Final Project Option 2: Habitation Systems Concept Studies

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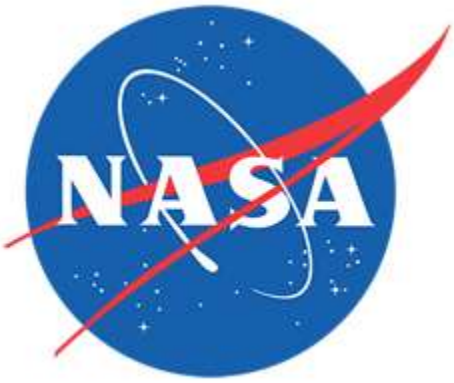


Habitat System 1: C. Crew Health, Component: Exercise Equipment

Space is the final frontier. The very frontier that puzzled early astronomers, like Galileo and Keplar, for centuries. Thanks to modern technology astronauts have been able to visit the moon and establish a sky lab, the ISS, in Low Earth Orbit. This station that flies over the Earth at 17500 mph holds Earth's bravest pioneers. These astronauts live in the microgravity environment of space for months at a time.

Space exploration could not happen without a healthy crew. Crew health is one of the most important habitat systems for success in space. One vital component of keeping a crew healthy is exercise. Exercise is so important that NASA requires its astronauts to train 2 hours a day (Dempsey, 2007) Exercise is also proven to boost immunity and morale. Both are highly important for mission success in a microgravity environment. In microgravity astronauts aboard the ISS suffer muscle atrophy and bone loss (Lewis, 2017). This is because astronauts do not have to fight earth gravity (equal to 1g) to sit or stand. Their bodies adapt to their new environment. However, upon return to Earth gravity the weakened astronauts can be subject to strained muscles and stress fractures due to the sudden increase in gravity.

To combat this the ISS has three pieces of exercise equipment. The Cycle Ergometer with Vibration Isolation System (CEVIS), the Combined Operational Load-Bearing External Resistance Treadmill (COLBERT or T2) , and the Advanced Resistive Exercise Device (ARED). These pieces of equipment are specifically designed to work in microgravity. They are each unique in the way they train the astronauts' body. This is vital because the muscles of the body need to be worked at different angles and with enough time under tension to stay strong.

CEVIS is important for maintaining cardiovascular health and endurance. CEVIS is like a stationary bike on Earth. It lacks a seat because a seat is not needed in microgravity. Astronauts lean against a back rest and pedal. CEVIS is equipped with shock absorbing springs that keep it from shaking the space craft. This is important because shaking the ISS could cause the solar panel arrays to shift and not absorb enough sunlight. All of the exercise equipment aboard the ISS share shock absorption abilities.

COLBERT is like an Earth treadmill except it has two bungie cords on either side that hook into a harness. This forces the astronauts down onto the treadmill so that they can run. The purpose of this machine is to build and maintain cardiovascular endurance. It also helps astronauts "muscle memory" for walking. COLBERT is unique in that it is named after the talk show host Stephen Colbert. It uses springs and dampeners to reduce vibrations (Siceloff, 2009).

ARED is the crown jewel of the ISS gym. ARED is a weightlifting machine that can be used for basic compound movements like squats and deadlifts. It is unique from the other two because it provides an adjustable work load up to 600 lbs. The way it works is by using a system of vacuums and pistons to produce resistance. This machine is vital for astronauts because it works the joints, ligaments, and muscles in ways that CEVIS and T2 can't. All together they are vital to the overall health and fitness of the astronauts.

Company or Agency: NASA

Since NASA's creation in 1958 they have been the world leaders in aeronautics and space exploration. NASA has also been a main contributor in establishing the International Space

Station. They have provided all of the current workout equipment because NASA understands just how vital it is to their mission success.

NASA is heavily focused on White House Space Policy Directive 1. This directive states that NASA should direct its resources to another manned lunar mission followed by the first manned Mars mission. According to NASA Administrator Jim Bridenstine we are going to explore past the ISS and focus on building Lunar Gateway (NASA Video, 2019). Lunar Gateway will be smaller than the ISS and will orbit the moon. It will be a vital operating center for future exploration. It will also be in deep space so astronauts will need to be able to be as independent as possible.

Since Gateway will be a hub for stays up to three months in deep space it must have exercise equipment. The astronauts there will be in microgravity and will have to maintain their fitness just like on the current ISS. NASA developed the current exercise equipment on the ISS and possibly will build the equipment for Lunar Gateway in 2022.

Next Phase of Component:

Currently the next phase for the equipment will be utilizing it in deep space on Gateway. Gateway is scheduled to begin construction in deep space in 2022 (Mahoney, 2018). The biggest difference between the ISS and Gateway will be the size. Gateway is about the size of an apartment which is much smaller than the ISS. The smaller size means that it cannot hold three pieces of exercise equipment. Every square inch is valuable. A new design is absolutely necessary for deep space.

Currently all of NASA's exercise equipment works well in microgravity. However, Gateway calls for a piece of equipment that combines the adjustable weight resistance of ARED

with the cardiovascular benefits of COLBERT. At the same time it must be light and take up minimal space. So far NASA hasn't announced any new equipment that might be in the pipeline for Gateway.

What needs to happen next is the design of this equipment. Deep space survival aboard the Gateway will require a hybrid machine. This hybrid machine will be able to efficiently train most muscle groups and the cardiovascular system. It must also fold away and be fairly light. This is a lot of criteria to meet but it is not impossible.

Bridging the Gap:

For this piece of equipment we need to look at small machines that train multiple muscle groups at once and adapt it for space. By training multiple muscle groups at once we can have a more efficient machine.

Step 1 would start with the row machine. The row machine is a popular machine in gyms that simulates rowing. It is a top exercise for building cardiovascular endurance by using a flywheel to generate resistance. Using a similar design as the wheel in CEVIS the machine could still produce resistance in microgravity. The bungie tie downs from COLBERT could keep the astronaut from floating off the machine. Even with these modifications the machine could still fold similarly to the way it does in commercial gyms.

Step 2 would be to add some ARED elements to it. There could be a second housing that had pistons with adjustable resistance. Replacing the barbell concept with a smaller dumbbell or cable concept would save space. The astronauts could do standing dumbbell type exercises to exercise the push muscle groups that aren't trained in the pulling motion using in rowing. ARED type pistons could be linked to the seat for leg press type movements. This would ensure a total

body workout that trained the push muscle groups, pull muscle groups, lower body, and cardiovascular system.

Step 3 would be to test aboard the ISS. Given the minimal size it shouldn't be too difficult to fit onto the ISS. In microgravity the same springs and dampeners that CEVIS uses could be applied here.

Step 4 would be to launch to Gateway.

Habitation System 2: D. Extra Vehicular Activity (EVA) Component: Space Suit

The space suit is a highly important piece of equipment for space exploration. As we explore farther into deep space the challenges our astronauts face increase. One of those is extended space walks on planetary surfaces.

The space suits are vitally relevant to space exploration because they provide the basic life support functions humans need in space. This includes radiation protection, a breathable atmosphere, and methods for waste collection and temperature control. Without these suits humans would die in the vacuum of space. The current space suit (EMU) has been in use by NASA since 1981 with only minor changes ("Building A Better Space Suit," 2019). These suits are cumbersome and take a long time to put on. However, they serve their purpose well in a microgravity environment. Given that astronauts need little muscular movement to propel themselves through microgravity flexibility of the suit, particularly the lower half, is a non-issue. As humans explore deeper into space the performance needs of space suits changes.

Once on extraterrestrial planets astronauts will need the most efficient suit for surface exploration. This includes a suit that doesn't hinder an astronaut's natural biomechanics while exploring. They must be able to crouch, walk, and move safely over uneven terrain. This will require a significant improvement in flexibility the current EMU doesn't offer. At the same time the suit can't be too thin, or it risks punctures and insufficient radiation protection. This suit will also need to be somewhat comfortable as astronauts will be exploring in them for up to eight hours every day. This will include measures for waste, sweat, and temperature control. The new suits will also need strong communication equipment so that astronauts can effectively coordinate movements.

The Aerospace Corporation helped develop the Z2 which NASA took and developed into the Exploration Extravehicular Mobility Unit (xEMU) ("Exploration Extravehicular Mobility Unit (xEMU),"2019). This suit was introduced publicly on October 15, 2019 and will be tested on the ISS shortly before being launched to the moon in 2024. The xEMU consists of several major upgrades from the EMU. This includes sealed bearings for increased movement, unlimited carbon dioxide scrubbing, and expanded field of vision. Without this component NASA would only be sending unmanned satellites and rovers into space. Without space suits there would be no ISS, no moon landing, and no research on the effects of microgravity on humans.

Company or Agency: NASA and Aerospace Corporation

NASA is one of the agencies working on this suit. Since its creation NASA has been at the forefront of space exploration for the world. NASA has been the only agency to send humans to the moon and has revolutionized the field of aerospace engineering. On December 11, 2017 President Donald Trump signed the White House Space Policy Directive 1. This Directive states that NASA will devote resources in sending more astronauts to the moon followed by a manned mission to Mars (Wang, 2017).

Directive 1 is a primary focus for NASA. The successful development of this suit is one of the significant benchmarks that NASA is close to another lunar mission. Without this component and habitat system Directive 1 could not exist. Like mentioned earlier in this paper there would be no astronauts at NASA without space suits. Without this equipment NASA's focus would not be on manned space exploration, but more on the aeronautics side. NASA would solely consist of scientists, engineers, and rover teams that explored from the surface of

Earth. There would also be no ISS, no space walks, no great astronauts like Scott Kelly or Sunita Williams, and no lab experiments in microgravity. So this component is what the entirety of successful space exploration hinges off of.

The Aerospace Corporation is a nonprofit in El Segundo, California that was founded in 1960. They operate a federally funded research and development center (FFRDC) that contracts with NASA for several projects. They're primary focus is working with government and commercial companies for flight and space travel consulting. They're expertise ranges from launch assurance, satellites and orbit, and space exploration. They played a major role in space suit production by providing NASA with the Z2 prototype ("Building A Better Space Suit," 2019). The Z2 became the Z2.5 and eventually the xEMU. They have engineers that have worked on all three versions at the Johnson Space Center in Houston. This directly contributes to their goal of providing resources for space exploration. Like previously mentioned space research and exploration hinges off the success of a space suit. The Aerospace Corporation has also heavily influenced designs for satellites and the Lunar Gateway.

Next Phase of Component:

According to Chris Hansen, who is the Manager of the EVA Office at NASA, the next phase of xEMU will be space testing onboard the ISS ("Houston We Have A Podcast,"2019). Before suits can be used in space they must be able to work in a vacuum chamber. This testing can be dangerous but is necessary. After clearing vacuum testing the suits will be shipped to the ISS to test in several EVAs (space walks) by 2023. Once it completes EVA testing it will be ready for the lunar landing in 2024.

Bridging the Gap:

The final gap between xEMU and deep space exploration is its qualification testing. Once it passes these tests it will be ready for the next lunar mission.

Step 1 is to build a Development Verification Test (DVT) unit of the xEMU. The DVT is the final design of the xEMU and will have all the features necessary for deep space. The DVT will be tested to the absolute limits in a vacuum chamber. After it passes unmanned testing in the vacuum chamber it is time to test manned suits in the chamber.

Step 2 is to build two qualification suits. Two are necessary for parallel testing. These suits will be used for human tests in a vacuum chamber. This is dangerous but risks can be mitigated with proper precaution. Once the suits pass the battery of human tests it will move to the next step.

Step 3 is to build the flight suit. This suit will go to space. It must pass some preflight checks and then it will be sent to the ISS

Step 4 is space testing. This will consist of several EVAs with the EMU and xEMU side by side. This will give NASA the data it needs to compare the performance of xEMU to the EMU. After that the xEMU will be authorized as the suit for the next moon landing.

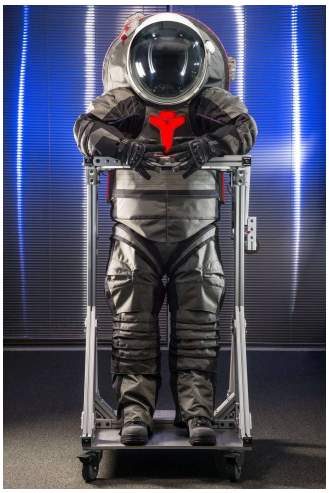
Step 5 is the moon landing in 2024. This will be historic because it will mark the return of man to the moon along with the first ever female to walk the moon's surface. It will also be a huge stepping-stone for the Mars landing in the mid 2030s. After xEMU completes this mission it will be the suit used to walk the surface of Mars for the first time in Milky Way history.

NASA Administrator Jim Bridenstine

Introduces xEMU Oct. 15, 2019

NASA Z-2 Prototype Designed

By Aerospace Corporation



Astronaut Sunita

Williams using CEVIS

Astronaut Demonstrates ARED

With Cable Attachment

Astronaut Sunita Williams Using

The COLBERT

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