Student perspective and lessons learned from participating in the European Rover Challenge 2021

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Abstract

The European Rover Challenge (ERC) is a competition where multiple teams from all around the world must face the technical, logistical, scientific and managerial difficulties of designing, building and operating a rover capable of performing a myriad of different tasks in a Mars analogue terrain (also known as Mars Yard). The competition, held in Kielce, Poland and organized by the Kielce University of Technology in collaboration with the European Space Foundation, regional governments, the European Space Agency, the Mars Society and other honorary patrons showcases each team's creativity, innovation, drive and passion to an expecting audience, serves as an entry point to complex large-scale engineering projects for students from all backgrounds, supplying them with essential soft skills often overlooked during regular university education and connects like-minded individuals from different countries, encouraging international communication and collaboration in the aerospace industry. The authors of this paper participated in last year's competition, ERC2021, and achieved 10th position. In this paper the insider perspective from first-time ERC participants will be discussed, including all the steps made to apply and qualify, the issues faced along the way, the lessons learned and the final experience of the on-site trials.

Keywords

Rover; European Rover Challenge; Robotics; Planetary Science; Planetary Exploration; Mars Analogue

Acronyms/Abbreviations

SSEA	*Symposium on Space Educational Activities*
UPC	*Universitat Politècnica de Catalunya*
ESEIAAT	*Escola Superior d'Enginyeries Industrial, Audiovisual i Aeroespacial de Terrassa*
UPCSP	*UPC Space Program*
ERC	*European Rover Challenge*
MY	*Mars Yard*
PDR	*Preliminary Design Report*

1. Introduction

As of the date of writing this paper, the only hope for humanity's exploration beyond the confines of our own planet lies in using remote exploration robots that, either from orbit or on another planet's surface, serve as our eyes, ears and other senses. Currently there are a total of 4 rovers exploring foreign cosmic objects [1], [2], [3]. Studies and investigations carried out by these rovers provide better insight into the mysteries of planetary geology than satellites thanks to their mobility and close proximity to points of interest. The technical complexity they entail, however, is a challenge on a global scale and problems faced in day-to-day rover operations are tackled by the international community. With this in mind plenty of competitions worldwide task up and coming engineering students with facing similar problems and coming up with creative and feasible solutions which might be applicable to martian or lunar rovers. One of these competitions is the European Rover Challenge.

2. The European Rover Challenge

The European Rover Challenge (ERC) [4] is an educational robotics and space event where teams from across the world design, build and operate a rover to perform a number of tasks in Mars analogue terrain, the Mars Yard (MY), built specifically for each year's edition in Kielce, Poland. The tasks that each rover needs to accomplish covers a broad range of technical challenges which are present in nowadays space exploration, and to qualify the teams are tasked with documenting their work to prove their capacity to face the following tasks:

- **Science task:** Before the competition begins the teams have delivered a science planning which is then executed in the MY. After exploring a science report must be delivered shortly after.
- **Maintenance task:** The rover must activate switches, measure voltage and connect jumpers and an ethernet cable on a maintenance panel.
- **Probing task:** The rover must place a total of 3 probes in the MY in previously selected locations and after performing other tasks collecting the probes back.
- **Navigation task:** The team is given a total of 4 waypoints which must be reached. During operation, however, the rover's operator must not be able to see from any cameras, and the rover must internally calculate its position and communicate it to the operator.
- **Presentation task:** The teams must present the project, the team and the rover in an oral presentation in front of the jury.

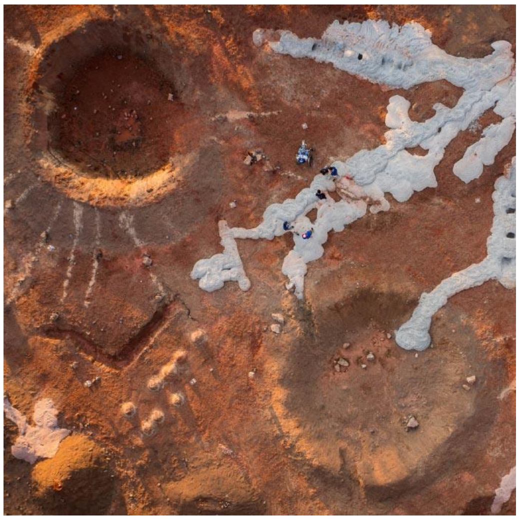

Figure 1. Mars Yard from above. [4]

3. The team

The team is part of the UPC Space Program [6] student association, which has the aim of acquiring knowledge and experience and transmitting it to the newer generations of engineering students. The UPC Space Program is currently separated in 5 missions: Ares, which designs and builds solid fuel rockets; Aldora, which develops and builds drones; Zephyros, which develops and builds high altitude balloons; Horus, which designs subsystems for CubeSats; and GRASS, which develops exploration rovers. The robotics branch of the UPC Space Program has a main objective of getting students acquainted with robotic exploration through the design and development of a rover for international competitions. The student association is predominantly multidisciplinary, with members ranging from aerospace engineering to industrial, mechanical and electrical engineering. The mission started in 2017 with the construction of mechanical parts and a first iteration of the electronics, but due to the members finishing their studies the mission was stopped. However, it was recovered in 2019 using the leftover materials of the 2017 rover to start testing new technologies such as terrain mapping, experimenting with new 3D printing techniques in order to build a new electronics box and a robotic arm to attach to the new base. The next year, however, the team focused on participating in international competitions, mainly the UAV Challenge Medical Rescue 2020. It was unfortunately postponed due to the COVID-19 pandemic, so an alternative was found in the European Rover Challenge.

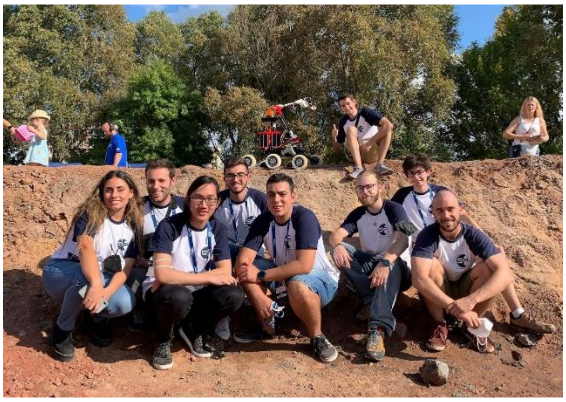

Figure 2. Team members with the rover in the background. [5]

4. First phases: Documentation

The first step to apply is to produce a very brief document which includes the team's interpretation of the rulebook, the approach to solving each task and a preliminary risk assessment [6]. The format and the specific points included are a great guide on how to define the technical requirements for a project. With this proposal produced and delivered, the team is now in the competition and must start working on both the rover and the next keystone, the Preliminary Design Report.

Two months after, in May, comes the deadline for the most important document of the process: the Preliminary Design Report (PDR) [6]. In this PDR the process mentioned before in the proposal is repeated in more depth. The architectures, components, the budget, the safety systems and in general a Work Breakdown Structures (WBS) must be defined, even if it's not the final iteration. This serves as a follow-up guide on the more complicated aspects of managing such a project: thinking about inter-dependencies of the different subsystems, budget monitorization and constraints, and a deeper risk matrix with mitigation and contingency procedures. An initial science planning must also be delivered. After the delivery of the PDR all the documents delivered up to that point are evaluated, and the 15 teams with the most points qualify for the On-Site trials in Kielce, Poland. In this year's ERC there was a 3-way tie for 15th place, so a total of 17 teams qualified for the event. By mid-summer the final report with the final version of all previous sections with all the definitive components, schematics, and most importantly the reflection upon previous risk assessments, identifying strengths and weaknesses and the lessons learned along the project. A report on the radio communication systems of the rover and a science plan where the selected points of interest and what can be learned from them is explained.

The science report produced after the competition is delivered the same day as the science exploration. This year, in our case, due to technical issues that will be mentioned in sections 6 & 7, we didn't reach our selected point of interest and we had a very small amount of visual information to use for science purposes.

5. Qualification: Construction

After the design phase was completed in May with the delivery of the preliminary design report, the construction phase of the rover began. In this phase, 3d printed elements were produced and assembled and final code, electronics and wiring were planned to be implemented. Nonetheless, due to pandemics restrictions and mobility problems, all the construction phase was finally delayed causing a lack of validation and verification processes.

The difficulty of having face-to-face meetings generated misunderstandings that led to incompatibilities in the assembly. As a result, the final structure had several tolerance problems and many different kinds of unions that impeded making quick changes. For these reasons, a design review had to be executed in order to accomplish the assembly between the different interfaces.

The delays in the final assembly and the last time modifications forced the electronics department to manage against the clock in the wiring interface, since the planned design, which incorporated elaborated connections and a complex wiring system, was substituted by welded cables and protoboard connectors.

As regards to the software implementation, the final structure for testing was not available until a few weeks before the competition and many of the tests that were successful months before failed in the assembly general test. As an example, PID controllers were not able to ensure a soft motion of the assembled robotic arm or compensate for the imbalance between the wheels. Moreover, due to the inexperience of the software team, some advanced requirements such as location algorithms were in an embrionary phase in the last few days. Nevertheless, the communications between the rover and ground station were tested successfully and the rover was able to do some basic tasks before departing to Poland.

6. Journey to Kielce & trials in the MY

In order to manage the logistics of the transport, the rover was disarmed and transported in protected baggages. For this reason, at the arrival in Poland, some of the pieces suffered damages, which afterwards were repaired with in-situ materials, affecting the expected performance. Aside from this, due to a problem related to the power supply, the Raspberry pi, which was the master communicator between the ground station and the rover, was damaged and a reprogramming of the Jetson was required to accomplish this task. Hence, this implied the loss of the stereo vision, since the deteriorated device was also in charge of it. Moreover, since the power supply of the robotic arm was not able to fulfill its task also, a trip to Warsaw was needed to achieve some new operational electronic components.

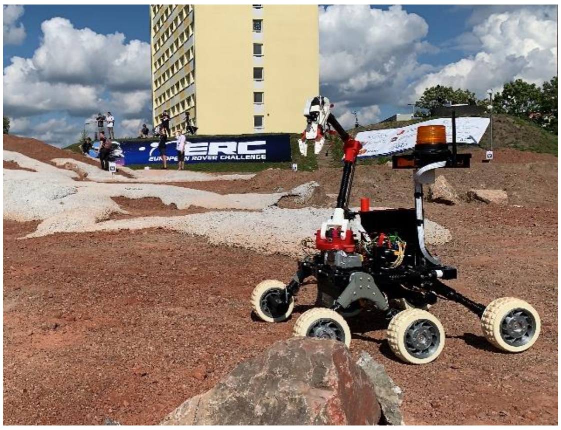

Figure 3. The GRASS rover in the MY [5].

During the probing and maintenance tasks, due to the aforementioned complications, some issues related to the robotic arm were encountered. Even trying to solve these problems by changing some pieces and postponing the tasks, some of them were not able to be accomplished. In the navigation task, the rover was supposed to drive blindly, nevertheless, due to a malfunction and the lack of time to verify and validate the associated performances, as stated in the construction stage, the position of the robot could not be adequately found, therefore, the task was invalid. After switching on the cameras, the rover could move through the Mars Yard, however, it got blocked and, consequently, only one picture was taken.

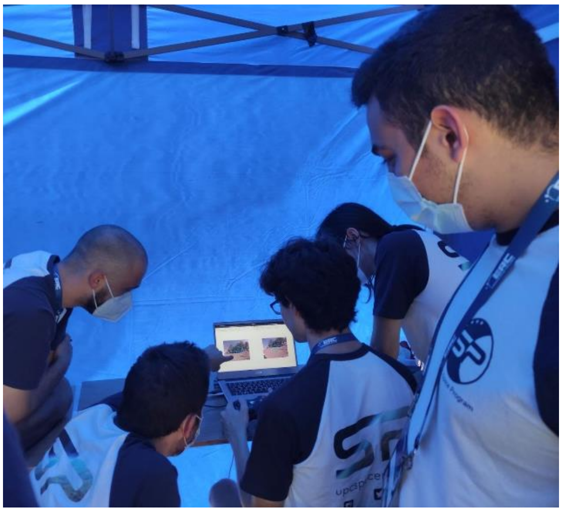

Figure 4. Team members during the probing & science task. [5]

7. Results

In summary, a relevant number of components failed in their performance, for instance the stereo vision did not work, the robotic arm resulted uncontrollable and the navigation algorithm was not satisfactory.

Despite all these encountered issues and thanks to the produced documentation, including the preliminary science planning, and the small amount of points obtained from each task, the team was placed in 10th position.

8. Discussion

The results achieved this year were due to a clear lack of focus from early on in the project, apart from the lack of time and resources. Work started on the rover fairly late, and a lot of work was obsolete and incohesive. The lack of knowledge led to preventable errors, like the lack of care for the logistic aspects which led to the technical problems mentioned before. No members of the university were asked to provide support in the form of technical advice. From the point of view of the team, it was also a not ideal way of tackling such a challenge, since it entailed periods of crunch.

In essence, the participation in ERC2021 has been a nourishing experience for all the team members, which resulted in important lessons for the future of the mission. Since the structure of ERC2022 remains more or less similar to the previous year, thanks to the acquired background in the contest, the team is more capable of paying attention to the aforementioned errors and trying not to repeat them. Moreover, the most part of the elaborated documentation is available for this next edition, given its high rating in the previous one. Regarding the overall difficulties, they were mainly based in planning miscalculations and, for this reason, an early solid management process is currently being implemented for the participation of ERC2022.In reference to the technical part, the lack of specific knowledge is being overcome by the support of docents specialized in different areas, such as navigation and control systems. As future goals, the team aims to achieve a competitive baseline, become a habitual ERC participant and expand onto other international competitions across the globe.

9. Conclusions

This paper revolves around the experience of the UPC Space Program GRASS team in the European Rover Challenge 2021. The competition is explained, the team is introduced, and then the process through which the challenge was tackled is described. The results yielded by this process, which were not the best, are analysed and the reasons for the issues faced along the competition are explored. The nonoptimal results stem from improper management structures and a lack of clear focus, knowledge and resources. From this analysis, the lessons learned are disclosed and the steps to improve as a team that either are already in place or will be implemented in the future are enumerated.

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References

Here you have some examples of references.

[1] NASA Website: https://mars.nasa.gov/mars2020/ , last visited: 11th March 2022

[2] NASA Website: https://mars.nasa.gov/msl/home/ , last visited: 11th March 2022

[3] ECNS, English-language website of the China News Service: http://www.ecns.cn/news/2019-12-13/detail-ifzrtayn1411959.shtml , last visited: 11th March 2022

[4] ERC Website: https://roverchallenge.eu/en/main-page/, last visited: 14th March 2022

[5] UPC Space Program Website: https://upcprogram.space/, last visited 14th March 2022

[6] ERC Space and Robotics Event, ERC-STUDENT 2021 Rules, 54 pages.

[7] Losiak, A., et al. "Teaching Planetary Geology to Engineers During European Rover Challenge (ERC)." Lunar and Planetary Science Conference. No. 2548. 2021.

[8] SSEA22 Website: www.sseasymposium.org, last visited: 14th March 2022