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Chapter 23

PROJECT MANHIGH: A BALLOON-BORNE PREDECESSOR FOR PROJECT MERCURY*

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Project Manhigh, one of the most ambitious aerospace medical efforts of the 1950s, used balloons to transport humans to the edge of space. Managed by the Aeromedical Field Laboratory at Holloman Air Force Base near Alamogordo, New Mexico, Manhigh can be viewed as a precursor to NASA's first manned space effort, Project Mercury. This paper traces the development of high-altitude balloon research at Holloman Air Force Base and the origins of Project Manhigh. The conduct of the program and hardware development are examined, and parallels to Project Mercury are highlighted. To reinforce the connection between Manhigh and Mercury, the contributions of Manhigh participants to the later space program are discussed.

How can an Air Force manned balloon ascent program be related to the orbital flights of Project Mercury? There is the obvious similarity of having a lone pilot in a small, self-contained capsule. There are also such coincidental similarities as the way the Manhigh flight test program evolved, and the philosophy of providing redundancy for all major capsule systems. Not necessarily so obvious, but perhaps most important of all, was that the astronaut medical evaluation and selection process used for Mercury was first tested during Manhigh, and many of the medical team who supported the balloon program later worked on NASA's first manned space effort.

Initiated in 1955 under the name Daedalus, Project Manhigh sought to place a lone pilot in a small, pressurized capsule above 30,480 meters for at least 24 hours [1]. At such an altitude, the pilot would be above 99% of the atmosphere and would be in the equivalent of a space environment. The flights would provide answers for two questions about spaceflight. First, Manhigh would investigate man's ability to live for an extended period of time in a spacecraft-like sealed cabin. Also, at such altitudes, scientist could gather additional data on the effects of cosmic radiation on living organisms.

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The Manhigh system was comprised of an aluminum capsule suspended beneath a helium-filled polyethylene plastic balloon. The capsule, or gondola, was an upright cylinder with hemispherical ends. A tubular aluminum frame on the capsule's base served as a launch stand and landing gear.

Balloons are the oldest form of aircraft; the first ones flew in 1783. Over the years, a variety of gases and materials have been used. Heated air, hydrogen, and helium have provided lift for buoyant flight; balloon materials have included paper, fabric, rubber, and plastic. For high-altitude research, balloons are made from very thin polyethylene plastic film and filled with helium. Work with such balloons, which are still used today, began shortly after World War II at Holloman Air Force Base [2].

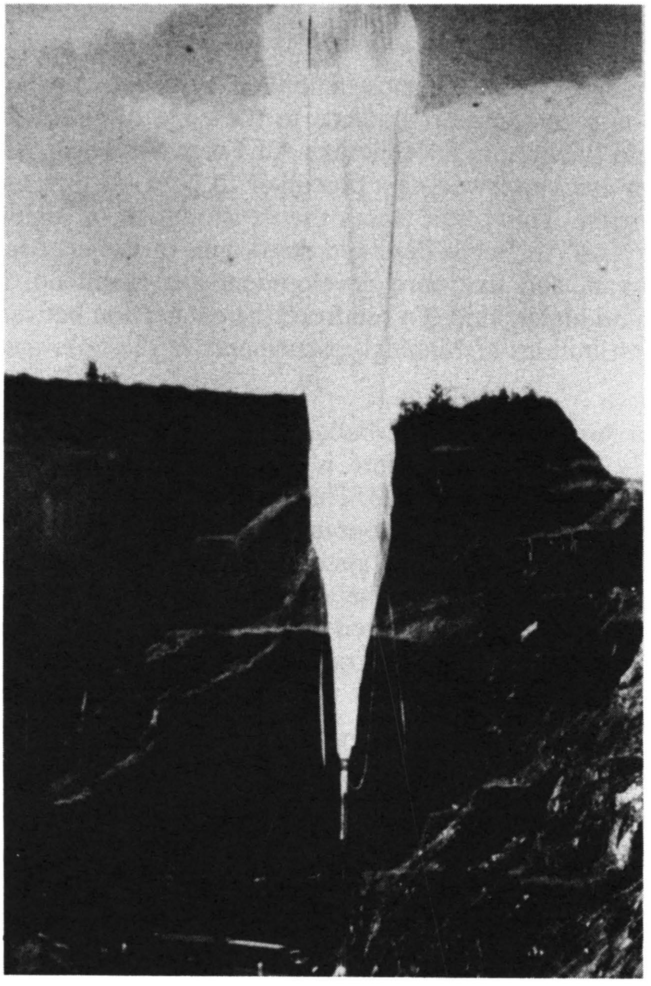

Figure 1 Manhigh balloon just prior to release. The balloons were only partially filled at launch to allow for gas expansion during ascent.

High-altitude balloons are only partially filled at launch; as they rise, the internal gas expands and inflates the envelope (Figure 1). After the balloon is fully inflated, the excess gas which made it rise is vented to maintain a constant ceiling altitude. These balloons are gigantic: the *Manhigh II* balloon had a volume of 85,000 cubic meters. Made from 1.5-mil polyethylene, it had 70 gores. At launch, it was 85 meters tall and weighed 435 kilograms. Fully inflated, it was 61 meters in diameter [3]. Winzen Research, Inc., of Minneapolis, Minnesota, then the world's largest manufacturer of polyethylene high-altitude balloons, designed and built the Manhigh balloons and capsule for the Aeromedical Field Laboratory.

The capsule was 0.91 meters in diameter and 2.4 meters tall. Its occupant sat in a nylon mesh seat amongst a maze of instruments and life support equipment. Fully equipped, the gondola weighed 680 kilograms [4] (Figure 2).

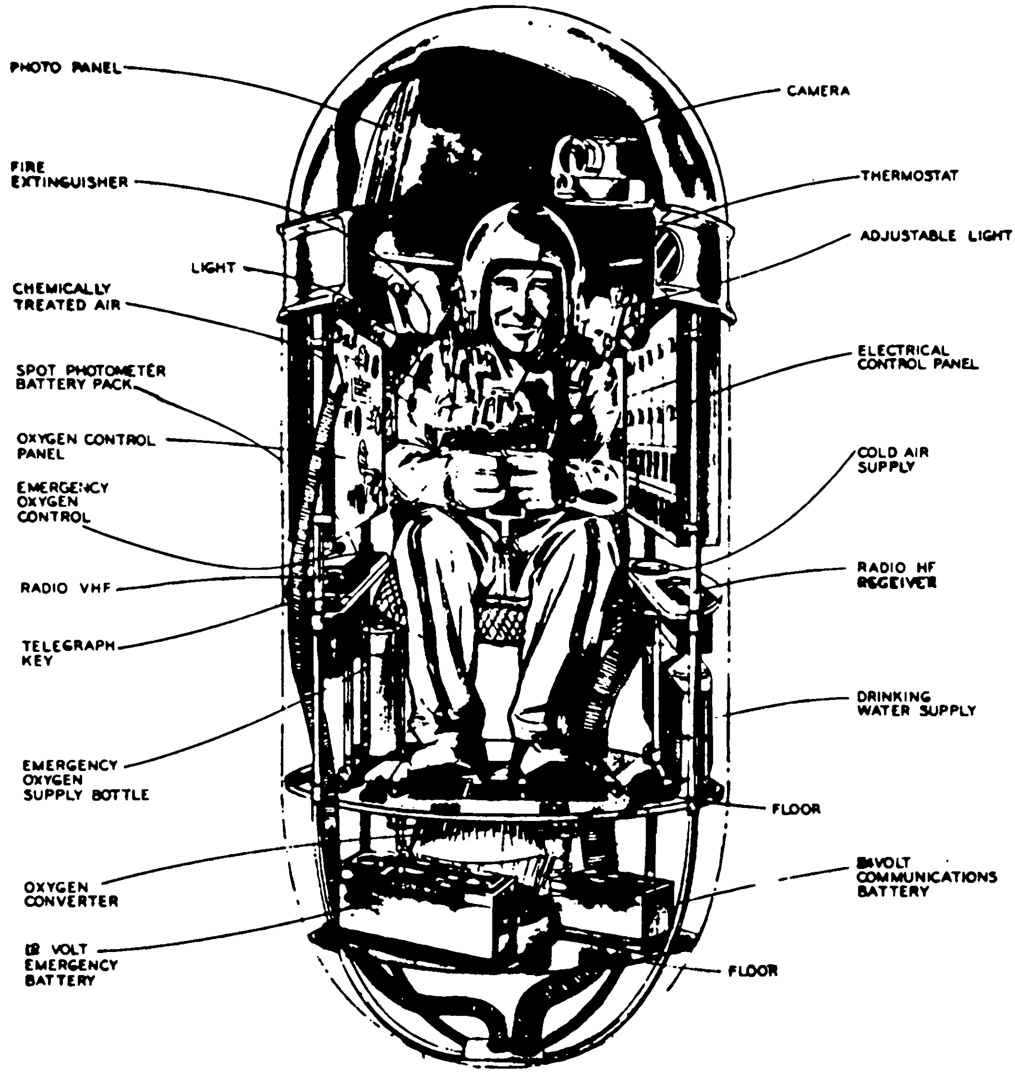

Figure 2 Manhigh balloon gondola schematic.

The cabin atmosphere was a mixture of 60% oxygen, 20% nitrogen, and 20% helium at a pressure of 37.9 kilopascals [5]. This provided a pressure altitude equivalent to 7,900 meters [6]. As a back-up to the capsule's life support system, the pilot wore an MC-3 partial pressure suit with an MA-1 helmet. Chemical scrubbers removed moisture and carbon dioxide from the atmosphere. Oxygen was replenished from a 5-liter liquid oxygen bottle, which was enough to last for 48 hours. In addition, there was a 45-minute emergency oxygen supply connected directly to the pressure suit, and a 15-minute bailout bottle affixed to the pilot's parachute harness.

For heat removal, the capsule had a water-core heat exchanger, which removed up to 1,600 BTU's from the cabin per hour. This system was as simple as it was ingenious. At 30,480 meters, water boils at 7.2°C. The heat exchanger comprised a finned container of water which, when vented to the reduced air pressure outside the capsule, would boil. As the water boiled away, the steam took excess cabin heat with it [7]. There was no heater; capsule designers felt enough heat emanated from the pilot and on-board electrical equipment to eliminate the need for one. Insulation consisted of layers of corrugated cardboard and aluminized mylar covering the capsule's exterior.

Both the air regeneration and thermal control systems had their air blowers, which operated independently. However, in an emergency, either blower could operate both systems.

Lead-acid aircraft batteries on the aluminum landing gear powered the capsule. These had parachutes attached, and they doubled as ballast, which could be released to control the balloon's rate of descent. Emergency batteries were carried inside the gondola for the communications and life-support systems.

Communications consisted of VHF voice and HF morse code links. There were also telemetry channels for biomedical data.

The capsule was suspended from the balloon through an open 12.3-meter diameter cargo parachute. Normal landing procedures called for the pilot to descend by venting helium from the balloon, but the parachute could be used as an alternative means. Suspending it from the balloon in an extended position virtually assured its success if needed. Unmanned tests of the Manhigh system showed the parachute had an opening shock of only 2.5 g's. There were three means of releasing the gondola and parachute from the balloon: by pilot command; by ground command; or, by an on-board timer set to function at sunset of the second day.

The pilot also had a personal parachute inside the cabin. If both the balloon and cargo parachute failed, he could jettison the lower portion of the capsule and bail out. This was viewed as a last resort, however, as the pilot was to jettison the lower shell only after he reached an altitude of 4,570 meters.

Thus, every major system—life support, electrical, communications, and recovery—had at least one back-up. Similar redundancy would later be incorporated into the Mercury spacecraft to assure crewman survival.

Also like Mercury, the Manhigh flight program began with a series of unmanned and animal ascents. These flights provided data on launching techniques, life support system performance, balloon performance, and recovery methods. Six test flights were made, and some of these carried colonies of small animals, which placed the same demands on the cabin life support system as a human pilot [8]. One flight contained an anthropomorphic dummy [9]. It is probably appropriate at this time to mention one significant difference between Manhigh and later manned space projects. Where Mercury used a fresh spacecraft for each mission, and the astronauts trained in elaborate simulators, most Manhigh ground and flight tests were conducted with the same capsule.

Figure 3 Lieutenant Colonel David G. Simons, M.D. in the **Manhigh II** capsule prior to take-off.

While the capsule was in testing, the first two Manhigh pilots underwent training. Both individuals, Capt. Joseph W. Kittinger, and Major David G. Simons, had been with Manhigh since its inception in 1955 [10] (Figure 3). Simons, a physician, headed the Space Biology Branch of the Aeromedical Field Laboratory, and Kittinger was a test pilot assigned to the Center's* Flight Test Division. Since it was assumed these two would pilot Manhigh, they underwent a qualification and training program as opposed to selection tests. Their qualification included parachute jumps, balloon training in the Winzen Research Sky Car open gondola, 24-hour claustrophobia tests in the capsule, a low-pressure, low-temperature simulated flight in a test chamber, and a battery of physiological evaluations. As chief scientist and Air Force Project Officer for Manhigh, Simons understandably wanted to make the first ascent.

However, Colonel John P. Stapp, who headed the Aeromedical Field Laboratory, selected Kittinger for *Manhigh I*, because he viewed it as the last test flight [11] (Figure 4). Simons would be held in reserve until *Manhigh II*, the first full-scale research flight.

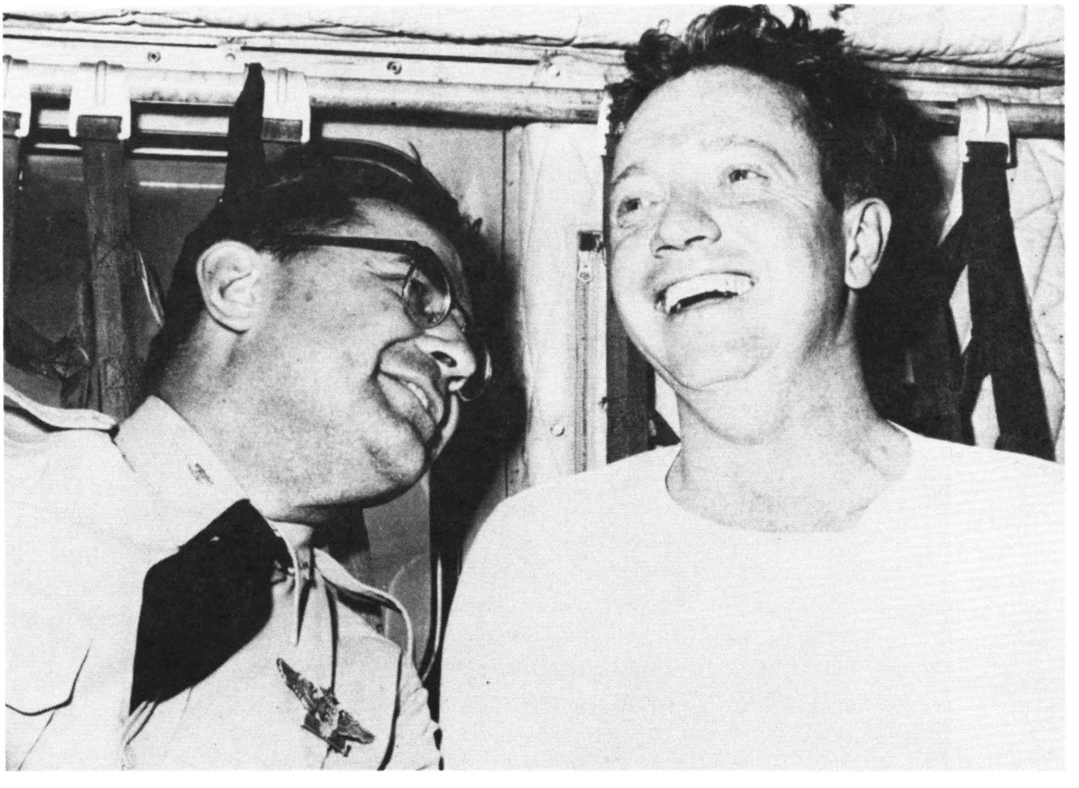

Figure 4 Colonel John P. Stapp, M.D., Ph.D. (left) and Manhigh pilot Joseph W. Kittinger (right).

Manhigh I, a planned 12-hour flight, began at 6:23 a.m. on June 2, 1957 from Fleming Field, South Saint Paul, Minnesota. The reason for flying from this location was that one of the principal objectives of Manhigh was to evaluate the effects of cosmic rays on the human body. At lower latitudes (i.e. New Mexico) the Earth's

* Originally Holloman Air Development and later, Air Force Missile Development Center.

magnetic field deflects such radiation. Only above the northernmost regions of the United States do cosmic rays reach low enough in the atmosphere to be investigated with balloons.

As a test flight, *Manhigh I* used a smaller balloon than planned for the scientific flights: it had a volume of only 56,600 cubic meters. Kittinger reached a ceiling of 29,000 meters slightly less than two hours after launch. During ascent, the voice communications system failed, forcing Kittinger to use the back-up morse code transmitter. Shortly after launch, Kittinger noticed the capsule internal pressure was not responding to the change in altitude. However, the capsule pressure response rate had never been observed under actual flight conditions, so he continued the flight. The first real indication of trouble came at 8:07 a.m. when, after reaching peak altitude, Kittinger reported the main oxygen supply tank was less than half full. Major Simons, Colonel Stapp, and Otto Winzen conferred, and they decided the problem lay in the cabin pressure controller. At 8:54, they ordered Kittinger to descend immediately. His initial response of "Come and get me" shocked ground controllers. They first feared he was suffering from the so-called "breakaway phenomenon," a feeling of detachment from the Earth reported by high-altitude aircraft pilots. However, Kittinger's response had been a joke, and their fears proved groundless. At 12:57, he landed on the bank of Indian Creek, north of Weaver, Minnesota, about 130 kilometers southeast of the launch area. At the instant of landing, Kittinger released the balloon, and the capsule toppled into the shallow creek. The liquid oxygen tank was nearly empty. Almost immediately, two chase helicopters landed alongside, and the personnel helped the pilot, who had just reached the highest sustained altitude on record, from the capsule. Post flight examination showed someone had accidently reversed the pressure supply and oxygen vent lines to the pressure regulator so instead of oxygen being supplied to the capsule, it was dumped overboard [12]. The communications malfunction proved to be nothing more serious than a loose channel selector switch. These problems were corrected and the capsule was refurbished for *Manhigh II* [13]. Then, the project hit a seemingly impassable obstacle.

In mid-1957, the national debt reached its legal ceiling, and military research funding was drastically reduced. After the near mishap during *Manhigh I*, Colonel Stapp directed that before *Manhigh II* proceeded, a 24-hour simulation in an altitude chamber be completed. *Manhigh I* depleted the project's money, and the test and another flight would cost approximately $14,000 more than was available. Otto Winzen, president of Winzen Research, offered to underwrite the chamber test and the flight, feeling that the publicity and official goodwill generated by the ascent would make the investment worthwhile. The chamber test went well, so preparations contained for *Manhigh II* [14].

On August 19, 1957, Simons took off at 9:22 a.m. from a 130-meter deep open pit near Crosby, Minnesota. The take-off was made from the pit to protect the 107-meter tall aerostat from surface winds, which could whip the balloon like a sail and destroy the entire aircraft. *Manhigh II* used an 85,000-cubic meter balloon, so Simons expected to attain a ceiling in excess of 30,480 meters.

Two hours and eighteen minutes after launch, he reached 31,100 meters. Simons spent the day floating above 99% of the atmosphere, making observations with both the unaided eye and a 12.7-centimeter telescope, taking photographs, and measuring sky brightness with a spot photometer. Photographic plates taped to his body would show cosmic ray tracks. Since the position of the plates was known, Dr. Simons could be examined for the effects from any hits.

After sundown the balloon cooled, and Simons descended to 25,600 meters. During the night, a line of severe thunderstorms rolled in beneath him. One of Simons' observations was that the storm clouds towered higher than previously believed, and as he watched the lightning flashing beneath him, he feared it would strike the capsule [15]. As the balloon continued to cool, it descended to 21,300 meters. He lightened the craft by dropping two 23-kilogram batteries and rose to a higher altitude, safely above the ferocity of the storm.

After sunrise the balloon began to heat, and once again rose to 27,400 meters. Still, the storm raged menacingly below. Then a new problem surfaced. Partly because the lithium hydroxide in the air scrubbers had cooled during the night, lowering their efficiency, the carbon dioxide level in the cabin reached four percent. Simons donned the faceplate to his helmet, and breathed pure oxygen for ten minutes. This gave the air scrubbers time to work, and he could remove the face mask until carbon dioxide built up again. By 11:00 a.m., the chemicals warmed up enough to keep the carbon dioxide level just below three percent [16].

The balloon had also drifted clear of the storm, and Simons could begin his descent. However, returning wasn't quite as easy as ascending, and each time he carefully valved off gas and descended, the balloon would heat up and rise again. This yo-yo motion continued for some time, and it wasn't until 2:00 in the afternoon that he began a steady descent. Finally, 32 hours and 10 minutes after launch, Major Simons landed in a South Dakota farm. A thorough physical examination showed he was none the worse for wear from his flight. Following the success of *Manhigh II*, Brigadier General Don Flickinger, then Director of Human Factors of the Air Research and Development Command, approved a third flight [17]. Just a few years later, General Flickinger would participate in Project Mercury as a member of the NASA Special Committee on Life Sciences [18].

It was *Manhigh III* which most closely paralleled Project Mercury. The purpose of the third Manhigh ascent was to make scientific observations through the eyes of a pilot directed by a panel of experts on the ground. General Flickinger suggested that candidates be screened to meet the physiological and psychological qualifications anticipated for future space crews [19]. Since there were no astronauts at that time, qualifications for space men of the future would be established by Manhigh. Six candidates were screened in a process which included a preselection interview to determine motivation and scientific background, a four-day medical evaluation at the Lovelace Clinic in Albuquerque, and a 24-hour stress test to assess each candidate's response to confinement in the Manhigh capsule. Further evaluations included a full day of tests by a clinical psychologist, psychiatric interviews, and a session in a soundproof, unlighted chamber. Further stress testing included centrifuge runs, one hour in a "hot box" (68.3°C and 85% humidity), and immersion of the subject's feet in iced water. The tests used in 1959 to select the seven Mercury astronauts were nearly identical, including the foot immersion [20]. Dr. W. Randolph Lovelace II, Director of the Lovelace Foundation during Manhigh, would eventually head NASA's first Special Committee on Life Sciences, and he became the agency's Director of Space Medicine.

Dr. George E. Ruff, an expert on the effects of stress, participated in both the Manhigh and Mercury selection processes. The Mercury candidates also underwent physical evaluation at the Lovelace Clinic.

Lieutenant Clifton McClure, a 25-year old Air Force officer with a degree in ceramics engineering, was selected to pilot *Manhigh III*. This flight used a new, larger capsule, and was planned to take place in Minnesota. However, by the time everything was ready, the Minnesota weather had deteriorated for the season, so the flight was moved to Holloman. McClure took off at 6:51 on the morning of October 8, 1958, on what became a testimonial to the power of human will (Figure 5).

Shortly after boarding the capsule, McClure accidently opened his personal parachute. Rather than report the mishap and abort the flight, which may have terminated the entire project because of a shortage of balloons, McClure chose to remain silent and re-pack the parachute! He succeeded, but began perspiring so heavily, he overloaded the moisture removing capacity of the life support system. The excess moisture reacted with the potassium hydroxide in the air scrubbers, producing heat [21]. The gondola overheated, and so did the pilot. Ground controllers realized something was wrong when McClure's voice showed signs of sluggishness at 1:00 that afternoon. Asked to report his rectal temperature, he replied it was 38.3 degrees. Telemetry indicated McClure's pulse rate was 140 beats per minute. Yet, telemetry also indicated the cabin temperature was only 24.4°C. Was the cabin temperature indication on the ground correct? Asked to read the mercury thermometer inside the cabin, McClure reported a temperature of 35.5°C. At 1:30, McClure's internal temperature had reached 39.0°. Lieutenant Colonel Rufus Hessberg, then chief of the Aeromedical Field Laboratory, decided to terminate the flight [22]. During the descent, the groggy McClure broke the radio foot switch when he dropped the photometer. For most of the descent, he couldn't transmit to the ground. Still, McClure retained control of the aerostat and finished his descent from 30,400 meters at 6:30 that evening. His temperature was an incredible 42.5°, yet he remained lucid and walked by himself to the recovery helicopter [23]!

Project Manhigh was over. Project Mercury, the first American manned space program would soon follow. In April 1960, Lt. Col. Simons served as a member of the NASA Space Task Group, Department of Defense Medical Advisory Board. This board comprised a panel of medical officers who reviewed Project Mercury medical plans to insure that astronaut pre-flight examinations, in-flight monitoring, and post-flight examinations had been thoroughly considered and provided for [24]. Simons was also one of Mercury's Aeromedical Monitoring Personnel. These were a group of Defense Department physicians, who spent time at NASA tracking stations training other personnel to be medical monitors for Project Mercury. Simons was assigned to Baja, California [25].

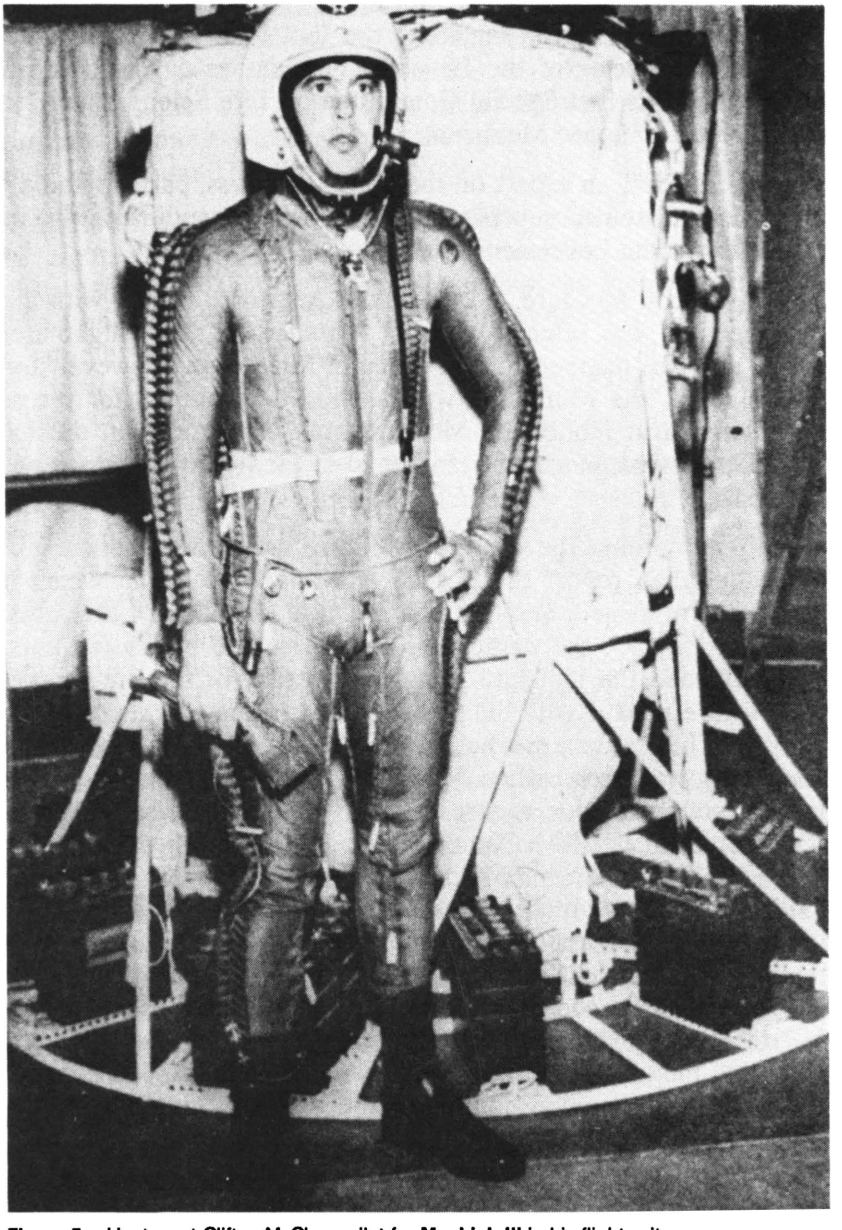

Figure 5 Lieutenant Clifton McClure, pilot for **Manhigh III** in his flight suit.

During Mercury, six astronauts would cross the threshold into space, surpassing Manhigh. Mercury was a stunning success, and its achievements in blazing new trails in uncharted realms cannot be denied. However, Mercury owes at least a portion of its success to Manhigh, for this project, which used the oldest form of aircraft to carry humans to the edge of space, laid much of the aeromedical foundation, which later manned space programs were built upon.

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