NSBE Space MDRS Projects: Power and Sensor Requirements for Everyday Health Benefits

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Abstract - *As the NSBE Space Project looks to go to the Mars Desert Research Station (MDRS) in the Utah Desert, the medical officer will be responsible for checking the health of the crew. This paper proposes a power and sensor pack that would power the entire NSBE suit that can monitor certain health aspects of the member. It will provide a literature review of current sensors useful to the Medical Officer and a design that would be comfortable enough to for the wearer to wear all day for the sensors to give information. This paper will focus on designing a power pack that will power the suit material, gloves, tricorder connection, and take the heartbeat, temperature, and blood pressure of the wearer.*

Keywords: *Space Suit Requirements, Power Requirements, Health Sensors.*

1 Introduction

1.1 Mars Desert Space Station

The Mars Desert Research Station (MDRS), owned and operated by the Mars Society, is a full-scale analog facility in Utah that supports Earth-based research in pursuit of the technology, operations, and science required for human space exploration. [1] Crews work during an eight month rotation during the year to simulation astronaut training sessions. These are two week rotations with a crew of six astronauts that have defined roles to carry out planned experiments and missions in a simulated environment.

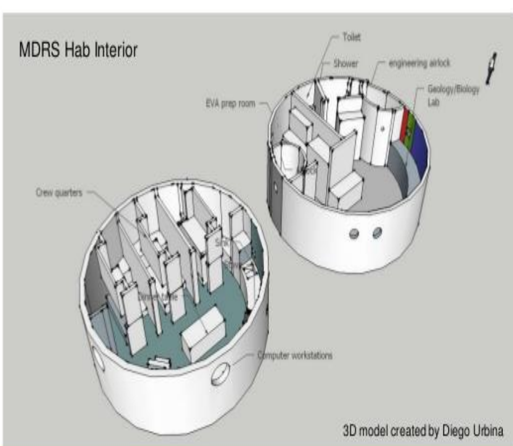


Figure 1: MDRS Layout [2]

The NSBE Space SIG has been going to the MDRS since 2007 with various members going on crew rotation. In preparation for an all NSBE crew mission, an experiment of NSBE space suits was proposed to monitor health effects of the a simulation mission on the body. This research has implications in multiple arenas such as sports medicine and long duration exertions. The proposed project will send health data directly to Command from the MDRS station as well as to scientist to analyze the health data in real time to give suggestions to the Leader and Chief Medical Officer (XO).

1.2 MDRS Roles

There are four distinctive roles at MDRS: The Leader, Chief Medical Officer (XO), Chief Engineer, and Payload Specialists. The leader is in charge of the day to day routines and important decisions for the crew's health and safety as well as the use of the habitat. The Chief Medical Officer makes all decisions regarding health and injury throughout the rotation. The chief engineer is in charge of the functional working of the habitat, greenhouse and astronomy section. The Payload specialists are astronauts that bring specific experiments to the rotation, such as biological, geological, and agricultural experiments. Each member follows the hierarchy of the Leader, XO and Chief Engineer regardless of their experiments. All crew members answer to Command with their daily reports and any direction given from Command.

2 Literature Review

Figure 1 shows the layout of the MDRS Living and Science quarters. There is a shower and toilet on the MDRS habitat, but a schedule is made at the beginning of the rotation that dictates the water schedule.There are six individual bedrooms on the second floor that provides privacy, but there is no standard suiting for the participants. Currently, the simulation has the astronauts wear their own clothes under the simulated astronaut suits. Figure 2 shows the MDRS simulation suits. The Author went in 2008, and wore her own clothes underneath the simulation suits. This discussion looks at standard suiting for day to day operations in the Habitat, as well as under suits for the astronaut suits for simulation. This paper in particular looks at the health sensors that can provide quantitative information on the health of the simulated astronauts.

Figure 2: Christianna Taylor, PhD in Astronaut Suit at MDRS in 2008

2.1 Space Suits Requirements

The day to day space suit has certain requirements in order to maintain comfort, flexibility, sanity, and most importantly monitor the health of the simulated astronauts. It was round that it should weigh no more than 10-15% of the body weight when they tested children carrying backpacks. [1, 4] In this case, these were middle aged (10-15) children carrying back packs and assessing the effect on their spines. In our case, we are not carrying an external load, but keeping the sensors as close to the body as possible and integrated into the suit. Therefore, the suit is distributing weight evenly throughout the suit without introducing extra torques and forces on the body. Assuming that the clothes weigh 2.5 lbs. or 1.13kg without shoes. [5] This study weighed adults over a year period and found that for men the average weight of their clothes was 2.5 lbs., while for women the weight was 1.75 lbs. or 0.8 kg. For the purpose of this paper, we will assume a male at 85 kg, which would make the maximum mass requirements of 8.5 kg, with a minimum of 0.8kg for clothing requirements. This paper assumes that the actual fabric will be 0.8 kg to allow for maneuverability, and the least amount of stress upon the simulated astronauts. It will put a further constraint of 0.5 kg for all the health sensor systems combined. Since the sensors will be integrated into the suit system, this will put a total mass constraint of 1.3kg without shoes on the simulated astronauts.

2.2 Health Sensors

The first generation of health sensors are looking at the basic vital signs taken by a triage nurse before making assessments to a doctor. These are the body temperature, pulse rate, blood pressure, and respiration rate and hydration levels. A deviation of ± 3.5°C from the resting temperature of 37°C can result in physiological impairments and fatality. [6] Therefore, monitoring the body temperature of the astronauts is extremely important.

MDRS is in the middle of the Utah desert which can range from -7°C to 27°C. In an emergency situation, the team can evacuate to Huntsville, Utah, which is an hour away, but information leading up to any emergency situations can help diagnose information based upon the continued monitoring of the astronauts. Monitoring the pulse rate of an astronaut can identify stress, disease, or oxygen content. Pulse rates can vary from 6 breathes per minutes for yogi's up to 24 breathes per minutes after a vigorous exercise. Blood Pressure is monitored to determine information on heart disease or stressors. In the case of a cut or blood thinners or at various elevations can change the blood pressure of an astronaut. Finally, the Respiration can give even more information on the stress of an astronaut monitoring their breathes per minute. This can let a commander know if they need to work with the experiment another day, or require an astronaut to take a break.

This generation is only the sensors associated with the basic exertions of the astronauts. Using these health sensors will give Command and the XO a general idea of how the astronauts dealing with the environment that they are working within. Their health sensors will be passive solutions that provide continuous data. It will quantify the qualitative assessments done in the field if an astronaut is dehydrated, exhausted, stressed, etc. by assessing these basic vital signs.

2.3 Power Requirements

The power requirements have primary and secondary sources. The primary can be charged overnight, while the secondary can be charged in the sun using solar cells. The health sensors will give the maximum power requirements needed, with a body constraint of how much the body can handle. A secondary innovation may be powering sensors as the body moves forward through some electrical equipment. This is similar to how energy is generated when riding a bike or through wind energy. The energy done through the work the body does as it moves will transform to sensors.

3 Health Sensors

Each health sensor must be strategically placed upon the body based upon where the measurement is being taken. The sensor must not stress out the muscle, with too much weight, be non-invasive, and ultimately take measurements continuously.

3.1 Body Temperature

Body temperature can be taken from multiple areas of the body. This includes oral, axiliary (armpit), forehead, pulmonary artery, rectal, bladder, esophagus, nasopharynx (nasal cavity), and tympanum (middle ear) sites. [12] Since this assessment was looking for non-invasive solutions, the armpit (axilla) was selected as the placement of the health sensor for temperature readings. This has some drawbacks. For one, most astronauts utilize deodorant of some sort which can be a caustic agent that can interfere with the reading. On MDRS it is recommended to utilize natural products because the water supply is a precious entity. Any water utilized in showers is considered grey water which can then be utilized in the green hab to grow food. Black water is the next step utilized in the sanitation system. While astronauts may use natural deodorants and disinfectants, this may still interfere with this sensor. Therefore this sensor must be water proof to protect itself from sweat and possible caustic agents from deodorants.

The body temperature is around 37°C, so the body temperature sensor should range from 30°C to 45°C for the actual body temperature. The external temperature should be from -10°C to 30°C with thermal insulation that allows for the external temperature to be measured without the interference of the body temperature. Therefore, the difference between the outside temperature and body temperature can be shown.

Thermo coupling sensors must give the relative temperature, which is the difference between the temperature of the suit, temperature outside, and actual temperature of your body. Non-invasive placement that can take temperature of these three. The requirements is that you want breathable material that will allow for the body to cool and release heat, but also allow for the movement of the suit. The solution must also be waterproof and anti-microbial since it is anticipated that sweat and bacteria will accumulate here due to physical exertion. Two sensors were looked at as seen in Figure 3and Figure 4. Figure 3 shows a Temperature Ribbon with a cost $243 from TemSek. Figure 4 shows a lilipad temperatures sensor at $4.95 from Arduino. These temperature sensors will be place in the underarm pads which would have four sensors per armpit, for a total of 8 sensors. The four sensors will be redundant where two will give the body temperature, one will give the suit temperature and the third will give the outside temperature.

Figure 3: Temperature waterproof ribbon sensor [7]

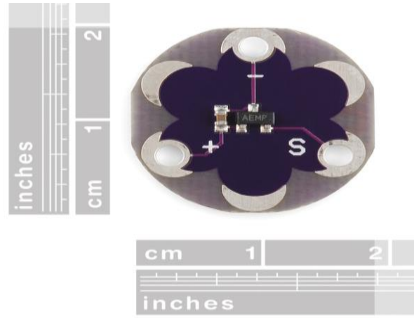


Figure 4: Lilipad temperature sensors [8]

3.2 Heart Beat (Pulse Rate)

There are multiple places to check your pulse rate as well: wrist or neck, temple area, groin, behind the knee, or top of your foot. For a non-invasive heart beat solution this solution will look at taking the pulse rate behind both knees, and at the crook of both elbows. Having four places are a redundancy, but will allow for multiple checks and accuracy. The neck and wrists were not selected due to the fact that this suit is not expected to encompass the neck areas, and the writs may have other objects attacked to them: watches, pedometers, or tricorders for example. The other reason is that the Utah dessert climate can be extremely hot or extremely cold for an astronaut, so if the astronaut wants to wear their suit with their sleeves rolled up to the elbow or pants rolled up to the knee, the sensors will still give relevant data, but provide comfort for the astronaut.

Figure 5 : Heart Beat Pulse Rate Sensor [9]

Figure 5 shows a heartbeat pulse rate sensor from Arduino that costs $24.95. The heart beat sensors will be place behind both knees and at the crook of both elbows for a total of four pulse rate sensors. This redundancy will provide for Command and the XO to monitor the stress rate of the astronaut. In some runners after a long distance, the blood begins to pool around the legs making the runner light headed. The same thing happens to astronauts that come down from the ISS. They will faint because their internal systems are not use to the pooling of blood in their legs instead of evenly spaced throughout their body. Monitoring their heart rate can give the Leader, XO, and Command information if an astronaut is about to faint and allow them to sync their heart beat sensors throughout the body on their suits.

3.3 Blood Pressure

The blood pressure is a combination of taking the pressure of the arm and the pulse rate at the same time. There are two numbers given when blood pressure is read: the systolic and diastolic. Section 3.2 explained the monitoring of the heart rate sensors and the redundancy that will be applied. Figure 6 shows a Flexi force Pressure Sensor for $24.95 which will work in accordance with the pulse rate sensor. These sensors will be placed in the crook of the elbows and knees making two sensors to be integrated into the suit. The crook of the elbow will therefore have both a pressure sensor and a heartbeat sensor. This redundancy will once again add to the health monitoring of an individual. If the blood pressure is different in different parts of the body it could be a sign that the body is stressed or about to faint. A warning signal could be made if certain conditions happen within the programming of these sensors.

Figure 6: Blood Pressure Sensor [10]

3.4 Respiration Sensor

The respiration sensor will count the number of breathes taken. This is a sensor placed on the chest and sides to determine the number of breathes taken per minute. This will be a spatial sensor that measures the change from the heart to the side to determine the change in the lung function. This is a form of pneumography. Figure 7 shows a Piezo Vibration Sensor for $2.95 from Arduino shop. These sensors will be placed on both sides of the body and two placed on the chest. This will take the change in measurement of the lung capacity as the body inhales and exhales.

Figure 7 : Respiration Sensor [11]

It is a known fact from SCUBA diving that women have a longer lung capacity than men when diving under water. Measuring the lung capacity of NSBE members and taking into account their genders can produce some interesting science experiments that may have implications for lung capacity and exercise data.

3.5 Sensor Placement

The sensors will be placed upon the suits as shown below in Figure 8. Each sensor will be place into the suit to provide skin contact with the waterproof requirements for each solution as deemed necessary.

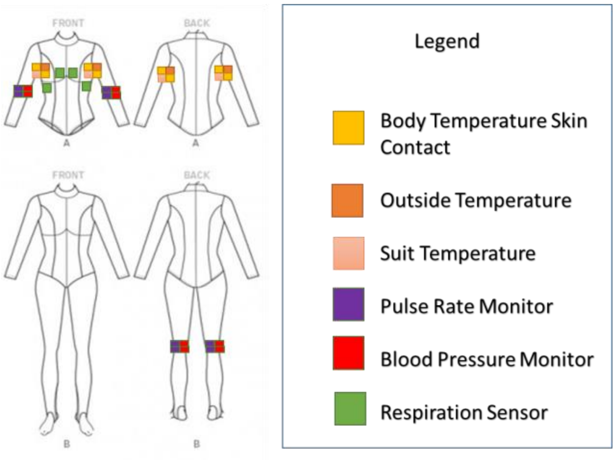


Figure 8: Placement of sensors on NSBE MDRS suits

The sensors will be integrated into the suit to provide the skin to skin contact, but the actual power requirements will be a separate piece of equipment in the form of a short vest or power belt that will take the weight of the garment (0.5 kg) to the high pressure points of the body. The hips and shoulders will carry this weight to supply the power to the sensors and any external tools utilized by the astronauts.

4 Power Requirements

The power requirements must power the continuous power of the sensors, the software needed to record the data, and the eventual transmission. These sensors described in Section 3 have a maximum power requirement of 5V as shown Table 1 from this break down. Increasing that requirement to give a 25% margin makes a power requirement of 30V It is assumed that a Raspberry Pi is used, which has a mass of 45g, and 5V of power. Every sensor requires 5 V of power.

Table 1 : Power Requirements for Health Sensors

Health Sensor	*Max Power Requirement (V)*
Thermal	5V
Pulse Rate	5V
Blood Pressure	5V
Respiration	5V
Raspberry Pi	5 V

4.1 Primary Charge

The primary charge will be batteries of the AAA batteries which will provide the 5V of charge needed for the sensors. Rechargeable batteries will be used that will be charged by the solar cells during the day, and charged at night. Future versions will have sensors that can be added onto the NSBE suit and taken off, but the first version will have all of the sensors integrated into the suit. Any senor that can be taken off of the body suit that is not integrated into the system can be charged separately. In order to clean the suits, the entire suit of sensors will be able to be taken out in order to get the suit wet, although there will be special instructions on the care and cleaning of the NSBE suits. One of the requirements is that the suits utilize the leas amount of water since it is such a precious resource on MDRS and hence Mars. Therefore, alternative cleaning methods will be employed. These cleaning methods will sill require that the integrated sensors be taken out so that they are not damaged during the cleaning, and so that the primary charging units are not damaged either.

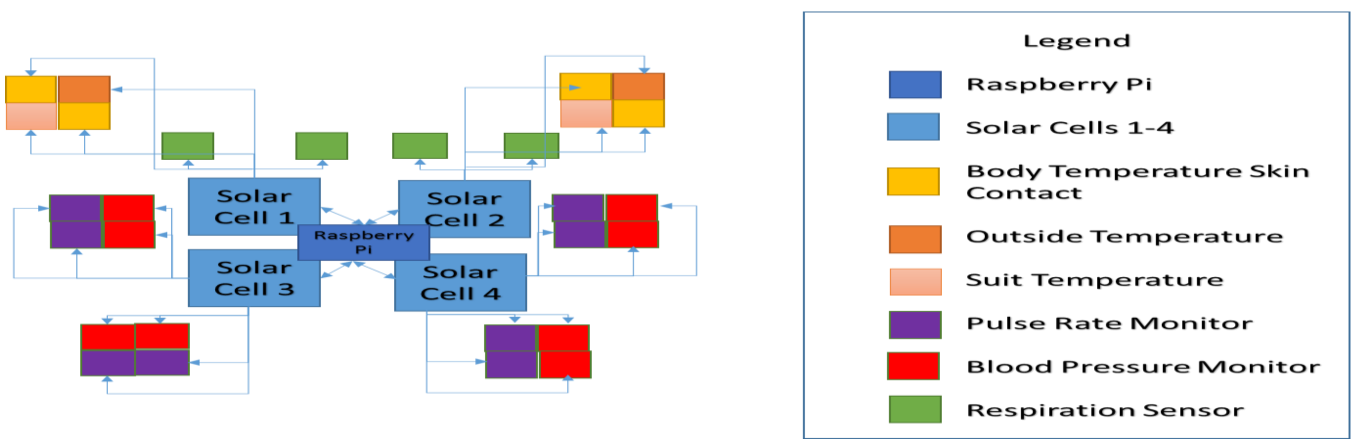
4.2 Secondary Charge

Flexible Solar cells can be attached to the suit on the chest area along with the computer board of the suit. This external vest will contain the computer, the connections to the suit and sensor, the charge capacity to the tricorder or gloves, and anything needed to be charged on the utility belt that is worn by the astronaut. The secondary charge would need to provide at a maximum of 7 V. One large Arduino solar cell voltage can provide 8.15 V. The chest vest will have 4 solar cells, two on the front and two on the back to maximize the charging. The astronauts will not always be in ideal charging conditions. That will provide 32.5 V of power for a secondary charging solution which can process each one of the sensors as well as the tricorder, and any extra tools that need powering.

5 Schematics

Figure 9 shows a general schematic of the power placement to the four sensor types and a legend explaining them. The idea if that the blood pressure and pulse rates will be powered by separate solar cells than the temperature and respiration sensors. In this case, the solar cells power the raspberry pi which will transmit the information to the Leader, XO, and Command.

Figure 9: Schematic of sensor power placement and legend



6 Conclusions

This paper provided the basic health sensor and power requirements for a space suit expedition to the MDRS. The environment there is a desert environment in the Utah desert that serves as a simulation environment for astronauts. While it does not simulate the zero-G effects, it does provide a test bed for health sensors to be integrated into the suits that will be worn below the astronaut suits. The continued monitoring of astronaut health will generate multiple data sets for the NSBE Space SIG and allow for new generations of space suits to integrate health sensors. This has implications for long duration exercise and military needs. Long term health monitoring can be established and MDRS is the perfect test bed for such a project.

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