

## Is it Really Possible to See the Great Wall of China from Space with a Naked Eye?

Dear Editor:

In October 2003, after the first Chinese astronaut Yang Liwie returned from his first journey into Space, a popular belief was apparently called into question when he stated that he had not been able to see the Great Wall of China. Liwie's observation contradicted the information previously presented in several books, board games and various television contests, to quote a few examples. After Liwie's declarations, the Chinese government asked for his statement to be removed from various reports.

The problem arose a few months later when the American astronaut Eugene Cernan stated at a conference that according to the news from the European Space Agency (ESA) issued on the last 11<sup>th</sup> of May, in an orbit between 160 and 320 km, the Great Wall is visible to the naked eye. Various international newspapers rushed to explain that Cernan attributed his colleague Liwie's error to bad atmospheric and/or lighting conditions at the moment of his observation.

In an attempt to further clarify things, the ESA published together with Cernan's declarations a picture of a part of the "Great Wall" photographed from Space. In this picture the wall looked like a route full of bends that resembled river meanders. One week later, when everything seemed perfectly clear and the myth had been finally reborn, another communication from the ESA dated the 19<sup>th</sup> of May 2004 (no longer available in the ESA's website) acknowledged that the Great Wall in the picture was actually a river! The ESA had been warned of its error by Mr. Albert Kisskoy, Pr. Gary Li of the University of the State of California and Dr. Zhimin Man from the Fundan University of Shanghai.



FIGURE 1  
Picture of the Great Wall of China (courtesy of Viviana Fernández).

After this little uproar it is still unclear for some people whether the myth is true or not. In order to answer this question, it is not necessary to go into Space and look: it suffices to know a little about the human visual system and its limits. Not even the best of human eyes at a simple glance could see the Great Wall of China from Space. The impossibility is due to the limitation of the human eye when it comes to seeing small diffusing objects. The relevant parameter is not the Wall's length (about 7300 km), but its width, which is usually less than 6 m. See *Figure 1*. To illustrate this with a simple example, looking at the Great Wall from a distance of 160 km would be the same as looking at a 2 cm diameter cable from more than half a kilometre away! No matter how good the atmospheric conditions, lighting and contrast are—unless the object was self-illuminated or it reflected the sun as a small mirror—it would be totally impossible to see this cable (or, for similar reasons, the Great Wall) at a simple glance, because the eye would need a visual acuity greater than approximately 20/3, which is 7.7 times the normal visual acuity<sup>1</sup>, and more than three times the maximum acuity reached by a falcon<sup>2</sup>, an eagle<sup>3</sup>, or a human eye<sup>4</sup>. Even an optically perfect human eye<sup>5-7</sup> would not be able to see the monument for two reasons. First, the sampling due to the finite cone spacing in the central fovea<sup>5-7</sup> imposes a limit to the visual acuity of 2.3 (about 20/9). In this case, a perfect image of the Great Wall would be about one third the size of a single cone excluding pupil diffraction effects. Second, pupil diffraction effects also limit the human visual acuity to 5 (20/4)<sup>6-8</sup> (for a 6 mm pupil and a 555 nm wavelength). In other words, the edges of the Wall have a spatial frequency that is about two and a half times higher than the cut-off frequency (189 c/deg) of a perfect human eye with a 6 mm pupil. Nevertheless, according to Westheimer experiments<sup>9</sup>, the minimum angle subtended by a line for it to be seen from the distance is approximately only 2 seconds of arc. Such angle is smaller than the one subtended by the Great Wall when observed from Space. Westheimer's results are based on the detection of a black line against a bright background; in this scenario, the black line causes a local dip in the luminance of the image, which makes it possible for the eye to detect it. Such a great local change in luminance also makes the detection of the stars at night possible (if bright enough), as does the reflection of the sun in a small distant mirror (as used in a boat to indicate its position). Therefore, in principle, if the Great Wall reflected the sunlight as a long mirror or it were self-illuminated with high-power lamps it could probably be seen from Space. However, in this hypothetical case, the astronaut would not be seeing the Wall but either the lamps or the sunlight reflection. Moreover, natural sun reflection would be very unlikely due to the type of material it was built with (limestone, clay, granite and brick).

Obviously, it would be even less likely to see the Great Wall from the moon, situated at a minimum distance of 350,000 km, because the visual acuity would have to be 17,000 times (!) better than that of the normal human eye (in this case it would amount to seeing the cable from a distance of more than 1000 km). In this sense, if the question was: "Could we see the Great Wall of China at a simple glance from Space?" The answer would also have to be "no", because an astronaut located on the limit of the atmosphere, about 80 km (50 miles) away, would need a visual acuity of approximately 3.9 (about 20/5) to be able to see it.

As a simple exercise, Google Earth® can be used to see the Wall at lat.=40.48234, lon.=116.180592 if one is close enough to the ground. However, once you are more than 40 miles away, it cannot be seen. This simple experiment does not really answer the question since the visualization of the Wall will depend not only on our vision, but also on the satellite image resolution, our computer screen, etc. Despite this, it can be observed that, at a height of 40 miles, the Wall is not visible but the landing runway of the Yongning Airport, located about 4 miles WNW to the Wall, is. Moreover, if the Great Wall was visible from Space, then, contrary to common claims, it would not be the only visible manmade object since astronauts would also enjoy the view of the Pyramids of Egypt, the Golden Gate Bridge, the Eiffel

Tower, and probably their own house in case it is more than 6 m wide and long.

For some unknown reasons (perhaps marketing-related) this belief is one of the "unscientific walls" that has become popular, imposing a false limit to our vision of the world.

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