SCIENTISTS IN THE FIELD

Where Science Meets Adventure

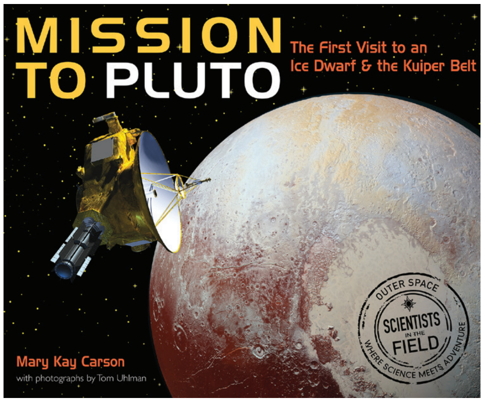
DISCUSSION AND ACTIVITY GUIDE

Mission to Pluto: The First Visit to an Ice Dwarf and the Kuiper Belt

By Mary Kay Carson (Photographs by Tom Uhlman)

About the Series

Mission to Pluto is part of the award-winning Scientists in the Field series, which began in 1999. This distinguished and innovative series examines the work of real-life scientists doing actual research. Young readers discover what it is like to be a working scientist, investigate an intriguing research project in action, and gain a wealth of knowledge about fascinating scientific topics. Outstanding writing and stellar photography are features of every book in the series. Reading levels vary, but the books will interest a wide range of readers.



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About the Book

Think of a place near you that is about nine miles away. *New Horizons*, the spacecraft that traveled to Pluto, would get there in one second. It would take this vessel less than ten minutes to fly from the easternmost part of Maine to San Diego, California. The mission to Pluto took over nine years at this approximate rate of speed to travel more than three billion miles away! As if this were not enough, *New Horizons* had to arrive in exactly the correct spot at exactly the right time or the data returned would be virtually useless. And to think that the discovery of Pluto in the first place was predicated on erroneous information and scientific mistakes!

About the Author

Mary Kay has always loved science, and she earned her college degree in biology. After serving in the Peace Corps, Mary Kay began her award-winning writing career by working on a classroom magazine, *SuperScience,* for Scholastic. She became a freelance writer and has written more than thirty books for young people, including *Park Scientists*. She lives in Cincinnati with her dog, Ruby, and her photographer husband, Tom Uhlman, whose photography graces several of her books, including this one.

About the Photographer

Tom Uhlman has been a freelance photographer for more than twenty years. He enjoys taking all kinds of photographs, but his favorite is nature photography. Tom is the self-employed owner of Tom Uhlman Media Productions. He often works with his wife, Mary Kay Carson, on books for young readers.

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Pre-Reading Activity

Discuss with students what we learn from mistakes. Research scientific errors through history, including errors by scientists who are called geniuses. If really great thinkers make blunders, what does that tell us about our own mistakes? Discuss the differences between making a mistake doing something like performing heart surgery and making a mistake calculating the weather. What sort of scientific calculations demand perfection, and when does science ask us to take risks?

When knowledge becomes accepted truth, people have a tendency to merely accept it without much comment or thought. Examine why the general public used to think that the world is flat. Pretend that you have been whisked back in time and it is your job to convince folks who embrace the accepted wisdom that our Earth is indeed round.

Have students make a wish list of projects they are interested in today that they can envision themselves still working on ten or twenty years from now. Have students jot down notes for how they would organize the work and what changes in society or technology would help or hinder this work.

Pre-reading activities that review the differences in the various types of celestial bodies will prove to be very useful. What is a planet? What is a moon? What is an ice dwarf? What is the difference between a planet and a moon? What is the difference between a planet and a star? What is a galaxy? What is an asteroid, a shooting star, a comet, or a dwarf planet? If possible, find a place to look at the night sky. Identify constellations, planets, and other objects.

Discussion Questions

Alan Stern thinks that the reclassification of Pluto from a planet to a dwarf planet "defies common sense." He still thinks of Pluto as a planet. Is Pluto still a planet?

Pluto is so far away that it takes four and a half hours (nine hours roundtrip) for information to travel from Pluto to Earth. It is so far away that it takes about nine years to reach Pluto traveling at the incredibly fast speed of nine miles per second. It requires a team of scientists, a spacecraft, and loads of very expensive equipment. Why should we spend money on studying Pluto? What are the pros and cons (in addition to the amount of time and the cost)?

Say you are taking a test or doing a project for a class. How would you feel if you did not find out whether or not you passed or failed for more than nine years? We are accustomed to prompt feedback. Our digital age has some of us frustrated by response times that take more than just a couple of seconds. Would you be able to handle completing work that could prove to be insignificant? Would you be able to handle not knowing whether or not your project will provide any useful information for several years? Let's assume that the Pluto mission was a complete failure. Argue about whether or not the time and money was spent wisely.

What will happen to the *New Horizons* spacecraft over the next fifty or more years?

Astronomers and astrophysicists have stated that there are more stars in the sky than there are grains of sand on all the beaches on Earth. What does this mean to you personally? What surprises do you predict are out there awaiting discovery? Do you expect to see evidence of any surprises in your lifetime? Just to make it real, grab a big handful of sand and count the grains!

Look at the pictures throughout this book. Many of them show dozens of people waiting and watching and cheering for the pictures that eventually made their way back to Earth from Pluto. Obviously it took a lot of people to plan and implement and monitor and interpret the results from this mission. How adept at working in groups are you? Considering that this team had to make sure *New Horizons* made it to the correct spot at the correct time, there was not room for much in the way of surprises in space, nor was there room for miscalculations. This means that everyone had to pull their weight. What do you suppose the crew argued about, and more important, how do you think differences were resolved? How does this compare with your own group work? If your own group work is not something that seems useful, what makes it different from the work on this mission?

Clyde Tombaugh built his own telescope from farm equipment and old car parts. He even constructed his own lenses out of glass from a ship's porthole window. What do you know how to build? Do our schools do enough to encourage students to invent things? Do you know how basic things like electric lights work? Radios? DVD players? Smartphones? Computers? Would you be able to build any of these items?

Applying and Extending Our Knowledge

New Horizons traveled for over nine years to reach Pluto, about three billion miles away. Many students have little context for a number that large.

- Have students create various types of analogies or similes for three billion. How many trips around the Earth? Or back and forth to the moon? If we went forward in time three billion seconds, what year would it be?
- Have students try to put together these efforts and illustrate them so that very young students have an idea of how much one billion is.
- We know that *New Horizons* traveled at about nine miles per second. Where would the spacecraft be after just one million seconds, one hundred million seconds, one billion seconds, etc.? How far did *New Horizons* travel in the length of one school day?
- If you were granted one hour's worth of travel at *New Horizon*'s rate of speed and one day to travel, where would you go? Plan your day. Show pictures and have brief written rationales for your choices. Create a brochure attempting to sell classmates on joining you for this trip.
- In the discussion questions is a suggestion to attempt to count the grains of sand in one handful. Have students grapple with methods for predicting the number of grains of sand in an area of beach about the size of a football or soccer field. If you do not live by a sandy beach, use a sand bag or a number of sand bags. Make sure students factor in a basic definition of what we mean by a grain of sand, the average grain size, and the depth of sand before the ground turns into something that does not have sand. Students could support their calculations with a brief justification of their methods.

Common Core Connections

CCSS.ELA-Literacy.RH.6-8.7 Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts.
CCSS.ELA-Literacy.SL.7.5 Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.
CCSS.ELA-Literacy.W.7.7 Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation.
CCSS.ELA-LITERACY.W.6.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content.
CCSS.ELA-LITERACY.W.6.1(a-d) Write arguments to support claims with clear reasons and relevant evidence.

Alan Stern, principal investigator for the mission to Pluto, worked for more than thirty years to get *New Horizons* to Pluto (and beyond). Whether or not you are interested in space science, what sort of group research projects, if any, would you enjoy investigating?

- Think back over your own educational journey. Make a list of all the group projects you can remember of which you were a member. What was the purpose? What was your part of the project? What was the result? Is there anything you would do differently if you were in charge of designing these projects? Discuss in small groups.
- Brainstorm with students some big projects that our country should be investigating more actively. Vote for a few of the best projects. Divide these popular projects into teams of students. Have the students prepare mock proposals to persuade the government to fund each one. Work with your math/social studies teachers to help students prepare budget reports to go along with a persuasive argument. Turn some of these proposals into a debate with teams of students arguing persuasively

(and politely) both for and against.

- Do an online search of schools and other educational groups that have done or are still doing long-term projects, especially any that may involve astronomy. Have students prepare an annotated list of links of these projects for other students to browse.

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On page 13 we read, "Errors in measurement and math had been made along the way, including overestimating Neptune's mass. There never was a Planet X to be found. Discovering Pluto was sort of an accident, like finding a diamond in the couch while looking for a ring that was never really lost." Based on the best science available, we discovered Pluto despite errors that, if caught, would not have allowed anyone to look for Pluto in the first place.

- Most students have heard something akin to, "We learn from our mistakes." Schools, however, rarely spend any class time celebrating student mistakes. Science, however, is about testing and failing, testing and failing, testing and failing until many moons later we succeed. Spend some time sharing your own mistakes teaching. Listen to students speak about colossal blunders they have lived to tell about. The purpose of this activity is to normalize the trial-and-error mentality that is (or should be) essential for thinking people. Make sure to explain what we attempted to do, what went wrong, why it went wrong, what we would do differently next time (and think of ways to share this by changing just one or two variables—as we might do in a scientific investigation).
- Including the discovery of Pluto, there have been a multitude of great discoveries via mistakes and serendipity! Have students research breakthroughs in science that arrived quite by accident. [Note: Be prepared to deal with students who chance upon the discovery of Viagra, which was a total surprise to the scientists who were working on cures for heart attacks.] If you wish for fewer class surprises, you could assign students favorite breakthroughs, such as the discovery of penicillin, pacemakers, microwave ovens, Einstein's cosmological constant, inkjet printers, Post-it notes, or your own favorites. Make sure students explore what the person was attempting to do or make or learn. Have them explain what went wrong and what was learned. Investigating some of these breakthroughs could be a very useful in-depth research project that explores thoroughly both the initial scientific investigation, the mistake or fluke, a detailed explanation for how the mistake was transformed, and the status of the initial research.
- Return to the discussion question concerning Clyde Tombaugh. Tombaugh built his own telescope, using farm equipment and car parts. Have students bring in various flotsam and jetsam (clean and safe!) from recycled bins, junkyards, rummage sales, dollar stores, Goodwill/Salvation Army stores, etc. Can your students make something useful? Have students build something and create an iMovie or video showing the sequential procedure for building what they did. The introduction should explain what they are attempting to build, why they are building it, the materials used, mistakes made during the process, and the final product. Have students pass out "recipe" cards when presenting their video of their object. Can your students make a telescope?
- There are plenty of online links on how telescopes work, including at least one that suggests a six-inch telescope will allow viewers to read the writing on a dime that is 150 feet away. In addition, there are amateur astronomy clubs in which students build their own telescopes and enjoy viewing the night sky. Some students may have access to telescopes in their home or neighborhood. Encourage students to build, use, and enjoy a telescope at night. If nothing else, have

students prepare an online or visual explanation of reflector and refractor telescopes, including a Venn diagram (or similar) that explains the differences between these two basic types of telescopes.

Common Core Connections

CCSS.ELA-Literacy.SL.7.5 Include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points.
CCSS.ELA-Literacy.SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.
CCSS.ELA-Literacy.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

Longitude and latitude are the guides that allow scientists to report precisely where on Earth things are located. Tracking devices are able to report GPS coordinates that allow scientists to precisely place something. What happens, however, when we go into space? Is there a GPS app for the *New Horizons* craft?

- Have students in the class point to where they believe Pluto is located. Discuss as a class where the various guesses might take us.
- Since Pluto is moving, play a game in which one student is shown an object labeled as Pluto. Then the student is blindfolded while students move Pluto one-twelfth of an orbit (around the room). When the blindfold is removed, the student guesses where Pluto might be now. The student is blindfolded and guesses until the orbital pattern of Pluto is determined. Once a student has figured out the pattern, try this again without removing the blindfold. Have the student point to where the Pluto should be. When this task is completed with a reasonable accuracy rate, try it again but this time spin the blindfolded student in several circles before pointing.
- Just how do we know where planets, moons, stars, and other celestial objects are located? Planets orbit around the sun, which means they will not be in the same location. Planets also spin. Our solar system is vastly larger than our planet Earth. Have students work with your school librarian (or public librarian) to find credible sources, links, etc., that show how scientists map the night sky in any given month. Have students prepare an online demonstration or explanation for how this is calculated. Include in this presentation relevant data on how scientists determined how fast planets spin (how long a day is) and how long it takes to complete an orbit (how long a year is).
- Share your exact GPS location (which can be found online through a longitude-latitude search: www.findlatitudeandlongitude.com). Discuss why it is important to have a standard reference. Discuss why a simpler numbering system might be easier. Now take this concept of how we direct people to an exact spot and discuss whether or not that same approach would work for mapping the night sky. The purpose of this activity is related to the fact that *New Horizons,* traveling at 9 miles per second, had to travel about 3.7 billion miles through space to reach a very specific location near Pluto at a very specific time.
- If your school has access to remote-controlled moving objects or spacecraft, have students design a challenging route that takes nine and a half minutes. The spacecraft must move at the exact same speed for at least nine minutes (allowing 30 seconds to get started). At the finish line, have cameras timed to go off in exactly nine and a half minutes. The cameras should be focused not on the spacecraft but at the finish line only. Spacecraft may not back up or speed up. Winners are the students whose spacecraft shows up in the pictures from the camera. Depending on your space, design a route rubric specifying the length of the route, the number of turns, and other logistics. Set a timer so that photographers make sure to take pictures at the exact time. At the end of the journey, have students write a reflection on designing *New Horizons* and making sure it reached Pluto in the correct location and at the correct time.

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use appropriate eye contact, adequate volume, and clear pronunciation.
CCSS.ELA-Literacy.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
CCSS.ELA-Literacy.W.7.7 Conduct short research projects to answer a question, drawing on several sources and generating additional related, focused questions for further research and investigation.

New Horizons carried with it seven scientific instruments: Alice, Ralph, SDC, SWAP, PEPSSI, REX, and LORRI.

- Take each of these instruments and create groups to study and present (in detail) what each instrument does, how it works, the information collected by each one (show pictures, especially newer shots since this book was published). Work with your school librarian to find reliable information on these instruments.
- Much of the information that comes from pictures of Pluto and the solar system is in the form of revealing information from across the light spectrum, including invisible light. See the diagram on page 31. Have groups of students prepare info graphics on radio waves, microwaves, infrared, visible light, ultraviolet, x-rays, and gamma rays. Make sure students answer the question—what are the pros and cons of each way of seeing?
- All of the instruments and, in fact, the entire *New Horizons* spacecraft was made without any moving parts. All of the equipment and the spacecraft itself were put through tests that were designed to see if the team could break the equipment or the spacecraft. To give students an inkling of this process, have them do the classic egg drop. Give each student a raw egg. They have to invent a container (and feel free to add rubrics about the type of material, weight, etc.) that when dropped from above thirty feet, will keep the egg safe and from breaking. Add to this by having them try to design a container that will keep the egg from freezing when placed in a freezer overnight. Or one that keeps an egg from cooking when placed in a preheated oven (350 degrees F) for fifteen minutes (but monitor this one to make sure that student safety is not compromised by putting something in an oven that will burn or release hazardous chemicals, and if in doubt, do not do it). Students will need to prepare a list of materials, a sequential list of steps, and a brief description of all the failed attempts.

Common Core Connections

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In addition to the scientific instruments, *New Horizons* included a few mementos: flags, coins (two quaters), a Pluto stamp, an artifact from SpaceShipOne, the ashes of Clyde Tombaugh, a CD with pictures of the team members, and a CD with names of supporters.

- Write a persuasive argument for why these mementos were necessary. Then write another persuasive argument for why they should not have been included.
- Conduct a mock trial complete with lawyers, a judge, witnesses, and a jury (or have the "jury" be the whole class voting) arguing the pros and cons of these "stowaways."
- If you were designing mementos to take with you to Pluto, what changes would you make?
- Assume that you are making a CD that includes music that you hope falls into the hands of intelligent life forms somewhere out in the Kuiper Belt when *New Horizons* comes to the end of its working life. What music would you have on this CD? What other information would you wish to share with beings that will not understand, perhaps, your frame of reference?

Common Core Connections

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CCSS.ELA-LITERACY.W.6.1(a-d) Write arguments to support claims with clear reasons and relevant evidence.
CCSS.ELA-Literacy.RH.6-8.7 Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts.

When the mission to Pluto began, Pluto was the ninth planet. Many students grew up repeating "My Very Educated Mother Just Served Nine Pizzas"—or a close variation—which helped in remembering the names of the planets and their distance from the sun. Several years into the project, however, and Pluto was removed as the ninth planet and given a new classification as a dwarf planet. Alan Sterns, however, continues to call Pluto a planet and believes that one day Pluto will be returned as the ninth planet.

- Create a children's story or play or musical depicting Pluto's new status. Does this story have to be a sad one? Try to create this story with at least two very different points of view—one, say, from the perspective of the International Astronomical Union (IAU) and one from the perspective of Alan Stern and his "a Chihuahua is still a dog" argument. Form partnerships with younger students and present this play, as well as providing nonfiction information about Pluto and our solar system in student-friendly graphics and illustrations.
- Do an oral presentation explaining the IAU criteria for planets and why Pluto does not qualify. Then make a case either for Pluto as a planet or Pluto as an ice dwarf.
- Pluto is a popular Disney character, a figure from Greek mythology, and a planet discovered quite by accident. Write a brief description of the planet from the perspective of Pluto the Disney dog, from the perspective of Homer (ancient Greek author), and from today's IAU perspective.
- While *Mission to Pluto* is among the more up-to-date books on the discoveries of *New Horizons,* perhaps the more exciting details are yet to come. Whether or not Pluto remains a dwarf planet or is returned to planetary status, it is very likely that a new planet will be discovered very soon. Research the most current news about Kuiper Belt discoveries and update this book. If a new planet is discovered, what do you suggest for its name? Make your case!

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Among the multitude of data and images returning from Pluto over the course of this mission are the discovery of new moons on Pluto, the actual size of Pluto, the shapes of the moons, the density of the planet, the differences in color between Pluto and Charon, moving ice, the possibility of the Pluto equivalent of an earthquake, and much more.

- While it is very difficult to make a scale model of the solar system, it will be easier to make a model of Pluto and its moons. Be sure to show the orbit, its relation to Charon, the updated color scheme, and other interesting facts.
- We also assumed for years that Pluto was always the farthest from the sun. While this is mostly true, there are times when Pluto is not the farthest away. With your model or with an online Animoto or slide show, show the differences in Pluto's orbit and how this moves it closer to the sun than Neptune.
- There is snow on Earth and there is snow on Pluto. If you made a snowball on Pluto and threw it and a snowball on Earth and threw it, what would be the same and what would be different? Create a Venn diagram (or similar) and explain all the similarities and differences in these two snowballs.

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Other Websites to Explore

The Exploratorium has a great site that includes a scale model calculator showing how big the various planets would have to be if the sun is *x* inches or centimeters: www.exploratorium.edu/ronh/solar_system.

NASA has an excellent site for folks interested in astronomy: www.nasa.gov.

NASA also has a dedicated section of information on *New Horizons*: www.nasa.gov/mission_pages/newhorizons/main/index.html.

Space.com is a commercial site that has a large collection of videos and images from across the solar system, as well quizzes (including one on Pluto) and videos for building telescopes: www.space.com/science-astronomy.

National Geographic made a video about the New Horizons mission: www.youtube.com/watch?v=mU9Tl7KTbX4.

Further Reading

Carson, Mary Kay. *Far-Out Guide to the Solar System*. Bailey Books, 2011. (This series includes twelve titles, including one entitled *Icy Dwarf Planets.*)

Consolmagno, Guy and Dan M. Davis. *Turn Left at Orion: Hundreds of Night Sky Objects to See in a Home Telescope—and How to Find Them*. Cambridge University Press, 2011.

Kanas, Nick. *Solar System Maps: From Antiquity to the Space Age*. Springer Praxis Books, 2014.

Kortenkamp, Stephan. *Demoting Pluto*. Capstone Press, 2015.

Leedy, Loreen. *Postcards from Pluto: A Tour of the Solar System*. Holiday House, revised 2006. (This is revised but it is from prior to Pluto's demotion—still filled with fun facts and lovely illustrations.

Thimmesh, Catherine. *Team Moon: How 400,000 People Landed Apollo 11 on the Moon*. Houghton Mifflin, 2006.

Teacher Guide by Ed Spicer