International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Fixing the Obsolete Spacesuit

Arnav Venkatesh[1], Sanay Pareek[2], Miss Sitara[3]

[1,2]Student, NHVPS, Bangalore
[3]Instructor, NHVPS, Bangalore

ABSTRACT:
Since the 1930's, spacesuits have been an inseparable part of space exploration. In the 21st century, with space exploration posing more challenges than ever, space suit design has been on the minds of several corporations in order to facilitate the growing necessity.
Out of the several problems of spacesuits, some include bulkiness, water circulation issues, obsoleteness and among others[13]. These problems have various solutions each, however the task that the corporations have, is to consolidate all of these issues solved, into one space suit.
These problems are solved by the adaptation of a hybrid mechanical pressure and polyethylene suit. Similar to MIT's BioSuit, our suit uses mechanical pressure to deliver the necessary pressure, but eliminates the BioSuit's need for constant heat supply using electric sources by using a phase-change material namely Rubitherm RT82. A polyethylene-nanoparticle layer provides the necessary radiation protection.

KEYWORDS: Mechanical pressure, polyethylene, graphene, carbon-nanotubes, Phase-Change Materials, Kevlar

INTRODUCTION:
Spacesuits are apparel that are worn to protect the human body in unearthly conditions. They mainly provide pressure, oxygen, water, cooling, protection from ionising radiation and micro-meteorites to the astronaut. Existing spacesuits are called Extravehicular Mobility Units(EMU).
Private organisations such as SpaceX have taken up Mars landing by 2026-2027[4]. With this just around the corner, SpaceX, NASA, JPL and among other corporations have been eyeing for the right spacesuit for just this task.
The need for a better spacesuit in the current world is more than ever today, due to the high development in space technologies. The current space suit has many issues like water leaks[8], audio/radio communications problems, mobility hindrances, etc. Resolving these issues is necessary for the safety of the astronaut, especially knowing that future Mars missions are upcoming and such missions require a slightly versatile design. In the case of Mars, developing a suit requires us to take into account its harsh climate, which has high radiation and just between 600-700 Pa atmospheric pressure.[1]
As we also know that pressure in space is zero, there is quite a difference in the development of a spacesuit for deep space and Mars. Thus, building a versatile spacesuit common for both such missions, is our aim.

LITERATURE REVIEW:
NASA xEMU
https://oig.nasa.gov/docs/IG-21-025.pdf

The NASA xEMU is the newest spacesuit, engineered by NASA, the first of which was released after more than 3 decades. The Exploration Extravehicular Mobility Unit (xEMU) is NASA's prototype next-generation spacesuit for lunar and beyond exploration. Featuring a unique design with increased mobility, and improved flexibility, it aims to surpass the limitations of the current EMU. Challenges remain in schedule and cost, but xEMU promises enhanced astronaut comfort, safety, and performance for future deep space missions. Axiom
Space has its own version of the AxEMU.[2]

MIT BioSuit

https://news.mit.edu/2014/second-skin-spacesuits-0918

MIT researchers introduce a prototype "second-skin" spacesuit featuring active compression garments with shape-memory alloy coils that contract with heat of about 60ºC[16]. Designed to improve astronaut mobility and comfort, these coils, heated via electrical current eliminate bulky pressurisation systems. The technology of mechanical pressure illustrated by this BioSuit will be utilised by our paper.

LIMITATIONS of EXISTING SOLUTIONS:

1. The MIT BioSuit is a new idea and a great invention, but it has a major problem, that is, it requires a constant heat of around 60ºC to maintain the pressure using the micro-springs embedded inside the suit [5].
2. The xEMU suit is a novel concept, requiring several rounds of testing before it can become more widespread and several sources claim it will not be completed before the Artemis missions take place [14] [6, pg 11-13]. It also has several technical issues related to the main computing system, and there are also several audio and radio communication problems.

Hence these limits and issues make the need for a new space suit that incorporates the problem solving components of these suits while eliminating their issues.

GOALS of DESIGNING a better SPACESUIT:

Providing necessary pressure to the astronaut’s body without using gas pressure-

Providing necessary pressure to the astronaut’s body without using the standard gas pressure is important. That’s because the gas pressure hinders the mobility of the astronauts and takes up large portions of the backpack space. If we decrease the pressure, then the chances of the astronaut contracting decompression sickness increases. Thus, by eliminating gas pressurised suit, the mobility and spaciousness of the astronaut will increase.[18]

Providing protection from ionising radiation-

Providing better protection from ionising radiation in a smaller form factor is one of the goals. Current suits have many layers to do just this, which makes the suit bulky. So, by using a thinner layer to provide protection from radiation, we can decrease the suit's bulkiness.

Reducing the bulkiness of the suit-

Current suits are very bulky due to which they become a problem as they reduce the mobility of the suit. They also make wearing/removing the suit very tedious, especially in the ISS. By reducing the bulkiness of the suit, the mobility will be increased and wearing/removing the suit will also become much easier for the astronauts.

Providing cooling to body-

Providing effective cooling to the body is necessary as astronauts’ bodies tend to get heated up because their body heat cannot dissipate. Thus, without an effective cooling system the astronaut may not be able to sustain comfortably in the suit.

Eliminating the issue of flawed fitting

In the current spacesuits, there are many sizes for different parts of the suit and no perfect suit for an astronaut. They must use what best fits them, which has caused issues in the past. Fixing this problem will help provide better comfort to the astronauts and eliminate the need for different components of different sizes.

This will make the usage of the suit more efficient.

Increasing mobility of the suit-

Increasing mobility of the suit is very important, as it allows the astronauts to perform tasks in space with ease. Current suits do not have great mobility. For example, it's a fact that astronauts had to bunny hop on the moon instead of walking and have had issues with finger movements while performing repairs in space. By increasing the mobility, it makes the basic tasks of astronauts easier.

DEFINITIONS:

1. BULKINESS: A feature of the suit that takes up too much space, causes congestion and makes it tough to walk and work on extraplanetary surfaces.
2. PHASE-CHANGE MATERIALS: Phase change materials (PCMs) are substances which absorb or release large amounts of so-called 'latent' heat when they go through a change in their physical state, i.e. from solid to liquid and vice versa.
3. MECHANICAL PRESSURE: The pressure exerted by a mechanism, in this case micro-coils/springs, that is used to substitute for the gas pressure in EMUs.
4. SUITS: refers to spacesuit in general or biosuit/xEMU/EMU depending upon the context.

OUR DESIGN/HYPOTHESIS:

1. Regular gas pressure would be substituted with mechanical pressure suit similar to MIT's BioSuit.The micro-springs would provide approximately 0.25-0.3 bars of pressure that is considered sufficient for space.[19]
2. The problem of heating the mechanical pressure suit would be overcome by the usage of phase-change materials. By our calculations, the best suited PCM for this would be the commercially available Rubitherm RT82.[3]
3. This Rubitherm RT82 is a highly cost-efficient PCM with a congealing temperature 77-82ºC which is more than enough for our 60ºC requirements.
4. The PCM, in its heated liquid form, would be stored in the back storage unit of the astronaut connected to fluidic channels that further distribute into microfluidic channels throughout the suit. These channels will carry a liquid, like water or glycol that will continuously get heated as it passes through the PCM in the channels. They will be pumped using a general pump.
5. After an insulating layer of Kevlar,a unique design will be incorporated to protect the suit from ionising radiation. A study was conducted to review the credibility of polyethylene's radiation proof structure and its interaction with carbon nanotubes and graphene. These two components greatly support our model in several ways. Firstly, this mix has been proven to be a great radiation proof material.[10] Then it is a great insulator to trap the PCM heat.These materials are highly elastic and flexible in nature providing further incentive to use them as protection against radiation protection.

6. To ensure protection from wear & tear and micrometeorites, a layer of Kevlar would bring the whole suit together.[15]
7. The inner-helmet would still be pressurised by oxygen as there is no way to mechanically pressurise the face, safely.
8. Due to the layer of kevlar, the suit becomes a bit rigid, slightly decreasing mobility on the joints. So, a viable option would be to use aerospace-grade aluminium to construct bearings near the joints. To add protection to bearings themselves, their exposed layer would be coated with Zylon[16].
9. The backpack, in our low bulkiness design would consist of the following:

A. PCM material
B. Tube Heat Exchanger for a Liquid Cooling and Ventilation (LCVG) system that generally is the lowest layer. This also uses microfluidic channels to transport cool water to cool the astronaut's body. This is the smallest component in the backpack.
C. The existing technology of communications and suit operations would remain the same.
D. Oxygen tank
E. Pressurised gas for the Cold Gas Thrusters

METHODOLOGY:

1. The usage of the LCVG has been retained in our model as it does not provide much problems. However, microfluidic channels are used to facilitate cooling of the body, which prevents leakages.
2. Mechanical counter-pressure technology has been used in our project to provide necessary pressure on the body rather than using traditional gas pressurised suits to increase mobility.
3. In order to provide the required heat to the mechanical pressure suit,a PCM is being used instead of the battery packs that would provide electrical heating to it. The specific PCM used would be Rubitherm RT82.
4. A layer of Kevlar would be added on top of it to make sure the heat is retained.
5. The next layer would be polyethylene, carbon nanotubes and graphene nanoparticles that would protect against ionising radiation.
6. A thick kevlar layer would then be added to protect against micrometeorites, as has been done in EMUs of the past.

MAIN MATERIALS:

1. Suit- The mechanical pressure suit would be fabric lines with micro springs that are proprietary to MIT's BioSuit.
2. Rubitherm RT82- This best suits our model due to reasons like high melting and congealing temperature, cost effectiveness and availability.
3. Kevlar- A highly durable fabric which has high tensile strength and moderate flexibility. It is also a great thermal insulator. Due to this it is used in our project.
4. Zylon- A highly strong material that has been coated between aluminium bearings to provide protection.
5. Aero-space aluminium- A highly durable and lightweight aluminium material.

LIMITATIONS:

Since our model is a novel idea, it is nearly impossible to estimate its cost. We estimate it to be a bit expensive due to the inculcation of new technology that has yet to be mass produced. The research, time and development that will go into making this is huge, which will also be a factor in increasing the cost. But, with the removal of the gas pressure system we greatly reduce the cost of a general EMU. Also this suit must be tested properly before use, that is presently impossible to do so.

CONCLUSION:

Of all the 6 goals stated above, we believe our model can best achieve all of them.

1. Goal #1 is achieved with the usage of a mechanical pressurised suit(like the biosuit) which will eliminate the need for gas pressure.
2. Goal #2 is achieved with a layer of polyethene and nanoparticles.
3. Goal #3 is achieved by the whole space suit itself. By use of materials resembling the BioSuit, we can drastically reduce bulkiness, even in the backpack.
4. Goal #4 will be achieved with the introduction of microfluidic channels in the LCVG being used for cooling.
5. Goal #5 and #6 are achieved with the effective application of the BioSuit technology.

In addition to achieving the main six goals, most importantly, we have also solved the issue with the BioSuit itself, i.e., the problem of maintaining the BioSuit's temperature up to 60°C by using PCMs.

Humanity's adaptation to 1 ATM pressure has become a limiting factor for space exploration. The human body's susceptibility to radiation has also raised concerns about sending humans to such hostile conditions. This report not only solves the problems that corporations deal with like water leakages, mobility issues, etc., but also makes the suit durable and versatile. Its versatility can be demonstrated by its usage, both for space and interplanetary missions. The overall suit design is also quite flexible with good mobility making it a great option for all
kinds of space-exploration missions.

PICTURES:

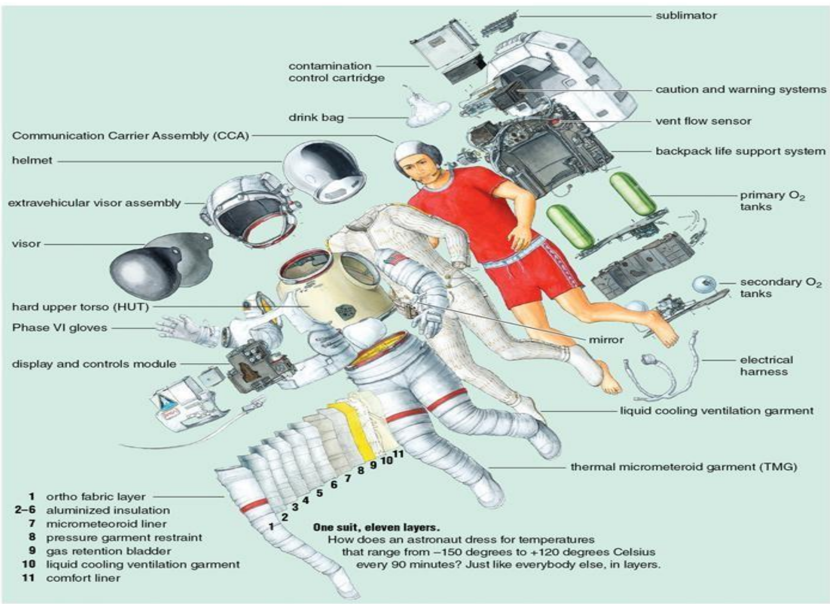

Fig (1) Existing EMU design with its 11+ layers

Fig (2) Our model

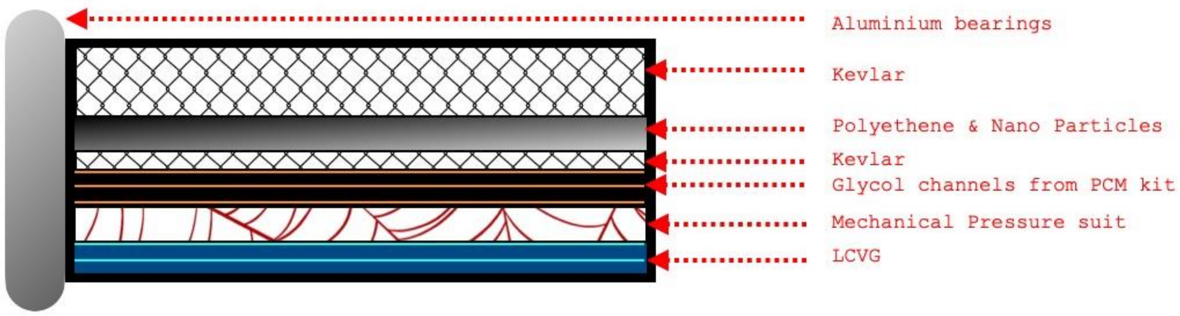

Fig (3) Layers of our suit

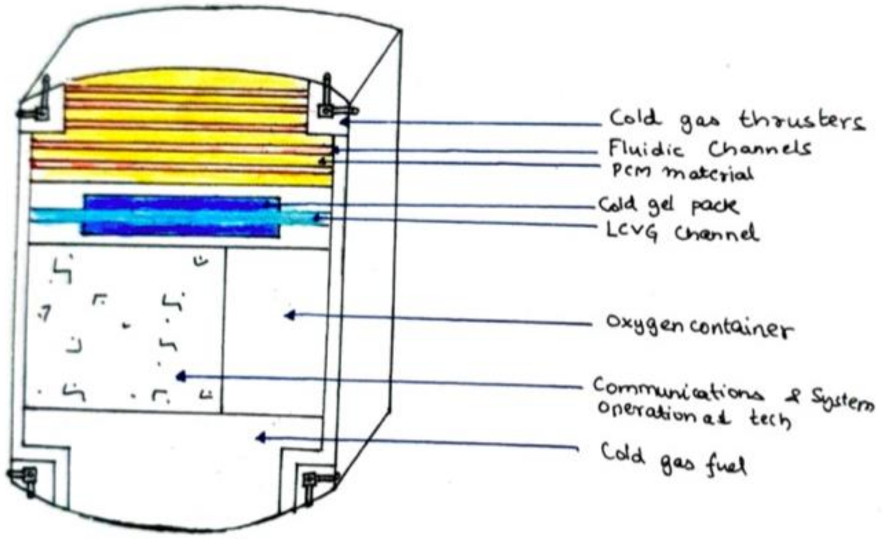

Fig (4) Backpack References

1. Arizona State University. (n.d.). *Atmosphere*. Mars Education | Developing the Next Generation of Explorers. Retrieved December 31, 2023, from https://marsed.asu.edu/mep/atmosphere
2. *Axiom Suit — Axiom Space*. (n.d.). Axiom Space. Retrieved January 1, 2024, from https://www.axiomspace.com/axiom-suit
3. Borden, S. (n.d.). *Garment, Liquid Cooling/Ventilation*. National Air and Space Museum. Retrieved January 1, 2024, from https://airandspace.si.edu/collection-media/NASM-A201300530 00cp01
4. Chang, K. (2023, October 13). Elon Musk Says SpaceX Could Land on Mars in 3 to 4 Years. *The New York Times*. https://www.nytimes.com/2023/10/05/science/elon-musk-spacex -starship-mars.html
5. Chu, J. (2014, September 18). *Shrink-wrapping spacesuits | MIT News | Massachusetts Institute of Technology*. MIT News. Retrieved January 1, 2024, from https://news.mit.edu/2014/second-skin-spacesuits-0918
6. *Final Report – IG-21-025 – NASA's Development of Next-Generation Spacesuits*. (2021, August 10). NASA OIG. Retrieved January 1, 2024, from https://oig.nasa.gov/docs/IG-21-025.pdf
7. Foster, W., & Meginnis, I. (2022, July 14). NASA Advanced Space Suit xEMU Development Report – Integrated Communication System. Retrieved January 1, 2024, from https://ttu-ir.tdl.org/server/api/core/bitstreams/540c96aead24-4128-b3be-858c5f3d904a/content
8. Foust, J. (2022, May 18). *NASA puts ISS spacewalks on hold to investigate water leak*. SpaceNews. Retrieved December 31, 2023, from https://spacenews.com/nasa-puts-iss-spacewalks-on-hold-to-investigate-water-leak/
9. *Japan researchers invent solar-cell fabric*. (2012, December 11). Phys.org. Retrieved January 1, 2024, from https://phys.org/news/2012-12-japan-solar-cell-fabric.html
10. McSwine, D. (2023, November 7). .,. Retrieved January 1, 2024, from https://www.sciencedirect.com/science/article/abs/pii/S0094 576520300898#preview-section-snippets
11. MIDWEST RESEARCH INSTITUTE. (n.d.). *LIQUID COOLED GARMENTS*. NASA Technical Reports Server. Retrieved January 1, 2024, from https://ntrs.nasa.gov/api/citations/19750007244/downloads/1 9750007244.pdf

12. NASA (Director). (2020). *NASA Introduces New Spacesuits for the Moon and Mars* [Film]. NASA YouTube. https://www.youtube.com/watch?v=yj6LYpZosRU
13. Nasir, S. (2022, April 29). How ageing spacesuits are a problem for astronauts during spacewalks. *The National*. Retrieved December 28, 2023, from https://www.thenationalnews.com/weekend/2022/04/29/how-agei ng-spacesuits-are-a-problem-for-astronauts-during-spacewalk s/
14. Roulette, J., & Kowsky, J. (2021, August 10). NASA's new space suits are delayed, making a 2024 Moon landing "not feasible". *The Verge*. https://www.theverge.com/2021/8/10/22618275/nasa-spacesuits -delay-inspector-general-report-2024-artemis
15. Wilson, B. (2017, October 5). *"Taternauts" and Spacesuits: How Astronauts Stay Safe in Space*. National Air and Space Museum. Retrieved January 1, 2024, from https://airandspace.si.edu/stories/editorial/taternauts-and-spacesuits-how-astronauts-stay-safe-space
16. *Feltman, R. (2014, September 18). MIT's futuristic spacesuit works like shrink wrap - The Washington Post. Washington Post. https://www.washingtonpost.com/news/speaking-of-science/wp/2014/09/18/mits-futuristic-spacesuit-works-like-shrink-wrap*
17. *Vigolo, B., Penicaud, A., Coulon, C., Sauder, C., Pailler, R., Journet, C., ... & Poulin, P. (2000). Macroscopic fibres and ribbons of oriented carbon nanotubes. Science, 290(5495), 1331-133.* https://www.science.org/doi/abs/10.1126/science.290.5495.1331
18. *Klaus, D., Bamsey, M., Schuller, M., Godard, O., Little, F., & Askew, R. (2006). Defining space suit operational requirements for lunar and Mars missions and assessing alternative architectures (No. 2006-01-2290). SAE Technical Paper. https://www.sae.org/publications/technical-papers/content/2006-01-2290/*
19. *Arroyo, M. (2021, September 22). ,. , - MIT. Retrieved January 7, 2024, from http://mvl.mit.edu/EVA/biosuit/index.html*
20. *Rubitherm. (n.d.). Data sheet. Data sheet. Retrieved January 7, 2024, from https://www.rubitherm.eu/media/products/datasheets/Techdata_-RT82_EN_09102020.PDF*