January 21, 2007

The Antarctic Sun

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Jerry Marty / Special to *The Antarctic Sun*

SPT
An Eye to the Past

Scientists seek big discoveries with new tool

By Steve Martaindale
Sun staff

John Carlstrom has taken some pleasure from stirring up things around the South Pole this summer during construction of the South Pole Telescope.

"This thing's sitting out there and it's erupting; it's growing," he said in December. "It's going to be the largest thing out there. Everyone is [excited about it]."

The principal investigator for the

See SCIENCE on page 11

Related stories:

- Astronomers love conditions at Pole. Page 7
- Why is the SPT so large? Page 8

Pole turns 50

By Steve Martaindale
Sun staff

A mere 20 days after it was demonstrated that an airplane could land and take off from the South Pole, a small team of men was deposited at that loneliest imaginable spot, charged with the task of building a permanent station.

That was in the early morning hours of Nov. 20, 1956. Barely 45 days later, on Jan. 4, 1957, the last of the 24 men returned to McMurdo Station, leaving behind a functioning facility in the hands of those who would spend the first winter ever at the South Pole.

The significance of that accomplishment was lost on neither those men nor on the people who today continue to maintain a human presence at 90 degrees south.

"It was a demanding team effort, and everyone I know who was involved takes great pride in it," said Dick Bowers, who led the construction of the station 50 years ago.

"They established a platform for a U.S. pres-

See BIRTHDAY on page 14

VIPs on Ice

New Zealand Prime Minister Helen Clark, second from right above, is flanked by Sir Edmund Hillary and Scott Base Station Manager Mike Mahon upon arriving Jan. 18. Pictured at left are National Science Foundation officials Arden Bement, left, and Erick Chiang. See more on page 2.

Photos by Peter Rejcek / *The Antarctic Sun*

A historic occasion

Peter Rejcek / *The Antarctic Sun*

Sir Edmund Hillary, center, talks to members of the New Zealand media at Pegasus White Ice Runway just minutes after arriving to the continent on Jan. 18. He traveled to Antarctica to commemorate the 50th anniversary of New Zealand's Scott Base. The New Zealand prime minister and National Science Foundation Director Arden Bement also arrived on the flight, along with several members of the U.S. State Department.

Scott Base was established on Jan. 20, 1957, during the 1955-58 Commonwealth Trans-Antarctic Expedition, which completed the first overland crossing of Antarctica via the South Pole. Hillary led a supply support team for the expedition, which was the group responsible for establishing Scott Base.

Hillary, now 87, was last in Antarctica in late 2004 for the dedication of Hillary Field Center, a field equipment supply center at Scott Base named in his honor.

Prior to establishing Scott Base, Hillary, along with Sherpa mountaineer Tenzing Norgay, became one of the first two climbers to summit Mount Everest in 1953. He is the only living New Zealander to appear on a banknote (the New Zealand five dollar bill).

Cold, hard facts

South Pole Telescope

Number of unique aluminum panels that make up the primary reflector: **218**

Operating temperature of superconducting detectors: **about 0.25 degrees Kelvin (a quarter of a degree above absolute zero)**

Number of structural bolts: **5,162**

Number of manual, micron-precision adjustments necessary to properly align panels: **1,744**

Amount of data to be generated daily during operation: **120 gigabytes**

Weight above the steel foundation: **600,000 pounds**

Height above snow: **75 feet**

Diameter of ground screen (to be built summer 2007-08): **150 feet**

Time to design: **2.5 years**

Time to fabricate parts: **1.5 years**

Source: spt.uchicago.edu

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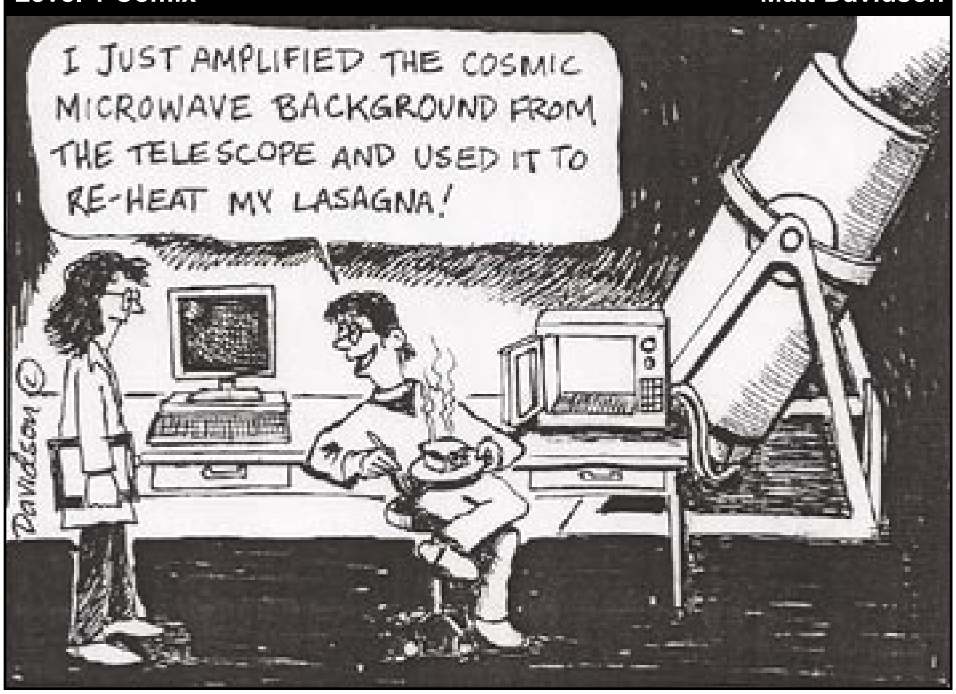


Peter Rejcek / *The Antarctic Sun*

Xavier Cortada:

"I've never been so PROLIFIC and INSPIRED as I've been here. It's been the ULTIMATE artist residency."

Miami artist Xavier Cortada puts the finishing touches on a painting he created while at McMurdo Station. He donated the piece to the local community.

Cortada reinvents style during Antarctic visit

By Peter Rejcek
Sun staff

Miami artist Xavier Cortada came to Antarctica to spread the word about climate change and to educate the public in the little-known scientific and historic facts about the seventh continent. But he didn't quite expect for his brief journey here to change his own artistic style so radically.

The artist's traditional work pulses with tropical colors, as if living jungle had flung itself onto canvas to be recast in Technicolor wonder. A mangrove seedling seems to serve as his most holy symbol, representing the roots of community in the way that the seed, when it washes up on a sandbar, grows and creates a new ecosystem.

Yet, in the scores of small watercolor paintings spread around a laboratory room in McMurdo Station's main science building, Cortada's bold colors, his familiar symbols and splashes of style, are missing. The cool blue colors of glacier ice swirl in abstract shapes on 8-by-11 papers, peppered with texture thanks to soil samples from the McMurdo Dry Valleys.

Boxes of paint tubes and bottles will return with him to Miami unused. Blank canvas sits in a nearby chair, folded like bed sheets.

"Instead of going home with drawings of icebreakers and mountaintops, I'm going home with abstract pieces created from samples of Antarctica, and I think that's good, that's the exploration and resonance it was created from," said Cortada, his round face beaded a bit with sweat from the overheated room. He was trying to dry the paintings, still wet from the sea ice that he had used both as a watery base for his paints and as a brush, before flying north the next day.

"I've never been so prolific and inspired as I've been here," he added. "It's been the ultimate artist residency."

It was also a fast-paced residency under the National Science Foundation's Antarctic Artists and Writers Program. Cortada churned out a half-dozen pre-planned projects in just two weeks, including several temporary installation pieces at the South Pole. He flew there for a one-day mad scramble, though at one point weather threatened to cancel the venture altogether.

But a window opened in the weather on Jan. 4 – 50 years to the day when construction of the first U.S. South Pole station was completed – and he and his partner Juan Carlos Espinosa, a musician and sound artist, reached 90 degrees south.

Cortada called one temporary exhibit Longitudinal Installation. It involved placing 12 pairs of nondescript black shoes around the ceremonial South Pole, which resembles a barbershop pole topped with a mirrored orb like the tip of some magician's wand. Inside the sole of all 24 shoes, he had painted degrees of longitude, so that each shoe would represent 15 degrees of distance. At the Pole, where the world converges, they conceptually come together in a tight circle.

He chose 24 news items from around the world that would roughly correspond to the longitudinal location of each piece of footwear. Each clip was a voice in the global wilderness, a warning about the impacts of environmental degradation. He read each news story aloud. Espinosa recorded the performance, which took place in temperatures that dipped to about negative 17 degrees Fahrenheit.

For example, one news item from Colorado at 105 degrees west said, "In Colorado, climate change means less snow, less water, more wildfires, less biodiversity and less economic opportunity, as there is less water available for development."

"I wanted to make the South Pole this global campfire where people would come and talk," Cortada explained. "The South Pole is where all these longitudes converge … by literally putting these people's voices inches apart from one another from where they stand on the world at the South Pole, I conceptually diminish the distance, so we can empathize and care more."

The next project was somewhat similar, but Cortada expanded the notion of how human-induced climate change affects not just people but also other species. He painted 24 flags with degrees of longitude and the scientific names of 24 endangered or threatened animals.

Both installations will be reproduced for a June exhibit in Oslo, Norway, for United Nations World Environment Day 2007, in a show the Natural World Museum is producing in partnership

See ART on page 4

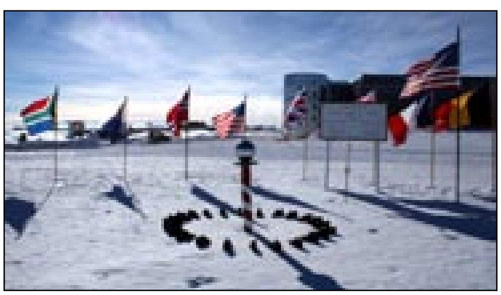
Art brings awareness to environmental issues

Courtesy of Xavier Cortada / Special to *The Antarctic Sun*

Xavier Cortada paints a flag for one of his installation pieces at the South Pole. The 24 flags represent endangered or threatened species.

Courtesy of Xavier Cortada / Special to *The Antarctic Sun*

Cortada donated a portrait that he painted of Ernest Shackleton to the South Pole Station.



Courtesy of Xavier Cortada / Special to *The Antarctic Sun*

Twenty-four shoes circle the ceremonial South Pole marker, representing lines of longitude that converge at the bottom of the world.

Peter Rejcek / *The Antarctic Sun*

Experimental water colors are laid out to dry in a lab room at the main science building in McMurdo Station.

From page 3

with the United Nations Environment Program. Cortada has created works for numerous public institutions, including the White House, the World Bank, the Florida capitol, the Florida Supreme Court and the Miami Art Museum.

Not all of the Antarctic projects revolved around the theme of climate change and global warming. A different concept played with time. Cortada poured South Pole water into the mold of a mangrove seedling to create an ice counterpart to one of his familiar symbols. He then buried the inorganic seed at the geographic Pole, which rests on a moving ice sheet. In about 150,000 years, Cortada said, that seed would reach the Weddell Sea.

Cortada said the piece reminds people that the immediacy of political or societal concerns is far less important than we might think. “We forget that we’re just a small passing moment in a broad spectrum of time.”

He stretched out a shorter timeline in Markers. For this installation, Cortada dug 50 holes to plant flags that correspond with the 50 spots where the geographic marker has stood over the last half-century. The ice sheet moves about 30 feet, or 10 meters, each year and the marker is relocated on New Year’s Day. Cortada chose pivotal, inspiring moments from history to represent each year. For instance, the marker for 1989 represents the fall of the Berlin Wall.

This geological timepiece was half a kilometer long. “I love the idea of a moving ice sheet to explain Antarctica,” Cortada said.

The prolific artist didn’t stop with these one-hit wonders designed to shock the mind off its normal line of thinking. He also painted a portrait of Antarctic hero and explorer Ernest Shackleton while he was in McMurdo and presented the painting to the South Pole station management during his brief visit.

“Shackleton to me is the epitome of the Antarctic hero,” Cortada said. “He opened up this continent to us.”

Shackleton failed to reach the Pole in life. Cortada imbued his painting of the famed British explorer with some unusual elements for his long overdue arrival. He used GIS maps of the continent that traced Shackleton’s various expeditions. He also overlaid historical photos for the portrait before painting it. The materials used in the paint included glacial ice, dirt from the Dry Valleys and even crushed crystals from Mount Erebus.

“I think the painting is very significant,” said Jerry Marty, the National Science Foundation representative at South Pole. “Shackleton’s Antarctica expeditions and his leadership pioneered – almost 100 years later – a continent being used for scientific research, without ownership, and for peaceful purposes.

“The temporary installations of climate change and notions of geologic timeline were very powerful,” he added.

Antarctica exerted its own power on Cortada, particularly for his last project, an 8-by-4-foot painting that he donated to the McMurdo community. The second-generation Cuban-American artist combined his traditional style with his emerging intuition for abstract images. He had solicited comments from people at McMurdo’s local art show for the piece. The question: why had they come to Antarctica?

Participants wrote their answers on note cards, which he adhered to the borders of the canvas, a GIS map of the Ross Island region. Jess Walker, a GIS analyst at McMurdo who creates the maps for the U.S. Antarctic Program, worked with Cortada on finding the right maps for his projects.

“I think there’s a lot about a map that lends itself to artistry,” Walker said. “We spent quite a bit of time looking at maps.”

The Ross Island map particularly appealed to Cortada because of a whimsical swirl on the left side of the digitally created image, the turning basin created by the annual icebreaker in the sea ice.

“It’s like a doodle on the water,” he exclaimed, apparently delighted by the playful imagery the shape lent to the overall image. Ross Island, where United States and New Zealand science stations sit, disappeared under a firework display of color created by Cortada’s brush. Over the note cards, he wrote in all of the science events for the season. The final layer of the painting again included some texture thanks to the Dry Valleys.

“I’ve used Dry Valleys’ dirt everywhere,” said Cortada. “I wanted Antarctica in the art.”

And Cortada wants back in Antarctica. He said he already has plans to apply for another NSF grant. The artist has not fully fleshed out the concept, but he would like to venture to the Dry Valleys or Mount Erebus with a field team for several weeks.

“Part of my excitement about this has been dealing with the Antarctic scientists,” he said.

NSF-funded research in this story: Xavier Cortada, Antarctic Artists and Writers Program, www.cortada.com/antarctica.

around the continent

PALMER

Tourist season in high gear

By Kerry Kells
Palmer correspondent

Palmer Station continues to host cruise ships and yachts for tours of the station.

The *Spirit of Sydney* stopped by with passengers from Australia, Great Britain, Canada and the United States. The 94-foot-long motorized yacht *Whale Song* also made a visit. The ice-strengthened yacht cruised from Massachusetts south to the Caribbean, then to northern South America. It traveled about 800 miles up the Amazon River and then down the Brazilian and Argentine coasts. The passengers traveled to the Falkland Islands and south to the Antarctic Peninsula.

Palmer also welcomed back the National Geographic *Endeavour* cruise ship. On board the *Endeavour* was former Palmer resident Fen Montaigne, who has written for National Geographic about the environment and research here at Palmer Station and also worked directly with the seabird research team.

Principal Investigators Richard Lee, from Miami University Department of Zoology, and David Denlinger, from Ohio State University in Columbus, recently returned to the station. Two research team members return this year with the entomology project: Ph.D. students Joshua Benoit and Michael Elnitsky. Glen Schulte, a high school science teacher, is here as part of the educational outreach program with Miami University and Lee's entomology group.

The team will investigate four Antarctic terrestrial arthropods found in the peninsula area. These include a springtail, or *Cryptopygus antarcticus,* which has six distinct legs and a segmented body; the mite (*Alaskozetes antarcticus*), which is one of several species in the area; the tick (*Ixodes uriae*), which feeds on penguins and other seabirds; and the midge, a wingless fly known as *Belgica antarctica*, the largest terrestrial animal that resides year-round in Antarctica.

Curt Smith / Special to *The Antarctic Sun*

Seabird researchers Brett Pickering and Hannah Lucas attach a radio transmitter to an Adélie penguin on Humble Island. The scientists have now attached the transmitters to 20 Adélies.

This project focuses on the stress tolerances of the midge, which exhibits remarkable resistance to environmental stresses such as cold, heat, dehydration, anoxia (lack of oxygen), freshwater, salinity and pH. The group will define microclimate variability and environmental extremes experienced by the midges. Its lab work will examine the insects' physiological and molecular mechanisms to these environmental stressors.

Schulte is a high school teacher from the Cincinnati, Ohio public school system. His Web site follows his daily experiences at Palmer Station as well as his participation and assistance in the collection of insects for the study. For more information, go to edonice.org.

The seabird researchers have attached radio transmitters to 20 Adélie penguins (10 males and 10 females) on Humble Island, which has a radio receiver. The transmitters alert the scientists to when the

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the week in weather

McMurdo Station	Palmer Station	South Pole Station
High: 45 F / 7 C	High: 50 F / 10 C	High: -5 F / -21 C
Low: 21 F / -6 C	Low: 33 F / 1 C	Low: -19 F / -28 C
Min. wind chill: 10 F / -12 C	Max. sustained wind: 34 mph / 55 kph	Peak wind: 35 mph / 56 kph
Max. sustained wind: 33 mph / 54 kph	Melted precipitation: 1 mm	Max. physio-altitude: 3,168 m

Continent

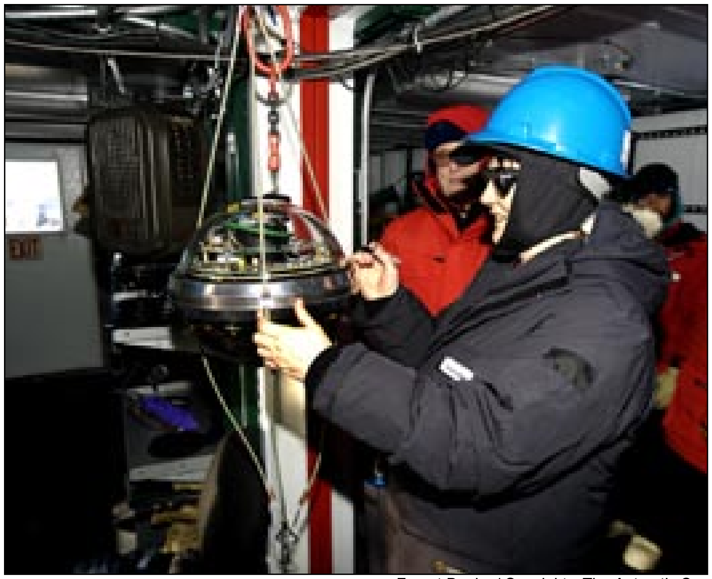
From page 5

penguins are on the island. This allows the researchers to see how long the penguins are away and how long they stay on the island.

The length of time the penguins are away gives the researchers an idea of where the penguins forage for food. The seabird researchers also continue to do giant petrel satellite transmitter work on Humble Island.

Weather has varied this past week, with sunny skies, rain, storm clouds and everything in between. Humpback whales were spotted off DeLaca and Janus islands several times.

The British Antarctic Survey vessel the HMS *Endurance* will soon visit Palmer Station.



Forest Banks / Special to *The Antarctic Sun*

New Zealand Prime Minister Helen Clark signs an IceCube digital optical module at the South Pole on Jan. 19. The prime minister is visiting the continent with several distinguished guests, including Arden Bement, director of the National Science Foundation, who can be seen watching Clark in the background.

SOUTH POLE

Pole breaks population record

By Katie Hess
South Pole correspondent

The second week of January was momentous for South Pole cargo, which successfully received just a little less than 1 million pounds of cargo and fuel from 34 LC-130 flights, according to cargo supervisor Paddy Douglas. These flights also delivered many passengers who bumped up station population to its record high of 266.

Several distinguished visitors toured South Pole Station last week including New Zealand Prime Minister Helen Clark; the director of the National Science Foundation, Arden Bement; and several members of the U.S. State Department.

An Antarctic Treaty inspection team made up of representatives from France, Sweden and New Zealand also joined us.

The IceCube neutrino detector group, South Pole's largest population of researchers, deployed its ninth string of digital optical modules last week. The team projects completing three more this season and may shoot for more than 12 next summer as the massive construction effort continues.

South Pole meteorology observed a record-breaking daily high wind speed for Jan. 14 of 30 mph. The previous record for this date was 28 mph set in 1980. The blustery storm decreased visibility to 100 meters, drifted much snow around buildings and down the skiway and pushed the mercury as high as negative 5.4 degrees F – the warmest temperature at the Pole so far this summer.

Meteorology also posted the annual report for 2006 last week. It notes four record daily maximum temperatures set in the month of January, followed by five peak wind gust records set in April and one in August. It also shows a whopping 13 daily minimum record temperatures set throughout the year, with a record average monthly low temperature set for October. Despite some exceptionally cold days, the overall average temperature for 2006 was only 1.8 degrees F below normal.

South Pole residents had their eyes to the sky last week as the McNaught Comet was visibly present in the daytime sky. Known officially as C/2006 P1, the comet has been estimated to be the brightest in decades and has been the source of much delight here at the South Pole.

When it comes to pure, creative recreational bliss, Polies anxiously welcomed the Jan. 20 premiere of the South Pole International Film Festival 2007, which highlights amateur films from station residents.

SHIPS

NBP

Compiled from reports by Jim Dolan
Marine projects coordinator

The *Nathaniel B. Palmer* returned to the southern end of the Adare Trough in the Ross Sea following a brief diversion last week. Scientists aboard the *NBP* continued scientific research related to seafloor spreading and other geological features of the seabed.

Fair weather and calm seas favored the ship for much of the week. Dredging operations got under way and the scientists recovered samples that included several glacial dropstones as well as indigenous volcanic material. The dredging procedure effectively recovered samples on virtually every opportunity.

The weather deteriorated by Jan. 15, with 10-foot seas.

LMG

Compiled from reports by Andrew Nunn
Marine projects coordinator

The Palmer Long Term Ecological Research cruise aboard the *Laurence M. Gould* continued, with the recovery and then redeployment of a sediment trap in the study area on Jan. 11.

The conductivity, temperature and density (CTD) cast stopped communicating at 100 meters during the first cast on Jan. 14.

Subsequent troubleshooting failed to restore communications so the instrument set was transferred to the backup CTD. While the CTD was re-configured, the *LMG* headed to Armstrong Reef at the south end of Renaud Island so that the bird researchers could go ashore for their annual survey.

The birders conducted shore operations at Armstrong Reef for 12 hours the next day. They visited five separate islands and reported success in placing transmitters, taking diet samples and conducting population surveys.

While the shore operations were taking place, the ship's Zodiac, equipped with an echosounder (on loan from Palmer Station), mapped a new route into the southern approach of the reef and charted a new, more sheltered waypoint at half the distance from the islands as the previous drop-off point. This new location should provide greater flexibility in conducting operations at Renaud under various weather conditions in future years.

After leaving Renaud Island, the *LMG* returned to its grid transect of the study area. It eventually arrived at Avian Island to conduct operations at the high-density grid (HDG). The HDG consists of continuous Biofish tows combined with three CTD stations and other work to map the foraging area south of Palmer Station.

Pole an ideal spot for astronomers

By Steve Martaindale
Sun staff

Searching for a minute change in microwave radiation that has traveled across space for some 14 billion years requires not only state-of-the-art equipment, such as the South Pole Telescope, but it needs to occur in special locations.

Antarctica is, among other things, Earth's highest, driest and coldest continent. The South Pole epitomizes those qualities, and it is also home to support facilities, making it an ideal vantage point for peering deep into our past.

When the South Pole Telescope (SPT) aims its huge 10-meter dish into the six-month night sky this winter, its operators know that their cold, isolated setting will enhance their opportunity to crack open secrets of the origin of the universe (see story on page 1).

Chris Danals / Special to *The Antarctic Sun*

A full moon and a 25-second exposure allowed sufficient light into this photo taken at the South Pole in July 2005. The 24-hour darkness is one ingredient in making the Pole an ideal site for astronomers. Red lights are used outside during the winter darkness as their spectrum causes less interference for observers. The green light in the sky is the aurora australis.

What makes the South Pole such a perfect spot for observing the universe is the minimal amount of moisture in the air. Water vapor absorbs microwaves, which is why a microwave oven works.

"We want to be in a place where the atmosphere is not going to absorb much," said John Carlstrom, principal investigator for the SPT. "There are two reasons for that. One is that a good absorber is a good emitter." Emitted radiation would interfere with readings obtained from space.

One way of limiting the amount of moisture in the atmosphere is to rise above it. The fact that the South Pole sits atop more than three kilometers of ice helps in that regard. And then there is the legendary cold.

"It's so cold that, even if the atmosphere is a hundred percent saturated, a hundred percent [relative] humidity, there's very little water vapor," Carlstrom said. "If you took all the water at the South Pole and compressed it down to a sheet, just got it out of the atmosphere, a typical average thickness of that sheet would be 250 microns," about the thickness of heavy-duty photo paper.

The second good reason for a dry atmosphere is uniformity. Since astronomers are seeking incredibly small fluctuations in temperature, it's nice when the atmosphere does little to interfere.

"If you took all the water at the South Pole and compressed it ... a typical average thickness of that sheet would be 250 microns."

– Astronomer John Carlstrom

"We can deal with the atmosphere changing," he said. "There's no way the atmosphere can be perfectly stable, but the more stable it is, the better it is."

One important ingredient in that stability is the fact that the sun does not rise all winter. In lower latitudes, the daily rising and setting of the sun heats the lower atmosphere and creates unwanted turbulence.

Sitting on Earth's axis of rotation has distinct advantages, too. The same sky is visible all winter; it doesn't sweep from east to west. That enables observers to make prolonged exposures.

"All you've got to do is account for the fact that it's spinning underneath you," Carlstrom said, "but the spot is always there."

Six months of darkness has another advantage, he said, in that it offers an opportunity to get an instrument working well and keep it going through the winter.

The last important element, he said, is the infrastructure. At Amundsen-Scott South Pole Station, support is in place for housing, food, telephone and Internet accesss, and electricity.

Carlstrom said the entire station has been involved in seeing the project through to completion.

And those providing the support are aware of their roles, said Jerry Marty, National Science Foundation representative at the South Pole.

"The community is excited about the projects and they're proud to be part of them. All the planning and all the work to bring the magnitude of materials and the support to bring the projects to where we are now is something that everyone feels pride in being a part of, and everyone's excited about the possibility of returns on the scientific research."

Scientific goals guide construction

By Steve Martaindale
Sun staff

When cosmologists – astronomers who study the origin and structure of the entire universe – must try to explain their work to laymen, they sometimes struggle to put the topic into words and images others can relate to.

For instance, why does the South Pole Telescope have to be so large?

John Carlstrom, a senior collaborator on the telescope with a 10-meter-wide dish (see story on page 1), explained that the experiment researchers want to do requires "an arc-minute resolution." At arm's length, hold up a finger toward the sky and look at it. Imagine a square in the sky roughly the size of your fingernail.

Such a spot would be about one square degree. Mentally, divide that fingernail-sized square into 3,600 squares and one of those infinitesimally small areas is what the South Pole Telescope is designed to look at – that one and about 14.4 million others.

"The other thing [in addition to resolution] is that we have to observe where the microwave background is emitting, and that's at a millimeter or two," Carlstrom said, speaking of wavelengths of radiation. "So, diffraction, as light spreads, means that in order to get that resolution, you need about a 10-meter telescope. ... If you just start with your science goal, you end up with a telescope like this."

Photos by Steve Martaindale / *The Antarctic Sun*

Thomas Crawford, of the University of Chicago, carefully aligns one of the 218 aluminum panels that form the primary reflector of the South Pole Telescope. Each of the panels is unique and requires eight precise adjustments. The photo at left steals a glance at the panels' rods.

If you build it ...

For those who think on that level and effortlessly speak the language, deducing the necessary size of the telescope may have been the easy part. What followed were two and a half years of design work and another year and a half to fabricate the parts.

"This is a one-of-a-kind telescope," said Carlstrom, of the University of Chicago. "You don't just order it from the catalog."

The required precision of the telescope, which is nearing completion at Amundsen-Scott South Pole Station and is scheduled to track the skies this austral winter, is intimidating enough, but then there are the challenges presented by its location.

The South Pole is perhaps the best spot on the planet for researching the cosmic microwave background (see story on page 7), but there is a price to pay.

One challenge is dealing with extremely cold temperatures. While it is plenty cold during the summer construction (with highs of about negative 15 Celsius), winter temperatures can drop to below negative 70 Celsius. Such temperature fluctuations can lead to expansion and contraction of materials, thus throwing off precise settings.

Even when designers work around those problems, they encounter one more challenge. Every part of the huge structure must fit into an LC-130 aircraft for transport to the Pole.

"Most of these pieces," Carlstrom said, "you would like, for stiffness and requirements like that, to have as one big weldment, set up in a huge shop, but you can't do that here."

So, where one might wish to have one solid piece of construction, there may be two or three joined together. Those joints require special attention or they "will flex like crazy."

Concerns about flexing and expanding come back to precision viewing of those tiny, dark spots in the sky, and it all begins with the dish.

Continued on next page

Construction

Get it together

The most visible feature is the telescope's 10-meter-diameter primary reflector. Rising more than 22 meters above the snow, equivalent to a seven-story building, it demands attention in an area where everything else sits much closer to ground level. And attention is what it has received with thousands of adjustments made to an accuracy of a millionth of a meter.

"It looks symmetric," Carlstrom said of the reflector dish. "It looks like this panel must be the same as that, et cetera, but it's an offset parabola. No two panels are alike."

The 218 aluminum panels are carefully machined on all six axes to fit together very tightly. They are etched chemically to achieve a dull finish.

"That's so if the sun goes in the beam, we don't get this incredible focus of the sun and burn a hole in things," he said. But, he added that at the microwave range that it is built to pick up, it is "a beautiful mirror."

Each panel has eight adjusters. Five are like pistons that move the panel up and down. The other three give it adjustments along the x and y axes and a rotation. They are set by hand to micron accuracy. There are 25,400 microns to an inch.

The scientists put the reflector together, operating underneath a huge white tent to shield them from the wind while they made fine adjustments. Placing the panels and making the initial 1,744 adjustments took the team four weeks.

"There's a bit of a standing joke at the moment that cosmology here involves sledge hammers and saws," said Steve Padin, SPT project manager, while reflector assembly was under way last month.

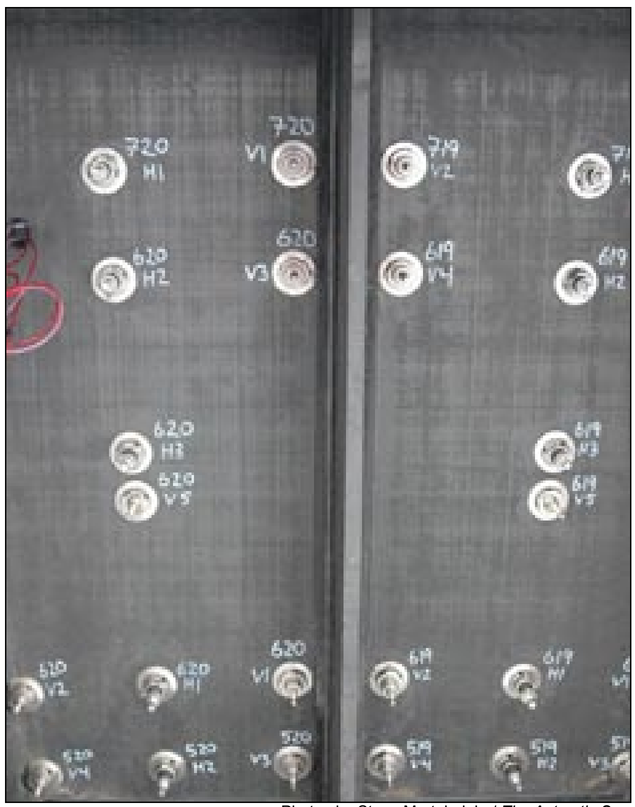
"It's very serious construction at this point, but that's part of the business, actually. I think that a lot of the students that have been involved in the project have been surprised just how hands-on astronomy can get."

The primary mirror reflects concentrated light toward the 1-meter secondary mirror, which sits to the side of the parabolic reflector. The secondary mirror is part of the optics cryostat, which is cooled to 10 degrees Kelvin. (Zero degrees Kelvin is absolute zero, the lowest temperature theoretically obtainable.)

The secondary mirror directs the light to the receiver cryostat, where it will be absorbed by tiny detectors on the focal plane, or the camera. This package of instruments is kept at a temperature of 250 milliKelvin, a quarter of a degree above absolute zero.

The detectors fill an area that is basically a circle with a diameter of 180 millimeters, smaller than the average salad plate. There are 960 detectors in that area. Each one consists of a 4-millimeter-diameter mesh that absorbs the microwaves, and is equipped with a sensor only 30 microns across, small enough to hide underneath a human hair.

"So, we've gone from 10 meters down to a thousandth of an inch," Carlstrom said.



Photos by Steve Martaindale / *The Antarctic Sun*

Above, Joaquin Vieira, left, and Ryan Keisler are on the receiving end of a panel being positioned on the SPT. The two University of Chicago graduate students are atop ladders underneath the primary mirror. The photo at left shows how each rod is labeled.

Getting warm

These sensors will not work like a digital camera, recording visual images. It

Continued on next page

Construction

is actually a bolometer, which is used to measure radiant heat, and was built by researchers at the University of California, Berkeley.

"With carefully chosen filters in front of the bolometers," Carlstrom said, "you're looking at a little window of frequency that you want to observe and you're actually letting the radiation heat up these little elements and measuring their temperatures."

The measurements are taken as the telescope slowly glides across the sky, quickly looking for miniature spots in the sky that emit radiation which is maybe 10 microKelvin warmer – 10 millionths of a Celsius degree.

"Our sensitivity is such that, in one second, integrating on the spot for one second, our precision, in a relative sense, is a couple of hundred microKelvin," Carlstrom said. "If you make that measurement over and over, you get to average them. That's how you get a higher precision. With this experiment, we hope to get below 10 microKelvin for every arc minute spot – know what the temperature is to a few microKelvin over 4,000 square degrees."

In 2010, he said they plan to begin polarization experiments in which they hope to get to a precision of about 10 nanoKelvin – 10 billionths of a degree. They will be surveying a smaller portion of the sky but will have to spend much more time focusing on that area.

Supporting role

While scientists were piecing together the primary reflector one panel at a time, ironworkers and heavy cranes were putting together the support structure responsible for bringing everything together in this finely tuned dance of accuracy.

"If you just made this whole structure and the backup structure out of steel, " Carlstrom said, "it would actually, from its own gravitational distortions, not meet the specs."

A couple of special materials were used to assure the precision requirements needed in such a cold environment. One is a carbon fiber reinforced plastic that is very light yet stiff enough to tilt at different angles without deforming. That was used as the backup structure to hold the primary reflector.

The other key material, Invar, was required to act as a buffer between the main steel structure, which will be affected by temperature changes, and the carbon fiber backup structure, which could be damaged or distorted by those expansions.

"So we have this adapter," Carlstrom said. "It's made out of Invar. Invar is a very high-nickel content steel which you can match the coefficient of thermal expansion to that of the carbon fiber. And then you design it so that it takes all of the stress and all the deformation from the main steel structure without transmitting it to [the backup structure and reflector]."

The entire support structure sprouts out of a control room that is linked to the Dark Sector Laboratory. The telescope was designed to maximize the number of moving parts that could be accessed from inside a warm environment, especially anything that would more likely need to be worked on during the winter months of operation.

In fact, at the end of the arm extending from the structure which supports the primary reflector is a receiver cabin that can be lowered onto and accessed through a hatch in the roof of the control room.

Coming together

On Jan. 3, two cranes coordinated to lift the backup structure and primary reflector assembly onto the structure while another crane positioned workers to bolt everything together, giving the South Pole Telescope the appearance of completion.

Steve Martaindale / *The Antarctic Sun*

Tom Pi, a member of the IceCube project, visits with Steve Padin, fronted by reflector panels destined for the primary mirror of the South Pole Telescope.

The plan is to start receiving light through the telescope in early February before the winter season begins and to put the instruments to work as the six-month night sets in.

"To get from nothing to a working instrument at this scale size and doing science experiments in a short time is pretty hard," said Padin, who will winterover to run the operation. "So we'll do the bulk of that work during the summer season, when we can bring lots of people in. But, for sure, it's going to drag on into the winter."

"The goal is to actually get some real science out," he said, "so we want to make a start on a galaxy cluster survey."

South Pole Telescope Collaborators

University of Chicago
University of California, Berkeley
University of Illinois at Urbana-Champaign
Harvard-Smithsonian Astrophysical Observatory
Case Western Reserve University
University of California, Davis
McGill University
NASA Jet Propulsion Laboratory
Cardiff University
University of Colorado at Boulder

Science

From page 1

project, Carlstrom said the excitement started with the first flights that brought in summer workers who flew down "with this part of it or that part of it." Meanwhile, they have been able to watch it grow on the horizon about a kilometer from the elevated station.

People at Amundsen-Scott South Pole Station are no strangers to astronomical research. Conditions there make it an ideal location for staring deep into space. However, the South Pole Telescope (SPT) has raised some eyebrows as the towering structure (see story, page 8) has raised the skyline at this desolate, isolated place.

"It's really exciting to see 600,000 pounds-plus of steel arrive and be assembled and have a telescope that dwarfs large buildings that were landmarks on the horizon," said Jerry Marty, National Science Foundation representative at the South Pole. "People are always excited about seeing the telescope."

Within the next few weeks, the telescope with the 10-meter dish will move, turn and go to work seeking out secrets of the universe.

The goal

"Everyone questions where we're coming from and how did this happen and what's out there," Carlstrom said in explaining interest in the SPT and exploring the universe in general. "I think they, like me, just like to be a part of this."

And answering questions is what science is all about, even if the answer is wrong. Carlstrom explained what astronomers will look for with the SPT by telling the tale of Albert Einstein's cosmological constant.

Early in the 20th century, it was thought that the universe was stable, neither expanding nor contracting. However, when Einstein solved his famous general relativity field equations and applied them to the universe, they indicated that a static universe was not possible. If it had matter in it and was static, then it would eventually collapse on itself.

By the time he worked out the math, Einstein had derived a constant of integration that would explain the discrepancy. Its

Steve Martaindale / *The Antarctic Sun*

Carpenter's apprentice Michael Mumm and astronomer Steve Padin discuss work in the control room of the South Pole Telescope last month. This is the base of the telescope, which is designed so that most of the critical elements can be accessed from an environmentally controlled area.

application seemed to resolve the conflict between his theory and a static universe.

"So, basically, his constant of integration, his cosmological constant, acted like a repulsive force at large distances," explained Carlstrom. "It was like a property of space, an energy of the vacuum, if

> *"Everyone questions where we're coming from and how did this happen and what's out there."*
>
> – Astronomer John Carlstrom

you will. And that would act like a counter, negative gravitation, to basically balance the mass."

Edwin Hubble's observations of redshift showed that distant galaxies are indeed moving away from us and that the universe is expanding. Einstein has been quoted as claiming the cosmological constant was his greatest blunder because it kept him from predicting that the universe was expanding.

Keep that "blunder" in mind, Carlstrom advised, because it would play a later role in the evolution of the SPT's story. That is something else that is apparent: The pursuit of answers is not necessarily a hasty one.

"It's a very conservative, cautious process, science is," said Steve Padin, project manager for the SPT construction, "where you come up with a new idea, you make predictions, you test them. So there's a tremendous amount of inertia built into that process, and that's not a bad thing. It means that new ideas have to have credibility, but occasionally it means that we get it spectacularly wrong and we miss a good idea. And I think that's OK, as long as you keep picking away, asking questions."

Soon after Hubble discovered that many of the fuzzy spots in the night skies were distant galaxies, astronomers computed that there was not enough visible matter present to justify the movements of those galaxies. What evolved was the opinion that there was a substantial amount of unseen material throughout the universe, which was called dark matter.

"People's beliefs have changed," Carlstrom said, "but astronomers have known about dark matter at least 50 years, if not longer."

As we began to get better looks at those distant galaxies, it was determined that some were bunched together. These galaxy clusters, as they are known, are the largest objects in the universe, he said. Analyses of their movements showed that far more mass than what was visible had to be present.

"So we know where [dark matter] is," Carlstrom said. "We know that it clumps up. We know it is the source of the gravi-

Continued on next page

Science

SPT An Eye to the Past

tational force that keeps galaxy clusters together, that keeps our galaxy together, and we know from this that there is about 10 times more mass in that component than there is in the stars and stuff that we see.

"We don't know what it is."

Somewhat amazingly, there is still plenty of dark in the sky. Even with 100 billion stars in our galaxy and some 100 billion other galaxies in the observable universe, we can still see a lot of space between them all, to the very beginning of time.

Carlstrom explained that as we look deeper into space, further back in time, eventually we get to the point when the universe was ionized. This is the cosmic microwave background, nearly uniform radiation coming from every direction in the sky, a spherical puzzle that defines the edge of the observable universe.

"What this tells us is that if you go back beyond 10 billion years, or something like that, there are no galaxies. That doesn't mean there aren't seeds of galaxies and something happening. But it's important to realize that it's back in time. ... This doesn't tell you that the universe is finite. It just tells us, time-wise, that there's a tale to be told."

The bewildering aspect of the cosmic microwave background was that the intensity of the radiation is virtually the same from every direction, even though their sources are billions of light-years apart. An explanation for this was finally developed in the 1980s with the theory of inflation.

"Remember Einstein had his cosmological constant," Carlstrom said. "His equations show that if you had what was called a false vacuum, some uniform energy density of the vacuum, then you would get this exponential expansion."

That is what the inflation theory states, that in an incredibly brief time – about 10^{-30} of a second – there was an expansion far greater than the speed of light and our universe was created from a small subatomic region. Inflation would explain why the background is so uniform – what the astronomers term smooth – because it all once "pertained to a very, very small part of causally connected space."

Inflation gave scientists enough information to predict the average energy density of the universe, something they determined to be about three hydrogen atoms per cubic meter. This presented another problem. All of the visible matter in the universe and the much larger amount of dark matter totaled to an average of only about one hydrogen atom per cubic meter.

"What we find is that there's some other component that in the present day accounts for about 70 percent of the universe," Carlstrom said.

"It's called dark energy. The best model for dark energy, the one that looks most compelling although we don't understand it, is Einstein's cosmological constant, energy of a vacuum."

Learning more about dark energy is

Continued on next page

Steve Martaindale / *The Antarctic Sun*

Ironworker James Morrison walks past the South Pole Telescope support structure, which runs through the control room. Several steps are involved in keeping the cold temperatures from affecting the shape of the dish antenna.

Photos by Jerry Marty / Special to *The Antarctic Sun*

A pair of cranes are used to lift the 10-meter dish in the photo above. Below, they place it on the support structure of the South Pole Telescope while a third crane lifts scientists to bolt it into position.

Science

what led to the design of the South Pole Telescope, he said.

"The whole big-bang scenario looks as though it's a pretty good explanation of what happened, and that's a huge step forward for us," said Padin, project manager for the construction of the SPT. "Twenty years ago, nobody was really sure if a process like that occurred. They weren't really sure how to test it. So, we've had an exciting 20 years here, and I hope it continues and we actually figure out if this really is the right story."

The procedure

SPT will target uncharted, far-flung galaxy clusters. Once these clusters are located, they can be studied for additional clues to the size, age and origins of the universe.

Beginning this austral winter, Padin and his winterover team of Zak Staniszewski and Allan Day will employ the Sunyaev-Zel'dovich effect to find these galaxies. To adequately survey most of the viewable sky will take about three winter seasons, even though the SPT is 5,000 times faster than previous telescope experiments, Carlstrom said.

The cosmic microwave background emits radiation at a uniform level, but it has been discovered through the Sunyaev-Zel'dovich effect that galaxy clusters can augment those photons ever so slightly. Carlstrom said there is about a 1 percent chance that a photon that escaped from the cosmic microwave background might interact with an electron while passing through a galaxy cluster.

Such a photon would have very little energy by the time it reached the cluster and the much more energetic electron would scatter the photon, distorting the background spectrum and creating a hot spot that would not ordinarily be there.

"With a telescope like the South Pole Telescope," Carlstrom said, "we can look at these objects. In fact, we can survey the sky looking for these objects and we can find them, no matter where they are, because they distort the background."

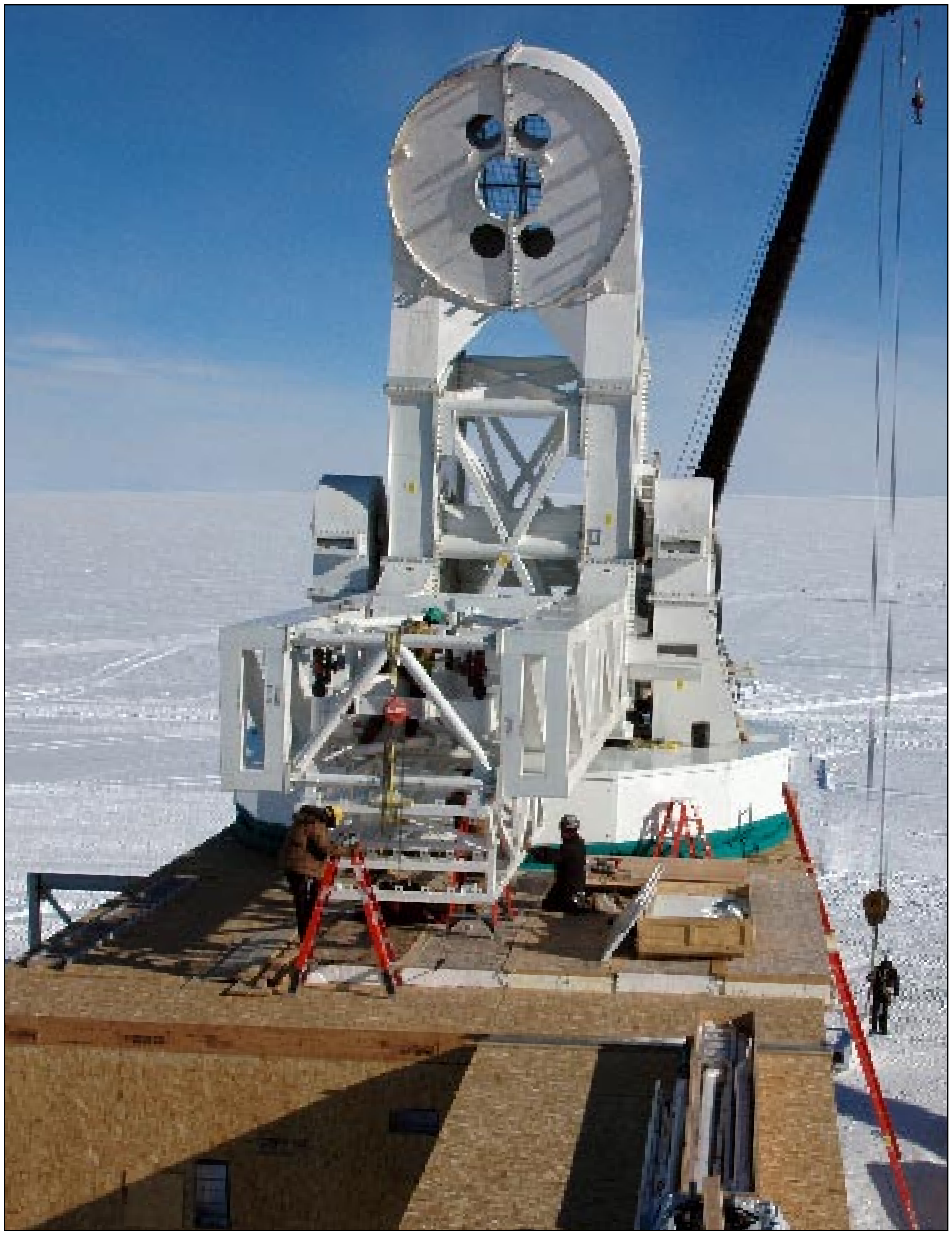
Galaxy clusters are never small things, he said, and a large enough telescope can always resolve them. In fact, it does not matter how far away they are, the effect is the same, but it is very subtle. He said the SPT's camera, using multiple exposures of the sky, should be able to resolve temperature differences as slight as a millionth of a degree Celsius, hovering just above absolute zero, the lowest temperature theoretically obtainable.

Carlstrom said researchers are going to gather the information they can about galaxy clusters and "that will let us solve the cosmic time of this tug-of-war of [visible and dark] matter trying to pull things together or dark energy trying to cause things to expand. We want to test those theories of dark energy. That's our first experiment."

Padin suggested the excitement, for him, is in the search, even if the theory tested ends up being wrong.

"It's just more exciting, in a sense, when you come up with a measurement that is completely at odds with what you expect. That causes a rethink, and sometimes that's the key to unleashing a huge amount of progress."

The last 20 years, he said, things have turned out pretty much as expected, and that's satisfying, "but some of the folks working in theoretical cosmology ... were way too pleased with themselves at this point so they're almost insufferably happy at this stage."



Steve Martaindale / *The Antarctic Sun*

With the stark South Pole horizon as a backdrop, workers piece together the 10-meter telescope's supporting structure last month. The structure grows out of the control room, where scientists can run the operation in relative comfort during the winter observing period.

NSF-funded research: John Carlstrom, University of Chicago, spt.uchicago.edu.

Birthday

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ence at the geographic South Pole," added Jerry Marty, National Science Foundation representative at the Pole. "They established the recognition that man could survive. They built an infrastructure to support science in man's first winter at South Pole in 1957, based on what they did between Nov. 20 and Jan. 4."

Bowers was a lieutenant junior grade in the U.S. Navy when he was part of the initial deposit of men, supplies and a dog team on the two-mile-high ice shelf in central Antarctica. His first order of business was to confirm their location, and he found they were eight miles off-target. He said the dogs came along as a backup plan should they have trouble getting planes off of the snow, something that had only been done once before. The canine team was put to work hauling the first supplies to the actual geographic Pole.

In short order, his full team – mostly Navy Seabees, members of the construction battalion – arrived and a flurry of airdrops and deliveries of materials ensued. Combating the effects of altitude sickness and the extreme cold, the men set about constructing buildings.

Speaking from his current home in Indianapolis, Bowers said they carried an awareness of why they were called on to do the job.

"We had a very general idea of how the [International Geographic Year] came about via a group of forward-thinking scientists who wanted to get this thing started ... because science was advancing so rapidly," he said. "These people were really extraordinary, far-thinking individuals. We knew that, and ... those who understood the mission could really appreciate it."

Paul Siple / Special to *The Antarctic Sun*

The U.S. Navy Seabees who built the first South Pole Station beginning in late November 1956. Standing: Bristol, Speirs, Williamson, Tyler, Wagner, Bevilacqua, McCormick, Randall, Patton, Roberts, Goodwin, Bowers. Kneeling: Scott, Chaudoin, Hisey, Prescott, Powell, Nolan, Montgomery, Hubel, Woody, McGrillis, Slaton. Paul Siple was the chief scientist at the South Pole during the International Geophysical Year (IGY), 1957-1958, and was the photographer for this picture. The shadow of the South Pole marker can be seen down the middle.

Marty, whose first involvement with the U.S. Antarctic Program (USAP) was in 1969, is in his 17th season at Amundsen-Scott South Pole Station, as the station was ultimately named to honor the first two explorers to reach the Pole.

He agreed that the station was a goal that has paid significant dividends, listing accomplishments such as learning more about the origin of our planet and our universe, the climate and our effect on it.

Team effort

While Marty made a point of singling out the leader of the team that constructed seven major buildings in less than seven weeks, Bowers would hear nothing of it, going to great lengths to heap praises on the other members of his group, the flight crews who delivered supplies and personnel, and the hundreds who supported the operation from McMurdo Station and beyond.

"We were very proud of it," he said at one point. "I say 'we' because no one ever does anything down there as an individual. It's always a group activity."

"We were surrounded with very competent people, hundreds of them, hard-working people. The plans, early on, had been quite nebulous about many facets – whether we could land, whether we could take off, what materials were actually required, what we would face. ... Basically, we were surrounded by men who were capable of doing so much and had so much drive and energy, people who didn't get frustrated when things went wrong. It was a humbling experience."

Bowers even made a point of listing some of the other stations built during the early years of Operation Deep Freeze, adding that "all the stories of those other stations were incredibly impressive to me, maybe because I could understand some of the things they were going through."

Many members of those long-ago missions still keep in touch, he said, and try to gather at least every two years. He said current USAP members such as Marty make an effort to keep them updated and will join their meetings.

"They keep us advised, and we tell them about how it was back then and they laugh," Bowers said. "Then they tell us about how it is now and we laugh. We enjoy every bit of it."

"Those guys just sit back in awe in terms of the magnitude, the size of the pieces of equipment and everything," Marty said. "We talk about the challenges of logistics,

Continued on next page

Dick Prescott / Special to *The Antarctic Sun*

U.S. Navy Seabees in the South Pole galley in 1956. Left to right are Nolan, Williamson, Randall, Wagner and Bowers.

Birthday

the challenges of sometimes things don't fit quite right in the field – really, nothing has changed."

The challenges remain, for sure, but the scope of science at the South Pole has certainly reached new depths and heights. Two ambitious programs are in construction now. The IceCube project (see the Jan. 29, 2006, issue at antarcticsun.usap.gov) is burying strings of detectors more than 2 kilometers deep into the ice in an array to search for elusive neutrinos. The South Pole Telescope (see story on page 1) is within weeks of aiming its huge 10-meter dish at the darkest parts of the night sky in search for clues of the origin of the universe.

And who knows what will come next?

"I think there's a platform, there's an infrastructure here now that's truly going to support 21st century science," Marty said. "I don't see South Pole Station as remaining stagnant from a scientific research standpoint in terms of monitoring our climate change and/or telescope observations. I think those areas are probably going to expand in the future.

"I think the South Pole may find itself as being a support base for projects going away from South Pole but coming back to South Pole for infrastructure support."

In fact, he cited a recently completed project by glaciologist Sridhar Anandakrishnan, which researched a subsurface lake 16 kilometers from the Pole.

"That's the beginning, I think, of more of that type of scientific research to come," Marty said. "I think you'll find more 10-meter, more IceCube type of projects at South Pole in the future."

Jerry Marty / Special to *The Antarctic Sun*

In a Jan. 4 birthday ceremony, flags such as this one (right) for Dick Bowers were flown at the South Pole. They were sent to the surviving men who built the original station.

Jerry Marty / Special to *The Antarctic Sun*

Flags to be delivered to the men who built the original South Pole Station await their turn to fly over the Pole.

Empowering the future

The recent flurry of gigantic projects also underscores a need to evaluate how to support future growth of research at the South Pole.

"I think the jury is still out on what the true plans are," Marty said. "I think we have to recognize that when we formulated the basis of design for the new station in the early '90s, the projects of the magnitude and infrastructure demand – power, logistics, IT, connectivity, population and equipment hours – to support projects such as an IceCube project and a 10-meter really hadn't been envisioned. We hadn't realized that we were going to be discovered and that this was truly a location that was ideal for these types of experiments."

For example, the South Pole Telescope (SPT) is projected to generate data at the rate of 120 gigabytes a day.

"To put that in perspective," said John Carlstrom, principal investigator of the project, "the current amount of data you can get from the South Pole up to the continental U.S. during the day, currently is 10 gigabytes."

He said there is a scheduled upgrade to, hopefully, 70 gigabytes a day and Carlstrom's group anticipates it can compress its data to about 30 gigabytes. All the data will be recorded at the Pole, but the hope is that they will be able to upload it daily so the whole team can look at the results.

Another challenge is electricity, of which, "every kilowatt at the South Pole is an issue these days," Carlstrom said.

The SPT, as it is scanning the sky, will require power at uneven intervals, creating peak demands that, along with other needs, could overburden the power station, he said.

To moderate that, the SPT will have a power load leveler – 10,000 pounds of batteries – built into the system to keep the power draw steady.

Those are the sorts of needs that will be driving National Science Foundation officials as they consider the next steps of development at the South Pole.

"The future on how we're going to handle power, connectivity and all of those items that I mentioned will have to be part of long-range planning," Marty said. "The science has expanded and exploded so quickly, we're desperately trying to determine what are those needs. ... We're in the embryonic stages of identifying options and solutions."

Honoring the past

Marty carved time out of the South Pole Station's busy schedule on Jan. 4, the 50th anniversary of the date the station was handed over to researchers and the winter staff, to recognize the work of the 24 men who built the original station.

For each of the 15 surviving Seabees, a United States flag was flown at the South Pole marker. Those flags, certificates, letters of thanks and photos were sent to each of those survivors and a 16th flag to the Seabee Museum.

Bowers, in typical fashion, continued to spread the praise.

"You really realize all your own frailties when you run up against the extreme conditions down there," he said. "You realize how you depend on others; it's just a great feeling. We still have that, and we get together, and we enjoy each other, and we keep track of what [current USAP participants] are doing because what you're doing is so important."

BICEP adds muscle to CMB research at Pole

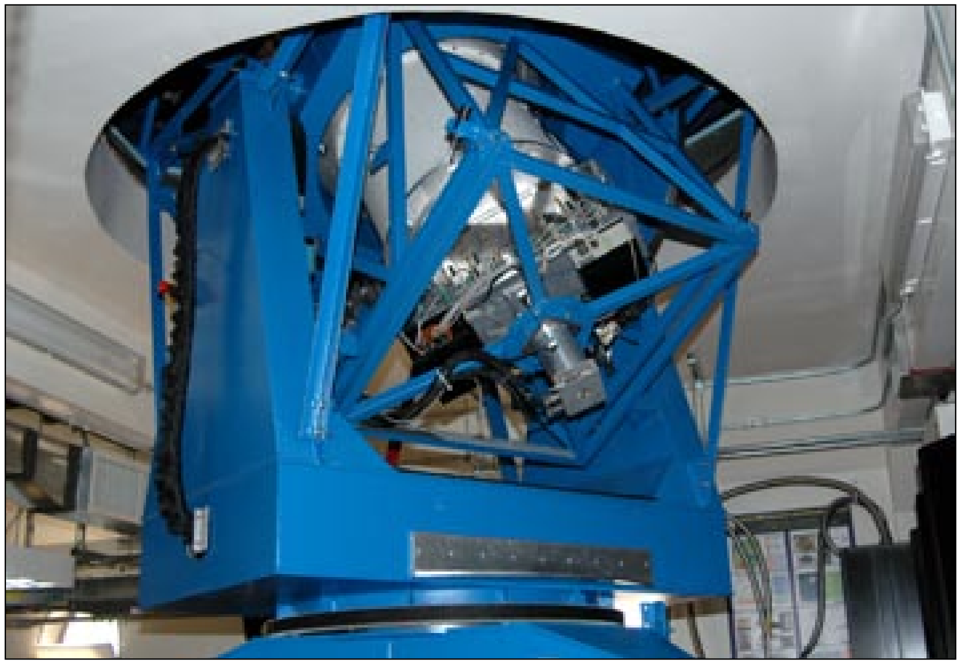
By Peter Rejcek
Sun staff

Imagine a universe that exploded into existence and expanded exponentially, faster than the speed of light. Cosmologists operating a new telescope at Amundsen-Scott South Pole Station hope to put that crucial moment and the millennia that followed after the big bang into focus – and, in the process, nudge the study of physics into a new era.

They believe BICEP has the muscle to give them that push. BICEP (Background Imaging of Cosmic Extragalactic Polarization) is an experiment to measure the polarization of the Cosmic Microwave Background (CMB). The telescope was installed last austral summer in the Dark Sector Laboratory. It operated throughout the winter with hardly a hiccup, according to Jamie Bock, the co-principal investigator for the project from NASA's Jet Propulsion Laboratory.

"Our first season of observations went incredibly smoothly," said Bock, following a visit to the Pole in December to assist with upgrades and calibration of the instrument. "I think everyone is still a little surprised that we didn't have some unforeseen problem, which is the usual situation. A lot of the credit for this goes to our first-season winterover Denis Barkats. We're still analyzing all of the polarization data from the first season."

The study of the CMB and events even further back to the very beginning of time involves some rather abstract theories involving such things as "inflation" and "curls." You don't have to have a degree in Star Trek physics to appreciate this quest to understand the alpha and omega of the universe, but a little Cosmology 101 may be helpful.



Steve Martaindale / *The Antarctic Sun*

The BICEP telescope made its first observations of the cosmic microwave background this past winter with hardly a hiccup. The telescope received upgrades this summer and will be back at work in 2007.

It all started with a bang

Recall that the most widely accepted theory about the existence of the universe is that it all began with a big bang, which created all the mass and energy in the universe. Scientists generally believe that a fraction of a fraction of a second later, the universe burst forth at incredible speed and slowed its expansion almost as quickly.

About 400,000 years after this cataclysmic event, the universe cooled enough to allow electrons to combine with nuclei (what's known as recombination). The universe glowed with light before recombination, but after recombination, it became transparent.

Fast forward 14 billion years as the universe continued to expand. That brilliant light that started as ultra-high energy gamma rays stretched into X-rays, was visible light at recombination, and has now stretched all the way to microwaves. That faint hiss of microwaves, with a temperature of 2.7 degrees above absolute zero (Kelvin), is the cosmic microwave background or CMB. This radiation comes from every direction in the sky.

"Images of the CMB are basically a picture of the universe at that time," Bock explained. "It was a much different place than our universe of today. There were no stars or galaxies. Instead, we see an almost perfectly uniform plasma."

Plasma is an ionized gas of free electrons and protons. It is also opaque. As Bock explained: "You can see this for yourself if you look at a candle and notice that you can't easily see through the yellow part of the flame. In a similar way, you can't see past the plasma at the time of the CMB, so maps of the CMB are basically maps of the surface of this opaque plasma."

The ancient radiation of the CMB possesses much valuable information about the early universe. It contains "hot" and "cold" spots that are slight irregularities on an otherwise uniform plasma. These spots can tell cosmologists something about the geometry of the universe, the amounts and types of dark matter and energy that make up the cosmos, and even something about the universe's ultimate fate.

This opaque plasma causes a problem if you're interested in learning what happened in the first 400,000 years, when the newborn universe was still rattling with freely roaming atomic particles. In effect, the CMB surrounds us like the walls of a cage, and it takes some ingenuity to see between the bars.

Seeing between the lines

In recent years, scientists have learned something about the polarization of light from the CMB. In this case, polarization is the alignment of light waves as they travel. For instance, polarized sunglasses are able to block road glare because when light hits the road it polarizes in a horizontal direction and the glasses are designed to block photons oriented that way.

Similarly, the alignment of photons emanating from the CMB polarized parallel to the last scattering surface, that cloud of plasma. The polarization contains information about the universe at recombination, when electrons combined with their nuclei.

The rapid expansion of the universe is referred to as inflation. Inflation stretched the universe out to give it a flat appearance sometime in that first fraction of a second after the big bang. This inflation produced gravitational radiation, ripples in space-time that occurred right after the birth of the universe. Gravitational waves producd a signature after inflation, which squeezes space in one direction and expands it in the other. When these waves interact with the plasma, it gives a polarization with a spiral quality called curl, which would look like

See BOCK on page 17

Bock: Project could discover new physics

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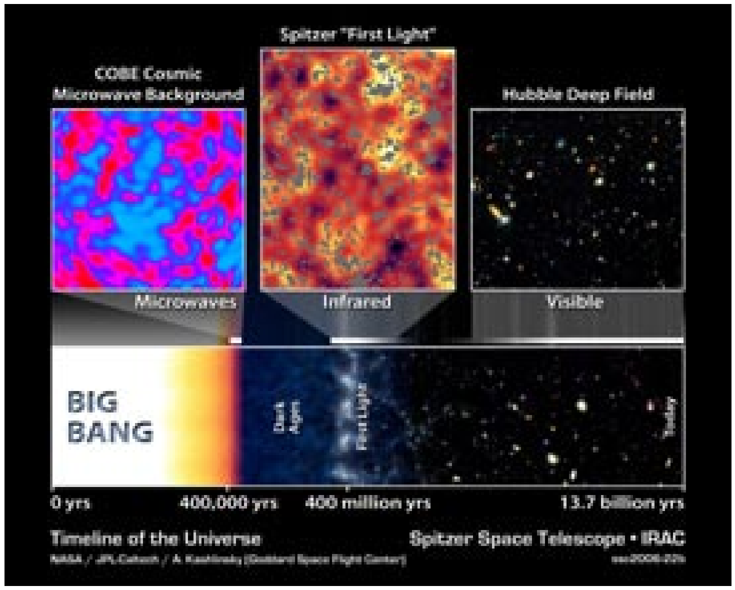
hurricanes in a hypothetical map of the polarization of the CMB.

"These gravitational waves make subtle changes in CMB images, because they slightly stretch space when the universe was 400,000 years old," Bock said. "In particular, there should be a distinctive effect in the polarization of the CMB, and that is what BICEP is looking for. If we see it, then we can say something about what happened in the first moments after the big bang."

BICEP is specially designed to search to very deep levels for this polarization signal, according to Bock. It might look somewhat "puny" matched up to the 10-meter South Pole Telescope (SPT) currently under construction next to the Dark Sector Laboratory. But the signal scientists are after, while faint, does not require a large aperture. The telescope has an aperture of 30 centimeters but has a wide field of view.

"And our focal plane is packed with detectors, so just because we're small, it doesn't mean we aren't powerful," he said, adding that being compact has its advantages. For example, the whole instrument can fit into one LC-130 airplane. Its relatively small size also allowed the team to outfit it with a series of baffles, or plates, to block out "terrestrial contamination" such as the horizon. It is also possible to fill the entire telescope beam with a polarized calibration source, which would be practically impossible to do on a large telescope, according to Bock.



The universe began in an explosion known as the big bang about 13.7 billion years ago. BICEP will observe the cosmic microwave background in hopes of learning more about the moments just following the tremendous birth of the universe.

"All of these things make BICEP the ideal instrument for measuring CMB polarization on large angular scales," he said. "Large telescopes like the SPT are naturally complementary because they access the small angular scales we can't see."

A new frontier

Three universities are collaborating with NASA's Jet Propulsion Laboratory on the experiment – California Institute of Technology, the University of California Berkeley and the University of California San Diego.

The telescope made observations throughout the winter. It easily picked out the temperature signals of the cold and hot spots in the CMB, though the polarization signals were not nearly as strong.

"A few years ago, these temperature signals would have made a big stir, but now we use them to calibrate," Bock noted. "It just shows we have moved into a new era."

Cosmologists believe there is an indirect upper limit for how bright the polarization signal from inflation might be. The BICEP team's goal is to get below that upper limit and determine how faint that signal could be. It is possible BICEP could make a discovery, and there are plans to make a more powerful successor instrument that could go even deeper, according to Bock.

"Detection would be quite a stunning achievement – imagine deducing how the universe behaved just an instant after the big bang," he said. "This is even more exciting when you consider that the physics driving inflation are out of reach by other means, because inflation probably happens at energy scales beyond even the most capable particle accelerators in high-energy physics.

"So not only would we learn about the universe in its first moments, we would learn new physics."

NSF-funded research in this story: Jamie Bock, NASA Jet Propulsion Laboratory; and Andrew Lange, California Institute of Technology, www.astro.caltech.edu/~lgg/bicep_front.htm.

Continental Drift — What would you put in a time capsule at your station?

"Considering they never found the time capsule at the Pole in 2000, I'd put in a locator beacon."

Lynn Hamann
McMurdo Station
MAPCON data specialist
Grand Junction, Colo.
seventh season

"A detailed photographic atlas of the Palmer Station area and its islands so that those in the future can see where the Adélie Penguins had colonies … and how Palmer Station was connected via a glacier to Anvers Island."

Brett Pickering
Palmer Station
field biologist
La Junta, Colo.
11th season

"My dance shoes and 300 Club patch."

Andres Martinez
South Pole Station
winter site manager
Denver, Colo.
sixth season

Profile Staying longer than expected

By Steve Martaindale
Sun staff

Like many others working in Antarctica, Gerald Crist first came down thinking he would "do something really far out for a couple of years" before settling back into a more normal existence in his hometown of Greybull, Wyo.

"That was in 1989," he said, "and I'm still here."

Not only is he back for his 18th consecutive summer season, he has also brought the kids – all three of them.

Shannon, the youngest, was the first to follow his father to the Ice and works as a science carpenter. Next came Dawn, the oldest, who is the meteorologist technician and cook at Marble Point. Shawn rounded out the sibling set when he took a job on the Ice. He now works in cargo. Each has been down for two or more seasons.

Dawn said the kids were not immediately enraptured with the Ice even though they were proud of their dad working here.

"We feigned interest at the first photos, but by the 11th one of [Mount] Erebus with the sun striking it from a slightly different angle, well, he lost us," she said.

Years later, however, finding she needed a break from teaching, Dawn said it occurred to her that she had taken advantage of every opportunity offered to her but the chance to work in Antarctica, so she took it.

Debbie Crist, wife and mother, has been termed "our one-year wonder," Gerald said, because she has only been to Antarctica for one season. She really enjoyed the Antarctic experience but works as a speech therapist back home and loves working with school-aged children, he said.

Steve Martaindale / *The Antarctic Sun*

Gerald Crist steps into a grader at McMurdo Station. This is his 18th consecutive summer season in the U.S. Antarctic Program.

"Sometime, I'll probably have to be forced out so I can learn how to quit."

– Gerald Crist, fleet operations supervisor

Birth of a runway

In some ways, it seems that Gerald, who is fleet operations supervisor, has added an additional member of the family while in Antarctica, an ice runway named Pegasus.

During Gerald's first summer on the Ice, he was part of a team scouting for a spot to test the feasibility of landing airplanes on a glacier.

The Pegasus runway "was an experiment; there was no intention of it going operational," Gerald said. "... However, when we did our test flights and it proved to work, they immediately went operational the same year. We flew off, I think, 15 flights with an old plane that was a non-ski-equipped C-130 – double zero was the tail number on it – and [the air field has] been in operation ever since. People quickly forgot that it was just supposed to be an experiment."

As the baby Pegasus field grew into its second season, it was successfully tested with the considerably larger and heavier C-141, and that airplane immediately went operational.

"So, we've redeployed from there ever since," Gerald said.

He said he stayed close to the development of Pegasus, including its transition from a "blue ice" runway, where the strip was prepared on the glacial ice, to its current makeup where fresh winter drift snow is super compacted into "white ice" and caps the glacier ice to protect it from the summer sun.

"Everything has to keep growing and evolving to meet the needs of the program," he said. "We've been on a continual change. ... That's what keeps me coming back every time; there's always a new challenge."

Currently, one challenge is the installation of a more direct route to Black Island. During the winter, people who have to work there must travel a course that circles all the way around the island and that puts them out of radio contact for an extended period. The reason is that there have been too many crevasses and melt pools along the more direct route.

He said they have learned a lot about building such traverses, in large part due to the work at Pegasus, and they have almost completed that new route.

In addition to air fields and the town's roads, Gerald's department also builds and maintains the ice pier (see story in Jan. 8, 2006, edition at antarcticsun.usap.gov), long-distance balloon launch pads, and traverses to Marble Point and Black Island. The department also does earth work and crane work for construction projects, drilling of sea ice holes for science groups and moving huts around on the sea ice.

When he is not working on some snow and ice endeavor, he said he enjoys applying his carpentry skills to projects at home but he plans to keep coming back as long as he can.

"Sometime, I'll probably have to be forced out so I can learn how to quit," he said. "I probably won't pass the physical or something, but it won't be what I want to do. Of course, I have a wife at home that I'd like to spend more time with, so there's always a silver lining, but I'll always miss the place."