Immediately after the main stage command was sent, a violent explosion occurred in the vicinity of the control compartment. The compartment and warhead were blown free, and the V-2 toppled over and exploded. Analysis of the photographic coverage indicated that the missile had risen approximately six inches (15.26 cm) from its launcher when the initial explosion occurred. Results of an extensive post-flight investigation determined a short circuit had energized the warhead blow-off squib, effecting a premature blow-off [40].

Significant Experiments/Investigations

Solar spectrographs were one of the first type of experiment packages carried aloft during the V-2 program. The need to recover the spectrographic film quickly dictated a mounting location somewhere other than the V-2 nose. The location found to be best was in one of the fins, and V-2 #12, launched on October 10, 1946, had a spectrograph mounted in its number II fin. Recovery of the spectrograph and film was successful, although in-flight experiment performance resulted in the package not achieving all of its goals. Nevertheless, a fin-mounted spectrograph was successfully demonstrated.

Flight #12 was notable, not only because of its fin-mounted spectrograph, but also because of the overall success of other experiments it carried. Trailing-wire antennas were installed to investigate ion density in the ionosphere, and although the longer antenna was pulled off the vehicle at launch, valuable information was gathered. A successful demonstration of a compressed air canister ejection system was also accomplished.

Several experiments were conducted during the V-2 program to investigate the various properties of the ionosphere. Measurements were taken of electron and ion densities, radio wave propagation, and ionospheric electrical current transfer. A variety of methods were used in collecting data, including various antenna configurations on the V-2 for transmitting during flights, on-board electrical current flow measurements, and analysis of in-flight Doppler results. Significant successes in this area of investigation occurred on flights #5, 9, 21, 28, 34, Bumper 5, 47, and 49.

The investigation of cosmic rays also saw considerable activity during the V-2 program. Cosmic ray data were collected by various methods, including photographic emulsion detectors, cloud chambers, ionization chambers, and Geiger counters. One variation of the Geiger counter was an arrangement of counters to detect, not only the quantity, but also the direction of, cosmic rays. This arrangement was referred to as a cosmic ray telescope. The Applied Physics Laboratory conducted early experiments concerned with simply a counting rate at various altitudes. These experiments were carried on Round #9, 17, 22, 23, 30 and 35, using single Geiger tubes. Later flights used counter telescopes, and they included different layers of lead shielding to better characterize cosmic ray energy levels. Geiger counters were also used as triggering mechanisms for cloud chamber cameras. The V-2 cosmic ray investigations added a significant body of measured data to a field of scientific knowledge that had heretofore been developed largely on theory.

A set of investigations was conducted to increase the existing data base on solar radiation. As previously described, a spectrograph was successfully flown on V-2 #12. Round #22 and #30 included more exotic spectrographs developed by the Applied Physics Laboratory. These instruments were mounted in the V-2 nose, and used armored film cassettes. Another notable flight occurred on Round #47, which was launched just before sunset and used three spectrographs. Round #49 carried two photon counters that verified the emission of X-rays by the Sun.

Scientific instrument packages to measure various atmospheric temperatures and pressures were carried on many flights. Evacuated bottles also were carried aloft to recover atmosphere samples from different altitudes. These bottles were either recovered after vehicle impact or ejected during the flight. An example of the former was Round #30, launched on July 29, 1947. Bottles were placed in the V-2's mid and aft sections and were successfully recovered at impact, although some contamination apparently occurred during handling. Later efforts used improved techniques, culminating in the flight of Round #59 on May 20, 1952. Two sets of three sampling bottles were mounted near the nose, ejected, and recovered by parachute.

High altitude photography was pioneered by the V-2 flights at White Sands, providing a perspective of Earth that had never been seen before by human eyes. The V-2 photographs served two functions: to provide broad area views of the Earth from extreme altitudes, and to record the in-flight attitude of the V-2 during frequent intervals after burn-out. The V-2's orientation during this coast phase could then be correlated with the results of other on-board experiments.

Motion pictures of the Earth were taken from V-2 #13, launched on October 24, 1946. The best pictures, obtained at approximately 65 miles (105 km) altitude, covered an estimated 40,000 square miles (104,000 square km) and clearly showed the curvature of the Earth. The 35 mm camera used was encased in a 3/8-inch (0.95 cm) thick Duralumin box and had a film cassette with walls one-inch (2.54 cm) thick. Warhead blow-off was achieved at only 25,000 feet (7620 m). The film cassette survived the impact, although the camera was destroyed.

On July 26, 1948, V-2 #40 was launched at 1103 MST in conjunction with an Aerobee sounding rocket, which had been launched 76 minutes earlier. Both missiles were equipped with cameras designed to take pictures once every 1.5 seconds. Over two hundred frames were recorded by each missile, providing a view of what was believed to be one of the largest sections of Earth ever recorded in such a short period of time.

Although many experiments attempted on V-2 flights failed because of missile malfunctions, these have not been emphasized. Notably, Princeton University attempted a number of experiments on missiles that somehow always managed to fail. This was the primary reason Princeton dropped out of V-2 flight participation at a relatively early phase.

Finally, biological experiments were flown on many V-2 flights. Beginning with Round #17 which launched a quantity of fungus spores to study the effects of cosmic rays on biological material, a variety of experiments with seeds, spores, and fruit flies were conducted. However, a special Air Force project called "Blossom" flew the most significant biological experiments of the entire V-2 program [41].

Blossom Project

A special flight experiment program was conducted by the newly constituted United States Air Force, under the auspices of the Air Force's Air Material Command (AMC). The first flight of this program, in fact, was performed prior to the Air Force being formally established as a separate military service. Ten V-2 flights were sponsored by AMC with the goals of testing experiment package ejection and recovery by parachute, and of flying a variety of biological payloads and recovering them successfully. The effort was known as the "Blossom Project," and it was implemented at White Sands by the Air Force's Cambridge Research Laboratory Field Station, an element of AMC.

The first flight of this series was launched on February 20, 1947, and carried an assortment of instruments and payloads. The V-2 was #20, and peak altitude for this flight was 68 miles (109 km). An instrument canister was ejected at apogee, and an eight foot (2.4 m) diameter ribbon parachute deployed to slow the canister's descent. The parachute was constructed of ribbons to reduce the opening shock, and the ribbons were covered with a metallic mesh to aid in radar tracking. A second parachute, 14 feet (4.27 m) in diameter, was released at approximately 30 miles (48 km) altitude. The canister took 50 minutes to descend, and was found nine miles (14.5 km) east and 1.5 miles (2.4 km) north of the blockhouse. This was the first known recovery of equipment by parachute from an altitude above 200,000 feet

(61,000 m). The canister carried fruit flies and various types of seeds to study the possibility of biological mutations being induced by cosmic rays in the upper atmosphere. Photo-electric cells were also carried, to measure light being scattered by the atmosphere. Two cameras were carried in the canister, and four were carried in the main body of the missile. One canister camera took color pictures of the parachute and the sky, and the other took pictures of the Earth during the descent. The four cameras in the missile body photographed the horizon and the Earth [42].

As part of the AMC Blossom Project, five live animal flights were conducted by the Aero-Medical Laboratory of Wright-Patterson Air Force Base. The specific intent of these tests was to investigate the possible dangers and limiting factors of the space environment, with applications to future manned space flight. The five flights were known as the "Albert Series," named after the nine pound (4.1 kg) Rhesus monkey used in the first test. Round #37 carried the anesthetized Albert I to an altitude of 39 miles (62.8 km) on June 11, 1948. Unfortunately, the mission was plagued by failures from start to finish. The instruments used to transmit the monkey's respiratory data failed before launch. Other information indicated the monkey died of breathing difficulties because of the cramped conditions in the recovery capsule. Had the monkey not already been dead, he would have been killed at impact. The capsule ejected safely, but the parachute system malfunctioned.

Because of the problems caused by the limited space on V-2 #37, an enlarged payload compartment was developed. The new compartment increased the length of the V-2, and was first flown on March 21, 1949. Round #41 was an AMC-sponsored flight, carrying a scientific instrument package, to be ejected at altitude and recovered by parachute. The ejection system failed, and the missile remained completely intact, and was destroyed at impact. As a result of this incident, a recommendation was made to equip all future V-2s for warhead blow-off, even if an ejection and recovery system was on board.

Albert II was launched aboard V-2 #47 on June 14, 1949 (Figure 9), carried in an ejectable capsule. The capsule had been expanded in size, and could be accommodated by the new, enlarged payload compartment first flown on V-2 #41. This flight was the second Aero-Medical Laboratory live animal test. Improved instrumentation provided respiratory and cardiological measurements throughout the flight. The capsule ejected safely, and the physiological data telemetered down indicated the space environment was not noticeably harmful to the monkey. Once again, however, the parachute recovery system failed, and the animal died at impact. This prevented full accomplishment of the mission goals to investigate the effects of cosmic rays on the genes and chromosome structures of living cells.

V-2 #32 was launched on September 16, 1949, and it carried a third Rhesus monkey. A violent explosion occurred in the tail section of the missile at 10.7 seconds, caused by a leak in the alcohol system. The missile attained only three miles (4.83 km) altitude, and was destroyed completely.

Albert IV was flown aboard V-2 #31 on December 8, 1949. The Rhesus monkey showed no gross disturbances or ill effects from missile acceleration and free fall conditions. Heart and respiratory data were telemetered throughout the flight, but the parachute failed once again, causing the monkey's death upon impact. However, the information gathered by this flight substantiated the theory that brief exposures to micro-gravity conditions presented no major physiological hazards.

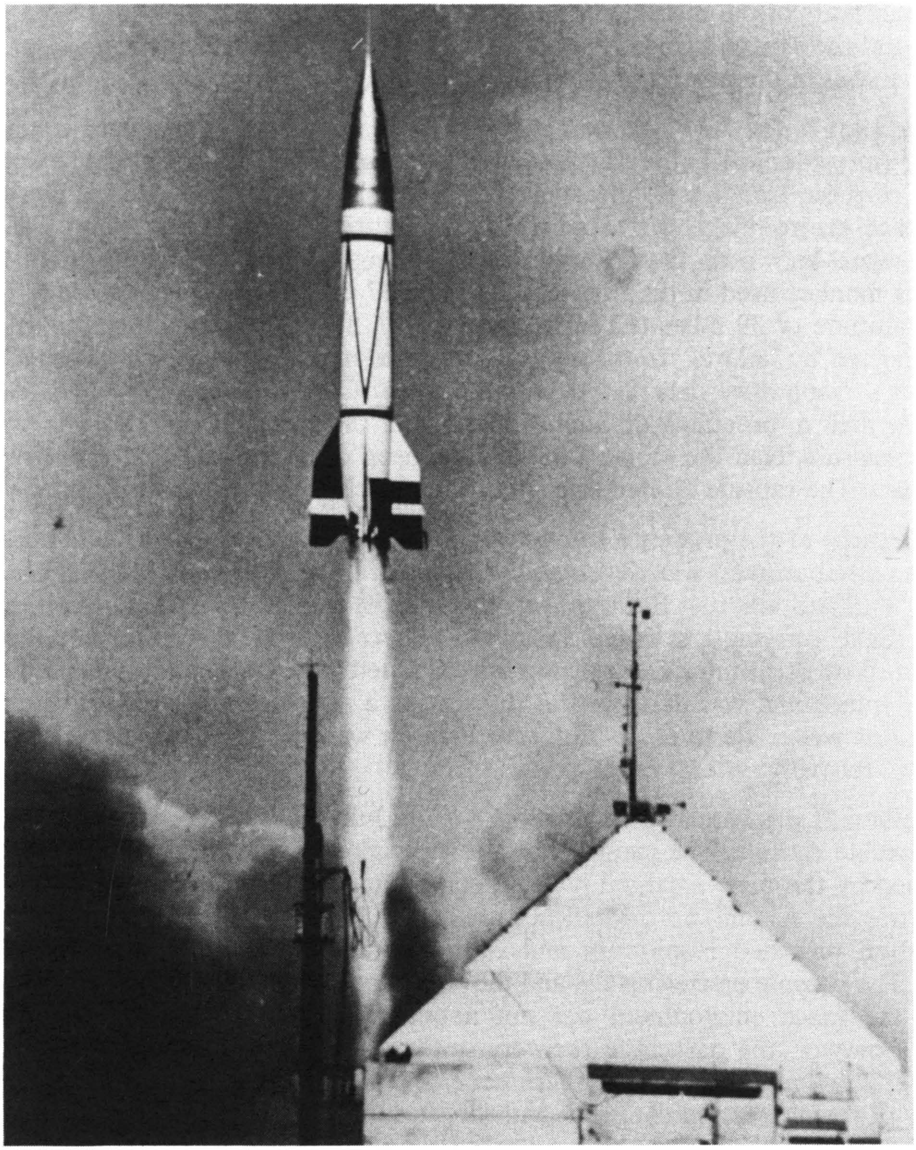

Figure 9 V-2 #47, Blossom Project, carrying Albert II.

The final live animal test by the Aero-Medical Laboratory used as its subject a mouse instead of a monkey. The payload was placed in Round #51, launched on August 31, 1950. A camera was installed to photograph the mouse at fixed intervals during the flight. The mouse was not anesthetized, and no attempt was made to record heart or respiratory action. The primary purpose of this test was to record reactions of the mouse to the micro-gravity environment. Missile performance was satisfactory, but the unreliable nature of the recovery system surfaced again, resulting in parachute failure and the mouse's death at impact. Despite the failure, the camera's film survived intact. The photographs showed that the mouse retained muscle coordination and spatial orientation throughout free-fall. These results provided additional data, establishing that micro-gravity conditions had no adverse physiological effects, at least for short periods.

The last two AMC-sponsored V-2 flights both ended in complete failure. Round #57 was launched on March 8, 1951, and Round #52 was launched on June 28, 1951. Both V-2s had similar failures, with alcohol system leaks causing tail explosions very early in the flight. These failures were also similar to those on the AMC-sponsored V-2 #32 and Bumper #4 flights. Round #52 was the last V-2 test conducted under the auspices of Project Hermes.

The Blossom Project had a number of significant accomplishments, despite the many recovery system failures. The data gathered directly influenced the development of space medicine and future manned space flight efforts. Lessons learned from the recovery system failures helped to perfect later systems that were able to return live animals safely [43].

THE TRAINING FLIGHTS

Army Launch Teams

When the Hermes Project ended on June 30, 1951, the V-2 flight program did not terminate. Five training flights were conducted by the Army, using an all "green-suit" launch team. The missiles were launched by Detachment #2 of the 1st Guided Missile Support Battalion, stationed at White Sands Proving Ground. The primary Army goal was to provide training opportunities under realistic field conditions, but once again, the scientific community was not forgotten. With the exception of the first flight, each of the training flights carried significant scientific instrumentation. Nine static tests of V-2 propulsion systems were also conducted by Army personnel.

The Last Five Flights

V-2 #TF-1 was launched on August 22, 1951 (Figure 10), less than two months after the Hermes Project had terminated. The transition of documentation, equipment, and skills was smooth, and it was aided by the fact the Army had been observing, and in some cases supporting, launch activities since the V-2 flight program's inception. TF-1 carried no scientific instrumentation, but it had instead been optimized for attaining the highest altitude possible. Launch occurred at 1200 MST, and the vehicle climbed to 132.6 miles (213.5 km), the highest altitude reached by a V-2 during the entire White Sands program.

V-2 #60 originally was to have been launched by General Electric under the Hermes Project, and it had been committed to the University of Michigan for a pressure and temperature experiment. The Army honored this commitment and launched #60 on October 29, 1951. The vehicle performed well and reached an altitude of 87.6 miles, but the on-board instrumentation failed. An unusual aspect of #60 was that it carried an exhortation to "Buy Bonds" painted on its side, possibly the first use of a missile for advertisement purposes.

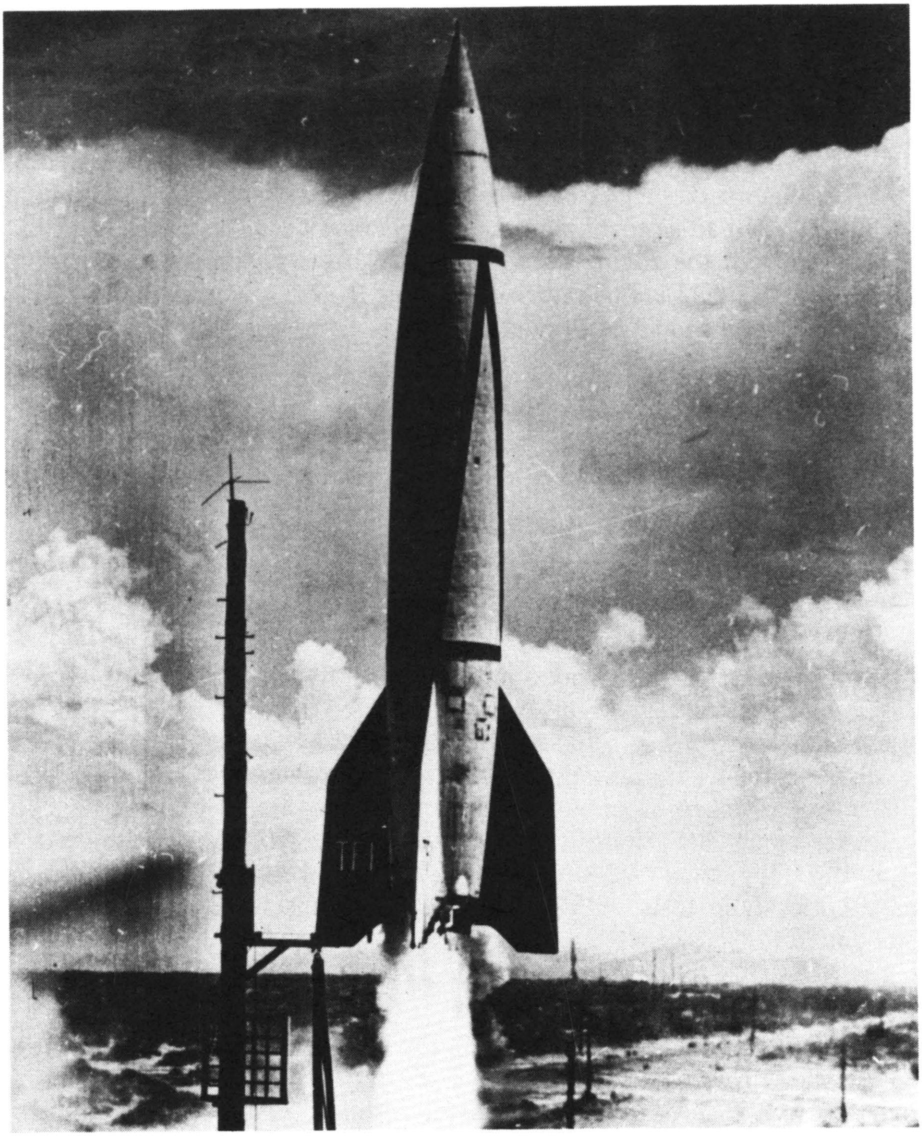

Figure 10 TF-1, launched August 22, 1951.

On May 20, 1952, another University of Michigan experiment was launched on V-2 #TF-2. Also known as V-2 #59, the vehicle carried a package of evacuated air bottles. The bottles gathered air samples at altitude, then were ejected and recovered by parachute. The V-2 attained 64.3 miles (103.5 km) in altitude.

V-2 #TF-3 was the first V-2 completely assembled, serviced, checked out, and fired by a 100 percent Army team. This was the ultimate goal of these training flights, and it was a credit to the personnel involved that the goal was accomplished in so short a time. TF-3 was launched on August 22, 1952, and the Naval Research

Laboratory was the prime scientific agency involved. The vehicle carried a variety of equipment, including night sky infrared instrumentation. Unfortunately, the engine shut down 20 seconds early, for unknown reasons, limiting the peak altitude to 98.5 miles (158.6 km). This altitude was too low for useful data gathering by much of the instrumentation.

The final flight of the American V-2 program occurred on September 19, 1952. The vehicle was designated #TF-5, and carried the same University of Michigan experiment as #TF-2. Ironically, the White Sands V-2 program ended as ingloriously as it began. An apparent explosion in the hydrogen peroxide tank completely destroyed the propulsion system, and the vehicle only reached ten miles (16.1 km) in altitude. Despite the many failures, the V-2 program as a whole was a great success. In particular, these training flights demonstrated to the U.S. military the utility of tactical missile systems operated in the field by military personnel.

One other V-2 launch was planned, but it never occurred. V-2 #TF-4 had been scheduled for launch in October, 1952, to test new extreme range tracking systems for the Ballistic Research Laboratory, but the systems were not ready until 1954 [44].

HOW MANY FLEW?

The question of exactly how many V-2s actually flew in the V-2 program at White Sands has received a variety of answers over the years. To give an accurate answer, certain qualifiers have to be made. First, the count is limited to those V-2s actually launched from White Sands Proving Ground, thus eliminating Bumpers 7 and 8 and the Operation Sandy launch. The Round #1 static test is not considered a flight, but the six-inch rise of Round #55 is. The projects using radically modified V-2 airframes are counted as V-2 flights, so the Bumper, Hermes II, and Blossom efforts from White Sands are all included. Finally, all five of the post-Hermes training flights are counted. Given these qualifiers, the total number of V-2s that flew from White Sands Proving Ground is 74.

THE WHITE SANDS V-2 LEGACY

The Technical Legacy

The paper has given an overview of White Sands V-2 operations to foster a better understanding of the V-2's impact on American space technology. Although the program accomplished many technical achievements, several stand out as truly significant contributions to the American space effort. The demonstration of a workable staged launch vehicle during the Bumper project was vital to the development of vehicles able to carry large payloads to Earth orbit and beyond. The knowledge base in upper atmospheric science was dramatically expanded, paving the way for advances in communications systems, weather forecasting, solar study and manned space flight. A better understanding of high-speed aerodynamics, ballistics, and other aerospace technologies was gained, allowing the successful development of a variety of aerospace vehicles and systems. The technical legacy of the White Sands V-2 program advanced American space technology.

The Psychological Legacy

The psychological legacy of the V-2 on the minds of the American technical community and public was arguably as important as its technical legacy. The V-2 missile was an invaluable gift to American military and scientific personnel, representing a ready-to-operate system immediately usable for a variety of research activities. The fast-paced technical accomplishments and rapidly expanding scientific knowledge base demonstrated to engineers and scientists the enormous potential of missile and space technology. The V-2 photographs of a curved Earth from a 100-plus miles (161-plus km) altitude had a significant psychological effect on people throughout the world. Space became a reality, and not just the stuff of science fiction. The American imagination was captured by the numerous magazine and newspaper articles on the V-2 written during the 1946-1952 period. A *National Geographic* article in October 1950 even tied the V-2 launches to a future flight to the Moon. The V-2 program in America provided a belief in the exploration of space, and a vision of how it might be accomplished, to the American people. The technical and psychological legacy of this weapon-turned-research tool will be preserved forever as footprints in the dust of the Moon.

REFERENCES

1. W. von Braun, 'Investigation of the Upper Atmosphere with the A4 (V2) Rocket,' WSMR Technical Library, 1946.
2. 'Origin and Construction of White Sands Proving Ground,' WSMR Technical Library, 1947.
3. Carl T. Schooley, 'The V-2 Program at White Sands Proving Ground,' WSMR Technical Library, no date.
4. Schooley, *Ibid.*
5. National Park Service Survey, 'American V-2 Rocket Facilities,' WSMR Public Affairs Office, no date.
6. National Park Service Survey, *Ibid.*
7. P. F. Gavaghn, 'Historical Background General Electric Company,' WSMR Technical Library, no date.
8. Gavaghn, *Ibid.*
9. Gavaghn, *Ibid.*
10. James A. Van Allen, *Origins of Magnetospheric Physics,* Smithsonian Institution Press, Washington, 1983.
11. J. Gordon Vaeth, *200 Miles Up*, Ronald Press, N.Y., 1951.
12. Letter, H. G. Davisson on Procurement of V-2 Parts from England, WSMR Technical Library, September 22, 1948.
13. Frederick I. Ordway III and Mitchell R. Sharpe, *The Rocket Team*, Crowell, N.Y., 1979.
14. R. W. Porter, summary of address to N.Y. section of the American Rocket Society, WSMR Technical Library, no date.
15. Porter, *Ibid.*
16. Schooley, *Ibid.*

17. Vaeth, *Ibid.*

18. 'White Sands - A Brief History,' WSMR Technical Library, no date.

19. Eric Burgess, *Frontier to Space*, Collier Books, N.Y., 1962.

20. Vaeth, *Ibid.*

21. E. H. Krause, 'Upper Atmosphere Research with the V-2,' *The Guided Missiles*, July 1946.

22. Krause, *Ibid.*

23. Willy Ley, *Rockets, Missiles, and Space Travel*, The Viking Press, N.Y., 1959.

24. Carl T. Schooley, 'General Characteristics of the German V-2 Rocket,' WSMR Technical Library, no date.

25. 'White Sands History,' WSMR Technical Library, no date.

26. R. W. Porter, 'First American Showing of the V-2,' *The Guided Missile*, July 1946.

27. Porter, *Ibid.*

28. 'V-2 Story Fact Sheet,' WSMR Public Affairs Office, 1972.

29. 'White Sands History,' *Ibid.*

30. Ordway and Sharpe, *Ibid.*

31. 'White Sands History,' *Ibid.*

32. 'White Sands History,' *Ibid.*

33. 'White Sands - A Brief History,' *Ibid.*

34. 'Preliminary Information and Firing Report of Project Bumper,' Redstone Arsenal, Huntsville, 1949.

35. Gregory P. Kennedy, *Vengeance Weapon 2*, Smithsonian Institution Press, Washington, 1983.

36. Burgess, *Ibid.*

37. Burgess, *Ibid.*

38. Milton W. Rosen, *The Viking Rocket Story*, Harper & Brothers, N.Y., 1955.

39. Carl T. Schooley, 'The V-2 Program at White Sands Proving Ground,' *Ibid.*

40. 'White Sands History,' *Ibid.*

41. 'White Sands History,' *Ibid.*

42. Blossom Project press release, February 20, 1947, WSMR Technical Library.

43. 'White Sands History,' *Ibid.*

44. Letter, Nathan Wagner to Frederick I. Ordway III on Rocket Firings at White Sands Proving Ground, WSMR Technical Library, no date.