ERC
EUROPEAN ROVER CHALLENGE

RULES

STUDENT

2020

www.roverchallenge.eu

Change record

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General information

What is the ERC?

The European Rover Challenge (ERC) is an integrated programme working towards technological developments, specifically those in GPS-denied environments, with space exploration and utilisation as the leading theme. The ultimate goal of the ERC is to become a standardised test trial and benchmark for planetary robotic activities, coupled with strong professional career development platform.

The European Rover Challenge is owned and coordinated by the European Space Foundation, organised in cooperation with a group of independent experts who make up the steering and jury boards. Mars Society Polska is a partner of the programme.

What is ERC-Student?

One of the main components of the ERC is the ERC-Student track (hereafter referred to as the ERC or ERC2020). ERC-Student consists of an engineering project where university teams build robots to compete on an extraterrestrial inspired arena performing tasks based on international roadmaps for space robotics. This means that the competition tasks present the same level of problems as industry drivers for space robotics which have been devised for future decades. Perhaps most importantly, whilst set against the background of a competition, ERC-Student is a continuous mentoring effort which is intended to educate the next generation of multidisciplinary engineers, boost innovation in research and business, and popularise STEM (Science, Technology, Engineering and Mathematics) advancements, all conceptually rooted in future space exploration.

Schedule and Venue

ERC is a venue independent, year-round programme. For information about the ERC2020 edition venue, please follow our updates on the challenge website (see *Information channels and contacts*). The official schedule can be found in the appendix to this document.

Information channels and contacts

The Challenge website address: www.roverchallenge.eu

Teams' Contact Point email address: teams@roverchallenge.eu

The official communication channel for challenge announcements is the list of email addresses supplied by teams during the registration process.

Teams

Qualification

The ERC2020 programme is planned for a limited number of teams. Together with the challenge jury, the organiser will choose which of the registered teams will be invited to compete in the challenge. The choice will be made based on the registration Proposals and Preliminary Reports (content described in the *Documentation* section), which teams are required to send to the organiser by the deadline given in the program schedule. The organiser will announce qualifying teams before another deadline given in the same schedule.

Team members

75% of a team must be comprised of higher education students and recent graduates: undergraduate and masters-degree level students (with no limitations) and PhD students. It is highly recommended that teams cooperate with specialists from different institutions, but students must prepare and sign all of the required documentation themselves.

A team may consist of students of more than one higher education institution. An institution may also be affiliated with more than one team. Team membership is exclusive – each person can only be a member of one team.

Registration

For registration dates, please refer to the challenge schedule. Registration details will be sent to the organiser in English, via the team's contact point email address (see *Information channels and contacts*). In cases where this information is not submitted prior to the specified deadline, the team will not be allowed to participate in the challenge.

The team registration email should include:

a) The name of the higher education institution with which the team is affiliated (if the team is affiliated with more than one institution, please list all the names, in descending order of involvement);
b) Team name;
c) Rover name (this may be the same as the team name);
d) Project proposal (see the *Documentation* section);
e) The approximate number of team members who plan on coming to the challenge (i.e. appearing on site);
f) Team contact point: the contact's name and surname, telephone number and email address;
g) University team coordinator/supervisor: name and surname, telephone number and email address;
h) Project website address or/and Facebook fan-page;
i) The following declaration in English:
'By sending this application and registering the team to the European Rover Challenge each team member fully accepts all terms and provisions of the ERC rules and all final decisions of the European Rover Challenge organizer.'

Rover system requirements

Each rover must be compliant with the requirements listed below in order to take part in the challenge. Special cases of non-compliance should be discussed with the organiser as soon as possible in the development process. The organiser has the right to exclude the team from field trials, especially when non-compliances are reported too late (e.g. during the challenge event). It is highly recommended that teams present their status of compliance with the specified requirements in a transparent way in their technical reports.

General requirements

The rover has to be a standalone, mobile platform. No cables or tethers are allowed for connection to external data links or power sources during its operation.

Teams should design and build their own rover, but COTS (Commercial-Off-The-Shelf) components are allowed and recommended. A COTS rover platform would be considered, but all such applications will be discussed separately to ensure that the competition abides by the standards of fair play.

System weight

The suggested rover weight, including payload, is 50kg. The limitation applies to every task (i.e. task-relevant rover configuration) separately. Equipment used for rover maintenance and preparation, unused spare parts, and elements not mounted during a particular task are not included in this limit.

There is no weight limit on equipment used to steer and control the rover from the rover control area, communications equipment in that area or maintenance equipment.

Rovers which are lighter than the limit will be rewarded, while those which are heavier will be penalised by a number of points defined in the scoring rules (see appendix to this document).

Rover control and operations

The maximum speed of the rover cannot be greater than 0.5 m/s.

The team should be able to control the rover via a radio link in real-time. Each task will require the rover to travel a certain distance, but never more than 100m from the starting point. The starting point will be no farther than 50 meters from the antenna mast. All communication equipment, including antennas, should be deployed in the vicinity of the control station. Teams should be prepared to place their antenna mast at a maximum of 20m from the control station location.

The rover should be built to handle challenging terrain, appropriate dust and general weather conditions resistance described in *Field Trials* section. The operational temperature range should be between +10 and +30 degrees Celsius.

Rover autonomy

Rover autonomy or capabilities of automation of particular tasks or its elements are highly rewarded and can provide a major advantage in scoring for all the tasks.

In automated control, states and commands defined below should be differentiated:

- 'idle' state - initial state, motors deactivated, the rover awaits a command;
- 'start' command - the command to be sent at the beginning of the task attempt;
- 'working' state - nominal work during an attempt;
- 'wait' command - enter the 'wait' state. The team can use this command at any time for sensor readings stabilization purposes;
- 'waiting' state - the rover should wait stationary for a 'resume' command. This state should be automatically entered if the rover reaches a task check-point. The system should be prepared to compensate or allow for the fact that sensors may be obstructed by the judge or team members who are present in the rover's vicinity (e.g. checking the distance to the check-point). An operator cannot influence the system during this state and reaching this state does not stop the task time;
- 'resume' command - a transition from the 'waiting' to a 'working' state;
- 'abort' command - leading to autonomy abort and the rover coming to an immediate stop, the rover then transits to 'idle' (not to be confused with Emergency Stop) - control can be switched to manual.

The above list is not exhaustive, and teams can define additional states and commands.

In order to score points for autonomy or single task automation, the team cannot touch the controls once the attempt begins. The only exception is to send the commands listed above. If team members touch the controls, then the autonomy points for that attempt will not be awarded. However, team may switch to manual controls to complete the task by tele-operating their rover at any point. Telemetry of the rover should be monitored during autonomous/automatic operations and recorded. It is highly recommended (but not required) that these recordings be archived and shared in open access after the event.

In autonomy mode, extra safety precautions should be taken. Minimum requirements are specified in the *Rover Safety* section of this document.

Rover Safety

Elements listed in this section are mandatory for all teams and compliance with them should be clearly presented in both the technical documentation and during checks before task attempts. This compliance will be strictly checked and failure to ensure it may result in the disqualification of the team from the entire challenge.

Emergency stop

The rover shall be equipped with an easily accessible red emergency stop button. It must be part of a highly reliable circuit designed to isolate the batteries from the system by a single button hit and until reset a procedure is executed. Only laptops with their own batteries can remain powered on. Therefore, an unmodified, industrial, commercial-off-the-shelf, emergency stop button and other parts of the safety circuit are required. If an unsafe event occurs, judges must be able to access this button and deactivate the rover without any additional actions being necessary. The operation must be possible by means of an open hand hit. The button mounting should be capable of withstanding a hard hit and should be attached to a stiff element of the rover's body.

Even if the RF certified EM button is in use, at least one physical emergency button must be placed on the rover construction.

Activity Indicator

Rover should be equipped with an indicator lamp. It should be active whenever the rover is ready to perform an action (e.g. drive or operate a manipulator) at least 5 seconds before the action is executed. During this time the rover should be completely still and safe. The indicator should be clearly visible from at least 10m attracting the attention of people in the vicinity by blinking or flashing. Suggested colours are: yellow, orange or red. It is highly recommended to use industrial-grade device.

Automatic/Autonomous functionality

Any autonomous or automatic operation should start with a delay of at least 5 seconds after issuing the command.

By all means, teams should avoid situations when an immediate or rapid movement is executed after the activation of the system or issuing a command. An overflow of any communication/interface buffers or broadcast of multiple commands to the rover or its subsystems when it should stay still or deactivated should be prevented by means of the design.

Communication requirements

General

Radio communication with the rover has to use legally available frequencies and power levels. It is expected that the maximum distance between the rover and the antenna mast would be less than 100m. Direct line-of-sight between the control base and rover antennas may be occluded by different forms of terrain morphology.

Accepted frequencies

Radio amateur bands

Accepted bands up to 1W signal transmitted and up 10W EIRP.

144 - 146 MHz

430 - 440 MHz

1240 - 1300 MHz

5650 - 5850 MHz

It is highly recommended that each team should have at least one member with an amateur radio license (CEPT class T/R 61-01). When using amateur radio bands, team should provide a scan of the licence of at least one member.

2.4 GHz band (2412 - 2472 MHz)

Only WiFi communication standard is accepted (IEEE 802.11). Any other systems such as analog video cameras or RC controllers are forbidden.

- accepted channels: 1-13 (2412MHz – 2472MHz)
- up to 100mW EIRP
- accepted standards: IEEE 802.11 b/g/n
- Rover can use only one 20MHz channel

SSID should be set to “ERC_teamname”.

5 GHz low band (5150 - 5725 MHz)

In the band 5150 - 5725MHz team can use one 80MHz channel for Wireless Access Systems: WiFi and AirMax only. Up to 1W EIRP power is permitted.

SSID should be set to “ERC_teamname”.

5 GHz high band (5725 - 5875 MHz)

In the band 5725 - 5875 MHz team can use one 30 MHz channel for any communication system - FPV etc.

ISM bands

It is possible to use ISM bands within their limitations but team must designate which rule is in compliance with European regulations (https://cept.org/files/4940/TCAM%20Subclasses%20(17)08%20rev%202%20-%20RED%20Subclasses%20of%20Class%201%20Valid%20as%20of%201%20January%202018.pdf).

The ERC does not accept ISM bands which are not accepted in Europe (e.g. 915 MHz).

Voice communication using a 500 mW PMR licensed transceiver is allowed on following channel frequencies (MHz):

1. 446,00625
2. 446,01875
3. 446,03125
4. 446,04375
5. 446,05625
6. 446,06875
7. 446,08125 - *reserved for organising team*
8. 446,09375 - *reserved for organising team*

Other frequencies

Other frequencies are only allowed when a relevant licence, valid in the territory of the venue, is presented by the team. Those communication channels must be described in the documentation and agreed with the organisers.

Other communication rules

Channels on different bands will be assigned to the teams on the warm-up day of the competition.

Before the competition, rovers and ground stations must be checked and accepted by the radio communication judge during an EMC (electromagnetic compatibility) test, ensuring proper channels and power limits have been set.

During the competition, rovers and ground stations will be randomly EMC tested. Unauthorized changes to the RF configuration may result in immediate disqualification.

The usage of any communication channels for testing (at any time outside of the duration of the competition attempt) must be consulted with the RF judge. Testing that can be conducted without RF communication is preferred. The organiser will provide rules for the usage of RF links for the main parts of the challenge venue. Requests to limit the usage of RF links can be expected and should be respected throughout the entire duration of the event.

For the whole duration of the challenge, the team is responsible for the legal use of the frequencies used in the venue's territory. The organiser can only help with frequency coordination and does not take responsibility for any license violations, such as exceeding RF power, frequency band or area of use.

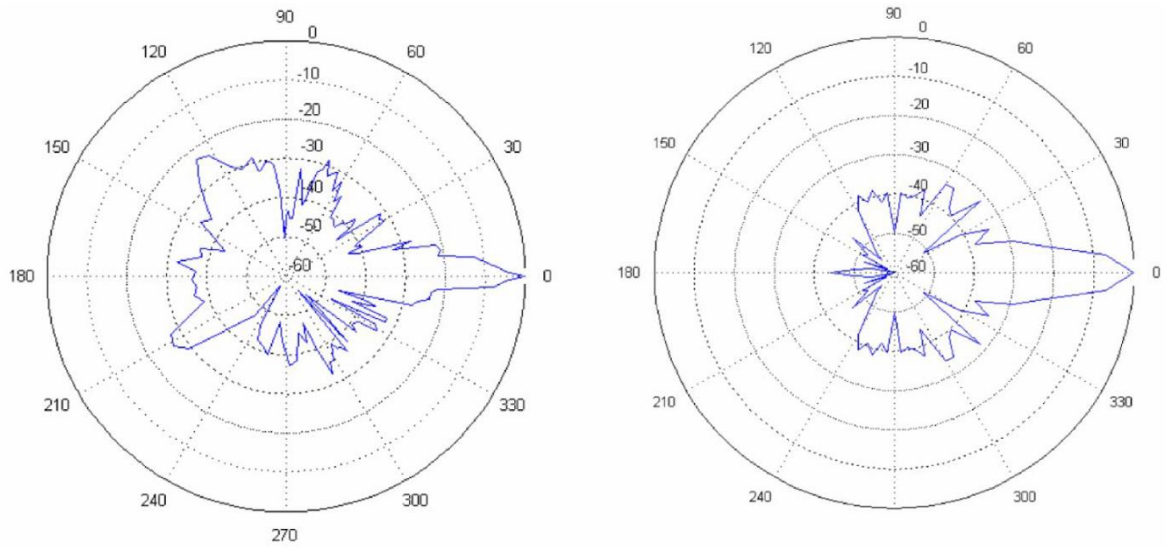
Radio Frequency Form

Each Team must fill in a Radio Frequency Form for every RF module used. It should be included in the relevant technical reports as an appendix (see documentation

specification). If these documents are not submitted in the requested form, the team will not be allowed to participate in the challenge.

The RF Form must contain:

a) Team name;
b) Country;
c) Name of the person responsible for the communication system;
d) Contact to the person responsible for the communication system (email address);
e) Photo of the rover;
f) Photo of the ground station;
g) Number of different communication systems;
h) System information (this part should be completed for every RF system):
    - RF system name;
    - Short description;
    - Models of the used transceivers;
    - Access point software version
    - Frequency;
    - Bandwidth;
    - RF power (output power + EIRP);
    - Modulation;
    - Antennas on the rover and ground station - models, radiation patterns (see Pic 1 for an example), pictures;



Pic. 1.: Example of a horizontal and vertical RF antenna radiation pattern for a ground station

Documentation

General

Each team must provide technical documentation for their project.

The project documentation is divided into three parts. The first set of information, called the Proposal, should be submitted with the registration form. The second and third are called the Preliminary Report and the Final Report, accordingly. Additionally, teams are required to deliver video material. All should present content and quality of professional engineering documentation, therefore it is strongly recommended to have it reviewed by experienced engineers.

All documents are scored and counted as a part of the challenge final points (for details, see the *Scoring* appendix). Scoring is designed to consider documentation as an aspect that can influence the order of teams on the podium, therefore it is important to deliver all documents in the best possible quality according to the requirements listed below and on time according to the schedule (see the *Schedule* appendix).

Proposal

The proposal should introduce the team and provide information as to why the project presented by the team should be chosen for ERC2020 based on technical expertise, team experience, and the first draft of the proposed solution. It should confirm that the team has read, analysed and understood the system requirements (rules of the competition).

In the proposal, the teams must include the following information:

1) A team introduction, containing information about the team's experience and expertise (short profiles of key people, the experience of the team, esp. in similar engineering projects and research work key for delivering this project on time and good quality, general focus, other projects etc.); please highlight experience in any past ERC competitions;
2) A short presentation of the proposed (initial) solution to the challenge. That should state your initial compliance with the rules (understood here as the ERC rules), and clearly present achievable (within the project timeline) ideas, initial project assumptions and an analysis of challenge tasks (including scientific aspects of the Science task);
3) A first draft of project risk analysis and planned mitigations;
4) First conclusions as to how your project or its parts could be commercialised/which elements and how it could be continued as further potential research, considering current technological trends.

Document requirements:

1) First page: Team name, project name, heading 'European Rover Challenge 2020', affiliation, title 'Proposal';
2) Format: A4, searchable PDF;
3) Length: max 6 pages (including a title page);
4) Language: English;

5) Appendices: no.

Preliminary report

This document should be written after the analysis and design phase, meaning that the team should present an idea how to solve the presented problems with the limitations and boundaries listed in the requirements and others which may have been additionally identified by a team. It should be the next iteration of the team's proposal, without repeating any basic, already closed points. The document should also contain a management and system breakdown of the project, the technologies chosen, and a technical solution meant to achieve the goal.

The Preliminary Report should include the following information:

1) Definition of technical requirements (compare them with those presented in the proposal, if changed, please describe why and how the changes will have an impact on the project; make a full list of your technical requirements and present the way in which you plan to meet them) and a test plan covering the requirements and other aspects important to show that your design is compliant with the requirements and can demonstrate a readiness for the trials;
2) Mission analysis: system use cases and scenario specific considerations including a scientific exploration plan – a detailed chapter following an outline of the scientific proposal and including: a) description of a problem to be solved based on the task description and literature review, b) hypothesis, c) methods to be used, with an analysis of their limitations, d) a design of traverse and sampling locations based on the provided Mars Yard project e) expected results;
3) Project assumptions (compare them with those presented in the proposal, if changed, please describe why and how these changes will have an impact on the project);
4) Architecture, technical budgets, technologies you plan to use and designs you have or are working on (at any stage of readiness);
5) Safety system description, with a special focus on the emergency stop circuit (circuit design and analysis - e.g. signal sequence etc.);
6) Preliminary System Breakdown Structure – a diagram with a short description covering the system dependencies at both a management and technical level (not to be confused with the technical architecture diagram or system schematics);
7) Financial planning (sources and expenditures/allocations);
8) Risk analysis - problems, issues and other risks (management, engineering, logistics, etc.) and how you plan to mitigate them;
9) The Preliminary Radio Frequency Form as an appendix (see *Communication Requirements* for details).

Document requirements:

1) First page: Team name, project name, heading 'European Rover Challenge 2020', affiliation, title 'Preliminary report';
2) Format: A4, searchable PDF;
3) Length: max 25 pages (including a title page);
4) Language: English;
5) Appendices: yes, if part of the same document (optional; only additional information which could not be included in the main document, for example large, detailed drawings and charts).

Final report

The Final Report is a continuation and extension of the Preliminary Report. It should contain detailed information on the elements presented in the Preliminary Report and summarise the project after the manufacturing and testing phase:

1) Final project assumptions (fixed);
2) Final technical requirements (fixed);
3) Test plan covered by test report;
4) Final update of scientific exploration plan and operational scenarios - use cases
5) Final design:
    a) System Breakdown Structure + description;
    b) System architecture - hardware and software diagrams and description;
    c) Technical budgets (mass, power, communication, etc.)
    d) CAD drawings (2D, 3D, dimensions, assembly, details);
6) Safety Systems description;
7) Final financial report (sources and expenditures);
8) Risk assessment update - difficulties and solutions applied;
9) Final Radio Frequency Form (RFF) as an appendix (the final version of the form presented in the preliminary documentation).

Document requirements:

1) First page: Team name, project name, heading 'European Rover Challenge 2020', affiliation, title 'Final report';
2) Format: A4, searchable PDF;
3) Length: max 30 pages (including a title page);
4) Language: English;
5) Appendices: yes, if part of the same document (optional; only additional information which could not be included in the main document, for example large, detailed drawings and charts).

Video material

Each team should prepare promotional video material presenting their readiness for the competition. This deliverable must be completed and submitted by the date presented in the challenge schedule (see the *Schedule* appendix). The material should be uploaded to one popular video service (e.g. YouTube) and a relevant link must be delivered to the organiser by the specified deadline. Teams that fail to deliver this recording will not be allowed to participate in the challenge.

The video should be a maximum of 5 minutes in length and present the rover's capability to take part in the challenge, containing the following elements:

1) Introduction of team name, rover name, and the higher education institution name;
2) Introduction of team and present teamwork;
3) Introduction of the reasons for proposing the team to the challenge;
4) Presentation of safety systems (including emergency stop button) performance;
5) Presentation of the remote control - mobility and task related subsystems;
6) Presentation of the rover's ability to resolve the challenge tasks;
7) An explanation of what scientific project will be performed by the team, and why it matters;
8) Quality and proper visual aesthetics for a video clip and presentations skills.

In special cases, the video may be the basis to request more details concerning the team’s readiness to participate in the competition. Failure to present the requisite level of readiness may influence the extent to which the team is allowed to participate in the trials.

Field trials

Field trials are organised as a benchmarking activity to compare the performance of teams in the resolution of several tasks. Each task presents an independent set of problems to be solved and which are related to the particular technologies required by future space robotics missions.

General

a) The challenge tasks take place in front of an audience in the form of a public event;
b) Challenge attempts are independent. Teams are permitted to change their rover configuration between tasks. A certain amount of time will be scheduled in between tasks to allow teams to modify, repair and optimize their rovers;
c) The challenge jury consists of a number of specialists selected by the organizer. While judging the challenge, the jury acts independently of the organiser but adheres to the schedule provided by the organizer. In the case of any unforeseen issues not specified in the competition rules, the jury board will propose a solution.
d) Technology priorities assigned to each task describe the focus areas for each task in order of priority. This order will be reflected by the scoring system summarised in the appendices.
e) The scoring of each task is independent and summarised in a separate appendix to this document.
f) Excellence shown in a particular task can be rewarded with additional points or multiplication factors (see scoring details).

Schedule

a) On the first day, teams should register at the challenge venue;
b) Additionally, for all teams, a warm-up day is planned for the day before the challenge. This day should be used for calibration and other preparation activities. The organiser will give each team a limited time slot within which teams are allowed to do any kind of measurements agreed with the organiser and based on the final report specifications. Some task elements which are considered too detailed may be removed for this day by the organiser. All dynamic elements may not be placed in their final locations. The organiser cannot guarantee that the challenge area and its elements will be fully ready for this day;
c) On the last day of the challenge, total scores are calculated, the winners announced and prizes awarded.
d) A detailed schedule containing the exact time window for each task will be announced by the organizer one week before the event in a preliminary version, with the final one being issued on the first day of competition;
e) Each team is obliged to respect the schedule. Any request for the modification of start slots etc. may be rejected by the jury without any reason being required. A certain amount of time will be scheduled in between tasks to allow teams to modify, repair and optimize their rovers.

Challenge site details

a) Each challenge task can be organized either indoors or outdoors. The outdoor challenge elements may be placed under tents. Teams can expect typical interior

furnishings, buildings, industrial installations (metal pipes etc.) and natural objects (e.g. trees, bushes) in the vicinity of the challenge arenas.

b) For outdoor tasks, teams and their systems should be prepared for a range of weather conditions. Temperatures between 15 and 30 degrees Celsius, wind gusts, light drizzle, strong or weak levels of sunlight are all acceptable. During conditions unfavourable for the particular design, the team may request a reschedule but the final decision will be made by the trial judge. This will be made based on the schedule, other requests and the potential impact on team performance. In the case of major weather problems, the organiser will make all reasonable efforts to reschedule/reorganise the trials within the available period and facilities. However, it cannot be guaranteed that all of the trials will take place or will be organised strictly in accordance with the presented specifications.
c) The organizer will provide each team with a workspace equipped with tables, chairs and 230V, 50Hz power socket (‘type E’, compatible with the ‘German type F’);
d) The challenge location is separate from the team area to avoid RF interference but the organiser cannot guarantee that extra precautions will not be requested to avoid disruption to the challenge attempts;
e) The challenge field (the place where terrain dependent tasks are held) will be artificially landscaped specifically for the event. Sandy, non-cohesive soil, as well as hard, dry terrain, all at a variety of slope angles, should be expected. In the case of tasks which do not score locomotion aspects, a flat industrial surface (e.g. concrete) can be also expected.

Operations

a) The aim of the challenge is to demonstrate and evaluate the performance and robustness of the proposed solutions. All tasks are designed to eliminate ‘luck’ from challenges. Therefore, teams should present a high level of readiness for each task and platforms should be equipped with all the devices needed to solve all task elements. Rovers that are not equipped with all of the necessary elements may not be allowed to attempt a task;
b) For the reasons stated above, teams can expect dynamic elements in the task description i.e. elements that will be defined separately for each team at the beginning of the attempt (e.g. changing the start position, different positions of task elements etc.). In those cases, the jury will propose fair modifications and the team cannot influence those decisions.
c) Teams will control their rovers from rover control stations. The stations will be set up so that team members will not see their rover during the tasks;
d) Each team has about 20-25 minutes (if a task description does not state otherwise) to complete a task. This value will be fixed by the time of the final schedule release.
e) Each team must designate two observers who are allowed to follow the rover at a safe distance to ensure the safety of the machine and others around. Observers are allowed to communicate with the team from the control area only through a judge, and only in one way - from control base to observer - and solely to coordinate actions unrelated to task details like task reset, abort or unsafe event. No communication during the normal execution of the task is allowed. The observers must be able to carry the rover, but they should remain at a safe distance from the working machine and cannot interfere with any of the rover's sensors (e.g. be visible on the image from the camera) during the realisation of the task attempt;
f) During tasks, only judges and team observers can access the field of the task. No manual intervention is allowed, except during events where the task rules state otherwise;

g) Any maintenance made by the team during tasks (any operations made by the team to the rover hardware on the field) causes a restart of the task to the start line and cancellation of all previously earned points for this task;
h) The team can use video systems to tele-operate the rover if the task requirements do not state otherwise;
i) The team must not use any voice/visual communication with the crew on the field. Only the judge can communicate between the task arena and the control base.
j) The operator has the right to abort the task at any time by notifying the judge about it. The team will receive the points gathered to the moment of notification according to the rules of the task;
k) Throughout the entire event, no rover or any other part of the system may do harm or interfere with the systems of other teams. Any reports of such breaches will be investigated independently by the judges or the organizer, and any violation of this rule can lead to disqualification from the challenge;
l) Any erratic behaviour of the rover or one causing damage to the task's infrastructure can result in the immediate interruption of the task attempt and collected points being annulled.

Task specification

Science task

The aim of the task is to obtain samples of the surface and subsurface layers of the soil each taken from different locations, chosen by the team based on your analysis delivered in the scientific design reports. Samples should be cached in prepared containers. Additionally, in-situ measurements and automatic documentation (photographic etc.) of the collection place, as well as samples, will be scored.

Technology priorities

1) drilling - different levels of soil cohesion and hardness (soil or rock)
    1) separation of reaction forces from rover body
    2) robustness and repeatability
    3) task automation
    4) performance (energy, scalability, operation time)
2) caching
    1) delivery - the quality of operation transporting the sample from sampling place to container
    2) accuracy of placement - putting samples accurately into the container and in a controlled way
    3) quality of container sealing design
    4) accuracy of container design regarding real missions requirements.
3) in-situ sample analysis/processing
    1) effectiveness and quality of self-made solutions for sample analysis/processing
    2) accuracy of proposed solutions regarding real missions requirements.
4) surface sampling - unknown soil density
    1) separation of reaction forces from the rover body
    2) robustness and repeatability
    3) task automation
    4) performance (energy, scalability, operation time)

Task Scenario

a) Present your scientific exploration plan poster: select a specific sampling location within an allocated area and explain to judges what hypothesis will be tested with this particular sample;
b) Reach the sampling areas indicated by the judge and target the sampling location accurately;
c) Collect and cache 4 geological samples from terrain:
   - 3 surface samples from different locations,
   - deep sample (15-30cm below the surface);
d) Prepare photographic documentation;
e) Collect several measurements of samples or the sampling area that might be valuable for planetary science, such as sample weight, volume and other parameters;
f) Deliver samples in sealed containers;
g) Present scientific report: compare results with your scientific exploration plan: explain if and why the sample you collected will be sufficient to answer the stated hypothesis.

General requirements

a) Within the area of this task multiple layers of different soil types will be prepared;
b) The surface sampling device should be prepared to handle different type of loose soil;
c) The deep sampling device should be prepared to handle materials from loose soil to hard gypsum;
d) The deep sample should at least contain material from the deepest point reached. In an ideal scenario, the team should present an unmixed, undisturbed cross-section of all the layers from the surface to the deepest point reached;
e) The rover should be equipped with at least one sampling device;
f) The rover must be equipped with at least one sample container;
g) Samples should be delivered in dedicated containers, one container for each sample;
h) Containers can be manipulated and removed from the robot only in the company of the judge;
i) The minimum resolution of the images is 800x600 pixels. The sample location or the sample itself should occupy a major part of the image. Image quality should be reasonable for scientific needs;
j) Any additional physical parameters must be documented in the control station and stored until the judge's inspection, after the task attempt ends. The judge will evaluate the quality of the data received;
k) The method for sampling reaction forces/torques separation from the rover body, should be presented and will be scored by the judge based on the stability (3D) of the platform during operation;
l) The science exploration plan should be presented to the judge in the form of a poster. The poster should be prepared as a conference poster (single page of A0 size) and based on the science exploration plan prepared for the final reports. This material might be displayed to the public;
m) Teams can be requested to present their scientific report orally at the Science task control station or on paper, to be submitted within the time specified by the judge. The Science task judge will specify the way that information should be delivered during preparation for the task attempt. The teams should be ready to present all related material: science exploration plan, relevant task's results and other complementary information at the control station directly after task attempt. This reporting will not be counted to the task time.

Expected results

a) Samples of required weight in separate, sealed containers:
    1. each sample should weigh at least 25g and preferably 50-100g according to scoring (see appendix),
    2. a deep sample containing at least the deepest material, ideally a cross-section from the surface to the deepest point;
b) Results of in-situ measurements and observations of the samples and sampling area. Scored higher for automatic acquisition of measurements;
c) Photographic documentation showing different aspects of samples, sampling areas and operations - a minimum of 3 images for any collected sample: 1) image of the area where the image will be taken, 2) a close up image before 3) a close up image after collection;
d) All data should be stored until at least it has been reviewed by the judge;
e) Presentation of the scientific exploration plan poster and scientific report: explanation of the execution of the task and relevance of results to your scientific exploration plan assumptions;
f) Presentation of innovative methods for samples extraction (e.g. device design, operation, way to mitigate transfer/elimination of reaction forces/torques to rover body etc.), measurements (custom made sensors design, sample preparation and interaction methods) and caching (including cache design specifics).

Additional information

a) Every additional manipulation of the containers/samples (adding material, shaking/hitting the rover etc.), not done by the rover equipment during the task attempt, will be the basis to cancel all points for this task;
b) Teams are not required to follow the sample extraction method suggested in the rules;
c) After the rover returns to the start line, each sample will be judged and weighed;
d) Judges will verify the sampling depth based on the sample material characteristics according to the reference key;
e) No part of the additional task payload or equipment can operate in a standalone manner;
f) The deep sample should be clearly visible in an undisturbed state at least before the sample is placed in the container. It is possible to leave a detached part of the sampling device inside the container, but ideally only the deepest part of the sample should be placed into the container (not mixed with upper layers of soil);
g) Extra points may be awarded if the deep sample caching is done without sample exposure to above-surface conditions.

Maintenance task

The maintenance task is intended to demonstrate the ability of both rovers and teams and alike and their performance in operating a variety of manipulation elements mounted on a panel. The team has to use the rover's manipulating device to set switches to the required positions, measure electrical parameters, set other panel controls and observe indicator feedback.

Technology Priorities

1) task automation
    a) automatic elements detection (e.g. spatial parameters, possible actions etc.)
    b) automatic approach
    c) automatic manipulation
2) teleoperator interface

    a) dynamic operator feedback (e.g. presentation of feedback measures, force-feedback/control interfaces, etc.)
    b) operator situational awareness (e.g. vision, parameters presentation and displays ergonomics, etc.)
    c) ergonomics of the operator control interface
3) end-effector performance
    a) tool relevance for a specific scenario
    b) multiple tool systems (interfaces, exchange) or universal tool design
    c) operation robustness (flexibility etc.)
    d) operation accuracy and quality for a specific scenario
4) manipulator performance
    a) operation robustness
    b) operation accuracy and quality for a specific scenario

Task Scenario

1) set the 'main' switch located on the side wall of the panel to the ON position;
2) sector 1: align the platform by accurately making contact with the positioning pin and report your position in reference to it; optionally align the field of view with reference markers and detect them;
3) sector 2: (all elements in a predefined position) change the state of a group of switches, make contact with terminals and report the measured voltage, pull the plug out and insert back to the socket;
4) sector 3: (all elements in random positions) actuate 2 (out of 3) push buttons sensitive to excessive force, detect and localise (position and orientation) buttons and the socket.

General requirements

a) The rover should be equipped with a manipulation device allowing interaction with the control panel designed for a human operator
b) Switches and other controls will be industrial grade elements;
c) Switches can be lever or rotational type;
d) The panel will have the form of a box positioned flat on the ground with dimensions of 0.72x0.72m at the base and a height of about 0.30-0.40m;
e) Controls can be mounted on the top or sides of the panel;
f) The panel surface will be divided into 3 sectors between which the rover will need to be relocated;
g) All switches should be manipulated one by one - the activation of more than one in a single move will cause the reset of all the elements;
h) Voltage measurement is to be conducted on standard 'German type F'/'French type E' or similar power socket (https://en.wikipedia.org/wiki/AC_power_plugs_and_sockets#CEE_7.2F3_and_CEE_7.2F4_.28German_.22Schuko.22.3B_Type_F.29) or terminals with similar dimensions and connection requirements;
i) Voltage to be measured is between 1.0VDC and 24.0VDC and should be reported to within 0.5V accuracy;
j) Some panel elements can be sensitive to forces and torques exceeding operational limits. Those elements should not be 'damaged' during operations and can be scored differently than stiff ones;
k) Some of the panel elements may be covered by MLI-like (Multi-Layer Insulation) material attached e.g. with Velcro and thus additional manipulation capabilities may be necessary to remove it/uncover those elements without causing any damage to the covering material;

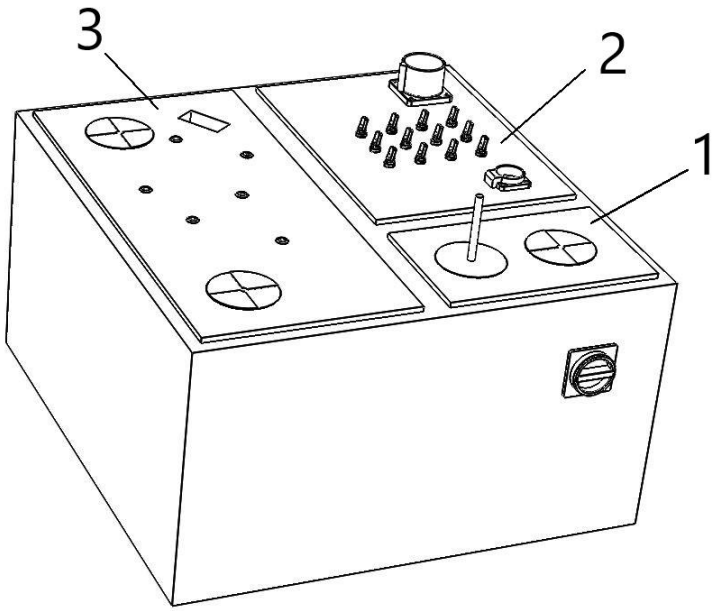


Fig: The preliminary design of Maintenance task's panel with sectors numbered (final design may differ)

Expected results

a) Arrival at sector 1:
    a. MAIN switch set to ON position as the first;
    b. Contact with positioning pin confirmed by the judge, the position of rover platform in reference to the pin reported to the judge, optionally all reference markers detected in a field of view;
b) Traverse to sector 2:
    a. Group of switches set to required positions;
    b. Voltage level reported to the judge;
    c. Plug re-inserted in the socket;
c) Traverse to sector 3:
    a. Positions and orientations of buttons and socket reported to the judge;
    b. Activation of push-buttons without pushing them inside the panel box (autonomous operation for max points);
d) No panel damage incurred (control elements, connectors, covers etc.);
e) Task automation efforts and results presented to the judge.

Additional information

a) Most of the panel elements will be specified before the challenge by means of a photo and general dimensions. The location of known panel elements (not random ones) will be defined. Position of random elements could be changed between task attempts;
b) Dimensions of the positioning pin, some of the crucial elements and reference markers will be defined before competition;
c) Multiple AR/QR tags will be placed on the panel surface. Tag type will be specified before the challenge. The relative distance between tags will be published;

Collection task

This task intends to demonstrate the ability of the system to perform a cache fetching scenario. The team has to reach locations marked on the map, search and pick up the cache and place it in a container on-board in a required orientation, before delivering the full container to the final destination.

Technology priorities

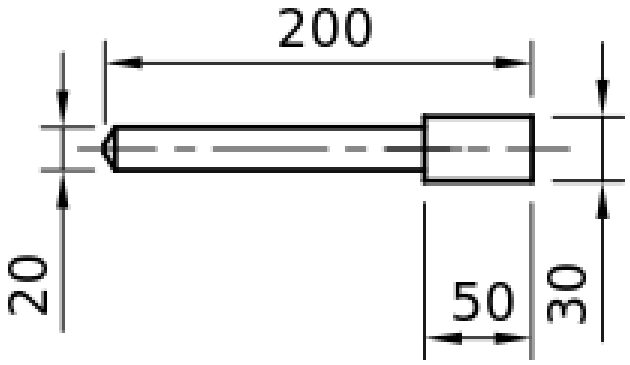
1) task automation
    a) automatic element detection and localisation
    b) automatic approach
    c) automatic pickup
    d) automatic insertion to container
2) end-effector performance
    a) tool relevance for a specific scenario
    b) operation robustness
    c) operation accuracy, repeatability and quality for a specific scenario
3) container and cache design
    a) container/mechanism design allowing the placement of caches with a limited accuracy manipulator into a container with the key requirement being a high degree of cache protection
    b) accuracy of container design regarding real mission requirements
4) manipulator performance
    a) operation robustness
    b) operation accuracy, repeatability and quality for a specific scenario

Task Scenario

a) Collect 3 caches from different locations
    a. Reach the area where the cache was dropped;
    b. Search for a cache
    c. Approach the cache, take a photo and pick it up
    d. Place the cache into the on-board container
b) Deliver the container with the catches to the designated area
c) Place the entire container, with caches inside, in the marked spot

General requirements

a) The rover should be equipped with a manipulation device which is able to pick up the cache and place it into the on-board container;
b) The rover should be equipped with a detachable container allowing for the stable transport of caches over challenging terrain;
c) The rover system should be able to deliver the container with caches to a designated place;
d) The container should keep caches in a vertical position and prevent any movement;
e) There should be at least 4 slots for caches in the container;
f) The cache is a green cylinder with the dimensions presented in the figure below. The maximum weight of the cache is 300g and the COG position is unknown. The caches should be stored cone-shaped-end (thinner-end) down.



Schematic view of cache design.

Expected results

a) Demonstration of rover manipulation equipment (a robotic arm or equivalent) and operator performance via remote or autonomous control;
b) Demonstration of system automation capabilities;
c) Placement of the caches in the proper position into the container;
d) Delivery of container to the final destination;
e) Presentation of operational approach algorithms used and other system solutions;
f) Presentation of proposed container design and accompanying elements.

Additional information

a) The cache will be lying on the soil, but could also be partially buried and end-effector should be able to stable grasp cache in such different conditions;
b) The cache could be partially covered with soil and detection system should be prepared for such a situation.

Traverse task

This task is intended to demonstrate the system's ability for semi to fully autonomous traverse. The team has to develop a project which gradually evolves into a fully autonomous system, traversing and gathering important data on its way. At an early stage, the system can be decoupled with the operator in the loop, but all planning and parameter estimation must be done by the computer system itself. This limits the operator to navigate the rover blindly i.e. without access to visual or any other spatial information, however, any kind of data can be processed on-board, providing the operator with support information about the localisation and state of the system. A smart navigation strategy, sensor fusion and image data processing are essential in this task.

Task scenario

a) Send the rover the start position and waypoint information;
b) Reach 4 waypoints;
c) Reach an additional point located in more challenging terrain;
d) After the traverse, present techniques used, visualise the system data, compare the results with the plan calculated at the beginning etc.

General requirements

a) The rover mobility system should be able to drive over challenging terrain in the conditions described in the *General Rules* in the *Test Trials* section;

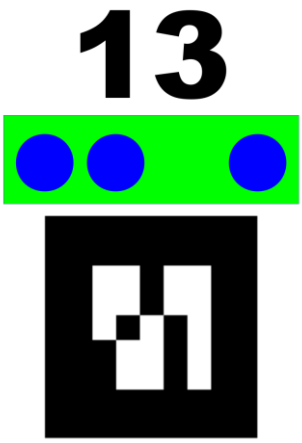
b) An on-board data processing application should be used for rover localisation based on natural terrain features, however, navigation landmarks will be placed for absolute reference;
c) The rover system can utilise a coarse heightmap of the arena provided by organisers;
d) Use of GNSS receivers is not allowed. Any other type of sensor (i.e. camera, lidar, IMU, odometer, sonar, etc.) can be used for on-board processing;
e) At any time during the task attempt, the only data that can be transmitted from the rover to the control station are position ([x, y, z]) and orientation (Euler angles or quaternion);
f) The rover start position and waypoint coordinates (and landmark positions upon a team's request) will be provided in a local coordinate frame directly before the task attempt;
g) The system should be able to plan an optimal path based on a given map and waypoint coordinates.

Expected results

a) Reach all waypoints;
b) Present a system that supports the operator in rover control;
c) Reach a waypoint in hard terrain;
d) Present the systems and methods used for autonomous traverse and gathered data (e.g. map, paths, plans, reached waypoints, position errors etc.).

Additional information

a) Initial rover position and orientation will be drawn at the beginning of each trial from a set of designated locations and with a limited heading;
b) The rover can be teleoperated, but only using the position and orientation estimate available. This data can be visualised in any form (e.g. projecting the rover's position on the arena map provided or a top view picture etc.);
c) If the rover has to be moved for any reason, it can only be moved back to the last successfully reached waypoint and/or rotated towards any point or back to the starting point. In both cases, penalties for manual intervention apply.
a) Technical Reports should include a list of all sensors, together with detailed information about working modes, ways they are used in the navigation task and how the rover will be operated. Teams are entitled to consult all solutions with the judges before submission. Documentation will be verified by the judges and in case of any doubts, the team may be asked to reconfigure devices and/or their control strategy. Any difference between the approved configuration and the one used during the challenge can lead to a disqualification (0 points for this task);
b) Task arena:
    a. Final map with grid coordinates and POIs (Point Of Interest) will be provided on the warm-up day, if not agreed otherwise;
    b. Most landmarks will be visible from the starting point, but it must be taken into account that some may be obscured by terrain or other objects during a traverse;
    c. Two types of landmarks are foreseen: natural landmarks which are elements of the landscape placed on the map, e.g. craters, small embankments, hills and artificial landmarks, e.g. artificial points for localisation purposes. Artificial landmarks can contain characteristic hi-visibility labels, unique geometric figures, alphanumeric signs or an AR/QR tag matching a POI label on the map; An example landmark (A4 size) design using an ARTag marker is presented below:



d. The artificial landmarks will be visible for cameras from different directions on a field (each landmark has 4 sides with identical faces) and will have a physical base which can be detected by proximity/range sensors (e.g. placed on an element of infrastructure or natural landmark);
e. The team cannot place any additional passive landmarks or active beacons on the challenge field outside the starting area, but such elements can be deployed using the rover during the trial. All landmarks must be documented in the technical reports and presented for approval at least 10 working days before the submission of the final documentation. This equipment may be subject to negotiation, so teams should leave enough time to redesign/modify it in case of comments/rejection by jury. Such equipment must comply with the other rules of the competition e.g. if active radio beacons are used, they must be compliant with the radio communication rules (see *Radio Communication* section) and described in RF form;

c) The rover can be stopped and moved/rotated by team members when it is stuck or in case of any other technical problems. A judge has to be informed before any action is undertaken;
d) During a task attempt, several photos of the current state of the arena will be delivered to the team by the task judge. The photos will be delivered periodically but the frequency is intended to not allow the team to accurately navigate their rover. The photos will be taken from a static position (in perspective, top-view or both) and can be used to correct the control methodology by the operator or the control software;
e) Details of the task, such as exact appearance of landmarks, location, map format, allowed custom landmarks and beacon types etc. will be discussed with the teams and presented during the preliminary design phase. Teams are encouraged to initiate and actively participate in these discussions.

Presentation Task - project review

The presentation task lets teams introduce themselves and present their projects. The jury expect to learn how the team worked on the project, what kind of technical solutions are implemented in the rover, and how the team solved problems and issues which occurred during development. The team should also be prepared for a Q&A session.

Goals

a) Introduce the team (expertise and experience) and project;

b) Present organizational structure, management methods and work-flow;
c) Present an engineering approach;
d) Present the technical design;
e) Present the scientific project design;
f) Present difficulties which occurred and methods applied to solve them;
g) Present elements designed to fulfil the rest of the trial tasks;
h) Present team outreach.

General requirements

a) The time for the presentation is limited to 15 minutes and after that time the presentation will be immediately interrupted;
b) The Q&A session takes 5-10 minutes;
c) The team can use a projector provided by the organizer (HDMI connector as a standard, other connectors may be available);
d) The organiser does not provide computers;
e) The presentation must be given in English;
f) The presentation can be done in any format and creativity is welcomed.

Expected results

a) Demonstration of team presentation skills;
b) Detailed information on technical key-drivers which influenced the team to build precisely this design, engineering approach, system breakdown structure, management, difficulties and solutions;
c) Scientific/engineering inventions, design propositions;
d) Spin-off, spin-out/in ideas and opportunities;
e) Team outreach and promotion of ERC.

Miscellaneous

Awards and recognitions

The first three best teams will be awarded. Multiple other awards are planned to recognise excellence in different parts of the programme and competitions. The form of the awards will be specified on the challenge website. The organizer may also allow awards funded by third parties. Third-party award funders must have the organizer's approval.

By taking part in the ERC 2020, teams agree to place a promotional sticker on their rover (max. size of sticker: 10x10cm).

Organiser disclaimer

Teams take full responsibility for any damages, accidents, or unsettling events caused by their hardware-software as well as for the members of the team. Teams are obliged to follow all safety and good conduct rules specified by the organisers. Any breaches of safety rules and requirements will result in the disqualification of the team from the entire competition.

Changes to Competition Rules

The organiser retains the right to extend the deadline for the submission of documents and provide essential but inevitable changes to the competition rules. However, any changes introduced cannot concern key issues for the rover's design. All changes will be announced reasonably far in advance and provided on the challenge website.

Deadline extension

The organiser has the right to extend the deadline for submission of documents and announce it reasonably in advance and provide details on the challenge website.

Q&A

Answers to any challenge related questions that arise will be provided on the challenge website. If you have questions, please contact the challenge contact point (see *Information channels and contacts*).

The organizer will provide 'European Rover Challenge 2020 Questions & Answers' as a part of the competition rules. All arrangements contained therein are ultimately binding – even if they change the competition rules. The FAQ will be announced in advance and provided on the challenge website.

Challenge scoring issues

Any and all issues with scoring during the challenge will be resolved solely by the independent jury (i.e. challenge judges). Teams may not appeal to any other party.

Organizational issues

Organizational issues, including team eligibility, challenge organization and the execution of jury decisions, will be resolved by the organizer.

General Challenge issues

Should any conflict related to the challenge arise, the organizer's decision will be considered final and binding.

Disqualification

The organizer may disqualify a team in the event of a serious breach of the rules or fair play.

Personal data storage

Team members agree to their personal data, documentation delivered, and other promotional materials and visuals being stored and processed in the organiser's computer systems and also for the purpose of ERC programme.

On the other hand, the organizer will keep all technical documentation confidential and will not publish or disclose it to third parties without the prior approval of a team's

representatives. The sole exception to this is the challenge jury – technical documentation will be disclosed to judges for scoring and mentoring purposes only.

They also give the organiser, parties designated by the organiser and the audience, the right to disclose and publish any photos, videos or other visuals; their names and surnames, identifiable pictures of themselves and any other persons, as well as pictures of machines, devices and equipment in any and all of the available formats, by any and every known method, in any and every known medium.

Teams grant permission to the organizer to use promotional materials and visuals (e.g. photos and videos), as well as any additional photos, videos, portraits, documents, interviews and other materials resulting from participation in the challenge (using the name of the participant or not) on all media, in any language, anywhere in the world, in any manner, for advertising and promotional purposes.

Personal data and information about team members other than their names and surnames will not be published without the prior consent of each team member.

Team member responsibilities

Teams and team members accept sole responsibility for securing and ensuring the safety of their equipment and luggage in the challenge location. They indemnify and release the organiser of any responsibility in the event of damage, destruction or theft of any property.

Organizer responsibility

The organizer’s civil liability is limited solely to the responsibility for organising a mass event in accordance with Polish law and local regulations.

Copyright

The organiser retains all copyright to the competition rules, especially the description of the tasks. No alterations or additions to the competition rules may be made and their sale is expressly forbidden. The rules can only be used and/or copied for ERC-connected activity (e.g. registration process).

APPENDIX 1.

Challenge Schedule

The table below presents the schedule of the ERC2020 programme.

Event	**Date (2020)**
Rules publication	27th January
Registration start	27th January
Registration end	26th March
Preliminary Report	21st May
Qualification	11th June
Video documentation	16th July
Final Report + RF form	27th August
Competitions event	September (3 days)
• warm up day	10th Sept (evening opening ceremony)
• on-site registration	11-13th September
• closing ceremony	13th September

APPENDIX 2.

Challenge Scoring

General rules

The scoring of the competition is designed to reflect the Technology Priorities identified as well as gaps in the designs from previous editions. It is intended to motivate teams and, as a result, help the team develop the relevant expertise and provide missing solutions to previous challenges.

Some flexibility in scoring is left to reflect many aspects that cannot be covered by rules like the quality of solutions, its robustness and performance, but judges will be equipped with detailed guidelines to make the scoring as objective as possible.

Documentation

Proposal

ID	Element	Scored parameter	Max partial score [pts]	Max task score [pts]
SCR_DOC_P_010	Team introduction	Experience and expertise	3	3
SCR_DOC_P_020	Rules analysis	Initial project assumptions and initial technical requirements, derived assumptions, analysis of challenge tasks	10	10
SCR_DOC_P_030	Risk assessment	Project risk analysis and planned mitigations	7	7
SCR_DOC_P_040	Commercialisation ideas	Which elements (and how) could be commercialized/continued as further potential research considering current technological trends, other benefits	5	5

Proposal - SUM	25

Preliminary report

ID	Element	Scored parameter	Max partial score [pts]	Max task score [pts]
SCR_DOC_E_010	Project assumptions	Update with sub-system specific ones, comparison with proposal	4	4
SCR_DOC_E_020	Technical requirements	Update with sub-system specific ones, comparison with proposal, add proposed solution and testing methodology	8	8
SCR_DOC_E_030	Mission analysis	Tasks analysis and scientific exploration plan	7	7
SCR_DOC_E_040	Preliminary design	Description of the project, proposed solutions, technical budgets, preliminary architecture	5	5
SCR_DOC_E_050	Technologies	Used technologies and methodologies in technical and management side of the project	3	3
SCR_DOC_E_060	System Breakdown Structure	Dependency between subsystems and its development	4	4
SCR_DOC_E_070	Safety System	Description solutions for required aspects, (architecture, time sequence) diagrams,	4	4

		reliability analysis etc		
SCR_DOC_E_080	Preliminary financial budget	Estimation of the final cost (ROM), sources and costs in the project, ways forward	4	4
SCR_DOC_E_090	Lessons learnt	Current issues and challenges, proposed solutions (technical and other)	4	4
SCR_DOC_E_100	Risk assessment	Identified risks with assessment of impact and mitigation plan	4	4
SCR_DOC_E_110	Pre-final Radio Frequency Form	First version of RFF - see Communication Requirements	3	3
Preliminary report - SUM				50

Final report

ID	Element	Scored parameter	Max partial score [pts]	Max task score [pts]
SCR_DOC_F_010	Final project assumptions	Update with sub-system specific ones, comparison with preliminary document	4	4
SCR_DOC_F_020	Final project requirements	Update with sub-system specific ones, comparison with preliminary document	4	4
SCR_DOC_F_030	Testing methodology and test plan	Requirements reference, methodology, current status, comparison with preliminary ones	8	8

SCR_DOC_F_040	Final update of scientific exploration plan and operational scenarios	Analysis of the task with particular focus on science exploration plan (up to 80%)	10	10
SCR_DOC_F_051	Final design	System Breakdown Structure (SBS) + description	3	
SCR_DOC_F_052		System architecture - hardware and software diagrams and description	5	
SCR_DOC_F_053		Technical budgets	5	
SCR_DOC_F_054		CAD drawings (2D, 3D, dimensions, assembly, details)	4	
SCR_DOC_F_050	Final design - SUM			17
SCR_DOC_F_060	Safety Systems description	Diagrams, operation	5	5
SCR_DOC_F_070	Final financial report	Sources and expenditures	4	4
SCR_DOC_F_080	Lessons learnt	Difficulties and solutions applied	6	6
SCR_DOC_F_090	Risk assessment	Analysis of preliminary version of the document; Regarding system performance, attendance in competition tasks; with Impacts assessment and proposed mitigations	7	7
SCR_DOC_F_100	Final Radio Frequency Form	Final version of the form presented in the	5	5

		preliminary documentation		
Final report - SUM				70

Video material

ID	Element	Scored parameter	Max partial score [pts]	Max task score [pts]
SCR_DOC_V_010	Introducing team	Affiliation, location	1	1
SCR_DOC_V_020	Introducing the team members	Responsibilities, presenting teamwork	2	2
SCR_DOC_V_030	Reasons for participation	Challenges impact and opportunities	2	2
SCR_DOC_V_040	Safety system presentation	Emergency Stop functionality, safety features	4	4
SCR_DOC_V_050	Remote control - mobility and manipulation presentation	Driving the rover, showing a working manipulator during tests	4	4
SCR_DOC_V_060	Readiness for challenges	Ability to resolve challenge tasks (‘test report’)	8	8
SCR_DOC_V_070	Scientific project presentation	What science will be performed and why it matters	4	4
SCR_DOC_V_080	Quality and visual aesthetics	Resolution, clarity of image and harmony and reception	5	5

Promotional video - SUM	30

Tasks Scoring

Science Task

ID	Task Element	Scored parameter	Max partial score [pts]	Max task score [pts]
SCR_TSK_S_011	Surface Sample #1: Acquisition of surface sample form designated spot (within 10 cm diameter)	Minimum of 25g of designated soil sampled	5	
SCR_TSK_S_012		For every subsequent 25g of sample weight (max 150g)	2 (max 10 for sample) = 10	
SCR_TSK_S_013	Surface Sample #2: Acquisition of surface sample from designated spot (with a 5 cm diameter)	Minimum of 25g of designated soil sampled	5	
SCR_TSK_S_014		For every subsequent 25g of sample weight (max 150g)	2 (max 10 for sample) = 10	
SCR_TSK_S_015	Surface Sample #3: Acquisition of surface sample from a designated spot (with a 5 cm diameter, from challenging terrain - rocks, terrain formations)	Minimum of 25g of designated soil sampled	5	
SCR_TSK		For every subsequent 25g of sample weight	2 (max 10 for sample)	

_S_016		(max 150g)	= 10	
SCR_TSK_S_010	Surface Sample (Average score from Surface Sample #1-3)			15
SCR_TSK_S_021	Deep Sample: acquisition (one from listed options)	Minimum 25g reaching 15cm below surface level	10	
SCR_TSK_S_022		Minimum 25g reaching 25cm below surface level	15	
SCR_TSK_S_023		Minimum 25g reaching 35cm below surface level	20	
SCR_TSK_S_020	Deep Sample			20
SCR_TSK_S_030	Photographic documentation of sampling site	3 photos of each sample - area, close up before, close up after	2 per sample	8
SCR_TSK_S_040	On-board sample weight and volume measurements	For each sample with 20% accuracy	3 per measurement = 12	12
SCR_TSK_S_051	Caching - sample put to the container and sealed	For each cached sample (sample delivered to the container)	4 per cached sample = 16	
SCR_TSK_S_052		For each sealed container - sample stays inside when turned in different orientations	4 per sealed container = 16	
SCR_TSK_S_050	Caching - sum			32
SCR_TSK_S_061	Automation elements	Automatic target approach (from homed	7	

		position to contact with surface) - presented in 2 cases		
SCR_TSK_S_062		Automatic sampling (no damage to the tool etc.) (stopped after sample is lifted above ground) - presented in 2 cases	11	
SCR_TSK_S_063		Automatic placement of the sample into the container - presented in 2 cases	15	
SCR_TSK_S_060	Automation elements - sum			33
SCR_TSK_S_070	Scientific exploration plan poster and scientific report	Science key will be clarified before Final Report delivery	25	25
SCR_TSK_S_080	Excellence (judge score according to the key)	Performance, operation quality, level of sampling reaction forces transferred to the rover body and quality of proposed solution and final implementation	5	5
Science Task - SUM				150

Maintenance Task

ID	**Task Element**	**Scored parameter**	**Max partial score [pts]**	**Max task score [pts]**
SCR_TSK_M_010	Change state of main switch	State changed to desired	10	10

SCR_TSK_M_020	Contact with the positioning pin	Contact confirmed	5	5
SCR_TSK_M_030	Positioning pin position	Report of pin position in robot reference frame	10	10
SCR_TSK_M_040	Recognition of reference markers	Report of recognised reference markers	4 per marker	12
SCR_TSK_M_050	Change state of indicated elements in sector 2	State changed to required	Max 3 per switch	30
SCR_TSK_M_060	Connect with voltage measurement terminals	Insertion visually confirmed by judge	6	6
SCR_TSK_M_070	Voltage measurement	With 0.5V accuracy	3	3
SCR_TSK_M_080	Grasp and retrieve plug from socket	Plug dropped in designated area	10	10
SCR_TSK_M_090	Grasp and insert plug to the socket	Plug inserted to the socket with at least 80% connector contact	20	20
SCR_TSK_M_100	Actuation of excessive force sensitive elements	Actuation confirmed, no damage to panel caused	3 per button	6
SCR_TSK_M_110	Panel surface recognition and distance to camera/arm estimation	Recognised panel presented to the judge	10	10
SCR_TSK_M_120	Panel push-buttons position recognition	Positions of the buttons presented to the judge	10	10
SCR_TSK_M_130	Socket position and orientation recognition	Position and orientation of the socket presented to the judge	8	8

SCR_TSK_M_140	Automatic approach to panel element and element state change - presented in at least two cases	Actuation confirmed	10	10
Maintenance Task - SUM				150

Collection Task

ID	Task Element	Scored parameter	Max partial score [pts]	Max task score [pts]
SCR_TSK_C_010	Grasp cache and transport it on-board the rover	Cache at least dropped on-board rover	5 for each cache	15
SCR_TSK_C_020	Localisation of cache #3	Cache #3 found (search strategy efficiency)	5	5
SCR_TSK_C_030	Placement of the cache into the cache container	Cache placed secured from movement during traverse, in vertical position	10	10
SCR_TSK_C_040	Bonus for no dropped cache	1 point per each cache gently placed on-board, full if all collected without drop	5	5
SCR_TSK_C_050	Delivery of the cache container and placement on the designated spot with correct orientation		5	5
SCR_TSK_C_060	Automation	Automatic detection of the cache in rover field of view	5 per cache	15

SCR_TSK_C_070		Automatic approach, grasp and delivery on-board rover - done from the position where the cache is in the manipulator workspace	10 per cache	30
SCR_TSK_C_080		Automatic placement of the cache in the cache container	5 per cache	15
Collection Task - SUM				100

Traverse Task

ID	**Task Element**	**Scored parameter**	**Max partial score [pts]**	**Max task score [pts]**
SCR_TSK_T_010	Standard way-point reached	MAX (0, round (10 – (3 * d))) where d is a result of distance measurement of the rover (geometrical centre) from waypoint taken on team request; final score for a waypoint is an average from all started attempts.	10 for each waypoint	40
SCR_TSK_T_020	‘X’ way-point reached	MAX (0, round (15 – (4 * d))) where d is a result of distance measurement of the rover (geometrical centre) from waypoint taken on team request	15	15
SCR_TSK_T_030	Execution of pre-planned path	Presentation of driven vs pre-planned (sub-)optimal path showing intended	10	10

		following of plan		
SCR_TSK_T_040	Autonomous traverse bonus	Reaching waypoint one	5	5
SCR_TSK_T_050		Reaching waypoints two and three	10	10
SCR_TSK_T_060		Reaching waypoint four	10	10
SCR_TSK_T_070	Support elements	Recognition of the landmark and its position report	5	5
SCR_TSK_T_080	Penalty points	For each reset of rover position	-2 per request	0
SCR_TSK_T_090	Data presentation	Position projection, mapping, plan presentation, error visualisation	5	5
Traverse Task - SUM				100

Presentation Task

ID	**Task Element**	**Scored parameter**	**Max partial score [pts]**	**Max task score [pts]**
SCR_TSK_P_010	Presentation of project management	Organization structure, management methods and work-flow	5	5
SCR_TSK_P_020	Presentation of engineering approach	Design methodologies, used frameworks and tools	5	5

SCR_TSK_P_030	Presentation of technical design	Key design factors - drivers why your project was designed that way; equipment and methods used for automation/autonomous operations	5	5
SCR_TSK_P_040	Presentation of designs requested in other tasks	Elements specified in other tasks ‘expected results’ as need for presentation of some aspects (e.g. proposed cache design etc.)	5	5
SCR_TSK_P_050	Presentation of difficulties and solutions	Major issues and challenges during the project and their resolutions (from different domains e.g. technical, management, financial, etc)	5	5
SCR_TSK_P_060	Presentation of spin-off/out ideas	Application of designed technologies, business case ideas, inventions, possible IPR etc.	15	15
SCR_TSK_P_070	Delivery and introduction to outreach documentation	Presentation of summary and quick view on the rest of collected material (digital (pdf/ppt) material delivered to judges)	15	15
SCR_TSK_P_080	Presentation of feedback on ERC	Programme, event, suggested evolution	5	5
SCR_TSK_P_090	Presentation reception	Visual and structural quality of presentation and presentation skills	10	10
Presentation Task - SUM				70

Additional Points

ID	Element	Scored parameter	Max partial score [pts]	Max score [pts]
SCR_TSK_A_011	Mass of the rover - rover weighed before each task during EMC check - to receive these points, team must collect at least 20% of the task points; For scoring purposes, kilograms will be rounded upwards.	Rover lighter than 50kg	+0.5pt for every kilogram below 50 kgs	10 x 4 tasks
		Rover heavier than 60kg	-1pt for every kilogram above 60 kgs	-15 x 4 tasks
SCR_TSK_A_020	Report of energy consumed	Energy consumption per task, ideally per subsystem (driving, manipulating, processing, rest), measured during each task trial, delivered to the EMC judge after the task	5 per task	5 x 4 tasks