Routes Through Space

How evidence, theories, and engineering changed space exploration

ESS.3 "Research, evaluate, and communicate information about how the findings of early astronomers, including Aristotle, Ptolemy, Copernicus, Galileo, Brahe, Kepler, Newton, and Einstein, challenged the thinking of their time..."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB As you read, underline three observations or measurements that challenged an earlier idea. Number each one and circle the new explanation or advance it helped support.

From Sky Maps to Moon Rockets

1 Imagine planning a spacecraft route using a sky map that puts Earth at the center. Aristotle argued that Earth stood still, and Ptolemy built a mathematical model of planets circling Earth. His model predicted many visible positions well enough to remain useful for centuries, even though its basic picture was wrong. In the 1500s, Copernicus proposed that Earth and other planets orbit the Sun. This arrangement explained why planets sometimes seem to move backward against the stars. Yet an explanation is not automatically a fact: observers needed measurements that could distinguish competing models.

2 Galileo used a telescope to see Venus pass through a full set of phases. That observation conflicted with Ptolemy's arrangement of Venus, but by itself did not prove that Copernicus's model was the only possible one. Tycho Brahe measured planetary positions precisely without a telescope. Johannes Kepler used Brahe's measurements to show that Mars follows an ellipse, not a perfect circle, around the Sun. Isaac Newton then showed how gravity and motion could account for Kepler's orbital patterns. Together, measurements and mathematical explanations made it possible to predict where a planet would be, a skill spacecraft navigators still need.

3 Newton's equations work extremely well for many spacecraft routes, but Einstein's theory of general relativity predicts small differences when gravity is very strong or measurements must be exceptionally precise. Tests of light bending near the Sun supported Einstein's prediction, showing that even powerful theories have limits. Scientific ideas reach space through engineering, too. At NASA's Marshall Space Flight Center in Huntsville, Alabama, teams managed development of the Saturn V rocket that launched Apollo missions toward the Moon. A rocket needs a reliably predicted route, while instruments carried beyond Earth can gather new evidence. Space exploration both uses earlier discoveries and creates chances to revise them.

2 ANSWER WITH EVIDENCE

Use the passage

1. Why did Ptolemy's model remain useful, and what different explanation did Copernicus offer for planets' apparent backward motion?

2. What did Galileo observe about Venus, and what could that observation challenge without proving?

3. Trace how Brahe's measurements led to an advance that spacecraft navigators use.

4. How do Einstein's findings and the work at Marshall Space Flight Center show two different needs of space exploration?

3 YOUR TURN

Your own words

Imagine a new telescope finds that a planet's orbit does not fit a current model. Write four sentences that identify data to collect, explain how you would check the finding, connect your plan to one astronomer in the passage, and tell how a better model could help a future mission.

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PART 1 · READ AND MARK

As you read, underline three observations or measurements that challenged an earlier idea. Number each one and circle the new explanation or advance it helped support. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	Why did Ptolemy's model remain useful, and what different explanation did Copernicus offer for planets' apparent backward motion?	**Ptolemy's model predicted many visible planetary positions. Copernicus explained apparent backward motion with a model in which Earth and the other planets orbit the Sun.**
2	What did Galileo observe about Venus, and what could that observation challenge without proving?	**Galileo observed a full set of Venus's phases. This conflicted with Ptolemy's arrangement of Venus but did not prove that Copernicus's model was the only possible one.**
3	Trace how Brahe's measurements led to an advance that spacecraft navigators use.	**Kepler used Brahe's precise measurements to identify Mars's elliptical orbit. Newton explained orbital patterns using gravity and motion, helping make planetary positions predictable for spacecraft navigation.**
4	How do Einstein's findings and the work at Marshall Space Flight Center show two different needs of space exploration?	**Einstein's theory improves predictions when gravity is strong or great precision is needed. Marshall managed development of the Saturn V rocket, providing the engineering needed to launch Apollo missions.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

I would record the planet's position at many times to map its orbit. I would repeat the measurements and check the telescope before deciding that the model needs revision. Like Kepler, who used Brahe's measurements to identify an elliptical orbit, I would compare the data with the predicted path. A model that better predicts the planet's position could help navigators plan a spacecraft route.

Accept other evidence-based connections among observations, revised models, and mission planning. For the marking job, suitable evidence includes Venus's phases, Brahe's planetary measurements, and tests of light bending near the Sun.