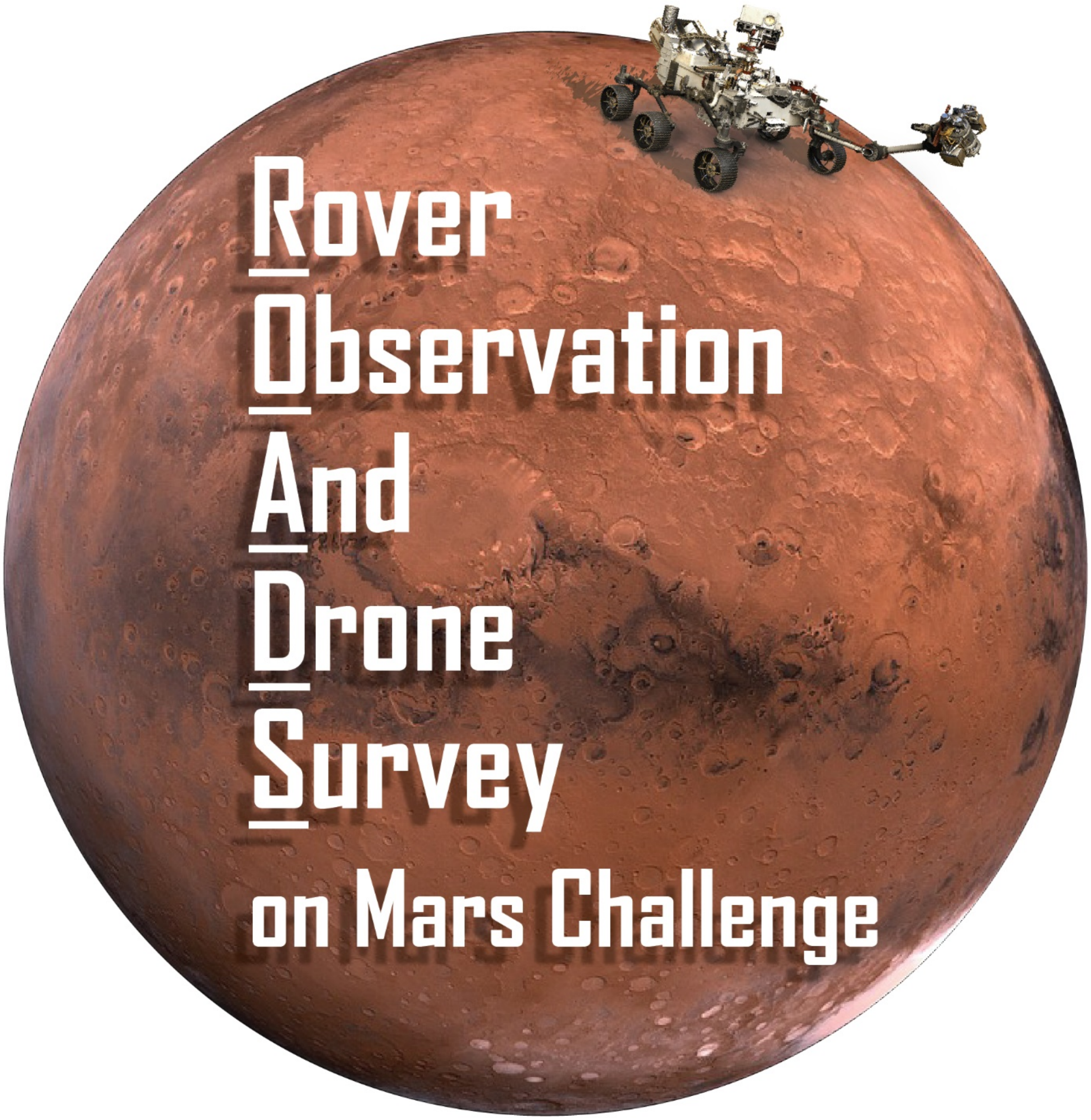

Rover Observation And Drone Survey on Mars Challenge

Official Manual

#ROADSonMars | #Mars2020

Version 1.2

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1 INTRODUCTION

1.1 About Northwest Earth and Space Sciences Pipeline

The Northwest Earth and Space Sciences Pipeline (NESSP) brings NASA science to the Northwest — from Oregon and Washington inland to Montana and the Dakotas. Funded through the NASA Science Mission Directorate, NESSP operates out of the University of Washington in Seattle where it's co-located with the Washington NASA Space Grant Consortium.

NESSP's goals are to strengthen science, technology, engineering, and math (STEM) education region-wide and to serve as a bridge into other NASA experiences for educators and students. Ultimately, we seek to increase pathways for students towards careers in STEM, particularly in underserved communities.

Our efforts, all of which support Next Generation Science Standards, comprise three types of activities:

- Outreach events in local communities, providing hands-on science exploration.
- Extended experiences, such as camps, providing immersive student opportunities.
- Teacher professional development, ranging from just one day to an entire week.

NESSP Challenges are nationwide endeavors that leverage our expertise in engaging students in technologies relevant for today's society and tomorrow's careers in order to excite and inspire the next generation of scientists and engineers.

Visit our website: nwessp.org

Contact us:

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1.2 About the ROADS Challenge

The ROADS on Mars Student Challenge gives teams of students grades 3–12 a chance to tackle a mission to Mars, following in the path of the next rover — Mars 2020. Just like NASA's rover, teams will face challenges including engineering and programming, analysis of biological signatures and geologic features, not to mention flying to Mars and successfully landing.

As of 2019, all of the major types of objects in our solar system, from planets and moons to asteroids and comets, have been at least surveyed by spacecraft — whether by flyby missions, orbiting spacecraft, or by landers. Mars, however, is the first planet to have been visited by robotic rovers. Rovers can offer close-up exploration of the surface of Mars by moving from place to place, and also give scientists the opportunity to conduct ongoing, long-term experiments and observations.

The first rover was **Sojourner**, part of the Mars Pathfinder mission that landed on July 4, 1997. Although Sojourner was designed for a mission lasting only 7 sols, it actually remained active for 83 sols (85 Earth days) and traveled just over 100 meters from Pathfinder's landing site. Next came **Spirit**, which landed at Gusev Crater, January 4, 2004, and Spirit's twin, **Opportunity**, which landed on the opposite side of Mars at Meridiana Planum. Spirit traveled about 8 kilometers and found evidence of impacts, explosive volcanoes, and water under the surface. Later in 2009, it became stuck in soft sand. Opportunity traveled a total of 45 kilometers, but dust accumulation on its solar panels greatly reduced travel times after 2007. Communications between NASA and Opportunity were lost completely after a large dust storm in 2018. Opportunity, like Spirit, found evidence of liquid water on the surface — and also discovered extra-Martian meteorites. Finally, **Curiosity** rover landed at Gale Crater on August 6, 2012. It is unique in that it is powered by a radioisotope thermoelectric generation, which should circumvent the limitations of solar panels. Curiosity has traveled about 21 kilometers so far and has found evidence that ancient Mars had the right chemistry, including sulfur, oxygen, phosphorous, and carbon, to support life.

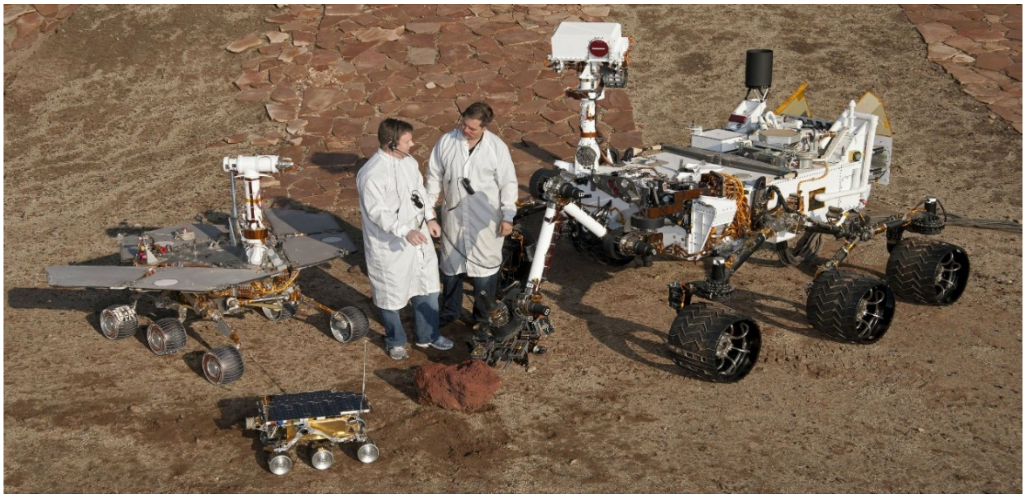

Figure 1: Mars Rover in order of size Sojourner, Spirit & Opportunity, and Curiosity.

Mars 2020 is the next rover mission. It's scheduled for launch between July 17 and August 5, 2020, and will land at Jezero crater on Mars on February 18, 2021. A high resolution image of the Jezero crater, taken by the Mars Reconnaissance Orbiter, is shown in *Figure 2*. Beyond the crater features, the landscape is marked by a canyon that appears to have been cut by water, with a delta feature at the canyon's mouth. Spectral imaging of the region shows the presence of clay and carbonates, just like a delta on Earth. These features make Jezero crater an ideal place to search for evidence of past life.

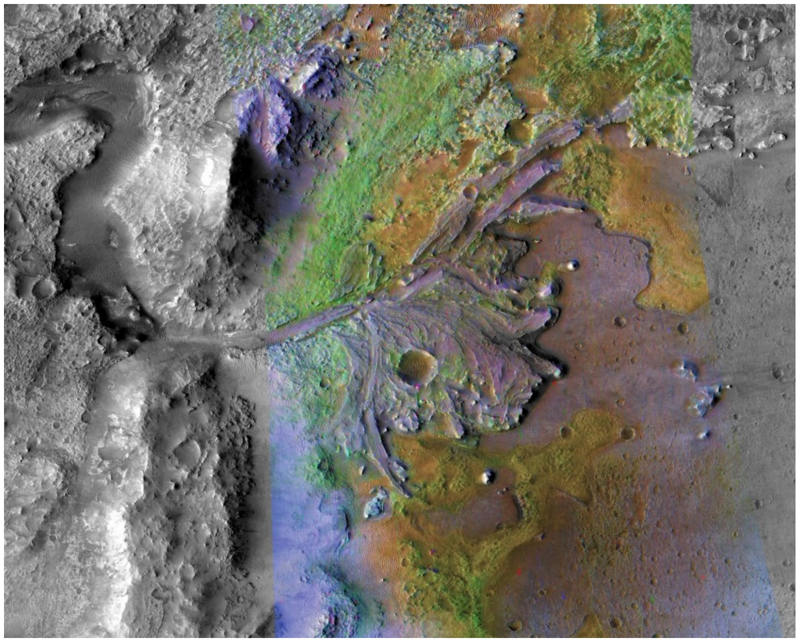

Figure 2: Delta and canyon at the edge of the Jezero crater from. The different colors indicate potentially different minerals including clay and carbonates. Image from: https://www.nasa.gov/sites/default/files/thumbnails/image/pia23239.jpg

The Mars 2020 rover will be similar to the Curiosity rover in size and power system, but will have new features including a core drill that will capture a sub-surface sample and then cache it on the surface of Mars so that it may return to Earth in future missions. The Mars 2020 rover will also include a drone to explore areas beyond the rover. This will demonstrate the ability to fly in Mars' thin atmosphere and be the first aircraft to fly on another planet.

While the rovers continue to assess Mars for human habitability, NASA is simultaneously working to return crews to the moon for the first time since the Apollo missions. Currently, the only established crewed base in space is the International Space Station. By the late-2020s, NASA aims to have a permanent human presence on the moon. These lunar bases will serve as a means to test the technologies needed to sustain ongoing science missions to Mars, and the data to be attained form Mars 2020 will be an important component to understanding key processes occurring on the surface of Mars.

The ROADS Regional Events will be held in spring 2020, which will also mark the 50th anniversary of the Apollo 13 flight. Check the NESSP Website for your Hub's event date(s). The mission's astronauts and ground control team worked to develop a solution for the loss of fuel cells destroyed by an explosion from the hydrogen and oxygen storage tanks. As a result of their ingenuity, a mission that could otherwise have ended in disaster became a success story of survival under truly extreme conditions.

ROADS seeks to engage students in science, technology, engineering, and math (STEM) that parallels the Mars 2020 effort, while honoring the heroism of the Apollo 13 astronauts, and the vision for the future of humans exploring the solar system.

Students participating in ROADS will develop an understanding of microbial life, geology, remote sensing of Earth and places beyond, computer programming, and engineering design. The Challenge promotes cooperative learning, quantitative problem solving, and critical thinking in a science and engineering environment using hands-on problems.

1.2.1 Components and Objectives

ROADS is structured to provide real-world experiences in science, technology, engineering, art, and math (STEAM) using terrestrial analogues that track the objectives of the Mars 2020 mission in a fun but challenging environment. By participating, team members will be able to more fully understand the impact of STEAM in their own lives, their communities, and their environment. Participating in the challenge will also aid their own ongoing school studies, and will introduce them to the complexity, challenges, and new insights that NASA missions can provide to the country.

An important feature of ROADS is that it is not just a robotic competition. It's an interdisciplinary enterprise that helps develop student expertise in biology, environmental sciences, social media, engineering design, robotics, programming, drones, and aviation. The challenge itself consists of three parts:

PART I — Landscape Morphology: Study how environments are modified by the action of water that may have formed the delta, and high velocity impacts that produce the catering in the vicinity of the Jerezo crater. This component, called Landscape Morphology, is particularly relevant today where regions are being impacted by record breaking storms each year.

PART II — Search for (Terrestrial) Life: Search for signs of small, unseen life — which we are abbreviating as "the search for life." Mars 2020 is searching for signs of *past* life that are invisible to the naked eye. This part of the ROADS challenge seeks to provide a similar experience by the detection of an invisible gas called methane. On Earth, methane is typically produced by inorganic geological processes sometimes associated with volcanic or geothermal processes, or by organic processes associated with the decay of organic material, such as human activity, livestock farming, rich agricultural fields, swampy areas, and even home gardens or compost heaps. After detecting regions of high methane, the task is to do sampling using a microscope to see if there are any macroinvertebrates (small animals with no backbones) in the area.

PART III — Robotic Exploration: Develop a rover and drone system to perform the required tasks on the official Mars challenge mat, which includes carrying a Mars Lander to the surface of Mars, landing in the designated area, programming a LEGO Mindstorms robot (or Ozobot, for Spirit Division teams) to traverse the course, avoiding craters and mountains, picking up model surface samples, and testing for the relative abundance of idealized samples for the potential for life. High school students will attempt to fly a mini-drone from their rover into the heart of a crater to take a picture of the crater wall.

Throughout these efforts, team members are encouraged to post their findings on social media (if allowed by their school).

1.2.2 Broadening Access

ROADS provides an opportunity for all participants to gain experience with the technologies necessary for the Challenge — a microscope, combustible gas detector, uncrewed aerial vehicle (UAV, also commonly known as a drone), and LEGO Mindstorms robot. Professional development (see Section 1.4) for Flight Directors will be available through regional, in-person workshops, video conferencing, and online resources. If a school district expects to have strong participation, in-person workshops may be available. Contact nwessp@uw.edu to inquire.

ROADS will offer "Meet a NASA Scientist" video conferencing during the school year where team members and Flight Directors will have the opportunity to ask questions directly to Mars science specialists.

ROADS may be able to offer basic Challenge supplies to organizations that do not have LEGO Mindstorms equipment, microscopes, or access to a UAV. For details on support in your region, see the ROADS website:

nwessp.org/mars/hubs

As part of NESSP's commitment to broadening STEM access for diverse communities, ROADS will provide students with skills to help them take their next giant leap towards STEM applications in tomorrow's world.

Regional Challenge Hubs bring student teams across the U.S. and its territories into ROADS. Schools, libraries, and other community organizations are encouraged to run practice challenges to allow as many students to be involved in the challenge as possible.

1.2.3 New for ROADS

For those that took part in the ANGLeS Challenge in 2018–19, NESSP would like to highlight some of the key changes for ROADS.

- We are expanding! ROADS will include a new list of Regional Hubs, so double-check when you register to see if there is a Hub closer to you.
- We are still expanding! ROADS will allow students in grades 3 and 4 to participate. This means there are four Divisions to take on the challenge: SPIRIT (grades 3 and 4, or no programming experience), OPPORTUNITY (grades 5-8), and CURIOSITY (grades 9-12). There is also a SOJOURNER Division for sight impaired teams in grades 3-12 that will be available in 2020.
- Teams are required to keep a Mission Development Log (Section 4.1.1). The log will detail the team's process and outcomes for each component of the challenge, and will be a significant component of the team's overall score.

1.2.4 Grand Prizes

The winning team from each School Year Regional Challenge Event will send one OPPORTUNITY or CURIOSITY team consisting of 5 team members and 1 adult to participate in a ROADS showcase at the launch of the Mars 2020 rover from Kennedy Space Center (KSC). If a winning team is composed of 5-7 members total (not just Flight Crew), there may be an opportunity for the entire team to attend, although this is not guaranteed. Only one team from each Hub will earn this trip.

There will also be at least one team from the SOJOURNER category eligible for the Kennedy Space Center visit. All travelling team members must meet the minimum age requirements.

For programs running the challenge through summer camps, a limited number of teams will be eligible for a funded trip to NASA's Jet Propulsion Laboratory (JPL). Nominees will have to submit their Mission Development Log (Section 4.1.1) and challenge efforts via video and a selection committee will decide the prize winners in this category. Due to timing of the Mars 2020 launch and time needed to complete the logistics, the trip to JPL will occur after the launch in late September.

The visits to the NASA Centers are contingent on the launch being on schedule within the current launch window, and availability of funding from NASA — some travel costs beyond the provided funding limit may have to be covered by the team depending on distance and airfares.

Only US Citizens or US Permanent Residents are able to attend the visits to the NASA Centers, and all team members visiting the center must be registered team members at the time of their regional Challenge Event — no substitutions are allowed. All visitors to the NASA Centers must be at least 11 years old at the time of the visit.

Due to the age restriction, SPIRIT teams are not eligible to visit NASA Centers. Winning SPIRIT teams will earn a Mars 2020 launch party funded in part by NESSP.

1.2.5 About the ROADS Logo

The cover image for ROADS features a NASA image of Mars with the Curiosity rover superimposed on the planet, created by Christina Jarvis.

1.3 National Dates & Deadlines

Anyone may use the ROADS modules in their curricula, but only teams who register with NESSP (through our website: nwessp.org/mars/registration/) are eligible for prizes, equipment support, and to participate in Regional Hub Challenge events. Registration is free!

Teams do not have to participate in Part I and Part II, but we strongly encourage participation in these events, particularly for those teams requesting equipment support. Teams that submit the required items for Part I and Part II by the deadlines outlined below will be eligible for a chance to win items for the next steps of the challenge. All components of the challenge must be completed and presented the day of the regional challenge event to be scored. This section lists the dates and deadlines that apply to all teams participating in ROADS. Additional dates and deadlines are defined by each Hub for their region. Please see the ROADS website for more information on Hub schedules:

nwessp.org/mars/hubs

1.3.1 School Year Challenge Dates

SEPT 23, 2019	Official launch of ROADS, registration opens
OCT - JAN	Professional development workshops
OCT 23, 2019	Virtual meeting with NESSP team to discuss ROADS Challenge
NOV 19, 2019	Virtual Meeting with a Mars Scientist (Jim Rice)
DEC 20, 2019	Delta Dynamics Model video submissions due
DEC 20, 2019	Crater Formation Model video submissions due
DEC 16, 2019	Virtual Meeting with a Mars Scientist (Briony Horgan)
DEC 17, 2019	School Year registration closes
JAN 8, 2020	Delta Dynamics Model Video awards announced
JAN 15, 2020	Search for Life Activity social media video submission due
JAN 22, 2019	Virtual Meeting with a Mars Scientist (Steve Ruff)
JAN 22, 2020	Virtual meeting with NESSP team for ROADS support and questions
JAN 30, 2020	Search for Life Activity video awards announced
FEB 14, 2020	Mission Patch submission due
FEB 19, 2020	Mission Patch awards announced
MAR 1-5, 2020	Nominate teams for Regional Challenge Event
MAR 15, 2020	Invitations to Regional Challenges announced
SPRING, 2020	Regional Challenges held
JUL 17-AUG 5, 2020	Grand Prize visit — Mars 2020 rover launch at Kennedy Space Center[1]

1.3.2 Summer Camp Schedule

Summer Camp teams may participate in the Delta Dynamics Model and Search for Life Activity, Mission Patch submission, and other pre-event activities during their summer camp program and may determine their own deadlines before the end of the summer.

JAN 1, 2020	Summer registration opens
MAR-APR, 2020	Summer Professional Development Workshops
JUL 1, 2020	Summer registration closes
JUN-AUG 15, 2020	Summer camp challenges undertaken with video submissions

[1] Date range signifies the launch window for the Mars 2020 rover; actual grand prize trips dates will be within this range.

SEPT 1, 2020	Summer camp winners announced
LATE SEPT, 2020	JPL Visit

1.4 Professional Development

Several "How to" videos are available on the challenge website for key components. Professional Development may be scheduled through the Regional Hubs — exact contact information will be available in autumn 2019. If a school district has strong participation (i.e. several schools and grades), professional development may be requested by emailing nwessp@uw.edu. Educators interested in the summer schedule should participate in school year PD sessions. Professional Development opportunities for the summer schedule will be limited. Please see the ROADS website for more information:

nwessp.org/mars/hubs

Video chats with the NESSP team will occur as noted in the National Dates & Deadlines Section 1.3. Teams and Flight Directors may also contact their Regional Hub lead at any time via email with questions.

1.5 Extended Curriculum Opportunities & Resources

Additional material will continue to be uploaded during the year, so please occasionally visit the website for new information, including the information to access NESSP's video conferencing. We will also send updates to all registered team leads. ROADS Educator resources folder is at the following link:

nwessp.org/mars/resources

1.6 Supporting Science and Programming Standards

ROADS is designed to involve students in the types of science, engineering, and technology that will be a central part of the Mars 2020 mission and which are key components of Next Generation Science Standards. NESSP seeks to introduce students to the abundant opportunities for them and their communities in order to create broader and more successful pathways into STEM careers with an emphasis on including underserved communities.

Science and engineering concepts supported in the challenge exercises include how to:

- Interpret different geological formations.
- Investigate macroinvertebrates.
- Research material for the different systems.
- Image the pickup and release mechanism for the Mars lander.
- Develop the more interesting solutions.
- Build a prototype.
- Test and evaluate.
- Improve the design as needed.
- Determine whether the system meets the requirements.

1.6.1 Computer Science Core Concepts

Team members will gain experience in the core concepts of computer science, including how to:

- Compare different algorithms that may be used to solve the same problem but have different speeds and/or flexibility.
- Develop programs, both independently and collaboratively, that include sequences with nested loops and multiple branches.
- Interpret the flow of execution of algorithms and predict their outcomes.
- Decompose a problem into parts and create solutions for each part.
- Design and develop a software artifact working in a team.
- Integrate grade-level appropriate mathematical techniques, concepts, and processes in the creation of computing artifacts.

1.6.2 Next Generation Science Standards

By participating in ROADS, team members will gain experience in the full engineering design process. In particular, the challenge supports K-12 Science and Engineering Design standards that are part of Next Generation Science Standards (NGSS), including:

4-LS1-1 Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction.

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-3 Ask questions and predict outcomes about the changes in energy that occur when objects collide.

MS-LS1-5 Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

MS-LS2-1 Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-3	Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
MS-ESS2-2	Construct an explanation based on evidence on how geoscience processes have changed the Earth surface on varying time and spatial scales.
MS-ESS2-4	Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.
MS-ESS3-1	Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.
MS-PS2-2	Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.
MS-PS2-4	Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.
HS-LS2-3	Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.
HS-PS2-1	Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
HS-PS2-2	Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.
HS-PS4-5	Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.

2 SAFETY

2.1 UAV Safety

All activities for ROADS will take place indoors. To prepare for the challenge, all UAV practice should also be conducted indoors. UAVs operated indoors are not affected by Federal Aviation Administration (FAA) regulations Part 107 regarding small Unmanned Aircraft Systems (sUAS).

Any and all UAV flight outdoors, however, is subject to FAA regulations and common sense. **Northwest Earth and Space Sciences Pipeline, ROADS, and Regional Hub organizations do not sanction outdoor UAV flight in relation to this challenge.**

UAVs are increasingly common and ROADS is an excellent opportunity for gaining familiarity with this technology. NESSP offers the following section on safety as advice on how to stay safe and operate within the law. Flight Directors are responsible for ensuring their team members understand and practice UAV safety.

2.1.1 UAV Safety Tips for Practicing

Here are some tips to help ensure a safe space for learning to fly a UAV and practicing for ROADS:

- Make sure that all necessary parts of the UAV are installed and functioning properly to ensure a stable and safe flight.
- Choose an indoor flying area with plenty of open space, a high ceiling, and little HVAC draft, such as a gymnasium or a classroom with the desks cleared to the side.
- Clear the flying area of any obstacles.
- Ensure that everyone in and around the flying area is aware and actively paying attention. Other activities can be a distraction and hazard to the UAV operator and to the participants of the other activity.

When learning to fly, trying to control a UAV can quickly become disorienting or overwhelming. It is best to start with small, progressive goals, and a lot of patience before attempting to fly around the room or far away.

- When taking off, quickly bring the UAV to eye level and away from the launch surface. UAVs are heavily affected by ground effect, which is a phenomenon where turbulent airflow from the drone hits a surface and recirculates back through the rotors. Ground effect makes UAVs very difficult to fly close to the ground or near ceilings and walls.
- On your first flight, once the UAV is at eye level, let go of the left control stick (if the drone model will allow you to) and only use the right control stick to control forward, backward, right, and left translation. The left control stick controls altitude and yaw, which can quickly become disorienting for a new pilot. Try to hover over the same spot
- Use slow, smooth inputs with the controls. New pilots often push too much on the controls or "tap" the controls to try to make small adjustments, however UAVs do not respond well to this type of input. Instead, be slow, smooth, and steady.

- Once you can hover, try to fly around the room, still just using the right control stick for translation. Once you are comfortable, use the left control stick to yaw the UAV and try repeating the same maneuvers. Some pilots find it helpful to rotate their body and the controller to the same direction the UAV is facing and turn their head to track it.
- Keep the UAV in sight at all times! When practicing for the landing portion of the challenge, make sure to have another Flight Crew member keep an eye on the UAV and alert the pilot of any difficulty.

2.1.2 UAV Safety at Challenge Events

While a UAV is in the air, no one may be between the challenge mat and the launch area. Once the UAV has returned to position on the launching pad, the Flight Crew is allowed to congregate around the challenge mat — but stepping onto the mat is prohibited.

If the UAV flies more than 3 feet out of bounds, or if instructed by an event official, the Flight Crew must land the UAV and shut it off immediately. If the team does not respond promptly to any requests from an event official, the team will be disqualified.

Additional safety rules may be added at any given Regional Hub depending on their local requirements. For example, some events may require the UAV to be tethered during the challenge.

For more information about UAV safety and FAA regulations, please see Appendix A: FAA UAV Information at the end of this document.

2.1.3 Non-UAV Schools

Some school districts may not allow the flight of a drone. A bean bag toss (best out of three) can be used to replace the drone aspect, but please coordinate with the contact for your Regional Hub Lead to confirm the replacement.

3 TEAMS

3.1 Team Divisions

The ROADS Challenge will have four Divisions to accommodate team members of different ages and skill sets. The different Divisions will have slightly different objectives described below.

The challenge Divisions are:

SPIRIT DIVISION	Grades 3-4, or no programming experience
OPPORTUNITY DIVISION	Grades 5-8
CURIOSITY DIVISION	Grade 9-12
SOJOURNER DIVISION	Sight impaired (Grades 3-12)

Requirements for the team structure are given in Section 3.2, with the detailed description of the challenge components given in Sections 4 and 5. A summary of tasks for the different Divisions is given in Section 5.4.

3.2 Team Structure

3.2.1 Flight Director

Each team requires one adult Flight Director to act as the team coach and primary point of contact between the team, the Regional Hub, and NESSP. The Flight Director is also responsible for the organization and safety of the team and for ensuring the team follows the rules and guidelines of their associated organization(s). A person may serve as Flight Director for multiple teams. The Flight Director must be at least 18 years old. They may be a teacher, educator, team parent or guardian, or other community member. Only Flight Crew members, not mentors or Flight Directors, may directly interact with the challenge equipment, team's equipment and programming, or field equipment during the Challenge Event.

3.2.2 Team Members

Student teams will work together to prepare for all aspects of the challenge. ROADS incorporates a variety of subject matter, so we strongly encourage teams to be interdisciplinary with diverse backgrounds and skills. Each team must have at least a Flight Crew, as defined in Section 3.2.3, but teams may have many additional members. Student members of a team may consist of a school class, for example.

Student team members must be enrolled in grades 3-12 or under the age of 18 at the time of registration to participate on the team. The team may be mixed grade. Mission objectives vary for elementary, middle, and high school teams and are determined using the highest grade level within the team at the time of registration. Teams may also opt to take on the challenge in an older Division;

however, due to age restrictions (see Section 1.2.4), only team members aged 11 or older are eligible for the OPPORTUNITY/CURIOSITY Division grand prize.

Challenge Hubs will do their best to accommodate team members with disabilities. To make arrangements for any specific accommodations your team requires to participate in ROADS, contact your Regional Hub using the contact information on the ROADS website:

nwessp.org/mars/hubs

3.2.3 Flight Crew

At the time of the regional events, a maximum of 5 team members, called the Flight Crew, will be allowed on stage to run the challenge course. All members of the Flight Crew must be student members who meet the requirements outlined in Section 3.2.2. Only Flight Crew members may directly interact with the challenge equipment, team's equipment and programming, or field equipment during the Challenge Event. Flight Directors and mentors will not be allowed on stage during the team's running of their systems.

Flight Crew should have some type of uniform so they can be easily distinguished. The uniform could be that of an astronaut or school colors or other culturally relevant attire. Be original and creative! It will be part of the team's overall score.

3.2.4 Mentors

In addition to the Flight Director, anyone who wishes to help and mentor the team members are encouraged to do so. Mentors may be a teacher, educator, team parent or guardian, older student (e.g. a high school student may mentor a middle school team), or other community member. Only Flight Crew members, not mentors or Flight Directors, may directly interact with the challenge equipment, team's equipment and programming, or field equipment during the Challenge Event.

3.3 Registration

NESSP recommends that teams be affiliated with an organization such as a school, library, museum, after-school program, or club. Regional Challenge Hubs will hold the Regional Challenge Events and will be the main point of contact for teams.

All teams participating in ROADS must be registered by the dates given in Section 1.3.1 and 1.3.2. Registration is free.

We encourage schools and other large organizations to have multiple teams across grades, and to develop runoff events to nominate teams to move forward to Regional Challenge Hub events, as there is a limited number slots available at the regional events.

Complete registration and Regional Challenge Hub information can be found online at:

nwessp.org/mars/registration/

3.3.1 Regional Challenge Event Invitation and Confirmation

Registration does not automatically nominate a team to attend the Hub event. A separate nomination form will be provided to all registered teams. Teams that plan to participate in a Regional Challenge Event must submit their team nominations by the Hub's due date using the form (that will become available in early 2020) at the following link:

nwessp.org/mars

Regional Challenge Hubs will send Regional Challenge Event invitations to selected teams by the Hub's due date. Teams must respond to confirm they will attend the Challenge Event and submit any requests for travel assistance by 11:59 p.m. (Pacific Time) on the Hub's due date. If for any reason a team is not able to attend an event for which it is registered, please notify the Regional Challenge Hub so another team may have the opportunity to participate. Regional Challenge Events will be held at different times at different Hubs. Please see your Hub's Regional Supplemental Manual for information specific to your Regional Challenge Event.

3.4 Support

ROADS is able to provide support for teams through the Regional Hubs and through NESSP. Each Hub has determined the best way to support teams within their region. Support may include funding, supply lending, or travel support. For details on support from your Hub, please see your Hub's information page on the ROADS website.

NESSP is also able to provide equipment support, particularly for teams coming from schools with >50% free and reduced lunch, or teams that have a significant number of underrepresented minority team members. This support can be requested at the time of registration, but to be eligible teams need to complete the necessary stages.

Another potential source of support may be through your state's NASA Space Grant Consortium.

We encourage teams that participated in the 2018–2019 ANGLeS challenge and purchased a mat to use the blank side of the mat as a blank canvas to draw the main requirements of the ROADS challenge. This can save money as well as provide an important means for teams to learn how to draw and interpret mats using the directions provided. The challenge mat, which is posted on the challenge website, has an easy conversion factor of 1-inch = 1-foot if printed on regular paper. See Section 5.3 for mat-making instructions.

4 CHALLENGE REQUIREMENTS FOR PARTS I AND II

4.1 Challenge Part I: Mission Log and Landscape Morphology

4.1.1 Mission Development Log (MDL)

All teams will develop a Mission Development Log (MDL) that will document the team's processes throughout Challenge. The MDL should show, for example, the scientific method the team uses when searching for microbes in their environment, the engineering design decisions made in completing Challenge tasks, and so forth. It's important for all team members to describe the decisions they make, whether they worked or not, and what modifications were needed if the initial outcome was not achieved. The MDL parallels standard scientific method and engineering design principles.

The MDL should include labeled sketches, diagrams, descriptions, bulleted lists, photos, and other documentation of initial and final design, modifications, successes — and failures. Scientists and engineers rarely get it right the first time! The required sections of the MDL are:

- ☐ Social Media Plan
- ☐ Delta Dynamics[2]
- ☐ Crater Formation[3]
- ☐ Mission Patch Design
- ☐ Methane Detection
- ☐ Search for Small Invertebrates
- ☐ Rover Design & Testing[4]
- ☐ Team Attire Design
- ☐ MO1 Landing System Design
- ☐ MO2 Communications Dish Design

The MDL Scoring Rubric is in the Educator Resources folder: nwessp.org/mars/resources

The MDL will be worth 40% of the total challenge points.

To be scored, teams must post a video of their Delta Dynamics Model and/or Crater Model on social media (Instagram, Twitter, or Facebook) using the hashtags **#ROADSonMars** and **#Mars2020**. Make sure your post is public, then submit it to NESSP through the ROADS website:

nwessp.org/mars

[2] Formerly called "Alluvial Fan Dynamics." We are logging our initial error! Thank you, NASA Scientist Jim Rice, for correctly identifying this.
[3] Crater Formation not required for Sojourner Division.
[4] Ozobots for Spirit Division, LEGO Mindstorms for Curiosity and Opportunity teams.

4.1.2 Delta Dynamics (~1-2 hrs)

In this task, team members will first theorize their own ideas about what might have created the features of Jezero crater (See *Figure 2* in section 1.2) and will then test their theories. The objective is for team members to develop evidence of their theories. To do this, teams can build a stream table as shown in *Figure 3*. The simplest way to create the model is to use a long, low plastic tub (such as under-bed storage containers available stores like Walmart or Target). See Appendix B for a list of supplies.

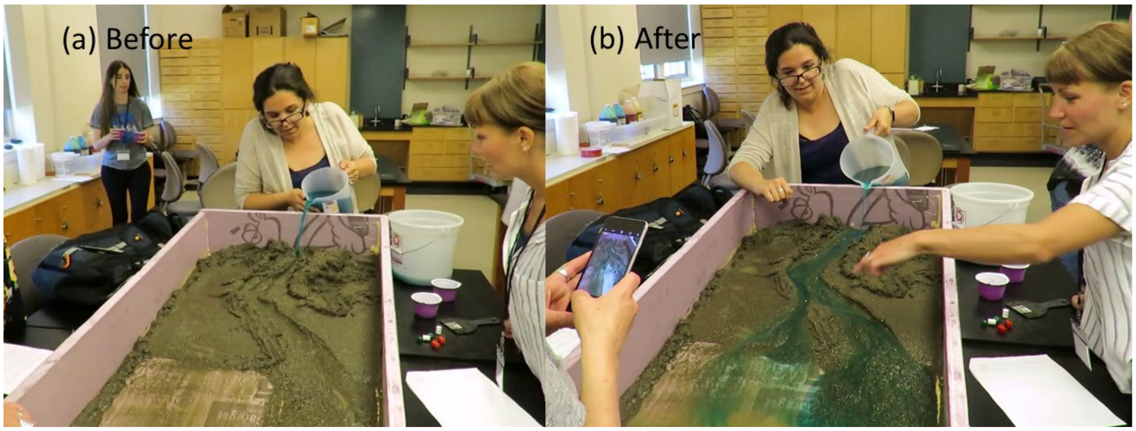

Figure 3: Stream water table show how flowing water modifies the initial terrain to produce a delta.

To create a larger stream table system, a more robust (although costlier) version can be built using wood if the team is inclined toward handy-craft work. A plastic tub version can be seen in the Delta Dynamics Model video on the ROADS website; a wood and Styrofoam version is shown in *Figure 3*.

We recommend adding a stop water valve (available from a hardware store) so the stream table so that the water can be drained into a bucket. This valve is attached by cutting a hole in the tub and using an adhesive such as gorilla glue to affix the valve and provide a water-tight seal.

Finally, add play sand (available at hardware and craft stores) to create your terrain. Teams may also want to add items to simulate a built environment — toy houses, people, or cars, etc. — or add trees, grass, and other features.

The goal is for the team to provide evidence for what they think are the processes responsible for the key features of the Jezero crater. There is no wrong answer in this exercise! Team members must simply provide evidence of their conclusions. All stages of the process, from formulating theories to running simulations in the stream bed, should be documented in the MDL.

For inspiration, the challenge website includes some sample videos. Specific questions team members might address are:

- Can water flow explain the delta in the Jezero crater? If so, was it produced by a fast flow (like a flash flood) or a slow continuous flow?
- If team members added trees, houses, or other features to their terrain, how did those items affect the water flow? How did the water flow affect those items?

- Are there places in your community or state where similar processes are occurring? What steps, if any, are being taken to address erosion?
- To look for evidence for past life, where would be the best places to take samples?

Video for the Delta Dynamics Model is best done using time-lapse (available on some smart phones) or increasing the playback speed in post editing (available on some software or apps). Be creative! — see, for example, LEGO Steve at https://www.youtube.com/watch?v=5bqJo5ze3Bk

4.1.3 Crater Formation (~1-2 hrs) — Not required for Sojourner Division

The other significant feature of the Mars 2020 landing site is Jezero crater itself — the very large crater in which the delta resides. There are also several other craters of varying sizes nearby, creating a geologically interesting area.

This part of the challenge asks team members to consider:

- How do craters form?
- Can crater formation provide insight into the processes that shaped other objects in the solar system?

The diagram in *Figure 4* presents one example of how a crater can change the landscape. An impacting object, such as a meteor, pushes the surface material down and out — and possibly melts and evaporates the surface material if the impact speed is sufficiently high. The action doesn't stop there! After the initial push downward, the material recoils and pushes back upwards so that in some cases the middle of the crater can be a high point.

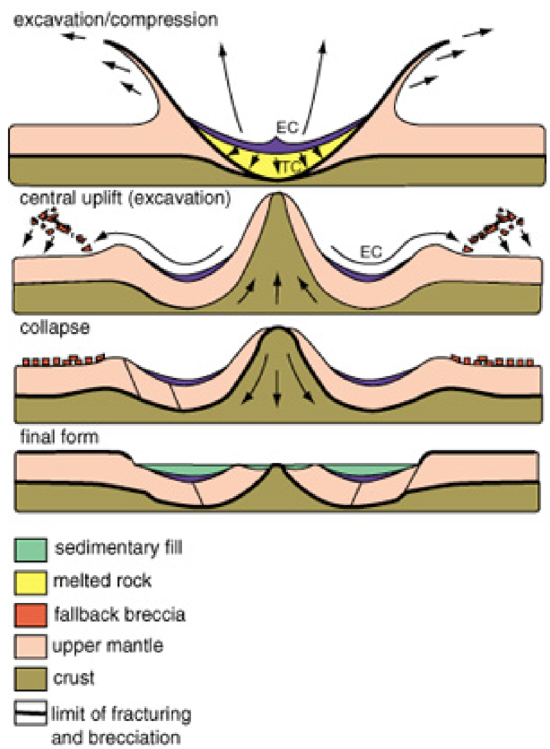

Figure 4: Crater formation

The objective for this task is to capture this process in slow motion (using, for example, a smart phone's slow motion video feature). Teams may attempt one of the following, but we encourage team members to be creative and select their own impacting object and surface/subsurface material!

- A drop of food dye into water
- A drop of water into sand
- A rock into water or sand

An excellent slow motion video of the process can be seen at: youtube.com/watch?v=6swY05e2iT4

The challenge website includes some sample videos with a few ideas.

All stages of the process should be documented in the MDL.

4.2 Challenge Part II: Search for (Terrestrial) Life

When scientists talk about "the search for life" on Mars, we mean life in its most basic form — microbes. The search for microbial life is challenging because it requires specialized equipment. The search for past life on Mars is even more difficult because we don't know what forms life on Mars might have taken. That's why the search for signs of past life starts by searching for terrestrial, or Earth-like, life.

The objective for this two-part task is to seek out these Earth analogues of "signs of past life" in the team's local environment. By searching for microbial life in their own community, team members will begin to gain experience in the detection of terrestrial life that cannot be easily seen by the human eye. The Search for (Terrestrial) Life task of ROADS requires equipment valued around $100 total. Teams that need support and have completed both parts of the Landscape Morphology task (sections 4.1.2 and 4.1.3) are eligible for support if they also meet the eligibility requirements in Section 3.3.

To be scored, teams must post a video of their Search for Life Activity and/or methane detection activity on social media (Instagram, Twitter, or Facebook) using the hashtags **#ROADSonMars** and **#Mars2020**. Make sure your post is public, then submit it to NESSP through the ROADS website:

nwessp.org/mars

4.2.1 Methane Detection (~1 hr)

One signature of life is methane — a relatively abundant gas on Earth. For example, methane is the main component of the natural gas used to heat homes. And, of course, there are cow farts: methane is a greenhouse gas, which, when released, can lead to warming of the atmosphere.

Methane is also odorless so it cannot be detected by smell. However, its presence is often associated with other gases such as sulfur dioxide, which we can smell. Swampy areas, livestock farms, and compost piles are some places to start trying to detect methane.

Figure 5: Combustible gas detector (~$26)

This task requires teams to start with their sense of smell to identify potential locations of methane or other combustible gases in their communities, then support their theories by using a combustible gas detector (available on Amazon). The detector gives an audible tone if gases like methane are present.

Humans also generate methane through processes of the bacteria in their stomachs. Team members must first calibrate the sensitivity of the detector so that it can detect a team member's breath. There is an instructional video on the NESSP YouTube channel on how to do this.

Teams will make a map of their community (a downloaded google map will suffice), mark areas of high methane detection, and log them into their MDL.

The ROADS website includes videos that provide demonstrations on how to use the gas detector and offer inspiration on where to search for methane.

4.2.2 Search for Small Invertebrates in Your Local Area. (~1-2 hrs) — Not required for Sojourner Divisions

The second step in our search for life is to investigate samples under a microscope. Teams should visit locations they identified as high in methane (and which is safe and permissible to visit) and collect samples and small invertebrates called macroinvertebrates. There is an instructional video on the NESSP YouTube channel on how to do this.

Next, it's time to try imaging the macroinvertebrate. A microscope is the best tool for the job. We know that some teams may not already have access to microscopes. There are small digital microscopes available at Amazon that cost about $60. A supply list is in Appendix B.

Teams must:

- Identify at least two different small invertebrates.
- Show how they found and identified the small invertebrates.

The objective for this task is to understand that lifeforms at macroscopic and microscopic levels are very different from the lifeforms that we, as humans, interact with on a daily basis.

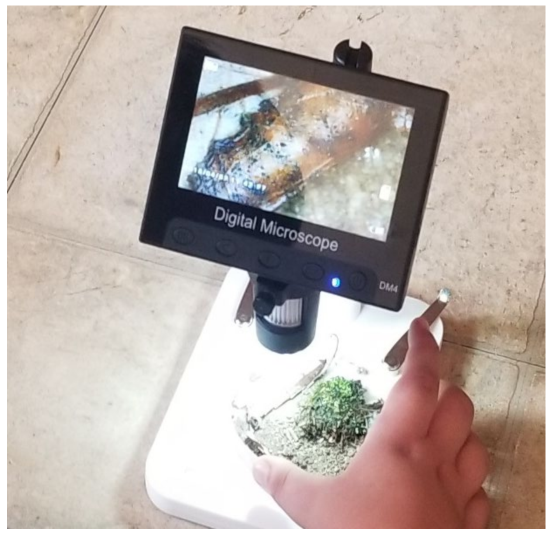

Figure 6: Digital microscope (~$60) and image of a small mite.

Documentation for this task in the team's MDL may include a map of where samples were collected and how they match up with where the team previously detected methane, a discussion of which sites produced the most interesting or most boring samples, and so forth. In particular, teams should include documentation showing how their identified their lifeforms — photos showing team members exploring their samples (such as in *Figure 6*) on the microscope can be pasted into the MDL.

4.3 Mission Patch (Estimated time: Several Brainstorming Sessions)

With the completion of Parts I and II, teams will have an idea both of the processes that likely shaped the landing site and of the research done by NASA Scientists for Mars 2020. The teams are now ready for robotic exploration planning and development. But before developing mission hardware, the team should design a mission patch that represents their objectives and community values. A few examples of mission patches for past Mars missions are shown in *Figure 7*.

Figure 7: Example Mission Patches

Teams are encouraged to get creative and design a mission patch that represents themselves, their community, and their mission in the ROADS Challenge. Mission patch posts on social media should include a short explanation of the components of the patch and their significance to the team.

To be scored, teams must create and submit a Mission Patch by posting the image on social media, using the hashtags **#ROADSonMars** and **#Mars2020**, and sharing the link through the submission form provided on the ROADS website:

nwessp.org/mars/

4.4 Submission of the Mission Development Log

At the Regional Events, the MDL will be submitted to the officiating team during the "On Deck" period unless stated otherwise by a specific Hub. Teams will have documented in their MDL all activities from Parts I and II, including the processes, designs, testing, and modifications required to complete the mission objectives described in the following sections. The MDL will be presented and described to the officiating team during their "On Deck" preparation time (15 minutes) prior to the actual running of the robotic exploration challenge. See 4.1.1 for more information about the MDL.

5 CHALLENGE REQUIREMENTS FOR PART III: ROBOTIC EXPLORATION

5.1 Challenge Layout

Part III of the challenge involves UAVs, programmable robots, and student-built components. The actual requirements for these components are dependent on the chosen Division for the team, as described below. However, all teams will undertake the challenge in a room no smaller than 15 feet by 25 feet with a floor layout as shown in *Figure 8*. Teams will be provided with a table for a laptop and remote controls for the UAVs. Teams do not need to bring their own LEGO Samples or any 3D structures of the mat: They will be provided at the Regional Hub challenge events. Should the drone at any time leave the Safety Zone labeled in *Figure 8*, the team will be required to use the emergency shutoff on the drone's remote to immediately land it.

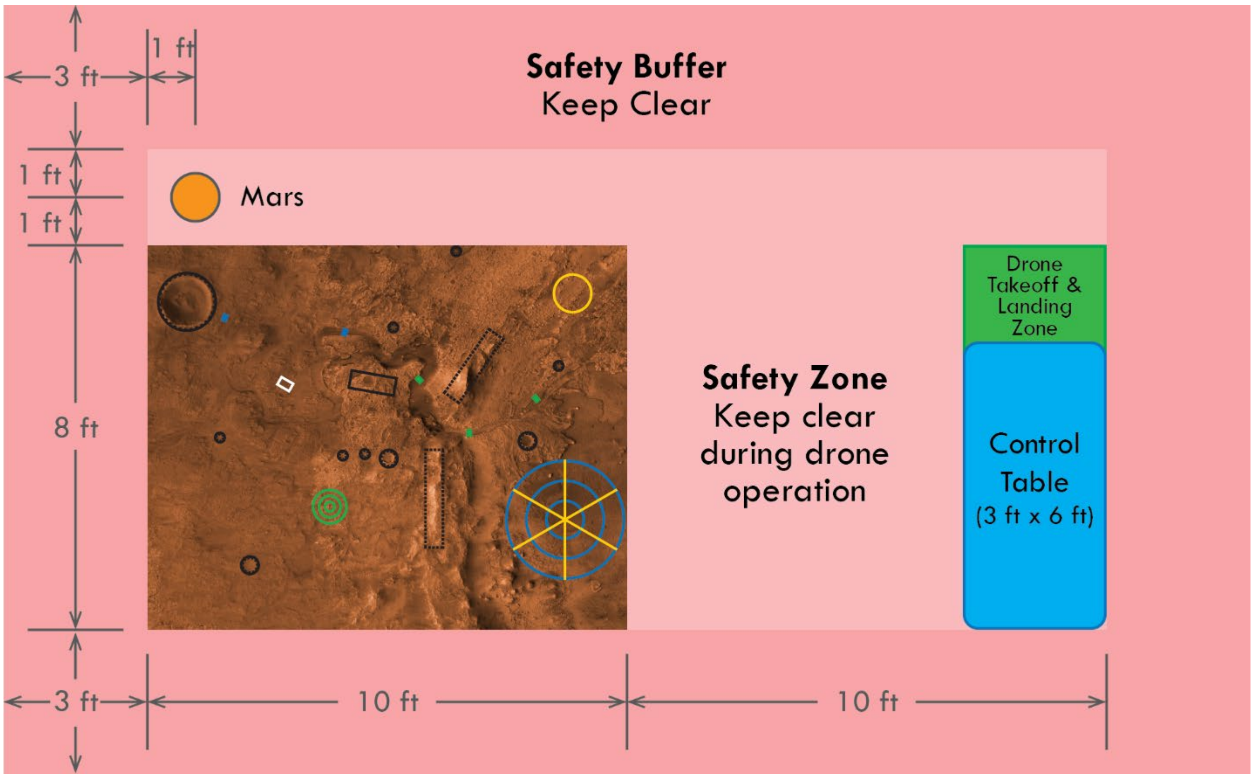

Figure 8: ROADS on Mars Challenge Layout

5.2 Challenge Mat

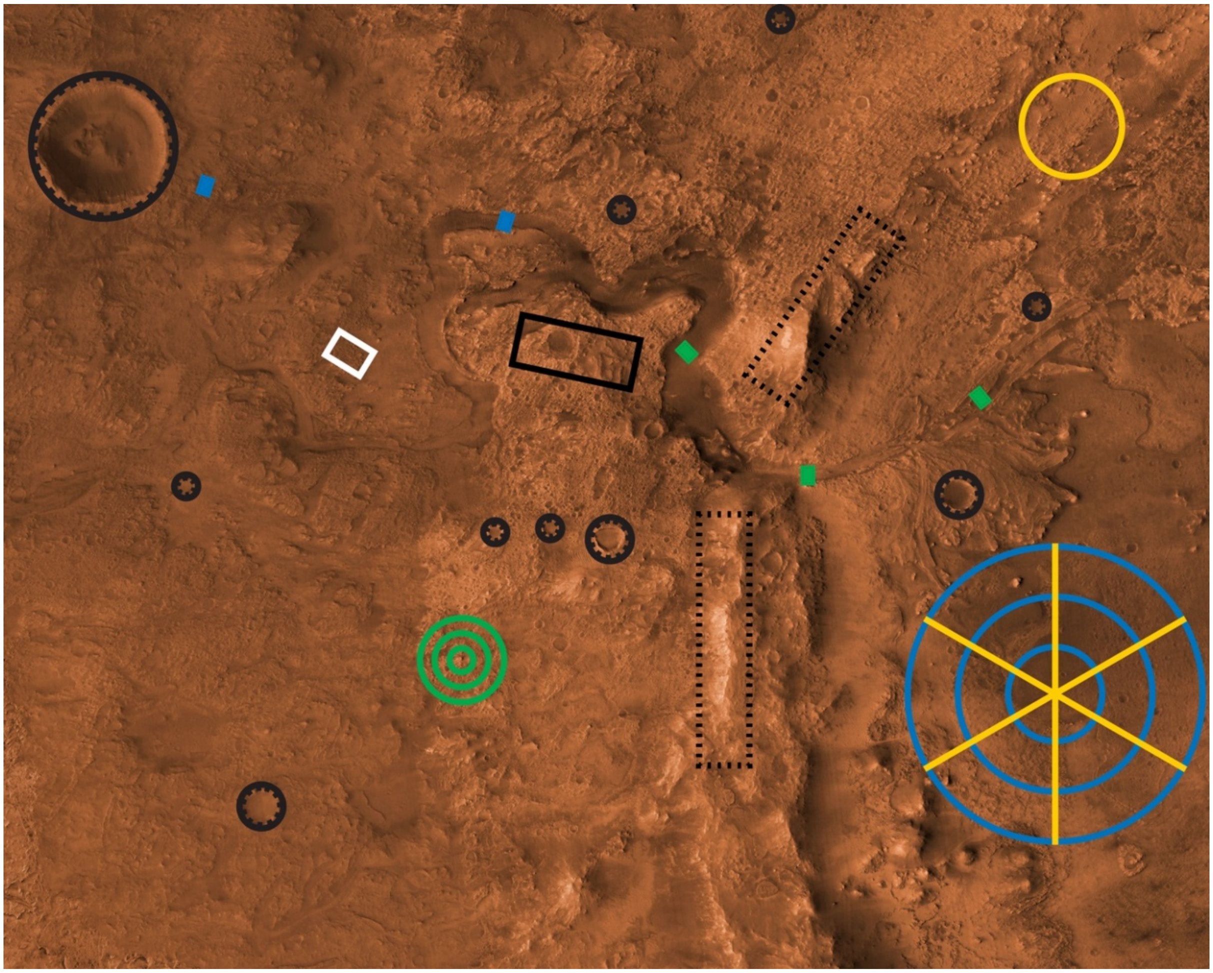

Figure 9: ROADS on Mars Challenge Mat

The Challenge vinyl mat is 8 feet by 10 feet with an additional white border edge approximately 2 inches wide (the same size used in the 2018–19 ANGLeS Challenge). We recommend that teams with mats from the ANGLeS Challenge flip them over and draw out the main features listed below for practice. Teams in the Sojourner Division can request the Challenge mat at no cost. Email nwessp@uw.edu to inquire.

For robotic exploration, the main features are shown in *Figure 10*.

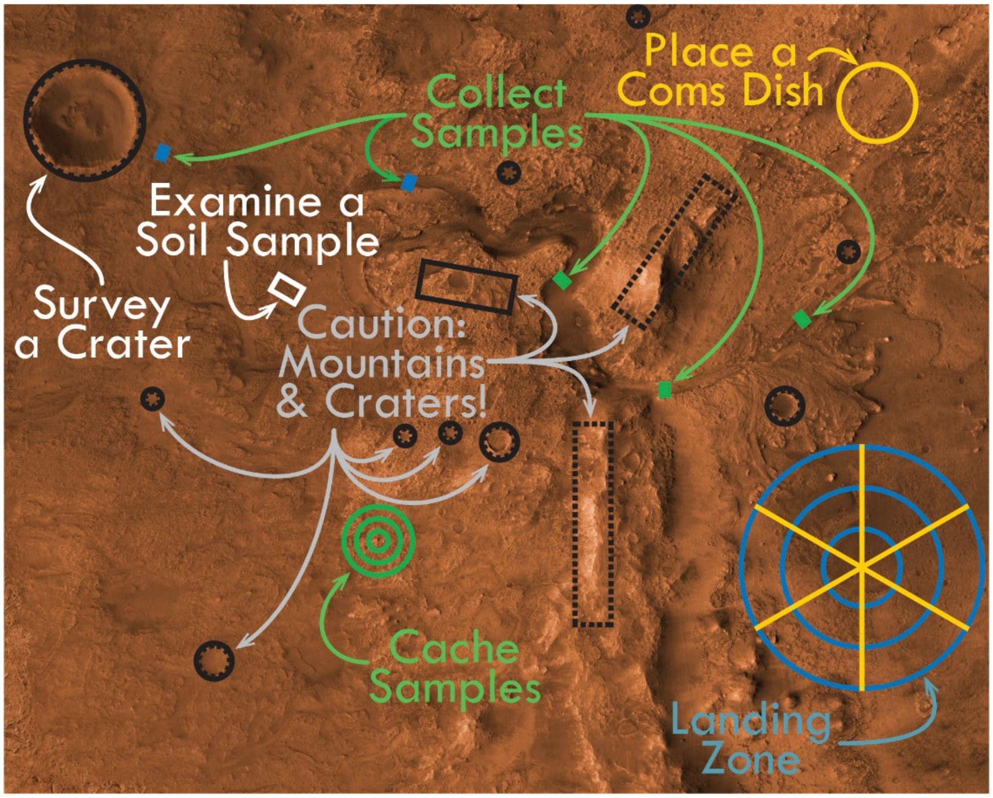

Figure 10: Annotated Mars Mat

- The blue concentric circles with yellow crosshairs (bottom right) is the Landing Zone—The Rover landing location will be judged by the landing leg closest to the center of the concentric circles with different point values associated with each circle.
- The yellow circle (top right) will be the area where the communication dish is placed.
- The black circles are craters that should be avoided by the rover.
- The blue and green rectangles shown in *Figure 10*,) represent the positions of the two types of LEGO Samples, *Figure 11* that can be collected by the rover. Collecting and caching the blue LEGO Samples is worth more points than for the green LEGO Samples.
- The green circles are the Cache Zone area where the LEGO Samples will be dropped off (recreating the caching of samples by the Mars 2020 rover for later return to Earth).

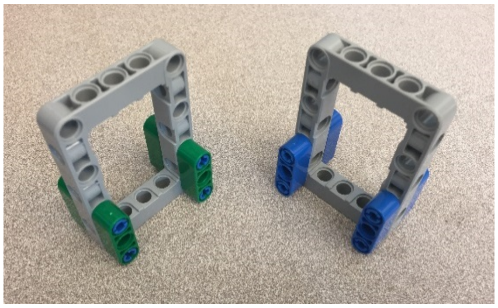

Figure 11: LEGO Samples

- The white rectangle will contain a Regolith Sample where the rover will attempt to measure the moisture content.

The terrain on the challenge mat has several features that make access difficult for the robotic exploration. These barriers will be simulated by 4 raised features. See Section 5.3 for drawings of the supports for these features:

- The solid black rectangles will contain a sloped terrain representing the cliff in the area nearby;
- The black dashed line rectangle will contain triangular mountains;
- The largest crater in the corner of the mat will have a raised crater 3D structure.

An image of the first version of raised features is shown in *Figure 12*.

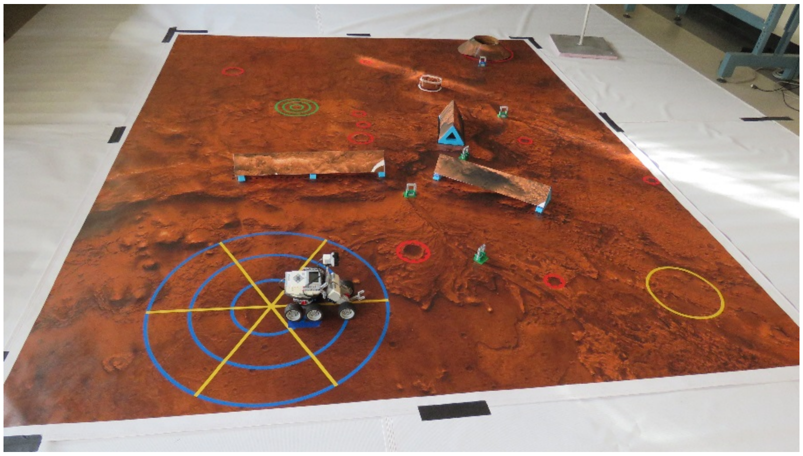

Figure 12: A view of the raised features on the Challenge Mat

5.3 Mars Mat Features

This section contains the dimensions and locations of each mat feature. It can be used to create a practice mat by hand and is a good way to get familiar with the mat and challenge objectives.

The full-size mat image can be found on the ROADS on Mars website and may be used for reference or to print your own. The colors of the markings on the official mat are based on the colors of LEGO bricks. RGB and CMYK values can be found below.

The mat is 10 feet by 8 feet, with approximately 2 inches of additional white border for the purposes of taping or otherwise securing the mat to the floor. The white border also marks the out of bounds area for the rover. The mat and example measurements are shown in *Figure 13*.

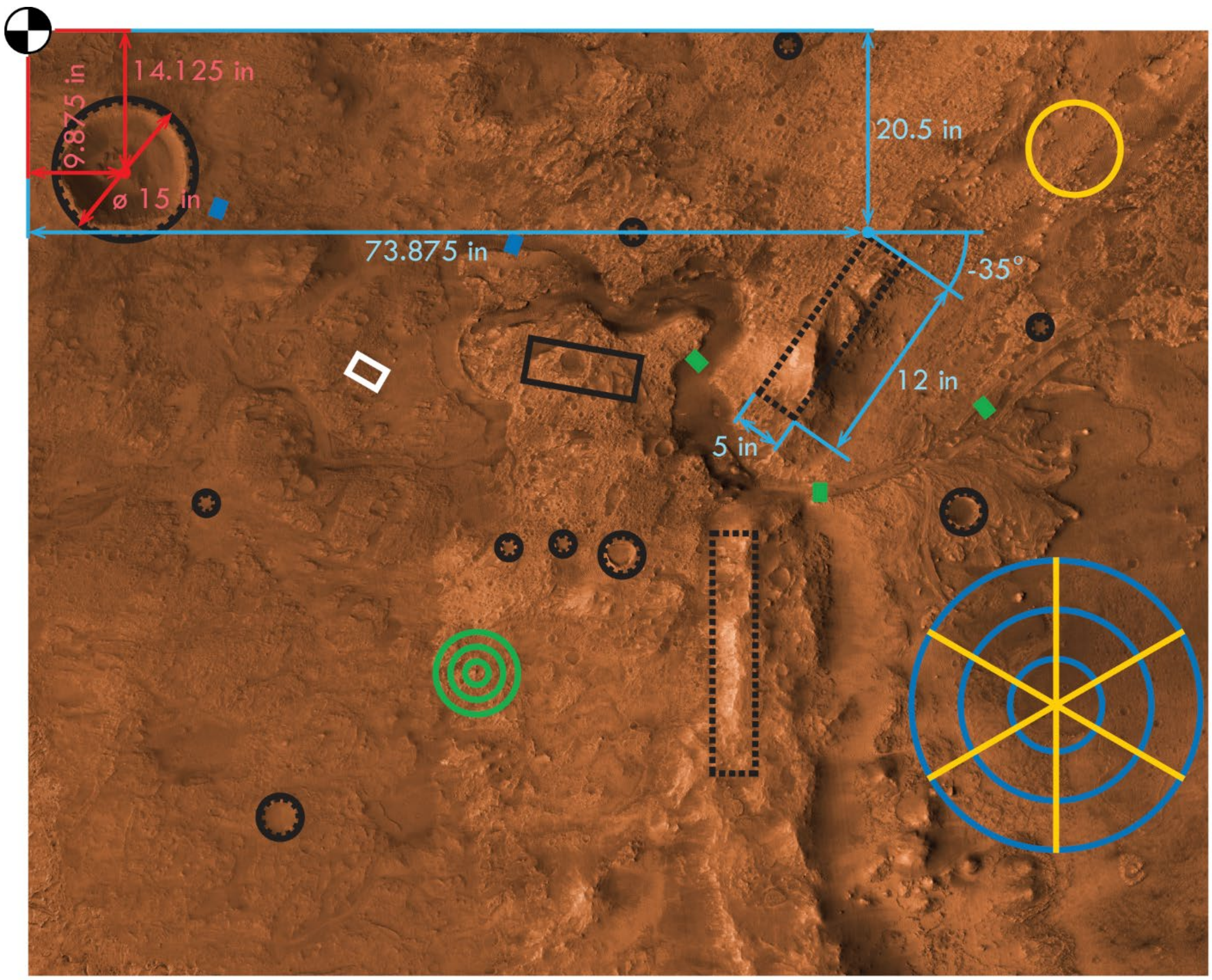

Figure 13: Challenge Mat with Example Measurements

Each feature is listed in the tables on the following pages with a center point location and outer diameter. All center points are measured from the top left corner of the mat, as marked with the circle with radial lines in *Figure 13*, with the x-axis along the horizontal edge and the y-axis along the vertical edge closest to the landing zone. All diameters are the outer diameter of the feature, with a 0.625 in (1.6 cm) thick line inside the given diameter or rectangular dimensions.

5.3.1 Landing Zone, Drop Zone, and Communication Dish

The table below lists the location measurements of the landing zone and drop zone circles and the landing zone radials.

Color	Feature Name	Inches		Centimeters	
		Center (x, y)	Diameter	Center (x, y)	Diameter
Blue	Landing Zone 1	104.5, 68.5	10	265.4, 174.0	25.4
Blue	Landing Zone 2	104.5, 68.5	20	265.4, 174.0	50.8
Blue	Landing Zone 3	104.5, 68.5	30	265.4, 174.0	76.2
Yellow	Landing Zone Radials	Start at center and extend to the outside edge of Landing Zone 3. Radials are 60° apart, starting parallel to the y-axis.			
Green	Drop Zone Circle 1	45.625, 65.25	3	115.9, 165.7	7.6
Green	Drop Zone Circle 2	45.625, 65.25	6	115.9, 165.7	15.2
Green	Drop Zone Circle 3	45.625, 65.25	9	115.9, 165.7	22.9
Yellow	Communication Dish Circle	106.375, 12	10	270.2, 30.5	25.4

5.3.2 Craters

All craters have a black outline. In order to make them more noticeable, craters also have additional shaping on the inside. This effect was created on the computer by putting a dashed circle just inside the solid circle, each of 0.625 in (1.6 cm) thickness.

Color	Feature	Inches		Centimeters	
		Center (x, y)	Diameter	Center (x, y)	Diameter
Black	Crater 1	77.25, 1.5	3	196.2, 3.8	7.6
Black	Crater 2	9.875, 14.125	15	25.1, 35.9	38.1
Black	Crater 3	61.5, 20.5	3	156.2, 52.1	7.6
Black	Crater 4	102.875, 30.125	3	261.3, 76.5	7.6
Black	Crater 5	18.125, 48	3	46, 121.9	7.6
Black	Crater 6	95.125, 48.875	5	241.6, 124.1	12.7
Black	Crater 7	54.375, 52.125	3	138.1, 132.4	7.6
Black	Crater 8	48.875, 52.5	3	124.1, 133.4	7.6
Black	Crater 9	60.375, 53.25	5	153.4, 135.3	12.7
Black	Crater 10	25.675, 79.875	5	65.2, 202.9	12.7

5.3.3 Crater 2

Crater 2 is a 3D feature on the mat contained within the black circle. The crater can be made with two paper or vinyl arcs using the pattern and dimensions shown in *Figure 14*. Cut out the arcs and bend them around to make cone sections and attached them to the triangular supports, shown in *Figure 15*, as shown in *Figure 16*. The official mats will use four 3D-printed triangular supports with Velcro tape to attach the vinyl surfaces to the supports and attach the supports to mat. A full size template of the 3D supports can be found in Appendix C: Mat Support Templates.

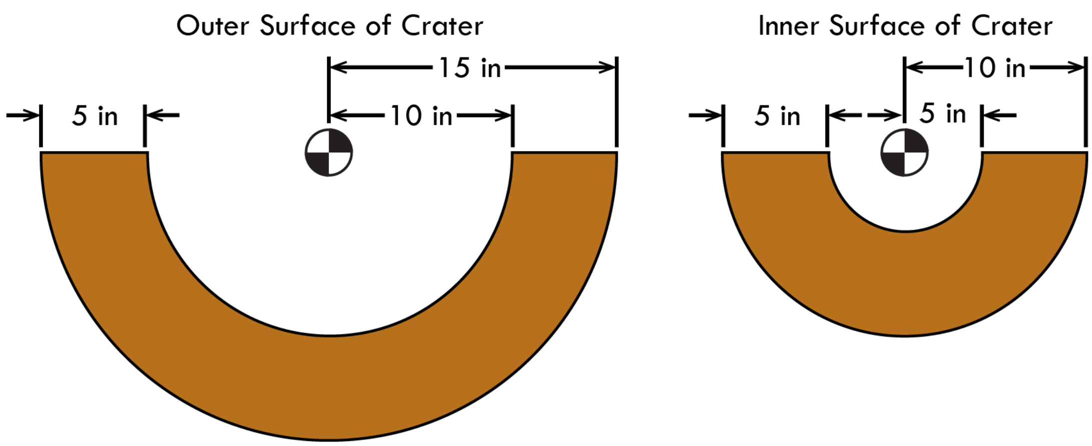

Figure 14: Crater 2 Surface Template

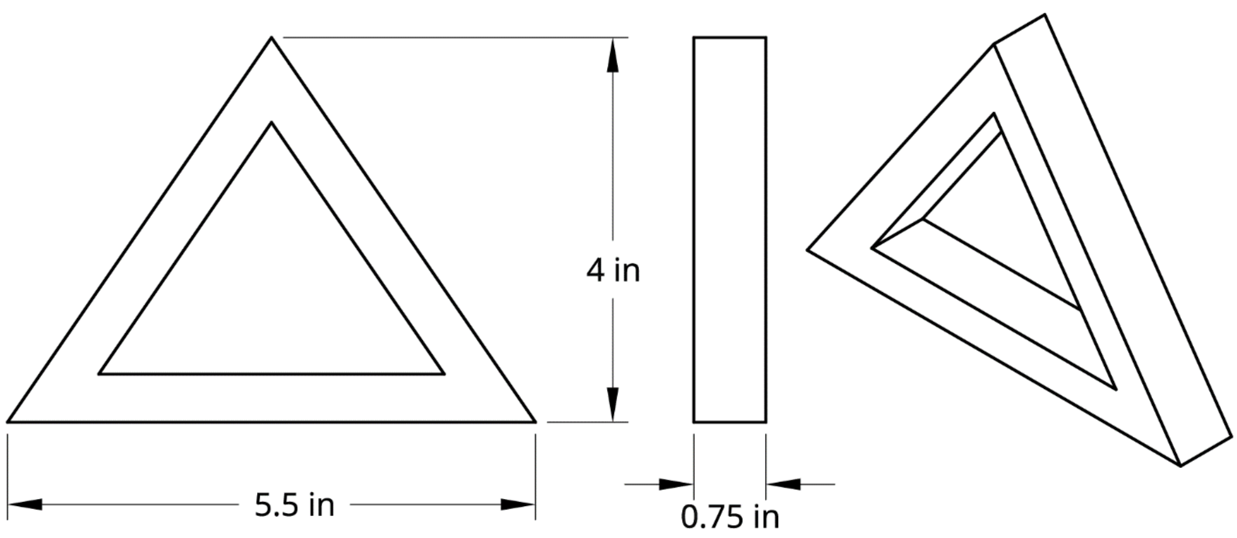

Figure 15: Crater 2 Triangular Support

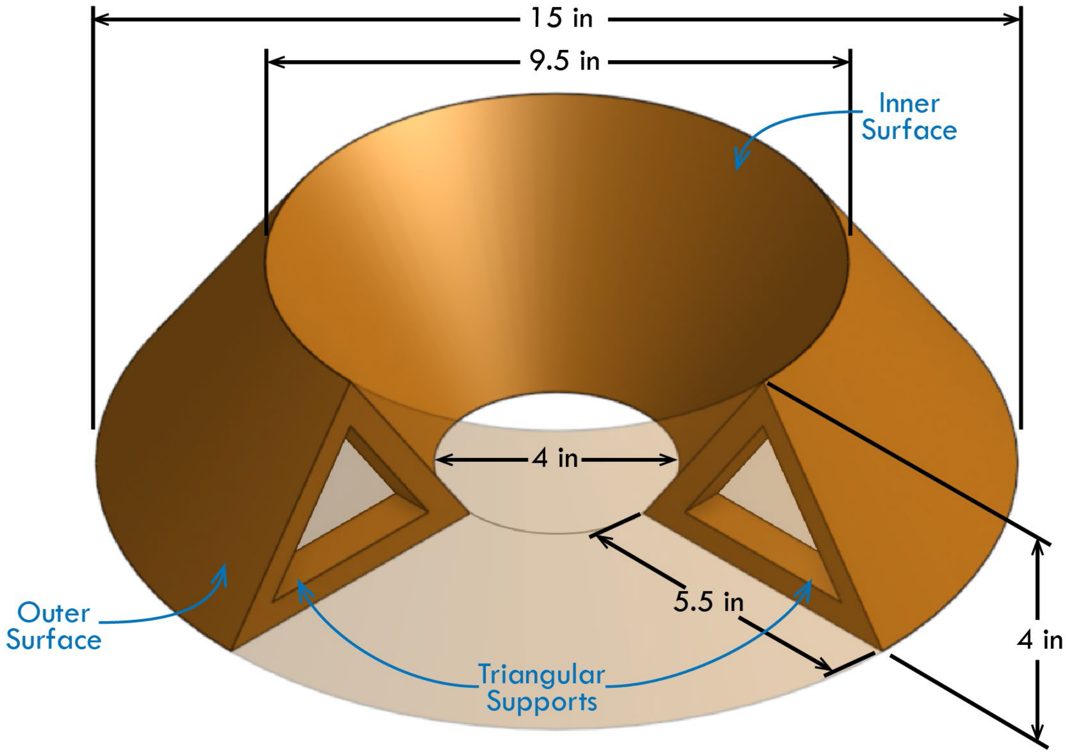

Figure 16: Crater 2 Assembly Cutaway

5.3.4 Ridges and the Cliff Face

The coordinates below are for the top left corner of the ridges and cliff face placement boxes on the mat. Each box is given with width (x-direction) and height (y-direction) dimensions, then rotated around the top left corner by the angle given, with counterclockwise being the positive direction. For clarification, this is illustrated by the north ridge in *Figure 13*. The official mats will use three 3D-printed supports in each ridge and two 3D-printed supports for each cliff face, with Velcro tape to attach the vinyl surfaces to the supports and attach the supports to mat. A full size template of the 3D supports can be found in Appendix C: Mat Support Templates.

Color	Feature	Location of Top Left Corner (x, y) (in)	(cm)	X Length (in)	Y Length	X Length (cm)	Y Length	Angle of rotation (deg)
Black	North Ridge	73.875, 20.5	187.6, 52.1	5	12	12.7	30.5	-35
Black	South Ridge	69.25, 50.75	175.9, 128.9	5	25	12.7	63.5	0
Black	Cliff Face	50, 30.75	127.0, 78.4	12	5	30.5	12.7	-10
White	Sample Area	32, 32.5	81.3, 82.55	4	2.75	10.0	7.0	-25

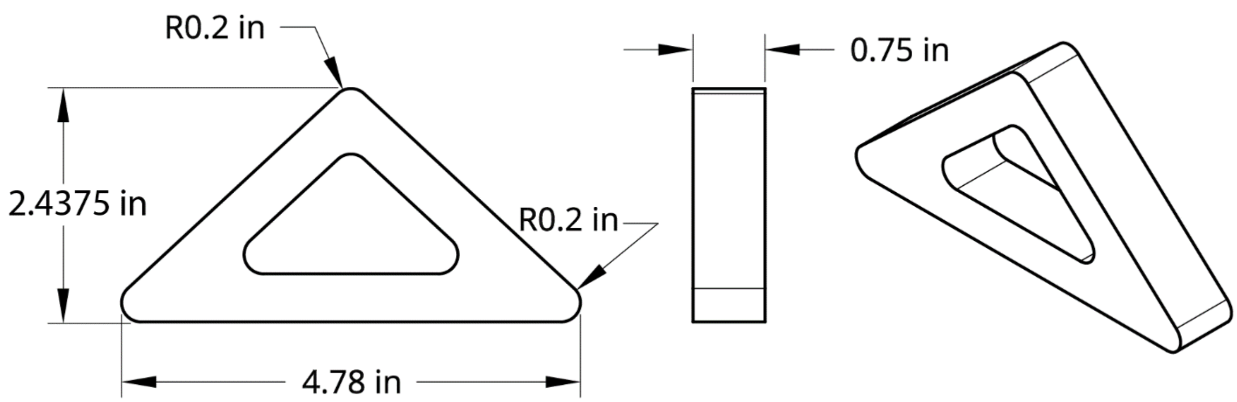

Figure 17: Ridge Triangular Support

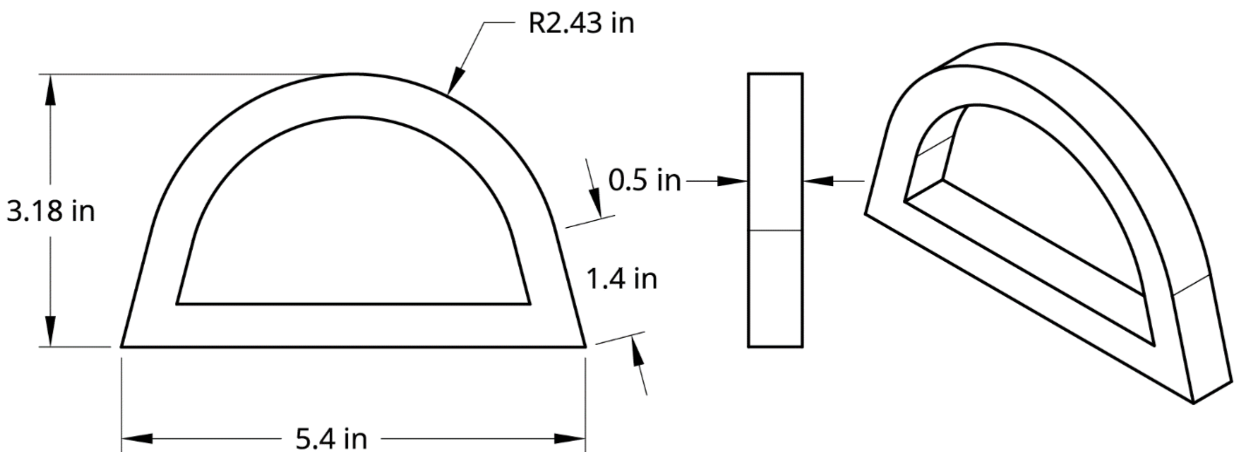

Figure 18: Cliff Face Support

5.3.5 LEGO Sample

The coordinates below are for the top left corner of the LEGO Sample placement boxes on the mat. Each box is 1.5 in (3.8 cm) wide (x-direction) by 2 in (5.1 cm) tall (y-direction), then rotated around the top left corner by the angle given, with counterclockwise being the positive direction. For clarification, this is illustrated by the north ridge in *Figure 13*. The precise sample location is shown by the black dashed line inset 0.25 in (0.6 cm) inside the green or blue box.

Color	Feature	Location of Top Left Corner (x, y)		Angle of rotation (deg)
		Inches	Centimeters	
Green	Sample 1	96, 38	243.8, 96.5	40
Green	Sample 2	79.25, 45.875	201.3, 116.5	0
Green	Sample 3	66.75, 33.375	169.5, 84.8	45
Blue	Sample 4	49, 20.5	124.5, 52.1	-20
Blue	Sample 5	19, 16.875	48.3, 42.9	-20

5.3.6 Regolith Sample

The coordinates below are for the top left corner of the Regolith Sample placement box on the mat. The box is given with width (x-direction) and height (y-direction) dimensions, then rotated around the top left corner by the angle given, with counterclockwise being the positive direction. For clarification, this is illustrated by the north ridge in *Figure 13*. The Regolith Sample will be in a plastic container, shown in *Figure 19*. The container is 5 in long, 3.875 in wide, and 2 in tall.

Color	Feature	Location of Top Left Corner (x, y)		X Length	Y Length	X Length	Y Length	Angle of rotation
		(in)	(cm)	(in)		(cm)		(deg)
White	Regolith Sample	32, 32.5	81.3, 82.6	4	2.75	10.2	7	-30

Figure 19: Regolith Sample Container

5.3.7 Color Specifications

Color	RGB	CMYK
White	255, 255, 255	0, 100, 100, 0
Black	35, 31, 32	70, 67, 64, 74
Blue	0, 116, 189	100, 47, 0, 0
Yellow	255, 205, 3	0, 18, 100, 0
Green	0, 172, 77	88, 0, 100, 0

5.4 Mission Objectives

All space missions have several objectives, some of which need significant amounts of training and some of which are riskier than others. Mission control, therefore, has to make decisions about which objectives should be attempted and which objectives should be considered too risky. In this part of the manual we list the overall objectives so that the team may decide which objectives can best be completed. Teams will have 10 minutes to complete the Challenge. Teams should allocate time to complete as many objectives as possible, but may find that they prefer to forego others. There are no deductions for not achieving an objective.

Unlike the ANGLeS Challenge, the ROADS Challenge will limit the number of commands sent to the rover to 6 (not including the first command).

5.4.1 Required Mission Objectives Prior to Challenge Event

MO1 Landing System (All Divisions)

Build a landing system that can be flown on a Force 1 Blue Heron Drone. A team's Mars Lander, for example, could be a lightweight model of your own Mars rover (LEGO Mindstorms), or any one of the Mars Landers such as in *Figure 20*. We encourage you to put your personal touch on your Mars Lander! The only maximum weight of your Mars Lander is determined by how much your drone can carry. Teams are encouraged to determine the carrying capacity through experimentation.

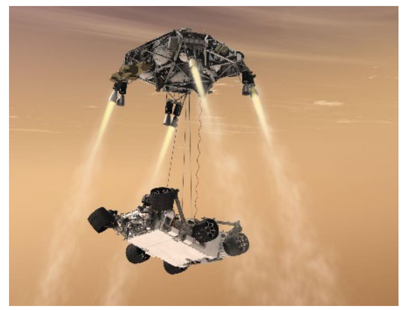

Figure 20: Artist Rendering of Curiosity's Sky Crane System

MO2 Communication Dish Design (All Divisions)

Design, build, and assemble a communication dish (similar to *Figure 21*) with the base able to fit within the yellow circle (top right corner of challenge mat). The satellite dish must:

- Have at least ten components (tape, adhesives, string do not count toward your ten components);
- Have at least one round component that fits within a square component (in recognition of the problem faced during the Apollo 13 mission);
- Be free standing when built;
- Be no larger than a 12-inch diameter or maximum length;
- Be designed to represent the team's community.

Figure 21: Deep Space Communication Dish

Once you have successfully assembled your dish and are confident in your process, disassemble it and bring it to the challenge event. In the spirit of Apollo 13, this dish must be put together live during the challenge.

5.4.2 Required Mission Objectives During the Challenge Event

MO3 Flying to Mars (Spirit, Opportunity, Curiosity Divisions)

Fly the UAV and model landing system to Mars and complete at least one orbit around the planet. As shown schematically in *Figure 22*, Mars will be on a 3-foot tall post and to the side of the challenge mat. Mars will be 16 inches in diameter.

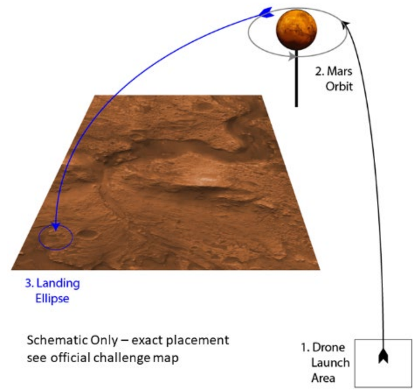

Figure 22: Approximate placement of Mars

MO4 Assemble Communication Dish (All Divisions)

Upon arrival of the drone at Mars, the team will assemble the satellite dish, which must be self-supporting. Teams can practice building the dish before the Challenge but must assemble the dish in real time during the Challenge. Your UAV must remain in orbit around Mars while the team is assembling the dish.

MO5 Entry, Descent, and Landing (Spirit, Opportunity, Curiosity Divisions)

Only after completion of the communications dish will the team be allowed to attempt to place the lander on the surface of Mars in the specified blue Landing Zone circles using their Landing system.

Entry, Descent, and Landing (Sojourner Division)

Teams in the Sojourner Division can fly directly from the launch area to the Landing Zone. After landing, the team will then place the communication dish in the specified area.

MO6 Surface Navigation (Spirit Division)

Spirit Division teams will use Ozobots as their rover for surface exploration. Teams should creatively modify the cover of the Ozobot to resemble a Mars Rover. Before the event, each Spirit Division team will need to create their own paper overlay to guide their rover. The team will draw lines and Ozobot codes on the overlay that will guide the rover through completing the other Mission Objectives. Teams will need to bring their completed overlay to the Challenge Event and will lay out on the official mat before starting MO3.

The overlay should at least cover from the center of the Landing Zone, where the rover will start, through all of the LEGO Sample location, the green Drop Zone circles on the mat. It must fit between the raised topological features of the mat and have cut outs for the LEGO Samples, craters, and Drop Zone on the Official Mat.

The rover will collect the LEGO Samples by driving up to them one at a time and then continuing on to its final destination, the Drop Zone. The rover needs to perform at least 6 Ozobot color code sequence commands during its journey, with at least 3 different commands.

MO7 Surface Navigation, LEGO Sample Collection, and Caching (Opportunity, Curiosity, Sojourner Divisions)

For all Divisions except for Spirit, a LEGO Mindstorms robot will be used as a rover to perform the exploration of the Mars surface. We encourage teams to develop the code in a series of subroutines that can be carried out independently. To simulate limited communications between Mars and the Earth, the team will only be allowed to transmit and run adjusted codes using the play buttons (as seen in *Figure 23*) in the software up to 6 times. Teams that are not using the LEGO Mindstorms software will determine the equivalent with the judge on the day of the challenge before selecting the startup command.

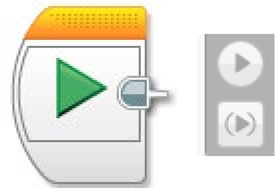

Figure 23 Lego Mindstorms software play buttons

The rover will be started at the center of the blue landing zone circles and can be pointed in any direction that the team desires. It will need to traverse the mat collecting as many LEGO Samples (located on the green and blue rectangles) as possible and drop them off at the caching site (green circles). For a rover to collect a LEGO Sample, the rover must have full control of the LEGO Sample either by picking up, pushing, pulling, or dragging. Judges will determine if a rover is in full control of LEGO Sample. Both LEGO sample types, blue and green, can be collected for points (*Figure 11*). The two blue LEGO Samples are worth more points than the three green LEGO samples.

The rover will be deducted points for crossing into or over any craters or going out of bounds (the white border of the Challenge Mat). Crossing into a crater or going out of bounds is defined as any part of the rover that normally touches the ground, such as a wheel or leg, or any part of the rover contained within that area crossing over a black crater boundary circle marking or the white border of the mat. Safe and unsafe behavior around craters is shown in *Figure 24: Be Safe Around Craters*.

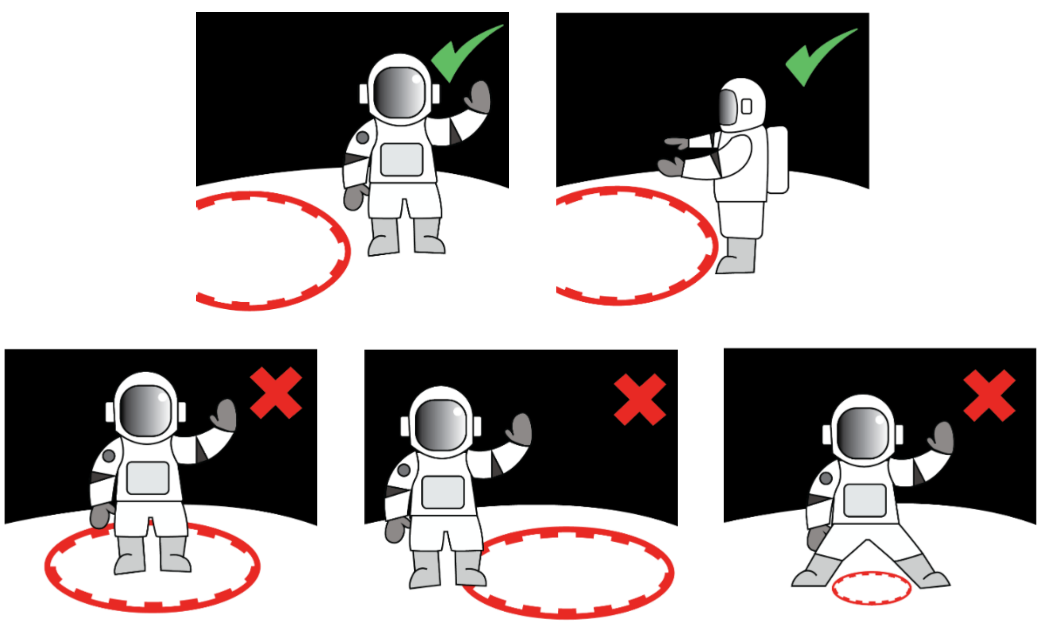

Figure 24: Be Safe Around Craters

MO8 Probing the Surface (Opportunity, Sojourner Divisions)

The rover needs to drive to the white rectangle and insert or place a LEGO piece simulating a probe into a Regolith Sample located at the white rectangle.

Probing the Surface (Curiosity Division)

Teams in the Curiosity Division will also have the rover navigate to the white rectangle. However, they will use a Vernier Soil Moisture Sensor to determine whether the soil has a significant water content or not. A video on how to use the probe is available at the Challenge website.

MO9 Methane Detection (All Divisions)

After the rover has collected its first LEGO Sample, a team member will be given a combustible gas detector and mystery sample by the officiating judges and the team will determine whether the sample is a source of combustible gas or not using the combustible gas detector.

MO10 Organic or Inorganic? (Spirit, Opportunity, Curiosity Divisions)

After the rover has collected a second LEGO sample, the team will be given microscope slide(s) and allowed access to a digital microscope to determine if the sample(s) are organic or inorganic in origin. Sample slides will posted on the Challenge website in early 2020.

MO11 Crater Exploration (Curiosity Division)

Fly a mini-drone carried by the LEGO Mindstorms robot into the center of the large 3D crater. Use the mini-drone camera to take a photo of the inside wall of the crater and return it to the LEGO robot. The mini drone is not required to enter the crater. It is okay to hover above to obtain the photo.

Appendix A: FAA UAV Information

This section is to provide some clarification on the FAA regulations regarding UAVs and how these apply in ROADS and provide some tips on staying within the regulations. Keep in mind all official activities for ROADS will take place indoors and therefore any practice required should be able to take place indoors. The FAA regulations do not apply to indoor flight[5], but any and all outdoor flight is subject to FAA regulations and guidelines, even if it is over your own property[5].

The information contained here is taken and interpreted from the FAA website on Unmanned Aircraft Systems[6], FAA *Advisory Circular 107-2*[7], the FAA's *Memorandum: Educational Use of Unmanned Aircraft Systems (UAS)*[8], and conversations certified flight instructors and an FAA representative. The information in this document does not constitute legal advice and it is always recommended to get the most up to date information directly from the FAA website:

www.faa.gov/uas/

When referencing drone licenses and drone registration, there is often confusion between these terms and to what they apply. For clarity, the terms used by the FAA and in this document, are Remote Pilot Certificate (RPC), what some may refer to as a drone pilot license, and Unmanned Air System (UAS) Registration, which is a registration just for the drone. Both are governed under the FAA's Part 107 regulations for Small Unmanned Air Systems (SUAS), but the applicability of each is completely different and independent of the other.

Starting with the UAS Registration, any drone between 0.55 lb and 55 lb (250 g and 25 kg) needs to be registered with the FAA, whether it is used for "recreational, commercial, government, or other purposes."[9] Basically, any drone that weighs between 0.55 lb and 55 lb needs to be registered, regardless of the intended use or who is flying it.

The UAVs permitted to be used in ROADS, as discussed in Appendix B: Equipment, are required to weigh less than 0.55 lb (250 g). Therefore, the specified drones for the challenge do not need to be registered with the FAA.

The Remote Pilot Certificate (RPC) is required for anyone flying a small unmanned aircraft, unless for hobby or recreation, as stated in *Advisory Circular 107-2*[10]:

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5 FAA. Unmanned Aircraft Systems (UAS) Frequently Asked Questions, Registration. Retrieved in December 2018 from https://www.faa.gov/uas/faqs/#reghttps://www.faa.gov/uas/faqs/ - reg.

6 FAA. Unmanned Aircraft Systems. Retrieved in December 2018 from https://www.faa.gov/uas/.

7 FAA. *Advisory Circular 107-2*. Retrieved in December 2018 from https://www.faa.gov/uas/media/AC_107-2_AFS-1_Signed.pdf.

8 FAA. *Memorandum: Educational Use of Unmanned Aircraft Systems (UAS)*. Retrieved in December 2018 from https://www.faa.gov/uas/resources/uas_regulations_policy/media/Interpretation-Educational-Use-of-UAS.pdf.

9 FAA. FAADroneZone. Retrieved in December 2018 from https://faadronezone.faa.gov/#/.

10 FAA. *Advisory Circular 107-2*, 4.1 Applicability, p. 4-1. Retrieved in December 2018 from https://www.faa.gov/uas/media/AC_107-2_AFS-1_Signed.pdf

Applicability. This chapter provides guidance regarding the applicability of part 107 to civil small UA operations conducted within the NAS. However, part 107 does not apply to the following:

1. Model aircraft that are operated in accordance with part 101 subpart E, Model Aircraft), which applies to model aircraft meeting all of the following criteria:
   - The aircraft is flown strictly for hobby or recreational use;
   - The aircraft is operated in accordance with a community-based set of safety guidelines and within the programming of a nationwide community-based organization;
   - The aircraft is limited to not more than 55 pounds unless otherwise certified through a design, construction, inspection, flight test, and operational safety program administered by a community-based organization;
   - The aircraft is operated in a manner that does not interfere with and gives way to any manned aircraft;
   - When flown within 5 miles of an airport, the operator of the aircraft provides the airport operator and the airport air traffic control (ATC) tower (when an air traffic facility is located at the airport) with prior notice of the operation;
   - The aircraft is capable of sustained flight in the atmosphere; and
   - The aircraft is flown within Visual Line of Sight (VLOS) of the person operating the aircraft.
2. Operations conducted outside the United States;
3. Amateur rockets;
4. Moored balloons;
5. Unmanned free balloons;
6. Kites;
7. Public aircraft operations; and
8. Air carrier operations.

It is important to note that RPC applicability is given in regards to the <u>use</u> of the UAV and not whether the drone is a registered drone. Thus, an RPC is required for all non-hobby/recreation operation, regardless of whether the drone needs to be registered. The FAA clarifies hobby and recreation stating[11]:

> In the FAA's Interpretation… the FAA relied on the ordinary, dictionary definition of these terms. UAS use for hobby is a "pursuit outside one's regular occupation engaged in especially for relaxation." UAS use for recreation is "refreshment of strength and spirits after work; a means of refreshment or diversion."

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[11] FAA. Unmanned Aircraft Systems (UAS) Frequently Asked Questions, Flying for Fun Under the Special Rule for Model Aircraft. Retrieved in December 2018 from https://www.faa.gov/uas/faqs/#ffrhttps://www.faa.gov/uas/faqs/ - reg:

In regards to educational use, the FAA issued a memorandum[12] that covers many cases and can get confusing, but has a clear intention: the FAA does not want a person or business getting compensated for giving drone flight lessons without an RPC. Team members may fly UAVs for education purposes, with adults or staff present for safety, but no flight instruction should be given.

All outdoor UAV operation should always be conducted in accordance to FAA regulations[13]:

Part 107 Operating Rules

- Unmanned aircraft must weigh less than 55 pounds, including payload, at takeoff
- Fly in Class G airspace
- Keep the unmanned aircraft within visual line-of-sight
- Fly at or below 400 feet
- Fly during daylight or civil twilight
- Fly at or under 100 mph
- Yield right of way to manned aircraft
- Do not fly directly over people
- Do not fly from a moving vehicle, unless in a sparsely populated area

If Flight Directors or team members are interested in obtaining an RPC, the requirements are fairly simple[14]:

To become a pilot you must:

- Be at least 16 years old
- Be able to read, speak, write, and understand English (exceptions may be made if the person is unable to meet one of these requirements for a medical reason, such as hearing impairment)
- Be in a physical and mental condition to safely operate a small UAS
- Pass the initial aeronautical knowledge exam at an FAA-approved knowledge testing center

Pilot certificate Requirements

- Must be easily accessible by the remote pilot during all UAS operations
- Valid for 2 years — certificate holders must pass a recurrent knowledge test every two years

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[12] FAA. *Memorandum: Educational Use of Unmanned Aircraft Systems (UAS).* Retrieved in December 2018 from https://www.faa.gov/uas/resources/uas_regulations_policy/media/Interpretation-Educational-Use-of-UAS.pdf.

[13] FAA. Fly under the Small UAS Rule. Retrieved in December 2018 from https://www.faa.gov/uas/getting_started/part_107/

[14] FAA. Becoming a Pilot. Retrieved in December 2018 from https://www.faa.gov/uas/getting_started/part_107/remote_pilot_cert/.

Appendix B: Equipment

Delta Dynamics Model activity materials:

- PVC water valve (~ $2.50 at hardware store)
- Long plastic under bed storage bin (~ $10 at a general merchandise store)
- Gorilla Glue
- Sand (~$5 for 50 pounds at home improvement or gardening store)
- Small pebbles or vegetation
- Items to prop up stream table (e.g. blocks of wood, large books, etc.)
- Water pitchers or buckets
- Modern cell phone with time lapse feature in camera

Cratering activity materials:

- Flour
- Clear tubs or trays
- Small rocks (preferably smooth and rounded)
- Rulers
- Straw
- Water
- Food dye (optional)
- Colored sand (optional, can be made by adding food coloring to the sand and allowing sand to dry)
- Modern cell phone with slow motion feature in camera

Search for Life activity materials:

- Combustible gas detector ($27 on Amazon; see your Regional Hub Supplemental Manual for support options)
- Digital Microscope ($59 on Amazon; see your Regional Hub Supplemental Manual for support options)
- Map of the area studied (hand drawn or printed from Google Maps or other mapping service)
- Petri dishes (optional)
- Microscope (optional)
- Yeast (optional)
- Sugar (optional)
- Warm water (optional)
  Effervescent tablets (optional)

Drones:

- Force 1 Blue Heron (See nwessp.org/mars/ for information on ordering at NESSP's discounted price)
- Cheerwing CW10 Mini Drone ($30 on Amazon)

Robotics:

- Ozobot (Spirit Division) ($99)
- LEGO Mindstorms Robot (Opportunity, Curiosity, and Sojourner Divisions) ($411.95 Education Core Set + $31.95 Charger)
- Vernier Soil Moisture Sensor ($109)
- Vernier NXT Sensor Adapter ($39)

Mats:

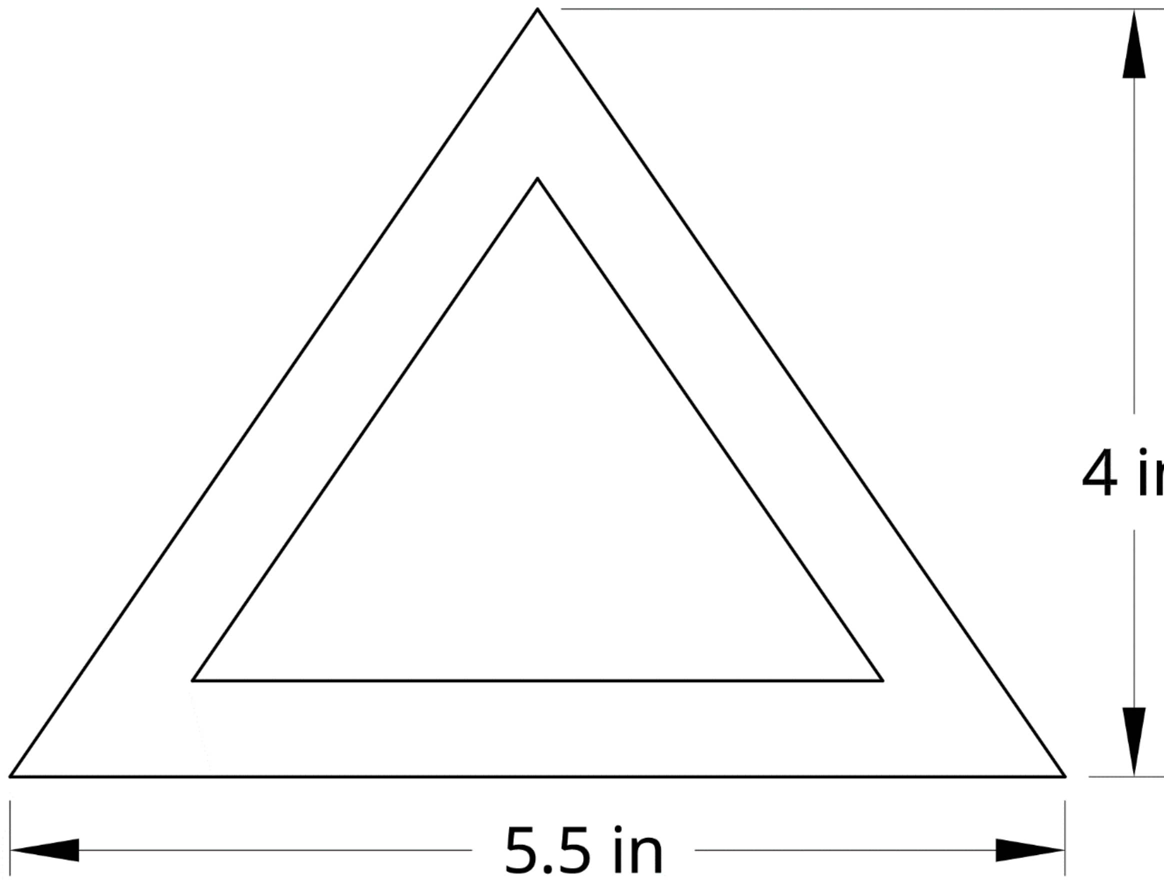
- Available from Seattle Design and Print in late autumn 2019 (See nwessp.org/mars/ for information on ordering)

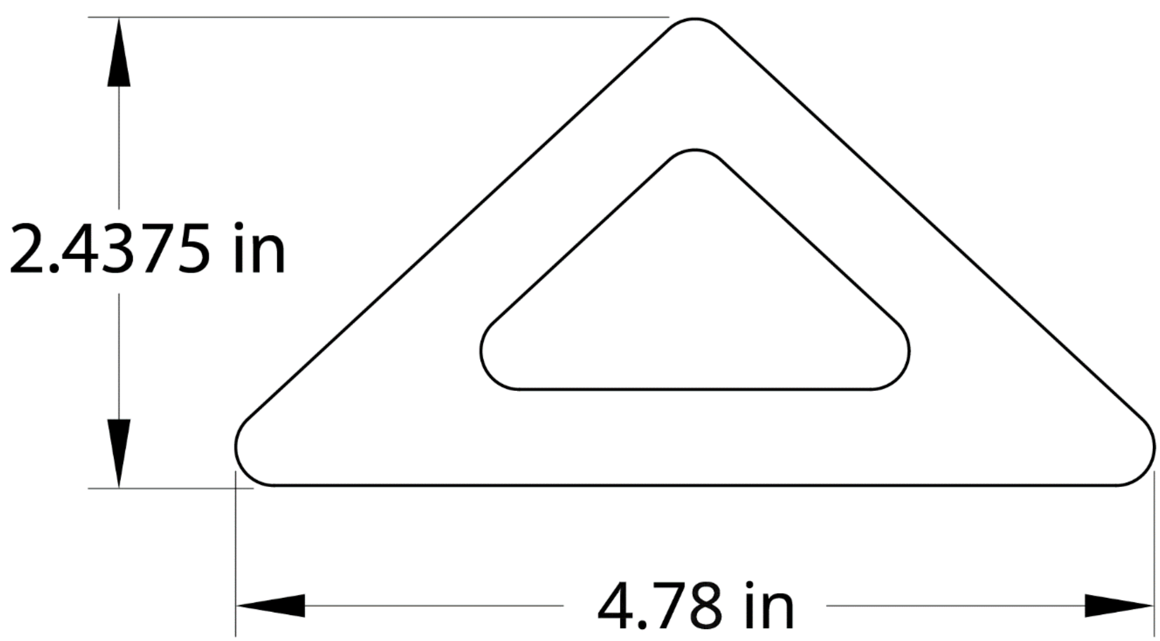
Prohibited Items:

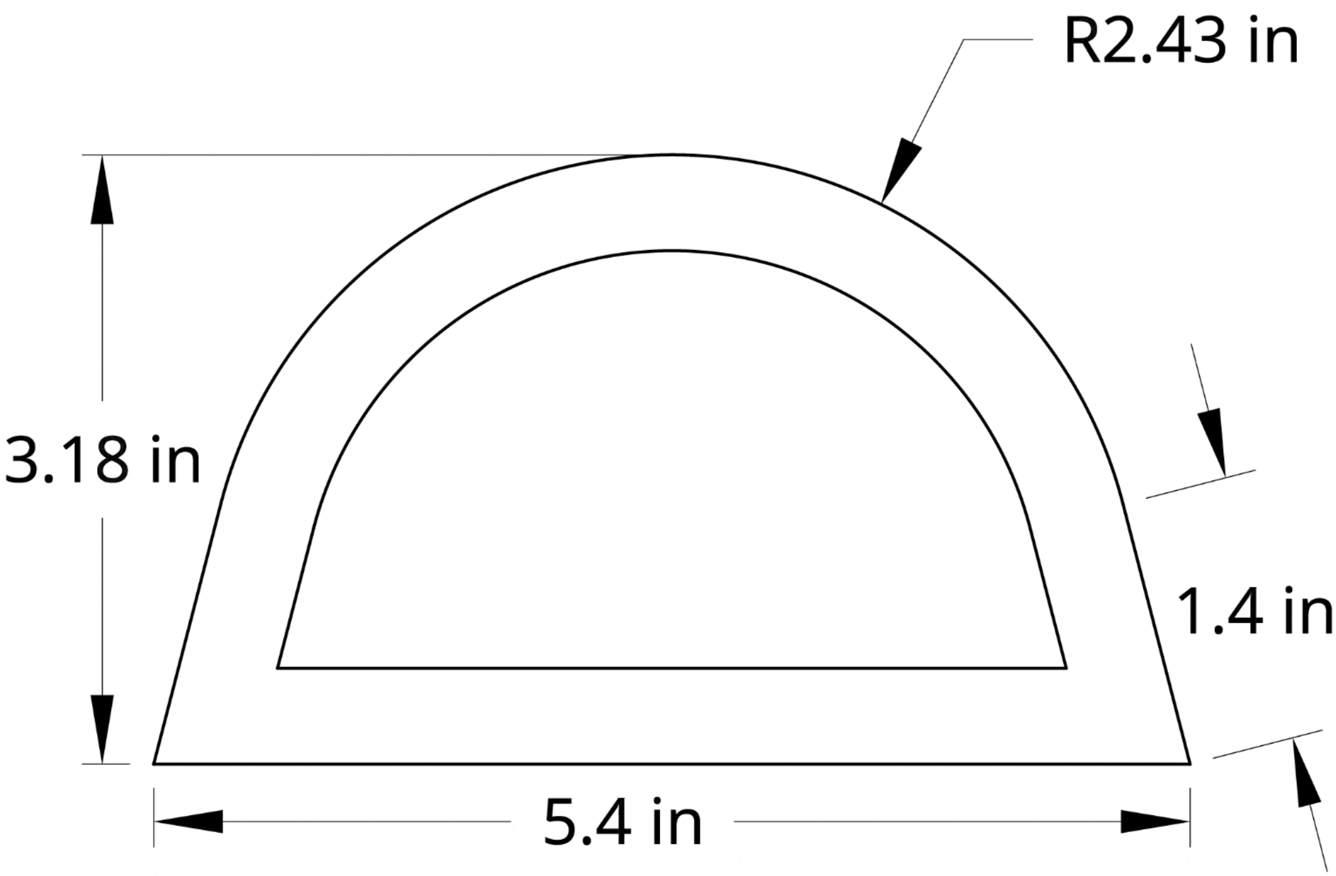
Teams may not use any of the following methods or materials during the challenge:

- Pyrotechnics or explosives
- No adhesives in contact with the challenge mat other than to secure the mat to the floor.
- Drones may not be modified in any way that increases flight performance characteristics.
- Any form of remote control or direct operator interface for the rover.

Appendix C: Mat Support Templates



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APPENDIX D: CHANGE LOG

Version 1.1

- Section 1.3.1: changed dates for:
  - Virtual meet a Mars Scientist (Jim Rice) from Nov 15 to Nov 19
  - School Year Registration Closes from Dec 15 to Dec 17
  - Environment Mini-Challenge Submissions Due from Dec 10 to Dec 20
  - Environment Mini-Challenge Awards Announced from Dec 15 to Jan 8
  - Virtual Meet a Mars Scientist (Briony Horgan) from Feb 5 to Dec 1
- Sections 4.1.2, 4.1.3, 4.2.1, and 4.2.2:
  - Changed from: "We also encourage teams to post videos" … "on social media (Instagram, Twitter, or Facebook)." to: "To be scored, teams must post a video" … "on social media (Instagram, Twitter, or Facebook) using the hashtags **#ROADSonMars** and **#Mars2020**."
- Appendix B: Equipment
  - Added "Cheerwing CW10 Mini Drone ($30 on Amazon)"
- Grammar, minor wording, and document error corrections

Version 1.2

- Changed all mentions of the "alluvial fan" to "delta". We had an initial error that was corrected by NASA Scientist Jim Rice. If you already started your projects and refer to the older term prior to this change, your submission won't lose any points.
- Changed all mentions of "erosion model", "erosion demo", "erosion experiment", "environment mini challenge", and "alluvial fan dynamics", to "Delta Dynamics Model" to reflect that all these terms were referring to the same part of the ROADS on Mars Challenge.
- Changed all mentions of "Search for Life mini-challenge" to "Search for Live Activity" to reflect that all these terms were referring to the same part of the ROADS on Mars Challenge.
- Sections 1.2 and 1.3.1: Changed date of Regional Hub events from "April 2020" to "Spring 2020"
- Section 4.1.1 added:

  The required sections of the MDL are:

  - Mission Patch Design
  - Team Attire Design
  - Social Media Plan
  - Delta Dynamics
  - Crater Formation
  - Methane Detection
  - Search for Small Invertebrates
  - Rover Design & Testing

- MO1 Landing System Design
- MO2 Communications Dish Design

The MDL Scoring Rubric is in the Educator Resources folder: nwessp.org/mars/resources

- Section 5.2: Updated to match Mission Objectives.
- Section 5.3.4: Added: "The official mats will use three 3D-printed supports in each ridge and two 3D-printed supports for each cliff face, with Velcro tape to attach the vinyl surfaces to the supports and attach the supports to mat."
- Section 5.4.1:
  - MO1: Added "The only maximum weight of your Mars Lander is determined by how much your drone can carry. Teams are encouraged to determine the carrying capacity through experimentation."
  - MO2: Changed: "Design a Communication Dish" to Communication Dish Design"
- Section 5.4.2:
  - MO6: added clarity to the requirements for this Mission Objective:

    Spirit Division teams will use Ozobots as their rover for surface exploration. Teams should creatively modify the cover of the Ozobot to resemble a Mars Rover. Before the event, each Spirit Division team will need to create their own paper overlay to guide their rover. The team will draw lines and Ozobot codes on the overlay that will guide the rover through completing the other Mission Objectives. Teams will need to bring their completed overlay to the Challenge Event and will lay out on the official mat before starting MO3.

    The overlay should at least cover from the center of the Landing Zone, where the rover will start, through all of the LEGO Sample location, the green Drop Zone circles on the mat. It must fit between the raised topological features of the mat and have cut outs for the LEGO Samples, craters, and Drop Zone on the Official Mat.

    The rover will collect the LEGO Samples by driving up to them one at a time and then continuing on to its final destination, the Drop Zone. The rover needs to perform at least 6 Ozobot color code sequence commands during its journey, with at least 3 different commands.
  - MO7:
    - Changed:

      The rover will be started at the center of the blue landing zone circles and can be pointed in any direction that the team desires. It will need to traverse the mat picking up as many LEGO Samples (located on the green and blue rectangles) as possible and drop them off at the caching site (green circles).

Both LEGO sample types, blue and green, are optional to collect for additional points (*Figure 11*) for the Opportunity, Curiosity, and Sojourner Division teams. LEGO Sample collection is required by Spirit Division teams (see MO6). No points will be deducted if samples are not collected. The two blue LEGO Samples are worth more points than the three green LEGO samples.

Be careful not to cross over craters, because each time the rover crosses a crater points will be deducted.

To:

The rover will be started at the center of the blue landing zone circles and can be pointed in any direction that the team desires. It will need to traverse the mat collecting as many LEGO Samples (located on the green and blue rectangles) as possible and drop them off at the caching site (green circles). For a rover to collect a LEGO Sample, the rover must have full control of the LEGO Sample either by picking up, pushing, pulling, or dragging. Judges will determine if a rover is in full control of LEGO Sample. Both LEGO sample types, blue and green, can be collected for points (*Figure 11*). The two blue LEGO Samples are worth more points than the three green LEGO samples.

The rover will be deducted points for crossing into or over any craters or going out of bounds (the white border of the Challenge Mat). Crossing into a crater or going out of bounds is defined as any part of the rover that normally touches the ground, such as a wheel or leg, or any part of the rover contained within that area crossing over a black crater boundary circle marking or the white border of the mat. Safe and unsafe behavior around craters is shown in *Figure 24: Be Safe Around Craters*.

- Added *Figure 24: Be Safe Around Craters*.

- MO8: removed "After dropping off the samples" and "after dropping off the samples at the caching point" (This may be done any time after starting MO7.)
- MO9: changed "After the rover has reached the Soil Sample site" to "After the rover has collected its first LEGO Sample"

- MO10: changed "After the rover has reached the second sample site" to "After the rover has collected a second LEGO sample"; changed name of Objective to Organic or Inorganic. grammar, minor wording, and document error corrections
- Changed mentions of "Soil Sample" to "Regolith Sample" throughout the manual