too costly, says Ennis. For example, fitting the amplifiers on the satellites with better filters to reduce the intermodulation effects responsible for the unwanted, out-of-band emissions, would make the satellites heavier, and therefore costlier to launch.

In June 1994, NRAO signed a memorandum of understanding with Motorola. In it, Motorola guarantees radio-quiet periods, during which out-of-band emissions from Iridium's downlink signals in the 1610.6–1613.8 MHz band will be limited: For Green Bank Observatory in West Virginia, for example, unwanted signal may not exceed –238 dBW/m^2 Hz for four continuous hours late each night; for the Very Large Array in Socorro, New Mexico, and the ten scattered Very Long Baseline Array sites, the agreement specifies higher thresholds that apply 24 hours a day. (These two telescope arrays use interferometry, and can therefore distinguish better than single-dish telescopes between wanted and unwanted signals.) "We have lost some flexibility," acknowledges Thompson. "But we use the hydroxyl band less than 4 hours a day, so we did not have a strong case for objecting to this arrangement." He adds that the agreement "guarantees some unpolluted time, which may become an important precedent as commercial uses of the spectrum continue to grow."

Negotiations between Motorola and Arecibo Observatory—the other major US site for radio astronomy—have yet to be resolved. The Arecibo telescope is a 300 m single-dish telescope—the largest, and therefore the most sensitive, in the world. The Arecibo group sent a proposal to Motorola in August that, like the NRAO/Motorola memorandum, involves time sharing. "But it should be at least a fifty-fifty split," says Baan, who would not reveal more details since the negotiations were still in progress at press time. He is "optimistic that the proposal will lead to an agreement with Motorola."

Outside the US, where Motorola has also been negotiating with radio astronomers for several years, the satellite company is meeting more vocal opposition. In the UK, for example, "Motorola proposes to operate the downlink as if our radio telescopes did not exist," says Cohen. "We could not sign a memorandum of understanding on that basis." Cohen adds that member countries of the European Science Foundation's Committee on Radioastronomy Frequencies, which he chairs, voted unanimously last year not to sign any memorandum of understanding.

Radio astronomers in Australia, too, declined this year to sign an agreement similar to the one Motorola made with NRAO. "Motorola has gone to the trouble of talking to radio astronomers, and I think that they have genuinely attempted to provide protection," says John Whiteoak, deputy director of the Australia Telescope National Facility in Narrabri, New South Wales. "But I was disappointed that they seem to view the NRAO agreement as an indication that radio astronomers are willing to accept harmful interference."

US radio astronomers feel pressure to compromise, in part because, as Thompson observes, "Iridium is the kind of project that is good for the government, good for foreign trade." Some suggest that such economic pressures may soon find their way to Europe and elsewhere: Iridium LLC is an international company, with about 70% of its stock held by non-US interests. (Motorola owns about 25%, according to Bertiger.) Govind Swarup, a radio astronomer who recently retired from the Tata Institute of Fundamental Research in Bombay, India (see the article below), notes that the Indian telecommunications agency is a partner in Iridium LLC, "so we will soon discuss this issue with our government." Emphatically, Swarup adds that "radio astronomers must work together to protect access to the electromagnetic spectrum."

TONI FEDER

India Gets New Radio Telescope

When it becomes fully operable by the end of this year, India's Giant Metrewave Radio Telescope (GMRT) will be the most sensitive telescope in the world in the 38–1430 MHz frequency range.

Located about 80 km north of Pune, at about 19° north latitude, GMRT will be used to observe all of the northern sky and a major part of the southern sky. It consists of 30 fully steerable 45 m antennas: 12 are positioned in a central area that covers about 1 km^2, and the rest form a Y-shaped array around this area that could be circumscribed by a circle approximately 25 km in diameter. GMRT's interferometry design and data collection electronics are modeled partly on those of the Very Large Array (VLA) in Socorro, New Mexico.

GMRT was built for about $17 million awarded to the Tata Institute of Fundamental Research in Bombay by the Indian government. By contrast, the VLA, which was completed in 1981, cost $78.6 million (in 1972 dollars).

Govind Swarup, the project's creator and its director until he retired from the Tata Institute last April, recounts some of the strategies he and his team used to meet the challenge of completing the telescope—including roads and buildings—on this relatively small budget. The antennas in the GMRT array are made of thin stainless

PREM KUMAR

TWO OF THE THIRTY 45 M ANTENNAS that make up the Giant Metrewave Radio Telescope near Pune, India. The angular resolution at 21 cm (1420 MHz), the shortest wavelength at which the array operates, is about 2 arcseconds, equivalent to a single 25 km diameter dish.

steel wire mesh and steel rope trusses (see photo on page 73). This design, explains Swarup, "allows wind to pass through," and thus presents less wind resistance than would a solid dish. Moreover, the wire mesh dishes weigh less than solid ones, so that smaller—and cheaper—gear boxes and motors can be used to steer them. And, adds Swarup, the radio-wave reflection is good: "About 95% at the shortest wavelengths, and better for longer wavelengths."

To see how the antennas would hold up in a hailstorm, Swarup and his colleagues froze water-filled balloons, and then hurled them from a moving car at test panels made of wire mesh. "Nothing broke when we threw 2 cm ice balls at 70 km/hr," says Swarup, "and hail will not have a stronger force than that." Willem Baan, a radio astronomer at Arecibo Observatory in Puerto Rico, says, "GMRT will be an important telescope, and it is very impressive what they have done on such limited funds." Nearly all parts of GMRT were made in India.

GMRT will be used to observe a series of radio astronomy spectral lines, including the 1420 MHz atomic hydrogen line. Swarup, who is now emeritus but remains very involved, says that at this frequency, "We will look for supergalactic-sized hydrogen clouds to test Big Bang theory predictions regarding galaxy formation."

Swarup says that some of the antenna receivers will be modified in 1998 to extend the observation range of GMRT to include the 1612 MHz hydroxyl spectral line. This, of course, means that he and his colleagues are concerned about possible interference from the Iridium global mobile telephone system. "So far, it is relatively radio-quiet in India. It's an underdeveloped country, and even taxi drivers don't have walkie-talkies. But this is changing."

TONI FEDER

IUPAP General Assembly Held in Sweden

The International Union of Pure and Applied Physics (IUPAP) held its general assembly in Uppsala, Sweden, in September. Burton Richter, director of the Stanford Linear Accelerator Center and winner of the 1976 Nobel Prize in Physics, was elected president-designate. Sweden's Jan Nilsson moved from that position to become president,

JAN NILSSON

BURTON RICHTER

succeeding Japan's Yoshio Yamaguchi, now past president. And France's René Turlay was elected secretary general. The new office holders will serve until the next general assembly is held in 1999, in Atlanta, Georgia. Each has a seat on IUPAP's governing council.

IUPAP is a nongovernment organization and a member of the International Council of Scientific Unions (ICSU). It has 20 commissions (and 2 affiliate commissions) representing various physics fields, including a new commission for computational physics that was established at this year's general assembly. The assembly also approved a request by the acoustics commission to change its status next year to that of an affiliate—a change that will somewhat weaken its ties to IUPAP. "Acoustical societies have many nonphysicist members, and they need better international representation than IUPAP provides," explains commission member Lawrence Crum, of the University of Washington.

In addition, the assembly delegates, who represented member physics academies from about 45 countries, voted to give commission chairs seats on the council for the first time: 5 of the 8 seats that have always been for vice presidents were redesignated. The change was made so that the IUPAP council will get more input from the commissions, or, as Richter puts it, "from where the action is."

IUPAP sponsors about 30 international conferences each year. Nilsson, who has been active in IUPAP governance for nearly 25 years, says that he wants IUPAP to take a more active advisory and lobbying role in, for example, the setting of guidelines for the establishment and use of large international physics facilities (for which a resolution was passed in Uppsala). He also wants IUPAP to create international guidelines in communications and publications "to ensure a reliable flow of scientific information to all scientists, including in developing countries."

"During the cold war, IUPAP was a bridge for scientists between the East and West," says Richter. He and Nilsson agree that now the main aim is to figure out what IUPAP's role in the future should be, and to set new long-term goals.

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AIP Surveys Find Enrollment Losses, Salary Gains

US enrollments in physics continued to fall in 1995, but at least some physics degree recipients commanded higher starting salaries than in the previous year, according to two surveys recently released by the American Institute of Physics.

According to the graduate student survey, there were about 13 300 physics graduate students in the US in 1994–95, down 6% from the previous year; that group included a first-year class of 2600, which was 10% smaller than in 1993–94. A total of 1461 physics PhDs and 985 master's degrees (excluding a master's earned en route to a PhD) were conferred in the US during the 1994–95 academic year. Women comprised about 16% of the graduate student population, 17% of master's degree recipients and 12% of PhD recipients.

Among the PhD recipients who found work in the US, 59% accepted postdoctoral appointments and 9% took temporary positions other than postdocs. Of the remaining 32% who