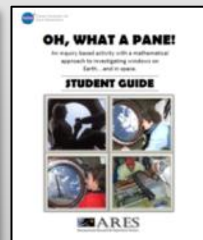
Expedition Earth and Beyond

Getting students actively involved with NASA exploration and discovery.

http://ares.jsc.nasa.gov/ares/eeab/

Getting Started

Launchpad Activities



Standards-aligned, inquiry-based, hands-on activities.

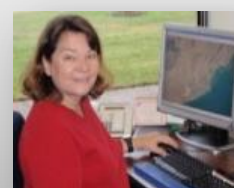
Modeling the Process of Science

Student Investigation Resources

Resources that help facilitate student-led investigations about Earth and/or planetary comparisons.

Enrichment Components

Team Wiki Pages



Interacting w/ Scientists

Data Requests

Team Presentations

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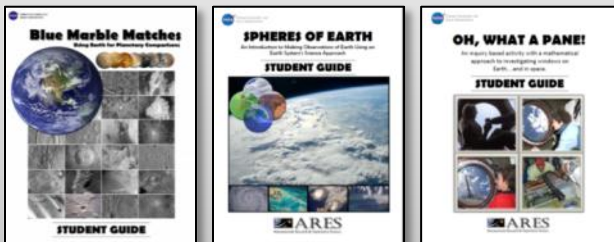

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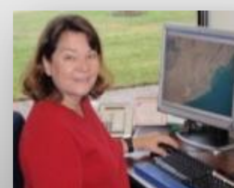

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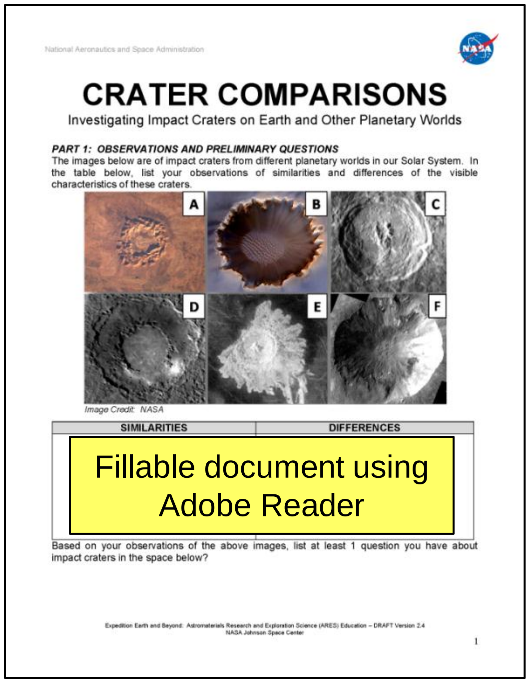
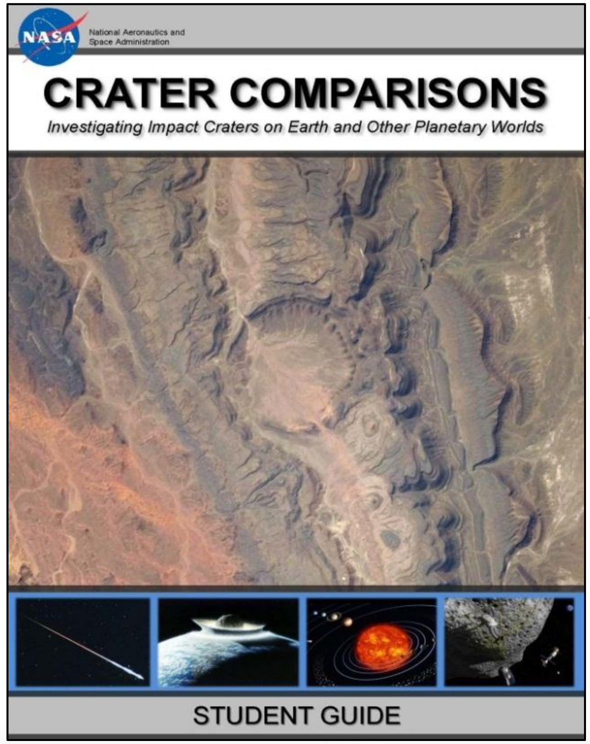
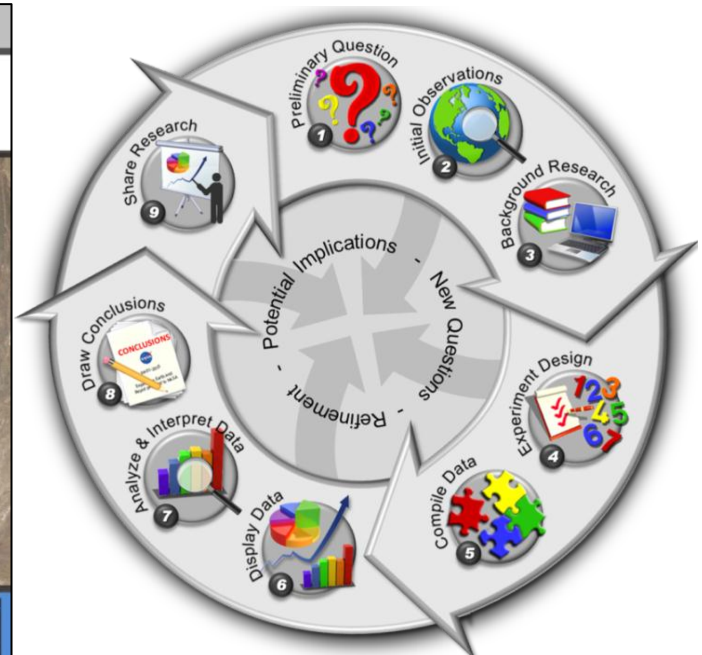
CRATER COMPARISONS

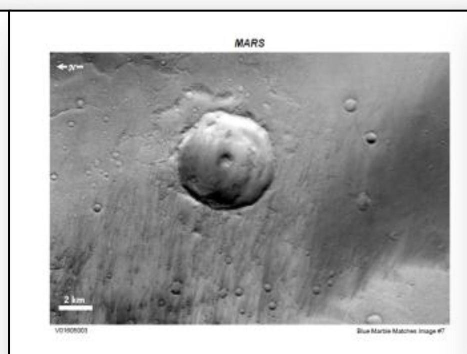
Investigating Impact Craters on Earth and Other Planetary Worlds

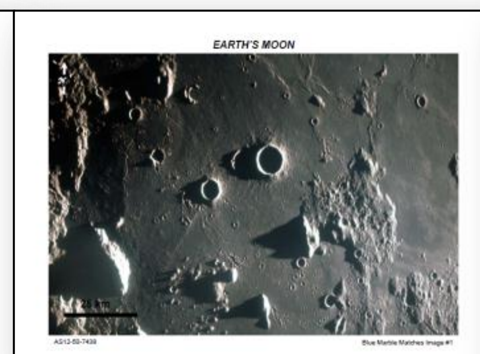
An "all-inclusive" activity designed to help introduce and guide you/your students through each step of the process of science.

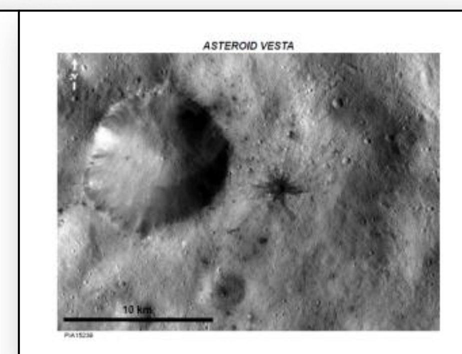




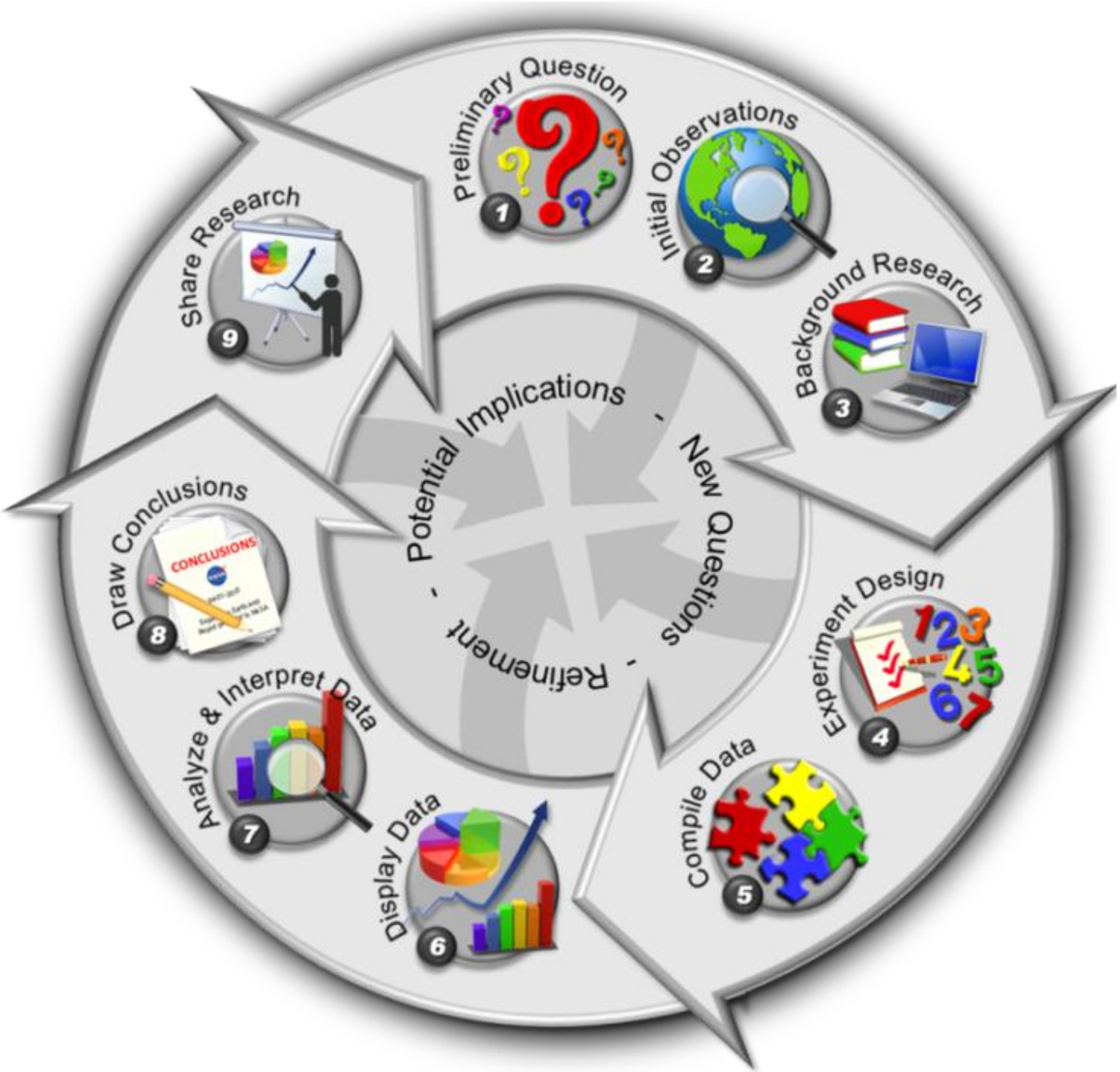








PROCESS OF SCIENCE



CRATER COMPARISONS

Overarching Goals & Structure of Activity

Goal: To introduce students to the process of science through the completion of a structured mini-research investigation focusing on impact craters on Earth and other planetary worlds.

❖**Parts 1 through 4:**

A) Informally introduces students to Steps 1-3 of the process of science;

B) Helps lay the foundation to complete the remaining aspects of the investigation.

❖**Part 5:**

A) Formally introduces the process of science;

B) Introduces, illustrates, and guides students through each of the remaining steps involved in the process of science.

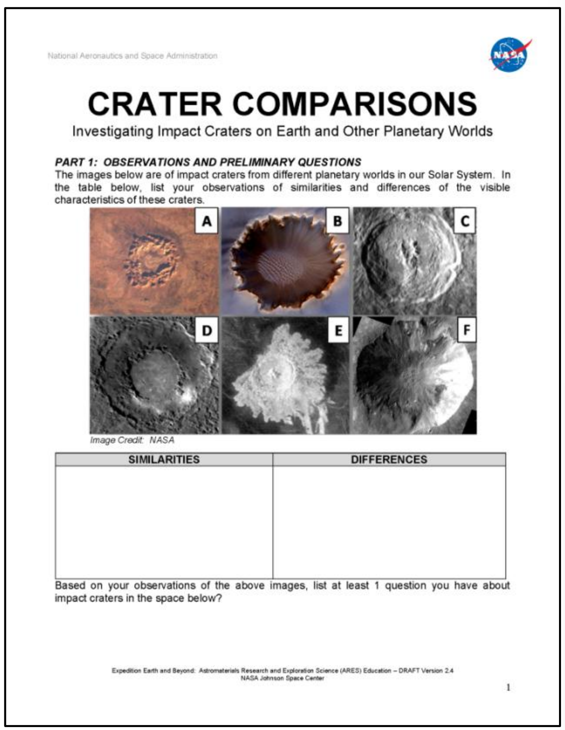
❖**Part 6:** A) Assesses student mastery of objectives.

CRATER COMPARISONS

Investigating Impact Craters on Earth and Other Planetary Worlds

PART 1: OBSERVATIONS AND PRELIMINARY QUESTIONS

- Observe the images of impact craters.
- List your observations (similarities and differences of visible characteristics)
- List at least 1 question you have about craters.


National Aeronautics and Space Administration

CRATER COMPARISONS

Investigating Impact Craters on Earth and Other Planetary Worlds

PART 1: OBSERVATIONS AND PRELIMINARY QUESTIONS

The images below are of impact craters from different planetary worlds in our Solar System. In the table below, list your observations of similarities and differences of the visible characteristics of these craters.

Image Credit: NASA

SIMILARITIES	DIFFERENCES

Based on your observations of the above images, list at least 1 question you have about impact craters in the space below?

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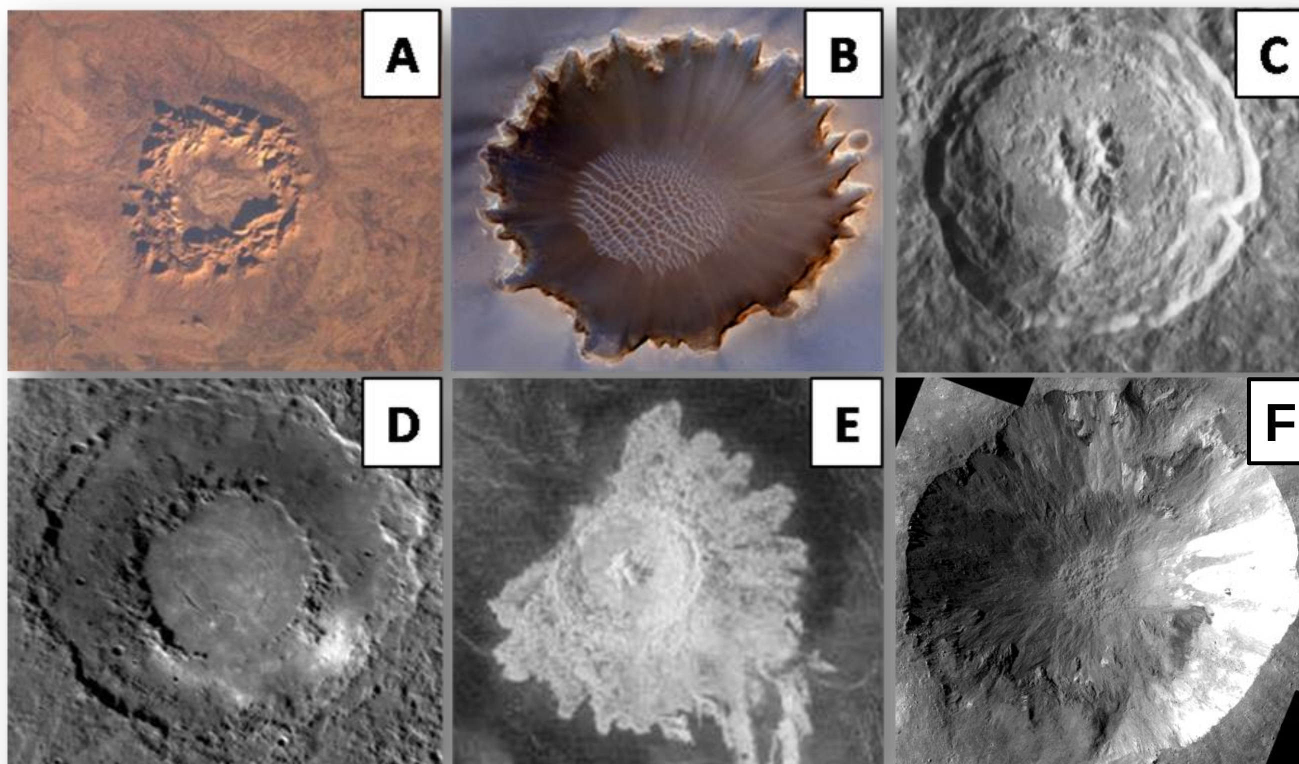
NASA Johnson Space Center

1



PART 2: BACKGROUND INFORMATION ON IMPACT CRATERS

A. CAUSES OF IMPACTS:

Impact craters are features created on the surface of a planetary body when a meteoroid strikes the surface creating a bowl-shaped hole.

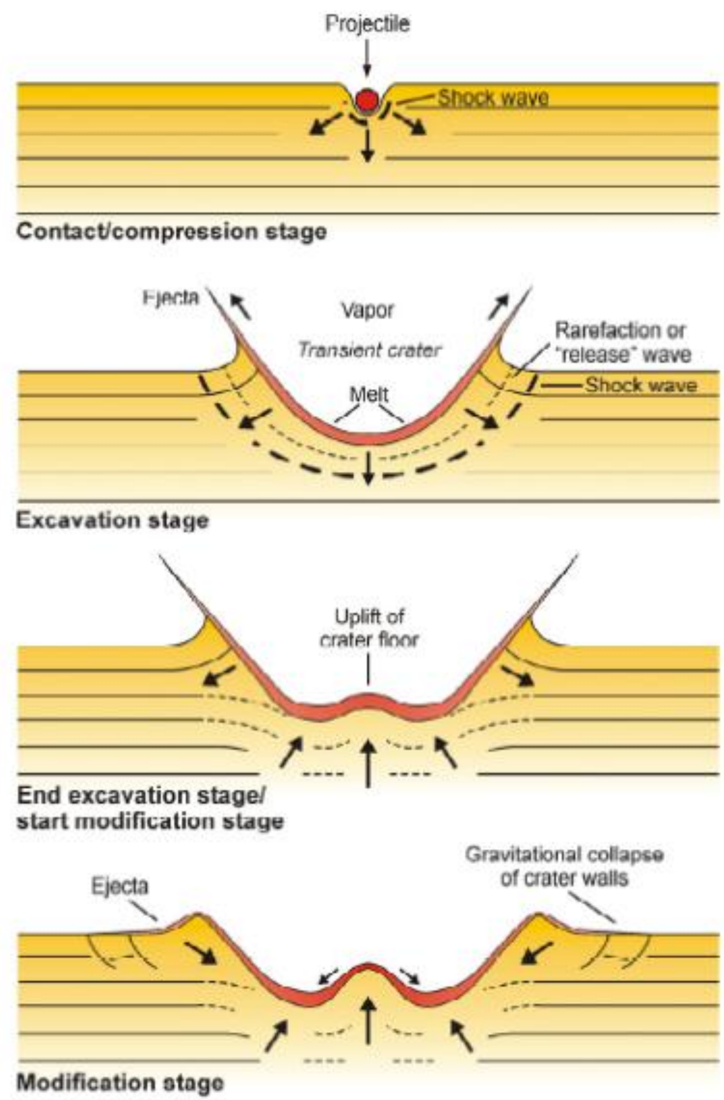


Image Credit: Planetary Science Institute

B. FORMATION OF CRATERS:

Stage 1: Contact/Compression Stage

- Meteoroid strikes the surface

Stage 2: Excavation Stage

- Material gets ejected or thrown out

Stage 3: Modification Stage

- Ejecta settles out onto surface and materials in the walls begin to slump.

The crater formation process occurs in seconds. The final crater will continue to be modified by gravity, erosion, and/or other geologic processes.

Background Information

C. CRATER CHARACTERISTICS:

Five main parts of a crater:

- **Rim:** The raised area around the edge of the crater.
- **Wall:** The sides of the crater.
- **Floor:** The bottom of the crater.
- **Central peak:** An uplifted mound in the floor of the crater.
- **Ejecta:** The material from inside the crater that was thrown our during the impact event. Ejecta appear as rays or sometimes as a blanket of material surrounding the crater.

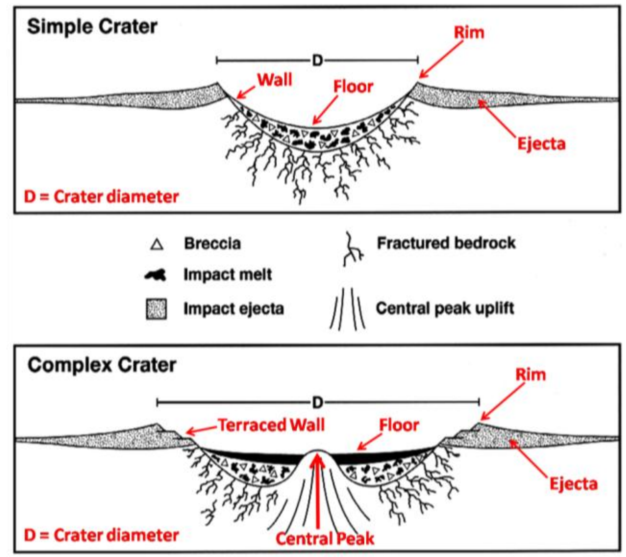
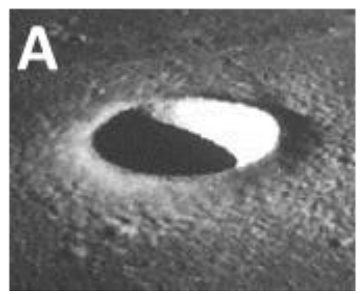


Image Credit: NASA/GSFC (modified)

Two general types of craters:

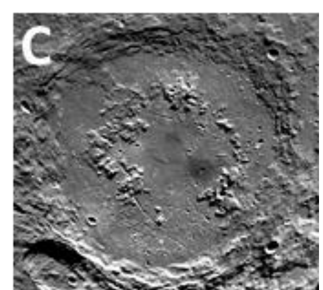
1) Simple Crater (A)

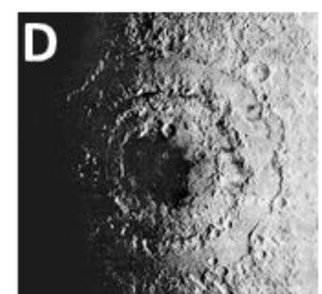
- Simple bowl shape
- **Generally smaller and younger than complex craters**



2) Complex Crater (B, C, D)

- **Much larger and older than simple craters**
- Characteristics can include:
  - Central peak (B)
  - Ring of peaks (C)
  - Multi-ring structure (D)
  - “Slump”





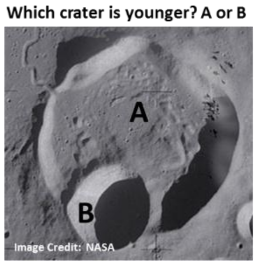
Background Information

D. USING CRATERS TO REVEAL THE GEOLOGIC HISTORY OF A SURFACE

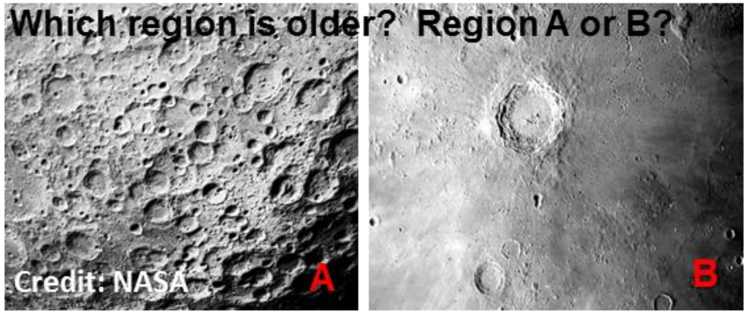
- ***OLDER*** **versus** ***YOUNGER*** **Surfaces: “Resurfacing”**

- **IMPORTANT GEOLOGIC RULES/PRINCIPLES:**

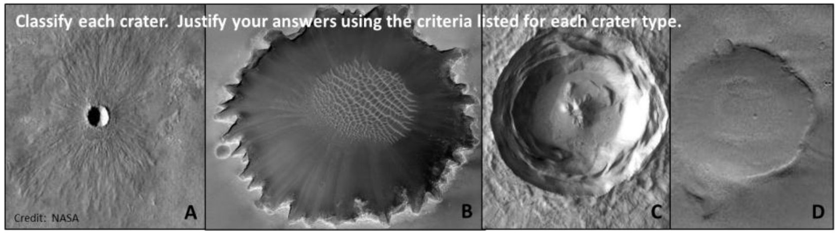
1. **Principle of Superposition:** The order of layers or geologic features found on the surface provide information about which features are older or younger. Features found on top are the youngest.



2. **Crater Density:** When comparing areas of equal sizes, the more craters on the surface, the older that surface is.



3. **Crater Classification:** The more modified a crater, the older it is.
   - **Preserved craters** = youngest, best preserved craters *(circular craters, raised rims, look fresh, can sometimes see ejecta)*
   - **Modified craters** = middle aged craters with evidence of some modification *(uneven or irregular shaped rim, floor may be partially filled in w/sediment, evidence of modification, range from slightly to severely modified)*
   - **Destroyed craters** = oldest craters that have been severely altered *(broken rims, almost completely filled in, appear flat and very worn away)*

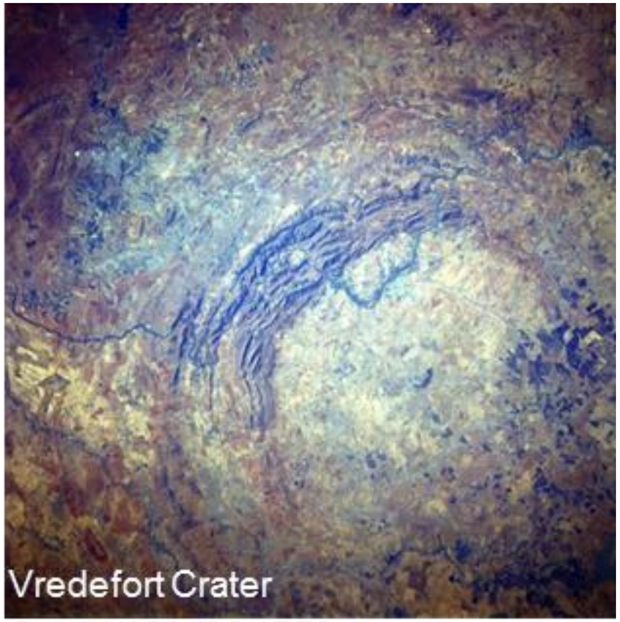


PART 3: GEOLOGIC HISTORY PRACTICE SCENARIOS

- Scientists apply these geologic principles (and others) to study impact craters which can help them learn about the history of our Solar System.
- Classification of craters can be useful in determining *when* processes may have occurred on a planetary surface. (currently, early *or* throughout history, never)
- The surface of Earth is constantly being modified by Earth's active processes. Do you think there are many preserved craters on Earth?

Credit: NASA JSC/ARES

~50,000 years "young"
~1.2 km in diameter
Classification: modified



Credit: NASA JSC/ARES

~2 billion years old
~160 km in diameter
Classification: destroyed

PART 3: GEOLOGIC HISTORY PRACTICE SCENARIOS
Applying what you know

For each scenario you will be asked the following 2 questions:

Question 1: Is the planetary surface relatively young or old? Explain.

Answer Hints:

- *Does the planetary surface have many or few impact craters on the surface?*
- *Does the planetary surface have many large impact craters?*

Question 2*:* What can you infer about the geologic processes affecting these planets? Explain.

Answer Hints:

- *Are the impact craters modified? This may mean there are (or were) active processes shaping the surface.*
- *Are some impact craters preserved? This may mean there are (or were not) any active processes changing the surface when those craters formed.*

Background Inf…

USEFUL HINTS HIGHLIGHTED ON THIS SLIDE

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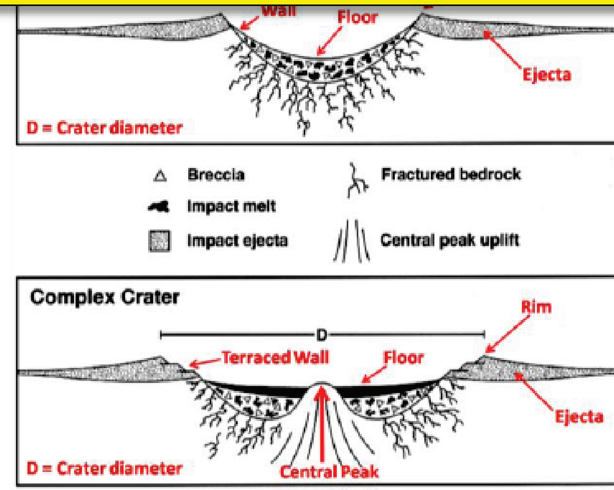

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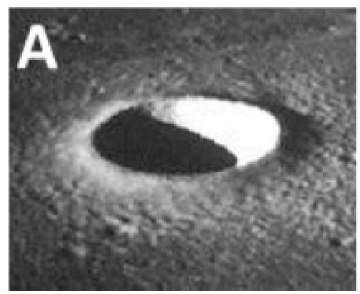

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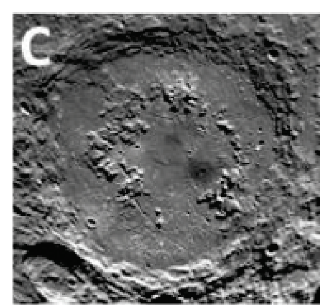

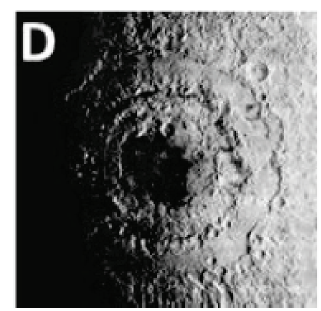

Background Inf

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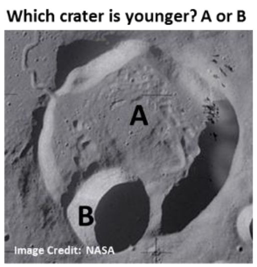

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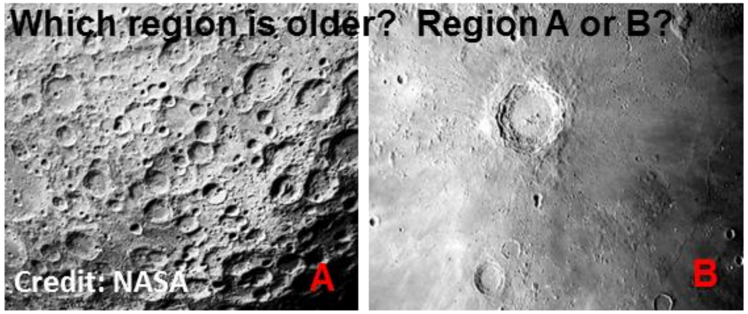

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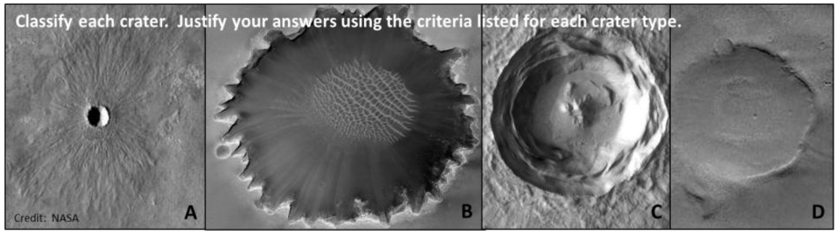

PART 3: GEOLOGIC HISTORY PRACTICE SCENARIOS
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- *Does the planetary surface have many large impact craters?*

Question 2*:* What can you infer about the geologic processes affecting these planets? Explain.

Answer Hints:

- *Are the impact craters modified? This may mean there are (or were) active processes shaping the surface.*
- *Are some impact craters preserved? This may mean there are (or were not) any active processes changing the surface when those craters formed.*

SCENARIO #1

This planet has many impact craters. Craters range in size from relatively small (~1 km) to very large craters (~100+ km). Most of the larger craters are complex and some have visible central peaks, central rings of peaks, or look to be multi-ring basins. Most of the larger craters are modified. A few very large craters are destroyed. Smaller craters have raised rims and look preserved.

PART 3: GEOLOGIC HISTORY PRACTICE SCENARIOS
Applying what you know

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PART 3: GEOLOGIC HISTORY PRACTICE SCENARIOS
Applying what you know

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SCENARIO #2

This planet has few impact craters. Craters range in size from relatively small (~1 km) to very large craters (~100+ km). All of the craters are modified or destroyed. Surface appears rugged in some areas; some areas appear to have evidence of water or ice; sand dunes are visible in other areas.

PART 3: GEOLOGIC HISTORY PRACTICE SCENARIOS
Applying what you know

For each scenario you will be asked the following 2 questions:

Question 1: Is the planetary surface relatively young or old? Explain.

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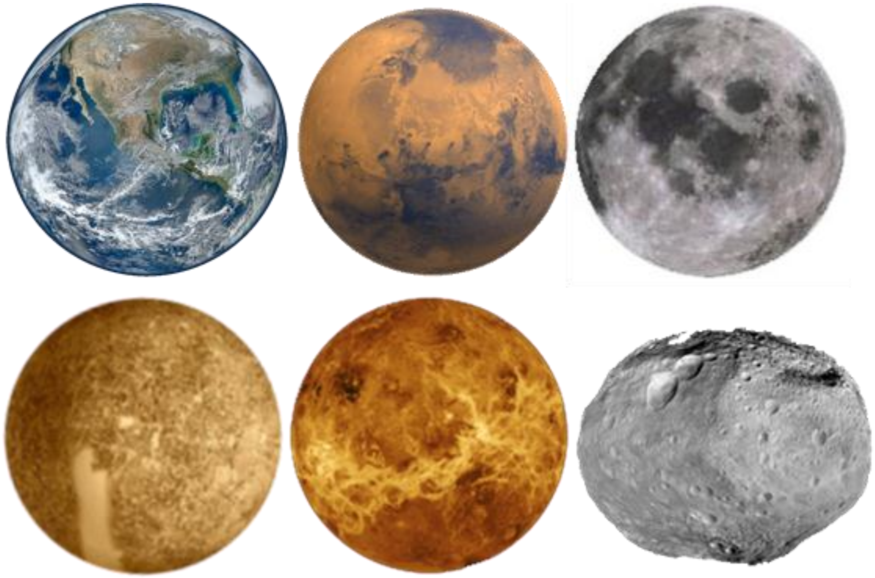
PART 3: GEOLOGIC HISTORY PRACTICE SCENARIOS
Applying what you know

- You must critically think about may aspects to make inferences about the geologic history of a given planetary surface. **JUSTIFICATION** of your thinking is extremely important.

- As you investigate planetary worlds within our Solar System, you may end up asking some of the same questions scientists have asked for years:
  - *Are there any other planetary worlds that may have once been able to support life?*
  - *How has the Solar System changed over time?*
  - *How have the sizes of impacts changed over time?*
  - *In the future, will Earth be struck by a large objects?*
  - *Is there data to support the idea that material impacting planetary surfaces today is relatively small compared to material that has impacted surfaces in the past?*

- Although you may not be able to answer all of these questions, these ideas are part of thinking about **the bigger picture**.



A global view of: Top Row: Earth, Mars, Earth's Moon; Bottom Row: Mercury, Venus, and asteroid Vesta. Planetary sizes not to scale. *Images courtesy of NASA.*

PART 4: INITIAL OBSERVATIONS AND THE BIG PICTURE

Look at the initial set of images. Images are of craters on Earth (A), Mars (B), Earth's Moon (C),Mercury (D), Venus (E), and Vesta (F).

Use a check mark to select the type and classification of each crater:

	Image A	Image B	Image C	Image D	Image E	Image F
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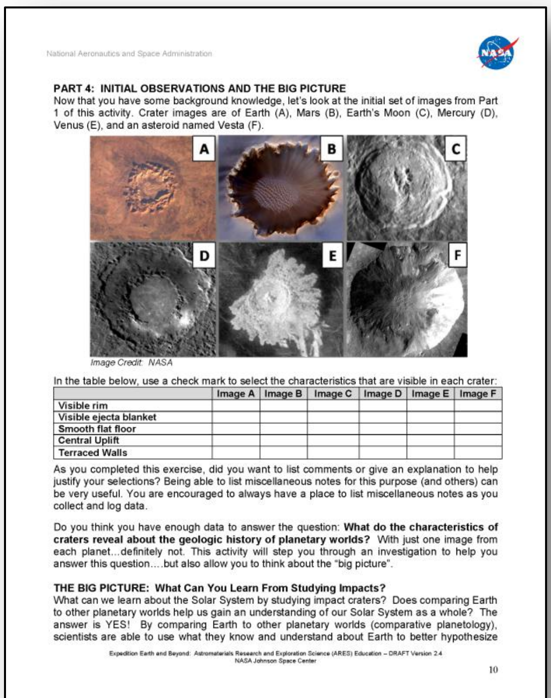
National Aeronautics and Space Administration

PART 4: INITIAL OBSERVATIONS AND THE BIG PICTURE
Now that you have some background knowledge, let's look at the initial set of images from Part 1 of this activity. Crater images are of Earth (A), Mars (B), Earth's Moon (C), Mercury (D), Venus (E), and an asteroid named Vesta (F).

Image Credit: NASA

In the table below, use a check mark to select the characteristics that are visible in each crater:

	Image A	Image B	Image C	Image D	Image E	Image F
Visible rim						
Visible ejecta blanket						
Smooth flat floor						
Central Uplift						
Terraced Walls						

As you completed this exercise, did you want to list comments or give an explanation to help justify your selections? Being able to list miscellaneous notes for this purpose (and others) can be very useful. You are encouraged to always have a place to list miscellaneous notes as you collect and log data.

Do you think you have enough data to answer the question: **What do the characteristics of craters reveal about the geologic history of planetary worlds?** With just one image from each planet...definitely not. This activity will step you through an investigation to help you answer this question….but also allow you to think about the "big picture".

THE BIG PICTURE: What Can You Learn From Studying Impacts?
What can we learn about the Solar System by studying impact craters? Does comparing Earth to other planetary worlds help us gain an understanding of our Solar System as a whole? The answer is YES! By comparing Earth to other planetary worlds (comparative planetology), scientists are able to use what they know and understand about Earth to better hypothesize

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NASA Johnson Space Center

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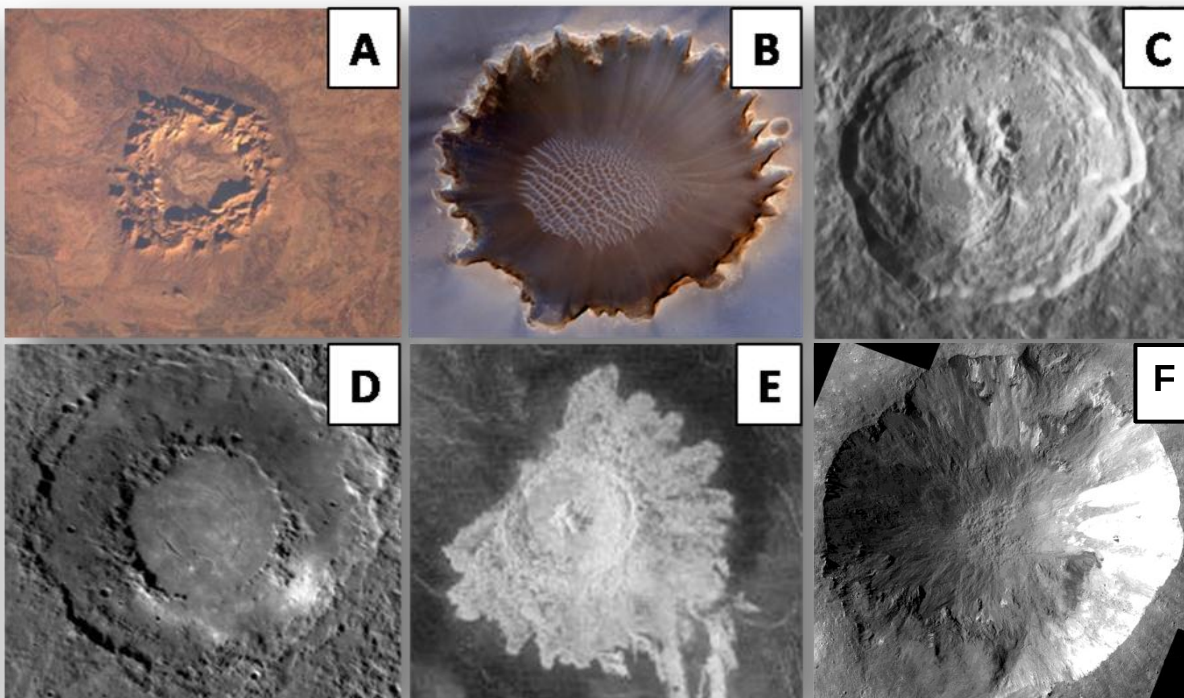

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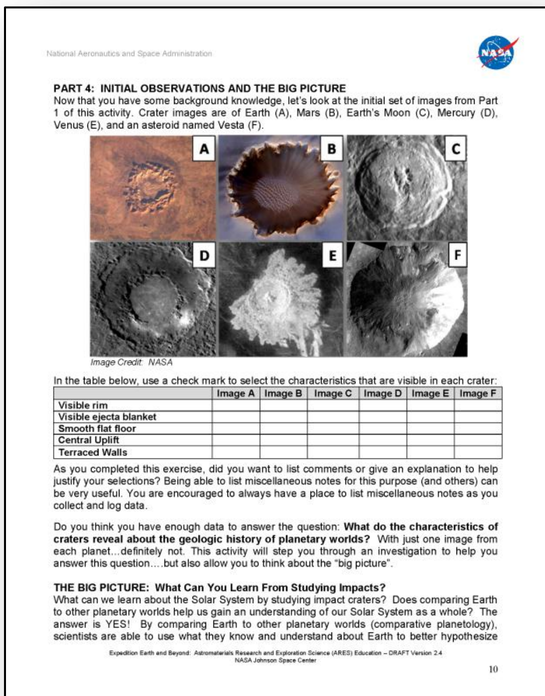
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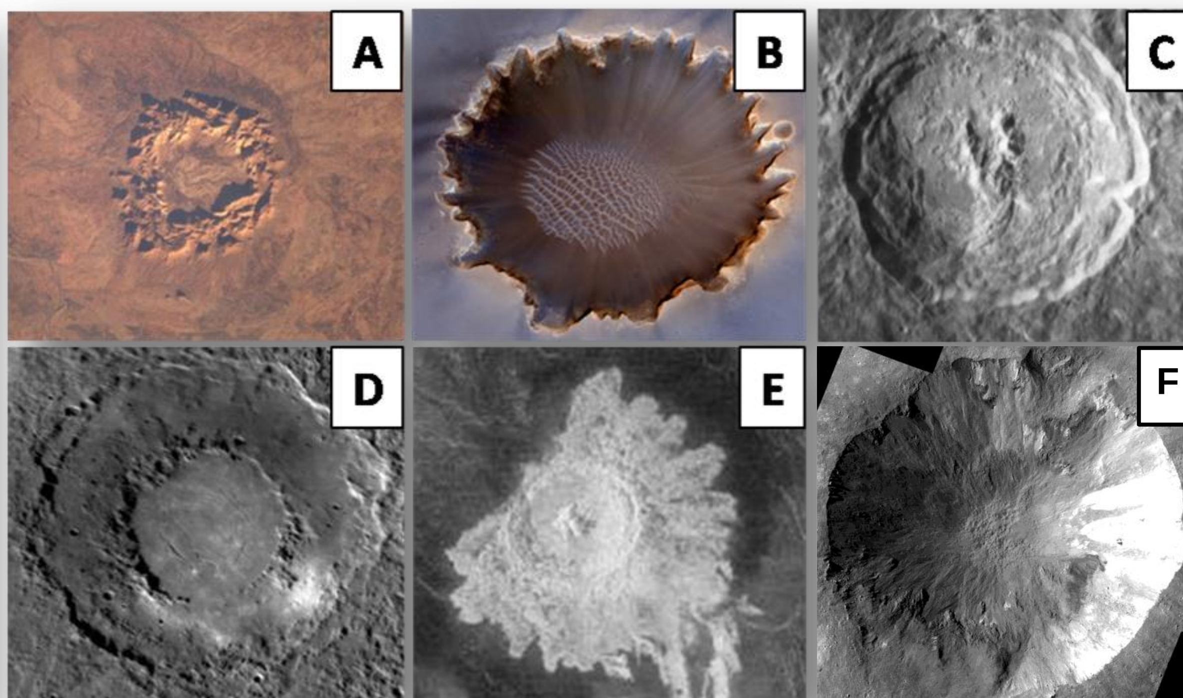

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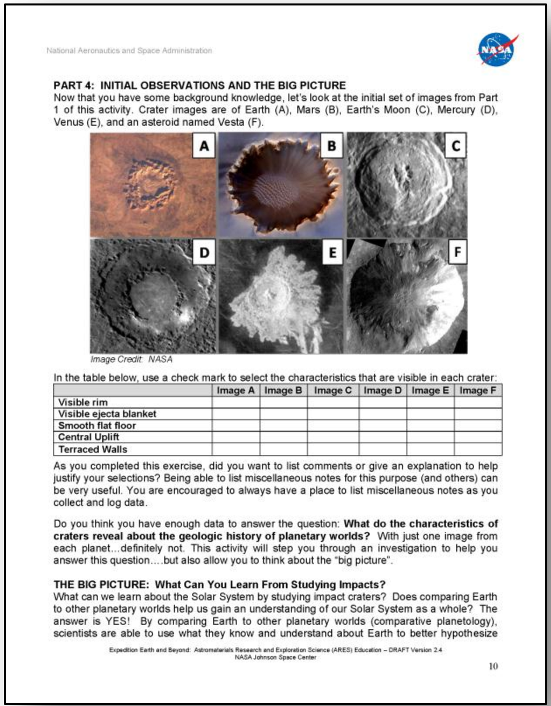
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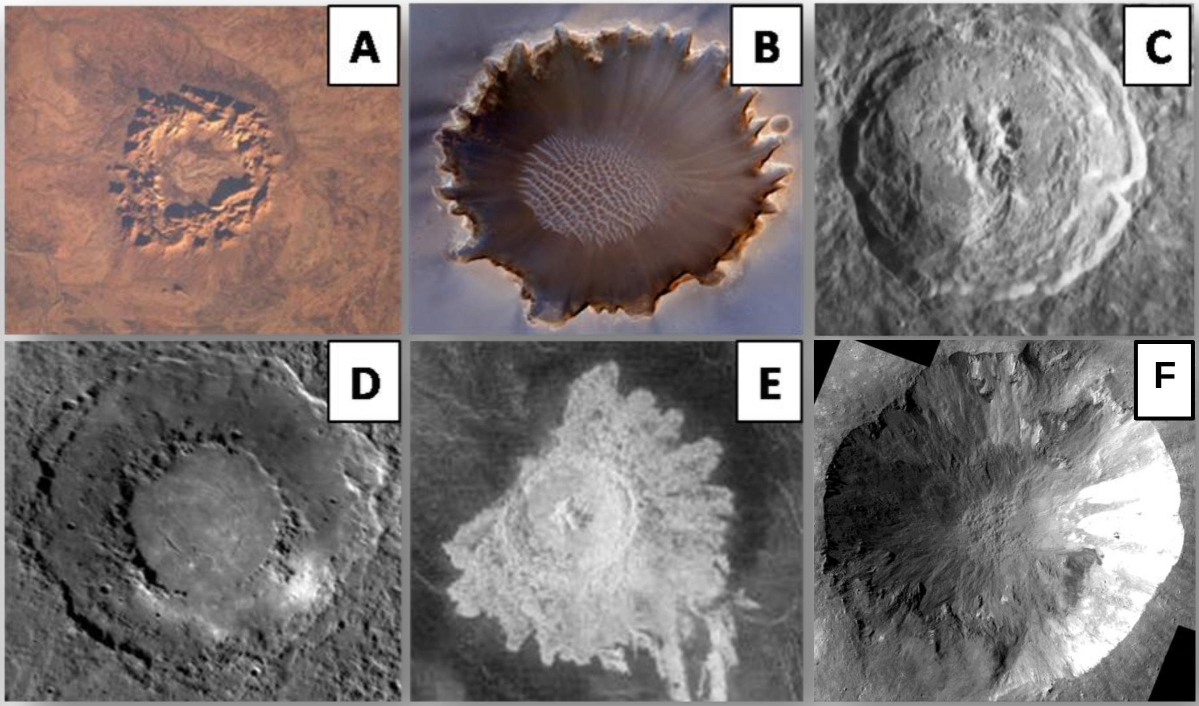

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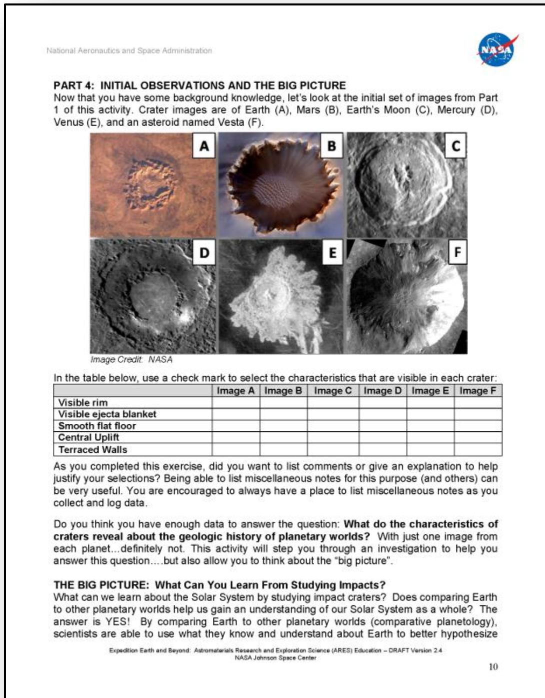
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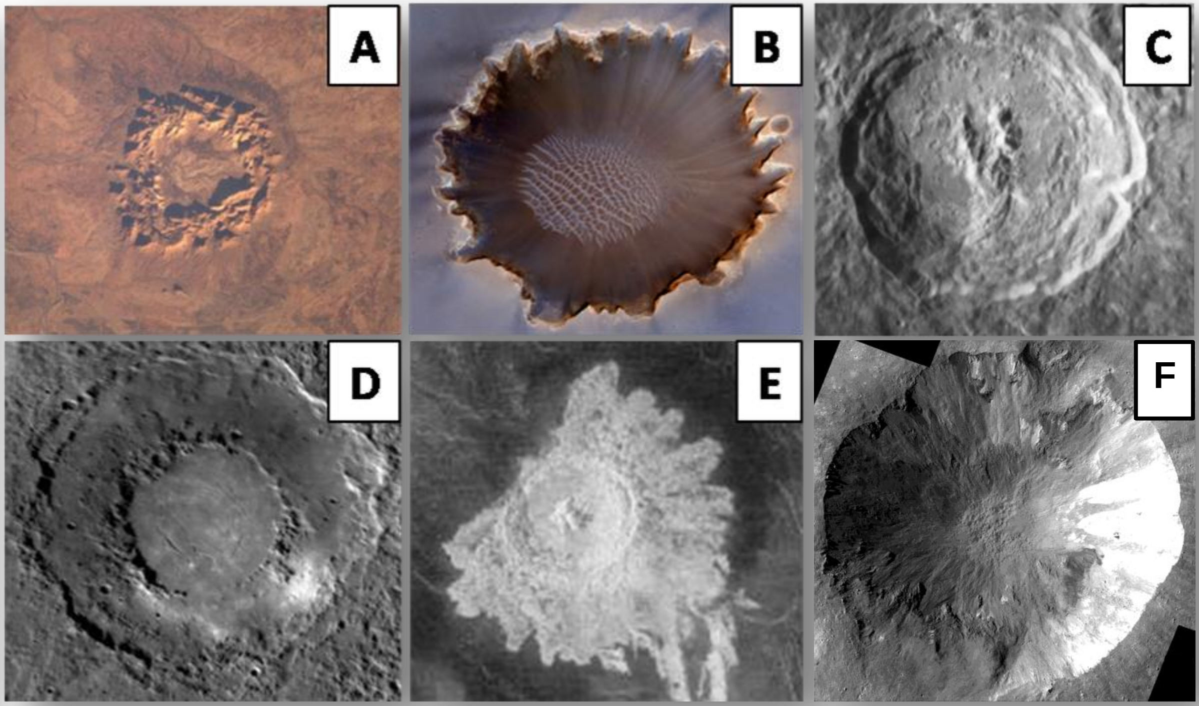

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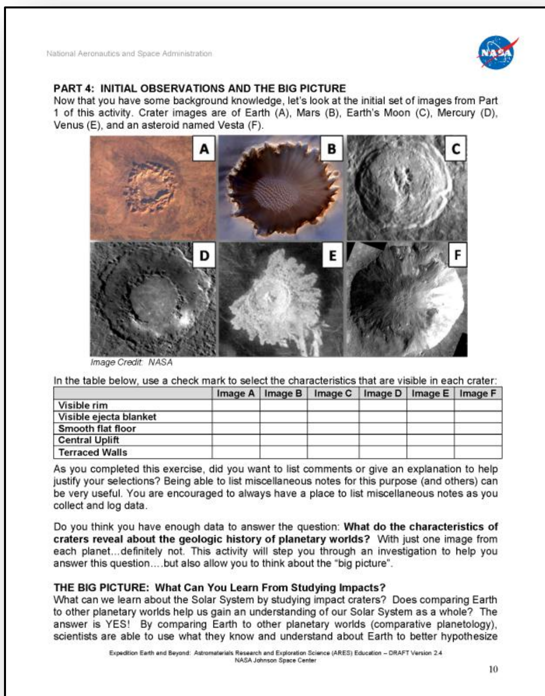
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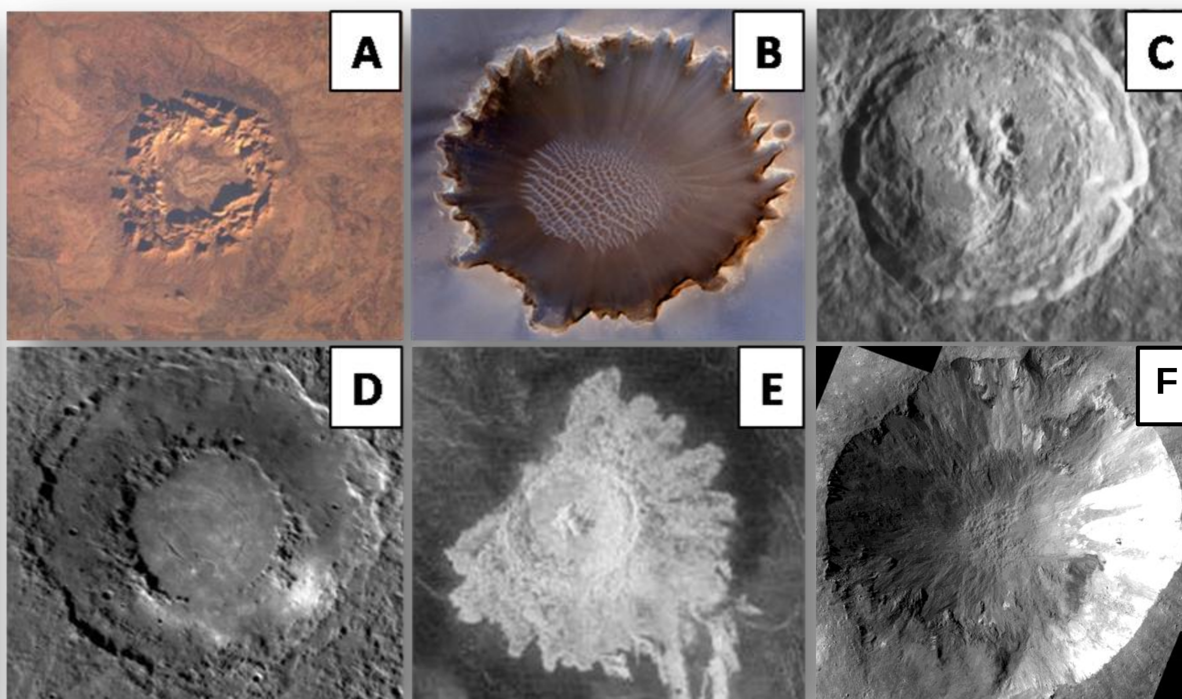

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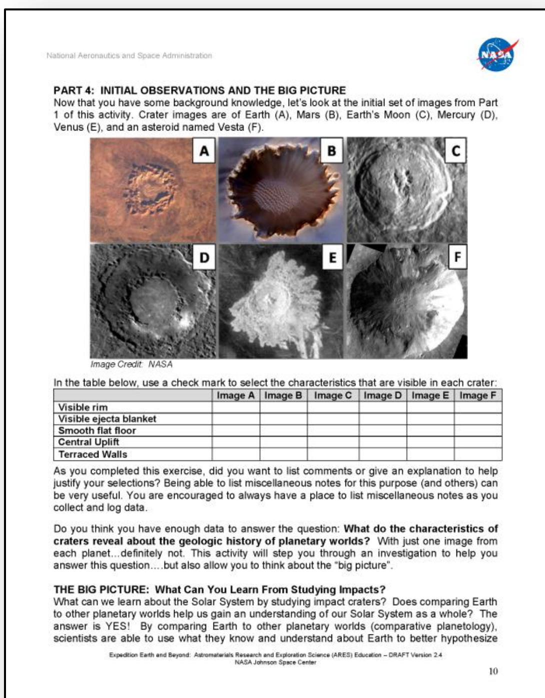
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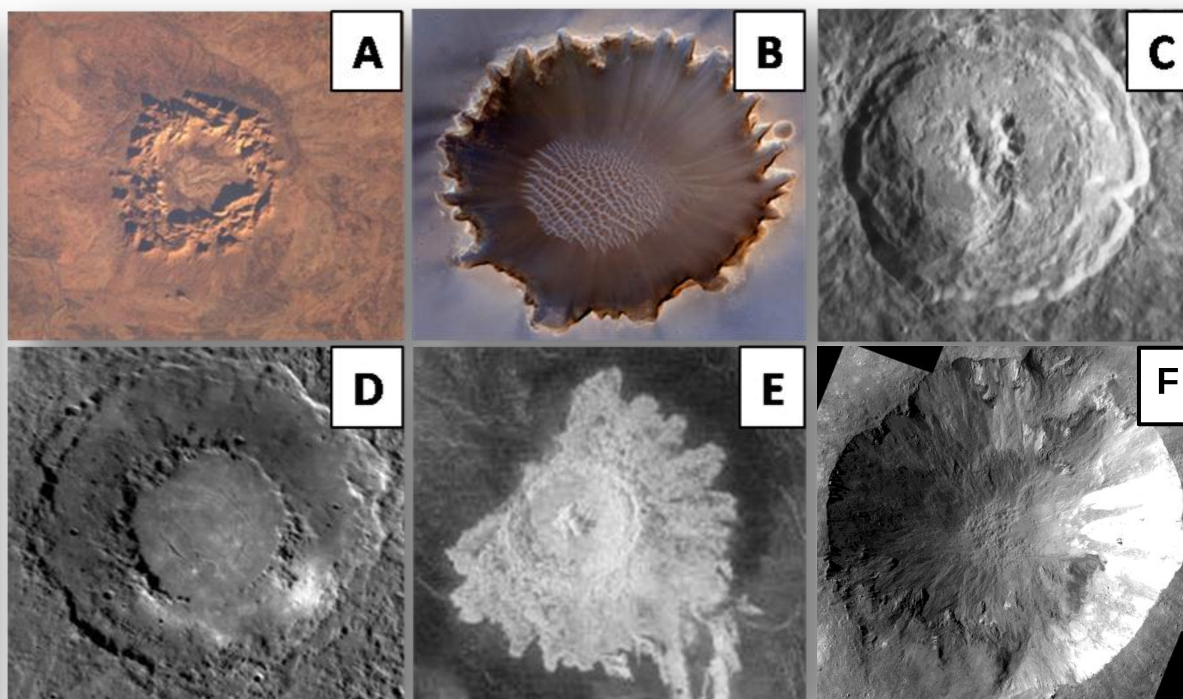

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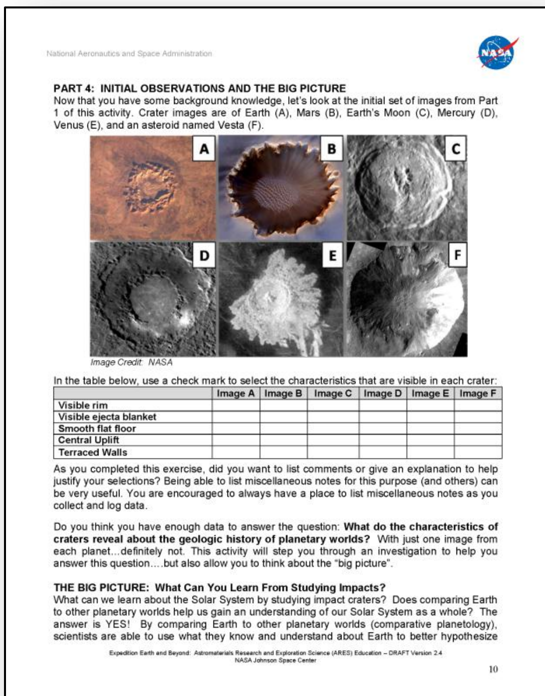
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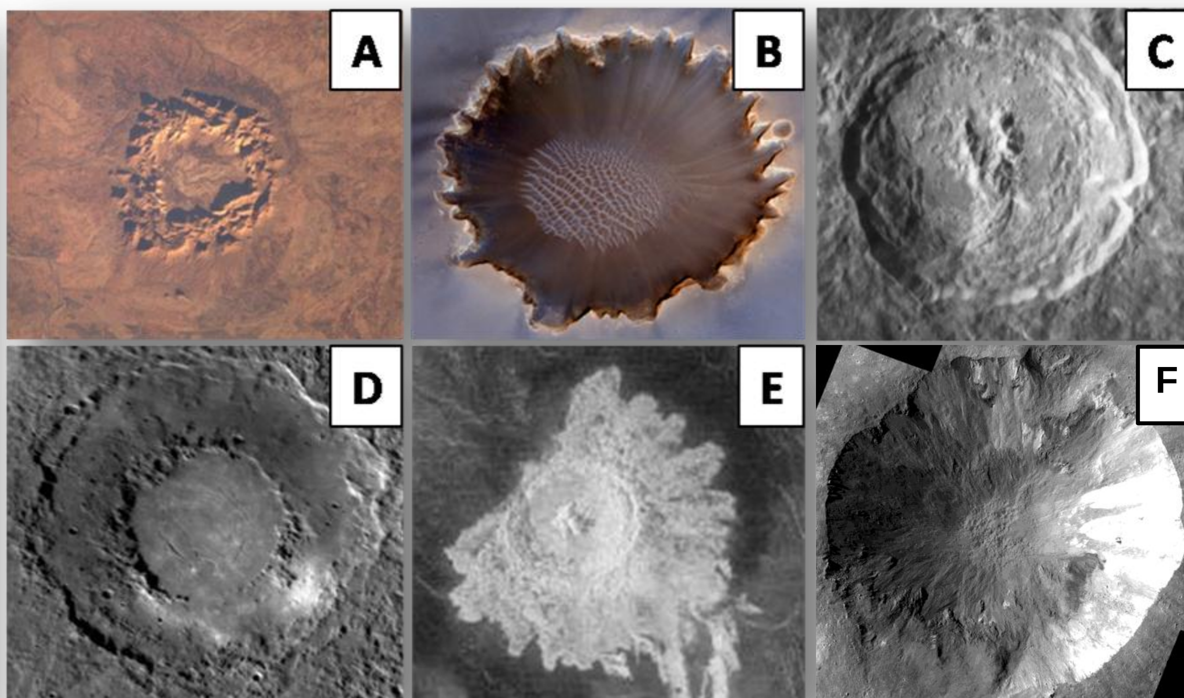

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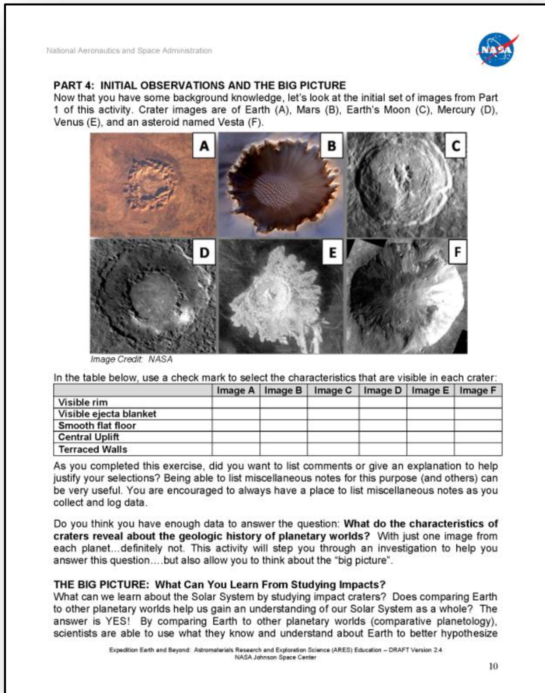
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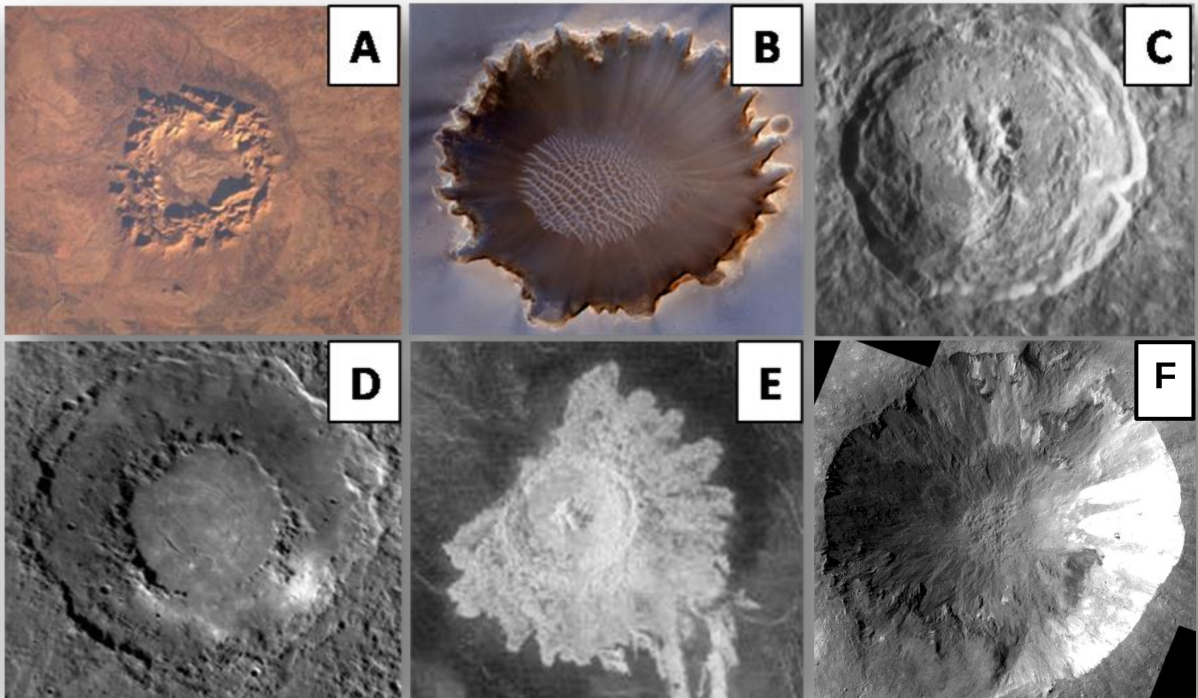

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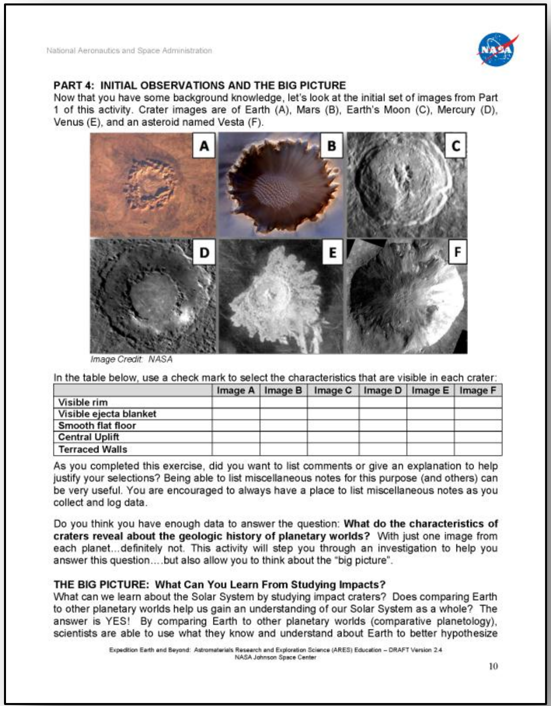
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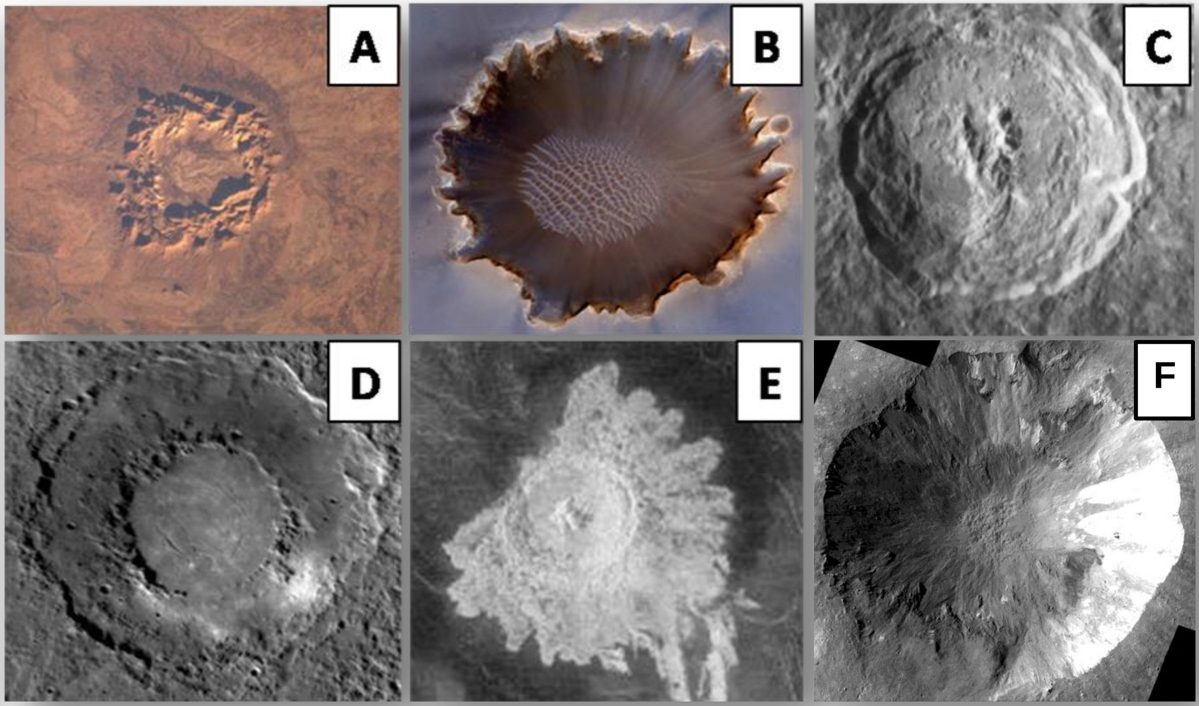

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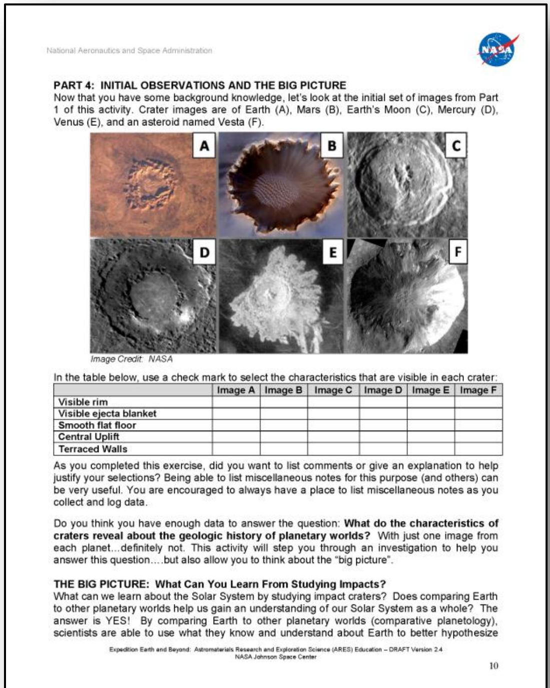

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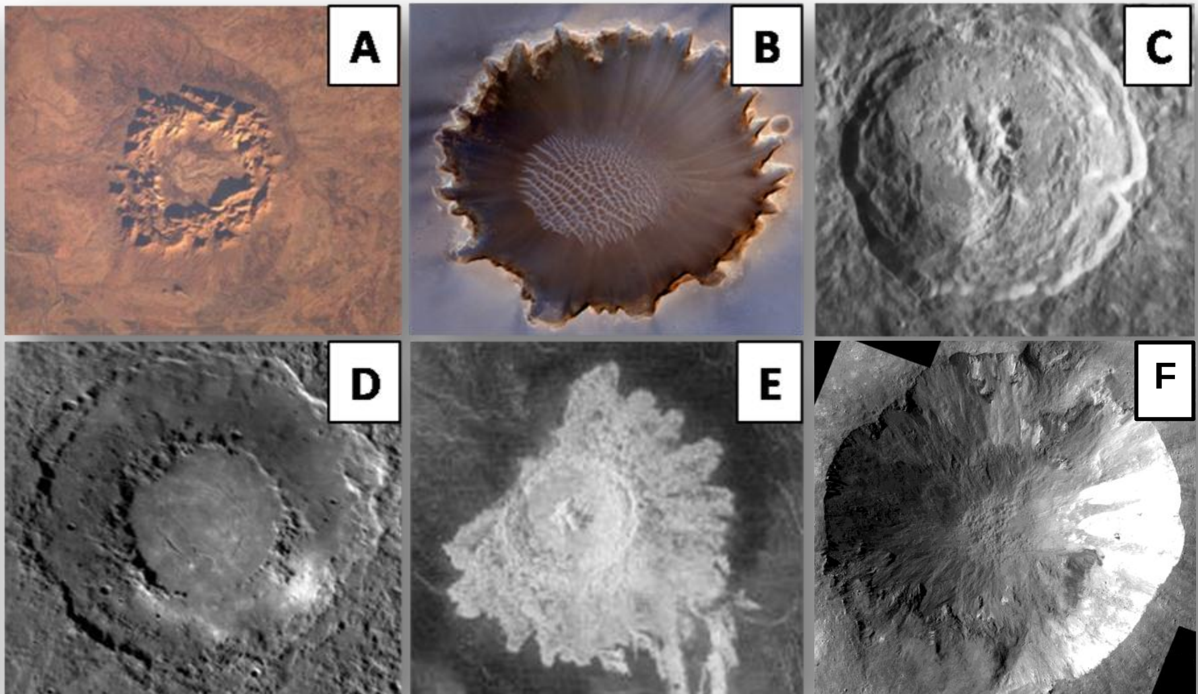

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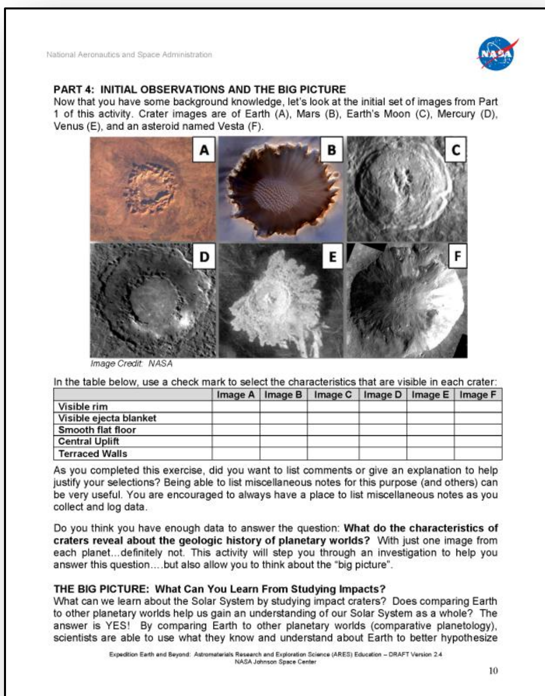
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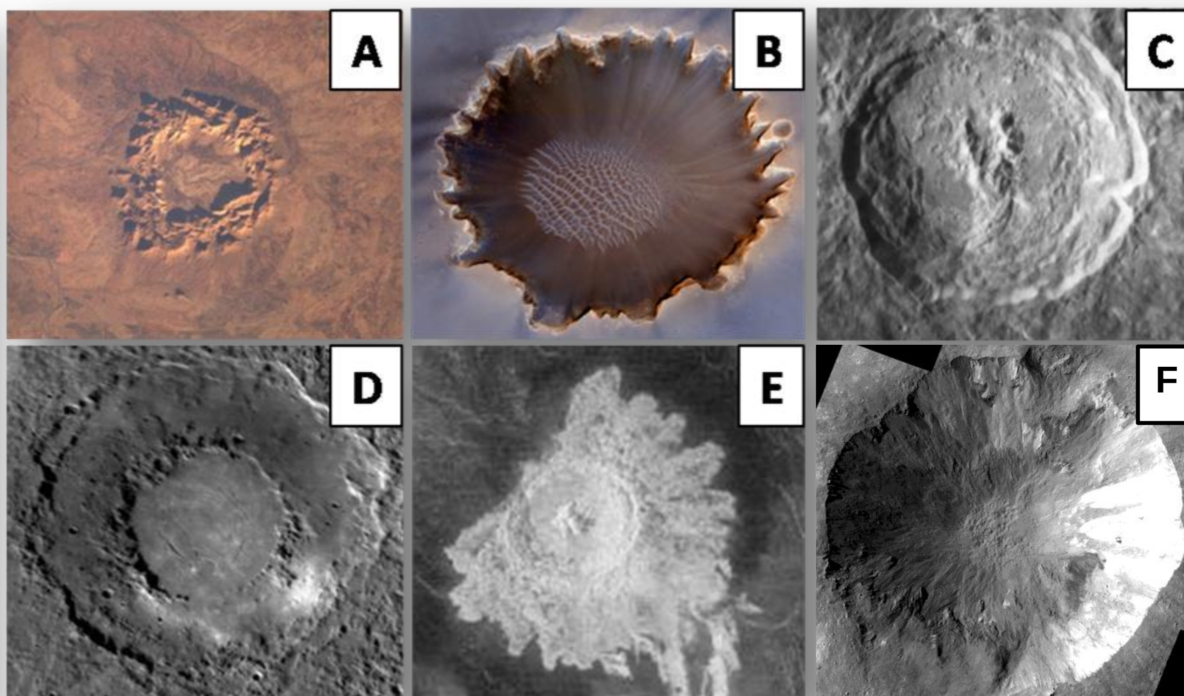

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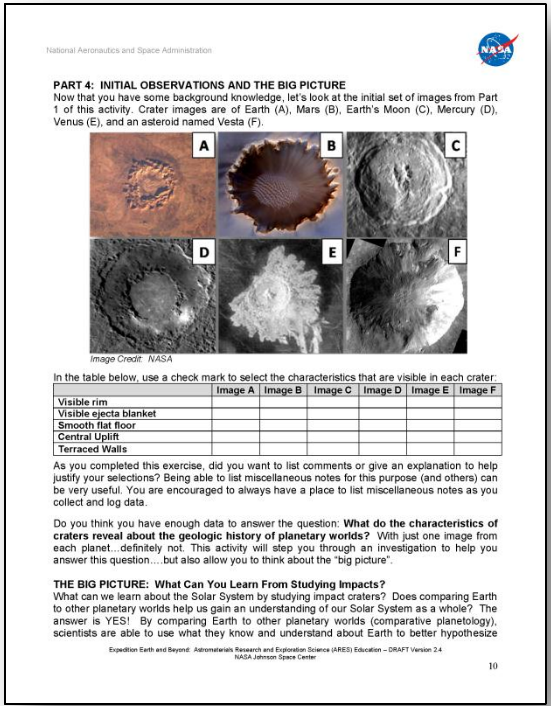
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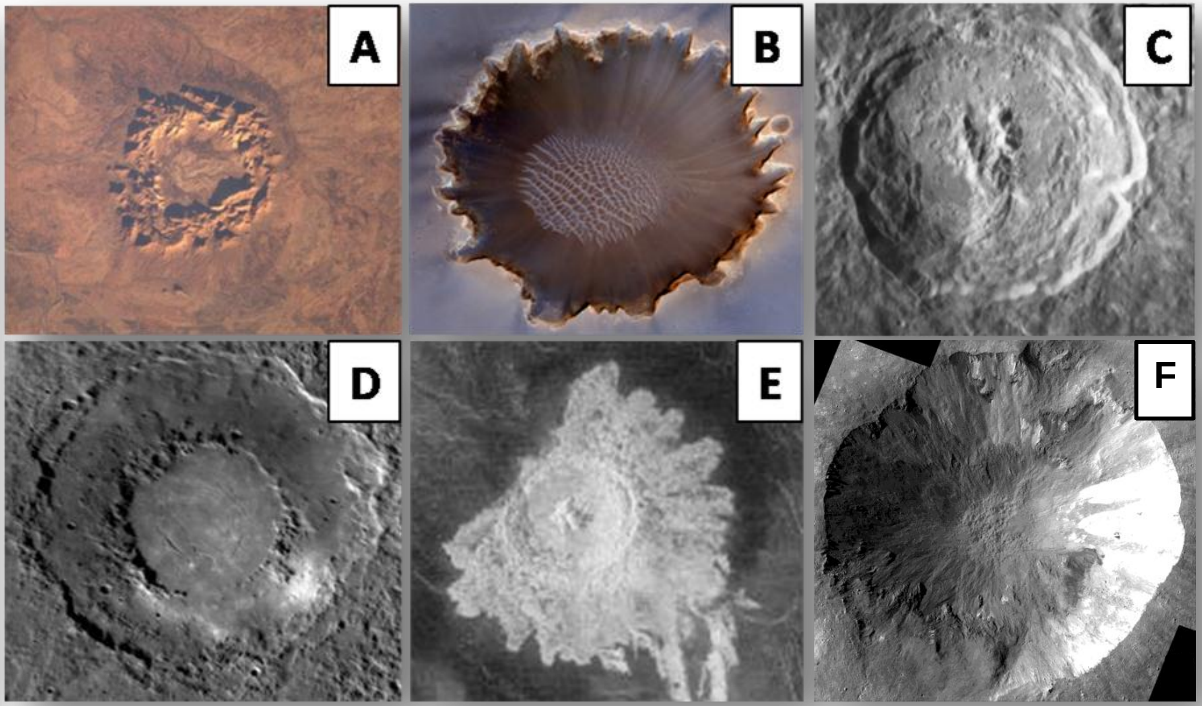
What can we learn about the Solar System by studying impact craters? Does comparing Earth to other planetary worlds help us gain an understanding of our Solar System as a whole? The answer is YES! By comparing Earth to other planetary worlds (comparative planetology), scientists are able to use what they know and understand about Earth to better hypothesize

Expedition Earth and Beyond: Astromaterials Research and Exploration Science (ARES) Education – DRAFT Version 2.4
NASA Johnson Space Center

10

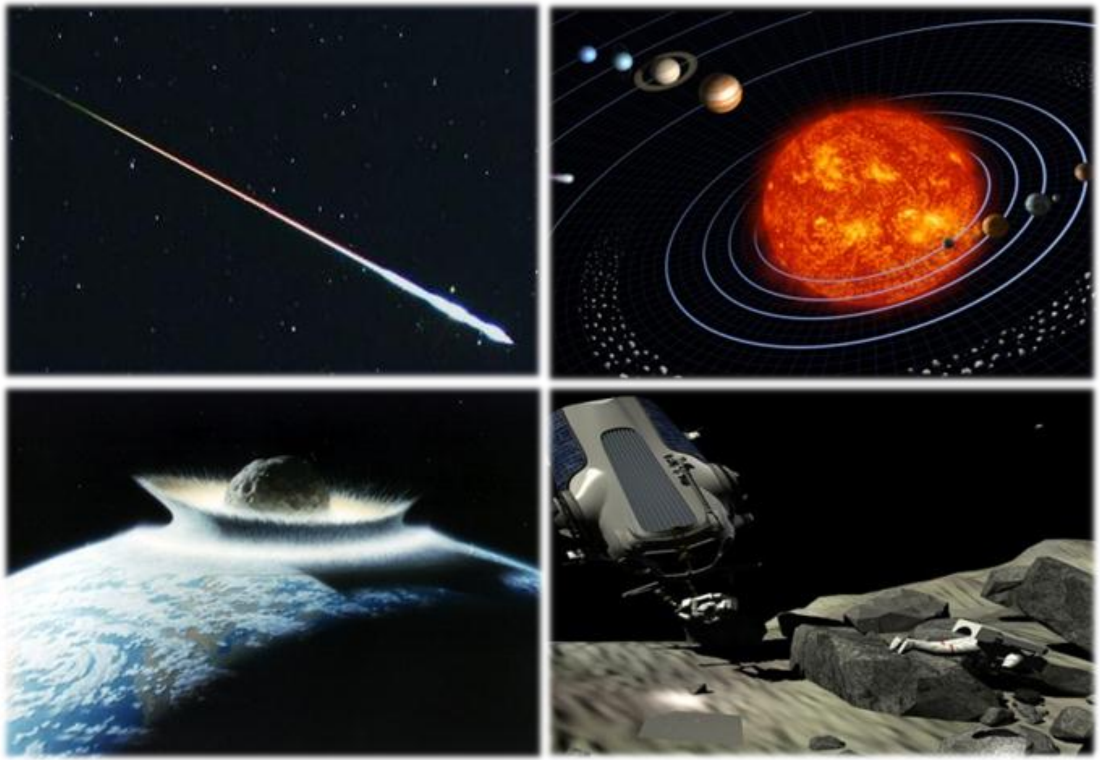


PART 4: INITIAL OBSERVATIONS AND THE BIG PICTURE

The Big Picture: What Can You Learn from Studying Impacts

- We can learn about the geologic history of different planetary worlds, which in turn can provide insight into the history of our Solar System. In particular we can:

  1) better understand the history of our Solar System,
  2) make predictions about potential future impacts,
  3) better understand factors that may influence future robotic or even human exploration of other worlds.



PART 5: CONTINUING OUR CRATER INVESTIGATION

As you work through this investigation, you will be modeling the skills and practices used by professional scientists. The image below is an illustration of the process of science. Scientists generally follow a process similar to this when conducting investigations.

Step 1: Preliminary Question

Step 2: Initial Observations

Step 3: Background Knowledge

Step 4: Experiment Design

Step 5: Collecting & Compiling Data

Step 6: Displaying Data

Step 7: Analyzing & Interpreting Data

Step 8: Drawing Conclusions

Step 9: Sharing Research

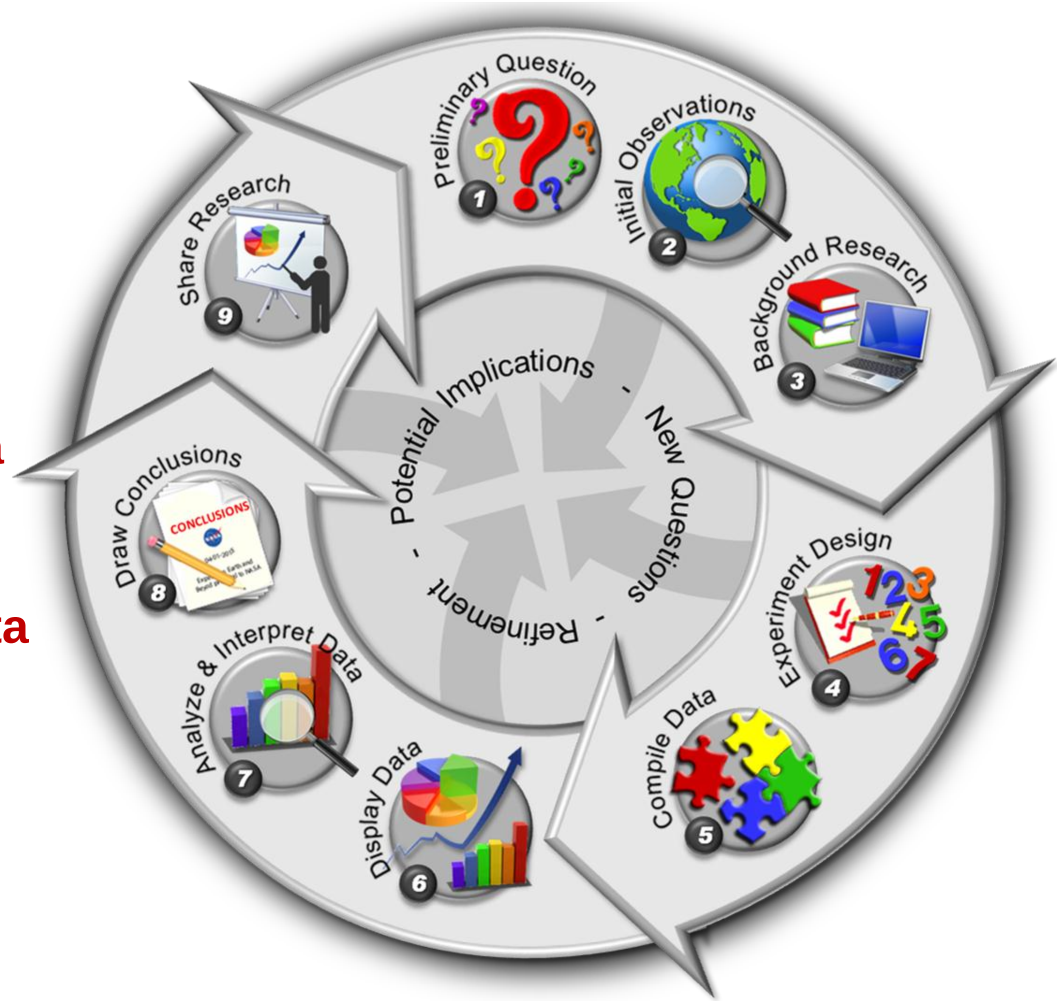


Image Credit: NASA/JSC/ARES/EEAB

PART 5: CONTINUING OUR CRATER INVESTIGATION

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Step 1: **Preliminary Question**

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Step 3: **Background Knowledge**

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Step 5: **Collecting & Compiling Data**

Step 6: **Displaying Data**

Step 7: **Analyzing & Interpreting Data**

Step 8: **Drawing Conclusions**

Step 9: **Sharing Research**

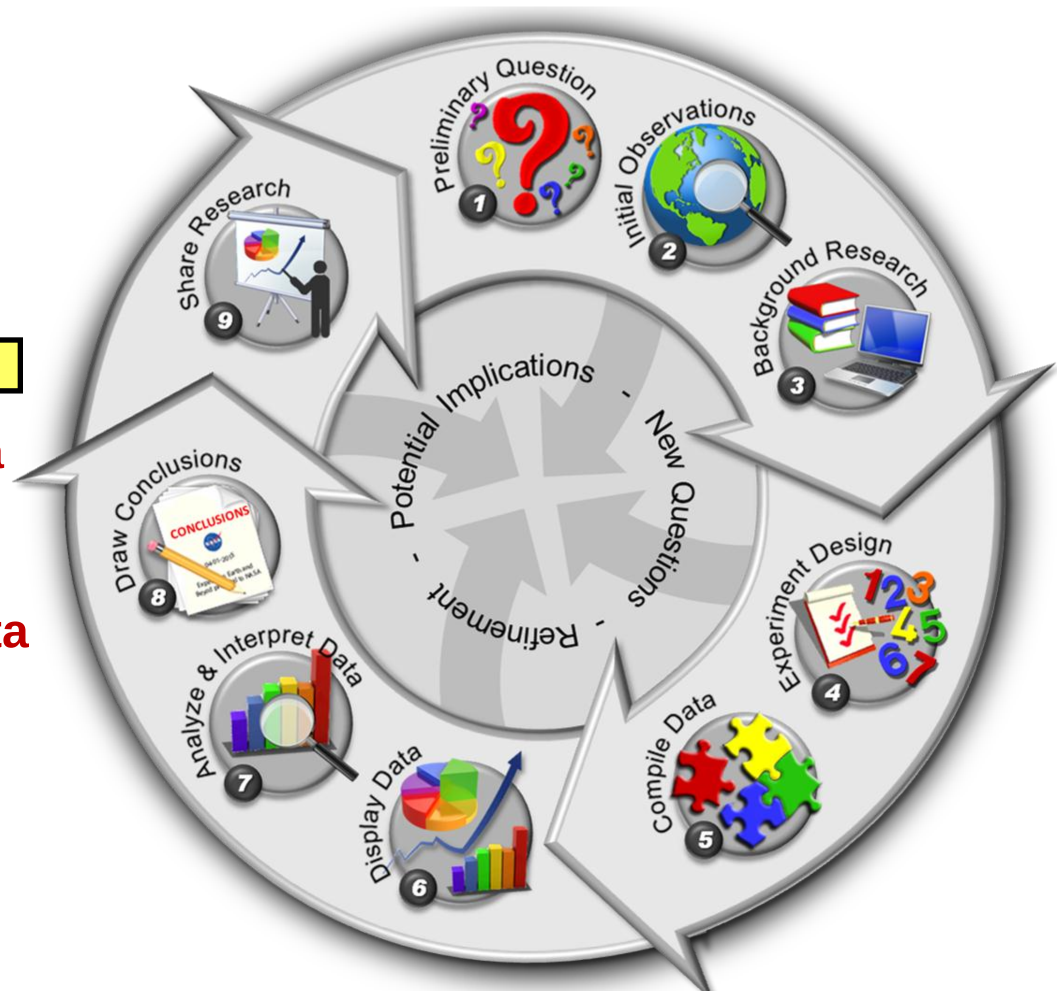

Image Credit: NASA/JSC/ARES/EEAB

Step 4: Experiment Design

Research Question & Hypothesis/es

1. Familiarize yourself with the research question: *What do the characteristics of craters reveal about the geologic history of planetary worlds?*

2. Formulate a set of hypotheses:
    - **Suggestion:** Fill out the information in hypothesis/es table based on the images you have observed so far, and what you know about impact craters in our Solar System.

Research Question: What do the characteristics of craters reveal about the geologic history of planetary worlds?

Hypothesis/es: Based on the images we have observed so far, and what we know about impact craters in our Solar System, we hypothesize the following…..

	RELATIVE AGE OF SURFACE *Relatively young or old*	**ACTIVE GEOLOGIC PROCESSES** *Early in its history; throughout its history; currently; likely never existed*
EARTH		
EARTH'S MOON		
MARS		
VENUS		
MERCURY		
VESTA		

Step 4: Experiment Design

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	RELATIVE AGE OF SURFACE *Relatively young or old*	**ACTIVE GEOLOGIC PROCESSES** *Early in its history; throughout its history; currently; likely never existed*
EARTH	Relatively young	Throughout its history and currently
EARTH'S MOON		
MARS		
VENUS		
MERCURY		
VESTA		

- Fill out the information for whichever planetary worlds the class will focus on.
- Be prepared to explain/justify your current thinking.

Step 4: Experiment Design

Methods/Procedures & Considerations

RESEARCH CONSIDERATIONS:

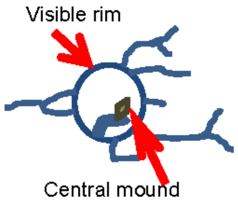
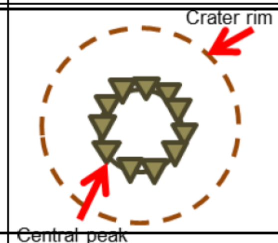
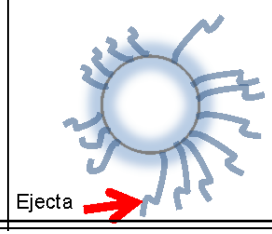
1. **Image Data Collection**: Where will you retrieve your imagery?
2. **Specific Data to Collect**: What specific data will you collect? *
3. **Number of Images:** How many images is enough?
4. **Geographic Regions:** Will you focus on a particular region?
5. **Other Data Sets**: Where will you retrieve your planetary data?
6. **Measurements**: How will you make measurements?
7. **Sources**: What sources will allow others to retrieve the data you used (or find additional data)?

* **ESPECIALLY CRITICAL – Each listed item will become a column heading in your data table.**

Step 4: Experiment Design

Methods/Procedures: Setting up a Data Table

Each piece of data you collect will become a separate column heading on your data table.

Image Id#	Crater Name	Lat. (N)	Lon (E)	Planetary Body	Geographic Location	Crater Diameter *(km)*	CRATER TYPE *(Simple or Complex)*	CRATER CLASSIFICATION *(preserved, modified, or destroyed)*	Misc. Notes or Observations	Sketch(es)
ISS012-E-15881	Manicouagan	51.5	-68.5	Earth	Canada	65	Complex	Modified	Crater has central peak, though it is not easily detected. Diameter listed in Earth Impact Database as ~85 km. Only ~65km is actually visible in image. "Arms"/rivers extend out from the rim.	
ISS015-E-17360	Gosses Bluff	-23.9	132.3	Earth	Australia	15	Complex	Modified	Crater has central peak. In reading information on NASA website about this crater, the well-defined bumpy circular feature is part of that central uplift. The faded outer rim is barely visible. This outer rim was used to determine the crater diameter.	
ISS018-E-14908	Tenoumer	22.9	-10.4	Earth	Mauritania	1.9	Simple	Modified	Simple bowl shaped crater. The rim of this crater looks soft – the rim is not sharp and raised – likely due to erosion. There looks to be evidence of eroded ejecta around the rim. Ejecta extends out further on the right.	

Step 5: Collect & Compile Data

DATA TABLE - CRATERS ON ______________________________

Please note that latitudes are provided as North latitudes [Latitude (N)]. Latitude with a (-) is a South latitude: Example: -27.8 is the same as 27.8S.

Also note that longitudes are provided as East longitudes [Longitude (E)]. Longitude with a (-) is a West longitude: Example: -68.5 is the same as 68.5W.

The first three data logged here are of Earth. They can be used as examples, or if you are collecting data on Earth, you now have 3 data points.

Image Id#	Crater Name	Lat. (N)	Lon (E)	Planetary Body	Geographic Location	Crater Diameter *(km)*	CRATER TYPE *(Simple or Complex)*	CRATER CLASSIFICATION *(preserved, modified, or destroyed)*	Misc. Notes or Observations	Sketch(es)

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Collect & log data for at least 12 craters.

TOOLS:

1) **Data Collection Log Sheets**
2) **Planetary Images**
3) **Meta data Info Sheets**

Step 5: Collect & Compile Data

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Please note that latitudes are provided as North latitudes [Latitude (N)]. Latitude with a (-) is a South latitude: Example: -27.8 is the same as 27.8S.
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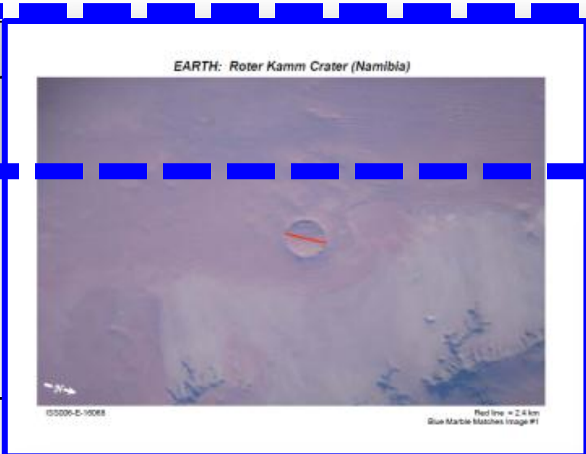

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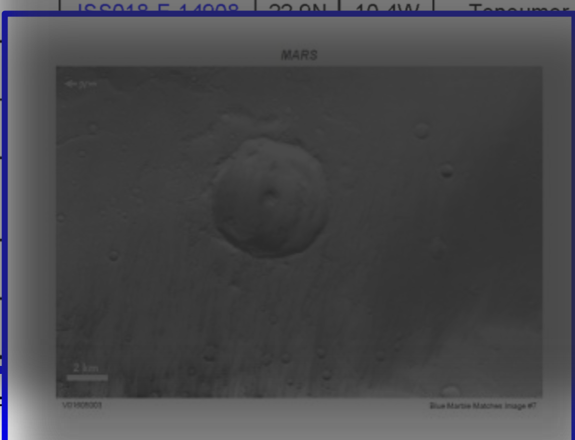
…rth, you now have 3 data points.

…. Notes or Observations	Sketch(es)

CRATER IMAGE METADATA

EARTH IMAGES

BMM Image #	Image ID#	LAT.	LONG.	Crater Name	Country or Geographic Region	Date Acquired	Camera/ Instrument	Lens Focal Length
1	ISS006-E-16068	27.8S	16.4E	Roter Kamm	Namibia	12/28/2002	E4: Kodak DCS760C	400 mm
2	ISS012-E-15881	51.5N	68.5W	Manicouagan	Canada	1/24/2006	E4: Kodak DCS760C	50 mm
3	ISS014-E-11841	24.4N	24.4E	Oasis	Libya	1/13/2007	E4: Kodak DCS760C	400 mm
4	ISS014-E-15775	35N	111W	Barringer	United States	3/1/2007	E4: Kodak DCS760C	400 mm
5	ISS014-E-19496	29N	7.6W	Ouarkziz	Algeria	4/16/2007	E4: Kodak DCS760C	800 mm
6	ISS015-E-17360	23.9S	132.3E	Gosses Bluff	Australia	7/13/2007	E4: Kodak DCS760C	400 mm
	ISS018-E-14908	22.9N	10.4W	Tenoumer	Mauritania	12/20/2008	Nikon D2X	800 mm
					India	1/28/2009	Nikon D2X	800 mm
					South Africa	8/29/1985	Hasselblad	250 mm
					Canada	11/1/1985	Hasselblad	250 mm
					Australia	7/6/2011	Nikon D2X	200 mm
					Australia	1/15/2013	Nikon D2X	180 mm



Collect & log data for at least 12 craters.

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Step 5: Collect & Compile Data

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Image Id#	Crater Name	Lat. (N)	Lon (E)	Planetary Body	Geographic Location	Crater Diameter *(km)*	CRATER TYPE *(Simple or Complex)*	CRATER CLASSIFICATION *(preserved, modified, or destroyed)*	Misc. Notes or Observations	Sketch(es)

CRATER IMAGE METADATA

EARTH IMAGES

BMM Image #	Image ID#	LAT.	LONG.	Crater Name	Country or Geographic Region	Date Acquired	Camera/ Instrument	Lens Focal Length
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3	ISS014-E-11841	24.4N	24.4E	Oasis	Libya	1/13/2007	E4: Kodak DCS760C	400 mm
4	ISS014-E-15775	35N	111W	Barringer	United States	3/1/2007	E4: Kodak DCS760C	400 mm
5	ISS014-E-19496	29N	7.6W	Ouarkziz	Algeria	4/16/2007	E4: Kodak DCS760C	800 mm
6	ISS015-E-17360	23.9S	132.3E	Gosses Bluff	Australia	7/13/2007	E4: Kodak DCS760C	400 mm
7	ISS018-E-14908	22.9N	10.4W	Tenoumer	Mauritania	12/20/2008	Nikon D2X	800 mm
8	ISS018-E-23713	20N	76.5E	Lonar	India	1/28/2009	Nikon D2X	800 mm
	STS51I-33-56AA	27S	27.3E	Vredefort	South Africa	8/29/1985	Hasselblad	250 mm
	STS61A-35-86	56.5N	74.7W	Clearwater Lakes (East & West)	Canada	11/1/1985	Hasselblad	250 mm
	ISS028-E-14782	25.52S	120.53E	Shoemaker	Australia	7/6/2011	Nikon D2X	200 mm
	ISS034-E-29105	17.32S	128.25E	Piccaninny	Australia	1/15/2013	Nikon D2X	180 mm

•**DIAMETER** = **28 km**

- **CRATER TYPE** ***(Simple or Complex)***: **Complex** (it does not have a simple bowl shape)
- **CLASSIFICATION** ***(Preserved, modified or destroyed):*** **Destroyed** (broken rim, almost completely filled in by sediment and water, very worn away)

ARTH: Shoemaker (Australia)

ISS028-E-14782

Red line ≈ 28.0 km

•Diameter?
•Simple or Complex?
•Classification?

EARTH: Manicouagan Crater (Canada)

ISS012-E-15881

Red line ≈ 65.0 km
Blue Marble Matches Image #2

•Diameter?
•Simple or Complex?
•Classification?

EARTH: Gosses Bluff Crater (Australia)

ISS015-E-17360

Red line ≈ 4.2 km
Blue Marble Matches Image #6

•Diameter?
•Simple or Complex?
•Classification?

EARTH: Tenoumer Crater (Mauritania)

ISS018-E-14908

Red line ≈ 1.9 km
Blue Marble Matches Image #7

Step 5: Collect & Compile Data

DATA TABLE - CRATERS ON ________________________________

Please note that latitudes are provided as North latitudes [Latitude (N)]. Latitude with a (-) is a South latitude: Example: -27.8 is the same as 27.8S.
Also note that longitudes are provided as East longitudes [Longitude (E)]. Longitude with a (-) is a West longitude: Example: -68.5 is the same as 68.5W.

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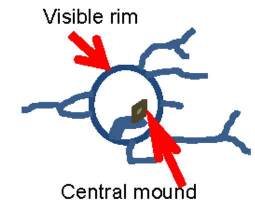
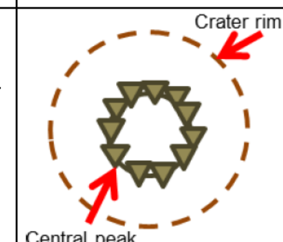
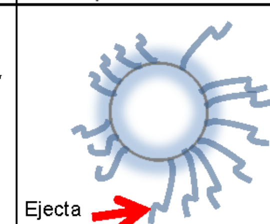
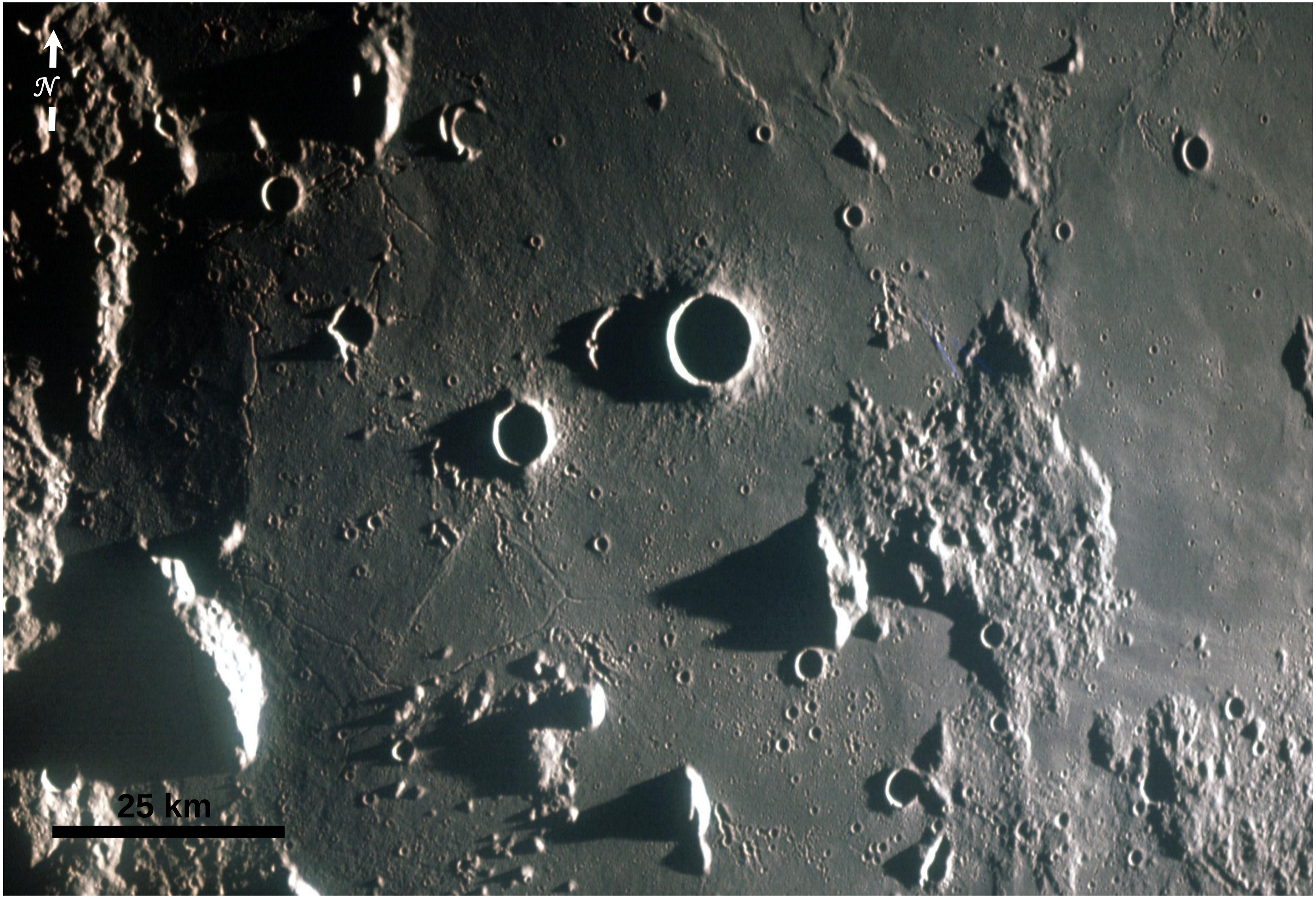
Image Id#	**Crater Name**	**Lat. (N)**	**Lon (E)**	**Planetary Body**	**Geographic Location**	**Crater Diameter** *(km)*	**CRATER TYPE** *(Simple or Complex)*	**CRATER CLASSIFICATION** *(preserved, modified, or destroyed)*	**Misc. Notes or Observations**	**Sketch(es)**
ISS012-E-15881	Manicouagan	51.5	-68.5	Earth	Canada	65	Complex	Modified	Crater has central peak, though it is not easily detected. Diameter listed in Earth Impact Database as ~85 km. Only ~65km is actually visible in image. "Arms"/rivers extend out from the rim.	
ISS015-E-17360	Gosses Bluff	-23.9	132.3	Earth	Australia	15	Complex	Modified	Crater has central peak. In reading information on NASA website about this crater, the well-defined bumpy circular feature is part of that central uplift. The faded outer rim is barely visible. This outer rim was used to determine the crater diameter.	
ISS018-E-14908	Tenoumer	22.9	-10.4	Earth	Mauritania	1.9	Simple	Modified	Simple bowl shaped crater. The rim of this crater looks soft – the rim is not sharp and raised – likely due to erosion. There looks to be evidence of eroded ejecta around the rim. Ejecta extends out further on the right.	

Update any information listed here to match your observations and findings.

Some images will have **more than 1 crater** that you can log on your data table. How many craters can you see in this image? How should you deal with this?

EARTH'S MOON



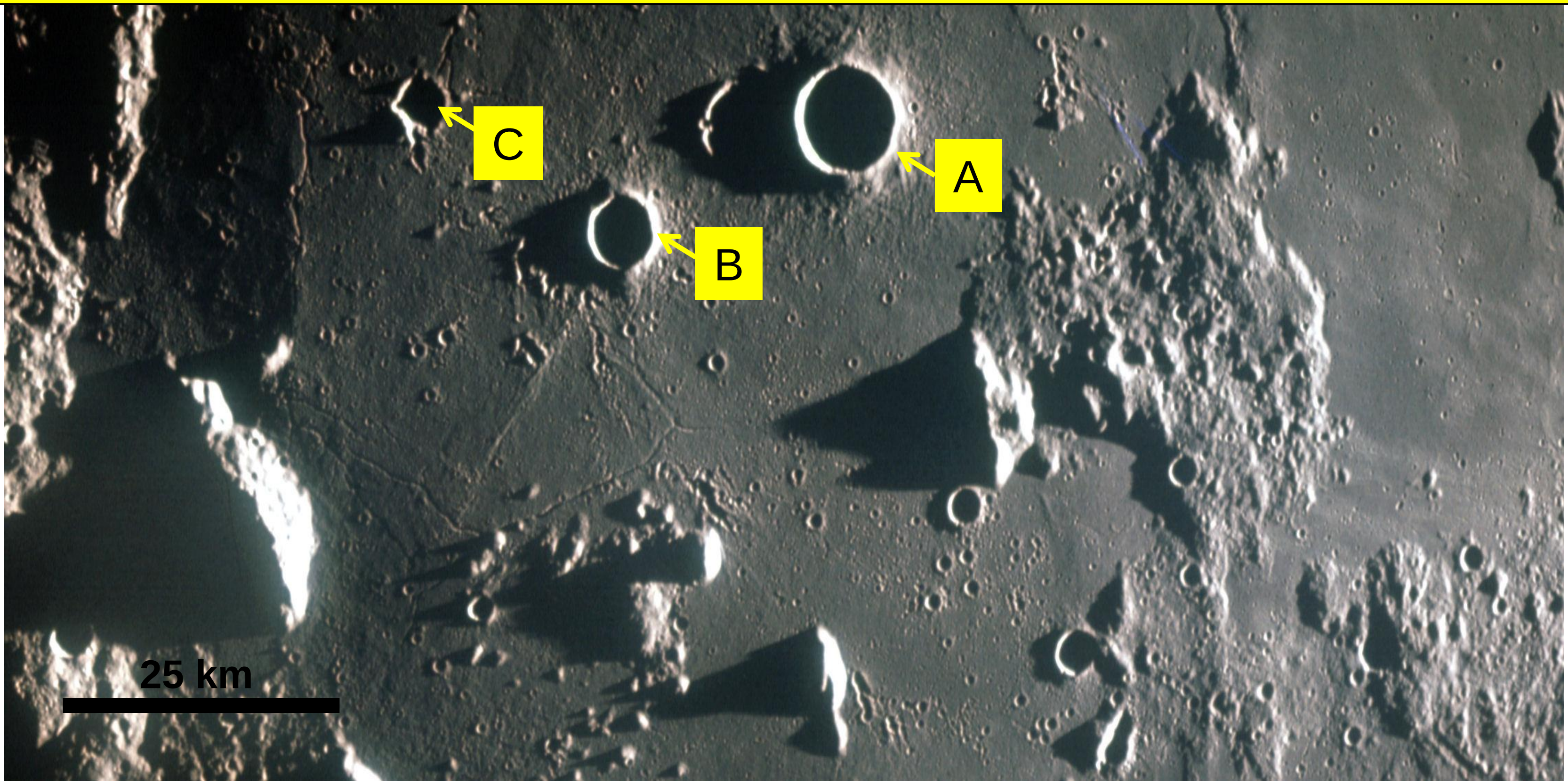
AS12-50-7438

Recommendations include:

1. Identify/label craters (A, B, C, etc.) and separately log the data for <u>each</u> crater on your data table.

   OR

2. Consider logging data for two or three craters and include a comment in the notes section of your data table stating there are numerous other craters in the image. ***<u>Example Note</u>: There were over 50 other impact craters visible in the image. Most were very small (less than 5 km) and appeared to be preserved.***
   (Remember, higher crater density = older surface.)



AS12-50-7438

Blue Marble Matches Image #1

Step 6: Display Data

After you finish collecting and compiling your data it is time to:

1. Decide how to display your data:
   A) Sorted Data Table B) Graphs C) Maps D) Image Illustrations
2. Create your data displays
3. List 2-3 observations of each data display.

Be thinking about your research question and hypotheses as you create your data displays:

Research Question: What do the characteristics of craters reveal about the geologic history of planetary worlds?

Hypothesis/es: Based on the images we have observed so far, and what we know about impact craters in our Solar System, we hypothesize the following…..

	RELATIVE AGE OF SURFACE *Relatively young or old*	**ACTIVE GEOLOGIC PROCESSES** *Early in its history; throughout its history; currently; likely never existed*
EARTH	Relatively young	Throughout its history and currently
EARTH'S MOON		
MARS		
VENUS		
MERCURY		
VESTA		

This information should not change from what was initially written.

Step 6: Display Data

A) Sorted Data Table B) Graphs C) Maps D) Image Illustrations

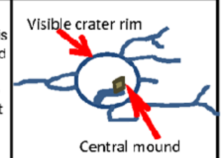
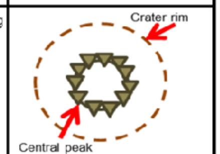
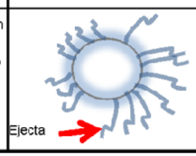
DATA TABLES

Your completed or master data table provides you with very useful information. Sorting your data is important as it allows you to look for patterns. Remember, with each data display be sure to list 2-3 observations.

The sample table below has been sorted by *crater diameter.* Observations are listed below the table.

DATA TABLE - CRATERS ON ______________________

Please note that latitudes are provided as North latitudes [Latitude (N)]. A latitude with a (-) is a South latitude: Example: -27.8 is the same as 27.8S.
Also note that longitudes are provided as East longitudes [Longitude (E)]. A longitude with a (-) is a West longitude: Example: -68.5 is the same as 68.5W.
(The first three data logged here are of Earth. They can be used as examples, or if you are collecting data on Earth, you now have 3 data points.)

Image Identification #	Crater Name *(if known)*	Latitude (N)	Longitude (E)	Planetary Body	Geographic location *(country or region)*	Crater Diameter (km)	Crater Type *(simple or complex)*	Crater Classification *(preserved, modified, destroyed)*	Miscellaneous notes or observations	Sketch(es) of Craters *(optional)*
ISS012-E-15881	Manicoua-gan	51.5	-68.5	Earth	Canada	65	Complex	Modified	Crater has central peak, though it is not easily detected. Diameter listed in Earth Impact Database as ~85 km. Only ~65km is actually visible in image. "Arms"/rivers extend out from the rim.	
ISS015-E-17360	Gosses Bluff	-23.9	132.3	Earth	Australia	15	Complex	Modified	Crater has central peak. In reading information on NASA website about this crater, the well-defined bumpy circular feature is part of that central uplift. The faded outer rim is barely visible. This outer rim was used to determine the crater diameter.	
ISS018-E-14908	Tenoumer	22.9	-10.4	Earth	Mauritania	1.9	Simple	Modified	Simple bowl shaped crater. The rim of this crater looks soft – the rim is not sharp and raised – likely due to erosion. There looks to be evidence of eroded ejecta around the rim. Ejecta extends out further on the right.	

Observation #1: The larger the crater diameter, the more likely it is complex.
Observation #2: There smaller the crater, the more likely it is a simple crater.
Observation #3: Only two craters observed have a central uplift.

NOTE:

- Observations should state general patterns or notable information the data display is illustrating.
- Observations **do not** attempt to decipher what those patterns mean.
- Observations should generally not be questionable. Everyone should be able to agree on stated observations.

Step 6: Display Data

A) Sorted Data Table B) Graphs C) Maps D) Image Illustrations

This sample table was sorted by *latitude.* Observations are listed below the table.

DATA TABLE - CRATERS ON ______________________

Please note that latitudes are provided as North latitudes [Latitude (N)]. A latitude with a (-) is a South latitude: Example: -27.8 is the same as 27.8S.
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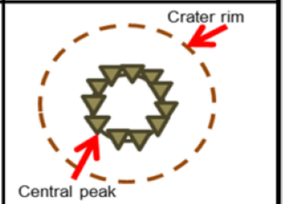
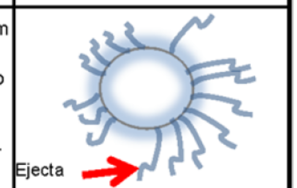
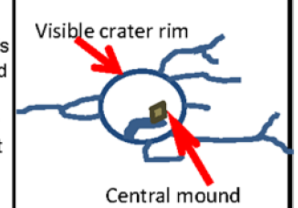
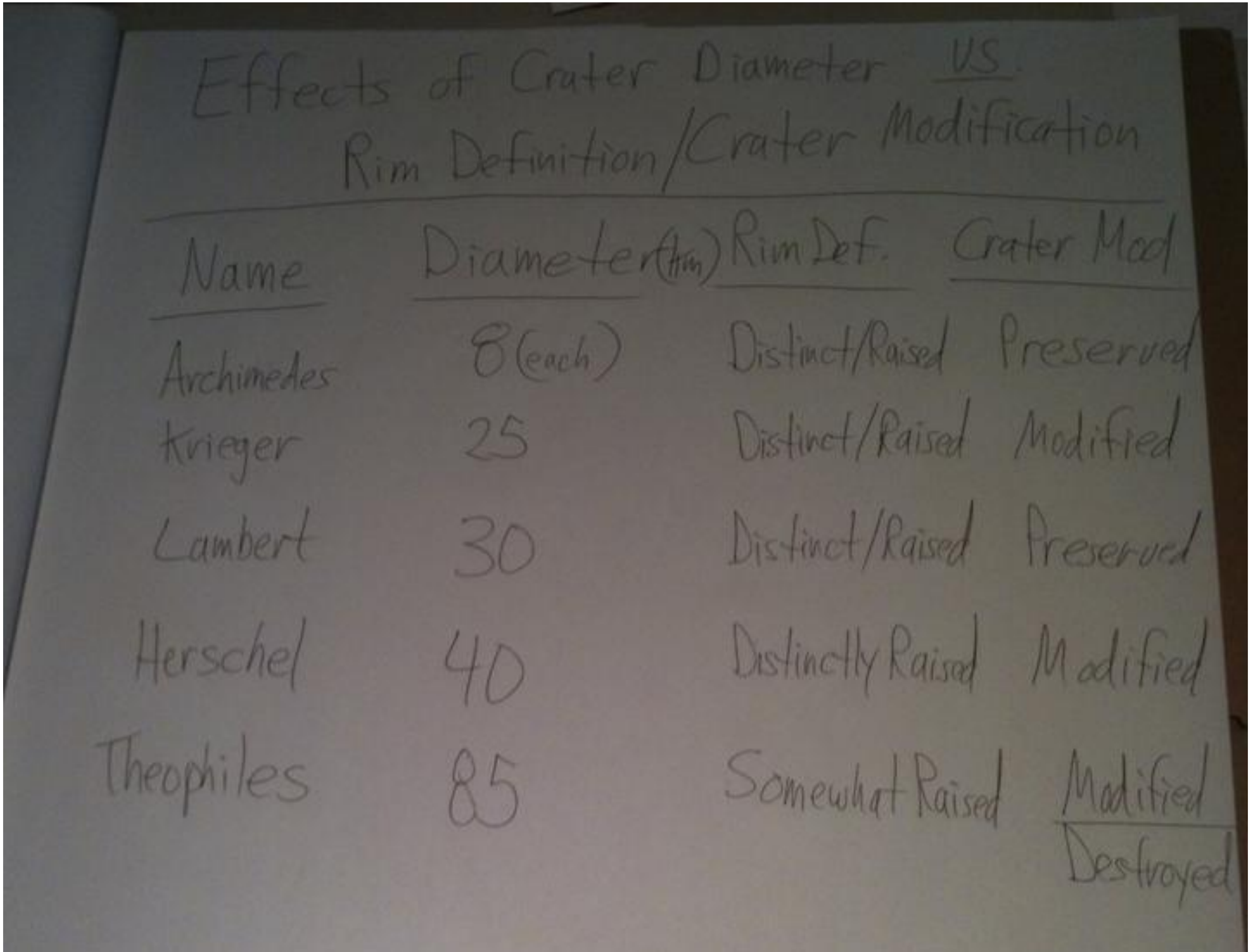
(The first three data logged here are of Earth. They can be used as examples, or if you are collecting data on Earth, you now have 3 data points.)

Image Identification #	Crater Name *(if known)*	Latitude (N)	Longitude (E)	Planetary Body	Geographic location *(country or region)*	Crater Diameter (km)	Crater Type *(simple or complex)*	Crater Classification *(preserved, modified, destroyed)*	Miscellaneous notes or observations	Sketch(es) of Craters *(optional)*
ISS015-E-17360	Gosses Bluff	-23.9	132.3	Earth	Australia	15	Complex	Modified	Crater has central peak. In reading information on NASA website about this crater, the well-defined bumpy circular feature is part of that central uplift. The faded outer rim is barely visible. This outer rim was used to determine the crater diameter.	
ISS018-E-14908	Tenoumer	22.9	-10.4	Earth	Mauritania	1.9	Simple	Modified	Simple bowl shaped crater. The rim of this crater looks soft – the rim is not sharp and raised – likely due to erosion. There looks to be evidence of eroded ejecta around the rim. Ejecta extends out further on the right.	
ISS012-E-15881	Manicoua-gan	51.5	-68.5	Earth	Canada	65	Complex	Modified	Crater has central peak, though it is not easily detected. Diameter listed in Earth Impact Database as ~85 km. Only ~65km is actually visible in image. "Arms"/rivers extend out from the rim.	

Observation #1: Craters located in both the southern and northern hemisphere of Earth are modified.
Observation #2: Craters located in both the southern and northern hemisphere of Earth have central uplifts.
Observation #3: Complex craters are located in both the southern and northern hemisphere of Earth.

SORTED OR SUBSET DATA TABLE:

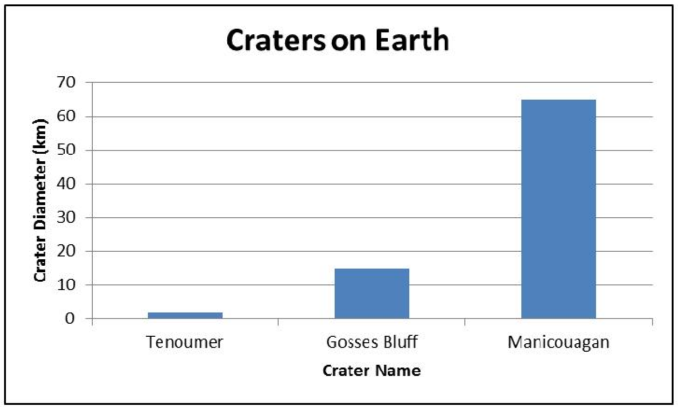
Create electronically or on butcher paper



Step 6: Display Data

A) Sorted Data Table	**B) Graphs**	**C) Maps**	D) Image Illustrations

GRAPHS
Graphs can allow you to visualize and illustrate your data, again allowing you to look for patterns. The graph below is showing the diameters of different craters on Earth.



Observation #1: Crater diameters on Earth, based on those observed, range from ~2km to ~65km.

Observation #2: There are not many craters of similar sizes on Earth

Observation #3: The range of craters sizes on Earth is wide.

Note: The more data you graph, the easier it is to make observations and look for notable patterns.

MAPS
Maps can allow you look for local, regional, or global patterns. The map shown here indicates the global distribution of impact craters (referred to as structures) on Earth.

Observation #1: Impact Craters are located on *most* continents on Earth.

Observation #2: The craters we observed are in North America, Africa, and Australia.

Observation #3: There are no impact craters found in Greenland or Antarctica.

World Impact Structures Sorted according to Location

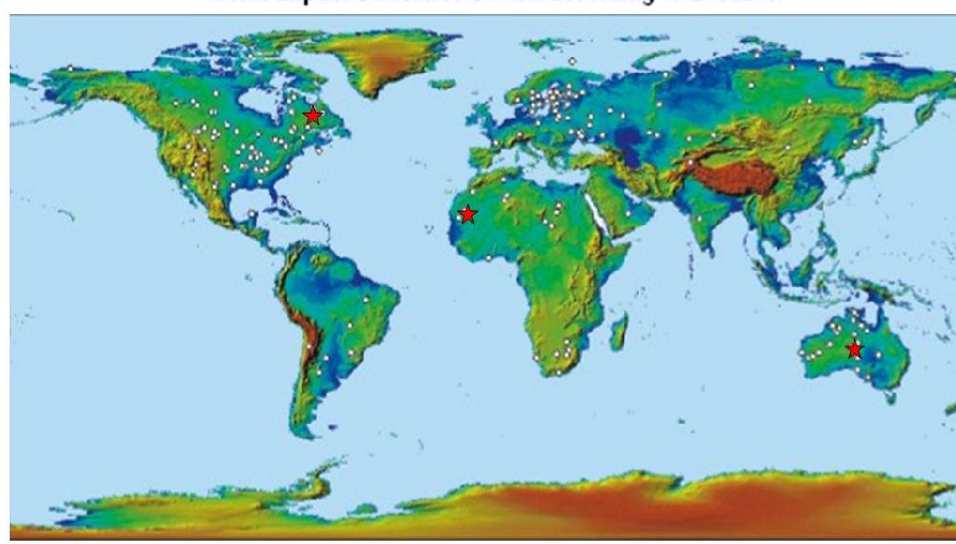
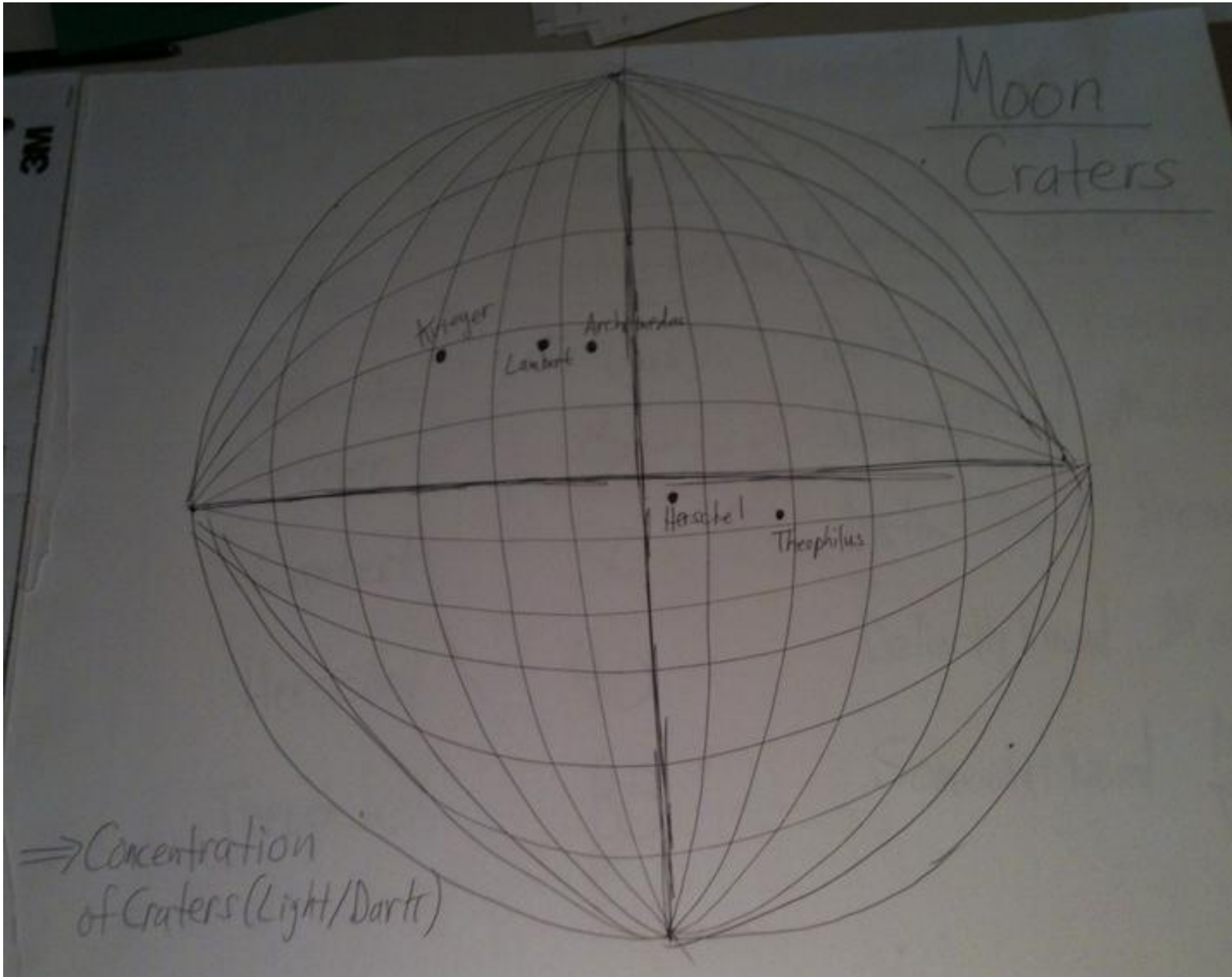


Image Credit: Earth Impact Database: http://www.unb.ca/passc/ImpactDatabase/CILocSort.html

★ = craters observed

GRAPHS OR MAPS:

Create electronically or on butcher paper



Step 6: Display Data

A) Sorted Data Table B) Graphs C) Maps **D) Image Illustrations**

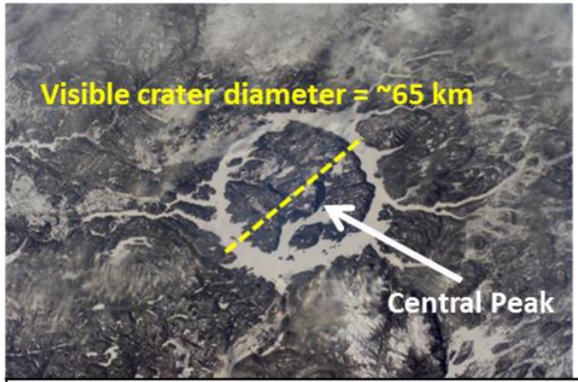
IMAGE ILLUSTRATIONS

To help you illustrate your observations so readers of your research have a better understanding of your observations, image illustrations can be very powerful. See the two image illustration examples below.

IMAGE ILLUSTRATION #1: BARELY VISIBLE RIMS

Image Illustration #1: Most craters on Earth appear to be extremely modified (eroded) or destroyed. Rims like the one shown in the image above are oftentimes barely visible. (ISS028-E-14782: Shoemaker Crater)

IMAGE ILLUSTRATION #2: CRATER MODIFICATION



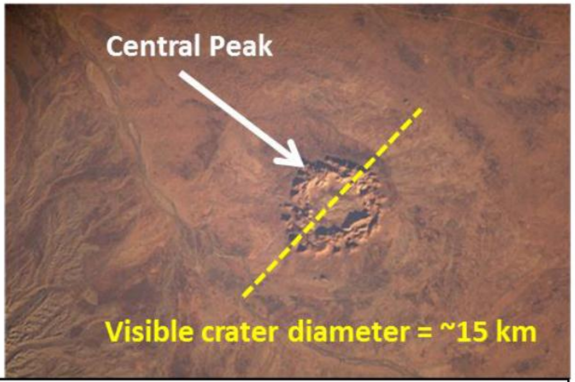


Image Illustration #2: Craters on Earth are modified by wind, water, ice, or volcanic processes. Oftentimes this modification makes it difficult to detect a central peak (if one exists). Additionally, the visible extent of the crater diameter may different from crater diameters indicated in the Earth Impact Database. For example, Manicouagan is listed as having a diameter of 85 km (~65 km visible here) and Gosses Bluff is listed as having a diameter of 22 km (~15 km visible here).

IMAGE ILLUSTRATION #1:

Observation #1: The rim of this crater is "broken" and barely visible.

Observation #2: This crater has been heavily modified by different processes, including water erosion.

Observation #3: The crater in this image is destroyed with hardly any visible detection of a wall, rim, or ejecta.

IMAGE ILLUSTRATION #2:

Observation #1: Central peaks in these craters on Earth are difficult to identify.

Observation #2: The terrain/environment of these two impact craters appear to be very different.

Observation #3: The original crater diameters (retrieved from the Earth Impact Database) are larger than the crater diameter measured using the measurement reference lines provided with each image. Manicouagan has a visible measured diameter of ~65km; diameter of Gosses Bluff is ~15km.

Step 6: Display Data

WHAT TO DO:

1. Decide how to display your data:

   A) Sorted Data Table B) Graphs C) Maps D) Image Illustrations

2. Create your data display(s)
3. List 2-3 observations of each data display.

Be thinking about your research question and hypotheses as you create your data displays:

Research Question: What do the characteristics of craters reveal about the geologic history of planetary worlds?

Hypothesis/es: Based on the images we have observed so far, and what we know about impact craters in our Solar System, we hypothesize the following…..

	RELATIVE AGE OF SURFACE *Relatively young or old*	**ACTIVE GEOLOGIC PROCESSES** *Early in its history; throughout its history; currently; likely never existed*
EARTH	Relatively young	Throughout its history and currently
EARTH'S MOON		
MARS		
VENUS		
MERCURY		
VESTA		

This information should not change from what was initially written.

Step 7: Analyze & Interpret Data

PROCESS OF SCIENCE STEP 7: Analyze & Interpret Data
Once you display your data **and** have listed observations of those data displays, you are ready to do one of the most important steps of your research – analyze and interpret the data. Analysis and interpretation of data are done by thinking about how specific observations and knowledge you have directly relate to your question. Your goal is to be able to draw conclusions about your research with supporting evidence.

Be sure to focus your analysis on the research question and your hypotheses:

Research Question: What do the characteristics of craters reveal about the geologic history of planetary worlds?

Hypothesis/es: Based on the images we have observed so far, and what we know about impact craters in our Solar System, we hypothesize the following…..

	RELATIVE AGE OF SURFACE *Relatively young or old*	ACTIVE GEOLOGIC PROCESSES *Early in its history; throughout its history; currently; likely never existed*
EARTH	Relatively young	Throughout its history and currently
EARTH'S MOON		
MARS		
VENUS		
MERCURY		
VESTA		

This information should not change from what was initially written.

For this step you will:

1. Fill out an *Analysis and Interpretation of Data* table
2. Share your analysis with the class.

Analysis and Interpretation of Data

TABLE IS DIVIDED INTO THREE COLUMNS:

1) Specific observations from Data Displays
2) Your interpretation of what those observations mean.
3) Evidence that support your interpretation

Focus your analysis on data you logged: **1) *crater classification,*** **2) *crater diameter,*** **3) *crater type*.**

Sample table focusing on data collected from Earth craters. This same table structure would be used for *each* planetary world:

ANALYSIS AND INTERPRETATION OF DATA Planetary World: EARTH		
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)
IMPORTANT: Be sure to list a relevant observation you listed with one of your data displays.	*IMPORTANT: Describe how this observation can be interpreted – what does it reveal about the age of the planetary surface or the processes affecting the surface.*	*IMPORTANT: Provide additional evidence that supports your interpretation. Did you illustrate this point in another data display; did you read something about this in the text provided or somewhere else?*

Analysis and Interpretation of Data

Sample table focusing on data collected from Earth craters. This same table structure would be used for *each* planetary world:

ANALYSIS AND INTERPRETATION OF DATA Planetary World: EARTH		
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)
IMPORTANT: Be sure to list a relevant observation you listed with one of your data displays.	*IMPORTANT: Describe how this observation can be interpreted – what does it reveal about the age of the planetary surface or the processes affecting the surface.*	*IMPORTANT: Provide additional evidence that supports your interpretation. Did you illustrate this point in another data display; did you read something about this in the text provided or somewhere else?*
1. CRATER CLASSIFICATION: Example: This crater is being modified by different processes, including water erosion. (Image Illustration #1, Observation # 2)	Example: Impact craters on Earth are mostly modified and are therefore middle-aged to old. Not observing any preserved craters allows us to infer that Earth has not been impacted by any significant object recently. As all observed craters are modified, this can be interpreted to mean there are active processes currently modifying craters on Earth.	Example: Earth has current and active weathering and erosion processes that continually modify/shape the surface of the planet. (Source: Crater Comparison Student Guide pg. 6)
2. CRATER DIAMETER: Example: Crater diameters on Earth, based on those observed, range from ~2km to ~[illegible]5km. (Earth Graph, Observation #1)	• What does this observation lead you to infer about the age of the planetary surface? • What does this observation lead you to infer about the geologic processes affecting the surface and when those processes may have occurred?	• Is there another data display you created that supports this interpretation? • Is there text provided in this guide (or some other source you have researched – textbook, internet, etc.) that supports this interpretation?
3 [illegible] ([illegible] • [illegible]	• [illegible] bservation lead you to infer about the [illegible] ary surface? • [illegible] bservation lead you to infer about the [illegible] ses affecting the surface and when [illegible] may have occurred?	• Is there another data display you created that supports this interpretation? • Is there text provided in this guide (or some other source you have researched – textbook, internet, etc.) that supports this interpretation?

Observation from specific data table display is listed The parenthesis state the name of the display and observation # for reference.

Analysis and Interpretation of Data

Sample table focusing on data collected from Earth craters. This same table structure would be used for *each* planetary world:

ANALYSIS AND INTERPRETATION OF DATA Planetary World: EARTH		
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)
IMPORTANT: Be sure to list a relevant observation you listed with one of your data displays.	*IMPORTANT: Describe how this observation can be interpreted – what does it reveal about the age of the planetary surface or the processes affecting the surface.*	*IMPORTANT: Provide additional evidence that supports your interpretation. Did you illustrate this point in another data display; did you read something about this in the text provided or somewhere else?*
1. CRATER CLASSIFICATION: Example: This crater is being modified by different processes, including water erosion. (Image Illustration #1, Observation #2)	Example: Impact craters on Earth are mostly modified and are therefore middle-aged to old. Not observing any preserved craters allows us to infer that Earth has not been impacted by any significant object recently. As all observed craters are modified, this can be interpreted to mean there are active processes currently modifying craters on Earth.	Example: Earth has current and active weathering and erosion processes that continually modify/shape the surface of the planet. (Source: Crater Comparison Student Guide pg. 6)
2. CRATER DIAMETER: Example: Crater diameters on Earth, based on those observed, range from ~2km to ~65km. (Earth Graph, Observation #1)	• What does this observation lead you to infer about the age of the planetary surface? • What does this observation lead you to infer about the geologic processes affecting the surface and when those processes may have occurred?	• Is there another data display you created that supports this interpretation? • Is there text provided in this guide (or some other source you have researched – textbook, internet, etc.) that supports this interpretation?
3. CRATER TYPE: (simple versus c… • Include a speci… observation yo… your data displ…	• What does this observation lead you to infer about the … t the … n	• Is there another data display you created that supports this interpretation? • Is there text provided in this guide (or some other source you have researched – textbook, internet, etc.) that supports this interpretation?

How can this observation be applied to your question/hypotheses:

- **Relative age of planetary surface**
- **Inferences about when geologic processes may have been active**

Analysis and Interpretation of Data

Sample table focusing on data collected from Earth craters. This same table structure would be used for *each* planetary world:

ANALYSIS AND INTERPRETATION OF DATA Planetary World: EARTH		
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)
IMPORTANT: Be sure to list a relevant observation you listed with one of your data displays.	*IMPORTANT: Describe how this observation can be interpreted – what does it reveal about the age of the planetary surface or the processes affecting the surface.*	*IMPORTANT: Provide additional evidence that supports your interpretation. Did you illustrate this point in another data display; did you read something about this in the text provided or somewhere else?*
1. CRATER CLASSIFICATION: Example: This crater is being modified by different processes, including water erosion. (Image Illustration #1, Observation # 2)	Example: Impact craters on Earth are mostly modified and are therefore middle-aged to old. Not observing any preserved craters allows us to infer that Earth has not been impacted by any significant object recently. As all observed craters are modified, this can be interpreted to mean there are active processes currently modifying craters on Earth.	Example: Earth has current and active weathering and erosion processes that continually modify/shape the surface of the planet. (Source: Crater Comparison Student Guide pg. 6)
2. CRATER DIAMETER: Example: Crater diameters on Earth, based on those observed, range from ~2km to ~65km (Earth Graph, Observation	• What does this observation lead you to infer about the age of the planetary surface? • What does this observation lead you to infer about the geologic processes affecting the surface and when	• Is there another data display you created that supports this interpretation? • Is there text provided in this guide (or some other source you have researched – textbook, internet, etc.) that supports this interpretation?
3. CRATER TYPE: (simple versus complex • Include a specific and observation you listed your data displays.	bout the bout the when	• Is there another data display you created that supports this interpretation? • Is there text provided in this guide (or some other source you have researched – textbook, internet, etc.) that supports this interpretation?

What additional evidence (other data displays or background knowledge you have) supports this interpretation.

BLANK *ANALYSIS & INTERPRETATION* TABLE

ANALYSIS AND INTERPRETATION OF DATA: Planetary World: ______________________________		
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)

Step 7: Analyze & Interpret Data

SHARE YOUR ANALYSIS

1) Be prepared to discuss your information related to all 3 crater characteristics
2) Be prepared to show any related data displays that allow you to illustrate your specific observations and help support your interpretations.
3) Be prepared to discuss any limitations (not enough data, needed more area to be shown in images, etc.)

SUMMARY TABLE (use additional paper, as necessary)

	Earth	______	______	______
Crater Diameter				
Crater Type				
Crater Classification				
Other Notes or Limitations				

Step 8: Draw Conclusions

PROCESS OF SCIENCE STEP 8: Draw Conclusions
Now that you have completed all the above steps, you are now ready to draw conclusions about your question and hypothesis/es. 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.

1**. RESEARCH QUESTION:** What do the characteristics of craters reveal about the geologic history of planetary worlds? Based on your research and analysis of data, what do you think is the answer to your question? Provide specific details.

2. **HYPOTHESIS/ES:** Based on your research and analysis of data, indicate whether your hypothesis/es were supported or refuted? Summarize pertinent evidence. [Be sure to list your original set of hypotheses. If a hypothesis was refuted, include a hypothesis revision statement to indicate your new understanding.] Use additional paper as necessary.

	RELATIVE AGE OF SURFACE *Rel. young or old*	Supported or Refuted	Summary of pertinent evidence	ACTIVE PROCESSES *Early in its history; throughout its history; currently; likely never existed*	Supported or Refuted	Summary of pertinent evidence
EARTH						
EARTH'S MOON						
MARS						
VENUS						
MER-CURY						
VESTA						

Step 8: Draw Conclusions

PROCESS OF SCIENCE STEP 8: Draw Conclusions

Now that you have completed all the above steps, you are now ready to draw conclusions about your question and hypothesis/es. 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.

1**. RESEARCH QUESTION:** What do the characteristics of craters reveal about the geologic history of planetary worlds? Based on your research and analysis of data, what do you think is the answer to your question? Provide specific details.

Answer should indicate **how you can use the characteristics of craters to make inferences about the geologic history of the planetary world.**
(Include specifics that allow you to know if the surface is young or old and how you can infer when geologic processes may have occurred).

EARTH						
EARTH'S MOON						
MARS						
VENUS						
MER-CURY						
VESTA						

Step 8: Draw Conclusions

PROCESS OF SCIENCE STEP 8: Draw Conclusions

Now that you have completed all the above steps, you are now ready to draw conclusions about your question and hypothesis/es. 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.

1**. RESEARCH QUESTION:** What do the characteristics of craters reveal about the geologic history of planetary worlds? Based on your research and analysis of data, what do you think is the answer to your question? Provide specific details.

Answer should indicate **how you can use the characteristics of craters to make inferences about the geologic history of the planetary world.**
(Include specifics that allow you to know if the surface is young or old and how you can infer when geologic processes may have occurred).

RESEARCH QUESTION & SAMPLE ANSWER:
What do the characteristics of craters reveal about the geologic history of planetary worlds? *Characteristics of craters can help reveal whether a planetary surface is relatively young or old and approximately when that planetary surface may have had active geologic processes. Specific characteristics that enable you to do this include the sizes and classifications of craters. For example, a planetary world with many craters, including relatively large craters is likely old. If the craters are modified or destroyed, this can lead you to infer the planetary world had active processes at some point in its history. Finding preserved craters on a planetary surface may indicate that active geologic processes modifying the surface of that world no longer existed when those impact craters were formed.*

VESTA						

Step 8: Draw Conclusions

PROCESS OF SCIENCE STEP 8: Draw Conclusions
Now that you have completed all the above steps, you are now ready to draw conclusions about your question and hypothesis/es. 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.

1**. RESEARCH QUESTION:** What do the characteristics of craters reveal about the geologic history of planetary worlds? Based on your research and analysis of data, what do you think is the answer to your question? Provide specific details.

2. **HYPOTHESIS/ES:** Based on your research and analysis of data, indicate whether your hypothesis/es were supported or refuted? Summarize pertinent evidence. [Be sure to list your original set of hypotheses. If a hypothesis was refuted, include a hypothesis revision statement to indicate your new understanding.] Use additional paper as necessary.

	RELATIVE AGE OF SURFACE *Rel. young or old*	Supported or Refuted	Summary of pertinent evidence	ACTIVE PROCESSES *Early in its history; throughout its history; currently; likely never existed*	Supported or Refuted	Summary of pertinent evidence
EARTH						
EARTH'S MOON						
MARS						
VENUS						
MER-CURY						
VESTA						

Conclusions/Hypotheses Table Sample

	RELATIVE AGE OF SURFACE *Rel. young or old*	Supported or Refuted	Summary of pertinent evidence	ACTIVE PROCESSES *Early in its history, throughout its history, currently, likely never existed*	Supported or Refuted	Summary of pertinent evidence
EARTH	*relatively young*	*Supported*		*Throughout its history and currently*	*Supported*	
EARTH'S MOON	*relatively old*	*Supported*		*likely never existed*	*refuted*	
MARS	*relatively old*	*Somewhat refuted:*		*likely never existed*	*refuted*	
VENUS						
MER-CURY						
VESTA						

*Since this hypothesis was somewhat refuted, include a summary of pertinent evidence and also include a **HYPOTHESIS REVISION** statement (what is your new hypothesis that your data now supports).*

*Since these hypotheses were refuted, include a summary of pertinent evidence and also include a **HYPOTHESIS REVISION** statement (what is your new hypothesis that your data now supports).*

This information should not change from what was initially written.

Conclusions/Hypotheses Table Sample

	RELATIVE AGE OF SURFACE *Rel. young or old*	Supported or Refuted	Summary of pertinent evidence	ACTIVE PROCESSES *Early in its history, throughout its history, currently, likely never existed*	Supported or Refuted	Summary of pertinent evidence
EARTH	*relatively young*	*Supported*	*-relatively few craters* *-variety of crater sizes, some large but most relatively small*	*Throughout its history and currently*	*Supported*	*-most of the craters are modified or destroyed illustrating Earth has active processes modifying these craters.*
EARTH'S MOON	*relatively old*	*Supported*	*-lots of craters* *-large number of both large and small craters*	*likely never existed*	*refuted*	*-older larger craters are modified or destroyed.* *-smaller craters preserved* *-**HYPOTHESIS REVISION:** geologic process active relatively early in the Moon's history.*
MARS	*relatively old*	*Somewhat refuted:*	*-lots of craters* *-large number of both large and small craters* *-some areas are relatively young and others relatively old* *-**HYPOTHESIS REVISION:** relative age is "middle-aged"*	*likely never existed*	*refuted*	*-older larger craters are modified or destroyed.* *-some small craters are preserved but others are modified* *-planet appears to have processes that may be currently active – especially wind* *-**HYPOTHESIS REVISION:** geologic processes active throughout Mars' history; some are currently active.*
VENUS						
MER-CURY						
VESTA						

This information should not change from what was initially written.

WHAT DOES IT ALL MEAN?

Based on your investigation, discussion the following:

1. Which are older: large complex craters or small simple craters? What does that tell you about the size of materials that may be have impacted planetary worlds early in the history of the Solar System versus the size of materials that have more recently impact surfaces? Explain your answer.

2. If the Earth or other planetary worlds were to be impacted by an object in the future, do you think this object would likely be relatively large or small? Explain your answer.

3. NASA plans to send astronauts to visit another planetary world in the future to help us better understand our Solar System. If you had the opportunity to choose which planetary world to visit, which would you choose and why?

PART 6: EVALUATE

National Aeronautics and Space Administration

CRATER COMPARISION ASSESSMENT

Name: ______________________________

Date: ______________________________

Complete the follow questions to demonstrate your understanding of the process of science and impact craters.

1. List at least 3 ways you can display data:

   1) ________________________ 2) _________________________ 3)________________________

2. What is the name of the plan that describes the methods and details of how you will go about implementing your research?

   a) Draw Conclusions b) Background Research c) Experiment Design d) Collect & Compile Data

3. True or False (Circle your answer):
   - As you display your data, you should immediately interpret what the data mean?

4. True or False (Circle your answer):
   - As you formulate a hypothesis you are guessing what the answer to your question is without thinking about any prior knowledge or prior observations.

5. Which of the following statements is true?

   a. Everyone should agree on both observations and interpretations. These statements are not disputable and should be the same for everyone.
   b. Everyone should agree on observations only. Interpretations can be disputable and may not be the same for everyone.
   c. Everyone should agree on interpretations only. Observations can be disputable and may not be the same for everyone.
   d. It is rare to have anyone agree on observations or interpretations.

6. True or False (Circle your answer):
   - When doing comparative planetology research, it is highly recommended to collect the same type of data for every planetary body included in your research.

PART 6: EVALUATE

7. Which of the following statement(s) is/are true? Select all that apply.
   As you analyze and interpret data you should:
   a. Simply list your interpretations of your research.
   b. Not need to worry about listing evidence that support your interpretations.
   c. Interpret how specific observations from data displays relate to your research.
   d. Use background knowledge you have learned as well as additional data displays to provide evidence to support your interpretations.

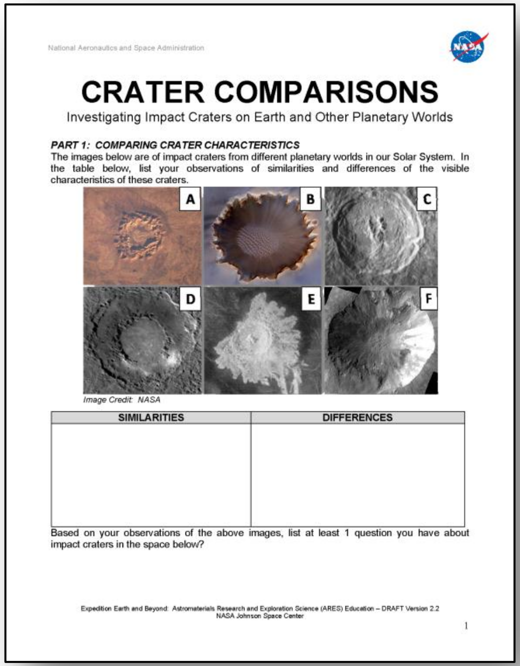
8. Which of the following lists the correct order of steps involved in the process of science?
   a. Draw Conclusions, display data, collect and compile data, analyze and interpret data
   b. Display data, collect and compile data, analyze and interpret data, draw conclusions
   c. Collect and compile data, analyze and interpret data, display data, draw conclusions
   d. Collect and compile data, display data, analyze and interpret data, draw conclusions

9. True or False (Circle your answer):
   - When conducting a research investigation, one data point is all you need.

10. Which of the following statement(s) is/are true? Select all that apply.
   a. Impact craters are formed when a meteoroid strikes the surface of a planetary body.
   b. All craters are complex craters
   c. Craters can be modified by geologic processes such as wind, water, or volcanic activity.
   d. Three stages in the formation of craters are the contact/compression stage, excavation stage, and modification stage.
   e. Impact craters are not found on the surface of the Earth.
   f. There are three classifications of craters that help provide information about the relative age of a crater. Classifications include preserved, modified, and destroyed craters.
   g. Complex craters are larger structures than simple craters and oftentimes have a central peak.
   h. A “younger” surface is one that has been recently resurfaced by some process as opposed to an “older” surface that has not been altered for a longer period of time.
   i. The crater formation process takes thousands of years.
   j. Impact craters are found on most of the rocky planets and moons in our Solar System.
   k. Impact craters open up a window into the history of our Solar System.

CRATER COMPARISONS

Investigating Impact Craters on Earth and Other Planetary Worlds


National Aeronautics and Space Administration

CRATER COMPARISONS

Investigating Impact Craters on Earth and Other Planetary Worlds

PART 1: COMPARING CRATER CHARACTERISTICS

The images below are of impact craters from different planetary worlds in our Solar System. In the table below, list your observations of similarities and differences of the visible characteristics of these craters.

A B C D E F

Image Credit: NASA

SIMILARITIES	DIFFERENCES

Based on your observations of the above images, list at least 1 question you have about impact craters in the space below?

Expedition Earth and Beyond: Astromaterials Research and Exploration Science (ARES) Education – DRAFT Version 2.2
NASA Johnson Space Center

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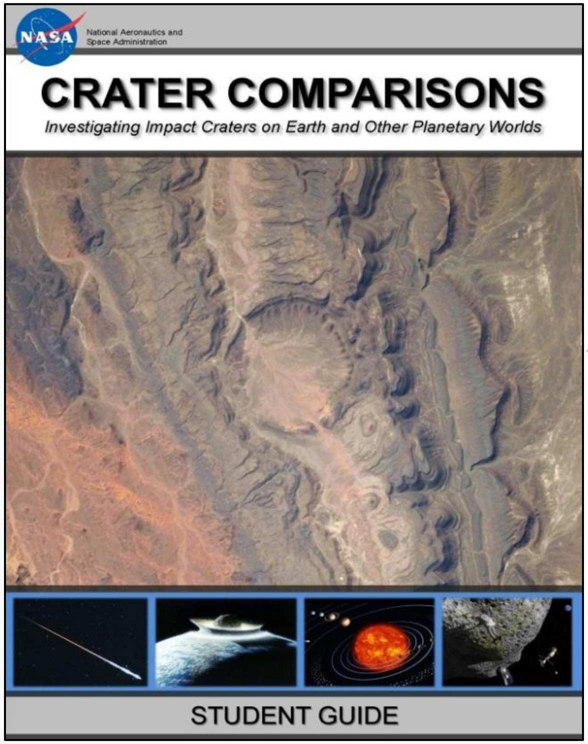
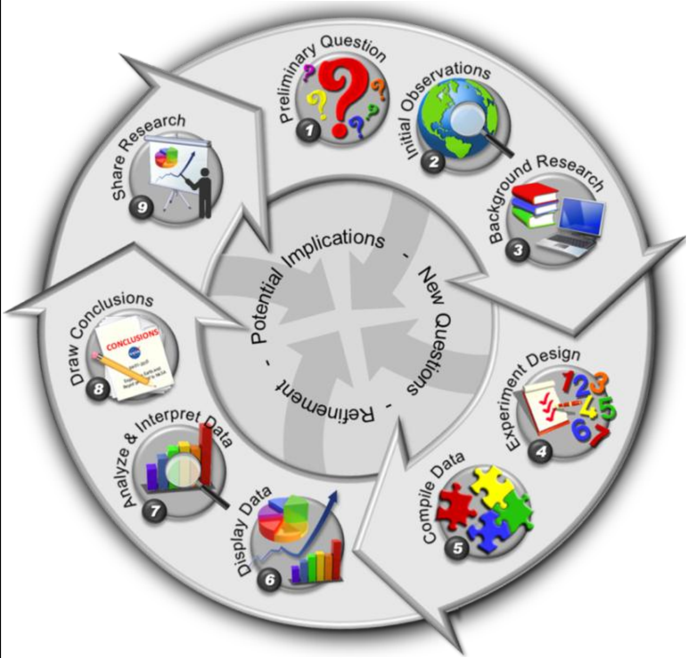
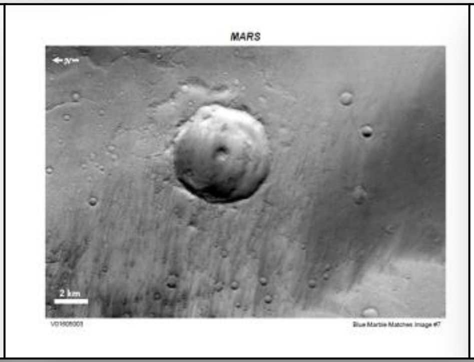




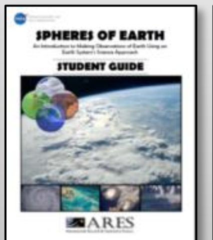


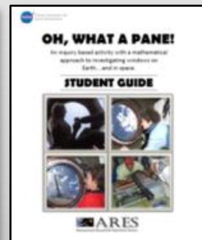
Getting students actively involved with NASA exploration and discovery.

http://ares.jsc.nasa.gov/ares/eeab/

Getting Started

Launchpad Activities





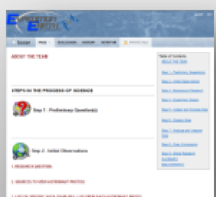
Standards-aligned, inquiry-based, hands-on activities.

Modeling the Process of Science

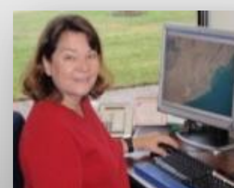
Student Investigation Resources

Resources that help facilitate student-led investigations about Earth and/or planetary comparisons.

Enrichment Components



Team Wiki Pages



Interacting w/ Scientists

Data Requests

Team Presentations

Educator Trainings

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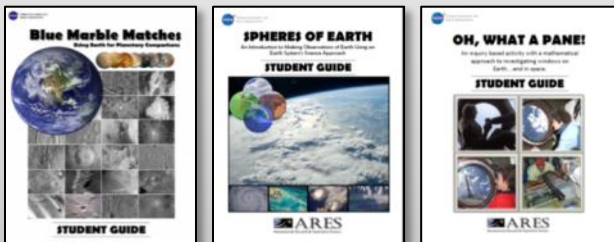

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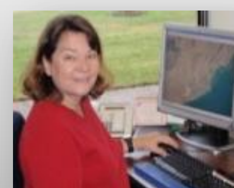

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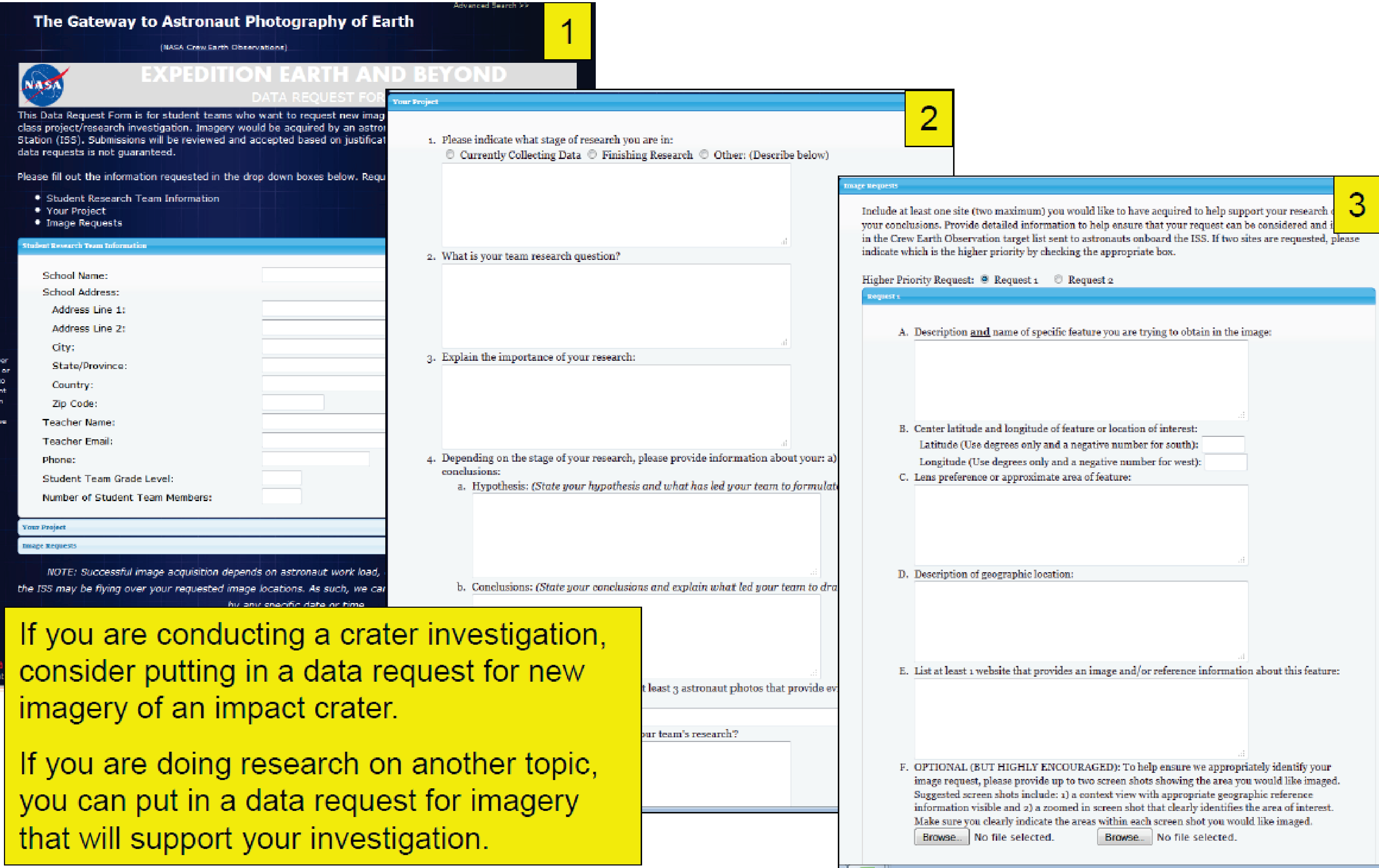
Online DATA REQUEST FORM

Includes three sections: 1) Team info, 2) Project info, 3) Image Requests

http://eol.jsc.nasa.gov/DataRequest/EEAB.htm



1

Advanced Search >>

The Gateway to Astronaut Photography of Earth

(NASA Crew Earth Observations)

EXPEDITION EARTH AND BEYOND

DATA REQUEST FOR

This Data Request Form is for student teams who want to request new imag class project/research investigation. Imagery would be acquired by an astro Station (ISS). Submissions will be reviewed and accepted based on justificat data requests is not guaranteed.

Please fill out the information requested in the drop down boxes below. Requ

- Student Research Team Information
- Your Project
- Image Requests

Student Research Team Information

School Name:
School Address:
Address Line 1:
Address Line 2:
City:
State/Province:
Country:
Zip Code:
Teacher Name:
Teacher Email:
Phone:
Student Team Grade Level:
Number of Student Team Members:

Your Project

Image Requests

NOTE: Successful image acquisition depends on astronaut work load, the ISS may be flying over your requested image locations. As such, we ca by any specific date or time.

2

Your Project

1. Please indicate what stage of research you are in:
   Currently Collecting Data   Finishing Research   Other: (Describe below)
2. What is your team research question?
3. Explain the importance of your research:
4. Depending on the stage of your research, please provide information about your: a) conclusions:
   a. Hypothesis: *(State your hypothesis and what has led your team to formulat*
   b. Conclusions: *(State your conclusions and explain what led your team to dra*

t least 3 astronaut photos that provide ev

ur team's research?

3

Image Requests

Include at least one site (two maximum) you would like to have acquired to help support your research your conclusions. Provide detailed information to help ensure that your request can be considered and i in the Crew Earth Observation target list sent to astronauts onboard the ISS. If two sites are requested, please indicate which is the higher priority by checking the appropriate box.

Higher Priority Request: Request 1   Request 2

Request 1

A. Description and name of specific feature you are trying to obtain in the image:
B. Center latitude and longitude of feature or location of interest:
   Latitude (Use degrees only and a negative number for south):
   Longitude (Use degrees only and a negative number for west):
C. Lens preference or approximate area of feature:
D. Description of geographic location:
E. List at least 1 website that provides an image and/or reference information about this feature:
F. OPTIONAL (BUT HIGHLY ENCOURAGED): To help ensure we appropriately identify your image request, please provide up to two screen shots showing the area you would like imaged. Suggested screen shots include: 1) a context view with appropriate geographic reference information visible and 2) a zoomed in screen shot that clearly identifies the area of interest. Make sure you clearly indicate the areas within each screen shot you would like imaged.
   Browse... No file selected.   Browse... No file selected.

If you are conducting a crater investigation, consider putting in a data request for new imagery of an impact crater.

If you are doing research on another topic, you can put in a data request for imagery that will support your investigation.

EARTH IMPACT DATABASE

http://www.passc.net/EarthImpactDatabase/index.html

Structure Name	Location	Lat	Lon	Age (Ma)*	Diameter (km)
Acraman	South Australia	32.0S	135.5E	~ 590	90
Amelia Creek	N. Territory, Australia	20.9S	134.8E	1640 - 600	~20
Ames	Oklahoma, U.S.A.	36.3N	98.2E	470 ± 30	16
Amguid	Algeria	26.1N	4.4E	< 0.1	0.45
Aorounga	Chad	19.1N	19.3E	< 345	12.6
Aouelloul	Mauritania	20.3N	12.7E	3.0 ± 0.3	0.39
Araguainha	Brazil	16.8S	53.0E	244.4 ± 3.25	40
Avak	Alaska, U.S.A.	71.3N	156.6E	3-95	12
Barringer	Arizona, U.S.A.	35.0N	111.0E	0.049 ± 0.003	1.19
Beaverhead	Montana, U.S.A.	44.6N	113.0W	~ 600	60
Beyenchime-Salaatin	Russia	71.0N	121.7E	40 ± 20	8
Bigach	Kazakhstan	48.6N	82.0E	5 ± 3	8
Boltysh	Ukraine	48.8N	32.2E	65.17 ± 0.64	24
Bosumtwi	Ghana	6.5N	1.4W	1.07	10.5
Boxhole	N. Territory, Australia	22.6S	135.2E	0.0054± 0.0015	0.17
B.P. Structure	Libya	25.3N	24.3E	< 120	2
Brent	Ontario, Canada	45.1N	78.5W	396 ± 20	3.8
Calvin	Michigan, USA	41.8N	86.0W	450 ± 10	8.5
Campo Del Cielo	Argentina	27.6S	61.7W	< 0.004	0.05
Carancas	Peru	16.7S	69.1W	0.000004	0.0135
Carswell	Saskatchewan, Canada	58.5N	109.5W	115 ± 10	
Charlevoix	Quebec, Canada	47.5N	70.3W	342 ± 15	
Chesapeake Bay	Virginia, U.S.A.	37.3N	76.0W	35.3 ± 0.1	
Chicxulub	Yucatan, Mexico	21.3N	89.5W	64.98 ± 0.05	
Chiyli	Kazakhstan	49.2N	57.9E	46 ± 7	
Chukcha	Russia	75.7N	97.8E	< 70	
Clearwater East	Quebec, Canada	56.1N	74.1W	290 ± 20	
Clearwater West	Quebec, Canada	56.2N	74.5W	290 ± 20	36
Cloud Creek	Wyoming, USA	43.1N	106.8W	190 ± 30	7
Connolly Basin	Western Australia	23.5S	124.8E	< 60	9
Couture	Quebec, Canada	60.1N	75.3W	430 ± 25	8
Crawford	South Australia	34.7S	139.0E	> 35	8.5
Crooked Creek	Missouri, U.S.A.	37.8N	91.4W	320 ± 80	7
Dalgaranga	Western Australia	27.6S	117.3E	~ 0.27	0.024
Decaturville	Missouri, U.S.A.	37.9N	92.7W	< 300	6
Deep Bay	Saskatchewan, Canada	56.4N	103.0W	99 ± 4	13
Dellen	Sweden	61.8N	16.8E	89.0 ± 2.7	19
Des Plaines	Illinois, U.S.A.	42.1N	87.9W	< 280	8
Dhala	India	25.3N	78.1E	> 1700 < 2100	11
Dobele	Latvia	56.6N	23.3E	290 ± 35	4.5
Eagle Butte	Alberta, Canada	49.7N	110.5W	< 65	10
Elbow	Saskatchewan, Canada	51.0N	106.7W	395 ± 25	8
El'gygytgyn	Russia	67.5N	172.1E	3.5 ± 0.5	18
Flaxman	South Australia	34.6S	139.1E	> 35	10

How can you find additional craters on Earth you might want to request to have imaged by astronauts on the International Space Station (ISS)?

Check out the formatted **Earth Impact Database** spreadsheet of impact craters on Earth.

Chicxulub

Crater Name	Location	Latitude	Longitude	Diameter (km)****	Age (Ma)*	Exposed	Drilled	Target Rock**	Bolide Type***
Chicxulub	Yucatan, Mexico	N 21° 20'	W 89° 30'	150	64.98 ± 0.05	N	Y	M	Chondrite

As you consider what crater you may want to have imaged by astronauts, check to make sure the crater is exposed (visible). This crater is <u>not exposed</u>, therefore it would NOT be a good choice for a request.