Narrowing those limits proved difficult—until Kim, then at Rutgers University, returned from Asymptopia with a differential equation that solved the problem.

Kim's proof starts with a graph that has no edges. He then picks pairs of points at random and connects them whenever doing so does not create a triangle. By working in Asymptopia, he can view the graph as being arbitrarily large, and consequently each edge represents an infinitesimal change. That allows him to describe the process of adding edges with a differential equation, which relates the rate at which edges are added to the total number of additions attempted.

Roughly speaking, the solution to the differential equation shows that edges are added at too high a rate for a large independent set of points to remain unless the graph is very large. When the asymptotic dust settled, Kim found he had bumped the lower bound for $R(3,k)$ up to a multiple of $k^2/\log k$, thus bounding $R(3,k)$ between two different multiples of $k^2/\log k$. "It's an exciting achievement" in Ramsey theory, says Spencer.

Graph theorists aren't the only ones who can benefit from a trip to Asymptopia, Spencer notes. Physicists, especially in statistical mechanics, are accustomed to blurring the line between finite and infinite systems, turning sums into integrals and differences into derivatives. Their intuition is usually very good, says Spencer, but he thinks they might also profit from the mathematicians' rigorous approach. "The hope here is that one can think like a physicist and prove like a mathematician," says Spencer. "If you can do that, then you're way ahead of the game."

–Barry Cipra

ARCHAEOLOGY

Shuttle Radar Maps Ancient Angkor

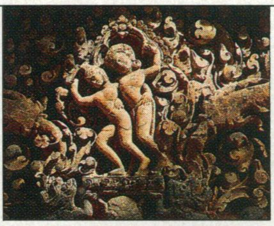
One morning last April, John Stubbs, program director for the World Monuments Fund (WMF) in New York, was leafing through the *New York Times* as he rode the subway to work, when his eye fell on a story about a new earth-imaging radar aboard the Space Shuttle. The story described how the radar had led to the rediscovery of an ancient city in the Arabian desert. Stubbs was so excited by what he read that he got off the subway at the next stop and put in a call to the National Aeronautics and Space Administration.

Stubbs was excited because the WMF has been working since 1989 at the ancient Cambodian city of Angkor, capital of the Khmer empire that ruled much of Southeast Asia from the 9th to the 13th centuries. Much of the site, however, is hidden in jungle, and some lies in territory controlled by the Khmer Rouge. Stubbs realized that the shuttle radar offered a way around these obstacles. NASA agreed, and on 30 September, the Space Shuttle Endeavour passed over Angkor, its radar on.

The resulting image was released last week by NASA's Jet Propulsion Laboratory (JPL) and discussed at a symposium at Princeton University sponsored by the WMF, the Royal Angkor Foundation, and the J. M. Kaplan Fund. The image lives up to Stubbs' hopes. It reveals new clues to the system of canals and reservoirs that sustained ancient Angkor—and has convinced archaeologists that the radar's sensitivity to slight variations in vegetation pattern could be a boon at Angkor and other poorly surveyed forest sites. It's "an unprecedentedly flexible research tool," says Elizabeth Moore, a specialist in Cambodian art and archaeology at the University of London.

The radar, developed by space scientists from JPL and the German and Italian space agencies, combines data collected over a long exposure from the moving spacecraft to simulate an antenna many miles long. The maps that result show features as small as a few meters. That's no better than the resolution of satellite photographs, such as Landsat images. But unlike Landsat, which is sensitive mainly to differences in composition, the shuttle radar, officially known as Spaceborne Imaging Radar-C/X-band Synthetic Aperture Radar, can discern subtle variations in texture. It collects data at three different wavelengths—3, 6, and 24 centimeters—each of which is sensitive to features of a particular size.

The longest of the three—24 centimeters—can also penetrate as deeply as 5 meters into dry ground. That's how an earlier version of the system disclosed the location of the 4800-year-old city of Ubar in the Arabian desert, and how the current radar revealed new details along the ancient Silk Road in the Taklamakan desert. The archaeologists and space radar experts at Princeton agreed that the instrument will never be much use for below-ground mapping in forested areas, because radar can't penetrate moist soil. But the Angkor image shows off the value of the radar's sensitivity to texture. Long after a forest has regrown to cover ancient fields, paths, or canals, subtle alterations of vegetation pattern trace the disturbed areas—clues that the space radar is adept at detecting.


JAMIE JAMES


JPL


JAMIE JAMES

Views of Angkor. The main temple complex of Angkor Wat *(left)* is the bright square near the center of the space radar image; dark rectangles are ancient reservoirs. At top is a relief of a mythological scene.

When Stubbs analyzed the new radar image, he saw linear features to the north of Angkor that Diane Evans, the JPL project scientist, suggested were "residual tracks or paths that hadn't grown over by exactly the same amount as the surrounding areas." Moore, meanwhile, saw evidence of a dam she hadn't noticed in satellite images and aerial photographs. The dam, perhaps part of the ancient kingdom's irrigation scheme, could not have been detected on the ground either, she adds, as it lies in an area controlled by the Khmer Rouge.

Moore is eager to extract more information about ancient Angkor from the space radar image. She has asked Evans and her JPL team to manipulate the data to suppress the rectilinear structures characteristic of classic Angkor, which was under the influence of Indian civilization, and enhance preexisting native circular forms. Stubbs, meanwhile, is hoping to enlist NASA to do more high-tech archaeology, at WMF sites as far-flung as Easter Island, the 2600-year-old city of Butrint in Albania, and the Katmandu Valley in Nepal.

–Jamie James

Jamie James is collaborating on a book about the archaeology of Southeast Asia with anthropologist Russell Ciochon of the University of Iowa.