Technical Concept Report: the X-Suit

Executive Summary:

Our product, X-Suit, is based on a very simple philosophy: to provide tomorrow's astronauts with the most effective, efficient, and safe space suits possible. In addition, our space suit will be on the forefront of today's and tomorrow's technologies, which can be integrated into the medical, defense, and leisure industries.

Our suit will be based on the concept mechanical counter-pressure, or more specifically, using durable yet elastic material in order to simulate atmospheric pressure, thus eliminating the need for pressurized gas as is necessary with today's space suits, such as NASA's Extravehicular Mobility Unit. In addition, our space suit will be packed with features which will serve to make the astronaut safer, more comfortable, more agile, and more physically fit, which will intern help the astronaut utilize his/her time more efficiently and effectively. Like today's space suits, our suit will circulate breathable oxygen throughout the astronaut's helmet, but unlike today's life support systems which pump oxygen into the entire suit, our suit will only contain atmospheric pressure in the helmet. The X-Suit will provide heating and ventilation first, through a garment specifically designed to wick away moisture from the astronauts skin in order to keep the astronaut dry and second, by using layered insulation. We believe that a cooling garment will be unnecessary because the astronaut's sweat will keep him/her sufficiently cool.. In addition to providing sufficient pressurization, oxygen and heating/cooling capabilities, the suit will also consist of the state-of-the-art materials of tomorrow's market, which will sufficiently protect the astronaut from ultraviolet, thermal, and particle radiation, as well as protection from micrometeorites without the need for a bulky and cumbersome exoskeleton, as is necessary in today's suits. However, our suit not only provides the basic necessities for sustaining life, but also goes far beyond those requirements in order to provide space agencies and individual astronauts with unparalleled comfort, extreme performance, and seamless systems integration.

Our suit will be embedded with state-of-the-art sensors which will be capable of sensing, recording, and broadcasting the structural and mechanical integrity of the suit to the crew of the mission. In addition, sensors will provide information regarding the health status of the individual astronauts in aspects such as blood pressure, cholesterol level, heart rate, body temperature, metabolic rate, levels of essential vitamins, stress level, respiration rate, and then be able to broadcast this information to team members and mission control in real-time through the use of small and lightweight, yet powerful micro-computers and transmitters. In addition to sensors, high-tech communications will allow the astronaut to communicate clearly and effectively with his/her team members inside and outside of the spacecraft, as well as with mission control. These communications equipment will also be able to relay information regarding the triangulated position of the astronaut using the Lunar Positioning System (LPS), a derivative of the Global Positioning System. In addition, the built-in micro-computers used to monitor and record the status of the astronaut's health will serve the dual purpose of monitoring the astronaut's natural circadian rhythms and will give him/her advice as to when to eat, sleep and wake up so as to most effectively fight the effects of asthenia syndrome. These functions related to sensing and real-time updates will be wired directly to the astronaut's helmet, which will be fitted with a heads-up display (HUD), similar to that used by fighter pilots, which will allow the astronaut to monitor his health without taking his mind off of the mission at hand. In addition, the built-in micro-computer will have the ability to play for the astronaut calming nature sounds and manipulate a motor in the gloves in order to simulate a soothing massage therapy, proven to prevent certain effects of stress and anxiety.

However, the highlight of our suit will be its ability to simulate muscle actions through the use of electro-muscle stimulation, which can help simulate and intensify exercise, stimulate blood flow through blood vessels, stimulate nerve cells, and prevent the effect that low-gravity environment have on an astronaut's body' weight-bearing capability. In addition, this capability, once refined, can be adapted into medical and civilian applications such as physical therapy and personal-training.

Background Information:

Ever since humans began playing a role in space travel, space travel has represented the forefront of human ingenuity and the vast abilities of the human intellect. However, one cannot possibly be enamored by the possibilities of future breakthroughs in space flight without being aware of the health risks and problems present in space flight.

A major problem associated with space travel has much to do with the fact that space is a vacuum. While unprotected inside a vacuum, a human can expect irreversible tissue damage, if not rapid death. In a vacuum, the human body would experience hypoxia, a phenomenon in which all gases leave the human's blood, causing unconsciousness in 9-12 seconds and death within 2 minutes (NASA). The human would also experience ebullism, a phenomenon which would cause the blood to boil, causing the body to bloat to twice its normal size and causing

frost to form on the skin due to the rapid evaporation caused by gases leaving the body (Cooke and Bancroft, 1966). An additional problem caused by a vacuum is rapid decompression, also caused barotrauma, in which the lungs, eardrums, and sinuses rupture (Harding, 1989). Our suit will eliminate this danger by providing effective and efficient counter-pressure through the use of durable and elastic materials used through the body of the suit.

Another danger is the lack of oxygen in space, particularly because humans need at least a partial pressure of Oxygen at 20 kPa (Harding, 1989). In order to combat this, our suit will have a life support unit which will pump pressurized oxygen directly to the helmet, maximizing efficiency and preserving the health of today's pioneers on the next frontier.

An additional issue in spaceflight is the cold, which can be as low as 3 Kelvin. However, due to a lack of conduction and convection in space, loss of heat would be extremely slow, and insulation as well as thermal radiation has proved to be highly effective at heating the body locally and thus, we will use the next generation of extremely efficient insulation for our space suit.

Other issues which ensue danger present in spaceflight is ultraviolet and particle radiation, which can result in an increased risk of cancer, cataracts, and chromosomal aberrations in blood lymphocytes which can lead to a higher risk of infection amongst the crew due to immunodeficiency (Cucinotta, 2001). In order to prevent this, we will use effective protection in order to prevent radiation.

A major hindrance to extended space travel today is the microgravity environment found in space. The microgravity in space presents many health-related challenges, for example, the microgravity environment disrupts the otolith organs in the inner-ear, altering perception of linear acceleration and resulting in nausea, headaches, intense discomfort, motion-sickness, and visual-orientation illusions, referred to today as space adaptation sickness, which usually lasts around three days (Science Daily, 2008). In addition, the lack of gravity causes body fluids to redistribute themselves in the upper portion of the body, resulting in bulgy neck veins, puffy face, and nasal/sinus congestion. The mechanical counter-pressure produced by our suit will be effective in preventing body fluids from accumulating in the upper portion of the body and redistributing themselves in an unnatural way. In addition, the microgravity environment in space causes the blood plasma content of the blood to decrease, resulting in orthostatic intolerance upon returning to earth (Zhang, 2001). However, the most worrying effects of microgravity on the human body are on the bones and muscles. Extended space travel can also result in loss of bone and muscle mass, the changing of slow-twitch muscle fibers to fast-twitch muscle fibers, and the formation of kidney stones as a result of elevated blood calcium levels (Nicogossian, Huntoon, and Pool, 1993). This problem of muscle atrophy can be combated by the electro-muscle stimulation found in our suit.

Additional hazards to the health of astronauts that can be found in space are micrometeorites and lunar dust. Micrometeorites today pose the threat of puncturing and depressurizing a suit, resulting in the undesirable effects of hypoxia, ebullism, and loss of oxygen. However, this will not be a danger to our suit, as our suit will utilize mechanical counter-pressure in place of air pressurization. In addition, lunar dust, an extremely abrasive substance, poses the threat of causing severe structural damage to a suit. Luckily, however, our suit will be made of tough fabrics and composite materials that will be highly resistant to abrasion from lunar dust and thus help prevent injury caused to the astronaut as a result (everything2, 2001).

The final hazard we will address is the psychological effects of a long-term space flight on an astronaut. During a long term space-flight, the disruption of circadian rhythms along with the lack of light and dark contrast can result in excessive stress and sleeplessness in the crew. As a result, the crew on a long-term space-flight can suffer from asthenia syndrome, which has symptoms including back and abdominal pain, fatigue, listlessness, psychosomatic worries, stress, insomnia, anxiety, and even depression (Styf, Hutchinson, Carlsson, and Hargens). In order to prevent these symptoms, our suit will be packed with features that will serve to improve and maintain the emotional well-being of the astronaut, such as a heads-up display which the astronaut can use to communicate with his/her loved ones, a microprocessor to monitor and provide information to the astronaut regarding how to best time his basic functions (eating and sleeping) so as to best prevent the disruption of the astronaut's natural circadian rhythms.

Thus, our product, the X-Suit, will be packed with features that address the must dire hazards faced by astronauts today in order to best protect them in space, both inside the vehicle and out.

Concept Details

Our product, X-Suit, aims to tackle and combat the problems mentioned in the previous sections through careful design and engineering; it is the overall design which we will cover in this section. As previously mentioned, our concept will be based upon the idea of mechanical counter-pressure. We will utilize a highly durable yet elastic mix of Kevlar, nylon-spandex, urethane painted foam, elastic, primary pressure cording, Teflon, Gore-Tex, Nomex, Dacron, and aluminized Mylar, which replaces the need for air pressurization necessary in today's space suits. Furthermore we will be adding "smart fabrics" which are made from dipped 1.5-millimeter thick cotton yarn into a solution of carbon nanotubes in water and then into a solution of a special sticky polymer in ethanol. It is dipped just a few times into both solutions and dried (University of Michigan, 2008). Also, the antibody anti-albumin is added in order to increase the sensitivity of the suit. This design presents many benefits...

First of all, it reduces the amount of energy and increases the efficiency of the Primary Life support System and will exert a pressure of 100 kPa (750 torr). Second, it increases the efficiency of the Primary Life support System by eliminating the need for ventilation, thus saving additional energy. Third, it is more durable, as a puncture only depressurizes the exact location in which the puncture is located; in today's space suits a single puncture results in the depressurization of the entire suit, thus endangering the life of the astronaut. Unlike today's suits, this suit will be lighter and more comfortable; will be tailored to the astronaut's profile; and will have a helmet with a wider range of vision, maximizing comfort and mobility. It will also allowing the astronaut to turn his/her head further, thus eliminating the phenomenon known today as "alligator head," characterized by decreased mobility of the head as a result of a fixed, rigid helmet. In addition, due to the high level of pressure exerted on the astronaut by the suit, there will be no need for pre-breathing which will prevent the occurrence of decompression sickness (Patel, 2005). The resistance material can monitor health and relay the information to the astronaut and other personnel of interest.

Like all other aspects of our suit, our oxygen delivery system, part of the primary life support system, will be state-of-the-art. The primary life support unit of the space suit will pump pressurized oxygen directly into the helmet. In addition, like the most advanced suits available today, the primary life support system will be capable of purifying oxygen from contaminants such as moisture (through the use of a separate sublimator, vacuum, and rotary separator), carbon dioxide (through the use of lithium hydroxide), and odors (by filtering waste through charcoal). The collected wastes will then be expelled into space via pressure swing absorption, with the remaining unused oxygen being returned to the primary breathing apparatus. In addition, in case of emergency, the primary life support system will be fitted with an optional once-through oxygen purge system in order to purge breathing apparatus of contaminants, a standard feature in today's most advanced space suits.

Like other space suits available in today's highly specialized market, our space suit will contain a specialized undergarment. The purpose of this will be to ventilate the astronaut's skin while at the same time keeping the astronaut either cool or warm, depending on the condition. However, what makes our space suit so unique is its ability to keep an astronaut warm without excessive consumption of power, Unlike in today's inefficient suits, our suit will provide the astronaut with a tight-fitting, highly specialized layer of insulation, which will prevent the astronaut from losing heat to the harsh external environment, as well as maximize the astronaut's body heat produced from metabolism. In addition, in order to prevent the astronaut's body temperature from rising too much and to prevent the accumulation of sweat from building up under the suit, both the undergarment and the external space suit will be highly breathable. This will allow the space suit to whisk away excess moisture from the astronaut's body without using excessive energy for cooling purposes, and simultaneously avoid the need to compromise either the astronaut's safety or comfort. In addition, there will be no need for a liquid cooling garment or other form of mechanical cooling, as the astronaut's sweat will keep him/her sufficiently cool under virtually all viable conditions.

In additional, in order to protect the astronaut from such hazards as ultraviolet radiation, particle radiation, micrometeorites, and abrasive lunar dust; our space suit will be composed of a highly durable yet elastic mix of nylon-spandex, urethane painted foam, elastic, primary pressure cording, Teflon, Gore-Tex, Kevlar, Nomex, Dacron, and Aluminized Mylar (Samir, 2005). The various materials utilized in this space suit will provide the optimal mix of resistance from thermal, ultraviolet, and particle radiation, as well as from micrometeorites, and abrasion caused by lunar dust. One major benefit of this novel mix of layered fabrics and composite materials is the elimination of the need for a rigid external skeleton and cumbersome, rigid joints, both of which negatively impact the comfort and mobility of the astronaut during a high-stakes mission.

In order to provide the astronaut, as well as mission control and other team members, with the structural integrity of the suit, the suit will be fitted with small, precise sensors capable of sensing, recording (on a small and lightweight, yet fast and powerful micro-computer), and broadcasting information regarding potential problems

which could arise with the suit (however unlikely) in real-time, thus providing the astronaut with the highest sense of safety and security imaginable.

However, the sensing capabilities of our suit go far beyond the structural integrity and physical state of the suit. In addition, our suit will be capable of monitoring the status of the astronaut's health through a variety of aspects including, but not limited to; blood pressure, cholesterol level, heart rate, body temperature, metabolic rate, levels of essential vitamins, stress level, and respiration rate. It will also broadcast health-related emergencies directly to mission control and team members, so that they will never be left guessing with regard to the health of a team member. In addition, it will allow doctors back in mission control to provide an accurate diagnosis with respect to the particular health issue in question, and then provide appropriate and relevant medical advice to the rest of the crew. In addition, this system will be capable of alerting the astronaut of an impending problem, such as a slowly decreasing level of essential nutrients, or an increasing level of bad cholesterol, thus preventing a health-related emergency before it even happens.

In addition to the various sensing capabilities of our suit, our suit will be fitted with the most advanced satellite communications systems. This will render it fully operational with voice-command, and capable of much faster and clearer transmission than any of today's suits. This completely hands-free communication in high-fidelity will prevent the need for repetitive transmissions and the often occurring problem of missed or misunderstood commands.

The micro-computer onboard the space suit will serve other functions as well. It will not only monitor the status of the suit's structural integrity and the health of the astronaut, but will also monitor the astronaut's circadian rhythms and provide him/her with advice about other tasks, such as; when to go to sleep, when to wake, and when to eat. The purpose of this component is to prevent asthenia syndrome which is caused by a disruption of an individual's natural circadian rhythms due to a lack of light and dark contrasts from day to night. The symptoms of asthenia syndrome are highly detrimental to the psychological well-being of the astronaut, not only during long space-flights, but during his/her routine daily schedule. Symptoms include, but are not limited to: back and abdominal pain, fatigue, listlessness, psychosomatic worries, stress, insomnia, anxiety, and even depression (Styf, Hutchinson, Carlsson, and Hargens). This information will then be relayed from the suit to the lunar module, International Space Station, and Mission Control back on Earth, as well as projected onto the heads-up display integrated into the astronaut's helmet. Furthermore, since accurate and continuous information regarding the astronaut's health will be constantly updated in real-time, doctors back on Earth will be able to provide the crew on the journey who are in charge of the care of their comrade with an accurate diagnosis. In addition, relevant and safe information will be transmitted regarding the proper procedures for treating the sick astronauts. This will allow him/her to be able to rely on world class medical care, even when he/she is thousands of miles away from the nearest hospital. Another worthwhile feature of the in-suit micro-computer is that it will be capable of playing for the astronaut a carefully selected compilation of relaxing nature sounds from various wildlife scenes and ecosystems, ranging from the Pacific coastline to the Amazon rainforest. And, in order to make the astronaut feel as much at home as possible, the communication system fitted on the X-Suit will be capable of allowing the astronaut to communicate directly with his/her loved ones through cellular phones, landlines, and even internet-based communications such as Vonage and Skype. Thanks to an advanced satellite-based system, the astronaut will also be able to communicate with virtually any person on any corner of the Earth, including video-chats using a wide variety of social networking applications in vogue today.

Our suit will also contain a resistance element. This will facilitate and exert resistance upon the individual and increase the effectiveness of a workout, which will help maintain bone and muscle mass, further stimulating nerve cells and blood vessels, and preventing the loss of fluid plasma from the blood. This blood loss could be extremely hazardous to the astronauts upon his/her return to Earth. Our resistance element will be electronically controlled and customizable in real-time, allowing the astronaut to choose and update the resistance level in order to achieve the greatest possible workout. It will also not interfere with the extravehicular missions presented to the astronaut throughout the expedition. This resistance element will be able to function as both a source of resistance and as a source of amplification, due to the electronic signal sent out by the integrated lithium ion battery, This signal will change the way in which the fabric fibers interlock, providing resistance or amplification through a process similar to muscle contraction without using the energy needed in similar applications.

In addition to the various benefits and improvements that can be found in almost every aspect of our suit, the true highlight is the Electro-Muscle Stimulation system embedded throughout it in various areas. The benefits of utilizing electro-muscle stimulation are numerous and have a wide range of both health-related and financial benefits. First of all, the electro-muscle stimulation pads will be focused on key muscle groups that need exercise the most during a long-term space flight. More specifically, our electro-muscle stimulation system will be focused primarily on deltoid, pectoralis major, rectus abdominis, abdominal external oblique, quadriceps femoris, biceps

brachii, tibialis anterior, pronator teres, trapezius, levator scapulae, latissimus dorsi, gluteus maximus, biceps femoris, gastrocnemius, soleus, and tibialus posterior (Starr, 2006). By utilizing electro-muscle stimulation on key muscle groups, a space agency can save the time normally attributed to exercise (usually 2 hours daily) while at the same time saving the space and fuel needed to haul large and heavy exercise machines to space. In addition, it can provide a better-rounded and better-targeted workout, while at the same time reducing and even preventing the effects of muscle atrophy by increasing the stimulation of nerve cells and blood vessels (Blomqvist and Staltin, 1983). By doing so and by effectively utilizing the electro-muscle stimulation system in the X-Suit, the astronaut will be better equipped to prevent the effects of bone- and muscle-mass deterioration, the formation of kidney stones, and the change of slow-twitch muscle fibers to fast-twitch muscle fibers- all of which have a detrimental effect on the astronaut's capability of readjusting to Earth's higher gravity environment. Especially after an extremely long-term in space, an astronaut might never fully readjust and live a healthy life on Earth.

Thus, our product, X-Suit, will provide tomorrow's astronauts with the cutting-edge of today's most advanced technologies in order to best protect astronauts and provide them with the tools they need to venture ever further into the space, the new frontier. The astronauts of today, like the pioneers of yesterday, represent the forefront of human ingenuity, all the while laying the foundation for the future of mankind.

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