second angular resolution, says Phil Diamond, head of the UK's MERLIN radio telescope array at Jodrell Bank. "That effectively means seeing cool hydrogen throughout the universe, or peering back to the earliest stages of galaxy formation."

The long list of things to look for with the SKA includes the intergalactic medium just after the Big Bang, star and galaxy formation and evolution, evidence of gravitational waves, and extraterrestrial signals. Says Harvey Butcher, a member of the SKA steering committee and director of the Netherlands Foundation for Research in Astronomy, "As with all megaprojects, it will provide ample scope for as yet unseen discoveries. Scientific fashions evolve on the timescale of large projects, and one does not wish to have an instrument that cannot address the hottest issues of the day, whatever those may turn out to be."

Technically, the SKA could be built today, but not at an affordable price. "We could build 200 copies of the Green Bank telescope, which just opened," says Diamond, but at $70 million apiece, that would be $14 billion (see box on page 72). "We have to prove that for $1 billion, we can build the SKA to cover the science we want."

That will mean detecting signals across two frequency decades, from 0.15 to 20 GHz. SKA planners also want to multibeam, or collect data simultaneously from more than one part of the sky, and to counter interference from the ballooning telecommunications industry. "These capabilities will be ripe for implementation during the coming decade and will make the SKA an entirely new kind of telescope," says Butcher. One of the biggest challenges, adds Diamond, "will be to write clever software to handle all the data."

Another challenge will be choosing a site for the SKA—Australia, China, and the southwestern US are on people's lips. It's likely, says Diamond, that there will be one site with 50–70% of the collecting area, plus smaller outlying arrays scattered over thousands of kilometers, or even globally.

Mammoth to mini

So far, radio astronomers from Australia, Canada, China, Germany, India, Italy, the Netherlands, Poland, Sweden, the UK, and the US have signed on to the project. They're exploring designs for the SKA, ranging from a few mammoth dishes to many mini ones.

ARRAYS OF SPHERICAL LENSES are what Australian radio astronomers hope will prove economically and technologically best for the Square Kilometre Array. (Computer generated image courtesy of Ben Simons/Sydney VisLab/CSIRO.)

On the huge end is China's proposal to line 500-meter geological bowls, called karsts, with panels to form spherical antennas. Nicknamed "Super Arecibo," after the telescope in Puerto Rico on which it's modeled, the Chinese plan would be to create an array of 30 such antennas.

Next in size is the Canadian design, which would use 50–100 nearly flat reflectors, each some 200 meters across. The flatness puts the focal plane a few hundred meters in the air, so receivers would hang from tethered blimps. This design couldn't multibeam, but it's the only one that could cover the full frequency range, says SKA project scientist Russ Taylor of the University of Calgary, adding that manufacturing flat panels would make this design "10 times cheaper than any other."

Jumping down more than an order of magnitude in antenna size is the US idea for the SKA, which would use 50 000 satellite dishes 5 meters or so in diameter. This design is expected to work for a big chunk of the desired frequency band, or 500 MHz–11 GHz (see next story). Metal mesh antennas being developed in India could bring down the price of this approach.

Scientists in Australia are looking into a completely different approach: spherical Luneberg lenses 5–10 meters in diameter that could look in many directions at once (see figure). The lenses would have small conducting splinters, to create an artificial dielectric with a wavelength-dependent index of refraction, embedded into cheap, lightweight Styrofoam.

On the tiny end is the Dutch proposal, with each antenna only 10–15 cm across and no moving parts. The small size would give a huge field of view, and arrays—some or all of the 10 million or so individual antennas—could be electronically steered by phasing signals to pick out a given part of the sky. The electric field, not the radiation energy, is recorded, explains Butcher. "So the interferometery can take place in the computer rather than in the focal plane before detection." This approach would give the best multibeaming, flexibility, and suppression of unwanted noise, he adds, "but it costs too much for the higher frequencies."

It's too early to say which design will be used. They vary in frequency range, possibilities for simultaneous observations, cost, and other factors. "It's a friendly competition," says Taylor. "Everyone would like to have their technology be successful, of course. But I think that if we come up with what we think is best, everyone will fall behind it." Increasingly, radio astronomers expect the final SKA design to be a hybrid.

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Search for Extraterrestrial Life Gets a Steady Eye

Is anyone out there? The chance of spotting signals from extraterrestrials is about to soar, say SETI (Search for Extraterrestrial Intelligence) Institute scientists, who, together with radio astronomers at the University of California, Berkeley (UCB) have begun building the first telescope to look around the clock for life on other planets.

The new telescope got the go-ahead this past August, thanks to $11.5 million from Microsoft cofounder Paul Allen, plus $1 million from physicist and former Microsoft technology chief Nathan Myhrvold. The telescope, an array of mass-produced satellite dishes, will be built at UCB's Hat Creek Observatory near Mt. Lassen, 290 miles northeast of San Francisco.

The Allen Telescope Array is being designed to pick up frequencies from 500 MHz to 11 GHz. SETI scientists will scan signal spectra for narrow bandwidth pulses and continuous waves; radio astronomers, for their part, will use the array in imaging mode to look at such things as pulsars,

Green Bank Telescope Opens

Arrays of radio antennas may be the trend, but, says Phil Jewell, "single dish telescopes still have their place in radio astronomy. They're more sensitive to large-scale structures in the sky, and they can do rapid imaging of large fields." Jewell is site director of the National Radio Astronomy Observatory in Green Bank, West Virginia, where the world's largest fully steerable, single-dish telescope was named in honor of state senator Robert C. Byrd on 25 August.

The Robert C. Byrd Green Bank Telescope replaces the site's 300 Foot Telescope, which collapsed in 1988 under its own weight. The new 100-meter dish was a decade in the making and cost the National Science Foundation about $75 million. It can detect wavelengths from 3 mm to 3 m (0.1–100 GHz).

The Green Bank telescope will be tested over the next few months. Starting next year scientists will use it to study distant galaxies, star formation, pulsars, and astrochemistry, among other things. Says Jewell, "The Green Bank telescope adds another weapon to the overall arsenal we have. It's extremely complementary to [radio telescope] arrays."

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star formation, and galactic remnants. "This is a win–win situation," says Jill Tarter, research director of the Mountain View, California-based SETI Institute. "The Allen Telescope Array can be used by both radio astronomers and SETI scientists all the time."

US radio astronomers are also crossing their fingers that the Allen array design will be chosen for the planned 100-fold larger Square Kilometre Array (see story on page 70).

The clever innovation of the Allen Telescope Array is to use hundreds of commercial-type satellite dishes to keep down the price tag while still getting a large collecting area. The computationally intensive plan banks on Moore's Law continuing; that is, on computing power doubling every 18 months. Says UCB radio astronomer Leo Blitz, "We are looking to design the telescope so that software is the capital cost—the permanent part of the telescope—and the hardware is the operating cost, because we know that whatever we build will effectively be obsolete in about five years. No telescope has yet been designed like this." Details, such as whether to go with 500 5-meter dishes or 1000 3-meter ones—a trade-off between keeping down computing and electronics costs and getting a larger field of view—still have to be worked out.

HUNDREDS OF SATELLITE DISHES will give the Allen Telescope Array a large collecting area at a comparatively low cost. (Artist's rendering courtesy of the SETI Institute.)

The money raised so far should cover building a prototype array by 2003. If that goes well, it's hoped that Allen and other private investors will pony up the rest of the $26 million for the full array, which is scheduled to go online in 2005. The private funding has meant a speedy path from concept to construction. "A government-funded project of this scope necessarily takes much longer," says Blitz.

Coming up with about $1.5 million a year to run the array will fall largely to the academics on the team. But you can help: Donate $50 000 and get your name on a dish.

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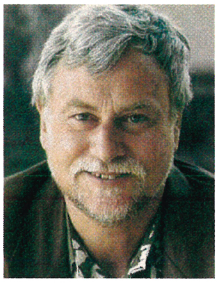
Hawaiian Astronomy Gets New Director, Plans Expansion

Rolf-Peter Kudritzki takes the helm of the University of Hawaii's Institute for Astronomy this month, just in time to start implementing recently approved plans to expand the observatories on Mauna Kea—a job that includes coping with some community opposition and seeking outside telescope builders. The political side of the job made it hard to fill, and Kudritzki's appointment caps a three-year search to replace Donald Hall, who lost the directorship amid claims that he treated solar astronomy unfairly (see PHYSICS TODAY, October 1996, page 62).



KUDRITZKI

The university's plans for beefing up the observatories on Mauna Kea call for, among other things, building a 25–50-meter telescope, doubling the number of antennas in the submillimeter array from 12 to 24, and upgrading many of the site's aging observatories. Up to six 1.8-meter telescopes are also to be added to the twin Keck telescopes, which would make the collection the largest optical interferometer in the world.

However, the university doesn't own most of the telescopes—although it does get free viewing time—so it must attract outside projects to realize these plans. So far, only the Keck additions have been funded, by NASA. "The rest is a projection of what we may expect to be proposed over the next 20 years," says interim director Bob McLaren.

The observatories lie on state conservation land that is sacred to native Hawaiians and home to rare insect species, and a 1998 state audit found the university's management of the mountaintop was inadequate. Although the development plans were scaled back, Nelson Ho of the Sierra Club says there are still too many new telescopes, unnecessary public access restrictions, and not enough funds for environmental and cultural protections.

But Kudritzki says the plans are well balanced and "preserve Mauna Kea as a cultural and ecological site." Among other things, they limit the total area of development to 150 acres, cancel two of the five new observatories originally proposed by the university, require case-by-case approval for all proposals, and rule out building on pristine summit cones, or *pu'u*.

Kudritzki, whose current research interests include the study of hot massive stars and telescope instrumentation, is leaving the directorship of Munich's Institute for Astronomy and Astrophysics to come to Hawaii. He