Space Suits: An Evolution of Protection

Throughout the history of space exploration, back through to the very first sparks of imagination, space suits have been a way to protect our bodies from the dangers of space. A space suit by definition is a special suit that is designed to keep astronauts alive in outer space, and in some cases, a fully functioning one-person spacecraft. In the course of just over half a century the world has taken the idea of a space suit from a set of metal tubes to one of the most complex devices ever developed in human history. Through the space suit, humankind has been able to withstand the extremes of the outer space environment and discover marvels within Earth's orbit and on the surface of the moon. The space suit will continue to evolve and will hopefully bring us the opportunity to walk on places like Mars and bring more findings with improved technology.

The basic capabilities of a working space suit are to keep the astronaut alive. This what the human body needs for that to happen is a stable internal pressure, a breathable oxygen supply, the ability to move, a temperature control system, a communication system, and a waste collection system. Some other important additions for a space suit include particle and radiation shielding, particle shielding, and shuttle/station/capsule docking.

Of the first legitimate space suits ever made, Litton Industries' Litton Mark I came the closest. In the mid 1950's the United States Air Force was looking to solve some of its problems with electronics and vacuum tubing. Developed by company scientist Dr. Siegfried Hansen who also happened to be working with vacuum tubing, the Mark I was Hansen's first of many space suits (Litton). Of these space suits many even predated the launch of Russia's Sputnik and the US creation of NASA. In the vacuum chamber built at Litton Industries by the United States Air Force, the Mark I alone already proved to be a major step in space suit design as it proved to be functional for over 600 hours at a simulated altitude of 100 miles. Unfortunately the hard-suit concept was never able to progress as other designs took the stage for NASA's first missions (Factsheets).

In NASA's first manned mission to space, the Mercury mission borrowed the designs of the Goodrich US Navy Mark IV high altitude jet aircraft pressure suit. Turning the Navy's Suit into NASA's first space suit required few modifications but most notably there was the replacement of the dark outer fabric layer with an aluminum-nylon layer. Though the Mark IV had pressurization capabilities what NASA needed for space exploration was the additional ability to control temperature which they achieved with the aluminum. The full use of the Mercury suit was scarce however as pressurization was merely a back up to capsule cabin pressure. As pressurization brought issues with human mobility the Mercury suit was worn unpressurized at all times during flight (Mercury).

In the period after the Mercury missions there was a need for a new step in the abilities of a spacesuit. The Gemini mission needed to prove the abilities of extravehicular activity. Like the Mercury suit the Gemini space suits were decedents of airplane suits. The manufacturer of the suit derived the suit layout from suits worn by X-15 pilots. One of the key features of the Gemini suits was that they used a net containment system for pressurized areas. The holding of inflation by the net allowed for limb movement with a fully pressurized suit, a feature required in future missions. On June 3rd, 1965 Edward White moved out of the Gemini 4 capsule and performed the very first spacewalk by the United States. During this excursion White tested a piece of equipment called the Hand Held Maneuvering Unit or HHMU in addition to NASA's new suit. The HHMU was basically a couple of oxygen gas tanks held by hand used to propel the holder.

The Gemini missions continued to test the capabilities of the suit and on the missions after, improvements were made to its overall structure and donning process and also to its life support systems. The G5C suit, which evolved from the G3C, had only two layers instead of four and a two piece

helmet with a hard helmet in addition to a soft, hood helmet for ease of mobility. The G5C also was also much easier to take on and off so that astronauts could move inside the spacecraft in cotton garments. Development of life support was just as great with the already impressive Ventilation Control Module to the Extravehicular Life Support System which allowed for the astronaut to be independent of the space craft and was also able to triple the oxygen supply (Kennedy).

As one of the main features of the Cold War, the Space Race is often described as one of the most progressive time periods in scientific history. Ending the Space Race competition between the US and the USSR was the Apollo 11 mission with American astronauts landing and walking on the moon. The lunar landing was no easy feat however. Designers not only had to design a lander which could deliver astronauts safely to the moon but also provide the astronauts with suits able to withstand the moon environment. The challenges encountered included resisting jagged moon rocks, resisting day time temperatures of the moon, the ability to bend down to the surface, and the capacity of life support to accommodate several hour expeditions.

From the inside the Apollo A7L has a liquid cooling garment which is a full body suit the tubes embedded into the suit circulate cool water in and out of the garment and into the backpack to dissipate the energy. The next two layers consisted of a nylon fabric and Neoprene-coated nylon for pressure sealing. Nylon and Neoprene were two materials which were discovered decades ago but still were highly effective in containing air and being highly mobile. Like the Gemini suits another layer of nylon netting is added on the Neoprene bladder to prevent ballooning. Thin layers of alternating Kapton and glass-fiber cloth were then added to provide thermal insulation to protect the astronaut from the high temperature of the moon surface. On the final fittings there are Mylar and spacer alternations to provide micrometeorite shielding. Teflon coated glass-fiber Beta cloth made the final outer layer to protect from solar radiation. The Apollo suit was also a hybrid suit making it one of the first to incorporate soft materials like those of traditional space suits and hard materials like in its Hard Upper Torso or HUT and joint rings to provide greater mobility.

In addition to the overall suit structure numerous other devices were added to insure survival of the astronaut. To protect from the rocky surface the installation of “moon boots” were made so that the suit feet were protected from puncturing. A design to make the helmet area less bulky for the astronaut was to modify the entire head area as to have the astronauts head free from loading. The glove system was also different from previous space suits. As the astronauts on the moon had to interact with the environment the gloves were formed from silicone rubber to allow the astronaut to have a sense of feel. One of the most notable improvements though in the Apollo suits was in the Portable Life Support System or PLSS. The PLSS was an enormous isolated life support system which allowed for the astronaut to be independent in space for a full seven hours. The PLSS was a hardened backpack fitted onto the HUT (Wardrobe).

Though the Apollo Mission suits were a major step in space exploration, it should be noted that the improvements made were in conjunction to all the previous space suits before the Apollo series like those in Mercury, Gemini, and those not even in the exploration of space

In the evolution of space suits however older designs are not subject to obsolesce. The Gemini suits were used again but this time for the use of the space shuttle. In an effort to protect shuttle astronauts in contingency NASA derived from the Gemini suits the Advanced Crew Escape Suit or ACES. ACES was an emergency spacesuit worn by those traveling on the space shuttle and granted bailing capabilities at altitudes 30 kilometers or lower. As opposed to the Launch-Entry Suit which came before it, ACES had several significant improvements. Using the newly developed suits for jets called the S1035 on the SR-71 Blackbird, ACES included covering for the entire body as a full body pressure suit. The suit also carried integrated life support systems so that not only did the astronauts have a breathable oxygen supply but a completely isolated system so that shuttle depressurization or contamination would not affect the crew if sudden depressurization or leaking were to occur. ACES also provided many survival

items in the case of bailing such as a parachute and a one-person life raft. In addition the ACES suit was more comfortable to wear than its Gemini predecessors as a layer of liquid cooling and improved ventilation systems were used for the frequent trips off and to Earth's surface (ACES). Unfortunately due to the closure of the Space Shuttle program in 2011 the use of ACES has been scarce.

Of the regularly active space suits none is more seen than the Extravehicular Mobility Unit or EMU. The EMU was the spacesuit used for EVA aboard the space shuttle and is still in use aboard the ISS. In many ways the EMU bears a striking resemblance to the Apollo mission suits. Of its many components, the EMU holds components nearly exactly like those on the Apollo mission like the HUT, PLSS, and a liquid cooling garment. The EMU did have significant additions however as it worked in conjunction to the ISS. An improved umbilical cord for the suit allowed for extended stays outside of the space shuttle and ISS as its connection to the Service and Cooling Umbilical attached to the PLSS added a lifeline. Another important addition to the EMU was the Simplified Aid for EVA Rescue jetpack or SAFER. SAFER was added to the PLSS pack to act as an emergency thruster device in the case that an astronaut was to become separated from his or her base of operation. SAFER uses a gas jet propellant to maneuver in empty space. Thankfully there have been no emergencies needed for SAFER to be used (Space Shuttle).

Though the EMU is the best spacesuit commercially available, complications are still present even after half a century of improvement. The process of putting on the suit often requires aid and an excess of half an hour. Even after that the pressure capacity of suit is not high enough to allow astronauts to move from a craft environment straight into space. An experience most often felt by divers called the bends is the reason for several hours of waiting for the astronaut to breathe pure oxygen before he or she can enter into space. The bends is a pressure effect which a body can experience if the rate of pressure change is too great. In the case of rapid depressurization, like if a diver swims up too fast or an astronaut goes into space without proper preparation, nitrogen in the person's blood will boil throughout the body causing immense pain and possible long term damage to the body. Also despite constant improvements the EMU and other pressurized suit require a great deal of strength to move in due to the balloon effect. As one moves within the suit the suit will always pull back to the position with largest volume and least restrictive force. A problem often encountered by EVA astronauts is exhaustion and bruising due to the forces required to move and hold positions in space.

In an attempt to solve the issues presented in the current space suit many experimental designs have been proposed to provide substantial relief to the hindrances seen in EMU. The designers of the EMU, ILC Dover have come up with a new line of spacesuits which started with the Mark III hard-suit and have just recently developed plans for the Z-2 space suit. The Mark III through the Z-2 used a different mechanism for pressurization abilities. Starting with the Mark III an increase of hard shells was used. The pursuit of the idea of a majority hard-shell had not been seen since the beginning of space exploration but with improved technologies some advantages were clear. The hard-shell concept would be less susceptible to puncturing and would also be able to pressurize to greater levels. With a special feature of the pressurization already the Mark III has been proven to be functional at pressures of over 8 psi meaning there would be no need for a depressurization period like for the EMU (ILC).

Of the most unique designs seen there is the Bio-Suit developed by MIT. In contrast to the ILC Dover suits, the Bio-Suit focuses on a different method of pressurization by means of mechanical counter pressure or MCP. MCP focuses on having a skin tight suit which can be adjusted to any pressure desired. What the Bio-Suit tries to accomplish is for an astronaut to have a second skin in which full range of motion can be made. In addition the Bio-Suit also tries to conserve weight for transportation (a maximum of several pounds versus the over 300 pound EMU) and provide safer alternative to the bulkiness of gas-pressure suits. The Bio-Suit also tries to solve issues found in donning time by making the suit like a jumpsuit found on earth. Though mechanical pressure can be achieved, gas pressurization is still required for a headpiece though an advantage to having the oxygen only at the head area means

that less of a supply of gas is needed for the same amount of time a gas-pressurized suit would have (Judnick). One of the challenges faced in this design is the joining of the gas-pressurized head piece to the mechanical counter pressure torso.

Throughout the history of human space travel, space suits have always been a requirement whether the astronaut was just in a shuttle for the ride or on a mission to venture into space. Space suits have ranged from the iconic Apollo moon lander suit to the old metal frame suits from the mid 1950 to the newest and most novel designs yet seen. The space suit has really been an evolution in of itself with one type leading to another and some better fitted to some environments than others but none of them ever completely dead, simply reincarnated into another form in its descendants. With more advancing technologies emerging and discovery of potential materials and techniques the possibilities for a space suit are endless. What we see with the MIT Bio-Suit or the ILC Dover Z-2 suit may only be the beginning of a new stage of space suits which will be worn in the future.

In the next step of human exploration there is a place where no man has gone before – Mars. Mars is the next giant leap and any human who sets foot on the Martian surface better be prepared. How humans get to Mars is not only by spacecraft and rockets but of preservation of human life itself via a well thought out spacesuit. The suit which would be selected to go to Mars would have to with stand freezing temperatures, dust storm, and the Force of gravity one third of the Earth. The suit would have to be mobile and resistive to radiation. What we bring to Mars to protect the first humans to set foot on its surface one can only imagine.

For my project visual I have created a website:
http://was-space-suits.weebly.com/

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