Spacewalking History

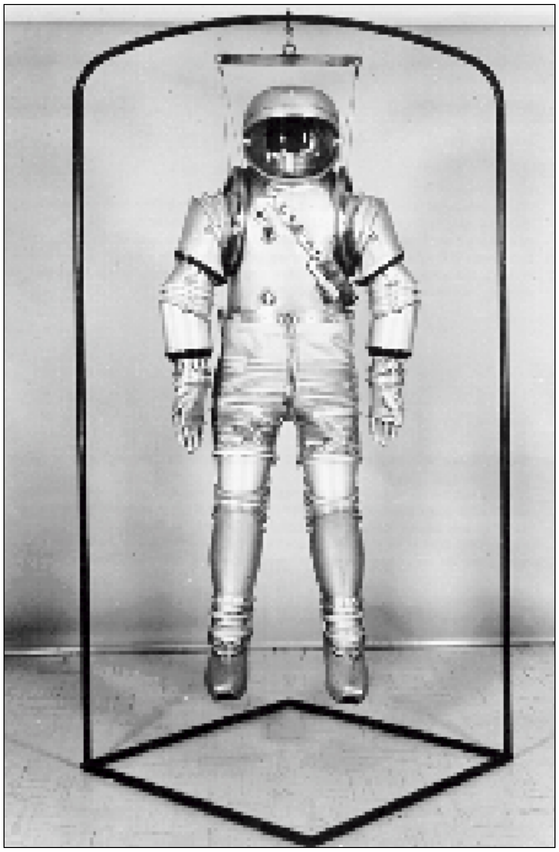
The Extravehicular Mobility Unit worn during spacewalks by NASA's Space Shuttle astronauts represents more than 60 years of development and testing of pressure suits in the U.S., Russia, France, Italy, Germany, and other countries. It all began with high-altitude flyers,and one of the first was an American, Wiley Post. Post, an aviation pioneer of the 1930s, was seeking to break high-altitude and speed records. Post, as well as others, knew that protection against low pressure was essential. Through experience, aviators had learned that Earth's atmosphere thins with altitude.

At 5,500 meters, air is only one-half as dense as it is at sea level. At 12,200 meters, the pressure is so low and the amount of oxygen is so small that most living things perish. For Wiley Post to achieve the altitude records he sought, he needed protection. (Pressurized aircraft cabins had not yet been developed.) Post's solution was a suit that could be pressurized by his airplane engine's supercharger.

First attempts at building a pressure suit failed since the suit became rigid and immobile when pressurized. Post discovered he couldn't move inside the inflated suit, much less work airplane controls. A later version succeeded with the suit constructed already in a sitting position. This allowed Post to place his hands on the airplane controls and his feet on the rudder bars. Moving his arms and legs was difficult, but not impossible. To provide visibility, a viewing port was part of the rigid helmet placed over Post's head. The port was small, but a larger one was unnecessary because Post had only one good eye!

Aviation pioneer Wiley Post.

During the next 30 years,pressure suits evolved in many ways and technical manufacturing help was gained from companies that made armor, diving suits, galoshes, and even girdles and corsets.



Early spacesuit design.

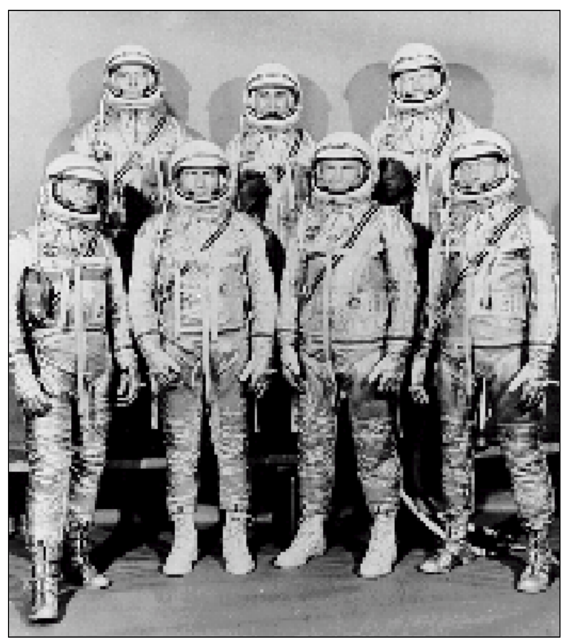
Designers learned in their search for the perfect suit that it was not necessary to provide full sea-level pressure. A suit pressure of 24.13 kilopascals (sea level–101 kilopascals) would suffice quite nicely if the wearer breathed pure oxygen. Supplying pure oxygen at this low pressure actually provides the breather with more oxygen than an unsuited person breathes at sea level.(Only one-fifth of the air at sea level is oxygen.)

Various techniques were used for constructing pressure garments. Some approaches employed a rigid layer with special joints of rings or cables or some other device to permit limb movements. Others used non-stretch fabrics—laced-up corset fashion.

With the advent of pressurized aircraft cabins, comfort and mobility in the suit when it was unpressurized became prime objectives in suit design.The suit could then be inflated in the event that the aircraft cabin lost pressure.

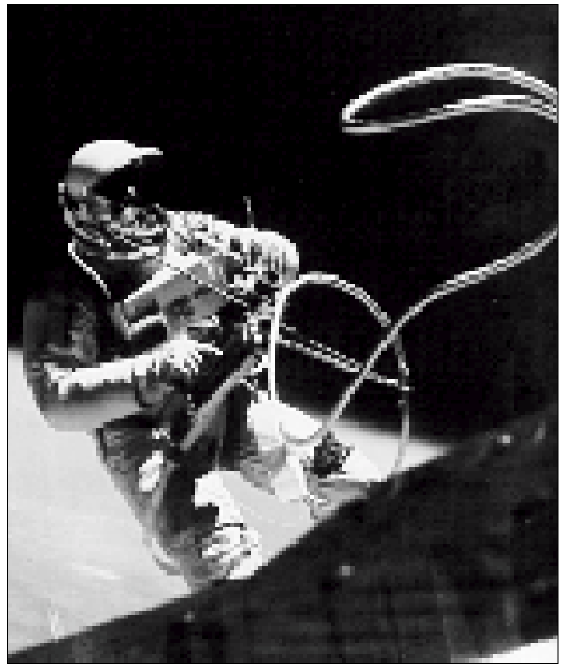
Project Mercury

By the time NASA began the Mercury manned space flight program,the best full-pressure suit design consisted of an inner gas-bladder layer of neoprene-coated fabric and an outer restraint layer of aluminized nylon. The first layer retained pure oxygen at 34.5 kilopascals; the second layer prevented the first from expanding like a balloon. This second fabric restraint layer directed the oxygen pressure inward on the astronaut. The limbs of the suit did not bend in a hinge fashion as do human arms and legs. Instead, the fabric arms and legs bent in a gentle curve, which restricted movement. When the astronaut moved one of his arms, the bending creased or folded the fabric inward near the joints, decreasing the volume of the suit and increasing its total pressure slightly. Fortunately for the comfort of the Mercury astronauts,the Mercury suit was designed to serve only as a pressure backup if the spacecraft cabin decompressed. No Mercury capsule ever lost pressure during a mission, and the suits remained uninflated.



Project Mercury astronauts.(Front row, left to right) Walter M.Schirra,Jr., Donald K.Slayton,John H.Glenn,Jr.,M.Scott Carpenter. (Back row, left to right) Alan B.Shepard, Jr., Virgil I. Grissom,L.Gordon Cooper, Jr.

Project Gemini



Edward H. White's historic spacewalk.

The six flights of the Mercury series were followed by ten flights in the Gemini program. Suit designers were faced with new problems. Not only would a Gemini suit have to serve as a pressure backup to the spacecraft cabin, but also as an escape suit if ejection seats had to be fired for an aborted launch and as an EMU for extravehicular activity. To increase mobility and comfort of the suit for long-term wear, designers departed from the Mercury suit concept. Instead of fabric joints, they chose a construction that employed a bladder restrained by a net. The bladder was an anthropomorphically shaped layer of neoprene-coated nylon. That was covered in turn with a layer of Teflon®-coated nylon netting. The netting, slightly smaller than the pressure bladder, limited inflation of the bladder and retained the pressure load in much the same way automobile tires retained the load in inner tubes in the days before tubeless tires. The new spacesuit featured improved mobility in the shoulders and arms and was more comfortable when worn unpressurized during space flights lasting as long as 14 days.

The first Gemini astronaut to leave his vehicle ("go EVA") was Edward White, II. White exited from the Gemini 4 space capsule on June 3,1965—just a few months after Leonov made the first Soviet spacewalk. For a half-hour, White tumbled and rolled in space, connected to the capsule only by an oxygen-feed hose that served secondary functions as a tether line and a communication link with the capsule. Although the term "spacewalk" was coined for the Gemini program, no actual walking was involved.On his spacewalk, White used a small hand-held propulsion gun for maneuvering in space. When he pulled a trigger, the gun released jets of nitrogen that propelled him in the opposite direction.It was the first personal maneuvering unit used in space.

Upon completion of the Gemini program, NASA astronauts had logged nearly 12 additional hours of EVA experience. Approximately one-half of that time was spent merely standing up through the open hatch.

One of the most important lessons learned during the Gemini program was that EVAs were not as simple as they looked. Moving around in space required a great deal of work.The work could be lessened, however, by extensive training on Earth. The most effective training took place underwater. Wearing specially-weighted spacesuits while in a deep tank of water gave later Gemini crew members adequate practice in maneuvers they would soon perform in space. It was also learned that a better method of cooling the astronaut was required.The gas cooling system could not remove heat and moisture as rapidly as the astronaut produced them, and the inside of the helmet visor quickly fogged over making it difficult to see.

Project Apollo

Following Gemini, the Apollo program added a new dimension in spacesuit design because actual spacewalks (on the surface of the Moon) were now to occur for the first time. As with Mercury and Gemini space garments, Apollo suits had to serve as a backup pressure system to the space capsule. Besides allowing flexibility in the shoulder and arm areas, they also had to permit movements of the legs and waist. Astronauts needed to be able to bend and stoop to pick up samples on the Moon. Suits had to function both in microgravity and in the one-sixth gravity of the Moon's surface. Furthermore, when walking on the Moon, Apollo astronauts needed the flexibility to roam freely without dragging a cumbersome combination oxygen line and tether. A self-contained portable life-support system was needed.

The Apollo spacesuit began with a garment that used water as a coolant. The garment, similar to long johns but laced with a network of thin-walled plastic tubing, circulated cooling water around the astronaut to prevent overheating. A multi-layered pressure garment was worn on top of the cooling suit. The innermost layer of this garment was a comfort layer of lightweight nylon with fabric ventilation ducts. On top of this was a layer of neoprene-coated nylon surrounded by a nylon restraint layer. This layer contained the pressure inside the suit. Improved mobility was achieved by bellow-like joints of formed rubber with built-in restraint cables at the waist, elbows, shoulders, wrist, knees, and ankles. On top of the pressure layer were five layers of aluminized Mylar® for heat protection, mixed with four spacing layers of non-woven Dacron®. Above these were two layers of Kapton and beta marquisette for additional thermal protection and a nonflammable and abrasion-protective layer of Teflon®-coated filament beta cloth. The outermost layer of the suit was white Teflon® cloth.The last two layers were flame resistant. In total, the suit layers provided pressure, served as a protection against heat and cold, and protected the wearer against micrometeoroid impacts and the wear and tear of walking on the Moon.

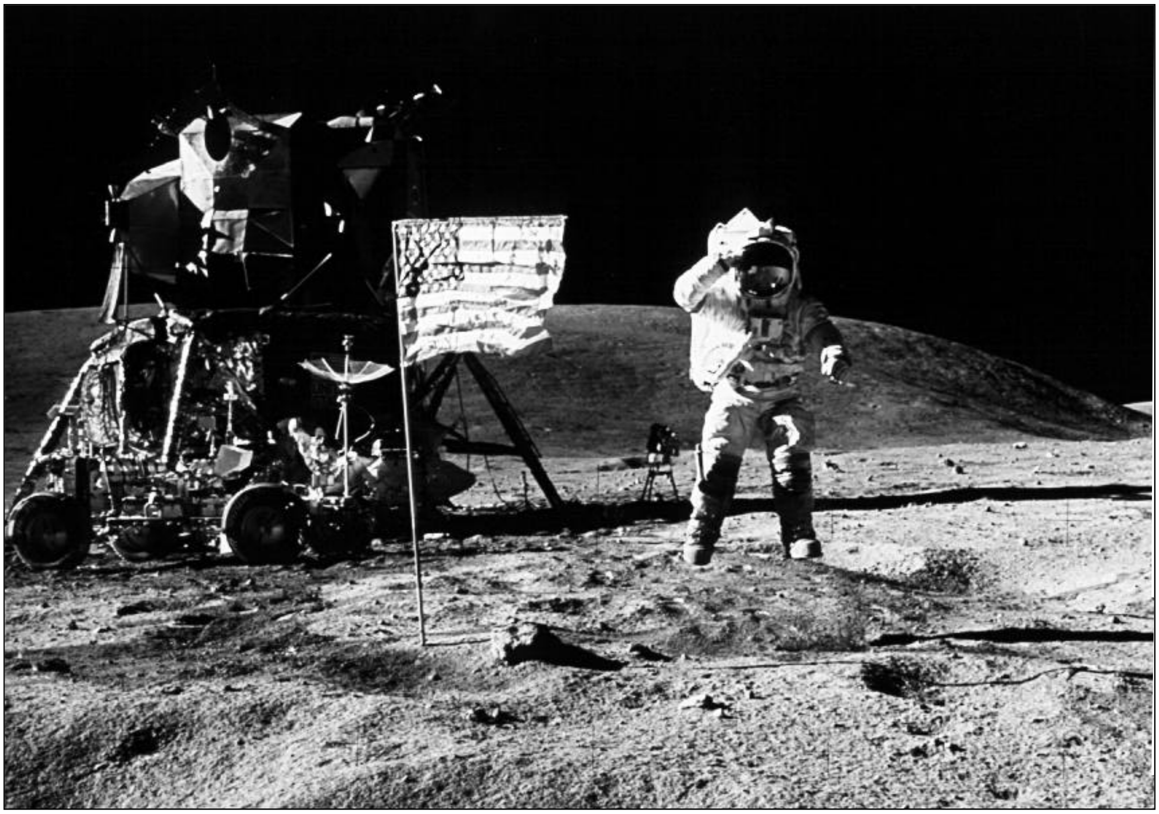
Capping off the suit was a communications headset and a clear polycarbonate-plastic pressure

Astronauts Harrison H.Schmitt (foreground) and Eugene A.Cernan practice sampling lunar sediment in a simulated Moon site constructed at the Kennedy Space Center in Florida.The Apollo 17 astronauts were the last humans to walk on the Moon.

helmet. Slipped over the top of the helmet was an assembly consisting of sun-filtering visors and adjustable blinders for sunlight protection. The final items of the Apollo spacesuit were lunar protective boots, a portable life-support system, and custom-sized gloves with molded silicone-rubber fingertips that provided some degree of fingertip sensitivity in handling equipment.

The life-support system, a backpack unit, provided oxygen for breathing and pressurization, water for cooling, and radio communications for lunar surface excursions lasting up to eight hours. Furthermore, back inside the lunar lander the life-support system could be recharged with more oxygen and battery power for additional Moonwalks.

During the Apollo program, 12 astronauts spent a total of 161 hours of EVA on the Moon's surface. Additional EVAs were spent in microgravity while the astronauts were in transit from the Moon to Earth. During a total of four hours, one



John W. Young, Commander ofthe Apollo 16 lunar landing mission to the Descartes region, salutes the American flag as he jumps upward in the one-sixth Earth gravity on the Moon. Behind him are the lunar module "Orion" and the lunar roving vehicle.

astronaut, the command module pilot, left the capsule to retrieve photographic film. There was no need for the portable life-support system away from the Moon, as those astronauts were connected to the spacecraft by umbilical tether lines supplying them with oxygen.

Skylab

NASA's next experience with EVAs came during the Skylab program and convincingly demonstrated the need for astronauts on a spacecraft. Spacesuited Skylab astronauts literally saved the Skylab program.

Skylab was NASA's first space station. It was launched in 1973, six months after the last Apollo Moon landing. Trouble developed during the launch when a micrometeoroid shield ripped away from the station's outer surface. This mishap triggered the premature deployment of two of the six solar panels, resulting in one being ripped away by atmospheric friction. The second was jammed in a partially opened position by a piece of bent metal. In orbit, Skylab received insufficient electrical power from the remaining solar panels: the station was overheating because of the missing shield. Instead of scrapping the mission, NASA assigned the first three-astronaut crew the task of repairing the crippled station. While still on board the Apollo command module, Paul Weitz unsuccessfully attempted to free the jammed solar panel as he extended himself through the open side hatch. On board Skylab, the crew poked an umbrella-like portable heat shield through the scientific airlock to cover the area where the original shield was torn away. Later, on an EVA, the metal holding the jammed solar arrays was cut, and the panel was freed to open. During an EVA by the second Skylab crew, an additional portable heat shield was erected over the first.

The Skylab EMU was a simplified version of the Apollo Moon suits. There was no need for the portable life-support system because the crew member was attached to the station by an umbilical tether that supplied oxygen and cooling water. An astronaut life-support assembly, consisting of a pressure-control unit and an attachment for the tether, was worn on the chest, and an emergency oxygen package containing two supply bottles was attached to the right upper leg. A simplified visor assembly was worn over the pressure helmet. Lunar protective boots were not needed. Skylab astronauts logged 17.5 hours of planned EVA for film and experiment retrieval and 65 hours of unplanned EVA for station repairs.