

## • Advanced Critical Reading - Hubble

The 32,000–word novella The Time Machine by H.G. Wells, published in 1895, is generally credited with popularizing the idea of time travel by means of a time machine, a vehicle which takes the occupant backward or forward in time. Dozens of sequels and adaptations over the years have further promoted the notion. Indeed, Albert Einstein’s Theory of Special Relativity lays the foundation for the possibility of time travel. So far, no one has demonstrated the ability to travel in time. However, time machines have been constructed, and they do allow glimpses into the past.

The most efficacious time machine currently in existence is the Hubble Telescope, named after the American astronomer Edwin P. Hubble. Its capability to locate distant astronomical targets and lock in on them, permitting their faint light to aggregate on its detectors, allows it to peer far into the past. Light travels 186,000 miles per second. The Hubble Telescope has looked back in time at 10,000 galaxies whose light left them billions of years ago. Therefore, utilizing the telescope as time machine, astronomers are able to contemplate galaxies as they were eons ago.

Although the telescope was launched into space in 1990, its inception was almost a half–century earlier as astronomer Lyman Spitzer, Jr. mulled over the possibility of a large space telescope in a 1946 report, “Astronomical Advantages of an Extra–Terrestrial Observatory.” Because the earth is bathed in its constantly churning atmosphere, earth–based telescopes cannot penetrate deep space; the atmosphere distorts the view. Telescopes were constructed on mountains, but there was still no way to wholly escape the effects of the layers of gases enveloping the earth.

During the 1960s, the Space Race between the then–Soviet Union and the United States was accelerating. The National Aeronautics and Space Administration (NASA) was established. Funds for space endeavors were abundant, and plans for a large space telescope, by then designated the LST, were underway. The designs called for a 2.4–meter primary telescope mirror which could be transported into space by one of NASA’s rockets. According to National Geographic’s Imaging Space and Time, the resolving power of the deep space telescope would be “equivalent to being able to distinguish the left and right headlights of a car in California seen from New York, or features less than 1/30,000<sup>th</sup> the size of the full moon. This was at least a tenfold increase over the atmospheric limit.”

One of the primary challenges involved in successfully transporting the telescope into space was protecting the mirror from the jarring vibrations that occur during launch. It was crucial that the mirror be able to withstand the shuttle’s vicissitudes as well as the volatile atmospheric conditions found in space. If not, the precise shape of the mirror could be compromised, and its imaging capability significantly weakened.

After the telescope had been launched, astronomers subsequently realized that the primary mirror had not been ground correctly. A lens in the test instrument was about one millimeter askew, which is large by optical standards. In 1993, space–walking astronauts installed corrective lenses which improved the eyesight of the Hubble. In 2009, the corrective lenses themselves were replaced with a supersensitive spectrograph with built–in corrective lenses. The new spectrograph is expected to provide insight into the origins of stars and galaxies.

The successor to Hubble, the James Webb Space Telescope, is expected to be launched in 2014. It will observe only in infrared, so it will complement the Hubble Telescope, which observes in the visible and ultraviolet light ranges.

45 Hubble currently has the capability to view galaxies that were formed 13.7 billion years ago, long before humans existed, in an area called the Hubble Ultra Deep Field. Astronomers aspire to see beyond the Hubble Ultra Deep Field to a time that is devoid of galaxies, a time before galaxies had formed. If H.G. Wells was onto something in his novella, that time may be close at hand. As one of the characters in the popular work asked, “If Time is really only a fourth  
50 dimension of Space, why is it, and why has it always been, regarded as something different? And why cannot we move in Time as we move about in the other dimensions of Space?”

55 Less than a decade after Wells’ novella, Einstein’s Special Theory Relativity seemed to concur with Wells’ character by proposing that traveling through space at the speed of light would alter time by causing it to dilate, raising the possibility of not merely glimpsing the past, but perhaps traveling to it.

## Questions

1. According to the passage, which of the following statements is/are true of the Hubble Telescope?

- I) It is unable to observe light on the infrared part of the spectrum.
- II) It will be replaced by the James Webb Space Telescope in 2014.
- III) It was initially constructed in 1946, but not launched until 1990.

- A) I only
- B) II only
- C) III only
- D) I and II only
- E) II and III only

2. According to the passage, who had the idea for the Hubble Telescope?

- A) H.G. Wells
- B) Albert Einstein
- C) Lyman Spitzer, Jr.
- D) Edwin P. Hubble
- E) James Webb

3. In line 33, *vicissitudes* most closely means

- A) long delays which may compromise the shuttle launch
- B) toxic emissions which may cause corrosion around the mirror
- C) sound waves which may penetrate the mirror
- D) atmospheric conditions which may compromise the mirror
- E) shaking and quivering which may cause changes in the mirror

4. In the context of the passage, which of the following best articulates the author's opinion of the inception of the Hubble?
- A) It was a pipedream with little imminent chance of success.
  - B) It was a literary vehicle with little basis in reality.
  - C) It was an emergency response to the quickening Space Race.
  - D) It was based on a scientific proposition which was not proven.
  - E) It was a waste of time and money which were needed elsewhere.
5. The primary purpose of the passage is to
- A) draw a comparison between H.G. Wells' notion of time travel with Albert Einstein's Special Theory of Relativity.
  - B) discuss the construction of the Hubble Space Telescope as a tool for exploring deep space.
  - C) examine difficulties which precipitated construction of corrective lenses for the Hubble's primary mirror.
  - D) describe the circumstances which underlay the mid-century national drive toward a large space-based observatory.
  - E) dispute the argument that the Hubble Telescope functions as a modern-day time machine.
6. It can be inferred that the author regards time travel as
- A) an effective hook for a work of fiction, but an improbability in the reality of astronomy.
  - B) an interesting literary notion, but proven to be impossible by Einstein's Special Theory.
  - C) a persuasive topic in fiction, as well as a hypothetical possibility in light of Einstein's Special Theory.
  - D) a ridiculous idea whose time has come and gone, as well as an astronomical improbability.
  - E) the incoherent literary construction of a fictional author, with little relevance to today's scientific community.
7. It can be inferred from the passage that scientists believe that time is
- A) a constant.
  - B) unidirectional.
  - C) a spatial dimension.
  - D) an impenetrable mystery.
  - E) an imaginary construction.

## Answers and Explanations

1. The correct answer is **A**.

- I) Correct. It is unable to observe light on the infrared part of the spectrum. It will be replaced by the James Webb Space Telescope in 2014.
- II) Incorrect. It will not be *replaced* by the James Webb Space Telescope in 2014; it will be *complemented* by it.
- III) Incorrect. It was initially constructed as part of the Space Race, but not launched until 1990.

- A) I only
- B) II only
- C) III only
- D) I and II only
- E) II and III only

2. The correct answer is **C**.

- A) Incorrect. H.G. Wells wrote a novella about time travel.
- B) Incorrect. Albert Einstein theorized about space and time.
- C) Correct. Lyman Spitzer, Jr. wrote a 1946 paper about a space-based observatory.
- D) Incorrect. The Hubble Telescope was named after Edwin P. Hubble.
- E) Incorrect. The successor to the Hubble Telescope is named after James Webb.

3. The correct answer is **E**.

- A) Incorrect. There was no mention of launch delays in the passage.
- B) Incorrect. There was no mention of toxic emissions in the passage.
- C) Incorrect. There was no mention of sound waves in the passage.
- D) Incorrect. Although volatile atmospheric conditions were mentioned in the same sentence, this factor that may occur in addition to vicissitudes experienced during launch.
- E) Correct. Vicissitudes are jarring changes or difficulties. Therefore, shaking and quivering which may cause changes in the mirror is the best answer. Even if you don't know the definition of this difficult GRE vocabulary word, you can infer its meaning from the sentences which come before and after. The passage states that, "One of the primary challenges involved in successfully transporting the telescope into space was protecting the mirror from the jarring vibrations that occur during launch," and if this was not accomplished, then, "The precise shape of the mirror could be compromised, and its imaging capability significantly weakened."

4. The correct answer is **A**.

- A) Correct. Astronomer Lyman Spitzer, Jr. mulled over the possibility of a large space telescope in a 1946 report, as explained in lines 16–17. He did not plan the observatory. It was a pipedream with little imminent chance of success.
- B) Incorrect. It was a literary vehicle at the time of H.G. Wells, as shown in line 1. By the 1940s, it was a possibility, as shown in line 17.

- C) Incorrect. It was built during the Space Race because money was available, as explained in line 24.
- D) Incorrect. It was based on scientific facts, as Spitzer explained in his 1946 report, line 17.
- E) Incorrect. A successor telescope is being planned, which would not happen if it were a waste of time or money, lines 42–43.

5. The correct answer is **B**.

- A) Incorrect. Although the passage draws a comparison between H.G. Wells' notion of time travel with Albert Einstein's Special Theory of Relativity, the passage goes on to discuss the Hubble Space Telescope as a time machine.
- B) Correct. The passage discusses the construction of the Hubble Space Telescope as a tool for exploring deep space, such as the Hubble Ultra Deep Field and beyond.
- C) Incorrect. The passage only briefly touches on the difficulties which precipitated construction of corrective lenses for the Hubble's primary mirror.
- D) Incorrect. The passage does not describe the circumstances which underlay the mid century national drive toward a large space-based observatory.
- E) Incorrect. The passage does not dispute the argument that the Hubble Telescope functions as a modern-day time machine.

6. The correct answer is **C**.

- A) Incorrect. The author regards time travel as an effective hook for a work of fiction, but hopes for its implementation in the reality of astronomy.
- B) Incorrect. The author regards time travel as an interesting literary notion, but time travel has not been proven to be impossible by Einstein's Special Theory.
- C) Correct. The author regards time travel to be a persuasive topic in fiction, as well as a hypothetical possibility in light of Einstein's Special Theory.
- D) Incorrect. The author does not suggest that time travel is a ridiculous idea whose time and come and gone, nor does the author suggest that it is an astronomical improbability. The author says that H.G. Wells' idea was popular, and expresses the hope of eventual possible time travel.
- E) Incorrect. The author does not suggest that time travel is the incoherent literary construction with little relevance to today's scientific community. The author says that H.G. Wells' idea was popular, and that the Hubble is, in fact, a time machine.

7. The correct answer is **C**.

- A) Incorrect. Einstein's Special Theory suggests that time can be manipulated through speed of travel, as explained in lines 53–54, so time is not a constant.
- B) Incorrect. Since time might be manipulated through speed of travel, as explained in lines 53–54, it is not necessarily considered unidirectional.
- C) Correct. It is thought to be some sort of spatial dimension, alluded to in lines 46–54.
- D) Incorrect. Einstein's Special Theory suggests that it is not an impenetrable mystery, lines 4–5 and 53–54.
- E) Incorrect. Scientists hope to be able to view beyond the Hubble Ultra Deep Field, which is a time, as explained in lines 45–48. It is not an imaginary construction.

