EUROPEAN ROVER CHALLENGE

ERC STUDENT Rules

2018

www.roverchallenge.eu

Table of contents

Change record

Date	Section	Description
30.12.2017	All	Preliminary public document version
1.02.2018	All	• Major modifications/corrects in general wording and introduction; • Scoring added; • Schedule updated; • Rover System Requirements: rover weight relaxation • Safety System: safety test added • Rover System Requirements: added Miscellaneous chapter - data logging • Documentation: Changes in Preliminary and Final documentation - adding risk assessment, test plan etc. • Field Trials: Excellence award rules change • Operations: time relaxation for autonomy attempts • Science task: minor changes in samples depth and weight • Maintenance Task: specifications in General requirements - broader definition of activation element and sensitivity to forces and torques • Traverse Task: added Technology priorities, some changes in requirements and expected results • Presentation task: new element - outreach presentation-report

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.

ERC is split between two program tracks. ERC-Student delivers career development platform with major focus on space engineering. It includes workshops, and all year activities and mentoring around designing and building student planetary rover. All the effort is finalised by yearly event where student teams compete on specially landscaped area.

Second track, called ERC-Pro is designed to provide opportunity to demonstrate abilities in solving field tasks inspired by space robotics roadmaps. It is suited for startups, any companies, research groups and others working in space robotics domain. On the other hand, those not yet connected with space industry and having solutions solving given tasks can benefit from participation by presenting their strengths and getting introduced to the domain challenges and community of 'doers' in this specific field.

In a long term ERC-Pro want to provide platform for monitoring and benchmarking on realisation of robotics exploration roadmaps to strategic institutions and other interested actors. As a implication of aforementioned activities, ERC-Pro is aspiring to disrupt pattern of single-mission systems and following best practices form terrestrial robotics, bring iterative development and improvement in field of space robotics projects by annual trials and demonstrations.

Both tracks are the part of one community network managed under ERC flag. Such solution provides unique opportunity to collect people on different level of career focused on (robotic) space exploration. Community works as a motor of continuous improvement effort one way, providing transfer of expertise and feedback from professional teams to students and other, creating transfer of talents to engaged companies. It also connects universities, companies and other institutions promoting their strengths and identifying opportunities for collaboration.

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. Elements of ERC-Student

ERC-Student track includes:

a) During a year lasting project:
   - creation of the team
   - submission of proposal
   - organisation of the project and acquisition of the funds
   - design and build / iterative improvement of robotic mobile platform with accompanying equipment according to requirements
   - delivery of preliminary documentation
   - delivery of final documentation
   - organisation of test campaign
   - delivery of promotional video
   - feedback and mentoring from domain professionals

b) At the Challenge event:
   - participation in 4 terrain tasks
   - presentation of different project aspects
   - participation in the workshops and meetings with guests
   - networking

c) Life lasting:
   - participation in broad community of people focused around topic of space exploration and robotics
   - excellent opportunity to build experience, hard and soft skills, create long lasting teams and businesses and have a lot of great fun!

1.3. Schedule and Venue

ERC is an venue independent, all-year programme. For information about ERC 2018 event 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. General

The 2018 edition of the challenge is planned for limited number of teams. ERC Board will select which of the registered teams will be invited to compete in the challenge. The choice will be made based on documentation which teams are required to send to the organizer by deadlines 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 email address (see *Information channels and contacts*). If this document is not submitted before specified deadline, team will be not allowed to participate in the challenge.

The team registration email 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 participate in the Challenge event (i.e. appearing on site of the event);

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 social media fanpage (preferably Facebook as a main social media platform used by ERC team);

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 cases will be discussed separately to ensure that competition is fair play.

3.2. Dimensions and weight

The suggested rover weight is 50-60kg and envelope about 0.75m radius. 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 or dimensions 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 penalized by number of points defined in Scoring rules in appendix to this document.

3.3. 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 rover to travel a certain distance, but never further 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 *FIeld Trials* section.

3.4. 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:

a) “start” command - command to be send at the beginning of the attempt;
b) “working” state - nominal work during attempt;
c) “wait” command - enter “wait” state. Team can use it at any time for sensor readings stabilization;

d) ”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;
e) “resume” command - transition from “waiting” to “working” state;
f) “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. Rover telemetry 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. Safety System

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, could be tested by judge during any EMC test and failure to present it can result in disqualification of the team from entire trials.

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 on-board. 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.

Judge should be informed about all planned autonomous/automatic attempts before they are executed.

It is also recommended that platform is equipped with additional indicator showing that robot is performing task (or its part) autonomously.

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

3.6.2.1. 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).

3.6.2.2. 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.

3.6.2.3. ISM bands

It is possible to use ISM bands within their limitations but team must designate which rule is compilant 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*

3.6.2.4. 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.

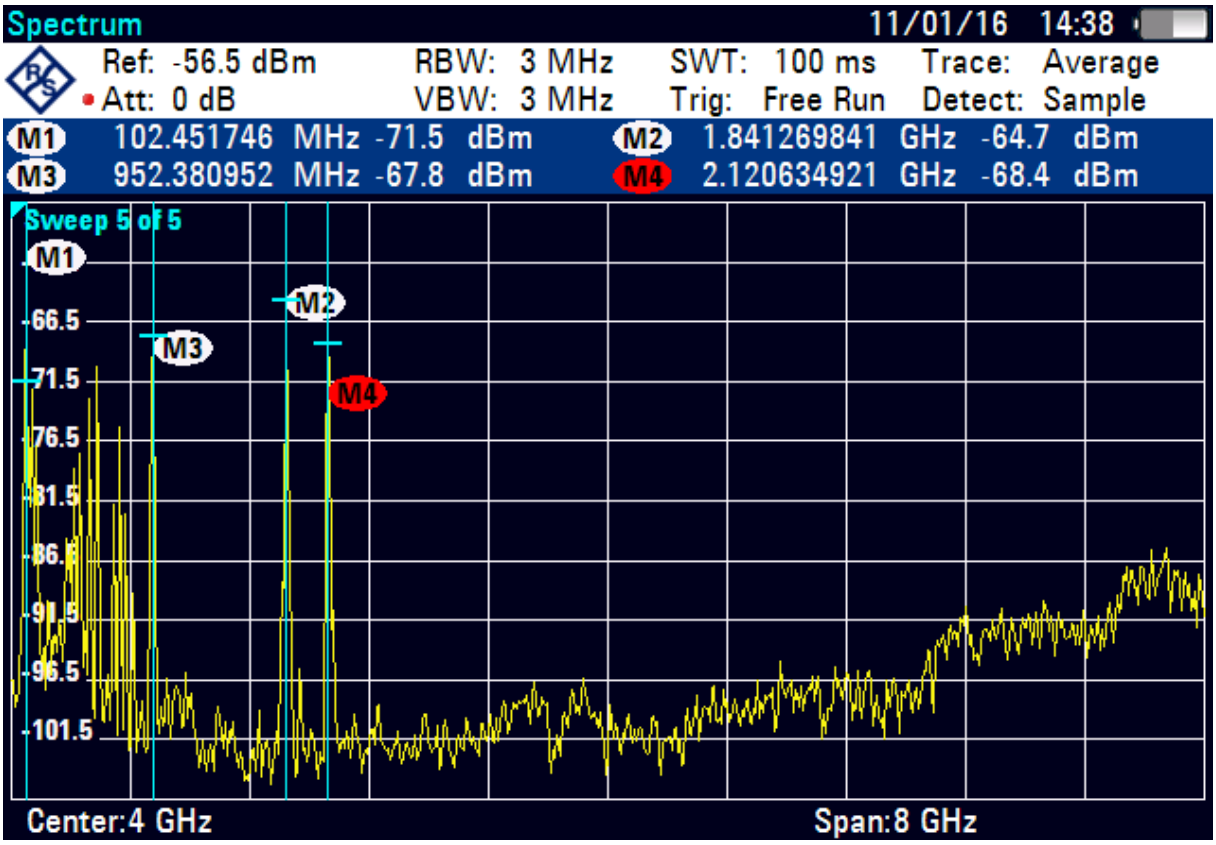
For the whole duration of the challenge, the team is responsible for the legal use of frequencies on venue territory. The organiser can only help in frequency coordination, but does not take responsibility for any license violation like exceeding RF power, frequency band or area of use.

3.6.4. Radio Frequency Form

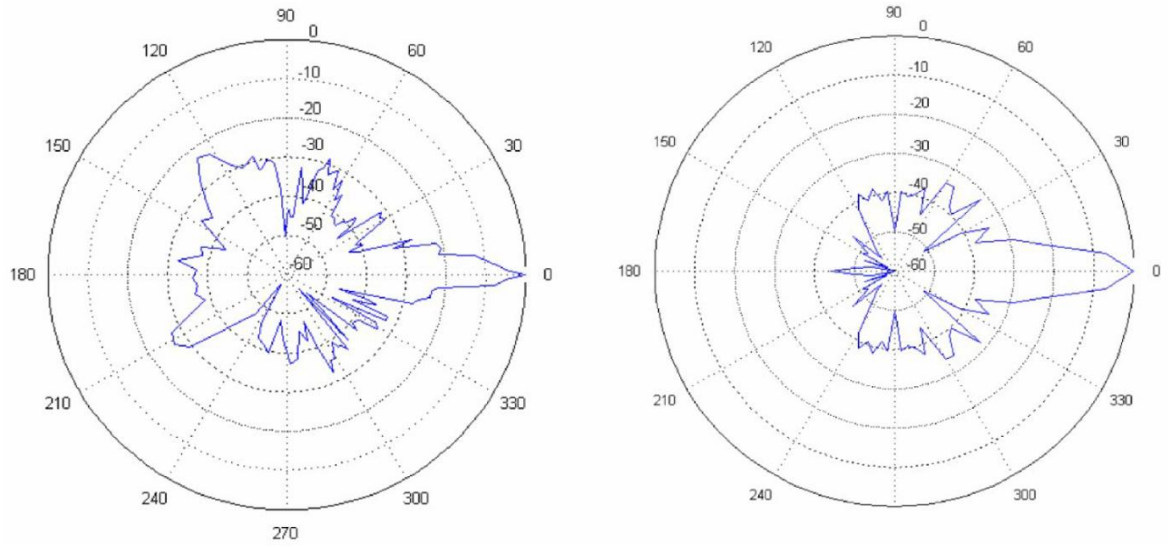
Each Team must fill Radio Frequency Form for every RF module used. It shall be included in relevant Technical Reports as an appendix (see documentation specification). If these documents are not submitted in the requested form, team will not be allowed to participate in the Challenge.

RF Form shall contain:

a) Team name;
b) Country;
c) How many different communication systems are planned to be used;
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

3.7. Miscellaneous

It is recommended that teams will collect data (e.g. power parameters, accerations, received commands and other system states) about state of their rover for future evaluations.

During trial team could be asked for (non-invasive) access to their main power line cables (connecting with battery) and designated spot for attachment of external logging system. Details will be agreed individually during design phases.

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 ERC competitions 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.);
2) Initial project assumptions and initial technical requirements, derived assumptions, 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 2018”, 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);
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) Lesson learnt - present problems and issues you are facing (management, engineering, logistics, etc.) and how you solved them and/or plan to solve;
8) Risk assessment - identified risks for continuation of the project development and attendance in competitions (main focus (but not limited to) technical aspects) with assesment of impact and mitigation plan;
9) 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 2018", 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) Testing methodology and test plan;
4) Final design:
    a) System Breakdown Structure (SBS) + description;
    b) System architecture - hardware and software diagrams and description;
    c) Operational scenarios;
    d) CAD drawings (2D, 3D, dimensions, assembly, details);
5) Safety Systems description;
6) Final financial report (sources and expenditures);
7) Lessons learnt - difficulties and solutions applied;
8) Risk assessment;

9) 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 2018”, 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).

4.2. Promotional video

Each team shall prepare a promotional video, which must be completed and submitted by the date presented in challenge schedule (see *Schedule* appendix). The file should be submitted in MP4, MOV or AVI format with information about any necessary codecs to view it. The organizer will provide an FTP server to which the video file must be uploaded. If the promotional movie is not submitted in the correct form (or it is not playable by organizer) and within the time laid down, team will not be allowed to participate in the challenge.

Promotional video shall be 3-5 minutes long and shall present rover’s capability to take part in the challenge and it shall contain 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 question and 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.

4.3. 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 earlier approval of a team representatives. The sole exception to this is the Challenge jury board.

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) Excellence showed in particular task will be awarded.

g) 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 Celcius, wind gusts, light drizzle, strong or weak sunlight level are acceptable. During conditions unfavorable 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 and promote repeatability. 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 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. In case of successful autonomous operation judge can award team with additional time but only to compensate longer autonomy operation comparing to manual control. Length of this bonus time is a decision of the judge and cannot be challenged. Judge can stop the task at any time outside task original time window.

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 to 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.

5.5.1.1. 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)

5.5.1.2. 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 (15-35cm 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.

5.5.1.3. 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.

5.5.1.4. Expected results

a) Samples with correct weights in separate, sealed containers:
    1. each sample should weigh at least 25g and preferably 50-150g 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).

5.5.1.5. 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.
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 reasons 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 needs support for many operations to increase their awareness about situation and robustly automate tasks that need higher level of focus for longer time what is tiring (e.g. safely approaching switch that shouldn't be damaged). This is why roadmaps are specifying need 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 panels 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. These units are placed in two different locations, thus mobility capabilities in fine positioning of a rover are also necessary to achieve a goal.

5.5.2.1. Technology Priorities

1) 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

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

5.5.2.2. Task Scenario

1) Approach panel 'A';
   a) Set switches into states specified by judge;
   b) Measure voltage on panel terminals;
2) Approach panel 'B';
   a) Turn designated switch on;
   b) Set knob to value specified by judge;
3) Grasp the high-power plug from the ground and insert it into the socket.

5.5.2.3. 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 could need different forms of translation or rotation of handle element to change their state;

d) Controls can be located on vertical panels between 0.2m and 1.5m above the ground;

e) 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_7.2F

4_.28German_.22Schuko.22.3B_Type_F.29) power socket or terminals with similar dimensions and connection requirements;

f) Voltage level is between 1.0VDC and 24.0VDC and should be reported with 0.5V accuracy;

g) Knob value display/scale can placed not further than 15cm from rotation axis;

h) High-power plug type is IEC 60309 with maximum 10cm handle diameter;

i) Any excessive force transferred to the Challenge infrastructure can result with assignment of zero points for particular element and if behaviour will be repeated judge can finish task attempt immediately;

j) Some panel elements are sensitive to forces and torques exceeding operational limits; Those elements should not be 'damaged' during operations and are scored differently than stiff ones;

k) 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.

5.5.2.4. Expected results

a) Panel 1: switches set to correct positions and voltage measurement reported to the judge;

b) Panel 2: switch set to "ON" position and knob adjusted to desired position;

c) High-power plug inserted into the socket;

d) No panel damage events occured (control elements, connectors, covers, foils etc.);

e) Presentation of design proposition for control elements suited for human-robot cross-operation.

5.5.2.5. 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) Examples 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.

5.5.3.1. 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

5.5.3.2. 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

5.5.3.3. 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 movements during traverse;
e) There should be at least 4 slots for cache in the container
f) Cache is be represented by green cylinder (20mm diameter, 200mm height). One end of cylinder is cone-shaped and 50mm part from second is thicker (30mm diameter). Maximum weight of cache is 300g and COG position is unknown. The caches should be stored cone-shaped-end (thinner-end) down. Detailed design of cache will be given for preliminary design phase.

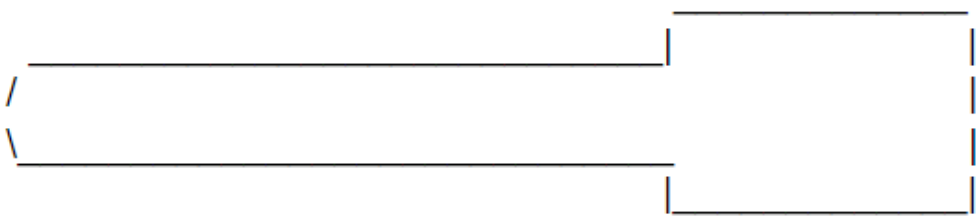


Fig. Schematic view of preliminary cache design.

5.5.3.4. 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.

5.5.3.5. 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.

5.5.4.1. Technology priorities

a) autonomous navigation
b) robust traverse
c) data processing and fusion
d) localisation
e) obstacle avoidance
f) mapping
g) planning
h) trajectory control
i) Data processing and visualisation

5.5.4.2. Task scenario

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

5.5.4.3. 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.
c) The rover system can utilise coarse heightmap of the arena provided by organisers, however solutions working without usage of a-priori map will be scored extra
d) Use of GNSS receivers and any other localisation reference system is not allowed. Any other type of sensor (i.e. camera, lidar, IMU, odometer, sonar, etc.) can be used for on-board processing.
a) Teams should take care to minimise usage for navigation purposes of features that are not part of competition area (e.g. infrastructure around, people etc.) by e.g. limiting field of view of the sensors to necessary minimum.

e) At any time during task attempt only data can be presented to the operator are position ([x, y, z]) and orientation (Euler angles or quaternion)
f) The rover start position and way-points coordinates to reach will be given in local coordinate frame, before task attempt
a) System should be able to plan optimal path based on given map and way-points coordinates and refine it when more data available.

5.5.4.4. Expected results

a) Reach all way-points;
b) Present system that support operator in rover control;
c) Reach way-point X;
d) Present autonomous traverse capabilities and gathered data anaysis (e.g. map, paths, plans, reached way-points position errors etc.).

5.5.4.5. 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) Team can make multiple attempts toward next way-point and final way-point score will be the average from all started attempts;
d) If for some reason rover has to be moved, the way-point attempt is scored with 0 points and rover can be placed back to the:
    - last successfully reached way-point preserving original orientation
    - 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 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.

5.5.5.1. 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 trial tasks expected results;

g) Present project outreach and impact.

5.5.5.2. 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.

5.5.5.3. Expected results

a) Demonstration of team presentation skills;

b) Detailed information on:

   a. technical key-drivers which influenced the team to build exactly this design, engineering approach, system breakdown structure, management, difficulties and solutions;

   b. Scientific/engineering inventions, design propositions;

   c. Spin-off, spin-out/in ideas and opportunities;

   d. Outreach - promotion of programme and event as well as research/technical activities (where ERC was clearly promoted); social project impact; research - thesis / side projects; activities and results derived from ERC like new projects opportunities, startups, campaigns, generated IPR; All documented (only summary should be presented but detailed information should be put after end

slide) with relevant factors values (e.g. number of people, number and details of theses (e.g. title, short description of topic, affiliation), value of the projects, number of events) and photo documentation possibly presenting direct promotion of ERC.

6. Miscellaneous

6.1. Awards

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.

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.

6.3.2. 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 2018 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 announced in advance and provided on the challenge website.

6.3.3. 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.

6.3.4. Organizational issues

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

6.3.5. 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.

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.

Challenge Schedule

Please find the schedule of 2018 edition of competitions.

Event	**Date**
Rules publication	Dec 30th 2017
Registration start	26th Jan 2018
Registration end	31st Mar 2018
First qualification	16th Apr 2018
Preliminary Report	10th May 2018
Qualification	24th May 2018
Video documentation	26th Jul 2018
Final Report + RF form	23rd Aug 2018
Competitions event	
• warm up day	13th Sep 2018
• on-site registration	14th Sep 2018
• competitions	14th-16th Sep 2018
• closing ceremony	16th Sep 2018
Mentoring workshops	17th Sep 2018

APPENDIX 2.

Challenge Scoring

1. General rules

Scoring of competition is designed to reflect identified Technology Priorities and gaps in last editions designs. It is trying to motivate teams and as a result, bring missing expertise to the team and missing solutions to the Challenges.

Some flexibility in scoring is left to reflect many aspects that cannot be covered by rules like quality of solutions, its robustness and performance, but judges will be equipped with detailed guidelines to make scoring as objective as possible. Judge has always final decision. 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 one person from the team can challenge judge scoring. When scoring card is signed there is no further appeal possible. Judge can decide to finish scoring consultation at any time especially when further discussions can impact schedule.

2. Documentation

2.1. 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	9	9
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	6	6
Proposal - SUM				25

2.2. 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	8	8
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	Technologies	Used technologies and methodologies in technical and management side of the project	4	4
SCR_DOC_E_040	System Breakdown Structure	Dependency between subsystems and its development	5	5
SCR_DOC_E_050	Safety System	Description solutions for required aspects	4	4
SCR_DOC_E_060	Preliminary financial budget	Estimation of final cost (ROM), sources and costs in the project, ways forward	4	4
SCR_DOC_E_070	Lessons learnt	Current issues and challenges, proposed solutions (technical and other)	4	4
SCR_DOC_E_080	Risk assessment	identified risks with assessment of impact and mitigation plan	5	5
SCR_DOC_E_090	Pre-final Radio Frequency Form	First version of RFF - see Communication Requirements	3	3
Preliminary report - SUM				45

2.3. 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_041	Final design	System Breakdown Structure (SBS) + description	3	
SCR_DOC_F_042		System architecture - hardware and software diagrams and description	5	
SCR_DOC_F_043		Operational scenarios	5	
SCR_DOC_F_044		CAD drawings (2D, 3D, dimensions, assembly, details)	4	
SCR_DOC_F_040	Final design - SUM			17
SCR_DOC_F_050	Safety Systems description	Diagrams, operation	5	5
SCR_DOC_F_060	Final financial report	sources and expenditures	4	4
SCR_DOC_F_070	Lessons learnt	difficulties and solutions applied	6	6
SCR_DOC_F_080	Risk assessment	Analysis of preliminary document version; Regarding system performance, attendance in competition tasks; with impacts assessment and proposed mitigations	7	7
SCR_DOC_F_090	Final Radio Frequency Form	final version of the form presented in preliminary documentation	5	5
Final report - SUM				60

2.4. Promotional video

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 team work	3	3
SCR_DOC_V_030	Reasons for participation	Challenges impact and opportunities	3	3
SCR_DOC_V_040	Safety system presentation	Emergency Stop functionality, safety features	4	4
SCR_DOC_V_050	Remote control presentation	Ability to tele-operate rover	4	4
SCR_DOC_V_060	Mobility and manipulation presentation	Driving rover, showing working manipulator during tests	8	8
SCR_DOC_V_070	Quality and visual aesthetics	Resolution, clarity of image and harmony and reception	7	7
Promotional video - SUM				30

3. Tasks Scoring

3.1. 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	Minimum of 25g of designated soil sampled	5	

	diameter)			
SCR_TSK_S_012		For every next 25g of sample weight (max 150g)	1 (max 5 for sample) = 5	
SCR_TSK_S_013	Surface Sample #2: Acquisition of surface sample form designated spot (within 5 cm diameter)	Minimum of 25g of designated soil sampled	5	
SCR_TSK_S_014		For every next 25g of sample weight (max 150g)	1 (max 5 for sample) = 5	
SCR_TSK_S_015	Surface Sample #3: Acquisition of surface sample form designated spot (within 5 cm diameter, from challenging terrain - rocks, terrain formations)	Minimum of 25g of designated soil sampled	5	
SCR_TSK_S_016		For every next 25g of sample weight (max 150g)	1 (max 5 for sample) = 5	
SCR_TSK_S_010	Surface Sample (Average score from Surface Sample #1-3)			10
SCR_TSK_S_021	Deep Sample: acquisition (one from listed options)	Minimum 25g reaching 15cm below surface level	5	
SCR_TSK_S_022		Minimum 25g reaching 25cm below surface level	8	
SCR_TSK_S_023		Minimum 25g reaching 35cm below surface level	11	
SCR_TSK_S_020	Deep Sample			11
SCR_TSK_S_030	Photographic documentation of sampling site	Photo of each surface sampling site after acquisition and photo before and after operation of deep sampling	1 per photo = 5	5
SCR_TSK_S_040	On-board sample weight measurements	For each sample with 20% accuracy	1 per measurement = 4	4

SCR_TSK_S_053	Trench excavation	For excavation	4	
SCR_TSK_S_054		For photo with dimensions measurement (20% accuracy)	3	
SCR_TSK_S_050	Trench excavation - sum			7
SCR_TSK_S_061	Caching - sample put to the container and container sealing	For each cached sample (sample delivered to the container)	2 per cached sample = 8	
SCR_TSK_S_062		For each sealed container - sample stays inside when turned in different orientations	3 per sealed container = 12	
SCR_TSK_S_060	Caching - sum			20
SCR_TSK_S_071	Automation elements	Automatic target approach (from homed position to contact with surface) - presented in 2 cases	12	
SCR_TSK_S_072		Automatic sampling (no damage to the tool etc.) (stopped after sample is lifted above ground) - presented in 2 cases	6	
SCR_TSK_S_073		Automatic placement of the sample into the container - presented in 2 cases	12	
SCR_TSK_S_070	Automation elements - sum			30
SCR_TSK_S_080	Time of operation - from start to finish line	For each 5 min faster than max time, all samples delivered	1 per 5min faster	3
SCR_TSK_S_090	Sample handing quality (judge score according to key)	Quality of sample to cache transfer, cleanness of operations, cross-contamination of samples, presentation of core from	5	5

		deep sampling		
SCR_TSK_S_100	Excellence (judge score according to 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				100

3.2. Maintenance Task

ID	Task Element	Scored parameter	Max partial score [pts]	Max task score [pts]
SCR_TSK_M_010	Change state of indicated elements (standard)	State changed to desired	4 per switch	8
SCR_TSK_M_020	Change state of indicated elements (challenging)	State changed to desired	7 per switch	14
SCR_TSK_M_030	Plug into the measurement socket / connect with terminals	Insertion visually confirmed by judge	5	5
SCR_TSK_M_040	Voltage measurement	with 0.5V accuracy	1	1
SCR_TSK_M_050	Change state of covered the switch	Uncover part of the control panel - covering material secured and not destroyed	9	9
SCR_TSK_M_060		Change state of the uncovered switch	4	4
SCR_TSK_M_070	Adjust knob value	Knob setting adjusted within tolerance	Max error of 1 unit = 9, er	9

			ror of 2 units = 5,	
SCR_TSK_M_080	Grasp and plug high power plug to the socket	Plug inserted to the socket with at least 80% connector contact	10	10
SCR_TSK_M_090	Quality of operation	Collisions with infrastructure,	5	5
SCR_TSK_M_101	Automation (showing automation of other crucial elements)	Panel elements recognition and labeling	5	
SCR_TSK_M_102		Panel elements positions	5	
SCR_TSK_M_103		Panel elements tracking	5	
SCR_TSK_M_104		Automatic approach to panel element (to the event of contact) - presented in at least two cases	10	
SCR_TSK_M_105		Automatic operation of control element state change - presented on at least two elements	10	
SCR_TSK_M_100	Automation - SUM			35
Maintenance Task - SUM				100

3.3. 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	5	5

		efficiency)		
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		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 cache is in the manipulator workspace	10 per cache	30
SCR_TSK_C_080		Automatic placement of the cache to the cache container	5 per cache	15
Collection Task - SUM				100

3.4. 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, 10 – (3 * round(d))) where d is a result of distance measurement of the rover from way-point taken on team request; final score for a way-point is an average from all started attempts.	10 for each way-point	40
SCR_TSK_T_020	'X' way-point reached	MAX(0, 15 – (4 * round(d))) where d is a result of distance measurement of the rover from way-point taken on team request	15	15

SCR_TSK_T_030	Autonomous traverse bonus	Reaching waypoints one and two	10	10
SCR_TSK_T_040		Reaching third waypoint	10	10
SCR_TSK_T_050		Reaching forth waypoint	10	10
SCR_TSK_T_060	Support elements	No use of provided height map	5	5
SCR_TSK_T_070		No use of artificial landmarks	5	5
SCR_TSK_T_080	Data presentation	Position projection, mapping, plan presentation, error visualisation	5	5
Traverse Task - SUM				100

3.5. 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	3	3
SCR_TSK_P_020	Presentation of engineering approach	Design methodologies, used frameworks and tools	3	3
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	Major issues and challenges during project and their resolutions (from	5	5

	solutions	different domains e.g. technical, management, financial, etc)		
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)	25	25
SCR_TSK_P_080	Presentation reception	Visual and structural quality of presentation and presentation skills	9	9
Presentation Task - SUM				70

3.6. Additional Points

ID	**Element**	**Scored parameter**	**Max partial score [pts]**	**Max task score [pts]**
SCR_TSK_A_011	Mass of the rover - rover weighted before each task during EMC check - to receive those points team must collect at least 20% of task points; For scoring purposes, kilograms will be rounded upwards.	Rover lighter than 50kg	+0.5pts for every kilogram of difference but no more than 10pts per task	
SCR_TSK_A_012		Rover heavier than 60kg	-1pts for every kilogram of difference but no more than -15pts per task	
SCR_TSK_A_010	Mass of the rover - SUM			30
Additional Points - SUM				30