ERC
EUROPEAN ROVER CHALLENGE

RULES

STUDENT

2019

www.roverchallenge.eu

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Change record

Date	Section	Description
07.01.2019	All	Preliminary public document version

1. General information

1.1 What is ERC

The European Rover Challenge (ERC) is an integrated programme towards technological development specifically in a area of space exploration and utilization. The ultimate goal of ERC is to become standardised test trials and benchmark for planetary robotic activities with strong professional career development platform.

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

1.2 What is ERC-Student

One of the main part of ERC is ERC-Student track. ERC-Student consists of engineering project where university teams build robots to compete on extraterrestrially-inspired arena in tasks strongly inspired by international roadmaps for space robotics. This means that competition tasks present the same level of problems as space robotics industry drivers for next decades. What is more important, in a background of competitions, ERC is a continuous mentoring effort to educate next generation of multidisciplinary engineers, boost innovation in research and business and popularize STEM (Science, Technology, Engineering and Mathematics) advancements, all conceptually placed into future space exploration.

1.3 Schedule and Venue

ERC is an venue independent, all-year programme. For information about ERC2019 edition venue please follow updates on challenge website (see *Information channels and contacts*). Official schedule can be found as appendix to this document.

1.4 Information channels and contacts

The Challenge website address: www.roverchallenge.eu

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

Official communication channel for challenges announcements is list consists of emails given by teams during registration.

2. Teams

2.1 Qualification

The ERC2019 programme is planned for limited number of teams. The organizer together with the challenge jury will choose which of the registered teams will be invited to compete in the challenge. The choice will be made based on Registration Proposals and Preliminary Reports (content described in section *Documentation*) which teams are required

to send to the organizer by deadline given in program schedule. The organizer will announce qualified teams by deadline given in program schedule.

2.2 Registration

For registration dates please refer to challenge schedule. Registration details shall be sent to the Organizer in English, via teams contact point e-mail address (see *Information channels and contacts*). If this document is not submitted within specified form time, team will be not allowed to participate in the Challenge.

The team registration e-mail shall include:

a) 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 (may be the same as team name);
d) Project proposal (see section Documentation);
e) Approximate number of team members who plan on coming to the challenge (i.e. appearing on site);
f) Team contact point: person name and surname, telephone number and e-mail address;
g) University team coordinator/supervisor: name and surname, telephone number and e-mail 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 European Rover Challenge rules and all final decisions of the European Rover Challenge organizer."

2.3 Team members

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

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

3. Rover system requirements

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

3.1 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. COTS rover platform would be considered, but all such applications will be discussed separately to ensure that competition is fair play.

3.2 System weight

The suggested rover weight 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.

Rover lighter than limit will be rewarded and heavier penalised by number of points defined in scoring rules in appendix to this document.

3.3 Rover control and operations

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

Team should be able to control rover via 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 vicinity of control station. Teams should be prepared to place antenna mast maximum 20m from control station location.

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

3.4 Rover autonomy

Rover autonomy or capabilities of automation of particular tasks are highly recommended to be presented during competition trials. They can provide major advantage in scoring for all the tasks.

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

- “start” command - command to be send at the beginning of the attempt;
- “working” state - nominal work during attempt;
- “wait” command - enter “wait” state. Team can use it at any time for sensor readings stabilization;
- ”waiting” state - rover should wait still for “resume” command. This state should be automatically entered if rover reaches task check-point. System should be prepared that during this state sensors can be obstructed by judge or team members presence in rover vicinity (e.g. checking distance to the check-point). Operator cannot influence a system during this state. Reaching this state do not stop task time;
- “resume” command - transition from “waiting” to “working” state;
- “stop” - rover immediate stop - control can be switched to manual.

Above list is not exhaustive and teams can define additional states and commands.

In order to achieve points for autonomy or single task automation, teams cannot touch the controls once the attempt begins. The only exception is to send commands listed above. If team members touch the controls, then the autonomy points for that attempt will not be awarded. However, at any point teams may switch to manual control to complete the task tele-operating rover. Telemetry to monitor the rover operation should be monitored during autonomous/automatic operations and its recording and open access sharing after the event is highly recommended but not mandatory.

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

3.5 Rover Safety

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

3.5.1 Emergency stop

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

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

As additional safety recommendation, teams should avoid implementation of safety switched in software e.g. on the ground control application as it can cause operator to relay (even not fully consciously) on this feature instead informing his teammates to use hardware switch. That doesn't mean that team shouldn't implement stop button in control application at all, but operator should be trained to use other more reliable solution if exists.

3.5.2 Activity Indicator

Rover should be equipped with indicator lamp informing about readiness to receive commands. Indicator should be clearly visible from at least 10m attracting attention of people in vicinity by blinking or flashing. It should be active in any case when rover is ready to move (drive or e.g. operate manipulator). Recommended colours are: yellow, orange or red. It is highly recommended to use industrial grade device.

Activity indicator lamp should be active for 5 seconds before any rover operation is executed. During this time rover should be completely still and safe.

3.5.3 Automatic/Autonomous functionality

Any autonomous or automatic operation should start with delay of at least 5 seconds after activation.

By all means teams should prevent overflowing any communication/interface buffers or keeping commanding rover or its subsystems when should be still or deactivated to avoid situations when immediate or rapid movement is executed after system activation or commanding.

3.6 Communication requirements

3.6.1 General

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

3.6.2 Accepted frequences

Radio amateur bands

Accepted bands up to 1 W signal transmitted and up 10 W 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 radio amateur license (CEPT class T/R 61-01).

WiFi

At 2.4 and 5 GHz WiFi bands only WiFi communication standard is accepted. Other systems like analog video cameras or RC controllers using frequencies 2412-2472 Mhz and 5260-5700 MHz are forbidden.

For 2.4GHz:

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

For 5GHz:

- accepted channels: 52, 56, 60, 64, 100, 104, 108, 112, 116, 120, 124, 128, 132, 136, 140 (5260 MHz – 5700 MHz)
- up to 100 mW EIRP.
- accepted standards: 802.11a/h/n (802.11ac forbidden);
- Rover can use only one 40 MHz channel.

WiFi SSID should be set to "<erc_teamname>".
Channels will be assigned by judge during RF check before each task attempt.

ISM bands

It is possible to use ISM bands within their limitations but team must designate which rule is compliant with in accordance to Polish regulations (http://prawo.sejm.gov.pl/isap.nsf/download.xsp/WDU20140001843/O/D20141843.pdf).

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

Voice communication using 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 allowed only when relevant licence valid on venue territory is presented by the team. Those communication channels must be described in documentation and agreed with organisers.

3.6.3 Other communication rules

Before the competition, rovers and ground stations must be checked and accepted by radio communication judge during EMC (electromagnetic compatibility) test.

During competition, rovers and ground stations will be randomly EMC tested. Unauthorized changes to the RF configuration may result in immediate disqualification. Usage of any communication channels for testing (any time outside competition attempt duration) must be consulted with organiser/judge. Testing that could be done without RF communication is preferred. The organiser will provide rules of RF links usage for main parts of challenge venue and any requests limiting usage of RF links can be expected and should be respected during entire duration of the event.

For the whole duration of the challenge, the team is responsible for the legal use of frequencies on venue territory. The organiser can only help in frequency coordination, but does not take responsibility for any license violation like exceeding RF power, frequency band or area of use.

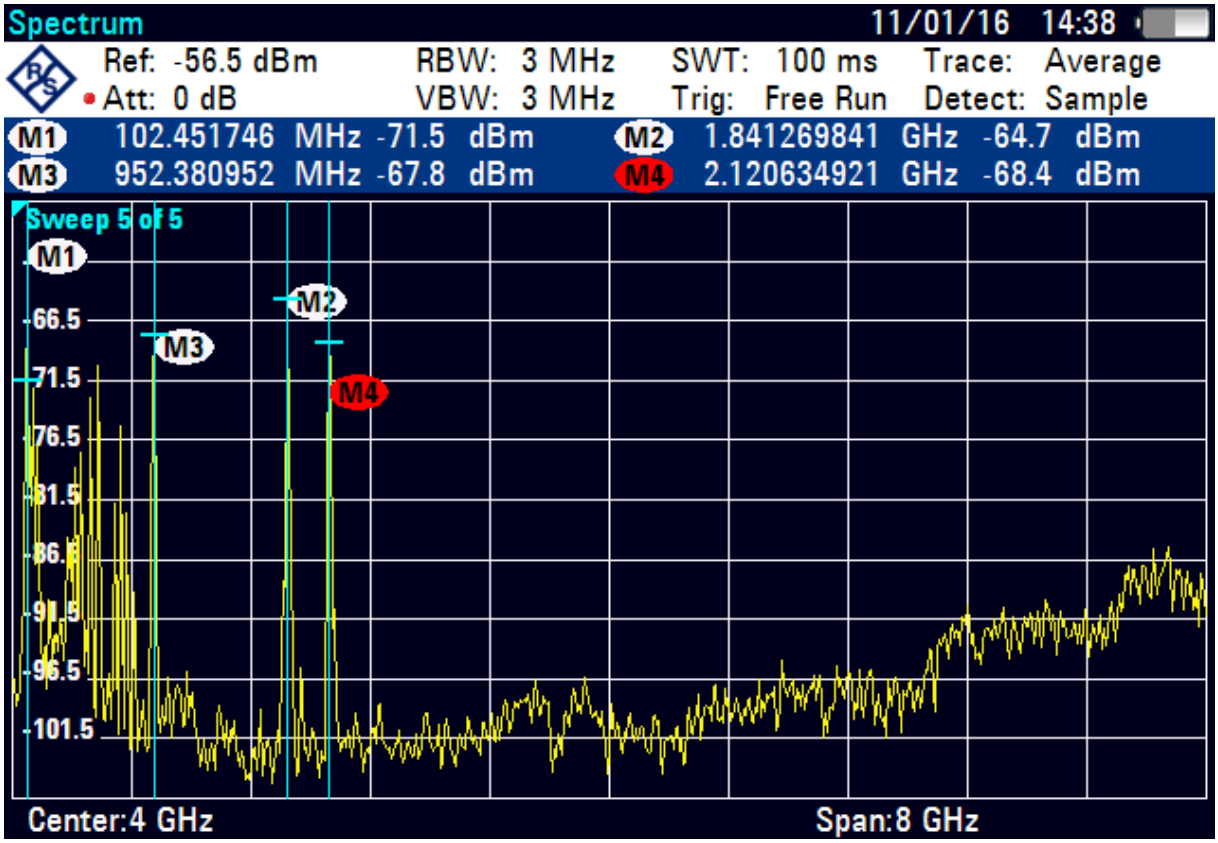
3.6.4 Radio Frequency Form

Each Team must fill Radio Frequency Form for every RF module used. It shall be included in relevant Technical Reports as an appendix (see documentation specification). If these documents are not submitted in the requested form, team will not be allowed to participate in the Challenge.

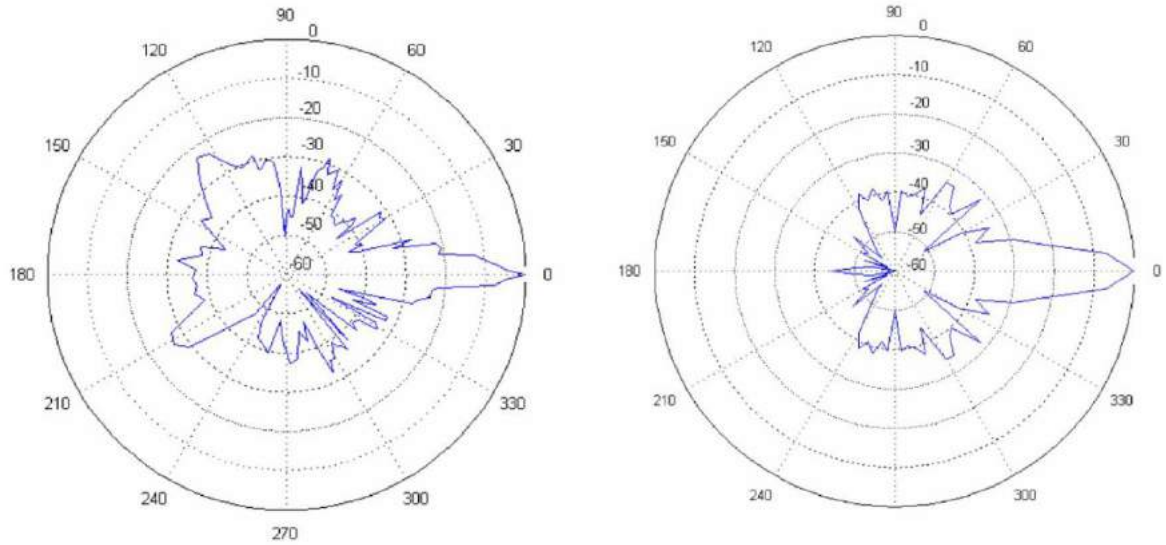
RF Form shall contain:

a) Team name;
b) Country;
c) How many different communication system will you use?;
d) Name of the person responsible for communication system;
e) Contact to the person responsible for communication system (e-mail address);
f) Photo of the rover;
g) Photo of the ground station;
h) System information (this part should be filled for every RF system):
    - RF system name;
    - Frequency;
    - Bandwidth;
    - RF power (output power + EIRP);
    - Antennas on rover and ground station - models, radiation patterns (see Pic 2 as example);
    - Modulation;
    - Short description

i) Two RF spectrum measurements - when all systems are on and off. Spectrum must be measured from 100 kHz up to double maximum frequency + 1 GHz used by Team (for example if highest band used is 2.4 GHz, Team has to measure pattern up to 2.4*2+1= 5.8 GHz); See example in the Pic 1. It is advised to measure RF spectrum using wideband reference antenna in RF anechoic chamber but it is not obligatory.



Pic. 1.: Example of the RF spectrum analyses



Pic. 2.: Example of the Horizontal and Vertical RF antenna radiation pattern for ground station

4. Documentation

4.1 General

Each Team shall provide a technical documentation which will cover following topics:

- management,
- technical design,
- safety,
- financial.

The project documentation is divided into three parts. The first set of information, called Proposal, shall be submitted with the registration form. The second and third, called Preliminary Report and Final Report accordingly should be submitted until dates designated in challenge schedule (see *Schedule* appendix) to the organizer.

The documentation is intended to be a substantial set of information describing a project and giving a clear image on how the project is being managed and developed.

Furthermore, the intention of documentation is to motivate the teams to develop their project according to the standards widely used in space industry. The organizer wants to emphasize quality management, strategy of development and risk management and testing topics. The intention is to improve quality of the rovers and minimize a risk of occurring simple and obvious errors and mistakes which might negatively impact on the project performance. The workflow of the three phases shall present how you manage the project, how you work on systems and subsystems and how you solve discovered problems and issues. Please note that the documentation is not intended to be a big paper with lot of excessive information. The documentation should be “from engineers to engineers”.

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

4.1.1 Proposal

Proposal should introduce Team and contain information why project presented by the Team should be chosen for ERC2019 based on technical expertise, team experience and first draft of proposed solutions. It should confirm that Team read, analysed and understood system requirements (rules of the competition).

In the Proposal the Teams shall include following information:

1) Team introduction contains information about team experience and expertise (short profiles of key people, experience of team esp in similar engineering projects and research work key for delivering this project in time and good quality, general focus, other projects etc.); please highlight experience in ERC competitions.
2) Short presentation of proposed (initial) solution to herein challenge. That should state your initial compliance with rules (understanding of ERC rules), and clearly

present achievable (within project timeline) ideas, initial project assumptions and analysis of challenge tasks;
3) First draft of project risk analysis and planned mitigations;
4) First conclusions how your project could be commercialised/which elements and how could be continued as further potential research considering current technological trends.

Document requirements:
1) First page: Team name, project name, heading “European Rover Challenge 2019”, affiliation, title “Proposal”;
2) Format: A4, searchable PDF;
3) Length: max 6 pages (including a title page);
4) Language: English;
5) Appendixes: no.

4.1.2 Preliminary report

This document should be written after analysis and design phase, what means that team should present in it idea how to solve presented problems under limits and boundaries listed in requirements and additional identified by a team. It should be a next iteration of team proposal without repeating basic, already closed points. Document should also contain (management and system) breakdown of the project and chosen technologies and technical solution to achieve goal.

The Preliminary Report shall include following information:
1) Project assumptions (compare them with those presented in the proposal, if changed, please describe why and how changes have an impact on the project);
2) Technical requirements definition (compare them with those presented in the proposal, if changed, please describe why and how changes have an impact on the project; make a full list of your technical requirements and present the way you want to fulfill them) and test plan covering requirements and other aspects important to show that your design is compliant with requirements and present readiness for trials
3) Technologies you want to use, designs you have and you are working on (at any stage);
4) Pre-final System Breakdown Structure (pSBS);
5) Safety Systems description;
6) Present preliminary financial planning (sources and expenditures);
7) Present problems and issues you are facing (management, engineering, logistics, etc.) and how you solved them and/or plan to solve;
8) Pre-final Radio Frequency Form (pRFF) as an appendix (see *Communication Requirements* for details).

Document requirements:
1) First page: Team name, project name, heading “European Rover Challenge 2019”, affiliation, title “Preliminary report”;
2) Format: A4, searchable PDF;
3) Length: max 20 pages (including a title page);

4) Language: English;
5) Appendixes: yes (optional; only additional information which could not be included in main document, for example: drawings and charts).

4.1.3 Final report

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

1) Final project assumptions (fixed);
2) Final technical requirements (fixed);
3) Test plan covered by test report;
4) Final design:
    5) System Breakdown Structure (SBS) + description;
    6) System architecture;
    7) Operational scenarios;
    8) CAD drawings (2D, 3D, dimensions, assembly, details);
9) Safety Systems description;
10) Final financial report (sources and expenditures);
11) Difficulties and solutions applied;
12) Final Radio Frequency Form (RFF) as an appendix (final version of the form presented in preliminary documentation).

Document requirements:

1) First page: Team name, project name, heading “European Rover Challenge 2019”, affiliation, title “Final report”;
2) Format: A4, searchable PDF;
3) Length: max 30 pages (including a title page);
4) Language: English;
5) Appendixes: yes (optional; only additional information which could not be included in main document, for example: drawings and charts).

4.1.4 Video material

Each team shall prepare a video material presenting readiness for the competition and at the same time being a promotional material of the team. This deliverable must be completed and submitted by the date presented in challenge schedule (see *Schedule* appendix). The material should be uploaded to one of widely known video services (e.g. YouTube) and relevant link must be send to contact point. If the promotional movie is not submitted in the correct form (or it is not playable by organizer) and within relevant deadline, team will not be allowed to participate in the challenge.

Video shall be of maximum 3 minutes length and shall present rover’s capability to take part in the challenge containing following elements:

1) Introducing team name, rover name, and the higher education institution name;
2) Introducing the team members and their responsibilities, presenting team work;
3) Introducing the reasons for proposing the team to the challenge;

4) A presentation of a safety systems (including emergency stop button) performance;
5) A presentation of remote control ability;
6) A presentation of rover's ability to ride and operation of manipulation subsystem;
7) Quality and proper visual aesthetics value of the movie and presentations skills.

In special cases video could be the basis to request more details about team readiness to participate in the competitions. Failure to present enough level of readiness can influence to what extend team will be allowed to participate in the trials.

4.1.5 Official statement

By providing the Organizer with the design draft, technical specification, other data, promotional materials and visuals (e.g. photos and videos), the Teams indicate they agree to any and all of this data being stored and processed in the Organizer's computer systems.

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.

On the other hand, the Organizer will keep all technical documentation confidential and will not publish or disclose it to third parties without the express approval of a Team's representatives. The sole exception to this is the Challenge Jury – technical documentation will be disclosed to the Judges for scoring and mentoring purposes only.

5. Field trials

Field trials are organised as benchmarking activity allowing to compare performance of teams in resolution of several tasks. Each task present independent set of problems to be solved connected to particular technologies required by future space robotics missions.

5.1 General

a) The challenge tasks take place in front of an audience as a public event;
b) Challenge attempts are independent. Teams will be permitted to change 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, jury acts independently of the organizer, but adheres to the schedule provided by the organizer. In case of any unforeseen issue not specified in competition rules jury board will propose a solution.
d) Technology Priorities assigned to each task describe areas of focus of each task in priority order. This order will be reflected by scoring summarised in appendix.
e) Scoring of each task is independent and summarised in appendix to this document.
f) Each team receive scoring sheet which must be presented every time to judge checking rover before task attempt (weighting, RF check) and to the task judge after each task. Task scoring is finished with the moment of signing the scoring card by

judge what should be done after collection and measurement of all necessary inputs. Only team leader can challenge/discuss task scoring with judge. When scoring card is signed no further appeal is possible. Judge can decide to finish scoring consultation at any time especially when prolonged discussions can impact schedule. Judge has always final decision. Scoring card is a sole responsibility of team leader - all the required information and signatures must be collected within relevant deadlines and after last task should be delivered to designated collection point. Failure to do so can cause that team will not be counted to final classification.

g) Excellence showed in particular task will be promoted by additional points or multiplication factors (see scoring details).
h) Technology priorities and excellence promotions could be adjusted for different editions to focus teams on elements with low quality or robustness presented in previous editions. Changes will also reflect shift of focus in international roadmaps.

5.2 Schedule

a) On the first day, teams shall register themselves at the challenge location;
b) Additionally, for all teams, warm-up day is planned the day before challenges. This day should be used for calibration and other preparation activities. Organiser gives each team limited time slot. Teams are allowed to do any kind of measurements agreed with organiser based on final report specification. Some of tasks elements,considered as too detailed, can be removed for this day by organiser. All dynamic elements could be presented not in final locations. Organiser cannot assure that challenge area and its elements will be 100% ready for this day;
c) At the last day of the challenge, total scores are calculated, winners announced and the prizes awarded.
d) Detailed schedule, also containing the exact time window for each task, will be announced by the organizer one week before the event in preliminary version and final one on the first day of competitions;
e) Schedule is rigid – no team is allowed to exceed the permissible time limit or postpone time window designated for task attempt. A certain amount of time will be scheduled in between tasks to allow teams to modify, repair and optimize their rovers.

5.3 Challenge site details

a) Each challenge task can be organized indoor or outdoor independently. The part of outdoor challenge elements can be placed under the tents. Teams can expect typical interior furnishing, buildings, industrial installations (metal pipes etc.) and natural objects (e.g. trees, bushes) in vicinity of challenge arenas.
b) For outdoor tasks, teams and their systems should be prepared for different weather conditions. Temperatures between 15 and 30 degrees Celsius, wind gusts, light drizzle, strong or weak sunlight level are acceptable. During unfavorable conditions for particular design, team can ask for task reschedule but final decision will be made by trial judge considering schedule, other requests and impact on team performance. In case of major weather problems organiser will put effort to reschedule/reorganise trials within available days and facilities but it cannot be assured that all trials will take place or will be organised strictly following presented specifications.

c) The organizer will provide a map of the challenge area no later than at the first day of competition with all reference points;
d) The organizer provides each team with workspace equipped with tables, chairs and a 230V, 50Hz power socket (type E, compatible with 'German' type F);
e) Challenge location is separated from teams area to avoid RF interferences but organiser cannot guarantee that extra precautions will not be requested to avoid disruption of the challenge attempts;
f) The challenge field (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 should be expected. In case of tasks which do not score locomotion aspects, flat industrial surface (e.g. concrete) can be expected.

5.4 Operations

a) The challenges aim is to demonstrate and evaluate performance and robustness of the proposed solutions. All tasks are designed to eliminate 'luck' from challenges. Therefore, teams should present high level of readiness for each tasks and platforms should be equipped with all devices allowing solving all task elements. Rovers that are not equipped with all necessary elements could be not allowed to attempt task;
b) For the same reasons stated above, teams can expect dynamic elements in task description i.e. elements that will be defined separately for each team at the beginning of the attempt (e.g. changing start position, different positions of task elements etc.). In those cases jury will propose fair modifications and team cannot influence those decisions.
c) Teams will control their rovers from rover control areas. The areas will be set up so that team members will not see their rover during the tasks;
d) Each team have about 25 minutes (if task description does not state different) to complete a task. This value will be fixed in time of final schedule release.
e) Each team must designate two observers, who are allowed to follow the rover at a safe distance to ensure the machine basic safety. Observers are allowed to communicate with team from control area only through judge and only one way - from control base to observer - to react for non-task situations like task reset, abort or unsafe event. No communication during task normal execution is allowed. The observers must be able to carry rover but they should stay in safe distance from the working machine and cannot interfere with any rover's sensors (e.g. be visible on the image from the camera) during realisation of the task attempt;
f) During tasks only judges and team observers can access field of the task. No manual intervention is allowed except events for which task rules stand different;
g) Any maintenance made by the team during tasks (any operations made by the team with rover hardware on the field) causes restart of the task from the start line and cancellation of the all earned points;
h) The team can use video systems to tele-operate the rover if task requirements do not state different;
i) The team shall not use any voice/visual communication with the crew on the field. Only judge can communicate between task arena and control base.
j) The operator has the right to interrupt 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) During entire event rover or any other part of the system must not do harm or interfere with systems of the other teams. Any report about such breach will be investigated independently by judges or organizer and violation of this rule can lead to disqualification from the challenge;
l) Any erratic behaviour of the rover or one causing damage of task infrastructure can result with immediate interruption of the task attempt and cancellation of collected points.

5.5 Tasks descriptions

5.5.1 Science task

For any scientific or prospecting mission rover need to be able to deliver measurements of samples of soil properties from different geological layers. In general, samples taken from deeper layers are more valuable due to weathering conditions on the bodies surface (space weathering effects appears also on bodies without atmosphere due to e.g. solar radiation). It is also worth to mention that many scientifically and resources-wise samples require drilling in water reach soil under really low temperatures which can be harder than concrete. Equipping rover with complicated laboratory devices is limited because of system mass, volume, power requirements, risks of failure related to complex systems etc. Rovers should be able to assess sample quality and cache it for delivery to more sophisticated laboratory (in particular to Earth as Sample Return type mission). Because sampling environment conditions and ecosystem itself could be dramatically different than laboratory one, it is crucial to prevent any cross-contamination and isolate samples to keep them in conditions similar to original ones.

The aim of the task is to obtain samples of surface and subsurface layers of the soil each taken from different locations specified by judge. Samples should be cached into prepared containers. Additionally in-situ measurements and automatic documentation (photographic etc.) of collection place as well as samples will be scored.

Technology priorities

1) drilling - different level 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 - quality of operation of transporting sample from sampling place to container
    2) accuracy of placing - controlled way to put samples accurately to the container
    3) quality of container sealing design
    4) accuracy of container design regarding to 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 to real missions requirements.

4) scooping - unknow soil density
    1) separation of reaction forces from rover body
    2) robustness and repeatability
    3) task automation
    4) performance (energy, scalability, operation time)

Task Scenario

a) Reach sampling areas pointed by judge and target sampling location accurately;
b) Collect and cache 4 geological samples from terrain:
    - 3 surface samples from different locations,
    - deep sample (15-30cm below surface);
c) Prepare photographic documentation;
d) Collect several measurements of samples or sampling area that could be valuable for planetary science like each sample weight, volume and other parameters;
e) Excavate trench and document result;
f) Deliver samples in sealed containers.

General requirements

a) For this task multiple layers of different soil are prepared;
b) Surface sampling device should be prepared to handle different type of loose soil;
c) Deep sampling device should be prepared to handle materials from loose soil to hard gypsum;
d) Deep sample should at least contain material from the deepest reached point. In ideal scenario team should present unmixed, undisturbed cross-section of all layers from the surface to the deepest reached point.
e) The rover should be equipped with at least one sampling device.
f) 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 judge;
i) Container design and sample insertion method/device should be inspired by real missions requirements;
j) Minimum resolution of the images is 800x600 pixels. Object of the image (sample location or sample itself) should occupy major part of the image. Image quality should be reasonable for scientific needs;
k) Any additional physical parameters must be documented in the control station and stored till judge inspection after task attempt end. Judge will evaluate quality of received data;
l) The trench should have minimum 30cm length, minimum 5cm depth and at least one wall steep enough to present clearly visible soil layers. This findings should be documented on a photo.
m) The method for sampling reaction forces/torques separation from rover body should be presented and will be scored by judge based on operation observation.

Expected results

a) Samples with correct weights in separate, sealed containers:
    1. each sample should weight at least 25g and preferably 50-100g according to scoring (see appendix)
    2. deep sample containing at least the deepest material, ideally cross-section from surface to the deepest point
b) Results of in-situ measurements and observations of the samples and sampling area. Scored higher for automatic measurements acquisition;
c) Photographic documentation showing different aspects of samples, sampling areas and operations;
d) All data stored at least until reviewed by the judge;
e) Presentation of innovative methods of 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 rover etc.), not done by the rover equipment during 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 sampling depth based on the sample material characteristics according to the reference key;
e) Additional points could be scored if extra functionalities of the system will be demonstrated during task. No part of additional equipment can operate standalone;
f) The deep sample should be clearly visible in undisturbed state at least before the sample is placed into the container. It is possible to leave detached part of sampling device inside container but ideally only deepest part of the sample should be placed into container (not mixed with upper layers of soil).
g) Extra points could be awarded if deep sample caching is done without sample exposure to above-surface conditions.

5.5.2 Maintenance task

Most of manned missions tries to limit human operation outside orbiting or surface habitats. For this reason astronauts need dexterous robotic systems to support extravehicular operations on infrastructure suited to be operated by humans. Expecting human-robot cross-operation on such infrastructure it is also important to properly design future infrastructure elements to simplify operational aspects. Due to operations complexity, this tasks can be tele-operated but humans still needs support for many operations to increase their awareness about situation and robustly automate tasks that need intense concentration for longer time (e.g. safely approaching switch that shouldn’t be damaged). This is why roadmaps highlight needs for fully immersive teleoperator interfaces with

extended spatial awareness, force feedback, intuitive interfaces design and systems with automation of typical tasks like manipulator approaches, low level control etc.

The maintenance task is intended to demonstrate rovers and teams ability and performance in operating electrical panel on which several switches and other electrical components are mounted. The Team has to use rover's manipulating device to set switches to correct positions, measure electrical parameters, set other panel controls and observe device feedback.

Technology Priorities

1) tasks automation
   a) automatic elements detection (e.g. spatial parameters, possible actions etc.)
   b) automatic approach
   c) automatic manipulation
2) tele-operator 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 ergonomy, etc.)
   c) ergonomy of operator control interface
3) end-effector performance
   a) tool relevance for specific scenario
   b) multiple tool systems (interfaces, exchange) or universal tool design
   c) operation robustness (flexibility etc.)
   d) operation accuracy and quality for specific scenario
4) manipulator performance
   a) operation robustness
   b) operation accuracy and quality for specific scenario

Task Scenario

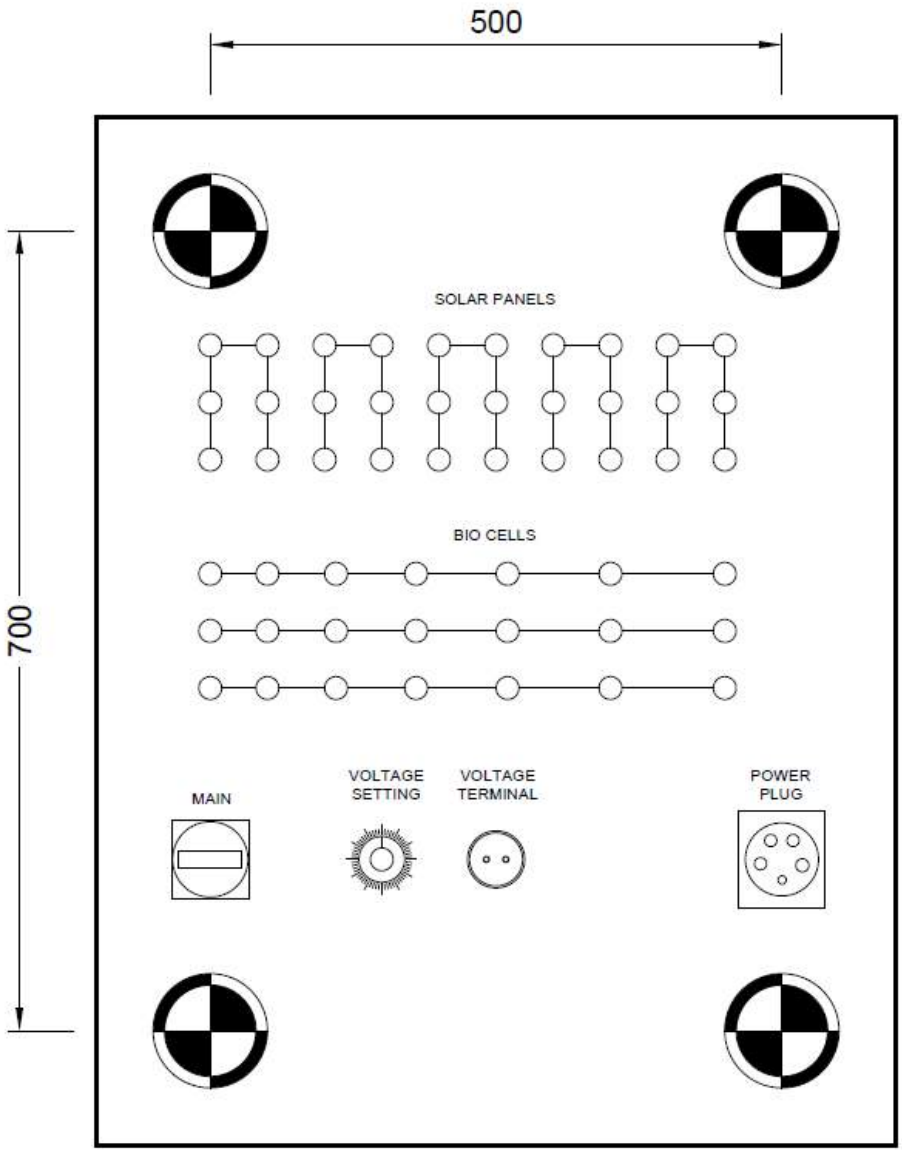
1) set MAIN switch to ON position
2) set sequence of evenly distributed group (1) of switches to state requested by judge
3) set group 2 of switches (without particular distribution pattern) to state requested by judge
4) set knob to the value requested by judge
5) measure voltage on panel terminalsrasp the high-power plug from the ground and insert it into the socket.

Tasks automation should be presented in one or more cases.

General requirements

a) The rover should be equipped with manipulation device allowing to interact with control panel designed for human operator
b) Switches and other controls will be industrial grade elements;
c) Switches can be lever or rotation type;

d) Controls can be located on vertical panels between 0.2m and 1.5m above the ground;
e) All switches should be manipulated one by one - actuation of more than one in single move cause reset of all elements;
f) Voltage measurement is conducted on standard German type F/French type E similar (https://en.wikipedia.org/wiki/AC_power_plugs_and_sockets#CEE_7.2F3_and_CEE_7.2F4_.28German_.22Schuko.22.3B_Type_F.29) power socket or terminals with similar dimensions and connection requirements;
g) Measured voltage level is between 1.0VDC and 24.0VDC;
h) Voltage should be reported with 0.5V accuracy;
i) Knob value display/scale can placed not further than 15cm from rotation axis;
j) High-power plug type is IEC 60309 with maximum 10cm handle diameter;
k) Some panel elements are sensitive to forces and torques exceeding operational limits; Those elements shouldn't be 'damaged' during operations and are scored differently than stiff ones;
l) Some of the panel elements can be covered by MLI-like (Multi-Layer Insulation) material attached e.g. with velcro and additional manipulation capabilities could be necessary to remove it/uncover those elements without causing any damage to material.
m) preliminary design of panel is presented below (final panel could slightly differ from one presented here):



Expected results

a) MAIN switch set to ON position as first;
b) Group 1 and Group 2 switches set up to requested positions;
c) knob set up to requested position
d) voltage measurement reported to the judge
e) High-power plug inserted into the socket;
f) No panel damage events occured (control elements, connectors, covers, foils etc.);
g) task automation efforts and results presented to the judge.

Additional information

1) Most of panel elements will be specified before challenges by photo and general dimensions. Location of panel elements will be unknown and could be changed between task attempts.
2) Multiple AR/QR tags will be placed on the panel surface. Tags type will be specified before challenges. Relative distance between tags will be published.

3) Example additionally scored elements:
    a) presenting results from automatic panel controls detection and characterisation. All or some of the parameters like element position, element type, element dimensions, possible actions, direction of possible action etc. should be presented on operators screen at least based on single picture;
    b) tracking of controls positions and etiquettes during robot and arm movement;
    c) depth position of reported elements;
    d) automatic end-effector approach and optional homing to the 'idle' position. Functionality presented on few elements. 'Idle' position is defined as any point where end-effector is in the distance of minimum 20 cm from the panel surface.
    e) full automatic manipulation presented on multiple elements - approach, desired action and homing.

5.5.3 Collection task

Scientific rovers are precious piece of laboratory and they should be used to examine areas suggested by scientists. When one of mission objective is a delivery of samples to the more sophisticated laboratory (or return them to Earth in particular case), their work should not be spent on delivery activities which can take substantial amount of time. Additionally such scenario creates single point of failure - if scientific rover fails to deliver samples, all the samples are lost. For that reason concept of Sample Fetching Rover (SFR) was introduced. In this scenario scientific rover leaves cached samples on the ground reporting their location and continues its work. Then, another rover (characterised with better mobility and generally faster) responsibility is to collect them and deliver to specified location. In time when SFR arrive to cache location different weather activities can cause that cache will not be fully visible etc. so system must be prepared to search and identify cache. Additionally, ground control in the loop of SFR operations can slow mission down so it is highly desired to automate mission elements as much as possible. Moreover, some specific missions like sample return to earth specifies extra requirements on design of the container that should be used for samples collection.

This task is intended to demonstrate ability to perform cache fetching scenario. The Team has to reach locations marked on map, search and pick up the cache and place it into container on-board in a required orientation, then deliver container with caches to final destination.

Technology priorities

1) tasks automation
    a) automatic elements detection and localisation
    b) automatic approach
    c) automatic pickup
2) end-effector performance
    a) tool relevance for specific scenario
    b) operation robustness
    c) operation accuracy and quality for specific scenario
3) container and cache design

a) container/mechanism design allowing placing caches by limited accuracy manipulator into container with requirements for high cache protection
b) accuracy of container design regarding to real missions requirements

4) manipulator performance
   a) operation robustness
   b) operation accuracy and quality for specific scenario

Task Scenario

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

General requirements

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

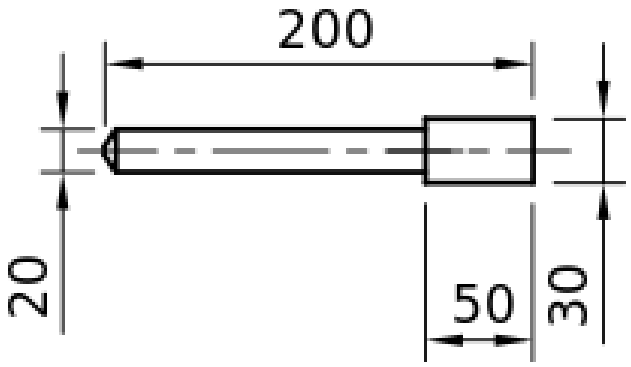


Fig. Schematic view of cache design.

Expected results

a) Demonstration of rover manipulation equipment (a robotic arm or equivalent) and operator performance in remote control;
b) Demonstration of system automation capabilities;
c) Placement of the caches in a proper position into the container;
d) Delivery of container to final destination;

e) Presentation of operational approach, used algorithms and other system solutions;
f) Presentation of proposed container design and accompanying elements.

Additional information

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

5.5.4 Traverse task

A traverse task is core element of rover operation. It must be fully robust and optimised activity. It is probably one of most critical operations and at the same time having major impact on overall system performance. Traverse through unknown planetary surface characterised by properties that are not intuitive for humans due to harsh environment, neglected effects in Earth scenarios and different gravity by non-maintainable, non-recoverable vehicle is a great challenge. On the other hand, safe traverse operation is costly in terms of time and resources limiting science outcomes from relatively short rover lifetime. Obviously, major operation optimisation can be found in removing ground control from control loop, thus making traverse autonomous. Traverse is not single element but rather chain of many operations that need to be coordinated like: perception sessions, planning, traverse execution and monitoring. Moreover, what if during traverse some scientifically valuable, easy accessible - just “on the way” spots can be missed? This is why concept of autonomous scientist was introduced into roadmaps guiding towards future missions.

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

Task scenario

a) Send rover position and way-points positions to the system
b) Reach 4 way-points;
c) Reach additional point located in more challenging terrain;
d) After traverse present used techniques, visualise system data, compare results with plan calculated at the beginning etc.

General requirements

a) The rover mobility system should be able to drive over challenging terrain in conditions described in *General Rules* in *Test Trials* section.
b) On-board data processing application should be used for rover localisation based on natural terrain features, however navigation landmarks can be placed for absolute reference on team request. Use of landmarks result with penalty points.
c) The rover system can utilise coarse heightmap of the arena provided by organisers, however solutions working without using predefined map will be scored extra
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 task attempt only data that can be transmitted from rover to control base are position ([x, y, z]) and orientation (Euler angles or quaternion)
f) The rover start position and way-points coordinates to reach will be provided in local coordinate frame directly before task attempt
g) System should be able to plan optimal path based on given map and way-points coordinates.

Expected results

a) Reach all way-points;
b) Present system that support operator in rover control;
c) Reach way-point X;
d) Present systems and methods used for autonomous traverse and gathered data (e.g. map, paths, plans, reached way-points 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 in limited heading.
b) The rover can be tele-operated but only with position and orientation estimate available. Those data can be visualised in any form (e.g. projecting rover position on provided arena map or top view picture etc.)
c) If for some reason rover has to be moved, it can only be moved (penalties applied):
    - back to the last safe position (assistants define it) and/or rotated towards any point;
    - back to the last successfully reached way-point and/or rotated towards any point;
    - back to the start point.

a) Technical Reports shall include a list of all sensors together with detailed information about working modes, ways they are used in navigation task and how rover will be operated. Teams are entitled to consult all solutions with judges before documentation submission. Documentation will be verified by judges and in case of any doubts team could be asked to reconfigure devices and/or communication strategy. Any difference between approved configuration and the one used during challenges can cause a disqualification (0 points for this task);
b) Task arena:

- Final map with grid coordinates and POIs (Point Of Interests) will be provided not later than 3 days before the competition and will be subject of updates till the first day of trials;
- Most landmarks will be visible from starting point but it must be taken into account that part of them could be obscured by terrain or other objects during traverse;
- Two types of landmarks are foreseen: natural landmarks which are elements of 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 figure, alphanumeric sign or AR/QR tag matching POI label on the map;
- Artificial landmarks will be visible for camera from different direction on a field and will have physical base which can be detected by proximity/range sensors (e.g. placed on element of infrastructure or natural landmark);
- Check-points will be flat characteristic elements with similar labels like on artificial landmarks;
- First definition of the way-points and landmarks will be provided for preliminary design period and final one not later than 30 days before the competition;
- Team cannot place any additional passive landmarks or active beacons on challenge field outside starting area but such elements can be deployed using rover during trial. All those landmarks must be documented in Technical Reports and presented for judges acceptance at least 10 working days before submission of the final documentation. These equipment can be subject of negotiations so teams should leave enough time to redesign/modify it in case of comments/rejection by judges. Such equipment must comply with other rules of the competitions and if active radio beacons are used, they must be compliant with radio communication rules (see *Radio Communication* section) and described in RF form;

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

5.5.5 Presentation Task - project review

The presentation task lets teams to introduce themselves and present their projects. The Judges 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 occurred during development. The Team should be also prepared for Q&A session.

Goals

a) Introduce team (expertise and experience) and project;
b) Present organization structure, management methods and work-flow;
c) Present an engineering approach;
d) Present technical design;
e) Present difficulties occurred and applied methods to solve them;
f) Present elements designed to fulfill rest of the trials tasks.

General requirements

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

Expected results

a) Demonstration of team presentation skills;
b) Detailed information on: technical key-drivers which influenced the team to build exactly 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.

6. Miscellaneous

6.1 Awards and recognitions

The award for 1st place, Grand Prix ERC, is a cash award. Smaller cash awards will be given for the 2nd and 3rd place. The award amounts will be announced on the challenge website. The organizer will also give a separate Special Excellence Award to the team with the outstanding performance during challenges. The form of the award will be specified on the challenge website. The organizer may also announce other awards and allow awards funded by third parties. Third party award funders must have the organizer's approval.

By taking part in the ERC 2019, teams agree to place on their rover sticker promoting the competition (the sticker max. size: 10x10cm).

6.2 Organiser disclaimer

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

6.3 Changes to Competition Rules

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

6.3.1 Deadline extension

The organizer has the right to extend the deadline for submission of documents and announce it reasonably in advance and provide 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, contact the challenge contact point (see *Information channels and contacts*).

The organizer will provide 'European Rover Challenge 2019 Questions & Answers' as a part of the competition rules. All arrangements contained therein are ultimately binding – even if they change the competition rules. FAQ will be reasonably announced in advance and provided on the challenge website.

6.3.2 Challenge scoring issues

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

6.3.3 Organizational issues

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

6.3.4 General Challenge issues

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

6.4 Disqualification

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

6.5 Personal data storage

Team members agree to their personal data being stored and processed in the organizer's computer systems and also for the purpose of ERC's integrated programme towards technological development specifically in a area of space exploration and utilization. They also give the organizer, parties designated by the organizer 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. Personal data and information about team members other than their names and surnames will not be published without prior consent of the each team member.

The organizer provides to the team members an opportunity of sending their resumes to ERC Student Teams' contact point: teams@roverchallenge.eu and lets team members to introduce themselves to the ERC's partner and sponsor companies.

Any team member providing a Resume should add a following information clause within the CV document:

"*I hereby give consent for my personal data included in my Resume to be processed by the European Space Foundation and ERC's partner and sponsor companies looking for interns and new employees, under Art. 23 ust 1 pkt 1 of the Personal Data Protection Act as of 29 August 1997, consolidated text: Journal of Laws 2016, item 922 as amended and under Art. 6 ust.1 lit. a of Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such GDPR (Dz. U. UE. L. z 2016 r. Nr 119.) from the day this regulation enters into force.*"

Any Resume without such information clause will not be taken into consideration and will be deleted from the database.

6.6 Team members responsibility

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 organizer of any responsibility in the event of damage, destruction or theft of any property.

6.7 Organizer responsibility

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

6.8 Copyrights

The organizer keeps all the copyrights to the competition rules especially description of the tasks. You may not make alterations or additions to the competition rules, or sell it. Rules can be used and/or copied only for ERC-connected activity (eg. registration process).

APPENDIX 1.

7.Challenge Schedule

Please find below preliminary schedule of 2019 edition of competitions.
Final schedule will be delivered to end of Jan 2019.

Event	**Date (2019)**
Rules publication	Jan
Registration start	mid Jan
Registration end	end Mar
Preliminary Report	mid May
Qualification	end May
Video documentation	end Jul
Final Report + RF form	end Aug
Competitions event	Sep (3 days)
• warm up day	T-1
• on-site registration	T0
• closing ceremony	T+2

APPENDIX 2.

8.Challenge Scoring

This part will be delivered soon.