OLYMPUS ROVER TRIALS 2023–24

RULES & REQUIREMENTS

UKSEDS COMPETITIONS

SUPPORTED BY

AIRBUS

UKRI Science and Technology Facilities Council

RAL Space

Contents

1 Introduction

The Olympus Rover Trials challenges student teams to design, construct and operate a rover for an analogue space mission. Students create a rover concept, trade off performance parameters and pass through a rigorous review process with panels of engineers from the space sector. The competition aims to:

1. Challenge students to perform a complex, systems engineering task of the development of a vehicle to a set of real **space mission requirements**;
2. Enable students to apply taught technical skills and learn new ones relevant to a job in the space industry in an applicable project environment;
3. Provide students with an opportunity to develop and practise other important and **transferable skills**, such as teamwork, leadership and project management;
4. Foster **interest in the activities of the space sector**, especially in space engineering and robotics.

1.1 Organisations Involved

1.1.1 UK Students for the Exploration and Development of Space (UKSEDS)

Formed in 1988 and now with over 1000 members and 27 affiliated societies located up and down the country, the UK Students for the Exploration and Development of Space (UKSEDS) is a charity run by student volunteers, for students. We support students and enthusiasts across the country by running space projects, hosting conferences and workshops, and doing outreach to inspire and educate the next generation of space enthusiasts. We run and support multiple events throughout each year, including events, workshops, competitions and conferences. Our most popular being the National Student Space Conference (NSSC), which is held annually every March.

Our sister site www.SpaceCareers.uk has done an outstanding job of matching students and recent graduates with the huge number of different careers paths in the space sector and has been hailed as “a crucial service to thousands of people across the country” by the former Prime Minister, Theresa May.

i.

1.1.2 Airbus

Airbus pioneers sustainable aerospace for a safe and united world. The Company constantly innovates to provide efficient and technologically-advanced solutions in aerospace, defence, and connected services. Airbus is the global leader for

modern and fuel-efficient airliners and associated services. Airbus is a European leader in defence and security and one of the world's leading space businesses. In helicopters, Airbus provides the most efficient civil and military rotorcraft solutions and services worldwide. Airbus Defence and Space is the UK's largest space company with turnover in excess of £1 billion and is the third largest aerospace and defence employer in the UK with more than 3,500 highly skilled employees. Airbus Defence and Space makes up over 70 per cent of the UK's space industry, providing a vital national industrial capability; and leverages its capability as a system prime to develop SME supply chains, maintain links with UK and global academic institutions, and bring forward the next generation of talent for a future STEM-based workforce both in the space sector and beyond.

ii.1.1.3 RAL Space

RAL Space is the UK's national laboratory advancing the understanding of space and our environment for the benefit of all. They carry out world-class science research and technology development with significant involvement in more than 210 instruments on missions to date. RAL Space works with UK and overseas agencies, universities and industrial companies on space and ground-based space projects. Our unique position between industry and academia enables us to strengthen the UK space community. We do this through scientific research, technology development, providing cutting edge facilities, strategic advice to external partners.

RAL Space has over 60 years of experience and expertise in space programmes. Our experts work throughout the lifecycle of space missions: leading concept studies for future missions; developing bespoke innovative scientific instrumentation; providing space test and ground-based facilities; operating ground-stations; processing and analysing data.

We employ more than 335 highly skilled staff in the heart of the Harwell Space Cluster and at the Chilbolton Observatory. We provide a graduate training programme, apprenticeships and placement student opportunities, as well opportunities for engineers, scientists and technicians throughout their careers.

1.2 Team Structure

The competition is open to UKSEDS members and students from UK schools and universities, as well as any students on Internships or people on Grad Schemes. It has been designed to be carried out as a group project towards a degree, or by

a UKSEDS branch team. If you do not fit in either of these categories, please email rovers@ukseds.org to enquire about eligibility.

There is a limit of **10 team members per team**. The names of the team members must be provided to UKSEDS in a team roster and should be kept up to date if there are any changes. There may be an additional limit on the number of attendees to the competition event. Additionally, the work should be demonstrable as being done by the team members, and not academic supervisors or other advisers.

1.3 This Document

This document is formatted in the style of a European Space Agency (ESA) Invitation to Tender (ITT). ESA publishes ITTs when it wants companies to bid for contracts.

It is organised as follows:

2. A brief competition overview discussing the mission background and scenario
3. A comprehensive State of Work (SoW) - a description of the activities and deliverables during the competition
4. A series of Appendices:
    a. Competition Rules - discussing team structure, funding opportunities and the competition format
    b. Technical Specification - a full set of requirements and specifications needed to design the rover
    c. Document Requirements Specification - requirements for the documents delivered by teams in the competition

2 Competition Overview

2.1 Mission Background and Scenario

A new space race has begun. With the commercialisation of Low Earth Orbit (LEO) access the great space agencies of the world have shifted their sights towards resuming the efforts of human exploration that were paused some 50 years ago. NASA and ESA are leading these efforts with the Artemis missions, which will return humans to the surface of the Moon and pave the way for future crewed missions to Mars.

But setting foot on the surface of another world once again is only the beginning, to stay will require a concerted effort to construct a permanent outpost complete with power generation, life support, and scientific facilities. None of this can be accomplished without a capable and coordinated logistics system.

Once cargo such as base construction materials, solar panels, fuel and oxygen tanks, communication and scientific equipment have been delivered to the surface of a planet, they must be transported from their landing site to where they are needed. An Integrated Logistics Rover (ILR) is seen as being a leading solution to this problem. Such a rover would be capable of transporting cargo up to a defined volume and mass around an unprepared planetary environment.

Your team is being asked to take part in a study for an ILR mission called X, which is being planned for operations on the Martian surface. The rover is expected to operate from a logistics depot, where it shall:

- Collect and transport cargo delivered from orbit by a Large Logistics Lander (L3) to sites within 5 km of the Logistics Depot.
- Return spent or produced cargo from these sites back to the depot for repair, reuse, or delivery back to orbit.

The rover must be capable of performing these operations remotely, as these operations must be performed before the arrival of crewed missions on the surface.

2.2 Mission Tasks

The challenge is to design, build and operate an Integrated Logistics Rover (ILR) which will collect and deliver a variety of cargo components on an analogue Martian surface. The primary mission objective for the competition is to collect and transport cargo from the Logistics Depot to a remote site and deliver the cargo. The rover will then return with a different cargo item collected from the remote site back to the depot. This consists of four phases, which may be repeated across the sites of interest so that multiple items can be collected:

1. Traversing to the cargo area: the rover will need to collect a standardised cargo item from the depot, traverse to the remote site up and down slopes and around rocks, to one of many cargo locations.
2. Delivering cargo items: the rover must deliver the cargo item to a dedicated cargo slot at the remote site.
3. Collect cargo items: the rover should then collect a non-standard cargo item from the remote site.
4. Return to the depot: the rover must then return with the cargo item to the depot and place the cargo in the slot.

Further details on how these tasks are marked will be contained in the Rules and Scoring Criteria sections of the Appendix. The competition itself consists of two components; an attempt to complete the objectives, and a vibration test on a vibration table.

3 Description of Work

For the project, the competing companies are expected to follow an accelerated variation of the ESA project lifecycle. This shall be split into four stages: **Preliminary Definition, Detailed Definition, Qualification & Production and Utilisation**. Each of these stages shall be completed upon the deliverance of a document that shall be reviewed by the customer and feedback provided upon review.

3.1 Preliminary Definition

The main deliverable at the end of Preliminary Definition Stage is the **Preliminary Design Review (PDR).** This is normally held at the end of Phase B of the project process defined in the space project management standard (ECSS-M-ST-10C

Rev. 1). The following excerpt is taken directly from this document, and describes what is expected in a PDR.
The deliverable expected at this stage is the **Preliminary Design Review (PDR)**. The primary objectives of the PDR are:

- Verification of the preliminary design of the selected concept and technical solutions against project and system requirements.
- Release of management, engineering and product assurance plans
- Release of product tree, work breakdown structure and specification tree
- Release of the verification plan (including model philosophy)

It is therefore expected that you present methodology resembling this format. The primary deliverables for the project at this stage shall be:

- Project Management
    - Assigned Roles
    - Preliminary Work Breakdown Structure
    - Preliminary Timeline
    - Preliminary Budget
    - Project Risks and Mitigation
- Preliminary Concept
    - Derivation of more requirements from the initial ones provided
    - Preliminary system architecture
    - Functional definition of the subsystems
    - Evidence of trade-offs and explanation of decisions made

3.2 Detailed Definition

The main deliverable at the end of the Detailed Definition Phase is the **Critical Design Review (CDR)**. This is a major milestone in the development of a space mission, and it is similarly an important obstacle in this competition. It is normally carried out at the end of Phase C (detailed definition) of a project, and according to ECSS-M-ST-10C Rev. 1 should address the following objectives:
The primary objectives of the CDR are:

- Assess the qualification and validation status of the critical processes and their readiness for deployment for phase D
- Confirm compatibility with external interfaces
- Release the final rover design
- Release assembly, integration and test planning
- Release flight hardware/software manufacturing, assembly and testing

The expected deliverables for the CDR are:

- Project Management
    - Assigned Roles
    - Complete Schedule
    - Complete Budget
    - Project Risks and Mitigation
    - Initial Test Procedure
- Critical Design
    - Complete description of System design
    - Complete description of Electronic design
    - Complete description of Mechanical design
    - Complete description of Software design
- Requirements Verification
    - Indicate new requirements and/or pivots from the PDR.
    - Indicate how **all** requirements (both in this document and the PDR) have been met by the design

The Critical Design Review should be to a level of detail where the proposed rover design is ready to build in its entirety.

3.3 Qualification & Production

Upon completion of the CDR teams shall be able to begin the build of their rovers. Once completed, teams shall be required to demonstrate the key features of their rover to demonstrate that they are able to safely perform the tasks required of them on competition day. For the TRR the teams shall submit videos of their rover to confirm the following:

- Demonstration of functioning kill switch.
- Demonstration of rover under user control, moving on sand or another granular surface.
- Demonstration of rover's ability to connect to the vibration table (demonstrate that the rover can be connected to the vibration plate with M5 bolts).
- Visual demonstration of batteries and wires being protected and not exposed.
- Demonstration of the end effector system (movement of the mechanism).

The TRR shall not be graded but be based on a "pass" or "fail" system. In order to be guaranteed to be deployed in the Mars Yard, the rover must "pass" the TRR. If

the rover upon review is considered to pose a threat to safety it may not be permitted to participate on the competition day.

Appendix A: Acronyms

Table A-1: Table of Acronyms

Acronym	Description
ASD	Acceleration Spectral Density
CAE	Computer Aided Engineering
CDR	Critical Design Review
ECSS	European Cooperation for Space Standardisation
ITT	Invitation To Tender
ORT	Olympus Rover Trials
PDR	Preliminary Design Review
TRR	Test Readiness Review
UKSEDS	UK Students for the Exploration and Development of Space

Appendix B: Useful Reference Documents

Table B-1: Table of Useful Reference Sources

No.	Document	Description
1	ECSS-M-ST-10C Rev. 1	**Space project management - Project planning and implementation**
2	ECSS-S-ST-00-01C	**Glossary of Terms - A list of commonly used terms in ECSS documents**

Appendix C: Competition Rules

Competition Authority

The ORT rules are issued by UKSEDS annually. Official announcements by UKSEDS should be considered to have the same validity as these rules. UKSEDS reserve the right to alter the rules, clarify ambiguities and disqualify teams at any point from taking part in the competition, for safety reasons or otherwise. Teams that enter agree to comply with the rules, and report ambiguities or mistakes to UKSEDS at rovers@ukseds.org.

Table C-1: Competition Rules

1	**Team Eligibility**
1.1	All students enrolled in a UK School, University, Apprenticeship or Graduate Scheme are eligible to participate
1.2	Teams shall not be composed of more than 10 members at a time
2	**Plagiarism**
2.1	Teams must reference any work that is not performed by the 10 team members (support from mentors, lecturers etc.)
2.2	Teams are not permitted to reuse software or scripts that were created by previous teams
3	**Requirements Specification**
3.1	Teams shall be compliant with ALL requirements stated in Section
4	**Submission Deadlines**
4.1	Teams must submit all competition documentation within the deadlines (unless an extension has been agreed upon with reasonable notice).
5	**Funding**
5.1	Teams shall keep accurate record of their spending for the project and show proof of spend via receipts from purchase. Any misrepresentation of funds that results in teams saving money shall be considered seriously
6	**Reuse of Previous Components**

6.1	Teams may reuse COTS components from previous entries. (e.g. microcontrollers, screws etc.). COTS components that are reused must have a justification beyond "being readily available" or any equivalent wording.
6.2	Any reused COTS parts must have their market value accounted for within the team budgets. They cannot be assumed to be free. These however must be noted as being previously purchased to ensure accurate repayment by the matched funding system.
6.3	Teams may not reuse raw components or components that have been processed by previous teams from previous years (e.g. metal from chassis, complete arm assemblies.
6.4	Teams may not reuse any code or software from previous competition entries. This constitutes as plagiarism
7	**Competition Day**
7.1	Teams and participants shall adhere to all rules and regulations enforced by UKSEDS or competition day hosts and partners.

Appendix D: Competition Information & Support

D.1 Team Structure

By its nature, robotics is incredibly interdisciplinary. We recommend building a team with students from a number of disciplines. Key disciplines are mechanical engineering, electronic or electrical engineering, computer science (particularly for autonomy) and geology (understanding the properties of the surface).

Standard engineering practices are advised for creating a team structure. It is also recommended that at least one team member takes the role of systems engineer. This role will be critical in defining how different parts of the rover interface with one another.

Example Team Structure

An example Team structure is provided below. This is not considered the "best" organisation method as teams may find structures that better suit their skills.

- Project Manager
  - Team Organisation
  - Budget Allocation
  - Project Schedule
  - Document Overseeing
- Systems Engineer
  - Interfacing all the different disciplines with one another
  - Top level architecture of the rover
  - Monitoring requirements compliance
- Electronics Lead
  - Top level electronics decisions
- Electronics Engineer
- Mechanical Lead
  - Top level mechanical decisions
- Mechanical Engineer
- Software Lead
  - Top level software decisions
- Software Engineer

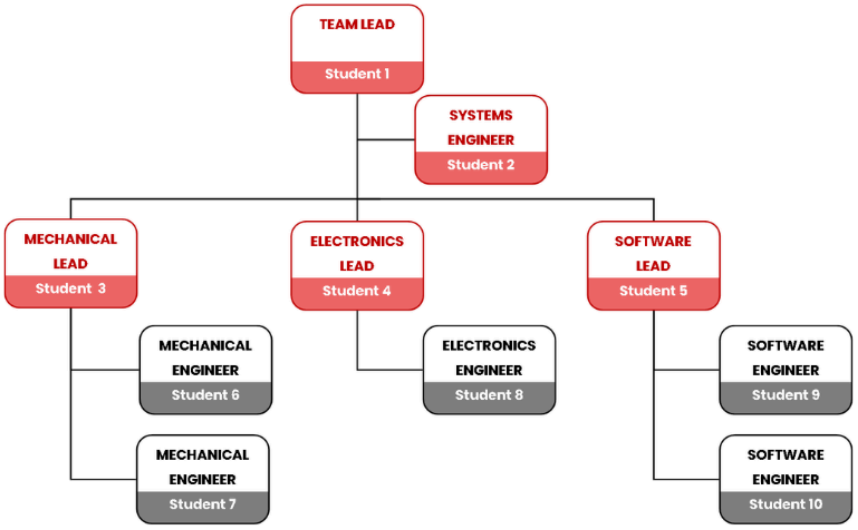

Figure D-1: Example Team Structure

Support: Finding Team Members

UKSEDS have an extensive network of contacts at branches and in departments at universities across the country and might be able to help find team members if it is proving to be tricky. Please get in touch with the team contact if you need some support in organising a team.

Support: Team Connect

Designing, building and testing a rover is a multidisciplinary and collaborative exercise. In the real world, these projects are carried out by hundreds or thousands of scientists and engineers, all over the world. If your group does not have all the expertise you think you need, please get in touch with your team contact. We may be able to find another group that has a complimentary skillset at another university for you to collaborate with.

For example:

- University 1 consists of a group of mechanical and electronic engineers, with very little experience or skills in software development
- University 2 are a group of computer science students
- UKSEDS puts university 1 in touch with university 2, who form a team together

D.2 Competition Schedule

The rover competition consists of several stages, which have been illustrated in fig. 2. A comprehensive overview of the tasks and deliverables are located in the Description of Work (section 3) and in appendix E. Each deliverable must be handed in on time to the competition organisers for a team to progress to the next stage.

Table C-1 provides a preliminary schedule for the competition, presenting the major milestones, paperwork deadlines and other events within the competition itself. Please note these dates may be subject to change, where the UKSEDS competition team shall be responsible to notify all teams if this does occur.

Table D-1: Competition Schedule

Date & Time	Activity
17/12/2023 23:59	Submit PDR
14/01/2024 08:00	PDR Feedback Released
03/03/2024 23:59	Submit CDR
08/04/2024 08:00	CDR Feedback Released
23/06/2024 23:59	Submit TRR
28/06/2024 08:00	TRR Verdict Received

D.3 Costs and Funding

There is no fee to enter the competition. Teams should source funding for the project themselves, via grants from their universities, student unions or departments or sponsorship. There are two types of financial support available through UKSEDS: a competition grant and diversity grant.

Competition Grant

Teams who pass their CDR are eligible to apply for a grant through the competition sponsors' grant pool. This grant operates on a cost-match basis. The grant will match external funding (i.e. from universities, sponsors etc.) up to **£250**, for example:

Table D-2: Example of how the competition grant is structured

Source	Amount
Department	£100
Universities' Student Union	£150
Match Funding from UKSEDS	£250
Total	**£500**

Competition grants have a rolling application deadline. Teams can only apply for funding once. If teams are ready to submit earlier in the competition phase, the application can be processed quickly and the funds reimbursed at an earlier date. Teams will receive a Google form to which they must attach a bill of materials on an excel spreadsheet and copy of receipts. The following terms and conditions are attached to this funding:

1. The grant can be applied for only after passing the CDR
2. The grant shall not exceed funding raised from other sources
3. The grant shall not exceed £250
4. The grant shall only be used for components or the construction of the rover
5. The grant will be paid in arrears after the competition day upon receiving:
    a. A completed claim form (will be distributed at a later date)
    b. A rover Bill of Materials
    c. Receipts demonstrating the spend on components or construction
    d. Evidence of matched funding

Gender Diversity Grant

Following the recent announcement of Orbex becoming title sponsor of the National Rocketry Championship, we are pleased to also announce the Orbex Gender Diversity Grant, a new funding source for teams in our Rocket, Satellite, and Rover competitions with 50%+ women or non-binary members.

If your team has 50% or more women or non-binary members taking part in the competition, and your team passes the CDR report, you will be able to apply for a £250 grant. The Grant has a rolling application deadline. Teams can only apply for funding once. The team structure can meet the criteria at the PDR, CDR or TRR

Stage. Additionally, this grant qualifies as external funding and could be listed as such for the competition match-funding (see example below).

Table D-3: Example of how the diversity grant is structured

Source	Amount
Orbex Gender Diversity Grant	£250
Match Funding from UKSEDS	£250
Total	**£500**

If you qualify for this grant, please send an email to rovers@ukseds.org. Similarly to the competition grant, teams will receive a Google form to complete. The following terms and conditions are attached to this funding:

1. The grant can be applied for only after passing the CDR
2. The team has 50% or more women or non-binary members at the PDR, CDR or TRR stages
3. The grant shall not exceed £250
4. The grant shall only be used for components or the construction of the rover
5. Representation on the competition day should reflect the diversity of your team

D.4 Test Readiness Review (TRR)

A mandatory Test Readiness Review will be conducted at least 2 weeks prior to the competition day. The rovers must clearly demonstrate the functionalities described in the requirements documents though do not necessarily have to be fully completed at this point. If the rovers fail any high priority requirements (e.g. with regard to Safety, Command & Control, Power & Locomotion), they will not be able to progress to the next stage of the competition.

D.5 Competition Day

The final part of the Mars Rover Competition is the test on the competition day. This will be held at RAL Space at Harwell Campus in Oxfordshire. The date and travel and accommodation arrangements will be released at a later date.

Prizes

Table D-4 provides a full description of the prizes available for this year's competition.

Table D-4: Full List of Prizes

Prize	Description
Best Rover	For the best rover based on the successful completion of the mission objectives (awarded to the team with the most points).
Best Outreach	For the team with the best outreach programme connected to their rover (decided by the judges). How do we mark this? Number of groups reached out to? Number of students at schools the team has reached out to?
Best Innovation Award	To the team with the best innovative engineering solution (decided by the judges).
Best CDR	The highest scoring CDR shall receive this award
Automation Prize	A prize for the team with the most impressive automation capabilities will be awarded a special prize. The judges will assess this award.

D.6 Test Definition

Each team will have one attempt to complete the objective. The attempt may involve more than one traversal between the logistics depot and a cargo area. Subsequently, the rover will be tested on the vibration testbed. An area will be provided for teams to prepare their rovers, carry out any repairs, and otherwise spend time. The following sections include some information on key aspects of the testing process.

Competition Trials Area

The test runs shall be carried out in RAL Space's Yard. This is a predominantly soil-based terrain with a few rocks scattered. It is also predominantly flat though the nature of the surface is uneven and this shall have to be considered in the design. The teams shall be set up to the side

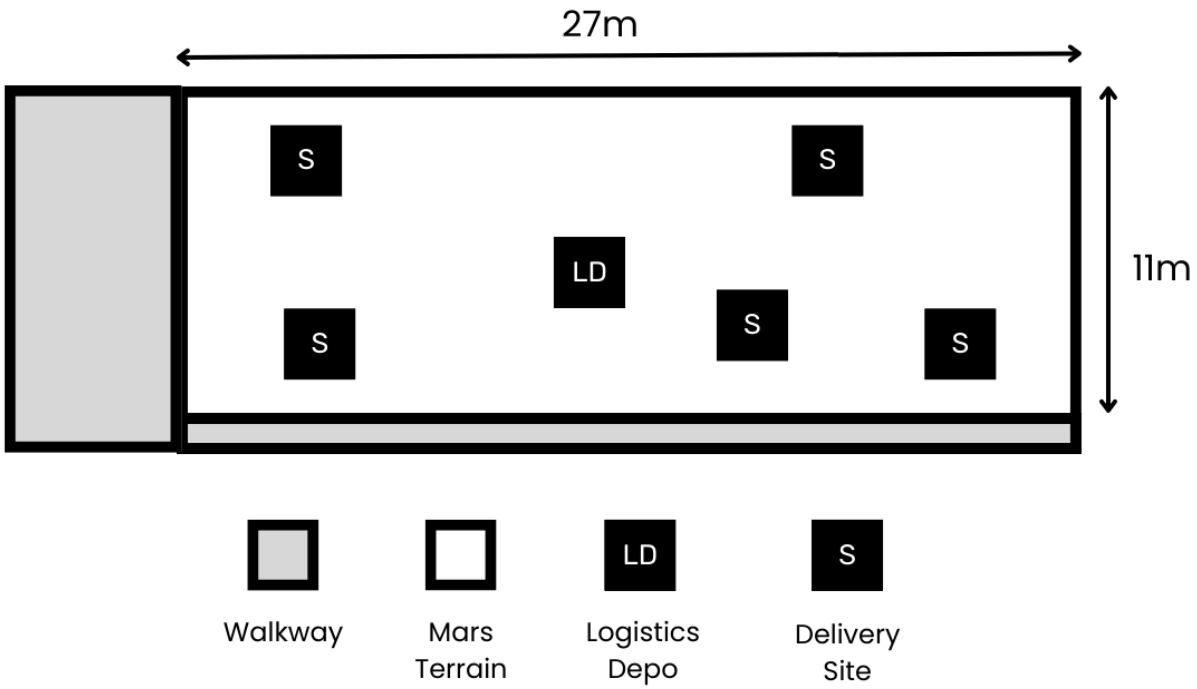

Figure D-2: RAL Space Yard - Architectural Schematic (preliminary Logistics Depo and cargo site locations demonstrated - these may change on the day)

Figure D-3: RAl Space Yard surface conditions

Test Format

There is a 30-minute time limit for each test run. Each team will make one or more traverses from the logistics depo to a cargo area, where they will collect and then return with their chosen cargo item. A single rover team will be on the Mars Yard surface at any one time. Teams will be able to control their rover from a control area. Teams will have line-of-sight view from the control area, though the cargo areas may be up to 30 metres away from the control room. It is therefore advised to have an adequate camera(s) and/or sensor(s) for the mission.

There will be a separate preparation area near to the Mars Yard. Teams will need to navigate the rover from the logistics depo position to the cargo areas and back to the depot. No charging will be allowed for the rover during the test.

Once a rover has performed its test run, it will be mounted on the vibration test bench, as shown in Figure C-5. The vibration specification for the rover is described in appendix D.2, and mechanical specification in appendix D.3.

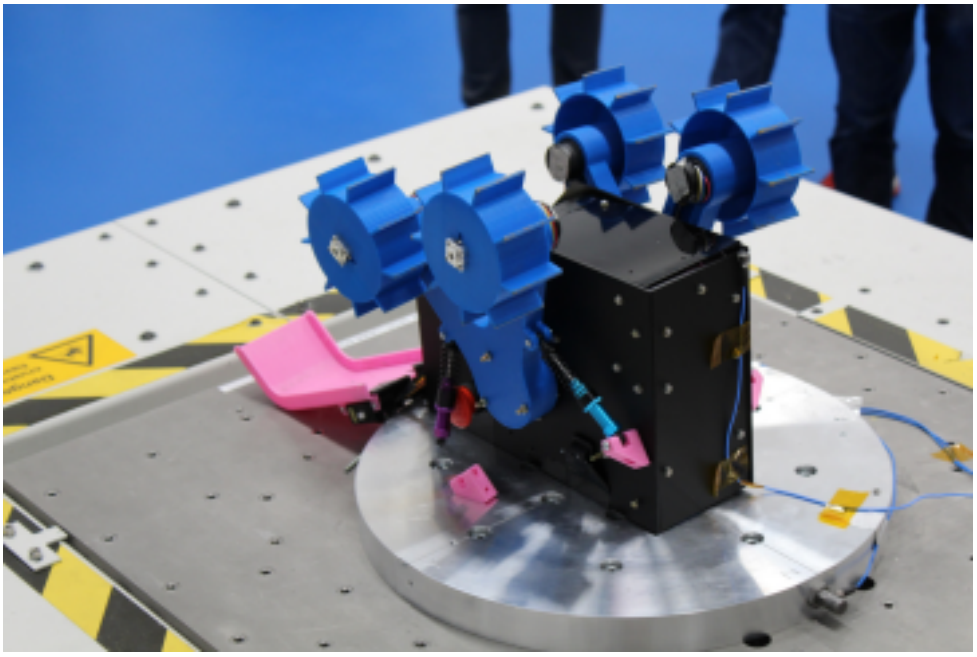

Figure D-4: Vibration Testbench Setup

Test Restart or Repairs

During the test, a team may wish to restart or make emergency repairs to their rover. These will be allowed, but the 30-minute clock will not be paused or reset. If a repair is made, the rover will restart from the logistics depot. If the rover run is reset one or more times, the attempt which accumulates the most points will be counted.

There will be a competition judge on the sand to return the rover to the starting position if required.

Test Cargo Collection

Multiple items of 'standard' cargo will be distributed around the Logistics Depo. An updated version of the Mars Yard map (fig. 3) and (fig. 4) identifies the current understanding of where the cargo site will be selected during the competition. This location may change closer to the day due to RAL's own use of the Mars Yard, with an update provided in such an event. The properties of the cargo are described in appendix D.4 (page 20).

Each piece of 'standard' cargo will have at least one interface either in the vertical or horizontal position on the ground. Designated locations to drop the 'standard cargo' will be located at each Delivery Site.

A variety of 'non-standard' cargo (one item per location) will be located at each Delivery Site to be returned to the Logistics Depo. These could be an antenna, a solar panel or propellant tank as an example. Again at least one of the mentioned interfaces will be present on each item.

Presentation

Teams shall present their work throughout the competition for 10-15 minutes, focusing on the method and process for deciding on the final payload design, what could be improved and what the next steps will be. Furthermore, we advise teams to aim for a slide a minute to stay concise and engaging to the audience.

D.7 Scoring

Vibration

A team can earn a maximum of 1000 points for vibration if the rover is operational, from which points will be subtracted depending on the level of damage as described in the table below. Negative marking is at the judge's discretion. Negative points will be given for the following types of damage:

Minor No impact on performance (i.e. loss of fasteners of non-mission critical part)	-50
Loss of one function (i.e. driving, communication, cargo collection abilities)	-250
Loss of multiple functions (i.e. at least 2 of driving, communication, cargo collection abilities)	-500
Catastrophic Loss of mission (i.e. rover non operational)	-1000

Test Run

A team gets a maximum of 2000 points for the test run. Each team has the opportunity to perform cargo deliveries and collections to and from up to 5 remote sites. Teams may deliver one standard cargo item to each site, and may collect one non-standard cargo item from that site for their return journey to the depot. Each site will have a number of available raw points, scaled based on the distance between the depot and site, and on the assessed difficulty of the terrain between the depot and site. The available raw points for each site are then combined and a scaling factor applied to get the total number of scaled points.

available points = distance x difficulty x scaling factor

The total number of available points will be scaled so that up to 2000 points can be collected for completing all delivery and retrieval tasks. Each leg of a site run (i.e. depot to site or site to depot) will be scored separately, as follows:

Table D-5: Ratio of points available for each site

Scoring component	Outward journey (depot to site)	Return journey (site to depot)
Traverse distance (how close the rover gets to the target site)	1/5 available points	1/5 available points
Cargo delivered within 50 cm of target slot	1/10 available points	1/5 available points
Cargo delivered inside target slot	1/10 available points	1/5 available points

The traverse distance will be calculated as the minimum achieved linear distance from the target position (site or depot). The outward leg of the journey is considered complete when the rover gets within 50 cm of the target. If the rover fails to reach this goal the return leg will not score points, e.g:

> *Team A only got to within 1.5 m of the cargo site on their outward journey, so their return journey will not accumulate any traverse distance points.*
>
> *Team B got to within 50 cm of the cargo site but did not carry a cargo item. They will get the traverse points for the outward journey, but not the cargo points. They can still get traverse and cargo points on their return journey as they reached the target threshold.*

Note that the number of cargo points available on the outward journey is lower than that available on the return journey. This is because the cargo items on the outward journey are standardised and will be easier to carry than those on the return journey.

An example scoring spreadsheet, with example distances and difficulties, will be released before the CDR submission deadline

Power Consumption

The total power consumption of each rover will also be measured at the end of each test run. The battery will be recharged to full, providing a mAh consumption for the moving time on the sand. This will be converted into an average power consumption.

The overall power efficiency score will be calculated as follows:

Efficiency score = (9000 - mass (kg)*time taken (seconds))/5

Presentation

The list below provides the key points to focus on when presenting to the audience on the challenge day:

- Quality of presentation deck
- Content of the presentation (two categories to score)
    - Evolution of the project
    - The main challenges faced
- Performance of the presenter/s

Appendix E: Technical Specification

The technical specification given here contains all the requirements that must be met by a team to progress through both the PDR and CDR, and to progress to the competition event.

E.1 Rover Requirements

Table E-1: Structure and Mechanics

#	Requirement	Description
1.1	Mass	The integrated rover shall have a combined mass of no more than 5kg.
1.2	Volume	The rover shall be limited to a boxed volume envelope of 0.03 cubic metres. There are no specific dimension limits.
1.3	Vibration Environment	The rover shall be designed to survive the launch vibration environment as specified in appendix D.2. Note on use of adapter plates: Simple spring adapter plates typically lead to low resonant frequencies which would cause large increases in the loads experienced by the rover and as such are not recommended. Complex designs, which would be allowed for space use, are likely to be cost prohibitive. The mass of any adapter plates will be included in the calculation of requirement #1.1.
1.4	Vibration Test Attachment Mechanism	The rover shall be attached to the vibration system with the interface described in appendix D.3.
1.5	Static Stability	The integrated rover and sample collection system shall be statically stable in all directions to an angle of at least 30 degrees.
1.6	Cargo Collection	The cargo must be held or stowed on-board the rover, off the ground, during the delivery journey.

Table E-2: Power and Propulsion

#	Requirement	Description
2.1	Atmosphere	In fitting with the Mars setting of the competition, the Rover shall use a form of locomotion that does not require a significant atmosphere (i.e. no aircraft).
2.2	Surface	The rover shall be able to traverse an unknown surface of soil and rocks (a description of material conditions is available in appendix C). Rock dimensions range from a vertical height of between 5 to 40 cm, with a nominal diameter range of 5 to 30 cm. The rock distribution should be considered random. The maximum incline of the slope is approximately 15 degrees.
2.3	Travel Distance	The expected distance of travel that the rover will have to cover during the test is 60 m total. Adding a safety margin to this value is recommended.
2.4	Time on Surface	The rover must have sufficient power to enable 30 minutes of on-sand operations.
2.5	Power Efficiency	The power used by the rover over the duration of the on-sand time will be tested to determine the overall power efficiency of the rover.

Table E-3: Command and Control

#	Requirement	Description
3.1	Primary communication	Communication between the operating base and the rover shall be wireless (refer to the range in the test pit specification). No time delay is added to the communication system.
3.2	Backup communication	An alternative communications capability shall be included. This may be wired (e.g. Ethernet) and will only be used if unpredictable external factors influence the testing (such as interference). An Ethernet cable will be

		available for use on the day.
3.3	Legality	All wireless communications must use UK legal frequencies, and should be used responsibly.
3.4	Equipment placement	RF Equipment may be placed at the landing site (location of the rover start).
3.5	Light of sight and sensing	The teams shall not have line of sight with their rover during the challenge. The team shall be able to operate the rover using its onboard navigation systems only

Table E-4: Safety

#	Requirement	Description
4.1	Live Voltage	No exposed point or area of vehicle shall carry a live voltage > 12V at any point during operation for the rover.
4.2	Battery	The vehicle's batteries shall be protected from the following conditions - over voltage, under voltage, over current, over temperature, short circuit and reverse connection. Lead Acid batteries are not allowed. The batteries shall be removable. Battery good practice shall be followed (check out the Resources page of the competition website). In the case of LiPo batteries, charge bags and a CE marked LiPo charger shall be used.
4.3	Kill Switch	The rover shall have an external and easily accessible manual hardware kill switch that isolates battery power from the rest of the rover.
4.4	Declaration of Autonomy	Rovers with autonomous capabilities shall be highlighted to the judges to ensure that sufficient safety measures are in place.
4.5	Locomotion Design	Motors & motor connections must be protected from the environment to reduce the risk of exposed wires in

		the event of a collision.

E.2 Vibration Specification

The rovers should be built to withstand a vibration test on a shaker table, as with any qualified spacecraft hardware. Vibration tables are used to simulate the conditions of a rocket launch and a propulsive landing on Mars. Teams shall build their rovers to withstand the mission vibration environment described here. It is recommended that teams take into account both the mechanical and electrical/electronic problems associated with vibration.

Table E-5: High Sine Test

Frequency range	Amplitude	Sweep
5 – 7.7 Hz	25mm	2 octave/min
7.7 – 100 Hz	3g	2 octave/min

Table E-6: Random Test 60 seconds

Frequency	Amplitude Spectral Density g^2/Hz
20 - 80 Hz	+6 dB/octave
80 - 500 Hz	0.025
500 – 2000 Hz	-6 dB/octave
Overall	**4.5 G_{RMS}**

E.3 Mechanical Interface Specification

To attach to the vibration testbed at RAL Space the rover must have an appropriate mounting mechanism. If this requirement is not fulfilled, the rover will not be attached to the vibration table, and the rover will not be able to score points for the vibration test.
The rover must be attached to the RAL Space mechanical vibration interface plate with M5 threaded holes. It must be mounted directly, without any additional

components that do not exist on the rover during nominal use. The engineering drawing is shown in fig. E-1. There shall be a minimum of three attachment points. The rover will be accelerated in only one lateral axis (i.e. in the plane of the table). The teams are free to choose which lateral axis in which the rover will be vibrated, and design accordingly. When attached to the vibration bench the rover shall not touch anything apart from the interface plate.

Note that holes identified as "Shaker attachment holes" in fig. E-1 are not available for use by teams when attaching the rover to the interface place.

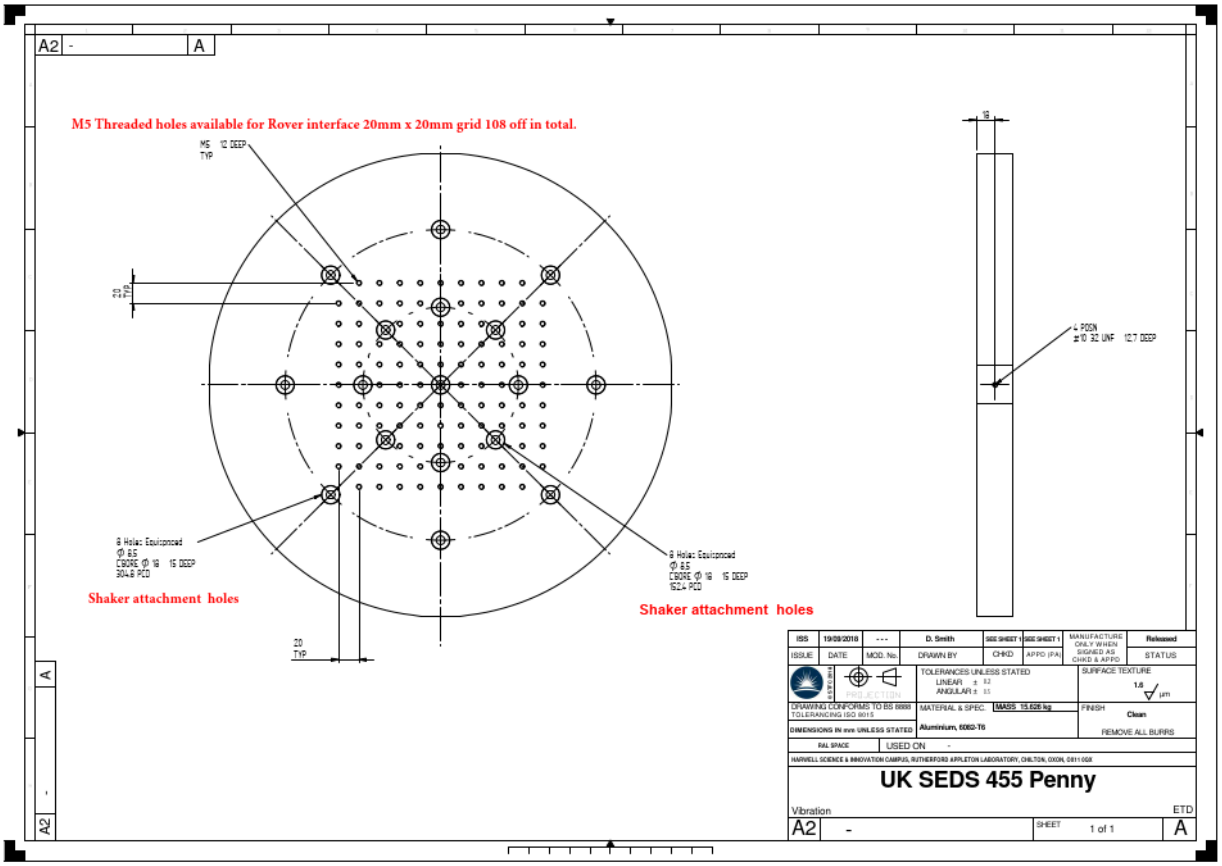

Figure E-1: RAL Space Vibration interface plate

E.4 **Cargo Interface Specification**

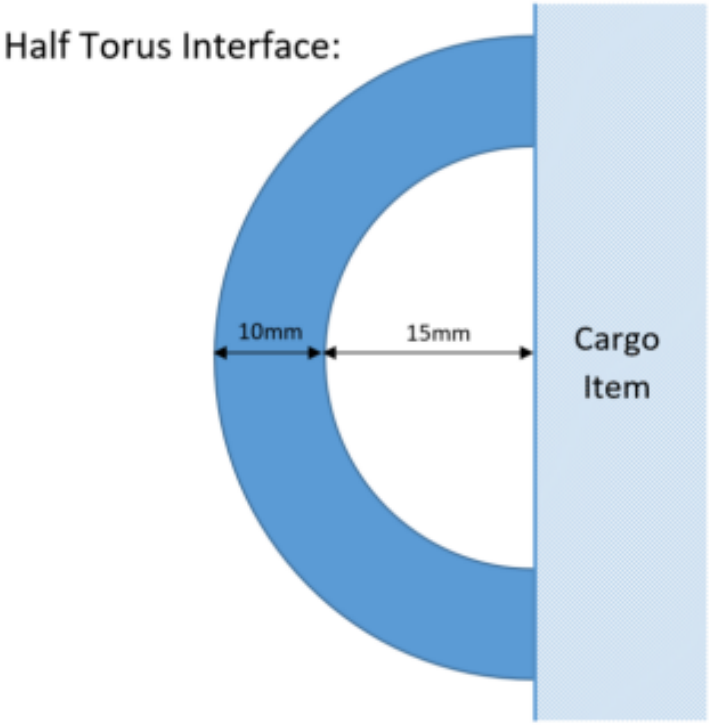

Figure E-2: The Half-torus cargo interface

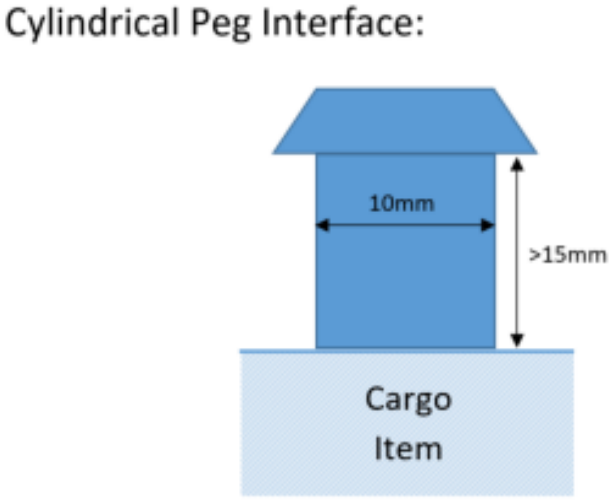

Figure E-3: The Cylindrical Peg cargo interface

NOTE: at least one interface will be present on any cargo item, though the orientation of the interface may vary prior to collection. The mass of each payload shall not exceed 120g

Appendix F: Outreach Award

One of the most important parts of our roles in this industry is to inspire future generations to look at STEM areas for career opportunities. Therefore, we want to encourage teams to perform outreach through their entry into the competition. To win the outreach prize this year, there are two major ways of scoring points; **social media outreach** and **direct outreach** by visiting schools and other groups to talk about STEM.

Social Media Outreach

To be involved in Social Media Outreach, teams shall create a **rover-specific** public Instagram and/or Youtube account for their rover and share the link of the page to their ORT Point of Contact (If the team already have a rover specific account they can use this as well). Teams can then choose to create posts of their work for the rover and/or any outreach they have performed at schools (if consent from the school and any relevant parties has been granted).
Teams shall not be marked based on the number of likes and/or views of their posts. They shall be scored based on the quality and consistency of their posts and/or videos.

Direct Outreach

NOTE: Before performing any outreach activities, please speak to your university outreach/EDI teams to ensure that they can help support you. Some universities may already have rules in place regarding outreach.
Direct reach is the best way for us to inspire future generations to find interest in STEM. Here teams shall be judged on the total number of hours they spend participating in STEM outreach for schools. Each outreach activity shall be recorded with suitable information.

How to record an event

To record an event you shall need to create a STEM UK account and register as a STEM UK Ambassador. Once done you shall need to apply for a Disclosure & Barring Service (DBS) check. Most schools require STEM volunteers to have completed this before they attend schools. This process can take two weeks and shall require a short reference. This likely would be best provided by your university mentor. Once your account is completed, you can complete the introduction information on how to attend and record a volunteering event.

What counts

Any outreach-related activities can count toward your team's score. This can be presentations, tutorials or anything else. Bonus points can be awarded if the work done is related to your Mars Rover project. The number of students reached out to however shall not impact the scoring. This is because smaller events can also offer a lot of benefits to students and provide more educational benefits than just lectures. The uniqueness of the outreach activities shall also play a factor in the scoring.

END OF DOCUMENT

