Experiment collaboration program during a Martian analogue mission to introduce young students to human space exploration

Léa Rouverand[1], Cerise Cuny[1], Elena Lopez-Contreras Gonzalez[1], Marine Prunier[1], Mathéo Fouchet[1], Nicolas Wattelle[1], Valentine Bourgeois[1], Quentin Royer[1], Marie Delaroche[1]

Abstract

The last decade has demonstrated an increased public and private interest towards crewed missions through the emergence of New Space and the Artemis program. There is therefore a need to form the next generation of scientists to prepare future crewed space exploration missions. In this context, it is important to familiarize teenagers with the scientific issues of today's world and to inspire them to engage in the space sector. Crew 263 is a group of seven students preparing a Martian analogue mission at the Mars Desert Research Station (MDRS) in the desert of Utah (United States). A Martian analogue mission at the MDRS, because is the perfect set-up to introduce young students to human space exploration. In the context of their mission, Crew 263 has organized a program of space educational activities for middle and high school students surrounding the topics of altered gravity, astronomy, health and safety procedures and robotic systems. Precisely, a set of four experiments that will be performed by the students was conceived to bring into light the various scientific topics surrounding space exploration missions.

The experiment "Plants in Microgravity" aims to illustrate the influence of gravity on plant growth by planting seeds in pots mounted on a rotating platform in a vertical plane, which will disturb their gravitational cues. "Beginner Astronomer" aims to introduce students to astronomy and astrophotography by establishing with the students a list of galaxies/nebulas to be observed during the Mission. Then, for "Emergency situation at the MDRS" students will put into practice the scientific approach by creating protocols to mitigate risk situations during space exploration missions. Finally, for the "Perseverance's little brother" experiment, students will develop a small rover to analyze the atmosphere condition around the MDRS station.

To maximize their involvement, prior to the mission at the MDRS, the middle and high school students prepare the experiments with the support of the crew. Then, the prepared experiment will be performed in parallel with the crew while they are simulating Martian life. To allow students to be immersed in the mission when the crew will be at the MDRS, short podcasts will be recorded describing the crew's daily life and the evolution of the different experiments. This podcast will be sent to the classes during the simulation, thus allowing the students to have an insight on the daily life of the analogue astronauts at the station.

Keywords

Analog, Education, Human, Outreach, Spaceflight

[1] ISAE-Supaero, France

Nomenclature

r	*Radius*
V	*Volt*

Acronyms/Abbreviations

EVA	*Extra-vehicular activity*
HAB	*Habitation Module*
ISAE	*Institut Supérieur de l'Aeronautique et de l'Espace*
ISS	*International Space Station*
MDRS	*Mars Desert Research Station*

1. Introduction

Inspiring the next generation of scientists in the space field and especially extra-terrestrial exploration is one of the goals of Club M.A.R.S, an association of the French Higher-Education Institute ISAE-Supaero specialised in educational outreach and martian analogue missions.

In the past 8 years, a crew from Club M.A.R.S performs a simulation mission at the Mars Desert Research Station (MDRS). In 2022, Crew 263 performed a 3-week isolation mission from February 20th to the 12th of March.

Figure 1. Aerial shot of the MDRS by Crew 263

During a simulation mission at the MDRS, on top of performing an isolation mission with the linked constraints, in communication, energy and water resource, scientific experiments are performed to study the human factors surrounding such missions as well as technological testing to prepare future crewed missions to the moon and mars.

Parallelly, Club M.A.R.S performs outreach activities at local middle schools and high schools about Martian robotic missions and human spaceflight.

Crew 263 wished to include this outreach activity in their mission. Indeed, a Martian analogue mission at the MDRS, because of its completeness in terms of accurate simulation and experiments performed, is the perfect set-up to introduce young students to human space exploration.

The developed educational activity consisted of a thorough program with a pre-mission preparation, experiments during the mission and post-mission de-brief sessions. Precisely, 9 classes in France chose an activity from a set of 4 space-related experiments. Preparing the experiment set-up and protocols was performed with the support of Crew 263 between September 2021 and January 2022. During the mission, the experiments set-up by the various classes were operated either by Crew 263 or jointly by Crew 263 and the classes. After the mission, a de-brief session on the analogue mission and on the experiments is planned.

To allow an immersive experience to the mission, a series of podcast was made by the Crew Journalist Nicolas Wattelle to give an update on the mission and on the various experiments.

The planned space educational activity experiment ranged from biology, astronomy, robotics to risk and safety topics surrounding crewed missions. Namely, the experiments "Plants in Microgravity", "Beginner Astronomer", "Emergency situation at the MDRS" and "Perseverance's little brother" experiments are detailed in Section 2 of this paper.

2. Activity Content

Crewed space missions represent a multidisciplinary domain with many areas of expertise involved. To allow a full scope vision to the young students regarding the future of crewed space exploration, it is important to allow an introduction to various topics.

Hence, 4 different experiments were produced leaving the choice of the activity to perform to the concerned classes. This allows a maximization of the student interest towards the activity. The 4 experiments are detailed in this section.

2.1. Plants in Microgravity

Analysing the effect of gravity to understand the effects of long-term spaceflights is of importance.

During the first preparation sessions the various plant growth experiments performed on-board the ISS were presented as well as basics of mechanics to familiarize the students to the topic.

Then, during later sessions, the experimental set-up to alter the gravity experienced by the plants were identified with the students. Two rotational platforms were selected to alter the plant gravity reference frame, a horizontal one, like Knight's experiment, and a vertical one to further understand the physical relationships between the forces acting upon a plant.

The platforms were a 30 cm radius wooden made apparatus powered by a 12V motor connected to a power generator.

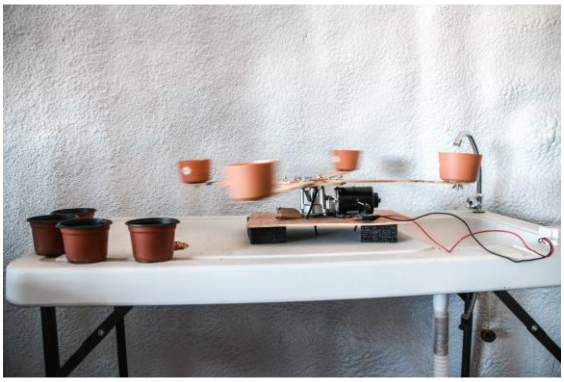


Figure 2. Horizontal Rotation Platform

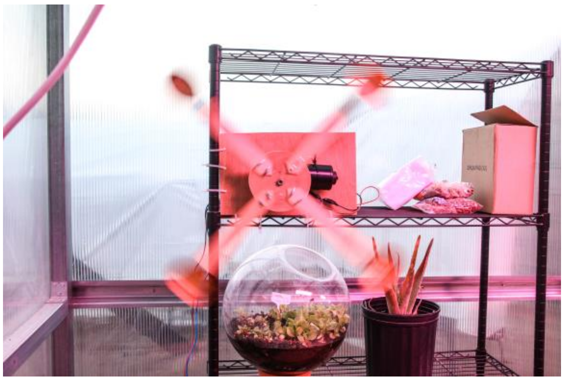


Figure 3. Vertical Rotation Platform

Rotational platforms were made by the students with the support of Crew 263. This manufacturing process were adapted to each class level with an easier assembly process for lower grade classes and/or adapted to the time allocation for the Space Educational Activity in each school. An assembly process booklet was made for each class.

The same rotational platforms were made for use at the MDRS, these are illustrated in Figures 2 and 3.

During the mission period (20th of February – 12th of March), the rotational platforms were turned on to put the plants in constant acceleration for 3 weeks. At the same timeframe the school platforms were also turned on to allow observation by the school students.

The growth parameters such as length and direction of growth were then to be recorded for the school plants and the mission plants. This observation grid is as presented in Figure 4.

DATE	NOMBRE DE JOURS	HORIZONTAL TOURNANT			TEMOIN VERTICAL			TEMOIN HORIZONTAL		
		PLUS LONG GERME (en mm)	ANGLE A L'HORIZONTALE	DIRECTION	PLUS LONG GERME (en mm)	ANGLE A L'HORIZONTALE	DIRECTION	PLUS LONG GERME (en mm)	ANGLE A L'HORIZONTALE	DIRECTION

Figure 4. Gravitropism observation grid

2.2. *Beginner Astronomer*

Introducing students to Astronomy not only introduces them to scientific topics but also leads to broadening the students' perspectives on our planet, the Earth, in its global scale.

During the first sessions of this Activity, the students were familiarized with the comparisons between Earth and Mars. A topic of interest was also Astronomy in the context of crewed missions. Indeed, during a crewed mission, an understanding of the deep space and Martian environment is of importance to ensure the Astronaut safety. An example is monitoring the Sun's activity during crewed missions to prevent Solar storms which could lead to radiation poisoning. The MDRS is equipped with the Musk Observatory designed to observe the sun and allows the Crew Astronomer to monitor the analog Astronauts safeties during their mission.

To introduce students to this astronomical observation process, the *"Beginner Astronomer"* consists of introducing students to the observation of nebulae and galaxies.

To do so, a simplified Messier Catalog was presented to the students to aid them in the selection of nebulae to observe from the MDRS.

An introduction to other astronomical bodies using Stellarium was also performed during these pre-mission sessions.

The selected Nebulae were then observed during the mission by the Crew Astronomer.

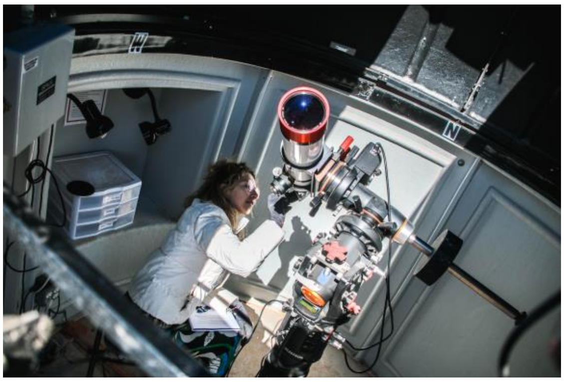


Figure 5. Crew 263's Astronomer in the Musk Observatory

2.3. *Emergency situation at the MDRS*

In any scientific experiment, the operator's risk and safety must be carefully considered. An understanding of the experimental set-up is of importance when preparing and establishing experiment protocols. This activity aims to cover such topics in the context of crewed space exploration missions.

During the pre-mission sessions, the topics of crewed space missions and existing safety protocols such as fire evacuation procedures are presented. Then, through a presentation of the facilities and tools present in the MDRS, safety protocols are established by students. Namely two scenarios of interest are studied:

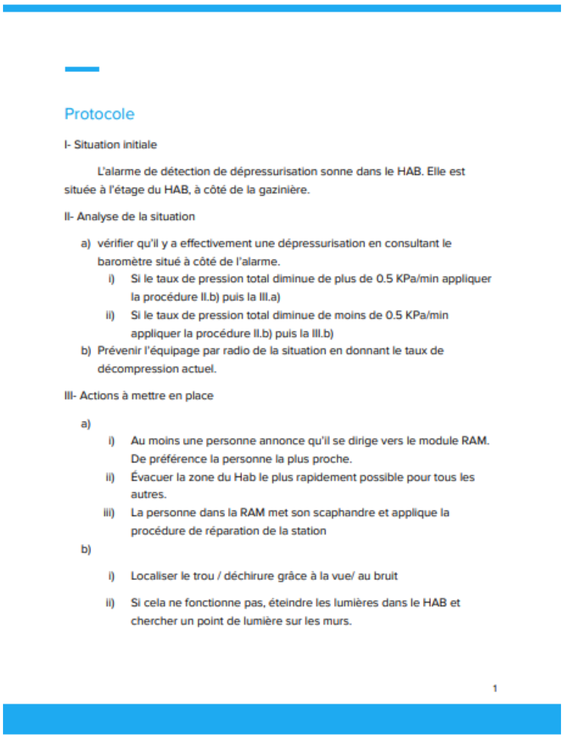
- HAB module depressurization
- Injured Astronaut during an EVA.

The first scenario corresponds to a depressurization of the Astronaut's habitation module (HAB). The Astronauts must identify the issue and act according to the depressurization level to place them in a safe situation by following the developed protocol.

The second scenario covers an injured astronaut during an EVA. The protocol shall indicate the course of action to be followed by the other (non-injured) EVA members to place the injured member in a safe place, evaluate the environment they are in, seek for external support and support the injured astronaut.

The ISS safety protocols are recalled for a comparison to the established protocols.

The two upper mentioned scenarios are simulated during Crew 263's mission and the student protocols are followed. The emergency situation timeline is recorded to provide feedback on the student protocols.



Protocole

I- Situation initiale

L'alarme de détection de dépressurisation sonne dans le HAB. Elle est située à l'étage du HAB, à côté de la gazinière.

II- Analyse de la situation

a) vérifier qu'il y a effectivement une dépressurisation en consultant le baromètre situé à côté de l'alarme.
   i) Si le taux de pression total diminue de plus de 0.5 KPa/min appliquer la procédure II.b) puis la III.a)
   ii) Si le taux de pression total diminue de moins de 0.5 KPa/min appliquer la procédure II.b) puis la III.b)
b) Prévenir l'équipage par radio de la situation en donnant le taux de décompression actuel.

III- Actions à mettre en place

a)
   i) Au moins une personne annonce qu'il se dirige vers le module RAM. De préférence la personne la plus proche.
   ii) Évacuer la zone du Hab le plus rapidement possible pour tous les autres.
   iii) La personne dans la RAM met son scaphandre et applique la procédure de réparation de la station
b)
   i) Localiser le trou / déchirure grâce à la vue/ au bruit
   ii) Si cela ne fonctionne pas, éteindre les lumières dans le HAB et chercher un point de lumière sur les murs.

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Figure 6. Part of HAB depressurization protocol established by students with the support of Crew 263

2.4. *Perseverance's little brother*

2021 marked a successful year in Martian exploration missions with the Perseverance rover accomplishing new milestones and successful lights of the Ingenuity Helicopter.

To generate student enthusiasm about space exploration missions and more generally, scientific projects, space robotic systems are introduced through the "Perseverance little brother" activity.

Students are firstly introduced to Martian robotic missions and subsystems involved in space systems are presented.

With the support of Crew 263, the students then decided on a Mission Objective, manufactured a rover to be operated at the MDRS.

The selected mission objective by students is an atmospheric mapping experiment which ais to map atmospheric conditions surrounding the MDRS such as temperature and pressure as well as the rover health parameters (battery level, acceleration, and GPS location).

3. Activity Timeline

As mentioned in the introduction section, the MDRS Space Educational Activity counted 3 main parts. A pre-mission preparation, a during-mission operation and a post-mission analysis part.

The pre-mission part corresponds to slide supported presentation with interactive discussion parts including quizzes. Then, manufacturing of the experiment for the gravitropism and rover activities with the support of the Crew.

During the Mission, the students followed Crew 263's mission and the updates of the Educational Activities through podcast updated on a dedicated Youtube Channel: https://www.youtube.com/channel/UCeiAeMiOo-RhkQF9UoW_74g

Each podcast episode covered a different aspect of crewed missions from EVAs to the daily routine of Astronauts in the Habitation Module. The podcast format is in accordance with the data limitation at the MDRS to simulate the isolated environment.

Finally, a post-mission debrief is planned for the April to July 2022 period to share the obtained results by the students and Crew 263.

Figure 7. Steps of the Space Educational Activity by Crew 263

4. Results and Discussions

During their mission at the MDRS, Crew 263 and students obtained the results summarized in this section for the developed Space Educational Activity.

4.1. Plants in Microgravity

The rotational platforms were initially installed in the GreenHab, the MDRS greenhouse. However, due to a whitefly infection, the greenhouse had to be shutdown. The experiment apparatus thus had to be moved to the MDRS ScienceDome. The environment changes and low temperature in the ScienceDome led to a perturbation in the growth of the plants. The growth rate was not enough to observe gravitropism.

However, in the respective schools, no environment change was necessary for the rotational platform. A plant growth aligned to the centrifugal force was observed demonstrating gravitropism.

4.2. Beginner Astronomer

Introduction sessions to Astronomy were completed. However, for the Nebulae selection session, COVID-19 translated to rescheduling of the sessions. Hence, the selection by students were not performed before the mission by the students.

However, Nebulae and Galaxy observations were made by the Crew Astronomer, Marine Prunier. Thus, their observations will be presented to the students during interactive sessions in April-July 2022.

Figure 7. Galaxy M81, captured by Marine, Crew 263's astronomer

4.3. Emergency situation at the MDRS

The student developed protocols were tested out on 3 different situations.

The injured astronaut protocol was tested twice and the HAB depressurization once.

To test out the ability of Astronaut to follow the protocol and assess the effectiveness of the developed protocol while being in a simulation, an external stress factor could be included. Indeed, for the injured astronaut protocol, the analog astronaut who was supposed to simulate the injury switched to account for this additional stress factor. The stress response of the Analog Astronauts were recorded for this study and showcased a handled response as illustrated in Figure which shows normal heartrate responses.

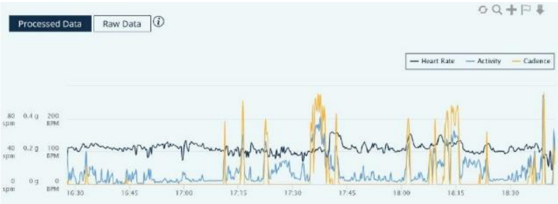

Figure 7. Heartrate response of the Analog Astronauts

While staying in simulation, the protocols allowed the injured astronauts to be recovered by the rescue crew and the astronauts in the breached HAB to move safely in a pressurized module.

Ways to improve the protocols were identified such as required additional information on first aid steps, additional ways to inform the rescue drone, additional ways to identify the breached area in the HAB .

4.4. Perseverance's little brother

Students at the Lycée International de Saint-Germain-en-Laye developed the *Kepler* rover (Figure 7) designed to take atmospheric measurements.

The rover mechanical part design, manufacture and assembly was successfully completed by the students. However, the students faced difficulties in the navigation code scripting related to operational constraints in the area surrounding the MDRS.

The rover will be tested out by the ISAE-Supaero 2023 Crew during their mission at the MDRS.

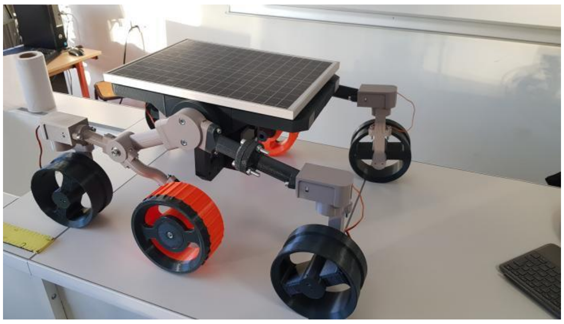

Figure 7. Kepler Rover

4.5. Mission Operation

All these experiments were part of an analog mission and hence, illustration of the full scope of crewed missions was of importance to give a global view to the students. Indeed, it helped understanding the environment present to operate the experiments. Podcast episodes dedicated to different aspects of a crewed missions were created.

The first episode covered SOL 0 to SOL 2, the first EVA and the explanation of atmospheric experiments: https://youtu.be/gJ3SfJVWgik

The second episode about SOL 3 to SOL 5 focused on human factor experiments, the gravitropism experiment, and the role of the Crew Astronomer: https://youtu.be/lC8IfZt5WGE

The third episode's focus (SOL 6 to SOL 8) were spirulina growth experiments through the GreenHab Officer's role and geology field studies presented by the Crew geologist : https://youtu.be/utLbL10MqUw

The fourth episode's covered SOL 9 to SOL 11, the emergency protocol experiments and radio communication experiments: https://youtu.be/33oURy4jzv4

The fifth episode (SOL 12 to SOL 14) detailed the EVAs in more detail and the role of the Crew Commander: https://youtu.be/qjua9auxdpE

The final episode (SOL 15 to SOL 17) presented the Crew Engineer's role, ultrasound medical surveillance surveys as well as the Space Educational Activities: https://youtu.be/j88USgAho1Y

5. Conclusions

Although some in-mission results could not be obtained due to environmental constraints or schedule issues related to the COVID-19 pandemic, an interactive and multi-disciplinary outreach to students was possible through Crew 263's mission at the MDRS.

The studied activities were all related to the national middle school and highschool study programs; this allowed both to generate enthusiasm

Acknowledgements

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