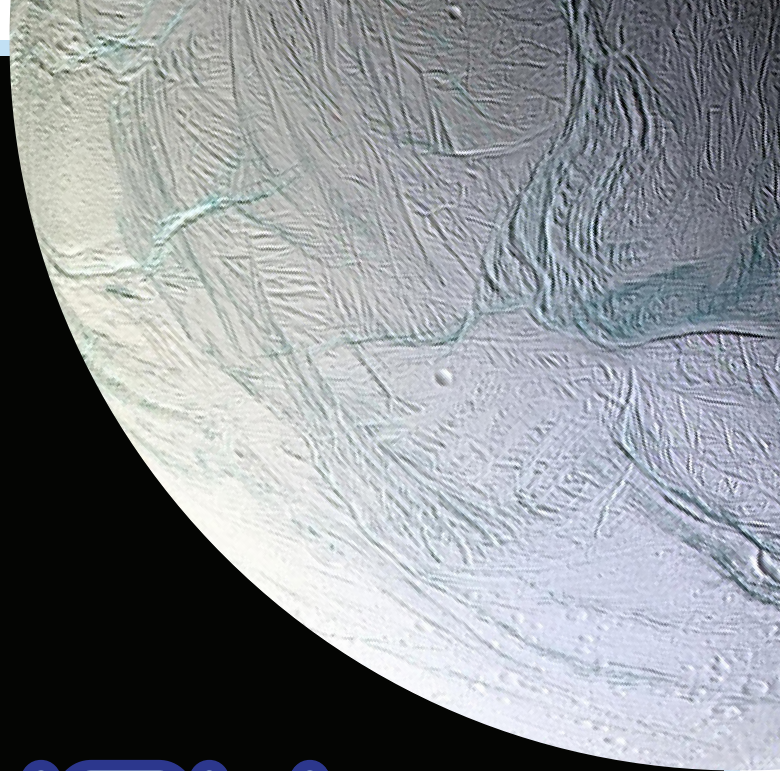
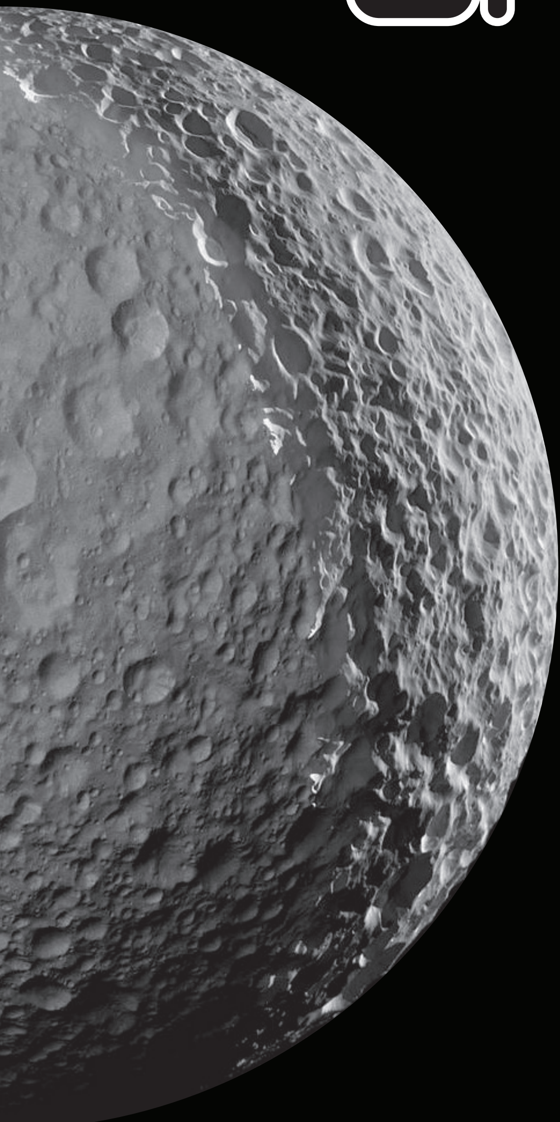


ROADS ON



ICY WORLDS

2021-2022
STUDENT
CHALLENGE

ROVER OBSERVATION AND DRONE SURVEY ON ICY WORLDS

OFFICIAL
MANUAL
(ENGLISH)

NORTHWEST EARTH AND SPACE SCIENCES PIPELINE
NESSP

NASA Partner

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 2021–2022 we're going to icy worlds!

WELCOME TO

ROADS

on Icy Worlds

FOR?

Teams of students in grades 3–12.

STEM CONCEPTS

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

- Mission planning
- Communications
- Planetary dynamics
- Biological sampling & pH
- Astrobiology/biology
- Robotics
- Programming

ACTIVITIES

- Creating mission documentation
- Explore planetary dynamics and use the knowledge to model a new object
- Take biological samples and explore them with a microscope
- Use provided calculations to create your own map of an icy moon site
- Operate a drone to simulate space flight
- Robotics & programming — use a robot to navigate your map

HOW CAN I USE THIS 'FRAMEWORK'?

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

During the 2021–2022 academic year, while Icy Worlds 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.

2021–2022 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 2021 – April 2022.

Companion course. Use the full set of the ROADS on Icy Worlds Companion Course units and lessons, or select just a few relevant to your curriculum. Registering for the 2021–2022 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 2022.

Are you reading this manual in the future? Even if it's not 2021–2022 any longer, you can still use these activities and the companion course 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.

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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 through 2021. In 2022, NESSP moves to Central Washington University in Ellensburg, Washington.

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.

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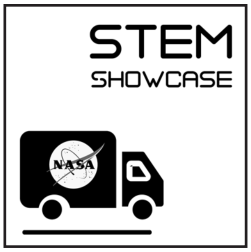
ABOUT NESSP

OUR PROGRAMS

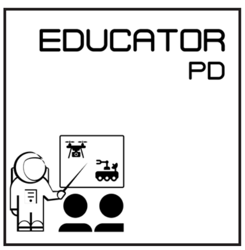


STEM SHOWCASES

Through our STEM Showcase program, NESSP brings NASA-related science directly into communities. A showcase is a half- or full-day of hands-on STEM activities designed to inspire and excite students, educators, and families. Activities range from flying drones to programming robots to watching the night sky inside a portable planetarium. Available only in the Northwest.

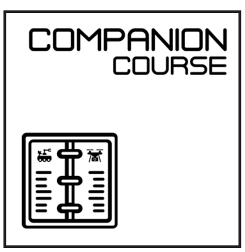
MINI-MISSIONS / SUMMER CAMPS

With our Mini-Mission program, NESSP offers guidelines and supplies for STEM programs that you lead over one (or more!) days at your organization. Is it a summer camp? Is it a STEM academy? Call it what you like as you guide students through NESSP-created activities related to NASA science.



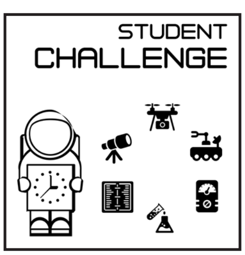
EDUCATOR PD

Interested in leading a mini-mission program for your organization? Looking to add new STEM activities to your formal classroom? Our Educator Professional Development program trains teachers and para-educators in NESSP activities and NASA mission-related science.



COMPANION COURSE

Our Companion Course program turns our student challenges into teachable lessons and units that you can use to supplement your existing curriculum. The course is aligned with NASA missions and supports Next Generation Science Standards. The program also offers supplies as well as sessions with undergraduate teaching assistants.



NATIONAL STUDENT CHALLENGES

The National Student Challenge program gives teams of students in grades 3–12 a chance to model their own NASA mission, including flying to the mission site (via drone), surveying the landscape (via robot), and taking and analyzing samples. Teams document their mission in text and video, then submit their materials to NESSP for the chance to win prizes — maybe a trip to a NASA center!

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 companion course and mini-mission / summer camp programs as well. We also offer ROADS on Icy Worlds training to educators through our professional development program.

ABOUT ROADS

OVERVIEW

IN THIS MANUAL

This manual will give you quick introductions to our ROADS on Icy Worlds professional development, mini-mission / summer camp, and companion course programs. More information on each of these is available on our website: nwessp.org

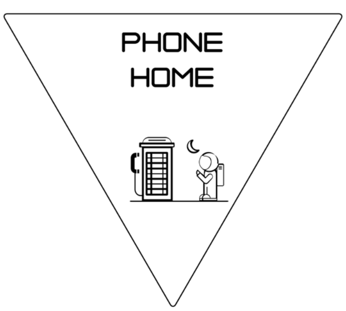
The bulk of the manual provides the information a team will need to participate in NESSP's 2021–2022 National Student Challenge — all the dates and deadlines, details on each Mission Objective, and a list of relevant supplies.

GETTING ON THE ROAD(S)

Educators are welcome to use any aspect of the ROADS on Icy Worlds challenge and companion course that meets your needs —

- whether you're using the full companion course or just one or two units or lessons;
- whether you're officially registering a team for the 2021–2022 student challenge or just using the activities to guide your Scouts in completing badge requirements;
- whether you're leading a community club in a STEM academy activity or you're preparing a summer program.

ROADS on Icy Worlds offers immersive opportunities for students in communications, planetary dynamics, biology (including life in extreme environments), 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 Icy Worlds for the national student challenge or you're using just one of our companion course 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!

ABOUT ROADS on Icy Worlds

THE MISSION

THE ROADS ON ICY WORLDS MISSION

For 2021–2022, ROADS is exploring icy worlds. There are many icy planetary bodies in our solar system — some of Saturn's moons (Mimas and Enceladus, for example), or Pluto and Charon (often considered a binary dwarf planet system). In particular, though, we'll be going to Europa, one of Jupiter's moons.

> The search for life beyond Earth is one of NASA's primary objectives. If humans are to truly understand our place in the universe, we must learn whether our planet is the only place where life exists. So the search is on!
>
> *(From NASA's Europa Clipper site)*

Why an icy world?

Where there's ice, there's water. And where there's water, there might be life.

Why this area of Europa?

The landing site for this year's ROADS challenge is called Castalia Macula, a large, dark colored depression on the surface of Europa. Europa has a pretty rugged terrain overall, but Castalia Macula is comparatively smooth, which offers a more low-risk landing site for scientific equipment.

But we're not going to Castalia Macula just for the smooth landing! Remember, where there's water there might be life. And there's a lot of evidence to strongly suggests that beneath Europa's frozen surface there lies an ocean of *liquid* water.

Thanks to information collected during the Galileo space probe's many visits to Europa, scientists have been able to really consider the various dark and light colored areas of this moon — and they theorize that as features on Europa age, they grow lighter in color. This means that Castalia Macula, which you'll remember is dark-colored, is probably relatively young.

These darker, younger features of Europa are likely to contain material that has been recently erupted from the moon's subsurface.

And what's subsurface on Europa? Possibly an ocean ... which means water ... which means, ***potentially***, life!

So — let's find out!!

Teams will plan and simulate a mission to Europa. The mission objectives lead students through:

- Mapping and modeling the Europa site, inside and out
- Understanding the environmental limits of biological life
- Managing aeronautics to fly and land a drone carrying a payload
- Writing and executing a robot's program to navigate Europa's surface and collect samples
- Navigating communication within the team and with other people invested in the mission (such as NESSP, your teachers, families, and communities, and yes — even NASA!)

NASA MISSIONS TO RELEVANT ICY WORLDS

Europa

Past flyby missions: Pioneer 10 (1973), Pioneer 11 (1974), Voyager 1 (1979), Voyager 2 (1979), New Horizons (2006–2007).

Past longterm mission: Galileo space probe (1995-2003).

Upcoming missions:

- Europa Clipper
  - Launch target: October 2024
  - Mission website: https://europa.nasa.gov/
- JUICE (JUpiter ICy moons Explorer)
  - Launch target: 2022
  - Mission website: https://solarsystem.nasa.gov/missions/juice/

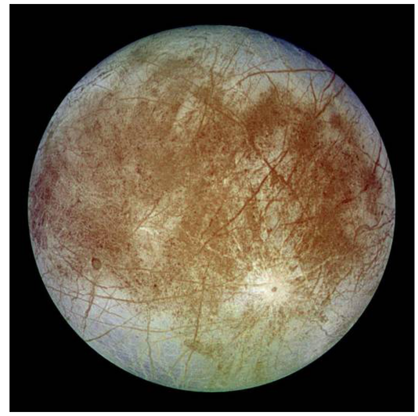
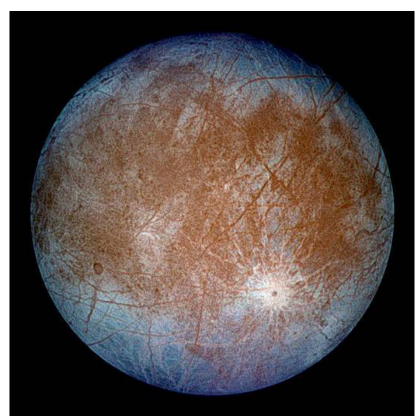
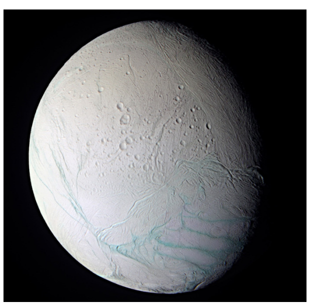


Image credit: NASA/JPL-Caltech/DLR

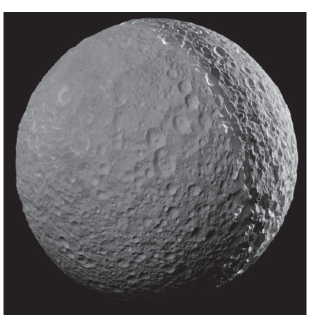
These images show two views of the trailing hemisphere of Europa. The image above shows the approximate natural color appearance of Europa. The image below is a false-color composite version combining violet, green and infrared images to enhance color differences in the predominantly water-ice crust of Europa. (From NASA.gov)





Enceladus (one of Saturn's moons)

Past flyby missions: Voyager 1 (1980), Voyager 2 (1981), Cassini (two dozen flybys during 2005–2015).



That's no Death Star....

Mimas (one of Saturn's moons)

Past flyby missions: Pioneer 11 (1979), Voyager 1 (1980), Voyager 2 (1981), Cassini (six flybys during 2008–2010).

See more in Appendix A — "Why icy worlds?"

ABOUT ROADS on Icy Worlds

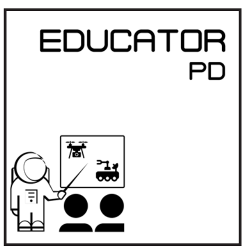
PROFESSIONAL DEVELOPMENT

NESSP'S PROGRAMS + ICY WORLDS =

During the 2021–2022 academic year, while Icy Worlds is our active ROADS framework, NESSP's usual programming is offered with a ROADS on Icy Worlds focus — encompassing our professional development, mini-missions / summer camps, companion course, and annual student challenge. The next few pages introduce how each of these programs fits into the ROADS on Icy Worlds year.

Educators who register their 2021–2022 ROADS on Icy Worlds 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



EDUCATOR PD

ROADS on Icy Worlds training for teachers, organizers, and other science educators, was offered August–November 2021.

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.

MINI-MISSIONS / 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/icyworlds.

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 2022, we will note what support we will be able to offer.

MORE INFORMATION

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

COMPANION COURSE

COMPANION COURSE

Our companion course program offers a curriculum for educators to integrate concepts from the ROADS on Icy Worlds 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 ICY WORLDS COMPANION COURSE

The ROADS on Icy Worlds companion course is organized around the guiding question "How can we use experiments, models, and rehearsals here on Earth to understand other solar system objects and plan a successful mission to Icy Worlds?" The course's units and lessons support Next Generation Science Standards and is aligned with NASA missions.

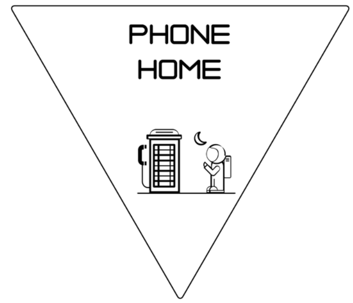
Units

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/icyworlds/

ABOUT ROADS on Icy Worlds

COMPANION COURSE



SUPPORT FROM NESSP

If you are using our ROADS on Icy Worlds companion course 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 Icy Worlds 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 Icy Worlds: nwessp.org/icyworlds/

ABOUT
ROADS on Icy Worlds

COMPANION COURSE

COMPANION COURSE

COMPANION COURSE UNITS & LESSONS ⇆ **CHALLENGE MISSIONS OBJECTIVES**

STUDENT CHALLENGE

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

- The companion course supports the challenge by strengthening a student's grasp of the scientific and engineering principles.
- The student challenge supports the course by giving students fun, hands-on experiences with the topics.

There are more units and lessons in the companion course than there are Mission Objectives (MO) in the challenge, but each MO lines up with at least one lesson. The chart on the next page provides a quick glance at how the course 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.

(Continues ▸▸▸)

ABOUT ROADS on Icy Worlds

COMPANION COURSE

UNIT & LESSON	MISSION OBJECTIVE (MO)
Unit 1: Mission Planning **L3:** Documenting the Mission	**MO-01:** Mission Development Log (MDL) *(Started in this lesson; continues throughout)*
Unit 1: Mission Planning **L5:** Mapping Other Worlds	**MO-02:** Map Development [Checkpoint Challenge]
Unit 2: Planetary Geology **L1:** Planetary Formation and Structure	*(Contributes to...)* **MO-03:** Inside Europa Model
Unit 2: Planetary Geology **L2:** Planetary Dynamics	**MO-03:** Inside Europa Model
Unit 2: Planetary Geology **L3:** Landform Dynamics	*(Contributes to...)* **MO-04:** Explaining Europa's Surface
Unit 2: Planetary Geology **L4:** Crater Formation	**MO-04:** Explaining Europa's Surface
Unit 3: Astrobiology **L3:** The Limits of Life	**MO-05:** Yeast ID Card [Checkpoint Challenge]
Unit 4: Robotics and Drones **L1:** Human and Machine Communication	*(Contributes to...)* **MO-06:** Landing Site — Drone Landing **MO-07:** Surface Navigation **MO-08:** Sample Collection
Unit 4: Robotics and Drones **L2:** Drone Development	**MO-06:** Landing Site — Drone Landing
Unit 4: Robotics and Drones **L3:** Programming and Robots	**MO-07:** Surface Navigation **MO-08:** Sample Collection **MO-09:** Advanced Surface Navigation (HS only)
Unit 4: Robotics and Drones **L4:** Mission Integration and Iteration	**MO-10:** Mission Patch Development
Unit 5: Final Mission and Communication **L1:** Executing and Evaluating the Mission	*(Includes documentation video of...)* **MO-06:** Landing Site — Drone Landing **MO-07:** Surface Navigation **MO-08:** Sample Collection (+ **MO-09:** Advanced Surface Navigation for HS)
Unit 5: Final Mission and Communication **L2:** Presenting the Mission to Clients	*(Final evaluation of...)* **MO-01:** Mission Development Log (MDL)

ABOUT **ROADS on Icy Worlds**

2021-2022 NATIONAL STUDENT CHALLENGE

NATIONAL STUDENT CHALLENGE 2021-2022

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 in STEM, 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 Icy Worlds is designed in a way that tasks can be completed consistent with social distancing requirements. For example, in the past, teams have tackled activities during group meetings. Where 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.

Submissions will be made virtually through the NESSP website.

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 on 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 Icy Worlds: nwessp.org/icyworlds/

STEPS ON THE ROAD[S]

The ROADS on Icy Worlds 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.

1 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 Mission Advisor (an adult teacher, coach, or mentor).

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

The ROADS on Icy Worlds 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 Icy Worlds 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:

JUICE Division	Grades 3-4, or no programming experience
Clipper Division	Grades 5-8
Voyager Division	Grades 9-12
Galileo Division	Visually impaired (grades 3-12)

(Continues ▶▶▶)

STEPS ON THE ROAD(S)

Step 2 : Complete the Mission Objectives

The activities in the ROADS on Icy Worlds 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 checkpoints as they are important milestones toward the final challenge!

Step 3 : Submit your materials for the final challenge

The ROADS on Icy Worlds "final event" will be held virtually in April 2022. 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 through 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 2022.

PRIZES!!

Our intention with the ROADS 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. ***However,*** restrictions in place for the pandemic continue to make travel difficult or impossible. As of preparing this manual, public access to NASA centers has not yet resumed and we do not know when they will be open again. If NASA center visits are not available in 2022, 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:

- JUICE Division
- Clipper Division
- Voyager Division
- Galileo Division

Checkpoint challenges

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

- Map development [MO-02]
- Yeast ID card [MO-05]
- Wing it like Winglee

SCHOOL-YEAR CHALLENGE SCHEDULE

November 2021	Launch of ROADS on Icy Worlds
	School-year registration opens
December 6, 2021 (Monday)	School-year registration closes
December 10, 2021 (Friday)	ROADS on Icy Worlds Challenge Q&A
January 7, 2021 (Friday)	Mission Advisor workshop
February 7–11, 2022	Virtual “Meet an Expert” this week
February 18, 2022 (Friday)	***Optional*** Checkpoint MO-02 (Map development) due
March 14–18, 2022	Virtual “Meet an Expert” this week
March 18, 2022 (Friday)	***Optional*** Checkpoint MO-05 (Yeast ID card) due
April 4–8, 2022	Virtual “Meet an Expert” this week
April 15, 2022 (Friday)	Final challenge submissions due
	Optional Checkpoint “Wing it like Winglee!” due
May 2022	Top teams announced

ABOUT
ROADS on Icy Worlds

2021-2022 NATIONAL STUDENT CHALLENGE

MISSION OBJECTIVES (MOs)

MO-01: MISSION DEVELOPMENT LOG (MDL)

A Mission Development Log is the record of your mission, beginning to end. Document your planning discussions, your trials, failures, and successes, and modifications made as ideas evolve. Each member should contribute!

MO-02: MAP DEVELOPMENT [CHECKPOINT CHALLENGE MO-02]

Ready, set, geometry! We've provided the dimensions and features of the map, now teams will build their own version — including areas that can't be traversed, which their robotic system must navigate around.

MO-03: INSIDE EUROPA MODEL

MANY forces and processes, in the past and the present, form and change planets and moons. Make a model of Europa to explain its interior and how what's happening inside influences what happens to the surface.

MO-04: EXPLAINING EUROPA'S SURFACE

Make your claim! Pick a targeted area of Europa's surface and make a claim — about forces or processes that created the feature, the order features formed, or any other claim you can support with evidence from your work.

MO-05: YEAST ID CARD [CHECKPOINT CHALLENGE MO-05]

All organisms need certain conditions to survive and thrive. Your objective: learn as much as you can about the limits of one hardy organism — yeast — and present your findings in the form of an identification card.

MO-06: LANDING SITE — DRONE LANDING

Launching a rover, NASA uses data from orbiters and flyby missions to select a site. Use your drone's camera to survey the two potential landing sites. Take an image, select your landing site, then drop your payload!

MO-07: SURFACE NAVIGATION

Europa has challenging terrain, and your rover needs to get around without crashing in areas too dangerous to traverse. Use your programming skills to get your rover safely from the landing site to the places of interest!

MO-08: SAMPLE COLLECTION

What's happening below the surface of Europa? A future lander will drill into the ice and samples. Your rover will navigate to 4/5 sample collection areas, trying to find essential ingredients for the chemistry of life.

MO-09 (VOYAGER DIVISION TEAMS ONLY): ADVANCED SURFACE NAVIGATION

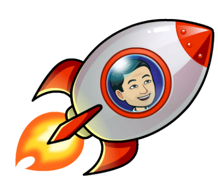
Europa's chaos regions are produced by disruptions to the icy crust. What's going on over there? Using your color sensor, take a data reading at the yellow chaos region site. Identify a different color and continue on.

MO-10 MISSION PATCH DEVELOPMENT

A mission patch is an important symbol of any NASA mission, reflecting the team, the object of study, the spacecraft, the mission goals, or a combination! How will you represent your Icy Worlds mission with imagery?

WING IT LIKE WINGLEE! [CHECKPOINT CHALLENGE]

As NESSP's founding director, Dr. Winglee, might remind us, sometimes you gotta wing it! Describe something you tried for Icy Worlds that didn't go as expected. What happened, what did you learn, and what happened next?



MISSION OBJECTIVES (MOs)

The ROADS on Icy Worlds 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.

Also, 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 icy worlds. 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 Icy Worlds challenge should be clear on what is required and what is not.

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

1. Mission Development Log (outlined in MO-01)
2. Mission Video (MOs 02–09 for Voyager/high school teams; MOs 02–08 for all other teams)

Checkpoint challenge awards — Two of the checkpoint challenges align with MO-02 and MO-05, *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 checkpoint 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 nevertheless continue onward. 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 to have a strict deadline for checkpoint submission while also considering the checkpoint challenges as optional.

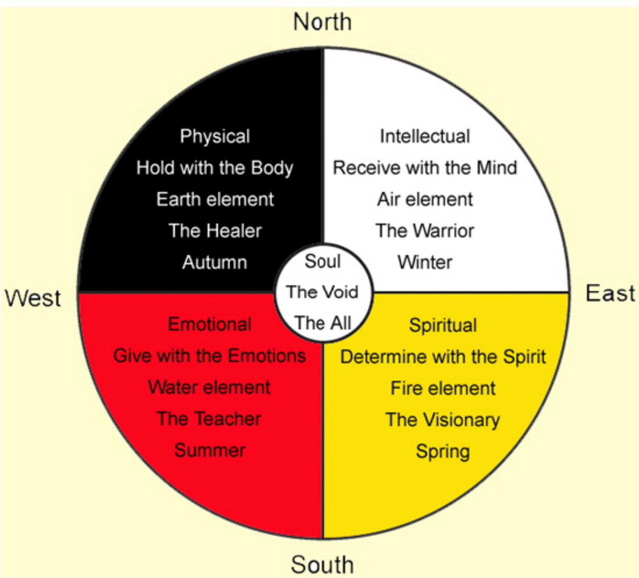
The three checkpoint challenges are as follows.

- Map development — MO-02
- Yeast ID card — MO-05
- Wing it like Winglee

TEAMWORK AND DIVERSITY

The ROADS on Icy Worlds 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 Icy Worlds 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.



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's 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 shown on the left, 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 Icy Worlds, 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 in 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.

MO-01: MISSION DEVELOPMENT LOG (MDL)

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 2022

Companion course / For more science:

- Unit 1, Lesson 3: Documenting the Mission *(Started in this lesson; continues throughout)*

A Mission Development Log is the record of your mission, beginning to end. Document your planning discussions, your trials, failures, and successes, and modifications made as ideas evolve. Each member should contribute!

The MDL will document a team's scientific explorations, initial and final designs, modifications, successes and failures. Yes — successes AND failures! Scientists and engineers rarely get it right the first time. In that way, your MDL will truly parallels standard scientific and engineering design principles. Changes always occur as more information becomes available, and getting it wrong provides a wealth of information on how to successfully proceed — in other words it is *okay to fail*. Even though your final product should be designed so that these failures no longer occur, it's absolutely normal to make mistakes and to fail as you learn how to get to that final successful product.

Failure IS an option??

Yes, sometimes! See the Wing it like Winglee Checkpoint Challenge at the end of these MOs.

"Documentation" can take **the form** of labeled sketches, diagrams, descriptions, bulleted lists, or photos.

The **types of things** your team will document include:

- Initial plans and how they evolved over time
- What worked and what did not work
- A timetable to complete the mission's tasks, with updates throughout the challenge as the timetable shifts — including why the schedule shifted

The MDL **must** include sections for all mission objectives:

- Inside Europa model
- Explaining Europa's surface
- Yeast ID card
- Landing site — drone landing
- Surface Navigation (plus Advanced surface navigation for Voyager/HS teams)
- Sample collection
- Mission patch development

ALL team members should participate in compiling the MDL — it should not be the work of one single documentarian/secretary.

MO-02: MAP DEVELOPMENT [CHECKPOINT CHALLENGE]

For ROADS on Icy Worlds, **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 5 ft. The map could be made from foamboard, taped cardboard, or just an area taped on the floor of 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.

For challenge teams:

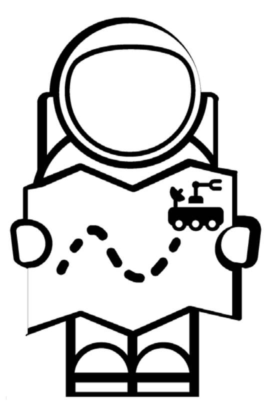
- Divisions: ALL
- Award eligibility: Checkpoint Challenge
- Checkpoint challenge entry: February 2021
- Award eligibility: Required for Top Team prize(s) as part of final challenge submission; Also eligible for Best of MO-02 Award
- Submission due: Part of final challenge submission — Due April 2022

Companion course / For more science:

- Unit 1, Lesson 5: Mapping Other Worlds

The pages that follow contain specific instructions for grade bands:

- Upper elementary
- Middle school
- High school



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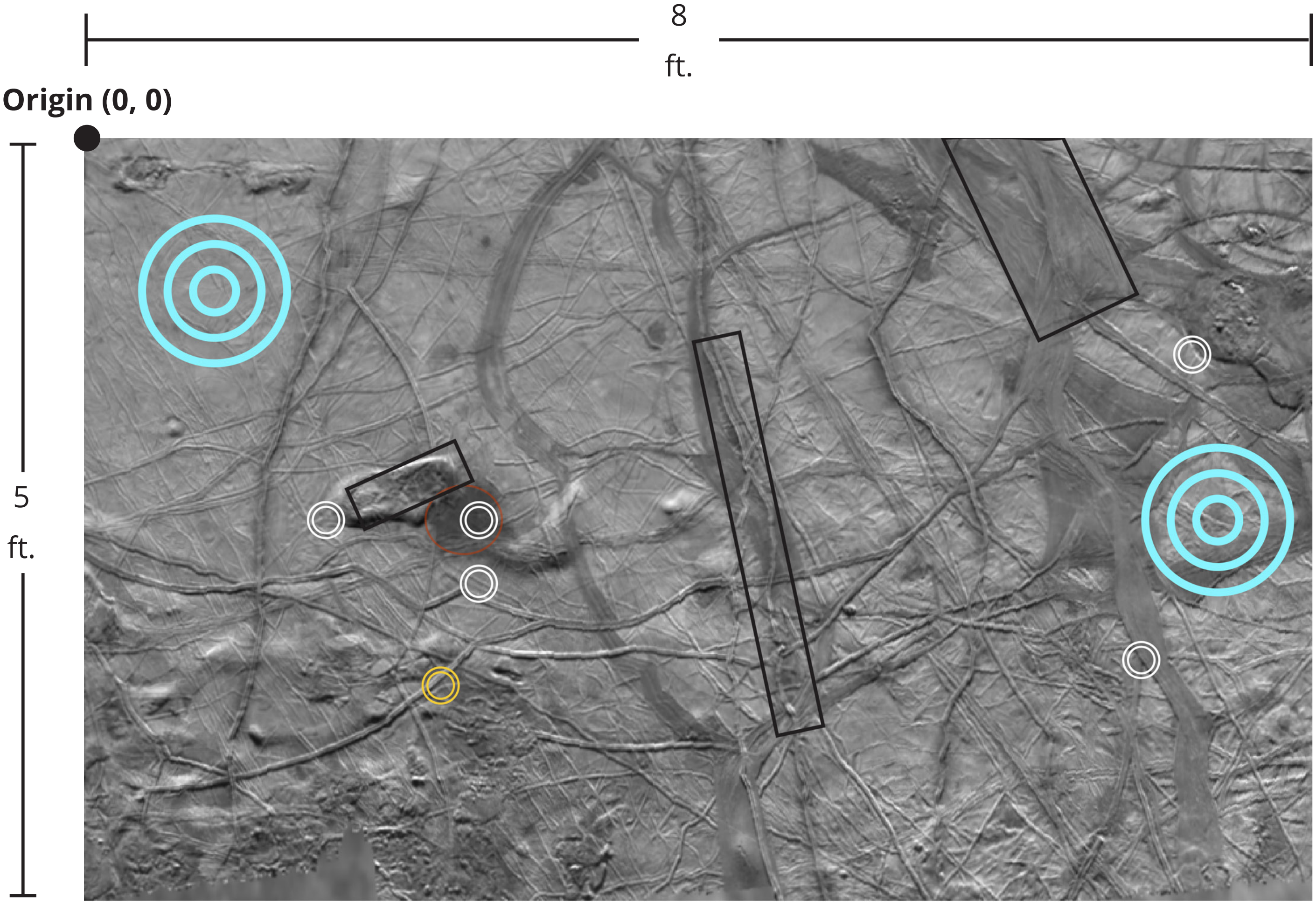
All grades

The map area is 8 ft x 5 ft. Origin is in the upper left hand corner. The goal is to create a challenge map with the correct features, including:

- Drone landing zones
- Sample sites
- Point of interest
- Barriers

Your students' map *may or may not* include the image of Europa's surface — the image of the surface is optional and is not required to complete the challenge.



Example of a ROADS on Icy Worlds challenge map with the image of Europa's surface with all features marked.

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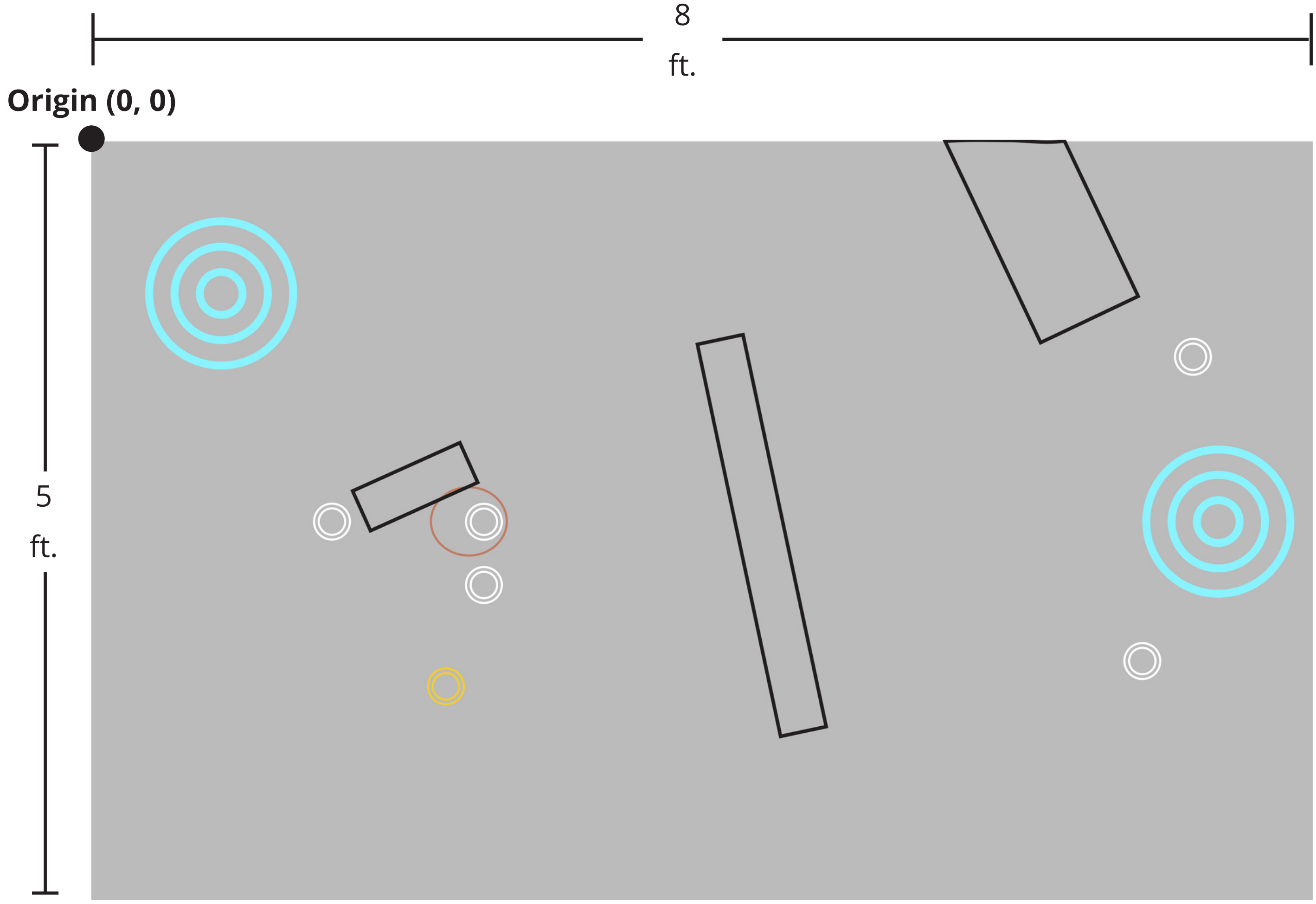

Example of a ROADS on Icy Worlds challenge map with all features marked, but without the image of Europa's surface.

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Upper Elementary

Landing Targets	*Center X (in)*	*Center Y (in)*	*Diameter (in)*		
Option 1	10	-12	12		
Option 2	89	-30	12		
Sample Sites	*Center X (in)*	*Center Y (in)*	*Diameter (in)*		
Sample 1	19	-30	3		
Sample 2	31	-30	3		
Sample 3	31	-35	3		
Sample 4	83	-41	3		
Sample 5	87	-17	3		
Sample 6 (HS Only)	28	-43	3		
Point of Interest (red circle)	Center X (in)	Center Y (in)	Diameter (in)		
	30	-30	6		
Barriers	*Lower left corner (in)*	*Lower right corner (in)*	*Upper right corner*	*Upper left corner*	*Suggested min height (in)*
Rectangle ABCD	A=(22, -31)	B=(30 ½, -27)	C=(29,-23 ¾)	D=(20 ½, -28)	2
Rectangle EFGH	E=(54 ½ ,-47)	F=(58,-46)	G=(51,-16)	H=(47,-17)	2
Trapezoid NOPQ	N=(75, -16)	O=(83, -12)	P=(77,0)	Q=(67, 0)	2

(Continues ▶▶▶)

Middle School

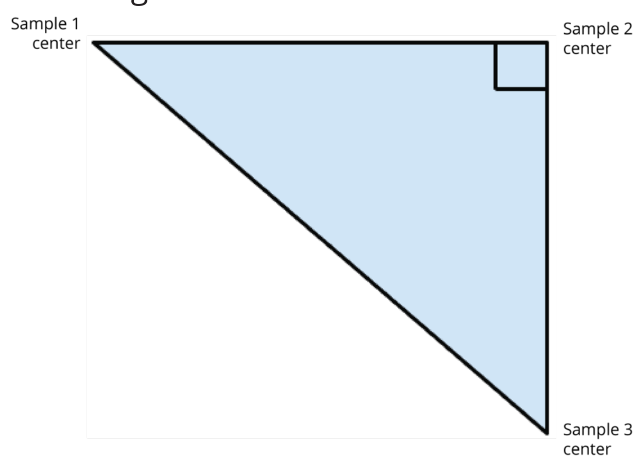
Use the following information to find the location and size of each object. For any calculations required, round the final answer to the nearest whole number.

Drone Landing Zones

1. The first possible landing zone is a circle. The center of the circle is located at (10,-12) and the circumference of the circle is equal to about 37.68 in. (using 3.14 for pi)
2. The second possible landing zone is also a circle. The center of this circle is (89, -30) and the area of the circle is equal to about 113.04 in2 (using 3.14 for pi)

Sample Sites

- The centers of Sample Sites 1,2,3 form a right triangle. Sample 1 is located at point (19,-30). This diagram may help you visualize the triangle.
- The horizontal distance between the center of Sample 1 and Sample 2 is 12 inches.
- The side connecting Sample 1 and Sample 3 form the hypotenuse of the right triangle. The distance between the center of Sample 1 and Sample 3 is about 13 in.
- Use this information to find the location of the center of Sample 2 and Sample 3.
- Note: Sample 1 and Sample 2 are perfectly horizontal to one another. Sample 2 and Sample 3 are perfectly vertical to one another. Watch your negative signs!



- The center of Sample 4 is located at (83,-41). The midpoint between Sample 4 and Sample 5 is (85, -29). Use this information to find the location of the center of Sample 5.
- All 5 sample sites are circles with diameters equal to 6 in.

(Continues ▶ ▶ ▶)

Middle School

Point of Interest

- This area of interest is in the shape of a circle. The center of the circle is located at (30, -30) and the diameter is 6 in.

Barriers

- Barriers can be physical obstructions (minimum suggested height, 2 inches) or simply "no-go rectangles" on the map.
- To find the location and size of the **rectangular** barriers use the following information:
  - For **Rectangle ABCD** use the following informations to help you find the coordinates of the rectangle
    - Formula for Line AD: y= -2.175X+ 16.895
    - Formula for line BC: y=-2.175X+39.739
  - The **lower left** corner of Rectangle ABCD or Point A is a point on Line AD. The y-coordinate of A is -31. Solve to find the y-coordinate. Round your calculated answer to the nearest whole number.
  - The **lower right** corner of Rectangle ABCD or Point B is a point on Line BC. The x-coordinate of B is 30.5. Solve to find the x-coordinate. Round your calculated answer to the nearest whole number.
  - The **upper right** corner of Rectangle ABCD or Point C is a point on Line BC. The y-coordinate of C is -23.75. Solve to find the y-coordinate. Round your calculated answer to the nearest whole number.
  - Look at the points A, B, and C. *Before moving to the next step*, approximate the coordinates of Point D.
  - The **upper left** corner of Rectangle ABCD or Point D is on the line AD. The x-coordinate of D is 20.5. Solve to find the y-coordinate. Round your calculated answer to the nearest whole number.
  - For **Rectangle EFGH** use the following equations to help you find the coordinates of the rectangle:
    - The formula for Line EF is y =0.245x-60.502
    - The formula for FG is y =-4.076x+190.882

(Continues ▶▶▶)

Middle School

- The **lower left** corner of Rectangle EFGH or Point E is a point on Line EF. The x-coordinate of E is 54.5. Solve to find the y-coordinate. Round your calculated answer to the nearest whole number.
- The **lower right** corner of Rectangle EFGH or Point F is a point on Line EF. The x-coordinate of F is 58. Solve to find the y-coordinate. Round your calculated answer to the nearest whole number.
- The **upper right** corner of Rectangle EFGH or Point G is a point on Line FG. The y-coordinate of G is -16. Solve to find the x-coordinate. Round your calculated answer to the nearest whole number.
- Look at the points E, F, and G. *Before moving to the next step*, approximate the coordinates of Point H.
- To find the location of the **upper left** corner of Rectangle EFGH or point H, find the equation for the line passing through point H, G. The y-coordinate of point H is -17.
  - When solving for "b" in the equation y=mx+b, round your final answer for "b" to the nearest **tenth**.
  - When solving for the x-coordinate of H, round your final answer to the nearest **whole number**.
  - *Hints: What do you know about the properties of rectangles? What is the relationship between opposite sides of rectangles? If two sides are parallel what do you know about the slopes for those two lines? Have you calculated the coordinates of any point on the line HG that could help you find the value of "b" in y=mx+b.*

- To find the location of the **trapezoidal** barrier use the following information
  - The horizontal distance between the upper right and upper left corner is 10 units. The location of the upper left corner is (67,0). Use this information to find the location of the upper right corner.
  - The bottom two corners are points on the line y=0.5x - 53.5. Use this equation to help you find the location of each corner. Round your calculated answer to the nearest whole number.
    - The lower left has an x coordinate of 75
    - The lower right has a y-coordinate of -12

(Continues ▶▶▶)

High school

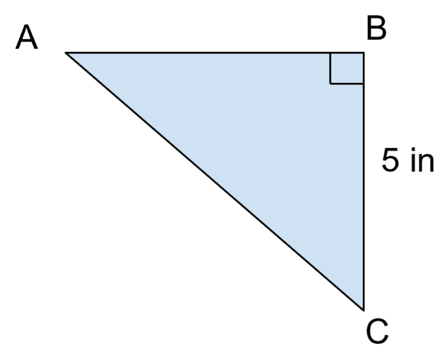
Origin is in the upper left hand corner of paper. Use the following information to find the location and size of each object. For any calculations required, round the final answer to the nearest whole number.

<u>Drone Landing Zones</u>

- The equation for the first possible landing zone is $(x-10)^2 + (y+12)^2=36$. Use this equation to identify the center of the circle and the radius.
- The equation for the second possible landing zone is located at $(x-89)^2 + (y+30)^2=36$. Use this equation to identify the center of the circle and the radius.

<u>Sample Sites</u>

- The centers of Sample Sites 1,2,3 form a right triangle ABC. Where A is the center of sample 1, B is the center of 2, and C is the center of sample 3. ∠B is a right angle.
  - The center of Sample 1 is located at point (19,-30).
  - Use the diagram and the following information to find the lengths of the other sides.
    - sin∠A = 0.3846, sin∠C = 0.9231. Round your calculated answer for each side length to the nearest whole number.
    - *Hint: Use the law of sines to help you find the length of side AB. Then use the pythagorean theorem or see if you recognize a pythagorean triple.*
    - Once you have found the lengths of the side of the triangle, use that information to find the coordinates for the centers of Sample 2 (Point B) and Sample 3 (Point C).
    - **Note:** A and B are perfectly horizontal to one another. Points B and C are perfectly vertical to one another. Watch your negative signs!



- The center of Sample 4 is located at (83,-41). The midpoint between Sample 4 and Sample 5 is (85, -29). Use this information to find the location of the center of Sample 5.
- All 5 sample sites are circles with diameters equal to 3 inches.
- The equation for Sample 6 is located at $(x-28)^2 + (y+43)^2=2.25$. Use this equation to identify the center of the circle and the radius.

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HIGH SCHOOL

Point of Interest

- This area of interest is in the shape of a circle. The center of the circle is located at (30, -30) and the circumference of the circle is equal to about 18.84 inches. (using 3.14 for pi).

Barriers

- Barriers can be physical obstructions (minimum suggested height, 2 inches) or simply "no-go rectangles" on the map.
- To find the location and size of the **rectangular** barriers use the following information:
  - For **Rectangle ABCD** use the following functions to help you find the coordinates of the rectangle
    - f(x) =-2.175X+39.739
    - g(x)= 0.46x-41.036
    - h(x):-2.175X+ 16.895
  - The **lower left** corner of Rectangle ABCD or Point A is located at the intersection of functions g(x) and h(x). First solve for the x-coordinate and round to the nearest whole number. Then solve for the y-coordinate and round your calculated answer to the nearest whole number.
  - The **lower right** corner of the Rectangle ABCD or Point B can be found by solving for g(30.5). Round your calculated answer to the nearest whole number at the very end.
  - The **upper right** corner Rectangle ABCD or Point C can be found by solving for x, when f(x)=-23.75. Round your calculated answer to the nearest whole number at the very end.
  - Look at the points A, B, and C. ***Before moving to the next step***, approximate the coordinates of Point D.
  - The x-coordinate of the **upper left** corner of Rectangle ABCD or Point D is 20.5. Use the function h(x) to find the y-coordinate. Round your calculated answer to the nearest whole number at the very end.

(Continues ▸▸▸)

High school

- For **Rectangle EFGH** use the following functions to help you find the coordinates of the rectangle:
  - a(x)= -4.076x+175.165
  - b(x)=0.245x-60.502
  - c(x)=-4.076x+190.882
- The **lower left** corner of Rectangle EFGH or Point E is located at the intersection of functions a(x) and b(x). First solve for the x-coordinate and round to the **nearest tenth**. Then solve for the y-coordinate and round your calculated answer to the **nearest whole number**.
- The y-coordinate of the **lower right** corner of Rectangle EFGH or Point F can be found by solving for b(58). Round your calculated answer to the nearest whole number at the very end.
- The x-coordinate of the **upper left corner** of Rectangle EFGH or Point G can be found by solving for x when c(x)=-16. Round your calculated answer to the nearest whole number at the very end.
- Look at the points E, F, and G. ***Before moving to the next step***, approximate the coordinates of Point H.
- The y-coordinate of the **upper right** corner of Rectangle EFGH or Point H is -17. Use the function a(x) to find the x-coordinate. Round your calculated answer to the nearest whole number at the very end.

• The final barrier is a trapezoid. Use the following information to locate Trapezoid NOPQ

- The coordinates of N are (75,-16). The slope of the line passing through NO is ½. The x-coordinate of O is 83. Round your calculated answer to the nearest whole number at the very end.
  - *Hint: Create the equation of the line NO.*
- The equation for the line passing through Points P and Q is y=0. The distance between P and Q is 10 units. The x coordinate of P is greater than the x-coordinate of Q. Q is located at (67,0). Round your calculated answer to the nearest whole number at the very end.

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MO-03: INSIDE EUROPA MODEL

For challenge teams:

- Divisions: ALL
- Award eligibility: Required for Top Team prize(s) as part of final challenge submission; Also eligible for Best of MO-03 Award
- Submission due: Part of final challenge submission — Due April 2022

Companion course / For more science:

- Unit 2, Lesson 1: Planetary Formation and Structure
- Unit 2, Lesson 2: Planetary Dynamics

MANY forces and processes, in the past and the present, form and change planets and moons. Make a model of Europa to explain its interior and how what's happening inside influences what happens to the surface.

Inside Europa?? Yup! For this MO you'll diagram and describe the interior of Europa — even though no rovers have yet visited or collected samples from this moon. How can this even be accomplished?

Fortunately, scientists do know a lot about the formation, structure, and dynamics of other planetary bodies, and these ideas can be applied to even to objects that haven't been visited. When we take ideas about known processes and apply them to an as-yet-unknown object, this is a type of modelling.

Your model — Can be 2D, such as a hand-drawn diagram or a computer-generated image. Or it can be 3D, maybe something like a diorama made with papier mache. Use your imagination and creativity, but don't forget to add explanatory labels!

Your explanation — Can be a written text or a short video that explains your model.

Your team's results for this MO should include:

- What Europa is like on the inside
- How it got that way
- What might be happening inside Europa that influences what the surface looks like

Document your experimentation and findings in your MDL. If your model and explanation are 2D (such as a drawn diagram and written explanation), include those in your MDL as well. If your model is 3D, you can include photos in your MDL or include shots of it in your team's mission video submission.

MO-04: EXPLAINING EUROPA'S SURFACE

Make your claim! Pick a targeted area of Europa's surface and make a claim — about forces or processes that created the feature, the order features formed, or any other claim you can support with evidence from your work.

Now that your team has modelled the interior of Europa and speculated how interior processes affect the surface, let's look at what processes might occur on the surface itself to affect the landscape.

First, take a minute to re-read the information in this manual on:

- The ROADS on Icy Worlds mission — Pages 6–7
- Why did NESSP choose icy worlds for this year's ROADS? — Appendix A

Then, spend some time looking again at the section of Europa we selected for the Icy Worlds mission site — Page 22 (a larger image is also available online at our Icy Worlds website if you'd like to zoom in).

What processes are occurring inside Europa (as you modelled in MO-03) — how might they affect Europa's landscape? What processes are occuring on the surface, or ***to*** the surface, and how could they be impacting the landscape?

If you'd like to conduct some experimentation, read the companion course lessons linked in the box above.

In your MDL, document your team's claims, evidence, and reasoning.

FOR CHALLENGE TEAMS:

- Divisions: ALL
- Award eligibility: Required for Top Team prize(s) as part of final challenge submission; Also eligible for Best of MO-04 Award
- Submission due: Part of final challenge submission — Due April 2022

COMPANION COURSE / FOR MORE SCIENCE:

- Unit 2, Lesson 3: Landform Dynamics
- Unit 2, Lesson 4: Crater Formation

ABOUT
ROADS on Icy Worlds

2021-2022 NATIONAL STUDENT CHALLENGE

MO-05: YEAST ID CARD [CHECKPOINT CHALLENGE]

All organisms need certain conditions to survive and thrive. Your objective: learn as much as you can about the limits of one hardy organism — yeast — and present your findings in the form of an identification card.

To investigate this MO, design and carry out experiments to test the environments yeast can survive in. Your goal is to learn some of yeast's limits by tweaking variables one by one and seeing how the yeast responds. You can get some ideas of what variables your team might want to test and how to conduct the experiments by reading the companion course lesson linked in the box above.

For challenge teams:

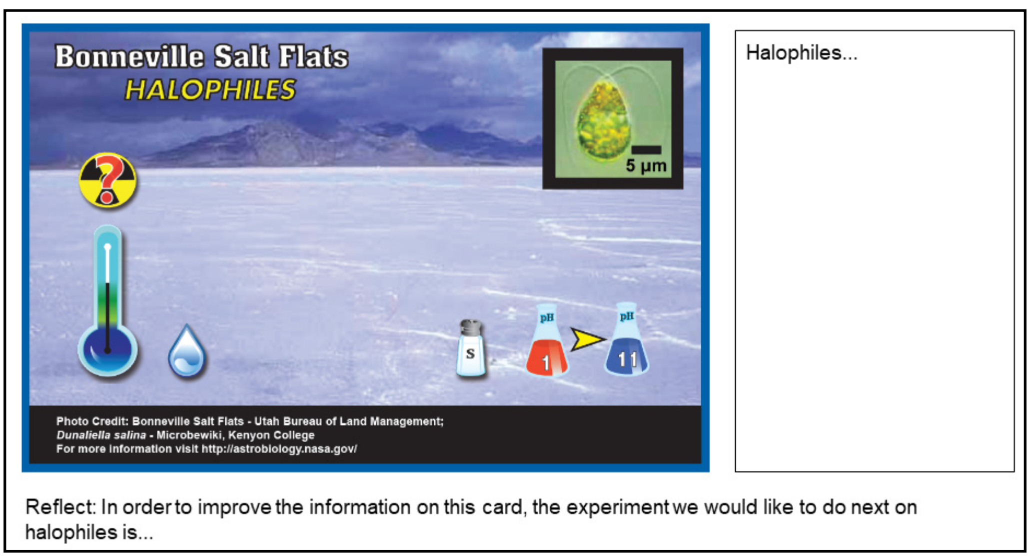
- Divisions: ALL
- Award eligibility: Checkpoint Challenge
- Checkpoint challenge entry: March 2021
- Award eligibility: Required for Top Team prize(s) as part of final challenge submission; Also eligible for Best of MO-05 Award
- Submission due: Part of final challenge submission — Due April 2022

Companion course / For more science:

- Unit 3, Lesson 3: The Limits of Life

In your MDL, document your findings by creating an identification card for yeast. The ID card will be provide a quick, one-page overview of yeast's properties — something like the nutritional label you find on packages in the supermarket. Your team's ID card should include:

- A photo your team took of yeast (possibly taken through a microscope such as a Foldscope!)
- Symbols representing yeast's properties
- Text noting any other important information you learned about yeast
- A brief sentence on possible further experimention



One example of an ID card (for halophiles) is pictured. You can find this example, a template, and examples of symbols in the Google Slide deck at this link:

https://www.nwessp.org/icyworlds/

MO-06: LANDING SITE — DRONE LANDING

Launching a rover, NASA uses data from orbiters and flyby missions to select a site. Use your drone's camera to survey the two potential landing sites. Take an image, select your landing site, then drop your payload!

Although we're not launching a rover like NASA, we still need to know where we'll be landing our drone before we take off! On your map, you'll see two potential landing sites — let's explore those landing sites to pick the one we want to land on. 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 system.

For challenge teams:

- Divisions: ALL
- Award eligibility: Required for Top Team prize(s) as part of final challenge submission; Also eligible for Best of MO-06 Award
- Submission due: Part of final challenge submission — Due April 2022

Companion course / For more science:

- Unit 4, Lesson 1: Human and Machine Communication
- Unit 4, Lesson 2: Drone Development
- Unit 5, Lesson 1: Executing and Evaluating the Mission

Whether you recreated your map to fit your space or printed out the image provided, here's what you'll do:

1. Check that your drone is working, connected to your device and ready to fly.
2. Make sure your map is clearly accessible and there is a clear path for the drone.
3. Safely secure the payload to your drone so that it can be dropped off at the landing site.
4. Time for takeoff!
5. Take a picture of the landscape with your drone and choose your landing site.
6. Navigate the drone to the landing site your team has selected and drop off the payload at the landing site.
7. Once you've dropped off the payload, fly your drone back to your base for safe shutdown

Payload?

Your payload for this mission can be anything you like! The only requirements are that it has to fly on the drone and be released onto the map's surface.

Let your imaginations run wild!

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.

ABOUT ROADS on Icy Worlds

2021-2022 NATIONAL STUDENT CHALLENGE

MO-07: SURFACE NAVIGATION

Europa has challenging terrain, and your rover needs to get around without crashing in areas too dangerous to traverse. Use your programming skills to get your rover safely from the landing site to the places of interest!

Woohoo! You made it to Europa safely. After you've dropped your payload and secured your drone (flying it back to your base and properly shutting it down) for MO-06, swap out your payload for your rover. Simply remove your payload from the map and place your robot in the same exact place.

For challenge teams:

- Divisions: ALL
- Award eligibility: Required for Top Team prize(s) as part of final challenge submission; Also eligible for Best of MO-07 Award
- Submission due: Part of final challenge submission — Due April 2022

Companion course / For more science:

- Unit 4, Lesson 1: Human and Machine Communication
- Unit 4, Lesson 3: Programming and Robots
- Unit 5, Lesson 1: Executing and Evaluating the Mission

Now it's time to explore this Icy Moon! The focus of this MO is on how you program your robot to safely navigate the obstacles on the map — but where are you navigating ***to***? Look ahead to MO-08 to understand what sample collection will be like, and also look ahead to MO-09 if your group is doing the additional high school surface navigation (required for Voyager teams, but optional for everyone else!). Now, plan your robot's navigation across Europa and compose your code appropriately.

Some guidelines:

1. With your rover at the landing site, begin your robot's maneuvers. You should have already programmed code to follow the path your team has chosen to navigate the challenging terrain and natural barriers.
2. It's up to your group to decide which samples to collect, the order to collect them, and the route the robot will take.
3. Given the terrain and various obstacles, your group may want to have multiple different routes in the event that your rover gets stuck somewhere along the way. Always have a backup plan (or two)!

MO-08: SAMPLE COLLECTION

What's happening below the surface of Europa? A future lander will drill into the ice and samples. Your rover will navigate to 4/5 sample collection areas, trying to find essential ingredients for the chemistry of life.

Looks like you've gotten around pretty well so far — you've arrived at a sample collection area! You'll be selecting which 4 areas you'd like to collect from. Here are some steps to get you started.

1. You arrive at your first sample collection area.
2. Collect the sample via rover and return the sample to the landing site safely.
    - OPTIONAL: Depending on your rover, you may be able to hold more than one sample at a time. If this is the case, after you collect one sample, move on to collect the next. Otherwise, return to the landing site to drop off the sample before moving on to collect the next one.
3. Repeat this process until you have collected all 4 sample collections. Middle school should collect a total of 4 samples.
    - High school only — Collect an extra sample and return it to the satellite extraction point.

FOR CHALLENGE TEAMS:

- Divisions: ALL
- Award eligibility: Required for Top Team prize(s) as part of final challenge submission; Also eligible for Best of MO-08 Award
- Submission due: Part of final challenge submission — Due April 2022

COMPANION COURSE / FOR MORE SCIENCE:

- Unit 4, Lesson 1: Human and Machine Communication
- Unit 4, Lesson 3: Programming and Robots
- Unit 5, Lesson 1: Executing and Evaluating the Mission

MO-09: ADVANCED SURFACE NAVIGATION (VOYAGER / HIGH SCHOOL ONLY)

Europa's chaos regions are produced by disruptions to the icy crust. What's going on over there? Using your color sensor, take a data reading at the yellow chaos region site. Identify a different color and continue on.

First, calibrate the color sensor. LEGO provides a calibration PDF at this link:

https://ev3lessons.com/en/ProgrammingLessons/intermediate/scratch-Calibrate.pdf

For challenge teams:

- Divisions: Voyager division / high school only
- Award eligibility: Required for Voyager Division Top Team prize(s) as part of final challenge submission;
- Submission due: Part of final challenge submission — Due April 2022

Companion course / For more science:

- Unit 4, Lesson 3: Programming and Robots
- Unit 5, Lesson 1: Executing and Evaluating the Mission

Now, travel to Europa's chaos region, denoted on the map by the yellow circles. Take a color reading — you can take a reading of the yellow circle itself, or you can lay down a colored card (or Post-It note or something similar). No matter what you use as your color sample on the map, your sensor data must match the color.

From there, your robot returns to the landing site.

ABOUT ROADS on Icy Worlds

2021-2022 NATIONAL STUDENT CHALLENGE

MO-10: MISSION PATCH DEVELOPMENT

A mission patch is an important symbol of any NASA mission, reflecting the team, the object of study, the spacecraft, the mission goals, or a combination! How will you represent your Icy Worlds mission with imagery?

A good mission patch represents the team's objectives and community values. Examples on this page include both NASA missions and mission patches from previous ROADS teams!

Notes for challenge teams:

- Divisions: ALL
- Award eligibility: Required for Top Team prize(s) as part of final challenge submission; Also eligible for Best of MO-10 Award
- Submission due: Part of final challenge submission — Due April 2022

Notes for curriculum teachers:

- Unit 4, Lesson 4: Mission Integration and Iteration

Teams are encouraged to get creative and design a mission patch that represents themselves, their community, and their mission in the ROADS on Icy Worlds challenge.

Mission patch submissions should include two things:

1. An imaged of the patch (can be hand-drawn or computer generated)
2. A short explanation of the components of the patch and their significance to the team

Mission patches are due in April as part of your final challenge submission. Include your patch and explanation as part of your MDL.

We are always delighted to see mission patches posted to social media (Instagram, Twitter, Facebook using the hashtag #ROADSonIcyWorlds), but social media posting is not required for this MO!

WING IT LIKE WINGLEE! [CHECKPOINT CHALLENGE]

Notes for challenge teams:

- **OPTIONAL** CHECKPOINT CHALLENGE!
- Award eligibility: Eligible for Wing it like Winglee Award
- Submission due: Part of final challenge submission — Due April 2022

As NESSP's founding director, Dr. Winglee, might remind us, sometimes you gotta wing it! Describe something you tried for Icy Worlds that didn't go as expected. What happened, what did you learn, and what happened next?

As a rocket scientist, Dr. Winglee was well-known to embody the saying "Stand back! I'm about to do science!" For the "Wing It Like Winglee" Challenge, describe something that didn't go as planned — or even something that went horribly wrong!

Explain:

- What happened?
- What did you learn from it?
- What did your team do next?

Your entry for this challenge can be a write-up, photos, a video, or a combination of all three that shows/describes what happened.

Make sure you let us know which part of the challenge you were working on when you had to "wing it!"

APPENDIX A

WHY DID NESSP CHOOSE ICY WORLDS FOR THIS YEAR'S ROADS?

The icy worlds of our solar system present some tantalizing challenges for exploratory science. What lies beneath the icy surface? If there's water, could there be life? And will we need ice skates on our lander?

WHAT ARE THE ICY WORLDS YOU WILL BE EXPLORING IN THIS CHALLENGE?

An "icy world" is defined as a body whose outer surface is composed mostly of water ice that's so cold it's as hard as rock on Earth. The interiors of the largest of these icy bodies may also have a global subsurface ocean of liquid water and a rocky inner core.

The most well-known icy moon is Jupiter's moon Europa; however, nearly all of the outer planets' moons are considered to be icy worlds. The surface below the dense atmosphere of Saturn's moon Titan is also composed of rock hard water ice and scientists think Titan also has an internal global water ocean. Another fascinating icy world is Triton, which has large plumes erupting from its complex surface.

Not all icy worlds are moons. The dwarf planets Pluto and Charon are both considered to be icy worlds, along with Ceres in the asteroid belt.

As you can see, there are many icy worlds. For this mission, we will be focusing on Jupiter's moon Europa, the target of NASA's upcoming Europa Clipper mission.

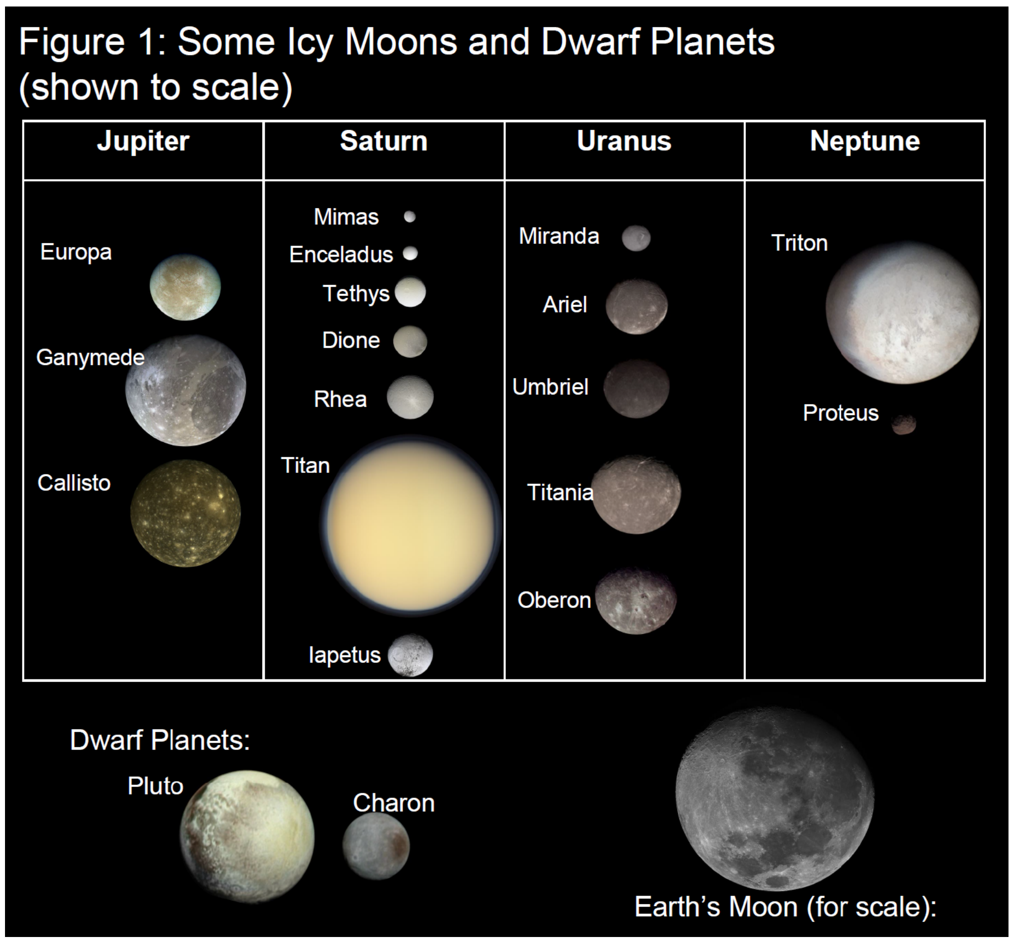


Figure 1: Some of the icy moons of the outer planets and dwarf planets Pluto and Charon. The moons, Pluto, and Charon are shown on the same scale as the Earth's moon, which is not an icy world but is provided for scale. (Adapted from montage by Emily Lakdawlla] with free use for educational purposes under the Creative Commons license. Original images: NASA/JPL)

APPENDIX A

WHY ICY WORLDS?

WHY DO SCIENTISTS WANT EXPLORE THE ICY WORLDS OF OUR SOLAR SYSTEM?

Do you think life could survive (or even thrive) in a dark salty ocean under miles of ice?

Scientists believe that Jupiter's moon Europa has a global ocean 10 to 15 miles (16 to 24 km) beneath its icy surface. Europa's ocean could be up to 100 miles (160 km) deep and contain twice as much water as all of the Earth's oceans combined. That's a lot of water, considering Europa has a diameter of only 1,940 miles (3,120 km), making it only a fraction of the size of Earth (with a diameter of 7,920 miles). In fact, many of the icy worlds in the solar system are what NASA calls "ocean worlds." These worlds are probably home to most of the liquid water in our solar system.

On Earth, where there is water there is life! Therefore, these watery, icy worlds are the perfect place to explore the limits of habitability in our solar system and beyond.

YOU MIGHT BE WONDERING — WHY ARE THESE BODIES COMPOSED OF ICE INSTEAD OF ROCK LIKE THE EARTH?

To answer that question we have to go back about 4.5 billion years to the formation of our solar system.

Icy worlds formed outside what is known as the frost or snow line. This theoretical line occurred about 500 million miles, or approximately 5 astronomical units, from our young sun — almost the distance to Jupiter. Beyond the front line it was cold enough for water and other compounds like methane and ammonia to freeze into solids. Bodies like Saturn and Jupiter accumulated a large amount of material over their long orbits and became massive enough to capture light gasses like hydrogen and helium in their atmospheres. Scientists think that material that didn't go into making these gas giants formed the many icy moons that now orbit them.

Other icy bodies formed out of material orbiting the sun. Most of these bodies, like Pluto and Charon, are small and orbit in a region known as the Kuiper belt.

BUT IF IT'S SO COLD OUT THERE, WHAT KEEPS THE LIQUID WATER OCEANS INSIDE ICY WORLDS FROM FREEZING?

Good question!

Most of the worlds that scientists think have liquid water oceans are moons of one of the gas giants, like Jupiter or Saturn. The strong gravitational force of the massive gas giants push and pull on the surface of the moons in a process known as tidal forcing.

We also experience tidal forces on Earth. Have you gone to the coast and explored a tide pool or built a sandcastle during low tide only to come back hours later to discover the same rocks and sand covered with water? It's the gravitational pull of our moon that causes the surface of the ocean to move up and down, periodically hiding and revealing stretches of shoreline.

As tidal forcing works on the icy moons it causes constant deformation of the surface and the interior of the icy moons, which in turn is the source of energy and heat that keeps the interior liquid. You can observe how forces produce heat at home by bending a paperclip back and forth. If you do it quickly enough (without breaking it!) you should feel the paper clip getting warm.

These tidal forces, as they break up or deform the surfaces of the icy worlds, also produce an interesting variety of surface features — which you'll see first-hand when you plan your mission to explore the map of Europa!

THESE DARK, COLD, ICY WORLDS SEEM LIKE THEY'RE A PRETTY UNCOMFORTABLE PLACE TO LIVE, SO WHY DOES NASA THINK THEY MIGHT SUPPORT LIFE?

Earth has shown that life can survive and thrive in a wide variety of habitats. In fact, so far, scientists have found life on Earth everywhere liquid water exists.

That's right, if there's water there is life!

Some of you might have visited Yellowstone National Park and have been warned about getting too close to the boiling hot hydrothermal pools. Those pools aren't so good for human life, but extreme life forms called thermophiles love the heat! Scientists have even found life in near-freezing lakes in Antarctica, like Lake Whillans, where the water is shielded from the Sun by a half-mile of ice.

Why is water so essential to life as we know it? One very important reason is that it provides a liquid environment for our cells' working units, like proteins, to move about. It also dissolves nutrients for organisms to eat, transports important chemicals within living cells, and allows those cells to get rid of waste.

Of course, like you, life needs more than water to survive. Life also needs a source of energy and food. Earth has shown that life has found ways to utilize many sources of energy. Organisms even live around vents deep within our ocean, called black smokers. The organisms use nutrients and heat leaking from beneath the ocean floor to produce the energy. No sunlight required! Scientists think that the boundary between the liquid oceans and the rocky cores inside icy moons may have similar vents. If they do, these vents might provide enough energy and nutrients to support simple lifeforms.

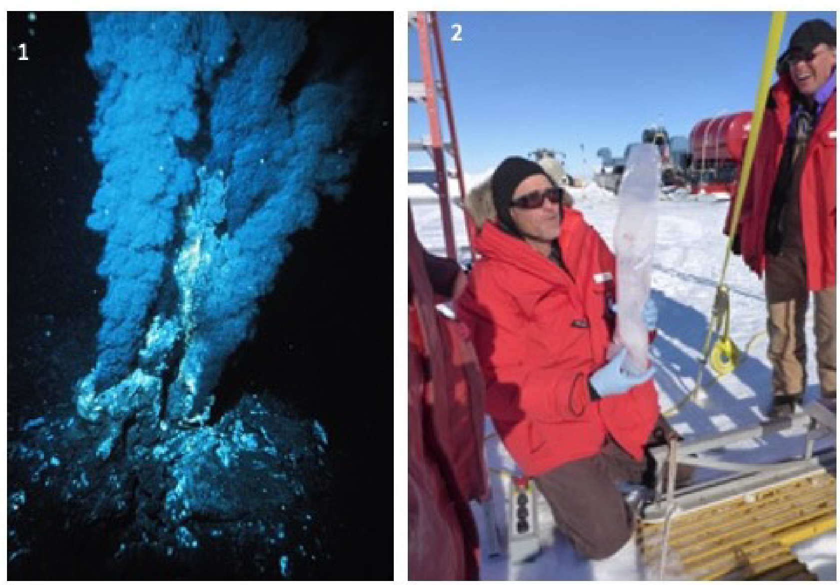


Figure 2: Scientists look for extreme life on Earth to try to understand where life might exist in the solar system and beyond. (1) This figure shows a black smoker on the dark surface below the Atlantic ocean. (2) This Shows a scientist examining an ice core produced when drilling a hole to so that robotic crafts could search for life in Lake Whillians. (images: (1) Wikimedia Commons (2) NASA/JPL).

WHAT ARE NASA'S GOALS FOR EXPLORING ICY WORLDS?

Scientists come together every decade to produce a list of scientific goals that will drive how NASA missions explore our solar system. In 2019, these scientists determined the most important goals for the icy worlds are:

1. Determining which of the icy moons harbor liquid oceans
2. Characterizing the properties of those oceans
3. Conducting research both in space and on Earth to better understand how life might exist in a subsurface ocean

To achieve these goals, scientists are trying to better understand the energy sources within these bodies that allow global liquid oceans to exist. They are also working on techniques to remotely sense the properties of these oceans using measurements taken from orbiting spacecraft. Finally, scientists are designing lab experiments and searching the Earth for life in extreme environments to better understand the biology that might exist under the surface of these icy worlds.

Scientists are hard at work today, but did you know that the next two missions NASA plans to send to Europa and Titan won't arrive until 2030 or later? By then, you just might be ready to join these missions and help NASA achieve its objectives.

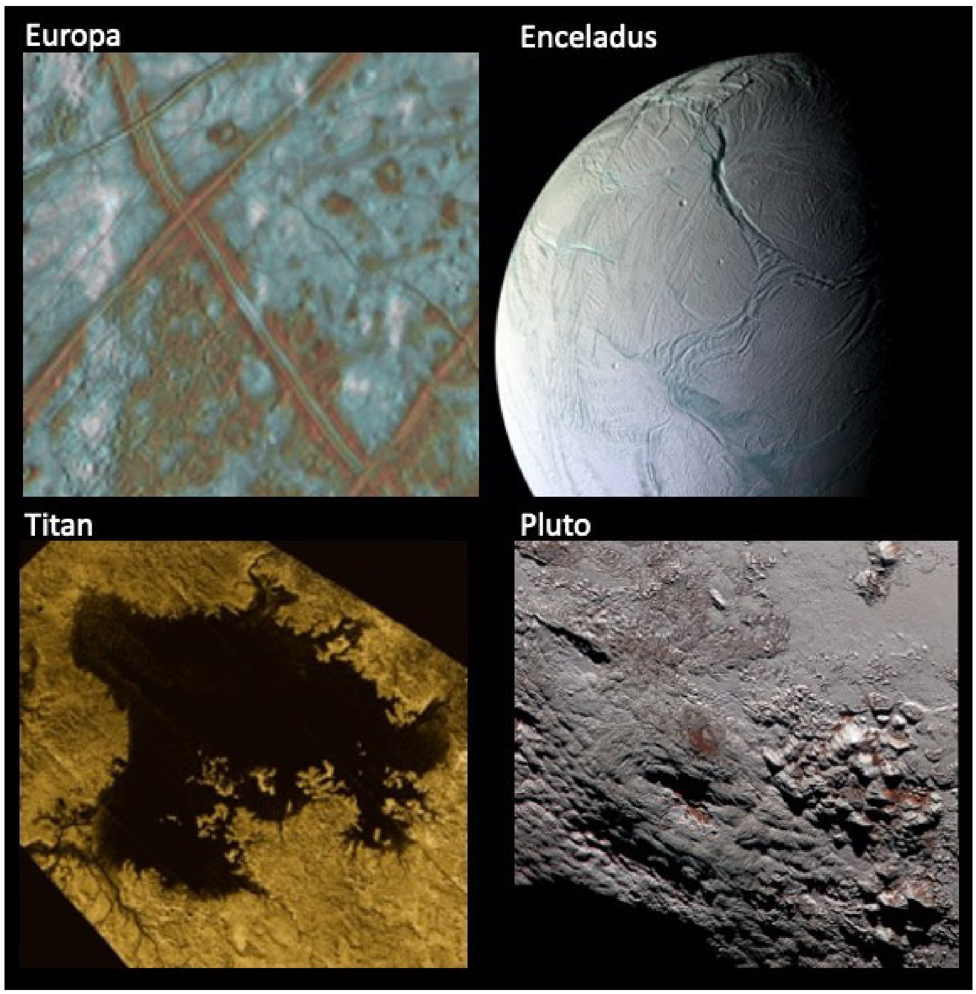


Figure 3: The complex surfaces of some of the icy worlds imaged by the Galileo (Europa), Cassini (Enceladus and Titan), and New Horizons (Pluto) spacecraft. (images: NASA/JPL)

PAST MISSIONS TO THE ICY WORLDS

Although Galileo Galilei first discovered Jupiter's four largest moons (Io, Europa, Ganymede, and Callisto) in 1610, we knew little about the icy bodies in the outer solar system until the early 1970s when the Pioneer and Voyager probes returned images of their surfaces. These probes discovered that the icy bodies of the outer solar system are diverse and complex, both puzzling and exciting scientists. On Europa, images showed a fractured terrain that made it appear as the surface periodically broke into pieces, shifted, and re-froze. Titan, a moon of Saturn, had a thick, orange, dense atmosphere that prevented the spacecraft from peering at its surface. Neptune's moon Triton had icy lava flows and active plumes that launched material nearly 5 miles (8 km) above the surface. In the course of a few years, the solar system became a much more interesting place.

Next up was the Galileo spacecraft, which orbited Jupiter for over 7 years (1995–2003) and took higher-resolution images. It also made multiple flybys of each of Jupiter's large icy moons. The Galileo spacecraft discovered Europa's subsurface ocean using a technique called magnetic induction. It also detected Ganymede's magnetic field and got a close-up view of the powerful volcanic activity on Io.

From 2005 to 2017, the Cassini mission provided similar data at Saturn. During its first Titan flyby, Cassini released the Huygens probe which sent back the first images of Titan's surface as it slowly descended through the dense atmosphere. Later in the mission, Cassini used radio waves to remotely observe many liquid lakes on the northern and southern poles of Titan. Another exciting discovery of the Cassini mission was the detection and direct sampling of plumes coming out of the south pole of the small white inner moon Enceladus.

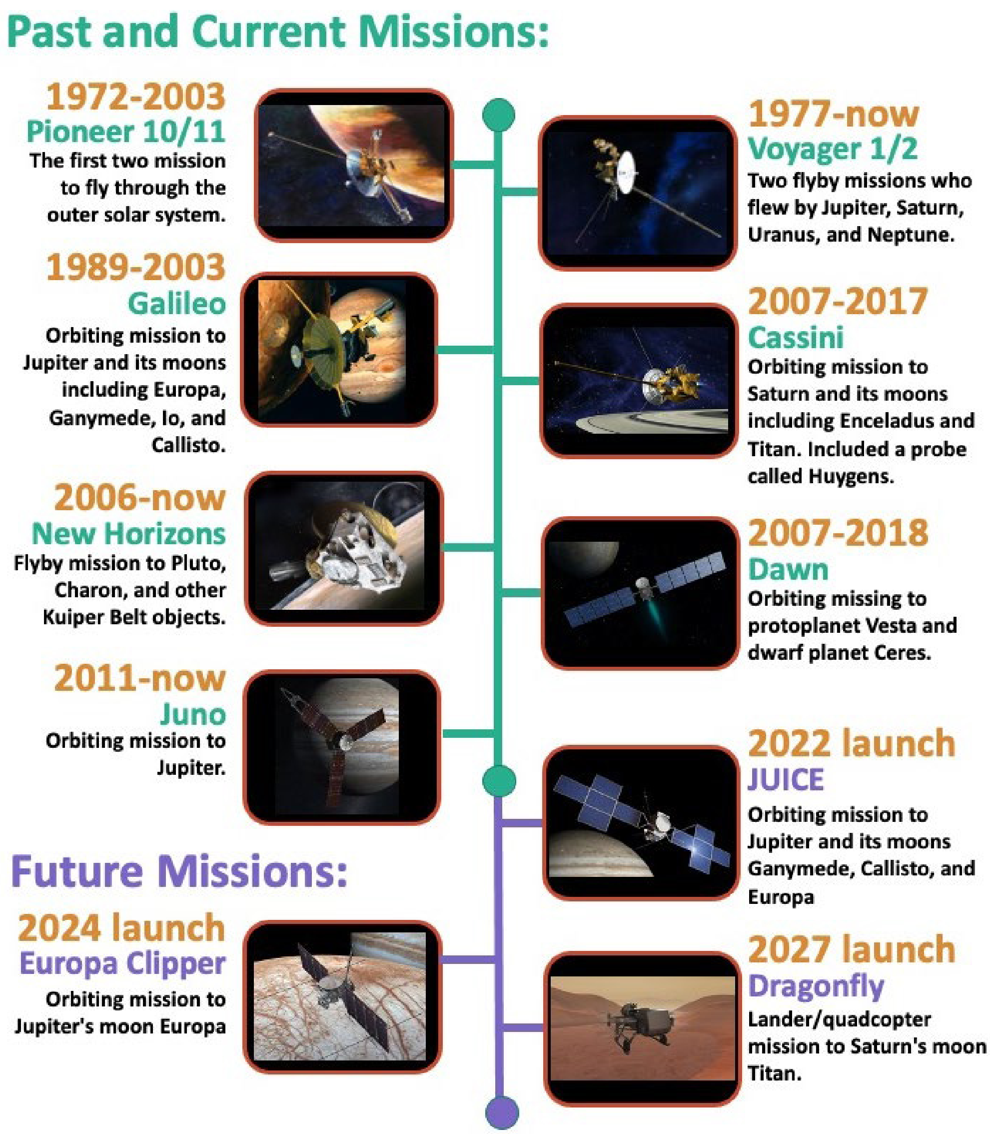


Figure 4: A timeline of past, current, and future missions to the icy worlds in our solar system. (spacecraft images: NASA/JPL and ESA)

In 2015, New Horizons became the first spacecraft to take close-up images of Pluto's surface. The spacecraft was moving so fast when it reached far-away Pluto it could only quickly zip by. Despite this, New Horizons provided amazing high-resolution imagery of nearly all of Pluto's surface and directly measured the properties of its atmosphere. Again, scientists were blown away by the unexpected. Pluto's cold surface was shown to be as complex as any other icy body with intense light and dark color variation and tall mountain ridges. Pluto's atmosphere was also much denser than scientists previously thought.

Around the same time, the spacecraft Dawn went into orbit around Ceres, a dwarf planet in the asteroid belt between Jupiter and Mars. Unlike many of the icy worlds we have discussed so far, Ceres' surface is a mixture of rock and ice because it orbits much closer to the Sun. Dawn discovered Ceres has a unique surface that is heavily cratered but also speckled with salty bright spots.

CURRENT AND FUTURE MISSIONS TO THE ICY WORLDS

NASA's ongoing mission Juno was launched in 2011 and got to Jupiter in 2016. Although its primary goal is to probe and better understand the interior of Jupiter, this mission has also taken dazzling images of Jupiter's icy moons. In fact, the public gets to help choose the target of Juno's cameras through their interactive website, a first for NASA.

Future missions include the European Space Agencies' mission JUpiter ICy moons Explorer — aka JUICE. This mission is all about Jupiter's icy moons and will have several flybys of Ganymede, Europa, and Callisto. ESA plans on launching JUICE in 2022, which puts arrival at Jupiter in late 2029. JUICE's main science objectives include detecting and characterizing subsurface oceans, probing the internal structures of the moons, and better characterizing the moons' diverse surfaces and atmospheres.

Following closely behind JUICE will be NASA's Europa Clipper mission, which will launch in 2024 and arrive in 2030. This mission will orbit Jupiter but will have many close flybys of Europa's surface. Clipper seeks to not only study the complex surface and tenuous atmosphere of the moon, but to probe beneath the surface to better understand the properties of Europa's liquid ocean and rocky core. Recent Hubble data has indicated that similar to Triton, Enceladus, and Io, material may occasionally erupt from Europa's surface. This may give the spacecraft an opportunity to directly sample material from beneath the icy surface with chemical sniffing mass spectrometers.

NASA is also developing the Dragonfly mission that will peer below Titan's dense atmosphere and reveal its complex Earth-like surface. The Dragonfly quadcopter (a four-propeller drone) will land on the surface of Titan and suck samples into its instruments using its bug-like feet. It will also collect atmospheric data and images as it hops around the surface of the large moon. Dragonfly is currently planned to launch in 2027 with an arrival in 2036.

Get ready and stay tuned!

APPENDIX B

SUPPLIES FOR THE MISSION OBJECTIVES

SUPPLY LOCKER

This page covers the main supplies your team will need to run the ROADS on Icy Worlds challenge. All of the supplies are available from NESSP — mark what you need when you register your team at this URL: https://www.nwessp.org/icyworlds/registration/

Robot

You will need a programmable (not remote-controlled) robot. The robot is your rover for MOs 07 and 08 (plus MO-09 for high school teams). For 2021–2022, NESSP is providing the LEGO SPIKE robot pictured to the right.

Drone

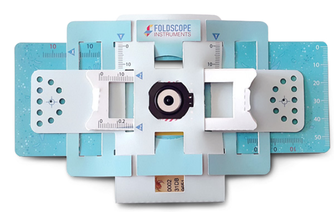
The drone is your team's spacecraft for journeying to the challenge exploration site. Any drone that can carry your team's payload will do. For 2021–2022, NESSP is providing small drones that can be flown indoors (picture to come).

Hydrometer

A hydrometer measures the density of liquids. You'll need this tool for MO-05. For 2021–2022, NESSP is providing an aquarium hydrometer similar to the one pictured to the right.

Microscope

A microscope, of course, let's you see things that are far too small to see with just your eye alone. You'll need this tool for MO-05. You can use any microscope your school may have available. For 2021–2022, NESSP is providing (unassembled!) Foldscope microscopes. Once assembled, they'll look like the one pictured to the right.



Sampling kit

To complete MO-05, you'll also need tools to take samples and analyze them, including:

- pH paper
- thermometer
- vials / sample bottles
- pipettes

For 2021–2022, NESSP is providing sample kits that contain all of these items (picture to come).

NOTE — To complete the challenge, your team will also need some standard supplies that NESSP does not provide but that your school or community group may have on hand. For example: For MO-02, where you make your challenge map, you will need things like markers, tape, cardboard or poster board.

APPENDIX C

CHALLENGE SCORING

Available 2022.

FAA REGULATIONS & DRONE SAFETY

When you're flying a drone, you are technically flying a type of aircraft. The FAA (the U.S.'s Federal Aviation Administration) considers a drone to be an unmanned aircraft systems, or UAS, and has rules covering how to properly use them.

Any team member who will take a turn flying the drone, and all of the team's Mission Advisors, should spend some time reviewing the FAA's information on drone flying. Specifically, look at the FAA's sections on recreational flyers and on educational users (educational use is a subset of recreational use, so both are important). There's quite a lot of information available from the FAA, so we'll link you directly to the relevation sections:

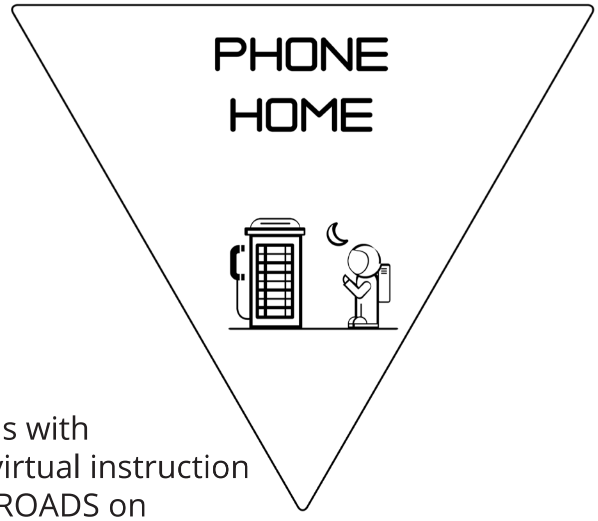
- FAA website — Recreational flyers: https://www.faa.gov/uas/recreational_fliers/
- FAA website — Educational users: https://www.faa.gov/uas/educational_users/

DRONE SAFETY TIPS

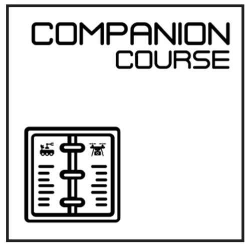
The following tips are a quick introduction to drone safety. These do not cover everything you need to know about safely flying a drone! **Please** take the time to review the FAA information linked to above.

- Know the controls — Review and understand your drone's controls before you begin. Be especially aware of how your drone's emergency stop function works.
- Check the weather — Don't fly in wind, rain, or other bad weather. Even if you're flying indoors, check for drafts from heating/cooling systems.
- Keep your eyes on the drone — You should always be aware of where the drone is. Don't fly it out of your own line of sight or your observer's line of sight.
- Be a safe pilot — Make sure you feel ready to pilot before you turn on your drone. Don't fly if you're feeling unwell. And if you have long hair, by all means tie it back!
- Scout the area — Be aware of other people in the flying area as well as any large objects or other drones. Always fly your drone so that you don't hit anyone or anything.
- Be airspace smart — The FAA closely controls the U.S.'s airspace. Use the FAA's B4UFLY mobile app to check your proposed flying zone to be sure it's okay to fly there. And always fly below 400 feet in Class G (uncontrolled) airspace.

SUPPORT FROM NESSP



ARE YOU TEACHING THE COMPANION COURSE?



You can request any of the following support from NESSP:

Teaching Assistant sessions

We offer classroom support in the form of Zoom sessions with undergraduate teaching assistants. These sessions offer virtual instruction with hands-on experiments for any of the units from our ROADS on Asteroids companion course curriculum.

The TAs are undergraduates in STEM majors at the University of Washington. If you need supplies, they will be mailed in advance so that your students are prepared for the hands-on components.

Supply kits

We're able to loan the supplies you'll need for our companion course lessons! Supply kits include one each of:

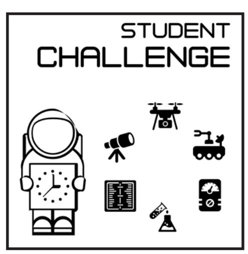
- Robot
- Drone
- Hydrometer
- Foldscope microscope
- Sampling kit (includes pH paper, thermometer, vials/sample bottles, and pipettes)

Request support

Visit our website! Please complete this form to register your class and indicate what support you'd like.

https://www.nwessp.org/programs/pages/curriculum/icyworlds/registration/

ARE YOU RUNNING THE STUDENT CHALLENGE?



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- Hydrometer
- Foldscope microscope
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Visit our website! Please complete this form to register your class and indicate what supplies you need.

https://www.nwessp.org/icyworlds/registration/