EXPEDITION EARTH

AND BEYOND

STUDENT SCIENTIST GUIDEBOOK

NASA

EXPEDITION EARTH AND BEYOND

Student Scientist Guidebook

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The *Expedition Earth and Beyond Student Scientist Guidebook* is designed to help student researchers model the process of science and conduct a research investigation. The *Table of Contents* listed below outlines the steps included in this guidebook.

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EXPEDITION EARTH AND BEYOND

Student Scientist Guidebook

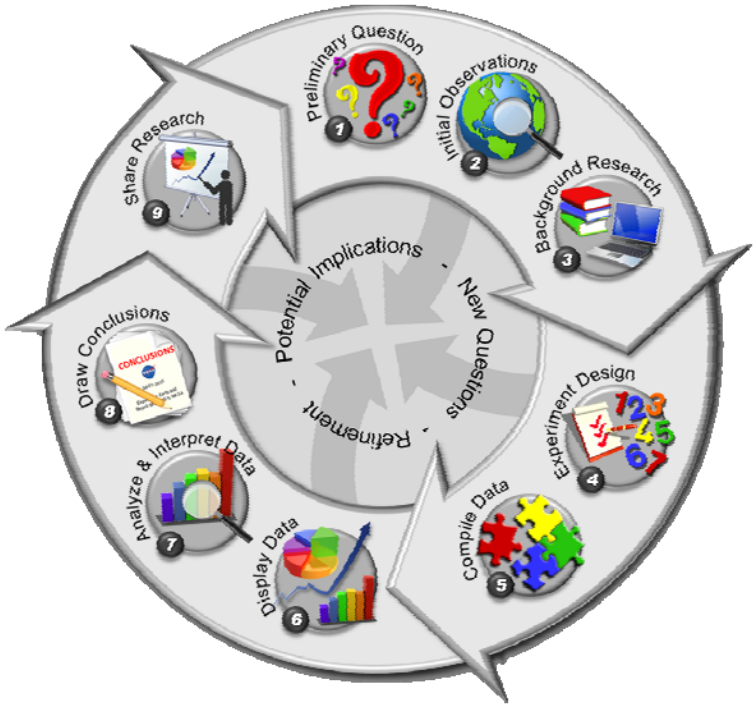
GET ACTIVELY INVOLVED IN NASA EXPLORATION, DISCOVERY, AND THE PROCESS OF SCIENCE

As you begin your expedition of conducting research about Earth and/or a planetary comparison, it will be helpful to use the 9-step process of science as a guide. It is a good idea to take a look at each step of this process as a quick preview, to make sure you know what to expect as you get started with your investigation.

OVERVIEW OF THE PROCESS OF SCIENCE

The steps and activities in this *Student Scientist Guidebook* will provide strategies for you to use as you conduct your research investigation. This 9-step process models what scientists do as they conduct their own research.

The process of science is an iterative process. This means you will sometimes repeat or go back to refine a step within the process to help strengthen your overall investigation. Throughout each step, your team should focus on your research question which you may refine and change more than once. As you gather background research, this will help you finalize your research question and decide on the methods (experiment design) your team will use to collect, display, and analyze data to help you draw conclusions about your research. Although your research should focus on something very specific, make sure you think about the bigger picture. This includes thinking about potential implications of your research -- how what you are researching may help you (or others) gain a better understanding of processes on Earth and/or other planetary bodies.



A model of the process of science

The nine steps in this iterative process of science are described below:

STEP 1: Preliminary Question All science begins with observations that lead to a question. This preliminary question evolves from your observations, ideas, or prior knowledge and curiosity you may have about a particular topic. This helps drive what you want to investigate.

STEP 2: Initial Observations You must make initial observations and formally log data to figure out what details or characteristics of a feature(s) you may be interested in investigating. These observations will help you refine your question and formulate an initial hypothesis.

STEP 3: Background Research Background research from books, scientific journals, magazines, the internet, or scientists is essential to help you understand what is already known about what you may be researching. It is important to keep track of sources you use as part of your research so you can cite them appropriately.

STEP 4: Experiment Design With your developing knowledge and observations, you will likely adjust and refine your preliminary question. Once you "finalize" your question, you must decide on a strategy to answer your question. This strategy includes a list of steps or methods to gather data consistently. This is called an experimental design.

STEP 5: Collect and Compile Data Collecting and compiling data is extremely important. You must make sure everyone is logging the same data and recording it consistently. Once team members have collected data, it needs to be compiled so all the data can be displayed and later analyzed. The more data you have, the better your conclusions.

STEP 6: Display Data Displaying your data helps you organize it. Data can be displayed in tables, in graphs, on maps, or even as annotated or captioned image illustrations. General observations of data displays help you think about general trends the data are showing.

STEP 7: Analyze & Interpret Data Using the knowledge you have gained, along with observations from your data displays, you will be able to analyze your data. This will help you interpret or make sense of what the data mean and how it applies to your question and hypothesis.

STEP 8: Draw Conclusions Once you have analyzed your data you will be able to draw conclusions. This includes answering your question as well as deciding if your hypothesis was supported or refuted.

STEP 9: Share Research Publishing or presenting your science research (even to your classmates) is an extremely important part of science. Sharing your discoveries will allow others to learn from and build on your previous research.

Your contributions to science and the implications of your research can help drive future work that needs to be done. Your research will likely spark new questions you or someone else may want to investigate. New knowledge helps drive new science. Science is ongoing and continual as shown in the model of the process of science on page 3.

As you conduct your investigation, be sure to always focus on your scientific question. This question must drive every aspect of your research as you go through the process of science.

Let's get started….

CONDUCTING YOUR RESEARCH INVESTIGATION

STEP 1: Preliminary Question

Based on activities you may have completed in class, discuss your observations and interests in small groups. In the space below, create a preliminary research question your group would like to investigate. Be sure to focus your question on a specific VISIBLE aspect or characteristic of a feature(s) that can be observed in astronaut photographs.

- Feature: _____
- Visible Aspect/Characteristic of feature: _____
- Research Question:

STEP 2: Initial Observations

As you begin to further explore your preliminary question, you need to start thinking about and logging initial observations. As you have likely already observed astronaut photographs, these photos should be one source of your observations and data collection. Depending on your research, you may use other data sets as well. The observations you log of astronaut photos (which is part of data gathering), will help you formulate a hypothesis as you look for patterns or trends. It may also help you refine and focus your question. This is a natural part of the process of science.

The outline and set of items listed on the following pages, as part of Step 2, are designed to help you start thinking about your initial observations and initial structure of your research.
List information for each of the following:

A. FINDING ASTRONAUT PHOTOGRAPHS: Where will you find astronaut photos? Try these sources:

- Source #1: Expedition Earth and Beyond Quick List of Images: http://ares.jsc.nasa.gov/ares/eeab/atmosphere.cfm
- Source #2: Gateway to Astronaut Photography of Earth: http://eol.jsc.nasa.gov

List additional sources (websites or other resources) as you find them: (Use additional paper as necessary):

- Source #3: _____

  _____

- Source #4: _____

  _____

B. CONSIDER WHAT DATA AND OBSERVATIONS TO LOG: Once you know where to find astronaut photos, you need to consider what specific information to log. Use the list below to help you consider some options. Be sure the information will be useful for your research question.

Sample data to log: *Image Identification number, latitude, longitude, date image was taken, instrument used to collect data (For example: Camera/lens used or other scientific instrument used to collect data), city, state, country, continent, specific observations of feature you are investigating (be specific as to what you will log), specific measurements you will make, notes/comments or miscellaneous observations, sketches, other??*

Create a bulleted list of the specific data you will log:

C. CREATE AN INITIAL DATA TABLE: How will you organize your data? One way to organize your data is to create a data table. As you create your *Initial Data Table* on the next page, be sure to include a title and column headings for each individual piece of data you will collect. Use the bulleted list you just created to help you organize your *Initial Data Table.* Use the Sample Master Data Table (below) as an example.

SAMPLE MASTER DATA TABLE - SAND DUNES ON EARTH

Image ID#	Latitude (N)	Longitude (E)	Sand Dunes (Y or N)	Sand Dune Type (B=Barchan; L = Longitudinal, C=Crescent; S=Star; N/A = none; U = Unsure)	Country	Date Acquired	Camera	Camera Focal Length (mm)	Qualitative Observations	Quantitative Observations	Notes/Comments
STS61A-43-78	16	(-4)	Y	L	Mali	11/2/85	Hasselblad	100	Series of long dunes seen around river and lake.	None at this time but could measure the distance between dune crests.	Earth From Space Image Collection image view has best image quality.
STS085-501-14	22.5	55	Y	L	Oman	8/?/1997	Linhof	250	Very visible dunes that run up against mountains; dunes are tannish/orangish in color; near water.	None at this time but could measure the distance between dune crests.	Great detail in this image.
ISS018-E-14770	24.5	12.1	Y	S	Lybia	12/20/08	NikonD2X	400	Image only shows dunes in great detail, no other context; dunes appear orangish in color.	None at this time but could measure the distance between dune crests.	
ISS017-E-8290	23.3	30.6	Y	C	Egypt	5/31/08	NikonD2X	800	Dunes seem to be moving along the land and are near body of water; dunes are tannish in color.	None at this time but could measure the distance between dune crests.	
ISS010-E-10124	29.4	4.4	Y	U	Algeria	12/11/04	Kodak DCS760C	400	Seems to be a combination of dune types that are hard to decipher; may have flat mesas between dunes.	None at this time but could measure the distance between dune crests.	

Create your *Initial Data Table* here:

D. LOGGING INITIAL OBSERVATIONS

Once you have discussed and finalized your *Initial Data Table* including a title and columns headings, use it to start logging data. In small groups, log observations from 5-10 images. This will help you get a sense of logging each piece of information. It may also help you realize if you want to adjust your data table in any way. Use the sources listed in **Step 2 section A** to find images you can use as you begin your data collection.

E. HYPOTHESIS DEVELOPMENT

AFTER you log your initial 5-10 observations, discuss your observations with other team members. Are you noticing any patterns or trends? Formulate a hypothesis based on these initial observations and what you may already know. A hypothesis is an educated guess about the answer to your question. It should be formulated based on information and observations that can support it. Your hypothesis should also be testable. List the information in the area below:

- Research Question:

- Current Hypothesis:

- Explain what observations or information you have researched so far that directly supports this hypothesis:

F. DISCUSSION AND DEBATE OF TEAM RESEARCH QUESTION

Classes working as one team have the opportunity to work with an online mentor and request new data from the International Space Station (ISS). The goal of this section is to help you decide on one research question the class should focus on as a team. Each group should prepare to discuss and debate their preliminary research question. Use the work you have done so far to present a compelling argument to convince your classmates that your group's question is best for the overall team research. Your presentation should include:

- **Preliminary Question** (refine it if necessary)
- **Data Collection Methods** (what data will you log)
- **Other Comments:** Think about other comments you want to make to the class. Is this project easily doable? What makes this question interesting? Does it relate to something you are already studying in class? Are there important implications of your study for you, your class, or society?

As each group presents their information, listen carefully. At the end of all group presentations you will need to discuss, debate, and vote on which research question the class should focus on as a team. Once you decide which research question is best, don't hesitate to tweak it. It is important to make sure the scope of your project is clear, focused and doable.

After the discussion, debates, and voting process, discuss, refine, and finalize the following:

1. List the team research question:

2. List the current hypothesis and supporting details:

3. List any new sources to gather data:

4. Sketch a view of your data table, clearly showing the column headings of your table in the space below:

STEP 3: Background Research

Once you decide on a team research question, which may still get further refined, it is important to become familiar with what other scientists already know about the subject. Conducting background research is an ongoing process. You should continually gain knowledge and become aware of information that already exists.

Potential Sources for Background Research

As you conduct your background research, you must keep track of references you use to obtain facts, general information, figures, or images. When you log and post information or write up your results, you **should** cite your references.

The following four sources you may be useful for your research: 1) Books, 2) Journal Articles/Magazines, 3) Electronic Sources (Internet), 4) Scientist/Science Expert.

As you find and use any of these sources, make sure you log the information shown below. These details should be listed in your bibliography, except for the summary information. The summary information helps you remember what details you obtained from that source for possible referencing later in your project.

BOOK/JOURNAL/MAGAZINE	ELECTRONIC SOURCE (Internet)	SCIENTIST/SCIENCE EXPERT
a) Author Name(s) (Last name, first name)	a) Author Name(s) (if one exists)	a) Scientist Name (Last name, first name)
b) Name of Book/Journal/Magazine	b) Name of website	b) Affiliation (where scientist works)
c) Publisher	c) Publication date (if one is listed)	c) Date of conversation
d) Year of publication	d) Date(s) you accessed the site	d) Means of communication (Wiki, distance learning connection, personal communication)
e) Pages where information was obtained	e) Website address	
f) Summary of information obtained	f) Summary of information obtained	e) Summary of information obtained

Basic Background Research and Information
As you conduct your research, consider gaining knowledge related to the following:

1. **Important Definitions**: Name and define the feature(s) you are studying as the focus of your research. Include other terms associated with your research that are important to understand.

2. **Earth System Information:** Explain basic information about this feature(s) including which Earth system(s) it is related to (geosphere, hydrosphere, atmosphere, or biosphere) and how it is related to each system.

3. **Formation Process:** Describe and/or draw a sketch or diagram with labels to explain the process of how this feature is formed.

4. **Feature Description or Characteristics:** Describe specific criteria used to identify this feature.

5. **Astronaut Images with This Feature:** Be sure you can list the image identification numbers for multiple astronaut photographs that include the feature(s) you are investigating.

6. **Geographic Region of Focus:** Think about what specific geographic region(s) on Earth you will focus on to observe this feature(s), and why.

7. **Planetary Comparison:** If you plan to conduct a planetary body comparison, what planetary body will you compare this feature to on Earth? Why? *(You may want to complete your investigation of this feature focusing on Earth first before you expand your research to include a planetary comparison.)*

As you work as a team, consider dividing up the work and assigning small groups different tasks. As some groups focus on certain aspects of the background research, others should continue to collect data.

Be sure to make time for groups to share their new knowledge. Everyone on the team should have a good understanding of the research and knowledge gained.

STEP 4: Experiment Design

You are now at the point where you will finalize your research question, hypothesis, and how you will go about answering your question (experiment design). Think about your current research question. Based on new knowledge, additional observations, and data collected, discuss and refine your team question and hypothesis if necessary. From this point on, your question and hypothesis should not change again.

Current Research Question	
Final Refined Research Question (After discussing options with the class)	
Hypothesis (Include observations and other knowledge that support this hypothesis.)	

EXPERIMENT DESIGN (METHODS)

As your research question may have changed throughout the process, at this point you are ready to finalize your experiment design, or methods, to answer that question and support or refute your hypothesis. It is important to make sure you are (and have been) collecting all the data you feel you need for your research. Think about the following:

1. **Image Data Collection:** Be sure you can name and describe the specific data set you will use as the primary source of image data for your research of Earth.

2. **Specific Data to Collect:** List each specific piece of data you will log from each image you observe (refer to your latest data table and make sure you don't want to change anything).

3. **Number of Images:** Consider how many images, at a minimum, will you observe overall in order to draw conclusions about your research.

4. **Geographic Region(s):** Think about what regions on Earth (or other planetary world) you will focus on to gather your data.

5. **Other Data Sets:** What other data sets will you use, if any, to support your research? Think about how you will use each of these other data sets to help support your research. Create additional data tables as necessary.

6. **Measurements:** Be sure you can describe the procedure you will use to ensure all measurements are made in a consistent manner.

7. **Sources:** Be sure to keep track of the bibliographical information and summary information from each source *(Books, Journals, Magazines, Electronic Source, Scientist/Science Expert)* you use as part of your research.

STEP 5: Collect and Compile Data

At some point in your research, you will have all the data you planned to collect. As this data may have been collected from different team members, you will want to compile the data from each team member into one *Master Data Table*. If you have data tables for multiple types of data you may have more than one *Master Data Table.* Make sure every data table includes a complete set of logged data. If you have a hand-written data table, consider recreating it using a spreadsheet (i.e., Microsoft Excel, Google Docs).

If you would like to have new data acquired from an astronaut on the International Space Station (ISS), consider submitting an Expedition Earth and Beyond (EEAB) *Data Request Form.* This new data (image) should support your research. Completion of your research should not depend on this new image as it may take a month, semester, or more for your specific image request to be acquired. Keep in mind that only one *Data Request Form* can be submitted per class. Be sure to carefully fill out the information on the form. Your teacher should email the completed form to the *Expedition Earth and Beyond* (EEAB) staff.

STEP 6: Display Data

Science research investigations are strengthened by the data that provides evidence to support conclusions. Therefore, displaying your data to help make sense of what it is showing is extremely important. Once you have finished collecting and compiling your data you will need to make sure you can list, organize, and display your data clearly. This will help you find supporting evidence to answer your question and support or refute your hypothesis.

With every aspect of your research, but especially as you get ready to display your data, it is important for you to focus on your research question and hypothesis. State these below.

With your question and hypothesis in mind, there are three action items you should follow as you consider displaying your data. Each action item is described in more detail on the next page.

DISPLAY DATA ACTION ITEMS:

A. **Discuss data display options:** Look at the four data display options and decide which ones best apply to your research.

B. **Create your data displays:** Discuss and decide on a strategy for the team to have groups or individuals create your data displays.

C. **Make observations of each data display:** Once you have your data displays created, it is important to make observations of what the data are showing. Be sure to share and discuss observations of each data display as a team.

A. DATA DISPLAY OPTIONS

Scientists often use graphs, tables or other techniques to represent their information visually. Consider the following four options to display your data. Discuss these as a team and decide which ones best apply to your research.

1. **Data Table:** Think about your *Master Data Table(s).* Consider the following: 1) How should you sort your data? Would it be helpful to sort your data in such a way to help you organize it by feature name, by latitude or some other way? 2) Should you pull out a subset of data from a *Master Data Table* to help focus in on data that will specifically help you draw conclusions about your question?

2. **Graphs:** Think about what types of graphs you can make to help you show relationships, highlight patterns, or make comparisons. Consider the following types of graphs:
   - **Graphs for Categorical Data:** Categorical data classifies information by topics or words – generally considered qualitative data. [*Example: A scientist might look at ten images and classify them by the different types of sand dunes.]*
     - o Graph types: Pie graphs, bar graphs, pictographs, line plot
   - **Graphs for Numerical Data:** Numerical data is given in numbers – generally considered quantitative data. *[Example: A scientist might record the elevation of ten mountains. (The elevation is the numerical data.)]*
     - o Graph types: Line graph, scatter plots, box and whisker plot

3. **Maps:** Think about if it might be useful to plot data on a map.

4. **Image Illustrations:** Consider how the use of images can help you illustrate your research to others. Can the use of images help you show the feature or the characteristics you are focusing on; can looking at two images side by side help you compare features; can labeling an image show a relationship among features?

B. CREATE DATA DISPLAYS

As a team, discuss each data display option and decide: 1) What data displays should be created, 2) Which team members will create which data displays, and 3) Create the data displays. You MUST complete this before you continue.

C. MAKE OBSERVATIONS: Now that you have your data displays, list 1-3 general observations of what the data display is showing. Observations should simply indicate general patterns or trends. At this point you should *not* make inferences or analyze what those observations may mean for your research. You will analyze your data in the next step.

Consider using the table below to help you organize your observations of each individual data display created. (Ask your teacher for additional copies as necessary.)

OBSERVATION TABLE				
Title of Data Display				
Type of Data Display (circle one)	◯ Data Table	◯ Graph	◯ Map	◯ Image Illustration
Summarize what the data display is illustrating.				
List 1-3 general <u>observations</u> or trends of what the data display is showing.				
Observation #1:				
Observation #2:				
Observation #3:				

IMPORTANT NOTE: Once observations have been made of each data display, discuss each set of observations as a team. **Circle or highlight observations** that seem especially relevant to your research.

STEP 7: Analyze & Interpret Data

Now that you have your data displayed and have made observations of those displays, you are ready to do one of the most important steps of your research – analyze and interpret your data. Analysis and interpretation of data are done by thinking about how specific observations and acquired knowledge directly relate to your question. Your goal is to be able to draw conclusions about your research with supporting evidence.

As with all steps of your research, when you analyze your data, focus on your research question and hypothesis.

Research Question:

To help you analyze and interpret your data, consider using the table provided on the next page. Include the following:

- **Specific Observations From Data Display(s):** Examine the observations your team made of each data display. Pay close attention to those that you circled or highlighted. Think about how those observations provide information related specifically to your question and/or hypothesis. List those observations on the table provided.
- **Interpretation(s) of What Observation Means With Respect To Your Question:** Think about how each observation you listed can be interpreted to help you make a connection or inference related to your question and/or hypothesis. Briefly describe your interpretation of each observation on the table provided.
- **Evidence That Supports Your Interpretation:** In the third column, list additional evidence that supports the interpretation of your observation. This can be specific evidence from other data displays or from background knowledge you gained throughout your research. Use additional paper as necessary to further discuss your observations, interpretations, and supporting evidence.

ANALYSIS AND INTERPRETATION OF DATA		
Specific Observation from Data Display	**Interpretation(s) of What Observation Means with Respect to Your Question and/or Hypothesis**	**Evidence That Supports Your Interpretation** (from specific data displays and/or background knowledge)
1.		
2.		
3.		
4.		

(Make additional copies of this table or use additional paper as necessary.)

Potential Issues, Errors, or Limitations

Considering potential errors, inaccuracies, or limitations of your data is another important part of this step in the process of science. Stating these challenges up front helps others know you were aware of these aspects and took them into consideration as you stated your final conclusions.

For example, suppose your question was, "What is the average length of sand dunes?" If you were only able to measure the lengths of one type of sand dune in only one desert, is that enough data for you to conclude that your average length is accurate for *all* dunes? What if the resolution of the images you viewed made it difficult to measure dune length with confidence? Perhaps the data you focused on did not allow you to obtain the information and/or measurements you needed to answer your question. These would be considered potential errors, inaccuracies, or limitations of your data that should be thought about as you draw your conclusions. An acknowledgement of the limitations you list could help strengthen future research related to your question.

Consideration of Issues, Potential Errors, or Limitations of Your Research	
Potential errors or inaccuracies	
Potential misinterpretations	
Limitations of data	
Other	

STEP 8: Draw Conclusions

You have done all your research, displayed and analyzed your data, and considered any potential errors, misinterpretations, or limitations. You are now ready to draw conclusions about your question and hypothesis. This is an essential part of your investigation, as it allows you to synthesize your overall research and state your results. It also allows others to expand or build on your research in the future.

Discuss and come to a consensus on the following as a team:

1. RESEARCH QUESTION: State your research question. Based on your research and analysis of data, what do you conclude is the answer to your question? Be sure you can provide supporting evidence.

2. HYPOTHESIS**:** State your hypothesis. Based on your research and analysis of data, was your hypothesis supported or refuted? Be sure you can summarize pertinent evidence.

It is also important to do the following:

- Think about new questions or explain what future research could be conducted, sparked by your investigation.
- Who would you like to acknowledge for helping you complete your investigation? This may include your teacher, mentor, parent, or anyone else that helped you or provided support throughout your investigation.
- Reflect on your research and think about how you could potentially improve your investigation.

STEP 9: Share Research

One of the final steps of research is sharing it with others. Science is about new ideas, new discoveries, and building on prior knowledge. If you don't share what you have researched, no one can build on or learn from your ideas. Consider any or all of the following options to share your research with others:

1. EEAB Team Workspace Wiki: You can "publish" your research on your own Team Wiki page.

2. Scientific Paper: Scientists often publish a cohesive write up of their research. This technical paper includes titled sections that discuss the details of the research. Sections generally included are as follows: Abstract, Introduction, Background, Experiment Design, Data, Data Analysis/Discussion, and Conclusion.

3. PowerPoint Presentation: A PowerPoint presentation should include a summary of the most important parts of your research. The content of the slides should include a mixture of short bullets of information, images, and data displays that you can expand on verbally during your presentation.

If your team is interested in sharing your research through any of the above options listed, your teacher should contact the *Expedition Earth and Beyond* staff. We look forward to seeing what you have accomplished!

Your participation in *Expedition Earth and Beyond* has provided you with an authentic experience in the process of science and the exploration of our Earth and possibly beyond. As NASA continues to explore our Earth and solar system, we hope you continue your journey of exploration both personally and professionally. NASA Centers and Universities across the nation and world are looking for the next generation of scientists and explorers...which could include you!

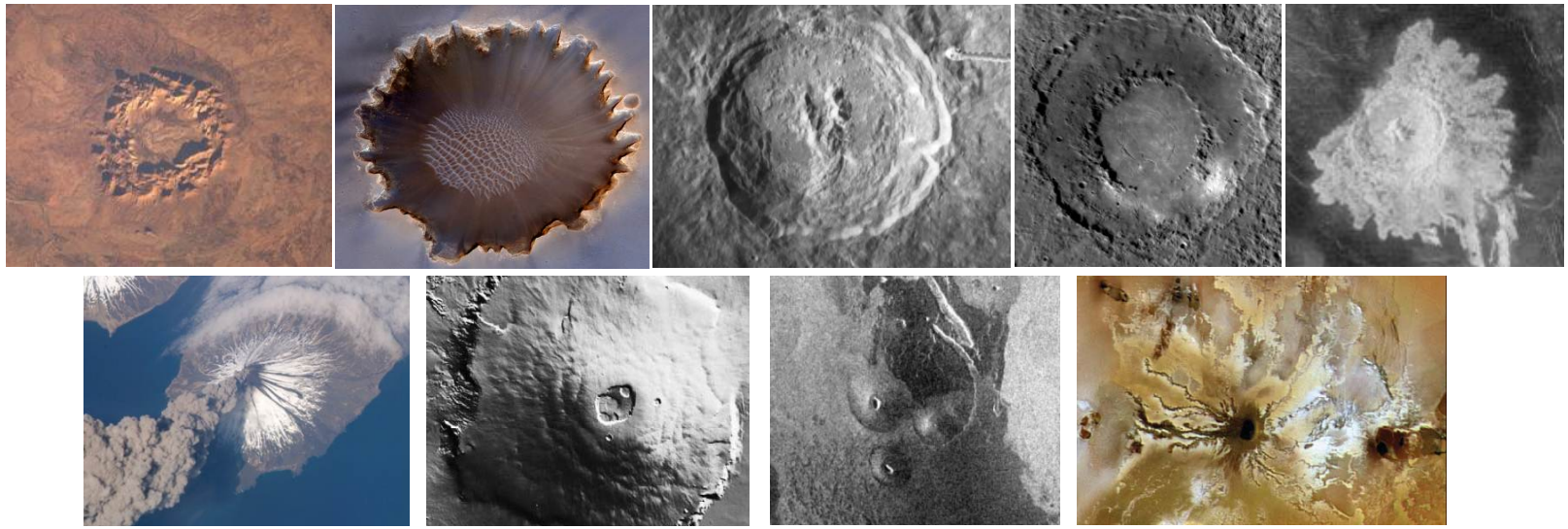
THE BEYOND

Now that you have a better understanding of the feature you investigated, have you ever thought about if that feature also exists on other planetary worlds? Does it exist on Earth's Moon, Mars, Venus, Mercury, or other planetary moons, or is it unique to Earth? Some planetary worlds in our solar system are similar to Earth in certain ways, while others are very different. Do other planetary worlds in our solar system have an atmosphere, geosphere, biosphere, and hydrosphere? Do the processes that shape the surface of Earth, shape the surface of other worlds? What does the feature you investigated on Earth look like on other planetary worlds? Are you curious? Maybe you want to expand your research or just simply investigate a bit on your own. Comparing Earth to other planets is really quite interesting!

If you decide to conduct a planetary body comparison, other terrestrial (rocky) bodies you may consider researching are:

-Mars
-Venus
-Earth's Moon
-Asteroids
-Mercury
-Moons of Jupiter (Io, Ganymede, Callisto, Europa)

These are a few examples of other worlds NASA is currently investigating. There are other planets in our solar system and other solar systems being explored. Comparative planetology is how researchers use what is known about Earth to better understand other planetary bodies in our solar system. Consider conducting a planetary comparison investigation and take your research out of this world…and beyond!



Impact craters (top row) and volcanoes (bottom row) on Earth and other planetary bodies in our solar system.