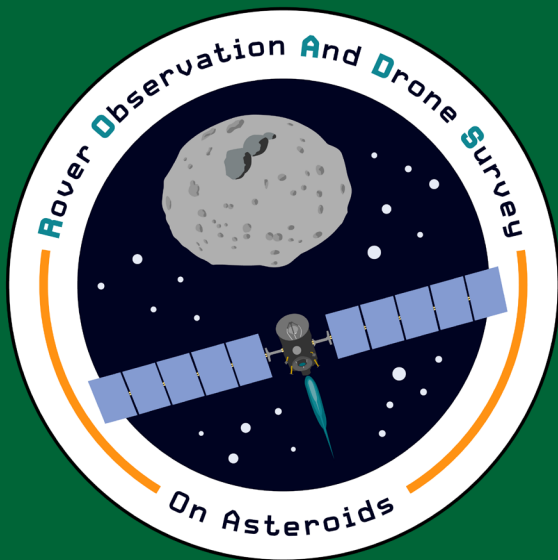


ROADS on Asteroids

Next Exits

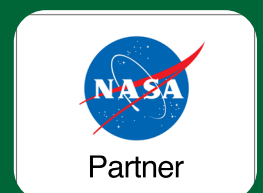
Ryugu	~35,502,827
Itokawa	~42,000,000
Didymos System	~120,987,239
Bennu	~327,700,000
Ceres	~425,857,334
Vesta	~445,613,352
Trojan Asteroids	~2,500,000,000



OFFICIAL MANUAL



2020-2021
STUDENT CHALLENGE



Our ROADS program (**R**over **O**bservation **A**nd **D**rone **S**urvey) is a framework that lets students explore STEM concepts through hands-on activities. ROADS takes inspiration from real NASA projects and guides students on a space-related mission.

Each year we update ROADS to tackle different science and engineering problems and to visit different solar system bodies. For 2020–2021 we're going to asteroids and comets!

WELCOME TO ROADS on Asteroids

FOR?

Teams of students in grades 3–12.

ACTIVITIES

- Creating mission documentation
- Take environmental readings — use gas detectors to locate CO₂ and methane
- Take biological samples and explore them with a microscope
- Use provided calculations to create your own map of an asteroid site
- Operate a drone to simulate space flight
- Robotics & programming — use a robot to navigate your map



STEM CONCEPTS

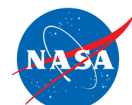
All activities align with Next Generation Science Standards (NGSS).

- Mission planning
- Interpret data from spacecraft
- Communications
- Earth sciences
- Taking samples
- Astrobiology/biology
- Robotics
- Programming
- Impacting a rocky object
- Planetary geology

HOW CAN I USE THIS "FRAMEWORK"?

There are many ways you can use ROADS on Asteroids with your students!

During the 2020–2021 academic year, while Asteroids is our active ROADS program, NESSP offers support ranging from loaner supplies to virtual TA sessions. We will also host virtual “Meet an Expert” meet-ups, giving students the chance to ask questions of experts working in space-related fields.



Partner

2020–2021 national student challenge!

Register your team with NESSP and complete the Mission Objectives at the same time as hundreds of other teams across the U.S. Top teams will win prizes! Challenge runs October 2020 – April 2021.

Course curriculum. Use the full set of the ROADS on Asteroids Companion Course units and lessons, or select just a few relevant to your curriculum. Registering for the 2020–2021 student challenge is encouraged but not required.

Summer program. ROADS activities also make great programs for summer camps. Support from NESSP will continue into summer 2021.

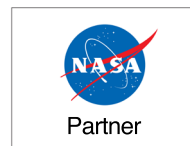
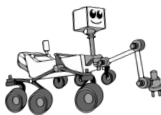
Are you reading this manual in the future? Even if it's not 2020–2021 any longer, you can still use these activities and the course curriculum to engage your students with STEM concepts! Support in the form of loaner supplies or TA sessions won't be available, but all reference material will remain on our website so you can use and adapt these ideas however you like.



TABLE OF CONTENTS



ROAD(S)MAP	i
ABOUT NESSP	1-2
ABOUT ROADS	3-4
ABOUT ROADS ON ASTEROIDS	5-39
PROFESSIONAL DEVELOPMENT	6
SUMMER CAMPS	7
COURSE CURRICULUM	8-9
2020-2021 NATIONAL STUDENT CHALLENGE	10-39
GENERAL INFORMATION	10-13
SCHEDULE	14
MISSION OBJECTIVES (MOs)	15-39
OVERVIEW	15-16
MO-01: MISSION DEVELOPMENT LOG (MDL)	18
MO-02: CRATER FORMATION AND EVOLUTION [CHECKPOINT CHALLENGE #1] ...	19-20
MO-03: SEARCH FOR SIGNS OF LIFE [CHECKPOINT CHALLENGE #2]	21-24
MO-04: TEAM MISSION PATCH [CHECKPOINT CHALLENGE #3]	25
MAP MAKING, DRONE, AND ROBOTIC MISSION OBJECTIVES	26
MO-05: MAKE YOUR MAP	27-33
MO-06: DRONE / SATELLITE FLIGHT	34
MO-07: IMPACTOR DROP AND SATELLITE LANDING	35-36
MO-08: MAP NAVIGATION	37-38
MO-09: EXPANDED MAP NAVIGATION (DART DIVISION / HIGH SCHOOL ONLY) ...	39
APPENDICES	I-XII
APPENDIX A: WHY ASTEROIDS?	I-VI
APPENDIX B: SUPPLIES	VII
APPENDIX C: DRONE SAFETY & FAA REGULATIONS	VIII-XII



ABOUT NESSP



The Northwest Earth and Space Sciences Pipeline (NESSP) is a K-12 education collaborative that brings NASA science to the northwest. Funded through NASA's Science Mission Directorate, NESSP (pronounced "nespy") is located at the University of Washington in Seattle where the program is led by staff from the Washington NASA Space Grant Consortium.

In the northwest, NESSP operates through a network of partners from Oregon and Washington inland to Montana and the Dakotas. Our goals are to strengthen science, technology, engineering, and math (STEM) education regionwide and to serve as a bridge into other NASA experiences for educators and students.

NESSP's programming is available to communities across the northwest region. We especially welcome relationships with educators from underserved and underrepresented communities to cocreate STEM exploration opportunities.

Through our ROADS national student challenges, we also offer our programming to students and educators across the United States.

CONTACT US

nwessp@uw.edu
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University of Washington
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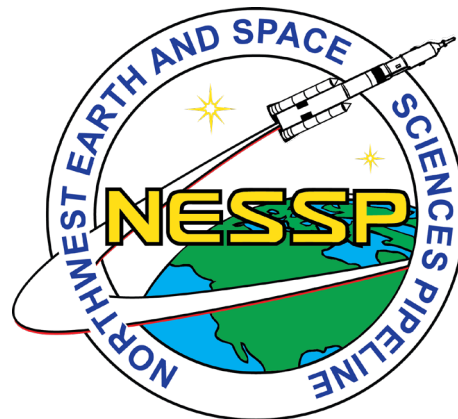
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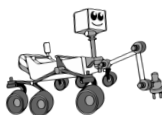
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Christine Dien

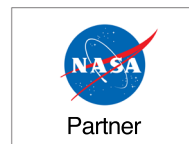


ROADS on Asteroids

Official Manual | Page 1



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ABOUT NESSP



OUR PROGRAMS

OUTREACH EVENTS in local communities, bringing hands-on STEM activities to students in schools, afterschool, or youth programs. Our outreach programs are provided by three of our partners, covering regions in Washington state and Oregon.

SUMMER CAMPS and other extended experiences, offering support to educator-led immersive student experiences across the northwest region.

COURSE CURRICULUM offering a companion course for educators to integrate concepts from our national challenges into their classroom program. Educators can adapt the five-unit curriculum and lesson plans to suit their needs. Our course curriculum program also offers sessions with an undergraduate teaching assistant to provide virtual instruction with hands-on experimentation. Equipment support is also available as supplies allow.

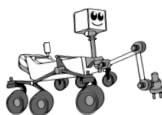
PROFESSIONAL DEVELOPMENT for teachers, organizers, and other science educators, ranging from just one day to an entire week.

NATIONAL STUDENT CHALLENGES offering our STEM education expertise to educators and students across the United States. Challenges center around a specific scientific topic or NASA mission and create opportunities for educators to participate in NESSP-provided professional development and for students to work together in teams to tackle STEM topics. Top teams in past challenges have earned visits to NASA centers such as Johnson Space Center, Goddard Space Flight Center, Kennedy Space Center, Ames Research Center, and the Jet Propulsion Lab.

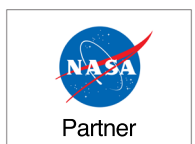


ROADS on Asteroids

Official Manual | Page 2



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Rover Observation And Drone Survey

NESSP has been directing nationwide student challenges for NASA since 2018. Starting with the ANGLEs Challenge, which celebrated the 50th anniversary of the Apollo 11 moon landing, we have been working our way across the solar system using ROADS — **R**over **O**bservation **A**nd **D**rone **S**urvey.

Our student challenges use ongoing NASA science missions as inspiration for hands-on experiences in science, engineering, and technology. The goal is to help students gain a better understanding of the interplay between the science they're learning in class, exploration of the solar system, and possible next steps toward careers in STEM.

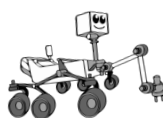


Since our first, moonshot challenge, the ROADS concept has evolved from focusing on a single challenge event to encompassing many ways of engaging students with STEM concepts. Our ROADS framework now incorporates our course curriculum and summer camp programs as well. We also offer ROADS on Asteroids training to educators through our professional development program.

IN THIS MANUAL

This manual will give you quick introductions to our ROADS on Asteroids professional development, summer camp, and curriculum programs. More information on each of these is available on our website: nwessp.org

(Continues ►►►)



ABOUT ROADS



OVERVIEW

IN THIS MANUAL (CONT'D)

The bulk of the manual provides the information a team will need to participate in NESSP's 2020–2021 National Student Challenge — all the dates and deadlines, details on each Mission Objective, and a list of relevant supplies.

GETTING ON THE ROAD(S)

Educators are welcome to use any aspect of the ROADS on Asteroids challenge and curriculum that meets your needs —

- whether you're using the full companion course curriculum or just one or two units or lessons;
- whether you're officially registering a team for the 2020–2021 student challenge or just using the activities to guide your Scouts in completing badge requirements;
- whether you're preparing a summer program or just looking for activities to help keep your own kids engaged during a time when school is virtual and hands-on activities are hard to come by.

ROADS on Asteroids offers immersive opportunities for students in ELA, communications, geology (including planetary aspects), biology (including life in extreme environments), physics, robotics and programming).

PHONE HOME

Think of NESSP as your Mission Control while you're on the ROAD(S). Whether you and your team are embarking on completing all the Mission Objectives of ROADS on Asteroids for the national student challenge or you're using just one of our curriculum units in your classroom, we're here to provide support. Visit our website for resources and to register your ROADS activity. If you have specific questions, drop us an email.

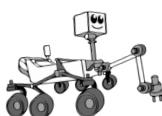
- nwessp.org
- nwessp@uw.edu

Stay safe, keep your rovers at the ready, and above all — have fun!

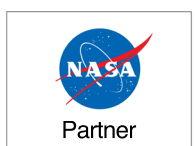


ROADS on Asteroids

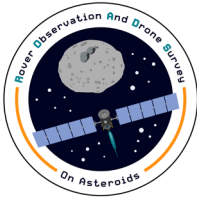
Official Manual | Page 4



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ABOUT ROADS on Asteroids



THE MISSION

THE ROADS ON ASTEROIDS MISSION

Teams will plan and simulate a mission to the “snowman” feature on the asteroid Vesta (see Figure 1.1). The mission will include an impactor from height onto the surface, drone landing and takeoff, and robotic navigation across potentially hazardous surfaces to look for the building blocks for life.

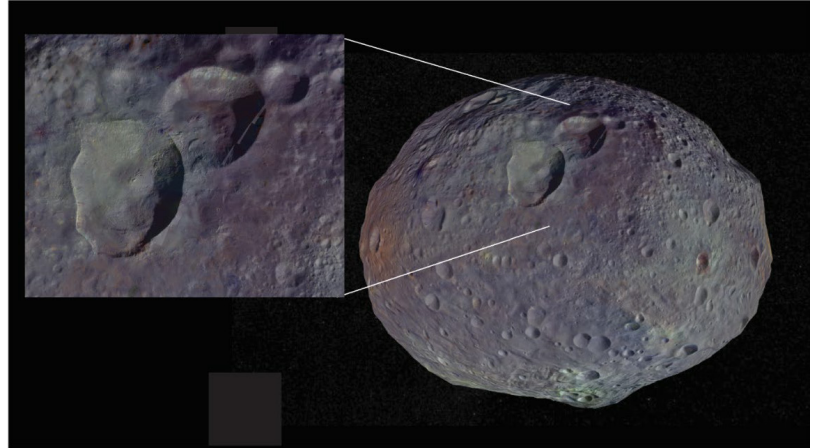


Figure 1.1: The craters on Vesta that form the snowman feature.

RELEVANT NASA MISSIONS

ROADS on Asteroids focuses on developing and executing a mission to the asteroids — specifically to Vesta in the asteroid belt. Each Mission Objective is designed to involve students in NASA science mission design and execution. ROADS on Asteroids is also aligned with Next Generation Science Standards, creating a fun, hands-on activity that helps students meet many NGSS requirements and thereby helps them to be more successful in their studies.

ROADS on Asteroids takes elements from four current or future NASA missions. Images for these spacecraft images are shown in Figure 1.2.

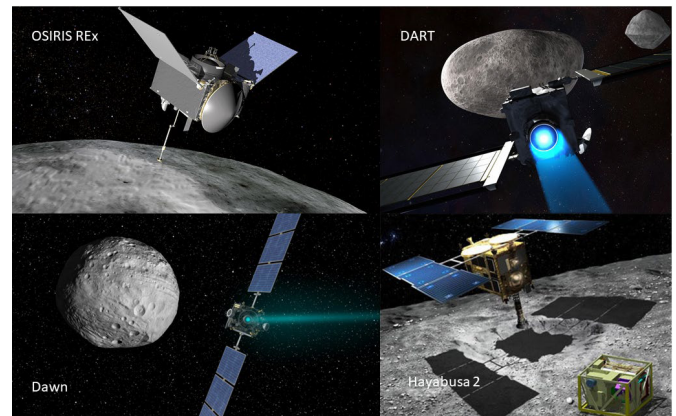
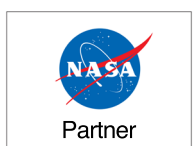
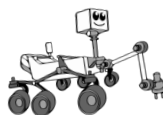


Figure 1.2: Current missions (OSIRIS REx, Dawn, Hayabusa 2) and DART to be launched in 2021.

1. Dawn (mission to Vesta and Ceres)
2. Hayabusa 2 (mission to Ryugu) ► [Explore the surface of Ryugu](#)
3. OSIRIS REx (mission to Bennu) ► [Explore the surface of Bennu](#)
4. DART (mission to Didymos)

Images from Dawn will be used for mission planning and to explore how scientists interpret data from spacecraft to create maps and to understand processes that have occurred (topics: communications, Earth sciences). Concepts from Hayabusa 2 and OSIRIS REx will be used to investigate the importance of taking local samples, how to interpret the data, and what the data means for both the search for the building blocks of life and robotic exploration (topics: astrobiology/biology, robotics, programming). Finally, from the Hayabusa 2 and DART missions, the challenge will incorporate the principles involved in impacting a rocky object (topic: planetary geology). Complete details on each Mission Objective are found later in the manual.



ABOUT ROADS on Asteroids



PROFESSIONAL DEVELOPMENT

During the 2020–2021 academic year, while Asteroids is our active ROADS framework, NESSP’s usual programming is offered with a ROADS on Asteroids focus — encompassing our professional development, summer camps, course curriculum, and annual student challenge. The next few pages introduce how each of these programs fits into the ROADS on Asteroids year.

Educators who register their 2020–2021 ROADS on Asteroids program with NESSP may be eligible to receive support such as equipment lending or undergraduate TA sessions. You can register the following:

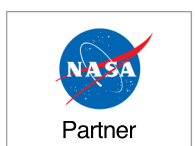
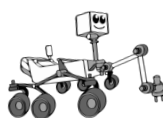
- National student challenge team
- Companion course curriculum usage
- Summer program challenge team

PROFESSIONAL DEVELOPMENT

ROADS on Asteroids training for teachers, organizers, and other science educators, was offered August–November 2020.

MORE INFORMATION

- NESSP’s profesional development program: nwessp.org/programs/pd/
- To be added to our announcement list for future trainings, email nwessp@uw.edu.



ABOUT ROADS on Asteroids



SUMMER CAMPS

SUMMER CAMPS

Our ROADS challenges are most commonly run as school-year activities, but they can also work well as part of a summer camp program.

Summer camp programs who register their activities with NESSP will be eligible for possible equipment support (as supplies allow). Information on summer camps and registration will be available on our website: nwessp.org/asteroids.

COVID-19 note: At the time of preparing this manual it remains unknown how many states will be allowing face-to-face summer camps in 2021. NESSP will continue to monitor public health guidelines throughout winter — expect an announcement in the early months of 2021 regarding summer camps. Our announcement regarding summer 2021 will include updates on whether in-person summer camps will be allowed, virtual summer camps as an alternative, and professional development trainings available for summer camp educators.

SUMMER CAMP CHALLENGE TENTATIVE SCHEDULE

March 2021	Summer camp registration opens
March – April 2021	Summer professional development
July 1, 2021 (Thursday)	Summer registration closes
June – August 2021	Summer camp challenges undertaken
August 16, 2021 (Monday)	Summer camp challenge submissions due
September 1, 2021	Summer camp top teams announced

SUPPORT FROM NESSP

For past summer programs, support from NESSP has taken the form of professional development and supply loan. When we are able to announce the status of summer programs for 2021, we will note what support we will be able to offer.

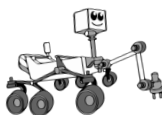
MORE INFORMATION

- NESSP's summer camps program: nwessp.org/programs/summer-camps/
- ROADS on Asteroids: nwessp.org/asteroids/
- To be added to our announcement list for summer camp information, email nwessp@uw.edu.



ROADS on Asteroids

Official Manual | Page 7



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ABOUT ROADS on Asteroids



COURSE CURRICULUM

COURSE CURRICULUM

Our companion course program offers a curriculum for educators to integrate concepts from the ROADS on Asteroids challenge into their classroom. Through our curriculum program, we offer both a five-unit curriculum (that educators can adapt to suit their needs) as well as sessions with an undergraduate teaching assistant to provide virtual instruction with hands-on experimentation. Support in the form of equipment loan may also be available.

ROADS ON ASTEROIDS CURRICULUM

The ROADS on Asteroids curriculum is being released free in a pilot format for the 2020–2021 school year. This course is organized around the guiding question "How can we, here on Earth, use scientific exploration to understand other solar system objects and use engineering planning to ensure successful missions to these objects?" The curriculum supports Next Generation Science Standards and are aligned with NASA missions.

Units

1. Mission Planning
2. Planetary Geology
3. Astrobiology
4. Robotics and Drones
5. Final Mission and Communication

Peruse all the units and lesson plans online:

nwessp.org/programs/pages/curriculum/asteroids/

SUPPORT FROM NESSP

If you are using our ROADS on Asteroids curriculum in your classroom and wish to request support from NESSP, please register on our website. Support you may request includes:

- Supply kits for loan
- Sessions with undergraduate teaching assistants

Priority for support requests will go to educators who have taken our ROADS on Asteroids professional development and to educators teaching underserved or underrepresented communities.

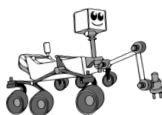
MORE INFORMATION

- NESSP's curriculum program (register & request support here): nwessp.org/programs/curriculum/
- ROADS on Asteroids: nwessp.org/asteroids/



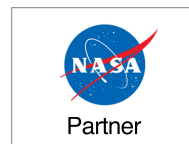
ROADS on Asteroids

Official Manual | Page 8



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ABOUT ROADS on Asteroids



COURSE CURRICULUM

COMPANION COURSE UNITS & LESSONS



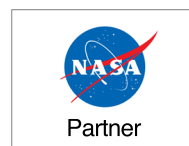
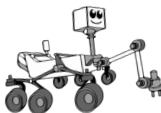
CHALLENGE MISSION OBJECTIVES

ROADS on Asteroids is both a course curriculum and a national student challenge.

- The course curriculum supports the challenge by strengthening a student's grasp of the scientific and engineering principles.
- The student challenge supports the curriculum by giving students a fun incentive to keep progressing through the topics.

There are more units and lessons in the curriculum than there are Mission Objectives (MO) in the challenge, but each MO lines up with at least one lesson. This chart provides a quick glance at how the curriculum and challenge support each other. The units and lessons associated with each MO are reiterated in the pages later in the manual that detail each MO.

UNIT & LESSON	MISSION OBJECTIVE (MO)
Unit 1: Mission Planning L3: Documenting the Mission	MO-01: Mission Development Log (MDL)
Unit 1: Mission Planning L4: Mapping Other Worlds	MO-05: Make your map
Unit 2: Planetary Geology L2: Crater Formation	MO-02: Crater formation and evolution [Checkpoint Challenge #1]
Unit 3: Astrobiology L2: Follow the Carbon	MO-03: Search for the building blocks of life [Checkpoint Challenge #2]
Unit 3: Astrobiology L4: Evidence of Life	MO-03: Search for the building blocks of life [Checkpoint Challenge #2]
Unit 4: Robotics and Drones L2: Drone Development	MO-06: Drone / satellite flight
Unit 4: Robotics and Drones L2: Drone Development	MO-07: Impactor drop
Unit 4: Robotics and Drones L3: Programming & Robots	MO-08: Map navigation
Unit 4: Robotics and Drones L3: Programming & Robots	MO-09: Expanded map navigation (DART division / high school teams only)
Unit 4: Robotics and Drones L4: Mission Integration and Iteration	MO-04: Team mission patch [Checkpoint Challenge #3]
Unit 5: Final Mission and Communication L2: Presenting the Mission to Clients	MO-01: Mission Development Log (MDL)



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

NATIONAL STUDENT CHALLENGE 2020–2021

The vast majority of students and educators who have participated in our ROADS programming in the past have done so through our national student challenges. Registering your team with NESSP and submitting your materials as part of the challenge means your team could earn prizes as one of our top teams! Registering your team also makes you eligible for support (such as equipment) from NESSP — see below for more information.

Our ROADS program is set up as a challenge and not a competition so that students completing any single component will have gained important experience and confidence to help them in their next steps, even if that path is not within the challenge itself. ROADS challenges are not a winner take all competition — our hope is to excite and inspire the next generation of scientists and engineers.

A TEAM CHALLENGE DURING COVID-19?

The ROADS challenges are activities for teams — an endeavor made more difficult, but all the more important, given the social distancing necessary during the COVID-19 pandemic. ROADS on Asteroids is designed where tasks can be completed consistent with social distancing requirements. For example, in the past, teams have tackled activities during group meetings. While social distancing prevents group meet-ups, components of the challenge could be done by individual members, with results shared with the team virtually to create a group product.

SUPPORT FROM NESSP

Throughout the challenge we schedule meetings for teams to ask questions of the NESSP staff along with opportunities to meet experts in fields related to the challenge. We also offer video demonstrations, tips, and resources via our website — nwessp.org. Check our website for upcoming events.

Support is available to educators (both formal and informal) working with underserved and underrepresented communities, including supplies to complete the challenge. Request support when registering your team(s).

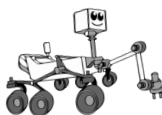
MORE INFORMATION

- ROADS on Asteroids: nwessp.org/asteroids/

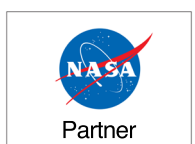


ROADS on Asteroids

Official Manual | Page 10



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ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

STEPS ON THE ROAD(S)

The ROADS on Asteroids challenge makes for an excellent team activity for an in-class group project, for a school robotics, programming, or other club activity, and for Scout troops or other community organizations.

The steps on this page provide a basic outline of what it means to “run the challenge” — detailed discussions of each activity involved in the challenge are found in the section on Mission Objectives (read those carefully!).

Pay close attention to the dates and deadlines in the “School-Year Challenge Schedule” as well.

STEP 1 : FORM & REGISTER YOUR TEAM

First, form your team. We recommend our ROADS challenges for groups of 3-8 team members. Groups larger than 10 will be encouraged to split into smaller teams. This is also not an appropriate project for a solo student — the greatest benefit comes from teamwork and group collaboration.

Teams will also need at least one adult teacher, coach, or mentor.

Next, register your team with NESSP: nwessp.org/asteroids

The ROADS on Asteroids challenge is open to teams from across the U.S. Teams from outside the U.S. may register, but will not be eligible for prizes.

Only teams who have registered with NESSP will be eligible for prizes. Registration is absolutely free!

Divisions: The ROADS on Asteroids challenge will have three divisions to accommodate students of different ages and skill sets. There is also a division for visually impaired students. The different divisions will have slightly different Mission Objectives.

A team’s division is determined by the grade level of the youngest team member. A team may, however, choose to run the challenge at the division of a higher-grade level if they’d like.

The challenge divisions are:

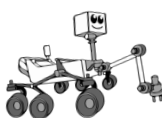
OSIRIS REx Division	Grades 3-4, or no programming experience
Dawn Division	Grades 5-8
DART Division	Grades 9-12
Hayabusa Division	Visually impaired (grades 3-12)

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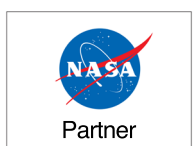


ROADS on Asteroids

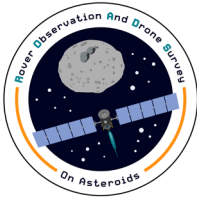
Official Manual | Page 11



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nwessp.org/asteroids



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

STEPS ON THE ROAD(S)

STEP 2 : COMPLETE THE MISSION OBJECTIVES

The activities in the ROADS on Asteroids challenge are organized according to Mission Objectives (MOs), which are detailed later in this manual. Teams will work through the activities to complete each MO, documenting their progress each step of the way in their Mission Development Log (MDL). The MOs do not have to be completed in any particular order.

STEP 2.5 (OPTIONAL!) : SUBMIT YOUR MATERIALS FOR THE CHECKPOINT CHALLENGES

Checkpoint challenges are an important (but not required!) component to ROADS. Working toward each checkpoint challenge helps teams to progress through the ROADS material and provides valuable hands-on experience with the challenge's technologies. Plus, we'll select top teams from each checkpoint challenge's submissions to receive awards!

We strongly encourage participation in these events as they are important milestones toward the final challenge! We particularly encourage checkpoint challenge participation for those teams that request equipment support during registration. Teams that do submit the required materials for the checkpoint challenges by the deadlines (outlined in the schedule below) will be eligible for a chance to win items for the next steps of the challenge.

STEP 3 : SUBMIT YOUR MATERIALS FOR THE FINAL CHALLENGE

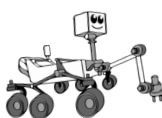
The ROADS on Asteroids "final event" will be held virtually in April 2021. Previous NESSP challenges culminated with in-person final events, but unfortunately COVID-19 safety precautions make it impossible to schedule events while so much is still uncertain.

Teams will have several pieces of documentation that must be submitted via NESSP's website in order to be eligible for scoring and prizes. We'll post complete details of the final submission requirements on our website in 2021.

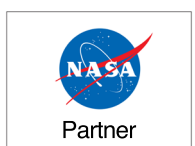


ROADS on Asteroids

Official Manual | Page 12



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ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

PRIZES!

Our intention with the RADS student challenge program has been to provide the top student teams in each division with the opportunity to visit a NASA center or to attend a mission launch. In 2021 there are two launches for missions to asteroids, and we do hope to send student teams to these launches if at all possible.

COVID-19 note: Restrictions in place for the pandemic continue to make travel difficult or impossible. As of preparing this manual, public access to NASA centers has been suspended and we do not know when they will be open again. If NASA center visits are unavailable in 2021, alternative prizes will focus on helping the students in their next steps in STEM.

Only teams residing in the U.S. or families of U.S. military wherever they are serving are eligible for equipment support for the challenge and for the prizes. Also, only U.S. citizens or permanent residents who are 10 years old or older are eligible to visit a NASA center.

TOP PRIZES

Prizes will be awarded to the top teams in each division:

- OSIRIS REx Division
- Dawn Division
- DART Division
- Hayabusa Division

CHECKPOINT CHALLENGES

Prizes will be awarded to the top teams for each checkpoint challenge:

- Crater Formation [Checkpoint challenge #1]
- Search for Signs of Life [Checkpoint challenge #2]
- Mission Patch [Checkpoint challenge #3]

SPECIAL PRIZES

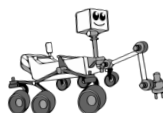
Special prizes will be awarded for Mission Objectives 01, 06, 08, and 09:

- Best Mission Development Log (MO-01)
- Innovations in Drone / Satellite Design (MO-06)
- Resolute Award (MO-08)
- Enterprise Award (MO-09)

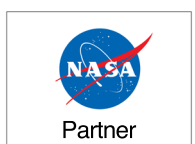


ROADS on Asteroids

Official Manual | Page 13



#ROADSonAsteroids
nwssp.org/asteroids



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

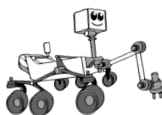
SCHOOL-YEAR CHALLENGE SCHEDULE

October 13, 2020 (Tuesday)	Official launch of RADS on Asteroids School-year registration opens
August – November 2020	Professional development Dispersing of supplies (requested during registration)
October 20, 2020 (Tuesday)	Virtual meeting with RADS teams to discuss challenge
November 20, 2020 (Friday)	School-year registration closes
December 15, 2020 (Tuesday)	Optional Checkpoint challenge #1 — Crater Formation submissions due
January 19, 2021 (Tuesday)	Checkpoint challenge #1 top teams announced Optional Checkpoint challenge #2 — Search for Signs of Life submissions due
January 2021	Virtual meet an expert
January 15, 2021 (Friday)	Virtual meeting with RADS teams for support and questions
February 12, 2021 (Friday)	Checkpoint challenges #2 top teams announced Optional Checkpoint challenge #3 — Mission patch submissions due
February 19, 2021 (Friday)	Mission patch top teams announced
February 2021	Virtual meet an expert
April 2021	ROADS on Asteroids final challenge held virtually
May 2021	Top teams announced

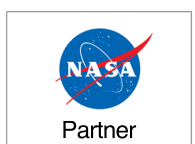


ROADS on Asteroids

Official Manual | Page 14



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nwessp.org/asteroids



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MISSION OBJECTIVES (MOs)

MO-01: MISSION DEVELOPMENT LOG (MDL)

Every mission starts with an idea, often sketched out on a scrap of paper. To make it a reality, details are added and modified through discussions with all your team members. Those discussions and decisions need to be documented. Your Mission Development Log is the record of your mission that tells us about your activities. Document what you planned and tried, what worked and what didn't.

MO-02: CRATER FORMATION AND EVOLUTION [CHECKPOINT CHALLENGE #1]

Vesta's snowman feature is formed by three craters in a line. Did they form at the same time or at different times? Research the processes that form craters and come up with an experiment(s) to prove your hypothesis. Are there examples of craters on Earth?

MO-03: SEARCH FOR SIGNS OF LIFE [CHECKPOINT CHALLENGE #2]

Asteroids and comets contain carbon compounds that are some of the building blocks of life. First, use gas detectors to survey your environment for some of these building blocks. Then, take a sample from the area and use a microscope to find living and non-living things. What adaptations have these creatures made to survive in these environments?

MO-04: TEAM MISSION PATCH [CHECKPOINT CHALLENGE #3]

All missions have a patch that represents the team's and the community's values. Engage your creative side to design a patch that symbolizes your mission, your team, and your community.

MO-05: MAKE YOUR MAP

This one's for the geometers and set designers! We've provided the overall dimensions of the map and positions of key features. Teams will build their own version of this map, including at least some portions of the crater walls over which their robotic system must navigate. In building this map, students will become familiar with coordinate systems. Teams will need to include a ramp system mimicking the slopes of the craters so that their robotic system is able to move between the different craters.

MO-06: DRONE / SATELLITE FLIGHT

For the ROADS challenge, we can't use a rocket (alas!) to travel to the asteroid site since the challenge is indoors. Instead, we'll use a drone to simulate spaceflight and delivery of a satellite.

MO-07: IMPACTOR DROP

Teams will build an impactor, representative of the technologies used in Hayabusa 2 and DART, and deploy it at the snowman feature. The impactor will rest on a pedestal and must be triggered by your drone/satellite such that the impactor falls and hit the marked target.

MO-08: MAP NAVIGATION

With the drone/satellite landed safely on the rover, navigation begins. Navigating across all three of the snowman craters, the rover must retrieve one sample and the team's impactor. Both objects must be cached in the small crater at the head of the snowman feature.

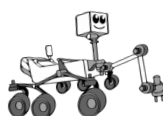
MO-09 (DART DIVISION TEAMS ONLY): EXPANDED MAP NAVIGATION

In addition to MO-08, DART/high school teams must also travel outside the craters to collect an additional sample from the plains. Teams are required to use an auxiliary motor on the robot when collecting the plains sample.

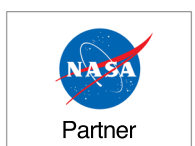


ROADS on Asteroids

Official Manual | Page 15



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nwssp.org/asteroids



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MISSION OBJECTIVES (MOs)

The ROADS on Asteroids challenge has many components, organized into Mission Objectives (MOs), so that students gain experience in the important interrelationship between science, technology, engineering, and math necessary to solve complex problems. The individual components do not have to be attempted in sequence, although this can be helpful in classroom settings — in real-life missions, developments in all aspects of a project are often occurring simultaneously in order to meet time schedules. Teams are encouraged to find a process and schedule that works best for them. And while all of the Mission Objectives should be attempted and must be covered in the Mission Development Log (see MO-01 below), we encourage teams to find approaches to each MO that make the science and engineering relevant to them and to their communities. The way we have outlined the individual components of each MO in this manual is merely a framework toward understanding missions to asteroids. Educators, mentors, and team members should work collaboratively to adapt components to best fit their educational goals and available equipment while still achieving the Mission Objectives.

A NOTE ON CHECKPOINT CHALLENGES VERSUS THE FINAL CHALLENGE SUBMISSION

Registered teams who are striving toward top team awards in the ROADS on Asteroids challenge should be clear on what is required and what is not.

Final challenge awards — There are two required submissions for the ROADS on Asteroids final challenge:

1. Mission Development Log (outlined in MO-01)
2. Mission Video (MOs 05–09 for DART/high school teams; MOs 05–08 for all other teams)

Checkpoint challenge awards — The checkpoint challenges align with MO #s 02–04, *but checkpoint challenge submissions are not required for the final challenge scoring*. We recognize that teams will go at their own pace during the year. The checkpoints challenges are to assist teams in keeping with an overall schedule. They are optional because some teams may not be able to submit on the given deadlines but teams to continue onwards regardless. However, we also wish to highlight teams successes as they move forward with the challenge. The only way we can accomplish these two goals is that have a strict deadline for submission but have the submissions optional.

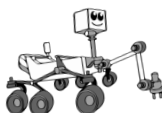
The three checkpoint challenges are as follows.

1. Crater formation and evolution — MO-02
2. Search for signs of life — MO-03
3. Team mission patch — MO-04

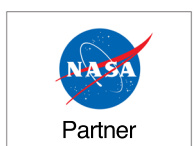


ROADS on Asteroids

Official Manual | Page 16



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nwessp.org/asteroids



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

TEAMWORK AND DIVERSITY

The ROADS on Asteroids challenge has been developed using a very traditional white Western approach to science and to engineering processes — the Mission Development Log (MDL) in particular shows the influence of a Western, linear approach. This approach in scientific and engineering disciplines is used around the world, but is by no means the *only* approach — not only worldwide, but also in the United States. Whether you're from a community with a differing cultural tradition regarding science and engineering or you aspire to work with scientific collaborators from a diversity of backgrounds, it's worth thinking about some of the varying approaches that inform how science and engineering are understood and practiced.

ROADS on Asteroids is set up to be a framework as much as possible. We encourage teams to modify their approach to the challenge to ensure that it's culturally relevant to their community, and to include areas of emphasis in the team's final MDL and video.

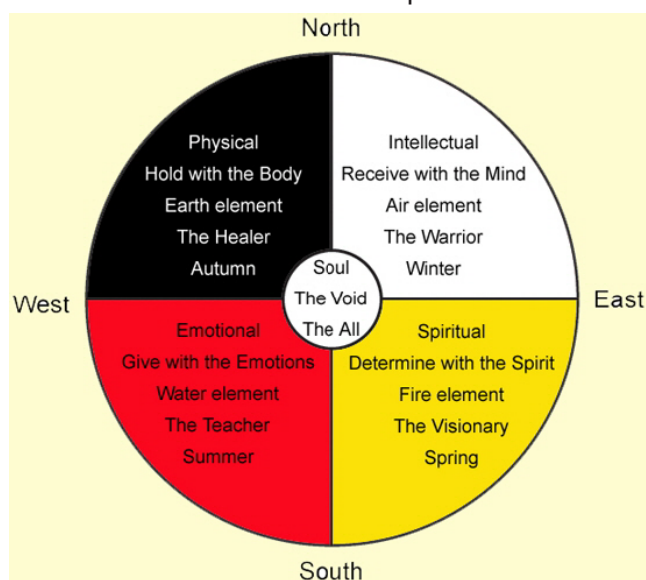


Figure 2.1: Medicine Wheel from

<http://www.mesacreativearts.com/html/medicinewheel.html>

One thing to consider is how to share the work of the challenge. In research labs, universities, and industry in the U.S., it is the norm for tasks to be assigned more or less according to discipline or expertise — perhaps someone on your team is great at biology, and so they carry out the parts of the challenge that require a microscope. By contrast, many Native American methodologies recognize that all the different components are required to make the whole successful. The medicine wheel in Figure 2.1, for example, expresses that the planet would not be whole without the four seasons, nor the body whole without including the intellectual, spiritual, emotional, and physical.

To be successful in ROADS on Asteroids, a team will have to have expertise in the different subject areas, but will also have to communicate ideas between

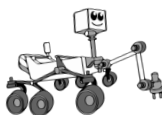
the disciplines in order to complete all components the mission. This experience is true to life for all large missions, whether it's on Earth or in space.

Also think about the order of accomplishing the tasks. A linear progression from MO-02 to MO-08 might make the most sense, as you apply skills learned from one Mission Objective to the next objective on the list and all team members gain the same expertise. Or perhaps your community prefers a cross-disciplinary approach, in which case you may have team members working on each aspect of the challenge simultaneously making use of their expertise and interests, and those team members collaboratively share that knowledge to the rest of the team.



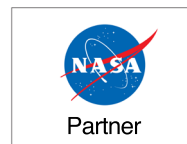
ROADS on Asteroids

Official Manual | Page 17



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nwessp.org/asteroids



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-01: 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, initial plans and how they evolved over time, what worked and what did not work. Teams should develop a timetable to complete perceived important tasks at the very beginning, and then as they progress on the challenge see how they are doing relative to the timeline and how the timeline and/or tasks need to be modified as the students gain a better understanding of the tasks needed to solve the challenge.

It's important for all team members take leadership on individual components and solicit input and help from the other team members. All team members should participate in making and documenting the decisions, 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. It's important for all students to understand that changes always occur as more information becomes available, and that **getting it wrong provides a wealth of information on how to successfully proceed** — in other words it is *okay to fail* (although the final product should be designed so that these failures no longer occur).

The MDL should include labeled sketches, diagrams, descriptions, bulleted lists, photos, and other documentation of scientific explorations, initial and final designs, modifications, successes and failures. Scientists and engineers rarely get it right the first time!

The MDL should include sections for all mission objectives:

- Crater formation and evolution
- Search for the building blocks of life
- Team mission patch design
- Drone and spacecraft design and testing
- Crater impactor
- Robot design, programming efforts and testing.
- Scoring

A scoring rubric for the MDL is available on the NESSP website: www.nwessp.org/asteroids

NOTES FOR CHALLENGE TEAMS:

- Divisions: ALL
- Award eligibility: Required for Top Team prize(s) as part of final challenge submission; Also eligible for Best Mission Development Log Award
- Submission due: Part of final challenge submission — Due April 2021

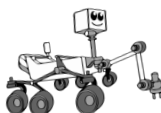
NOTES FOR CURRICULUM TEACHERS:

- Unit 2, Lesson 3: Documenting the Mission
- Unit 5, Lesson 2: Presenting the Mission to Clients

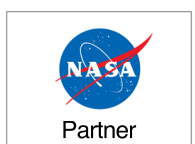


ROADS on Asteroids

Official Manual | Page 18



#ROADSonAsteroids
nwessp.org/asteroids



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-02: CRATER FORMATION AND EVOLUTION [CHECKPOINT CHALLENGE #1]

Craters are a ubiquitous feature on asteroids. Craters are also present on Earth, but most have disappeared over time due to the resurfacing of the Earth's surface over geological times scales. Surfacing occurs on asteroids as well but mainly due to impacts. Small impacts lead to the creation of fine-grained regolith or dust on the surface while larger impacts leave new craters. The dynamics for the creation of a single crater is shown in Figure 2.2. The impacting object, such as a small asteroid, 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. Debris ejected from the impact piles up on the side of the crater.

For the snowman feature of Vesta the situation is more complicated as there is a series of three craters. The questions to be answered for the checkpoint challenge are:

- Did these craters form at the same time or form at different times?
- What is the evidence for your team's decision?

Provide the evidence in video form for your conclusions.

NOTES FOR CHALLENGE TEAMS:

- Divisions: ALL
- Award eligibility: Checkpoint challenge #1
- Checkpoint challenge entry: December 2020

NOTES FOR CURRICULUM TEACHERS:

- Unit 2, Lesson 2: Crater Formation

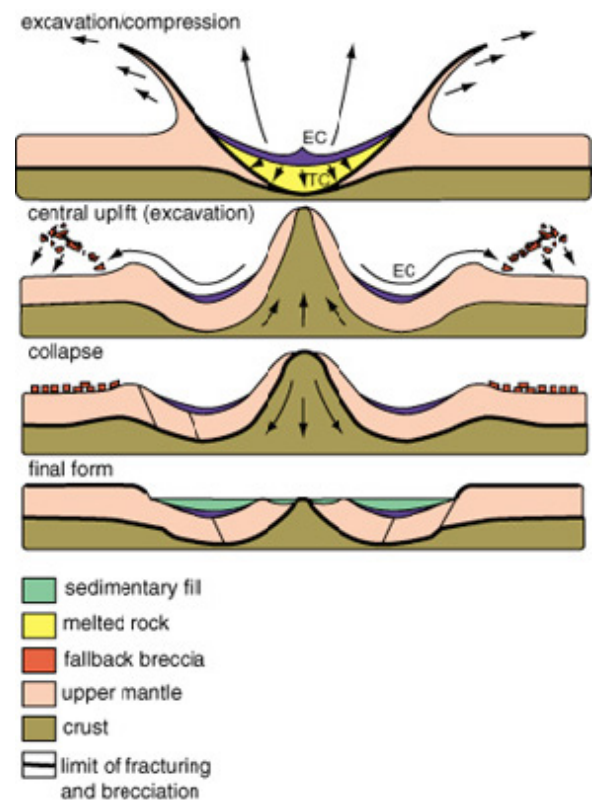
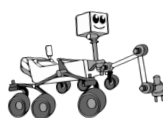


Figure 2.2: Crater formation.

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ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-02: CRATER FORMATION AND EVOLUTION [CHECKPOINT CHALLENGE #1] (CONT'D)

Scientists can use the type of rock around the impact site to do age identification. For the challenge we do not have that information available. However, we can use observations of the crater wall characteristics to make a relative age determination. When a pile of rocky material is created, the steepness of the pile reaches a maximum and then collapses. This angle is called the angle of repose and is illustrated in Figure 2.3.

This challenge requires you to capture crater formation with in slow-motion (a feature available on many smart phones), and then show how the steepness of the wall changes with subsequent impacts to decide the relative ages of the individual craters. Teams should try the experiment using different materials such as coarse sand, play sand, flour or washing powder, or layers of these different materials.

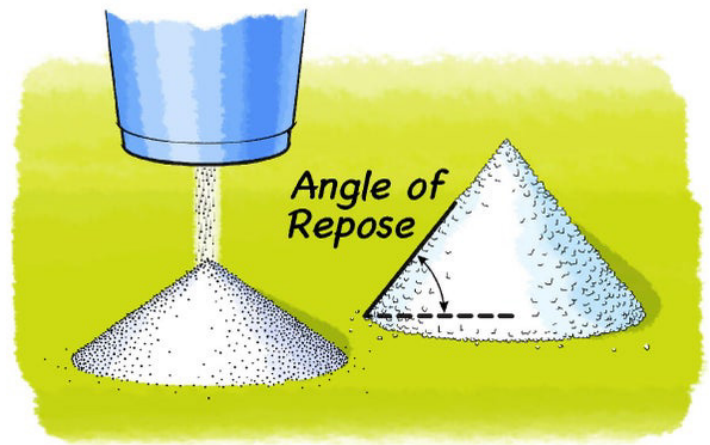


Figure 2.3: Angle of repose.

TIPS:

For Hayabusa teams

For visually impaired students, the spreading of the material from an impact can be possibly more readily experienced using a mixture of sand and washing powder under UV light.

RESOURCES:

An excellent slow-motion video of crater formation:

<https://www.youtube.com/watch?v=6swY05e2iT4>

An excellent video for angle of repose:

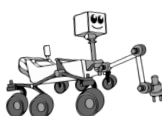
<https://www.youtube.com/watch?v=nf9rXcCR9Dw>

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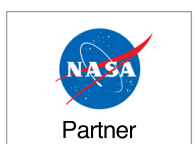


ROADS on Asteroids

Official Manual | Page 20



#ROADSonAsteroids
nwessp.org/asteroids



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-03: SEARCH FOR SIGNS OF LIFE [CHECKPOINT CHALLENGE #2]

All life that we know of consists of various carbon compounds. The simplest of these are carbon dioxide (CO_2) and methane (CH_4). Combine nutrients which might include nitrogen compounds, such as ammonia (NH_3) and various salts, with liquid water (H_2O), energy (either solar or geothermal) and sufficient time, and life can potentially take hold. In the cases

of asteroids, liquid water and sufficient time are missing, and so life isn't expected to be found on these solar system bodies. But the fact that the main ingredients for life may be on these asteroids undisturbed for billions of years could provide important insight into the origins of life on Earth.

While we cannot do the type of search that is presently underway by the different spacecraft missions, we can undertake an earth analogue search. The checkpoint challenge search for building blocks of life follows the carbon cycle on Earth as shown in Figure 2.4. By following the carbon cycle, students will gain insight into how the different chemical components seen on different solar systems come together to allow life to form if favorable conditions occur.

Carbon dioxide is taken out of the atmosphere by photosynthesis where plants use carbon dioxide and water to form sugars and release oxygen into the air. Animals use these sugars with oxygen for growth and movement. When both animals and plants die, some of the carbon is sequestered in the ground while some is released into the atmosphere in the form of methane. The carbon that is not released becomes part of the underlying rock and can be eventually returned into the atmosphere by geological or human activity.

The equipment needed to accomplish this checkpoint challenge costs about \$250 total. Those teams needing supplies can request support when registering for the challenge; classroom
(Continues ►►►)

NOTES FOR CHALLENGE TEAMS:

- Divisions: ALL
- Award eligibility: Checkpoint challenge #2
- Checkpoint challenge entry: January 2021

NOTES FOR CURRICULUM TEACHERS:

- Unit 3, Lesson 2: Follow the Carbon
- Unit 3, Lesson 4: Evidence of Life

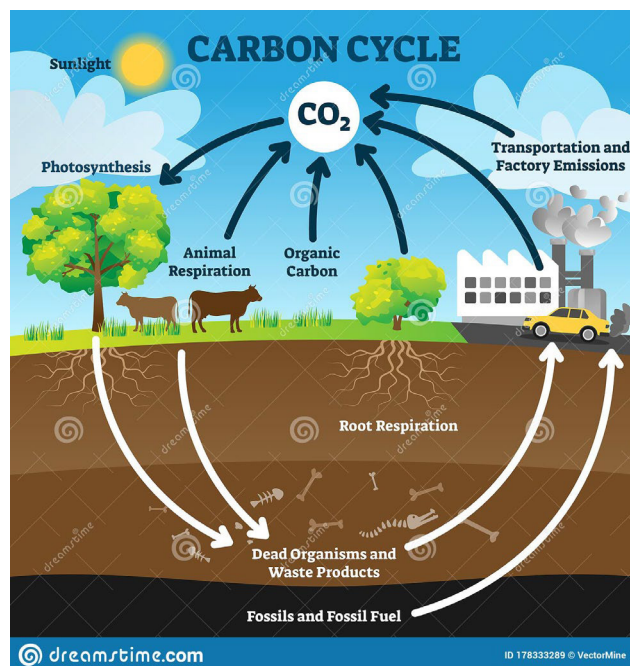
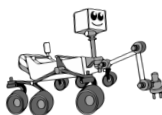


Figure 2.4: Carbon cycle.



ROADS on Asteroids

Official Manual | Page 21



#ROADSonAsteroids

nwessp.org/asteroids



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-03: SEARCH FOR SIGNS OF LIFE [CHECKPOINT CHALLENGE #2] (CONT'D)

teachers who need supplies can request support when registering their curriculum. This checkpoint challenge can be skipped if resources are not available to a team, but we do recommend that teams attempt the challenge due to the importance of the carbon cycle for life on Earth.

The checkpoint challenge has three components:

- Methane detection associated with dead or decaying organisms
- Carbon dioxide detection associated with respiration, geological, and/or human activity
- Search for small invertebrates

METHANE DETECTION

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 let us not forget 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.

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 (Figure 2.5). 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.

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.

TIPS:

The ROADS website has videos that demonstrate how to calibrate and use the methane detector and that also offer inspiration on where to search for methane.

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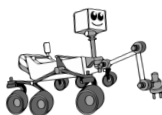
Figure 2.5: Combustible gas detector.

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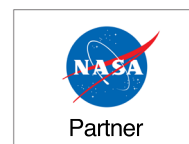
ROADS on Asteroids

Official Manual | Page 22



#ROADSonAsteroids

nwessp.org/asteroids



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-03: SEARCH FOR SIGNS OF LIFE [CHECKPOINT CHALLENGE #2] (CONT'D)

CARBON DIOXIDE DETECTION

There are multiple sources and sinks of carbon dioxide (CO₂) as described above in the carbon cycle. This goal of this Mission Objective component is to take observations and determine which ones show that the carbon cycle is in fact occurring. Take at least three out of five of the following measurements and interpret the data relative to the carbon cycle in Figure 2.4:

- Indoor **vs.** outdoor CO₂ levels (morning, noon, and night)
- Breathing into the sensor after holding your breath **vs.** breathing into the sensor without having held your breath
- Vinegar and baking soda mixed together **vs.** a different ratio of vinegar and baking soda mixed together
- Yeast in plain water **vs.** yeast in sugar water **vs.** sugar water (with no yeast)
- Plants in a clear **vs.** enclosed space; in direct sun **vs.** in the shade

It's okay to swap a different experiment of the team's choosing for an experiment on the list above **IF** the team can demonstrate its relevance to the carbon cycle.

Don't forget to log all of your activities — successes and failures alike! — in your team's MDL.

TIPS:

The ROADS website has videos that demonstrate how to use the carbon dioxide detector and that also offer inspiration on where to search for CO₂.

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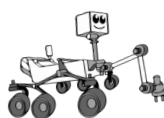
Figure 2.6: Carbon dioxide meter M2000C.

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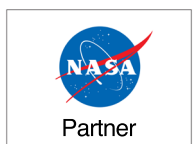


ROADS on Asteroids

Official Manual | Page 23



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MO-03: SEARCH FOR SIGNS OF LIFE [CHECKPOINT CHALLENGE #2] (CONT'D)

SEARCH FOR SMALL INVERTEBRATES IN YOUR LOCAL AREA

Now our search for the building blocks of life turns to analyzing samples under a microscope. Teams should visit locations they identified as high in methane or where there are variations in the carbon dioxide levels (as long as the locations are safe and you have permission to visit) and collect samples of small invertebrates called macroinvertebrates.

Once you have your sample, it's time to try imaging the macroinvertebrate. A microscope is the best tool for the job. Your team may have one available through school.

Some teams may want to purchase a small microscope of their own. There are small digital microscopes available at a cost of about \$60 (Figure 2.7). At an even lower cost are Foldscopes (Figure 2.8), which do involve some assembly but are fun to put together.

Teams must:

- Identify at least two different small invertebrates
- Show how they were found and discuss what adaptations they have made to survive in the environment where they were found 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.

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 2.7) on the microscope can be pasted into the MDL.

TIPS:

The ROADS website has videos that demonstrate how to use microscopes to image macroinvertebrates.

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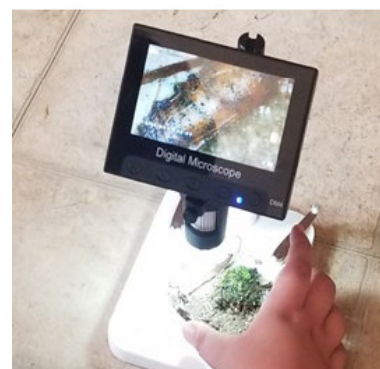
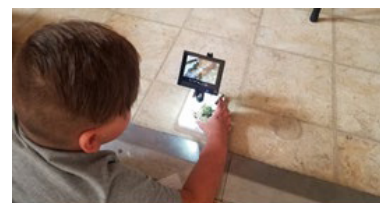
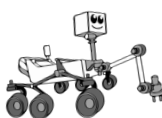


Figure 2.7: Digital microscope and image of a small mite.



Figure 2.8: Foldscopes provide a cheaper alternative to the digital microscopes.



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2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-04: TEAM MISSION PATCH (CHECKPOINT CHALLENGE #3)

With the completion of MOs 2 and 3, teams will have an idea of the processes that govern the landing site and science efforts for the challenge. The teams are now ready for the robotic exploration planning and development.

But before one develops mission hardware, the team should have a good mission patch that represents their objectives and community values. Figure 2.9 shows a few examples for past Mars missions. Teams are encouraged to get creative and design a mission patch that represents themselves, their community, and their mission in the ROADS on Asteroids challenge.

To submit your mission patch for the checkpoint challenge, make a post on social media — Facebook, Twitter, or Instagram. Mission patch posts should include a short explanation of the components of the patch and their significance to the team.

NOTES FOR CHALLENGE TEAMS:

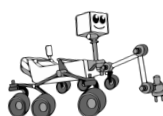
- Divisions: ALL
- Award eligibility: Checkpoint challenge #3
- Checkpoint challenge entry: February 2021

NOTES FOR CURRICULUM TEACHERS:

- Unit 4, Lesson 4: Mission Integration and Iteration



Figure 2.9: Examples of mission patches for Mars missions.



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MAP MAKING, DRONE, AND ROBOTIC MISSION OBJECTIVES

With an understanding of the science issues and the importance of the targeted solar system object covered in the first four Mission Objectives, the remaining MOs seek to engage teams with planning and executing the mission.

COVID-19 note: Remember to heed local public health guidelines that may restrict whether teams can gather. For the final mission video, teams are allowed to splice together videos of the map making and the drone and robotic MOs — but *individual videos* of the flight of the drone and the execution of the robotic programming must be done in a single uncut video.

Execution of the following MOs must be done within a total time limit of 12 minutes. If a tie-breaker is needed for team awards, it will be based on the shortest run time.

There are several objectives that must be included in the final challenge video report:

- Build your own map (MO-05), including the team's declaration and justification of which part of the snowman feature is youngest and which is oldest
- Modify a drone for the flight of a spacecraft (MO-06)
- Build and launch your impactor (MO-07)
- Land and navigate the obstacles and collect the two samples (MO-08)
- **High school only** — Collect extra samples and return them to the satellite extraction point (MO-09)

Any commercially available robotic system, e.g., LEGO Mindstorms, Vex, or Makebot, can be used for the challenge. The robots should be driven by programming and not by remote control, except for students in the OSIRIS REX division where remote control systems are allowed.

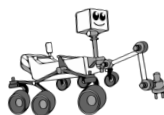
Similarly, any drone under \$100 cost can be used. NESSP is recommending the use of a mini-drone for the present challenge, because many of the challenge steps will be done in households as opposed to school classrooms, gymnasiums, and so forth. Larger drones, such as the Force1 Blue Heron (used in NESSP's previous RADS on Mars and ANGLES challenges) can still be used provided the team has sufficient space for safe flight. See the appendices for the rules on flying the drones outdoors.

As with the other components of the challenge, equipment support is available if certain criteria are met.

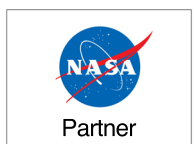


ROADS on Asteroids

Official Manual | Page 26



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ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-05: MAKE YOUR MAP

A closeup of how the snowman feature is to be navigated for the challenge is shown in Figure 2.9. For ROPS on Asteroids, teams will build their own map. This is a great exercise in mapping/graphing and in being able to interpret features on a map. We do recommend that, if at all possible, the version of the map be portable.

The map should be approximately 8 ft x 8 ft. The map could be made from foamboard, taped cardboard, or just an area taped on the floor of in a room, garage, et cetera. The team needs to decide what works best for them. The team's best effort, with the intent of the objectives maintained, is the goal — no points will be deducted if a team's map is not an exact replica. The exact position of the main features are given in Table 2.1 in inches and Table 2.2 in cm.

When preparing to run the final challenge for the video submission, teams should set up their challenge field to include:

- The map, its obstacles and ramps, and all the samples
- Their rover, placed in the starting position (noted below)
- Their impactor, placed on its pedestal (noted below)
- A base of operations outside of the map area — This is the space the team can occupy while running the challenge, and from which the drone is launched and recovered. You'll want a place for the drone pilot to stand or sit as well as a place for any computer you use to send commands to the rover.
- Before the mission starts, the team must report their determination of which part of the snowman feature is youngest and which is oldest as well as the reasons for their conclusion.

NOTES FOR CHALLENGE TEAMS:

- Divisions: ALL
- Submission due: Part of final challenge submission — Due April 2021
- Award eligibility: Required for Top Team prize as part of final challenge submission; Also eligible for a Best of Mission Objective 05 award

NOTES FOR CURRICULUM TEACHERS:

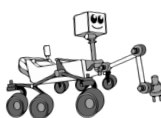
- Unit 1, Lesson 4: Mapping Other Worlds

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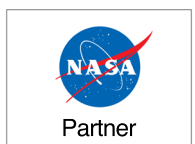


ROADS on Asteroids

Official Manual | Page 27



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ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-05: MAKE YOUR MAP (CONT'D)

The following is a step-by-step explanation of the map markings for the challenge map, which is shown in Figure 2.10. Full details about the relevant Mission Objectives are given in the following sections.

Note: *Only the prescribed features can be added to the competition mat.*

- ▶ **WHITE CIRCLES:** The snowman feature is represented by the three large white circles. Some representation of these boundaries must be included on the map. The robot wheels are not allowed to pass any part of these boundaries.
The team can add a physical boundary (e.g. cardboard, styrofoam, rocks, branches) around the circle to represent the crater walls and thereby prevent the robot from crossing the boundary. This is not required (because the circles are quite large!).
- ▶ **WHITE RECTANGLES:** The ramps between the craters are marked by the white rectangles. The ramps can be smaller than the rectangles but cannot exceed the space allocated to them. The exact shape and texture of the ramp system is up to the team, but both ramps must include a minimum height at the crater wall. This height is specified in the tables below.
- ▶ **SOLID RED CIRCLE:** Within the solid red circle, the team will place a pedestal from which the impactor is launched onto the surface of the snowman. The pedestal must be at least 3 feet high, although the impactor can be of any design that the team feels appropriate.
- ▶ **RED DASHED CIRCLES:** The objective is for the satellite to trigger the impactor and have the impactor land in the second crater. The scoring is determined by the first bounce of the impactor. Maximum points if the first bounce is within the smaller dashed red circle, half points if it is in between the two dashed red circles, and zero points if it misses the dashed circles or bounces out of the second crater.

For OSIRIS REx and Hayabusa divisions ONLY: The impactor can be placed back into the center of the red dashed circles for pick up.

For the Dawn and DART divisions: The samples must be picked up at the point where the impactor comes to rest. If the sample lands in a place where it is unrecoverable (which can occur in real missions!), the robot needs to proceed with its other objectives.

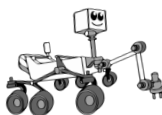
- ▶ **BLUE CIRCLE — LOWER LEFT:** After triggering the impactor, the satellite should land on the rover. The rover will have been placed in the starting position represented by the blue circle in the bottom left corner. If the drone crashes as it attempts to land, the team may place it on the rover but no landing points will be scored.

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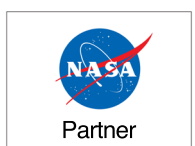


ROADS on Asteroids

Official Manual | Page 28



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ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-05: MAKE YOUR MAP (CONT'D)

- ▶ **GREEN CIRCLE:** Typical missions take more than one sample, and this is true of the present mission. The green circle represents the position of the first sample to be taken. Once the satellite is on the robot, the robot needs to collect this sample (by whatever mechanism the team finds most appropriate). The sample then needs to be moved by the robot over the ramps into the small crater at the head of the snowman formation.

The second sample is the impactor that has landed in the second crater. It, too, needs to be moved to the small crater at the top of the snowman formation. The actual order of the delivery of the samples to the small crater is arbitrary.

For the Dawn and DART divisions: This position is wherever the impactor lands within the second crater.

For the OSIRIS REx and Hayabusa divisions; As mentioned above, the impactor can be placed into the center of the red dashed circles for pick up.

- ▶ **BLUE TRAPEZOID & MULTI-COLORED CIRCLES — DART Division only:** The blue trapezoid is for high school teams only, and allows the robot to leave the crater to pick up one of two samples at the multi-colored circles near the bottom right corner. The team needs to declare which sample they will pick up. Points will be subtracted if the sample or robot leave the map area. The samples can be any design set by the team. The selected sample needs to be returned to the inside of the small crater at the head of the snowman feature. The sample can be collected either before or after the rover retrieves the impactor, but all samples and the impactor should be acquired before the rover makes its way to the departure point.

If, at any time, the robot flips or ejects the satellite/drone that it is carrying, the mission is over.

The actual construction materials of the map is up to the team. A walkthrough video for suggestions on making the map is available on the challenge site. Taped poster or foamboard works very well for the map surface. Old challenge maps (from the ROADS on Mars or ANGLEs challenges) also make for a good surface for the map.

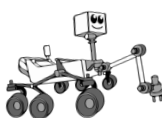
Students should be encouraged to map out the route before trying to program a solution. Students should log the different program strategies in their MDL to create a series of small programs called subroutines to execute particular tasks such as (a) left and right turns to collect the sample (small increments to the turns are best) and (b) powering (but not overpowering) up the ramps.

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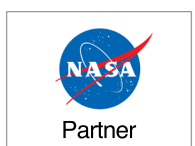


ROADS on Asteroids

Official Manual | Page 29



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ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-05: MAKE YOUR MAP (CONT'D)

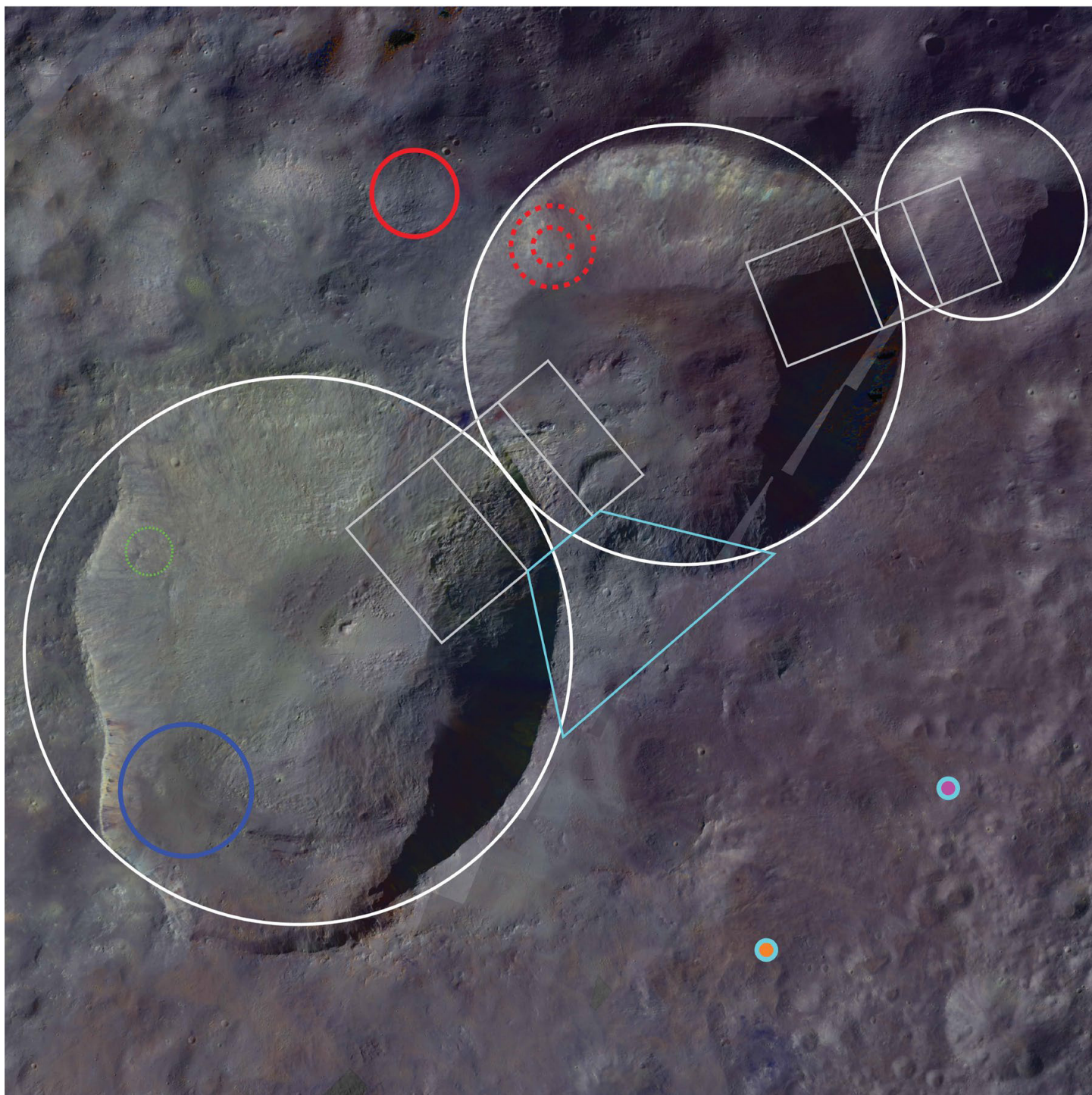


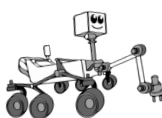
Figure 2.10: Challenge map. The origin is at bottom left hand corner

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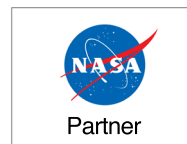


ROADS on Asteroids

Official Manual | Page 30



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ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-05: MAKE YOUR MAP (CONT'D)

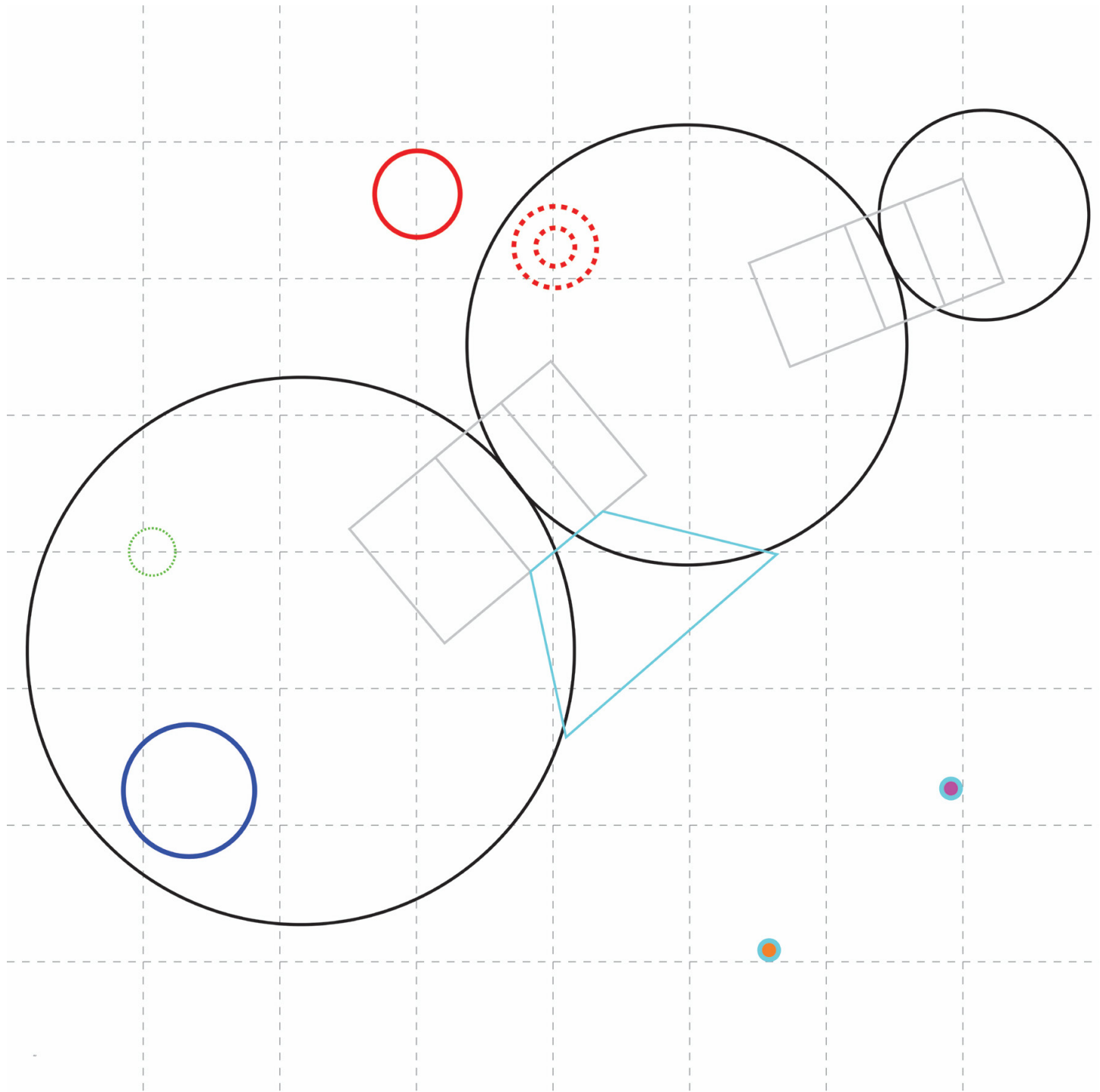


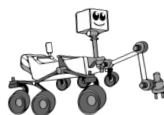
Figure 2.11: Challenge map on a grid; 1-foot spacing of grid lines.

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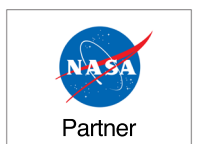


ROADS on Asteroids

Official Manual | Page 31



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ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-05: MAKE YOUR MAP (CONT'D)

Table 2.1 Parameters of key map features in inches. The origin is at the bottom left hand corner.

Craters	<i>Center X (in)</i>	<i>Center Y (in)</i>	<i>Diameter</i>
Cr1	26	39	48
Cr2	60	66	38.5
Cr3	86	78	18

Ramp	<i>Lower Left X(in)</i>	<i>Lower Left Y (in)</i>	<i>Max Length (in)</i>	<i>Max Width (in)</i>	<i>Min Height at crater wall (in)</i>
Rp1	38	40	28	12	4
Rp2	69	64	20	10	3
Rp3 (HS Only)	student choice	student choice	30	10 at junction with main ramps	

Robot	<i>Center X (in)</i>	<i>Center Y (in)</i>	<i>Diameter</i>
Landing Zone (LZ)	16	26	12
Extraction Zone (EZ)	Any point in 3d crater		

Projectile	<i>Center X (in)</i>	<i>Center Y (in)</i>	<i>Diameter</i>
Launch Area (LA)	36	80	<12 in
Inner Impact Area	48	75	4
Outer Impact Area	48	75	8

Sample 1	<i>Center X (in)</i>	<i>Center Y (in)</i>	<i>Diameter (in)</i>
Sample	13	48	2

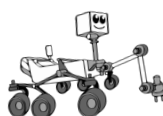
HS Samples	<i>Center X (in)</i>	<i>Center Y (in)</i>	<i>Diameter (in)</i>
Left Sample	67	13	1
Right Sample	83	27	1

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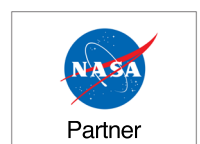


ROADS on Asteroids

Official Manual | Page 32



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ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-05: MAKE YOUR MAP (CONT'D)

Table 2.2 Parameters of key map features in metric. The origin is at the bottom left hand corner.

Craters	<i>Center X (cm)</i>	<i>Center Y (cm)</i>	<i>Diameter (cm)</i>
Cr1	66	100	123
Cr2	152	168	98
Cr3	218	197	46

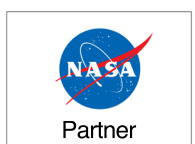
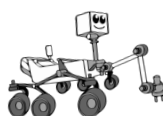
Ramp	<i>Lower Left X(cm)</i>	<i>Lower Left Y (cm)</i>	<i>Max Length (cm)</i>	<i>Max Width (cm)</i>	<i>Min Height at crater wall (cm)</i>
Rp1	97	102	71	30	10
Rp2	175	163	51	25	8
Rp3 (HS Only)	student choice	student choice	76	25 at the junction with main ramp	

Robot	<i>Center X (cm)</i>	<i>Center Y (cm)</i>	<i>Diameter (cm)</i>
Landing Zone (LZ)	41	66	30
Extraction Zone (EZ)	Any point within the 3rd crater		

Projectile	<i>Center X (cm)</i>	<i>Center Y (cm)</i>	<i>Diameter (cm)</i>
Launch Area (LA)	91	203	< 30
Inner Impact Area	122	191	10
Outer Impact Area	122	191	20

Sample 1	<i>Center X (cm)</i>	<i>Center Y (cm)</i>	<i>Diameter (cm)</i>
Sample	33	122	5

HS Samples	<i>Center X (cm)</i>	<i>Center Y (cm)</i>	<i>Diameter (cm)</i>
Left Sample	170	33	3
Right Sample	211	69	3



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-06: DRONE / SATELLITE FLIGHT

We can't use a rocket (alas!) to travel to the asteroid site because the ROADS challenge is indoors. Instead, we'll use a drone to simulate spaceflight and the delivery of the satellite to the surface. It's up to the team to decide the appropriate size of the drone consistent with their circumstances, e.g., large drones are okay for large areas but not well suited for household flights. Mini-drones are recommended for the present challenge.

The satellite can be fixed to the drone or suspended from the drone as shown in Figure 2.12. The team's choices on design are part of the engineering design process and teams should remember that there are several tasks that need to be accomplished by the drone/satellite system.

For teams using the folding drones, the position of the propeller arms should be checked before each flight.

The main requirements for the drone/satellite are:

- Must be sufficiently robust to trigger the impactor drop
- Must both land on the rover **and** stay on the rover during the map navigation Mission Objective
- Must be retrievable for the return flight to the base of operations.
- If the drone/satellite crashes during the attempt, the satellite can be placed on the rover but a point deduction will be applied

Some school teams may not have access to a drone. Teams are allowed to substitute a home-made device to satisfy the drone requirements. For example, the satellite could be delivered by flight on a string.

Innovations in Drone/Satellite Design Award — Most innovative design in drone/satellite construction.

NOTES FOR CHALLENGE TEAMS:

- Divisions: ALL
- Submission due: Part of final challenge submission — Due April 2021
- Award eligibility: Required for Top Team prize as part of final challenge submission; Also eligible for Innovations in Drone/Satellite Design Award

NOTES FOR CURRICULUM TEACHERS:

- Unit 4, Lesson 2: Drone Development

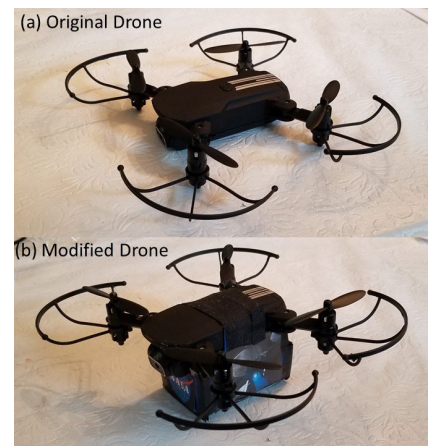
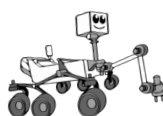


Figure 2.12: Possible drone/satellite configurations.



ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-07: IMPACTOR DROP & SATELLITE LANDING

As the Hayabusa and DART missions show, impactors are increasingly integral in missions to asteroids. The ROADS on Asteroids challenge will simulate an impactor drop as part of the drone/satellite's journey to the asteroid map. The requirements are shown schematically in Figure 2.13.

Teams will design their own impactor. When deciding on the design of their impactor, the team should be aware that it has to be eventually recovered by the rover and placed in the small crater at the head of the snowman feature.

NOTES FOR CHALLENGE TEAMS:

- Divisions: ALL
- Submission due: Part of final challenge submission — Due April 2021
- Award eligibility: Required for Top Team prize as part of final challenge submission

NOTES FOR CURRICULUM TEACHERS:

- Unit 4, Lesson 2: Drone Development

What is required of the impactor drop Mission Objective are the following:

- The impactor must be resting on a pedestal that is at least 3 feet high
- The impactor must be released by some action of the drone/satellite
- The scoring is determined by the first bounce of the impactor. Maximum points if the first bounce is within the smaller dashed red circle, half points if it is in-between the two dashed red circles, and zero points if it misses the dashed circles or bounces out of the second crater.
- **For OSIRIS REx, Hayabusa, and Dawn Divisions:** The impactor can be placed back into the center of the red dashed circles for pick up.

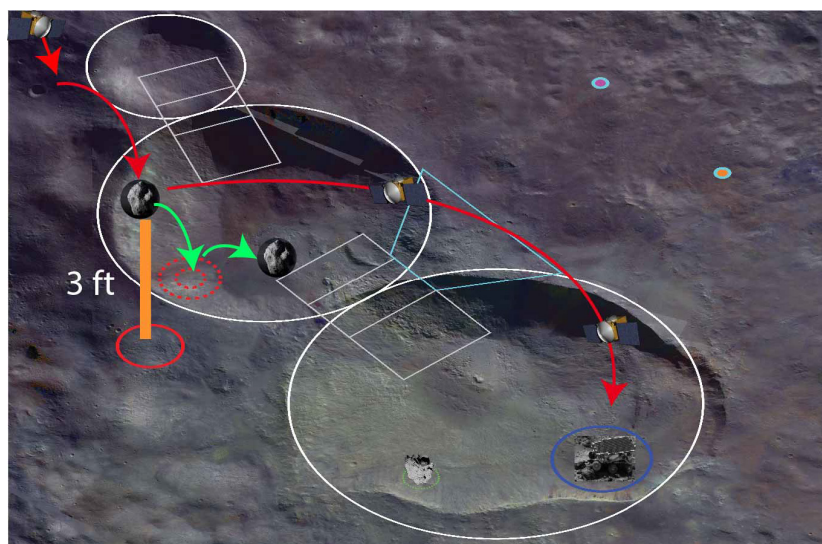


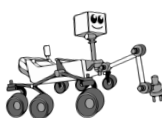
Figure 2.13: Launching the impactor and landing of the satellite on the rover.

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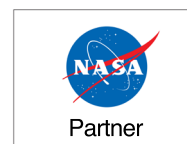


ROADS on Asteroids

Official Manual | Page 35



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ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

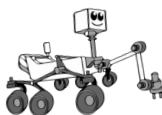
MO-07: IMPACTOR DROP & SATELLITE LANDING (CONT'D)

- Teams should consider the design of the crater walls in this section and the impactor itself so that the impactor does not bounce out of the crater.
- The drone/satellite must be able to continue to the rover, with at least the satellite landing on the rover. The drone is allowed to also land on the rover *provided* that it can remain on the rover throughout the map navigation Mission Objective. Whatever lands on the rover must be sufficiently secure that it doesn't come loose during the journey across the crater — if the drone cannot safely travel on the rover, then it should fly back to the team's base of operations.
- Student are allowed to power down the drone while the map navigation is being attempted.
- Maximum points will be award for smallest landing area on the rover.
- If the impactor lands in an unrecoverable spot (such as outside the crater), it can be placed at the center of the red dashed circles but there will be point deductions.
- If the satellite fails to land on the rover or the drone crashes, the satellite can be placed on the rover to continue the mission but no points will be award for the landing component

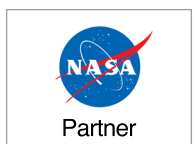


ROADS on Asteroids

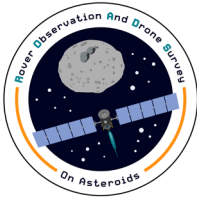
Official Manual | Page 36



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ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-08: MAP NAVIGATION

When taking samples in a region, a mission will also take a sample from a neighboring site to look for differences and similarities. ROADS on Asteroids follows this process by requiring a sample from each of the large craters.

The choice for the object that represents the sample is up to the team — keeping in mind that the sample has to be moved across the two ramps to the top crater.

To simulate the pickup of different samples:

- The satellite lands on the rover
- The rover travels to first sample site (green circle), as shown in Figure 2.14.
- The rover collects the sample and moves it to the small crater at the head of the snowman
- The rover then moves to the second crater (Figure 2.15) and undertakes collection of the impactor

For Dawn and DART divisions: The impactor has to be collected from wherever the impactor lands.

For OSIRIS REX and Hayabusa divisions: The impactor can be placed at the center of the dashed red circles for collection.

The rover is not allowed to pass out of any of the circles, and is only allowed to

NOTES FOR CHALLENGE TEAMS:

- Divisions: ALL
- Submission due: Part of final challenge submission — Due April 2021
- Award eligibility: Required for Top Team prize as part of final challenge submission; Also eligible for Resolute Award

NOTES FOR CURRICULUM TEACHERS:

- Unit 4, Lesson 3: Programming & Robots

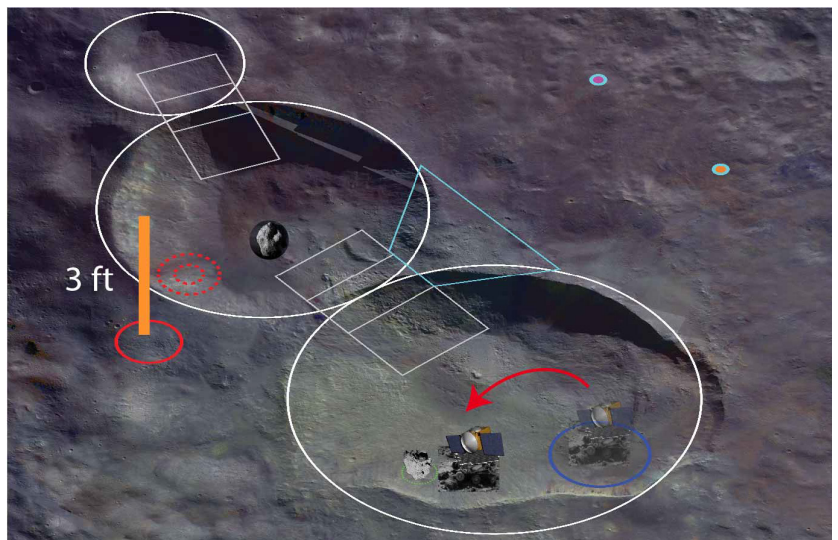


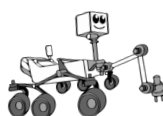
Figure 2.14: Map navigation — first sample site.

(Continues ►►►)

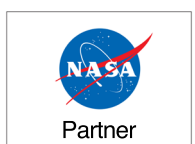


ROADS on Asteroids

Official Manual | Page 37



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ABOUT ROADS on Asteroids



2020–2021
NATIONAL
STUDENT
CHALLENGE

MO-08: MAP NAVIGATION (CONT'D)

move between craters using the ramps (*except* for DART division teams, who will collect additional samples from the plain in MO-09).

Point deductions will occur each time the rover crosses/touches the crater walls.

If the rover flips or if the satellite is tossed from the rover while traversing the ramps the mission is over.

Once the samples have been placed in the small crater at the head of the snowman feature, the satellite needs to be retrieved and flown back to base (Figure 2.16).

The drone should launch from the flat section of the ramp between the two craters. Students should check the drone prior to takeoff to ensure it's in a safe condition for launch. If using the folding drones, check the arms should be in the correction position for flight.

Resolute Award — Best placement of the two samples and rover to create the snowman's face.

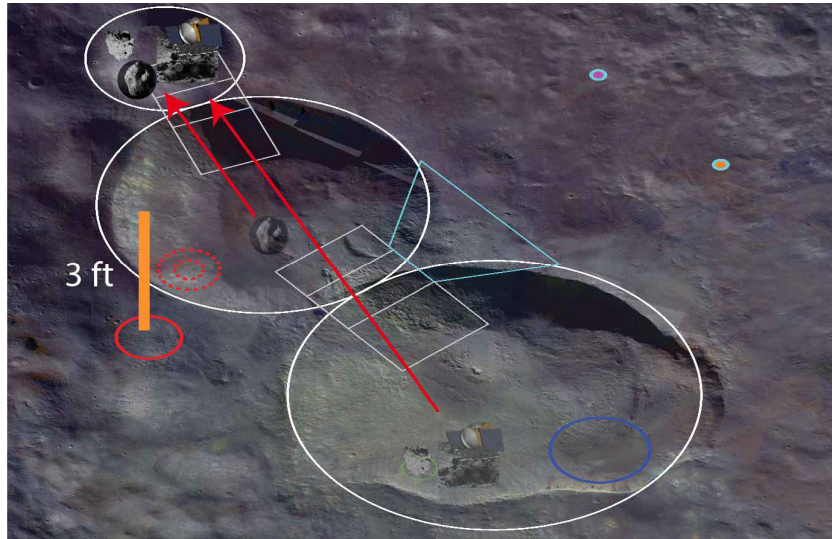


Figure 2.15: Map navigation — retrieving the impactor.

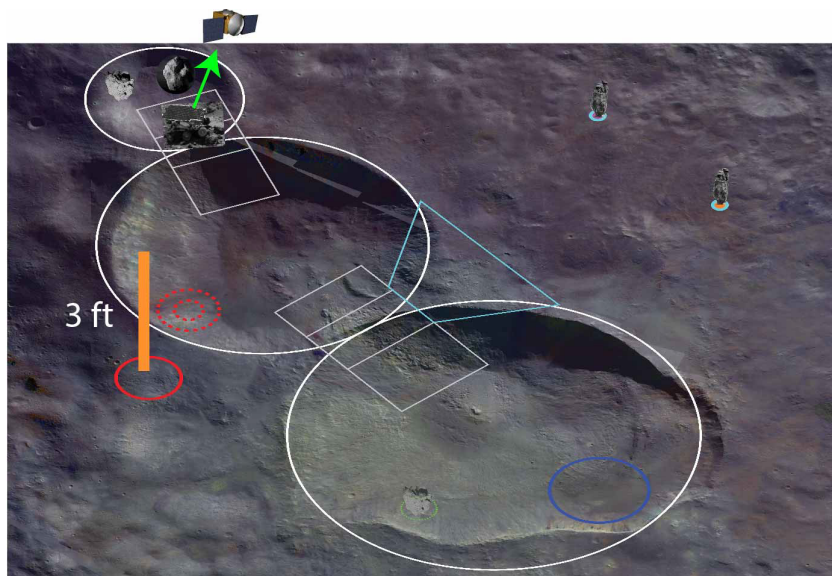
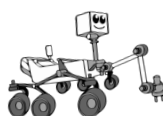


Figure 2.16: Map navigation — return to base.

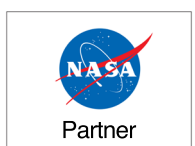


ROADS on Asteroids

Official Manual | Page 38



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ABOUT ROADS on Asteroids



2020–2021
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CHALLENGE

MO-09: EXPANDED MAP NAVIGATION (DART DIVISION / HIGH SCHOOL ONLY)

In addition to the map navigation in MO-08, DART division teams will retrieve a sample from the plains of the asteroid. This requires (a) construction of the extra ramp designated by the blue trapezoid in Figure 2.17 and (b) placement of an appropriate sample in the multi-color circles in the top right corner of the figure.

The sample collection is required to use an auxiliary motor on the robot/rover. Only one sample needs to be collected from the plains. However, the team is not allowed to bump into the sample that is not being collected.

The rover must return this third sample to the small crater at the head of the snowman feature. Once all three samples have been placed in the small crater, the satellite can be picked up and flown home to base.

There are no design requirements or restrictions for design of the plains samples — keeping in mind that it must be retrieved by a robot/rover that uses an auxiliary motor.

NOTES FOR CHALLENGE TEAMS:

- Divisions: DART division / high school) only
- Submission due: Part of final challenge submission — Due April 2021
- Award eligibility: Required for Top Team prize as part of final challenge submission; Also eligible for Enterprise Award

NOTES FOR CURRICULUM TEACHERS:

- Unit 4, Lesson 3: Programming & Robots

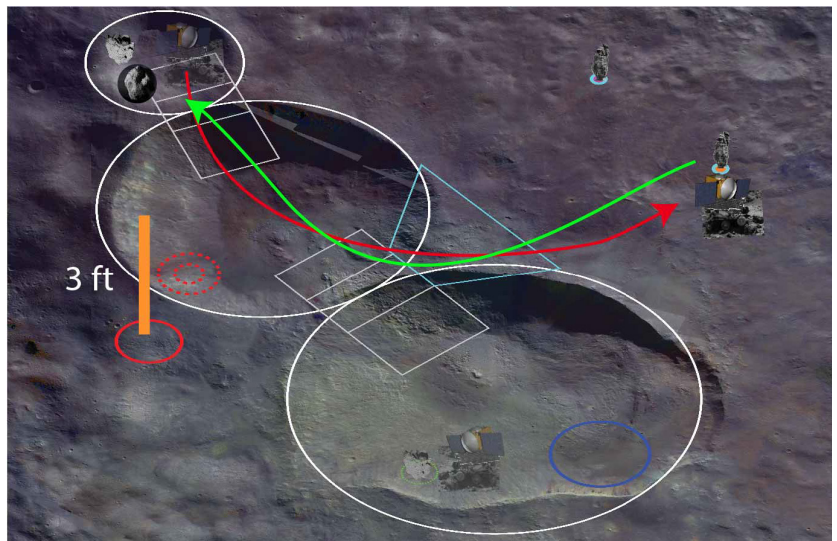
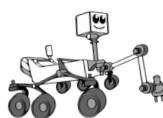
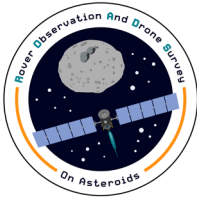


Figure 2.17: Map navigation — DART division / high school expanded effort.

Enterprise Award — Best placement of the three samples and rover to create the snowman's face.



APPENDIX A



WHY ASTEROIDS?

WHY DID NESSP CHOOSE ASTEROIDS (AND COMETS) FOR THIS YEAR'S ROADS?

Asteroids are an integral part of the solar system but probably don't get as much attention as missions to the planets. The asteroid belt lies between the orbits of Mars and Jupiter (Figure A.1).

Asteroids (and related bodies such as dwarf planets) are extremely important because they represent nearly pristine objects originating from the formation of the solar system. It's thought that the asteroid belt includes some icy objects composed of carbon-rich material from the outer solar system, while other components originate from the rocky inner part of the solar system.

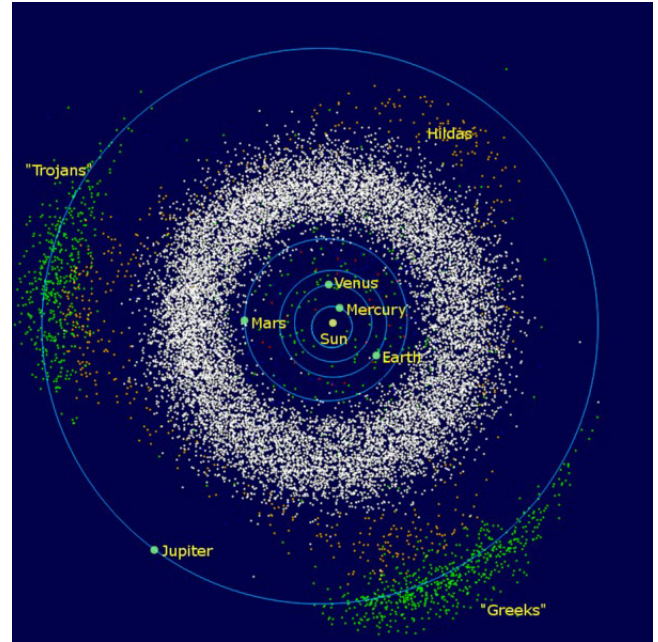


Figure A.1: Position of the asteroid belt relative to the inner planets and Jupiter.

<https://www.planetary.org/space-images/asteroid-classifications-in-the-inner-solar-system>

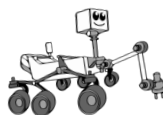


Figure A.2: Artist impression of the breakup of a large asteroid and the creation of a family of asteroids.

<https://phys.org/news/2017-08-astronomers-oldest-asteroid-family.html>

The belt exists because Jupiter produces such large gravitational perturbations that objects within the belt have continuing collisions that inhibit the formation of large objects (Figure A.2). While slow collisions lead to the building of larger asteroids, high speed collisions tend to produce fracturing of the incident objects. Within the asteroid belt there are millions of objects with a size less than 1 km and just a handful of objects with a diameter greater than 300 km.

Some of the asteroids have been kicked out of the belt. Of these ejected asteroids, some have fallen towards the inner solar system. Those that have been nudged into orbits in Earth's neighborhood are called near-earth asteroids. Some are kicked outwards, and settle into an orbit where the gravity forces of the sun are balanced by the gravity forces from Jupiter. The asteroids that are in Jupiter's orbit and are forward of the planet are called "Greeks" while the asteroids trailing Jupiter are called "Trojans."



APPENDIX A



WHY ASTEROIDS?

ASTEROIDS AND THEIR FAMILIES

Because of the continuing collisions, asteroids come in many shapes and sizes, as shown in Figure A.3. These objects, because of their many different characteristics, can provide us with clues on the role of gravity in the formation of the main constituents of the solar system as well as insight into their composition. Asteroids can also offer potential clues to the properties of the interiors of the planets since some of the asteroids may originate from small planets that have been broken up by previous collisions.

The largest body in the asteroid belt is the dwarf planet Ceres, which is about 950 km in diameter. Ceres, like Pluto, is considered a dwarf planet because although it has a spherical shape produced by its own gravity, it has yet to clear its orbit of other objects. It is also thought

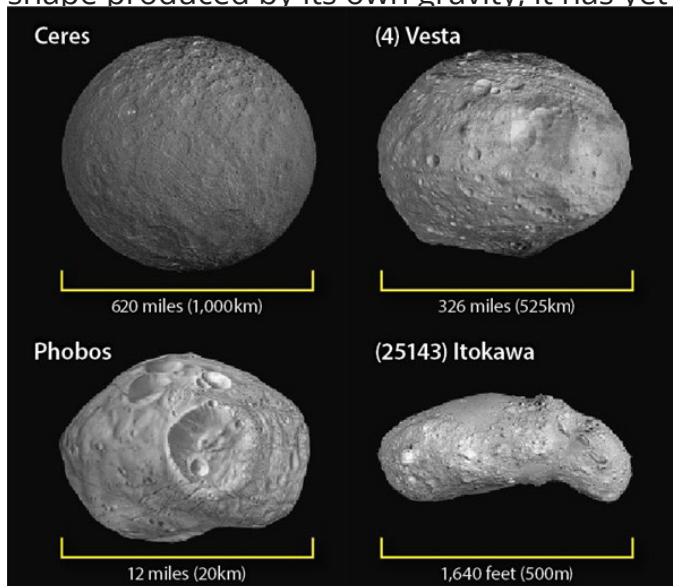


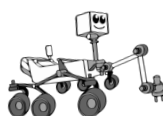
Figure A.3: Comparison of the shapes of Ceres with asteroids and the Martian moon Phobos. <https://astronomy.com/magazine/ask-astro/2017/08/the-diameter-of-spherical-bodies>

to have a core. The largest asteroid (and not a dwarf planet) in the asteroid belt is Vesta, which has a diameter of 525 km. As shown in Figure A.3, it has the appearance of a flattened sphere. Unlike most asteroids, Vesta shows signs of having had a liquid core at one time, with lava flows marking its surface. The large craters on Vesta are evidence of the violent impacts that occur in the asteroid belt — and astronomers have identified several thousand asteroids that are believed to have originated from Vesta. These asteroids are called V-type or “vestoids,” and some have even impacted the Earth.

Smaller asteroids like Itokawa, which is not part of the asteroid belt, can be very much more irregular in shape, as you can see in Figure A.3. For comparison, Figure A.3 also shows the Martian moon Phobos. It, too, is non-spherical

and there is controversy over whether it is a captured asteroid or whether it was produced by the impact of a Vesta-sized asteroid with Mars.

Regardless of which theory is correct in the case of Phobos, asteroids played an important role in the formation of the solar system and continue to provide clues on such processes. They also have the potential for providing important resources for human exploration beyond low Earth orbit, which was the aim of the now defunct company Planetary Resources, which championed the concept of asteroid mining.



APPENDIX A



WHY ASTEROIDS?

MISSIONS TO ASTEROIDS (AND COMETS)

Some of the key missions that observed small solar system objects are listed in Table A.1; the images of the relevant spacecraft are shown in Figure A.4.

FLYBY MISSIONS

Asteroids have made for excellent secondary science objectives for spacecraft that are “flying by” on their journeys to other targets in the solar system. Galileo, on its journey to Jupiter, provided the first close-up glimpse of asteroids — Gaspra and Ida in the asteroid belt. The asteroid Braille, also in the asteroid belt, was observed in a flyby mission by Deep Space 1, which was on its way to a technology demonstration of the use of plasma thrusters in deep space. The Stardust mission did a flyby of asteroid Annefrank as a secondary mission objective — its main objective was to fly into the tail of comet Wild 2 and bring back samples to Earth. These samples showed that comets contain several complex organic compounds that are fundamental building blocks of life on Earth.

In 2014, the New Horizons spacecraft, on its way to visit Pluto (one of the furthest known dwarf planets), flew by Arrokoth, a small object in an orbit beyond Neptune. Arrokoth is composed of two smaller chunks, called planetesimals, that are joined together. This makes it an interesting example of what happens when objects impact each other in a slow collision — exactly the type of collision that does not occur in the asteroid belt, as mentioned above.

Table A.1: Flyby missions of asteroids/comets

Date	Asteroid/Comet	Av Length (km)	Mission
1993	Ida	28	Galileo
1999	Braille	1.6	Deep Space 1
2002	Annefrank	8	Stardust
2004	Wild 2	4	Stardust
2012	Touttis	2.5	Chang’e 2
2014	Arrokoth	20	New Horizons

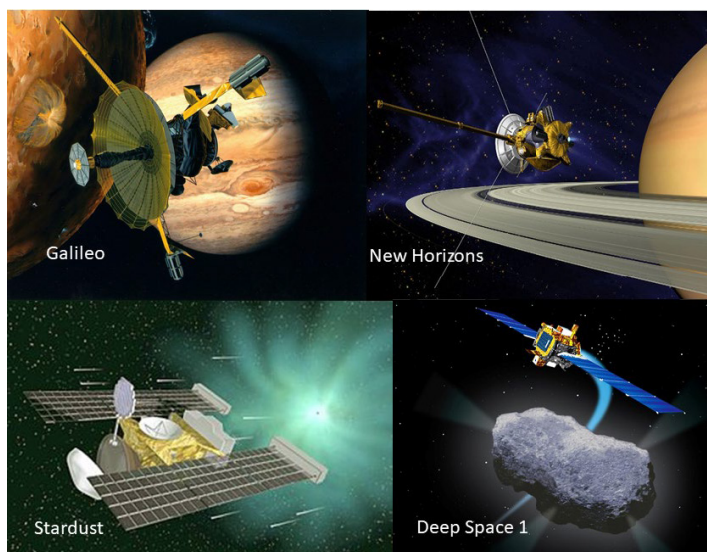
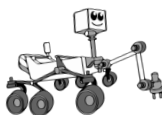


Figure A.4: Images of the spacecraft in Table A.1.



APPENDIX A



WHY ASTEROIDS?

SAMPLE RETURN MISSIONS

The fact that so many asteroids are relatively close to Earth and have low gravity has led to missions developed to orbit, land, and even return samples back to Earth. These missions are listed in Table A.2; images of the spacecraft are shown in Figure A.5.

Results from the Deep Impact mission to Tempel 1 showed that comets contain more rocky material than previously thought, which supports the theory that material from the inner solar system has been transported outwards and material from the outer solar system has been transported inwards.

The lander Philae, part of the Rosetta mission to comet Churyumov-Gerasimenko, unfortunately had a hard bounce upon landing and so the data return was limited. Philae's instruments nevertheless showed that the comet's surface is quite pungent, with ammonia, hydrogen cyanide, and hydrogen sulfide being present. Rosetta also found the presence of simple amino acids, which is the basis on life on Earth.

The samples returned during the Hayabusa mission to asteroid Itokawa suggested that Itokawa was probably part of a larger asteroid in its past. The samples from Itokawa also contained material like that of meteorites that have impacted Earth.

Table A.2: Orbiting, landing, and/or sample return missions to asteroids or comets

Date	Asteroid/Comet	Av Length (km)	Mission
1998	Eros	17	NEAR Shoemaker
2005	Itokawa	0.3	Hayabusa
2005	Tempel 1		Deep Impact
2008	Chiryumov-Gerasimenko	4.6	Rosetta/Philae
2011	Vesta	529	Dawn
2015	Ceres	952	Dawn
2019	Ryugu	0.8	Hayabusa 2
2019	Bennu	0.5	OSIRIS-Rex

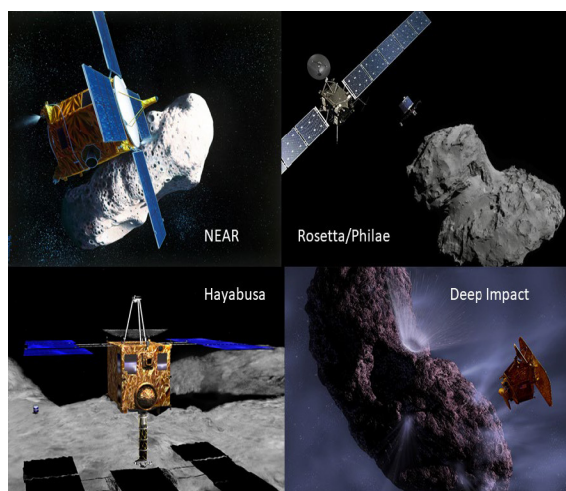
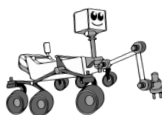


Figure A.5: Past missions to asteroids and comets.



APPENDIX A



WHY ASTEROIDS?

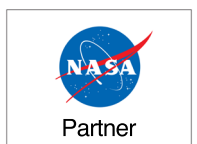
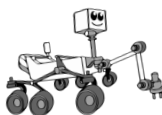
ROADS ON ASTEROIDS -RELATED MISSIONS

The Dawn mission surveyed the largest asteroid in the belt, Vesta, and showed that Vesta is rich in carbon material as well as material that needed water in order to form. Dawn then travelled (using plasma propulsion) to the inner most dwarf planet, Ceres, and found that it once had oceans. On the one hand, the presence of ancient oceans on Ceres suggests that the ingredients of life may have been present on the dwarf planet — but on the other hand, Ceres' relatively low gravity means the presence of such oceans would like have been short lived, and if so life would not have been able to take hold.

Currently, there are also two ongoing sample return missions to asteroids: the Hayabusa 2 mission to the asteroid Ryugu by JAXA (the Japanese space agency) and the OSIRIS REx mission to the asteroid Bennu by NASA. Hayabusa 2 is unique because it used a hypervelocity impactor to expose and collect underlying material to help better determine the age and origin of the asteroid Ryugu. Bennu is a carbonaceous asteroid, and the OSIRIS REx mission seeks to determine the potential abundance of water and organic compounds.

These sample return missions require a substantial amount of energy to make the necessary transfers in an out of orbit on its journeys both to and from the target objects. Using standard chemical rockets would be too expensive, and so these systems use plasma propulsion — where strong electric fields are applied to strip the electrons off atoms and the charged particles are accelerated to speeds nearly 10 times faster than can be attained within chemical rockets. Because this requires electrical power, Hayabusa 2 and OSIRIS REx carry large solar arrays. Yet even with this large array, the total mass is nevertheless much less than carrying chemical rocket systems.

The year 2021 will be an exciting year for asteroid research as there are two missions to be launched. The Double Asteroid Redirection Test (DART), scheduled to launch for asteroid Didymos in July 2021, seeks to redirect Didymos's "moonlet," a small secondary object in orbit around the asteroid. The Lucy mission, scheduled to launch in October 2021, will investigate the Trojan asteroids that trail Jupiter's orbit.



APPENDIX A



WHY ASTEROIDS?

RECOMMENDED READING ON MISSIONS TO ASTEROIDS

DART

<https://dart.jhuapl.edu/News-and-Resources/files/Fact-Sheet-DART.pdf>

<https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=DART>

DAWN

<https://www.jpl.nasa.gov/missions/dawn/>

<https://solarsystem.nasa.gov/missions/dawn/overview/>

HAYABUSA

<https://solarsystem.nasa.gov/missions/hayabusa/in-depth/>

<http://www.astronautix.com/h/hayabusa.html>

HAYABUSA2

<https://solarsystem.nasa.gov/missions/hayabusa-2/in-depth/>

<http://www.hayabusa2.jaxa.jp/en/>

LUCY

<https://www.nasa.gov/content/goddard/lucy-overview>

<http://lucy.swri.edu/>

OSIRIS REx

https://www.nasa.gov/sites/default/files/atoms/files/osiris_rex_factsheet5-25.pdf

<https://www.asteroidmission.org/objectives/>

RECOMMENDED READING ON ASTEROIDS

AND OTHER MISSIONS INTO DEEP SPACE

https://en.wikipedia.org/wiki/List_of_minor_planets_and_comets_visited_by_spacecraft

<https://nineplanets.org/asteroids/>

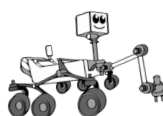
https://en.wikipedia.org/wiki/Asteroid_belt

<https://www.nasa.gov/topics/>



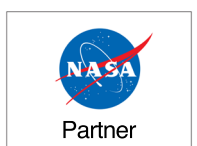
ROADS on Asteroids

Official Manual | Page VI



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APPENDIX B



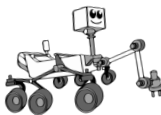
SUPPLIES

Coming soon....

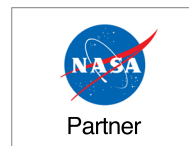


ROADS on Asteroids

Official Manual | Page VII



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APPENDIX C



DRONE SAFETY & FAA REGULATIONS

DRONE (UAV) SAFETY

For some activities, ROADS on Asteroids uses drones — also called UAVs for uncrewed (or unmanned) aerial vehicle. 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.

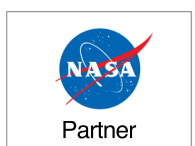
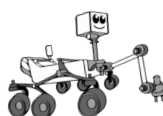
All drone practice and activities for ROADS on Asteroids should take place indoors. NESSP does not sanction outdoor UAV flight in relation to this challenge.

UAVs are increasingly common and ROADS activities are 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. Teachers, mentors, and coaches are responsible for ensuring their students understand and practice drone safety.

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.
- Everyone with long hair should wear some type of hair covering (e.g. baseball cap).
- 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.



APPENDIX C



DRONE SAFETY & FAA REGULATIONS

- 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 ROADS challenge (MO-06), make sure to have another team member keep an eye on the UAV and alert the pilot of any difficulty.

FAA UAV INFORMATION

This section is to provide some clarification on the FAA regulations regarding UAVs and how these apply to ROADS activities and provide some tips on staying within the regulations. Keep in mind all for ROADS should take place indoors and therefore any practice required should take place indoors as well. The FAA regulations do not apply to indoor flight¹, but any and all outdoor flight is subject to FAA regulations and guidelines, even if it is over your own property⁴.

The information contained here is taken and interpreted from the FAA website on Unmanned Aircraft Systems², FAA Advisory Circular 107-2³, the FAA's *Memorandum: Educational Use of Unmanned Aircraft Systems (UAS)*⁴, 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.

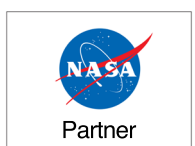
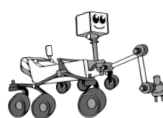
Starting with the UAS Registration, any drone between 0.55 lb and 55 lb (250 g and 25 kg) needs to be registered with the FAA, whether it is used for “recreational, commercial, government,

1 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>.

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

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

4 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.



APPENDIX C



DRONE SAFETY & FAA REGULATIONS

or other purposes.”⁵ 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 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.

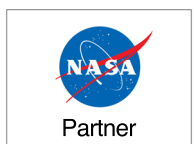
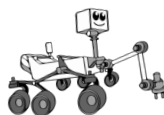
The Remote Pilot Certificate (RPC) is required for anyone flying a small unmanned aircraft, unless for hobby or recreation, as stated in *Advisory Circular 107-2*⁶:

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.

5 FAA. FAADroneZone. Retrieved in December 2018 from <https://faadronezone.faa.gov/#/>.

6 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



APPENDIX C



DRONE SAFETY & FAA REGULATIONS

It is important to note that RPC applicability is given in regards to the use 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 stating¹:

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."

In regards to educational use, the FAA issued a memorandum² 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. Students 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 regulations³:

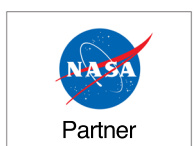
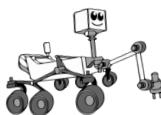
Part 107 Operating Rules

- 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

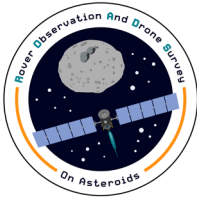
1 FAA. Unmanned Aircraft Systems (UAS) Frequently Asked Questions, Flying for Fun Under the Special Rule for Model Aircraft. Retrieved in December 2018 from <https://www.faa.gov/uas/faqs/#ffrhttps://www.faa.gov/uas/faqs/-reg>:

2 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.

3 FAA. Fly under the Small UAS Rule. Retrieved in December 2018 from https://www.faa.gov/uas/getting-started/part_107/



APPENDIX C



DRONE SAFETY & FAA REGULATIONS

If you or your students are interested in obtaining an RPC, the requirements are fairly simple⁴:

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

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

