PLANETARY ANALOGUE EVA MEDICAL EMERGENCY SIMULATIONS

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Future NASA planetary exploration will call for extended human presence in space, with long term missions to the Moon, Mars, and/or asteroids. This human presence in extra-terrestrial locations will require use of planetary surface extra-vehicular activities (EVAs), which will involve inherently dangerous procedures which can put crew safety at risk. An EVA is defined as any activity performed by a pressure-suited crewmember in unpressurized environments (internal or external to habitable modules). One need only peruse proposed EVA operations for future planetary surface missions to understand the risks astronauts will be exposed to. These EVAs will include activities such as base construction, base operation and maintenance, emergency and safety procedures, planetary surface exploration, planetary surface science, robotic operation and maintenance, and in-situ resource utilization (ISRU) operations. In cases where EVA crewmembers are faced with medical emergencies, they will have to be expeditiously transported back to a pressurized habitat, undergo the repressurization cycle to enter the habitat, and have the spacesuit removed to initiate emergency treatment. To help mitigate these EVA emergencies, astronaut training programs will spend substantial attention on preparing for planetary surface operations. One of the sites where emergency procedures can be developed is the Mars Desert Research Station (MDRS). This Mars analogue site provides an excellent platform for aerospace medical research investigating the complexities of medical science in a remote and hostile setting [1]. To this end, one of the main goals of MDRS Crew 126 was to assess EVA emergency rescue equipment and procedures, focusing on transportation operations using various configurations of wheeled stretcher concepts in varying terrain (i.e. smooth, medium, and rough terrain). This paper summarizes these EVA emergency simulations, provides recommendations, and identifies future areas of research.

Key words: *Emergency simulations, MDRS, Crew 126, Wheeled-stretcher configurations*

INTRODUCTION

The Red Planet contains all the elements needed to support life, similar to a world with a surface area the size of the combined continents of the Earth.

Moreover, as the nearest planet with all the required resources for technological civilization, Mars will be the decisive trial that will determine whether humanity can expand from its globe of origin to enjoy the open frontiers and unlimited prospects available to multi-planet spacefaring species.

In that regard, future NASA planetary exploration will call for extended human presence in space, with long term missions to the Moon, Mars, and/or asteroids. This human presence in extra-terrestrial locations will require use of planetary surface extra-

vehicular activities (EVAs), which will involve inherently dangerous procedures which can put crew safety at risk.

These simulations will be performed in the Mars Analogue Research Station in different parts of the world.

The main objective of the Mars Analogue Research Station (MARS) program of The Mars Society is to investigate the operational environment of a base on Mars, through these simulations of how it would be like to live and work on Mars-like environments here on Earth. Currently, The Mars Society operates two analogue bases: Flashline Mars Arctic Research Station (FMARS) in Devon Island, Canada and Mars Desert Research Station (MDRS) in Utah, USA. These receive researchers from various disciplines (physics, biology, geology, engineering, etc.) who carry out research aiming to make life viable on Mars [2].

Mars Analogue

A Mars-like environment on Earth is defined by the distribution of living organisms, organic matter and chemical properties of the soil. If it is chosen properly, it will guide the investigation of possible habitable environments on Mars. This Mars analogue site provides an excellent platform for aerospace medical research investigating the complexities of medical science in a remote and hostile setting [2].

To this end, one of the main goals of Crew 126 was to assess EVA emergency rescue equipment and procedures, focusing on transportation operations using various configurations of wheeled stretcher concepts in varying terrain (i.e. smooth, medium, and rough terrain). These simulations were performed in the Mars Desert Research Station, in Utah.

Extra Vehicular Activities (EVA)

An EVA is defined as any activity performed by a pressure-suited crewmember in unpressurized environments (internal or external to habitable modules) in order to understand the risks astronauts will be exposed to. These EVAs will include activities such as base construction, base operation and maintenance, emergency and safety procedures, planetary surface exploration, planetary surface science, robotic operation and maintenance, and in-situ resource utilization (ISRU) operations.

In cases where EVA crewmembers are faced with medical emergencies, they will have to be expeditiously transported back to a pressurized habitat, undergo the repressurization cycle to enter the habitat, and have the spacesuit removed to initiate emergency treatment.

To help mitigate these EVA emergencies, astronaut training programs will spend substantial attention on preparing for planetary surface operations.

This paper summarizes the EVA emergency simulations performed by Crew 126, at the same time we will provide recommendations, and identify future areas of research.

Crew 126 EVA Emergency Transportation Research

We as part of Crew 126 performed the following EVAs.

1. Four and two crewmembers carrying stretcher
2. Stretcher on ATV
3. Two-wheel stretcher (in series)
4. One-wheel stretcher
5. Two-wheel stretcher (in parallel)

6. Four-wheel stretcher (pulled up 30 deg hill)
7. Four-wheel stretcher (towed by ATV)
8. Average speed walk in space
9. Use of an emergency ladder
10. EVA connector test

MATERIALS AND METHODS

For these simulations Crew 126 use the following materials:

- Standard emergency military-type stretcher
- Bicycle wheels
- Small wheels
- Metal and PVC Tubes
- Aluminum foil
- Screws and joint connectors
- Drill
- Other basic tools

The method we use was to build different configurations of the stretcher combined with none, one, two and four wheels. These configurations ten were tested in various types of terrains.

The EVAs mentioned above were performed in the following types of terrain:

- **Rough Terrain:** Presented several big rocks and uneven slope which increase the difficulty to move through this terrain.

Rough Terrain (Utah, 2013)
Photo courtesy of Crew 126

- **Medium Terrain:** Less amount of rocks, middle sized rocks and uneven slope. The movement in this terrain was not as difficult as in the rough terrain.

Medium Terrain (Utah, 2013)
Photo courtesy of Crew 126

- **Flat/smooth terrain:** In this terrain there was no presence of big/medium rocks and the slope was almost none.

Flat/Smooth Terrain (Utah, 2013)
Photo courtesy of Crew 126

RESULTS AND DISCUSSION

I. Stretcher configurations

a. *Four and two crewmembers carrying stretcher*

The objective of this EVA was to develop a method of transporting EVA injured crewmember on an emergency stretcher. Each crewmember lifted a corner of the stretcher.

The stretcher we used was a standard military stretcher that we modified to fit the crewmember's backpack.

The height and strength of the team was balanced in order to distribute the load evenly and transport comfortably the Test Subject (TS, from now on), which in all the EVAs with the stretcher was me.

The weights were the following:

- Test subject: 136.4 lbs - 62kg
- Stretcher: 17.8 lbs - 9kg
- Suit: 26.0 lbs - 12kg
- Total weight: 180.2lbs - 82kg (That in Mars will be 1/3 of the weight)

The emergency site was a distance of 210 meters from the habitat. The crew tried two positions:

a. **Prone position:** The test subject noted the following:
   1) Being face down was generally uncomfortable,
   2) Portable Life Support System (PLSS) was heavy and at times made it difficult to breath,
   3) The TS had to lift her head upward to get an airway, which would not be advisable in the case she had suffered neck/spine injuries, and
   4) Her only view was the ground, which did not allow her to have any visual contact with the EVA paramedic.

b. **Supine position:** The TS noted that being face up was less uncomfortable compared to the prone position.

Supine position EVA (Utah, 2013)
Photo courtesy of Crew 126

The crew also attempted to carry the stretcher with only two crewmembers but that meant a heavy design. However this allowed them to rest because while two crewmembers were carrying, the other two were resting.

b. *Stretcher on ATV*

The objective of this EVA was to develop a method of transporting EVA injured crewmember on an emergency stretcher.

A stretcher adaptor was built with materials from the Antarctic Pile to support the stretcher on the ATV to transport the Test Subject. The crew used wood for the stretcher adaptor, PVC tubes, foil, screws, rope and other materials for the stretcher cover.

Using an ATV, ATV adaptor and stretcher, the team attempted to carry a simulated injured crewmember in the supine position using an ATV. The emergency site was a point with a distance of 210 meters from the habitat.

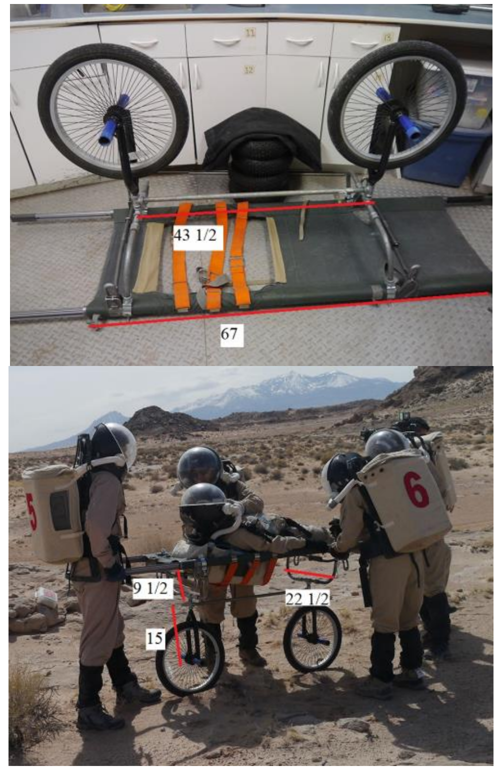
Stretcher on ATV (Utah, 2013)
Photo courtesy of Crew 126

The main observation was that the ATV driver could not sit down, as the ATV adaptor blocked the seat; the crewmember had to drive standing up. In this EVA, the injured crewmember noted the following during the transportation:

1) The transportation method was much more comfortable, when compared to non-ATV method of transportation,
2) The ATV adaptor cover efficiently protected the patient from the sun.

c. *Two-wheel stretcher (in series)*

In this EVA, two bicycle wheels where placed along the stretcher in series with a trapezoid structure made of steel pipes.
The measures of the stretcher are shown in the pictures below.



Two-wheel Stretcher (Utah, 2013)
Photo courtesy of Crew 126

In rough terrain, while the crewmembers were transporting the stretcher with the test subject in it, they passed through paths with a lot of rocks and slopes so every time they stepped one of those she bumped her head with the helmet.
In medium terrain, the soil was sandy so the discomfort was less than the previous terrain. However the test subject felt unstable while being transported.
For the flat/smooth terrain, the crewmember didn't feel any kind of discomfort.

d. *One-wheel stretcher*

In this EVA, a bicycle wheel was placed just under the backpack compartment of the stretcher with a trapezoid structure made of steel pipes.

The total length of the stretcher was 67 inches, the width was 22 ½ inches and the distance from the tube that connected the front support with the wheel to the middle of the wheel was 15 inches. The distance from this same tube to the stretcher was 9 ½ inches.

One-wheel Stretcher (Utah, 2013)
Photo courtesy of Crew 126

In rough terrain, the test subject felt unstable because for the other crewmembers it was hard to maneuver the stretcher with one wheel.

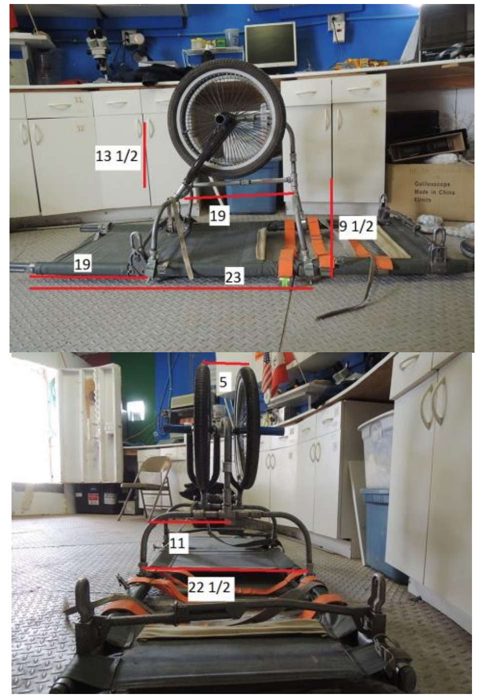
In medium terrain, the test subject felt once again unstable because of the same reason before (for the other crewmembers it was hard to maneuver the stretcher with one wheel).

In flat/smooth terrain, the transportation of the injured crewmember was much easier compared to the simulations in the other terrains.

e. *Two-Wheel stretcher (in parallel)*

This time, two bicycle wheels where placed at the middle of the stretcher in parallel with a trapezoid structure made of steel pipes. The first attempt unfortunately didn't work because there was a big gap between the wheels and the load was distributed unevenly.

The measures of the stretcher are shown in the pictures below.



Two-wheel Stretcher (Utah, 2013)
Photo courtesy of Crew 126

Because of this unsuccessful configuration, the crew decided to re-secure all the connections, especially the one for the right wheel which supported all the weight in the previous attempt.

Additionally, the crew moved the parallel two-wheel configuration closer to the center to even out the loads for the front and back. The four crewmembers then proceeded to evaluate the transportation of the injured patient with this updated configuration a distance of 50 meters in rough terrain.

In rough terrain, the test subject felt that she was going to one side and the other so it was uncomfortable for her and the other crewmembers had to struggle to balance the stretcher.

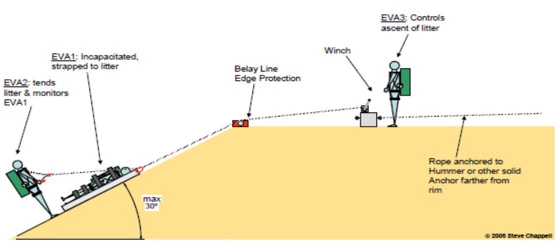
In medium terrain, the discomfort was less than in the rough terrain. It's important to mention that during tis EVA we added a helmet pad on the TS's head that improved the comfort level during transportation.

In flat/smooth terrain, the crewmember didn't feel any kind of discomfort.

f. Four-Wheel stretcher (pulled up 30 Deg Hill)

The objective of this EVA was to develop method of transporting EVA injured crewmember on an emergency four-wheel stretcher, a distance of 40 feet up a 30 degree slope. We based this EVA on the NASA research called Haughton Mars Project [1].

In this simulation the goal was to evaluate operational scenarios to develop medical requirements for lunar surface operations with 3 suited crewmembers, one of them with incapacitating injuries on sloped terrain. We took in consideration the results of this simulation and modified the stretcher adding wheels to obtained better results.



Haughton Mars Project (HMP, 2006)
Photo courtesy of R. Scheuring

Four-wheel Stretcher (Utah, 2013)
Photo courtesy of Crew 126

In our case the rope was pulled by an ATV at the top of the hill. The wheels were small in order that the stretcher was very close to the ground.

A recommendation is to place a foot stopper at the bottom of the stretcher so that the patient does not slide down as the stretcher is pulled up the hill.

The test subject didn't feel any kind of discomfort or pain during this test, she felt secure while being transported with the ATV because in a real emergency situation this will probably be the safest and fastest way to move the injured crewmember.

g. *Four-wheel stretcher (towed by ATV)*

The ATV pulled the four-wheel stretcher configuration a distance of 2 miles on flat terrain back to the habitat. The stretcher was tied to the ATV with a rope that was already rated to confirm that can support that kind of load. We based and modified a previous NASA simulation procedure.

Four-wheel Stretcher (Utah, 2013)
Photo courtesy of Crew 126

During the transportation the rope kept getting tangled with the stretcher wheels. A recommendation is to use a metal structure instead of the rope to connect the ATV and the stretcher.

Lateral perspective (Utah, 2013)
Photo courtesy of Crew 126

II. Spacewalk

Any time an astronaut gets out of a vehicle while in space, it is called a spacewalk [3]. A spacewalk is also an EVA. NASA already determined Lunar walking speed of 2.7 km/hr (assuming a walking speed with a reduction of 50%) [4].

This EVA was about MDRS walkback test to determine average MDRS walking speed in case of an ATV (rover) failure during an EVA.

The crew walked a distance of 2.78 km from the Hab to a Point selected by them, and the same distance to return to the Hab. This EVA took about 3 hours in being completed.

The MDRS average walking speed for a suited crewmember was determined to be 2.57 km/hr. Another important aspect was to determine the maximum waypoint that MDRS EVA crewmembers should go to.

III. Emergency ladder

The purpose of this EVA was to simulate a rescue mission using a ladder as a tool to get to a higher or lower place (i.e. a top or base of a hill). The ladder was secure in the soil using rocks and screws. This test successfully demonstrated that an emergency ladder can be used for EVA ascent or descend procedures.

Emergency ladder EVA (Utah, 2013)
Photo courtesy of Crew 126

IV. EVA connector test

The crew performed an EVA connector test using Boeing EVA connector mockup; this connector was a replica of ISS EVA connector.

EVA connector test (Utah, 2013)
Photo courtesy of Crew 126

For the crew to appreciate the difficulty in performing tasks with pressurized gloves, the crew put on two layers of latex gloves prior to putting the ski gloves on.

This has been proposed as a method to simulate the stiffness in pressurized spacesuit gloves. With the gloves on, the crewmembers tried to remove and connect the EVA connector (i.e. not powered).

It took at least two attempts for each crewmember to successfully connect and remove the EVA connector.

RECOMMENDATIONS

No wheels configuration

For this configuration, we tested carrying the stretcher with four, three and two crewmembers at the same time and ATV assist.

No wheels – four crewmembers: Each crewmember had to carry the stretcher. It was heavy so they had to stop to rest (loosing time).

- Transportation of injured in the prone position is not recommended.
- Transportation of injured in the supine position is recommended.

No wheels – two crewmembers: It was the heaviest design but it allowed them to rest because while two crewmembers were carrying, the other two were resting.

Using ATV and stretcher: Transportation of injured with an ATV, ATV adaptor and cover is recommended. The test subject felt comfortable and secure. The cover worked to protect her from the sun, wind and dust.

Wheeled configuration

For this configuration, the crew tested one wheel and two wheels on series and parallel.

One wheel: The crew had to be careful with the shape of the terrain because it was decisive to prepare ourselves to make a greater effort.

Two wheels – series: The crewmembers didn’t have to make a greater effort because the weight was well distributed between the two wheels. To flip the crew needed to put a major effort.

Two wheels – parallel: As expected, it was like a combination between the previous two. The weight was not as well distributed as the other; however it was much easier to flip than the previous case.

Four-Wheel stretcher (pulled up 30 Deg Hill): The rope was pulled by an ATV at the top of the hill, so the crewmember that conducted the ATV had to drive very carefully and checking the injured crewmember frequently.

Four-wheel stretcher (towed by ATV): During the transportation the rope kept getting tangled with the stretcher wheels. A recommendation is to use a metal structure instead of the rope to connect the ATV and the stretcher.

Spacewalk

The MDRS walkback test allowed determining average MDRS walking speed in case of a rover (ATV) failure during an EVA. For MDRS, Moon and Mars, maximum distances that can be travelled by EVA suited crewmembers were determined.

Emergency ladder

The emergency ladder test successfully demonstrated this can be used for EVA ascent or descend procedures.

EVA connector test

This test allowed the crewmembers to simulate and appreciate the stiffness of pressurized spacesuit gloves and the challenges this represent when trying to remove and connect the EVA connector (i.e. not powered).

CONCLUSION

Overall, for the stretcher EVAs as expected, the two-parallel wheel configuration was like a combination between the other two mentioned and it was determined to be the best configuration because it allowed maneuvering the stretcher and transporting comfortably the TS. The weight was not as well distributed as the other; however it was much easier to flip than the previous case.

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