

# University Rover Challenge 2023 – Requirements and Guidelines

The Mars Society's University Rover Challenge challenges students to build remotely operated rovers that can accomplish a variety of tasks that might one day assist astronauts working on the surface of Mars. Rovers will compete in four missions: 1) a Science Mission to investigate a site for the presence of life; 2) a Delivery Mission to deliver a variety of objects to astronauts in the field across rugged terrain; 3) an Equipment Servicing Mission to perform dexterous operations on a mock lander using a robotic arm; and 4) an Autonomous Navigation Mission to autonomously travel to a series of locations. For 2023 a drone (aerial vehicle) may be used instead of the rover in the Autonomous Navigation Mission, but is not required.

The 2023 University Rover Challenge will be held May 31 – June 3, 2023 at the Mars Society's Mars Desert Research Station (MDRS) near Hanksville, Utah, USA. The competition is open to both graduate and undergraduate students, although teams are permitted to include secondary (high school) students.

Any issues not covered by these published rule sets will be addressed on a case-by-case basis by the University Rover Challenge (URC) Director. Please consult the Questions and Answers (Q&A) portion of the URC web site (<http://urc.marssociety.org>) for updates. All matters addressed in the Q&A are applicable to the requirements and guidelines.

## 1. Competition Missions

- 1.a. The rover shall be judged in the four competition missions outlined below and also on the System Acceptance Review (SAR – described in section 2.b.iii).
  - 1.a.i. Each event and the SAR shall be worth 100 points, for a total of 500 points. Penalties for overweight rovers, interventions, and other penalties are additive: e.g. penalties of 10% and 20% would result in a score of 70% of the points earned. Missions are scored independently and it is not possible to score less than zero on a mission.
  - 1.a.ii. From the time teams are given access to their command station, they shall be able to set up all necessary systems, including all communications systems, and be **ready to compete in no more than 15 minutes**. Teams shall be able to fully disassemble all equipment in no more than 10 minutes at the end of the event, and may be asked to switch off radio equipment immediately.
  - 1.a.iii. For the four competition events, the rover is not required to be in the same configuration so modular pieces can be swapped between missions. On days that teams compete in the Science and Extreme Delivery Missions, teams will only compete in one Mission. Teams may be required to begin the Autonomous Navigation Mission as soon as 10 minutes after the completion of the Equipment Servicing Mission, operating from the same control station on an adjacent course.
  - 1.a.iv. **Teams do not need to return to the start gate, or collect any deployed items (radio repeaters, cameras, tools, etc) before the end of time for any of the missions.** However, they must be collected immediately after competing.
  - 1.a.v. The rover will be accessible throughout the competition and modifications can be made at any point.

## 1.b. Science Mission

The goal is to conduct in-situ analysis, including life-detection testing of samples to determine which would be the best to be cached for further analysis given a limited cache volume.

- 1.b.i. Teams will be given a field briefing by judges and will be tasked with investigating multiple sites of mineralogical and biological interest within a 0.5 km radius of the start gate. Teams will be given between 20 and 35 minutes to collect data with the rover.
- 1.b.ii. At each sample location the rover will need to determine the absence or presence of life. The rover may use cameras or other sensors to investigate the area, and may collect a small amount of regolith/soil for analysis by instrumentation/assays on-board the rover. Samples must be analyzed by the rover in-situ, and may not be brought back to the team for investigation or laboratory analysis. **The rover must have a life detection capability instrument or assay** of the team's choosing. All instruments/assays must be onboard the rover.
- 1.b.iii. One regolith/soil sample of the team's choosing that represents high scientific value will need to be collected and stored on-board the rover. The sample must be between 1-10 g, and stored in a closed container that can later be opened by judges. The judges will collect the sample from the team at the end of the roving time.
- 1.b.iv. Any tests or liquid, including water, must follow a no-spill policy of being contained on the rover and not spilt on the ground. **Hazardous chemicals are not allowed.** All reagents other than water must be pre-approved prior to competition by submitting a plan of usage, transportation, and safety precautions (submission form will be posted on the URC website). Hazardous chemicals are defined by the United States Department of Transportation (US DOT); information and a link to the Hazardous Materials Table can be found at <https://www.transportation.gov/check-the-box/getting-started-with-hazmat>. Teams are encouraged to submit plans as soon as possible so you have time prior to the competition to choose new chemicals if some are not approved (judges may suggest teams find alternative assays which can be performed with less hazardous chemicals).
- 1.b.v. Teams shall submit a written Science Plan by May 21, 2023, which will be factored into the judges' evaluation and score for the Science Mission. This will expand upon the science plan submitted in the System Acceptance Review (see Section 2.b.iii). Specifications for the plan will be posted to the URC website.
- 1.b.vi. Based on the onboard analysis teams will prepare a presentation for the judges to be given after the roving time is complete (presentation may begin immediately, or a few hours later, depending on schedule). Presentation and discussion with the judges will be between 10-15 minutes. The presentation and discussion with the judges is allowed/encouraged even if the team was unsuccessful in collecting data/samples with their rover, and shall include:
  - Conclusions for each soil sample regarding the presence or absence of life.
  - Results of rover's on-board tests including data and images.
  - Meaning of data collected with respect to the geology of the site (past and present) and implications of the site being suitable for life.
  - The scientific justification and quality of the sample chosen by the team.
  - Scientific knowledge of astrobiology and Mars based on responses to judges' questions.
  - Quality and applicability of the onboard analysis and how well this supports the team's conclusions.

## **1.c. Extreme Delivery Mission**

- 1.c.i.** This will be a staged mission in which rovers shall be required to pick up and deliver objects in the field, and deliver assistance to astronauts, all while traversing a wide variety of terrain, no further than 1 km from the start gate. Teams will be given a fixed amount of time for each stage. Each stage will include multiple tasks as described below, and teams must achieve a specified minimum score within a stage and the allotted time in order to proceed to the next stage. Any time remaining at the completion of a stage is added to the allotted time of the subsequent stage, which begins immediately. Total on-course time will be between 30 and 60 minutes.
- 1.c.ii.** The natural terrain around MDRS includes soft sandy areas, rough stony areas, rock and boulder fields, vertical drops and steep slopes. Terrain will range from flat close to the starting line, to exceedingly difficult obstacles at greater distances also involving navigation challenges. Portions of this mission, particularly in later stages, will be intentionally placed beyond direct line-of-sight of the control station antenna. A script giving a general description of the individual tasks will be given to the teams prior to the competition.
- 1.c.iii.** Objects to be retrieved in the field will consist of small lightweight hand tools (e.g. screwdriver, hammer, wrench), small instruments (actual or simulated, e.g. a small box), supply containers (e.g. toolbox, gasoline can), or rocks up to 5 kg in mass. All items except the rocks will have graspable features (such as a handle) no greater than 5 cm in diameter. The maximum dimensions shall be no larger than 40 cm x 40 cm x 40 cm, but teams should expect a variety of sizes and weights.
- 1.c.iv.** The rover teams can expect a combination of any or all of the following tasks:
- A defined course or path that requires precise maneuvering of the rover
  - A defined course or path that requires the rover to traverse rugged terrain, obstacles, vertical climbs or drops
  - A search over an extended area (search area radius less than 20 m) for a geological specimen of interest (specialized geological knowledge by the operators will be necessary to identify the desired specimen, but instrumentation beyond a visual camera is not required)
  - Carry a combination of tools, instruments, or a rock specimen picked up in the field over extended distances and possibly rugged terrain.
  - Chose to carry objects individually or use a small wagon to haul multiple objects at once.
  - Interaction with astronauts or other field elements that requires precise visual and manipulator dexterity
- 1.c.v.** Some tasks may have multiple ways of solving them, or may be done in varying order. These options will offer different tradeoffs in terms of time and complexity: for example, one option might be complex or challenging but could be faster, while another might be easier and simpler but could take more time. Teams are encouraged to plan and strategize their approach to tasks and time management on the field
- 1.c.vi.** Objects shall be picked up in the field and delivered to designated locations, which may include markers or astronauts identifiable by simulated space suits. Approximate Global Navigation Satellite System (GNSS) coordinates will be provided for each pickup/delivery location, although accuracy may vary. In certain cases, specific instructions will be provided for each object in advance, and in other cases, the object(s) to be delivered will be indicated at the delivery location (e.g. on a small sign held by an astronaut).

- 1.c.vii.** Teams will be scored on their ability to pick up and deliver the correct objects to the correct locations, and how close the object is placed to the objective within the allotted time. Points may be awarded for partial completion of any particular task.

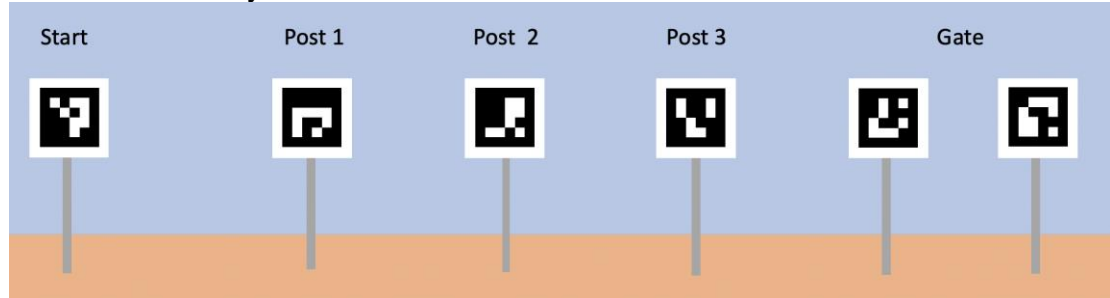
#### **1.d. Equipment Servicing Mission**

- 1.d.i.** Rovers shall be required to perform several dexterous operations on a mock-up equipment system. The rover shall have to travel up to 0.25 km across relatively flat terrain to reach the equipment. Equipment will be between 1.5m height and the ground. The equipment servicing mission will involve delivering a cached science sample to a lander and performing maintenance on the lander. It will include the following sub-tasks which may be performed in any order:
- Pick up the cache container and transport to the lander rocket. Cache will have a handle at least 10 cm long and not more than 5 cm in diameter. Cache will weigh less than 5 kg.
  - Open a drawer on the lander. Insert cache into a close-fitting space in the drawer, and close the drawer.
  - Tighten captive screw to secure drawer. Screw will be a 5/16" Allen (hex) head. Teams may build the hex driver into the rover, or pick up the screwdriver provided.
  - Undo a latch on a hinged panel of the lander and open panel.
  - Type commands on a keyboard and follow directions on computer display. Typing must be correct for full points, but spelling mistakes or repeated letters may be corrected using the backspace/delete button or ignored for partial points.
  - Operate a joystick (4-position, spring-return) to direct an antenna while observing a gauge. Gauge will be up to 20cm away from the joystick.
  - Pick up and insert a rugged USB memory stick into a USB (type A) slot on the lander.
  - Push buttons, flip switches, turn knobs.
- 1.d.ii.** Teams will receive points for every sub-task completed successfully. Teams will have 30 minutes to complete the mission.

#### **1.e. Autonomous Navigation Mission**

- 1.e.i.** Teams may be required to begin this mission as soon as 10 minutes after the completion of the Equipment Servicing Mission, operating from the same control station on an adjacent course. Total time on course will be 30 minutes, and the cumulative distance shall be no greater than 2 km.
- 1.e.ii.** **Teams may use a drone instead of their rover to complete any or all parts of this mission if they chose.** Rover and drone may not be on the course at the same time, but may trade off at any time. See section 1.f for drone requirements.
- 1.e.iii.** Rover/Drone shall be required to autonomously traverse to given GNSS-only locations, single posts, or between gates consisting of 2 posts, across easy and moderate terrain. **Teams may visit locations in any order, but must declare when they are attempting an objective out of order.** Teams will be provided with a high-accuracy coordinate at a start gate as a reference. Teams are strongly encouraged to implement differential GNSS for higher accuracy.
- 1.e.iv.** 3 locations will only have accurate GNSS coordinates without any visual markers to enable computer vision to be of assistance. Stopping within 3 m of the GNSS location will be considered successful. If a drone is used it must land within 3 m of the GNSS location.

- 1.e.v. 3 posts and a gate, will have GNSS coordinates that are within the vicinity of the posts (increasing in range from 5-20 m, approximately). For single posts, stopping/landing within 2 m of the post will be considered successful. For the gates, two posts will be placed 2 m apart. Rovers/drones must fully pass between both posts to be considered successful, and drones may be up to 2m from the ground.
- 1.e.vi. The posts and gate will have 3-sided visual markers with 20 x 20 cm faces, 0.5 – 1.5m off the ground. **Each marker will display a black and white ARUCO tag using the 4x4\_50 tag library as shown below.** Each tag will have a white border 1 cell in width, so cells are 2.5 cm across. The same tag will be displayed on each of the 3 sides so that it is visible from any direction.



- 1.e.vii. There must be an LED indicator on the back of the rover or underside of the drone, visible in bright daylight (e.g. LED array or high power LED), that will signal:
- **Red: Autonomous operation**
  - **Blue: Teleoperation (Manually driving)**
  - **Flashing Green: Successful arrival at a post or passage through a gate.**
- 1.e.viii. The rover/drone's on-board systems are required to decide when it has reached a post or passed through the gate. The rover must then stop and signal using the LED indicator. It must also display a message or signal on the operator's display for the control station judge to observe.
- 1.e.ix. Operators may at any point send a signal to the rover/drone to abort the current attempt and autonomously return to the previous post/gate or GNSS coordinate and stop within 10 m of it. **Operators may teleoperate back to the previous post or gate for a 20% penalty on the points available for that post. Teleoperation should take the most direct reasonable route back and may not go scouting for the post/gate.** There is no penalty for an autonomous return.
- 1.e.x. While stopped at any post (whether after a successful arrival, an unsuccessful arrival, or from an abort), teams may program the next or previous post and make any changes to the controls, but may not drive the rover.

## 1.f. Drone Requirements

- 1.f.i. Use of a drone is optional for the Autonomous Navigation Mission.
- 1.f.ii. Drones may be fixed or rotary wing, but no lighter-than-air vehicles are allowed as they are impractical on Mars. **Drones are exempted from the weight, size, and budget restrictions for the rover and other deployed equipment.**
- 1.f.iii. **Drones may not exceed 5 kg (11 lb). All drones in excess of 250 g (0.55 lb) must be registered with the United States Federal Aviation Administration (FAA) DroneZone and marked with the registration number.**
- 1.f.iv. **All pilots must complete the FAA TRUST (The Recreational UAS Safety Test), and carry proof of passing with them. It is a free online training course that takes about**

30 minutes, and is valid for 3 years.

- 1.f.v. Airborne vehicles must meet any and all FAA guidelines that apply to recreational drone operation. It will be the responsibility of each team to research and comply with FAA requirements. The area around MDRS is class G (uncontrolled) airspace, and drones are required to fly **below 400 feet (120m) above ground level**. Please beware that MDRS is fairly close to Capitol Reef National Park, and **drones are not permitted in National Parks**. It is also about 5 miles from the uncontrolled Hanksville airport, and drones must give way to any manned aircraft.
- 1.f.vi. **A spotter must maintain visual line of sight at all times.** The pilot will not have a direct view of the drone so someone must act as a spotter. In the event of an emergency the spotter will use radio communication with the pilot to avoid unsafe behavior of the drone, or may take direct control of the drone if a dual-pilot setup is used. The spotter may only intervene in the event of potentially unsafe operation, and may not otherwise participate in the mission.
- 1.f.vii. To simulate flight on Mars the **drone must carry a dummy (inert) mass of the same weight as the battery**. The dummy mass and battery must be easy to remove for weighing. **In the event of high winds (>24 kph/15 mph), the dummy mass requirement will be waived.**
- 1.f.viii. Drones should be able to operate in a 48 kph/30 mph wind. This requires a top speed of least 64 kph/40 mph for safe operation. Teams may fly their drone in any wind speeds they feel confident it can handle. Teams should expect highly variable wind conditions throughout URC, and are not guaranteed that they will be scheduled during a period of low wind.

## 2. Competition Rules

### 2.a. COVID

URC2023 is being planned amidst the ongoing global COVID-19 pandemic. At the time that these rules are being published it is uncertain what the state of the pandemic will be in June, 2023 for the URC2023 Finals. It is possible that the URC2023 Finals may need to be modified, or even cancelled, based on conditions at that time. Please continue to monitor the URC website (<http://urc.marssociety.org>) for updates. **Proof of full vaccination and a current booster will be required for anyone attending the URC2023 Finals.**

### 2.b. Schedule

Prospective teams will undergo a review and down-selection process, meaning that only teams who pass each milestone will be invited to compete in the field. Teams failing to qualify for the field competition are strongly encouraged to enter other Rover Challenge Series events (<http://rcs.marssociety.org/>). Specific details for each deadline (including deliverable format, submission requirements, and judges' expectations) will be posted to the URC web site (<http://urc.marssociety.org>). Judges may respond to teams with follow-up questions or requests for clarification at any of these milestones.

#### 2.b.i. Registration

Teams are required to register and declare their intent to compete **no later than Wednesday, October 26, 2022**. No significant deliverables are required for this deadline, aside from team details requested via the URC web site.

#### 2.b.ii. Preliminary Design Review

Teams are required to submit a Preliminary Design Review (PDR) document no later than Friday, December 2, 2022. The PDR document is expected to focus on the team

structure, resources, and project management plan (including a Gantt chart, initial budget, fund-raising plans, recruiting, and educational outreach). Technical details regarding the rover should include the current state of design, development, and prototyping. Judges will be assessing each team's overall likelihood of being ready in time to compete in the URC competition. Teams will be assessed on their own merits, not against other teams.

#### **2.b.iii. System Acceptance Review**

Teams are required to submit a System Acceptance Review (SAR) no later than Friday, March 3, 2023. The SAR will focus on demonstration of the capabilities and customization of the rover systems/sub-systems to perform each of the missions. This includes the overall system design, and progress to-date of the final system. The SAR will consist of both written and video components. The SAR is a competitive milestone and packages will be judged against other teams' submissions by the judges. The 36 teams who score the highest in the SAR milestone will be invited to compete in the field.

#### **2.b.iv. Field Competition**

May 31 – June 3, 2023 at the Mars Society's Mars Desert Research Station (MDRS) near Hanksville, Utah, USA.

### **2.c. Operations**

- 2.c.i.** Teams will operate their rovers in real-time from designated command and control stations. These stations will be metal trailer units (such as the back of a small moving truck provided by URC) or structures at the Mars Desert Research Station. **Visibility of the course to the operators in the control station will be blocked.** Basic power (120V, 60Hz), tables, and chairs will be provided. All of the competition events will be held in full daylight.
- 2.c.ii.** There should be radio communication line-of-sight from the command station to the rover for the Science, Equipment Servicing, and Autonomous Navigation Missions. For the Extreme Delivery mission, line of sight communication is not guaranteed for more than 50% of the course. Rovers are not expected to travel more than 1 km from the command station.
- 2.c.iii.** In the summer temperatures at MDRS can easily reach 100°F and winds frequently whip up dust. Rovers shall be able to withstand these conditions and also light rain, but will not be expected to compete in heavy rain or thunderstorms.
- 2.c.iv. Testing will not be allowed at MDRS before, during, or after URC 2023.** Teams may test in town or at other nearby sites where off-road vehicles are allowed (e.g. <https://www.blm.gov/press-release/blm-opens-5400-acres-ohv>), but must follow local regulations regarding off-road activity. Land controlled by the Bureau of Land Management, that is not specifically designated for off-road use, is strictly not allowed for any URC purposes.
- 2.c.v.** The Global Navigation Satellite System (GNSS) standard shall be the WGS 84 datum. Coordinates will be provided in latitude/longitude format (e.g. decimal degrees; degrees decimal minutes; degrees minutes seconds).

### **2.d. Team Members**

- 2.d.i.** There is no restriction on the number of team members allowed. Students must be enrolled at least half-time in a degree or high school diploma granting course. Students from multiple universities may compete on the same team. A single university may field multiple rovers and multiple teams, however there may be no overlap between



- team members and leaders, budget, donated equipment, or purchased equipment.
- 2.d.ii.** Teams are encouraged to work with advisors. Advisors should limit their involvement to academic level advising only. Nontechnical management duties, including tracking finances, registration, submission of deliverables, and communication with URC staff, fall within the duties of the students. Advisors can spectate from the field, but may not spectate from within the control station.
  - 2.d.iii.** All team members operating the rover must remain in the designated operators' area. Nobody may follow alongside the rover for the purpose of providing feedback to the operators. Members of the judging team, media, non-operator team members, and other spectators may only follow a rover at the judges' discretion. Team members following the rover may participate as runners in accordance with Section 3.d, or activate an emergency kill switch (in the event of an emergency), but may not otherwise participate in that mission.
  - 2.d.iv.** It is incumbent upon the student team leaders to ensure that their respective teams uphold the integrity of this competition.

## **2.e. Finances**

- 2.e.i.** Teams shall be required to track all finances as related to this project, and submit a final expense record no later than May 23, 2023 (if necessary, teams may submit an updated record on the first day of the URC event – May 31, 2023). Teams shall be penalized 10% of total points per day if they are late in submitting the expense report, and will be disqualified for not submitting their expense report by the end of the URC event (June 3, 2023).
- 2.e.ii.** The maximum allowable cash budget to be spent on the project is **\$22,000 US**, which shall include components for the rover, rover modules, rover power sources, rover communications equipment, and base station equipment including the antenna and transceiver, and all command and control equipment (i.e. base station computers, monitors, controllers, etc.).
- 2.e.iii.** The Director may allow certain sponsorships that are available to all teams to count as an extension of the budget limit.
- 2.e.iv.** The budget limit shall not apply to spare parts, tools, or travel expenses. Spare parts are defined as those that are replaced one-for-one in the case of damage to the original.
- 2.e.v.** If used equipment is purchased commercially the as-bought price may be used. Re-used equipment from prior competitions must be valued at either the original as-bought cost, or the current cost for a new version of the same or equivalent item.
- 2.e.vi.** Any equipment rented must be valued at purchase cost (new or used).
- 2.e.vii.** Shipping and taxes should be included in the cost since these are a standard part of the cost of any item.
- 2.e.viii.** Corporate sponsorship is encouraged. If **equipment or services** are donated to the team either free or at reduced cost, the full cost of a new or second-hand component must be used. Donations must be documented by the donor, but teams may use the cheapest rate commercially available for the same equipment or service.
- 2.e.ix.** Non-US teams have an allowable budget equivalent to \$22,000 US based on the most advantageous documented currency conversion rate between August 1, 2022 and May 23, 2023.
- 2.e.x.** Teams may be required to submit receipts as proof of budget upon request.



### 3. Rover Rules

#### 3.a. Size, Weight, Power

- 3.a.i. The rover shall be a stand-alone, off-the-grid, mobile platform. Tethered power and communications are not allowed. A single connected platform must leave the designated start gate. In the open field, the primary platform may deploy any number of smaller sub-platforms, so long as the combined master/slave sub-platforms meet all additional requirements published.
- 3.a.ii. Rovers shall be weighed by the judges during the set-up time of each mission. For weighing the rover **must fit completely within a 1.2 m x 1.2 m x 1.2m box**. Rovers may be placed in any orientation, and articulate/fold/bend to fit within the “transport crate,” but may not be disassembled to do so. This includes wheels, antenna, and any other system protruding from the rover. **Failure to fit within the specified dimensions at weigh-in will result in a 40% penalty. After weighing, rovers may unfold/expand to any size.**
- 3.a.iii. The maximum allowable mass of the rover when deployed for any competition mission is **50 kg**. The total mass of all fielded rover parts for all events is **70 kg**. For example, a modular rover may have a robotic arm and a sensor that are never on the rover at the same time. The combinations of rover plus arm and rover plus sensor must each be under 50 kg, but the total rover plus arm plus sensor must be less than 70 kg.
  - The weight limits do not include any spares or tools used to prepare or maintain the rover, but does include any items deployed by the rover such as sub-rovers, cameras, communication relays.
  - For each event in which the rover is overweight, the team shall be assessed a penalty of 5% of the points scored, per kilogram over 50.
- 3.a.iv. Rovers shall utilize power and propulsion systems that are applicable to operations on Mars. Air-breathing systems are not permitted: No power or propulsion system may ingest ambient air for the purpose of combustion or other chemical reaction that yields energy.
- 3.a.v. **All rovers shall have a “kill switch” that is readily visible and accessible on the exterior of the rover.** This switch shall immediately stop the rover’s movement and cease all power draw from batteries in the event of an emergency such as a battery fire.

#### 3.b. Communications Equipment

- 3.b.i. The rover shall be operated remotely using wireless communications with no time delay. The operators will not be able to directly view the rover or the site, and line-of-sight communications are not guaranteed for all of the missions. Normal wireless internet is not available in the field or at MDRS, and use of satellite internet is not allowed. Teams are required to power down communications equipment at the event sites while not competing, so as not to interfere with other teams.
- 3.b.ii. Wireless communication methods used by teams shall adhere to all applicable FCC (United States Federal Communications Commission) standards and regulations. Teams must submit details regarding communication devices and operator licenses (when applicable) to the URC Director no later than Friday, April 28, 2023. Team members are permitted to obtain and utilize any relevant licenses, but must document the license, applicable regulations, and devices as part of the communications documentation deadline. Teams must notify the URC Director immediately of any changes after this date.
- 3.b.iii. Both omnidirectional and directional antennae are allowed, but communications

equipment must not rely on the team's ability to watch and track the rover first hand. Steered directional antennae may use a mechanized antenna mounted outside that is controlled via an electronic signal from the command station. Signal strength, relayed GNSS, or other strategies may be used to give feedback on antenna direction, but it is not allowed to mount a camera on top of the antenna for visual feedback.

- 3.b.iv. Base station antenna height is limited to 3m**, and shall adhere to all applicable regulations. Any antennae must be documented as part of the communications documentation submitted by April 28, 2023. Antenna bases must be located within 5 meters of the team's command station, and any ropes or wires used for stability purposes only may be anchored within 10 meters of the command station. The exception to this is the use of structures at the MDRS where allowable antennae locations will be given by the judge and may be located up to 20m away from the Hab to avoid underground pipe and cables, and other structures which may block radio signals. **All teams should bring at least 25m of communications cable** to deal with this scenario.

### **3.c. Restrictions on the 900 MHz and 2.4GHz bands**

Teams must notify the organizers of the communications standards they will be using, including frequency bands and channels, by April 28, 2023.

- 3.c.i. 900 MHz frequency band (902-928 MHz):** Teams shall not use frequency bandwidths greater than 8 MHz. **Teams must also be able to operate exclusively within each of the following three sub-bands: "900-Low" (902-910 MHz), "900-Mid" (911-919 MHz), and "900-High" (920-928 MHz). The competition schedule will notify teams which sub-band may be used for each mission, and teams must be able to shift to another sub-band as required.** There is no limit on the number of 900 MHz channels a team uses, so long as they are all within the designated sub-band.
- 3.c.ii. 2.4 GHz frequency band (2.400-2.4835 GHz):** Teams shall use center frequencies that correspond to channels 1-11 of the IEEE (Institute of Electrical and Electronics Engineers) 802.11 standard for 2.4 GHz. Teams shall not use frequency bandwidths greater than 22 MHz. **The competition schedule will notify teams which channels may be used for each mission, and teams must be able to shift to other channels as required. Teams shall be limited to using no more than three channels in the 2.4 GHz band.**
- 3.c.iii. These restrictions apply to both the command station to rover communications and any local wireless network such as (but not limited to) on-board the rover between subsystems.**
- 3.c.iv.** Teams may use spread spectrum or narrowband (fixed channel allocation) within the sub-band limits as they fit.
- 3.c.v.** There will be spectrum monitoring on-site to ensure that teams are not interfering with channels outside those allotted. Teams should anticipate being within signal range of other teams operating on different 900 MHz sub-bands and different 2.4GHz channels and be able to operate their rover under these conditions. Teams must also be able to deconflict communications as specified above (the URC Director will mediate as necessary). Beyond this requirement a 0.5 km minimum separation between competition areas will be guaranteed, which will include large terrain barriers.
- 3.c.vi.** Teams are allowed and encouraged to operate in bands outside of 900 MHz and 2.4 GHz and are encouraged to obtain ham radio licenses to allow operation on less used bands., However, **in the event of interference outside of 900 MHz and 2.4 GHz, teams will not be granted additional time or special considerations.** Outside the

900MHz and 2.4GHz bands, teams are strongly encouraged to investigate spread spectrum, automatic channel switching, frequency hopping, or other interference-tolerant protocols.

### **3.d. Interventions**

If a rover suffers a critical problem during a mission that requires direct team intervention (including a loss of communication that requires the team to move the rover to reestablish communications), that intervention shall be subject to the following:

- 3.d.i. A request for an intervention can only come from the team members operating the rover, not any team members spectating in the field.** They may designate any number of team members who may go to repair or retrieve the rover (hereafter referred to as “runners”). Spectating team members may be asked to act as runners, and also rover operators may leave the command station and become runners. Spectating team members may carry tools and the command station may radio out to them to request an intervention.
- 3.d.ii. If a spectating team member intervenes with the rover without request from the operators, it counts as an emergency stop.** This is allowed such as to rescue the rover to prevent a fall or a fire. The current mission will be considered terminated although the rover may compete in other subsequent missions. All points earned in a mission to this point are preserved, and in the Science Mission teams may still conduct their field briefing.
- 3.d.iii. If a team member leaves the command station to become a runner they will not be permitted to return to the command station** to participate in operating the rover, or analysis of any data, after this point for the current mission. Runners will still be permitted to retrieve or repair the rover in future interventions.
- 3.d.iv.** Runners may fix the rover in the field without moving it, or return the rover to the command station, or return the rover to the start of that obstacle/mission as defined by the judge in the field. However, the judge may require the rover to be moved for the safety of the team members or preservation of the course.
- 3.d.v.** If the rover is returned to the command station, the operators may take part in the diagnostic and repair process, but runners and spectators may not communicate any details about the mission site to the operators.
- 3.d.vi.** When an intervention is called, the team members in the field may communicate directly with their team members operating the rover to facilitate repairs. **If teams wish to use radios for this purpose they must bring their own radios, but they may be used only during an intervention. All radio communication must be in English so judges can properly monitor conversations.**
- 3.d.vii.** Teams will be **penalized 20% of the total points in that mission for every intervention.** The mission clock will continue to run during an intervention. Multiple intervention penalties in a single mission are additive: e.g. two interventions would result in a score of 60% of points earned.