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Information Summaries

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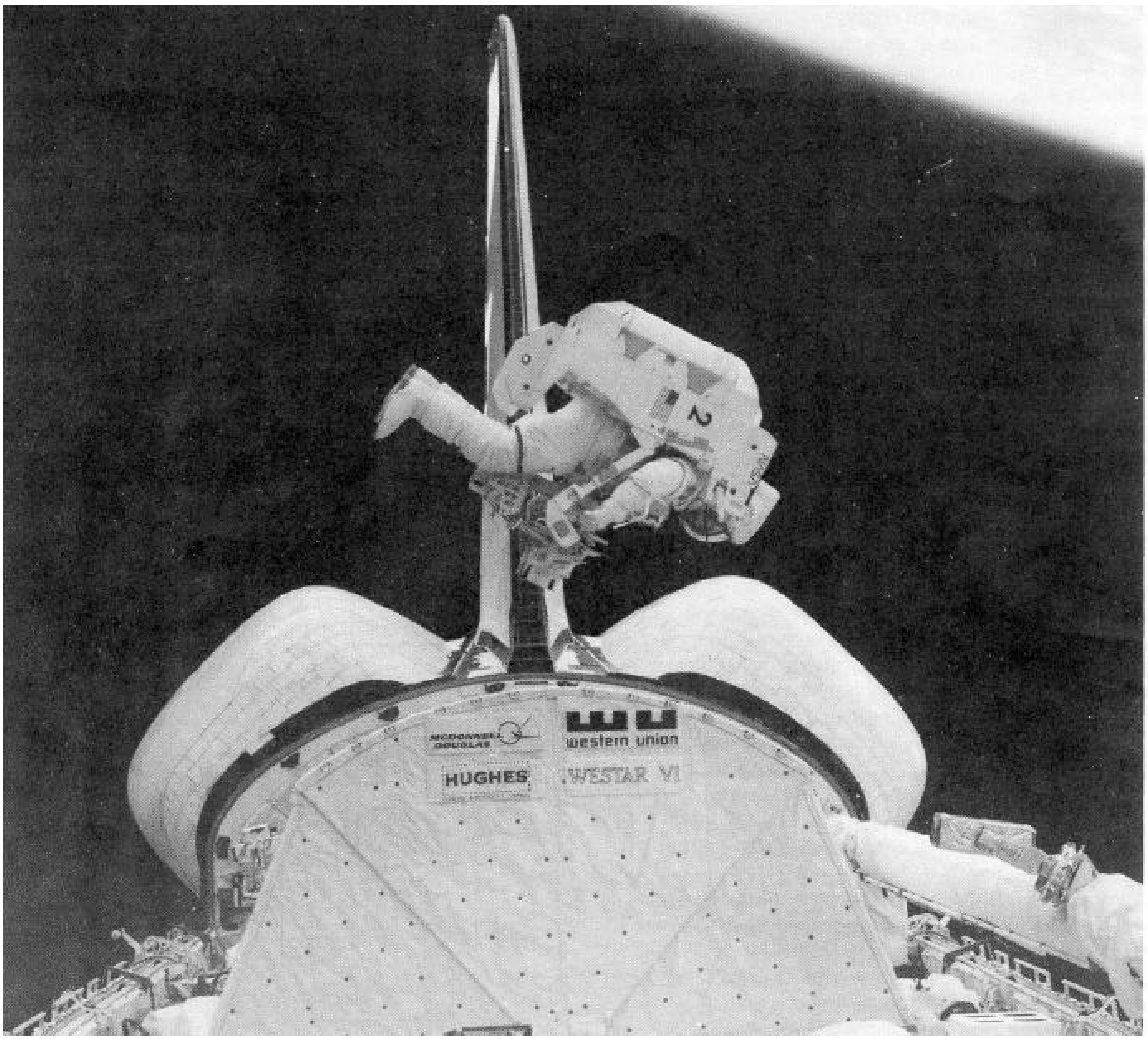
Wardrobe for Space



An astronaut working in the space shuffle orbiter cargo bay wears a spacesuit and a jet-powered, hand-controlled maneuvering unit. With this protection and equipment, the astronaut becomes an individual spacecraft able to move about and perform tasks in the microgravity of space.

WHY WEAR A SPACESUIT?

To explore and work in space, human beings must take their environment with them because there is no atmospheric pressure and no oxygen to sustain life. Inside the spacecraft, the atmosphere can be controlled so that special clothing isn't needed, but when outside, humans need the protection of a spacesuit.

Earth's atmosphere is 20 percent oxygen and 80 percent nitrogen from sea level to about 75 miles up, where space begins. At 18,000 feet, the atmosphere is half as dense as it is on the ground, and at altitudes above 40,000 feet, air is so thin and the amount of oxygen so small that pressure oxygen masks no longer do the job. Above the 63,000-foot threshold, humans must wear spacesuits that supply oxygen for breathing and that maintain a pressure around the body to keep body fluids in the liquid state. At this altitude the total air pressure is no longer sufficient to keep body fluids from boiling.

Spacesuits for the space shuttle era are pressurized at 4.3 pounds per square inch (psi), but because the gas in the suit is 100 percent oxygen instead of 20 percent, the person in a spacesuit actually has more oxygen to breathe than is available at an altitude of 10,000 feet or even at sea level without the spacesuit. Before leaving the space shuttle to perform tasks in space, an astronaut has to spend several hours breathing pure oxygen before proceeding into space. This procedure is necessary to remove nitrogen dissolved in body fluids and thereby to prevent its release as gas bubbles when pressure is reduced; a condition commonly called "the bends."

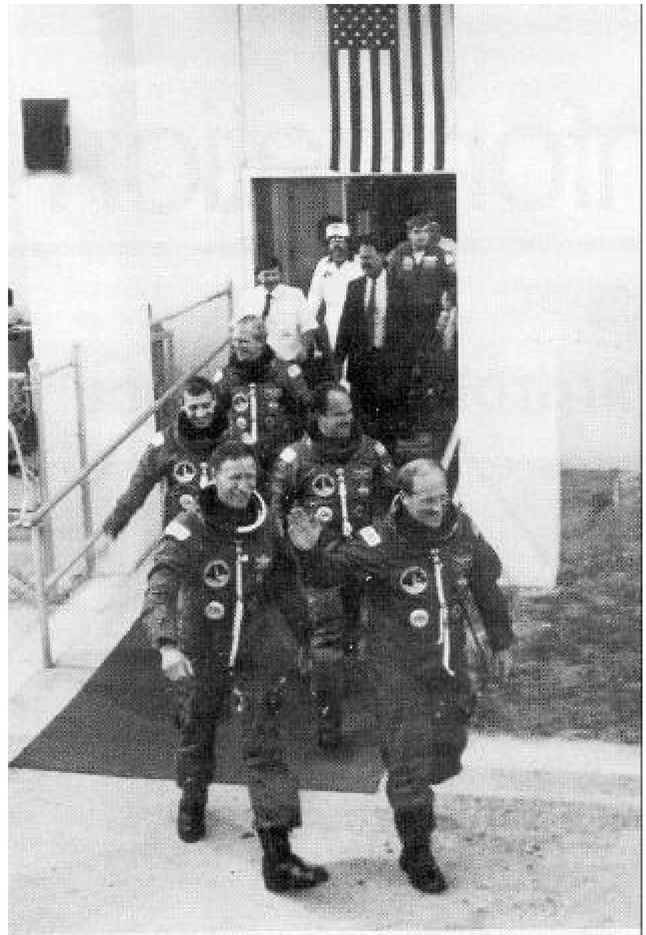
Spacesuits designed for the space station era will be pressurized to 8.3 psi; therefore, the pre-breathing period will be shortened or diminished.

The spacesuit also shields the astronaut from deadly hazards. Besides providing protection from bombardment by micrometeoroids, the spacesuit insulates the wearer from the temperature extremes of space. Without the Earth's atmosphere to filter the sunlight, the side of the suit facing the Sun may be heated to a temperature as high as 250 degrees Fahrenheit; the other side, exposed to darkness of deep space, may get as cold as -250 degrees Fahrenheit.

WARDROBE FOR THE SPACE SHUTTLE ERA

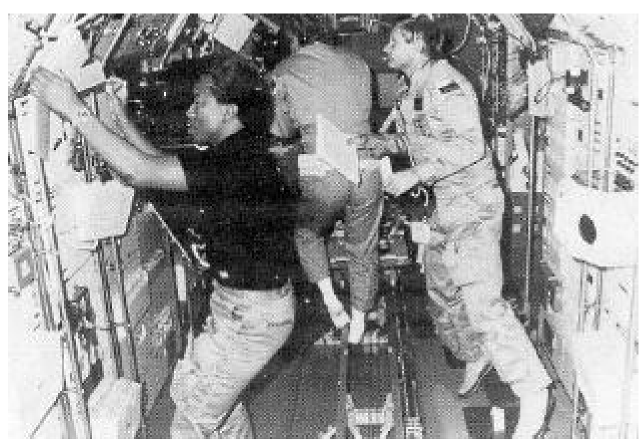
Astronauts of the space shuttle era have more than one wardrobe for space flight and what they wear depends on the job they are doing.

During ascent and entry, each crewmember wears special equipment consisting of a partialpressure suit, a parachute harness assembly, and a parachute pack. The suit, consisting of helmet, communication assembly, torso, gloves and boots, provides counterpressure and anti-exposure functions in an emergency situation in which the crew must parachute

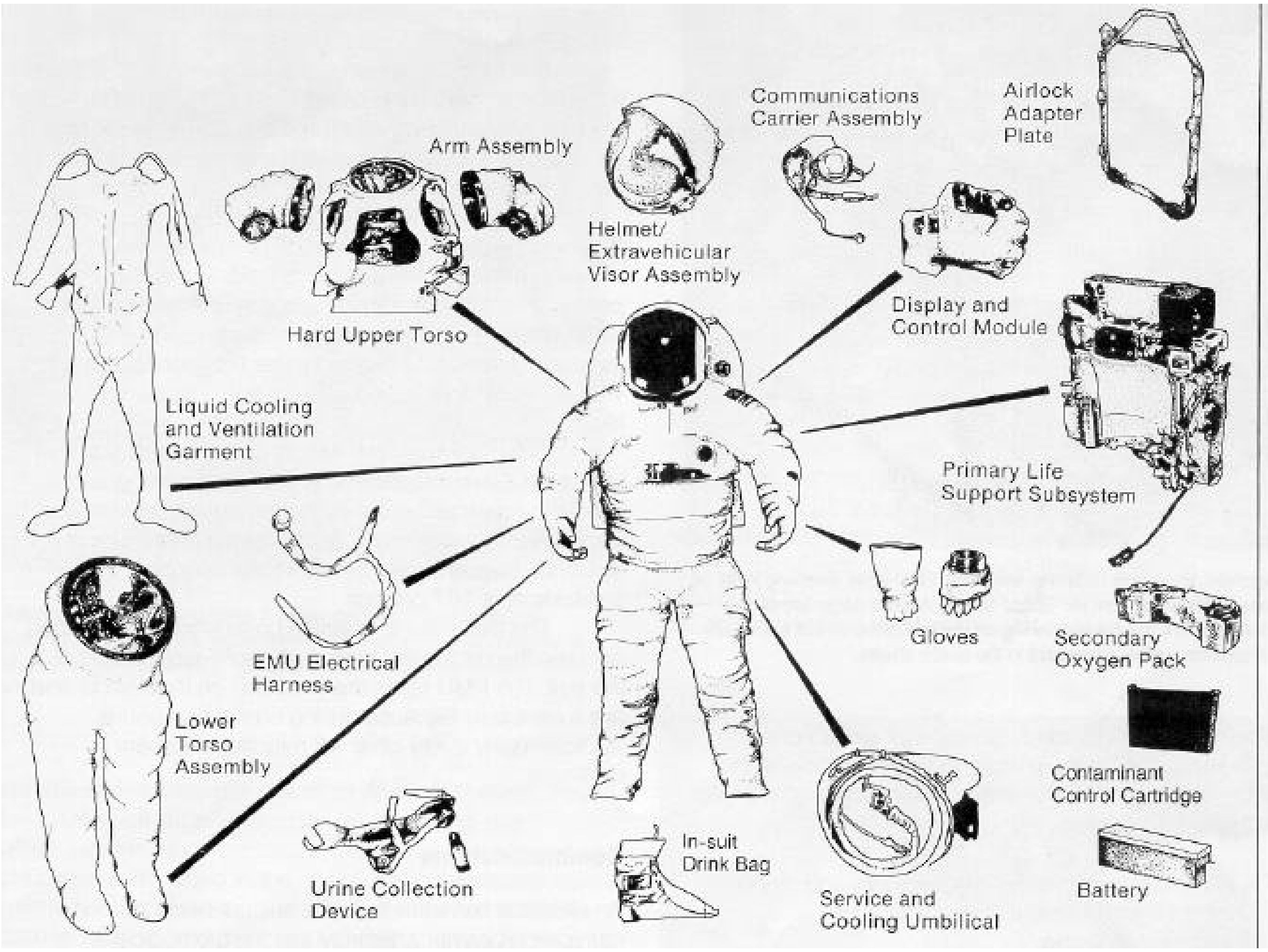


STS-26 crewmembers leave the Operations and Checkout Building at Kennedy Space Center, Florida, heading for the launch pad and lift-off. They are wearing partial pressure suits developed for the launch and entry phases of space flight.

from the orbiter, The suit has inflatable bladders that fill it with oxygen from the orbiter. These bladders inflate automatically at reduced cabin pressure. They also can be manually inflated during entry to prevent the crewmember



Crewmembers of mission STS 61 -A perform experiments in the spacelab module in the space shuttle orbiter cargo bay. Astronauts work in a controlled environment of moderate temperatures and unpolluted air at sea-level atmosphere.



Space shuttle EMU components

from blacking out. Without the suit pressing on the abdomen and the legs, the blood would pool in the lower part of the body and cause a person to black out as the spacecraft returns from microgravity to Earth's gravity. The partial-pressure suit and equipment will support a crewmember for a 24-hour period in a liferaft in case of an egress over water.

Working Inside the Space Shuttle

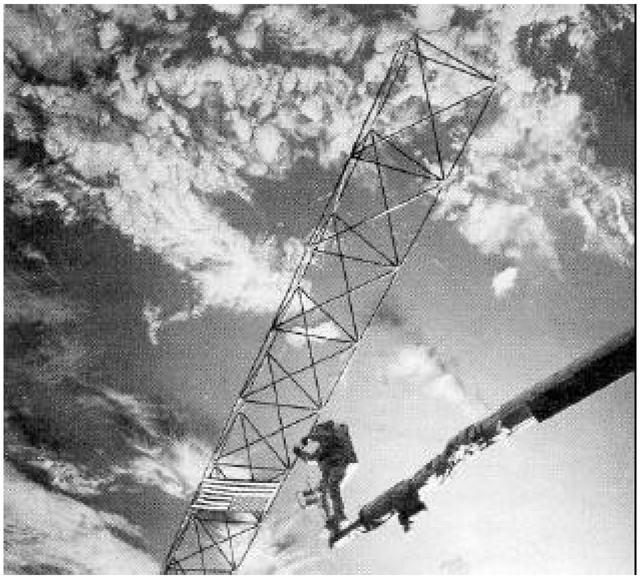
During orbit, astronauts work inside the space shuttle in shirtsleeve comfort. Prior to a mission, crewmembers are outfitted from a selection of clothing including flight suits, trousers, lined zipper jackets, knit shirts, sleep shorts, soft slippers, and underwear. The materials of every component of the clothing are flame retardant. Covering the exterior of the garments are closable pockets for storing such items as pens, pencils, data books, sunglasses, a multipurpose Swiss army pocketknife, and scissors.

Working Outside the Space Shuttle

To work in the open cargo bay of the space shuttle or in space, astronauts wear the shuttle extravehicular mobility unit (EMU) spacesuit, which was developed to be More durable and more flexible than previous spacesuits were. The suit is modular in design, with many interchangeable parts. The upper torso, lower torso, arms, and gloves are manufactured in different sizes and can be assembled for each mission in combinations needed to fit men and women astronauts. This design is cost-effective because the suits are reusable and not custom fitted as were spacesuits used in previous NASA manned space flight programs.

Suiting up

The EMU comprises the spacesuit assembly, the primary life support system (PLSS), the display and control module, and several other crew items designed for spacewalks and emergency life support. The EMU accommodates a variety of interchangeable systems that interconnect easily and



Astronaut Sherwood C. Spring wears the EMU while checking joints on a tower extending from the Space Shuttle Atlantis cargo bay during mission STS 61 -B. He is standing on the end *of* the arm *of* the remote manipulator system connected to the space shuttle.

securely in single-handed operation for either normal or emergency use. When preparing to work in space, the astronaut goes into the airlock of the space shuttle orbiter and puts on the following parts of the EMU:

- A urine-collection device that receives and stores urine for transfer later to the orbiter waste management system.

- A liquid cooling and ventilation garment, a one-piece mesh suit made of spandex, zippered for front entry, and weighing 6.5 pounds dry. The garment has water-cooling tubes running through it to keep the wearer comfortable during active work periods.

- An in-suit drink bag containing 21 ounces of potable water, the "Snoopy Cap," or communications carrier assembly, with headphones and microphones for two-way communications and caution-and-warning tones, and a biomedical instrumentation subsystem.

To put on the spacesuit, the astronaut first dons the lower torso assembly and then rises into the top section of the two-piece EMU spacesuit hanging on the wall of the airlock. The upper torso of the spacesuit is a hard-shell fiberglass structure that contains the primary life support system and the display control module. Connections between the two parts must be aligned to enable circulation of water and gas into the liquid cooling ventilation garment and return. Then, the gloves are added and last to be donned is the extravehicular visor and helmet assembly, which provides protection from micrometeoroids and from solar ultraviolet and infrared radiation. Bearings in the shoulder, arm, wrist, and waist joints allow the crewmember freedom of movement. Bending, leaning, and twisting motions of the torso can all be done with relative ease.

All fabric-to- hardware connections are made with either mechanical joints or adhesive bonding. Materials used in the construction of the suit are selected to prevent fungus or bacteria growth; however, the suit Must be cleaned and dried after flight use.

The entire suit assembly is rated with a minimum 8-year life expectancy. The nominal operating atmospheric pressure in the suit is 4.3 psid. The suit comprises several layers including a polyurethane-coated nylon pressure bladder, a polyester structural restraint layer with folded and pleated joints (for mobility), and a woven Kevlar, Teflon, and Dacron anti-abrasion outer layer.

The maximum total weight of the largest size spacesuit assembly, including the liquid cooling and ventilation garment, urine collection device, helmet and visor assembly, communications carrier assembly, insuit drink bag, and biomedical instrumentation subsystem, is 107 pounds,

The astronaut is ready to go to work in space and secures the necessary tools to the mini-workstation of the suit. The EMU lights are mounted on the helmet and are a necessity because during orbital operations approximately every other 45 minutes are spent in darkness.

Communications

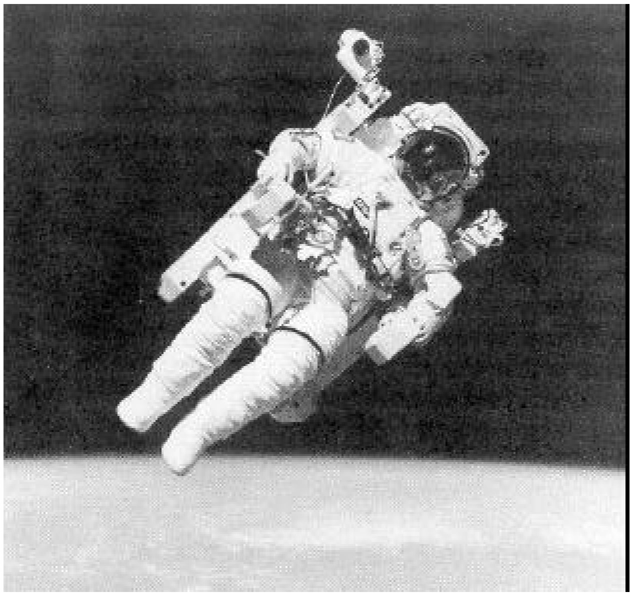
An electrical harness inside the suit connects the communications carrier assembly and the biomedical instrumentation equipment to the hard upper torso where internal connections are routed to the extravehicular communicator by means of a passthrough.

The extravehicular communicator attaches to the upper portion of the life support system at the back of the hard upper torso, The controls are located on the display and control module mounted on the chest at the front of the upper torso. The extravehicular communicator provides radio communication between the suited crewmember and the orbiter. In addition, electrocardiographic (EKG) information is telemetered through the extravehicular communicator to the orbiter and to flight surgeons in the Mission Control Center at Houston, Texas.

The radios for spacewalk communications have two single UHF channel transmitters, three singlechannel receivers, and a switching mechanism. These backpack radios have a "low profile" antenna - a footlong rectangular block fitted to the top of the PLSS. The radios weigh 8.7 pounds and are 12 inches long, 4.3 inches high, and 3.5 inches wide.

Primary life support system

The PLSS consists of a backpack unit permanently mounted to the hard upper torso of the suit and a



Astronaut Bruce McCandless 11 called the MMU "a great flying machine." McCandless was the first astronaut to use the MMU for a spacewalk on February 7,1984, during space shuffle mission STS 41-8.

Control-and-display unit mounted on the suit chest. The backpack unit supplies oxygen for breathing, suit pressurization, and ventilation. The unit also cools and circulates water used in the liquid cooling ventilation garment, controls ventilation gas temperature, absorbs carbon dioxide, and removes odors from the suit atmosphere. The secondary oxygen pack attaches to the bottom of the PLSS and supplies oxygen if the primary oxygen fails. The control-and-display unit allows the crewmember to control and monitor the PLSS, the secondary oxygen pack, and, when attached, the manned maneuvering unit.

Maneuvering in space

The manned maneuvering unit (MMU) is a one-man, nitrogen-propelled backpack that latches to the EMU spacesuit's PLSS. Using rotational and translational hand controllers, the crewmember can fly with precision in or around the orbiter cargo bay or to nearby freeflying payloads or structures, and can reach many otherwise inaccessible areas outside the orbiter. Astronauts wearing MMU's have deployed, serviced, repaired, and retrieved satellite payloads.

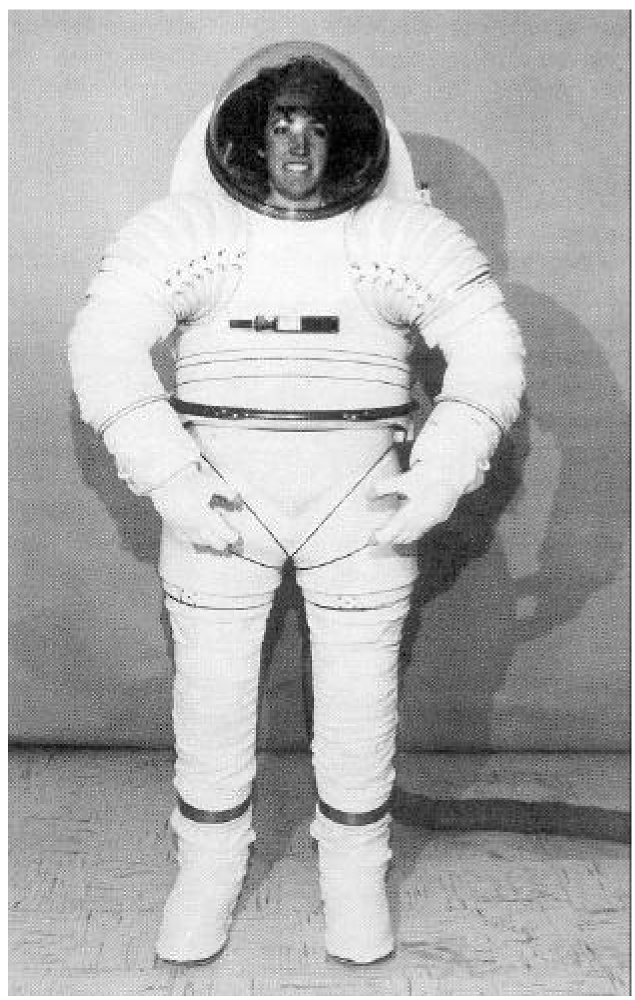
The MMU propellant - noncontaminating gaseous nitrogen stored under high pressure - can be recharged from the orbiter, The reliability of the unit is guaranteed with a dual parallel system rather than a backup redundant system. In the event of a failure in one parallel system, the system would be shut down and the remaining system would be used to return the MMU to the orbiter cargo bay. The MMU, which weighs 310 pounds, includes a 35-mm still photo camera that is operated by the astronaut while working in space.

SPACESUITS FOR SPACE STATION AND BEYOND

When Edward White opened the Gemini IV hatch in 1965 and became the first American to step into the vacuum of space, life-giving oxygen was fed to his spacesuit by a 25-foot umbilical to a chest-mounted pressure regulator and ventilation assembly.

Exploring the Moon, however, required tore independence from the spacecraft. The backpack portable life support system, a self-contained supply of breathing and pressurizing oxygen, filters for removing carbon dioxide, and cooling water, gave Apollo crewmen the independence they needed.

The PLSS supplied oxygen at 3.5 to 4 psi of pressure while circulating cooling water through the liquid-cooling garment worn under the spacesuit. Lithium hydroxide filters removed carbon dioxide from the crewman's exhaled breath, and charcoal and Orlon



The Mark III suit is modeled at Johnson Space Center, where it is being evaluated for use in the space station era

filters sifted out odors and foreign particles from the breathing oxygen. Metabolic heat was transferred from the cooling water loops to space through a water evaporator system in the PLSS.

Mounted atop the PLSS was an emergency 30-minute supply of oxygen and communications equipment for talking with fellow crewmen on the lunar surface and with flight controllers in Mission Control Center in Houston. Additionally, the communications systems relayed back to Earth biomedical data on the crewmen.

The Apollo lunar surface spacesuit and PLSS weighed 180 pounds on Earth, but only 30 pounds on the Moon because of the difference in gravity.

With the advent of the space station program, work outside the spacecraft will be expanded to provide numerous unique on-orbit service capabilities not fully achieved in previous space program operations. Currently, scientists and engineers at two NASA facilities are working on a new generation of spacesuits for use during activity in space.

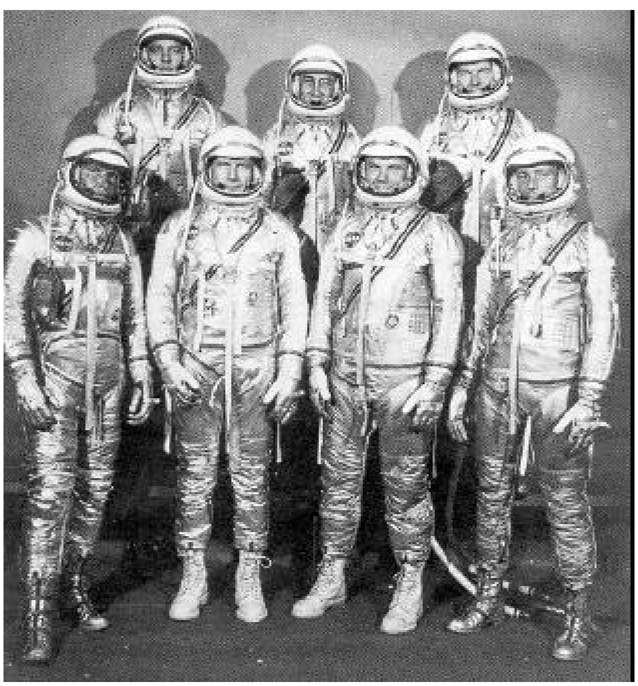
The Mark III suit, a combination of hard and soft elements, is being developed at the NASA Lyndon B Johnson Space Center (JSC) in Houston, Texas. The AX-5, a hard, all metal suit, is being developed by the NASA Ames Research Center (ARC) in California. Both suits share common design goals. For example, they must be easy to get into and out of, must be comfortable to wear, and must allow adequate mobility and range of motion for the jobs to be performed. Both are designed to be altered to fit different size astronauts

For use on space station, the suit must also be easily maintained and provide necessary protection from radiation, micrometeoroids, and manmade debris. In addition to these requirements, both the JSC Mark III and the ARC AX-5 suit have been designed to operate at a pressure of 8.3 psi. Current space shuttle spacesuits operate at 4.3 psi and require a time-consuming pre-breathing operation prior to the beginning of any spacewalk.

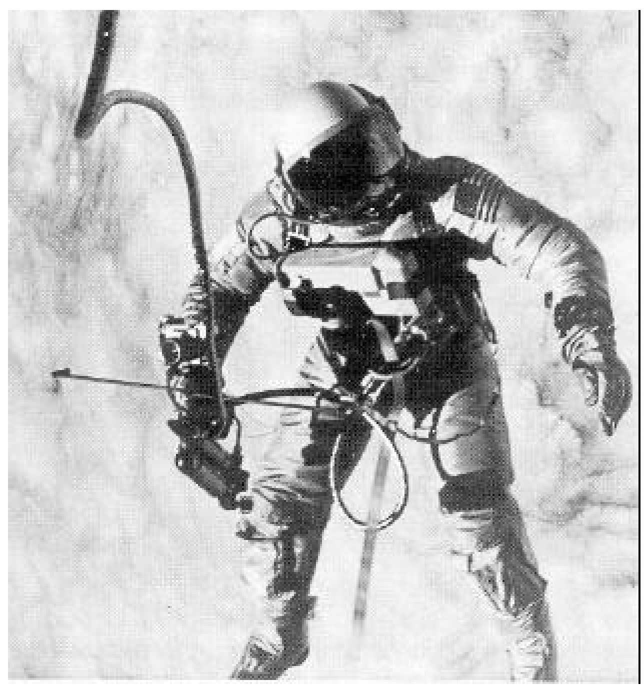
Pre-breathing allows the astronaut's body to adapt to the difference in pressure between the spacecraft cabin and the suit. By operating at a higher pressure, which more closely matches that of the space station, the new suit would greatly reduce or even eliminate the need for pre-breathing. Astronauts in the space station will be able to prepare for outside activity in much less time.

HISTORY OF WARDROBES FOR SPACE

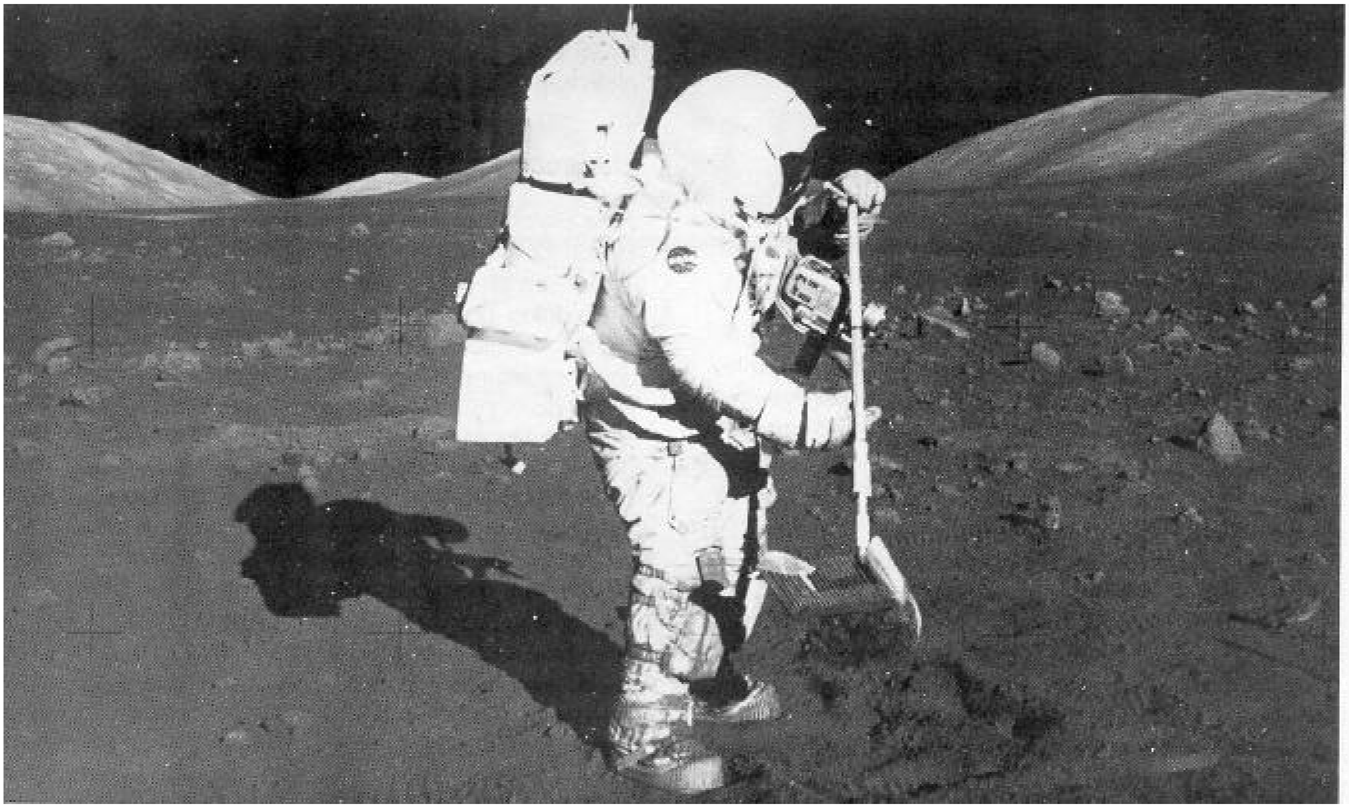
The Mercury spacesuit was a modified version of a U.S. Navy high altitude jet aircraft pressure suit. It consisted of an inner layer of Neoprene-coated nylon fabric and a restraint outer layer of aluminized nylon. Joint mobility at the elbow and knees was provided by simple fabric break lines sewn into the suit; but even with these break lines, it was difficult for a pilot to bend his arms or legs against the force of a pressurized suit. As an elbow or knee joint was bent, the suit joints folded in on themselves reducing suit internal volume and increasing pressure.



The first seven astronauts selected by NASA in 1959 wear the spacesuits developed for Project Mercury.



Astronaut Edward H. White 11 was the first U.S. crewman to float in the zero gravity of space. His spacewalk occurred during the flight of Gemini 4.



Apollo 17 scientist- astronaut Harrison H. Schmitt wears a protective spacesuit and helmet while collecting lunar samples at the Taurus-Littrow landing site in 1972. His backpack is the portable life support system.

The Mercury suit was worn "soft" or unpressurized and served only as a backup for possible spacecraft cabin pressure loss - an event that never happened. Limited pressurized mobility would have been a minor inconvenience in the small Mercury spacecraft cabin.

Spacesuit designers followed the U.S. Air Force approach toward greater suit mobility when they began to develop the spacesuit for the two-man Gemini spacecraft. Instead of the fabric-type joints used in the Mercury suit, the Gemini spacesuit had a combination of a pressure bladder and a link-net restraint layer that made the whole suit flexible when pressurized.

The gas-tight, man-shaped pressure bladder was made of Neoprene-coated nylon and covered by loadbearing link-net woven from Dacron and Teflon cords. The net layer, being slightly smaller than the pressure bladder, reduced the stiffness of the suit when pressurized and served as a sort of structural shell, much like a tire contained the pressure load of the innertube in the era before tubeless tires, Improved arm and shoulder mobility resulted from the multilayer design of the Gemini suit.

Tailored for Apollo Moon Walking

Walking on the Moon's surface a quarter million miles away from Earth presented a new set of problems to spacesuit designers. Not only did the Moon explorers' spacesuits have to offer protection from jagged **rocks and** the searing heat of the lunar day, but the suits also had to be flexible enough to permit stooping and bending as Apollo crewmen gathered samples from the Moon, set up scientific data stations at each landing site, and used the lunar rover vehicle, an electric-powered dune buggy, for transportation over the surface of the Moon.

The additional hazard of micrometeoroids that constantly pelt the lunar surface from deep space was met with an outer protective layer on the Apollo spacesuit. A backpack portable life support system provided oxygen for breathing, suit pressurization, and ventilation for moonwalks lasting up to 7 hours,

Apollo spacesuit mobility was improved over earlier suits by use of bellows-like molded rubber joints at the shoulders, elbows, hips and knees. Modifications to the suit waist for Apollo 15 through 17 missions added flexibility making it easier for crewmen to sit on the lunar rover vehicle.

From the skin out, the Apollo A7LB spacesuit began with an astronaut-worn liquid-cooling garment, similar to a pair of longjohns with a network of spaghettilike tubing sewn onto the fabric. Cool water, circulating through the tubing, transferred metabolic heat from the Moon explorer's body to the backpack and thence to space.

Next came a comfort and donning improvement layer of lightweight nylon, followed by a gas-tight pressure bladder of Neoprene-coated nylon or bellows-like molded joints components, a nylon restraint layer to prevent the bladder from ballooning, a lightweight thermal superinsulation of alternating layers of thin Kapton and glass-fiber cloth, several layers of Mylar and spacer Material, and finally, protective outer layers of Tefloncoated glass-fiber Beta cloth.

Apollo space helmets were formed from highstrength polycarbonate and were attached to the spacesuit by a pressure-sealing neckring. Unlike Mercury and Gemini helmets, which were closely fitted and moved with the crewman's head, the Apollo helmet was fixed and the head was free to move within. While walking on the Moon, Apollo crewmen wore an outer visor assembly over the polycarbonate helmet to shield against eyedamaging ultraviolet radiation, and to maintain head and face thermal comfort.

Completing the Moon explorer's ensemble were lunar gloves and boots, both designed for the rigors of exploring, and the gloves for adjusting sensitive instruments.

The lunar surface gloves consisted of integral structural restraint and pressure bladders, molded from casts of the crewmen's hands, and covered by multilayered superinsulation for thermal and abrasion protection. Thumb and fingertips were molded of silicone rubber to permit a degree of sensitivity and "feel." Pressure-sealing disconnects, similar to the helmet-to-suit connection, attached the gloves to the spacesuit arms.

The lunar boot was actually an overshoe that the Apollo lunar explorer slipped on over the integral pressure boot of the spacesuit. The outer layer of the lunar boot was made from metal-woven fabric, except for the ribbed silicone rubber sole; the tongue area was made from Teflon-coated glass-fiber cloth. The boot inner layers were made from Teflon-coated glass-fiber cloth followed by 25 alternating layers of Kapton film and glass-fiber cloth to form an efficient, lightweight thermal insulation.

Wardrobe for Skylab and Apollo-Soyuz

Nine Skylab crewmen manned the Nation's first space station for a total of 171 days during 1973 and 1974. They wore simplified versions of the Apollo spacesuit while doing the historic repair of the Skylab and changing film canisters in the solar observatory cameras. Jammed solar panels and the loss of a micrometeoroid shield during the launch of the Skylab orbital workshop necessitated several spacewalks for freeing the solar panels and for erecting a substitute shield.

The spacesuit changes from Apollo to Skylab included a less expensive to manufacture and lightweight thermal micrometeoroid overgarment, elimination of the lunar boots, and a simplified and less expensive extravehicular visor assembly over the helmet. The liquidcooling garment was retained from Apollo, but umbilicals and astronaut life support assembly (ALSA) replaced backpacks for life support during spacewalks.

Apollo-type spacesuits were used again in July 1975 when American astronauts and Soviet cosmonauts rendezvoused and docked in Earth orbit in the joint Apollo-Soyuz Test Project (ASTP) flight. Because no spacewalks were planned, U.S. crewmen were equipped with modified A7LB intravehicular Apollo spacesuits fitted with a simple cover layer replacing the thermal micrometeoroid layer.

Visitors to the Johnson Space Center in Houston, Texas, can see an exhibit of spacesuits.