Biomimetics- The Key to Better Space Suits

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Abstract

Current space suits are expensive, bulky, and hard to maintain. Space exploration will significantly benefit from advancements in space suit technology that allow for increased safety and mobility. Using biomimetics, implementing bio-inspired adaptations of flora and fauna into technology emphasizes the possibility of enhancing our modern-day space suits and revolutionizing the exploration of outer space. Here, we review the current challenges of space suits to form a baseline and better understand the limitations of space suits. The investigation underscored four significant concerns in space suit technology for space exploration: Radiation, thermoregulation, debris protection, and maneuverability. The research showed that biomimetics can be a powerful resource to model the next generation of space suits, resolving problems around radiation, thermoregulation, debris protection, and maneuverability. The research shows various flora and fauna with these characteristics and demonstrates potential for practical application. In conclusion, the research findings highlight the benefits of biomimetics in modern space suits.

Introduction

Space exploration is an arduous challenge that demands advanced technologies and equipment to ensure astronauts' well-being and safety in space. Space suits play an integral part in space exploration by protecting from space's harsh environment; however, current space suits have several shortcomings that restrict long-term exploration, radiation protection being of primary concern. Current space suits only offer enough protection for short-term living. NASA is exploring various techniques and technologies to mitigate radiation exposure during space travel.

Thermal protection in space suits needs improvement as its multiple layers impede astronauts' movements, making it harder for them to complete tasks outside their spaceship. Mobility is key for astronauts' quality of life as it will allow them to complete tasks outside the ship much more easily than with current space suits. Protection from micrometeoroid debris is also crucial, as they orbit Earth quickly and pose a high risk of colliding with astronauts. Innovation of space suits will be integral for successful long-term space exploration. Space suits need improvement for humanity's long-term interests in space exploration. Radiation protection is needed due to space's many health risks.

Biomimetics

Biomimetics, or imitating biology, is the study of using nature's designs as inspiration to advance space-suit technology for exploring space. Biomimicry has already been applied in some problem-solving efforts within space programs worldwide. Here are a few uses of biomimetics when designing space suits:

Design Inspiration: Biomimetics can serve as an avenue for space suit design inspiration, drawing from designs found within nature as sources.

Material Selection: Biomimetics can help select materials for space suits, using materials found in nature as inspiration to develop new space suit materials (for instance, spider silk as potential space suit material)

Functionality: Biomimetics can help enhance the functionality of space suits by drawing inspiration from nature for improving mobility and flexibility, such as imitating jellyfish movement as an example for improving mobility in space suits6

Biomimetics provides us with an effective means of creating space suits that are both efficient and sustainable, perfect for long-term exploration in space. By studying nature as our inspiration, we can develop spacesuits that offer greater performance & functionality for longer space exploration missions.

Several lifeforms on Earth can maintain thermoregulation even in extreme climates like space. The ever-growing debris in space poses a daunting obstacle that lightweight and flexible suits that allow an unrestricted range of motion will combat. Maneuverability poses essential criteria for the success of a space suit to enable the astronaut to have a more extensive range of movement outside of the shuttle to make repairs and conduct experiments. Although human civilization is only about 6,000 years old, nature has been changing and adapting to its surroundings for billions of years. Nature has developed efficient and effective solutions to various challenges over time, and these solutions can be studied and applied to improve technology, including space-suit technology. By studying the natural world, we can gain insights into how to create more sustainable and effective space suits that can help us explore and utilize the near-unlimited resources of space. Biomimetics is a field of study that involves learning from nature by imitating or taking inspiration from nature's designs and processes to solve human problems.[1]. This paper focuses on the emulation of biology and how we can use nature to advance space-suit technology to expand our horizons and use the near-unlimited resources of space.[2]

Protection from Radiation

1. Dangers of radiation [3]

Protection from radiation is imperative if we wish to travel into space. The lack of radioprotective space suits hinders the production of new cells in the brain. At the rate the body degrades due to amounts of radiation, the lack of neurogenesis can lead to reduced memory or brain damage. Radiation has catastrophic consequences on the cardiovascular system. It narrows arteries and removes the lining of the blood vessels, which causes several diseases. Radiation has the most significant impact on the DNA of humans. The four bases, guanine, cytosine thymine, and adenine, can easily be mutated, and these mutations eventually cause cancer in the body due to incorrect transcription of proteins. All cells in the body are endangered because of radiation, and there are many short- and long-term health consequences.

2. Hydrogenous materials [4]

Dihydrogen (H2) is an excellent radioprotective substance that shields against ionizing radiation that causes apoptosis of cells. This can help protect astronauts from the harmful effects of radiation during space travel. Ionizing radiation can break chemical bonds and strip electrons from atoms and molecules, causing serious damage such as cell death. Dihydrogen (H2) can protect against cell death caused by radiation, which is essential for the health and safety of astronauts during space travel. In conclusion, the radioprotective properties of dihydrogen (H2) can be useful in space suit design. By shielding against ionizing radiation, protecting against cell death, and potentially acting as an antioxidant, dihydrogen (H2) can help protect astronauts from the harmful effects of radiation during space travel.

3. Melanized Fungi [5]

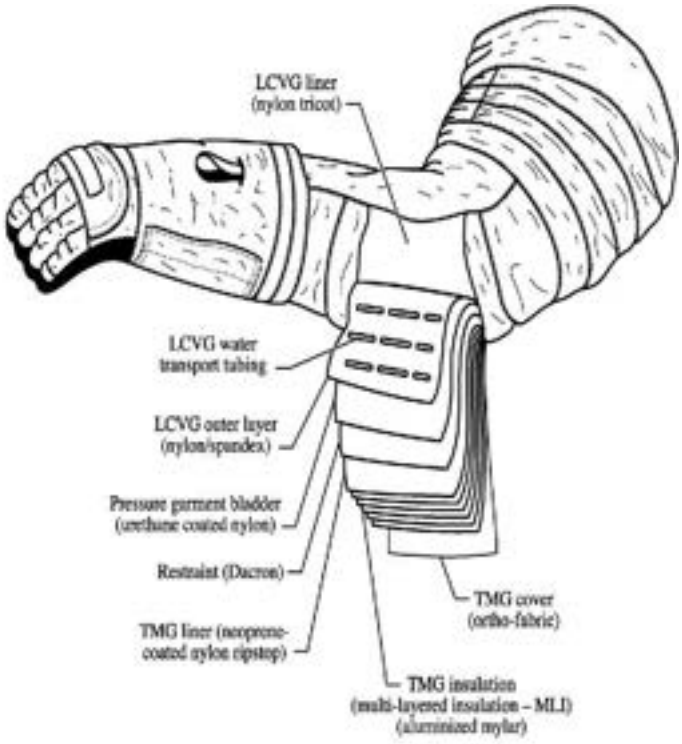
Melanin, the pigment of skin, has many radioprotective properties that can be applied to space exploration. On Earth, some environments have high background radiation, such as the remains of Chernobyl. Even still, animals can survive and adapt to their new surroundings. Melanized fungi are more common in Chernobyl areas, and studies reveal that non-melanized fungi can have the protective effects of melanin transferred to their cells. Melanin is a possible substitute for the several layers of current space suits that protect against radiation.

Thermoregulation

1. Fur

On Earth, there are several environments with subzero temperatures. Although these temperatures are daunting, several animals have adapted and now inhabit these areas. Fur is a natural insulator that animals use. When insulation is high, heat transfer is low. Seals and

whales also have a thick layer of blubber for insulation. Different parts of the body require different amounts of insulation. Thus, the amount of blubber can vary from the region of the body, which assists in movement.



2. Heat reflection (SWME)[6]

The human body cannot survive the harsh conditions of space and requires the assistance of technology to maintain comfortable conditions. Circulating water around the space suit allows it to absorb excess heat. The warm water is filtered through the SWME, where it is evaporated and recirculated. Furthermore, the SWME also prevents circulated water leakage, drastically improving astronaut safety. Although the SWME is highly experimental, it is a powerful way to maintain cool temperatures in space.

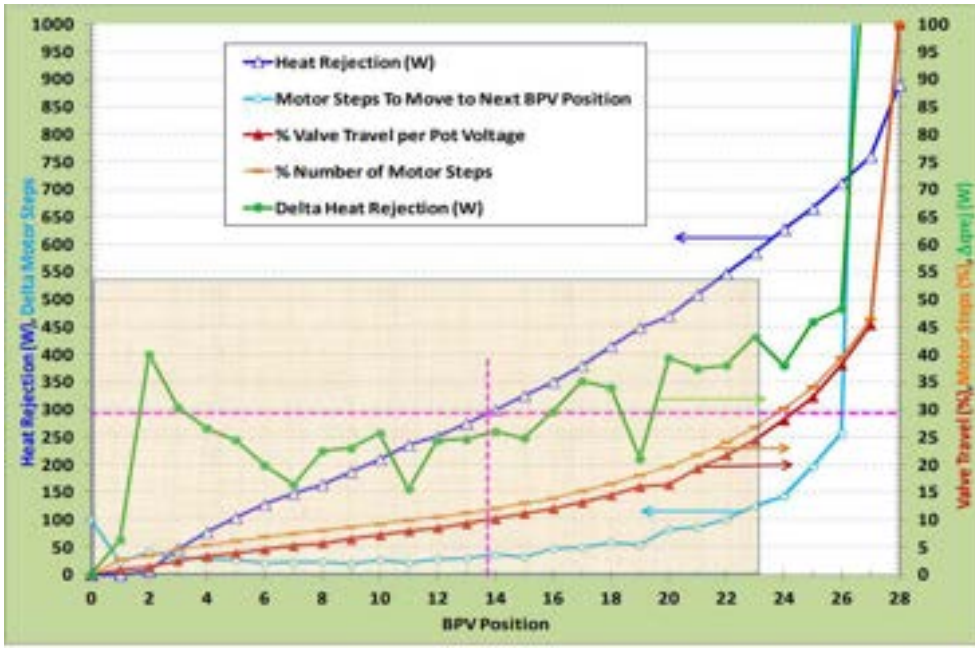


Figure 2: Heat Absorption from SWME. Increased water movement proportional to heat rejection

3. Thermal emitters [7]

Morpho butterflies have a distinct blue color that could be applied to achieve radiative cooling in space suits. The structure in the image below represents the pigmentation in the butterflies that can be integrated into space suits to decrease heat further.

Maneuverability

1. Boots[8]

Space suit boots cause significant problems when attempting extravehicular activities in space. Current space suits are not conducive to the advancement of science as scientists are almost always looking at the ground to ensure that they do not fall over anything. This is due to the number of layers astronauts must wear, resulting in their inability to feel the ground below them.

2. Custom space suits[9][10]

Current space suits are also highly oversized for the astronauts who wear them. Suppose custom space suits were created for each astronaut. Using new digital thread technology, astronauts can move like usual, as if on Earth. A small, stretchy, skin-like suit would be perfect for this type of technology, as digital thread technology could easily map out how tight the suit must be.

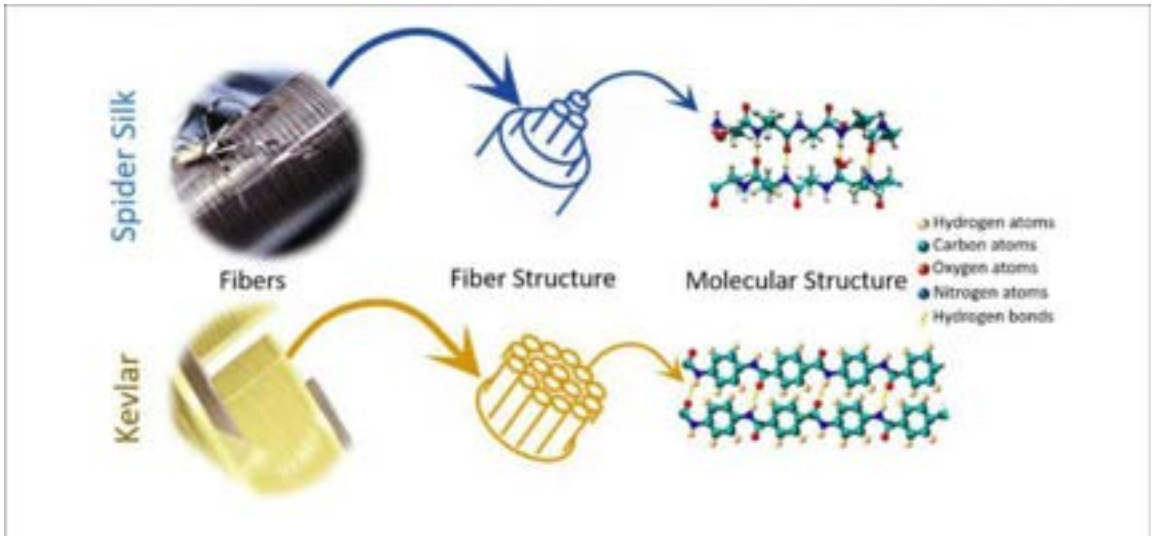
Debris protection

1. Spider Silk[11]

Spider silk is a robust material that could be applied in micrometeoroid protection. Spider silk is extremely durable due to the long strands of protein that compose it. Spider silk also comes in many variations. Some are strong and protective, while others are conducive to movement and flexibility. Spider silk is also easy to mass produce as genetically engineered goats make them along with their milk.

2. Kevlar[12]

Current debris protection technology in space suits mainly consists of kevlar padding around the suit to prevent injury to the astronaut and the technology in the suit. Kevlar also protects against leakages in the suit and helps to retain heat. Although Kevlar is highly versatile, it struggles against compressive strength and restricts astronaut movement.



Conclusion

Utilizing biomimetic design principles for modern space suits may yield several advantages. Biomimetic designs provide astronauts with enhanced safety during spacewalks and other activities by mimicking plant and animal features for added protection from radiation, debris, and other threats in space. Spacesuits with biomimetic designs offer greater protection during these activities by mimicking protective features found on plants and animals that help ensure astronauts' well-being in space.

Biomimetic designs also help increase the mobility of space suits by mimicking animal movements and flexibility to enable astronauts to perform tasks more easily and quickly. By

mimicking animal mobility and dexterity in design, spacesuits provide astronauts with a greater range of motion and dexterity.

Better Thermoregulation: Space suits designed with biomimetic designs can assist astronauts with maintaining optimal temperatures inside space suits, providing more precise temperature regulation during extreme temperatures. By mimicking animal fur or feather insulation properties, these suits may offer enhanced temperature management for astronauts.

Biomimetic designs can also make space suits more durable and easier to maintain by mimicking certain self-repairing features found in certain plants and animals; spacesuits designed using biomimetic designs will better stand up against space's harsh conditions, with fewer maintenance requirements over time.

Our understanding and ability to utilize space depends on our ability to improve space suits, specifically how we can use nature to our advantage with biomimetics. Although current space suits are functional, many aspects can be improved upon. Radiation protection, thermoregulation, enhanced mobility, and debris protection are only a few of the improvements that biomimetics can bring to the space industry to improve the lives of astronauts.

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