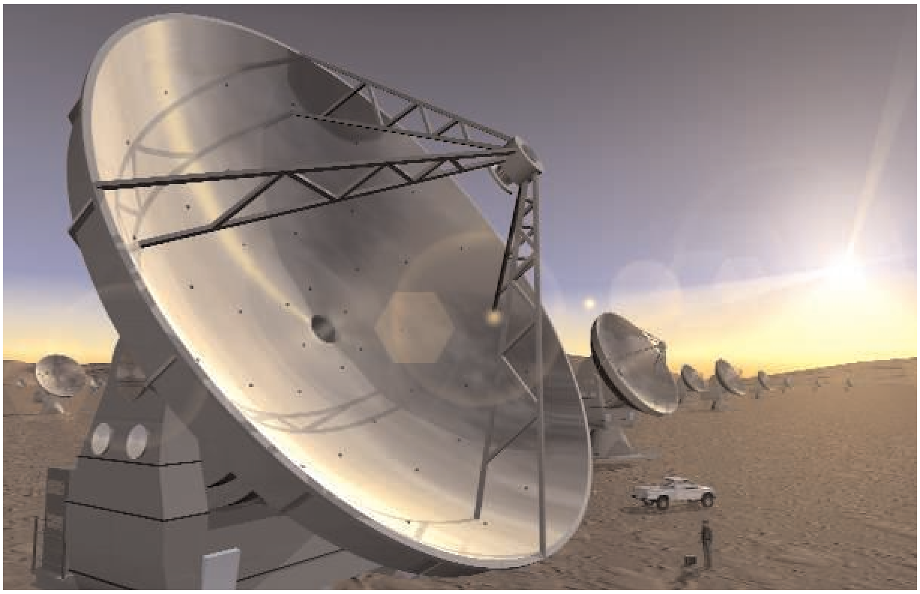
times. "This is something we couldn't have done 4 or 5 years ago," she says. In addition to the greater emphasis on accountability spawned by the 2001 federal No Child Left Behind law, Schielack cites the growing recognition that some countries, notably Singapore and China, excel on international student comparisons because of a national curriculum that focuses on a small number of topics and policies that give teachers the necessary training and resources to get the job done. "That's the biggest difference between the United States and the top-achieving nations," agrees Milgram. "Having NCTM come out with a statement to this effect should make an enormous difference on what we expect kids to learn."

Even so, nobody expects Common Ground and focal points, by themselves, to usher in a golden age of quality mathematics education. There's too much that remains to be done. "It's a long, long journey," says Hung-Hsi Wu, a mathematician at the University of California, Berkeley, who runs summer institutes for classroom teachers whose grasp of basic mathematics is often poor or nonexistent. "Better mathematics education in the United States won't take place in the next 10 years. I think it will take 30 years."

At the age of 60, Schaar doesn't plan on staying in the line of fire for quite that long. But he's not ready to saddle up and ride out of Dodge. Schaar believes that Common Ground, funded by NSF and TI and staffed by the Mathematical Association of America, has restored a measure of civility to the debate. And this month, after a coalition of 16 leading mathematical societies applauded his 2-hour presentation and told him to keep up the good work, he said that kind of support is exactly what's needed.

"I'm not looking for an endorsement," he says. "I'm looking for help in getting more people involved." A bigger "in" crowd means fewer outcasts. And that's good news for a sheriff.

–JEFFREY MERVIS



All together now. For different observing jobs, ALMA's 50 antennas can be rearranged with a giant purpose-built truck.

CREDIT: H. ZODET/ESO

ASTRONOMY

After a Tough Year, ALMA's Star Begins to Rise at Last

Cost hikes, scarce labor, and management changes have buffeted the first global telescope array, but new funding agreements may augur smoother sailing ahead

The world's largest ground-based astronomy project, the Atacama Large Millimeter Array (ALMA), is back on track after a tumultuous couple of years that have seen costs balloon by about 40% and the capability of the enormous microwave telescope scaled back.

ALMA, with an overall budget now in the region of $1 billion, is a collaboration between the United States, the European Southern Observatory (ESO), and Japan, plus minor partners Canada and Spain. As a result of skyrocketing prices in commodities needed to build its antennas and huge hikes in labor costs in Chile, where ALMA is being built, astronomers have had to go cap in hand to their funders for more money. ESO agreed to swallow its share of the increases last autumn, but it was not until last week that the U.S. National Science Foundation (NSF) won agreement from its governing board. "It's been a fairly intense 18 months," says astronomer Christine Wilson of McMaster University in Hamilton, Canada, chair of ALMA's scientific advisory committee.

"I'm told that most big projects go through something like this," Wilson says. "Cost increases are a given." But for researchers waiting to see whether funders would keep faith with the project, the process has been nerve-wracking. "We were holding our breath back in the summer and fall for ESO," Wilson says. "It's been a very stressful situation for everyone in the project." U.S. team members had to await the outcome of a series of cost reviews, but in a meeting on 10 May, the National Science Board gave NSF permission to increase U.S. spending on ALMA from $344 million to $499 million, subject to the approval of Congress. According to ESO's Thomas Wilson, European project scientist on ALMA, during these discussions there was an unspoken warning from the funders: "This is it. Don't come back and ask for more."

ALMA, the first truly global effort in ground-based astronomy, grew out of three separate projects. U.S. astronomers started discussing a Millimeter Array in the mid-1980s; European plans for a Large Southern Array took shape about a decade later. ESO and the U.S. National Radio Astronomy Observatory (NRAO) in Socorro, New Mexico, began discussions on merging the two projects in 1997 and in June 1999 agreed to build a joint instrument comprising 64 12-meter antennas spread over an area up to 12 kilometers across. The array took its new name from Chile's Atacama desert, where researchers had found a wide plateau, the Llano de Chajnantor, which at 5000 meters altitude is high enough and dry enough to avoid most of the atmospheric water vapor that blocks signals at the wavelengths ALMA is designed to receive.

The push for such an instrument came because better receivers, fast digital electronics, and antenna design were improving the capabilities of millimeter-wave telescopes. Astronomers calculated that a large number of receivers arranged as an interferometer could rival the resolutions of the best optical instruments, such as Hubble and ESO's Very Large Telescope in Chile. At millimeter and submillimeter wave-

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lengths, astronomers can study the lowest-energy emissions from simple molecules. With ALMA, they hope to peer into star-forming galaxies when the universe was young to see whether stars formed in a burst early on or more steadily over a long period. Closer to home, they can see whether disks of dust and gas around young stars—places where planets could form—are commonplace or rare.

Japan, which had been developing its own Large Millimeter and Submillimeter Array, joined the club in 2001. The plan is for Japan to construct a parallel instrument, the Atacama Compact Array (ACA), made up of 4 12-meter antennas and 12 7-meter antennas. Sited next to the main array, ACA will be better able to image extended diffuse objects. In addition, Japan is providing receivers to cover three extra wavebands for antennas in both ACA and the main array.

At first, everything moved along according to plan. Prototype antennas for the main array were ordered from two suppliers, one in Europe and one in the United States. Work crews began preparing the site at Llano de Chajnantor in late 2003. Once delivered, the prototype antennas were put through a series of tests at a specially built facility in Socorro, home of the Very Large Array radio telescope. Testing was completed in April 2004 with a view to awarding the antenna contracts—the biggest items on the ALMA shopping list—later that year.

ALMA researchers, however, were not happy. "The first round of tests were not conclusive," says Thijs De Graauw of SRON, the Netherlands Institute for Space Research, and chair of ALMA's management advisory committee. "There were valid concerns," adds astronomer Lee Mundy of the University of Maryland, College Park. "They were asking for a very precise antenna and wanted to make sure it could accomplish the science."

New tests were ordered, but the delay proved costly. At the time, the prices of commodities essential for the antennas' construction, such as steel, were going through the roof. And as the extra tests dragged on into 2005, ALMA managers had to ask the manufacturers to resubmit their bids for building the production antennas. The bids came in much higher than managers had expected and threw the project into crisis. Asked whether ALMA could make do with fewer antennas, the scientific advisory committee concluded that the array could achieve its primary science goals with 50 rather than 64 dishes, but observations would take longer and would be more prone to systematic errors. An array of less than 50 instruments would still be "a superb instrument," the advisers said, but its goals would be compromised.

"We decided to reduce the number of antennas so the cost increase would not be too large," says ESO Director General Catherine


High and dry. With a Chilean construction boom in progress, ALMA managers are having trouble finding people to work in the thin desert air 5000 meters above sea level.

CREDIT: HANS HERMANN HEYER/ESO

Cesarsky. The North American team went ahead in July 2005 and placed an order for 25 antennas, with an option to buy another seven. ESO was poised to follow suit, but then it hit another snag. Under its rules, it had to take the lowest bid that met specifications. ESO had planned to buy from the same company NRAO had ordered from, VertexRSI of Kilgore, Texas. But the European consortium led by French-Italian company Alcatel Alenia Space submitted a cheaper revised bid. Before signing on the dotted line, Cesarsky says ESO waited to see a cost review of the whole ALMA project that was completed in October and carried out a review of all its programs to see whether enough economies could be made to cover the extra costs.

Concerns remained even after ESO ordered its 25 antennas from Alcatel last December. Some researchers worried that having two sets of antennas from different suppliers would increase costs down the line because it would require double the number of technicians and spare parts. But in January, a "delta" review of the increased cost reported that it was unlikely to be more than 1% of ALMA's total budget. Meanwhile, other costs were also draining ALMA's coffers. Chile's economy has been booming, and the consequent boost to the construction industry has made labor hard to find and more expensive. In addition, copper prices are at an all-time high, and northern Chile has extensive copper deposits. Chilean workers, it turned out, would rather mine copper than work in the cold airlessness of 5000 meters.

Labor troubles have exacerbated another hurdle ALMA is working to overcome: learning to manage a global engineering project. "Astronomers are not used to this scale of project," Mundy says. "It's taking astronomy into the big league." Some have charged that managers' cost estimates at the start of the project were unrealistic and that ESO based its estimated construction costs on the other observatories it had built in Chile, which were all at lower altitudes. "Assumptions were optimistic," says De Graauw. "Errors came from not knowing in enough detail what was to be built." Says Mundy: "In a project of this scale, managers and management systems are needed. These were not components of the original pricing."

Cesarsky acknowledges that running the project with two management teams separated by the Atlantic has been difficult: "It was not clear who should make decisions. A strong central management was needed." More control has now been put in the hands of the Joint ALMA Office in Santiago, Chile's capital, Cesarsky says.

The flurry of reviews that have assessed the project from within and from outside have now given it a clean bill of health. "I think things are going along very well," says Al Wootten, ALMA's North America project scientist. But for researchers, the necessity to cut back the number of antennas to 50 rankles. "People are unhappy about it still," says ESO's Wilson. Cesarsky thinks there's still a possibility that the array can be built at full strength, "if we're lucky and have not spent our contingency." Not everyone is so positive. "Do we skimp and endanger the whole instrument? Surely it's better to do it right once," argues Mundy. "I haven't heard any way to get there, but the door is still open."

–DANIEL CLERY