MARS YARD DESIGN DURING THE EUROPEAN ROVER CHALLENGE (ERC) 2020-2022

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European Rover Challenge (ERC) is an international robotics competition in which teams perform tasks analogous to those of rovers on the surface of Mars. The project aims at stimulating and supporting a new generation of engineers by developing competencies, skills, and networks within the space sector. It is organized in Poland by a group of volunteers through the European Space Foundation. ERC is accompanied by a large science-outreach event and a conference for the representatives of the space industry in Europe. The first edition was in 2014 in Checiny and starting in 2019 it takes place at the Politechnika Swietokrzyska in Kielce. The 2020 edition was the only major robotics competition that took place during the time of the global pandemic (remote edition), and since then the event was performed in double editions: onsite and remote. In ERC2022 92 teams from 21 countries participated, out of which 30 qualified for the finale.

ERC is the only competition of this kind with a large scale (35x45 meters) geologically realistic Mars Yard. The **aim** of this abstract is to provide information on ERC and show how its Mars Yards design evolved between 2020 and 2022.

Competition Rules: The teams are required to perform five tasks during the onsite version of the competition (detailed explanations are provided here: roverchallenge.eu/en/competitor-zone/)

- Presentation: introduce the team and present their project as business pitch in an informative and interesting way.
- Science: perform a scientific exploration of Mars Yard (Fig. 1, Fig. 2). It is described in detail below (Science Task performed in this format from 2020).
- Navigation: design algorithms to navigate automatically and safely through Mars Yard and visit all prescribed waypoints (their locations were provided shortly before the traverse).
- Probing/Collection: collect either 3 surface samples from the locations indicated by the Judges or 1 deep sample (perform drilling in a single location), plus place and collect probes from the rover's cache in the indicated locations.
- Maintenance: use a robotic arm to set switches to the required positions and plug a variety of devices into proper sockets to demonstrate the ability of teams to perform in unknown conditions and flexibility and dexterity in tele-operating the manipulation device.

Fig. 1. Photo of the winning teams participating in the ERC 2022. Please note extensive signs of water on our Mars Yard. Source: @rover_challenge twitter

Science task: The aim of the science task is to prepare and execute a simple science-driven exploration plan of Mars Yard. The task was designed to mirror scientific activities performed before and during planetary missions. Because of that, most of the work is expected to be done before the mission based on the "remote sensing" data provided to the teams three weeks before the finale. Required activities are like ones performed during analog Mars missions: DRATS [2], MARS2013 [3], MARS2015 [4], AMADEE-18 [5].

The deliverables of the science task are divided into two parts:

Science Planning (submitted 1 week before the ERC):

a) Preparing a geological map based on drone images and the Digital Elevation Model of the Mars Yard.
b) Describing geological evolution of the Mars Yard.
c) Identifying a location on the Mars Yard where observations from the surface may help to validate a geological model of the Mars Yard based on remote sensing observations.
d) Formulating a hypothesis and describing a plan to test it in the field.

Scientific Exploration (submitted up to 2 hours after the traverse through the Mars Yard during the ERC final):

a) Verifying hypothesis described in the Science Planning phase including appropriate photographic documentation.
b) Discussion of how this new knowledge influences the understanding of the geology of this area along with an amended geological map.
c) *Ad hoc* science: within the Mars Yard we distribute a number of "interesting objects" such as: a plush żubr, a group of "Dragon Balls", a wide range of minerals and rocks, an artificial "Martian" flower, and a number of weird ceramic sculptures. Teams are expected to find, photograph, identify, and mark on the map 5 of those objects. The aim of this task is to ensure they pay attention to their surroundings during the traverse.

Mars Yard (MY) is re-designed and re-build each year (since 2019) to provide new data for geological mapping during the Scientific Task, and unexpected terrain for the Navigation Task. The design process is guided by the following requirements:

1) ***Geologically realistic***. It means it must be made of geological features that are interacting with each other in a geologically feasible way. Thanks to that, each design tells a consistent geologic history that should be discovered by the teams during their scientific exploration. Because of size limitations of the MY to 35x45 meters and necessity to fulfill other requirements, the relative size of geological features are not up to scale.

2) Represent ***various levels of complexity*** from the ***engineering*** point of view. The MY needs to include various types of surfaces and allow teams on different level of rover design maturity to participate, but at the same time to differentiate the quality of teams and enable us to select the best ones.

3) Allow the **competition to take place** within prescribed conditions. This means that the design needs to enable multiple teams to be able to perform their tasks at the same time without disturbing each other, within three days of the competition.

4) Mars Yard needs to **look good** in real life and in the pictures. ERC is accompanied by a large science fair where people are encouraged to observe the competition – MY needs to be attractive from their perspective. Because of that we have included some interactive elements like "erupting volcano" or formation of Recurring Slope Lineae in one of the craters. Secondly, because a significant part of the funding for ERC comes from sponsorship from private companies in exchange for PR opportunities, MY must look appealing and interesting on the photos used later in social media.

The design of geologically realistic Mars Yard is very challenging, e.g., its building takes a full week of a five-person team (plus some heavy equipment). But is a very effective tool for teaching planetary sciences to a large and diverse group of people, as shown by the evaluation reports from the teams taking part in the competition.

References: **[1]** Karahan et al. 2020. European Rover Challenge (ERC) – An Annual International Robotics Competition in Poland. LPSC 2020 Abstract # 2188. **[2]** Eppler et al. (2013) Desert Research and Technology Studies (DRATS) 2010 science operations: operational approaches and lessons learned for managing science during human planetary surface missions. Acta Astronaut 90:224–241. **[3]** Losiak et al. (2014) Remote Science Support during MARS2013: Testing a Map-Based System of Data Processing and Utilization for Future Long-Duration Planetary Missions. Astrobiology 10.1089/ast.2013.1071. **[4]** Lalla et al. (2019) Laboratory analysis of samples from the AMADEE-18 Mars analog mission in the framework of the Exploration Cascade. Astrobiology doi.org/10.1089/ast.2019.2038. **[5]** Groemer et al. (2016) The AMADEE-15 Mars simulation. Acta Astronautica 129: 277–290. [6] Sun and Stack (2020) Geologic Map of Jezero Crater and the Nili Planum Region, Mars Scientific Investigations Map 3464. [7] Horvath et al. (2021). Evidence for geologically recent explosive volcanism in Elysium Planitia, Mars. Icarus 365: 114499.

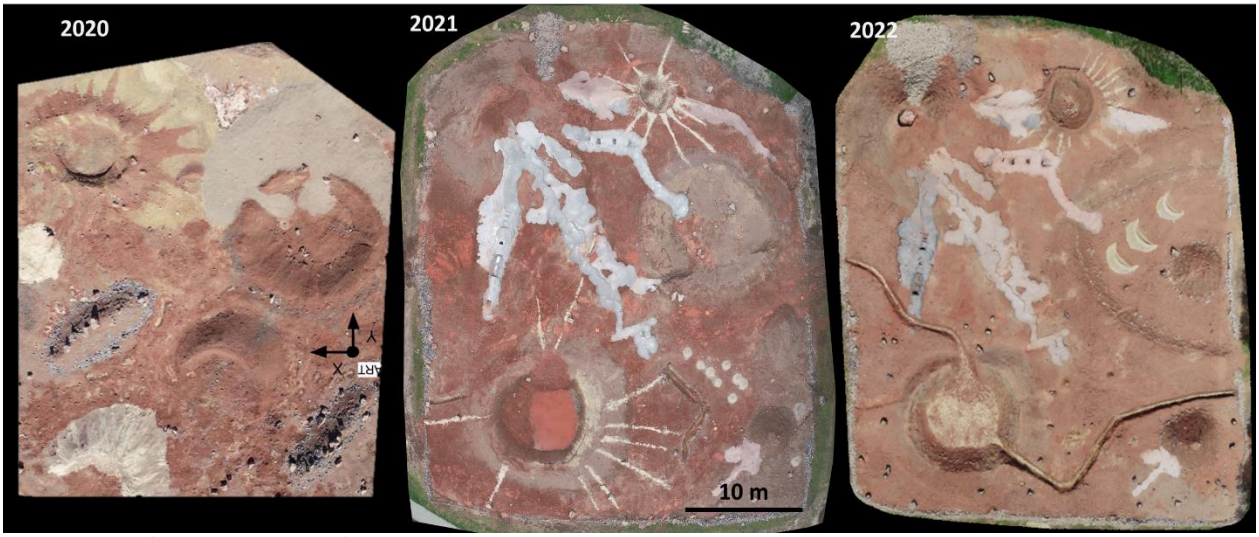

Fig. 1. Designs of ERC's Mars Yards from 2020, 2021 and 2022 (all images are based on photogrammetric DEMs and are presented in the same scale). The design for 2020 was inspired by the landing site of the Perseverance Rover. The area was made of elements that can be found in the Jezero Crater [6]: in the north there were two deltas/ alluvial fans (yellowish in the West and beige in the East), that interact with older (East) and younger (West) impact craters. There were also two inselbergs with a layered structure and the remains of the capping unit at the top. On the MY there were also dunes, and outcrops of older whitish rocks. 2021 design was inspired by papers describing possibility of recent/current volcanic activity on Mars: the design was based on SE Elysium near Cerberus Fossae [7]. Because of that we prepared a volcano five meters in height (Fig 1) with numerous lava flow (made of concrete), a smaller "active" volcano in the SE (volcanic gases were mimicked by a machine for making disco-fog connected to the "volcanic piping"). The area also had some signs of tectonic activity, e.g., in a form of a graben-like feature cutting through the older impact crater. 2022 design was similar to this of 2021 – but this time it was inspired by the area on Mars where Elysium borders with Utopia Planitia so it was possible to both see the volcanic and water-related structures. One of the main features was a river that flowed into a crater forming a small delta and after cutting through the crater rim flows outside. This river not only was an interesting geological feature, but also allowed us to divide the MY into zones what decreased the chance of unplanned rover-collisions during the competition. The crater in the SW was filled out by multiple layers of colored sand (mimicking lake deposits) allowing us to check what was exactly the depth of drilling performed by the teams.